The Faster Path to Discovery
A Growing Software Ecosystem
Platform Features
Software Applications Performance Summary

Proof Points:
- Intel Xeon Phi Processor vs. NVIDIA*
- Machine Learning
- Financial Services
- Life Sciences
- Manufacturing
- Climate and Weather
- Material Sciences
- Physics
- Geophysics
- Energy
- Performance Benchmarks
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.

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1 – As demonstrated by the BAW proof point in this presentation 2 – As demonstrated by the Embree proof point in this presentation
THE FASTER PATH TO DISCOVERY

Intel® Xeon Phi™ Product Family

The transformative path to deeper insight and innovation for research and commercial applications in science, visualization, and analytics.

• **Highly-parallel performance**: Up to 72 cores with deep out-of-order buffers, Intel® Advanced Vector Extensions 512 and 3x single-thread performance compared to the previous generation product

• **Power-efficient architecture**: Delivers significantly more compute per unit of energy consumed

• **Simplified code modernization**: Reduce programming efforts and downtime by sharing code and developer base with Intel® Xeon® processors

• **Seamless IT manageability**: Common x86 architecture delivers best utilization across any workload

• **Future-ready code investment**: Code is flexible, portable, and reusable into the future as it is optimized for a general-purpose architecture using open standards
Experts from Allinea*, Altair*, Convergent Science*, Kitware*, and LSTC* 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

- 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
INTEL® XEON PHI™ PROCESSOR PLATFORM FEATURES
SOLVE THE BIGGEST CHALLENGES FASTER
SCALABILITY

Reliability & Resiliency

Compute
Memory/Storage
Fabric
Software

Power Efficiency

Price / Performance

Intel Silicon Photonics

Intel® Scalable System Framework

Small Clusters Through Supercomputers
Compute and Data-Centric Computing
Standards-Based Programmability
On-Premise and Cloud-Based

Intel® Xeon® Processors
Intel® Xeon Phi™ Processors
Intel® Xeon Phi™ Coprocessors
Intel® Server Boards and Platforms
Intel® Solutions for Lustre®
Intel® Optane™ Technology
3D XPoint™ Technology
Intel® SSDs
Intel® Omni-Path Architecture
Intel® True Scale Fabric
Intel® Ethernet
Intel® Silicon Photonics
Intel® HPC Orchestrator
Intel® Software Tools
Intel® Cluster Ready Program
Intel Supported SDVis
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

Derive Unmatched 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

CPU Generation (2011-2016)

- >100X
- Up to 72 cores (288 threads)
- Intel® Advanced Vector Extensions 512 (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.
SOLVE THE BIGGEST CHALLENGES FASTER
ELIMINATE BOTTLENECKS, IMPROVE THROUGHPUT¹

Bootable host: No PCIe* Dependency

Memory: Integrated (MCDRAM) & Platform (DDR4)

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

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 Dependency
Bootable host processor

Topple Memory Wall
Integrated memory up to 16GB

Run Any Workload
Intel® Xeon® processor binary-compatible

Scale Out Seamlessly
Bootable CPU, element of Intel® SSF

Reduce Cost
Dual-port Intel® Omni-Path Fabric

Raise Memory Ceiling
Platform memory up to 384 GB (DDR4)
PERFORMANCE: INTEL® XEON PHI™ PROCESSOR VS NVIDIA*

Higher is better

Relative Performance¹ on the Intel® Xeon Phi™ Processor 7250

- Nvidia K80: 1.06
- Binomial Options SP: 1.24
- LINPACK: 1.3
- CP2K: 1.3
- STAC-A2: 1.37
- Warm Greeks: 1.57
- MonteCarlo SP: 2
- STREAM TRIAD: 2.72
- BlackScholes DP: 5
- MonteCarlo DP: 5.17
- LAMMPS: 5
- Embree vs OptiX (vs Titan X): 2.72

See more competitive Intel® Xeon Phi™ Processor results!

¹ – As demonstrated by respective 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 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/performancetests Source: Intel measured or estimated as of May 2016.
Life Sciences

LAMMPS COARSE-GRAIN WATER SIMULATION

LAMMPS 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 1.41X improved coarse-grain water simulation rate (Performance result) with up to 1.67X performance per watt compared to the Intel® Xeon® processor E5-2697 v4. 96% parallel efficiency with Intel® Omni-Path Architecture (8 Node chart result).

For configuration details, see slide 129.


Ice formation in water droplet wetting a flat surface with coarse-grain model in LAMMPS

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.
"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 v2.9.0**

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. More at [http://embree.github.io/](http://embree.github.io/).

**Application:** Embree v2.9.0

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

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**Value Proposition:** The kernels are optimized for photo-realistic rendering on the latest Intel® processors with support for SSE, AVX, AVX2, and the 16-wide Intel® Xeon Phi™ processor vector instructions.

**Results:** Up to 5.17X improved compared to the NVIDIA Titan X*.

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**Digital Content Creation**

![Digital Content Creation Image](Image Source: Intel)

For configuration details, see slide 129.  
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*
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*.

Image Source: US gov.

MONTE CARLO EUROPEAN OPTIONS BENCHMARK*

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

For configuration details, see slide 129.

SOURCE: INTEL MEASURED RESULTS AS OF JUNE, 2016
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).

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

![Normalized Results](Image)

**ENERGY EFFICIENCY**

- Up to 2.75X better
- Up to 1.4X better

<table>
<thead>
<tr>
<th>Single Precision Perf./Watt</th>
<th>Double Precision Perf./Watt</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVG Power: 358 Watts</td>
<td>AVG Power: 358 Watts</td>
</tr>
</tbody>
</table>

Power measurement: CPU and MEMORY

For configuration details, see slide 129.

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.
**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](http://www.intel.com/performance)

**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®.
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*.
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, 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.

For configuration details, see slide 129.
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.

Courtesy of ETH Zurich. (url)
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
- Intel® Xeon Phi™ processor 7250 enables to run larger problem size per node

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

Image Credit: Brookhaven Lab (BNL)

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](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.

For configuration details, see slide 130.

SOURCE: INTEL MEASURED RESULTS AS OF MAY, 2016
Data scientists, developers, and researchers gain insights previously out of reach.
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 33; 2.) see slide 34; 3.) see slide 35.
Train up to 50x faster with Intel® Xeon Phi™ Processor

Deep Learning Image Classification Training Performance – MULTI-NODE Scaling

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/datacenter. Configurations: 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.
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

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/datacenter. Configurations: 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 known 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).
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

The test data is based on Intel® Xeon® processor E5-2680 v3

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/datacenter. Configurations: CNN 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).

*Other names and brands may be property of others
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 128): Intel® Xeon Phi™ processor 7250 (68 Cores, 1.4 GHz, 16GB), 96GB memory, Red Hat® Enterprise Linux 6.6 vs. hosted NVIDIA Titan Z® [1] Fabian Gieseke, Cosmin Eugen Oancea, Ashish Mahabal, Christian Igel, and Tom Heskes. Bigger Buffer k-d Trees on Multi-Many-Core Systems. http://arxiv.org/abs/1512.02831, Dec 2015

*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. Configurations (more details see slide 128): Intel® Xeon Phi™ processor 7250 (68 Cores, 1.4 GHz, 16GB), 96GB memory, Red Hat® Enterprise Linux 6.6 vs. NVIDIA Titan X*. [1] J. Canny, H., Zhao, Y. Chen, B. Jaros, and J. Mao, “Machine Learning at the limit”, in IEEE International Conference on Big Data, 2015. See Table III: 300 dimensional word embeddings

*Other names and brands may be property of others
Over 45 applications optimized for Intel® Xeon Phi™ Processor family are available, with up to 6.5X (2X average) performance improvement\(^1\)

Intel® Xeon Phi™ processor 7250 relative performance normalized to 1.0 baseline of a 2 socket Intel® Xeon® processor E5-2697 v4)

\(^1\) As demonstrated by respective proof points in this presentation
For discovery and business innovation in science, visualization & analytics

Life Sciences – Genomics / Sequencing

Financial – Risk

Energy – Seismic / Reservoir

Weather

Scientific Visualization / Professional Rendering

Simulation, CAE & CFD

Data Analytics & Machine Learning

Defense / Security

And other emerging usages. Details in the following Business Verticals
Improving financial outcomes through faster simulations

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

Tested and proven performance for the most important Financial Services applications, with an average software performance improvement with the Intel Xeon Phi processor 7250 of 3.46X, 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 3.39X
- **MONTE CARLO**: Up to 4.65X
- **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
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.

Image Sources: Parsiaz.azimzadeh, finance.bi.no

For configuration details, see slide 131.

SOURCE: INTEL MEASURED RESULTS AS OF MAY, 2016

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

- 2S Intel® Xeon® processor E5-2697 v4 (36 cores)
- Intel® Xeon Phi™ processor 7210 (64 cores)
- Intel® Xeon Phi™ processor 7250 (68 cores)
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 4.65X improved Double Precision performance compared to the Intel® Xeon® processor E5-2697 v4.

For configuration details, see slide 129.

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

For configuration details, see slide 129. SOURCE: INTEL MEASURED RESULTS AS OF JUNE, 2016

Image Source: US gov.

For configuration details, see slide 129.
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.
**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](http://www.intel.com/)

**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.

![Black-Scholes Formula Performance Improvement with the Intel® Xeon Phi™ Processor](http://www.intel.com/)

**Black-Scholes Formula Performance Improvement with the Intel® Xeon Phi™ Processor**

<table>
<thead>
<tr>
<th></th>
<th>Single Precision</th>
<th>Double Precision</th>
</tr>
</thead>
<tbody>
<tr>
<td>2S Intel® Xeon® processor E5-2697 v4 (36 cores)</td>
<td>1.93 1.31X faster</td>
<td>0.57 1.92 3.39X faster</td>
</tr>
<tr>
<td>Intel® Xeon Phi™ processor 7250 (68 cores)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For configuration details, [see slide 129](#).

*Image Source: US gov*

For more information go to [http://www.intel.com/](http://www.intel.com/)
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.
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](http://www.intel.com/performance)

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.

For configuration details, [see slide 129](http://www.intel.com/performance).

Image Source: Science Direct

Power measurement: CPU and MEMORY

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

Options/Second – Higher is better

(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.

---

For configuration details, see slide 129.

SOURCE: INTEL MEASURED RESULTS AS OF JUNE, 2016

Image Source: Science Direct
Optimizing applications. Accelerating discovery.
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 **1.73X**, and an average performance/watt improvement of up to **1.67X**.

- **LAMMPS**: Up to 1.41X. See the [GPU comparative section](#).
- **AMBER 16 IMPLICIT**: Up to 2.66X
- **AMBER 16 EXPLICIT**: Up to 1.83X
- **ROME/SML**: Up to 2.36X
- **RELION**: Up to 1.31X
- **GROMACS**: Up to 1.22X, and up to 1.45X performance/watt
- **NAMD**: Up to 1.36X, and up to 1.91X performance/watt

¹ - Performance is the Intel Xeon® Phi™ Processor 7250 compared to the Intel® Xeon® processor E5-2697 v4
**AMBER 16 PMEMD IMPLICIT**

*Amber is a bio related simulation code for DNA, RNA, protein, and other bio-molecules. Particle Mesh Ewald Molecular Dynamics (PMEMD) is an Amber tool used for Molecular Dynamic Simulation. PMEMD includes two algorithms, Explicit and Implicit. PMEMD is written in Fortran 90 and is mainly MPI*, OpenMP* and Vectorization parallelized.*

**Application:** Amber 16 PMEMD Implicit

**Code:** License required from [http://ambermd.org/](http://ambermd.org/)

**Recipe:**
```plaintext
./configure --intelmpi --openmp --mic2 intel
```

On Intel® Xeon®: make install AMBERBUILDFLAGS="-xMIC-AVX512"

On Intel® Xeon Phi™: make install

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

**Results:** Up to 2.66X improved performance compared to the Intel® Xeon® processor E5-2697 v4 for the Rubisco workload.

For configuration details, see slide 130.

---

**Images Source:** Intel

**For configuration details, see slide 130.**

SOURCE: INTEL MEASURED RESULTS AS OF APRIL 2016
**AMBER 16 PMEMD EXPLICIT***

Amber* is a *bio* related simulation code for DNA, RNA, protein, and other *bio*-molecules. Particle Mesh Ewald Molecular Dynamics (PMEMD) is an Amber tool used for Molecular Dynamic Simulation. PMEMD includes two algorithms, Explicit and Implicit. PMEMD is written in Fortran 90 and is mainly MPI*, OpenMP* and Vectorization parallelized.

**Application:** Amber 16 PMEMD Explicit.

**Code:** License required from [http://ambermd.org/](http://ambermd.org/)

**Recipe:** ./configure –intelmpi –openmp –mic2 intel

  On Intel® Xeon®: make install AMBERBUILDFLAGS="-xMIC-AVX512"

  On Intel® Xeon Phi™: make install

**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 workload.

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For configuration details, see slide 130. 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.
ROME (Refinement and Optimization via Machine Learning for cryo-EM) is one of the major research software packages from 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


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

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

Testcase: experimental inflammasome dataset/deep 2d classification.
**RELION**

**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.


For configuration details, see slide 130.

SOURCE: INTEL MEASURED RESULTS AS OF APRIL 2016
RELION (REregularised 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 1.67X improved performance/watt 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.

For configuration details, see slide 131.

SOURCE: INTEL MEASURED RESULTS AS OF JUNE 2016
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.

---

For configuration details, see slide 131.

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

---

Life Sciences

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

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Intel® Xeon® processor E5-2697 v4 (290W TDP, 36 cores)</th>
<th>Intel® Xeon Phi™ processor 7520 (215W TDP, 68 cores)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADH_134k_pme</td>
<td>1.30</td>
<td></td>
</tr>
<tr>
<td>water_1.5M_rf</td>
<td>1.45</td>
<td></td>
</tr>
<tr>
<td>water_1.5M_pme</td>
<td>1.24</td>
<td></td>
</tr>
<tr>
<td>lignocellulose_3M_rf</td>
<td>1.39</td>
<td></td>
</tr>
<tr>
<td>peptides_12M_pme</td>
<td>1.41</td>
<td></td>
</tr>
</tbody>
</table>

Power measurement: CPU and MEMORY

Images Source: Used with permission

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 1.36X 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/](http://www.ks.uiuc.edu/Research/namd/)

Recipe: Check for availability [here](http://www.ks.uiuc.edu/Research/namd/)

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 1.91X improved energy efficiency compared to the Intel® Xeon® processor E5-2697 v4.
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 1.86X.

- **TACC LB3D**: Up to 3.65X
- **NASA OVERFLOW**: Up to 1.77X
- **OPENFOAM**: Up to 1.71X
- **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
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:** LBS3D (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 E5-2697v4.
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.

**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.

For configuration details, see slide 131.

**SOURCE:** NASA/Ames (Dennis Jespersen) April 2016

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

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

<table>
<thead>
<tr>
<th>Time in seconds</th>
<th>DLR/F6 36 Mpts</th>
<th>NAS rotor 91 Mpts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 1.77X faster</td>
<td>4.35</td>
<td>9.46</td>
</tr>
<tr>
<td>Up to 1.53X faster</td>
<td>2.45</td>
<td>8.51</td>
</tr>
<tr>
<td>2S Intel® Xeon® processor E5-2680 v3 (24 cores)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2S Intel® Xeon® processor E5-2680 v4 (28 cores)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intel® Xeon Phi™ processor 7250 (68 cores)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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
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


Recipe: [https://github.com/OpenFOAM/OpenFOAM-dev](https://github.com/OpenFOAM/OpenFOAM-dev)

**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 1.71X faster compared to the 2S Intel® Xeon® processor E5-2697 v4.

For configuration details, see slide 131.

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

**Runtime in Seconds** - LOWER IS BETTER

<table>
<thead>
<tr>
<th>Workload</th>
<th>Runtime (Seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DrivAer car 10M Cells</td>
<td>7797.89</td>
</tr>
<tr>
<td>MotorBike 20M Cells</td>
<td>4655.62</td>
</tr>
<tr>
<td>MotorBike 11M Cells</td>
<td>1724.38</td>
</tr>
<tr>
<td>MotorBike 4M Cells</td>
<td>932.06</td>
</tr>
<tr>
<td>DrivAer car 10M Cells</td>
<td>543.69</td>
</tr>
<tr>
<td>DrivAer car 10M Cells</td>
<td>237.81</td>
</tr>
<tr>
<td>MotorBike 11M Cells</td>
<td>1596.87</td>
</tr>
</tbody>
</table>

**Image Source:** Intel
OpenLB* Project

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.

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For configuration details, see slide 132.

Source: Intel Measured Results as of April 2016

For more information go to http://www.intel.com/performance

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

For configuration details, see slide 132.

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Manufacturing

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

- 64.08
- 56.88
- 51.75

**Options/Second**

- LOWER IS BETTER

- **2S Intel® Xeon® processor E5-2697 v4 (36 cores)**
- **Intel® Xeon Phi™ processor 7210 (64 cores)**
- **Intel® Xeon Phi™ processor 7250 (68 cores)**

---

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.
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 performance¹ for the most important applications, with an average software performance improvement with the Intel Xeon Phi processor 7250 of up to 1.66X, and an average performance/watt improvement of up to 1.98X.

- **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
- **GNAQPMs**: Up to 1.76X
- **WRF**: Up to 1.7X
- **HOMME**: Up to 1.53X
- **POP**: Up to 1.41X
- **MASNUM WAVE**: 1.4X

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

For configuration details, [see slide 132](#).
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](http://www.intel.com/performance)

**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.

### DMI HIROMB-BOOS-Model Performance Improvement with the Intel® Xeon Phi™ Processor

<table>
<thead>
<tr>
<th></th>
<th>Performance</th>
<th>Perf./Watt</th>
</tr>
</thead>
<tbody>
<tr>
<td>2S Intel® Xeon® processor E5-2697 v4</td>
<td>up to 1.7X faster</td>
<td>up to 2X more efficient</td>
</tr>
<tr>
<td>Intel® Xeon Phi™ processor 7250 (68 cores)</td>
<td>up to 1.47X faster</td>
<td>up to 1.28X faster</td>
</tr>
</tbody>
</table>

Test case: BaffinBay_2m, 1 MPI x N OMP

For configuration details, [see slide 133](http://www.intel.com/performance).

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.

Image Source: DMI
**Non-hydrostatic Icosahedral Model (NIM)**

*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.

For configuration details, [see slide 134](#).

**Source:** INTEL MEASURED RESULTS AS OF MARCH, 2016
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.
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 1.96X performance/power compared to the Intel® Xeon® processor E5-2697 v4 for EC_60to30_forward workload.
**GNAQPMS**

**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.

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

![GNAQPMS Performance Improvement Chart](image)

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

For configuration details, see slide 134.

SOURCE: INTEL MEASURED RESULTS AS OF April, 2016

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**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.**

---

**Recipe:**

1. **Input**
   - Meteorology data

2. **Core equations**
   - Conserved
   - Advection
   - Chemical reaction
   - Aerosol modules
   - Dry module
   - Dry deposition

3. **Key technology**
   - Multi-scale modeling
   - Process coupling
   - Source apportionment
   - Source contribution

4. **Output**
   - Concentration distribution
   - Emission statistics
   - Wet/Dry deposition

**Image Source:** PRC IAP

**Value Proposition:** Performance is enhanced by Intel® Advanced Vector Extensions 512 (Intel® AVX-512).
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: 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.
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 1.53X faster compared to the Intel® Xeon® processor E5-2697 v4.

Image source: Used by permission.


For configuration details, see slide 134.
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/

Recipe: Available here

POP with bench01 workload Performance Improvement with the Intel® Xeon Phi™ Processor

- 2S Intel® Xeon® processor E5-2697 v4 (36 cores)
- Intel® Xeon Phi™ processor 7210 (64 cores)
- Intel® Xeon Phi™ processor 7250 (68 cores)

Test case: POP with bench01 workload (0.1 degree high resolution)

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.
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

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.

For configuration details, see slide 135.
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 \(1.99\times\).

- **TRINITY BENCHMARKS**: Up to 3.3X
- **CP2K**: Up to 2.54X
- **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.
**TRINITY BENCHMARKS - SINGLE NODE OPTIMIZED (GFLOPS)**

Benchmark programs are for use as part of the joint NERSC / ACES NERSC-8/Trinity system procurement.

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

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

Optimizations

Speedups affected Intel® Xeon Phi™ processor and Intel® Xeon® processor E5-2697 v4:

- **MiniFE:**
  - Xeon Phi: 42 GHz -> 47 GFLOPS
  - Xeon: no change

- **UMT:**
  - Xeon Phi: 42 GHz -> 47 GFLOPS
  - Xeon: no change

- **MILC:**
  - Xeon Phi: 108 GHz -> 138 GFLOPS
  - Xeon: 71 GHz -> 102 GFLOPS

- **MiniGhost:**
  - Xeon Phi: 28 GHz -> 381 GFLOPS
  - Xeon: 54 GHz -> 114 GFLOPS

- **Xeon Phi Optimizations:** 1.34x
- **Xeon Optimizations:** 1.17x
- **Overall Xeon Phi vs. Xeon:** 1.7x

For configuration details, see slide 135.

**Geomean Xeon Phi Optimized:** 68.6 GFLOPS

**Geomean 2S Xeon Optimized:** 41.3 GFLOPS

**Overall Xeon Phi Optimized Speedup:** 1.7x

**SOURCE:** INTEL MEASURED RESULTS AS OF MAY, 2016
TRINITY BENCHMARKS - SINGLE NODE (GFLOPS)

Geomean Xeon Phi: 54.9 GFLOPS
Geomean 2S Xeon: 35.2 GFLOPS
Overall Xeon Phi Speedup: 1.6x

GFLOPS, Single Node Results
No Source Code Changes, MPI Only

- AMG: Parallel algebraic multigrid solver for linear systems
- MiniDFT (small problem): Plane-wave Density Function Theory mini-app;
  Results not in Graph as small problem size and not Trinity size.
  [Small problem size: Xeon Phi vs. 2S Xeon = 521 GFLOPS /435 GFLOPS =1.2x]
- MiniFE: Finite Element mini-app
- MiniGhost: Finite Difference mini-app
- MILC: MIMD Lattice Computation (MILC) collaboration kernel used to study quantum chromodynamics (QCD)
- GTC: Gyrokinetic Particle Simulation of Turbulent Transport in Burning Plasmas
- SNAP: Proxy application to model the performance of a modern discrete ordinates neutral particle transport application
- UMT: 3D, deterministic, multigroup, photon transport code for unstructured meshes

Value Proposition: Trinity workloads should be kept as a set. This set of workloads is what enabled Intel to win the Trinity deals.

Results:
Baseline Code: Up to 1.6X speedup over 2 socket Xeon E5-2697 v4
Optimized Code: Up to 1.7X speedup over 2 socket Xeon E5-2697 v4

For configuration details, see slide 135.

SOURCE: INTEL MEASURED RESULTS AS OF MAY, 2016
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

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 2.54X faster with the Intel® Xeon Phi™ processor 7250 compared to the Intel® Xeon® processor E5-2697 v4.

Workload: Electronic structure of 864 H2O molecules (2.5k atoms). Linear Scaling DFT (DFT LS) and 10 MD steps

Courtesy of ETH Zurich.
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

**Source:** [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://csmn.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.

For configuration details, see slide 135.

Testcases: GaAs 64 atoms quantum dot & GaAs 160 atoms structure; FFT Grid: 96x96x96 (GaAs64), 48x48x108 (GaAs160); Ecut: 18 Ry (245 ev); Q-Space nonlocal potential calculation; 20 SCF iterations.

For more information go to http://www.intel.com/performance  *Other names and brands may be claimed as the property of others.
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

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 energy efficiency compared to the Intel® Xeon® processor E5-2697 v4.
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 performance¹ for the most important applications, with an average software performance improvement with the Intel Xeon Phi processor 7250/7210 of up to 2X.

- **QPHIX**: Up to 2.44X
- **CLOVERLEAF**: Up to 2.3X
- **SOFT SPHERE SIMULATION**: Up to 1.81
- **PETSC**: Up to 1.8X
- **MILC**: Up to 1.69X

¹ - Performance is the Intel Xeon® Phi™ Processor 7250 compared to the Intel® Xeon® processor E5-2697 v4
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](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 2.44X improved performance compared to the Intel® Xeon® processor E5-2697 v4.

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

- **Wilson Dslash:** up to 2.13X faster
- **CG:** up to 2.44X faster

**Lattice:** 32*32*32*64

**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**

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 2.3X one node improved performance compared to the Intel® Xeon® processor E5-2697 v4. Over 77% parallel efficiency with Intel® Omni-Path Architecture (8 nodes).
Physics - Hydrodynamics

CLOVERLEAF*

The CloverLeaf* code investigates the behavior of fluids under high temperatures and pressures, which potentially cause shock fronts to form. It is common for hydrocodes to be constructed using one of two formulations – Lagrangian, in which a mesh is constructed and evolved through time, or Eulerian, where material flow is calculated relative to a fixed spatial grid.

Application: CloverLeaf

Code: https://github.com/UK-MAC/CloverLeaf

Recipe: make COMPILER=INTEL MPI_COMPILER=mpiifort C_MPI_COMPILER=mpiicc OPTIONS="-xMIC-AVX512" C_OPTIONS="-xMIC-AVX512"

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 2.3X improved performance compared to the Intel® Xeon® processor E5-2697 v4.
**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

---

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

<table>
<thead>
<tr>
<th>Processor Configuration</th>
<th>Time in Seconds</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>2S Intel® Xeon® processor E5-2697 v4 (36 cores)</td>
<td>7.01</td>
<td>-</td>
</tr>
<tr>
<td>Intel® Xeon Phi™ processor 7210 (64 cores)</td>
<td>4.39</td>
<td>up to 1.6X faster</td>
</tr>
<tr>
<td>Intel® Xeon Phi™ processor 7250 (68 cores)</td>
<td>3.88</td>
<td>up to 1.81X faster</td>
</tr>
</tbody>
</table>

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

**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.

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For configuration details, see slide 137.

SOURCE: INTEL MEASURED RESULTS AS OF MARCH, 2016
**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.

---

**Wall-clock time per simulated day – LOWER IS BETTER**

<table>
<thead>
<tr>
<th></th>
<th>43.46</th>
<th>24.17</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2S Intel® Xeon® processor E5-2697 v4 (36 cores)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Intel® Xeon Phi™ processor 7250 (68 cores)</strong></td>
<td></td>
<td>up to 1.8X faster</td>
</tr>
</tbody>
</table>

Test case: KSP ex42 incompressible, variable-viscosity Stokes flow
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
- Intel® Xeon Phi™ processor 7250 enables to run larger problem size per node

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

For configuration details, see slide 130. SOURCE: INTEL MEASURED RESULTS AS OF May 2016
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/AWPPODC. 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.
YASK HPC STENCILS, ISO3DFD 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 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 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

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.
**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/detials 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).**

### SPECFEM3D_GLOBE : Performance Improvement on a cluster of Intel® Xeon Phi™ Processor – Weak Scaling

<table>
<thead>
<tr>
<th>Solver Time (sec.)</th>
<th>LOWER IS BETTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 nodes - 55K Mesh</td>
<td>26.3</td>
</tr>
<tr>
<td>25 nodes - 220K Mesh</td>
<td>21.3</td>
</tr>
</tbody>
</table>

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

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

For configuration details, [see slide 138](#).

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/](http://www.intel.com/) *Other names and brands may be claimed as the property of others.
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/

Value Proposition:
- The Intel® Xeon Phi™ processor improves performance for scalable workloads.
- SPECFEM3D_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.

For configuration details, [see slide 138](#). SOURCE: INTEL MEASURED RESULTS AS OF MAY, 2016

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.
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-spacing, 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.

---

Sparse Matrix Vector Multiply using SpMV Performance Improvement with the Intel® Xeon Phi™ Processor

<table>
<thead>
<tr>
<th></th>
<th>SPmv</th>
<th>SPmv1</th>
<th>SPmv2</th>
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<tbody>
<tr>
<td>Time</td>
<td>24.49</td>
<td>19.83</td>
<td>17.5</td>
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<tr>
<td>Faster</td>
<td>1.45X</td>
<td>2.26X</td>
<td>2.3X</td>
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Source: INTEL MEASURED RESULTS AS OF APRIL, 2016

Image Source: US gov.
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

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

**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 2.18X faster compared to the Intel® Xeon® processor E5-2697 v4.
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)
Code: Available here. Recipe: See configuration details

High Performance Conjugate Gradients Performance Improvement with the Intel® Xeon Phi™ Processor

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.
TOOLS AND LIBRARIES

Intel® Software Development Tools & 3RD Party Support for Developers and System Administrators
• C++ and Fortran Compilers
• Standards Driven Parallel Programming Models & Libraries
• Performance Profiling for Optimization and Tuning
• Threading & Vectorization Design & Analysis for Performance

Faster Code Faster

• Powerful Data Analytics, Machine Learning and Scientific Compute Libraries
• Coming Soon – High Performance Python Distribution
INTEL® PARALLEL STUDIO XE

Intel® C/C++ & Fortran Compilers

Intel® Math Kernel Library
Optimized Routines for Science, Engineering & Financial

Intel® Data Analytics Acceleration Library
Optimized for Data Analytics & Machine Learning

Intel® VTune™ Amplifier
Performance Profiler

Intel® Inspector
Memory & Threading Checking

Intel® Advisor
Threading & Vectorization Architecture

Intel® Trace Analyzer & Collector
MPI Profiler

Intel® MPI Library
Image, Signal & Compression Routines

Intel® Threading Building Blocks
Task Based Parallel C++ Template Library

Intel® Integrated Performance Primitives

Intel® C/C++ & Fortran Compilers

Intel® Distribution for Python*
Performance Scripting

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

### Intel® Parallel Studio XE 2016

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Bundle or Add-on: Rogue Wave IMSL® Library

Add-on: Rogue Wave IMSL® Library

Add-on: Rogue Wave IMSL® Library

Additional configurations including, floating and academic, are available at: [http://intel.ly/perf-tools](http://intel.ly/perf-tools)
2017 Compiler Update

Productive language-level vectorization and parallelism models for advanced developers driving application performance

- Common to both C++ & Fortran
  - OpenMP 4.0 & 4.5 support
  - Great optimization/vectorization reports, integration with Vectorization Advisor
  - Extended thread-local storage support for MPC

- C++
  - Complete C++ 2011 & 2014 standards support
  - Intel SIMD Data Layout Templates

- Fortran
  - Nearly complete F2008 Standard support
  - Co-Array performance improved by 40%
2017 COMPILER UPDATE

Optimized Intel® Xeon Phi™ processor code generation and tuning

- Vectorized compress/expand support using vcompress/vexpand instructions
- Intel® Xeon Phi™ processor fine tuning gained more than 2% in run-time improvements in Trinity* benchmarks
- Neighboring Gather optimization being closely tuned for the Intel® Xeon Phi™ processor
  - Optimization handles all adjacent gathers of 4/8 byte data
  - Being finely tuned to Intel® Xeon Phi™ processor specific instruction characteristics
- Intel® AVX-512-specific improvements: small-table-gather-to-permute, vconflict loops fusion
- Tuning is still work in progress and will continue throughout the year.

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
INTEL® MATH KERNEL LIBRARY 2017

• Major new functionality (all optimized for the Intel® Xeon Phi™ processor along with existing functions)
  • Optimized math functions to enable neural networks (CNN and DNN) for deep learning
  • Integer type support for GEMM for machine learning applications
  • Extended Intel® Threading Building Blocks threading layer support for more functions
  • Improved ScaLAPACK performance for symmetric eigensolvers on HPC clusters
  • New data fitting functions based on B-splines and monotonic splines
• Major new functionality (all optimized for the Intel® Xeon Phi™ processor along with existing functions)

• Python* APIs (in addition to existing C++ and Java* APIs)

• Open source version under Apache* 2.0 license

• Support building neural networks for deep learning applications
  • Layers: convolution, pooling, fully connected, locally connected, dropout, etc.
  • Activation functions: logistic regression, hyperbolic tangent, ReLU, pReLU, soft ReLU, etc.
  • Function optimizations: SGD, L-BFGS, minibatch, Adagrad, etc.

• Support more types of data sources (Attribute-Relation File Format, PostgreSQL, asynchronous)

*Other names and brands may be claimed as the property of others
Improved interoperability with OpenMP* on Linux*

- Added template class opencl_node to flow graph API which allows flow graph to offload computations to OpenCL* devices.
- Added static_partitioner that minimizes overhead of parallel_for and parallel_reduce for well-balanced workloads.
- All functions in Intel® Threading Building Blocks are Intel® Xeon Phi™ processor ready
Intel® MPI Library will be ready for the Intel® Xeon Phi™ processor:

• Usage of specially optimized memcpy for the Intel® Xeon Phi™ processor in the Intel® MPI Library

• Tuning of shared memory collectives on single Intel® Xeon Phi™ processor nodes

• Tuning of multi-node collectives for the Intel® Xeon Phi™ processor is planned

• General optimization of Remote Memory Access

• General optimization and speed up startup time and MPI tune utility
INTEL® CLUSTER CHECKER 2017

for Linux* high performance compute clusters

An expert system approach that provides cluster systems expertise in a tool

- Verifies system health
- Offers suggested actions
- Provides extensible framework
- API for integrated support

https://clusterready.intel.com/intel-cluster-checker/

*Other names and brands may be claimed as the property of others
Memory Access analysis
- Shows performance problems by memory hierarchy
- Measure DRAM and MCDRAM bandwidth
- Helps define data structures to allocate to MCDRAM

General Exploration analysis
- Efficiency of code passing through the core pipeline

Scalability analysis with Advanced Hotspots
- Serial vs Parallel time
- MPI and OpenMP* imbalance, overhead cost, parallel loop parameters

Custom PMU event collection

*Other names and brands may be claimed as the property of others
EASIER VECTORIZATION - FASTER CODE FASTER

Intel® Advisor - Vectorization Advisor

The Right Data At Your Fingertips

- Sorts loops by potential performance gain
- Easy to read compiler reports on your source
- Vectorization tips
- Trip counts
- Dependencies
- Memory access pattern data

Focus on hot loops

What vectorization issues do I have?

Which Vector instructions are being used?

How efficient is the code?

Filter by which loops are vectorized!

Trip Counts

What prevents vectorization?
OPTIMIZE FOR INTEL® AVX-512 EVEN WITHOUT HARDWARE

Intel® Advisor

Native Advisor profiling for the Intel® Xeon Phi™ Processor and future platforms

- Vectorization Summary quickly compares Intel® Advanced Vector Extensions 512 (Intel® AVX-512) vs. other architecture

Optimize for Intel AVX-512 even without Intel AVX-512 hardware

- Explores Intel AVX-512 code paths characteristics
- Create speed-up estimates for Intel AVX512 (traits for different ISA, optimizations applied by compiler, vector length and etc.)

Survey Report provides Intel AVX-512 Traits

- Advisor highlights Intel AVX-512 instructions which could significantly affect vector code performance (e.g. Compress / Expand, Scatter, Conflict Detection)

NEW VECTORIZATION ANALYSIS FOR 2017 - INTEL® ADVISOR

Intel® Advanced Vector Extensions 512 (Intel® AVX-512) Recommendations in Survey

- User-friendly suggestions on how to fix detected issue and improve vector code performance to enable effective Intel AVX-512 usage (e.g. “speed-up or improve accuracy of reciprocal/SQRT/DIV”; “ineffective vectorized remainder due to low mask utilization”)

Gather/Scatter profiling and MAP Recommendations

- Identify when gather/scatter can be replaced with faster instructions depending on memory access pattern and locality

Mask utilization and mask-aware FLOPs profiler

- For each loop/function, dynamically measure mask register utilization, FLOPs and FLOPs/sec
  - Capture cases with vector register underutilization, consider mask utilization in Vector Efficiency calculation and accurately account effective mask-aware FLOPs
  - High accuracy. Support “arbitrary” hardware (not PMU based)
INTEL® DISTRIBUTION FOR PYTHON*!

UBUNTU PYTHON* PERFORMANCE BOOST ON SELECT NUMERICAL FUNCTIONS

Intel Distribution for Python (Technical Preview) vs. Ubuntu* Python

Configuration info: - Versions: Intel® Distribution for Python 2.7.10 Technical Preview 1 (Aug 03, 2015), Ubuntu* built Python*: Python 2.7.10, NumPy 1.9.2 built with gcc 4.8.4; Hardware: Intel® Xeon® CPU E5-2698 v3 @ 2.30GHz (2 sockets, 16 cores each; HT=OFF), 64 GB of RAM, 8 DIMMS of 8GB@2133MHz; Operating System: Ubuntu 14.04 LTS.

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. * Other brands and names are the property of their respective owners. Benchmark Source: Intel Corporation

Optimization Notice: Intel's compilers may or may not optimize to the same degree for non-Intel microprocessors for optimizations that are not unique to Intel microprocessors. These optimizations include SSE2, SSE3, and SSSE3 instruction sets and other optimizations. Intel does not guarantee the availability, functionality, or effectiveness of any optimization on microprocessors not manufactured by Intel. Microprocessor-dependent optimizations in this product are intended for use with Intel microprocessors. Certain optimizations not specific to Intel microarchitecture are reserved for Intel microprocessors. Please refer to the applicable product User and Reference Guides for more information regarding the specific instruction sets covered by this notice. Notice revision #20110804.
WEB RESOURCES


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


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 LADMP2312XXXX41, 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 LADMP2312XXXX41, 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
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=psmp 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-x86-64-intel
- https://github.com/cp2k/cp2k/raw/intel/cp2k/arch/Linux-x86-64-intel/psmp

Runing 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 : Qphix*

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® Omni-Path Host Fabric Interface Adapter 100 Series 1 Port PCIe x16

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

NVIDIA® GPU: 1x NVIDIA Titan X® GPU, ECC enabled, persistence enabled mode, full GPU Boost (auto), NVIDIA CUDA® 7.5.17, QUDA® v0.8. Host CPU was 2S Intel® Xeon® processor E5-2697 v3.

Configuration details: AMBER 16 IMPLICIT*

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® GPU: 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: AMBER 16 EXPPLICIT*

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, Turbo 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® 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, Turbo 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

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

Workload: provided by Intel® PSILB, Contact Youdong Ma youdong.mao@dfci.harvard.edu. (Performance data is based on 30 iterations). Workload Descriptions:

**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 on), Wildcat Pass, DDR4 128GB, 2400 MHz, BMC ver. 1.33.9832, Red Hat 7.2, BIOS 68B0271.R00, FRU/SDR Package 1.09, kernel 3.10.0-327.el7.x86_64, 1.10 TB SATA drive WD1003FZX-00MK2A0, Idle Power measurement 89W

Intel® Xeon® processor 7250: Intel® Xeon® Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. 6 x 16 GB 2400 MHz DDR4, BMC ver. 12.951, Red Hat 7.2, BIOS 10R00, FRU/SDR Package 1.1, kernel 3.10.0-327.el7.x86_64, 1.10 TB SATA drive WD1003FZX-00MK2A0, Idle Power measurement 125W

Configuration details: Nanoscale Molecular Dynamics program

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® processor 7210 (64 cores): 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 09D10, DDR4 2133 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode

Intel® Xeon® processor 7250: Intel® Xeon® Phi™ processor 7250 64 core, 272 threads, 1400 MHz core freq. (Turbo ON), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 09D10, DDR4 2400 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode

Configuration details: Nanoscale Molecular Dynamics program (perf./watt)

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 8x16GB 2400 MHz, BIOS 68B0271.R00, Motherboard Wildcat Pass, BMC ver. 13.99832, FRU/SDR package 1.09, Red Hat 7.2 kernel 3.10.0-327.el7.x86_64, System Disk 1 1.0 TB SATA drive WD1003FZX-00MK2A0, coprocessor N/A, Idle Power measurement 129W, energy usage to complete benchmark calculation in Joules: APOA1 – 4,565; STMV – 61,138.

Intel® Xeon® processor 7250: Intel® Xeon® Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (Turbo ON), 1700 MHz uncore freq., DDR4 6x16GB 2400 MHz quad cluster mode, MCDRAM 16 GB 6.4 GT/s flat memory mode, BIOS 10R00, Motherboard Adams Pass, Sleds per Chassis 1, BMC ver. 12.951, FRU/SDR package 1.0, Red Hat 7.2 kernel 3.10.0-327.el7.x86_64, System Disk 1 1.0 TB SATA drive WD1003FZX-00MK2A0, coprocessor N/A, Idle Power measurement 89W, energy usage to complete benchmark calculation in Joules: APOA1 – 3,899; STMV – 43,218.

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® processor 7210 (64 cores): 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 2400 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode

Intel® Xeon® processor 7250 (68 cores): 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 2400 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode

Configuration details: TACC LB3D

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® 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 10.R00, DDR4 16GB 2400 MHz, Red Hat 7.2, Quadrant cluster mode, MCDRAM+ DDR4 Flat mode

Intel® Xeon® processor E5-2697 v4: Dual Socket Intel® Xeon® processor E5-2697 v4 2.3 GHz (Turbo ON), 12 Cores/Socket, 24 Cores, 48 Threads (HT on), DDR4 128GB, 2133 MHz, SUSE Linux

Intel® Xeon® 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 16GB 2400 MHz, SLES 12 SP1, Quadrant cluster mode, MCDRAM cache mode

Intel® Xeon® 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; MCDRAM cache memory mode used for the 20M Cell Motorbike benchmark

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® 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; MCDRAM cache memory mode used for the 20M Cell Motorbike benchmark


*Other names and brands may be claimed as the property of others
**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 7210:** Intel® Xeon Phi™ processor 7210 64 core, 256 threads, 1300 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

**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 7.2 GT/s, DDR4 96GB 2400 MHz, Red Hat 7.2, Quadrant cluster mode, MCDRAM flat memory mode, Composer 2016.2.181

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**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, CentOS release 6.7, Composer 2016.2.181

**Intel® Xeon Phi™ processor 7210:** Intel® Xeon Phi™ processor 7210 64 core, 256 threads, 1300 MHz core freq. (HT and Turbo ON). MCDRAM 16 GB 6.4 GT/s, DDR4 96GB 2133 MHz, Red Hat 7.2

**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 7.2 GT/s, DDR4 96GB 2400 MHz, Red Hat 7.2

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**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, RHEL 6.5

**Intel® Xeon Phi™ processor 7210:** Intel® Xeon Phi™ processor 7210 64 core, 256 threads, 1400 MHz core freq., 1600 MHz uncore freq., MCDRAM 16 GB 6400 MHz, BIOS 09D10, DDR4 98 GB 2134 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

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**Configuration details: Other**

**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, RHEL 6.5

**Intel® Xeon Phi™ processor 7210:** Intel® Xeon Phi™ processor 7210 64 core, 256 threads, 1400 MHz core freq., MCDRAM 16 GB 6.4 GT/s, DDR4 96GB 2133 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

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**Additional details for TACOMA configuration:** 64x4 MPixOMP decomposition on Intel Xeon Phi Processor based systems. 32x1 MPixOMP for Intel Xeon processor E5-2697v4.

**Configuration details: NEMO**

**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 off), 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

**NEMO Recipe**

1. You should be registered at NEMO web-site [http://www.nemo-ocean.eu](http://www.nemo-ocean.eu)
2. Obtain NEMO code:
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 "icc –E", "%FC" to "mpiifort", "%LD" to "mpiifort", and "%FDLFLAGS" to "-lstdc++ -lifcore".
7. Use this instruction to build and run NEMO:
8. NEMO 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/NEMO/Configurations/GYRE](http://www.nemo-ocean.eu/Using-NEMO/Configurations/NEMO/Configurations/GYRE) (you should register and login to view most of technical information about NEMO).

(continued next slide)
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>jp_cfg</td>
<td>30</td>
<td>50</td>
<td>70</td>
</tr>
<tr>
<td>jpjdta</td>
<td>902</td>
<td>1500</td>
<td>2102</td>
</tr>
<tr>
<td>jpjdta</td>
<td>602</td>
<td>1000</td>
<td>1402</td>
</tr>
<tr>
<td>jpkdta</td>
<td>22</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>jpi glo</td>
<td>902</td>
<td>1500</td>
<td>2102</td>
</tr>
<tr>
<td>jpi glo</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. 11-1 TB SATA disk (Western Digital WD1003FZEX-00MKA0) 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. 11-1 TB SATA disk (Western Digital WD1003FZEX-00MKA20) installed.

**Recipe for The Intel® Xeon Phi™ processor:**

1. Building all the 3rd party libraries (NetCDF, ParallelNetCDF, PIO) are same as Intel Xeon.
2. Compilation of MPAS: In the Makefile, for ifort target, -xMIC-AVX512 is used as additional flag.

"FFLAGS_OPT = -O3 -xCORE-AVX2 -convert_big_endian -FR"
"CFLAGS_OPT = -O3 -xCORE-AVX2 *"
"CXXFLAGS_OPT = -O3 -xCORE-AVX2 *"

Command: make ifort CORE=ocean MODE=forward

3. Running instructions:

Intel® Xeon Phi™ processor memory mode: cache, cluster mode: quadrant.

Following environment variables should be set:

```bash
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.

<table>
<thead>
<tr>
<th>EC 30 to 60 benchmark</th>
<th>Time (sec)</th>
<th>Sys. Power (Watts avg.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel® Xeon® processor E5-2697 v4 (36 core)</td>
<td>4447</td>
<td>408.78</td>
</tr>
<tr>
<td>Intel® Xeon Phi™ processor 7250 (68 core)</td>
<td>3621</td>
<td>256.50</td>
</tr>
</tbody>
</table>

**Performance Increase**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.228113781</td>
<td>1.59</td>
</tr>
</tbody>
</table>

1.228 x 1.59 = 1.95X

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

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® 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® 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 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 (Maipo), 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 7.2 (Maipo), 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: GNAQPM5

**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), SN4C 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), SN4C cluster mode, MCDRAM cache memory mode, MPSP 1.2.2

**Code**: It was an MPI application and optimized using OpenMP.

Configuration details: Weather & Research Forecast Model*

**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 6.7

**Intel® Xeon Phi™ processor 7210**: Intel® Xeon Phi™ processor 7210 64 core, 256 threads, 1300 MHz core freq. (HT on), 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**: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 MHz core freq. (HT 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® 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: HOMME Atmospheric Dynamical Core*

**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, 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 11-TB STAT disk and 1 800GB SSD disk installed. Run details: Used 36 MPI ranks with 2 horizontal OpenMP threads per rank.

**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. 11-TB SATA disk installed. Run details: Used 64 MPI ranks with 2 horizontal OpenMP threads per rank.

**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
Configuration details: MASNUM WAVE

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 (64 cores): 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 2413 MHz, Red Hat 7.2 (Maipo), SNC4 cluster mode, MCDRAM cache memory mode

Intel® Xeon Phi™ processor 7250 (68 cores): 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

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, 72 Threads (HT off), DDR4 128GB, 2400 MHz, CentOS release 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 10R00, DDR4 96GB 2400 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., 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

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

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

**Workload**

**Xeon Phi 7250 Config**

**Xeon E5-2697 v4 Config**

<table>
<thead>
<tr>
<th>Workload</th>
<th>Xeon Phi 7250</th>
<th>Xeon E5-2697 v4</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; 307x307x307; 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>
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<tr>
<td>SNAP</td>
<td>SNC4 Flat; 32x64x68; 136 ranks</td>
<td>32x244x48; 36 ranks</td>
</tr>
<tr>
<td>GTC</td>
<td>Quad Flat; npar=10; micell=200; 128 ranks</td>
<td>Npar=10; micell=100; 36 ranks</td>
</tr>
<tr>
<td>MILC</td>
<td>SNC4 Flat; 16x32x32x34; 136 ranks</td>
<td>16x16x16s; 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 E5-2695 v4: Dual Socket Intel® Xeon® processor E5-2695 v4 2.1 GHz, 18 cores/socket, 36 cores, 72 cores (HT and Turbo ON), DDR4 64 GB, 2400 MHz, SUSE 11.3

Intel® Xeon Phi™ processor 7210: Intel® Xeon Phi™ processor 7210, 64 core (256 threads), 1.3 GHz base core freq. (Turbo ON), 1.6 GHz uncore freq., MCDRAM 16 GB 6.4 GT/s, BIOS 86B.01.01.0124, DDR4 96 GB 2133 MHz, SNC4 cluster mode, MCDRAM cache memory mode, RHEL 7.2, MPSP 1.3.0, Intel Compiler 2017

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 10R00, DDR4 96GB 2400 MHz, Red Hat 7.2, SNC4 cluster mode, MCDRAM cache memory mode

**Configuration details: BerkeleyGW (Sigma Phase) Benzene**

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), Wildcat Pass, DDR4 128GB, 2400 MHz, BMC ver. 1.33.9832, Red Hat 7.2, BIOS 68B0271.ROO, 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 7210 64 core (256 threads), 1.3 GHz base core freq. (Turbo ON), 1.6 GHz uncore freq., MCDRAM 16 GB 6.4 GT/s, RMS 86B.01.01.0124, DDR4 96 GB 2133 MHz, SNC4 cluster mode, MCDRAM cache memory mode, RHEL 7.2, MPSP 1.3.0, Intel Compiler 2017

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, BIOS 10R00, DDR4 96GB 2400 MHz, Red Hat 7.2, SNC4 cluster mode, MCDRAM cache memory mode

**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), 1.3 GHz base core freq., HT ON, Turbo ON, DDR4 1600 MHz, CentOS release 6.7

Intel® Xeon Phi™ processor 7250: Intel® Xeon Phi™ processor 7250 68 core, 272 threads, 1400 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 7.2, SNC4 cluster mode, MCDRAM cache memory mode, MKL: 11.3

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

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
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=psmp AVX=3 MIC=1 LIBXSMM=2
Either CP2K intel branch (git clone https://github.com/cp2k/cp2k.git cp2k.git)
Or master CP2K 4.0-development (https://github.com/cp2k/cp2k.git cp2k.git)
https://github.com/cp2k/cp2k/raw/intel/cp2k/arch/Linux-x86-64-intel.psm
Running CP2K
CP2K@KNL: CP2K_RECONFIGURE=1 (huge pages), CP2K_STACKSIZE=10000 (SMMs/batch),
I_MPI_PIN_DOMAIN=auto, I_MPI_PIN_ORDER=scatter, 64 ranks, 2 thread/core

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 and Turbo ON), DDR4 64 GB, 2400 MHz, RHEL 6.7

Intel® Xeon Phi™ processor 7250: Intel® Xeon® processor E5-2697 v4 1660 MHz base core freq. (Turbo ON), 1.3 GHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS GVPRCRB1.86B.0010.R00, DDR4 96 GB 2400 MHz, quad cluster mode, MCDRAM cache memory mode, RHEL 6.7, MPSP 1.3.0, Intel Compiler 2017

Running Quantum ESPRESSO

mpirun -n 68 <PATH_TO_BINARY>/pw.x -nk 2 -nt 34 -nd 25 -i ausurf.in

mpirun -n 36 <PATH_TO_BINARY>/pw.x -nk 1 -nt 36 -nd 36 -i ausurf.in

Configuration details: Ophiux*

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 128 GB, 2400 MHz, Red Hat 6.5, Intel® Omni-Path Host Fabric Interface Adapter 100 Series 1 Port PCIe x16

Intel® Xeon Phi™ processor 7250: Intel® Xeon® processor E5-2697 v4 68 core, 272 threads, 1400 MHz core freq. (Turbo OFF), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 09D10, DDR4 96 GB 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: Cloverleaf*

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 128 GB, 2400 MHz, Red Hat 6.5

Intel® Xeon Phi™ processor 7250: Intel® Xeon® processor E5-2697 v4 64 core, 256 threads, 1300 MHz core freq. (Turbo OFF), 1600 MHz uncore freq., MCDRAM 16 GB 6.4 GT/s, BIOS 09D10, DDR4 96 GB 2133 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode

Intel® Xeon Phi™ processor 7250: Intel® Xeon® processor E5-2697 v4 60 core, 272 threads, 1400 MHz core freq. (Turbo OFF), 1700 MHz uncore freq., MCDRAM 16 GB 7.2 GT/s, BIOS 09D10, DDR4 96 GB 2400 MHz, Red Hat 6.7 (Santiago), quad cluster mode, MCDRAM flat memory mode

*Other names and brands may be claimed as the property of others
**Configuration details: VLPL**

**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), SN4C 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), SN4C cluster mode, MCDRAM cache memory mode

**Configuration details: Soft Sphere Simulation**

**Intel® Xeon® processor E5-2697 v4**: Intel® Xeon® Dual Socket 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 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.

**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.

**Recipe details: YASK HPC Stencils, AWP-ODC Kernel**

**Intel® Xeon® processor E5-2697 v4**: 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

**Recipe:**
- Download code (version v20160606) from [https://github.com/01org/yask](https://github.com/01org/yask) and install per included directions
- make stencil=awp arch=hsw cluster=x=1,y=2,z=2 fold=y=8 omp_schedule=guided mpi=1
- ./stencil-run.sh -arch hsw -ranks 2 -bx 74 -by 192 -bz 20 -omp_schedule=guided mpi=1

**Intel® Xeon® processor E5-2697 v4**: 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 6.7

**Recipe:**
- Download code (version v20160606) from [https://github.com/01org/yask](https://github.com/01org/yask) and install per included directions
- make stencil=awp arch=knl INNER_BLOCK_LOOP_OPTS='prefetch(L1,L2)'
Recipe: YASK HPC Stencils, iso3DFD 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

Recipe:
- Download code (version v20160606) from https://github.com/01org/yask and install per included directions
- make stencil=iso3dfd arch=hsw mpi=1
- ./stencil-run.sh -arch hsw -ranks 2 -bx 256 -by 64 -bz 64 -dx 1024 -dz 768

NOTE: Download the current version and see the included documentation for updates to these results and recipes.

Recipe:
- Download code (version v20160606) from https://github.com/01org/yask and install per included directions
- make stencil=iso3dfd arch=knl
- ./stencil-run.sh -arch knl -bx 192 -by 96 -bz 96 -dx 1536 -dy 1024 -dz 768

NOTE: Download the current version and see the included documentation for updates to these results and recipes.

Recipe:
- Download code (version v20160606) from https://github.com/01org/yask and install per included directions
- make stencil=iso3dfd arch=kn
- ./stencil-run.sh -arch knl -bx 192 -by 96 -bz 96 -dx 1536 -dy 1024 -dz 768

NOTE: Download the current version and see the included documentation for updates to these results and recipes.

Recipe:
- Download code (version v20160606) from https://github.com/01org/yask and install per included directions
- make stencil=iso3dfd arch=kn
- ./stencil-run.sh -arch knl -bx 192 -by 96 -bz 96 -dx 1536 -dy 1024 -dz 768

NOTE: Download the current version and see the included documentation for updates to these results and recipes.

Recipe:
- Download code (version v20160606) from https://github.com/01org/yask and install per included directions
- make stencil=iso3dfd arch=kn
- ./stencil-run.sh -arch knl -bx 192 -by 96 -bz 96 -dx 1536 -dy 1024 -dz 768

NOTE: Download the current version and see the included documentation for updates to these results and recipes.

Recipe:
- Download code (version v20160606) from https://github.com/01org/yask and install per included directions
- make stencil=iso3dfd arch=kn
- ./stencil-run.sh -arch knl -bx 192 -by 96 -bz 96 -dx 1536 -dy 1024 -dz 768

NOTE: Download the current version and see the included documentation for updates to these results and recipes.

Recipe:
- Download code (version v20160606) from https://github.com/01org/yask and install per included directions
- make stencil=iso3dfd arch=kn
- ./stencil-run.sh -arch knl -bx 192 -by 96 -bz 96 -dx 1536 -dy 1024 -dz 768

NOTE: Download the current version and see the included documentation for updates to these results and recipes.

Recipe:
- Download code (version v20160606) from https://github.com/01org/yask and install per included directions
- make stencil=iso3dfd arch=kn
- ./stencil-run.sh -arch knl -bx 192 -by 96 -bz 96 -dx 1536 -dy 1024 -dz 768

NOTE: Download the current version and see the included documentation for updates to these results and recipes.

Recipe:
- Download code (version v20160606) from https://github.com/01org/yask and install per included directions
- make stencil=iso3dfd arch=kn
- ./stencil-run.sh -arch knl -bx 192 -by 96 -bz 96 -dx 1536 -dy 1024 -dz 768

NOTE: Download the current version and see the included documentation for updates to these results and recipes.

Recipe:
- Download code (version v20160606) from https://github.com/01org/yask and install per included directions
- make stencil=iso3dfd arch=kn
- ./stencil-run.sh -arch knl -bx 192 -by 96 -bz 96 -dx 1536 -dy 1024 -dz 768

NOTE: Download the current version and see the included documentation for updates to these results and recipes.
Configuration details: High Performance Conjugate Gradients*

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 ON), 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 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

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 (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)

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_IDENTITY=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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