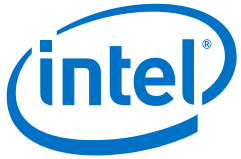

Intel® Xeon Phi™ Coprocessor

4th Tracking Workshop, CERN
Nov 27th, 2012

Klaus-Dieter Oertel, SSG, Intel

Legal Disclaimers

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.

Relative performance is calculated by assigning a baseline value of 1.0 to one benchmark result, and then dividing the actual benchmark result for the baseline platform into each of the specific benchmark results of each of the other platforms, and assigning them a relative performance number that correlates with the performance improvements reported.

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.

Results have been simulated and are provided for informational purposes only. Results were derived using simulations run on an architecture simulator or model. Any difference in system hardware or software design or configuration may affect actual performance.

Intel does not control or audit the design or implementation of third party benchmarks or Web sites referenced in this document. Intel encourages all of its customers to visit the referenced Web sites or others where similar performance benchmarks are reported and confirm whether the referenced benchmarks are accurate and reflect performance of systems available for purchase.

Intel® Hyper-Threading Technology Available on select Intel® Xeon® processors. Requires an Intel® HT Technology-enabled system. Consult your PC manufacturer. Performance will vary depending on the specific hardware and software used. For more information including details on which processors support HT Technology, visit http://www.intel.com/info/hyperthreading.

Intel® Turbo Boost Technology requires a Platform with a processor with Intel Turbo Boost Technology capability. Intel Turbo Boost Technology performance varies depending on hardware, software and overall system configuration. Check with your platform manufacturer on whether your system delivers Intel Turbo Boost Technology. For more information, see http://www.intel.com/technology/turboboost

Intel processor numbers are not a measure of performance. Processor numbers differentiate features within each processor series, not across different processor sequences. See http://www.intel.com/products/processor_number for details. Intel products are not intended for use in medical, life saving, life sustaining, critical control or safety systems, or in nuclear facility applications. All dates and products specified are for planning purposes only and are subject to change without notice

Intel product plans in this presentation do not constitute Intel plan of record product roadmaps. Please contact your Intel representative to obtain Intel's current plan of record product roadmaps. Product plans, dates, and specifications are preliminary and subject to change without notice

Optimization Notice

Optimization Notice

Intel's compilers may or may not optimize to the same degree for non-Intel microprocessors for optimizations that are not unique to Intel microprocessors. These optimizations include SSE2, SSE3, and SSE3 instruction sets and other optimizations. Intel does not guarantee the availability, functionality, or effectiveness of any optimization on microprocessors not manufactured by Intel.

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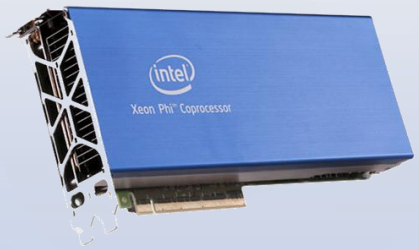
Notice revision #20110804

Shipping Now

Intel® Xeon Phi™ Coprocessor 5110P

Performance

Up to 1 TFLOP of double-precision (peak)[1]



More Memory
More Bandwidth

Programmability

C, C++, Fortran
Intel and 3rd party tools

Intel and
3rd party tools

Applications

Memory Bandwidth /
Capacity Bound workloads

Ideal for
Molecular Modeling,
Digital Content Creation,
and Energy

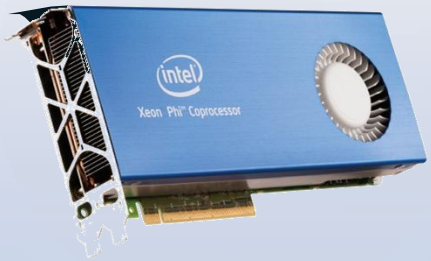
Ideal for memory bandwidth and memory capacity bound workloads

Stay Tuned in 2013

Intel® Xeon Phi™ Coprocessor 3100 Product Family

Performance

Up to 1 TFLOP of double-precision (peak)[1]



6GB GDDR5
240 GB/s Bandwidth

Programmability

C, C++, Fortran
Intel and 3rd party tools

Intel and
3rd party tools

Applications

Compute Bound workloads

Ideal for MonteCarlo,
Black-Scholes,
Life Sciences

Ideal for compute bound workloads

Introducing Intel® Xeon Phi™ Coprocessors

Highly-parallel Processing for Unparalleled Discovery

Groundbreaking: differences

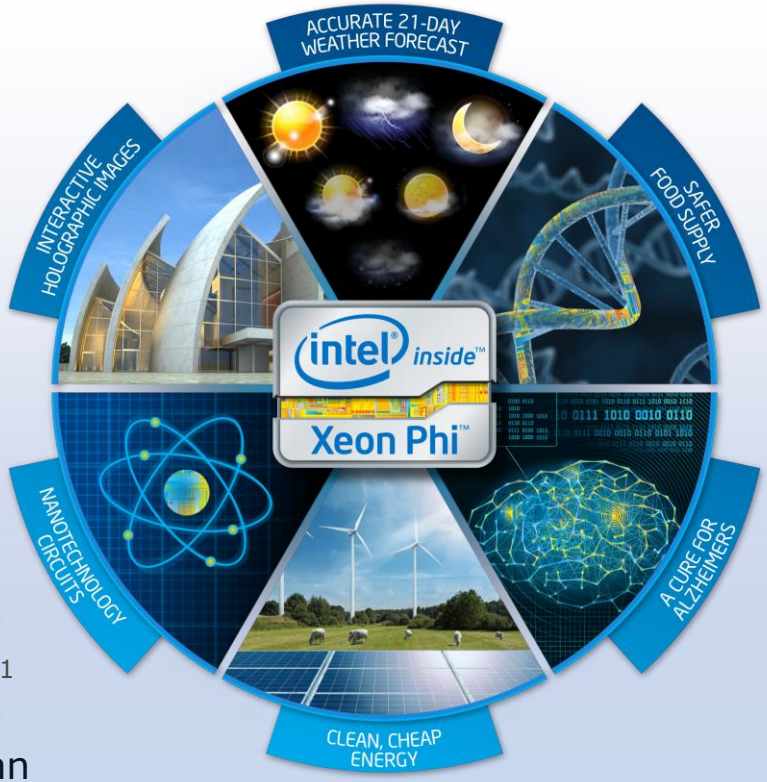
Up to 61 IA cores/1.1 GHz/ 244 Threads

Up to 8GB memory with up to 352 GB/s bandwidth

512-bit SIMD instructions

Linux operating system, IP addressable

Standard programming languages and tools



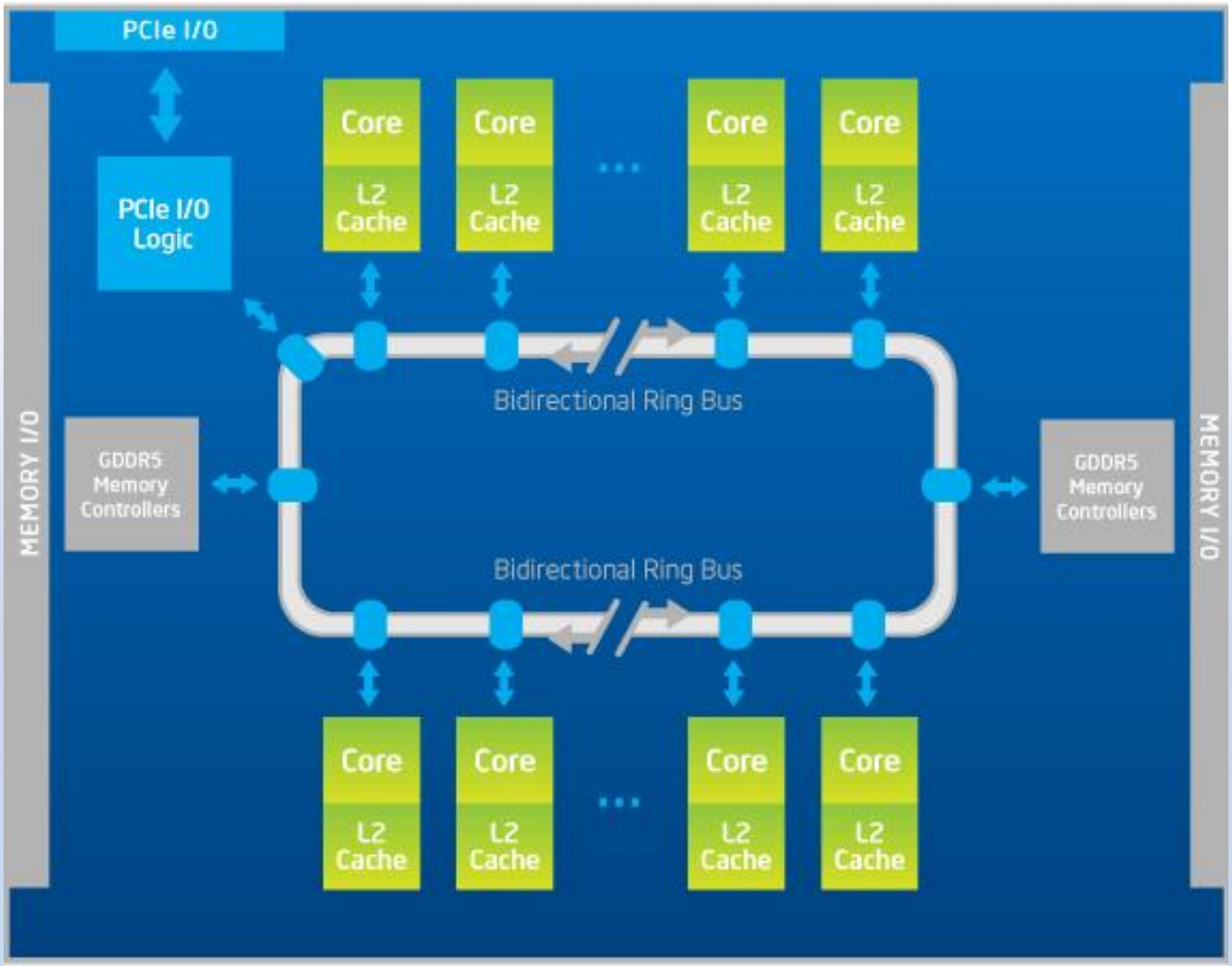
Leading to Groundbreaking results

Over 1 TeraFlop/s double precision peak performance[1]

Enjoy up to 2.2x higher memory bandwidth than on an Intel® Xeon® processor E5 family-based server.[2]

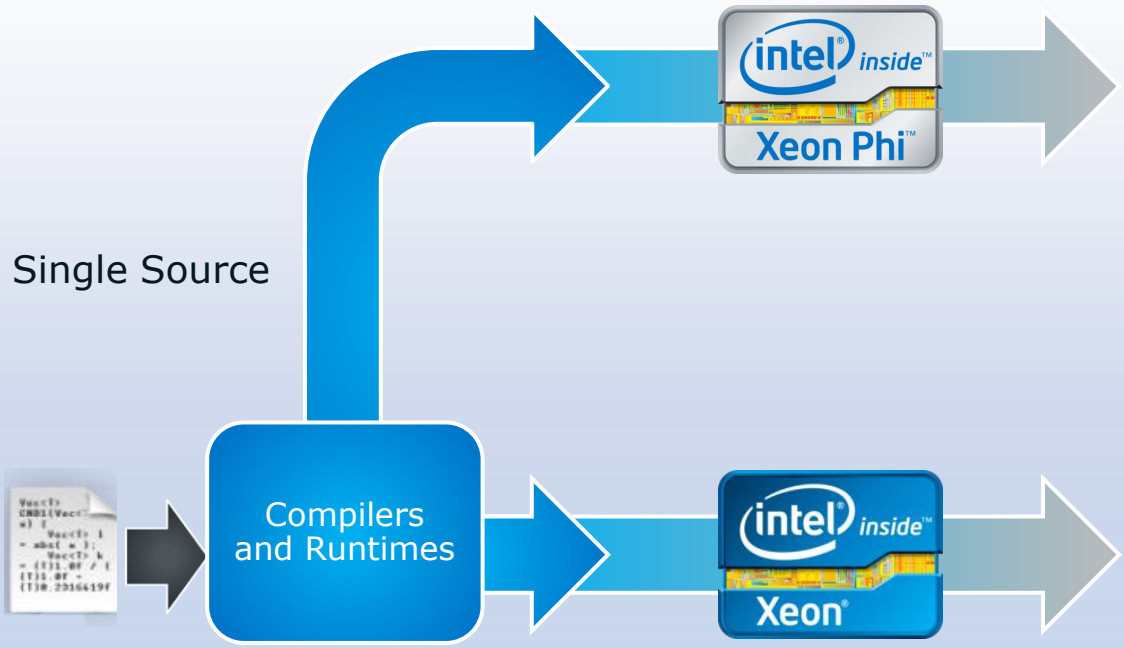
Up to 4x more performance per watt than with an Intel® Xeon® processor E5 family-based server. [3]

Intel® Xeon Phi™ Coprocessors Block Diagram



Highly-parallel Processing for Unparalleled Discovery

Seamlessly solve your most important problems of any scale



Intel® Xeon Phi™ product family

Based on Intel® Many Integrated Core (Intel® MIC) architecture

Leading performance for highly parallel workloads

Common Intel® Xeon® programming model seamlessly increases developer productivity

Launching on 22nm with >50 cores

Intel® Xeon® processor

Ground-breaking real-world application performance

Industry-leading energy efficiency

Meet HPC challenges and scale for growth

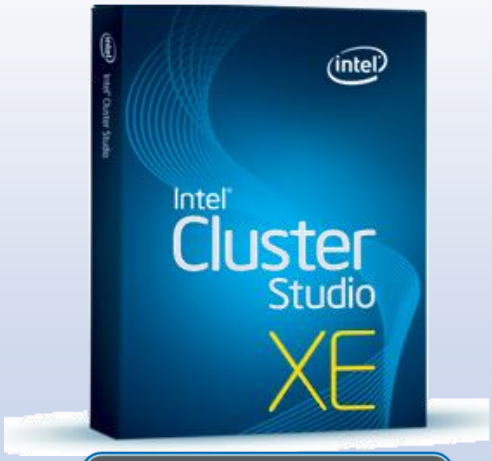
Intel® Development Tools extend to Intel® Xeon Phi ™ Coprocessor

Leading developer tools for performance on nodes and clusters

Shared Memory Programming Development

- Intel® C/C++ and Fortran Compilers w/OpenMP
- Intel® MKL, Intel® Cilk Plus, Intel® TBB, and Intel® IPP
- Intel® Inspector XE, **Intel® VTune™ Amplifier XE**, Intel® Advisor

Distributed & Shared Memory Programming Development



- Intel® MPI Library
- Intel® Trace Analyzer and Collector
- Intel® Parallel Studio XE

Support for Latest Intel Processors and Coprocessors

	Intel® Ivy Bridge microarchitecture	Intel® Haswell microarchitecture	Intel® Xeon Phi™ coprocessor
Intel® C++ and Fortran Compiler	✔ AVX	✔ AVX2, FMA3	✔ IMCI
Intel® TBB library	✔	✔	✔
Intel® MKL library	✔ AVX	✔ AVX2, FMA3	✔
Intel® MPI library	✔	✔	✔
Intel® VTune™ Amplifier XE†	✔ Hardware Events	✔ Hardware Events	✔ Hardware Events
Intel® Inspector XE	✔ Memory & Thread Checks	✔ Memory & Thread	✔ Memory & Thread††

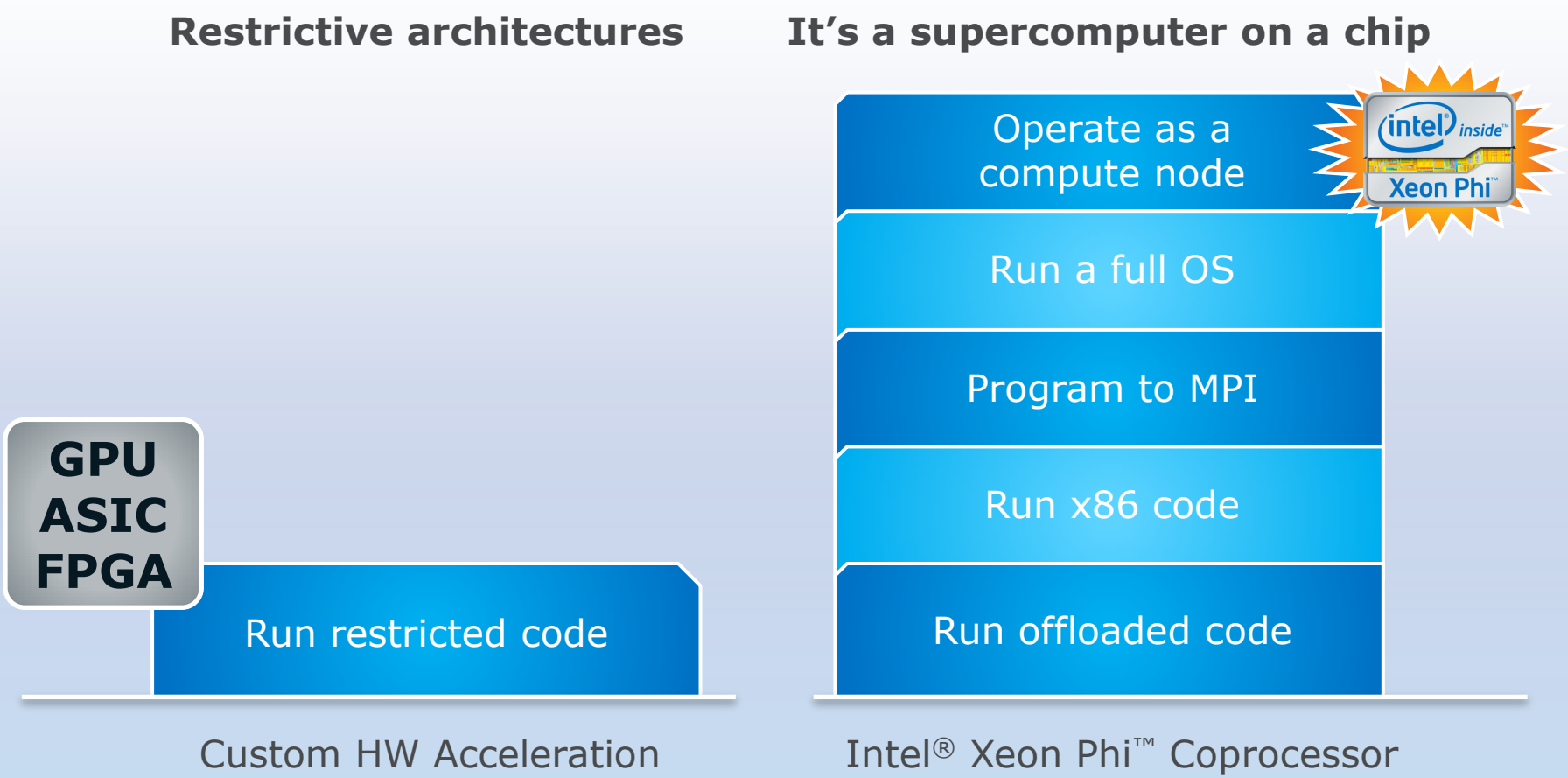
† Hardware events for new processors added as new processors ship.
†† Analysis runs on multicore processors, provides analysis for multicore and many-core processors.

Broad Ecosystem Support

Industry support for Intel® Many Integrated Core Architecture

Intel® Xeon Phi™ Coprocessors: They're So Much More

General purpose IA Hardware leads to less idle time for your investment.

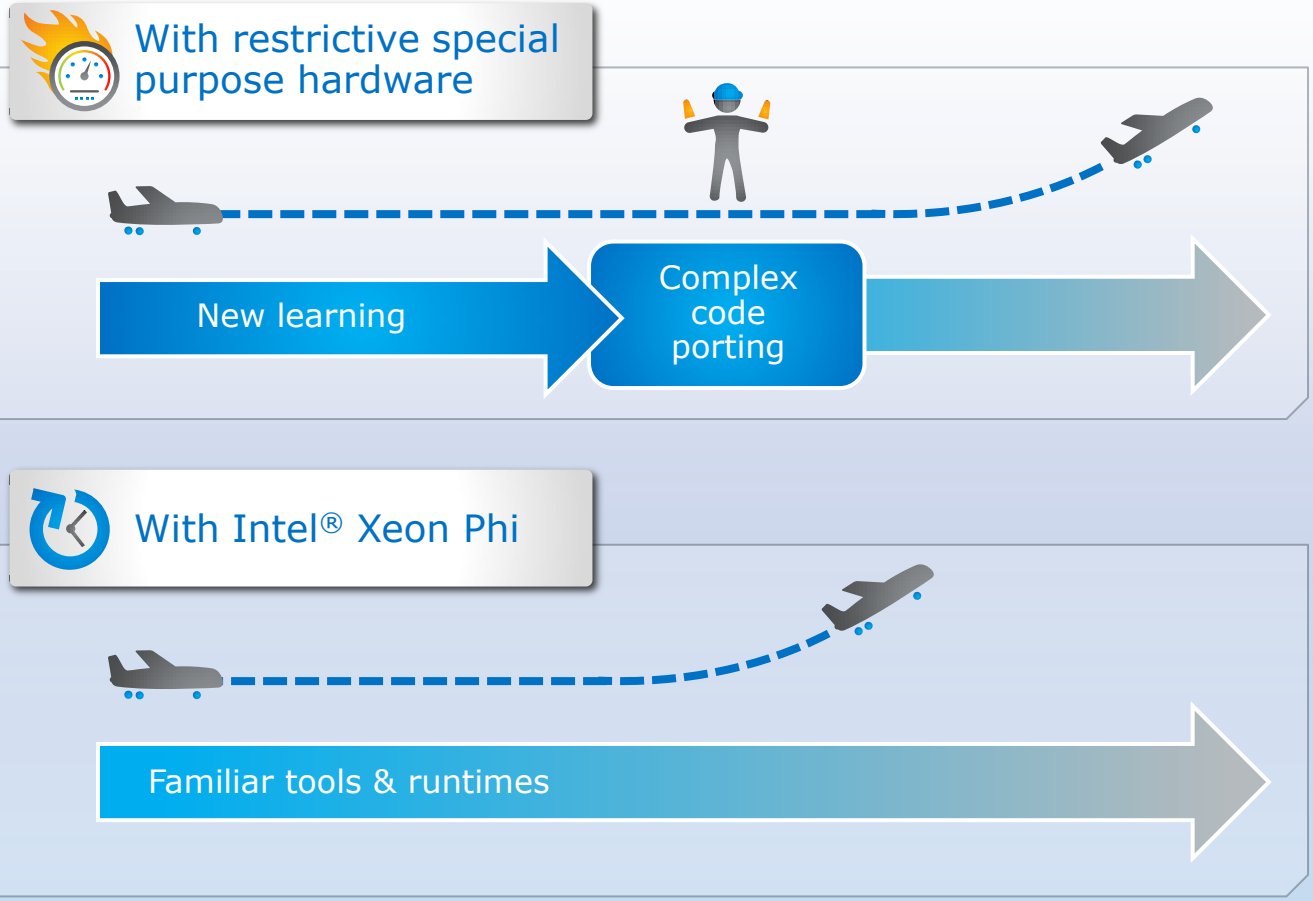


Restrictive architectures limit the ability for applications to use arbitrary nested parallelism, functions calls and threading models

Source: Intel Estimates

Intel® Xeon Phi™ - Game Changer for HPC

Build your applications on a known compute platform… and watch them take off sooner.



"We ported millions of lines of code in only days and completed accurate runs. Unparalleled productivity… most of this software does not run on a GPU and never will".

— *Robert Harrison, National Institute for Computational Sciences, Oak Ridge National Laboratory*

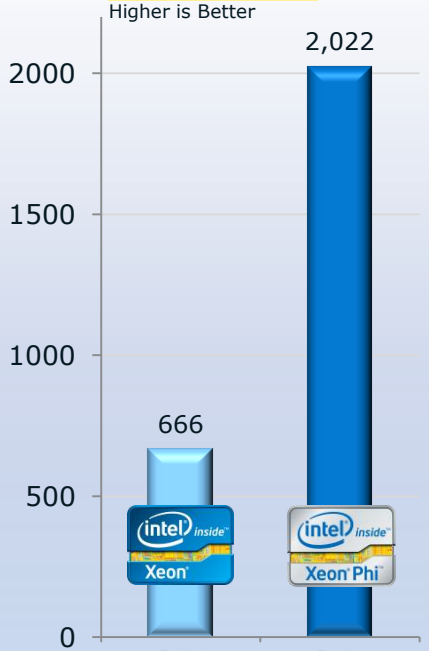
[7] Harrison, Robert. "Opportunities and Challenges Posed by Exascale Computing—ORNL's Plans and Perspectives." National Institute of Computational Sciences (NICS), 2011.

Theoretical Maximums

(Intel® Xeon® processor E5-2670 vs. Intel® Xeon Phi™ coprocessor 5110P)

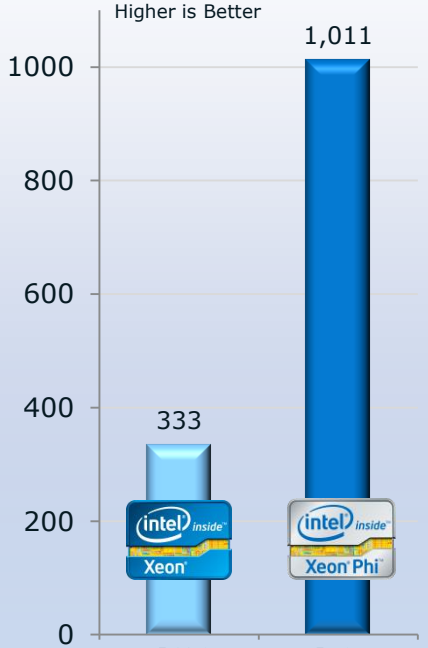
Single Precision (GF/s)

Up to 3.0x



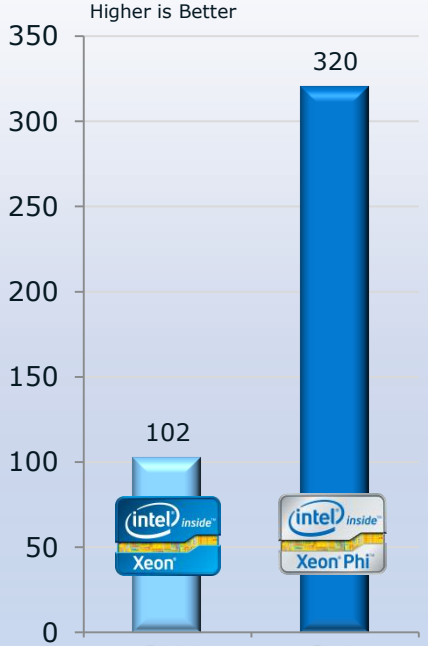
Double Precision (GF/s)

Up to 3.0x



Memory Bandwidth (GB/s)

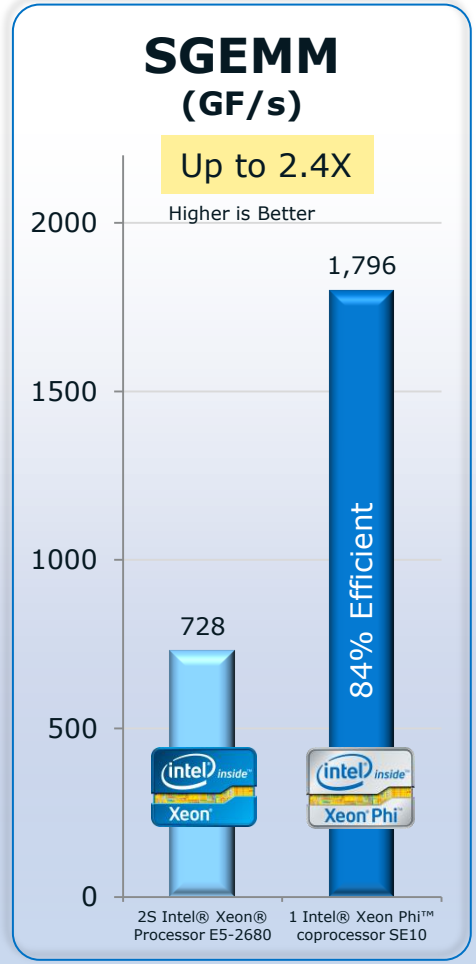
Up to 3.1x

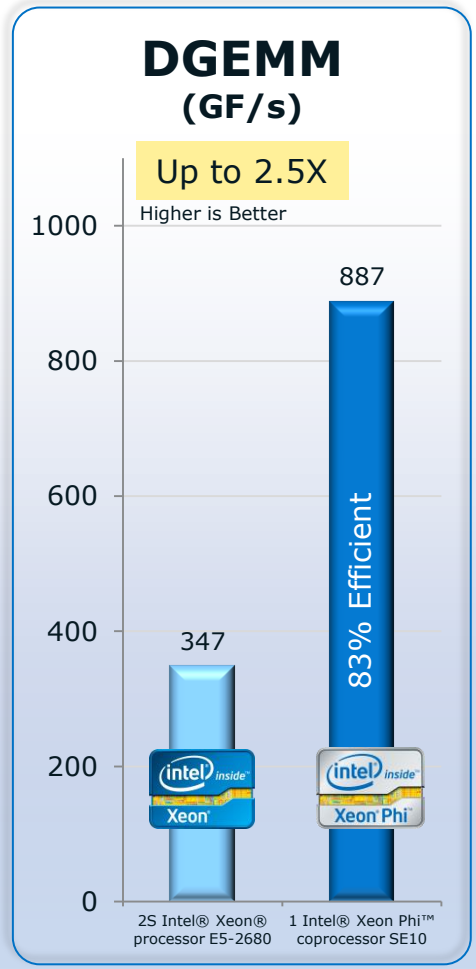


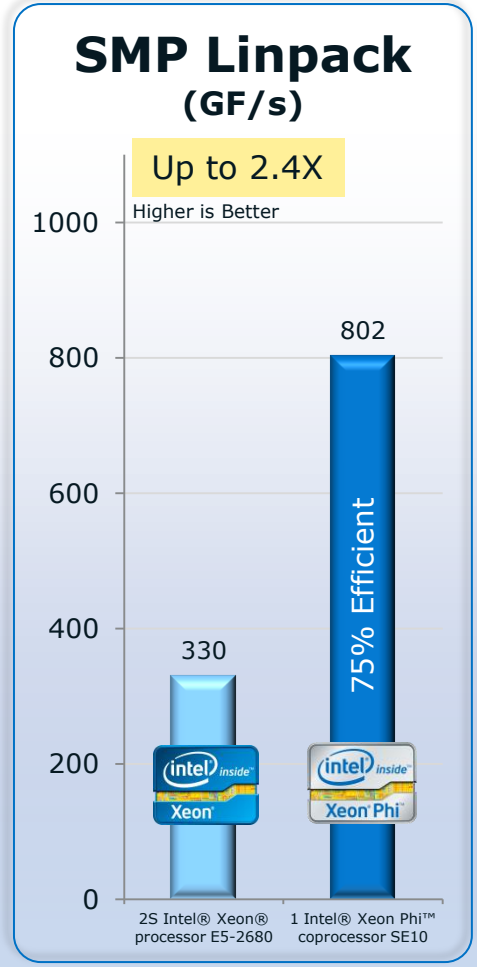
Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. Source: Intel as of October 17, 2012 Configuration Details: Please reference slide speaker notes. **For more information go to http://www.intel.com/performance**

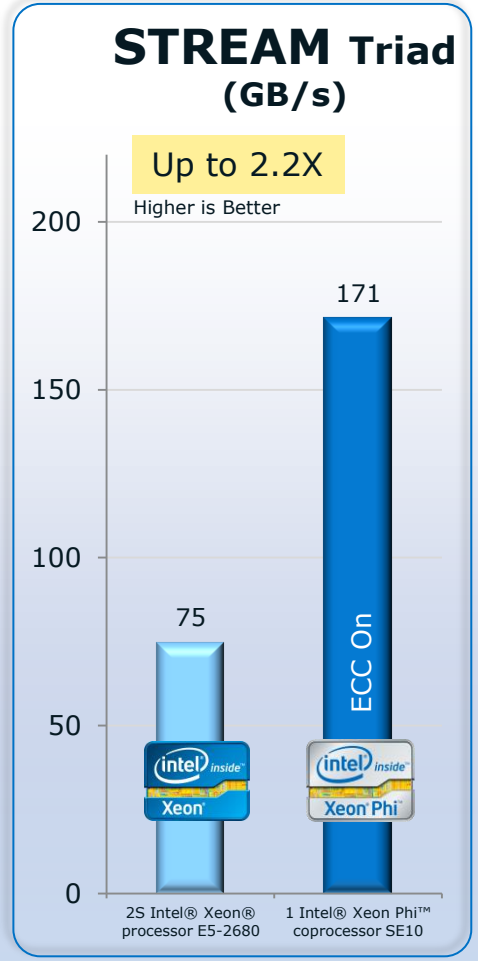
Synthetic Benchmark (Intel® MKL) (SE10P)

Measured on the TACC+ Stampede Cluster[3]









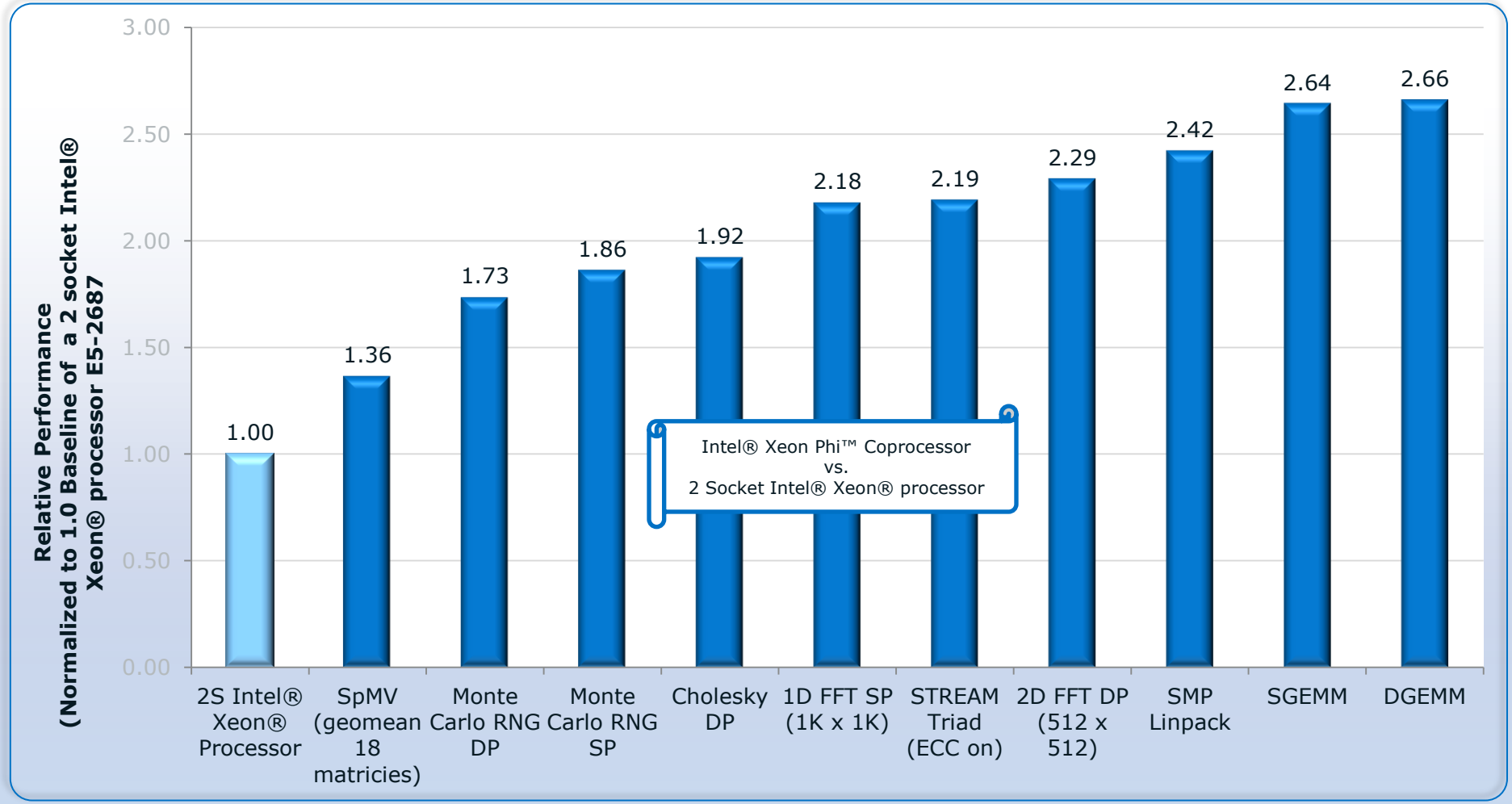
Coprocessor results: Benchmark run 100% on coprocessor, no help from Intel® Xeon® processor host (aka native)

Notes

1. Intel® Xeon® Processor E5-2680 used for all SGEMM Matrix = 12800 x 12800 , DGEMM Matrix 10752 x 10752, SMP Linpack Matrix 26000 x 26000
2. Intel® Xeon Phi™ coprocessor SE10P (ECC on) with "Gold" SW stack SGEMM Matrix = 12800 x 12800, DGEMM Matrix 12800 x 12800, SMP Linpack Matrix 26872 x 28672
3. Average single-node results from measurements across a set of nodes from the TACC+ Stampede* Cluster

+ Texas Advanced Computing Center (TACC) at the University of Texas at Austin.

Intel® Xeon Phi™ Coprocessor vs. 2S Intel® Xeon® processor (Intel® MKL)



Coprocessor results: Benchmark run 100% on coprocessor, no help from Intel® Xeon® processor host (aka native)

Notes

1. 2 X Intel® Xeon® Processor E5-2687 (3.1GHz, 8C, 150W) used for all except E5-2690 used for STREAM
2. Intel® Xeon Phi™ coprocessor SE10 (ECC on) with Gold RC SW stack

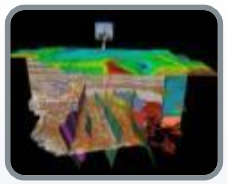
Source: Intel Measured results as of October 17, 2012 Configuration Details: Please reference slide speaker notes.

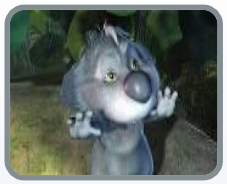
For more information go to http://www.intel.com/performance

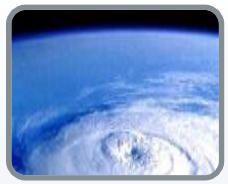
Extending to New Dimensions

Where does your application fit?

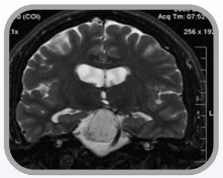
HPC Applications

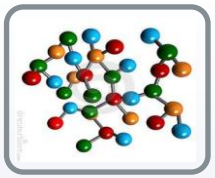

Energy – Seismic Applications

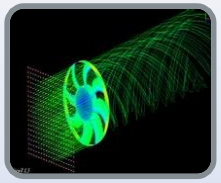

Digital content creation


Climate modeling & weather prediction

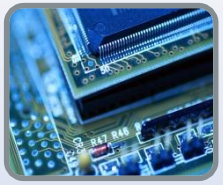
Financial analyses, trading


Medical imaging and biophysics


Molecular Modeling


Computational Fluid Dynamics


DNA Sequencing


Electronic Design Automation


Government/ Defense


Computer Aided Design & Manufacturing

Enterprise Applications

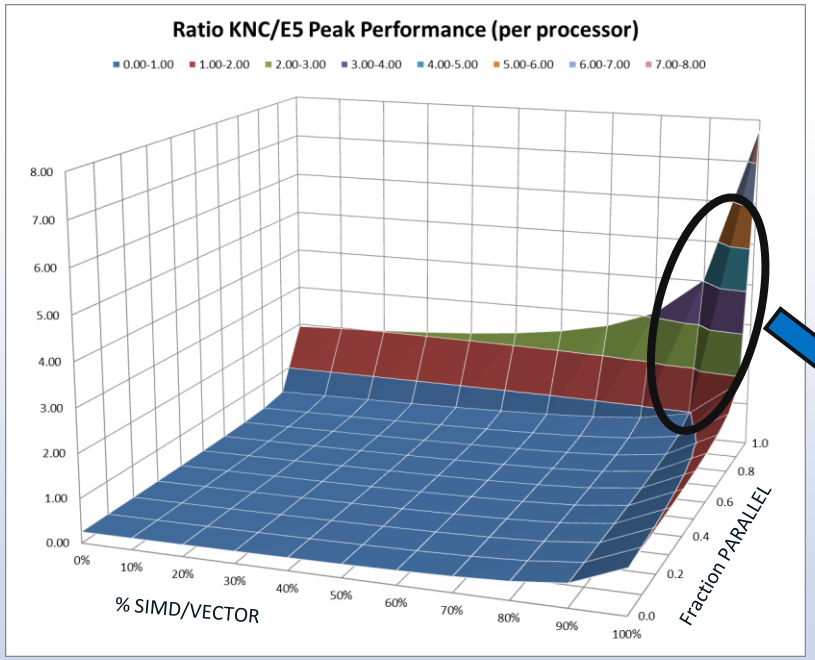

Search


Parallel Databases


Business Intelligence / Data Mining

...and more

Intel® Xeon Phi™ Coprocessor: Increases Application Performance up to 10x



- Intel® Xeon Phi™ coprocessor accelerates highly parallel & vectorizable applications. (graph above)
- Table provides examples of such applications

Application Performance Examples

Customer	Application	Performance Increase[1] vs. 2S Xeon*
Los Alamos	Molecular Dynamics	Up to 2.52x
Acceleware	8th order isotropic variable velocity	Up to 2.05x
Jefferson Labs	Lattice QCD	Up to 2.27x
Financial Services	BlackScholes SP Monte Carlo SP	Up to 7x Up to 10.75x
Sinopec	Seismic Imaging	Up to 2.53x[2]
Sandia Labs	miniFE (Finite Element Solver)	Up to 2x[3]
Intel Labs	Ray Tracing (incoherent rays)	Up to 1.88x[4]

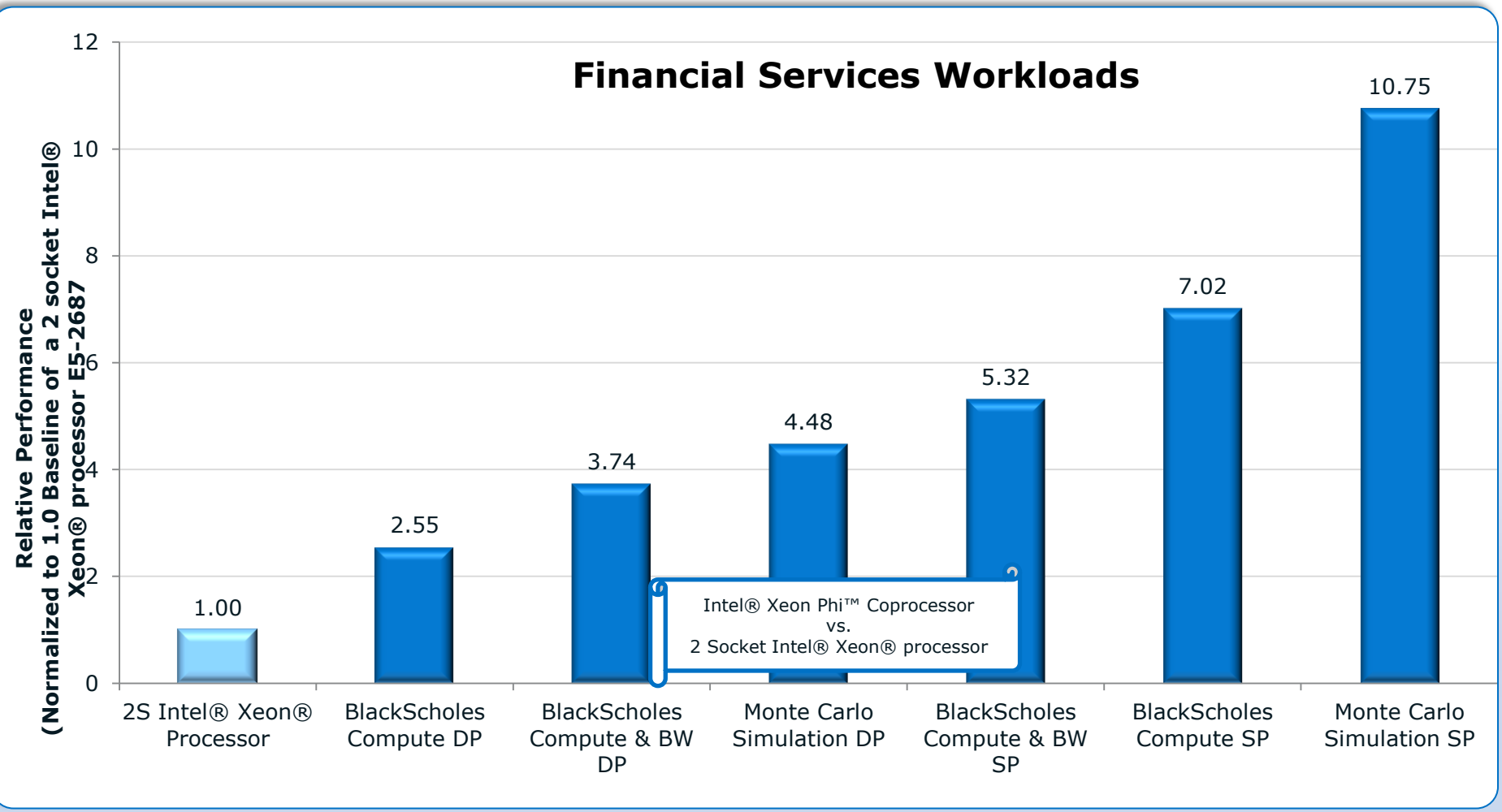
* Xeon = Intel® Xeon® processor;
* Xeon Phi = Intel® Xeon Phi™ coprocessor

Notes:

1. 2S Xeon* vs. 1 Xeon Phi* (preproduction HW/SW & Application running 100% on coprocessor unless otherwise noted)
2. 2S Xeon* vs. 2S Xeon* + 2 Xeon Phi* (offload)
3. 8 node cluster, each node with 2S Xeon* (comparison is cluster performance with and without 1 Xeon Phi* per node) (Hetero)
4. Intel Measured Oct. 2012

Source: Customer Measured results as of October 22, 2012 Configuration Details: Please reference slide speaker notes.
For more information go to http://www.intel.com/performance

Intel® Xeon Phi™ Coprocessor vs. 2S Intel® Xeon® processor (Intel® MKL)



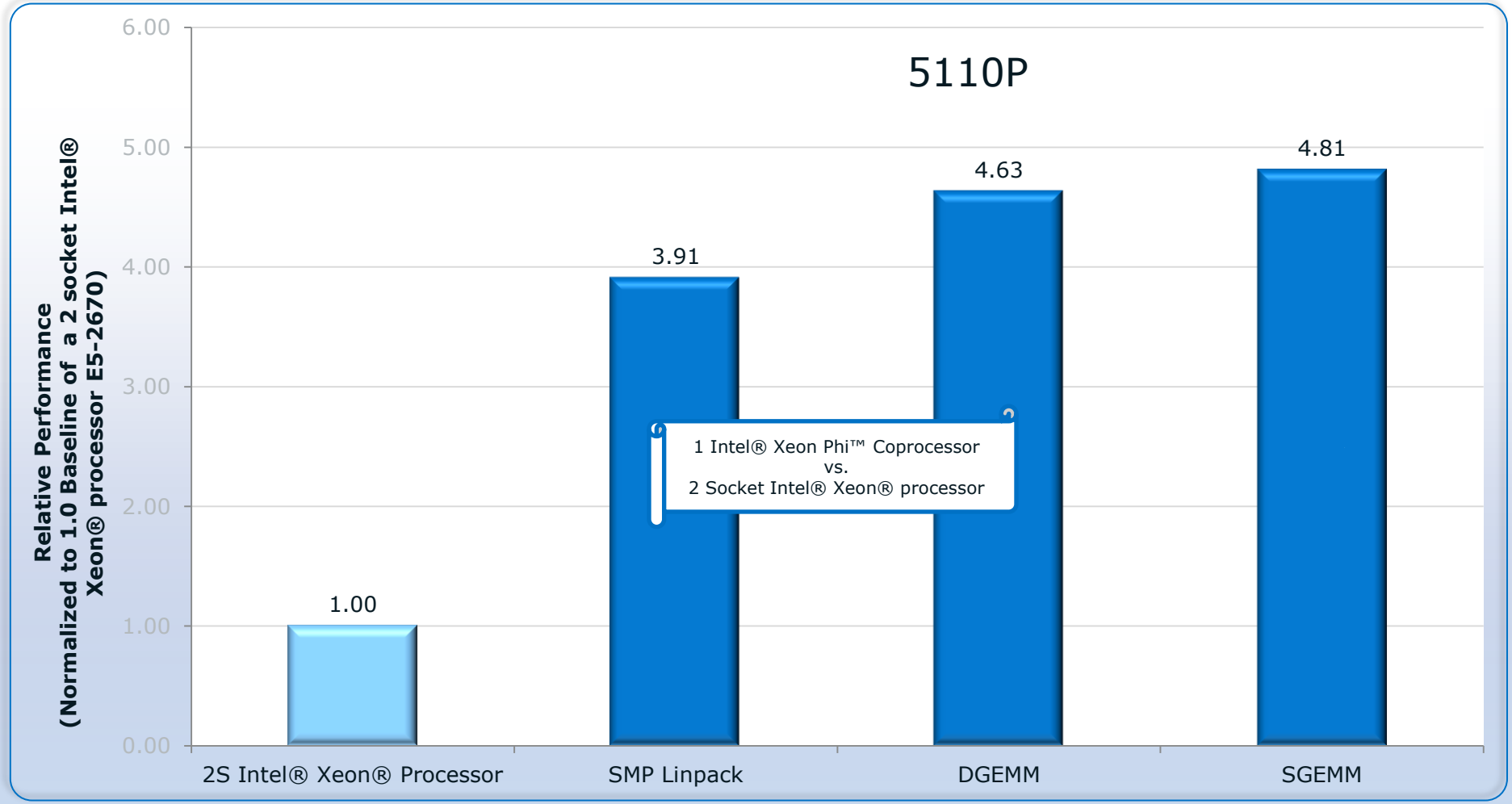
Coprocessor results: Benchmark run 100% on coprocessor, no help from Intel® Xeon® processor host (aka native)

Higher SP results are due to certain Single Precision transcendental functions in the Intel® Xeon Phi™ coprocessor which are not present in the Intel® Xeon® processor

Notes

1. 2 X Intel® Xeon® Processor E5-2670 (2.6GHz, 8C, 115W)
2. Intel® Xeon Phi™ coprocessor SE10 (ECC on) with pre-production SW stack

Performance per Watt
Intel® Xeon Phi™ Coprocessor vs. 2S Intel® Xeon® processor (Intel® MKL)



Coprocessor results: Benchmark run 100% on coprocessor, no help from Intel® Xeon® processor host (aka native)

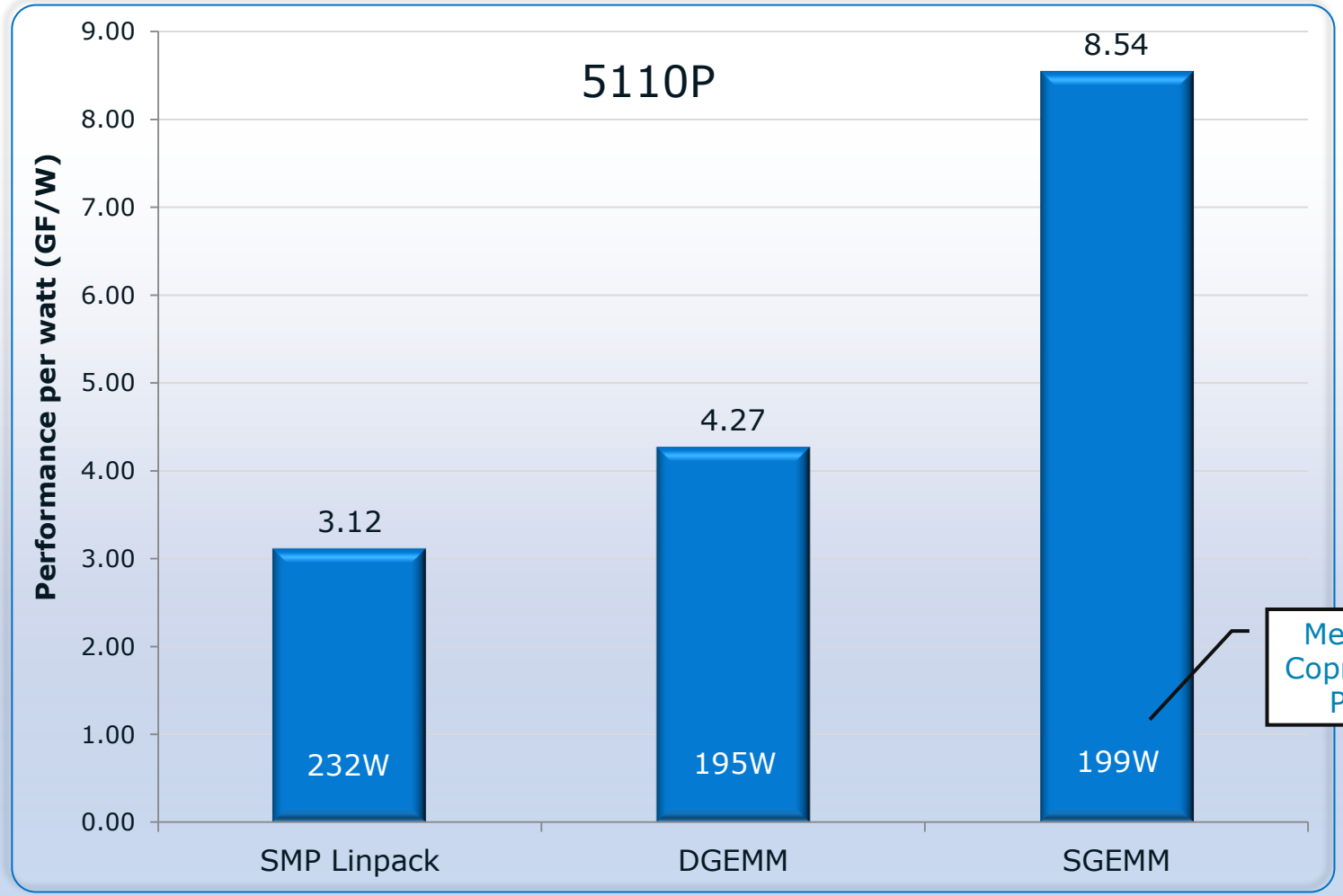
Notes:

1. **2 X Intel® Xeon® Processor E5-2670 (2.6GHz, 8C, 115W)**
2. **Intel® Xeon Phi™ coprocessor 5110P (ECC on) with Gold RC SW stack (Coprocessor power only)**

Source: Intel Measured results as of October 26, 2012 Configuration Details: Please reference slide speaker notes.

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

Performance Per Watt



Coprocessor results: Benchmark run 100% on coprocessor, no help from Intel® Xeon® processor host (aka native)

Notes

1. **Intel® Xeon Phi™ coprocessor 5110P (ECC on)**

Source: Intel Measured results as of October 26, 2012 Configuration Details: Please reference slide speaker notes.

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

Intel Roadmap to Exascale

Intel's Exascale Goal

Reach Exascale by 2018 with Intel technologies including Intel® Xeon Phi™ Coprocessors

Intel® Xeon Phi™ Product Family

Key ingredient in Intel Exascale Roadmap

- Programmability
- Power efficiency
- Scalability
- Resiliency

Get Started Now

Visit www.intel.com/xeonphi for more processor information

Highly-parallel processing to power your breakthrough innovations

Power your breakthrough innovations with the highly parallel processing of the Intel® Xeon Phi™ coprocessor. We've packed up to a teraFLOPS of double precision peak performance into every chip – the highest parallel performance per watt of any Intel® Xeon® processor.[1,2,3,4] Now you can think "reuse" rather than "recode" with x86 compatibility. Languages, tools, and applications run smoothly across the full spectrum of Intel® Xeon® family-based platforms. Plus, discover the flexibility of a coprocessor that can also host an OS.

With the launch of the Intel® Xeon Phi™ coprocessor 5110P, extracting extreme performance from highly parallel applications just got a lot easier. Part of the Intel® Xeon Phi™ product family, the 5110P is based on Intel® Many Integrated Core (MIC) architecture, and complements the industry- leading performance and energy efficiency of the Intel® Xeon™ processor E5 family.

The Intel® Xeon Phi™ coprocessor - illustrious performance per watt, built to perform brilliantly on your greatest challenges. The only thing more amazing than the Intel® Xeon Phi™ coprocessor is what your research will do with it.

Intel® Xeon Phi™ coprocessor 5110P: Ideal for high density environments.

- Highly parallel applications using over 100 threads
- Memory bandwidth- bound applications
- Applications with extensive vector use

Key Specifications:

- 60 cores/1.053 GHz/240 threads
- 8 GB memory and 320 GB/s bandwidth
- Standard PCIe x16 form factor, passively cooled
- Linux* operating system, IP addressable
- 512- bit SIMD instructions
- Supported by the latest Intel® software development products
- Built using Intel's 22nm process technology – Intel's most energy efficient process yet – featuring the world's first 3-D Tri-Gate transistors.

View more specifications>

More Information

Intel announces first Intel® Xeon Phi™ coprocessors >

Getting to Parallelism and Programmability >

High Performance Computing >

The Intel® Xeon Phi™ Coprocessor: Solution Brief >

Intel® Many Integrated Core (Intel® MIC) architecture >

Intel® Xeon® Processors Technical Resources >

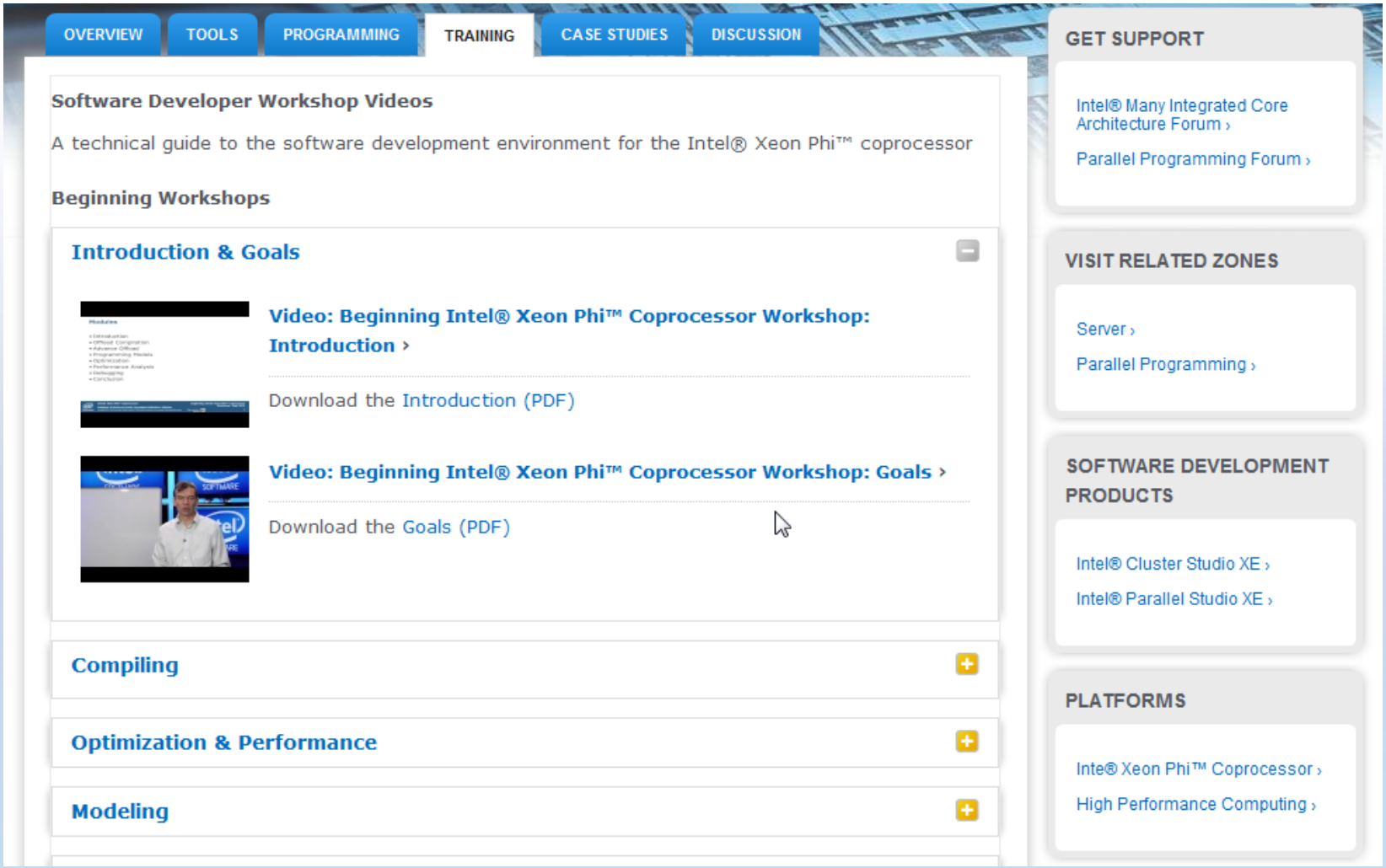
Coming Soon

The Intel® Xeon Phi™ Coprocessor 3100 Series: Ideal for compute bound workloads >

Intel® Solid-State Drive DC S3700 Series

Get Started Now (contd.)

Visit software.intel.com/mic-developer for developer information



Early Customer Quotes

MIC offers a sort of fast-path to quickly get codebases up and running on the device, and we're able to continue to use methods of task parallelization that we've used on shared memory systems for a decade.

Mike Showerman
Technical Program Manager
National Center for Supercomputing Applications

Programming models are the key to harness the computational power of massively parallel devices. Obviously, Intel has realized this trend and substantially supports open standards and invests in innovative programming models. [LRZ is] Writing MIC-accelerated code with minimal effort and great performance.

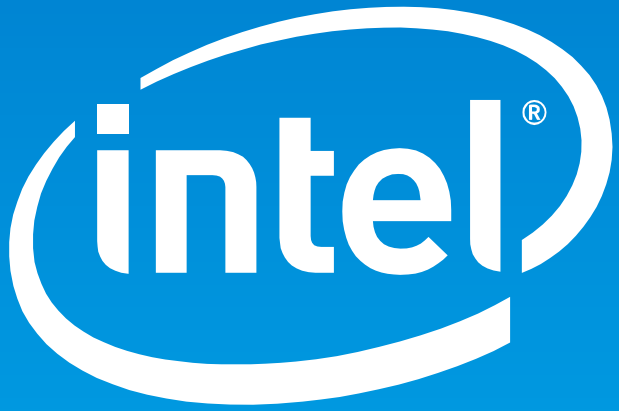
Dr. Arndt Bode, Head
Leibniz Supercomputing Centre

By just utilizing standard programming on both Intel® Xeon processor and Intel® MIC architecture based platforms, the performance met multi-threading scalability expectations and we observed near-theoretical linear performance scaling with the number of threads.

Hongsuk Yi
Heterogeneous Computing
Team Leader, KISTI
Supercomputing Center

Unlike other approaches to an accelerator like GPGPU, I believe that MIC is the most promising approach. An x86-based server with MIC forms a single architecture for the most powerful next generation PC cluster.

Professor Yutaka Ishikawa,
University of Tokyo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1. Peak DP FLOPS claim based on calculated theoretical peak double precision performance capability for a single coprocessor. 16 DP FLOPS/clock/core * 60 cores * 1.053GHz = 1.0108 TeraFlop/s.
2. Memory Bandwidth: 2 socket Intel® Xeon® processor E5-2600 product family server vs. Intel® Xeon Phi™ coprocessor (2.2x: Measured by Intel October 2012. 2 socket E5-2670 (8 core, 2.6GHz) vs. 1 Intel® Xeon Phi™ coprocessor SE10P (61 cores, 1.1GHz) on STREAM Triad benchmark 79.5 GB/s vs. 175GB/s) (TR 2012B)
3. Performance/Watt: 2 socket Intel® Xeon® processor E5-2670 server vs. a single Intel® Xeon Phi™ coprocessor SE10P (Intel Measured DGEMM perf/watt score 309 GF/s @ 335W vs. 829 GF/s @ 195W) (TR 2028B)

5110P Synthetic Benchmark Configuration Details

Configuration Details:
As of October 26, 1012

Intel® Xeon® Processor Platform:
2 Socket Canoe Pass Software Development Platform: 2x Intel Xeon processor E5-2670 (20M cache, 2.6GHz, 8.0GT/s Intel QPI, 115W TDP) 64GB Memory @ 1600MHz, RHEL 6.3, Turbo on, HT off, EIST Enabled, Power: Performance mode

Platform Hosting the Coprocessor:
2 Socket Crown Pass Software Development Platform: 2x Intel Xeon processor E5-2670 (20M cache, 2.6GHz, 8.0GT/s Intel QPI, 115W TDP) 32GB Memory @ 1600MHz, RHEL 6.0

Coprocessor Details:
Intel® Xeon Phi™ coprocessor SE10P: 61cores, 1.1GHz, 8GB Memory@5.5GT/s, (B1 step)

Software Stack:
"Gold" Release Candidate Software Stack:
MPSS 2.1.4346-16 (Flash: 2.1.01.0375; Coprocessor OS: 2.6.34.11-g65c0cd9; Driver: 4346-16)
Intel Cluster Studio XE 2013 Update 1 (Compiler: Composer_XE_2013.1.117; Intel® MKL: 11.0.1)

SGEMM/DGEMM/SMP Linpack

Xeon:	Source:	TR #TBD from Frank
Xeon Phi:	Source:	TR2028C

STREAM* Triad
2x Intel Xeon processor E5-2670 (20M cache, 2.9GHz, 8.0GT/s Intel QPI, 130W) 64GB Memory @ 1600MHz, Score 79.5GB/s. Source: Intel TR#1241
Intel Xeon Phi coprocessor: 64MB matrix size, 2MB pages enabled, ECC on/off (Oct 26, 2012, Gold RC SW stack) (Source: Intel TR #2012B)

Linpack and HPC Suite System Parameters

Which claims do these support?

2.1X Linpack claim based upon:

Baseline: 2S Intel® Xeon® E5-2680 score of 342.7Gflops based on Intel internal measurements as of 7 September 2011 using an Intel® Rose City platform with two Intel® Xeon® processor E5-2680, Turbo Enabled, EIST Enabled, Hyper-Threading Enabled, 64 GB memory (8 x 8GB DDR3-1600), Red Hat* Enterprise Linux Server 6.1 beta for x86_6

New Configuration: Intel® Xeon® 5600 processor platform with two Intel® Xeon® Processor X5690 (6-Core, 3.46GHz, 12MB L3 cache, 6.4GT/s, B1-stepping), EIST Enabled, Turbo Boost enabled, Hyper-Threading Disabled, 48GB memory (12x 4GB DDR3-1333 REG ECC), 160GB SATA 7200RPM HDD, Red Hat* Enterprise Linux Server 5.5 for x86_64 with kernel 2.6.35.10. Source: Intel internal testing as of Apr 2011. Score : 159.40 Gflops. Source Intel SSG TR#1224

1,6

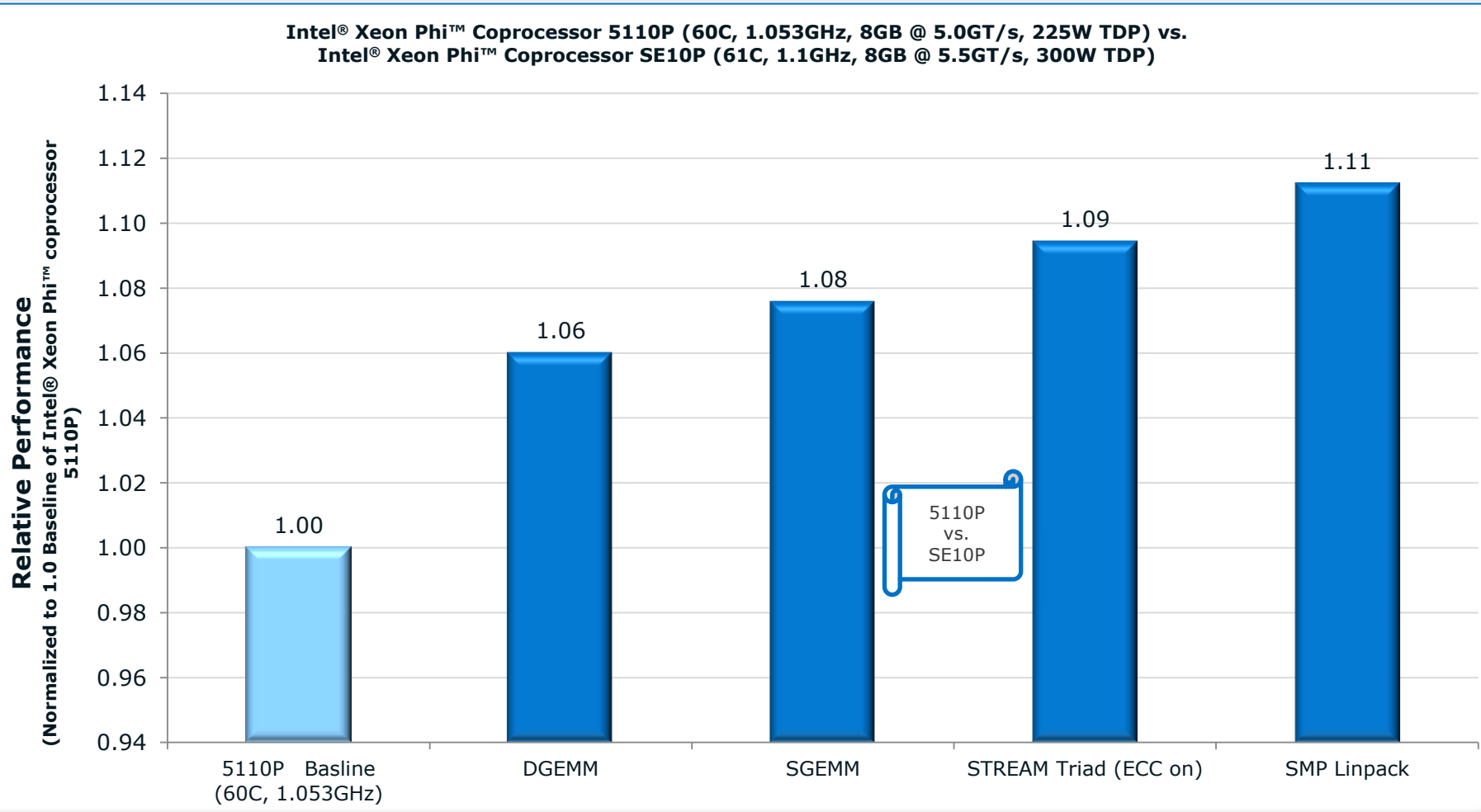
HPC suite claim based upon:

Baseline: 2S Intel® Xeon® X5690 HPC suite geometric mean of application measurements by vertical (CAE, Energy, FSI, Life Science, NWS), actual performance will vary by workload. Based on Intel internal measurements as of October 2011 using an Intel® Xeon® 5600 processor platform with two Intel® Xeon® X5690, Turbo Enabled, Best Hyper-Threading configuration, 48GB DDR3-1333 memory, Red Hat* EL5-U5.

New Configuration: 2S Intel® Xeon® E5-2680 HPC suite geometric mean of application measurements by vertical (CAE, Energy, FSI, Life Science, NWS), actual performance will vary by workload. Based on Intel internal measurements as of October 2011 using an Intel® Canoe Pass platform with two Xeon® E5-2680 (C0 step), Turbo Enabled, Best Hyper-Threading configuration, 32 GB DDR3-1600 memory, Red Hat* Enterprise Linux 6.1, 2.6.39.3 kernel

Backup

Intel® Xeon Phi™ Coprocessor (5110P vs. SE10P)



Intel® Xeon Phi™ coprocessor SE10P Delivers up to 11% higher performance vs. 5110P

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. Source: Intel Measured results as of October 26, 2012 Configuration Details: Please reference slide speaker notes. **For more information go to http://www.intel.com/performance**