INTEL® XEON PHI™ COPROCESSORS:
SOFTWARE ECOSYSTEM APPLICATIONS PERFORMANCE

2H 2015
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**Software Applications Proof Points**
- Life Sciences
- Material Sciences
- Manufacturing
- Financial Services
- Energy Industry
- Astrophysics
- Geophysics
- Physics
- Climate and Weather

**Additional Resources**
- Tools and Libraries
- Intel Developer Training
- Development Tools
Key Messages

- Developers show standards-based programming models benefits using Intel® Xeon® processors and Intel® Xeon Phi™ coprocessors:
  - Intel® Xeon Phi™ is the ideal platform for many core and wide vector code development (threads, vector lanes, memory).
  - Once you’ve optimized for the most cores, threads and wide SIMD vectors, your code scales everywhere – including on future Intel Xeon Phi generations and on future (highly-parallel) Intel® Xeon® processors.
  - Offload, symmetric, and native execution models are demonstrated in the proof points.

- Continued Momentum Across Verticals
  - 78 performance proof points (36 Haswell, 42 Ivy Bridge) in this updated guide, featuring 26 new proof points, 12 new codes and 5 new recipes. 24 are cluster proof points. 66 proof points are public and 10 are under NDA.
  - Several new Life Science (BLAST*, LAMMPS* and Johns Hopkins Bowtie2*) and Manufacturing proof points (ANSYS*, MSC Software*, HPCG benchmark, Sandia Mantevo*, and Fujitsu*) added. For more information about Life Sciences, click here.
  - Includes new proof points for Financial Services, Weather, Physics, and Digital Content Creation.

- Get started today with Intel and 3rd party tools/libraries:
  - Software tailored to support the Intel® Many Integrated Core Architecture.
  - Download the Application Catalog to see the list of available or in-flight codes.

- Leverage Intel® Parallel Studio XE 2015 and Intel® Cluster Ready to create faster code.

- Code Modernization – Drive faster breakthroughs through faster code: Get more results on your hardware today and carry your code forward to the future. More Code Modernization resources:
  - Intel® Code Modernization Enablement Program
  - What is Code Modernization?
moderncode developer challenge 2015

Code Modernization contest where HPC developers learn valuable skills and contribute to a social cause.

- In partnership with CERN*, OHSU Knight Cancer Institute* and British Columbia Cancer Agency*.

- Prizes include trips to CERN and to International Supercomputing event in Austin Texas. Scholarships for top student participants.

- Challenge will kick off in September.

- Developers will sign up for further details @ software.intel.com/modern-code/challenge
New or Updated Proof Points

NEW proof points (30):

- **Life Sciences:**
  - LAMMPS*
  - BLAST* (2)
  - Johns Hopkins Bowtie2* (2)

- **Manufacturing and DCC:**
  - ANSYS Mechanical* (5)
  - MSC Software*
  - HPCG benchmark
  - Sandia Mantevo miniFE
  - Autodesk Maya* (2)
  - Fujitsu HPC Gateway*

- **Financial Services:**
  - Monte Carlo* European Option Pricing
  - Monte Carlo Excel*-Based Option Pricing
  - QuantLib* (2)

- **Energy Industry:**
  - Iso3DFD
  - Distributed Iso3DFD
  - specfem3D
  - DownUnder GeoSolutions*

- **Physics:**
  - miniGhost* (2)
  - BerkeleyGW*
  - ASKAP*
  - Texas Advanced Computing Center*

- **Weather Research:**
  - ROMS*
New Proof Points and New Processor Speed Ups: Verticals Snapshot

**Average speed up in proof points**:  
- **Life Sciences**: 2.58X average speed up among new proof points and new processor.  
- **Manufacturing and DCC**: 2.44X average speed up among new proof points and new processor.  
- **Financial Services**: 3.86X average speed up among new proof points and new processor.  
- **Energy Industry**: 1.72X speed up in new proof point and new processor.  
- **Physics**: 1.6X average speed up among new proof points and new processor.  
- **Weather Research**: 1.46X average speed up among new proof points and new processor.

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1 - Performance demonstrated in proof points in this presentation.  
Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software operations and functions. Any change to any of 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.
This presentation demonstrates improved software performance for key applications in key business segments. The majority of the latest proof points show increases when adding the Intel® Xeon Phi™ coprocessor to the host Intel® Xeon® processor E5-2697 v2 or Intel® Xeon® processor E5-2697 v3. Some of the best examples are summarized below:

**Life Sciences Highlights:**
- Molecular systems with classical models simulation:
  - Up to 6.5X performance increase.
- Bimolecular simulations (Protein, DNA, RNA, virus etc.):

**Manufacturing and DCC Highlights:**
- Static structural analysis
  - Up to 4.7X single node performance increase.

**Financial Services Highlights:**
- European Option Pricing using Monte Carlo:
  - Up to 8.91X performance increase.

**Energy Industry Highlights:**
- Accurate imaging of complex subsurface structures:
  - Up to 2.2X performance increase.

**Physics and Astronomy Highlights:**
- Finite Difference mini-application which implements a difference stencil across a homogenous three dimensional domain:
  - Up to 1.76X performance increase.

**Weather Research and Forecasting Highlights:**
- A weather prediction system designed to serve atmospheric research and operational forecasting needs:
  - Up to 1.94X performance increase.
Application Performance Snapshot

Intel® Xeon Phi™ Coprocessor vs. NVIDIA Tesla* (2 socket Intel® Xeon® processor host)

Higher is Better

Relative performance

<table>
<thead>
<tr>
<th>Workload</th>
<th>DCC</th>
<th>Energy</th>
<th>Financial Services</th>
<th>Life Sciences</th>
<th>Physics</th>
</tr>
</thead>
<tbody>
<tr>
<td>NVIDIA*</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Embree Ray Tracing</td>
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<td>Black Scholes DP</td>
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<tr>
<td>ISO 3DP</td>
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<td>1.01</td>
<td>1.03</td>
<td>1.01</td>
<td>1.08</td>
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<td>Black Scholes SP</td>
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<tr>
<td>STAC-A2 WARM**</td>
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<tr>
<td>Monte Carlo Sim DP</td>
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<tr>
<td>STAC-A2 GREEKS* MAX_ASSETS**</td>
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<td>NAMD ApoA1 (2 nodes)</td>
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<td>BLASTp (Native)</td>
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</table>

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## Intel® Xeon® Processor E5-2697 v2 and Intel® Xeon® Processor E5-2697 v3 Better Together with Intel® Xeon Phi™ Coprocessor

### Software Performance Increases with 2-Socket Intel® Xeon® Processor E5-2697 v2 + Intel® Xeon Phi™ Coprocessor 7120 compared to Intel® Xeon® Processor E5-2697 v2

<table>
<thead>
<tr>
<th>Software Suite</th>
<th>Times Speed Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monte Carlo* European Options</td>
<td>8.91</td>
</tr>
<tr>
<td>QuantLib* SP Monte Carlo</td>
<td>6.93</td>
</tr>
<tr>
<td>ANSYS Mechanical</td>
<td>3.34</td>
</tr>
<tr>
<td>Sandia Mantevo*</td>
<td>2.30</td>
</tr>
<tr>
<td>Petrobas*</td>
<td>2.20</td>
</tr>
<tr>
<td>Black-Scholes* Formula Valuation</td>
<td>2.12</td>
</tr>
<tr>
<td>Monte Carlo Excel*-based</td>
<td>2.09</td>
</tr>
<tr>
<td>QuantLib* SP Black Scholes</td>
<td>1.84</td>
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<tr>
<td>Binomial Options*</td>
<td>1.85</td>
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<tr>
<td>ASKAP*</td>
<td>1.73</td>
</tr>
<tr>
<td>Iso3DFD</td>
<td>1.72</td>
</tr>
<tr>
<td>LAMMPS Production Protein</td>
<td>1.61</td>
</tr>
<tr>
<td>GROMACS*</td>
<td>1.56</td>
</tr>
<tr>
<td>miniGhost*</td>
<td>1.55</td>
</tr>
<tr>
<td>BWA-ALN*</td>
<td>1.50</td>
</tr>
<tr>
<td>OpenLB*</td>
<td>1.53</td>
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</tbody>
</table>

### Software Performance Increases with 2-Socket Intel® Xeon® Processor E5-2697 v3 + Intel® Xeon Phi™ Coprocessor 7120 compared to Intel® Xeon® Processor E5-2697 v3

<table>
<thead>
<tr>
<th>Software Suite</th>
<th>Times Speed Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>QuantLib* SP Monte Carlo</td>
<td>3.8</td>
</tr>
<tr>
<td>ANSYS Mechanical</td>
<td>2.61</td>
</tr>
<tr>
<td>Monte Carlo RNG* European Options</td>
<td>1.87</td>
</tr>
<tr>
<td>NAMD* 2.10 STMV</td>
<td>1.75</td>
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<tr>
<td>Autodesk Maya* 2014</td>
<td>1.74</td>
</tr>
<tr>
<td>Binomial Options*</td>
<td>1.54</td>
</tr>
<tr>
<td>NAMD* 2.10 ApoA1</td>
<td>1.52</td>
</tr>
<tr>
<td>BLASTn v.30</td>
<td>1.52</td>
</tr>
<tr>
<td>WRF*</td>
<td>1.49</td>
</tr>
<tr>
<td>LAMMPS* Liquid Crystal; 32 nodes</td>
<td>1.45</td>
</tr>
<tr>
<td>DMI*</td>
<td>1.33</td>
</tr>
<tr>
<td>AMBER* 14 Tobacco Virus</td>
<td>1.25</td>
</tr>
</tbody>
</table>

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1. Performance demonstrated in respective proof points in this presentation.

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Is Intel® Xeon Phi™ Coprocessor Performance Compelling Compared to NVIDIA*?

Software Performance Increases with 2-Socket Intel® Xeon® Processor E5-2697 v2 or v3 + Intel® Xeon Phi™ Coprocessor 7120 compared to Intel® Xeon® Processor E5-2697 v2 or v3 + NVIDIA GPU¹

<table>
<thead>
<tr>
<th>Software/Workload</th>
<th>Increase Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>QuantLib* SP Monte Carlo</td>
<td>5.17</td>
</tr>
<tr>
<td>Isotropic FD RTM Kernel*</td>
<td>4.78</td>
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<tr>
<td>LAMMPS* Stillinger-Weber</td>
<td>3.73</td>
</tr>
<tr>
<td>QuantLib* Black-Scholes</td>
<td>2.62</td>
</tr>
<tr>
<td>LAMMPS* Rhodopsin 512K</td>
<td>1.94</td>
</tr>
<tr>
<td>Embree* 2.2</td>
<td>1.76</td>
</tr>
<tr>
<td>Gyrokinetic Toroidal Code*</td>
<td>1.65</td>
</tr>
<tr>
<td>ASKAP*</td>
<td>1.43</td>
</tr>
<tr>
<td>Xcelerit*</td>
<td>1.25</td>
</tr>
</tbody>
</table>

¹ Performance demonstrated in 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. * Other names and brands may be claimed as the property of others.
Memory Comparison: Intel vs. NVIDIA*

- Intel has Higher Memory Capacity (16GB vs. 12GB)
- Intel has less impact to capacity when ECC is Enabled
- NVIDIA looses ~12.5% mem capacity when ECC is enabled vs. ~3.25% for Intel

Source:
Intel results Measured as Oct, 2013. NVIDIA* results values based on www.nvidia.com
K10 = capacity behind each GPU on the card

Some results have been estimated based on internal Intel analysis and are provided for informational purposes only. Any difference in system hardware or software design or configuration may affect actual performance.

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Intel Inside®
Xeon Phi™

K10 K20 K20X K40

Memory Capacity (GB)
Without ECC With ECC

<table>
<thead>
<tr>
<th>Memory Capacity (GB)</th>
<th>Without ECC</th>
<th>With ECC</th>
</tr>
</thead>
<tbody>
<tr>
<td>3120P</td>
<td>6.0</td>
<td>5.8</td>
</tr>
<tr>
<td>5110P</td>
<td>8.0</td>
<td>7.8</td>
</tr>
<tr>
<td>7120P</td>
<td>16.0</td>
<td>15.5</td>
</tr>
<tr>
<td>K10</td>
<td>4.0</td>
<td>3.5</td>
</tr>
<tr>
<td>K20</td>
<td>5.0</td>
<td>4.4</td>
</tr>
<tr>
<td>K20X</td>
<td>6.0</td>
<td>5.3</td>
</tr>
<tr>
<td>K40</td>
<td>12.0</td>
<td>10.5</td>
</tr>
</tbody>
</table>

3.25% Drop w/ECC On
12.5% Drop w/ECC On
Leverage Code Resources

Code Modernization benefits both the Processor & the Coprocessor

- 2S Xeon E5-2697 v2 (Original Parallel)
- 2S Xeon E5-2697 v2 (Optimized)
- 2S Xeon E5-2697 v2 + 1 Xeon Phi 7120A (Optimized)

Code Modernization results in significant improvements for both the processor and the coprocessor.

Amber 14 Cellulose NPT

- Original Parallel Code (Xeon Only)
- Optimized Code (Xeon Only)
- Optimized Code (Xeon + Xeon Phi)

LAMMPS Liquid Crystal

- Original Parallel Code (Xeon Only)
- Optimized Code (Xeon Only)
- Optimized Code (Xeon + Xeon Phi)

**Code Optimizations**
- Better Vectorization
- Mixed Precision support
- Misc changes for better parallelization

Xeon = Intel® Xeon® processor
Xeon Phi = Intel® Xeon Phi™ coprocessor
A Growing Ecosystem:

The Intel® Xeon Phi™ Coprocessors Applications & Solutions Catalog

One place for all current public announcements, collateral, recipes, articles, benchmarks and case studies:

- Provides insight into work-in-process optimization and porting efforts in the software communities
- Lists optimized, ported, and downloadable software
- Click here to Access the Catalog Now!
- Click here for companies offering Intel® Xeon Phi™ Coprocessors

Developer Zone

Intel.com/xeonphi
“Intel’s leading technology & product provide great high performance computing power which enable us achieve more genome scientific research success for genome application development for China and for the whole human being.”

Wang Bingqiang
Head of High Performance Computing, BGI

Optimizing applications. Accelerating discovery.

LIFE SCIENCES
LAMMPS*

Stillinger-Weber Water Benchmark

**Application:** LAMMPS*


**Availability:**
- **Code:** In main LAMMPS repository.
- **Recipe:** Available here.

**Usage Model:** Load balancer offloads part of neighbor-list and non-bond force calculations to Intel® Xeon Phi™ coprocessor for concurrent calculations with CPU.

**Highlights:**
- Improved results with Intel® Xeon® processor E5-2697 v3 and Intel® Xeon Phi™ coprocessor 7120A. Dynamic load balancing allows for concurrent:
  - Data transfer between host and coprocessor.
  - Calculations of neighbor-list, non-bond, bond, and long-range terms.
- Same routines in LAMMPS Intel Package also run faster on CPU.

**Results:** Simulation rate increase with Intel® Package is up to 3.6X. Concurrent Intel Xeon Phi coprocessor computations and MPI communications yield improved speedup and higher node counts.

**Source:** Intel measured results as of March, 2015

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**Comparative Performance**

LAMMPS* Stillinger-Weber Water Benchmark Speed Up

<table>
<thead>
<tr>
<th>1 Node (256K molecules)</th>
<th>32 Nodes (8.2M molecules)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2S Intel® Xeon® processor E5-2697 v3 (LAMMPS baseline)</td>
<td>3X</td>
</tr>
<tr>
<td>2S Intel® Xeon® processor E5-2697 v3 (LAMMPS IA Package)</td>
<td>3.41X</td>
</tr>
<tr>
<td>2S Xeon E5-2697 v3 + Tesla K40c*, boost off, ECC on</td>
<td>3.05X</td>
</tr>
<tr>
<td>2S Xeon E5-2697 v3 + Xeon Phi 7120A, turbo off (LAMMPS IA Package)</td>
<td>3.6X</td>
</tr>
</tbody>
</table>

1 Node (256K molecules) 1 0.9X 1
32 Nodes (8.2M molecules) 1 No testing on Tesla

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"Xeon E5-2697 v3" = Intel® Xeon® processor E5-2697 v3
"Xeon Phi 7120A" = Intel® Xeon Phi™ coprocessor 7120A

For configuration details, [go here.](#)

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Applications: 1) Bowtie2 version 2.2.3; Intel® AVX2 port. Bowtie 2 is an ultrafast and memory-efficient tool for aligning sequencing reads to long reference sequences. 2) NVBowtie version 0.9.9.3. NVBowtie is a GPU-accelerated re-engineering of Bowtie2, a widely used short-read aligner. While being completely rewritten from scratch, NVBowtie reproduces many (though not all) of the features of Bowtie2. http://nvlabs.github.io/nvbio/nvbowtie_page.html

Description: Bowtie 2, in addition to aligning sequencing reads to long reference sequences, is particularly good at aligning reads of about 50 up to 100s or 1,000s of characters, and particularly good at aligning to relatively long (e.g. mammalian) genomes.

Availability:
- Code: Available here.
- Recipe: Not available. Check for future availability here.

Usage Models: ERR161544, SRR002273_1, HEK001(TGen), ERR000589_1, SRR033552_1, SRR034966_1, ERR024139_1

Highlights: See more here.

Results: Bowtie2 running on the Intel® Xeon® processor E5-2697 v3 with Intel® AVX2 port faster than NVBowtie running on the Intel® Xeon® processor E5-2697 v2 and the NVIDIA Tesla K40* for 6 of 7 workloads. NVIDIA published data of K40 compared to Intel® Xeon® processor E5-2600 (6 cores) on one workload.

SOURCE: INTEL MEASURED RESULTS AS OF JANUARY, 2015
Johns Hopkins Bowtie 2*

TGen workload

Application: Johns Hopkins Bowtie2* SSE2 and Bowtie2 running on the Intel® Xeon Phi™ coprocessor. Bowtie 2 is an ultrafast and memory-efficient tool for aligning sequencing reads to long reference sequences.

Description: TGen workload – Analyzing cancer tumor RNA data from Translational Genomics Research Institute (TGen), available [here](http://example.com) and [here](http://example.com). This workload used in Intel® Xeon® processor launch benchmarks.

Availability:
- **Code:** Available [here](http://example.com).
- **Recipe:** Not available. Check for future availability [here](http://example.com).

Usage Model: Heterogeneous model: Process data on host (78 input files) and Intel® Xeon Phi™ coprocessor (36 input files), each file contains 500,000 reads. One Intel Xeon Phi coprocessor, 12 simultaneous jobs with 10 threads each, were run and one job with 24 threads was run on the host.

Highlights: [See more here](http://example.com).

Results: Up to 1.37X improved performance with the Intel® Xeon® processor E5-2697 v2 (host) and the Intel Xeon Phi coprocessor 7120A over the baseline host.

For configuration details, [go here](http://example.com).

SOURCE: INTEL MEASURED RESULTS AS OF JANUARY, 2015

For configuration details, [go here](http://example.com).

SOURCE: INTEL MEASURED RESULTS AS OF JANUARY, 2015
**Application:** Basic Local Alignment Search Tool (BLASTn) v.30.


**Availability:**
- **Code:** Available [here](http://).  
- **Recipe:** Available [here](http://).

**Usage Model:** #4 (multiple queries multiple db) 100 NCBI queries (concatenated) against db refseq_rna.00-02 are distributed to the Intel® Xeon® processor and Intel® Xeon Phi™ coprocessor for maximum speedup sweet spot. Experiment was repeated 20 times with the pick of queries randomized for a sweet spot split 80/20 and 59/23/18.

**Highlights:** Throughput for this load sharing model has a small sweet spot for a sufficiently large query set.

**Results:** Compared to the baseline, simulation rate speed up with Intel® Xeon® processor E5-2697 v3 and Intel® Xeon Phi™ coprocessor 7120A heterogeneous model is 1.52X. Performance is also improved on the CPU due to Output Formatting Section (OFS) parallelization.

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For configuration details, go [here](http://).  
 SOURCE: INTEL MEASURED RESULTS AS OF MARCH, 2015
**Application:** Basic Local Alignment Search Tool (BLASTp) v.30


**Availability:**
- **Code:** Available here.
- **Recipe:** Available here.
- **Usage Model:** #4 (multiple queries multiple db) 40 NCBI queries (concatenated) against db nr_sorted.00-02 are distributed to Intel® Xeon® processor and Intel® Xeon Phi™ coprocessor for maximum speedup sweet spot. Experiment was repeated 20 times with the pick of queries randomized for a sweet spot split 33/7 and 28/5/7.

**Highlights:** Throughput for this offload model has a small sweet spot for a sufficiently large query set. Throughput is limited due to GAT stage not parallelized.

**Results:** Compared to the baseline, simulation rate speed up with Intel® Xeon® processor E5-2697 v3 and Intel® Xeon Phi™ coprocessor 7120A heterogeneous model is 1.41X. Performance is also improved on the CPU due to Output Formatting Section (OFS) parallelization.

For configuration details, go here.
**NAMD* 2.10 Pre-Release**

**STMV**

---

**Application:** NAMD 2.10 pre-release; STMV

**Description:** A parallel, object-oriented molecular dynamics code designed for high-performance simulation of large biomolecular systems. More at http://www.ks.uiuc.edu/Research/namd/

**Availability:**

- **Code:** Intel® Xeon Phi™ coprocessor support is available as a pre-release. Use the nightly build.
- **Recipe:** Available here.

**Usage Model:** Single rank on host with 47 threads. Various computations are offloaded to Intel® Xeon Phi™ coprocessor from each thread.

**Highlights:** Intel® Xeon Phi™ coprocessor support is now in the development branch of NAMD 2.10 pre-release.

**Results:** For the STMV workload, the Intel® Xeon® processor E5-2697 v3 and the Intel® Xeon Phi™ coprocessor (32 nodes, 55 PPN) improved performance by up to 32X compared to the baseline processor (1 node, 47 PPN).

---

*Other names and brands may be claimed as the property of others*
**Application:** NAMD* 2.10 pre-release; ApoA1

**Description:** A parallel, object-oriented molecular dynamics code designed for high-performance simulation of large bio molecular systems. More at [http://www.ks.uiuc.edu/Research/namd/](http://www.ks.uiuc.edu/Research/namd/)

**Availability:**
- **Code:** Intel® Xeon Phi™ coprocessor support is available as a pre-release. Use the nightly build.
- **Recipe:** Available here.

**Usage Model:** Single rank on host with 55 threads. Various computations are offloaded to Intel® Xeon Phi™ coprocessor from each thread.

**Highlights:** Intel® Xeon Phi™ coprocessor support is now in the development branch of NAMD 2.10 pre-release.

**Results:** For the ApoA1 workload, 2-node performance can be accelerated by up to 2.61X using a single Intel® Xeon Phi™ coprocessor.

---

**Graph:**
- **Comparative Performance:**
  - **1 Node:**
    - Baseline: Intel® Xeon® processor E5-2697 v3 (1 node, 55PPN)
  - **2 Nodes:**
    - 1.52X Intel® Xeon® processor E5-2697 v3 (Baseline: 1 node, 55PPN)
    - 1.94X Intel® Xeon® processor E5-2697 v3 + Intel® Xeon Phi™ coprocessor B1-7110A (240T)
    - 2.61X Intel® Xeon® processor E5-2697 v3 + Intel® Xeon Phi™ coprocessor B1-7110A (240T)

For configuration details, [go here](#).

**SOURCE:** INTEL MEASURED RESULTS AS OF SEPTEMBER, 2014

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*
**Application:** NAMD 2.10 pre-release; ApoA1  
**Description:** A parallel, object-oriented molecular dynamics code designed for high-performance simulation of large biomolecular systems. More at [http://www.ks.uiuc.edu/Research/namd/](http://www.ks.uiuc.edu/Research/namd/)

**Availability:**  
- **Code:** Intel® Xeon Phi™ coprocessor support is available as a pre-release. Use the nightly build.  
- **Recipe:** Available here.

**Usage Model:** Single rank on host with 47 threads. Various computations are offloaded to Intel® Xeon Phi™ coprocessor from each thread.

**Highlights:** Intel® Xeon Phi™ coprocessor support is now in the development branch of NAMD 2.10 pre-release.

**Results:** For the ApoA1 workload, the Intel® Xeon® processor E5-2697 v3 and the Intel® Xeon Phi™ coprocessor (2 nodes, 55 PPN) improved performance by up to 3.14X compared to the baseline processor (1 node, 47 PPN).

For configuration details, [go here.](#)
Application: LAMMPS


Availability:
- Code: In main LAMMPS repository.
- Recipe: Available here.

Usage Model: Load balancer offloads part of neighbor-list and non-bond force calculations to Intel® Xeon Phi™ coprocessor for concurrent calculations with CPU.

Highlights: Improved results with Intel® Xeon® processor E5-2697 v3 and Intel® Xeon PHI™ coprocessor 7120A. Dynamic load balancing allows for concurrent:
- Data transfer between host and coprocessor.
- Calculations of neighbor-list, non-bond, bond, and long-range terms.

Same routines in LAMMPS Intel Package also run faster on CPU.

Results: Up to 6.5x performance improvement utilizing Intel® Xeon® processors and Intel® Xeon Phi™ coprocessors in combination with application optimization and generational improvements in architecture and higher core counts.

For configuration details, go here. SOURCE: INTEL MEASURED RESULTS AS OF AUGUST, 2014

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* Liquid Crystal Benchmark; 524K Atoms**

---

**Application:** LAMMPS*


**Availability:**
- **Code:** In main LAMMPS repository.
- **Recipe:** Available here.

**Usage Model:** Load balancer offloads part of neighbor-list and non-bond force calculations to Intel® Xeon Phi™ coprocessor for concurrent calculations with CPU.

**Highlights:**
- Improved results with Intel® Xeon® processor E5-2697 v3 and Intel® Xeon PHI™ coprocessor 7120A. Dynamic load balancing allows for concurrent:
  - Data transfer between host and coprocessor.
  - Calculations of neighbor-list, non-bond, bond, and long-range terms.
- Same routines in LAMMPS Intel Package also run faster on CPU.

**Results:**
- Up to 5.4X performance improvement utilizing Intel® Xeon® processors and Intel® Xeon Phi™ coprocessors with application optimization on a single node compared to the baseline configuration.
- Performance gains continue to hold at 5.3x when scaling up to 32 nodes.

---

**LAMMPS* Liquid Crystal Benchmark Performance (Mixed Precision)**

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Node (524K Atoms)</td>
<td>1</td>
</tr>
<tr>
<td>32 Nodes (16.8M Atoms)</td>
<td>5.3X</td>
</tr>
</tbody>
</table>

For configuration details, [go here](http://lammps.sandia.gov/).

SOURCE: INTEL MEASURED RESULTS AS OF AUGUST, 2014

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*
**Application:** LAMMPS*


**Availability:**
- **Code:** In main LAMMPS repository.
- **Recipe:** Available here.

**Usage Model:** Load balancer offloads part of neighbor-list and non-bond force calculations to Intel® Xeon Phi™ coprocessor for concurrent calculations with CPU.

**Highlights:** Improved results with Intel® Xeon® processor E5-2697 v3 and Intel Xeon Phi coprocessor 7120A. Dynamic load balancing allows for concurrent:
- Data transfer between host and coprocessor.
- Calculations of neighbor-list, non-bond, bond, and long-range terms.

Same routines in LAMMPS Intel Package also run faster on CPU.

**Results:** Up to 1.68X performance improvement utilizing Intel® Xeon® processors and Intel® Xeon Phi™ coprocessors with application optimization on a single node compared to the baseline configuration. Performance gains continue to hold at 1.47X when scaling up to 32 nodes.

**LAMMPS* Rhodopsin Benchmark Performance (Mixed Precision)**

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Node</td>
<td>1.07X</td>
</tr>
<tr>
<td>32 Nodes</td>
<td>1.47X</td>
</tr>
</tbody>
</table>

For configuration details, go here.

SOURCE: INTEL MEASURED RESULTS AS OF AUGUST, 2014
**Application:** AMBER* 14

**Description:** Bimolecular Simulations (Protein, DNA, RNA, virus etc.). Full double precision (DPDP). More at [http://ambermd.org/](http://ambermd.org/)

**Availability:**
- **Code:** [Available as a patch](#).
- **Recipe:** [Available here](#) (Section 18.7 of the manual).

**Usage Model:**
- Baseline is the Intel® Xeon® processor E5-2697 v2 compared to the Intel® Xeon® processor E5-2697 v2 and the Intel® Xeon Phi™ coprocessor 7120A.
- Offload processing on both, and using the released code, double precision code, across the platforms, 50% workload on the host and 50% on the coprocessor.

**Highlights:** The code was optimized, delivered to the AMBER community (whoever has license) and available as an update patch during code configuration. The benchmark information is at [http://www.ks.uiuc.edu/Research/STMV/](http://www.ks.uiuc.edu/Research/STMV/)

**Results:** Optimized Intel Xeon processor E5-2697 v3 and Intel Xeon Phi coprocessor 7120A offload demonstrated up to 2.41X improved performance over the Intel Xeon processor E5-2697 v2. Optimized offload process demonstrated 1.07X increased performance compared to NVIDIA K40 performance.

**Comparative Performance**

<table>
<thead>
<tr>
<th>Processor Configuration</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel® Xeon® processor E5-2697 v2 (baseline)</td>
<td>1</td>
</tr>
<tr>
<td>Intel® Xeon® processor E5-2697 v2 (optimized)</td>
<td>1.52X</td>
</tr>
<tr>
<td>Xeon E5-2697 v2 (optimized) + Intel® Xeon Phi™ coprocessor 7120A</td>
<td>2X</td>
</tr>
<tr>
<td>Xeon E5-2697 v2 (optimized) + NVIDIA* K40 DPFP</td>
<td>2.26X</td>
</tr>
<tr>
<td>Intel® Xeon® processor E5-2697 v3</td>
<td>1.93X</td>
</tr>
<tr>
<td>Xeon E5-2697 v3 (optimized) + Intel® Xeon Phi™ coprocessor 7120A</td>
<td>2.41X</td>
</tr>
<tr>
<td>“Xeon E5-2697 v2/v3” = Intel® Xeon® processor E5-2697 v2/v3</td>
<td></td>
</tr>
</tbody>
</table>

For configuration details, [go here](#).

SOURCE: INTEL MEASURED RESULTS AS OF SEPTEMBER, 2014
Application: LAMMPS*


Availability:
- Code: In main LAMMPS repository.
- Recipe: Available here.

Usage Model: Load balancer offloads part of neighbor-list and non-bond force calculations to Intel® Xeon Phi™ coprocessor for concurrent calculations with CPU.

Highlights:
- Improved results with Intel® Xeon® processor E5-2697 v2 and Intel Xeon Phi coprocessor 7120A. Dynamic load balancing allows for concurrent:
  - Data transfer between host and coprocessor.
  - Calculations of neighbor-list, non-bond, bond, and long-range terms.
- Same routines in LAMMPS Intel Package also run faster on CPU.

Results: Up to 5.07X performance improvement utilizing Intel® Xeon® processors and Intel® Xeon Phi™ coprocessors with application optimization on a single node compared to the baseline configuration. Performance at 4.84X when scaling up to 32 nodes.
**Application:** LAMMPS*  


**Availability:**
- **Code:** In main LAMMPS repository.
- **Recipe:** Available here.

**Usage Model:** Load balancer offloads part of neighbor-list and non-bond force calculations to Xeon Phi™ for concurrent calculations with CPU.

**Highlights:** Dynamic load balancing allows for concurrent:
- Data transfer between host and coprocessor.
- Calculations of neighbor-list, non-bond, bond, and long-range terms.

Same routines in LAMMPS Intel Package also run faster on CPU.

**Results:** Up to 1.71X performance improvement utilizing Intel® Xeon® processors and Intel® Xeon Phi™ coprocessors with application optimization on a single node compared to the baseline configuration. Performance increases up to 2.15X when scaling up to 32 nodes, out-performing the alternative configuration.

---

**LAMMPS* Rhodopsin Benchmark 256K Atoms**

<table>
<thead>
<tr>
<th>Comparative Performance</th>
<th>1 Node</th>
<th>32 Nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2S Intel® Xeon® E5-2697 v2 (LAMMPS baseline)</td>
<td>1</td>
<td>1.26X</td>
</tr>
<tr>
<td>2S Intel® Xeon® E5-2697 v2 (LAMMPS IA Package)</td>
<td>.94X</td>
<td>1.71X</td>
</tr>
<tr>
<td>2S E5-2697 v2 + Intel® Xeon Phi™ Coprocessor 7120A Turbo off (LAMMPS IA package)</td>
<td>1</td>
<td>1.56X</td>
</tr>
<tr>
<td>Cray XK7: 1S AMD Opteron* 6274 + NVIDIA Tesla* K20X; Cray Gemini* Interconnect, PCIe2.0* (LAMMPS GPU Package)</td>
<td>1.46X</td>
<td>2.15X</td>
</tr>
</tbody>
</table>

For configuration details, [go here.](http://www.nvidia.com/docs/IO/122634/computational-chemistry-benchmarks.pdf)

**SOURCE:** INTEL MEASURED RESULTS AS OF MAY, 2014

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.
**Application:** LAMMPS*


**Availability:**
- **Code:** In main LAMMPS repository.
- **Recipe:** Available here.

**Usage Model:** Load balancer offloads part of neighbor-list and non-bond force calculations to Intel® Xeon Phi™ coprocessor for concurrent calculations with CPU.

**Highlights:** Improved results with Intel® Xeon® processor E5-2697 v2 and Intel Xeon Phi coprocessor 7120A. Dynamic load balancing allows for concurrent:
- Data transfer between host and coprocessor.
- Calculations of neighbor-list, non-bond, bond, and long-range terms.

Same routines in LAMMPS Intel Package also run faster on CPU.

**Results:** Up to 1.78X performance improvement utilizing Intel® Xeon® processors and Intel® Xeon Phi™ coprocessors with application optimization on a single node compared to the baseline configuration. Performance gains continue to hold at 1.75X when scaling up to 32 nodes.

![Graph showing performance comparison](attachment:image.png)

For configuration details, go here.

*Other names and brands may be claimed as the property of others.
LAMMPS*
Rhodopsin Benchmark; 512K Atoms

Application: LAMMPS*
Description: Simulation of molecular systems with classical models. Wide variety of academic, government, and industry users. Popular due to its versatility and support for a wide range of force-fields/potential models: Materials Science, Chemistry, Biophysics, Solid Mechanics, Granular Flow, etc. More at http://lammps.sandia.gov/

Availability:
- Code: In main LAMMPS repository.
- Recipe: Available here.

Usage Model: Load balancer offloads part of neighbor-list and non-bond force calculations to Intel® Xeon Phi™ coprocessor for concurrent calculations with CPU.

Highlights: Improved results with Intel® Xeon® processor E5-2697 v2 and Intel Xeon Phi coprocessor 7120A. Dynamic load balancing allows for concurrent:
- Data transfer between host and coprocessor.
- Calculations of neighbor-list, non-bond, bond, and long-range terms.
Same routines in LAMMPS Intel Package also run faster on CPU.

Results: Up to 1.75X performance improvement utilizing Intel® Xeon® processors and Intel® Xeon Phi™ coprocessors with application optimization on a single node compared to the baseline configuration. Performance gains continue to hold at 1.72X when scaling up to 32 nodes, out-performing the alternative configuration.

For configuration details, go here. SOURCE: INTEL MEASURED RESULTS AS OF JULY, 2014

**Comparative Performance**

<table>
<thead>
<tr>
<th></th>
<th>1 Node</th>
<th>32 Nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2S Intel® Xeon® processor E5-2697v2 (LAMMPS Baseline)</td>
<td>1</td>
<td>.9X</td>
</tr>
<tr>
<td>2S Intel® Xeon® processor E5-2697v2 (LAMMPS IA Package)</td>
<td>1.21X</td>
<td>1.2X</td>
</tr>
<tr>
<td>2S E5-2697v2 + Intel® Xeon Phi™ coprocessor 7120A Turbo Off (LAMMPS IA Package)</td>
<td>1.75X</td>
<td>1.22X</td>
</tr>
<tr>
<td>Cray XK7: 1S AMD Opteron* 6274 + NVIDIA Tesla* K20X; Cray Gemini* Interconnect, PCIe* 2.0 (LAMMPS GPU Package)</td>
<td>1.2X</td>
<td>1.72X</td>
</tr>
</tbody>
</table>

**Comparative Performance** includes External NVIDIA* Results 2/K20X + 1S AMD*

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.
**Application:** LAMMPS*

**Description:** Simulation of molecular systems with classical models. Wide variety of academic, government, and industry users. Popular due to its versatility and support for a wide range of force-fields/potential models: Materials Science, Chemistry, Biophysics, Solid Mechanics, Granular Flow, etc. More at http://lammps.sandia.gov/.

**Availability:**
- **Code:** In main LAMMPS repository.
- **Recipe:** Available here.

**Usage Model:** Load balancer offloads part of neighbor-list and non-bond force calculations to Intel® Xeon Phi™ coprocessor for concurrent calculations with CPU.

**Highlights:** Improved results with Intel® Xeon® processor E5-2697 v2 and Intel Xeon Phi coprocessor 7120A. Dynamic load balancing allows for concurrent:
- Data transfer between host and coprocessor.
- Calculations of neighbor-list, non-bond, bond, and long-range terms.

Same routines in LAMMPS Intel Package also run faster on CPU.

**Results:** Up to 1.9X performance improvement utilizing Intel® Xeon® processors and Intel® Xeon Phi™ coprocessors with application optimization on a single node compared to the baseline configuration. Performance at 4.84X when scaling up to 32 nodes.

For configuration details, go here.

SOURCE: INTEL MEASURED RESULTS AS OF JULY, 2014
**Application:** AMBER* 14

**Description:** Bimolecular Simulations (Protein, DNA, RNA, virus etc.). Full double precision (DPDP). More at [http://ambermd.org/](http://ambermd.org/)

**Availability:**
- **Code:** Available as a patch.
- **Recipe:** Available here (Section 18.7 of the manual).

**Usage Model:**
- Baseline is the Intel® Xeon® processor E5-2697 v2 host (also measured in [http://ambermd.org/gpus/benchmarks.htm#Benchmarks](http://ambermd.org/gpus/benchmarks.htm#Benchmarks)) and speed up is shown with offload processing on both the Intel® Xeon® processor E5-2697 v2 and the Intel® Xeon Phi™ coprocessor 7120A.
- Performance shown for the released code, all double precision, across the platforms. 50% workload on the host, 50% on the coprocessor.

**Highlights:** The code had been optimized, will be delivered to the AMBER community (whoever has license) and available as update patch during code configuration.

**Results:** Optimized offload process demonstrated up to 2.2X improved performance over the baseline Intel® Xeon® processor E5-2697 v2.
Application: AMBER* 14
Description: Bimolecular Simulations (Protein, DNA, RNA, virus etc.). Full double precision (DPDP). More at http://ambermd.org/
Availability:
- Code: Available as a patch.
- Recipe: Available here (Section 18.7 of the manual).
Usage Model:
- Baseline is the host Intel® Xeon® processor E5-2697 v2 compared to the Intel® Xeon® processor E5-2697 v2 and the Intel® Xeon Phi™ coprocessor 7120A using double precision.
- Offload processing on both, using the released code, double precision across the platforms.
Highlights: The code was optimized, delivered to the AMBER community (whoever has license) and available as an update patch during code configuration.
Results: Optimized Intel Xeon processor E5-2697 v2 and Intel Xeon Phi coprocessor 7120A offload demonstrated up to 2.2X improved performance over the baseline Intel Xeon processor E5-2697 only code.
AMBER* 14

Particle Mesh Ewald (PME) Cellulose NPT

Application: AMBER* 14
Description: Bimolecular Simulations (Protein, DNA, RNA, virus etc.). Full double precision (DPDP). More at http://ambermd.org/

Availability:

Usage Model: Baseline is the Intel® Xeon® processor E5-2697 v2 compared to the Intel® Xeon® processor E5-2697 v2 and the Intel® Xeon Phi™ coprocessor 7120A with offload processing on both, and using the released code (double precision code across the platforms).

Highlights: The code was optimized, delivered to the AMBER community (whoever has license) and available as an update patch during code configuration.

Results: Optimized Intel Xeon processor E5-2697 v2 and Intel Xeon Phi coprocessor 7120A offload demonstrated up to 2X improved performance over the baseline Intel Xeon processor E5-2697 only code.

For configuration details, go here.

SOURCE: INTEL MEASURED RESULTS AS OF SEPTEMBER, 2014
**Application:** AMBER* 14

**Description:** Bimolecular Simulations (Protein, DNA, RNA, virus etc.). Full double precision (DPDP). More at [http://ambermd.org/](http://ambermd.org/)

**Availability:**
- **Code:** Available as a patch.
- **Recipe:** Available here (Section 18.7 of the manual).

**Usage Model:**
- Baseline is on the Intel® Xeon® processor E5-2697 v2 host only (also measured in [http://ambermd.org/gpus/benchmarks.htm#Benchmarks](http://ambermd.org/gpus/benchmarks.htm#Benchmarks)) and speed up is shown with offload processing on both the Intel Xeon processor E5-2697 v2 and the Intel® Xeon Phi™ coprocessor 7120A.
- Performance shown is for the released code, double precision across the platforms, 50% workload on the host, 50% on the coprocessor.

**Highlights:** The code had been optimized, will be delivered to the AMBER community (whoever has license) and available as update patch during code configuration.

**Results:** Optimized offload process demonstrated compelling cluster performance improvement, up to 2.8X, over the baseline Intel® Xeon® processor E5-2697 v2.

For configuration details, go here.

Source: INTEL MEASURED RESULTS AS OF SEPTEMBER, 2014
**Application:** AMBER* 14

**Description:** Bimolecular Simulations (Protein, DNA, RNA, virus etc.). Full double precision (DPDP). More at [http://ambermd.org/](http://ambermd.org/)

**Availability:**
- **Code:** Available as a patch.
- **Recipe:** Available here (Section 18.7 of the manual).

**Usage Model:**
- Baseline is on the Intel® Xeon® processor E5-2697 v2 host only (also measured in [http://ambermd.org/gpus/benchmarks.htm#Benchmarks](http://ambermd.org/gpus/benchmarks.htm#Benchmarks)) and speed up is shown with offload processing on both the Intel Xeon processor E5-2697 v2 and the Intel® Xeon Phi™ coprocessor 7120A.
- Performance shown is for the released code, double precision across the platforms, 50% workload on the host, 50% on the coprocessor.

**Highlights:** The code had been optimized, will be delivered to the AMBER community ( whoever has license) and available as update patch during code configuration.

**Results:** Optimized offload process demonstrated compelling cluster performance improvement, up to 2.6X, over the baseline Intel® Xeon® processor E5-2697 v2.
Application: Burrows-Wheeler Aligner*, version 0.5.10. BWA-ALN is represented in this benchmark. Workload is korean_female (read file 3.5 GB, 3.0 GB reference data base).

Description: BWA is a popular software package for mapping low-divergent sequences against a large reference genome, such as the human genome. More at http://bio-bwa.sourceforge.net/.

Availability:
- Code: Available here.
- Recipe: Available here.

Usage Model: Hybrid MPI + OpenMP* using symmetric mode.

Highlights: Results are identical to the unmodified run of BWA-ALN.

Results: The Intel® Xeon® processor E5-2697 v2 and the Intel® Xeon Phi™ coprocessor symmetric process demonstrated up to 1.86X improved performance over the baseline Intel® Xeon® processor E5-2697 v2.

For configuration details, go here.
**Application:** GROMACS* 5.0-RC1; Workload: 512K H2O with RF method

**Description:** GROMACS is a versatile package to perform molecular dynamics, i.e. simulate the Newtonian equations of motion for systems with hundreds to millions of particles. It is one of the fastest and the most popular Molecular Dynamics packages.

**Availability:**
- **Code:** Version 5.0-rc1 available [here](#) and [here](#).
- **Recipe:** [Available here](#).

**Highlights:**
- Highly optimized for Intel® Xeon® Processors (AVX-intrinsics).
- Able to run full simulation on Intel® Xeon Phi™ coprocessor natively + host processor using a symmetric model.
- Optimized with intrinsics for 512-bit vectorization on Intel Xeon Phi coprocessors.
- **Results:** Symmetric process demonstrated up to 1.79X improved performance over the baseline Intel® Xeon® processor E5-2697 v2.

For configuration details, [go here](#).

SOURCE: INTEL MEASURED RESULTS AS OF APRIL, 2014
### NWChem* CCSD(T) Method

**Application:** NWChem* is a computational chemistry software package that includes quantum chemical and molecular dynamics functionality. NWChem is developed the Environmental Molecular Sciences Laboratory (EMSL) at the Pacific Northwest National Laboratory (PNNL). More at [http://www.nwchem-sw.org](http://www.nwchem-sw.org)

**Availability:**
- **Code:** Available here and from the SVN repository.
- **Recipe:** Available here.

**Usage Model:** Offload using LEO and OpenMP*

**Highlights:** NWChem with Intel® Xeon Phi™ coprocessor 7120A offloading is a compelling and cluster compelling application for the NWChem community.

**Results:** Compared to the NWChem* 6.3rev2 and Intel® Xeon® processor E5-2697 v2 baseline:
1) NWChem 6.5 CCSD(T) performed up to 1.24X faster with the Intel® Xeon® processor E5-2697 v2.
2) NWChem 6.5 CCSD(T) performed up to 1.52X faster with the Intel® Xeon® processor E5-2697 v2 and the Intel Xeon Phi coprocessor 7120A.

**SOURCE:** INTEL MEASURED RESULTS AS OF JULY, 2014

### Comparative Performance

<table>
<thead>
<tr>
<th>1</th>
<th>1.24X</th>
<th>1.52X</th>
</tr>
</thead>
<tbody>
<tr>
<td>NWChem 6.3, 64S Intel® Xeon® processor E5-2697 v2</td>
<td>NWChem 6.5, 64S Intel® Xeon® processor E5-2697 v2</td>
<td>NWChem 6.5, 64S Intel® Xeon® processor E5-2697 v2 + 64 Intel® Xeon Phi™ Coprocessor 7120A 2</td>
</tr>
</tbody>
</table>

For configuration details, go here.

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

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32 NODES APPROVED FOR PUBLIC PRESENTATION

CLUSTER BENCHMARK
NWChem is a computational chemistry software package that includes quantum chemical and molecular dynamics functionality. It is designed for high-performance parallel supercomputers and aims to be scalable both in its ability to treat large problems efficiently, and in its usage of available parallel computing resources. NWChem is developed by the Environmental Molecular Sciences Laboratory (EMSL) at the Pacific Northwest National Laboratory (PNNL). More at http://www.nwchem-sw.org

Availability:
- Code: Available here and from the SVN repository.
- Recipe: Available here.

Usage Model: Offload using LEO and OpenMP*.

Highlights: NWChem with Intel® Xeon Phi™ coprocessor 7120A offloading is a compelling and cluster compelling application for the NWChem community.

Results: NWChem* 6.3rev2 CCSD(T) method performed up to 1.35X faster with the Intel® Xeon® processor E5-2697 v2 and the Intel Xeon Phi coprocessor 7120A compared to the Intel Xeon processor E5-2697 v2 baseline.

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

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Discover and design like never before.

MATERIAL SCIENCES
**Application:** miniGhost v. 0.9

**Description:** Finite Difference mini-application which implements a difference stencil across a homogenous three dimensional domain. More at [https://mantevo.org/download/](https://mantevo.org/download/)

**Availability:**
- **Code:** Available [here](https://mantevo.org/download/) or [here](https://mantevo.org/download/).
- **Recipe:** Available [here](https://mantevo.org/download/).

**Usage Model:** Symmetric model.

**Highlights:** The code is a proxy for the CTH (shock physics code) and can be used as a good test-case to measure network (interconnect bandwidth vs. latency) performance.

**Results:** Symmetric process (2S Intel® Xeon® processor E5-2697 v3 + Intel® Xeon Phi™ coprocessor 7120A) demonstrated up to 1.76X improved performance over the baseline processor.

---

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)
**Application:** miniGhost v. 0.9  
**Description:** Finite Difference mini-application which implements a difference stencil across a homogenous three dimensional domain. More at [https://mantevo.org/download/](https://mantevo.org/download/)

**Availability:**
- **Code:** Available [here](#) or [here](#).
- **Recipe:** Available [here](#).

**Usage Model:** Symmetric model.

**Highlights:** The code is a proxy for the CTH (shock physics code) and can be used as a good test-case to measure network (interconnect bandwidth vs. latency) performance.

**Results:** Symmetric process (2S Intel® Xeon® processor E5-2697 v3 + Intel® Xeon Phi™ coprocessor 7120A) demonstrated up to 1.48X improved performance over the baseline processor.

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For configuration details, [go here](#)

**SOURCE:** INTEL MEASURED RESULTS AS OF JANUARY, 2015

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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.
Quantum ESPRESSO* GRIR443

**Application:** Quantum ESPRESSO* 5.0.3

**Workload Description:** Quantum ESPRESSO* is an integrated suite of Open-Source computer codes for electronic structure calculations and materials modeling at the nanoscale. GRIR443 is a public PRACE benchmark suited for multi-node execution. ESPRESSO is an acronym for opEn-Source Package for Research in Electronic Structure, Simulation, and Optimization. More at [http://www.quantum-espresso.org](http://www.quantum-espresso.org/).

**Availability:**
- Code: Available here.
- Recipe: Available here.

**Usage Model:** Offload using OpenMP* and Intel® Math Kernel Library.

**Highlights:**
- Results are obtained from real-world, publicly available benchmarks – no special treatment.
- Effect of offloading heavily depends on the type of the workload – larger workloads (such as GRIR443) generate large dense matrix multiplications, benefiting from the Intel® Xeon Phi™ coprocessor 7120A.

**Results:** Quantum ESPRESSO 5.0.3 GRIR443 performed up to 1.4X faster with Intel® Xeon® processor E5-2697 v2 and the Intel Xeon Phi coprocessor compared to the Intel® Xeon® processor E5-2697 v2 baseline.

For configuration details, go here.

SOURCE: INTEL MEASURED RESULTS AS OF JULY, 2014

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.*
**Quantum ESPRESSO**

**AUSRUF112**

**Application:** Quantum ESPRESSO* 5.0.3 AUSRUF112

**Description:** Quantum ESPRESSO is an integrated suite of Open-Source computer codes for electronic-structure calculations and materials modeling at the nanoscale. AUSRUF112 is a publicly available DEISA benchmark suited for single node execution. ESPRESSO is an acronym for opEn-Source Package for Research in Electronic Structure, Simulation, and Optimization. More at [http://www.quantum-espresso.org/](http://www.quantum-espresso.org/)

**Availability:**
- Code: [Available here.](#)
- Recipe: [Available here.](#)

**Usage Model:** Offload using OpenMP* and Intel® Math Kernel Library.

**Highlights:**
- Results are obtained from real-world, publicly available benchmarks – no special treatment.
- Effect of offloading heavily depends on the type of the workload.

**Results:** Quantum ESPRESSO 5.0.3 AUSRUF112 performed up to 1.2X faster with Intel® Xeon® processor E5-2697 v2 and the Intel® Xeon Phi™ coprocessor compared to the Intel Xeon processor E5-2697 v2 baseline.

---

**Quantum ESPRESSO* 5.0.3 AUSRUF112 Speed Up**

<table>
<thead>
<tr>
<th>Comparative Performance</th>
<th>2S Intel® Xeon® processor E5-2697 v2</th>
<th>2S Intel® Xeon® processor E5-2697 v2 + 2 Intel® Xeon Phi™ Coprocessor 7120A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.2X</td>
<td></td>
</tr>
</tbody>
</table>

For configuration details, [go here.](#)
Improving simulations speed and quality.
ANSYS Mechanical* 16.0
V16sp-3 DMP

Application: ANSYS Mechanical* 16.0 DMP Mode
Description: V16sp-3 Harmonic Analysis, 1.7M DOF.
Availability:
- Code: Contact ANSYS for official V16 release, www.ansys.com
- Recipe: Available here.
Usage Model: Intel® MKL automatic offload.
Highlights: First commercial simulator supporting the Intel® Xeon Phi™ coprocessor. V15sp-3 speaker benchmark model.
Results: The Intel® Xeon Phi™ coprocessor provides speed-up over Intel® Xeon® E5-2697 v3 host on cluster runs, and dual Intel® Xeon Phi® coprocessors provide greater speed-up on both single node and on cluster runs.

For configuration details, go here.

SOURCE: INTEL MEASURED RESULTS AS OF FEBRUARY, 2015

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
ANSYS Mechanical* 16.0
V145sp-5 DMP (Previous Version Model)

Application: ANSYS Mechanical* 16.0 DMP Mode
Description: V145sp-5 Static Structural Analysis, 2.1M DOF.
Availability:
- Code: Contact ANSYS for official V16 release, www.ansys.com
- Recipe: Available here
Usage Model: Intel® MKL automatic offload.
Highlights: First commercial simulator supporting the Intel® Xeon Phi™ coprocessor. V145sp-5 turbine blade benchmark model (discusses impact of Intel® SSDs).
Results: At 1 MPI processes on the host, the Intel® Xeon Phi™ coprocessor provides up to 2.32X speed-up over the Intel® Xeon® processor E5-2697 v3 host, and the Intel® Xeon® processor E5-2697 v3 + the Intel® Xeon Phi™ coprocessor 7120A provides up to 4.6X speed-up over the Intel® Xeon® E5-2697 v2 host.

Note: Intel® Xeon® processor uses 1 core per MPI process
Application: ANSYS Mechanical* 16.0 DMP Mode
Description: V16ln-2 Dynamic Structural Modal Analysis, 2M DOF.
Availability:
- Code: Contact ANSYS for official V16 release, www.ansys.com
- Recipe: Available here.
Usage Model: Intel® MKL automatic offload.
Highlights: First commercial simulator supporting the Intel® Xeon Phi™ coprocessor.
Results: At 2 MPI processes on the host, the Intel® Xeon Phi™ coprocessor provides up to 1.78X speed-up over the Intel® Xeon® E5-2697 v3 host, and up to 2.44X speed-up over the Intel® Xeon® E5-2697 v2 host.

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.
ANSYS Mechanical* 16.0
V145sp-4 DMP (Previous Version Model)

Application: ANSYS Mechanical* 16.0 DMP Mode
Description: V145sp-4 Static Structural Analysis, 3.2M DOF.
Availability:
- Code: V16 preview 4 is now available. Contact ANSYS for official V16 release, www.ansys.com
- Recipe: Available here.
Usage Model: Intel® MKL automatic offload.
Highlights: First commercial simulator supporting the Intel® Xeon Phi™ coprocessor. V145sp-5 turbine blade benchmark model (discusses impact of Intel® SSDs).
Results: At 2 MPI processes on the host, a single Intel® Xeon Phi™ 31S1P provides up to 3.11x speed-up over Intel® Xeon® host E5-2692 v2 alone. Two Intel Xeon Phi 31S1P coprocessors provide a speed-up of up to 3.7x.

Note: Intel® Xeon® processor uses 1 core per MPI process

For configuration details, go here.
ANSYS Mechanical* 16.0
V16ln-2 SMP

Application: ANSYS Mechanical* 16.0 SMP Mode
Description: V16ln-2 Dynamic Structural Modal Analysis, 2M DOF.

Availability:
- Code: Contact ANSYS for official V16 release, www.ansys.com
- Recipe: Available here.

Usage Model: Intel® MKL automatic offload.

Highlights: First commercial simulator supporting the Intel® Xeon Phi™ coprocessor.

Results: At 1 thread on the host, the Intel® Xeon Phi™ coprocessor provides up to 1.72X speed-up over the Intel® Xeon® E5-2697 v3 host, and up to 2.06X speed-up over the Intel® Xeon® E5-2697 v2 host.

For configuration details, go here. SOURCE: INTEL MEASURED RESULTS AS OF FEBRUARY, 2015
**Application:** HPCG benchmark

**Description:** The HPCG benchmark is intended to complement the High Performance LINPACK benchmark used in the TOP500* system ranking by providing a metric that better aligns with a broader set of important cluster applications. The workload performs 50 iterations of CG method with Gauss-Seidel preconditioner and synthetic multigrid V-cycle.

**Availability:**
- **Code:** Available here. Intel Optimized Technical Preview for HPCG benchmark available by subscription. Contact intelmkl@intel.com.
- **Recipe:** Available here.

**Usage Model:**
HPCG is a hybrid (MPI + OpenMP*) code supporting symmetric and offload modes. The reference version is pure MPI code running one rank per core.

**Highlights:**
Symmetric mode provides performance benefit by freeing CPU cores used by data transfer in offload for computations.

**Results:**
Optimized version demonstrated 1.7X performance improvement compared to reference implementation and 4.48X with 2 Intel® Xeon Phi™ single node.

---

For configuration details, go here.

**SOURCE:** INTEL MEASURED RESULTS AS OF MAY, 2015
Application: Sandia Mantevo* MiniFE 2.0.1.

Description: Sandia National Laboratories; Intended to be the best approximation to an unstructured implicit finite that includes all important computational phases. More at https://mantevo.org.

Availability:
- Code: Available [here](#).
- Recipe: Available [here](#).

Usage Model: Baseline is the Intel® Xeon® processor E5-2697 v2 host, and the host and the Intel® Xeon Phi™ coprocessor in a symmetric mode.

Highlight: Porting ease using OpenMP*. The Intel® MPI Library enables rapid performance improvement when adding an Intel Xeon Phi coprocessor.

Results: Up to 2.58X speed up for the Intel® Xeon® processor E5-2697 v3 and the Intel® Xeon Phi™ coprocessor 7120A in symmetric mode over the host.

“Xeon E5-2697 v3” = Intel® Xeon® processor E5-2697 v3

Description: MSC Software Nastran sparse direct solver optimized for Intel® Xeon Phi™ coprocessors. Intel Xeon Phi coprocessors are especially well suited for large models that consist primarily of three-dimensional elements and have tightly-coupled multiphysics, such as noise, vibration, and harshness (NHV) studies.

Availability:
- **Code:** Contact an MSC Software representative.
- **Recipe:** Use hStreams* with MPSS 3.5 or later.

Usage Model: When large matrices are split into submatrices for processing, the solver offloads the largest submatrices from the Intel® Xeon® processor to the Intel® Xeon Phi™ coprocessor. Performance is maximized through asynchronous compute capabilities, which allow matrix computations on the coprocessor to start almost instantly once the data offload begins.

Highlight: This strategy has demonstrated performance gains across a range of solution sequences for MSC Nastran 2016 Alpha, including structural statics and modal decomposition, which account for the majority of customer workloads.

Results: Up to 2X speed up for the Intel® Xeon® processor E5-2697 v2 and the Intel® Xeon Phi™ coprocessor 7120A in offload mode over the host.
**Autodesk Maya* 2014 Viewport Plugin**

*Embree-based workloads*

**Application:** Embree-Based Viewport Plugin for Autodesk Maya* 2014

**Description:** An open-source, proof-of-concept Autodesk Maya 2014 viewport plugin which renders the scene being interactively edited using the Embree high-performance ray-tracing kernels and a modified version of the Embree sample path-tracer.

**Availability:**

- **Code:** Available here (branch “mayarender_v2.3.2”).
- **Recipe:** Available here.

**Usage Model:**

This plugin can do computation using only the host, only the coprocessor via offload, and on both the host and coprocessor via offload. It can also make use of multiple coprocessors. The plugin is invoked every time the screen updates during interactive content authoring.

**Highlights:**

- Workstation application for both Linux* and Windows*
- Makes use of the high-performance Embree ray-tracing kernels, which are optimized for both Intel® Xeon® processors and the Intel® Xeon Phi™ coprocessor

**Results:**

Dual Intel® Xeon® processor E5-2697 v2 + 1 Intel Xeon Phi coprocessor 7120A hybrid mode improves performance by up to 2.8X over the dual Intel® Xeon® processor E5-2697 v2 host alone.

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For configuration details, go here.

**SOURCE:** INTEL MEASURED RESULTS AS OF FEBRUARY, 2015

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Autodesk Maya* 2014 Viewport Plugin

Selected workloads

<table>
<thead>
<tr>
<th>Workload</th>
<th>Speed Up</th>
<th>Comparative Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinese Dragon with translucent material</td>
<td>1.4X</td>
<td>1.4X</td>
</tr>
<tr>
<td>Full-screen Crytek Sponza simple materials + textures</td>
<td>1.69X</td>
<td>1.69X</td>
</tr>
<tr>
<td>Power Plant</td>
<td>1.82X</td>
<td>1.82X</td>
</tr>
<tr>
<td>Rungholt</td>
<td>1.6X</td>
<td>1.6X</td>
</tr>
<tr>
<td></td>
<td>2.51X</td>
<td>2.51X</td>
</tr>
</tbody>
</table>

Application: Embree-Based Viewport Plugin for Autodesk Maya* 2014

Description: An open-source, proof-of-concept Autodesk Maya 2014 viewport plugin which renders the scene being interactively edited using the Embree high-performance ray-tracing kernels and a modified version of the Embree sample path-tracer.

Availability:
- Code: Available here (branch “mayarender_v2.3.2”).
- Recipe: Available here.

Usage Model:
This plugin can do computation using only the host, only the coprocessor via offload, and on both the host and coprocessor via offload. It can also make use of multiple coprocessors. The plugin is invoked every time the screen updates during interactive content authoring.

Highlights:
- Workstation application for both Linux* and Windows*
- Makes use of the high-performance Embree ray-tracing kernels, which are optimized for both Intel® Xeon® processors and the Intel® Xeon Phi™ coprocessor

Results:
Dual Intel® Xeon® processor E5-2697 v3 + 1 Intel Xeon Phi coprocessor 7120A hybrid mode improves performance by up to 2.51X over the dual Intel® Xeon® processor E5-2697 v2 host alone.

“Xeon E5-2697 v2 / v3” = Intel® Xeon® processor E5-2697 v2 / v3
“Xeon Phi 7120A” = Intel® Xeon Phi™ coprocessor 7120A

For configuration details, go here.

SOURCE: INTEL MEASURED RESULTS AS OF FEBRUARY, 2015
**OpenLB**

*Cylinder2d*

### Application:
OpenLB* 0.8r0. Workload is cylinder2d, which is based on D2Q9 lattice mode and comes from the example in the source code package; the size is 16384*4096.

### Description:

### Availability:
- **Code:** Available here.
- **Recipe:** Available here.

### Usage Model:
Hybrid MPI + OpenMP* on Intel® Xeon Phi™ coprocessor 7120A and MPI on Intel® Xeon® processor E5-2697 v2 using symmetric mode.

### Highlights:
Pure MPI mode shows the best performance on the host processor. For the coprocessor, MPI + OMP hybrid mode produces the best performance.

### Results:
The performance shows up to 1.53X speed up in symmetric mode over the baseline Intel® Xeon® processor E5-2697 v2.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Speed Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>2S Intel® Xeon® processor E5-2697 v2, baseline OpenLB* (12 Ranks)</td>
<td>1</td>
</tr>
<tr>
<td>2S Intel Xeon processor E5-2697 v2, optimized OpenLB (12 Ranks)</td>
<td>1X</td>
</tr>
<tr>
<td>2S Xeon E5-2697 v2 (12 Ranks) + Xeon Phi 7120A (12 Ranks * 20 thread per Rank)</td>
<td>1.53X</td>
</tr>
</tbody>
</table>

“Xeon E5-2697 v2” = Intel® Xeon® processor E5-2697 v2
“Xeon Phi 7120A” = Intel® Xeon Phi™ coprocessor 7120A

For configuration details, go here.

**SOURCE:** INTEL MEASURED RESULTS AS OF OCTOBER, 2014

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Data Center Server Demo: Fujitsu HPC Gateway*

The Fujitsu HPC Gateway* is an extendable Web desktop that provides easy access to HPC capabilities. This demo features the Intel® Xeon Phi™ coprocessor 7120P and the Intel® Xeon® processor E5-2600 v3 powering this integrated and intuitive HPC environment that can be adapted by organizations to meet specific requirements, such as access policies and licensing. See the video here.
Improving financial outcomes through faster simulations

FINANCIAL SERVICES
Monte Carlo *

European Option Pricing

Application: Monte Carlo European option
Description: Implements European Option Pricing using Monte Carlo. It compares the performance of
1) Java* code, 2) C/C++ native code, 3) C/C++ offload accelerated code, 4) C/C++ accelerated code using Hadoop*.
Availability:
- Code and Recipe: Available here.
Usage Model: Java (Managed Offload), Native on the host, Native and Accelerators, Hadoop on native and Accelerated.
Highlights:
- Java code can use parallelism but cannot vectorize any control flows
- Native C/C++ code can take advantage of both vectorization & parallelization
- Native Accelerated code offloads the whole workload to Intel® Xeon Phi™ Coprocessor.
- Hadoop distribute the workload to 4 remote modes using mapreduce
- Remote nodes accelerate the workload and send the run result back to the head node.
Results:
- Intel Java Stream can parallelize the workload but not vectorize
- Native interface bring vectorization and parallelization to the workload
- Acceleration extends the parallelism from Multicore to manycore
- Hadoop map reduce can further distribute the application into 4 nodes and achieve up to 31X improvement.

For configuration details, go here.
SOURCE: INTEL MEASURED RESULTS AS OF MARCH, 2015
Monte Carlo*
Microsoft Excel*-based option pricing

Application: Microsoft Excel*-based Monte Carlo option pricing.
Description: This application uses Excel to price Monte Carlo European Options. Traditionally these calculations are done on CPUs. This framework demonstrates how Excel can offload calculations to Intel® Xeon Phi™ x100 (Knights Corner) using Windows* stack.
Availability:
- Code: Available here.
- Recipe: Available here.
Usage Model: Offload, OpenMP*. No processing on the host; host offloads all data from Excel to the Intel® Xeon Phi™ coprocessor. All calculations were performed on the Intel Xeon Phi Coprocessor.
Highlights: Excel users can speed-up their compute intensive applications by offloading these tasks to the Intel Xeon Phi Coprocessor.
Results: Offloading calculations to Intel® Xeon Phi™ coprocessor 7120P resulted in up to 2.09X performance improvement compared to the Intel® Xeon® processor E5-2697 v2.

SOURCE: INTEL MEASURED RESULTS AS OF MARCH, 2015

Comparative Increase

Microsoft Excel*-based Monte Carlo Option Pricing Speed Up

"Xeon E5-2697 v2" = Intel® Xeon® processor E5-2697 v2
QuantLib* Single Precision Monte Carlo

Application: QuantLib* Singel Precision Monte Carlo
Description: Monte Carlo is a popular simulation mathematical model to value and analyze complex financial instruments, in this case European options. This version is single-precision. More at Accelerating Financial Applications on the GPU.

Availability:
- Code and Recipe: Available here.

Usage Model: Multi-option scenario; 400k paths, 4k options. This model uses a time-step of 250 per path. Uses OpenMP* for threads and Intel® MKL Library for vector of random numbers

Highlights: The optimized Intel® Architecture code is compared with the reference CUDA* version.

Results:
- Intel® Xeon® processor E5-2697 v3 demonstrates a speed up of up to 1.82X over Intel Xeon processor E5-2697 v2.
- Intel® Xeon Phi™ (native) demonstrates a speed up of up to 6.93X over Intel Xeon processor E5-2697 v2.
- NVIDIA Tesla* K40c demonstrates a speed up of up to 1.34X over Intel Xeon processor E5-2697 v2 (measurements do not include data transfer time).

For configuration details, go here.

SOURCE: INTEL MEASURED RESULTS AS OF MARCH, 2015
**Application:** QuantLib* Single Precision Black-Scholes  
**Description:** The QuantLib library is a popular library used for many areas of computational finance. Black-Scholes is a popular mathematical model for European option valuation. This is a single-precision version. More at [Accelerating Financial Applications on the GPU](#).  
**Availability:**  
- **Code and Recipe:** Available [here](#).  
**Usage Model:** Test Conditions: 5 million options, 2048 iterations. Uses OpenMP* for threads and Intel® TBB for memory alignment.  
**Highlights:** The optimized Intel® Architecture code is compared with the reference CUDA* version.  
**Results:**  
- Intel® Xeon® processor E5-2697 v3 demonstrates a speed up of up to 1.26X over Intel Xeon processor E5-2697 v2.  
- Intel® Xeon Phi™ (native) demonstrates a speed up of up to 1.84X over Intel Xeon processor E5-2697 v2.  
- NVIDIA Tesla* K40c demonstrates a slow down of up to 0.69X compared to the Intel Xeon processor E5-2697 v2 (measurements do not include data transfer time).
Monte Carlo* RNG
European Options; Double Precision

Application: Monte Carlo* RNG European option pricing; double precision.

Description: Monte Carlo RNG is a popular derivative pricing benchmark widely used by investment banks such as UBS*, Bank of America* and Goldman-Sachs*. More at https://software.intel.com/en-us/articles/case-study-achieving-high-performance-on-monte-carlo-european-option-using-stepwise.

Availability:
- Code: Available here.
- Recipe: Available here.

Usage Model: Hybrid or Asynchronous offload on one shared memory host node with up to two coprocessor devices.

Highlights:
- One of two most computational intensive workloads in FSI benchmark suites.
- More operations per option data set.
- Benefits from Intel® AVX2 FMA.

Results: The baseline Intel® Xeon® processor E5-2697 v3 is 1.39X higher performance than Intel® Xeon® processor E5-2697 v2. Adding one coprocessor card nearly doubles the baseline performance; adding two coprocessors nearly triples it.

SOURCE: INTEL MEASURED RESULTS AS OF JUNE, 2014

For configuration details, go here.
**Binomial Options*<br>**Double Precision**

**Application:** Binomial European Option Pricing.

**Description:** Binomial Options* is a popular derivative pricing benchmark widely used by investment banks such as UBS*, Bank of America* and Goldman-Sachs*. One of two most computational intensive workloads in FSI benchmark suites.

**Availability:**
- **Code:** Available here.
- **Recipe:** Available here.

**Usage Model:** Hybrid or Asynchronous offload on one shared memory host node with up to two coprocessor devices.

**Highlights:**
- More operations per option data set.
- Benefits from Intel® AVX2 FMA.

**Results:** The baseline Intel® Xeon® processor E5-2697 v3 is nearly double the performance of the Intel® Xeon® processor E5-2697 v2. Adding one coprocessor card increases the baseline performance by over 50%; adding two coprocessors more than doubles it.

For configuration details, go here.  
Source: Intel Measured Results As of June, 2014.
Monte Carlo* European Options

Application: Monte Carlo* RNG European option pricing.
Description: Monte Carlo RNG is a popular derivative pricing benchmark widely used by investment banks such as UBS*, Bank of America* and Goldman-Sachs*. More here.
Availability:
- Code: Available here.
- Recipe: Available here.
Usage Model: Single and double precision testing, host node with up to two coprocessor devices. Performance depends on raw computational power and the performance of exp2()Highlights: Dramatic performance scaling for both single-precision and double-precision calculations.
Results: For single precision, the Intel® Xeon® processor E5-2697 v2 performance improvement is up to 1.51X compared to the baseline, and the 2x Intel® Xeon Phi™ coprocessor performance improvement is up to 10.65X.

For configuration details, go here.

SOURCE: INTEL MEASURED RESULTS AS OF NOVEMBER, 2013
**Black-Scholes Formula Valuation**

**Single and Double Precision**

---

**Application:** Black-Scholes* financial modeling requires raw computational power plus high bandwidth between execution cores and memory

**Description:** Popular derivative pricing benchmarks widely used by investment banks such as UBS, Bank of America, Goldman Sachs

**Availability:**
- **Code:** Available here.
- **Recipe:** Available here.

**Usage Model:** Baseline is the Intel® Xeon® processor E5-2670 host only, and speed up is shown on the Intel® Xeon® processor E5-2697 v2 and on both the Intel® Xeon® processor E5-2697 v2 and on the Intel® Xeon Phi™ coprocessor 7120A.

**Highlights:** Dramatic scaling for both single and double precision computations.

**Results:** Up to 2.85X improved performance with Intel® Xeon Phi™ coprocessor 7120A over the baseline Intel® Xeon processor E5-2697 v2 for the double precision benchmark.
Monte Carlo* RNG

European Options

Application: Monte Carlo* RNG European option pricing; double precision.

Description: Monte Carlo RNG is a popular derivative pricing benchmark widely used by investment banks such as UBS*, Bank of America* and Goldman-Sachs*. More at https://software.intel.com/en-us/articles/case-study-achieving-high-performance-on-monte-carlo-european-option-using-stepwise.

Availability:
- Code: Available here.
- Recipe: Available here.

Usage Model: Single and double precision testing, host node with up to two coprocessor devices.

Highlights: Intel® Xeon Phi™ coprocessor fast exp2 and FMA instructions deliver high performance, high accuracy for single and double precision computations.

Results: For double precision, the Intel® Xeon® processor E5-2697 v2 performance improvement is up to 1.55X compared to the baseline, and the Intel® Xeon Phi™ coprocessor performance improvement is up to 1.81X.

For configuration details, go here. SOURCE: INTEL MEASURED RESULTS AS OF NOVEMBER, 2013
Binomial Options*  
Single and Double Precision

Application: Binomial European Option Pricing.
Description: Binomial Options* is a popular derivative pricing benchmark widely used by investment banks such as UBS*, Bank of America* and Goldman-Sachs*.

Availability:
- Code: Available here.
- Recipe: Available here.

Usage Model: Hybrid or Asynchronous offload on one shared memory host node with up to two coprocessor devices.

Highlights:
- L2 cache for IA is large enough for this algorithm, which is an advantage compared to GPU shared memory. Intel compiler based SIMD vectorization can handle certain loop carry dependencies while GPU has to explicitly synch.

Results: Adding one Intel® Xeon Phi™ coprocessor card increases the baseline Intel® Xeon processor E5-2697 v2 performance by up to 1.85X.

For configuration details, go here.

SOURCE: INTEL MEASURED RESULTS AS OF DECEMBER, 2013
**Application:** Xcelerit* LMM


**Availability:**
- **Code:**
  - Base version.
  - Optimized versions: Contact Xcelerit* at [http://www.xcelerit.com/](http://www.xcelerit.com/) Contact Names: Hicham Lahlou, hicham.lahlou@xcelerit.com, Jorg Lotze, jorg.lotze@xcelerit.com
- **Recipe:** Not available. Check for future availability at [here](http://www.xcelerit.com/).

**Usage Model:** Baseline is the Intel® Xeon® processor E5-2697 v2 host only and speed up is with native Intel® Xeon Phi™ coprocessor 7120A, double precision.

**Highlights:** The code has been optimized and delivered to Xcelerit.

**Results:** Optimized Intel Xeon Phi coprocessor is the best performing platform for all configurations.

For configuration details, [go here](http://www.xcelerit.com/).

**SOURCE:** INTEL MEASURED RESULTS AS OF SEPTEMBER, 2014
“Intel Xeon Phi coprocessors enable exciting applications; we are seeing a noticeable boost in the performance of computationally-intensive kernels of wave migration solutions that are vital to our partners in the energy field.”

Rishi Khan  
Vice President of Research and Development,  
ET International

Enhancing exploration and extraction processes.

ENERGY INDUSTRY
**Iso3DFD**

*16th Order Isotropic Kernel*

**Application:** Iso3DFD.

**Description:** Iso3DFD - 16th order Isotropic kernel that is at the heart of RTM algorithm. This code computes the wave propagation used in seismic imaging.

**Availability:**
- **Code:** Intel® Phi Xeon™ coprocessor version available [here](#).
  Intel® Advanced Vector Extensions 2 (Intel® AVX2) version not yet ready for publication
- **Recipe:** Available [here](#).

**Usage Model:** OpenMP*, no MPI, native Intel® Xeon Phi™ coprocessor. Domain sizes, cache blocking sizes, prefetching distances are auto-tuned to provide the maximum possible throughput for each platform.

**Highlights:** Intel® AVX2 intrinsics implementation. Auto-tuning used to find best set of parameters for Ivy Bridge, KNC and Haswell.

**Results:**
- Intel Phi Xeon coprocessor 7120P performance is up to 1.72X better than Intel® Xeon® processor E5-2697 v2 and up to 1.25X better than Intel® Xeon® processor E5-2697 v3.
- Intel® Xeon® processor E5-2697 v3 performance is up to 1.37X better than Intel® Xeon® processor E5-2697 v2.

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**Iso3DFD Speed Up**

<table>
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<tr>
<th>Comparative Increase</th>
<th>Intel® Xeon® processor E5-2697 v2 (turbo off)</th>
<th>Intel® Xeon® processor E5-2697 v3 (turbo off)</th>
<th>Intel® Xeon Phi™ coprocessor 7120A (native, turbo on)</th>
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*Other names and brands may be claimed as the property of others*
Distributed Iso3DFD*
16th Order Isotropic Kernel

Application: Distributed version of Iso3DFD.
Description: One dimensional domain decomposition Iso3DFD (16th order Isotropic kernel). Multi-node tests; cluster performance and scalability of MPI implementation.

Availability:
- Code: Not available.
- Recipe: Available [here](#). Optimization guide available [here](#).

Usage Model: Scaling analysis with each Intel® Xeon Phi™ coprocessor in a node solving a 14GB subdomain and each pair of Intel® Xeon® processors solving a 10GB subdomain.
- Symmetric MPI. One MPI process per node or device.
- OpenMP* within each MPI process on processor or coprocessor.
(Note: No disc I/O being performed to save seismic wave-fields.)

Highlights:
- Symmetric model allows host-coprocessor load balancing at MPI job launch time.
- Processes running either on host or MIC can be independently tuned.
- Enabled the remaining DDR3 node memory to be used for fast I/O and other tasks.

Results: Linear scalability confirmed to ensure no cluster-level limitation. 16GB memory on the coprocessors allows high overlap of computations and halo exchanges, hiding the cost of communication with the processors and other nodes.

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.

**Application:** Isotropic RTM has a major role in accurate imaging of complex subsurface structures.

**Description:** The 3D Isotropic RTM plays a major role in accurate imaging of complex subsurface structures. This benchmark measures performance and scalability of the compute kernel on a hybrid host + Intel® Xeon Phi™ coprocessor configuration. Halo exchanges are performed between devices. More at http://www.petrobras.com/en/home.htm.

**Availability:**
- **Code:** Proprietary.
- **Recipe:** Not available. Check for future availability here.

**Usage Model:** Intel® Xeon Phi™ coprocessor 7120A as a host in native mode concurrently executing with the Intel® Xeon® processor E5-2697 v2. Same code for both devices with OpenMP* and Intrinsics.

**Highlights:** Scalable; competitive performance/watt

**Results:** Intel® Xeon® processor populated with 4 Intel Xeon Phi cards show up to 5.6X scaling when compared to the baseline Intel® Xeon® processor E5-2697 v2.
ISO 3DFD* 16th Order Isotropic Kernel

Application: ISO 3DFD* 16th order Isotropic kernel.

Description: ISO 3DFD is a kernel that computes an isotropic wave propagation in 3D (ISO). These kernel types are the heart of Reverse Time Migration (RTM). RTM can also be computed with VTI or TTI kernels. ISO 3DFD computes the wave propagation in the 16th order in space and 2nd order in time. On a single Intel® Xeon Phi™ coprocessor, this kernel is able to update around 5800 Mcells/s (350 Gflops).

Availability:
- Code: Not available.
- Recipe: Available here.

Usage Model: Native mode with intrinsics. OpenMP* but no MPI.

Results: The Intel® Xeon Phi™ coprocessor increased performance by up to 1.66X compared to the Intel® Xeon® processor E5-2697 v2.
Data Center Server Demo: *DownUnder GeoSolutions*

DownUnder GeoSolutions Insight* is optimized with Intel® Software Development Tools for Intel® Xeon Phi™ coprocessors and the Intel® processor Xeon® E5-2600 v3, providing oil and gas industry with the tools and functionality required to perform standard oil and gas workflows more efficiently and to interactively manipulate and migrate data and to achieve results in minutes that previously took hours or days¹. See the video [here](#).

**Intel Better Together**

**Hardware**
- Intel® Xeon Phi™ coprocessor
- Intel® Xeon® E5-2600 v3 processor
- Intel® Solid-State Drives

**Software**
- Intel® Solutions for Lustre* software
“The Intel Xeon Phi coprocessor architecture provides truly impressive performance, and the potential to easily port applications represents a significant leap ahead.”

Greg Peterson,
Director, National Institute for Computational Sciences

Speeding discovery through faster, more accurate simulations.
BerkeleyGW* Sigma Phase

BerkeleyGW* Sigma Phase Speed Up

Application: BerkeleyGW* (Sigma)

Description: BerkeleyGW is a massively parallel computational package for electron-excited state properties. Sigma is the second half of the GW code. It gives the quasiparticle self-energies and dispersion relation for quasielectron and quasihole states.

Availability:
- Code: Available here (version 1.1 beta).
- Recipe: None. The exact input used is not available to the public although a similar input is available.

Usage Model: MPI+OMP. In symmetric mode, MPI ranks are distributed to both the host and KNC card. Each MPI rank uses OMP threads (Hybrid).

Highlights: Hybrid MPI+OMP allows code to be run on both Intel® Xeon® processors and Intel® Xeon Phi™ coprocessors without any source modifications.

Results: Intel® Xeon® processor E5-2697 v3 speed up is up to 1.31X, and Intel Xeon processor E5-2697 v3 + Intel® Xeon Phi™ coprocessor 7120A speed up is up to 1.58X over the baseline processor.

For configuration details, go here.

SOURCE: INTEL MEASURED RESULTS AS OF DECEMBER, 2014
**tHogBomClean**

**Application**: Australian Square Kilometer Array Pathfinder* (ASKAP) tHogBomClean.

**Description**: The tHogBomClean benchmark implements the kernel of the HogBom Clean deconvolution algorithm. This benchmark is quite minimal and actually omits the final step, convolution of the model with the clean beam, but this involves the similar operations to the other steps as far as the CPU is concerned. [More here.](#)

**Availability**:
- **Code**: Available here.
- **Recipe**: Not available. Check for future availability at [here.](#)

**Usage Model**: Native execution on Intel® Xeon® processor E5-2697 v3, Intel® Xeon Phi™ coprocessor 7120, and NVIDIA K40*, using the same codebase.

**Results**:
- The Intel Xeon processor E5-2697 v3 increased performance up to 1.39X compared to NVIDIA K40*.
- The Intel Xeon Phi coprocessor 7120 increased performance up to 1.57X compared to NVIDIA K40.
- The Intel Xeon Phi coprocessor 7120 increased performance up to 1.12X compared to Intel Xeon processor E5-2697 v3.

For configuration details, [go here](#).

1 NODE  
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NEW

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

Description: The tHogBomClean benchmark implements the kernel of the HogBom Clean deconvolution algorithm. This benchmark is quite minimal and actually omits the final step, convolution of the model with the clean beam, but this involves the similar operations to the other steps as far as the CPU is concerned. More here.

Availability:
- Code: Available here.
- Recipe: Not available. Check for future availability at here.

Usage Model: Offload using OpenMP*; host only (Intel® Xeon® processor E5-2697 v2) performs data initialization and transfers to the Intel® Xeon Phi™ coprocessor 7120A; all computing is performed by the Intel Xeon Phi coprocessor 7120A.

Results: The optimized, turbo on, Intel Xeon Phi coprocessor 7120A improved throughput speed by up to 1.78X compared to the baseline Intel® Xeon® processor E5-2697 v2.
Simulations – Fast, detailed, accurate.
Application: specfem3D, 300k Mesh, 1000 time steps simulation.

Description: SPECFEM3D Cartesian simulates acoustic (fluid), elastic (solid), coupled acoustic/elastic, poroelastic or seismic wave propagation in any type of conforming mesh of hexahedra (structured or not.) It can, for instance, model seismic waves propagating in sedimentary basins or any other regional geological model following earthquakes. It can also be used for non-destructive testing or for ocean acoustics. More here.

Availability:
- Code: Available here. Specific version is r20645e5-2697 v3

Usage Model: Symmetric run on 2S Intel® Xeon® processor and Intel® Xeon Phi™ coprocessor 7120P, MPI + OpenMP* programming, and with a large rank count.

Highlights:
- Hybridized code and major hotspots were multi-threaded.
- Performance gain with the Intel compiler flag “-xCORE-AVX2”.

Results:
- For 1 and 2 nodes, 1 Intel Xeon Phi coprocessor 7120P created up to 1.16X gain compared to a 2S Intel Xeon processor E5-2697 v3.
- For larger node counts, MPI dominates and there is no benefit using the Intel Xeon Phi coprocessor.

For configuration details, go here.
Data Center Server Demo: *Texas Advanced Computer Center*

The Texas Advanced Computing Center* (TACC) combines CT scan and simulation data to analyze aquifer permeability in order to protect freshwater supplies in Florida, utilizing Intel® Xeon Phi™ coprocessors, Intel® Xeon® processors, and several Intel® Software products, and features visualization techniques made possible by ray tracing kernels. See the video [here](https://www.intel.com/content/www/us/en/home/about/intel-white-papers.html).

**Hardware**
- Intel® Xeon Phi™ coprocessor 7120A
- Intel® Xeon® E5-2600 v3 processor
- Intel® Solid-State Drive Data Center for PCIe*

**Software**
- CentOS* 6.5, Intel® MPSS 3.4.1, VNC*, Intel® Parallel Studio XE 2015, Intel® SPC, Intel® True Scale Fabric, Intel® MPI Library
System: TACC Stampede*, a 10 petaflop supercomputer, one of the largest computing systems in the world for open science research, became operational on January 7, 2013. Stampede will begin a two-phase transition to the Intel 15 compiler and the compatible software stack on March 31, 2015. Please visit: Stampede Two-Phase Transition to Intel 15

Status: In service.

Workloads: Runs hundreds of applications for thousands of users around the world.

Performance:
- More than 7 petaflops using Intel® Xeon Phi™ coprocessors¹
- More than 2 petaflops using the Intel® Xeon® processor E5-2600 family¹

More Information:
- Stampede at the Texas Advanced Computing Center (Produced by Dell*/Intel): https://www.youtube.com/watch?v=f174GjUY1K4
- TACC HPC systems overview: www.tacc.utexas.edu/resources/hpc

¹http://www.tacc.utexas.edu/resources/hpc/stampede

SOURCE: INTEL MEASURED RESULTS AS OF MAY, 2014

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 names and brands may be claimed as the property of others.
Unlock, discover, innovate.
Gyrokinetic Toroidal Code*  
Princeton (GTC-P)

Application: The gyrokinetic toroidal code (GTC) is a particle-in-cell code for turbulence simulation in support of the burning plasma experiment ITER, the crucial next step in the quest for fusion energy*. GTC-P is optimized GTC code developed at Princeton Plasma Physics Lab. More here.

Availability:
- Code: Available here.
- Recipe: Available here.

Usage Model: Hybrid MPI + OpenMP* using symmetric processing.

Results: GTC-P shows performance increase of up to 1.18X on 4 node Intel® Xeon® processor E5-2697 v2 + Intel® Xeon Phi™ coprocessor 7120P clusters.

For configuration details, go here.
Increasing accuracy and timeliness of forecasts.
Weather & Research Forecast (WRF*)
WRFV3.6 CONUS2.5KM

Application: Weather & Research Forecast Model (WRF*) V3.6
Description: WRF Model is a numerical weather prediction system designed to serve atmospheric research and operational forecasting needs. More at here.

Availability:
- Code: Available here.
- Recipe: Available here.

Usage Model: Baseline is the Intel® Xeon® processor E5-2697 v2 host only, and speed up is shown with on both the host and on the Intel® Xeon Phi™ coprocessor 7120P, and on the Intel® Xeon® processor E5-2697 v3 + Intel® Xeon Phi™ coprocessor 7120P. Performance shown is for released code.

Highlights: The code had been optimized since 2011, delivered to the community, and available for download from the community site.

Results: Symmetric process demonstrated up to 1.94X improved performance over the baseline Intel® Xeon® processor E5-2697 v2.

For configuration details, go here.

SOURCE: INTEL MEASURED RESULTS AS OF SEPTEMBER, 2014
Application: ROMS idealized southern ocean benchmark; ROMS 3.6+ (svn version 709)

Description: ROMS is a free-surface, terrain-following, primitive equations ocean model that employs a split-explicit time-stepping scheme with special treatment and coupling between barotropic (fast) and baroclinic (slow) modes. The benchmark input file is "ocean_benchmark3.in" (distributed with publically available ROMS source code), modified to increase horizontal resolution in X and Y. See more at https://www.myroms.org/

Availability:
- Code: Available here. Patch available here (commit 37b3c86 applied).
- Recipe: Not available. Check for future availability at here.

Usage Model: Baseline is an Intel® Xeon® processor host only and speedup is shown with symmetric processing on the Intel Xeon processor the Intel® Xeon Phi™ coprocessor. Double precision code across the platforms.

Highlights: The code has been optimized and will be available to the ROMS community as an update patch.

Results: Symmetric process demonstrated 1.31X improved performance with the Intel Xeon processor E5-2697 v2 (host) and the Intel Xeon Phi coprocessor 7120A over the baseline host.
Improving speed and quality through digital design

DIGITAL CONTENT CREATION
**Application:** Embree 2.0

**Description:** Embree 2.0 is a simple ray tracing framework with optimized kernels for Intel® Xeon® processors and Intel® Xeon Phi™ coprocessors. It is useful for digital content creation (DCC), mechanical computer aided design (CAD), industrial design, and scientific visualization. More at [http://embree.github.io/](http://embree.github.io/).

**Availability:**
- **Code:** [Available here.](http://embree.github.io/)
- **Recipe:** [Available here.](http://embree.github.io/)

**Usage Model:** 4M (million) triangles scene, ambient occlusion.

**Results:** Up to 1.89X improved performance with the Intel® Xeon Phi™ coprocessor compared to the baseline Intel® Xeon® processor E5-2670.
TOOLS AND LIBRARIES

Intel® Software Development Tools & 3RD Party Support for Developers and System Administrators
Faster Code Faster
Intel® Parallel Studio XE 2015

Faster Code

- Explicit vector programming speeds more code.
- Optimizations for Intel® Xeon Phi™ coprocessor, Intel® Core™ M processor and Skylake microarchitectures.
- Intel® MPI Library now supports latest MPI-3 standard.
- Faster processing of small matrixes.
- Parallel direct sparse solvers for clusters.

Code Faster

- Comprehensive compiler optimization reports.
- Analyze Windows* or Linux* profile data on an OS X*.

Latest Standards Support


* Other names and brands may be claimed as the property of others.
How Intel® Parallel Studio XE 2015 Helps Make Faster Code Faster for HPC

**HPC Cluster**

- MPI Messages
- Vectorized & Threaded Node

**Cluster Edition**
- Multi-fabric MPI library
- MPI error checking and tuning

**Professional Edition**
- Threading design & prototyping
- Parallel performance tuning
- Memory & thread correctness

**Composer Edition**
- Intel® C++ and Fortran compilers
- Parallel models (e.g., OpenMP*)
- Optimized libraries
## Tools and Configuration

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Bundle or 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)

* Other names and brands may be claimed as the property of others.
Altair RADIOSS* and PBS Works*
Finite Element Analysis (FEA) / HPC Workload Management

RADIOSS

Accelerate FEA with Intel® Xeon Phi™ coprocessors

- Speed time to results for computer aided engineering (CAE) simulations with an optimized solver
- Perform linear and non-linear simulations of structures, fluids, fluid-structure interaction, sheet metal stamping, and mechanical systems
- Extend value through tight integration with the Altair HyperWorks CAE software platform

PBS Works

Schedule jobs for Intel Xeon Phi coprocessors

- Improve resource utilization with a commercial grade HPC workload management solution
- Improve value with advanced support for green provisioning, security, and policy-driven job scheduling
- Get more information: Video, press release, white paper, configuration toolkit

“With our support for Xeon Phi we are ensuring our users can run some of the most compute-intensive portions of their work on the most cutting-edge, high-performance architecture available.”

Eric Lequiniou
HPC Director, Altair

See the Altair Speeds Complex Simulation and Workload Management with the Intel® Xeon Phi™ Coprocessor case study!
Bright Cluster Manager*
Cluster Management Tools

Simplify management for clusters that include Intel® Xeon Phi™ coprocessors

- Install, manage and use clusters of any size, even if you have only minimal Linux* knowledge.
- Install, configure, schedule, monitor, and manage Intel Xeon Phi coprocessors in your cluster – with ease.

Get everything you need to enable Intel Xeon Phi coprocessors in a cluster

- Deploy a software environment that works "out of the box".
- Obtain full visibility and manageability.
- Perform pre-job health checks automatically.

“We package everything that’s necessary to get the Intel Xeon Phi coprocessor to work. With Bright it will work out of the box.”

Martijn de Vries
CTO at Bright Computing

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INTEL® XEON PHI™ COPROCESSORS RESOURCES
Intel® Xeon Phi™ Coprocessor Developer Site

- Architecture, setup, and programming resources
- Self-guided training
- Case studies
- Codes and Recipes
- Information on tools and ecosystem
- Support through community forum

View at: http://software.intel.com/mic-developer/
New Intel® moderncode Developer Community

Code for maximum performance on today's and tomorrow's hardware

- Online community to reach 400,000 developers with tools, trainings and support by 2016.
- Using Intel® Black Belt Software Developers in parallelism from Intel and the broader industry to scale coding skills broadly.
- Developer contest with OHSU Knight Cancer Institute* - Win a trip to CERN*.
- Three Intel® HPC Developer Conferences (China, US, India) where developers share proven techniques and best practices.
- Hands-on training for 10,000 developers with remote access to Intel® Xeon® processor and Xeon Phi™ coprocessor-based clusters.

software.intel.com/moderncode
Moderncode Developer Community

Online community engaging 400,000 unique developers by 2016

software.intel.com/moderncode

Developer Zone

- Code Modernization Zone
- How-to guides, parallel programming BKMs
- DPD Tools, training webinars
- Remote Access to hardware
- Support Forums

Topics

- Vectorization/single instruction, multiple data (SIMD)
- Multi-threading
- Multi node/clustering
- Take advantage of on-package high-bandwidth memory.
- Increase memory and power efficiency.

Experts

- Black Belts, & Intel Engineer experts
- Technical Content, Training -webinars, F2F; forum support
- Conference and Tradeshows: Keynotes, Presentations, BOFs, Demos, Tutorials
Intel® Developer Zone

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Intel® Software Development Tools
For The Intel® Xeon Phi™ Coprocessor

Intel® Parallel Studio XE 2015
- Video demonstration: https://www.youtube.com/watch?v=grAHTBhn_1Q

Intel® System Studio
- Video: https://www.youtube.com/watch?v=jraWWlc21gc

Intel® Integrated Native Developer Experience (Intel® INDE)
- Video: https://www.youtube.com/watch?v=PAGauYOLNGI&index=2&list=PLg-UKERBljNwPCLBBuJvgG1Wl_P0iQXsQ

Intel® Cluster Ready
- https://software.intel.com/cluster-ready

James Reinders: Capitalize on Parallelism with Intel® Xeon Phi™ coprocessors
- youtube.com/watch?v=g9ehO6duNuE&list=UUH5Rft7GYM8KZpxA-4Ohihg&index=9&feature=plcp

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Recommended Links

Getting Started:

- An Overview of Programming for Intel® Xeon® processors and Intel® Xeon Phi™ coprocessors
- Intel® Xeon Phi™ Coprocessor Developer’s Quick Start Guide
- http://software.intel.com/mic-developer:
  - The Training tab has Beginner and Advanced workshop videos, and links to past/future webinars.
  - The Tools and Downloads tab has a link to Intel and Third Party Tools and Libraries.
    - This page has links to available beta and production for developers.

Vectorization:

- Check out the 6 steps in the toolkit!

Performance:

- Life Sciences
- Manufacturing
- Financial Services
- Energy
- Physics
- Digital Content Creation
- Weather
## Hardware Configuration - Intel® Xeon® Processor E5-2697 v2

<table>
<thead>
<tr>
<th></th>
<th>Intel® Xeon® processor E5-2697 v2 + Intel® Xeon Phi™ coprocessor 7120A</th>
<th>Intel® Xeon® processor E5-2697 v2 + NVIDIA K40*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Platform</strong></td>
<td>Intel® Server System R2208GZ4GC platform, 2U chassis, hot-swap drives, 24 DIMMs, 1 750W Redundant Power Supply</td>
<td>Intel® Server System R2208GZ4GC platform, 2U chassis, hot-swap drives, 24 DIMMs, 1 750W Redundant Power Supply</td>
</tr>
<tr>
<td><strong>CPU/Stepping</strong></td>
<td>Intel® Xeon® processor E5-2697 v2, 2.7 GHz , 12 core, 8GT/s dual QPI links, 130 W, 3.5GHz Max Turbo Frequency, 768kB instr L1 / 3072kB L2 / 30MB L3 cache</td>
<td>Intel® Xeon® processor E5-2697 v2, 2.7 GHz , 12 core, 8GT/s dual QPI links, 130 W, 3.5GHz Max Turbo Frequency, 768kB instr L1 / 3072kB L2 / 30MB L3 cache</td>
</tr>
<tr>
<td><strong>Coprocessor</strong></td>
<td>Intel® Xeon Phi™ coprocessor 7110 and 7120; 61 cores, 1.1 and 1.238 GHz, ECC enabled, TURBO disabled. Software Details: MPSS version - 2.1.6720-13/16/19, Flash version - 2.1.03.0386</td>
<td>Nvidia K40c*, 2880 CUDA* Cores, 12GB memory, ECC enabled, Boost disabled. Software Details: CUDA Version 5.5</td>
</tr>
<tr>
<td><strong>Memory</strong></td>
<td>64GB total 8*8GB 1600MHZ Reg ECC DDR3</td>
<td>64GB total 8*8GB 1600MHZ Reg ECC DDR3</td>
</tr>
<tr>
<td><strong>Chipset</strong></td>
<td>Rev 4.6 SE5C600.86B.99.99.x069.071520130923</td>
<td>Rev 4.6 SE5C600.86B.99.99.x069.071520130923</td>
</tr>
<tr>
<td><strong>HDD Specs</strong></td>
<td>SEAGATE* ST9600205SS (scsi), 1x600 GB SAS HDD 10kRPM</td>
<td>SEAGATE* ST9600205SS (scsi), 1x600 GB SAS HDD 10kRPM</td>
</tr>
<tr>
<td><strong>OS</strong></td>
<td>RHEL* 6.4</td>
<td>RHEL* 6.4</td>
</tr>
</tbody>
</table>

**MSC Nastran 2016 Alpha**: Testing conducted by MSC Software on MSC Nastran* 2016 Alpha release, SOL 101. Baseline configuration: Intel® Xeon® processor E5-2679 v2 (2.6 GHz, 12 cores, 30 MB cache), 128 GB (8 x 16) DDR3 memory @ 1.6 GHz, 4 TB HDD (SATA @ 6 GB/s 5900 RPM), Intel® Math Kernel Library (Intel® MKL) 11.2.3, Intel® Manycore Platform Software Stack (Intel® MPSS) 3.5. Test configuration: Identical to baseline configuration with the addition of one Intel® Xeon Phi™ coprocessor 7120A.

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## Hardware Configuration – Intel® Xeon® Processor E5-2697 v3

<table>
<thead>
<tr>
<th>Platform</th>
<th>Intel® Server System R2208GZ4GC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CPU</strong></td>
<td>Intel® Xeon® processor E5-2697 v2 2.7 GHz, Dual socket 12 core, 8GT/s dual QPI links, 130 W, 3.5GHz Max Turbo Frequency 768kB instr L1 / 3072kB L2 / 30MB L3 cache</td>
</tr>
<tr>
<td><strong>RAM</strong></td>
<td>64 GB total/node, 8*8GB 1600MHz Reg ECC DDR3</td>
</tr>
<tr>
<td><strong>HDD</strong></td>
<td>SEAGATE* ST9600205SS (scsi), 1x600 GB SAS HDD 10kRPM</td>
</tr>
<tr>
<td><strong>Intel® Xeon Phi™ Coprocessor</strong></td>
<td>Intel® Xeon® processor E5-2697 v3  @ 2.60GHz / 9.6 GT/S, 145W, 14 core, Intel Smart Cache 35 MB</td>
</tr>
<tr>
<td><strong>RAM</strong></td>
<td>8x 8GB 2133 DDR4 DiMMs</td>
</tr>
<tr>
<td><strong>HDD</strong></td>
<td>SSDSA2B220, 200GB, Intel® SSD DC S3500 Series 800GB</td>
</tr>
<tr>
<td><strong>Intel® Xeon Phi™ Coprocessor</strong></td>
<td>Intel® Xeon® processor E5-2697 v3  @ 2.60GHz / 9.6 GT/S, 145W, 14 core, Intel Smart Cache 35 MB</td>
</tr>
<tr>
<td><strong>OS / Kernel / IB stack</strong></td>
<td>Red Hat Enterprise Linux Server* release 6.5 / 2.6.32-358.6.2.el6.x86_64.crt1 / OFED 3.5-2-MIC-rc1</td>
</tr>
<tr>
<td><strong>OS / Kernel / IB stack</strong></td>
<td>Red Hat Enterprise Linux Server* release 6.5 / 2.6.32-358.6.2.el6.x86_64.crt1 / OFED 3.5-2-MIC-rc1,IFS-7.2.2.0.8</td>
</tr>
</tbody>
</table>

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Any difference in system hardware or software design or configuration may affect actual performance

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