INTEL® XEON PHI™ PROCESSOR
(CODENAMED KNIGHTS LANDING)
SOFTWARE PERFORMANCE PROOF POINTS

October 2017
The Faster Path to Discovery
Software Applications Performance Summary
Platform Features
Software Success Stories
Business Segments Snapshot
A Growing Software Ecosystem
SDVis

Proof Points: (new indicated with NEW label)
- Intel Xeon Phi Processor vs. NVIDIA*
- Machine Learning
- Financial Services
- Life Sciences
- Manufacturing
- Climate and Weather
- Material Sciences
- Physics
- Geophysics

- Energy
- Performance Benchmarks
- Tools and Libraries
- Web Resources
- Proof Point Configuration Details
THE FASTER PATH TO DISCOVERY

Application Software Enablement Executive Summary

A new level of performance and innovation has arrived with the new Intel® Xeon Phi™ Processor, part of the Intel® Scalable System Framework, providing the capability to accelerate highly parallel computational workloads for science, industry, and research. Many of the open source codes have been optimized to simplify development and to increase application performance by up to 6.48X\(^1\) and by up to 5X compared to competitors\(^2\).

An ecosystem with a wide range of application and middleware ISVs are now ready to enable. The initial results are striking and span a number of key business segments. From data analytics to machine learning and visualization – across vertical industries as diverse as finance, life sciences, and geophysical seismic analysis – life-changing discoveries are being accelerated with systems powered by Intel® Xeon Phi™ Processor.

The software ecosystem is piloting applications and seeing immediate results. The potential is enormous. The results will impact nearly every area of human activity. Here you will see some examples of life-changing impacts made by scientists, researchers, and innovators like you.

\(^1\) – As demonstrated by the BAW proof point in this presentation
\(^2\) – As demonstrated by the LAMMPS proof point in this presentation
FOR DISCOVERY AND BUSINESS INNOVATION
IN SCIENCE, VISUALIZATION & ANALYTICS

See featured applications: Intel® Xeon Phi™ Processor Applications Showcase
Over 75 workloads optimized for Intel® Xeon Phi™ processor family are available, with up to 6.48X (2X average) performance improvement

Intel® Xeon Phi™ processor 7250 relative performance normalized to baseline (1) of a 2 socket Intel® Xeon® processor E5-2697 v4

1 – As demonstrated by respective proof points in this presentation
INTEL® XEON PHI™ PROCESSOR PLATFORM FEATURES AND VALUE
INTEL® SCALABLE SYSTEM FRAMEWORK

MODELING & SIMULATION
HPC DATA ANALYTICS
ARTIFICIAL INTELLIGENCE
VISUALIZATION

MANY WORKLOADS - ONE FRAMEWORK

A Flexible Framework for Today & Tomorrow

Enabling Breakthrough System Performance
HOW IT WORKS

INNOVATIVE TECHNOLOGIES + TIGHTER INTEGRATION AND CO-DESIGN

Learn More:
Intel.com/SSF
Intel® SSF Configurations

*Other names and brands may be claimed as the property of others.
How can I get higher performance & TCO for my apps?

Modernization (i.e. parallelization and vectorization) of your code is the solution

Performance is being left on the table

Intel believes most codes are here

VP = Vectorized & Parallelized (MT)
SP = Scalar & Parallelized (MT)
VS = Vectorized & Single-Threaded (ST)
SS = Scalar & Single-Threaded (ST)

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. Source: Intel measured as of Q3 2014 Configuration Details: Please slide speaker notes. For more information go to http://www.intel.com/performance. For configuration details, see slide 155.
Intel® Xeon Phi™ Processors
Your path to deeper insight

Leadership Performance

Bootable, Host CPU for Highly-Parallel Workloads

Integrated Memory

Integrated Fabric

...with all the benefits of a CPU

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

1 - Claims of 1st integrated fabric; bootable, host CPU for highly-parallel workloads; and integrated memory refer to Intel® Xeon® processors.
2 - For configuration details, see slide 155

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INTEL® XEON PHI™ PROCESSOR: YOUR PATH TO DEEPER INSIGHT
A FOUNDATIONAL ELEMENT OF INTEL® SCALABLE SYSTEM FRAMEWORK

Solve Biggest Challenges Faster
Highly-Parallel Eliminate Bottlenecks Scalability

Realize Compelling Value
Power Efficiency Programmability High Utilization

Maximize Future Potential
Future-Ready Code Broad Ecosystem Robust Roadmap

For discovery and business innovation in science, visualization & analytics
Intel® Xeon® Processors are increasingly parallel and require modern code.

Intel® Xeon Phi™ Processors are extremely parallel and use general purpose programming.

- Vectorized & Parallelized
- Scalar & Parallelized
- Vectorized & Single-Threaded
- Scalar & Single-Threaded

Up to 72 cores (288 threads)

Intel® Advanced Vector Extensions 512 (Intel® AVX-512)

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SOLVE THE BIGGEST CHALLENGES FASTER
ELIMINATE BOTTLENECKS, IMPROVE THROUGHPUT

Bootable host: No PCIe* Dependency

Memory: Integrated (MCDRAM) & Platform (DDR4)

Fabric: Integrated on-package Intel® Omni-Path Fabric

REALIZE COMPELLING VALUE
POWER EFFICIENCY AND COST SAVINGS

2 x

XÉON PHI inside

+ GPU

683W*

$13,750*

vs. GPU Accelerator

Up to 5x Perf/W

Up to 8x Perf/

Up to 9x Perf/"

1 x

XÉON PHI inside

378W¹

$7,300¹

*Intel measured results as of April 2016; see speakers notes for full configuration and performance disclaimers. For configuration details, see slide 155.
INTEL® XEON PHI™ PROCESSOR SOFTWARE SUCCESS STORIES
PROOF POINTS AND APPLICATIONS SPEED UPS: BUSINESS SEGMENTS SNAPSHOT

Intel® Xeon Phi™ Processor proof points¹:

- Various applications compared to NVIDIA® GPU: 2.17X average speed up
- Financial Services: 3.45X average speed up
- Life Sciences: 1.67X average speed up
- Manufacturing: 1.9X average speed up
- Climate and Weather: 1.63X average speed up
- Material Sciences: 1.6X average speed up
- Physics: 2.33X average speed up
- Geophysics: 2.17X average speed up

¹ - Performance demonstrated in proof points in this presentation. Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of these factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. *Other names and brands may be claimed as the property of others.
INTEL INSIDE. SOFTWARE OPTIMIZATION OUTSIDE ON THE INTEL® XEON PHI™ PRODUCT FAMILY

VIDEO: https://software.intel.com/en-us/blogs/2017/02/03/sc16-demos

High Performance Computing Server Demos

Accelerating Crucial Steps in Drug Development with Intel® Scalable System Framework

3D Imaging with Cryo-Electron Microscopy

3D Molecular Dynamics Simulation

Deep Learning for Virtual Cancer Screening

High Fidelity 3D Visualization of Evolving Brain Tumors

Clinical Trial Patient Screening via Genome Analysis

Intel® Scalable System Framework for Life Sciences

Advancing Cryo-Electron Microscopy for Life Sciences

*Other names and brands may be claimed as the property of others
VIDEO: Experts from Allinea*, Altair*, Convergent Science*, CST*, Kitware*, LSTC*, NAG*, QIAGEN*, Rescale*, Rogue Wave Software*, Roush Yates Engines*, University of Oregon, and the University of Pisa share some of the use cases and explore the significant advantages of running their applications on the Intel® Xeon Phi™ product family. See what the Intel Xeon Phi Processor can do for key software applications.

*Other names and brands may be claimed as the property of others.
MORE INTEL® XEON PHI™ PROCESSOR SOFTWARE ENABLEMENT

- HPC Hardware and Software Innovation Go Hand in Hand
- Optimizing Automotive Designs with Intel and Altair*
- Momentum Grows for Intel Scalable System Framework
- Incredible Machine Learning Advancements Made Possible by Intel and QCT*: The Viscovery Use Case
- The Next Giant Leap in Cray Adaptive Supercomputing* – The Intel Xeon Phi Processor
- Next-Generation Intel HPC Fabric Takes Flight
A GROWING ECOSYSTEM: DEVELOPING TODAY ON INTEL® XEON PHI™ PROCESSORS AND COPROCESSORS

INTEL.COM/XEONPHI/PARTNERS

*Other names and brands may be claimed as the property of others.
A GROWING ECOSYSTEM: DEVELOPING TODAY ON INTEL® XEON PHI™ PROCESSORS AND COPROCESSORS

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INTEL® PARALLEL COMPUTING CENTERS COMMUNITY

intel.com/xeonphi/partners

Collaborating to accelerate the pace of discovery

*Other names and brands may be claimed as the property of others.
Collaborating to accelerate the pace of discovery

*Other names and brands may be claimed as the property of others.
“LSTC* is working closely with Intel to evaluate the KNL platform and is exploring support in an upcoming release of LS-DYNA®”
Marsha Victory Marketing Director, LSTC

“Paradigm is evaluating Intel’s next generation Xeon Phi platform as part of our current technology partnership and we are working with Intel to best take advantage of Intel’s evolving platform for our products.”
Somesh Singh Chief Product Officer, Paradigm

“These achievements are enabling the LAMMPS user community to overcome barriers in computational modeling, enabling new research with larger simulation sizes and longer timescales”
Steve Plimpton, Sandia National Laboratories

“These可持续 achievement statements are enabling the LAMMPS user community to overcome barriers in computational modeling, enabling new research with larger simulation sizes and longer timescales”

“The Intel® Xeon Phi™ processor is a great step forward and provides awesome performance for molecular simulations with GROMACS”
Eric Lindahl, of KTH* and Stockholm University*, GROMACS* Project Leader

“We believe that the Knights Landing architecture has great potential for our customers, and we look forward to fully embracing this exciting new Xeon family member in our future product releases”
Dr. Wim Slagter, Director, HPC & Cloud Marketing, ANSYS

“….The Intel® Xeon Phi™ processor is at the forefront of CPU architectures poised to open the door to Exascale systems…”
Didier Juvin, Program Director CEA

“We’re looking forward to delivering solutions to market that take advantage of this many core platform to deliver improved experiences to our users”
Michael Russel Senior Manager Automotive, Autodesk

“SIMULIA* is working with Intel to evaluate the KNL platform and is exploring support in an upcoming release”
Matt Dunbar, SIMULIA R&D Senior Director HPC Cloud Services

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Software Defined Visualization

Software Defined Visualization (SDVis) is an open source initiative from Intel and industry collaborators to improve the visual fidelity, performance and efficiency of prominent visualization solutions – with a particular emphasis on supporting the rapidly growing “Big Data” usage on workstations through HPC supercomputing clusters without the memory limitations and cost of GPU based solutions. Existing applications can be enhanced using the high performing parallel software rendering libraries OpenSWR, Embree, and OSPRay. For more information and access to the libraries (including source) follow the links. For more background on the SDVis initiative, see this presentation at IEEE Vis 2016. A paper about OSPRay – A CPU Ray Tracing Framework for Scientific Visualization has been accepted at IEEE Vis as well (smaller version), see also the slides of the talk. Learn more at http://www.sdvis.org.
INTEL® XEON PHI™ PROCESSOR AND VARIOUS SOFTWARE APPLICATIONS PERFORMANCE COMPARED TO NVIDIA® GPU
INTEL® XEON PHI™ PROCESSOR
A HIGHLY-PARALLEL CPU THAT TRANSCENDS GPU ACCELERATORS

No PCIe Bottleneck
Bootable host processor

Topple Memory Wall
Integrated 16GB memory

Run Any x86 Workload
Intel® Xeon® processor binary-compatible

Scale Out Seamlessly
Efficient scaling like Intel® Xeon® processors

Reduce Cost¹
Dual-port Intel® Omni-Path Fabric

Raise Memory Ceiling
Platform memory up to 384 GB (DDR4)

¹Reduced cost based on Intel internal estimate comparing cost of discrete networking components with the integrated fabric solution
APPLICATION PERFORMANCE: INTEL® XEON PHI™ PROCESSOR VS NVIDIA*

Higher is better

Relative Performance on the Intel® Xeon Phi™ Processor 7250

Average application speedup of 1.96X

See more competitive Intel® Xeon Phi™ Processor results!

1 – As demonstrated by respective proof points in this presentation
LAMMPS Coarse-Grain Water Simulation Performance Improvement with the Intel® Xeon Phi™ Processor

LANMPS is a classical molecular dynamics code, and an acronym for Large-scale Atomic/Molecular Massively Parallel Simulator. It is used to simulate the movement of atoms to develop better therapeutics, improve alternative energy devices, develop new materials, and more.


Code: In main LAMMPS repository. Recipe: Available here

Value Proposition: Intel continues to advance the capabilities of HW and SW necessary for scientists to solve new and more complex problems that could not previously be achieved. The Intel® Xeon Phi™ processor improves power-efficient performance for scalable workloads.

Results: Up to 1.43X improved coarse-grain water simulation rate (Performance result) with up to 1.75X performance per watt compared to the Intel® Xeon® processor E5-2697 v4. 89% parallel efficiency with Intel® Omni-Path Architecture (16 Node chart result).
"LAMMPS is an established code in the molecular dynamics simulation community with users from a variety of disciplines including materials modeling, biology, and many others. Over the past twenty years, the code base has been refactored and extended with high performing kernels and more complex interatomic and coarse-grained potentials.

In partnership with Intel, software optimizations focused on several commonly-used LAMMPS models have enabled simulations on the latest Intel® processors to now run up to 7.6X faster with over 9X the energy efficiency, compared to LAMMPS runs a year ago on previous Intel processors. Furthermore, using a single Intel® Xeon Phi™ processor (codenamed Knights Landing), the optimized LAMMPS code now runs up to 1.95X faster with 2.83X better performance per watt, when compared to two Intel® Xeon® E5 v3 processors.

These achievements are enabling the LAMMPS user community to overcome barriers in computational modeling, enabling new research with larger simulation sizes and longer timescales."  Steve Plimpton, Distinguished Member of Technical Staff, Sandia National Laboratories.

- Steve Plimpton, Distinguished Member of the Technical Staff, Sandia National Laboratories

See the LAMMPS Technology Brief here
**Intel Embree v2.16.0 Alpha**

*Embree is a collection of high-performance ray tracing kernels, developed at Intel. The target user of Embree are graphics application engineers that want to improve the performance of their application by leveraging the optimized ray tracing kernels of Embree. Embree supports runtime code selection to choose the traversal and build algorithms that best matches the instruction set of the CPU.*

**Application:** Path tracer renderer using Embree 2.16.0-alpha, Intel® C++ Compiler 17.0.2, Intel® SPMD Program Compiler (Intel® ISPC) 1.9.1, NVIDIA* OptiX* 4.0.2, CUDA* 8.0.44.

**Code:** Available here  **Recipe:** Available here

**Value Proposition:** The kernels are optimized for photo-realistic rendering on the latest Intel® processors with support for SSE, AVX, AVX2, AVX-512, and the 16-wide Intel® Xeon Phi™ processor vector instructions. The code represents a typical ray tracing rendering pipeline used throughout DCC to show comparative performance on different types of hardware.

**Results:** Up to 1.92X improved compared to NVIDIA Tesla P100*.
The Vienna Ab initio Simulation Package (VASP) is a computer program for atomic scale materials modeling and performs electronic structure calculations and quantum-mechanical molecular dynamics from first principles.

**Application:** Vienna Ab initio Simulation Package (VASP)

**Code:** [Available here](#)  **Recipe:** Check for future availability [here](#)

**Value Proposition:** VASP provides scientists with fast and precise calculation of materials properties thus it is widely used and consumes up to 25% of supercomputers' time worldwide¹. Intel® Xeon Phi™ processor 7250 enables VASP to outperform alternatives for some workloads and to improve energy efficiency.

**Results:** Intel® Xeon Phi™ processor 7250 performs up to 1.67X better compared to NVIDIA Tesla P100*.

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1. Intel® Xeon Phi™ processor 7250 enables VASP to outperform alternatives for some workloads and to improve energy efficiency.
The Vienna Ab initio Simulation Package (VASP) is a computer program for atomic scale materials modeling and performs electronic structure calculations and quantum-mechanical molecular dynamics from first principles.

**Application:** Vienna Ab initio Simulation Package (VASP)

**Code:** [Available here](#)  **Recipe:** Check for future availability [here](#)

**Value Proposition:** VASP provides scientists with fast and precise calculation of materials properties thus it is widely used and consumes up to 25% of supercomputers time worldwide⁴. Intel® Xeon Phi™ processor 7250 enables VASP to outperform alternatives for some workloads and to improve energy efficiency.

**Results:** Intel® Xeon Phi™ processor 7250 running VASP workloads performs competitively with the new Intel® Xeon® Gold 6148 processor.
The Vienna Ab initio Simulation Package (VASP) is a computer program for atomic scale materials modeling and performs electronic structure calculations and quantum-mechanical molecular dynamics from first principles.

**Application:** Vienna Ab initio Simulation Package (VASP)

**Code:** [Available here](#)  **Recipe:** See configuration details. Also, check for future availability [here](#)

**Value Proposition:** VASP provides scientists with fast and precise calculation of materials properties thus it is widely used and consumes up to 25% of supercomputers time worldwide\(^1\). Intel® Xeon Phi™ processor 7250 enables VASP to outperform alternatives for some workloads and to improve energy efficiency.

**Results:** Up to 1.82X improved performance, and an average workload speedup of 1.43X, compared to the NVIDIA Tesla K80*

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\(^1\)Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to [http://www.intel.com/performance](http://www.intel.com/performance). *Other names and brands may be claimed as the property of others.

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**VASP* Performance Improvement with the Intel® Xeon Phi™ Processor Compared to NVIDIA GPU**

- **Loop time (seconds) - LOWER IS BETTER**
- **Average workload speedup of 1.43X**

<table>
<thead>
<tr>
<th>Material</th>
<th>Loop time (seconds)</th>
<th>2S Intel® Xeon® processor E5-2697 v4 + NVIDIA Tesla K80*</th>
<th>Intel® Xeon Phi™ processor 7520 w/Intel® OPA (68 cores)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pd02</td>
<td>51.98</td>
<td>38.25</td>
<td>up to 1.82X faster</td>
</tr>
<tr>
<td>Pd04</td>
<td>144.90</td>
<td>98.44</td>
<td>914.88</td>
</tr>
<tr>
<td>B.hR105</td>
<td>102.49</td>
<td>83.27</td>
<td>320.85</td>
</tr>
<tr>
<td>GaAsBi-64</td>
<td>102.44</td>
<td>58.03</td>
<td>286.18</td>
</tr>
<tr>
<td>CuC</td>
<td>1668.15</td>
<td>2340</td>
<td>1668.15</td>
</tr>
<tr>
<td>Si256</td>
<td>1668.15</td>
<td>1668.15</td>
<td>1668.15</td>
</tr>
</tbody>
</table>

**Source:** Intel MEASURED RESULTS AS OF AUGUST 2016

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**See Configuration Details Section, slide 160.**
**VASP**

The Vienna Ab initio Simulation Package (VASP) is a computer program for atomic scale materials modeling and performs electronic structure calculations and quantum-mechanical molecular dynamics from first principles.

**Application:** Vienna Ab initio Simulation Package (VASP)

**Code:** [Available here](#)  **Recipe:** See configuration details. Also, check for future availability [here](#)

**Power Data:** Total system wall power is measured out-of-band over iPMI interface, polling the BMC chip every half second. Energy usage is matched to internally timed code segment to arrive at performance-per-watt estimate.

**Value Proposition:** VASP provides scientists with fast and precise calculation of materials properties thus it is widely used and consumes up to 25% of supercomputers time worldwide¹. Intel® Xeon Phi™ processor 7250 enables VASP to outperform alternatives for some workloads and to improve energy efficiency.

**Results:** Intel® Xeon Phi™ processor 7250 running VASP workloads consumes up to 2.72X less energy compared to NVIDIA Tesla K80*.

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See Configuration Details Section, slide 160.

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**INTEL EMBREE v2.13**

**Embree** is a collection of high-performance ray tracing kernels, developed at Intel. The target user of Embree are graphics application engineers that want to improve the performance of their application by leveraging the optimized ray tracing kernels of Embree. Embree supports runtime code selection to choose the traversal and build algorithms that best matches the instruction set of the CPU.

**Application:** Path tracer renderer using Embree v2.13, ICC 2016 Update 1, Intel® SPMD program compiler (Intel® ISPC) 1.9.1, and OptiX* RT libraries.

**Code:** Available here  Recipe: Available here

**Value Proposition:** The kernels are optimized for photo-realistic rendering on the latest Intel® processors with support for SSE, AVX, AVX2, AVX-512, and the 16-wide Intel® Xeon Phi™ processor vector instructions. The code represents a typical ray tracing rendering pipeline used throughout DCC to show comparative performance on different types of hardware.

**Results:** Up to 2.59X improved compared to NVIDIA Titan X*.

---

**Embree Frames Per Second Performance Improvement with the Intel® Xeon Phi™ Processor**

<table>
<thead>
<tr>
<th>Scene</th>
<th>Frames per Second</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bentley (2.3M Tris)</td>
<td>35.5</td>
<td></td>
</tr>
<tr>
<td>Crown (4.8M Tris)</td>
<td>39.4</td>
<td></td>
</tr>
<tr>
<td>Dragon (7.4M Tris)</td>
<td>47</td>
<td>2.59X</td>
</tr>
<tr>
<td>Karst Fl. Flow (8.4M Tris)</td>
<td>20.4</td>
<td></td>
</tr>
<tr>
<td>Power Plant (12.8M Tris)</td>
<td>11.9</td>
<td></td>
</tr>
</tbody>
</table>

Up to 2.59X faster

**Frames per Second — Higher is Better**

*Source: Intel measured results as of June, 2016*

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Embree is a collection of high-performance ray tracing kernels, developed at Intel. The target user of Embree are graphics application engineers that want to improve the performance of their application by leveraging the optimized ray tracing kernels of Embree. Embree supports runtime code selection to choose the traversal and build algorithms that best matches the instruction set of the CPU.

**Application:** Path tracer renderer using Embree v2.13, Intel® C++ Compiler 17.0 and NVIDIA* OptiX* Prime 4.0.2, CUDA* 8.0.44.

**Code:** Available here  Recipe: Available here

**Value Proposition:** The kernels are optimized for photo-realistic rendering on the latest Intel® processors with support for SSE, AVX, AVX2, AVX-512, and the 16-wide Intel® Xeon Phi™ processor vector instructions. The code represents a typical ray tracing rendering pipeline used throughout DCC to show comparative performance on different types of hardware.

**Results:** Up to 1.48X improved compared to the NVIDIA Titan X*.

---

**Frames per Second – 1024 x 1024 Resolution**

<table>
<thead>
<tr>
<th></th>
<th>Frames per Second</th>
<th>Performance Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mazda (5.7M Tris)</td>
<td>113.9</td>
<td>Up to 1.48X faster</td>
</tr>
<tr>
<td>Villa (37.7M Tris)</td>
<td>83.78</td>
<td></td>
</tr>
<tr>
<td>Art Deco (10.7M Tris)</td>
<td>44.31</td>
<td></td>
</tr>
<tr>
<td>San Miguel (10.5M Tris)</td>
<td>49.6</td>
<td></td>
</tr>
</tbody>
</table>

**Source:** Intel measured results as of June, 2016

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance  *Other names and brands may be claimed as the property of others
MONTE CARLO EUROPEAN OPTIONS BENCHMARK*

Industrial standard benchmark that uses Monte Carlo method for pricing European call options. It pre-generates random numbers then uses them in all options pricing processes. Used by all financial firms to price derivatives with multiple dimensions. Uses the stock price, strike price and time as input streams then creates a call output stream.

Application: Monte Carlo European Options
Code and Recipe: Available here

Value Proposition:
- Foundation of Financial derivatives pricing
- Widely used all over financial libraries
- EMU benefits transcendental functions

Results: Up to 2.72X improved Double Precision performance compared to the NVIDIA Tesla K80*.

See Configuration Details Section, slide 160.

Image Source: US gov.

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**Monte Carlo European Options Benchmark**

*Industrial standard benchmark that uses Monte Carlo method for pricing European call options. It pre-generates random numbers then uses them in all options pricing processes. Used by all financial firms to price derivatives with multiple dimensions. Uses the stock price, strike price and time as input streams then creates a call output stream.*

**Application:** Monte Carlo European Options

**Code and Recipe:** [Available here](#)

**Value Proposition:**
- Improved performance/watt for single and double precision
- Foundation of Financial derivatives pricing
- EMU benefits transcendental functions

**Results:** Up to 2.75X improved Double Precision performance/watt compared to the NVIDIA Tesla K80* (double precision).

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**Monte Carlo European Options Performance/Watt Improvement with the Intel® Xeon Phi™ Processor**

- **Single Precision Perf./Watt**:
  - Avg Power: 350 Watts
  - Avg Power: 358 Watts
  - **up to 1.4X better**

- **Double Precision Perf./Watt**:
  - Avg Power: 355 Watts
  - Avg Power: 358 Watts
  - **up to 2.75X better**

**Power measurement:** CPU and MEMORY

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See Configuration Details Section, slide 160. SOURCE: INTEL MEASURED RESULTS AS OF JUNE, 2016

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Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to [http://www.intel.com/performance](http://www.intel.com/performance) *Other names and brands may be claimed as the property of others*
Black-Scholes Benchmark

Industrial standard benchmark that calculates call and put option price using the Black-Scholes-Merton Formula. Used by all financial firms to price derivatives with multiple dimensions. Stock price, strike price and time are input streams that create call and put as output streams.

Application: Black-Scholes formula

Code and Recipe: Available here

Value Proposition:
- Foundation of financial derivatives pricing
- Widely used all over financial libraries
- Performance enhanced by Intel® Advanced Vector Extensions 512 (Intel® AVX-512) and MCDRAM

Results: Up to 2X improved Double Precision compared to the NVIDIA Tesla K80.*

Images Source: US gov

See Configuration Details Section, slide 160.
**STAC-A2** Benchmark

**The STAC-A2 Benchmark suite is the industry standard created by the financial community to test technology stacks used for compute-intensive analytic workloads involved in pricing and risk management.**

**Application:** Intel Composer XE STAC Pack Rev. H

**Code:** [Available here](#)  **Recipe:** [Available here](#)

**Value Proposition:**
- The Intel Xeon Phi processor based-system takes up 1/8th the space (0.5U vs 4U) than the IBM Power8* based-system
- Performance enhanced by Intel® AVX512 and MCDRAM

**Baseline problem size results:** The Intel® Xeon Phi™ 7250 processor system is up to 1.52X faster in Cold runs, up to 1.3X faster than next competitor (NVIDIA K80® system) in warm runs, and is up to 2X more power efficient (not in chart), and is up to 5.7X more space efficient compared to the IBM Power8 system.

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**See Configuration Details Section, slide 160.**

**SOURCE:** STAC® AUDITED RESULTS AS OF MAY 2016

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The STAC-A2 Benchmark suite is the industry standard created by the financial community to test technology stacks used for compute-intensive analytic workloads involved in pricing and risk management.

Application: Intel Composer XE STAC Pack Rev. H
Code: Available here  Recipe: Available here

Value Proposition:
- The Intel Xeon Phi processor based-system takes up 1/8th the space (0.5U vs 4U) than the IBM Power8* based-system
- Performance enhanced by Intel® AVX512 and MCDRAM

Baseline problem size results: The Intel® Xeon Phi™ 7250 processor system is up to 1.88X faster in warm runs compared to NVIDIA K80* system) in warm runs, is up to 2X more power efficient (not in chart), and is up to 2X more power efficient (not in chart), and is up to 5.7X more space efficient compared to the IBM Power8 system.

STAC-A2 Benchmark Performance Improvement with the Intel® Xeon Phi™ Processor

<table>
<thead>
<tr>
<th>Benchmark</th>
<th>IBM POWER8*</th>
<th>NVIDIA Tesla K80* + 2S Intel® Xeon® processor E5-2690 v2</th>
<th>Intel® Xeon Phi™ processor 7250 (68 cores)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAC-A2,β2,GREEKS.5-25k-252.TIME</td>
<td>0.65</td>
<td>0.72</td>
<td>1</td>
</tr>
<tr>
<td>STAC-A2,β2,GREEKS.10-100k-1260.TIME</td>
<td>0.93</td>
<td>0.53</td>
<td>1</td>
</tr>
</tbody>
</table>

Higher is better

SSLAR FOOTPRINT

Image Source: Intel

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance

*Other names and brands may be claimed as the property of others
Binomial Options Pricing Benchmark

Binomial Tree Option pricing method is an industrial standard benchmark that calculates call option prices. Used by financial firms especially for options that involve early exercise clause. Uses stock price, strike price and time as input streams, then creates a call output stream.

**Application:** Binomial Tree Option Pricing

**Code and Recipe:** Check for availability [here](#).

**Value Proposition:**
- Foundation of Financial derivatives pricing
- Widely used by all financial libraries
- Unaligned penalty favors Intel® architecture

**Results:** Up to 1.06X improved Single Precision performance and performance/watt compared to the NVIDIA Tesla K80*.

---

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to [http://www.intel.com/performance](http://www.intel.com/performance) *Other names and brands may be claimed as the property of others.

**Image Source:** Science Direct

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See Configuration Details Section, slide 160.

SOURCE: INTEL MEASURED RESULTS AS OF JUNE, 2016
### Linear Scaling (LS) Density Function Theory (DFT)

**CP2K** is a powerful and scalable program for atomistic simulations of a wide range of systems, including condensed phase, molecular systems and complex interfaces. CP2K features a wide range of atomistic interaction models including classical potentials, semi-empirical schemes, Density Functional Theory (DFT), Hartree-Fock (HF), and post-HF correlation methods such as MP2 and RPA. The program was a Gordon Bell Finalist in 2015. CP2K is freely available.

**Application:** CP2K Quantum Chemistry & Solid State Physics Software Package

**Code:** Available Here  **Recipe:** Check for availability [here](#)

**Value Proposition:** CP2K optionally uses Intel’s Open Source Library for small BLAS operations (matrix multiplications) called LIBXSMM, which enables BLAS extensions on a drop-in basis, and automatically targets Intel® AVX, Intel® AVX2 and Intel® AVX-512 through future-proof just-in-time compilation techniques. LIBXSMM is also used in other scientific Open Source packages such as *SeisSol* and *Nek5000/NekBox*.

**Results:** Up to 2.4X faster with the 2x Intel® Xeon Phi™ processor 7250 compared to the Tesla K80.

---

**Bar Chart:**

<table>
<thead>
<tr>
<th>Workload</th>
<th>SCF Calculation Time (s)</th>
<th>Lower is Better</th>
</tr>
</thead>
<tbody>
<tr>
<td>2S Xeon 2697 v4 + Tesla® K80</td>
<td>534</td>
<td>1.3X faster</td>
</tr>
<tr>
<td>Xeon Phi 7250 LIBXSMM</td>
<td>372</td>
<td></td>
</tr>
<tr>
<td>2S Xeon 2697 v4 + 2x Tesla K80</td>
<td>305</td>
<td>2.4X faster</td>
</tr>
<tr>
<td>2x Xeon Phi 7250 LIBXSMM</td>
<td>198</td>
<td></td>
</tr>
</tbody>
</table>

- **Material Sciences**
- **CP2K**
- **LIBXSMM**
- **See Configuration Details Section, slide 160**
- **SOURCE: INTEL MEASURED RESULTS AS OF MAY, 2016**

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to [http://www.intel.com/performance](http://www.intel.com/performance) *Other names and brands may be claimed as the property of others*
CP2K is a powerful and scalable program for atomistic simulations of a wide range of systems, including condensed phase, molecular systems and complex interfaces. CP2K features a wide range of atomistic interaction models including classical potentials, semi-empirical schemes, Density Functional Theory (DFT), Hartree-Fock (HF), and post-HF correlation methods such as MP2 and RPA. The program was a Gordon Bell Finalist in 2015. CP2K is freely available.

**Application:** CP2K Quantum Chemistry & Solid State Physics Software Package

**Code:** Available Here  **Recipe:** Check for availability here

**Value Proposition:** CP2K optionally uses Intel’s Open Source Library for small BLAS operations (matrix multiplications) called LIBXSMM, which enables BLAS extensions on a drop-in basis, and automatically targets Intel® AVX, Intel® AVX2 and Intel® AVX-512 through future-proof just-in-time compilation techniques. LIBXSMM is also used in other scientific Open Source packages such as SeisSol and Nek5000/NekBox.

**Results:** Up to 2.4X faster with the Intel® Xeon Phi™ processor 7250 compared to NVIDIA K80, and up to 1.45X faster compared to 2 NVIDIA K40s.
Physics - QCD

The MILC Code is used to study quantum chromodynamics (QCD), the theory of the strong interactions of subatomic physics and is written by the MIMD Lattice Computation (MILC) collaboration.

Application: Trinity MILC provided by NERSC as part of Trinity8 suite

Code: Original NERSC Benchmark code is [here](#); contact Intel for Optimized Code

Recipe: Check for availability [here](#)

Value Proposition:
- MILC is widely deployed on numerous supercomputers and 2nd most used application at US DOE's National Energy Research Scientific Computing Center (NERSC)
- Intel's optimizations are being incorporated into mainline by MILC collaboration

Results: The Intel® Xeon Phi™ processor 7250 improved performance by up to 2.04X compared to the Intel® Xeon® processor E5-2697 v4 + NVIDIA K40.

Image Credit: Brookhaven Lab (BNL)

See Configuration Details Section, slide 160.
**Physics - QCD**

The **MILC Code** is used to study quantum chromodynamics (QCD), the theory of the strong interactions of subatomic physics and is written by the **MIMD Lattice Computation (MILC)** collaboration.

**Application:** Trinity MILC provided by NERSC as part of Trinity8 suite

**Code:** Original NERSC Benchmark code is [here](#); contact Intel for Optimized Code

**Recipe:** Check for availability [here](#)

**Value Proposition:**
- MILC is widely deployed on numerous supercomputers and 2nd most used application at US DOE's National Energy Research Scientific Computing Center (NERSC)
- Intel's optimizations are being incorporated into mainline by MILC collaboration

**Results:** The Intel® Xeon™ Phi™ processor 7250 improved performance by up to 1.58X compared to the Intel® Xeon® processor E5-2697 v4 & NVIDIA Titan X.

---

**Trinity MILC Performance Improvement with the Intel® Xeon Phi™ Processor**

1096

692

**up to 1.58X faster**

![Image Credit: Brookhaven Lab (BNL)](source)

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to [http://www.intel.com/performance](http://www.intel.com/performance)  *Other names and brands may be claimed as the property of others*
QPhiX is an optimized solver library for QCD on Intel® Xeon® and Intel® Xeon Phi™ processors and provides implementation for Dslash operator and CG, BICGStab and mixed precision solvers for Wilson and Clover improved Wilson Quarks.

Application: QPhiX Test Benchmark (time_dslash_noqdp), QUDA* (NVIDIA*)

Code: https://github.com/JeffersonLab/qphix

Recipe: Follow the instructions in the download package.

Value Proposition:
- Lattice calculations are an important component of the nuclear physics research.
- QPhiX helps speed up the computation by multiple folds on Intel processors.
- Intel® Xeon Phi™ processor further improves performance with features such as high bandwidth memory (MCDRAM) and Intel® AVX-512 vector instruction set architecture.

Results: Up to 1.05X improved performance compared to QUDA on an NVIDIA* Titan X* GPU.

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance

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

See Configuration Details Section, slide 160.
Data scientists, developers, and researchers gain insights previously out of reach.

MACHINE LEARNING
MACHINE LEARNING PERFORMANCE SUMMARY

Intel® Xeon Phi™ Processor Family

- Proven scaling proven at up to 128-nodes delivering 50x faster training\(^1\)
- Up to 38% better scaling efficiency compared to NVIDIA*\(^2\)
- Software improvements driving up to 30 times faster classification\(^3\)

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more complete information visit http://www.intel.com/performance. Configurations 1.) see slide 52; 2.) see slide 53; 3.) see slide 54.
Train up to 50x faster with Intel® Xeon Phi™ Processor

Deep Learning Image Classification Training Performance – MULTI-NODE Scaling

<table>
<thead>
<tr>
<th>Nodes</th>
<th>Normalized Training Time – Higher is better</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.0x</td>
</tr>
<tr>
<td>2</td>
<td>1.9x</td>
</tr>
<tr>
<td>4</td>
<td>3.7x</td>
</tr>
<tr>
<td>8</td>
<td>6.6x</td>
</tr>
<tr>
<td>16</td>
<td>12.8x</td>
</tr>
<tr>
<td>32</td>
<td>23.5x</td>
</tr>
<tr>
<td>64</td>
<td>33.7x</td>
</tr>
<tr>
<td>128</td>
<td>52.2x</td>
</tr>
</tbody>
</table>

Topology: AlexNet*

Dataset: Large image database

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Better Scaling Efficiency: Intel® Xeon Phi™ Processor

Deep Learning Image Classification Training Performance - MULTI-NODE Scaling

Up to 38% better scaling

32 NVIDIA Tesla* GPUs

Dataset: Large image database  # of Intel® Xeon Phi™ Processor 7250 (68-cores, 1.4 GHz, 16 GB) NODES

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*Other names and brands may be property of others
**CASE STUDY:**

**LeTV* CLOUD ILLEGAL VIDEO DETECTION**

Up to 30X faster classification by optimizing software

- LeTV Cloud (www.lecloud.com) is a leading video cloud provider in China
- LeTV Cloud provides illegal video detection service to 3rd party video cloud customers to help them detect illegal videos
- Originally, LeTV adopted open source BVLC Caffe plus OpenBlas as CNN framework, but the performance was poor
- By using Caffe + Intel MKL, they gained up to 30x performance improvement on training in production environment

LeTV Cloud Illegal Video Detection Process Flow

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KNN (K-NEAREST NEIGHBOR) – SCALABLE CLASSIFICATION

State-of-the-Art Single Node Performance and Near-Linear Scaling

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. NVIDIA* results are taken from [1] below.

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance. Configurations (more details see slide 156): Intel® Xeon Phi™ processor 7250 (68 Cores, 1.4 GHz, 16GB), 96GB memory, Red Hat* Enterprise Linux 6.6 vs. hosted NVIDIA Titan Z


*Other names and brands may be property of others
WORD2VEC*: UP TO 1.4X HIGHER THROUGHPUT VS. NVIDIA*

State-of-the-Art Single Node and Multi-Node Performance Scalability Efficiency

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. NVIDIA results are taken from [1] below.

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance.


*Other names and brands may be property of others
Improving financial outcomes through faster simulations

FINANCIAL SERVICES
INTEL XEON® PHI™ PROCESSOR FINANCIAL SERVICES APPLICATIONS PERFORMANCE

Tested and proven performance¹ for the most important Financial Services applications, with an average software performance improvement with the Intel Xeon Phi processor 7250 of 3.45X, an average performance/watt improvement of up to 4X, and an average performance improvement over NVIDIA* of up to 1.64X.

- **BAW AMERICAN OPTIONS**: Up to 6.48X
- **MONTE CARLO**: Up to 7.87X performance/watt
- **MONTE CARLO**: Up to 4.65X
- **BLACK-SCHOLES**: Up to 3.36X
- **BINOMIAL OPTIONS**: Up to 1.27X, and up to 2.29X performance/watt
- **STAC-A2**: Up to 1.52X faster than IBM*, 1.3X faster than NVIDIA, up to 2X more power efficient and is up to 5.7X more space efficient compared to the IBM Power8* system (see the GPU comparative section above)

1 - Performance is the Intel Xeon® Phi™ Processor 7250 compared to the Intel® Xeon® processor E5-2697 v4

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BAW American options Approximation Performance Improvement with the Intel® Xeon Phi™ Processor

**BAW AMERICAN OPTIONS APPROXIMATION BENCHMARK**

Popular analytical method of pricing exchange-traded American options using quadratic approximation. Uses an underlying asset and carrying cost rate as key inputs and prices commodity options, futures and foreign exchange options, precious metals, long-terms debt and stock indexes with continuous dividend yields. Uses the stock price, strike price and time as input streams and creates a call output stream.

**Application:** Barone-Adesi and Whaley (BAW) American Options Approximation

**Code and Recipe:** Available here

**Value Proposition:**
- Foundation of Financial derivatives pricing
- Widely used all over financial libraries
- EMU benefits transcendental functions

**Results:** Up to 6.48X improved Single Precision performance compared to the Intel® Xeon® processor E5-2697 v4.

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Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance *Other names and brands may be claimed as the property of others
Monte Carlo European Options Performance Improvement with the Intel® Xeon Phi™ Processor

- **Single Precision**: 818874.97
- **Double Precision**: 443122.83

- **Up to 4.25X faster**
- **Up to 4.65X faster**

**Industrial standard benchmark that uses Monte Carlo method for pricing European call options. It pre-generates random numbers then uses them in all options pricing processes. Used by all financial firms to price derivatives with multiple dimensions. Uses the stock price, strike price and time as input streams then creates a call output stream.**

**Application:** Monte Carlo European Options

**Code and Recipe:** Available here

**Value Proposition:**
- Foundation of Financial derivatives pricing
- Widely used all over financial libraries
- EMU benefits transcendental functions

**Results:** Up to 4.65X improved Double Precision performance compared to the Intel® Xeon® processor E5-2697 v4.

See Configuration Details Section, slide 160. SOURCE: INTEL MEASURED RESULTS AS OF JUNE, 2016

Image Source: US gov.
MONTE CARLO EUROPEAN OPTIONS BENCHMARK*

Industrial standard benchmark that uses Monte Carlo method for pricing European call options. It pre-generates random numbers then uses them in all options pricing processes. Used by all financial firms to price derivatives with multiple dimensions. Uses the stock price, strike price and time as input streams then creates a call output stream.

**Application:** Monte Carlo European Options

**Code and Recipe:** Available here

**Value Proposition:**
- Improved performance/watt for single and double precision
- Foundation of Financial derivatives pricing
- EMU benefits transcendental functions

**Results:** Up to 7.87X improved Double Precision performance/watt compared to the Intel® Xeon® processor E5-2697 v4.

See Configuration Details Section, slide 160.

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance *Other names and brands may be claimed as the property of others
Black-Scholes Benchmark*

Industrial standard benchmark that calculates call and put option price using the Black-Scholes-Merton Formula. Used by all financial firms to price derivatives with multiple dimensions. Stock price, strike price and time are input streams that create call and put as output streams.

Application: Black-Scholes formula

Code and Recipe: Available here

Value Proposition:
- Foundation of financial derivatives pricing
- Widely used all over financial libraries
- Performance enhanced by Intel® Advanced Vector Extensions 512 (Intel® AVX-512) and MCDRAM

Results: Up to 3.39X improved Double Precision compared to the Intel® Xeon® processor E5-2697 v4.

See Configuration Details Section, slide 160. SOURCE: INTEL MEASURED RESULTS AS OF MAY, 2016

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance *Other names and brands may be claimed as the property of others
**Black-Scholes Benchmark**

**Industrial standard benchmark that calculates call and put option price using the Black-Scholes-Merton Formula. Used by all financial firms to price derivatives with multiple dimensions. Stock price, strike price and time are input streams that create call and put as output streams.**

**Application:** Black-Scholes formula

**Code and Recipe:** Available here

**Value Proposition:**
- Foundation of financial derivatives pricing
- Widely used all over financial libraries
- Performance enhanced by Intel® Advanced Vector Extensions 512 (Intel® AVX-512) and MCDRAM

**Results:** Up to 5.72X improved performance/watt compared to the Intel® Xeon® processor E5-2697 v4.

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Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance *Other names and brands may be claimed as the property of others*
Financial Services

**BINOMIAL OPTIONS PRICING BENCHMARK**

Binomial Tree Option pricing method is an industrial standard benchmark that calculates call option prices. Used by financial firms especially for options that involve early exercise clause. Uses stock price, strike price and time as input streams, then creates a call output stream.

**Application:** Binomial Tree Option Pricing

**Code and Recipe:** Check for availability [here](#)

**Value Proposition:**
- Foundation of Financial derivatives pricing
- Widely used by all financial libraries
- Unaligned penalty favors Intel® architecture

**Results:** Up to 1.27X improved performance compared to Intel® Xeon® processor E5-2697 v4.

---

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance *Other names and brands may be claimed as the property of others.

See Configuration Details Section, slide 160. SOURCE: INTEL MEASURED RESULTS AS OF JUNE, 2016
Binomial Options Pricing Benchmark*  

**Binomial Tree Option pricing method is an industrial standard benchmark that calculates call option prices. Used by financial firms especially for options that involve early exercise clause. Uses stock price, strike price and time as input streams, then creates a call output stream.**

**Application:** Binomial Tree Option Pricing  
**Code and Recipe:** Check for availability [here](#)  

**Value Proposition:**  
- Foundation of Financial derivatives pricing  
- Widely used by all financial libraries  
- Unaligned penalty favors Intel® architecture  

**Results:** Up to 2.29X improved performance/watt compared to the Intel® Xeon® processor E5-2697 v4.
Optimizing applications. Accelerating discovery.

LIFE SCIENCES
Life sciences are in the midst of a dramatic transformation as technology redefines what is possible for life as we know it. With Intel® technology, healthcare IT moves faster in everything from sequencing genomes, speeding up molecular dynamics performance workloads, and connecting patience, care teams, and data. The following proof points show tested and proven performance¹ for the most important applications, with an average software performance improvement with the Intel Xeon Phi processor 7250 of up to **1.9X**, and an average performance/watt improvement of up to **2X**.

- **AMBER 16 IMPLICIT**: Up to 3X, and up to 3.46X performance/watt
- **AMBER 16 EXPLICIT**: Up to 1.83X, and up to 2.34X performance/watt
- **NWChem NWPW**: Up to 2.76X
- **ROME/SML**: Up to 2.36X
- **LAMMPS**: Up to 1.43X, and up to 1.75X performance/watt. See the GPU comparative section
- **RELION**: Up to 1.31X, and up to 1.67X performance/watt
- **NAMD**: Up to 1.36X, and up to 1.62X performance/watt
- **GROMACS**: Up to 1.22X, and up to 1.45X performance/watt

¹ - Performance is the Intel Xeon® Phi™ Processor 7250 compared to the Intel® Xeon® processor E5-2697 v4

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance *Other names and brands may be claimed as the property of others
**AMBER16* GENERALIZED BORN (IMPLICIT SOLVENT)**

Amber* is a bio related simulation code for DNA, RNA, protein, and other bio-molecules. Amber has two solvers: Particle Mesh Ewald (PME), known as Explicit, and Generalized Born (GB), known as Implicit. Amber is written in Fortran 90 and is mainly MPI*, OpenMP* and Vectorization parallelized.

**Application:** Amber 16 PMEMD Implicit

**Code:** In main Amber GIT repository. **Recipe:** [http://ambermd.org/intel](http://ambermd.org/intel)

**Value Proposition:** This application provides users with a research tool for investigating code modernization approach for bio-molecular dynamics applications.

**Results:** Up to 3X improved performance compared to the Intel® Xeon® processor E5-2697 v4 for the 2w49 125K atoms workload.

Images Source: Intel

---

**SOURCE:** INTEL MEASURED RESULTS AS OF NOVEMBER 2016

---

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to [http://www.intel.com/performance](http://www.intel.com/performance) *Other names and brands may be claimed as the property of others*
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Amber* is a bio related simulation code for DNA, RNA, protein, and other bio-molecules. Amber has two solvers: Particle Mesh Ewald (PME), known as Explicit, and Generalized Born (GB), known as Implicit. Amber is written in Fortran 90 and is mainly MPI*, OpenMP* and Vectorization parallelized.

Application: Amber 16 PMEMD Implicit

Code: In main Amber GIT repository. Recipe: [http://ambermd.org/intel](http://ambermd.org/intel)

---

**Value Proposition:** This application provides users with a research tool for investigating code modernization approach for Bio-molecular dynamics applications.

**Results:** Up to 1.8X improved performance at 2 nodes compared to the Intel® Xeon® processor E5-2697 v4 for the Rubisco 75K workload; ave. speedup for each cluster is 1.73X.

Images Source: Intel

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to [http://www.intel.com/performance](http://www.intel.com/performance)

*Other names and brands may be claimed as the property of others.
**AMBER16* GENERALIZED BORN (IMPLICIT SOLVENT)**

*Amber* is a bio related simulation code for DNA, RNA, protein, and other bio-molecules. Amber has two solvers: Particle Mesh Ewald (PME), known as Explicit, and Generalized Born (GB), known as Implicit. Amber is written in Fortran 90 and is mainly MPI*, OpenMP* and Vectorization parallelized.

**Application:** Amber 16 PMEMD Implicit

**Code:** In main Amber GIT repository. **Recipe:** [http://ambermd.org/intel](http://ambermd.org/intel)

**Value Proposition:** This application provides users with a research tool for investigating code modernization approach for bio-molecular dynamics applications.

**Results:** Up to 3.46X improved performance/watt for the largest workload compared to the Intel® Xeon® processor E5-2697 v4.

---

**Images Source:** Intel

See Configuration Details Section, slide 160. SOURCE: INTEL MEASURED RESULTS AS OF NOVEMBER 2016
**AMBER16* PME (EXPLICIT SOLVENT)**

*Amber* is a bio related simulation code for DNA, RNA, protein, and other bio-molecules. *Amber* has two solvers: Particle Mesh Ewald (PME), known as Explicit, and Generalized Born (GB), known as Implicit. *Amber* is written in Fortran 90 and is mainly MPI*, OpenMP* and Vectorization parallelized.

**Application:** Amber 16 PMEMD Explicit  
**Code:** In main Amber GIT repository.  
**Recipe:** [http://ambermd.org/intel](http://ambermd.org/intel)

**Value Proposition:** This application provides users with a research tool for investigating code modernization approach for Bio–molecular dynamics applications. The Intel® Xeon Phi™ processor is best suited for larger problem sizes.

**Results:** Up to 1.83X improved performance compared to the Intel® Xeon® processor E5-2697 v4 for the Poliovirus 4M atoms workload.

Images Source: Intel

---

**Source:** INTEL MEASURED RESULTS AS OF APRIL 2016

---

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to [http://www.intel.com/performance](http://www.intel.com/performance)  
*Other names and brands may be claimed as the property of others.*

See Configuration Details Section, slide 160.
Amber* is a bio related simulation code for DNA, RNA, protein, and other bio-molecules. Amber has two solvers: Particle Mesh Ewald (PME), known as Explicit, and Generalized Born (GB), known as Implicit. Amber is written in Fortran 90 and is mainly MPI*, OpenMP* and Vectorization parallelized.

Application: Amber 16 PMEMD Explicit
Code: In main Amber GIT repository. Recipe: [http://ambermd.org/intel](http://ambermd.org/intel)

Value Proposition: This application provides users with a research tool for investigating code modernization approach for Bio-molecular dynamics applications. The Intel® Xeon Phi™ processor is best suited for larger problem sizes.

Results: Up to 1.15X improved performance compared to the Intel® Xeon® processor E5-2697 v4.

Images Source: Intel
**AMBER16* PME (EXPLICIT SOLVENT)**

Amber* is a bio related simulation code for DNA, RNA, protein, and other bio-molecules. Amber has two solvers: Particle Mesh Ewald (PME), known as Explicit, and Generalized Born (GB), known as Implicit. Amber is written in Fortran 90 and is mainly MPI*, OpenMP* and Vectorization parallelized.

**Application:** Amber 16 PMEMD Explicit  
**Code:** In main Amber GIT repository.  
**Recipe:** [http://ambermd.org/intel](http://ambermd.org/intel)

**Value Proposition:** This application provides users with a research tool for investigating code modernization approach for Bio-molecular dynamics applications. The Intel® Xeon Phi™ processor is best suited for larger problem sizes.

**Results:** Up to 2.34X improved performance/watt compared to the Intel® Xeon® processor E5-2697 v4 for the Poliovirus 4M atoms workload.

---

**Normalized Speedup - Higher is Better**

<table>
<thead>
<tr>
<th>Workload</th>
<th>Performance improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellulose NVE 408K</td>
<td>1.35</td>
</tr>
<tr>
<td>Tobacco Virus 1M</td>
<td>1.43</td>
</tr>
<tr>
<td>Poliovirus 4M Atoms</td>
<td>2.34</td>
</tr>
</tbody>
</table>

**Energy Efficiency**

- Performance improves with larger (atoms) workloads
- up to 2.34X

**Images Source:** Intel

---

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to [http://www.intel.com/performance](http://www.intel.com/performance) *Other names and brands may be claimed as the property of others*
NWChem NWPW AIMD Simulation

NWChem is a computational chemistry software package which also includes quantum chemical and molecular dynamics functionality. It was designed to run on high-performance parallel supercomputers as well as conventional workstation clusters. It aims to be scalable both in its ability to treat large problems efficiently, and in its usage of available parallel computing resources.

Application: Ab-initio molecular dynamics simulation (NWChem NWPW), water128 benchmark


Value Proposition: Intel continues to advance the capabilities of HW and SW necessary for scientists to solve new and more complex problems that could not previously be achieved. The Intel® Xeon Phi™ processor improves power-efficient performance for scalable workloads..

Results: Up to 2.76X improved performance compared to the Intel® Xeon® processor E5-2697 v4.

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance *Other names and brands may be claimed as the property of others.
ROME (Refinement and Optimization via Machine Learning for cryo-EM) is one of the major research software packages from the Dana-Farber Cancer Institute. ROME is a parallel computing software system dedicated to high-resolution cryo-EM structure determination and data analysis, implementing advanced machine learning approaches optimized for HPC clusters. ROME 1.0 introduces SML (statistical manifold learning)-based deep classification, following MAP-based (maximum a posteriori) image alignment.

Application: ROME/SML

Code and Recipe: Available here

Results: The Intel® Xeon Phi™ processor 7250 improved performance by up to 2.36X compared to the Intel® Xeon® processor E5-2697 v4.


Value Proposition: Intel® Xeon Phi™ processor 7250 enables this application to significantly speed up the deep classification of cryo-EM images and subsequent reconstruction.

Testcase: experimental inflammasome dataset/deep 2d classification.
RELION (REgularised Likelihood Optimisation) is a stand-alone computer program that employs an empirical Bayesian approach to refinement of 3D reconstructions or 2D class averages in Cryo-EM.

Application: RELION 1.4  
Code and Recipe: Available here


Value Proposition:
- This application is based on C++ and uses MPI and pthread for different level parallelisation
- Intel® Xeon Phi™ processor 7250 enables this application to significantly speed up image processing

Results: Up to 1.31X improved performance compared to the Intel® Xeon® processor E5-2697 v4.

Testcase: Relion autorefine /5000 particle images processing

Run time (seconds) — LOWER IS BETTER

<table>
<thead>
<tr>
<th>Processor Model</th>
<th>Runtime (seconds)</th>
<th>Performance Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>2S Intel® Xeon® processor E5-2697 v4 (36 cores)</td>
<td>1035</td>
<td>1.23X Faster</td>
</tr>
<tr>
<td>Intel® Xeon Phi™ processor 7210 (64 cores)</td>
<td>840</td>
<td>Up to 1.23X Faster</td>
</tr>
<tr>
<td>Intel® Xeon Phi™ processor 7250 (68 cores)</td>
<td>787</td>
<td>Up to 1.31X Faster</td>
</tr>
</tbody>
</table>

SOURCE: INTEL MEASURED RESULTS AS OF APRIL 2016
RELION (REgularised Likelihood OptimisatioN) is a stand-alone computer program that employs an empirical Bayesian approach to refinement of 3D reconstructions or 2D class averages in Cryo-EM.

**Application:** RELION 1.4

**Code and Recipe:** [Available here](http://www.recb.org/)

**Value Proposition:**
- This application is based on C++ and uses MPI and pthread for different level parallelisation
- Intel® Xeon Phi™ processor 7250 enables this application to significantly speed up image processing

**Results:** Up to 1.67X improved performance/watt compared to the Intel® Xeon® processor E5-2697 v4.


---

**Relion Performance/Watt Improvement with the Intel® Xeon Phi™ Processor**

![Graph showing RELION Performance/Watt Improvement with the Intel® Xeon Phi™ Processor.](image_url)

- **AVG Power:**
  - 427 Watts
  - 337 Watts

- **Performance/Watt Ratio:**
  - Up to 1.67X better

**Software and Workloads Used in Performance Tests:**
Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to [http://www.intel.com/performance](http://www.intel.com/performance) *Other names and brands may be claimed as the property of others*
Nanoscale Molecular Dynamics program (NAMD) is a parallel molecular dynamics code designed for high-performance simulation of large biomolecular systems. Based on Charm++ parallel objects, NAMD scales to hundreds of cores for typical simulations and beyond 200,000 cores for the largest simulations.

**Application:** NAMD 2.11  
**Code:** [http://www.ks.uiuc.edu/Research/namd/](http://www.ks.uiuc.edu/Research/namd/)  
**Recipe:** Check for availability [here](http://www.ks.uiuc.edu/Research/namd/)

**Value Proposition:** NAMD is the 2nd most popular MD code. Intel® AVX 512 instructions are used heavily by the Assembler code. Source code performance tuning with intrinsics demonstrates MCDRAM and simultaneous multithreading advantages.

**Results:** Up to 1.24X improved performance compared to the Intel® Xeon® processor E5-2697 v4.

See [Configuration Details Section, slide 160](#). SOURCE: INTEL MEASURED RESULTS AS OF OCTOBER 2016

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to [http://www.intel.com/performance](http://www.intel.com/performance)
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Application: NAMD 2.11
Code: http://www.ks.uiuc.edu/Research/namd/
Recipe: Check for availability here

Value Proposition: NAMD is the 2nd most popular MD code. Intel® AVX 512 instructions are used heavily by the Assembler code. Source code performance tuning with intrinsics demonstrates MCDRAM and simultaneous multithreading advantages.

Results: Up to 1.24X improved performance compared to the Intel® Xeon® processor E5-2697 v4.
Nanoscale Molecular Dynamics program (NAMD) is a parallel molecular dynamics code designed for high-performance simulation of large biomolecular systems. Based on Charm++ parallel objects, NAMD scales to hundreds of cores for typical simulations and beyond 200,000 cores for the largest simulations.

Application: NAMD 2.11
Code: http://www.ks.uiuc.edu/Research/namd/
Recipe: Check for availability here

Value Proposition: NAMD is the 2nd most popular MD code. Intel® AVX 512 instructions are used heavily by the Assembler code. Source code performance tuning with intrinsics demonstrates MCDRAM and simultaneous multithreading advantages.

Results: Up to 3.13X improved performance with Intel® AVX-512 compared to Intel® Xeon® processor 2697 v4 with Intel® AVX2.

Image Source: Use approved by NAMD
Nanoscale Molecular Dynamics program (NAMD) is a parallel molecular dynamics code designed for high-performance simulation of large biomolecular systems. Based on Charm++ parallel objects, NAMD scales to hundreds of cores for typical simulations and beyond 200,000 cores for the largest simulations.

Application: NAMD 2.11
Code: http://www.ks.uiuc.edu/Research/namd/
Recipe: Check for availability here

Power Data: Total system wall power is measured out-of-band over iPMI interface, polling the BMC chip every half second. Energy usage is matched to internally timed code segment to arrive at performance per watt estimate.

Value Proposition: Assembler code makes high use of Intel® AVX 512 instructions. Performance tuning of source code with intrinsics shows advantages such as MCDRAM and simultaneous multithreading.

Results: Up to 1.62X improved energy efficiency compared to the Intel® Xeon® processor E5-2697 v4.
GROMACS (GROningen MAchine for Chemical Simulations) is a versatile package to perform classical Molecular Dynamics simulations. Heavily optimized for most modern platforms and provides extremely high performance compared to all other MD codes.

**Application:** GROMACS

**Code:** Available here

**Recipe:** All optimizations merged in GROMACS 2016 branch, MKL FFT

**Value Proposition:** This application provides users with wide range of functionality for chemical simulations and highest out-of-the-box performance across all MD codes. GROMACS on the Intel® Xeon Phi™ processor outperforms Intel® Xeon® processors for simulating large biochemical systems due to enabling new Intel® Advanced Vector Extensions 512 (Intel® AVX-512) features and enabling enhanced parallelism.

**Results:** Up to 1.22X improved performance compared to the 2S Intel® Xeon® processor E5-2697 v4.
GROMACS* (GROningen MAchine for Chemical Simulations) is a versatile package to perform classical Molecular Dynamics simulations. Heavily optimized for most modern platforms and provides extremely high performance compared to all other MD codes.

**Application:** GROMACS (Intel® AVX-512 speedup)

**Code:** [Available here](#)

**Recipe:** All optimizations merged in GROMACS 2016 branch, MKL FFT

**Value Proposition:** This application provides users with wide range of functionality for chemical simulations and highest out-of-the-box performance across all MD codes. GROMACS on the Intel® Xeon Phi™ processor outperforms Intel® Xeon® processors for simulating large biochemical systems due to enabling new Intel® Advanced Vector Extensions 512 (Intel® AVX-512) features and enabling enhanced parallelism and provides more performance simulations within the same energy envelope.

**Results:** Up to 1.85X improved performance with Intel® Xeon Phi™ processor with Intel® AVX-512 compared to the Intel® Xeon Phi™ processor with Intel® AVX-512

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to [http://www.intel.com/performance](http://www.intel.com/performance) *Other names and brands may be claimed as the property of others*
GROMACS (GROningen MAchine for Chemical Simulations) is a versatile package to perform classical Molecular Dynamics simulations. Heavily optimized for most modern platforms and provides extremely high performance compared to all other MD codes.

**Application:** GROMACS  
**Code:** Available here  
**Recipe:** All optimizations merged in GROMACS 2016 branch, MKL FFT  

**Power Data:** Total system wall power is measured out-of-band over iPMI interface, polling the BMC chip every second. Energy usage is matched to internally timed code segment to arrive at performance per Watt estimate.

**Value Proposition:** This application provides users with wide range of functionality for chemical simulations and highest out-of-the-box performance across all MD codes. GROMACS on the Intel® Xeon Phi™ processor outperforms Intel® Xeon® processors for simulating large biochemical systems due to enabling new Intel® Advanced Vector Extensions 512 (Intel® AVX-512) features and enabling enhanced parallelism and provides more performance simulations within the same energy envelope.

**Results:** Up to 1.45X better energy efficiency compared to the 2S Intel® Xeon® processor E5-2697 v4.

---

**Normalized Perf./Watt**

1. **ENERGY EFFICIENCY** - Higher is Better.

GROMACS Single Node NS/Day Performance/Watt Improvement with the Intel® Xeon Phi™ Processor

- **Intel® Xeon® processor E5-2697 v4** (290W TDP, 36 cores)
- **Intel® Xeon Phi™ processor 7520** (215W TDP, 68 cores)

**Source:** INTEL MEASURED RESULTS AS OF JUNE 2016

---

**Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance. “Other names and brands may be claimed as the property of others.”**
Improving simulations speed and quality.
Where breakthrough performance is expected, the Intel® Xeon Phi™ Processor, a foundational element of the Intel® Scalable System Framework (Intel® SSF), is helping manufacturing software companies take applications and middleware to new levels, with processing power and a familiar programming model for developers. The Intel Xeon Phi processor can help get products to market faster, solve complex problems faster, and power simulations that don’t require physical testing. The following proof points show tested and proven performance\(^1\) for the most important applications, with an average software performance improvement with the Intel Xeon Phi processor 7250 of up to 1.9X.

- **TACC LB3D**: Up to 3.65X
- **OPENFOAM**: Up to 1.9X
- **NASA OVERFLOW**: Up to 1.77X
- **OPENLB**: Up to 1.5X
- **HIFUN**: Up to 1.35X
- **GE TACOMA**: Up to 1.23X

\(^1\) Performance is the Intel Xeon® Phi™ Processor 7250 compared to the Intel® Xeon® processor E5-2697 v4.
**Texas Advanced Computer Center (TACC)*

**LB3D** is a 3D Lattice Boltzmann method kernel developed by Carlos Rosales of Texas Advanced Computer Center (TACC) and used in multiphase flows with applications in the multiphase reactors and separation systems.

**Application:** LB3D (Advanced support for multiphase flows with large density and viscosity ratios)

**Code:** [Available here](#)

**Recipe:** No code changes were required. Recompile with Intel® AVX-512.

**Value Proposition:** LB3D performance on the Intel® Xeon Phi™ Processor 7250 provides better performance, performance density and better energy efficiency than today’s best Intel® Xeon® processor based systems.

**Results:** Up to 3.65X performance improvement with the Intel® Xeon Phi™ processor 7250 compared to the Intel® Xeon® processor E5-2697 v4.

---

**TACC* LB3D Performance Improvement with the Intel® Xeon Phi™ Processor**

<table>
<thead>
<tr>
<th>120x120x120 case</th>
<th>MLUPS – higher is better</th>
</tr>
</thead>
<tbody>
<tr>
<td>2S Intel® Xeon® processor E5-2697 v4 (36 cores)</td>
<td>84</td>
</tr>
<tr>
<td>Intel® Xeon® Phi processor 7250 (68 cores)</td>
<td>322 up to 3.65X faster</td>
</tr>
</tbody>
</table>

**Source:** TACC (Carlos Rosales-Fernandez) April 2016

See Configuration Details Section, slide 160.

Public Presentation: Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance. Other names and brands may be claimed as the property of others.
**OpenFOAM**

OpenFOAM (for "Open source Field Operation And Manipulation") is a C++ toolbox for the development of customized numerical solvers, and pre-/post-processing utilities for the solution of continuum mechanics problems, including computational fluid dynamics (CFD).

**Application:** OpenFOAM

**Code:** [Available here]  **Recipe:** [Available here]

**Optimizations:** [https://github.com/OpenFOAM/OpenFOAM-Intel](https://github.com/OpenFOAM/OpenFOAM-Intel)

**Value Proposition:** Provides an extensive range of features to solve complex fluid flows involving chemical reactions, turbulence and heat transfer, acoustics, solid mechanics and electromagnetics. OpenFOAM on the Intel® Xeon Phi™ processor is great for computational fluid dynamics, structured grid or unstructured mesh.

**Results:** Up to 1.93X faster compared to the 2S Intel® Xeon® processor E5-2697 v4.

---

### OpenFOAM Performance Improvement with the Intel® Xeon Phi™ Processor

<table>
<thead>
<tr>
<th>WORKLOADS</th>
<th>Runtime in Seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>4M Cells</td>
<td>310.83</td>
</tr>
<tr>
<td>11M Cells</td>
<td>895.94</td>
</tr>
<tr>
<td>20M Cells</td>
<td>1697.54</td>
</tr>
<tr>
<td>simpleFoam</td>
<td>1615</td>
</tr>
<tr>
<td>pisoFoam</td>
<td>7495</td>
</tr>
</tbody>
</table>

**Image Source:** Intel

---

See Configuration Details Section, slide 160.  

**SOURCE:** INTEL MEASURED RESULTS AS OF NOVEMBER 2016

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performanc*Other names and brands may be claimed as the property of others.
OpenFOAM (for "Open source Field Operation And Manipulation") is a C++ toolbox for the development of customized numerical solvers, and pre-/post-processing utilities for the solution of continuum mechanics problems, including computational fluid dynamics (CFD).

Application: OpenFOAM

Code: Available here  Recipe: Available here

Optimizations: https://github.com/OpenFOAM/OpenFOAM-Intel

Value Proposition: Provides an extensive range of features to solve complex fluid flows involving chemical reactions, turbulence and heat transfer, acoustics, solid mechanics and electromagnetics. OpenFOAM on the Intel® Xeon Phi™ processor is great for computational fluid dynamics, structured grid or unstructured mesh.

Results: Up to 1.93X faster compared to the 2S Intel® Xeon® processor E5-2697 v4.

OpenFOAM Cluster Performance Improvement with the Intel® Xeon Phi™ Processor

Runtime in Seconds - LOWER IS BETTER

<table>
<thead>
<tr>
<th>Workload</th>
<th>2 Nodes</th>
<th>4 Nodes</th>
<th>16 Nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>DrivAer Car 25M Cells (pisoFoam)</td>
<td>1</td>
<td>1.33</td>
<td>1.36</td>
</tr>
<tr>
<td>Motorbike 100M Cells (simpleFoam)</td>
<td>1</td>
<td>1.22</td>
<td></td>
</tr>
</tbody>
</table>

up to 1.36X faster

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance  *Other names and brands may be claimed as the property of others

See Configuration Details Section, slide 160.

SOURCE: INTEL MEASURED RESULTS AS OF NOVEMBER 2016

Image Source: Intel
**NASA OVERFLOW**

**OVERFLOW is a 3D time marching implicit Navier-Stokes computational fluid dynamics simulator developed by NASA and used across aerospace and other industries.**

**Application:** OVERFLOW 2.2L has an extensive feature set supporting collision detection and modelling with support for thin layer and full viscous terms.

**Code:** [http://overflow.larc.nasa.gov/](http://overflow.larc.nasa.gov/)

**Recipe:** No code changes were required. Recompile with Intel® AVX-512.

---

**NASA OVERFLOW CFD Performance Improvement with the Intel® Xeon Phi™ Processor**

![Bar chart showing performance improvement](chart.png)

Time in seconds – LOWER IS BETTER

- **DLR/F6 36 Mpts:**
  - 2S Intel® Xeon® processor E5-2680 v3 (24 cores)
  - 2S Intel® Xeon® processor E5-2680 v4 (28 cores)
  - Intel® Xeon Phi™ processor 7250 (68 cores)

- **NASrrotor 91 Mpts**

**Value Proposition:** The Intel® Xeon Phi™ processor OVERFLOW performance outperforms Intel® Xeon® processor servers, with better performance density and better energy efficiency.

**Results:** Up to 1.77X performance improvement compared to the Intel® Xeon® processor E5-2680 v3.

**Manufacturing**

UH-60 Black Hawk helicopter and Navier-Stokes detached eddy simulation of a flexible UH-60 rotor using the OVERFLOW CFD code in forward flight.

Image Source: Neal Chaderjian and Tim Sandstrom, NASA Ames

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

[See Configuration Details Section, slide 160.](#)

SOURCE: NASA/Ames (Dennis Jespersen) April 2016

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, and functions. Any change to any of these factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to [http://www.intel.com/performance](http://www.intel.com/performance)
The OpenLB project provides a C++ package for the implementation of lattice Boltzmann simulations that is general enough to address a vast range of problems in computational fluid dynamics. The package is mainly intended as a programming support for researchers and engineers who simulate fluid flows by means of a Lattice Boltzmann method.

**Application:** OpenLB

**Code:** [Available here](#)  **Recipe:** [Available here](#)

**Value Proposition:** OpenLB is one of the most important simulation software for CFD with growing influence and widely used.

**Results:** Up to 1.5X improved performance by compared to the Intel® Xeon® processor E5-2697 v4.

Image Source: [Used with permission](#)
HiFUN is a general purpose flow solver employing unstructured data based algorithms and fine tuned to solve typical aerospace applications. The code has been extensively used for solving a number of problems, over a wide range of Mach numbers, ranging from airship aerodynamics to aerodynamics of hypersonic vehicles.

**Application:** HiFUN

**Baseline Code:** Proprietary code (2.5.1 beta version), [http://sandii.co.in/](http://sandii.co.in/)

**Optimized Code:** Proprietary code-Pending check-in

**Recipe:** “mpiifort OPTIONS=“-xMIC-AVX512 -O3”

**Value Proposition:** The Intel® Xeon Phi™ processor improves HiFUN single process performance. HiFUN benefits from Intel® AVX-512 and high bandwidth memory.

**Results:** Up to 1.35X performance improvement compared to the 2S Intel® Xeon® processor E5-2697v4.
**GE TACOMA**

*TACOMA is an explicit Navier-Stokes computational fluid dynamics software with structured and unstructured grid capability developed by General Electric*. It has an extensive feature set including multi-grid methods and is routinely used for the design of turbomachinery at GE.

**Application:** TACOMA  
**Code:** GE internal in-house proprietary code  
**Recipe:** Code optimized for outer-loop vectorization of key routines

**Value Proposition:** Provides better performance, performance density and better energy efficiency than Intel Xeon processor based systems.  
**Results:** Up to 1.23X performance improvement compared to the 2S Intel® Xeon® processor E5-2697v4.

**GE TACOMA Performance Improvement with the Intel® Xeon Phi™ Processor**

<table>
<thead>
<tr>
<th>Options/Second - LOWER IS BETTER</th>
<th>64.08</th>
<th>56.88</th>
<th>51.75</th>
</tr>
</thead>
<tbody>
<tr>
<td>2S Intel® Xeon® processor E5-2697 v4 (36 cores)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intel® Xeon Phi™ processor 7210 (64 cores)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intel® Xeon Phi™ processor 7250 (68 cores)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*TACOMA is a trademark of General Electric Corporation*
Increasing accuracy and timeliness of forecasts.

CLIMATE AND WEATHER
The most widely-used weather forecasting code runs in its entirety on the Intel platform only. Software codes used by various universities and meteorological services, oceanographic research, operational oceanography seasonal forecast and climate studies benefit from the technologies provided by the Intel Xeon Phi processor, including high memory bandwidth and Intel® Advanced Vector Extensions 512 (Intel® AVX-512). Improved forecasting of hazardous meteorological phenomena allow for improved weather forecasting which impacts critical infrastructure affecting human activity. The following proof points show tested and proven performance\(^1\) for the most important applications, with an average software performance improvement with the Intel Xeon Phi processor 7250 of up to **1.63X**, and an average performance/watt improvement of up to **1.93X**.

- **NEMO**: Up to 2.1X
- **Danish Meteorological Institute**: Up to 1.7X, and up to 2X performance/watt
- **NIM**: Up to 1.99X
- **MPAS Ocean 4.0**: Up to 1.23X, and up to 1.96X performance/watt
- **HOMME**: Up to 1.93X, and up to 2.36X performance/watt
- **GNAQPMS**: Up to 1.76X
- **WRF**: Up to 1.7X
- **IFS**: Up to 1.16X, and up to 1.42X performance/watt
- **POP**: Up to 1.41X
- **MASNUM WAVE**: Up to 1.4X

---

\(^1\) Performance is the Intel Xeon® Phi™ Processor 7250 compared to the Intel® Xeon® processor E5-2697 v4.
NUCLEUS FOR EUROPEAN MODELLING OF THE OCEAN* (NEMO)

Nucleus for European Modelling of the Ocean (NEMO) is an ocean modelling framework composed of "engines" in an "environment". The "engines" provide numerical solutions of ocean, sea-ice, tracers and biochemistry equations and their related physics. The "environment" consists of the pre- and post-processing tools, the interface to the other components of the Earth System, the user interface, the computer dependent functions and the documentation of the system. NEMO allows several ocean related components of the earth system to work together or separately.

Application: NEMO 3.6
Recipe: See configuration details or check availability here

Value Proposition: Provides users with a tool for oceanographic research, operational oceanography seasonal forecast and climate studies, and it is used by various universities and meteorological services.

Results: Up to 2.1X improved performance compared to the Intel® Xeon® processor E5-2697 v4.

Image Source: Sediment Dynamics in the Black Sea

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The Danish Meteorological Institute (DMI) institute was founded to make observations, communicate them to the general public, and to develop scientific meteorology.

Application: DMI HIROMB-BOOS-Model is a 3D ocean circulation model code forced by atmospheric meteo-fields from a weather model.

Code: To get access to the code and test cases, please contact DMI

Recipe: Check for availability here

Value Proposition: The improved performance from the Intel® Xeon Phi™ processor helps deliver improved forecasting of hazardous meteorological phenomena allowing for improved weather forecasting which impacts critical infrastructure affecting human activity.

Results: Up to 1.7X performance improvement compared to the Intel® Xeon® processor E5-2697 v4.
Non-hydrostatic Icosahedral Model (NIM) is developed by NOAA’s Earth System Research Laboratory. NIM is used for earth system modeling and weather and climate prediction. NIM is a multi-scale model designed to improve tropical convective clouds and to extend weather forecasts into intra-seasonal predictions.

Application: Non-hydrostatic Icosahedral Model

Code: To get access to the code and test cases, please contact NOAA

Recipe: Build and run instructions are similar to those for Intel® Xeon® processor E5-2697 v4, except build with –xMIC-AVX512 flag and run with “numactl –m 1” prepended to the command-line.

Value Proposition: The improved performance from the Intel® Xeon Phi™ processor helps deliver improved weather and climate forecasting.

Results: Up to 1.99X performance improvement compared to the Intel® Xeon® processor E5-2697 v4.
Non-Hydrostatic Icosahedral Model (NIM) is developed by NOAA’s Earth System Research Laboratory. NIM is used for earth system modeling and weather and climate prediction. NIM is a multi-scale model designed to improve tropical convective clouds and to extend weather forecasts into intra-seasonal predictions.

Application: Non-Hydrostatic Icosahedral Model

Code: To get access to the code and test cases, please contact NOAA

Recipe: Check for availability here

Value Proposition: The improved performance from the Intel® Xeon Phi™ processor helps deliver improved weather and climate forecasting.

Results: Up to 1.84X performance improvement for a 5-node cluster compared to the Intel® Xeon® processor E5-2697 v4.

(NIM)
MPAS (Model for Prediction Across Scales) is a suite of programs for atmosphere, ocean, and other earth-system simulation. LANL is primarily responsible for the MPAS Ocean (MPAS-O) model. MPAS-O has demonstrated the ability to accurately reproduce mesoscale activity. (workload contact: Doug Jacobson, LANL, jacobsen.douglas@gmail.com)

Application: MPAS-O

Code: [Available here](#)  
Recipe: See the configuration details slide

Value Proposition: Intel® Xeon Phi™ processor 7250 enables this application to outperform (time-to-solution) and performance/power of alternative processing solutions.

Power Data: Total system wall power is measured out-of-band over iPMI interface, polling the BMC chip every one tenth second. Energy usage is matched to internally timed code segment to arrive at performance per Watt estimate. Only power consumed during the time steps were used for efficiency calculations.

Results: up to 1.23X improved performance and up to 1.95X performance/power compared to the Intel® Xeon® processor E5-2697 v4 for EC_60to30_forward workload.

Testcase: EC_60to30_forward. The workload ran for 2 days of simulation time.

Power measurement: CPU and MEMORY

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance  
*Other names and brands may be claimed as the property of others
HOMME ATOMICPHRIC DYNAMICAL CORE * NUMERICAL CLIMATE SIMULATION

HOMME is the spectral element dynamical core that solves the equations of motion in the CAM5 atmospheric model, part of the Community Earth System Model (CESM) jointly developed by NSF and DOE.

Application: Baroclinic instability simulation in a “whole atmosphere” (extending to lower thermosphere) configuration.

Code: Request access to development branches here.

Recipe: cmake -DADD_Fortran_FLAGS="-O3 -xMIC-AVX512 -fp-model fast"

Value Proposition: CESM is a widely-used Earth system model and an important source of simulations used by the Intergovernmental Panel on Climate Change. Intel® Xeon Phi™ processors provide the high memory bandwidth required to advect many chemical tracers through the atmosphere.

Results: Up to 1.82X faster on a 16-node cluster compared to the Intel® Xeon® processor E5-2697 v4.

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See Configuration Details Section, slide 160.

SOURCE: INTEL AS OF OCTOBER, 2016
**HOMME Atmospheric Dynamical Core * Numerical Climate Simulation**

**HOMME is the spectral element dynamical core that solves the equations of motion in the CAM5 atmospheric model, part of the Community Earth System Model (CESM) jointly developed by NSF and DOE.**

**Application:** Baroclinic instability simulation in a “whole atmosphere” (extending to lower thermosphere) configuration.

**Code:** Request access to development branches [here](#).

**Recipe:**
```cmake
-DADD_Fortran_FLAGS="-O3 -xMIC-AVX512 -fp-model fast"
```

**Value Proposition:** CESM is a widely-used Earth system model and an important source of simulations used by the Intergovernmental Panel on Climate Change. Intel® Xeon Phi™ processors provide the high memory bandwidth required to advect many chemical tracers through the atmosphere.

**Results:** Up to 1.93X faster, with 2.36X power efficiency, compared to the Intel® Xeon® processor E5-2697 v4.

---

**HOMME “Whole Atmosphere” Configuration Simulation Performance Improvement with the Intel® Xeon Phi™ Processor**

<table>
<thead>
<tr>
<th>Normalized Results – Higher is Better</th>
<th>Performance</th>
<th>Power Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>2S Intel® Xeon® processor E5-2697 v4 (36 cores)</td>
<td>up to 1.93X faster</td>
<td>up to 2.36X more power efficient</td>
</tr>
<tr>
<td>Intel® Xeon Phi™ processor 7250 w/Intel® OPA (68 cores)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Test case: HOMME perfTestWACCM NE=8 baroclinic instability

GNAQPMS is an in-house code from the Institute of Atmospheric Physics (IAP), China Academy of Sciences (CAS), parallelized with hybrid MPI+OpenMP and written in Fortran. The application is the global multi-scale chemistry transport model which can simulate the trace gases including ozone, NOx, CO and main aerosols including dusts, sea salts, BC, OC, sulfate and nitrate in multi-special resolutions.

**Application:** GNAQPMS.

**Code:** In-house code. To access, please contact tangxiao@mail.iap.ac.cn

**Recipe:** Please contact tangxiao@mail.iap.ac.cn

**Value Proposition:** Performance is enhanced by Intel® Advanced Vector Extensions 512 (Intel® AVX-512).

**Results:** up to 1.76X improved performance by up to 1.76X compared to the Intel® Xeon® processor E5-2697 v4.

GNAQPMS Performance Improvement with the Intel® Xeon Phi™ Processor

Test case: 360x180x20 grid, nest=2, 1 hour simulation

See Configuration Details Section, slide 160. SOURCE: INTEL MEASURED RESULTS AS OF April, 2016
WEATHER & RESEARCH FORECAST MODEL* NUMERICAL WEATHER SIMULATION

The WRF Model is a numerical weather prediction system designed to serve atmospheric research and operational forecasting needs. Currently in operational use at NCEP, AFWA, NASA, NOAA, etc.

Application: The Weather & Research Forecast Model* (WRF) WRFV3.6.1 Conus12km. Community code is managed by NCAR. CONUS12KM benchmark is an adhoc industry standard workload and is widely cited.

Code: Available here. (WRF 3.6 & 3.6.1) Recipe: Select Intel MIC configuration on build. Check for availability here

Value Proposition: The most widely-used weather forecasting code runs in its entirety on the Intel platform only. Speed up the WRF weather simulation code and results with Intel® architecture.

Results: Up to 1.7X faster compared to the Intel® Xeon® processor E5-2697 v4.
The WRF Model is a numerical weather prediction system designed to serve atmospheric research and operational forecasting needs. Currently in operational use at NCEP, AFWA, NASA, NOAA, etc.

Application: The Weather & Research Forecast Model* (WRF) WRFV3.6.1 Conus12km. Community code is managed by NCAR. CONUS12KM benchmark is an adhoc industry standard workload and is widely cited.

Code: Available here, (WRF 3.6 & 3.6.1) Recipe: Select Intel MIC configuration on build. Check for availability here

Value Proposition: The most widely-used weather forecasting code runs in its entirety on the Intel platform only. Speed up the WRF weather simulation code and results with Intel® architecture.

Results: Up to 1.62X faster at 64 nodes compared to the Intel® Xeon® processor E5-2697 v4.

*Other names and brands may be claimed as the property of others
The WRF Model is a numerical weather prediction system designed to serve atmospheric research and operational forecasting needs. Currently in operational use at NCEP, AFWA, NASA, NOAA, etc.

**Application:** The Weather & Research Forecast Model* (WRF) WRFV3.6.1 Conus12km. Community code is managed by NCAR. CONUS12KM benchmark is an adhoc industry standard workload and is widely cited.

**Code:** [Available here](#) (WRF 3.6 & 3.6.1) **Recipe:** Select Intel MIC configuration on build. Check for availability [here](#).

**Value Proposition:** The most widely-used weather forecasting code runs in its entirety on the Intel platform only. Speed up the WRF weather simulation code and results with Intel® architecture.

**Results:** Up to 1.7X faster compared to the Intel® Xeon® processor E5-2697 v4.

---

**Power Consumption Improvement with the Intel® Xeon Phi™ Processor**

<table>
<thead>
<tr>
<th>Power Consumption - LOWER IS BETTER</th>
<th>Conus12km</th>
<th>Conu2.52km</th>
</tr>
</thead>
<tbody>
<tr>
<td>2S Intel® Xeon® processor E5-2697 v4 (290 TDP, 36 cores)</td>
<td>179.17</td>
<td>105.85</td>
</tr>
<tr>
<td>Intel® Xeon Phi™ processor 7250 (215 TDP, 68 cores)</td>
<td>2272.4</td>
<td>1379.7</td>
</tr>
</tbody>
</table>

Image Source: NOAA
Integrated Forecasting System (IFS) is a comprehensive Earth system modelling software developed by The European Centre for Medium-Range Weather Forecasts (ECMWF) in collaboration with Météo-France. IFS forms the basis of all data assimilation and numerical weather prediction activities at ECMWF.

Application: IFS RAPS14

Code and Recipe: IFS RAPS14 code is proprietary and available to consortium members under license. Minor source code changes were applied to some of the key routines to ensure vectorization. See the configuration details for code and recipe information. Check for future availability here.

Power Data: System wall power is measured out-of-band over iPMI, polling the BMC chip every 0.1 seconds. Energy usage is matched to the average of internally-timed code segments to arrive at performance/watt.

Value Proposition: Intel® Xeon Phi™ processor enables an established codebase to achieve better performance and energy efficiency.

Results: Up to 1.16X speedup and up to 1.42X better energy efficiency per time step compared to the Intel® Xeon® processor.
Parallel Ocean Program (POP) is an ocean circulation model that solves the three-dimensional primitive equations for ocean dynamics. It consists of the baroclinic and barotropic solvers that solve 3-D equations explicitly and 2-D surface pressure implicitly, respectively. It is widely used for oceanography. The code is Open Source.

**Application:** POP (Parallel Ocean Program).

**Code:** [http://www2.cesm.ucar.edu](http://www2.cesm.ucar.edu)

**Recipe:** Available here

---

Value Proposition:

- POP is developed by LANL USA and widely used in ocean and climate research. It is also incorporated into FIO-ESM (First Institute of Oceanography-Earth System Model) as the ocean component.
- Intel® Xeon Phi™ processor 7250 enables this application to significantly outperform (time-to-solution) alternative processing solutions.

**Results:** Up to 1.41X faster with the Intel® Xeon Phi™ processor 7250 compared to the Intel® Xeon® processor E5-2697 v4.

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Image Source: FIO, China

**See Configuration Details Section, slide 160.** SOURCE: INTEL MEASURED RESULTS AS OF MARCH, 2016

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to [http://www.intel.com/performance](http://www.intel.com/performance) *Other names and brands may be claimed as the property of others.*
MASNUM WAVE model is the 3rd generation surface wave model proposed early in 1990s in LAGFD (Laboratory of Geophysical Fluid Dynamics) from FIO. The application is used to simulate and predict the wave process by solving the wave energy spectrum balance equation and its complicated characteristic equations in wave-number space, which is written in Fortran and parallelized with MPI+OMP.

Application: MASNUM WAVE.

Code and Recipe: [Available here](http://www.intel.com)

**Value Proposition:** Performance is enhanced by Intel® Advanced Vector Extensions 512 (Intel® AVX-512).

**Results:** Up to 1.4X improved performance compared to the Intel® Xeon® processor E5-2697 v4, and uses 1.13X less energy.
Discover and design like never before.

MATERIAL SCIENCES
The technologies provided by the Intel Xeon Phi processor, including high memory bandwidth and Intel® Advanced Vector Extensions 512 (Intel® AVX-512) help Material Science applications realize meaningful performance gains. The following proof points show tested and proven performance\(^1\) for the most important applications, with an average software performance improvement with the Intel Xeon Phi processor 7250/7210 of up to 1.6X, and an average performance/watt improvement of up to 2.15X.

- **TRINITY BENCHMARKS**: Up to 7X
- **CP2K**: Up to 2.4X
- **VASP**: Up to 1.82X, and up to 2.72X less energy used. See the [GPU comparative section](#)
- **BerkeleyGW**: Up to 1.38X, and up to 1.59X performance/watt
- **PWMAT**: Up to 1.58X
- **Quantum ESPRESSO**: Up to 1.17X

---

1 - Performance is the Intel Xeon® Phi™ Processor 7250 compared to the Intel® Xeon® processor E5-2697 v4

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to [http://www.intel.com/performance](http://www.intel.com/performance) *Other names and brands may be claimed as the property of others*
**TRINITY BENCHMARKS - OPTIMIZED CLUSTER (GFLOPS)**

Trinity is a set of benchmark programs used as part of the joint NERSC/ACES NERSC-8/Trinity system procurement.

**Code:** In main [NERSC website](http://www.nersc.gov). **Recipe:** Check for availability [here](http://www.nersc.gov).

- **AMG:** Parallel algebraic multigrid solver for linear systems
- **MiniFE:** Finite Element mini-app
- **UMT:** 3D, deterministic, multigroup, photon transport code for unstructured meshes
- **SNAP:** proxy application to model the performance of a modern discrete ordinates neutral particle transport application
- **GTC:** Gyrokinetic Particle Simulation of Turbulent Transport in Burning Plasmas
- **MILC:** MIMD Lattice Computation (MILC) collaboration kernel used to study quantum chromodynamics (QCD)
- **MiniGhost:** Finite Difference mini-app

**Value Proposition:** Trinity benchmarks showcase the out-of-the-box performance of the Intel® Xeon Phi™ processor at single node and at the cluster.

**Results:** Up to 2.4X faster for a 16-node cluster with the optimized Intel® Xeon Phi™ processor compared to the non-optimized Intel® Xeon Phi™ processor.

---

See Configuration Details Section, slide 160.
Trinity is a set of benchmark programs used as part of the joint NERSC/ACES NERSC-8/Trinity system procurement.

**Code:** In main NERSC website. **Recipe:** Check for availability here

**Baseline Code:** No source code changes, MPI Only

**Optimized Code:** Source code changes, can use MPI and OpenMP.

Workload optimizations affect on Intel® Xeon Phi™ processor and Intel® Xeon® processor E5-2697 v4 GFLOPS:

- **AMG:** no change
- **MiniFE:** no change
- **UMT:**
  - Xeon Phi: 42 to 81
  - Xeon: no change
- **SNAP:** no change
- **GTC:** no change
- **MILC:**
  - Xeon Phi: 108 to 138
  - Xeon: 72 to 102
- **MiniGhost:**
  - Xeon Phi: 128 to 381
  - Xeon: 54 to 114

**Value Proposition:** Trinity benchmarks showcase the out-of-the-box performance of the Intel® Xeon Phi™ processor.

**Results:** Up to 7X faster with the optimized Intel® Xeon Phi™ processor compared to the non-optimized Intel® Xeon® processor 2697 v4. Xeon Phi optimizations: 1.46X ave. speedup. Xeon optimizations: 1.21X ave. speedup. Xeon Phi vs. Xeon: 2.58X ave. speedup.
Trinity is a set of benchmark programs used as part of the joint NERSC/ACES NERSC-8/Trinity system procurement.

Code: In main NERSC website. Recipe: Check for availability here

- AMG: Parallel algebraic multigrid solver for linear systems
- MiniFE: Finite Element mini-app
- UMT: 3D, deterministic, multigroup, photon transport code for unstructured meshes
- SNAP: proxy application to model the performance of a modern discrete ordinates neutral particle transport application
- GTC: Gyrokinetic Particle Simulation of Turbulent Transport in Burning Plasmas
- MILC: MIMD Lattice Computation (MILC) collaboration kernel used to study quantum chromodynamics (QCD)
- MiniGhost: Finite Difference mini-app

Value Proposition: Trinity benchmarks showcase the out-of-the-box performance of the Intel® Xeon Phi™ processor at single node and at the cluster.

Results: Up to 3.34X faster with the optimized Intel® Xeon Phi™ processor compared to the optimized Intel® Xeon® processor 2697 v4.
Material Sciences

TRINITY BENCHMARKS - SINGLE NODE OPTIMIZED (GFLOPS)

Trinity is a set of benchmark programs used as part of the joint NERSC/ACES NERSC-8/Trinity system procurement.

Code: In main NERSC website. Recipe: Check for availability here

- **AMG**: Parallel algebraic multigrid solver for linear systems
- **MiniFE**: Finite Element mini-app
- **UMT**: 3D, deterministic, multigroup, photon transport code for unstructured meshes
- **SNAP**: proxy application to model the performance of a modern discrete ordinates neutral particle transport application
- **GTC**: Gyrokinetic Particle Simulation of Turbulent Transport in Burning Plasmas
- **MILC**: MIMD Lattice Computation (MILC) collaboration kernel used to study quantum chromodynamics (QCD)
- **MiniGhost**: Finite Difference mini-app

Value Proposition: Trinity benchmarks showcase the out-of-the-box performance of the Intel® Xeon Phi™ processor at single node and at the cluster.

Results: Up to 2.97X faster with the optimized Intel® Xeon Phi™ processor compared to the non-optimized Intel® Xeon Phi™ processor.

See Configuration Details Section, slide 160.

SOURCE: INTEL MEASURED RESULTS AS OF MAY, 2016
**Linear Scaling Density Function Theory**

**CP2K** is a powerful and scalable program for atomistic simulations of a wide range of systems, including condensed phase, molecular systems and complex interfaces. CP2K features a wide range of atomistic interaction models including classical potentials, semi-empirical schemes, Density Functional Theory (DFT), Hartree-Fock (HF), and post-HF correlation methods such as MP2 and RPA. The program was a Gordon Bell Finalist in 2015. CP2K is freely available.

**Application:** CP2K Quantum Chemistry & Solid State Physics Software Package

**Workload:** Linear Scaling DFT used to compute the electronic structure of an amorphous material with 14K atoms using the DZVP-MOLOPT basis set.

**Code:** [Available Here](https://example.com)

**Recipe:** Check for availability [here](https://example.com)

**Value Proposition:** CP2K optionally uses Intel’s Open Source Library for small BLAS operations (matrix multiplications) called LIBXSMM, which enables BLAS extensions on a drop-in basis, and automatically targets Intel® AVX, Intel® AVX2 and Intel® AVX-512 through future-proof just-in-time compilation techniques. LIBXSMM is also used in other scientific Open Source packages such as SeisSol, NekBox, NEK5000, and Machine Learning applications via LIBXSMM’s highly optimized small convolution kernels used for Convolutional Neural Networks (CNN).

**Results:** Up to 1.33X faster on 16 nodes with the Intel® Xeon Phi™ processor 7250 (64 of 68 cores used) compared to the 2S Intel® Xeon® processor E5-2697 v4.

---

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance *Other names and brands may be claimed as the property of others*
CP2K is a powerful and scalable program for atomistic simulations of a wide range of systems, including condensed phase, molecular systems and complex interfaces. CP2K features a wide range of atomistic interaction models including classical potentials, semi-empirical schemes, Density Functional Theory (DFT), Hartree-Fock (HF), and post-HF correlation methods such as MP2 and RPA. The program was a Gordon Bell Finalist in 2015. CP2K is freely available.

**Application:** CP2K Quantum Chemistry & Solid State Physics Software Package  
**Workload:** Linear Scaling DFT used to compute the electronic structure of an amorphous material with 14K atoms using the DZVP-MOLOPT basis set.  
**Code:** Available Here  
**Recipe:** Check for availability here

**Value Proposition:** CP2K optionally uses Intel’s Open Source Library for small BLAS operations (matrix multiplications) called LIBXSMM, which enables BLAS extensions on a drop-in basis, and automatically targets Intel® AVX, Intel® AVX2 and Intel® AVX-512 through future-proof just-in-time compilation techniques. LIBXSMM is also used in other scientific Open Source packages such as SeisSol, NekBox, NEK5000, and Machine Learning applications via LIBXSMM’s highly optimized small convolution kernels used for Convolutional Neural Networks (CNN).

**Results:** Up to 1.19X faster on 32 nodes with the Intel® Xeon Phi™ processor 7250 (64 of 68 cores used) compared to the 2S Intel® Xeon® processor E5-2697 v4.
**Random Phase Approximation (RPA) using Exact Hartree-Fock Exchange Method Performance Improvement with Intel® Xeon Phi™ processor**

- **2 Nodes**: 715 seconds
- **4 Nodes**: 676 seconds

- **Time (seconds)**
- **LOWER IS BETTER**
- **Up to 1.05X faster**
- **Up to 1.3X faster**

**Application:** CP2K Quantum Chemistry & Solid State Physics Software Package

**Workload:** Random Phase Approximation (RPA) energies using hybrid XC functionals with exact Hartree-Fock Exchange (HFX).

**Code:** [Available Here](#)

**Value Proposition:** CP2K optionally uses Intel’s Open Source Library for small BLAS operations (matrix multiplications) called LIBXSMM, which enables BLAS extensions on a drop-in basis, and automatically targets Intel® AVX, Intel® AVX2 and Intel® AVX-512 through future-proof just-in-time compilation techniques. LIBXSMM is also used in other scientific Open Source packages such as SeisSol, NekBox, NEK5K, and Machine Learning applications via LIBXSMM’s highly optimized small convolution kernels used for Convolutional Neural Networks (CNN).

**Results:** Up to 1.3X faster on 4 nodes with the Intel® Xeon Phi™ processor 7250 (64 of 68 cores used) compared to the 2S Intel® Xeon® processor E5-2697 v4.

---

**Random Phase Approximation (RPA Using Exact HFX)**

CP2K is a powerful and scalable program for atomistic simulations of a wide range of systems, including condensed phase, molecular systems and complex interfaces. CP2K features a wide range of atomistic interaction models including classical potentials, semi-empirical schemes, Density Functional Theory (DFT), Hartree-Fock (HF), and post-HF correlation methods such as MP2 and RPA. The program was a Gordon Bell Finalist in 2015. CP2K is freely available.

**Application:** CP2K Quantum Chemistry & Solid State Physics Software Package

**Workload:*** Random Phase Approximation (RPA) energies using hybrid XC functionals with exact Hartree-Fock Exchange (HFX).

**Code:** [Available Here](#) **Recipe:** Check for availability [here](#)

---

**Value Proposition:** CP2K optionally uses Intel’s Open Source Library for small BLAS operations (matrix multiplications) called LIBXSMM, which enables BLAS extensions on a drop-in basis, and automatically targets Intel® AVX, Intel® AVX2 and Intel® AVX-512 through future-proof just-in-time compilation techniques. LIBXSMM is also used in other scientific Open Source packages such as SeisSol, NekBox, NEK5K, and Machine Learning applications via LIBXSMM’s highly optimized small convolution kernels used for Convolutional Neural Networks (CNN).

**Results:** Up to 1.3X faster on 4 nodes with the Intel® Xeon Phi™ processor 7250 (64 of 68 cores used) compared to the 2S Intel® Xeon® processor E5-2697 v4.
BerkeleyGW Package is a set of computer codes that calculates the quasiparticle properties and the optical responses of a large variety of materials from bulk periodic crystals to nanostructures such as slabs, wires and molecules. It is a massively parallel computational package for electron excited state properties that is based on many-body perturbation theory employing the ab initio GW and GW plus Bethe-Salpeter equation methodology. Sigma is the second half of the GW code. It gives the quasiparticle self-energies and dispersion relation for quasielectron and quasihole states.

Application: BerkeleyGW Sigma phase of Benzene analysis

Code: [http://www.berkeleygw.org](http://www.berkeleygw.org)


Recipe: -xMIC-AVX512 -Ofast –qopenmp

Value Proposition: Xeon™ Phi enables broader scaling, larger problem sizes and reduced runtimes within the same energy use envelope. Uses Intel® MKL, MPI and OpenMP for massive scaling.

Results: Up to 38% speedup compared to the Intel® Xeon® processor.
PWmat is a commercial software using plane wave pseudopotential method for density functional theory (DFT) material simulations. It is an ab initio code, meaning it uses initial atomic positions to predict the material properties. PWmat is developed and optimized by Beijing LongXun Inc. based on the open source code PEtot (PEtot has a BSD 3-Clause license).

Application: PWmat

Code: Commercial software. Contact LongXun Inc. (support@pwmat.com). PEtot can be downloaded as a reference (http://cmsn.lbl.gov/html/PEtot/PEtot.html).

Recipe: Evaluation binaries: http://www.pwmat.com/pwmat_performance (encrypted). Contact LongXun Inc. (support@pwmat.com) for approval at first.

Value Proposition: PWmat is local developed state-of-art material simulation software with growing influence in China.

Results: Up to 1.58X faster with the Intel® Xeon Phi™ processor 7250 compared to the Intel® Xeon® processor E5-2697 v4.
Quantum ESPRESSO is an integrated suite of Open-Source computer codes for electronic-structure calculations and materials modeling at the nanoscale. It is based on density-functional theory, plane waves, and pseudopotentials.

Application: Quantum ESPRESSO AUSURF112 (QE 5.4)
Code: [Available here](#)
Recipe: See the configuration details slide

**Value Proposition:** Utilizes Intel® Advanced Vector Extensions 512 (Intel® AVX-512), mostly for Fourier Transformation and ZGEMM, MPI + OpenMP* parallelization, and MCDRAM cache mode.

**Results:** Up to 1.17X improved performance compared to the Intel® Xeon® processor E5-2697 v4.

[Image Source: Argonne National Laboratory](#)

---

**Quantum ESPRESSO Performance Improvement with the Intel® Xeon Phi™ Processor**

<table>
<thead>
<tr>
<th>Time in Seconds - LOWER IS BETTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>277</td>
</tr>
<tr>
<td>236</td>
</tr>
<tr>
<td>up to 1.17X faster</td>
</tr>
</tbody>
</table>

See Configuration Details Section, slide 160. SOURCE: INTEL MEASURED RESULTS AS OF JUNE 2016
Quantum ESPRESSO is an integrated suite of Open-Source computer codes for electronic-structure calculations and materials modeling at the nanoscale. It is based on density-functional theory, plane waves, and pseudopotentials.

Application: Quantum ESPRESSO 6.0
Code: Available here. Recipe: See the configuration details slide

Value Proposition:
- Exploitable for many-core, vectors (Intel® AVX), and Intel® Omni-Path architecture via Intel® Development Tools (IMPI, IFORT, MKL, and our OSS efforts)
- Most if not all significant developments are done on IA; the key contributors such as CINECA deployed 100% IA
- This medium-sized PRACE benchmark is available for download from the official Quantum ESPRESSO website (http://www.qe-forge.org/gf/download/frsrelease/47/61/GRIR443.tgz)

Result: Up to 1.13X faster at scale with 16 nodes (16 sockets) with the Intel® Xeon Phi™ processor 7250 compared to 16 nodes (32 sockets) of the Intel® Xeon® processor E5-2697v4.
Quantum ESPRESSO is an integrated suite of Open-Source computer codes for electronic-structure calculations and materials modeling at the nanoscale. It is based on density-functional theory, plane waves, and pseudopotentials.

Application: Quantum ESPRESSO 6.0
Code: Available here. Recipe: See the configuration details slide.

Value Proposition:
- Exploitable for many-core, vectors (Intel® AVX), and Intel® Omni-Path architecture via Intel® Development Tools (IMPI, IFORT, MKL, and our OSS efforts)
- Most if not all significant developments are done on IA; the key contributors such as CINECA deployed 100% IA
- This large-sized PRACE benchmark is available for download from the web site of the Unified European Applications Benchmark Suite (http://www.prace-ri.eu/UEABS/Quantum_Espresso/QuantumEspresso_TestCaseA.tar.gz)

Result: Up to 1.10X faster at scale with 16 nodes (16 sockets) with the Intel® Xeon Phi™ processor 7250 compared to 16 nodes (32 sockets) of the Intel® Xeon® processor E5-2697v4.
Unlock, discover, innovate.

PHYSICS
With features such as high bandwidth memory (MCDRAM) and Intel® AVX-512 vector instruction set architecture, the Intel® Xeon Phi™ processor helps power discovery, insight, and solutions from Physics software. Designed to solve large problems faster than what was previously possible, the Intel Xeon Phi processor helps these important applications realize meaningful performance gains. The following proof points show tested and proven performance for the most important applications, with an average software performance improvement with the Intel Xeon Phi processor 7250/7210 of up to 2.33X, and an average performance/watt improvement of up to 3.18X.

- **QPHIX**: Up to 3.57X, and up to 4.35X performance/watt
- **MILC**: Up to 3X, and up to 2X performance/watt
- **CLOVERLEAF**: Up to 2.3X
- **CHROMA**: Up to 2.1X, and up to 3.2X performance/watt
- **SOFT SPHERE SIMULATION**: Up to 1.81
- **PETSC**: Up to 1.8X

1 - Performance is the Intel Xeon® Phi™ Processor 7250 compared to the Intel® Xeon® processor E5-2697 v4

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance *Other names and brands may be claimed as the property of others.
QPhiX is an optimized solver library for QCD on Intel® Xeon® processors and Intel® Xeon Phi™ processors and provides implementation for Dslash operator and CG, BiCGStab and mixed precision solvers for Wilson and Clover improved Wilson Quarks.

Application: QPhiX Test Benchmark (time_dslash_noqdp)

Code: Available here  Recipe: Follow the instructions in the download package

Value Proposition:
- Lattice calculations are an important component of the nuclear physics research.
- QPhiX helps speed up the computation by multiple folds on Intel processors.
- Intel® Xeon Phi™ processor further improves performance with features such as high bandwidth memory (MCDRAM) and Intel® AVX-512 vector instruction set architecture.

Results: Up to 3.57X improved performance compared to the Intel® Xeon® processor E5-2697 v4 (BiCGStab 4 nodes).
**Physics - QCD**

**QPhiX**

QPhiX is an optimized solver library for QCD on Intel® Xeon® and Intel® Xeon Phi™ processors and provides implementation for Dslash operator and CG, BiCGStab and mixed precision solvers for Wilson and Clover improved Wilson Quarks.

**Application:** QPhiX Test Benchmark (time_dslash_noqdp)

**Code:** [https://github.com/JeffersonLab/qphix](https://github.com/JeffersonLab/qphix)  
**Recipe:** Follow the instructions in the download package

**QPhiX Performance Improvement with Intel® Xeon Phi™ Processor**

- **CG:** up to 3.1X faster
- **BiCGStab:** up to 3.2X faster

**Lattice:** 32*32*32*64  
**SOURCE:** INTEL MEASURED RESULTS AS OF MAY, 2016

**Value Proposition:**
- Lattice calculations are an important component of the nuclear physics research.
- QPhiX helps speed up the computation by multiple folds on Intel processors.
- Intel® Xeon Phi™ processor further improves performance with features such as high bandwidth memory (MCDRAM) and Intel® AVX-512 vector instruction set architecture.

**Results:** up to 3.2X improved performance compared to the Intel® Xeon® processor E5-2697 v4.

**Flux tubes between 3 quarks.**  
Credit: Dr Derek Leinweber, Centre for the Subatomic structure of Matter (CSSM) and Department of Physics, University of Adelaide, 5005 Australia

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to [http://www.intel.com/performance](http://www.intel.com/performance)  
*Other names and brands may be claimed as the property of others*

See Configuration Details Section, slide 160.
QPhiX is an optimized solver library for QCD on Intel® Xeon® and Intel® Xeon Phi™ processors and provides implementation for Dslash operator and CG, BICGStab and mixed precision solvers for Wilson and Clover improved Wilson Quarks.

Application: QPhiX Test Benchmark (time_dslash_noqdp)
Code: Available here  Recipe: Follow the instructions in the download package

- Lattice calculations are an important component of the nuclear physics research.
- QPhiX helps speed up the computation by multiple folds on Intel processors.
- Intel® Xeon Phi™ processor further improves performance with features such as high bandwidth memory (MCDRAM) and Intel® AVX-512 vector instruction set architecture.

Results: up to 4.35X improved performance/watt compared to the Intel® Xeon® processor E5-2697 v4.

See Configuration Details Section, slide 160.
The MILC Code is used to study quantum chromodynamics (QCD), the theory of the strong interactions of subatomic physics and is written by the MIMD Lattice Computation (MILC) collaboration.

Application: Trinity MILC provided by NERSC as part of Trinity8 suite

Code: Original NERSC Benchmark code is [here](#); contact Intel for Optimized Code

Recipe: Check for availability [here](#)

**Value Proposition:**
- MILC is widely deployed on numerous supercomputers and 2nd most used application at US DOE's National Energy Research Scientific Computing Center (NERSC)
- Intel's optimizations are being incorporated into mainline by MILC collaboration

**Results:** The Intel® Xeon Phi™ processor 7250 improved performance scales by up to 3.16X compared to the Intel® Xeon® processor E5-2697 v4.
The MILC Code is used to study quantum chromodynamics (QCD), the theory of the strong interactions of subatomic physics and is written by the MIMD Lattice Computation (MILC) collaboration.

**Application:** Trinity MILC provided by NERSC as part of Trinity8 suite

**Code:** Original NERSC Benchmark code is [here](#); contact Intel for Optimized Code

**Recipe:** Check for availability [here](#)

**Value Proposition:**
- MILC is widely deployed on numerous supercomputers and 2nd most used application at US DOE's National Energy Research Scientific Computing Center (NERSC)
- Intel's optimizations are being incorporated into mainline by MILC collaboration

**Results:** The Intel® Xeon Phi™ processor 7250 improved performance scales by up to 3X compared to the original code / Intel® Xeon® processor E5-2697 v4.

Image Credit: Brookhaven Lab (BNL)
The MILC Code is used to study quantum chromodynamics (QCD), the theory of the strong interactions of subatomic physics and is written by the MIMD Lattice Computation (MILC) collaboration.

Application: Trinity MILC provided by NERSC as part of Trinity8 suite

Code: Original NERSC Benchmark code is here; contact Intel for Optimized Code

Recipe: Check for availability here

Value Proposition:
- MILC is widely deployed on numerous supercomputers and 2nd most used application at US DOE's National Energy Research Scientific Computing Center (NERSC)
- Intel's optimizations are being incorporated into mainline by MILC collaboration

Results: The Intel® Xeon Phi™ processor 7250 improved performance by up to 2.13X compared to the original code / Intel® Xeon® processor E5-2697 v4.

See Configuration Details Section, slide 160. SOURCE: INTEL MEASURED RESULTS AS OF May 2016
**Physics - QCD**

The **MILC** Code is used to study quantum chromodynamics (QCD), the theory of the strong interactions of subatomic physics and is written by the MIMD Lattice Computation (MILC) collaboration.

**Application:** Trinity MILC provided by NERSC as part of Trinity8 suite

**Code:** Original NERSC Benchmark code is [here](#); contact Intel for Optimized Code

**Recipe:** Check for availability [here](#)

**Value Proposition:**
- MILC is widely deployed on numerous supercomputers and 2nd most used application at US DOE’s National Energy Research Scientific Computing Center (NERSC)
- Intel’s optimizations are being incorporated into mainline by MILC collaboration

**Results:** The Intel® Xeon Phi™ processor 7250 improved performance by up to 1.69X compared to the Intel® Xeon® processor E5-2697 v4.

---

**Trinity MILC Performance Improvement with the Intel® Xeon Phi™ Processor**

- 1,176
- 693

**NERSC_Time (Sec) - LOWER IS BETTER**

- 16x32x32x36
- **up to 1.69X faster**

- 2S Intel® Xeon® processor E5-2697 v4 (36 cores)
- Intel® Xeon Phi™ processor 7250 (68 cores)

Test case: Optimized Trinity MILC running lattice s16x32x32x36

**Image Credit:** Brookhaven Lab (BNL)
Physics - QCD

The MILC Code is used to study quantum chromodynamics (QCD), the theory of the strong interactions of subatomic physics and is written by the MIMD Lattice Computation (MILC) collaboration.

Application: Trinity MILC provided by NERSC as part of Trinity8 suite

Code: Original NERSC Benchmark code is here; contact Intel for Optimized Code

Recipe: Check for availability here

Value Proposition:
- MILC is widely deployed on numerous supercomputers and 2nd most used application at US DOE's National Energy Research Scientific Computing Center (NERSC)
- Intel's optimizations are being incorporated into mainline by MILC collaboration

Results: The Intel® Xeon Phi™ processor 7250 improved performance/watt by up to 2X compared to the Intel® Xeon® processor E5-2697 v4.
Cloverleaf 2D Performance Improvement with the Intel® Xeon Phi™ Processor

<table>
<thead>
<tr>
<th>Workload: 3840^2 cells 2955 time steps (clover_bm16.in)</th>
<th>Normalized Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>2S Intel® Xeon® processor E5-2697 v4 (36 cores)</td>
<td>0</td>
</tr>
<tr>
<td>Intel® Xeon® 6148 Gold processor (40 cores)</td>
<td>1</td>
</tr>
<tr>
<td>Intel® Xeon Phi™ processor 7250 (68 cores)</td>
<td>2</td>
</tr>
</tbody>
</table>

Source: INTEL MEASURED RESULTS AUGUST 2017

**CloverLeaf® 2D** is a free, open source (GPL v3) explicit hydrodynamics mini-application developed and maintained by AWE plc in the UK in collaboration with UK academia. The codebase has also been accepted into the Mantevo suite of mini-applications maintained by Sandia National Laboratories. The code is primarily utilized as a research vehicle to more rapidly determine appropriate development choices for codebases within the explicit hydrodynamics domain.

**Application:** CloverLeaf 2D

**Code:** Available here

**Recipe:** See configuration details

**Value Proposition:**

- This application provides users with a research tool for investigating code modernization approaches for larger shock hydrodynamics applications.
- This application now significantly outperforms (time-to-solution) alternative processing solutions with the Intel® Xeon Phi™ processor 7250.

**Results:** Up to 3X improved performance compared to the Intel® Xeon® processor E5-2697 v4 because of improved memory bandwidth and vectorisation capabilities from Intel® AVX-512.

---

*Other names and brands may be claimed as the property of others*
CloverLeaf® 3D is a free, open source (GPL v3) explicit hydrodynamics mini-application developed and maintained by AWE plc in the UK in collaboration with UK academia. The codebase has also been accepted into the Mantevo suite of mini-applications maintained by Sandia National Laboratories. The code is primarily utilized as a research vehicle to more rapidly determine appropriate development choices for codebases within the explicit hydrodynamics domain.

Application: CloverLeaf 3D
Code: Available here
Recipe: See configuration details

Value Proposition:
- This application provides users with a research tool for investigating code modernization approaches for larger shock hydrodynamics applications.
- This application now significantly outperforms (time-to-solution) alternative processing solutions with the Intel® Xeon Phi™ processor 7250.

Results: Up to 2.34X improved performance compared to the Intel® Xeon® processor E5-2697 v4 because of improved memory bandwidth and vectorisation capabilities from Intel® AVX-512.
**TeaLeaf 2D**

TeaLeaf 2D is a free, open source (GPL v3) heat conduction mini-application developed and maintained by AWE plc in the UK in collaboration with UK academia. The codebase has also been accepted into the Mantevo suite of mini-applications maintained by Sandia National Laboratories. The code solves the linear heat conduction equation on a spatially decomposed structured grid using a 5 point stencil with implicit solvers.

**Application:** TeaLeaf 2D  
**Code:** Available here  
**Recipe:** See configuration details

---

**Value Proposition:**  
- Faster time-to-solution  
- More accurate simulation at same time-to-solution.

**Results:** Up to 3X improved performance compared to the Intel® Xeon® processor E5-2697 v4 because of more cores and improved memory.

---

**Tealeaf Performance Improvement with the Intel® Xeon Phi™ Processor**

- **0.163X faster**
- **2.93X faster**

**Cloverleaf 2D**

- 2S Intel® Xeon® processor E5-2697 v4 (36 cores)
- Intel® Xeon® 6148 Gold processor (40 cores)
- Intel® Xeon Phi™ processor 7250 (68 cores)

Workload: 3840^2 cells 87 time-steps (tea_bm16_short.in)

---

**Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to [http://www.intel.com/performance](http://www.intel.com/performance) *Other names and brands may be claimed as the property of others."**
The Chroma package supports data-parallel programming constructs for lattice field theory and in particular lattice QCD. It uses the SciDAC QDP++ data-parallel programming (in C++) that presents a single high-level code image to the user, but can generate highly optimized code for many architectural systems including single node workstations, multi and many-core nodes, clusters of nodes via QMP, and classic vector computers.

**Application:** Chroma “hmc”

**Code:** [Available here](#)  **Recipe:** Check for availability [here](#)

**Value Proposition:**
- Chroma is deployed on numerous supercomputers and one of the most used QCD applications/research kernels.
- Intel’s optimizations are incorporated into mainline Chroma.
- The optimizations are made available in the QPhiX library.

**Results:** Up to 2.1X improved performance with the Intel® Xeon Phi™ processor 7250 compared to the Intel® Xeon® processor E5-2697 v4.
Chroma "hmc" Solvers Performance Improvement with the Intel® Xeon Phi™ Processor

The Chroma package supports data-parallel programming constructs for lattice field theory and in particular lattice QCD. It uses the SciDAC QDP++ data-parallel programming (in C++) that presents a single high-level code image to the user, but can generate highly optimized code for many architectural systems including single node workstations, multi and many-core nodes, clusters of nodes via QMP, and classic vector computers.

Application: Chroma “hmc”
Code: Available here Recipe: Check for availability here

Value Proposition:
- Chroma is deployed on numerous supercomputers and one of the most used QCD applications/research kernels.
- Intel’s optimizations are incorporated into mainline Chroma.
- The optimizations are made available in the QPhiX library.

Results: Up to 2.1X improved performance with the Intel® Xeon Phi™ processor 7250 compared to the Intel® Xeon® processor E5-2697 v4.

See Configuration Details Section, slide 160.

SOURCE: INTEL MEASURED RESULTS AS OF DECEMBER 2016

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance *Other names and brands may be claimed as the property of others
**Chroma**

The Chroma package supports data-parallel programming constructs for lattice field theory and in particular lattice QCD. It uses the SciDAC QDP++ data-parallel programming (in C++) that presents a single high-level code image to the user, but can generate highly optimized code for many architectural systems including single node workstations, multi and many-core nodes, clusters of nodes via QMP, and classic vector computers.

**Application:** Chroma “hmc”

**Code:** [Available here](#)  **Recipe:** Check for availability [here](#)

**Value Proposition:**
- Chroma is deployed on numerous supercomputers and one of the most used QCD applications/research kernels.
- Intel’s optimizations are incorporated into mainline Chroma.
- The optimizations are made available in the QPhiX library.

**Results:** Up to 3.2X improved performance/watt with the Intel® Xeon Phi™ processor 7250 compared to the Intel® Xeon® processor E5-2697 v4.

---

**Power consumption:** CPU + Memory

**Source:** Intel measured results as of December 2016

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SOFT SPHERE SIMULATION*

Soft Sphere is a 3D Molecular Dynamic simulation of IPE-CAS (Institute of Process Engineering), China. Using sphere particles to simulate structured molecules and calculation based on BKS (Beest-Kramers-Santen) Experience Potential Model allows scientists to fight epidemics like the 2014 Ebola virus.

Application: Soft Sphere Simulation
Code and Recipe: Available here

The simulation of force-driven flow in the nano-scale channel
Image Source: IPE-CAS, China

Value Proposition: Intel® Xeon Phi™ processor 7250 enables this application to significantly outperform (time-to-solution) alternative processing solutions.

Results: Up to 1.81X faster with the Intel® Xeon Phi™ processor 7250 compared to the Intel® Xeon® processor E5-2697 v4.

Testcase: N=100x100x100, 5X cut-off radius, 200 timesteps.

Soft Sphere Simulation Performance Improvement with the Intel® Xeon Phi™ Processor

- Up to 1.6X faster
- Up to 1.81X faster

Source: Intel Measured Results as of March, 2016

See Configuration Details Section, slide 160.
**PETSc – Portable, Extensible Toolkit for Scientific Computation**

**PETSc – the Portable, Extensible Toolkit for Scientific Computation – is a suite of data structures and routines for the scalable (parallel) solution of scientific applications modeled by partial differential equations.**

**Application:** Solution of the incompressible, variable viscosity Stokes equation in 3d using Q1Q1 elements, using a state-of-the-art Schur complement-based approach robust to large viscosity jumps.

**Code:** PETSc development code is completely open and available here.

**Recipe:** “-g -O3 -fp-model fast” and “-xMIC-AVX512” or “-xCORE-AVX2

**Value Proposition:** PETSc is one of the world’s most widely-used software libraries in high-performance computing. Many PETSc solvers are limited by memory-bandwidth in practice, and the Intel® Xeon Phi™ processor can deliver the needed bandwidth for excellent performance.

**Results:** Up to 1.8X faster with the Intel® Xeon Phi™ processor 7250 compared to the Intel® Xeon® processor E5-2697 v4.
Simulations – Fast, detailed, accurate.
Intel Xeon Phi™ processor improves the software performance of Geophysics applications with features such as high bandwidth memory (MCDRAM) and Intel® AVX-512 vector instruction set architecture, helping these important applications realize meaningful performance gains. The following proof points show tested and proven performance\(^1\) for the most important applications, with an average software performance improvement with the Intel Xeon Phi processor 7250/7210 of up to 2.17X.

- **YASK AWP-ODC**: Up to 2.8X
- **YASK ISO3DFD**: Up to 2.5X
- **SEISOL**: Up to 1.59X
- **SPECFEM3D_GLOBE**: Up to 1.8X

\(^1\) Performance is the Intel Xeon® Phi™ Processor 7250 compared to the Intel® Xeon® processor E5-2697 v4.
YASK HPC STENCILS, AWP-ODC KERNEL

YASK, Yet Another Stencil Kernel, is a framework to facilitate design exploration and tuning of HPC kernels. One of the stencils included in YASK is awp-odc, a staggered-grid finite difference scheme used to approximate the 3D velocity-stress elastodynamic equations: http://hpgeoc.sdsc.edu/AWPODC. Applications using this stencil simulate the effect of earthquakes to help evaluate designs for buildings and other at-risk structures.

Application: YASK, AWP stencil (a single-node proxy for the compute kernel in the Anelastic Wave Propagation application)

Code and Recipe: Available here

Value Proposition: Intel® Xeon Phi™ processor 7250 enables this application to leverage the high-bandwidth memory and 512-bit SIMD for higher performance.

Results: Up to 2.8X improved performance compared to the Intel® Xeon® processor E5-2697 v4.

Testcase: AWP, 14GB problem size

See Configuration Details Section, slide 160.

Intel® Xeon® Processor E5-2697 v4 (36 cores)

Intel® Xeon Phi™ Processor 7250 (68 cores)

Geophysics

Image Source: USGS
YASK, Yet Another Stencil Kernel, is a framework to facilitate design exploration and tuning of HPC kernels. One of the stencils included in YASK is iso3dfd, a finite-difference code found in seismic imaging software used by energy-exploration companies to predict the location of oil and gas deposits.

**Application:** YASK, iso3dfd stencil  
**Code and Recipe:** Available here  

**Value Proposition:** Intel® Xeon Phi™ processor 7250 enables this application to leverage the high-bandwidth memory and 512-bit SIMD for higher performance.

**Results:** Up to 2.5X improved performance compared to the Intel® Xeon® processor E5-2697 v4.
SeisSol Seismic Solver

SeisSol software simulates wave propagation and dynamic rupture based on the arbitrary high-order accurate derivative discontinuous Galerkin method (ADER-DG). Characteristics include tetrahedral meshes to approximate complex 3D model geometries and rapid model generation use of elastic, viscoelastic and viscoplastic material to approximate realistic geological subsurface properties. The code is Open Source.

Application: SeisSol Seismic Solver.
Code: Available here
Recipe: Download code and follow instructions

Images Source: Intel Labs

Value Proposition: SeisSol relies on Intel’s Open Source Library for small BLAS operations (matrix multiplications) LIBXSMM, enabling BLAS extensions on drop-in basis and automatically targets Intel® AVX, Intel® AVX2 and Intel® AVX-512 through future-proof just-in-time compilation techniques. LIBXSMM is also used in other widely-used scientific Open Source packages such as CP2K and Nek5000/NekBox.

Results: Up to 1.59X faster compared to the Intel® Xeon® processor E5-2697 v4.

See Configuration Details Section, slide 160. SOURCE: INTEL MEASURED RESULTS AS OF MARCH, 2016

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance *Other names and brands may be claimed as the property of others
**SPECFEM3D_GLOBE**

**SPECFEM3D_GLOBE simulates the three-dimensional global and regional seismic wave propagation based upon the spectral-element method (SEM).** It is a time-step algorithm which simulates the propagation of earth waves given the initial conditions, mesh coordinates/ details of the earth crust.

**Application:** specfem3D_globe  
**Baseline Code:** [https://geodynamics.org/cig/software/specfem3d_globe/](https://geodynamics.org/cig/software/specfem3d_globe/)  
**Optimized Code:** Pending check-in. **Recipe:** Runs out-of-the-box.

**Value Proposition:**
- The Intel® Xeon Phi™ processor improves performance for scalable workloads.  
- SPECFEM3D_GLOBE benefits from AVX-512 and high-bandwidth memory available on the Intel® Xeon Phi™ processor.  

**Results:** The Intel® Xeon Phi™ processor 7250 improved the simulation rate by up to 1.37X when compared to the Intel® Xeon® E5-2697v4 processors.  
**Over 90% parallel efficiency with Intel® Omni-Path Architecture (for 6 and 25 node runs of 55K and 220K mesh size workloads respectively).**

---

Image Source: [https://geodynamics.org/cig/software/specfem3d_globe/](https://geodynamics.org/cig/software/specfem3d_globe/)

**See Configuration Details Section, slide 160.**  
SOURCE: INTEL MEASURED RESULTS AS OF MAY, 2016

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to [http://www.intel.com/performance](http://www.intel.com/performance) *Other names and brands may be claimed as the property of others.*
Geophysics

SPECHEM3D_GLOBE simulates the three-dimensional global and regional seismic wave propagation based upon the spectral-element method (SEM). It is a time-step algorithm which simulates the propagation of earth waves given the initial conditions, mesh coordinates/details of the earth crust.

Application: specfem3D_globe
Baseline Code: https://geodynamics.org/cig/software/specfem3d_globe/

Value Proposition:
- The Intel® Xeon Phi™ processor improves performance for scalable workloads.
- SPECHEM3D_GLOBE benefits from Intel® AVX-512 and high-bandwidth memory available on the Intel® Xeon Phi™ processor.

Results: Up to 1.31X improved 3-node simulation rate compared to the Intel® Xeon® E5-2697v4 processors. Over 88% parallel efficiency with Intel® Omni-Path Architecture (6 nodes).
Enhancing exploration and extraction processes.

ENERGY INDUSTRY
ISO3DFD (3D Acoustic Isotropic Finite Difference)*

Iso3DFD - The Iso-3D 16th order isotropic kernel is at the heart of RTM algorithm. It plays a major role on accurate imaging of complex subsurfaces. This kernel computes the wave propagation used in seismic imaging. The code is in-house code.

Application: Iso3DFD (3D Acoustic Isotropic Finite Difference)

Code: Check for availability here

Recipe: -O3 -xMIC-AVX512 -fp-model fast -fma -qopenmp -lmemkind

Value Proposition:
- Iso3DFD kernel makes use of Intel® Advanced Vector Extensions 512 (Intel® AVX-512) and MCDRAM High Bandwidth Memory.
- Intel® Xeon Phi™ processor 7250 enables this application to significantly speedup the computation of seismic wave propagation.

Results: Up to 1.71X faster with the Intel® Xeon Phi™ processor 7250 compared to the Intel® Xeon® processor E5-2697 v4.
Sparse matrix-vector multiplication (SpMV) is an important kernel for a diverse set of applications in which systems with sparse pattern are used, such as scientific computing, engineering, economic modeling, information retrieval, oil & gas, weather consulting, animation, aero-scaping, recommender systems in machine learning, and earthquake prediction.

Application: Sparse Matrix Vector Multiply

Code: Available here. Recipe: Check for availability here

Value Proposition: The SpMV benchmark validates the Intel Xeon Phi Processor’s generational performance improvement. SpMV is a high-bandwidth LINPACK-like workload for Sparse Matrix Multiplication seen in many codes.

Results: Up to 2.3X faster compared to the Intel® Xeon® processor E5-2697 v4.

See Configuration Details Section, slide 160. SOURCE: INTEL MEASURED RESULTS AS OF APRIL, 2016

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance *Other names and brands may be claimed as the property of others
High Performance Conjugate Gradients (HPCG) Benchmark project is an effort to create a new metric for ranking HPC systems. HPCG is intended as a complement to the High Performance LINPACK (HPL) benchmark, currently used to rank the TOP500* computing systems.

**Application:** High Performance Conjugate Gradients (V3.1 binary)

**Code:** Available here. **Recipe:** See configuration details

**Value Proposition:** The HPCG benchmark, and is the more accurate portrayal of HPC App behavior vs. LINPACK and is thought to be the replacement to the top Top500 potentially, and validates the Intel Xeon Phi Processor's generational performance improvement.

**Results:** Up to 2.68X faster compared to the Intel® Xeon® processor E5-2697 v4.

Image Source: Univ. Maryland, Baltimore Co.

For configuration details, see slide 160.
High Performance Conjugate Gradients Performance Improvement with the Intel® Xeon Phi™ Processor

The High Performance Conjugate Gradients (HPCG) Benchmark project is an effort to create a new metric for ranking HPC systems. HPCG is intended as a complement to the High Performance LINPACK (HPL) benchmark, currently used to rank the TOP500* computing systems.

Application: High Performance Conjugate Gradients (V3.0)


Image Source: Univ. Maryland, Baltimore Co.

Value Proposition: The HPCG benchmark, and is the more accurate portrayal of HPC App behavior vs. LINPACK and is thought to be the replacement to the top Top500 potentially. and validates the Intel Xeon Phi Processor's generational performance improvement.

Results: Up to 2.16X faster compared to the Intel® Xeon® processor E5-2697 v4.

For configuration details, see slide 133.

SOURCE: INTEL MEASURED RESULTS AS OF FEBRUARY, 2017

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance *Other names and brands may be claimed as the property of others.
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    - Vectorization and threading optimization tools
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  - Intel® Data Analytics Acceleration Library
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  - Intel® Math Kernel Library
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  - Intel® Distribution for Python*
- Image, Signal, and Compression Routines
  - Intel® Integrated Performance Primitives
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  - Intel® Threading Building Blocks

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- Multi Node/Clustering
- Take Advantage of On-Package High-Bandwidth Memory
- Increase Memory and Power Efficiency

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WEB RESOURCES


• Modern Code: https://software.intel.com/en-us/modern-code

• Intel® SSF Configurations: http://www.intel.com/ssfconfigurations


CONFIGURATION DETAILS
### Configuration Information

**Slide 9**

<table>
<thead>
<tr>
<th>Intel® Xeon® Processor</th>
<th>Unscaled Core Frequency</th>
<th>Cores/Socket</th>
<th>Num Sockets</th>
<th>L1 Data Cache</th>
<th>L1 Cache</th>
<th>L2 Cache</th>
<th>L3 Cache</th>
<th>Memory</th>
<th>Memory Frequency</th>
<th>Memory Access</th>
<th>H/W Prefetchers Enabled</th>
<th>HT Enabled</th>
<th>Turbo Enabled</th>
<th>C States</th>
<th>O/S Name</th>
<th>Operating System</th>
<th>Compiler Version</th>
</tr>
</thead>
</table>
| X5472                  | 3.0 GHZ                | 4            | 2           | 32K            | 32K      | 12 MB    | None     | 32 GB  | 800 MHZ         | NUMA          | Y                     | N          | Disabled  | Fedora 20         | 3.11.10-301.fc20     
| X5570                  | 2.93 GHZ               | 4            | 2           | 32K            | 32K      | 256K     | 8 MB     | 48 GB  | 1333 MHZ        | NUMA          | Y                     | Y          | Disabled  | Fedora 20         | 3.11.10-301.fc20     
| X5680                  | 3.33 GHZ               | 6            | 2           | 32K            | 32K      | 256K     | 12 MB    | 48 MB  | 1333 MHZ        | NUMA          | Y                     | Y          | Disabled  | Fedora 20         | 3.11.10-301.fc20     
| E5 2690                | 2.9 GHZ                | 8            | 2           | 32K            | 32K      | 256K     | 20 MB    | 64 GB  | 1600 MHZ        | NUMA          | Y                     | Y          | Disabled  | Fedora 20         | 3.11.10-301.fc20     
| E5 2697 v2             | 2.7 GHZ                | 12           | 2           | 32K            | 32K      | 256K     | 30 MB    | 64 GB  | 1867 MHZ        | NUMA          | Y                     | Y          | Disabled  | Fedora 20         | 3.11.10-301.fc20     
| E 2695 v3              | 2.3 GHz                | 14           | 2           | 32K            | 32K      | 256K     | 35 MB    | 64 GB  | 2133 MHZ        | NUMA          | Y                     | Y          | Disabled  | Fedora 20         | 3.11.10-301.fc20     
| E 2697 v4              | 2.3 GHz                | 18           | 2           | 32K            | 32K      | 256K     | 45 MB    | 76 GB  | 2400 MHZ        | NUMA          | Y                     | Y          | Disabled  | Fedora 20         | 3.11.10-301.fc20     

*Intel measured results as of April 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 WD1003FLEX-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 LADMP2312KXXXX41, 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 WD1003FLEX-00MK2A0 System Disk. Mean Benchmark System Power Consumption: 378W. Estimated list price: $7300 source Intel Recommended Customer Pricing (RCP).
MACHINE LEARNING CLAIM/CONFIGURATION DETAILS

Faster training, better scaling efficiency and software improvement claims

1. Up to 50x faster training on 128-node as compared to single-node based on AlexNet* topology workload (batch size = 1024) training time using a large image database running one node Intel Xeon Phi processor 7250 (16 GB MCDRAM, 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), 1.0 TB SATA drive WD1003FZEX-00MK2A0 System Disk, running Intel® Optimized DNN Framework, training in 39.17 hours compared to 128-node identically configured with Intel® Omni-Path Host Fabric Interface Adapter 100 Series 1 Port PCIe x16 connectors training in 0.75 hours. Contact your Intel representative for more information on how to obtain the binary. For information on workload, see https://papers.nips.cc/paper/4824-Large image database-classification-with-deep-convolutional-neural-networks.pdf.

2. Up to 38% better scaling efficiency at 32-nodes claim based on GoogLeNet deep learning image classification training topology using a large image database comparing one node Intel Xeon Phi processor 7250 (16 GB MCDRAM, 1.4 GHz, 68 Cores) in Intel® Server System LADMP2312KXXX41, DDR4 96GB DDR4-2400 MHz, quad cluster mode, MCDRAM flat memory mode, Red Hat* Enterprise Linux 6.7, Intel® Optimized DNN Framework with 87% efficiency to unknown hosts running 32 each NVIDIA Tesla* K20 GPUs with a 62% efficiency (Source: http://arxiv.org/pdf/1511.00175v2.pdf showing FireCaffe* with 32 NVIDIA Tesla* K20s (Titan Supercomputer*) running GoogLeNet* at 20x speedup over Caffe* with 1 K20).

3. Up to 30x optimization based on CNN classification training workload running 2S Intel® Xeon® processor E5-2680 v3 running Berkeley Vision and Learning Center* (BVLC) Caffe + OpenBlas* library and then run tuned on the Intel® Optimized Caffe (internal development version) + Intel® Math Kernel Library (Intel® MKL)

Training and Scoring Configurations:

Systems

- 2S Intel® Xeon® Processor E5-2699 v4 (22 Cores, 2.3 GHz), 128GB DDR4-2400 memory, Red Hat* Enterprise Linux 6.7, Intel Caffe
- NVIDIA® Tesla® M40® (core@923MHz, 12GB, mem@3004MHz, 250W), DIGITS® Deep Learning Machine hosted on 2S Intel® Xeon® Processor E5-2620 v3, 64GB DDR3-2133 memory, Ubuntu* 14.04, Nvidia* Driver version 352.41, cuDNN v4, BVLC/Caffe cuDNN v5 or NVIDIA/Caffe cuDNN v5
- NVIDIA® Tesla® M4® (core@923MHz, 4GB, mem@3004MHz, 75W), DIGITS® Deep Learning Machine hosted on 1S Intel® Xeon® Processor E5-2620 v3, 64GB DDR3-2133 memory, Ubuntu* 14.04, Nvidia* Driver version 352.68, cuDNN v4, BVLC/Caffe cuDNN v5 or NVIDIA/Caffe cuDNN v5
- Intel Caffe - https://github.com/intelcaffe
- NVIDIA cuDNN v5 - https://developer.nvidia.com/cudnn

*Other names and brands may be claimed as the property of others
**Configuration details: LAMMPS Coarse-Grain Water Simulation**

**Intel® Xeon® processor E5-2697 v4**: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz, 18 Cores/Socket, 36 Cores, 72 Threads (HT and turbo on), DDR4 128GB, 2400 MHz, Red Hat 7.2, Wildcat Pass Motherboard, BMC 1.33.9832, FRU/SDR Package 1.09, 1.0 TB SATA Western Digital® 1003FZEX-00MK2A0 System Disk, 458W mean power consumption for LAMMPS water simulation, Scalability tests performed on nodes with Intel® Omni-Path Host Fabric Interface Adapter 100 Series 1 Port PCIe x16, I_MPI_FABRICS=shm:tni; I_MPI_TMI_PROVIDER=psm2.

**Intel® Xeon Phi™ processor 7250**: Intel® Xeon Phi™ processor 7250, 68 core, 272 threads, 1400 MHz core freq. (turbo on), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 11.R1/10.R0, DDR4 96GB 2400 MHz, Red Hat 6.7/7.2 (nohz_full=2-271 nmi_watchdog=0 rcu_noobs=2-271), quad cluster mode, MCDRAM flat memory mode, Adams Pass Motherboard, BMC 12.951, FRU/SDR Package 1.1, 1.0 TB SATA drive Western Digital® 1003FZEX-00MK2A0 System Disk, 374W mean power consumption for LAMMPS water simulation, Scalability tests performed on nodes with Intel® Omni-Path Host Fabric Interface Adapter 100 Series 1 Port PCIe x16, I_MPI_FABRICS=shm:tni; I_MPI_TMI_PROVIDER=psm2; I_MPI_SHM_LMT=shm; LAMMPS "Long-Range Thread" mode used for Intel package.

**NVIDIA Tesla K80**: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz, 18 Cores/Socket, 36 Cores, 72 Threads (HT and turbo on), DDR4 128GB, 2400 MHz, Red Hat 7.2, Super Micro* SuperServer 7065R-T, BIOS Version 2.0a, Super Micro® X10DRG-H Motherboard, CSE-118GHTS-R1K66BP FRU, 500GB SATA Seagate* ST9500423AS System Disk, NVIDIA Tesla* K80 GPU, NVIDIA CUDA* 7.5.17 (Driver: 352.93), ECC enabled, persistence mode enabled. Number of MPI tasks on host varied to give best performance. CUDA MPS* used where possible. 594W mean power consumption for LAMMPS water simulation.

**LAMMPS CONFIGURATION**: 30 Jul 2016 (Git Hash: 22fe3fd17875), Intel® Compiler 16.0.3, Intel® MPI 5.1.3.210, Optimization Flags: “-O3 -use_fast_math”

**Configuration details: VASP**

**INTEL XEON PHI CONFIGURATION**: Intel® Xeon Phi™ processor 7250, 68 core, 272 threads, 1400 MHz core freq. (turbo on), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 11.R1/10.R0, DDR4 96GB 2400 MHz, Red Hat 6.7/7.2, quad cluster mode, MCDRAM flat/cache memory mode, Adams Pass Motherboard, BMC 12.951, FRU/SDR Package 1.1, 1.0 TB SATA drive Western Digital® 1003FZEX-00MK2A0 System Disk, Scalability tests performed on nodes with Intel® Omni-Path Host Fabric Interface Adapter 100 Series 1 Port PCIe x16, I_MPI_FABRICS=shm:tni; I_MPI_TMI_PROVIDER=psm2.

**NEW (INTEL XEON)** CONFIGURATION: Dual Socket Intel® Xeon® processor Gold 6148 2.4 GHz, 20 Cores/Socket, 40 Cores, 80 Threads, HT on, turbo off, BIOS 86B.01.00.0412, 192GB total memory, 2666 MT/s / DDR4 RDIMM, Red Hat Enterprise Linux* 7.2 Linux 4.15.0-84.2.1.el7.x86_64, Tesla P100 384GB total memory, 2560 MHz, Red Hat Enterprise Linux Server 7.2 / 3.10.0-327.67.el7.x86_64, Tesla P100-PCIE-16GB (GP100), 3584 CUDA Cores, 16GB HBM2 memory, Software Details: Driver Version: 375.20, CUDA Version 8.0.44, OptiX Version 4.0.2

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### Configuration details: VASP*

**Intel® Xeon® processor E5-2697 v4**: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz, 18 Cores/Socket, 36 Cores, 72 Threads (HT and turbo off), DDR4 128GB, 2400 MHz, Red Hat 7.2, Wildcat Pass Motherboard, BMC 1.33.9832, FRU/SDR Package 1.0, 1.0 TB SATA Western Digital® 1003FZEX-00MK2A0 System Disk. Scalability tests performed on nodes with Intel® Omni-Path Host Fabric Interface Adapter 100 Series 1 Port PCIe x16, Intel® FABRICS=shm:mtmi, Intel® TMI PROVIDER=psm2.

**Intel® Xeon Phi™ processor 7250**: Intel® Xeon Phi™ processor 7250, 68 core, 272 threads, 1400 MHz core freq. (turbo on), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 11.R1/10.R0, DDR4 96GB 2400 MHz, Red Hat 6.7/7.2, quad cluster mode, MCDRAM flat/cache memory mode, Adams Pass Motherboard, BMC 12.951, FRU/SDR Package 1.1, 1.0 TB SATA drive Western Digital* 1003FZEX-00MK2A0 System Disk, Scalability tests performed on nodes with Intel® Omni-Path Host Fabric Interface Adapter 100 Series 1 Port PCIe x16, Intel® FABRICS=shm:mtmi, Intel® TMI PROVIDER=psm2.

**Intel® Compiler 16.0.3, Intel® MPI 5.1.3.210, ELPA 2016.05.002.** Optimization Flags: -O3 -xMIC-AVX512, GPU Device Flags: -gencode=arch=compute_35,code=sm_35,compute_35.


**RECIPE**: -O3 -qopenmp, -xMIC-AVX512 for Intel Compiler, ELPA for eigensolvers, MKL BLAS/LAPACK and MKL FFT.

### Power details:

<table>
<thead>
<tr>
<th>Workloads</th>
<th>Energy consumption, Average Watt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel Xeon E5-2697 v4</td>
<td>Intel Xeon Phi 7520</td>
</tr>
<tr>
<td>PdO2</td>
<td>369</td>
</tr>
<tr>
<td>PdO4</td>
<td>421</td>
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<tr>
<td>B.hr105</td>
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<td>CuC</td>
<td>437</td>
</tr>
<tr>
<td>SI256</td>
<td>439</td>
</tr>
</tbody>
</table>

### Configuration details: Embree v2.13

**Baseline**: Intel® Xeon® processor E5-2699 v4 @ 2.2GHz, 256 GB total memory, BIOS Configuration: default, turbo on, hyperthreading on, CentOS release 7.2.1511 / 3.10.0-327.36.2.el7.x86_64

**Intel® Xeon Phi™ processor 7250**: Intel® Xeon Phi™ processor 7520, 64 GB DDR4 total, 16 GB MCDRAM in quad/cache mode BIOS: Version: 572C610.86B.01.01.0147.060202162105 06/02/2016 BIOS Configuration: default, turbo on, hyperthreading on, Embree Version 2.13.0, Fedora Core 23 Server / 4.8.13-100.fc23.x86_64, Linux Power Scheme: performance governor, 8 GB of pre-allocated 2MB pgs

**NIHDA® GPU**: NVIDIA® TITAN X (GP102), 3584 CUDA Cores, 12GB GDDR5X memory, Software Details: CUDA Version 8.0.44, OptiX Version 4.0.1, CentOS release 7.2.1511 / 3.10.0-327.36.2.el7.x86_64

**Embree Availability, Reproducibility & Collateralizable**

2XGK210B PCI Express GEN3 Dual GPU. Availability

- Embree library code and sample apps are available as an approved, Intel supported open source project and is continually improved for new Intel hardware/ISA's as well as with new features and performance optimizations.

- Reproducibility
  - This has been reproduced and executed by a TCG Visualization Engineering staff member not working directly on Embree via recipe instructions provided by the Embree core team.
  - The Vendors have used the path tracer application used for benchmarking are publicly available: [https://github.com/embree/embree-benchmark/tree/v2.12.0.zip](https://github.com/embree/embree-benchmark/tree/v2.12.0.zip)
  - The OptiX Prime version of the path tracer is in the process of getting released as Open Source.

- Embree v2.13.0 can be downloaded from here: [https://github.com/embree/releases/tag/v2.13.0](https://github.com/embree/releases/tag/v2.13.0)

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*Other names and brands may be claimed as the property of others.*
The models for benchmarking are available here:
http://www.turbosquid.com/3d-models/bentley-blower-4-5-3d-max/595423
https://github.com/embree/models/releases/download/release/crown.zip
https://github.com/embree/models/releases/download/release/asian_dragon.zip
http://gamma.cs.unc.edu/Powerplant/

http://www.evermotion.org/shop/show_product/scene-10-archexteriors-vol-15/7997
http://www.evermotion.org/shop/show_product/scene-09-archexteriors-vol-25/11876
http://www.evermotion.org/shop/show_product/scene-09-archinteriors-vol-32/11010

Karst Fluid Flow availability by request from FIU through TACC. pnaw@tacc.utexas.edu

Configuration details: Monte Carlo / Black-Scholes / Binomial Tree

NVIDIA Tesla K80*: 2XGK210B PCI Express GEN3 Dual GPU 2496 Processor cores Base Clock 560MGHZ Boost Range 562-875MHZ 12GB GDDR5 Memory Clock 2.5GHz. Red Hat 6.7 (Santiago) HOST: Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo ON), 18 Cores/Socket, 36 Cores, 72 Threads (HT on), DDR4 128GB, 2400 MHz, Red Hat 6.5

Intel® Xeon Phi™ processor 7210: Intel® Xeon Phi™ processor 7210 64 core, 256 threads, 1300 MHz core freq. (Turbo OFF), 1600 MHz uncle freq. MCDRAM 16 GB 7.2 GT/s, BIOS 09D10, DDR4 96GB 2400 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode.

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (Turbo OFF), 1700 MHz uncle freq., MCDRAM 16 GB 7.2 GT/s, BIOS 09D10, DDR4 96GB 2400 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode

Configuration details: STAC-A2

STAC SUT ID INTIC160428 - Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7290, 72 core, 288 threads, 1500 MHz core freq. (turbo on), MCDRAM 16 GB, BIOS DELL0.3.3, DDR4 292GB 2400 MHz, Red Hat 7.3, quad cluster mode, MCDRAM flat memory mode, Dell PowerEdge C630p, 12GB SATA SSD drive.

STAC SUT ID IBM150305 - IBM POWER8*: Dual Socket IBM Power System S824, 12 Cores/Socket, 24 Cores, SMT4 (96 Threads), DDR3 1TB 1600 MHz, RH7, Bios Version IBM FW810.20, 1x571GB HD.

STAC SUT ID NVDIA14116 - NVIDIA Tesla® K80 : Dual Socket Intel® Xeon® processor E5-2690 v3 3.0 GHz, 10 Cores/Socket, DDR3 128TB, CentOS 6.6, Supermicro® SuperServer 2027GR-TRFH, Bvesion 3.0b, 1TB HD WDC WD1000CHTZ-0, NVIDIA Tesla® K80 GPU, NVIDIA CUDA® 6.5 (Driver: 340.58), ECC enabled.

Configuration details: STAC-A2

STAC SUT ID INTIC160428 - Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7290, 72 core, 288 threads, 1500 MHz core freq. (turbo on), MCDRAM 16 GB, BIOS DELL0.3.3, DDR4 292GB 2400 MHz, Red Hat 7.3, quad cluster mode, MCDRAM flat memory mode, Dell PowerEdge C630p, 12GB SATA SSD drive.

STAC SUT ID IBM150305 - IBM POWER8*: Dual Socket IBM Power System S824, 12 Cores/Socket, 24 Cores, SMT4 (96 Threads), DDR3 1TB 1600 MHz, RH7, Bios Version IBM FW810.20, 1x571GB HD.

STAC SUT ID NVDIA14116 - NVIDIA Tesla® K80 : Dual Socket Intel® Xeon® processor E5-2690 v3 3.0 GHz, 10 Cores/Socket, DDR3 128TB, CentOS 6.6, Supermicro® SuperServer 2027GR-TRFH, Bvesion 3.0b, 1TB HD WDC WD1000CHTZ-0, NVIDIA Tesla® K80 GPU, NVIDIA CUDA® 6.5 (Driver: 340.58), ECC enabled.

Configuration details: STAC-A2

STAC SUT ID INTIC160428 - Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7290, 72 core, 288 threads, 1500 MHz core freq. (turbo on), MCDRAM 16 GB, BIOS DELL0.3.3, DDR4 292GB 2400 MHz, Red Hat 7.3, quad cluster mode, MCDRAM flat memory mode, Dell PowerEdge C630p, 12GB SATA SSD drive.

STAC SUT ID IBM150305 - IBM POWER8*: Dual Socket IBM Power System S824, 12 Cores/Socket, 24 Cores, SMT4 (96 Threads), DDR3 1TB 1600 MHz, RH7, Bios Version IBM FW810.20, 1x571GB HD.

STAC SUT ID NVDIA14116 - NVIDIA Tesla® K80 : Dual Socket Intel® Xeon® processor E5-2690 v3 3.0 GHz, 10 Cores/Socket, DDR3 128TB, CentOS 6.6, Supermicro® SuperServer 2027GR-TRFH, Bvesion 3.0b, 1TB HD WDC WD1000CHTZ-0, NVIDIA Tesla® K80 GPU, NVIDIA CUDA® 6.5 (Driver: 340.58), ECC enabled.

Configuration details: CP2K® Linear Scaling (LS) Density Function Theory (DFT) – May 2016

Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz, 18 cores/socket, 36 cores, 72 threads (HT and Turbo ON), DDR4 64 GB, 2400 MHz, RHEL 6.6

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7260, 68 core (272 threads), 1.4 GHz base core freq. (Turbo ON), 1.7 GHz uncle freq., MCDRAM 16 GB 7.2 GT/s, BIOS 868.01.01.0124, DDR4 96 GB 2400 MHz, quadran cluster mode, MCDRAM cache memory mode, RHEL 6.6, MPSP 1.3.0, Intel Compiler 2017

NVIDIA Tesla® K80*: 2XGK210B PCI Express GEN3 Dual GPU 2496 Processor cores Base Clock 560MGHZ Boost Range 562-875MHZ 12GB GDDR5 Memory Clock 2.5GHz. Red Hat 6.6 HOST: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz, 18 cores/socket, 36 cores, 72 threads (HT and Turbo ON), DDR4 64 GB, 2400 MHz, RHEL 6.6

*Other names and brands may be claimed as the property of others
Building CP2K

LIBXSMM: git clone https://github.com/hfp/libxsmm.git; git checkout tags/1.4.3

- Automatically selected when using ARCH files as mentioned below

CP2K: make ARCH=Linux-x86-64-intel VERSION=pssmp AVX=3 MIC=1 LIBXSMM=2

Either CP2K intel branch (git clone --branch intel https://github.com/cp2k/cp2k.git)
Or master CP2K 4.0-development (https://github.com/cp2k/cp2k.git)

- https://github.com/cp2k/cp2k/raw/intel/cp2k/arch/Linux
- https://github.com/cp2k/cp2k/raw/intel/cp2k/arch/Linux-x86-64-intel.psmp

Running CP2K: CP2K@intel@KNL: CP2K_RECONFIGURE=1 (huge pages), CP2K_STACKSIZE=10000 (SMMs/batch), 
_I_MPI_PIN_DOMAIN=auto, _I_MPI_PIN_ORDER=scatter, 64 ranks, 1 thread/core

Configuration details: Trinity MILC* 

Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo ON), 18 Cores/Socket, 36 Cores, 72 Threads (HT on), DDR4 128GB, 2400 MHz, Red Hat 6.5

Intel® Xeon Phi® processor 7250: Intel® Xeon Phi® processor 7250 68 core, 272 threads, 1400 MHz core freq. (Turbo OFF), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 09D10, DDR4 96GB 2400 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode

NVIDIA Titan X*: Persistence mode enabled, full GPU Boost (auto), NVIDIA CUDA* 7.5. Host CPU was 2S Intel® Xeon® processor E5-2697 v3.

Configuration details: Qphix*

Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo ON), 18 Cores/Socket, 36 Cores, 72 Threads (HT on), DDR4 128GB, 2400 MHz, Red Hat 6.5

Intel® Xeon Phi® processor 7250: Intel® Xeon Phi® processor 7250 68 core, 272 threads, 1400 MHz core freq. (Turbo OFF), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 09D10, DDR4 96GB 2400 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode

NVIDIA Titan X*: Persistence mode enabled, full GPU Boost (auto), NVIDIA CUDA* 7.5, host CPU was 2S Intel® Xeon® processor E5-2697 v3.

Configuration details: BAW

Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo ON), 18 Cores/Socket, 36 Cores, 72 Threads (HT on), DDR4 128GB, 2400 MHz, Red Hat 6.5

Intel® Xeon Phi® processor 7210: Intel® Xeon Phi® processor 7210 64 core, 256 threads, 1300 MHz core freq. (Turbo OFF), 1600 MHz uncore freq. MCDRAM 16 GB 7.2 GT/s, BIOS 09D10, DDR4 96GB 2400 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode

Intel® Xeon Phi® processor 7250 (64 cores): Intel® Xeon Phi® processor 7250 64 core, 256 threads, 1300 MHz core freq. (Turbo OFF), 1600 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 09D10, DDR4 96GB 2400 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode

Configuration details: AMBER 16 IMPLICIT/EXPLICIT*

Intel® Xeon® processor E5-2697 v4: 25 Intel® Xeon® processor E5-2697 v4 2.3 GHz, 18 Cores/Socket, 36 Cores, 72 Threads (HT and turbo on), DDR4 128GB, 2400 MHz, Red Hat 7.2, Wildcat Pass Motherboard, BMC 1.33.9832, FRU/SDR Package 1.09, 1.0 TB SATA Western Digital* 1003FZEX, Intel® Compiler 16.0.3, Intel® MPI 5.1.3.210, Optimization Flags: “-O3 -fp-model fast=2 -no-pref-div, ” GPU Device Flags: “-O3 --use_node_math”

Configuration details: ROME*/SMl

Intel® Xeon® processor E5-2697 v4: Dual socket Intel® Xeon® processor E5-2697 v4, @2.3GHz 145W, 18 cores/socket HT enabled, 128GB RAM, Red Hat® Enterprise Linux Server release 6.7 (Santiago)

Intel® Xeon Phi® processor 7250: Intel® Xeon Phi® processor 7250 68 core, 272 threads, 1400 MHz core freq. MCDRAM 16 GB 7.2 GT/s, DDR4 96GB 2400 MHz, Red Hat Enterprise Linux Server release 6.7 (Santiago), quad cluster mode, MCDRAM cache mode

Workload: provided by Intel® PCCSB, Contact Youdong Mao youdong_mao@dfci.harvard.edu. (Performance data is based on 30 iterations). Workload Descriptions: Inflamasome data: 16306 images of NLRC4/NAIP2 inflammasome with a size of 2502 pixels

RP-a: 57001 images of proteasome regulatory particles (RP) with a size of 1602 pixels

RP-b: 35407 images of proteasome regulatory particles (RP) with a size of 1602 pixels

*Other names and brands may be claimed as the property of others
Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo ON), 18 Cores/Socket, 36 Cores, 72 Threads (HT off), DDR4 128GB, 2400 MHz, CentOS release 6.7 (Final)

Intel® Xeon Phi™ processor 7210: Intel® Xeon Phi™ processor 7210 64 core, 256 threads, 1300 MHz core freq. (Turbo ON), MCDRAM 16 GB 6.4 GT/s, BIOS GVPRCR1.86B.0010.R00.1800.3251732, DDR4 96GB 2133 MHz, Red Hat 7.2 (Maipo), quad cluster mode, MCDRAM cache mode.

configuration details: RELION*

configuration details: GROMACS

configuration details: OVERFLOW

configuration details: NWCHEM

configuration details: TACC LB53D

configuration details: NASA OVERFLOW

configuration details: 34x2/4T MPixOMP decomposition on Intel Xeon Phi Processor based system. 36x1 MPixOMP for Intel Xeon processor based platforms.

Additional details for LB53D configuration:

Additional details for OVERFLOW configuration:

Additional details for NWCHEM configuration:

Additional details for RELION configuration:

Additional details for GROMACS configuration:

Additional details for OVERFLOW configuration:

Additional details for NWCHEM configuration:

configuration details: RELION*

configuration details: GROMACS

configuration details: OVERFLOW

configuration details: NWCHEM

configuration details: TACC LB53D

configuration details: NASA OVERFLOW

configuration details: 34x2/4T MPixOMP decomposition on Intel Xeon Phi Processor based system. 36x1 MPixOMP for Intel Xeon processor based platforms.

Additional details for LB53D configuration:

Additional details for OVERFLOW configuration:

Additional details for NWCHEM configuration:

Additional details for RELION configuration:

Additional details for GROMACS configuration:

Additional details for OVERFLOW configuration:

Additional details for NWCHEM configuration:
Intel® Xeon® processor: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz, Turbo mode ON, 18 Cores/Socket, 36 Cores (HT off), DDR4 128GB, 2400 MHz, Wildcat Pass Platform. Disk: 800GB Intel SSD Kernel: 3.10.0-229.20.1.el6.x86_64

Intel® Xeon Phi™ processor: Intel® Xeon Phi™ processor 7250 68 core, 1400 MHz Turbo mode ON, HT off, 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, DDR4 96GB 2400 MHz, cache mode, Adams Pass Platform. Disk: 480 GB Intel SSD, Kernel: 3.10.0-229.20.1.el6.x86_64.knl2

Configuration details: OpenFOAM
Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo ON), 18 Cores/Socket, 36 Cores, 72 Threads (HT ON), DDR4 128GB, 2400 MHz, Red Hat 7.1, Intel® Omni-Path Host Fabric Interface Adapter 100 Series 1 Port PCIe x16, I_MPI_FABRICS=shm:tmi; I_MPI_TMI_PROVIDER=psm2
Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1466 MHz core freq. (Turbo ON), 1700 MHz uncore freq., MCDRAM 16 GB 7200 MHz, BIOS 10.R00, DDR4 98 GB 2400 MHz, Quad cluster mode, MCDRAM flat memory mode.


Configuration details: OpenLB
Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz, 18 Cores/Socket, 36 Cores, 72 Threads (HT and Turbo ON), DDR4 128GB, 2400 MHz, CentOS release 6.7, Composer 2016.2.181
Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq., Turbo OFF, 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 10.R00, DDR4 98 GB 2400 MHz, Red Hat 6.7 (Continued)

Configuration details: HiFUN
Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo ON), 18 Cores/Socket, 36 Cores, 72 Threads (HT ON), DDR4 128GB, 2400 MHz, Red Hat 7.2
Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1466 MHz core freq., 1700 MHz uncore freq., MCDRAM 16 GB 7200 MHz, BIOS 10.R00, DDR4 98 GB 2400 MHz, Red Hat 6.7 (Continued)

Configuration details: GE Tacoma
Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo ON), 18 Cores/Socket, 36 Cores, 72 Threads (HT ON), DDR4 128GB, 2400 MHz, Red Hat 7.2
Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1466 MHz core freq., 1700 MHz uncore freq., MCDRAM 16 GB 7200 MHz, BIOS 10.R00, DDR4 98 GB 2400 MHz, Red Hat 7.2 (Continued)

Configuration details: HiPB
Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo ON), 18 Cores/Socket, 36 Cores, 72 Threads (HT ON), DDR4 128GB, 2400 MHz, Red Hat 7.2
Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1466 MHz core freq., 1700 MHz uncore freq., MCDRAM 16 GB 7200 MHz, BIOS 10.R00, DDR4 98 GB 2400 MHz, Red Hat 7.2 (Continued)

Configuration details: NEMO
Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz, Turbo mode ON, 18 Cores/Socket, 36 Cores (HT off), DDR4 128GB, 2400 MHz, Wildcat Pass Platform. Disk: 800GB Intel SSD Kernel: 3.10.0-229.20.1.el6.x86_64

Intel® Xeon Phi™ processor: Intel® Xeon Phi™ processor 7250 68 core, 1400 MHz Turbo mode ON, HT off, 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, DDR4 96GB 2400 MHz, cache mode, Adams Pass Platform. Disk: 480 GB Intel SSD, Kernel: 3.10.0-229.20.1.el6.x86_64.knl2

Configuration details: OpenFOAM
Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo ON), 18 Cores/Socket, 36 Cores, 72 Threads (HT ON), DDR4 128GB, 2400 MHz, Red Hat 7.1, Intel® Omni-Path Host Fabric Interface Adapter 100 Series 1 Port PCIe x16, I_MPI_FABRICS=shm:tmi; I_MPI_TMI_PROVIDER=psm2
Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (Turbo ON), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 09D10, DDR4 96GB 2400 MHz, Red Hat 7.1 quad cluster mode, MCDRAM flat memory mode, Intel® Omni-Path Host Fabric Interface Adapter 100 Series 1 Port PCIe x16, I_MPI_FABRICS=shm:tmi; I_MPI_TMI_PROVIDER=psm2.


Configuration details: OpenLB
Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz, 18 Cores/Socket, 36 Cores, 72 Threads (HT and Turbo ON), DDR4 128GB, 2400 MHz, CentOS release 6.7, Composer 2016.2.181
Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (HT and Turbo ON). MCDRAM 16 GB 6.4 GT/s, DDR4 96GB 2133 MHz, Red Hat 7.2, Quadrant cluster mode, MCDRAM flat memory mode, Composer 2016.2.181

Configuration details: HiFUN
Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo ON), 18 Cores/Socket, 36 Cores, 72 Threads (HT ON), DDR4 128GB, 2400 MHz, Red Hat 6.5
Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (Turbo ON). MCDRAM 16 GB 6.4 GT/s, DDR4 96GB 2133 MHz, Red Hat 7.2, Quadrant cluster mode, MCDRAM flat memory mode, Composer 2016.2.181

Configuration details: GE Tacoma
Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo ON), 18 Cores/Socket, 36 Cores, 72 Threads (HT ON), DDR4 128GB, 2400 MHz, Red Hat 7.2
Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (Turbo ON). MCDRAM 16 GB 6.4 GT/s, DDR4 96GB 2133 MHz, Red Hat 7.2, Quadrant cluster mode, MCDRAM flat memory mode, Composer 2016.2.181

Additional details for TACOMA configuration: 64x4 MPIxOMP decomposition on Intel Xeon Phi Processor based systems. 32x1 MPIxOMP for Intel Xeon processor E5-2697v4.
NEMO Recipe
1. You should be registered at NEMO web-site http://www.nemo-ocean.eu/
2. Obtain NEMO code:
svn co -r 6609 https://forge.ipsl.jussieu.fr/nemo/svn/branches/2016/dev_v3_6_STABLE_OMP/NEMOGCM
3. Obtain XIOS code and built it using following instruction:
4. Create custom .fcm file in NEMOGCM/ARCH directory based on avail configurations.
5. Add paths to NetCDF and XIOS in configuration.
6. Replace with “-r8 -O3 -openmp -xMIC-AVX512” (to build binary for the Intel® Xeon Phi™ processor) and with “-r8 -O3 -openmp -xCORE-AVX2” (to build binary for BDW) %FCFLAGS and change “%CPP” to “-iE”, “-%FC” to “mpifort”, “-%LD” to “mpifort”, and “-%LDFLAGS” to “-Istdc++ -ilfcore”.
7. Use this instruction to build and run NEMO:
8. GYRE is a default NEMO workload, avail in NEMO package. default grid resolution is 25, you can change it to make bigger or smaller grid. All instructions placed here - http://www.nemo-ocean.eu/Using-NEMO/Configurations/GYRE (you should register and login to view most of technical information about NEMO).
9. Create 3 workloads by modifying namelist_ref and namelist_cfg files:
   1. Switch creating mesh files to off by changing “nn_msh” to 0 in namelist_ref file.
   2. Enable benchmark mode by changing “nn_bench” to 1 in namelist_ref file.
   3. To create GYRE 30, GYRE 50 and GYRE 70 workloads set following params in namelist_cfg file:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>GYRE 30</th>
<th>GYRE 50</th>
<th>GYRE 70</th>
</tr>
</thead>
<tbody>
<tr>
<td>jpcfg</td>
<td>30</td>
<td>50</td>
<td>70</td>
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<tr>
<td>jpidta</td>
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<td>1500</td>
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<td>1402</td>
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<td>2102</td>
</tr>
<tr>
<td>jpiglo</td>
<td>602</td>
<td>1000</td>
<td>1402</td>
</tr>
</tbody>
</table>

Configuration details: Danish Meteorological Institute HIROMB-BOOS-Model*
Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo ON), 18 Cores/Socket, 36 Cores, 72 Threads (HT on), DDR4 128GB, 2400 MHz, Red Hat 6.7
Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (Turbo OFF), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 09D10, DDR4 96GB 2400 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode

Configuration details: MPAS Ocean 4.0*
Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz, Turbo mode ON , 18 Cores/Socket, 72 Threads (HT on), DDR4 128GB, 2400 MHz, Red Hat 7.2. BIOS 86B0271.R00. Wildcat Pass Platform BMC version 1.33.9832 FRU/SDR Package 1.09. 1 1-TB SATA disk (Western Digital WD1003FZEX-00MK2A0) installed.
Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. Turbo mode ON, 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 10R00, DDR4 96GB 2400 MHz, Red Hat 7.2, quad cluster mode, MCDRAM Cache memory mode. Adams Pass Platform BMC version 12.9511 FRU/SDR Package 1.10. 1 1-TB SATA disk (Western Digital WD1003FZEX-00MK2A0) installed.

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

mpirun 48 port (B0 silicon). Intel® OPA fabric software revision 10.0.1.0.

CORE=ocean MODE=forward

Performance Increase

<table>
<thead>
<tr>
<th>EC 30 to 60 benchmark</th>
<th>Watt Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel® Xeon® processor E5-2697 v4 (36 core)</td>
<td>1.228113781</td>
</tr>
<tr>
<td>Intel® Xeon Phi™ processor 7250 (68 core)</td>
<td>3621</td>
</tr>
</tbody>
</table>

Intel® Xeon Phi™ processor: cache, cluster mode: quadrant. Following environment variables should be set:

export I_MPI_PIN_DOMAIN=core
export I_MPI_FABRICS=shm
ulimit -s unlimited

1 MPI rank/core is used for 68 core Intel® Xeon Phi™ processor 7250. "mpirun" command is same as the Intel Xeon processor.

Configuration details: Non-Hydrostatic Icosahedral Model

Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz Turbo OFF, 18 Cores/Socket, 36 Cores, 72 Threads HT on, DDR4 128GB, 2400 MHz, Red Hat 6.5

Intel® Xeon Phi™ processor 7210: Intel® Xeon Phi™ processor 7210 64 core, 256 threads, 1300 MHz core freq. (Turbo OFF), 1600 MHz uncore freq., MCDRAM 16 GB 6.4 GT/s, BIOS 09D10, DDR4 96GB 2133 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (Turbo OFF), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 09D10, DDR4 96GB 2400 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (Turbo OFF), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 09D10, DDR4 96GB 2400 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (Turbo OFF), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 09D10, DDR4 96GB 2400 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode

Intel® OPA: Series 100 HFI ASIC (B0 silicon), Series 100 Edge Switch – 48 port (B0 silicon), Intel® OPA fabric software revision 10.0.1.0.50 (applies to cluster results only)

Configuration details: GNAQPMS

Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz, Turbo ON, 18 Cores/Socket, 36 Cores, 72 Threads (HT ON), DDR4 128GB, 2400 MHz, CentOS release 6.7 (Final)

Intel® Xeon Phi™ processor 7210: Intel® Xeon Phi™ processor 7210 64 core, 256 threads, 1300 MHz core freq., Turbo ON, 1600 MHz uncore freq., MCDRAM 16 GB 6.4 GT/s, BIOS 10D42, DDR4 96GB 2133 MHz, Red Hat 7.2 (Maipo), SNC4 cluster mode, MCDRAM cache memory mode, MPSP 1.2.2

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq., Turbo ON, 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 10R00, DDR4 96GB 2400 MHz, Red Hat 7.2 (Maipo), SNC4 cluster mode, MCDRAM cache memory mode, MPSP 1.2.2

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq., Turbo ON, 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 10R00, DDR4 96GB 2400 MHz, Red Hat 7.2 (Maipo), SNC4 cluster mode, MCDRAM cache memory mode, MPSP 1.2.2

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 136 threads, 1400 MHz core freq. (Turbo OFF), 1700 MHz uncore freq., DDR4 6x16GB 2400 MHz quadrant cluster mode, MCDRAM 16 GB 6.4 GT/s cache* memory mode, BIOS 10R00, motherboard Adams Pass, Sleds per Chassis 1, BMC 12.951, FRU/SDR package 1.1, Red Hat 7.2(nohz_full=2-271 nmi_watchdog=0 rcu_nocs=2-271) kernel 3.10.0-327.el7.x86_64, System Disk 1 1.0 TB SATA drive WD1003FZEX-0MK2A0, v3.6.1 with Intel MIC config file, Intel® Compiler 17.0.0.098, Intel(R) MPI Library 2017 for Linux

*Other names and brands may be claimed as the property of others
For single-node (including power) studies: BASELINE CONFIGURATION: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz, Turbo mode ON, 18 Cores/Socket, 72 Threads (HT on), DDR4 128GB, 2400 MHz, Red Hat 7.2. BIOS 6B0271.000. Wildcat Pass Platform BMC version 1.33.9832. FRU/SDR Package 1.09. 1 WDC WD1003FZEX-01-TB SATA installed.

XEON PHI CONFIGURATION: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. Turbo mode ON for single-node studies/OFF for cluster scaling. 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 10R00, DDR4 96GB 2400 MHz, Red Hat 7.2, quad cluster mode, MCDRAM flat memory mode. Adapts Pass Platform BMC version 12.9511 FRU/SDR Package 1.10. 1 WDC WD1003FZEX-01-TB SATA installed. For multi-node studies: BASELINE CONFIGURATION: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz, Turbo mode OFF, 18 Cores, 72 Threads (HT on), DDR4 128GB, 2400 MHz, Oracle Linux 7.2. BIOS SESC610.66B.01.01.0016.033120161139. Grantly-EP Platform. FRU/SDR Package 1.13. Scalability tests performed on nodes with Intel® Omni-Path Host Fabric Interface Adapter 100 Series 1 Port PCIe x16, I_MPI_FABRICS=shm:tm:; I_MPI_TMI_PROVIDER=psm2

XEON PHI CONFIGURATION: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. Turbo mode OFF, 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS GVPRCRB1.66B.0010.012.1606034232, DDR4 96GB 2400 MHz, Oracle Linux 7.2, quad cluster mode, MCDRAM flat memory mode. Adapts Pass Platform BMC version 12.9511 FRU/SDR Package 1.10. Scalability tests performed on nodes with Intel® Omni-Path Host Fabric Interface Adapter 100 Series 1 Port PCIe x16, I_MPI_FABRICS=shm:; I_MPI_TMI_PROVIDER=psm2

HOMME version: https://svn-homme-model.cgd.ucar.edu//branch_tags/dependencies/tags/dependencies200

Compiled with "-o3 -fp-model fast" plus "-xcORE-AVX2" (baseline) or "-xMIC-AVX512" (Xeon Phi)

Configuration details: IFS RAPS14

Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz, 18 cores/socket, 36 cores, 72 threads (HT and Turbo ON), BIOS GRRFSDP1.86B0271.R00.1510301446, DDR4 64 GB, 2400 MHz, RHEL 7.2, 1.0 TB SATA drive WD1003FZEX-00MK240, /proc/sys/vm/nr_hugepages=12000, Intel Compiler 2017 Beta Update1, tbbmalloc_proxy Processor settings: 18 MPI tasks, 2 OpenMP threads per task, NRPROMA=-4, NRPROMA=-12. Environment variables: OMP_STACKSIZE=48M, KMP AFFINITY=compact, I_MPI_FABRICS=shm, I_MPI_PIN_DOMAIN=omp, I_MPI_PIN_PROCESSOR_LIST=allcores, I_MPI_PIN_ORDER=bunch, TBB_MALLOC_USE_HUGE_PAGES=1

Intel® Xeon® processor 7250: Intel® Xeon® processor 7250 68 core, 272 threads, 1400 MHz base core freq., Turbo mode ON, 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS GVPRCRB1.66B.0011.02.16060440407, DDR4 96 GB 2400 MHz, Quadrant cluster mode, MCDRAM cache memory mode, RHEL 7.2, XPSL 1.4, 1.0 TB SATA drive WD1003FZEX-00MK240, /proc/sys/vm/nr_hugepages=24000, Intel Compiler 2017 Beta Update1, tbbmalloc_proxy. Processor settings: 34 MPI tasks, 4 OpenMP threads per task, NRPROMA=-4, NRPROMA=-48. Environment variables: OMP STACKSIZE=48M, KMP AFFINITY=compact, KMP BLOCKTIME=12, KMP_HW_SUBSET=2t, I_MPI_FABRICS=shm, I_MPI_SHM_LMT=direct, I_MPI_PIN_ORDER=scatter, TBB_MALLOC_USE_HUGE_PAGES=1


Recipe: Application was recompiled with Intel® AVX-512. Minor source code changes were applied to some of the key routines to ensure vectorization. IFS RAPS14 is available under a license from ECMWF. A full list of code modifications and compiler settings used has been delivered and is available to licensed developers from ECMWF. The same improved source code was used for testing both Intel® Xeon® and Intel® Xeon Phi™.

Average time step length: Average time step length computed by averaging the timings for 16 normal and 8 radiation time steps in a 24h forecast run.

Average energy consumption: Dual Intel® Xeon® processor E5-2697 v4 2.3GHz, 18 cores/socket 421W, Intel® Xeon Phi™ processor 7250, 68 cores (272 threads), 1.4 GHz 345W.

Configuration details: POP

Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz, 18 Cores/Socket, 36 Cores, 72 Threads (HT and Turbo ON), DDR4 128GB, 2400 MHz, Oracle Linux Server release 6.7

Intel® Xeon Phi™ processor 7210: Intel® Xeon Phi™ processor 7210 64 core, 256 threads, 1300 MHz core freq. (HT and Turbo ON), 1600 MHz uncore freq., MCDRAM 16 GB 6.4 GT/s, BIOS 10D28, DDR4 96GB 2133 MHz, Red Hat 7.2, quad cluster mode, MCDRAM cache memory mode, MPSP 1.2.2; MKL: 11.3.2

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (HT and Turbo ON), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 10D28, DDR4 96GB 2400 MHz, Red Hat 7.2, quad cluster mode, MCDRAM cache memory mode, MPSP 1.2.2; MKL: 11.3.2

Intel® Xeon Phi™ processor 7250 (64 cores): Intel® Xeon Phi™ processor 7210 64 core, 256 threads, 1300 MHz core freq. (HT and Turbo ON), 1600 MHz uncore freq., MCDRAM 16 GB 6.4 GT/s, BIOS 10D42, DDR4 96GB 2133 MHz, Red Hat 7.2 (Maipo), SNC4 cluster mode, MCDRAM cache memory mode

Intel® Xeon Phi™ processor 7250 (64 cores): Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (HT and Turbo ON), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 10R00, DDR4 96GB 2400 MHz, Red Hat 7.2 (Maipo), SNC4 cluster mode, MCDRAM cache memory mode

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

Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo ON), 18 Cores/Socket, 36 Cores, 36 Threads (HT off), DDR4 128GB, 2400 MHz, Red Hat 6.5

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (Turbo on: 1500 MHz), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, DDR4 96GB 2400 MHz, SUSE Linux 12, various cluster and memory modes

<table>
<thead>
<tr>
<th>Workload</th>
<th>Xeon Phi 7250 Config</th>
<th>Xeon E5-2697 v4 Config</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMG</td>
<td>SNC4 Cache; 60x60x60; 272 ranks</td>
<td>109x109x109; 36 ranks</td>
</tr>
<tr>
<td>MiniFE</td>
<td>Quad Flat; 30x30x30; 136 ranks</td>
<td>244x244x244; 36 ranks</td>
</tr>
<tr>
<td>UMT</td>
<td>SNC4 Cache; 7x7x7; 272 ranks</td>
<td>7x7x7; 36 ranks</td>
</tr>
<tr>
<td>SNAP</td>
<td>SNC4 Flat; 32x64x64; 136 ranks</td>
<td>32x24x48; 36 ranks</td>
</tr>
<tr>
<td>GTC</td>
<td>Quad Flat; npartdom=2, micell=200; 128 ranks</td>
<td>Npartdom=1; micell=100; 36 ranks</td>
</tr>
<tr>
<td>MILC</td>
<td>SNC4 Flat; 16x32x32x34; 136 ranks</td>
<td>16x16x16x36; 36 ranks</td>
</tr>
<tr>
<td>MiniGhost</td>
<td>SNC4 Flat; 268x268x272; 136 ranks</td>
<td>452x453x456; 36 ranks</td>
</tr>
<tr>
<td>MiniDFT</td>
<td>Quad Flat; Single Node Workload; 68 ranks</td>
<td>Single Node Workload; 36 ranks</td>
</tr>
</tbody>
</table>

Configuration details: CP2K® Linear Scaling (LS) Density Function Theory (DFT)

Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz, 18 cores/socket, 36 cores (HT ON), 72 threads (HT and Turbo ON), DDR4 64 GB, 2400 MHz, RHEL 7.1, Intel® Omni-Path Host Fabric Interface Adapter 100 Series 1 Port PCIe x16, I_MPI_FABRICS=shm:tmi; I_MPI_TMI_PROVIDER=psm2

Intel® Xeon Phi™ processor 7250 (68 cores): Intel® Xeon Phi™ processor 7260, 68 core (272 threads), 1.4 GHz base core freq. (Turbo ON), 1.7 GHz uncore freq., MCDRAM 16 GB 2400 MHz, quadrant cluster mode, MCDRAM cache memory mode, Intel® Omni-Path Host Fabric Interface Adapter 100 Series 1 Port PCIe x16, I_MPI_FABRICS=shm:tmi; I_MPI_TMI_PROVIDER=psm2, RHEL 7.1, MPSP 1.3.0, Intel Compiler 2017

Building CP2K - Build Recipe: see https://github.com/hfp/xconfigure#xconfigure for more details

LIBXSMM: git clone https://github.com/hfp/libxsmm.git

- LIBXSMM is automatically discovered when using the ARCH files as mentioned below

- **CP2K**: make ARCH=Linux-x86-64-intel VERSION=psmp AVX=3 MIC=1 LIBXSMM=2 (CP2K/intel branch, CP2K/master, or any regular release since CP2K 3.0 are fine)

  ARCH files may be taken from Intel's branch of CP2K:

  - https://github.com/cp2k/cp2k/raw/intel/cp2k/arch/Linux-x86-64-intel
  - https://github.com/cp2k/cp2k/raw/intel/cp2k/arch/Linux-x86-64-intel.psm

Runtime Environment

I_MPI_PIN_DOMAIN=auto, I_MPI_PIN_ORDER=scatter, OMP_NUM_THREADS (according to rank count)

Results shown are achieved with 2 threads/core, rank count usually to match a square number

Configuration details: BerkeleyGW (Sigma Phase) Benzene

Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo ON), 18 Cores/Socket, 36 Cores, 72 Threads (HT on), Wildcat Pass, DDR4 128GB, 2400 MHz, BMC ver. 1.33.9832, Red Hat 7.2, BIOS 680B271.R00, FRU/SDR Package 1.09, kernel 3.10.0-327.el7.x86_64, 1.0 TB SATA drive WD1003FZEX-00MK2A0, Idle Power measurement 89W

Intel® Xeon Phi™ processor 7210: Intel® Xeon Phi™ processor 7250 64 core, 256 threads, 1300 MHz core freq. 6 x 16 GB 2400 MHz DDR4, Memory mode = cache, Cluster mode=quadrant, BMC ver. 12.951, Red Hat 7.2, BIOS 10R00, FRU/SDR Package 1.1, kernel 3.10.0-327.el7.x86_64, 1.0 TB SATA drive WD1003FZEX-00MK2A0, Idle Power measurement 122W

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. 6 x 16 GB 2400 MHz DDR4, Memory mode = cache, Cluster mode=quadrant, BMC ver. 12.951, Red Hat 7.2, BIOS 10R00, FRU/SDR Package 1.1, kernel 3.10.0-327.el7.x86_64, 1.0 TB SATA drive WD1003FZEX-00MK2A0, Idle Power measurement 122W

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. 6 x 16 GB 2400 MHz DDR4, Memory mode = cache, Cluster mode=quadrant, BMC ver. 12.951, Red Hat 7.2, BIOS 10R00, FRU/SDR Package 1.1, kernel 3.10.0-327.el7.x86_64, 1.0 TB SATA drive WD1003FZEX-00MK2A0, Idle Power measurement 122W

*Other names and brands may be claimed as the property of others
Configuration details: PWmat

Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz, 18 Cores/Socket, 36 Cores, 72 Threads, HT ON, Turbo ON, DDR4 128GB, 2400 MHz, CentOS release 6.7

Intel® Xeon Phi™ processor 7210: Intel® Xeon Phi™ processor 7210 64 core, 256 threads, 1300 MHz core freq., HT ON, Turbo ON, 1600 MHz uncore freq., MCDRAM 16 GB 6.4 GT/s, BIOS 10R00, DDR4 96GB 2133 MHz, Red Hat 6.7, SNC4 cluster mode, MCDRAM cache memory mode, MKL: 11.3.2

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq., HT ON, Turbo ON, 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 10R00, DDR4 96GB 2400 MHz, Red Hat 7.2, SNC4 cluster mode, MCDRAM cache memory mode, MKL: 11.3.2

Configuration details: Quantum ESPRESSO®

Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz, 18 cores/socket, 36 cores, 72 threads (HT ON, Turbo OFF), DDR4 64, 2400 MHz, RHEL 6.6

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7260, 68 core (272 threads), 1.4 GHz base core freq. (Turbo ON), 1.7 GHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 10D42, DDR4 96GB 2133 MHz, quadrant cluster mode, MCDRAM cache memory mode, RHEL 6.6, MPSP 1.3, Intel Compiler 2017

Building Quantum ESPRESSO

• Ensure that make.inc uses
  -D__INTEL -D__OPENMP -D__DFTI -D__MPI -D__PARA -D__SCALAPACK -D__ELPA_2016
  -D__NON_BLOCKING_SCATTER -D__EXX_ACE
• Add -xMIC-AVX512 or -xCORE-AVX2 (depends on the target) to CFLAGS and FFLAGS

Runing QE: NNRANKS, NPOOL, NTASK, and NDIAG may require parameter exploration!

Intel® Xeon Phi™ processor 7250 (68 cores)
  • mpirun -n NNRANKS /path/to/binary.x -nk NPOOL -nt NTASK -nd NDIAG -i workload.in

Intel® Xeon® processor E5-2697 v4o
  • mpirun -n NNRANKS /path/to/binary.x -nk NPOOL -nt NTASK -nd NDIAG -i workload.in

Configuration details : Qphix®

Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo ON), 18 Cores/Socket, 36 Cores, 72 Threads (HT on), DDR4 128GB, 2400 MHz, Red Hat 6.5

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (turbo on), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 09D10, DDR4 96GB 2400 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode.

Intel® Xeon Phi™ processor 7210: Intel® Xeon Phi™ processor 7210 64 core, 256 threads, 1300 MHz core freq. (Turbo OFF), 1600 MHz uncore freq., MCDRAM 16 GB 6.4 GT/s, BIOS 09D10, DDR4 96GB 2133 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (Turbo OFF), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 09D10, DDR4 96GB 2400 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode

Configuration details: Cloverleaf®

Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo ON), 18 Cores/Socket, 36 Cores, 72 Threads (HT on),DDR4 128GB, 2400 MHz, Red Hat 6.5

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (turbo on), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 09D10, DDR4 96GB 2400 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode.

Intel® Xeon Phi™ processor 7210: Intel® Xeon Phi™ processor 7210 64 core, 256 threads, 1300 MHz core freq. (Turbo OFF), 1600 MHz uncore freq., MCDRAM 16 GB 6.4 GT/s, BIOS 09D10, DDR4 96GB 2133 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (Turbo OFF), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 09D10, DDR4 96GB 2400 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode

Configuration details: Chroma®

Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo ON), 18 Cores/Socket, 36 Cores, 72 Threads (HT on), DDR4 128GB, 2400 MHz, Red Hat 6.5

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (turbo on), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 09D10, DDR4 96GB 2400 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode.

Intel® Xeon Phi™ processor 7210: Intel® Xeon Phi™ processor 7210 64 core, 256 threads, 1300 MHz core freq. (Turbo OFF), 1600 MHz uncore freq., MCDRAM 16 GB 6.4 GT/s, BIOS 10D42, DDR4 96GB 2133 MHz, Red Hat 7.2 (Maipo), SNC4 cluster mode, MCDRAM cache memory mode

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq., Turbo ON, 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 10R00, DDR4 96GB 2400 MHz, Red Hat 7.2 (Maipo), SNC4 cluster mode, MCDRAM cache memory mode

*Other names and brands may be claimed as the property of others
Configuration details: MILC
Workload/Binary: ks_imp_rhmc compiled with Makefile (for double precision) included with MILC package (modified to enable QPhiX [KNL/SKX] and QUDA [P100]). Used Intel® Compiler and Intel® MPI part of Intel® Parallel Studio XE Cluster Edition 2017 update 4
Run Configuration: Lattice Volume: 24^4(4). Runs performed with optimal MPI x OpenMP configuration for the respective processors. KMP_AFFINITY=granularity= fine, scatter.
BASELINE: 2 socket, 2.4GHz, 36 cores, turbo and HT on, BIOS 860B271.R00, 128GB total memory, 8 slots / 16 GB / 2400 MHz / DDR4 RDIMM, 1 x 1TB SATA, Red Hat Enterprise Linux* 7.2 kernel 3.10.0-327
Intel® Xeon® 6148 Gold: Intel® Xeon® Gold processor 6148, 2.4GHz, 40 cores, turbo and HT on, BIOS 86B01.00.0412, 192GB total memory, 12 slots / 16 GB / 2666 MHz / DDR4 RDIMM, 1 x 800GB INTEL SSD SC22BA0, Red Hat Enterprise Linux® 7.2 kernel 3.10.0-327.
Intel® Xeon® Phi™ 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (turbo off), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, DDR4 96GB 2400 MHz, Red Hat 7.2, Quad cluster mode, MCDRAM Flat memory mode
Configuration details: CloverLeaf 2D
Workload/Binary: clover_leaf compiled with standard Makefile included with CloverLeaf package. Used Intel® Compiler and Intel® MPI part of Intel® Parallel Studio XE Cluster Edition 2017 update 4, with additional build options [-xCORE-AVX2 | -xCORE-AVX512 | -xMIC-AVX512] as required. Used PGI* Compiler and OpenMPI part of PGI version 17.3 for OpenACC runs, with additional build options [-ta=multicore -tp=haswell | -ta=teslaccc60] as required.
Run Configuration: 3840^2 and 960^2 mesh problem sizes simulate for 2955 time-steps. Runs performed with optimal MPI x OpenMP configuration for the respective processors. KMP_AFFINITY=granularity=fine, compact.
Intel® Xeon® E5-2697 v4: 2 socket, 2.3GHz, 36 cores, turbo and HT on, BIOS 868B271.R00, 128GB total memory, 8 slots / 16 GB / 2400 MHz / DDR4 RDIMM, 1 x 1TB SATA, Red Hat Enterprise Linux* 7.2 kernel 3.10.0-327
Intel® Xeon® Phi™ 7250: 1 socket, 68 core, 272 threads, 1400 MHz core freq. (turbo off), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, DDR4 96GB 2400 MHz, Red Hat 7.1, Quad cluster mode, MCDRAM Flat memory mode
Configuration details: CloverLeaf 3D
Workload/Binary: clover_leaf 3d compiled with standard Makefile included with CloverLeaf 3D package. Used Intel® Compiler and Intel® MPI part of Intel® Parallel Studio XE Cluster Edition 2017 update 4, with additional build options [-xCORE-AVX2 | -xCORE-AVX512 | -xMIC-AVX512] as required. Used PGI* Compiler and OpenMPI part of PGI version 17.3 for OpenACC runs, with additional build options [-ta=multicore -tp=haswell | -ta=teslaccc60] as required.
Run Configuration: 256^3 mesh problem sizes simulate for 87 time-steps. Runs performed with optimal MPI x OpenMP configuration for the respective processors. KMP_AFFINITY=granularity=fine, compact.
Intel® Xeon® E5-2697 v4: 2 socket, 2.3GHz, 36 cores, turbo and HT on, BIOS 868B271.R00, 128GB total memory, 8 slots / 16 GB / 2400 MHz / DDR4 RDIMM, 1 x 1TB SATA, Red Hat Enterprise Linux* 7.2 kernel 3.10.0-327
Intel® Xeon® Phi™ 7250: 1 socket, 68 core, 272 threads, 1400 MHz core freq. (turbo off), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, DDR4 96GB 2400 MHz, Red Hat 7.1, Quad cluster mode, MCDRAM Flat memory mode
Configuration details: TeaLeaf
Workload/Binary: tea_leaf compiled with standard Makefile included with TeaLeaf package. Used Intel® Compiler and Intel® MPI part of Intel® Parallel Studio XE Cluster Edition 2017 update 4, with additional build options [-xCORE-AVX2 | -xCORE-AVX512 | -xMIC-AVX512] as required.
Run Configuration: 3840^2 mesh problem size simulated for 10 time-steps. Runs performed with optimal MPI x OpenMP configuration for the respective processors. KMP_AFFINITY=granularity=fine, compact.
Intel® Xeon® E5-2697 v4: 2 socket, 2.3GHz, 36 cores, turbo and HT on, BIOS 868B271.R00, 128GB total memory, 8 slots / 16 GB / 2400 MHz / DDR4 RDIMM, 1 x 1TB SATA, Red Hat Enterprise Linux* 7.2 kernel 3.10.0-327
Intel® Xeon® Phi™ 7250: 2 socket, 4.2GHz, 40 cores, turbo and HT on, BIOS 86C620.86B.01.00.0470, 192GB total memory, 12 slots / 16 GB / 2666 MHz / DDR4 RDIMM, Red Hat Enterprise Linux* 7.3 kernel 3.10.0-314.
Intel® Xeon® Phi™ 7250: 1 socket, 68 core, 272 threads, 1400 MHz core freq. (turbo off), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, DDR4 96GB 2400 MHz, Red Hat 7.1, Quad cluster mode, MCDRAM Flat memory mode

*Other names and brands may be claimed as the property of others
**Configuration details: Soft Sphere Simulation**

Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz, 18 Cores/Socket, 36 Cores, 72 Threads (HT and Turbo ON), DDR4 128GB, 2400 MHz, Oracle Linux Server release 6.7

Intel® Xeon Phi™ processor 7210: Intel® Xeon Phi™ processor 7210 64 core, 256 threads, 1300 MHz core freq. (HT and Turbo ON), 1600 MHz uncore freq., MCDRAM 16 GB 6.4 GT/s, BIOS 10D28, DDR4 96GB 2133 MHz, Red Hat 7.2, quad cluster mode, MCDRAM cache memory mode.

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (Turbo Cache ON), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 10D28, DDR4 96GB 2400 MHz, Red Hat 7.2, quad cluster mode, MCDRAM cache memory mode.

**Configuration details: PETSC – Portable, Extensible Toolkit For Scientific Computation**

Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo OFF), 18 Cores/Socket, 36 Cores, 72 Threads (HT on), DDR4 128GB, 2400 MHz, Red Hat 6.5

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. Turbo mode ON, 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 10R00, DDR4 96GB 2400 MHz, Red Hat 7.2, quad cluster mode, MCDRAM flat memory mode. Adams Pass Platform BMC version 12.9511 FRU/SDR Package 1.10. 1 1-TB SATA disk installed.

**Configuration & Recipe details: YASK HPC Stencils, AWP-ODC Kernel**

Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo ON), 18 Cores/Socket, 36 Cores, 72 Threads (HT on), DDR4 128GB, 2400 MHz, Red Hat Enterprise Linux Server release 7.2

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (Turbo ON), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 86B.0010.R00, DDR4 96GB 2400 MHz, quad cluster mode, MCDRAM flat memory mode, Red Hat Enterprise Linux Server release 6.7

**Configuration & Recipe details: YASK HPC Stencils, iso3DFD Kernel**

Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo OFF), 18 Cores/Socket, 36 Cores, 72 Threads (HT on), DDR4 128GB, 2400 MHz, Red Hat Enterprise Linux Server release 7.2

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (Turbo OFF), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 86B.0010.R00, DDR4 96GB 2400 MHz, quad cluster mode, MCDRAM flat memory mode, Red Hat Enterprise Linux Server release 6.7

**Configuration details: SeisSol Seismic Solver**

Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz, 18 Cores/Socket, 36 Cores, 72 Threads (HT and Turbo ON), DDR4 128GB, 2400 MHz, RHEL 6.7

Intel® Xeon Phi™ processor 7210: Intel® Xeon Phi™ processor 7210 64 core, 256 threads, 1300 MHz core freq. (HT and Turbo ON), 1600 MHz uncore freq., MCDRAM 16 GB 6.4 GT/s, BIOS 09D10, DDR4 96GB 2133 MHz, RHEL 6.7, quad cluster mode, MCDRAM flat memory mode, MPSP 1.2.2; MKL: 11.3.2

Intel® Xeon Phi™ processor 7250 (68 cores): Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (HT and Turbo ON), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 09D010, DDR4 96GB 2400 MHz, SUSE 12, quad cluster mode, MCDRAM flat memory mode, MPSP 1.2.2; MKL: 11.3.2

**Configuration details: SPECFEM3D_GLOBE**

Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo OFF), 18 Cores/Socket, 36 Cores, 72 Threads (HT ON), DDR4 128GB, 2400 MHz, Red Hat 6.5

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (Turbo OFF), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 09D10, DDR4 96GB 2400 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode, Intel® Omni-Path Host Fabric Interface Adapter 100 Series 1 Port PCIe x16

**Configuration details: 3D Isotropic Finite Difference**

Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz, 18 Cores/Socket, 36 Cores, 72 Threads (HT ON, Turbo OFF), DDR4 128GB, 2400 MHz, Oracle Linux Server release 6.7

Intel® Xeon Phi™ processor 7210: Intel® Xeon Phi™ processor 7210 64 core, 256 threads, 1300 MHz core freq. (HT and Turbo ON), 1600 MHz uncore freq., MCDRAM 16 GB 6.4 GT/s, BIOS 10D28, DDR4 96GB 2133 MHz, CentOS 7.2, quad cluster mode, MCDRAM flat memory mode, MPSP 1.3.1

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (HT and Turbo ON), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 10D28, DDR4 96GB 2400 MHz, CentOS 7.2, quad cluster mode, MCDRAM flat memory mode, MPSP 1.3.1
Configuration details: Sparse Matrix Vector Multiply using SpMV*
Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo off), 18 Cores/Socket, 36 Cores, 72 Threads (HT on), DDR4 128GB, 2400 MHz, Red Hat 6.5
Intel® Xeon Phi™ processor 7210: Intel® Xeon Phi™ processor 7210 64 core, 256 threads, 1300 MHz core freq. (Turbo off), 1600 MHz uncore freq., MCDRAM 16 GB 6.4 GT/s, BIOS 09D10, DDR4 96GB 2133 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode
Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (Turbo off), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 09D10, DDR4 96GB 2400 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode

Configuration details: High Performance Conjugate Gradients*
Baseline: Intel® Xeon® Processor E5-2697V4, 18 cores, 2 processes per node, each has 18 threads
Intel® Xeon® Scalable Gold 6148 processor, Turbo off, SMT on, 20 cores, 2 processes per node, each has 20 threads
Intel® Xeon Phi™ Processor 7250, Turbo on, SMT on, FLAT mode, 68 cores, 16Gb MCDRAM, 4 processes per node, each has 34 threads

Configuration details: High Performance Conjugate Gradients* (cluster)
Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo ON), 18 Cores/Socket, 36 Cores, 72 Threads (HT on), DDR4 128GB, 2400 MHz, Red Hat 6.5
Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (Turbo ON), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 09D10, DDR4 96GB 2400 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode. Cluster results exploited Intel® OPA Fabric.
Intel® OPA: Series 100 HFI ASIC (80 silicon), Series 100 Edge Switch – 48 port (80 silicon). Intel® OPA fabric software revision 10.0.1.0.50 (applies to cluster results only)
Intel® MPI version was 5.1.3.181. OpenMP from Intel Compiler 16.0 update 1. MKL is not used/required for running HPCG. For optimal performance, KNL should be booted in Quadrant Cluster Mode, Flat Memory Mode, Turbo Mode enabled.

Running on 68-cores Xeon Phi 7250 node with MCDRAM on NUMA node 1: export KMP_PLACE_THREADS=17c,2t   export KMP_AFFINITY=granularity=fine,compact   #> mpiexec.hydra -n 4 -hosts knl7250 numactl --membind=1 xhpcg_knl --n=160
For multiple OPA linked nodes following OPA parameters used:
export PSM2_MQ_RNDV_HFI_WINDOW=4194304   export PSM2_MQ_EAGER_SDMA_SZ=65536   export PSM2_MQ_RNDV_HFI_THRESH=200000   export PSM2_IDENTIFY=1 export I_MPI_FABRICS=shm:tmi export I_MPI_TMI_PROVIDER=psm2 export I_MPI_FALLBACK=0
Running on several nodes made as follows: export KMP_PLACE_THREADS=17c,2t   export KMP_AFFINITY=granularity=fine,compact   #> mpiexec.hydra -n 8 -hosts knl1,knl2 -ppn 4 numactl --membind=1 xhpcg_knl --n=160

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Any difference in system hardware or software design or configuration may affect actual performance

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