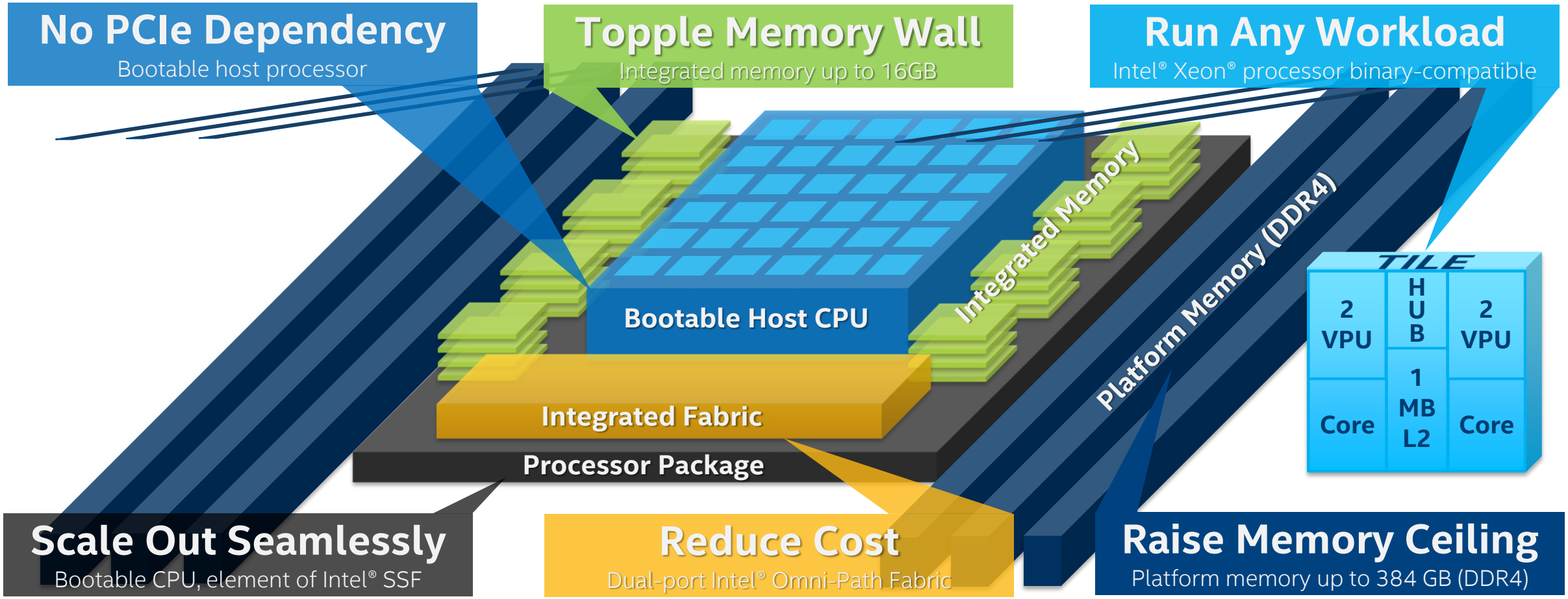
INTEL® XEON PHI™ PROCESSOR (CODENAMED KNIGHTS LANDING)

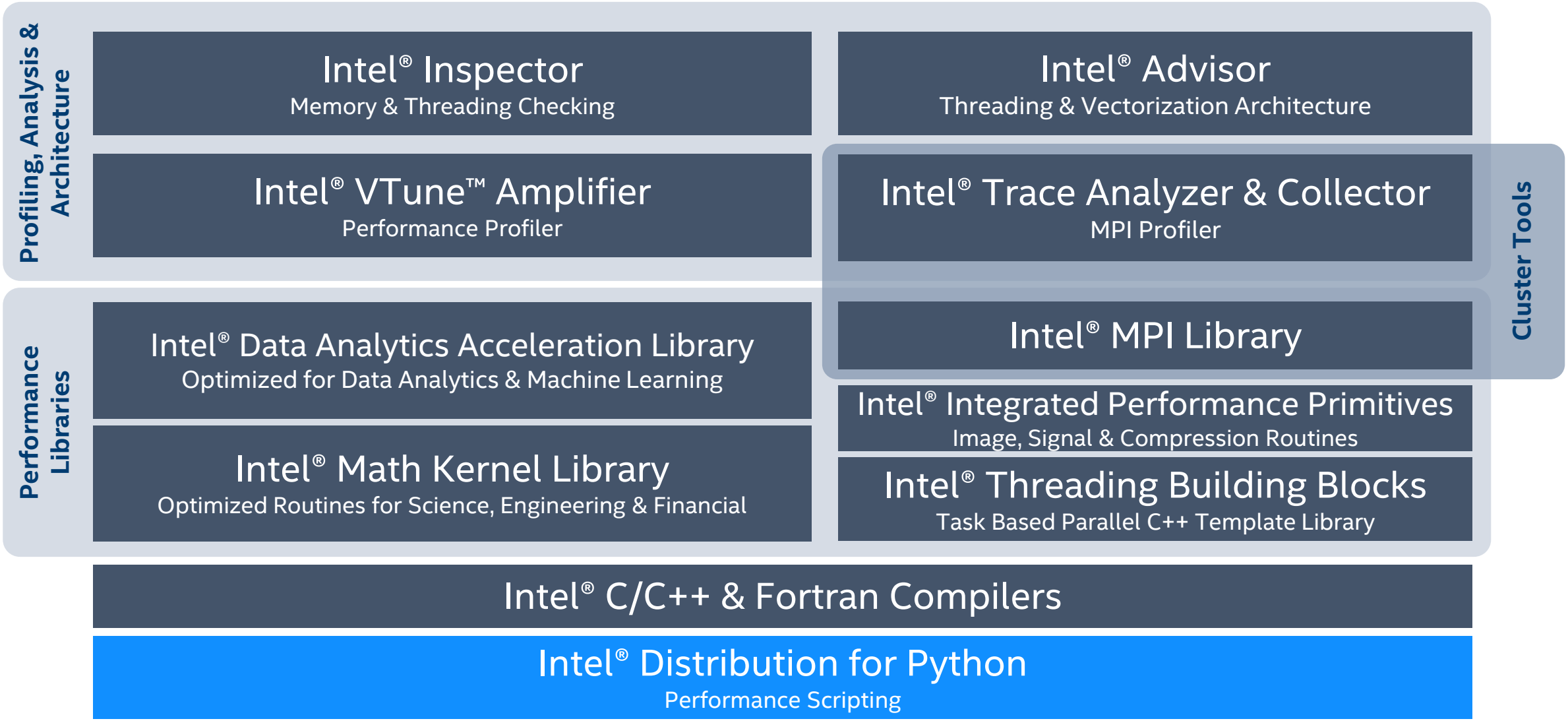
SOFTWARE ECOSYSTEM MOMENTUM GUIDE

INTEL® XEON PHI™ PROCESSOR

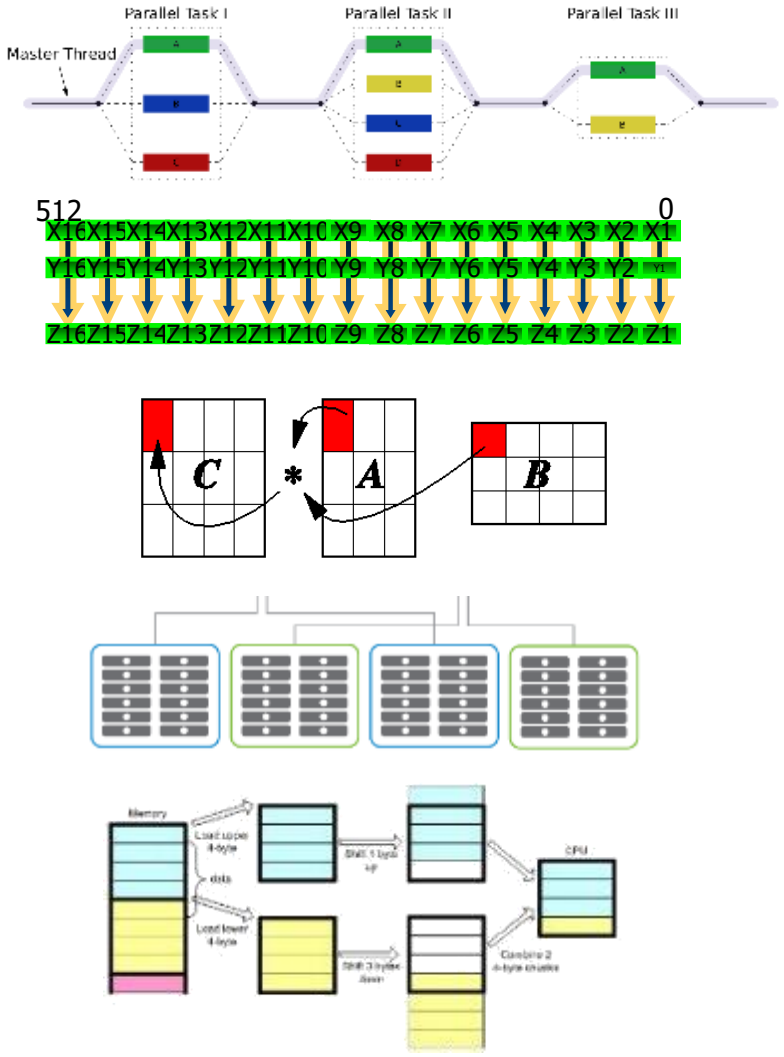
A HIGHLY-PARALLEL CPU THAT TRANSCENDS GPU ACCELERATORS



Intel® Parallel Studio XE



What is “Modernized” Code?



	What	Defined	Tools of the trade
1	**Thread Scaling**	Increase concurrent thread use across coherent shared memory	OpenMP, TBB, Cilk Plus
2	**Vector Scaling**	Use many wide-vector (512-bit) instructions	Vector loops, vector functions, array notations
3	**Cache Blocking**	Use algorithms to reduce memory bandwidth pressure and improve cache hit rate	Blocking algorithms
4	**Fabric Scaling**	Tune workload to increased node count	MPI
5	**Data Layout**	Optimize data layout for unconstrained performance	AoS→SoA, directives for alignment

Next Steps for Knights Landing Enablement

Your Code

Modernize Code using Intel® Xeon Phi™ coprocessor (threading, vectorization, cache-blocking, fabric scaling, data layout)

Evaluate Code Modernization

- Plot OpenMP thread scaling (concurrency)
- Plot performance vs. SIMD vector length (profitability)
- Plot performance vs # ranks/node (scalability)
- Use Intel® Parallel Studio XE 2017 tools to further profile and optimize your code

Performs well?

No

Yes

Prepare for KNL

1. Recompile for KNL (ICC with –MIC–AVX512)
2. Run on Intel® Software Development Emulator (SDE) with Intel® AVX-512 enabled to identify opportunities
3. Experiment with High Bandwidth (HBW) malloc API

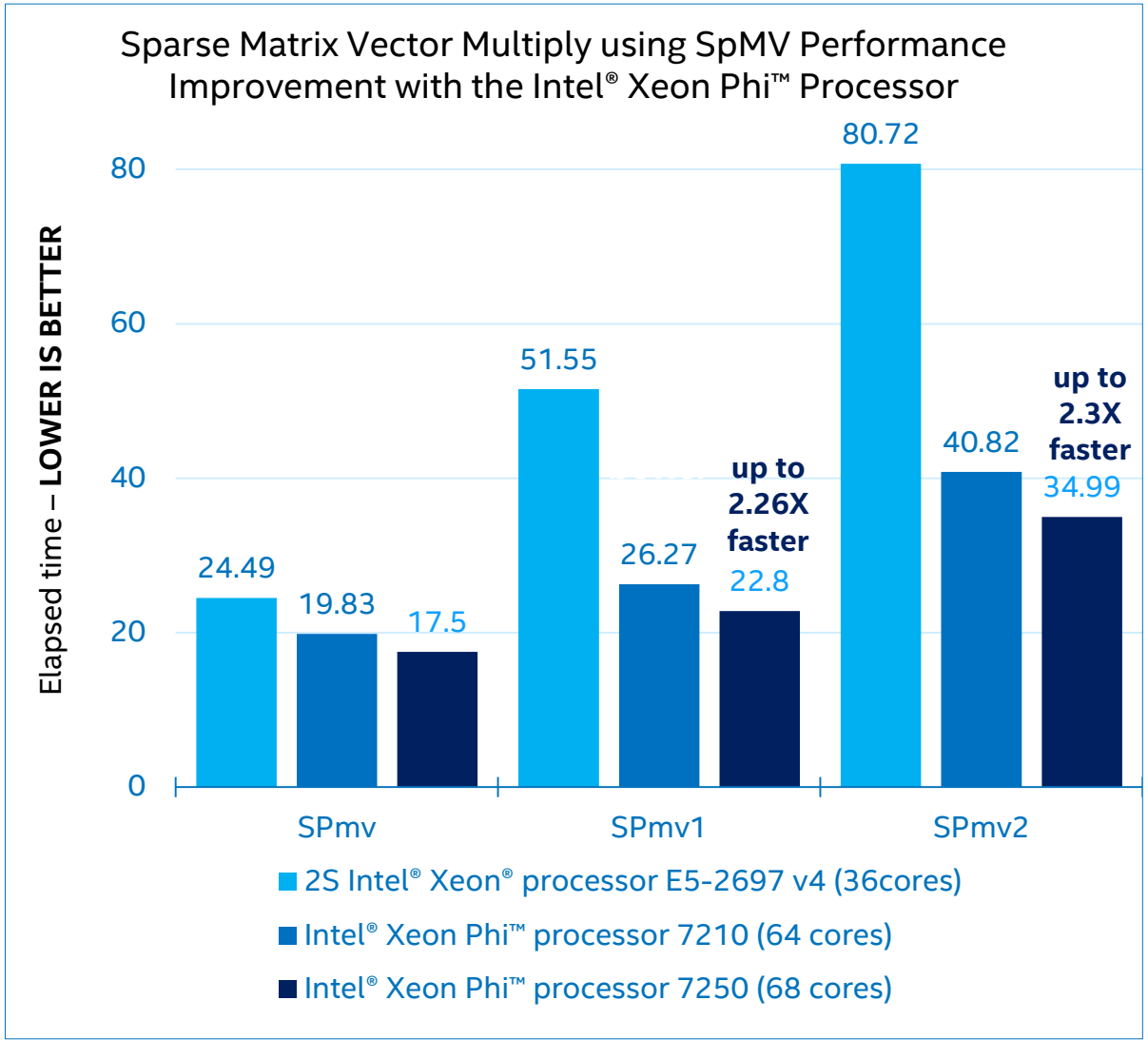
Code Modernization Enablement Program

SPECIAL OFFER

ACME MICRO SYSTEMS, advanced clustering technologies, inc., COLFAX, DAEHAN, EXXACT, FUJITSU, hp, inspur, KSC KING STAR COMPUTER, Lenovo, NAVIGARE, NorTech www.nor-tech.com, PowerLeader, Puget systems, THINKMATE

Performance

SPARSE MATRIX VECTOR MULTIPLY*



See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF APRIL, 2016

Sparse matrix-vector multiplication (SpMV) is an important kernel for a diverse set of applications in which systems with sparse pattern are used, such as scientific computing, engineering, economic modeling, information retrieval, oil & gas, weather consulting, animation, aero-spacing, recommender systems in machine learning, and earthquake prediction.

Application: Sparse Matrix Vector Multiply

Code: Available here. **Recipe:** In development

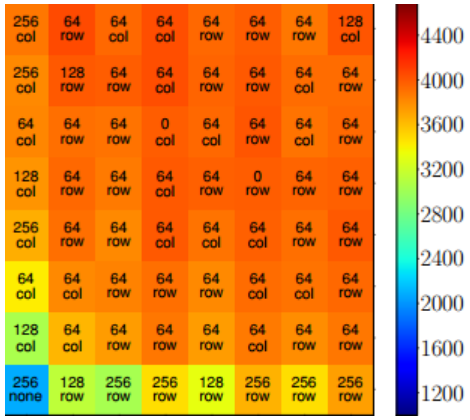


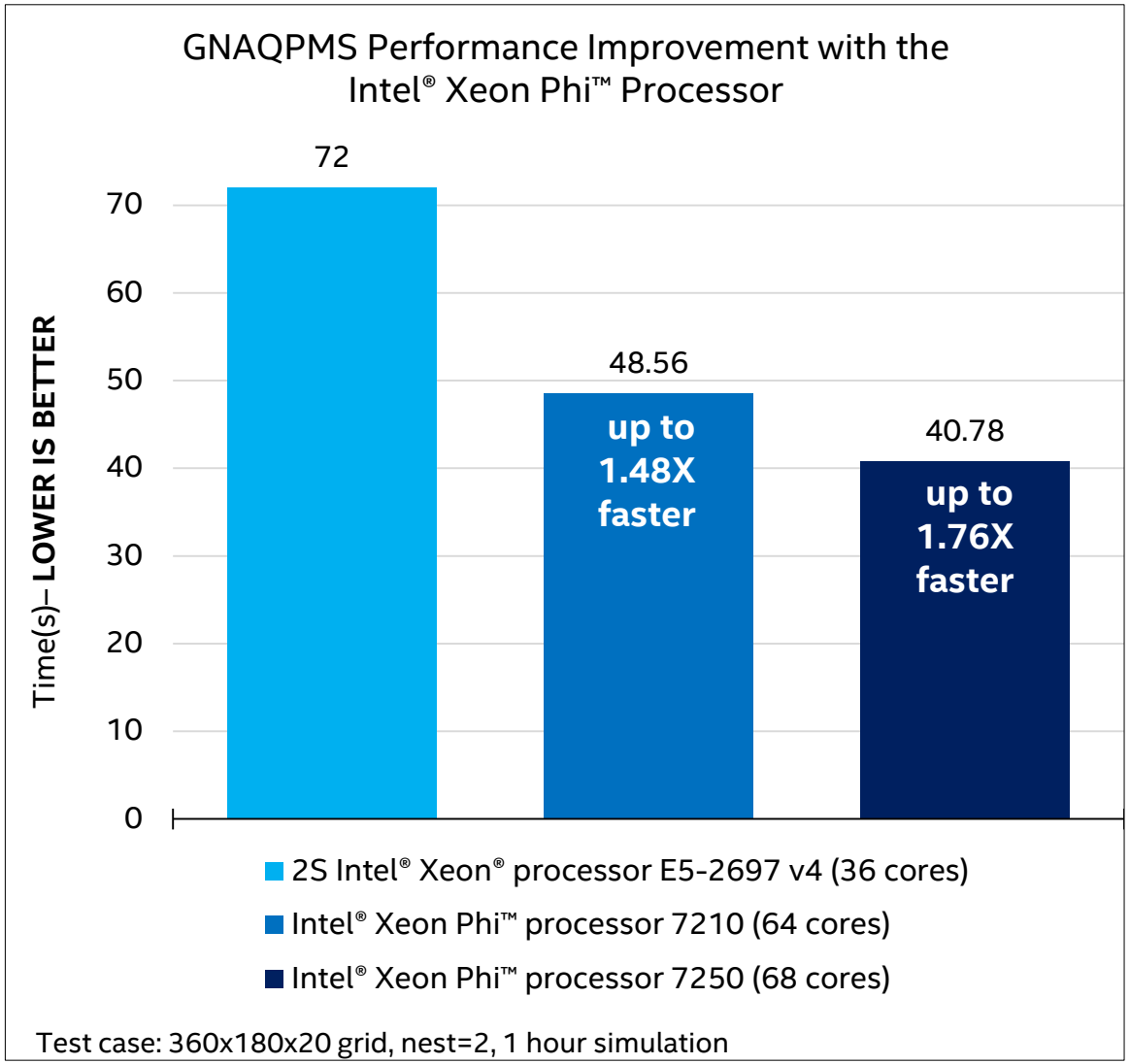
Image Source: US gov.

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

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

Climate & Weather

GNAQPMS*



See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF April,2016

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

Application: GNAQPMS.

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

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

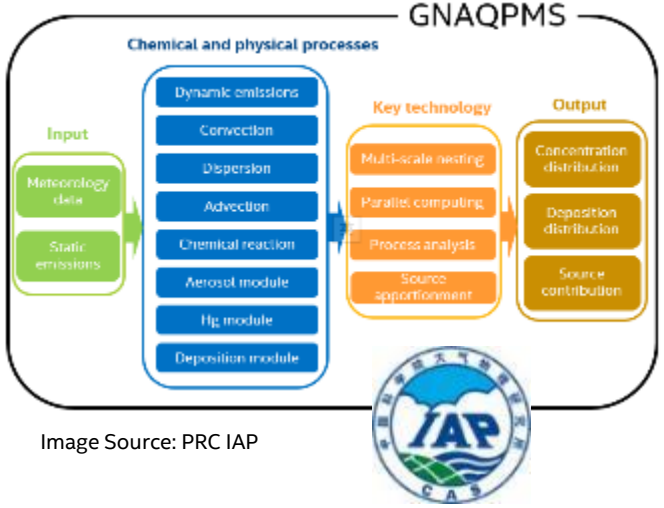
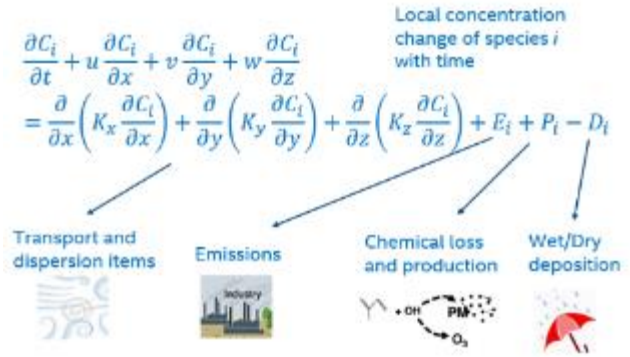


Image Source: PRC IAP

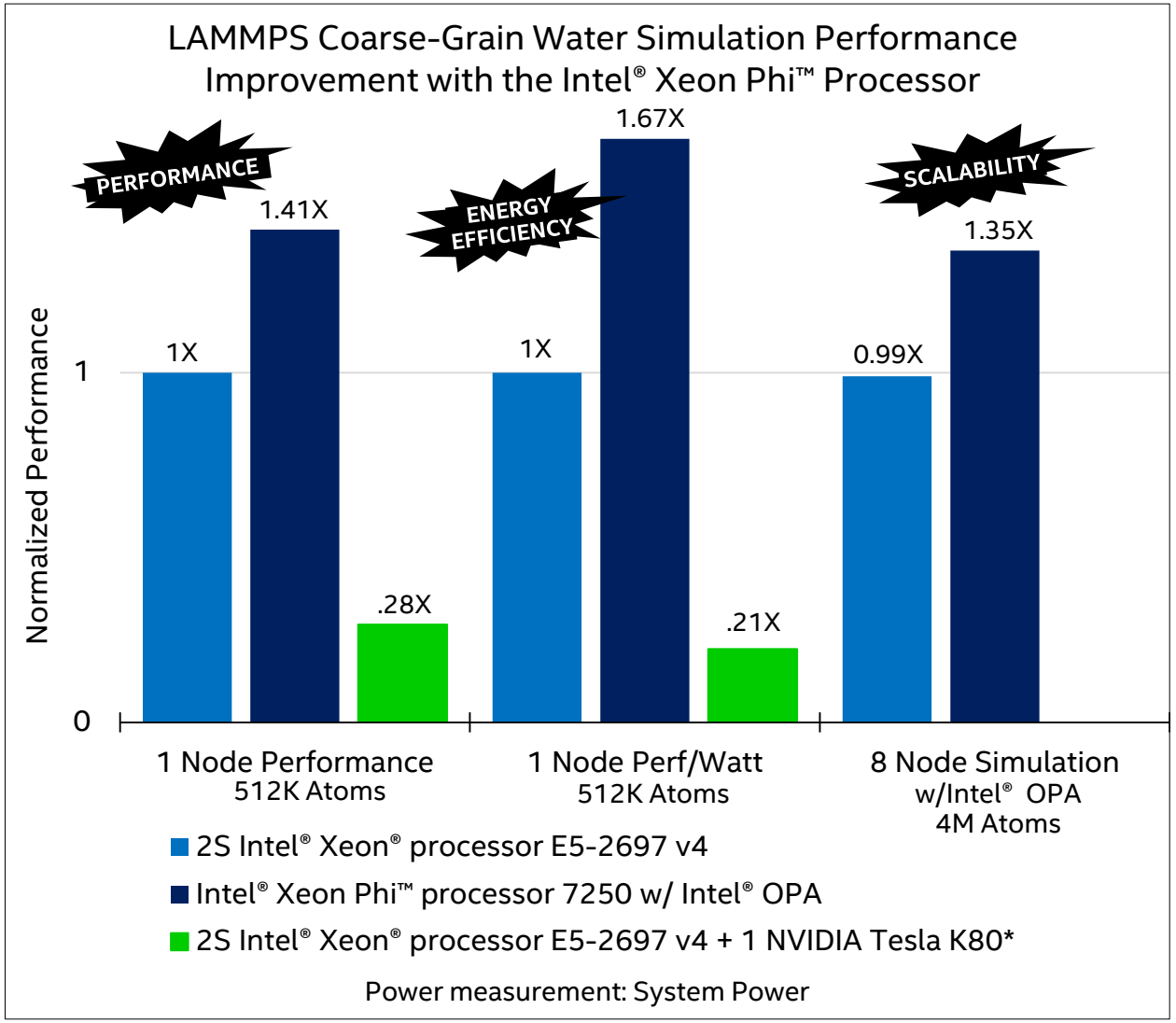


Value Proposition: Performance is enhanced by Intel® AVX512.

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

Life Sciences

LAMMPS COARSE-GRAIN WATER SIMULATION

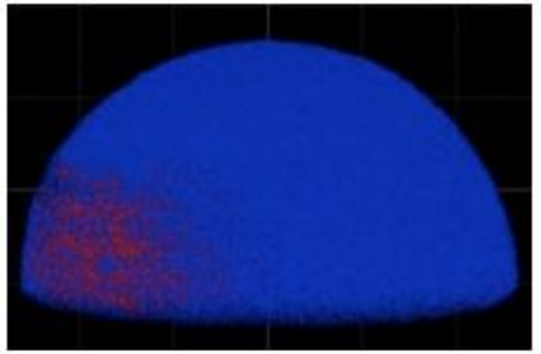


SOURCE: INTEL MEASURED RESULTS AS OF JUNE, 2016

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

Application: Coarse-grain water simulation with LAMMPS using Stillinger-Weber potential. More at http://lammps.sandia.gov/

Code: In main LAMMPS repository. **Recipe:** In development



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

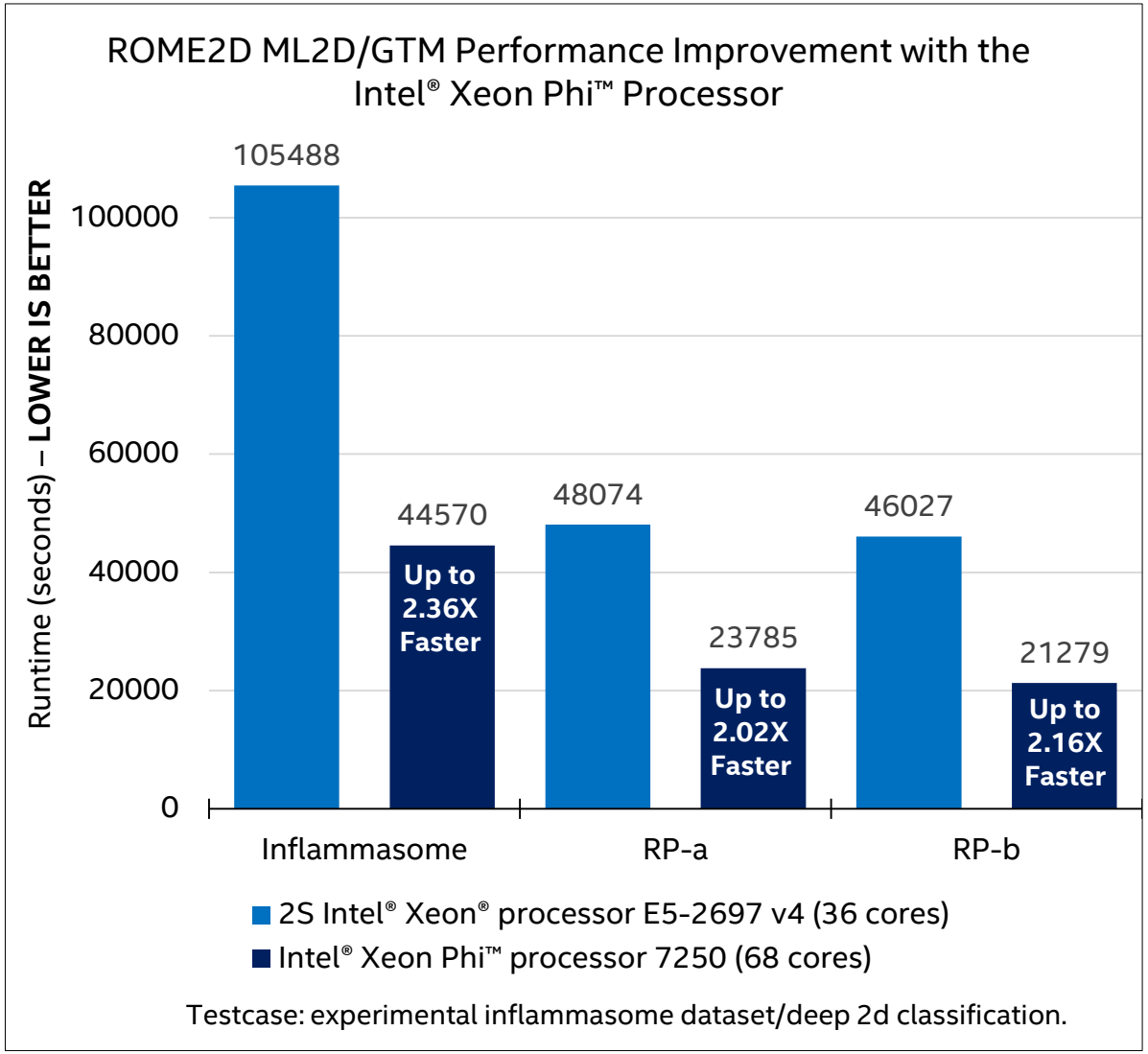
Image Source: Comput. Phys. Commun., 2013, 184, 2785-2793

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

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

Life Sciences

ROME/SML



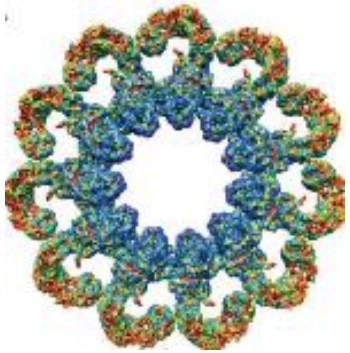
See next slide for configuration details.

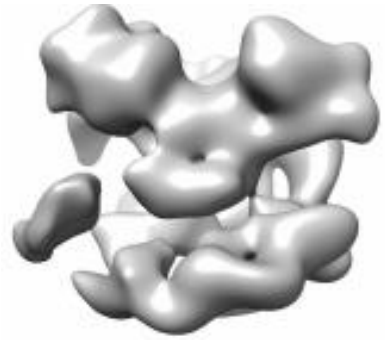
SOURCE: INTEL MEASURED RESULTS AS OF JUNE 2016

ROME (Refinement and Optimization via Machine lEarning for cryo-EM) is one of the major research software packages from Dana-Farber Cancer Institute. ROME is a parallel computing software system dedicated to high-resolution cryo-EM structure determination and data analysis, implementing advanced machine learning approaches optimized for HPC clusters. ROME 1.0 introduces SML (statistical manifold learning)-based deep classification, following MAP-based (maximum a posteriori) image alignment.

Application: ROME/SML

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





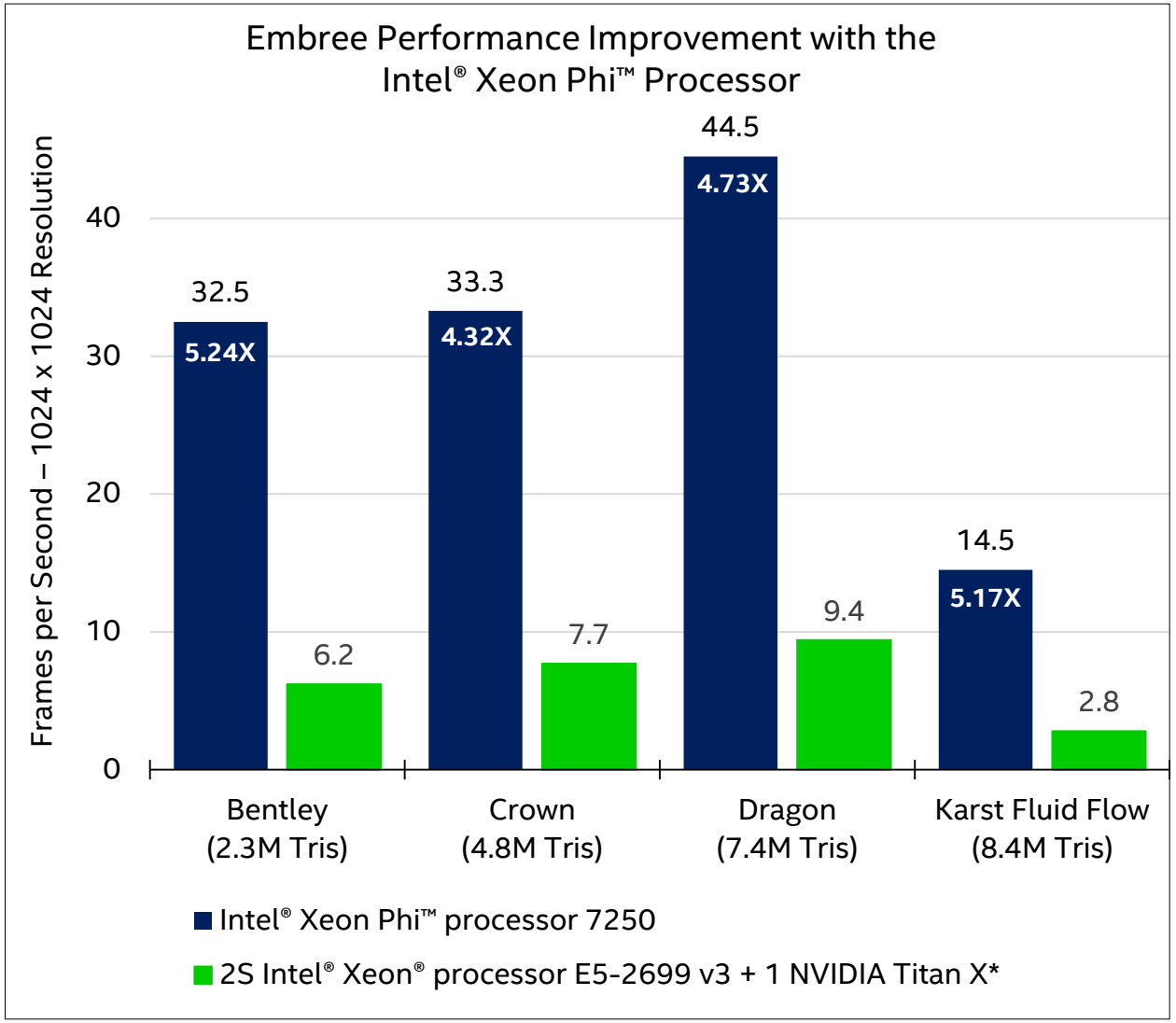
Images Source: L. Zhang, S. Chen, J. Ruan, J. Wu, A.B. Tong, Q. Yin, Y. Li, L. David, A. Lu, W.L. Wang, C. Marks, Q. Ouyang, X. Zhang, Y. Mao*, H. Wu*. Cryo-EM structure of the activated NAIP2-NLRC4 inflammasome reveals nucleated polymerization. Science 350, 404-409 (2015).

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

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

Digital Content Creation

INTEL EMBREE v2.9.0



See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF JUNE, 2016

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

Application: Embree v2.9.0

Code: Available here **Recipe:** In development

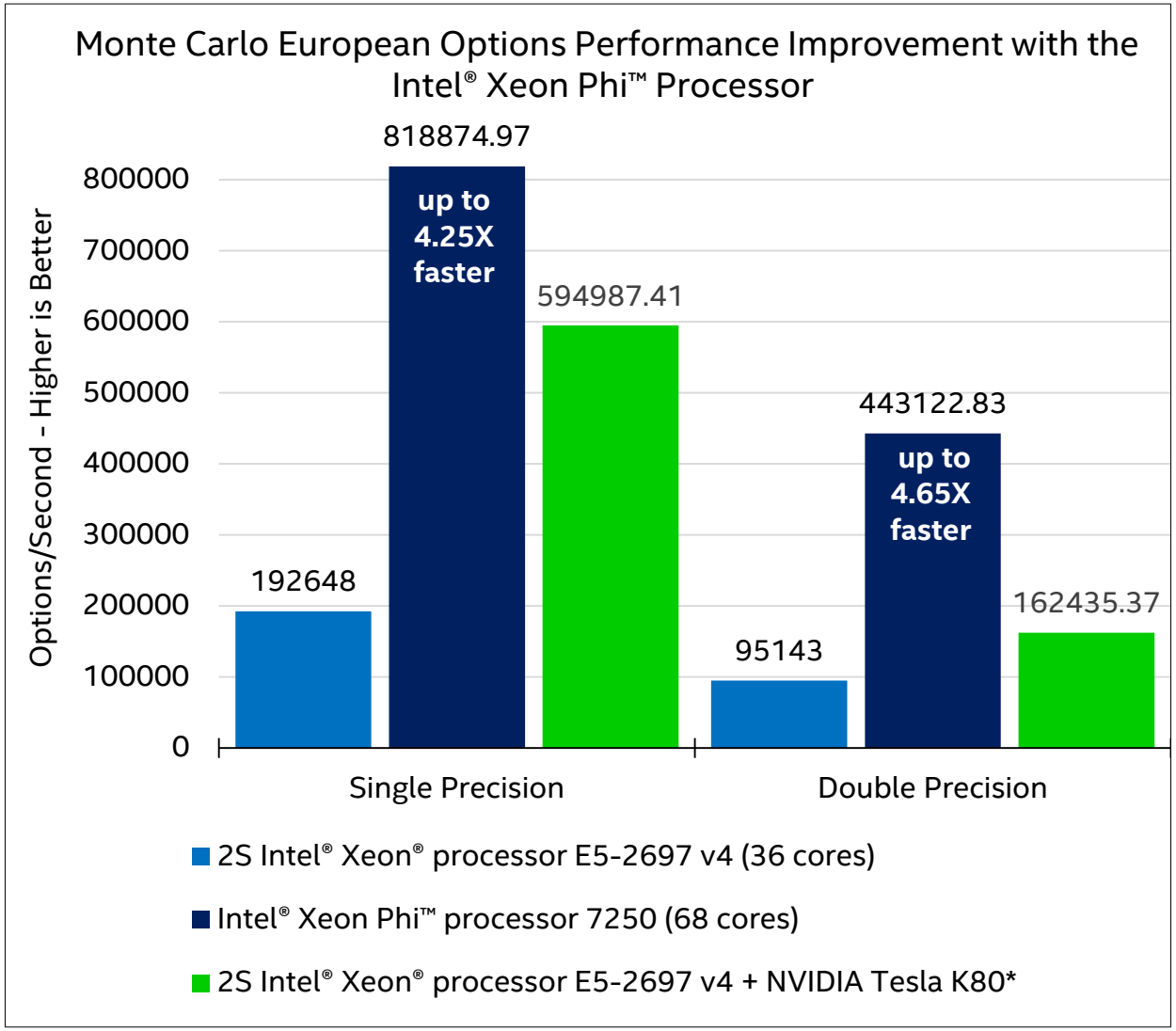
Image Source: Intel

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

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

Financial Services

MONTE CARLO EUROPEAN OPTIONS BENCHMARK*



See slide 27 for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF MAY, 2016

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

Application: Monte Carlo European Options

Code: Currently not available **Recipe:** Currently not available

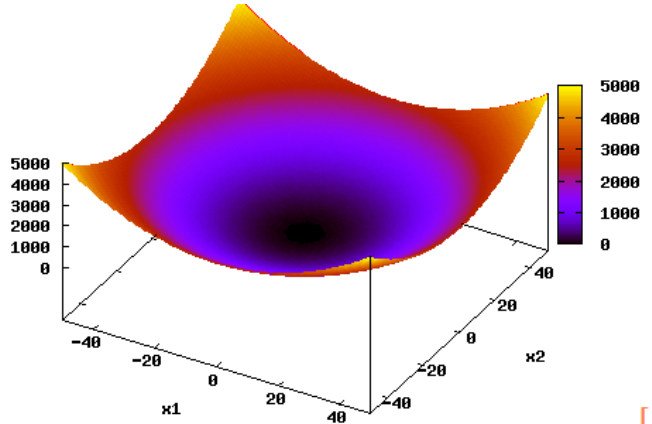


Image Source: US gov.

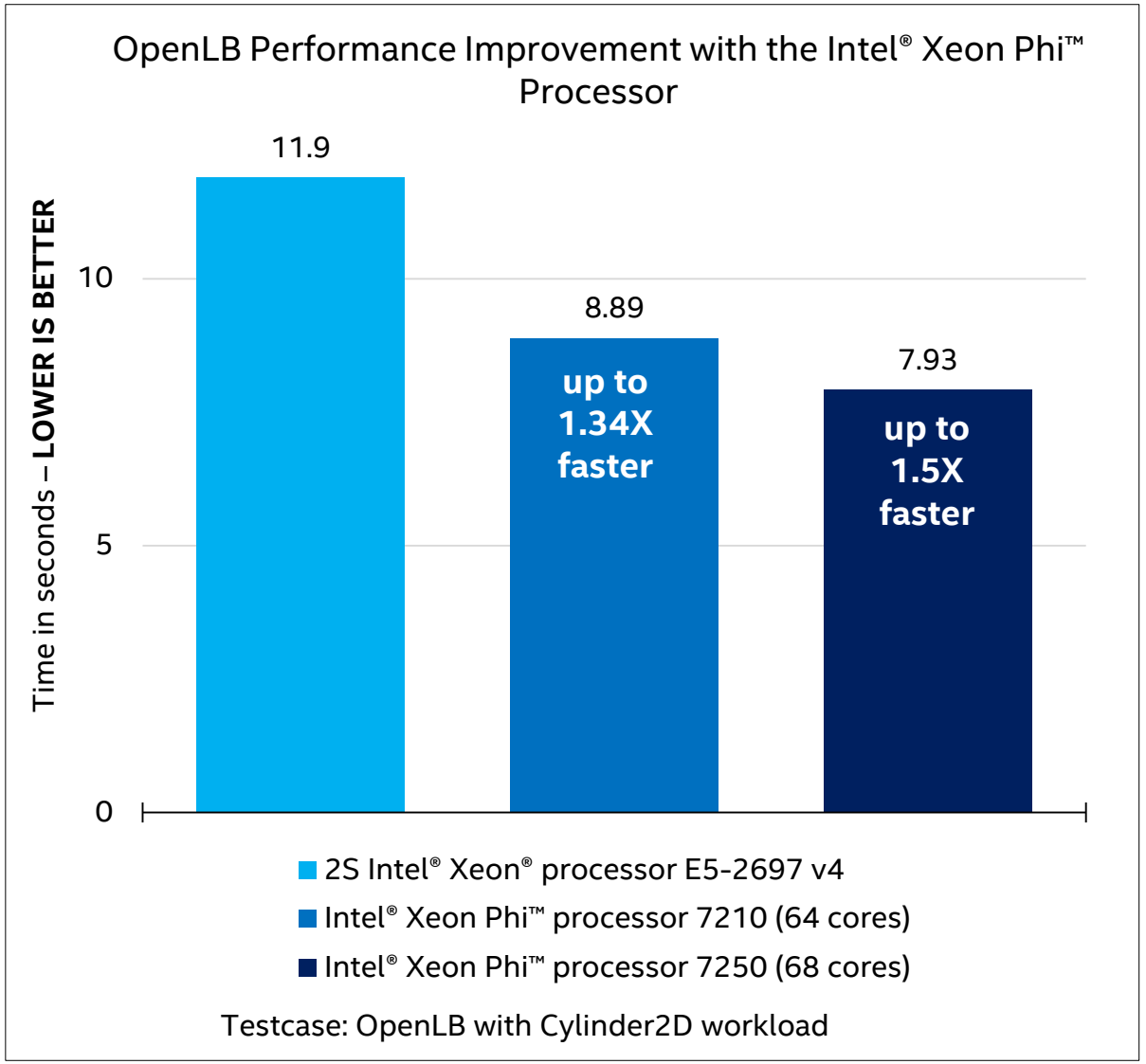
Value Proposition:

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

Results: Up to 4.65X improved Double Precision performance compared to the Intel® Xeon® processor E5-2697 v4 and up to 2.72X better than NVIDIA Tesla*.

Physics – CFD

OPENLB*



See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF APRIL 2016

The OpenLB project provides a C++ package for the implementation of lattice Boltzmann simulations that is general enough to address a vast range of problems in computational fluid dynamics. The package is mainly intended as a programming support for researchers and engineers who simulate fluid flows by means of a Lattice Boltzmann method.

Application: OpenLB

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

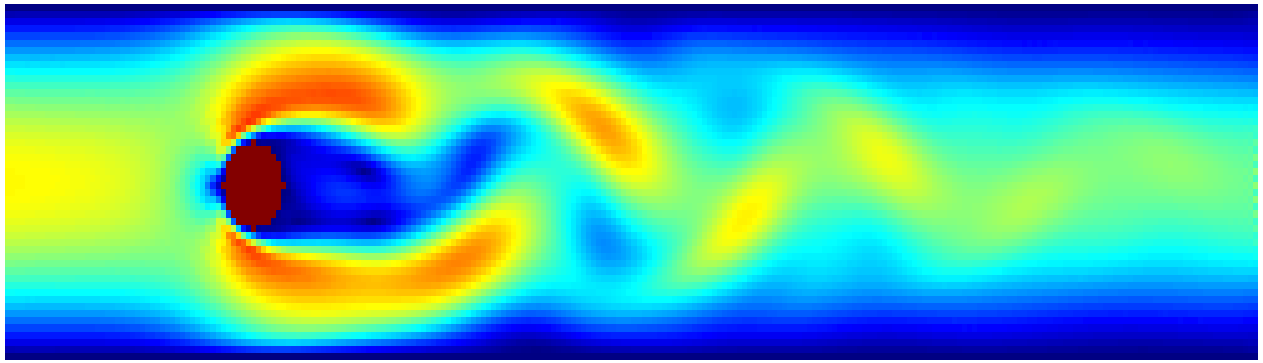


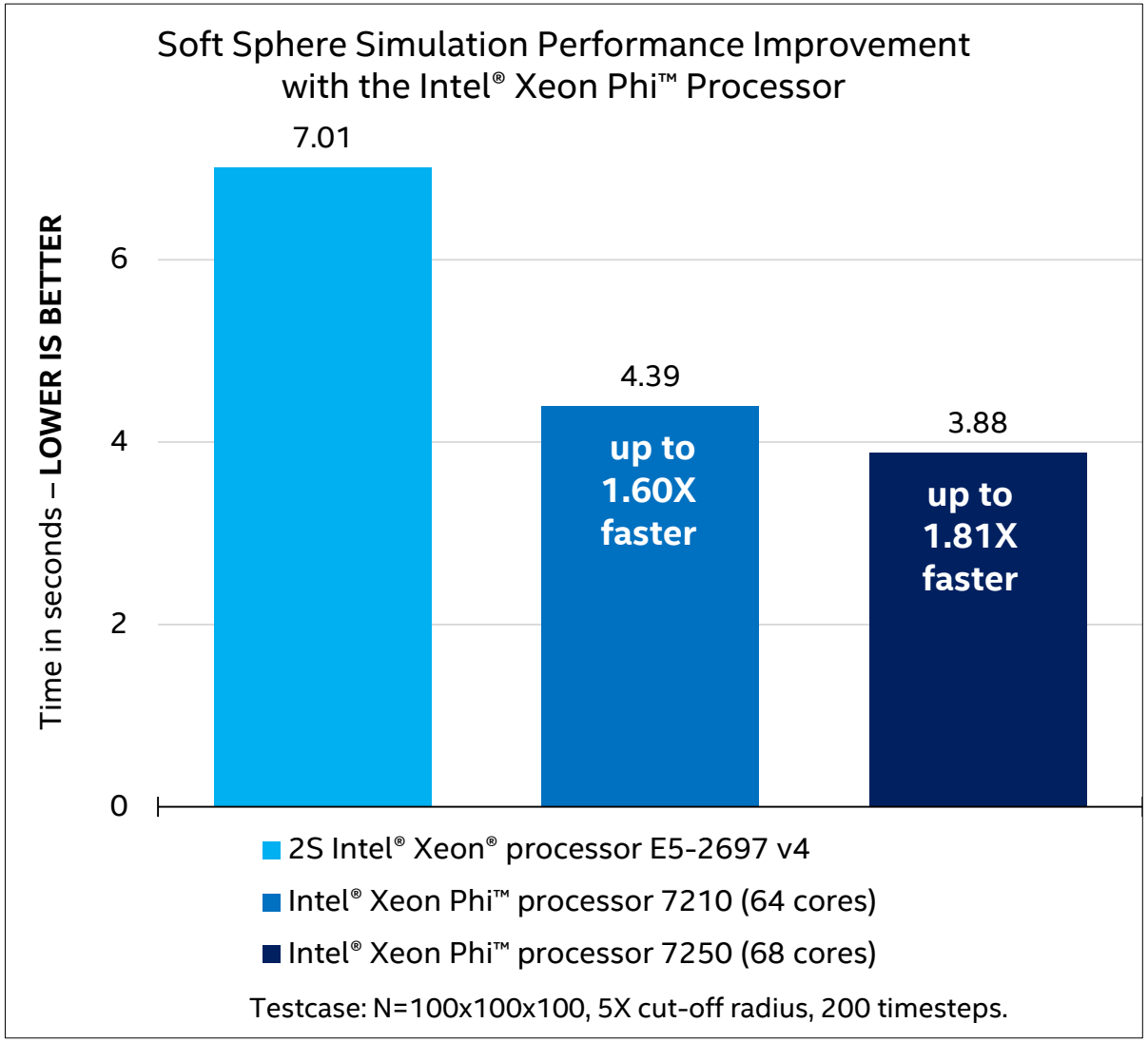
Image Source: Used with permission

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

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

Physics

SOFT SPHERE SIMULATION*



See next slide for configuration details.

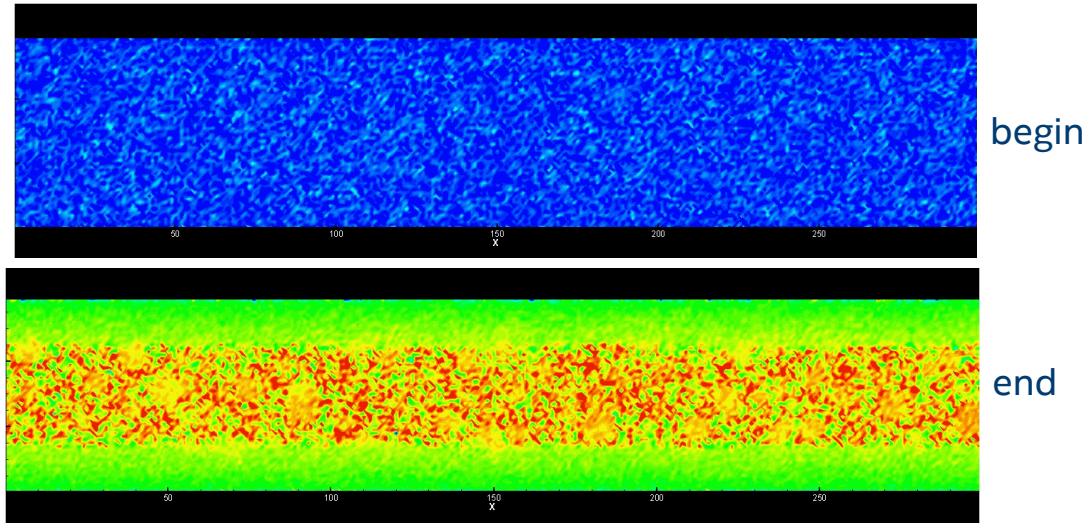
SOURCE: INTEL MEASURED RESULTS AS OF MARCH, 2016

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

Application: Soft Sphere Simulation

Code: in-house code, contact Prof. Ge at wge@ipe.ac.cn for code and workload

Recipe: Please contact Prof. Ge above.



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

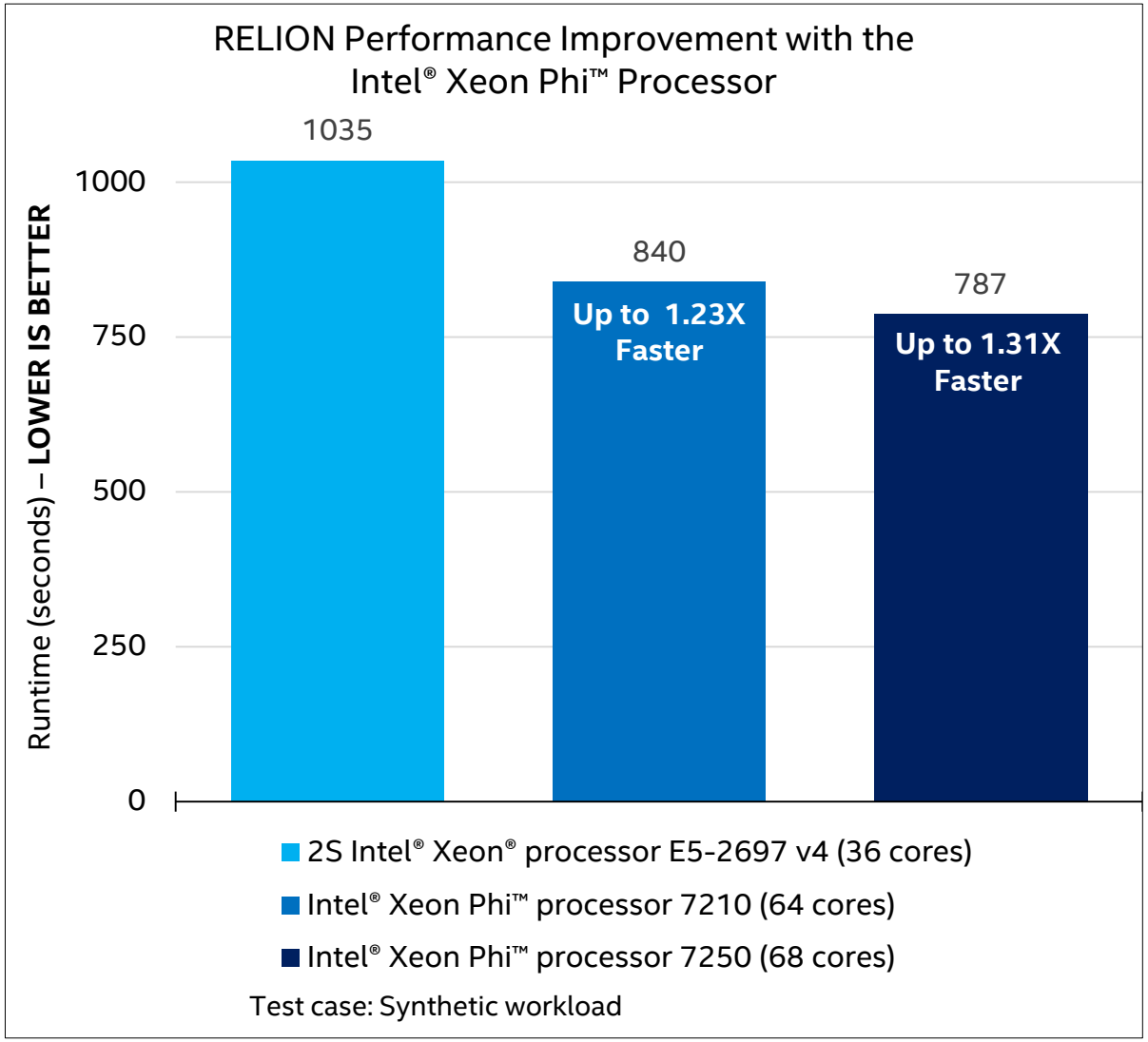
Value Proposition: Intel® Xeon Phi™ processor 7250 enables this application to significantly outperform (time-to-solution) alternative processing solutions.

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


intel
experience
what's inside™

Life Sciences

RELION



See next slide for configuration details.

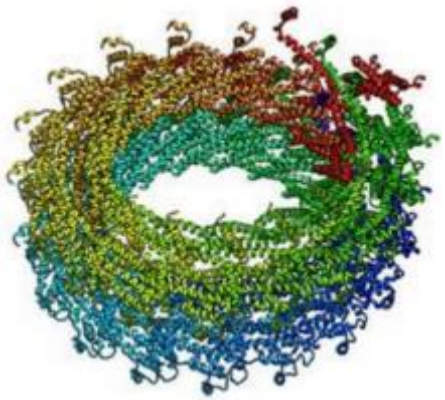
SOURCE: INTEL MEASURED RESULTS AS OF APRIL 2016

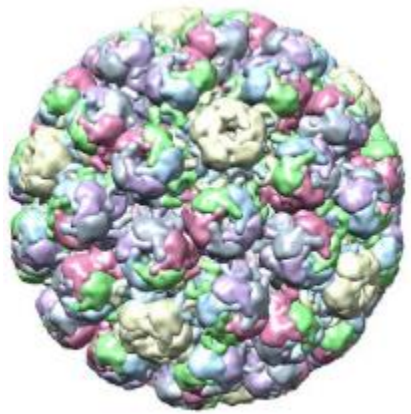
RELION (REgularised LIkelihood OptimisatioN) is a stand-alone computer program that employs an empirical Bayesian approach to refinement of 3D reconstructions or 2D class averages in Cryo-EM.

Application: RELION 1.4

Code: Available here

Recipe: "mpiicpc -O3 –xMIC-AVX512 -fno-alias -align"





Images Source: http://www.rcsb.org/

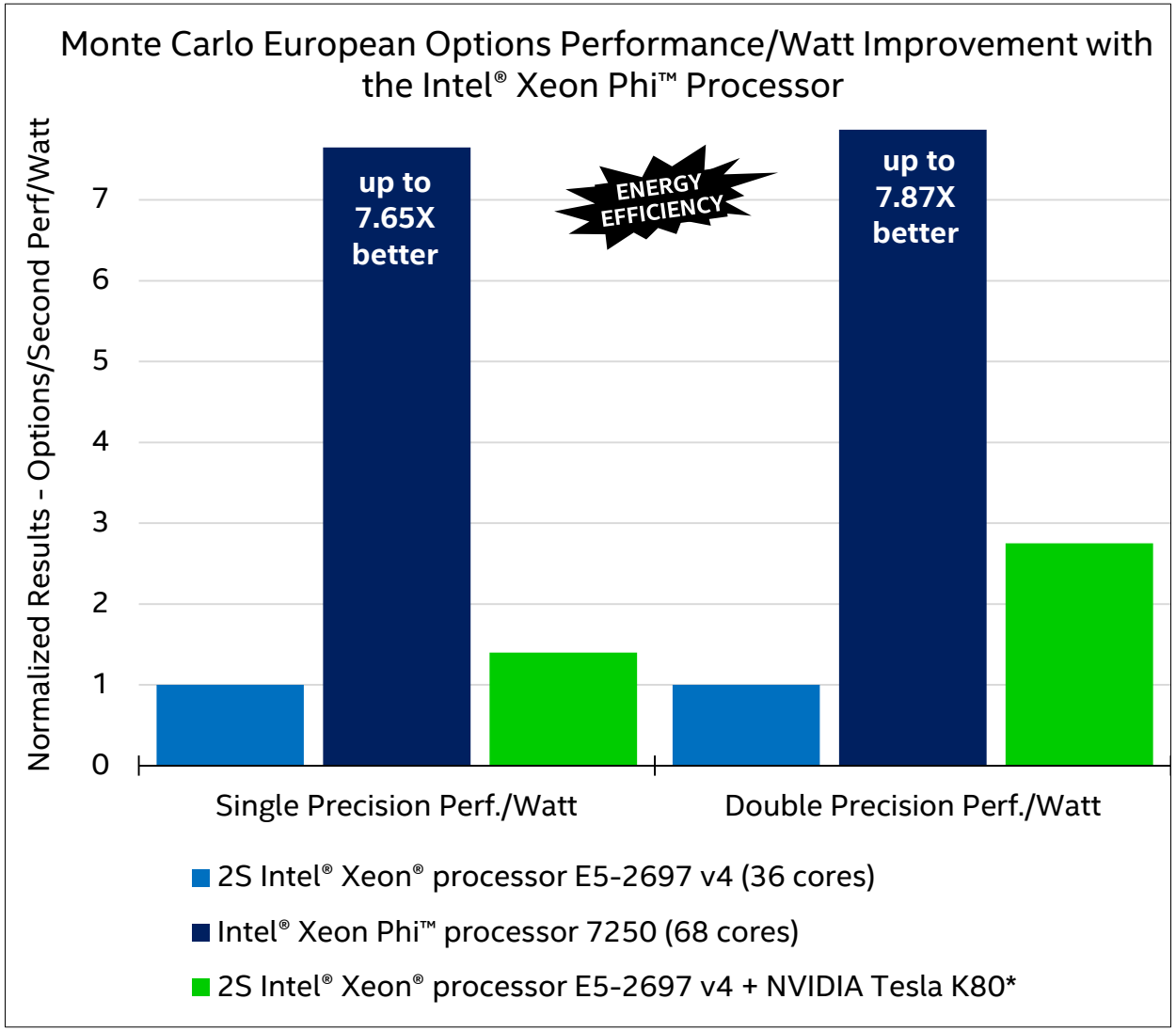
Value Proposition:

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

Results: Up to 1.3X improved performance compared to the Intel® Xeon® processor E5-2697 v4.

Financial Services

MONTE CARLO EUROPEAN OPTIONS BENCHMARK*



See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF MAY, 2016

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

Application: Monte Carlo European Options

Code: Currently not available **Recipe:** Currently not available

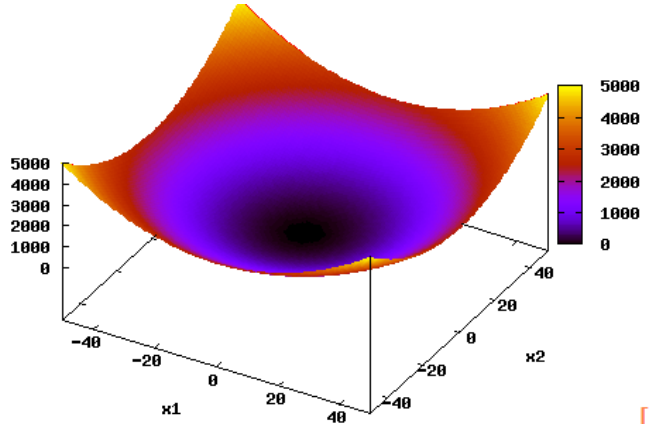


Image Source: US gov.

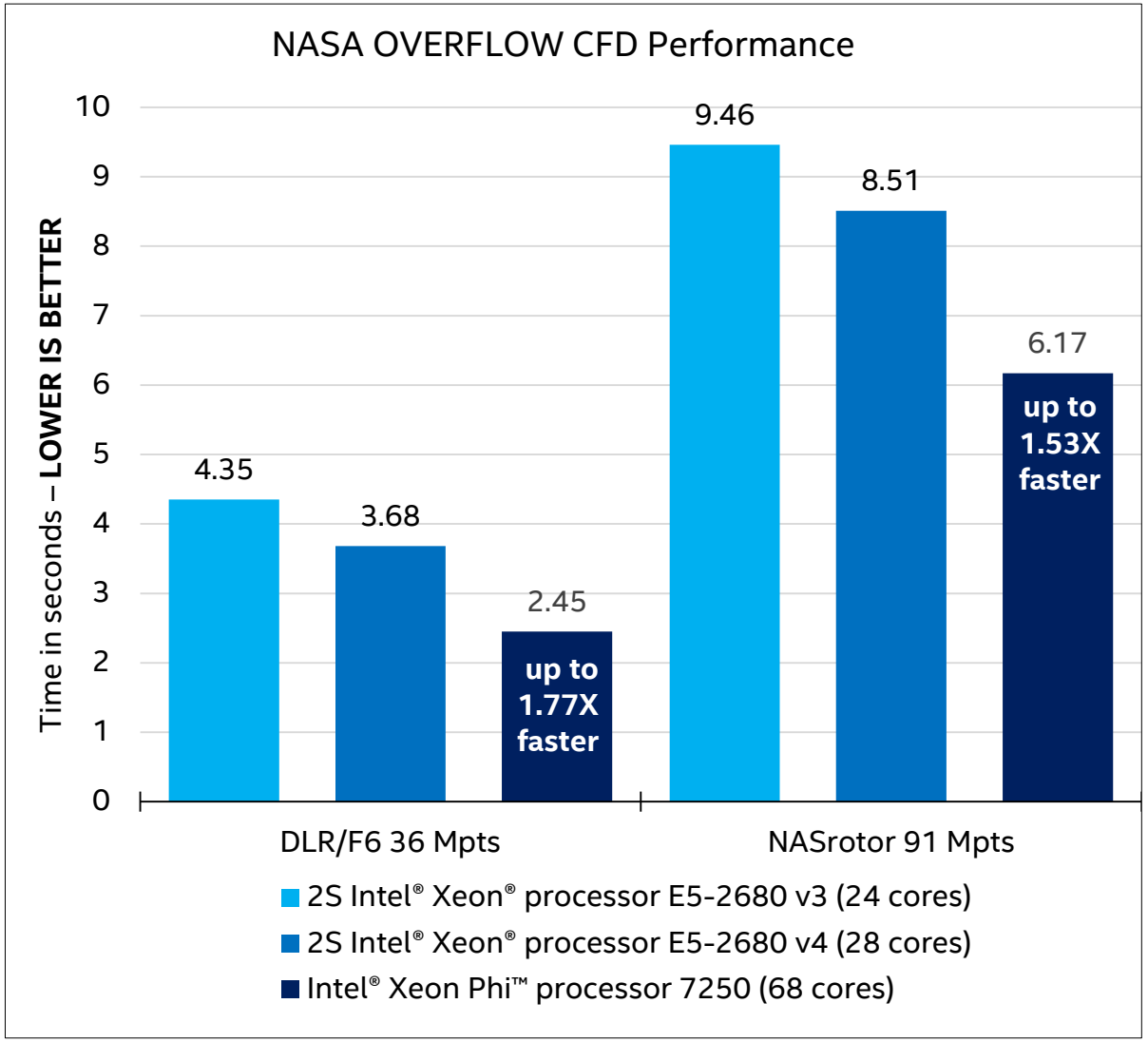
Value Proposition:

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

Results: Up to 7.87X improved Double Precision performance/watt compared to the Intel® Xeon® processor E5-2697 v4 and up to 5.46X better than NVIDIA Tesla* (single precision).

Manufacturing

NASA OVERFLOW*



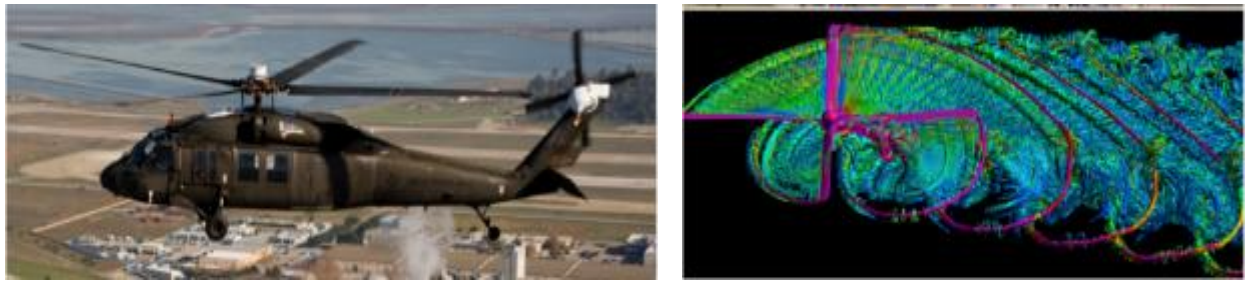
SOURCE: NASA/Ames (Dennis Jespersen) April 2016

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

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

Code: http://overflow.larc.nasa.gov/

Recipe: No code changes were required. Recompile with KNL AVX-512.



UH-60 Black Hawk helicopter and Navier-Stokes detached eddy simulation of a flexible UH-60 rotor using the OVERFLOW CFD code in forward flight.
Image Source: Neal Chaderjian and Tim Sandstrom, NASA/Ames

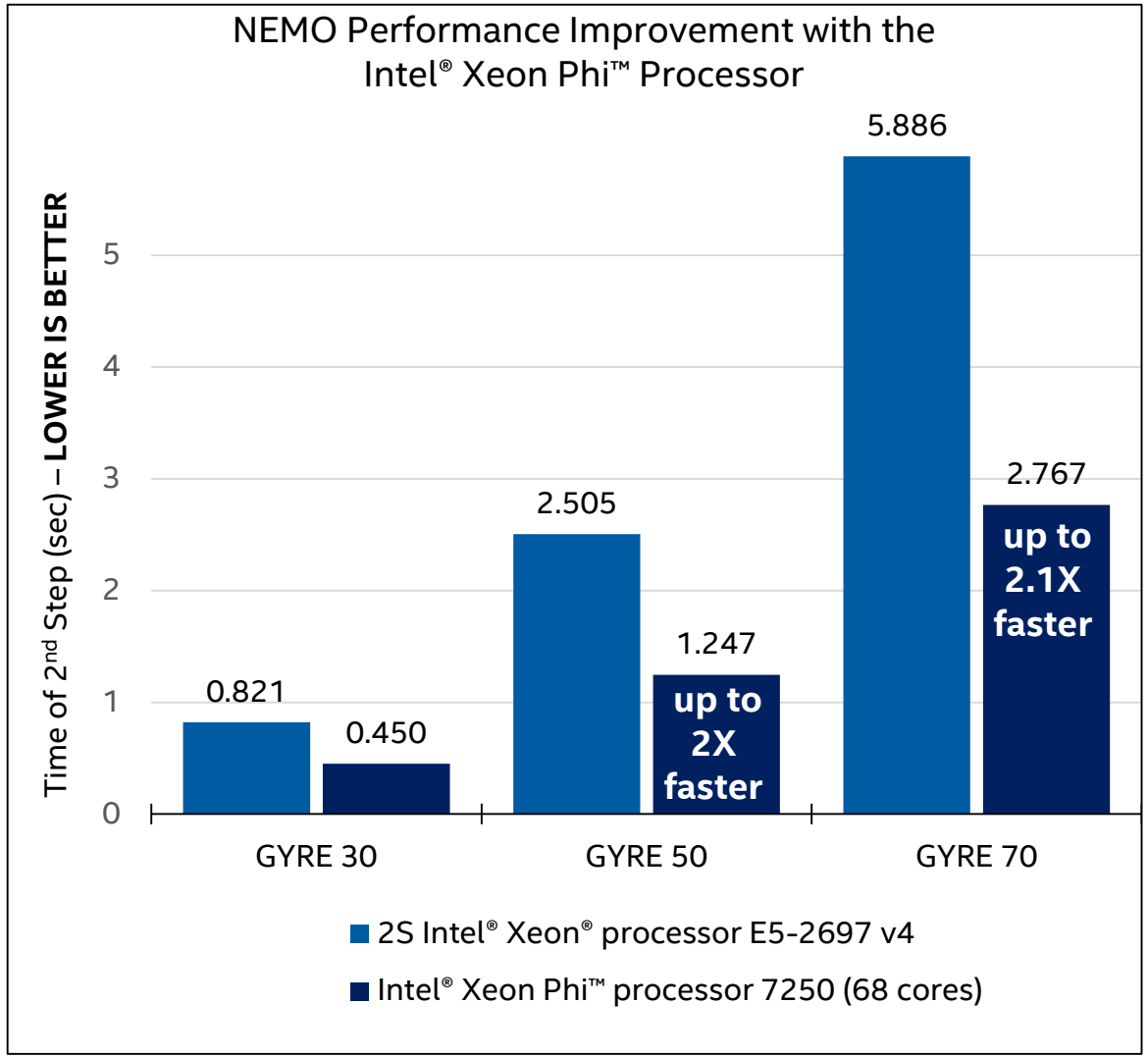
Value Proposition:

Overflow performance on KNL beats contemporary Haswell and Broadwell Architecture 2S servers. This provides better performance, performance density and better energy efficiency than today's best Intel Xeon processor based systems.

Results: Up to 1.78X performance improvement compared to the Intel® Xeon® processor E5-2680v3.

Climate & Weather

NUCLEUS FOR EUROPEAN MODELLING OF THE OCEAN* (NEMO)



See slide 69 for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF MARCH, 2016

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

Application: NEMO 3.6

Code: http://www.nemo-ocean.eu/

Recipe: See next slide

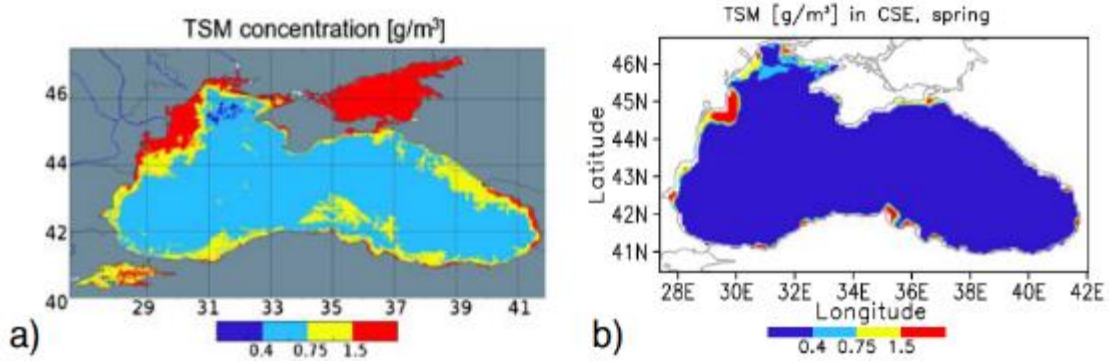


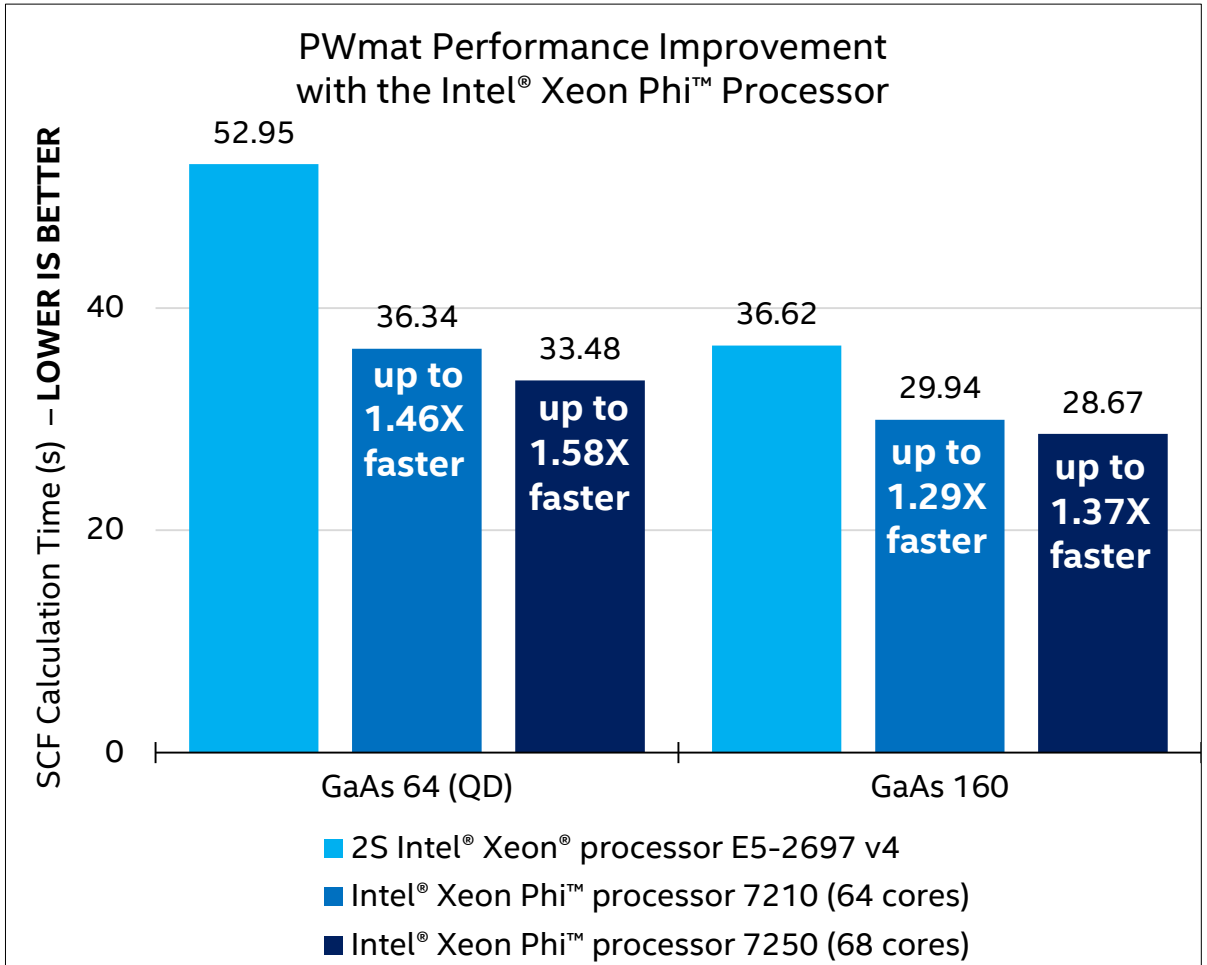
Image Source: Sediment Dynamics in the Black Sea

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

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

Material Sciences

PWMAT*



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

See next slide for configuration details.

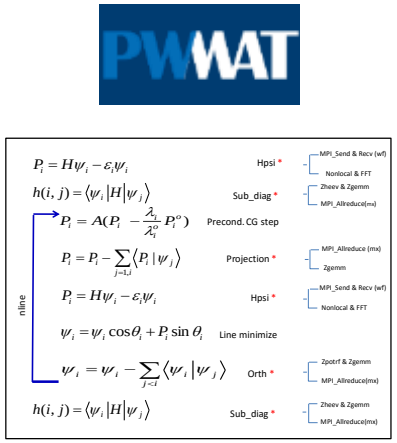
SOURCE: INTEL MEASURED RESULTS AS OF MAY, 2016

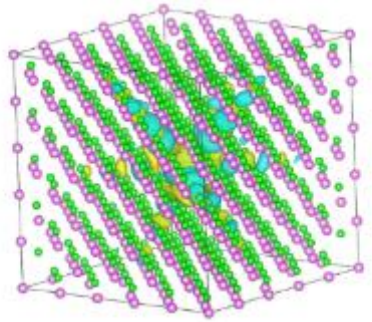
PWmat is a commercial software using plane wave pseudopotential method for density functional theory (DFT) material simulations. It is an ab initio code, meaning it uses initial atomic positions to predict the material properties. PWmat is developed and optimized by Beijing LongXun Inc. based on the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

Application: PWmat

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

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





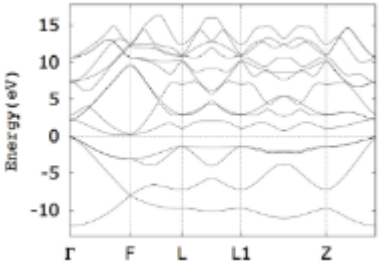


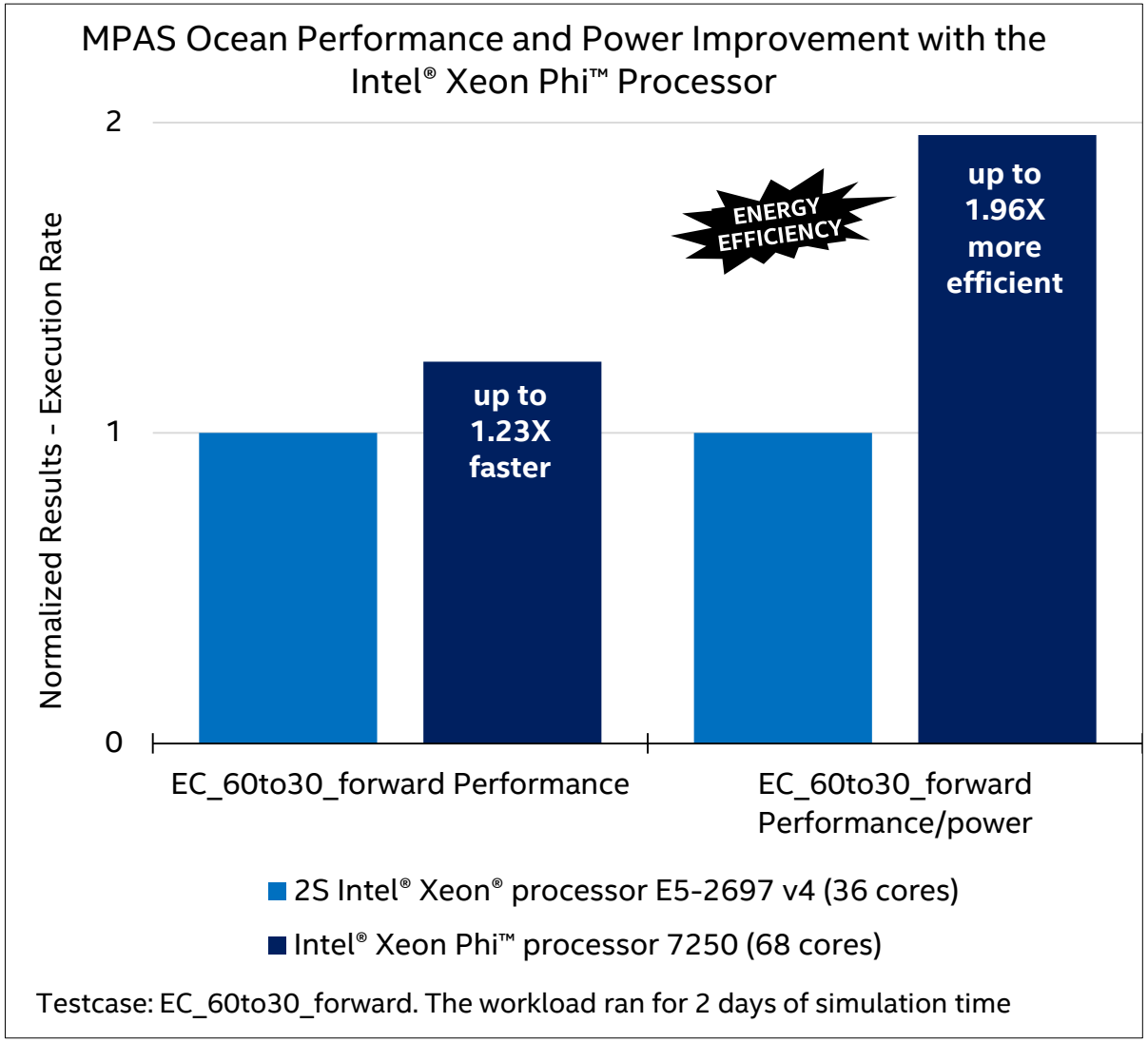
Image Source: LongXun Inc.

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

Results: Up to 1.58X faster with the Intel® Xeon Phi™ processor 7250 compared to the Intel® Xeon® processor E5-2697 v4.

Climate & Weather

MPAS OCEAN 4.0*



See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF MAY 2016

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

Application: MPAS-O

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

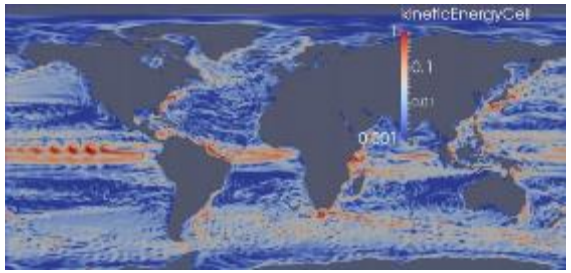


Image Source: Los Alamos National Laboratory

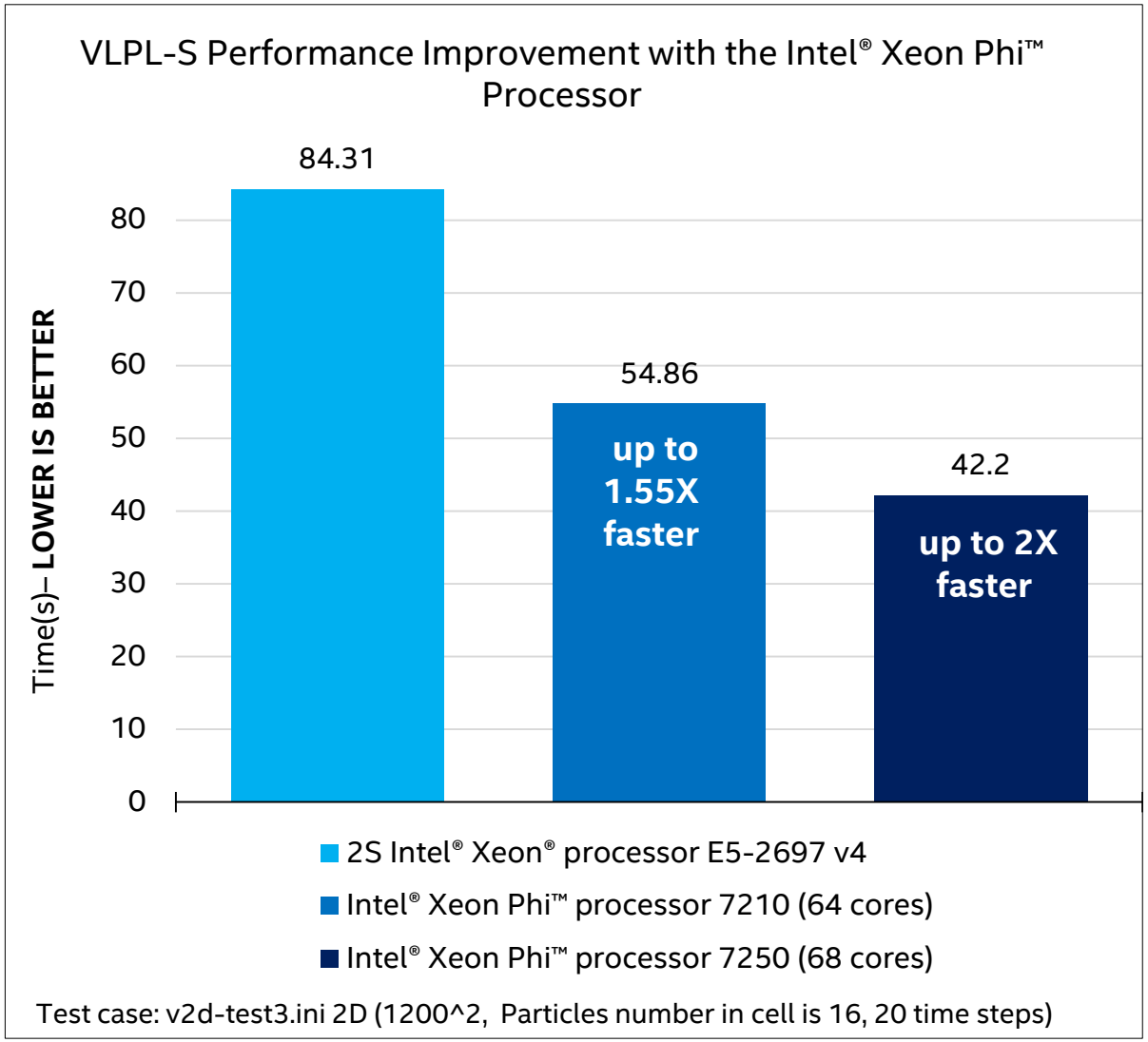
Value Proposition: Intel® Xeon Phi™ processor 7250 enables this application to outperform (time-to-solution) and performance/power of alternative processing solutions.

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

Results: up to 1.23X improved performance and up to 1.96X performance/power compared to the Intel® Xeon® processor E5-2697 v4 for EC_60to30_forward workload.

Physics

VLPL-S*



See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF APRIL,2016

VLPL-S is the in-house code from Germany Heinrich-Heine University of Dusseldorf (HHUD) and PRC Shanghai Jiao Tong University (SJTU), paralleled with MPI and written in C++. The application is about Particle-in-Cell method for laser plasma simulation by solving the particles motion equation, current density distribution and Maxwell equations.

Application: VLPL-S.

Code: In-house code. To get access to the code and test cases, please contact minchen@sjtu.edu.cn

Recipe: Please contact minchen@sjtu.edu.cn

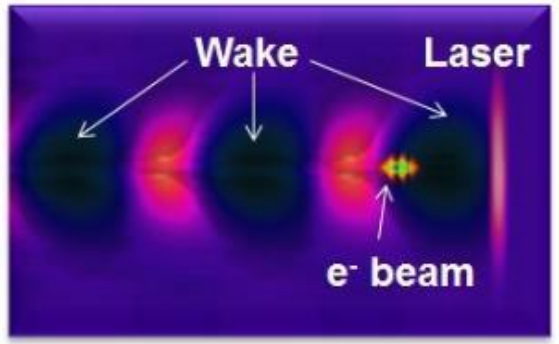
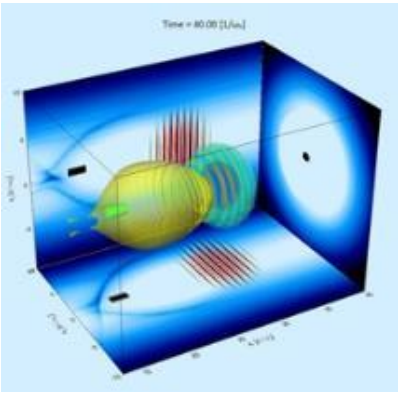


IMAGE SOURCE: PRC SJTU



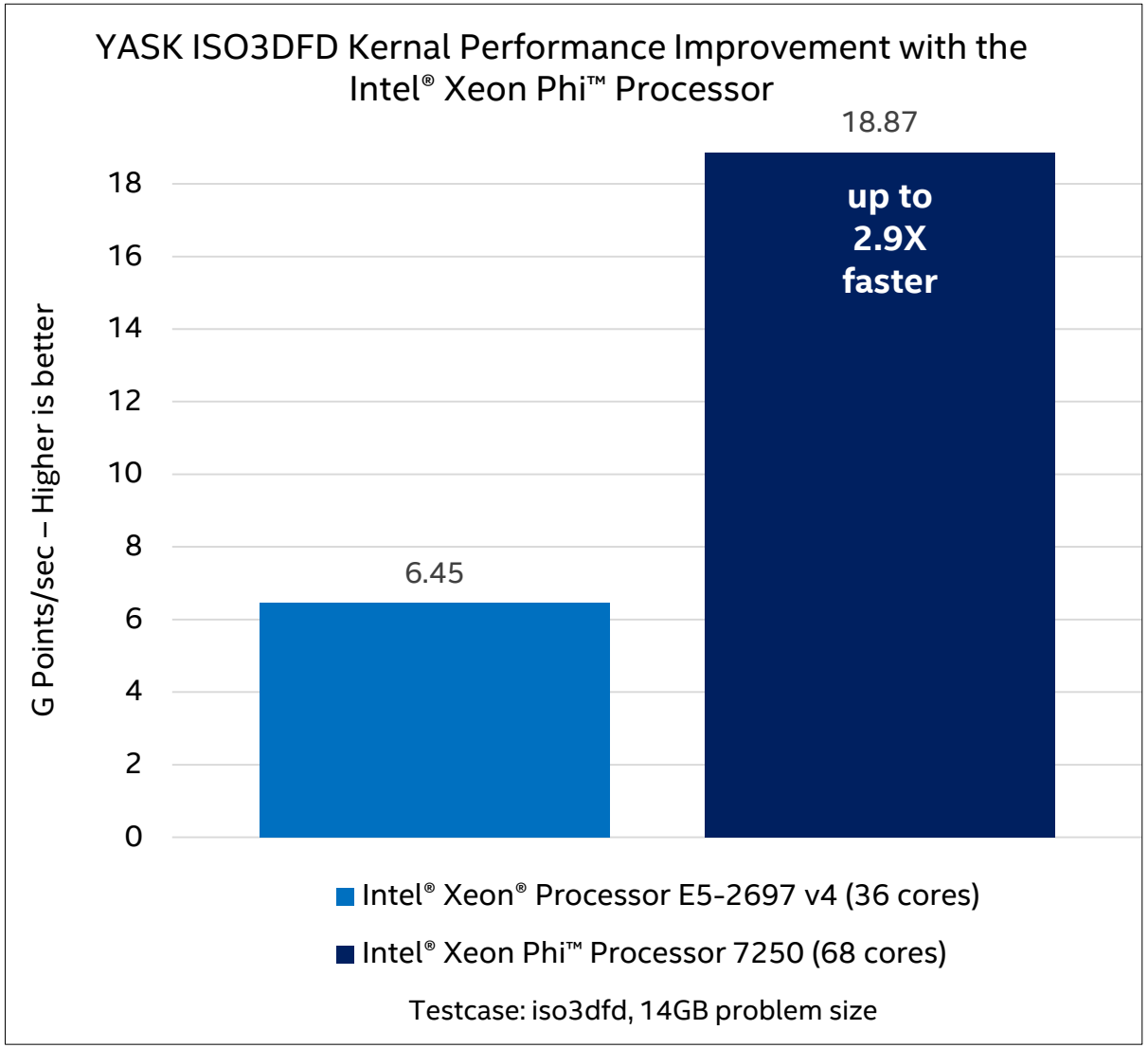
Value Proposition:

- Intel® Xeon Phi™ processor 7250 enables this application to significantly outperform (time-to-solution) alternative processing solutions.
- Performance is enhanced by Intel® AVX512.

Results: Up to 2X improved performance compared to the Intel® Xeon® processor E5-2697 v4.

Geophysics

YASK HPC STENCILS, ISO3DFD KERNEL



See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF May, 2016

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

Application: YASK, iso3dfd stencil

Code: Available here

Recipe: 1536*1024*768 problem size (see command lines in next slide)

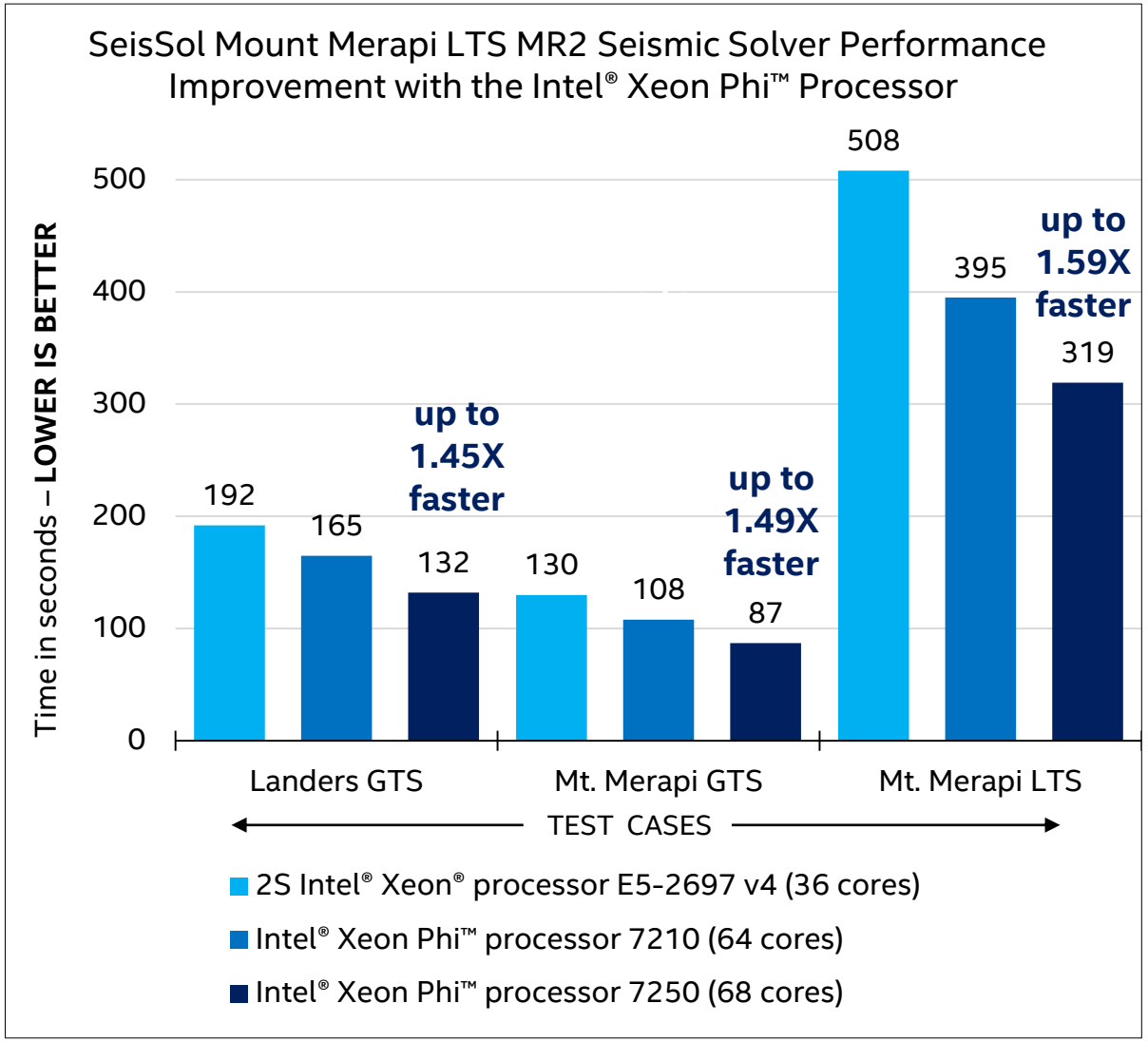
Image Source: US Dept. Energy

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

Results: Up to 2.9X improved performance compared to the Intel® Xeon® processor E5-2697 v4.

Geophysics

SEISSOL MOUNT MERAPI LTS MR2 SEISMIC SOLVER*



See next slide for configuration details.

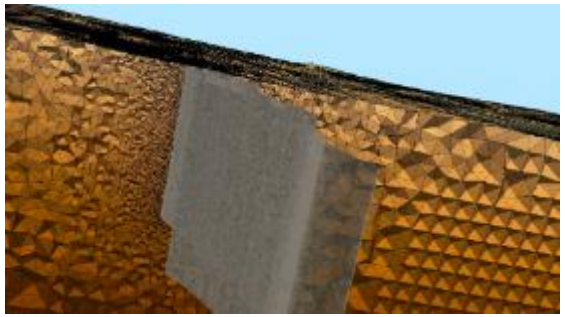
SOURCE: INTEL MEASURED RESULTS AS OF MARCH, 2016

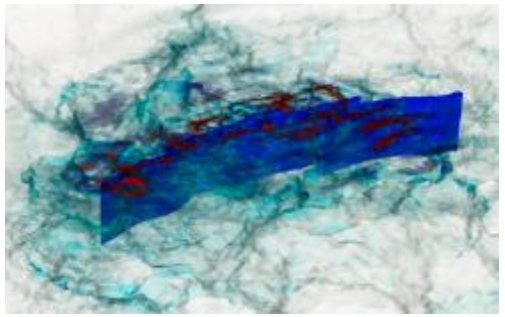
SeisSol software simulates wave propagation and dynamic rupture based on the arbitrary high-order accurate derivative discontinuous Galerkin method (ADER-DG). Characteristics include tetrahedral meshes to approximate complex 3D model geometries and rapid model generation use of elastic, viscoelastic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

Application: SeisSol Mount Merapi LTS MR2 Seismic Solver.

Code: Available here

Recipe: Download code and follow instructions





Images Source: Intel Labs

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

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

Technical, Enterprise & Cloud Development Tools

- C++ and Fortran Compilers
- Standards Driven Parallel Programming Models & Libraries
- Performance Profiling for Optimization and Tuning
- Threading & Vectorization Design & Analysis for Performance

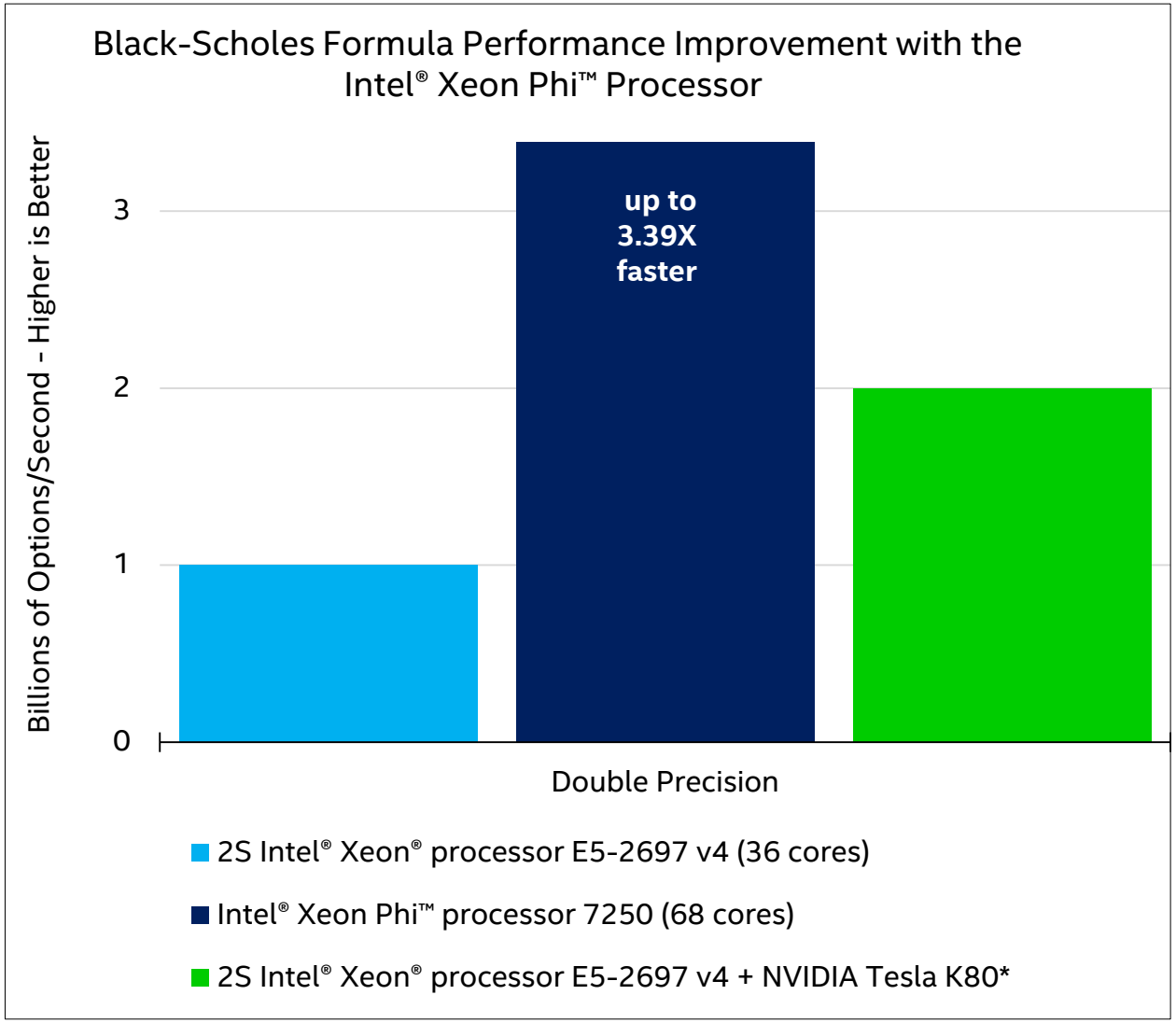
- Powerful Data Analytics, Machine Learning and Scientific Compute Libraries
- Coming Soon – High Performance Python Distribution

intel Software

Faster Code *Faster*

Financial Services

BLACK-SCHOLES BENCHMARK*



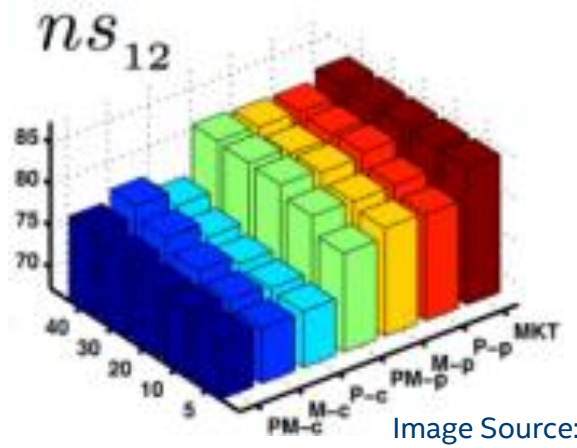
See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF MAY, 2016

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

Application: Black-Scholes formula

- **Code:** Currently not available **Recipe:** Currently not available



$$C(S,t) = N(d_1)S - N(d_2)Ke^{-r(T-t)}$$

$$d_1 = \frac{1}{\sigma\sqrt{T-t}}\left[\ln\left(\frac{S}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)(T-t)\right]$$

$$d_2 = \frac{1}{\sigma\sqrt{T-t}}\left[\ln\left(\frac{S}{K}\right) + \left(r - \frac{\sigma^2}{2}\right)(T-t)\right]$$

$$= d_1 - \sigma\sqrt{T-t}$$

Image Source: US gov

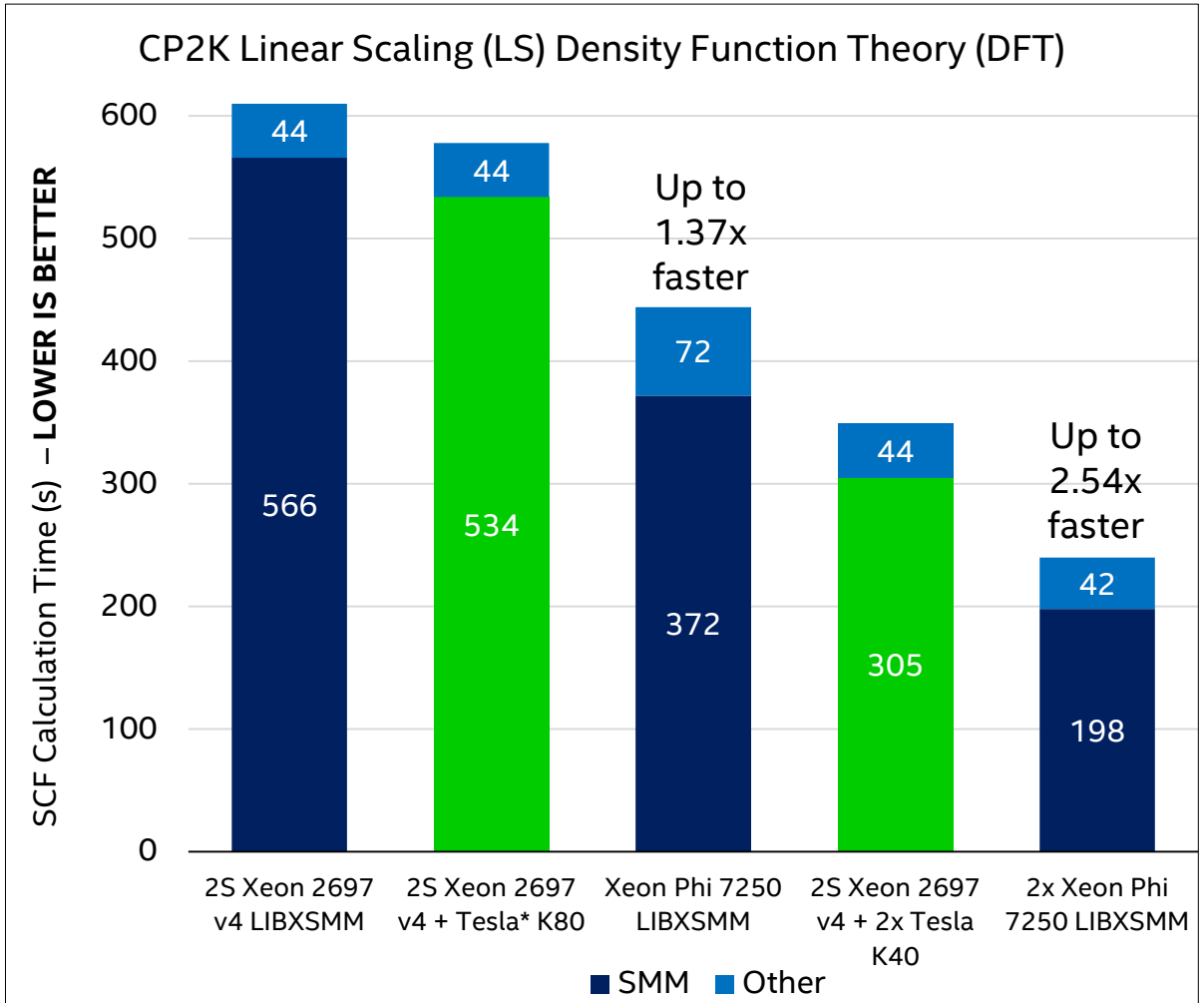
Value Proposition:

- Foundation of financial derivatives pricing
- Widely used all over financial libraries
- Performance enhanced by Intel® AVX512 and MCDRAM

Results: Up to 4.3X improved Double Precision compared to the Intel® Xeon® processor E5-2697 v4 and up to 2.5X better than NVIDIA Tesla*.

Material Sciences

LINEAR SCALING (LS) DENSITY FUNCTION THEORY (DFT)



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

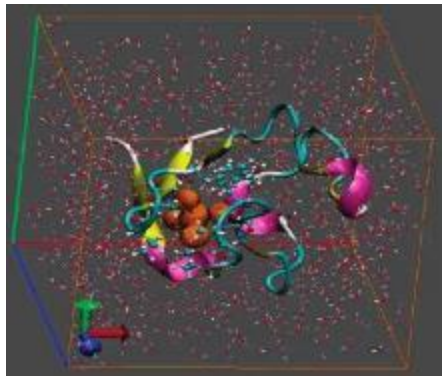
See next slide for configuration details.

MEASUREMENT: CP2K (Intel), LIBCUSMM (K40, K80)

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

Application: CP2K Quantum Chemistry & Solid State Physics Software Package

Code: Available Here



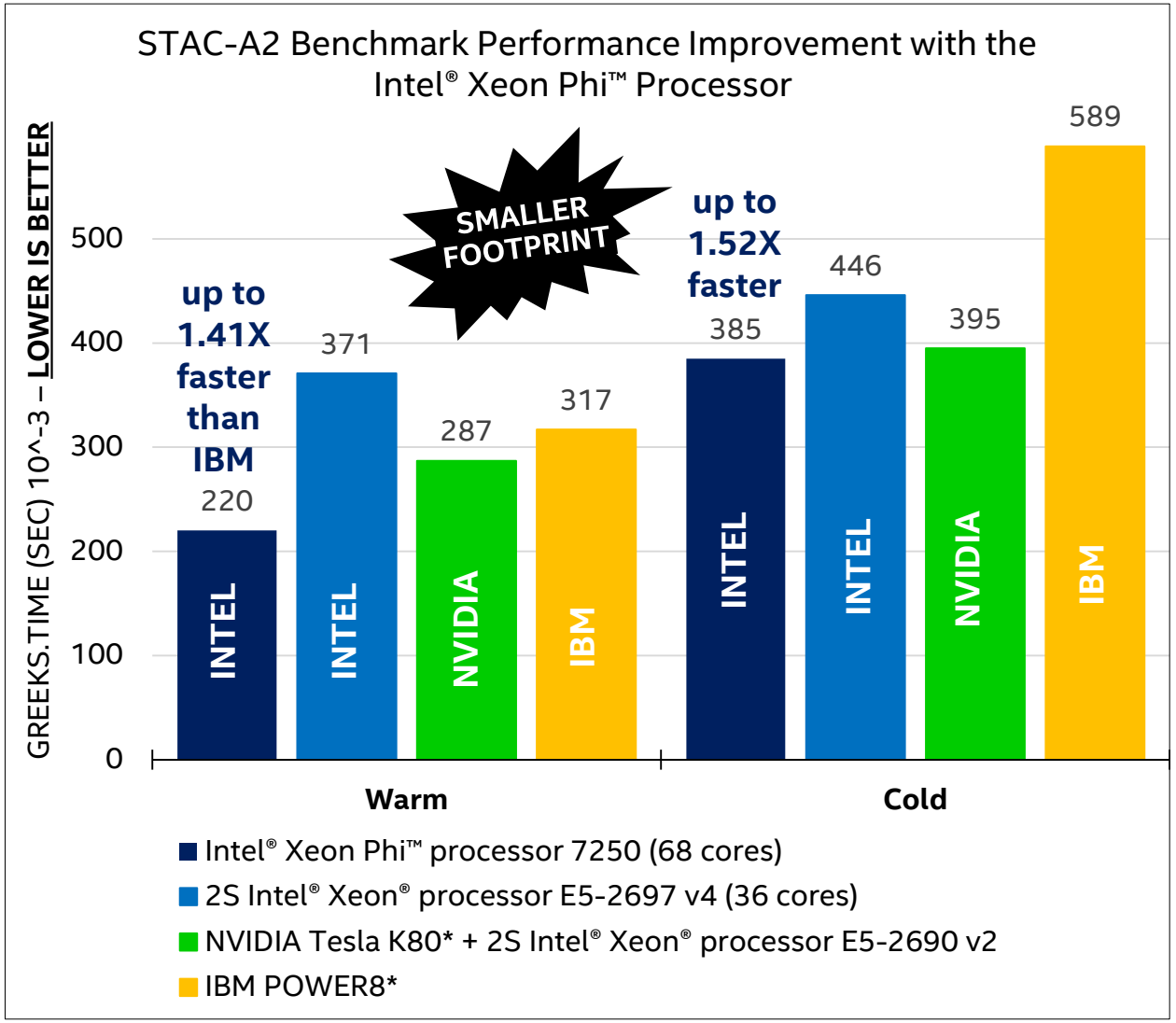
Courtesy of ETH Zurich. (url)

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

Results: Up to 1.37X faster with the Intel® Xeon Phi™ processor 7250 compared to the Intel® Xeon® processor E5-2697 v4.

Financial Services

STAC-A2* BENCHMARK



See next slide for configuration details.

SOURCE: STAC* AUDITED RESULTS AS OF MAY 2016

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

Application: Intel Composer XE STAC Pack Rev. H

Code: Available here

Recipe: Available here

STAC™ BENCHMARK COUNCIL

"STAC" and all STAC names are trademarks or registered trademarks of the Securities Technology Analysis Center LLC.

Image Source: Intel

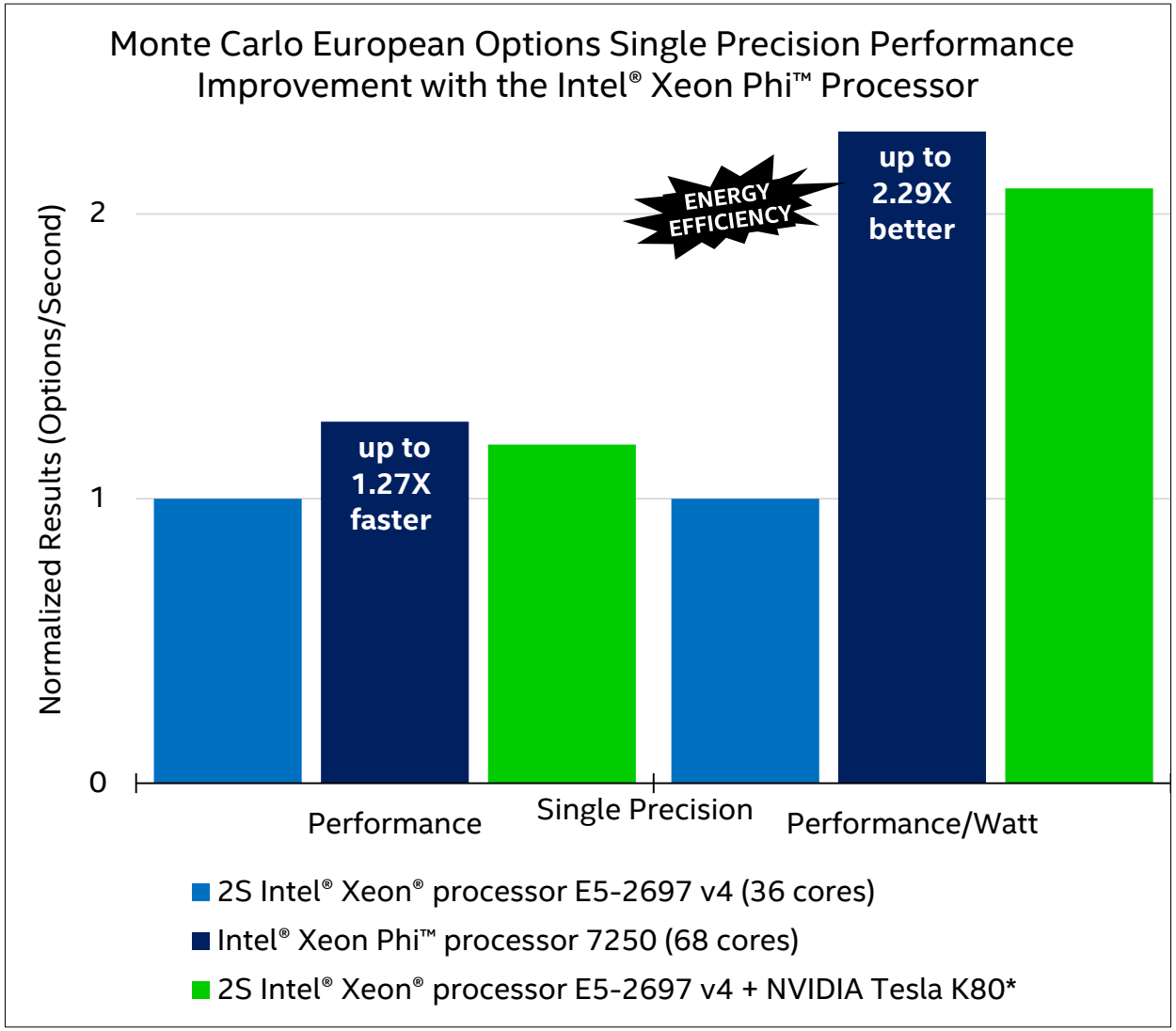
Value Proposition:

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

Baseline problem size results: The Intel® Xeon Phi™ 7250 processor system is up to 1.2X faster than next competitor (NVIDIA K80* system) in warm runs, and is up to 2X more power efficient and is up to 5.7X more space efficient compared to the IBM Power8 system.

Financial Services

BINOMIAL TREE OPTION PRICING BENCHMARK*



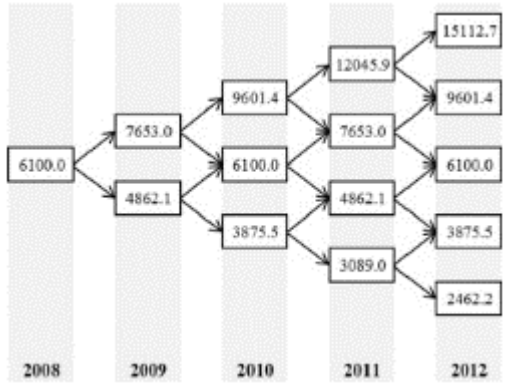
See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF MAY, 2016

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

Application: Binomial Tree Option Pricing

Code: Currently not available **Recipe:** Currently not available



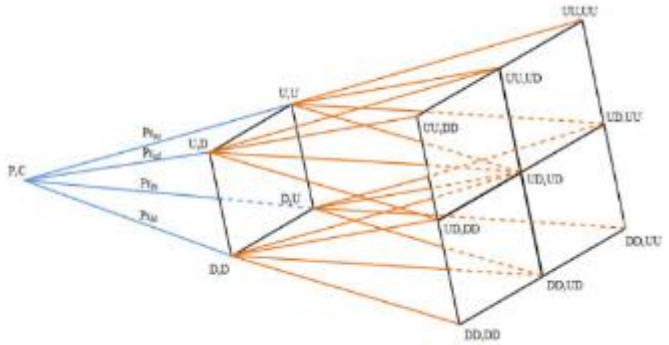


Image Source: Science Direct

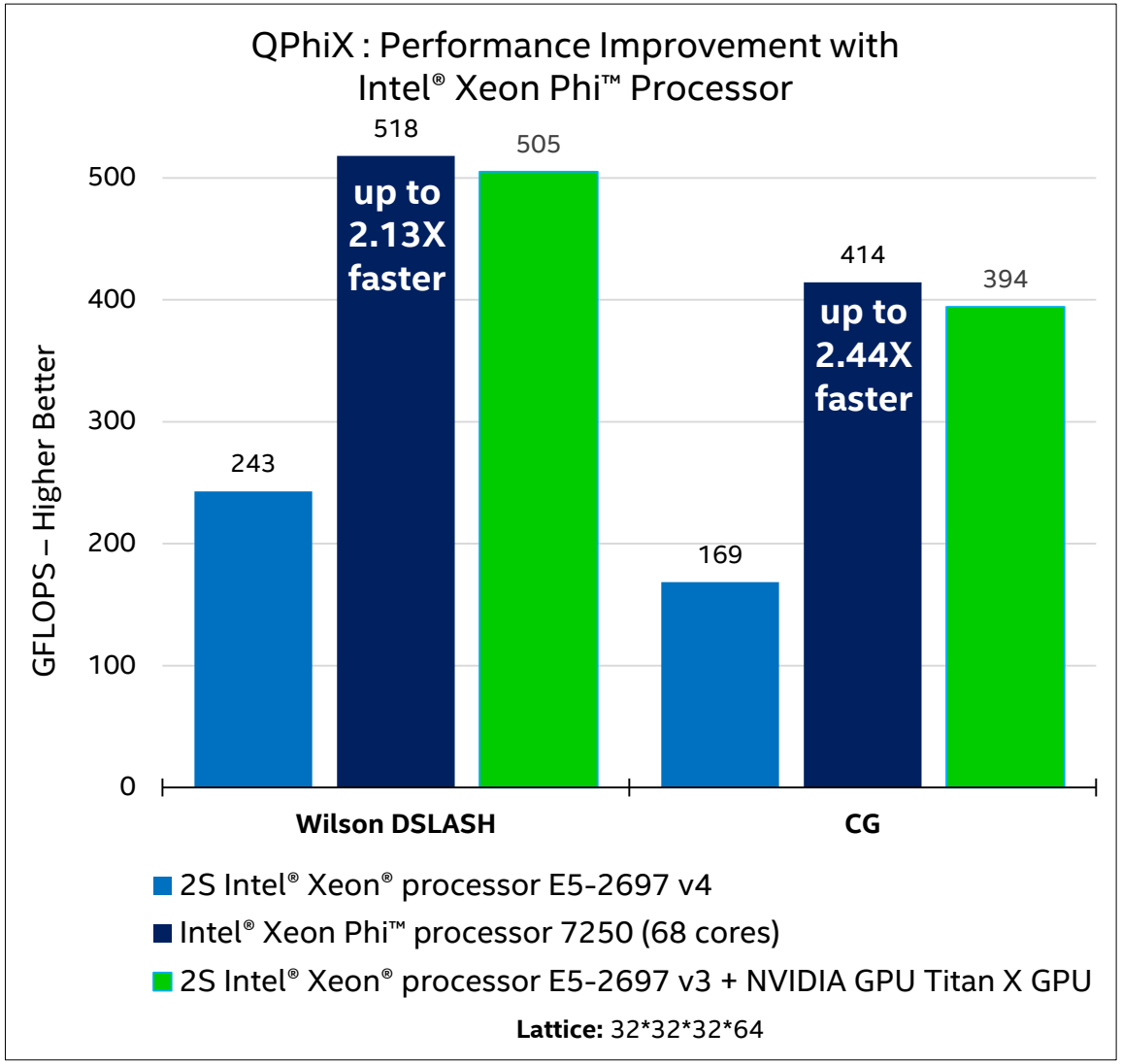
Value Proposition:

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

Results: Up to 1.27X improved Single Precision performance compared to Intel® Xeon® processor E5-2697 v4, and up to 1.09X better performance/watt compared to NVIDIA Tesla*.

Physics - QCD

QPHIX*



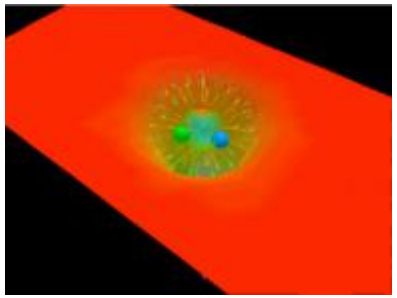
See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF MAY, 2016

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

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

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



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

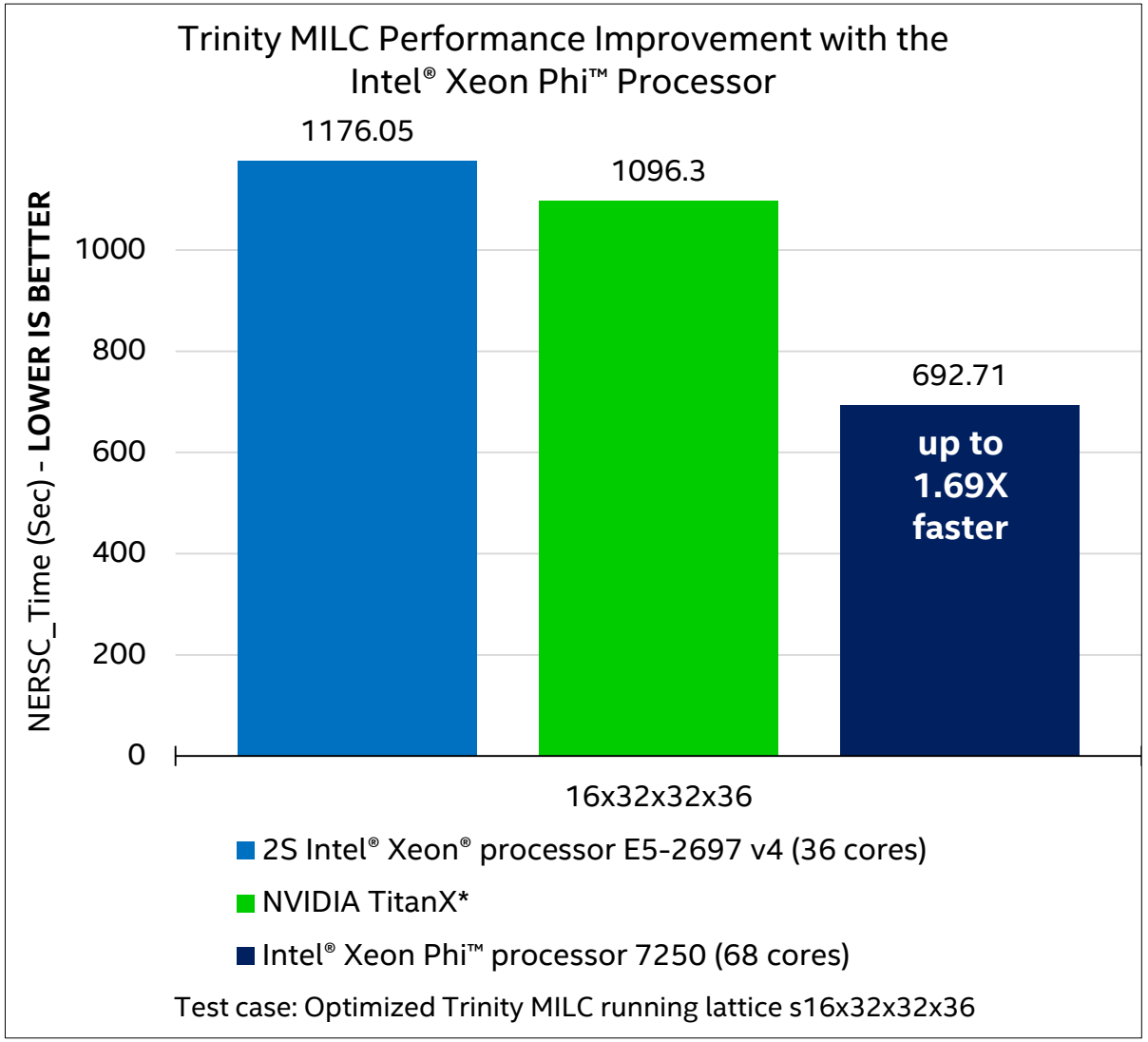
Value Proposition:

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

Results: up to 2.44X improved performance compared to the Intel® Xeon® processor E5-2697 v4. CG performance is ~1.05x better vs. QUDA on a NVIDIA* Titan X* GPU.

Physics - QCD

MILC*



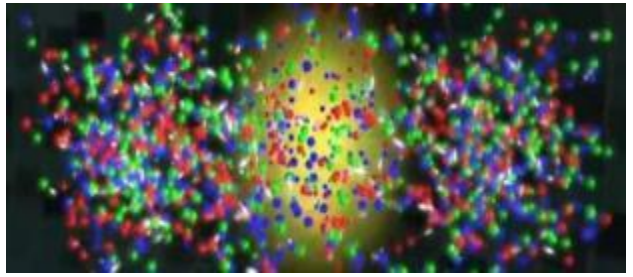
See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF May 2016

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

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

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



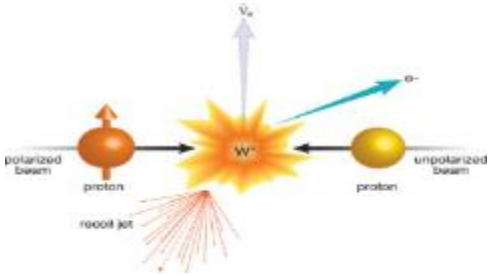


Image Credit: Brookhaven Lab (BNL)

Value Proposition:

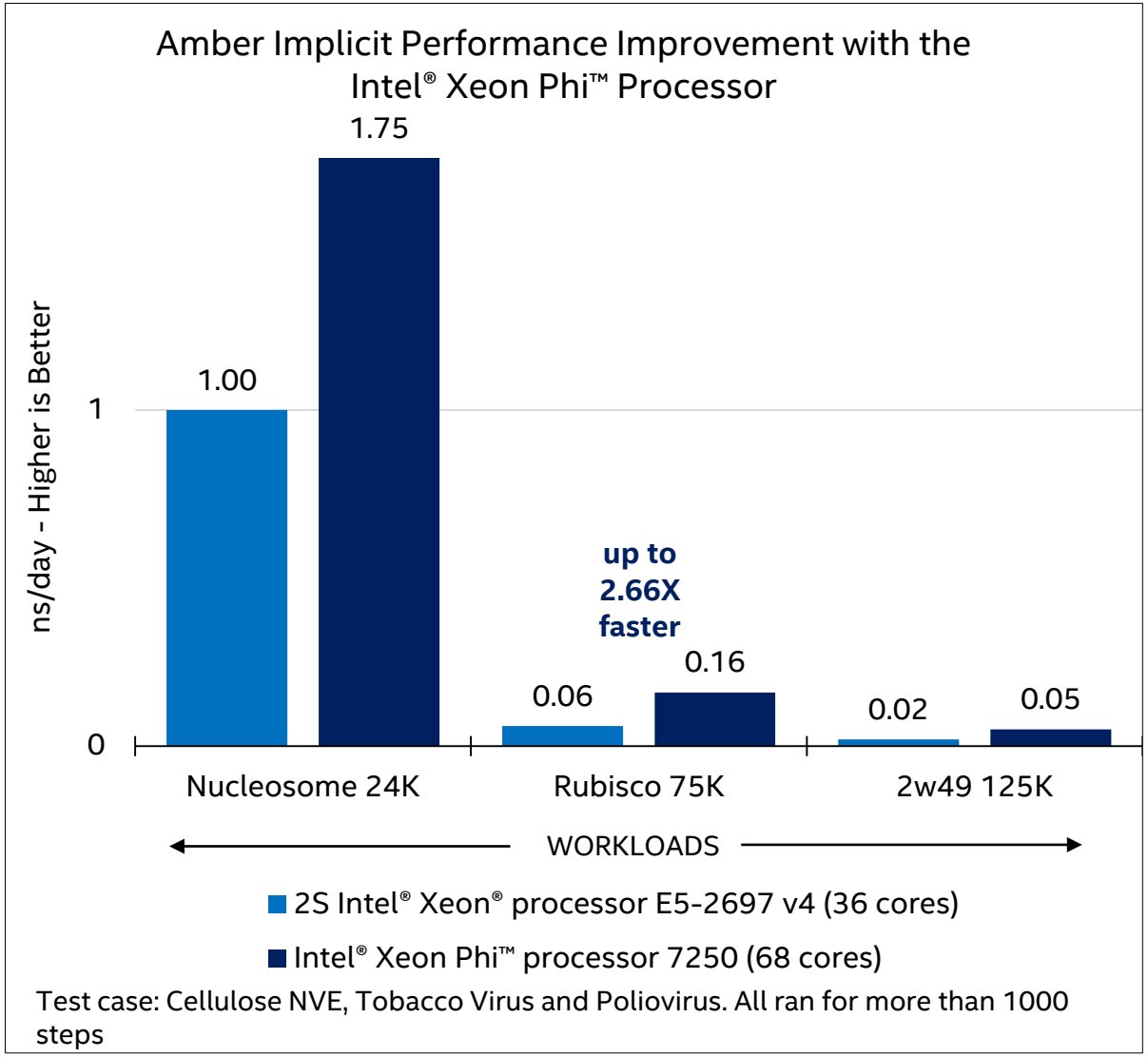
- MILC is widely deployed on numerous supercomputers and 2nd most used application at US DOE's National Energy Research Scientific Computing Center (NERSC)
- Intel's optimizations are being incorporated into mainline by MILC collaboration
- Intel® Xeon Phi™ processor 7250 enables to run larger problem size per node

Results:

The Intel® Xeon Phi™ processor 7250 improved performance by up to 1.69X and 1.5Xx compared to the Intel® Xeon® processor E5-2697 v4 and NVIDIA TitanX respectively

Life Sciences

AMBER 16 PMEMD IMPLICIT*



Test case: Cellulose NVE, Tobacco Virus and Poliovirus. All ran for more than 1000 steps

See next slide for configuration details.

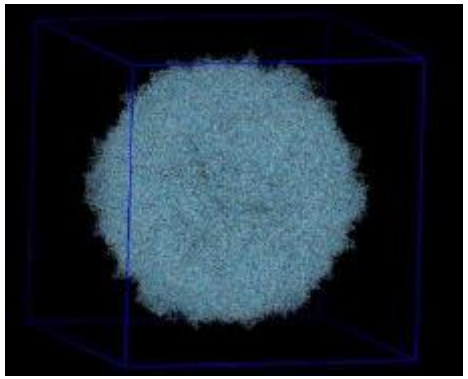
SOURCE: INTEL MEASURED RESULTS AS OF APRIL 2016

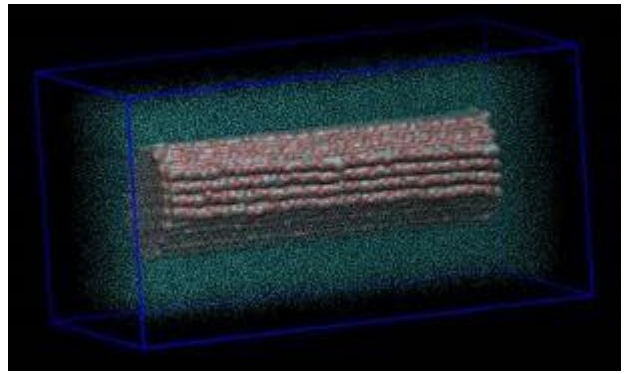
Amber* is a bio related simulation code for DNA, RNA, protein, and other bio-molecules. Particle Mesh Ewald Molecular Dynamics (PMEMD) is an Amber tool used for Molecular Dynamic Simulation. PMEMD includes two algorithms, Explicit and Implicit. PMEMD is written in Fortran 90 and is mainly MPI*, OpenMP*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

Application: Amber 16 PMEMD Implicit

Code: License required from http://ambermd.org/

Recipe: ./configure –intelmpi –openmp –mic2 intel
On Intel® Xeon®: make install AMBERBUILDFLAGS="-xMIC-AVX512"
On Intel® Xeon Phi™ : make install





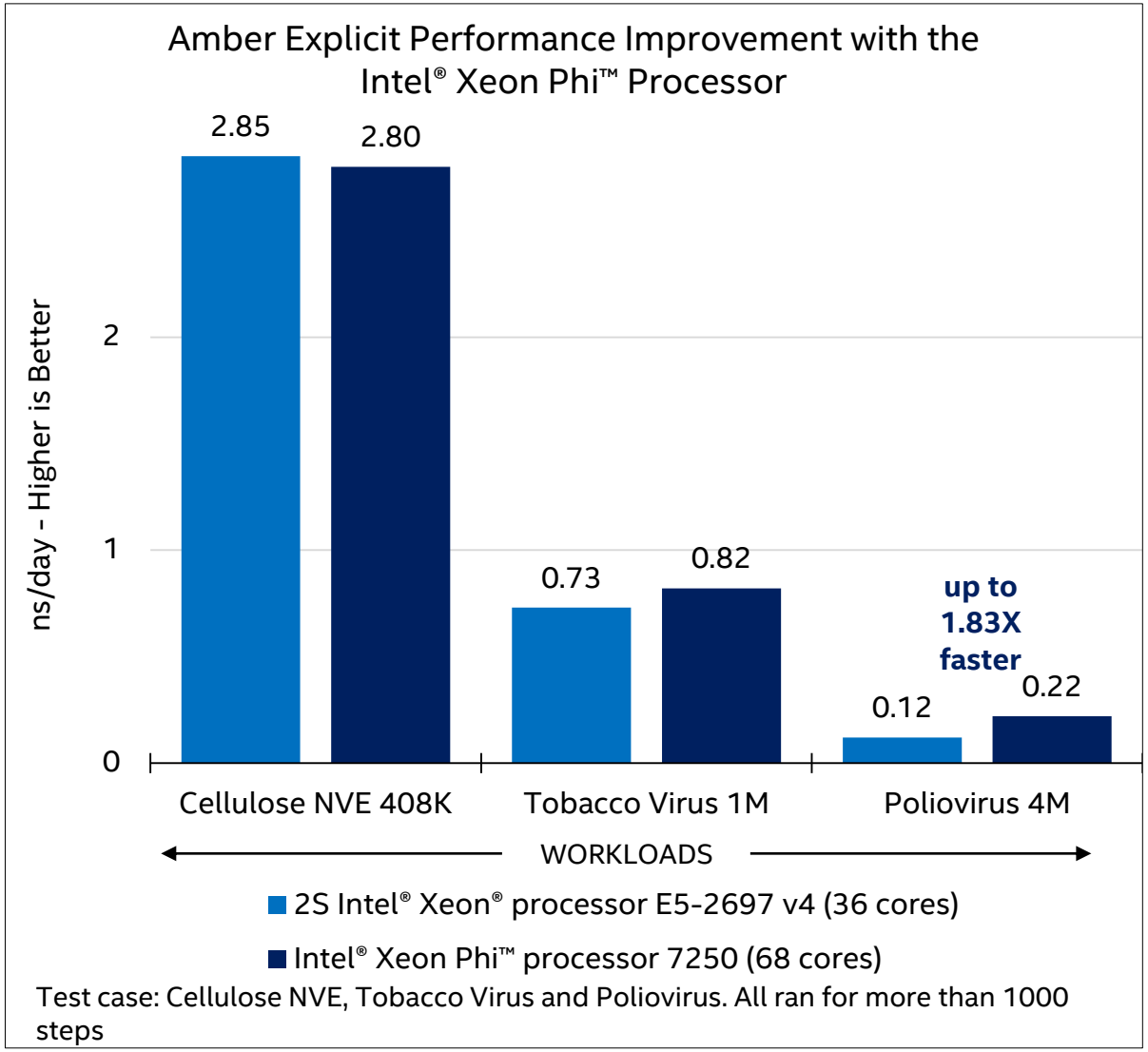
Images Source: Intel

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

Results: Up to 2.7X improved performance compared to the Intel® Xeon® processor E5-2697 v4 for the Rubisco workload.

Life Sciences

AMBER 16 PMEMD EXPLICIT*



Test case: Cellulose NVE, Tobacco Virus and Poliovirus. All ran for more than 1000 steps

See next slide for configuration details.

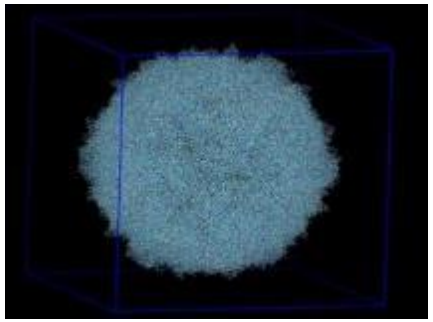
SOURCE: INTEL MEASURED RESULTS AS OF APRIL 2016

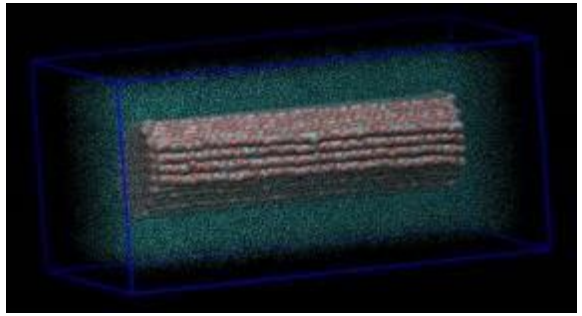
Amber* is a bio related simulation code for DNA, RNA, protein, and other bio-molecules. Particle Mesh Ewald Molecular Dynamics (PMEMD) is an Amber tool used for Molecular Dynamic Simulation. PMEMD includes two algorithms, Explicit and Implicit. PMEMD is written in Fortran 90 and is mainly MPI*, OpenMP*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

Application: Amber 16 PMEMD Explicit.

Code: License required from http://ambermd.org/

Recipe: ./configure –intelmpi –openmp –mic2 intel
On Intel® Xeon®: make install AMBERBUILDFLAGS="-xMIC-AVX512"
On Intel® Xeon Phi™ : make install





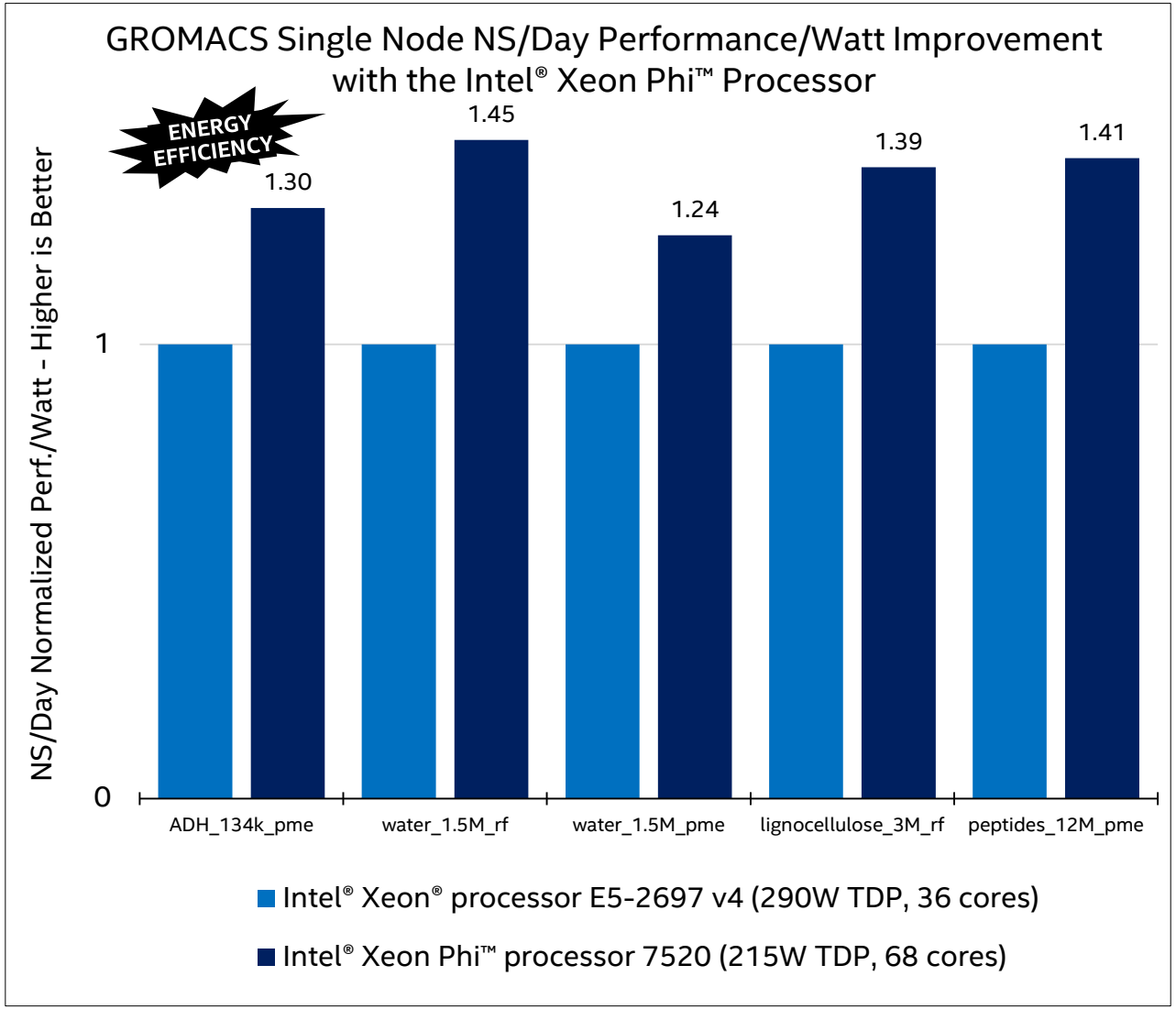
Images Source: Intel

Value Proposition: This application provides users with a research tool for investigating code modernization approach for Bio-molecular dynamics applications. KNL is best suited for larger problem sizes.

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

Life Sciences

GROMACS*



See next slide for configuration details.

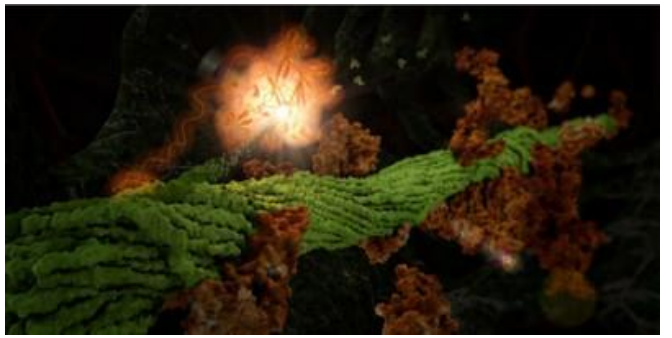
SOURCE: INTEL MEASURED RESULTS AS OF JUNE 2016

GROMACS (GROningen MAchine for Chemical Simulations) is a versatile package to perform classical Molecular Dynamics simulations. Heavily optimized for most modern platforms and provides extremely high performance compared to all other MD codes.

Application: GROMACS

Code: Available here

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



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

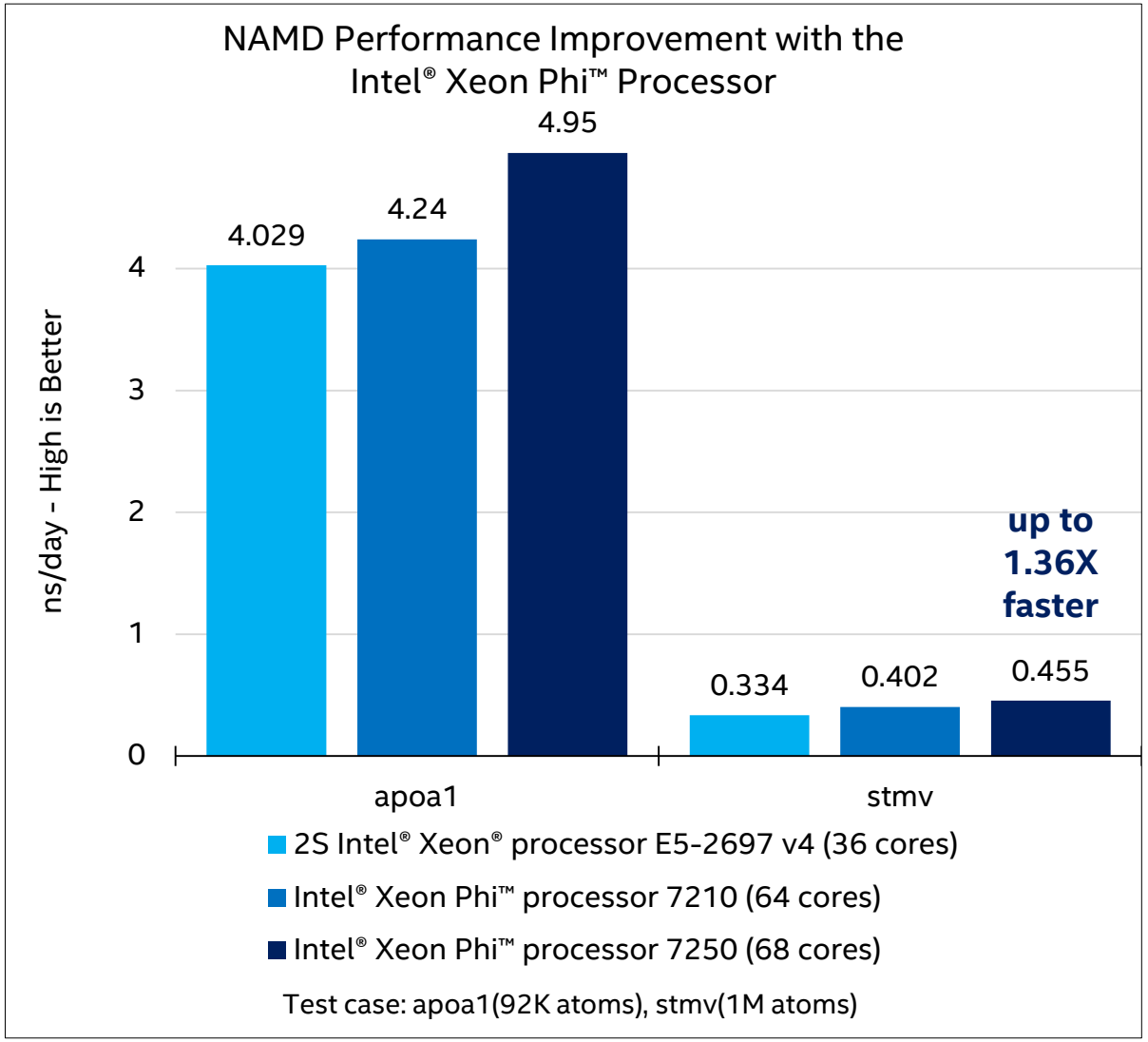
Images Source: Used with permission

Value Proposition: This application provides users with wide range of functionality for chemical simulations and highest out-of-the-box performance across all MD codes. GROMACS on the Intel® Xeon Phi™ processor outperforms Intel® Xeon® processors for simulating large biochemical systems due to enabling new Intel® AVX512 features and enabling enhanced parallelism and provides more performance simulations within the same energy envelope.

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

Life Sciences

NANOSCALE MOLECULAR DYNAMICS PROGRAM*



See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF APRIL 2016

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

Application: NAMD 2.11

Code: http://www.ks.uiuc.edu/Research/namd/

Recipe: Under development for external release

NAMD Scalable Molecular Dynamics

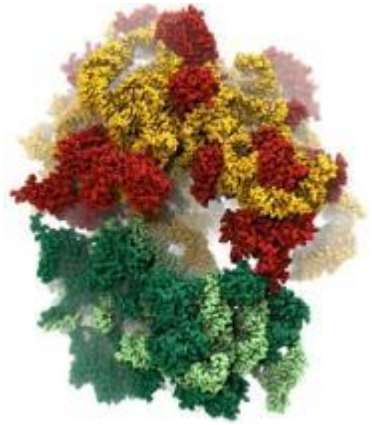


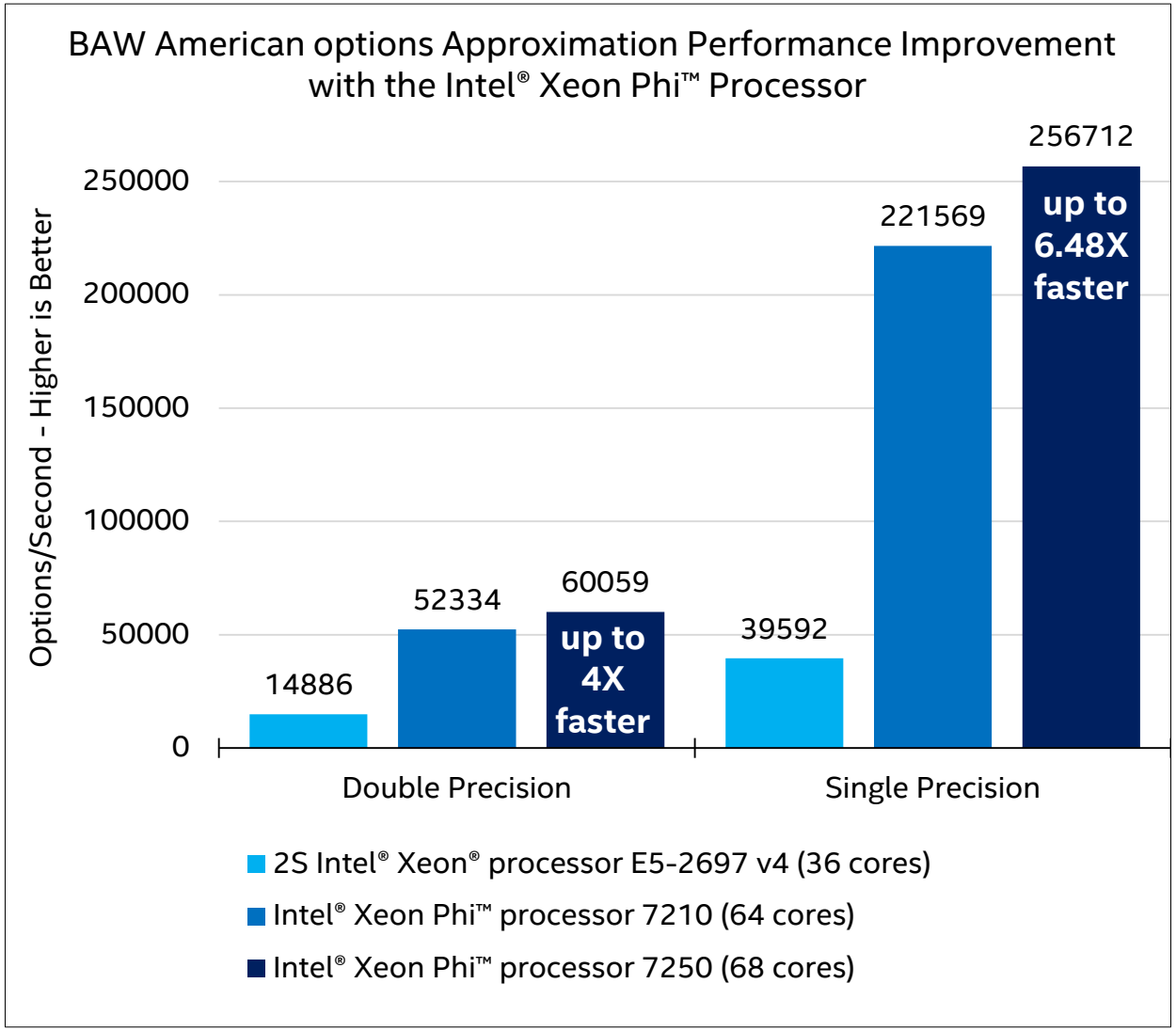
Image Source: Use approved by NAMD

Value Proposition: NAMD is the 2nd most popular MD code. Intel® AVX 512 instructions are used heavily by the Assembler code. Source code performance tuning with intrinsics demonstrates advantages of MCDRAM and SMT 4.

Results: Up to 1.36X improved performance compared to the Intel® Xeon® processor E5-2697 v4.

Financial Services

BAW AMERICAN OPTIONS APPROXIMATION BENCHMARK*



See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF MAY, 2016

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

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

Code: Currently not available **Recipe:** Available here (Original C/++, re-implemented on IA using parallel programming techniques)

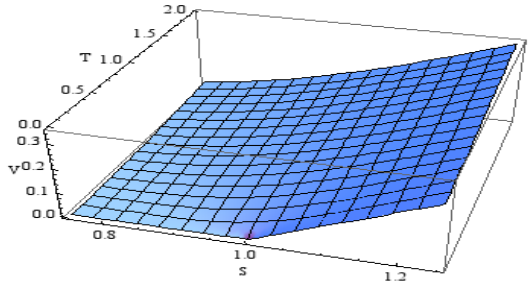
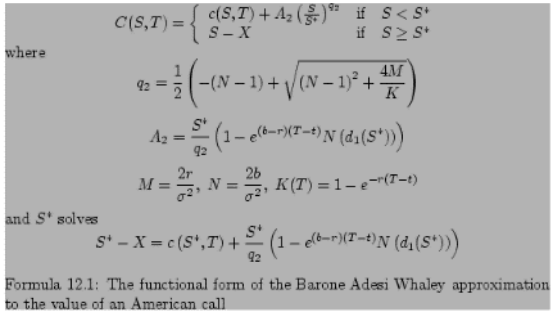


Image Sources: Parsiad.azimzadeh, finance.bi.no



$$C(S,T) = \begin{cases} c(S,T) + A_2\left(\frac{S}{S^*}\right)^{q_2} & \text{if } S < S^* \\ S - X & \text{if } S \geq S^* \end{cases}$$

where

$$q_2 = \frac{1}{2}\left(-(N-1) + \sqrt{(N-1)^2 + \frac{4M}{K}}\right)$$

$$A_2 = \frac{S^*}{q_2}\left(1 - e^{(b-r)(T-t)}N\left(d_1(S^*)\right)\right)$$

$$M = \frac{2r}{\sigma^2},\ N = \frac{2b}{\sigma^2},\ K(T) = 1 - e^{-r(T-t)}$$

and S^* solves

$$S^* - X = c(S^*,T) + \frac{S^*}{q_2}\left(1 - e^{(b-r)(T-t)}N\left(d_1(S^*)\right)\right)$$

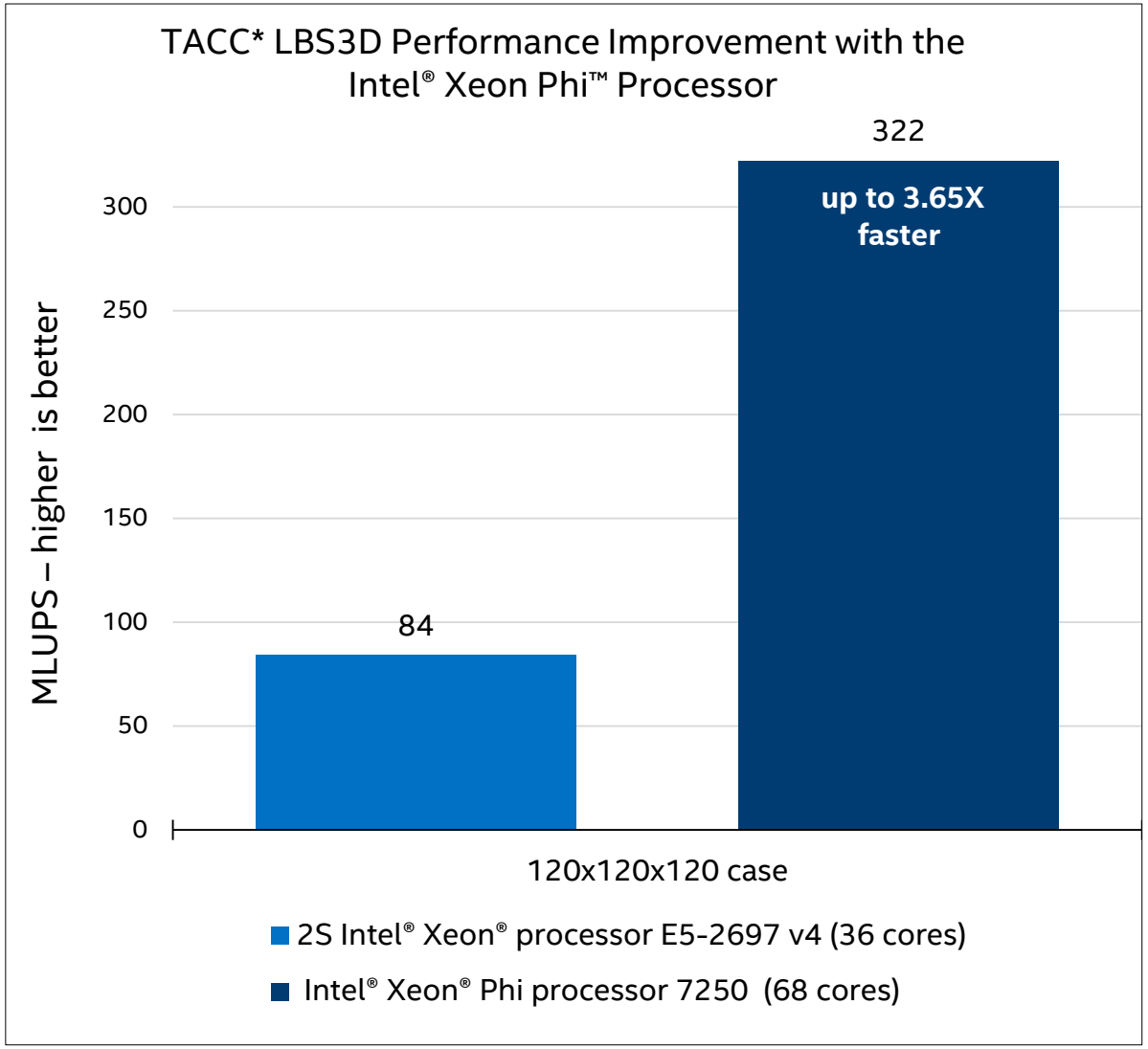
Formula 12.1: The functional form of the Barone Adesi Whaley approximation to the value of an American call

Value Proposition:

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

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

TEXAS ADVANCED COMPUTER CENTER LBS3D*



See next slide for configuration details.

SOURCE: TACC (Carlos Rosales-Fernandez) April 2016

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

Application: LBS3D (Advanced support for multiphase flows with large density and viscosity ratios)

Code: Available here

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

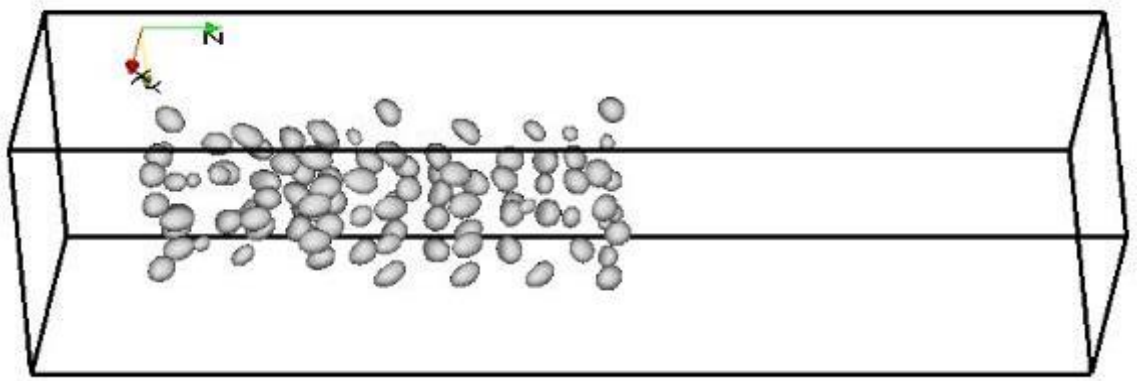


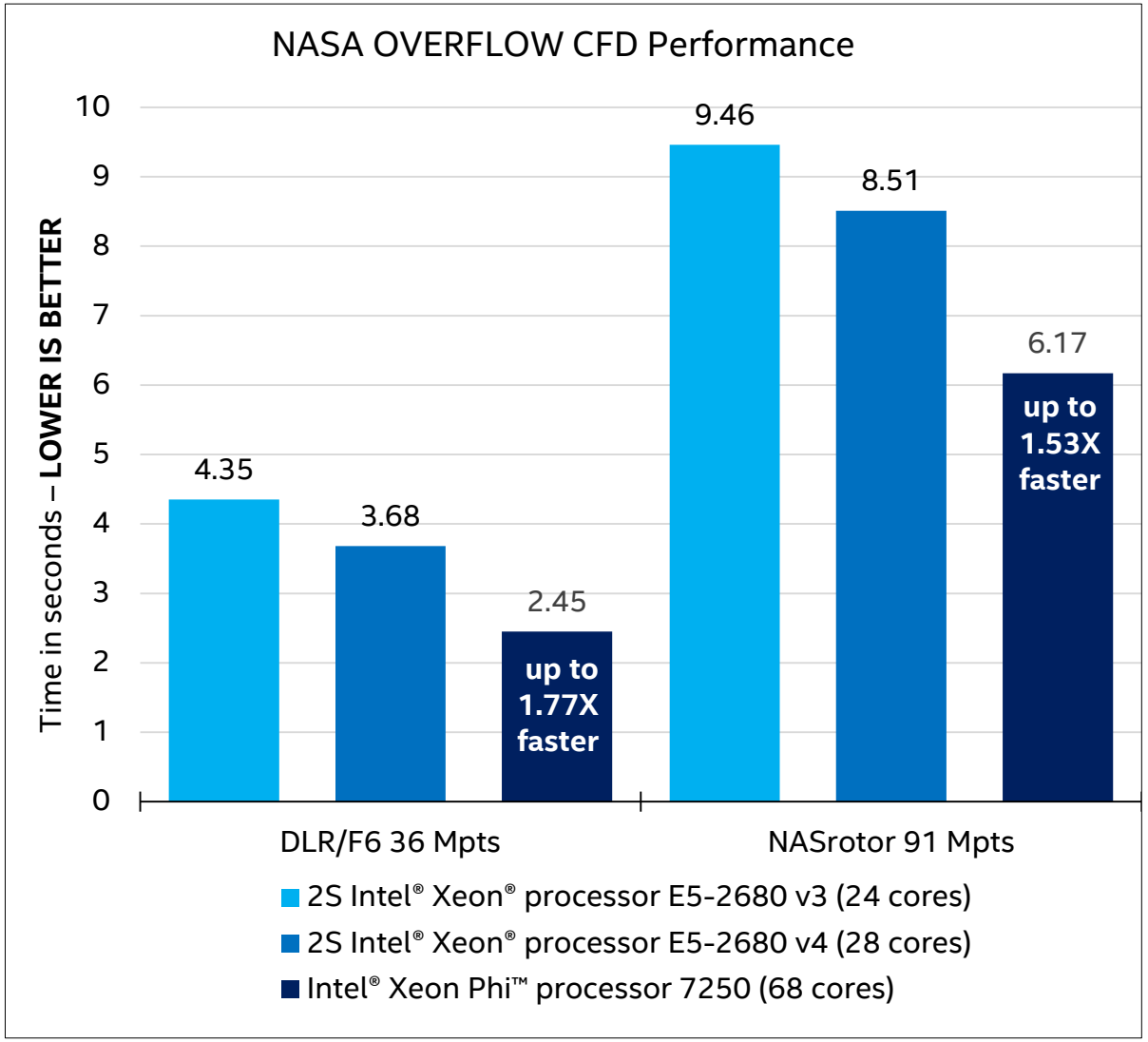
Image Source: Used with permission

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

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

Manufacturing

NASA OVERFLOW*



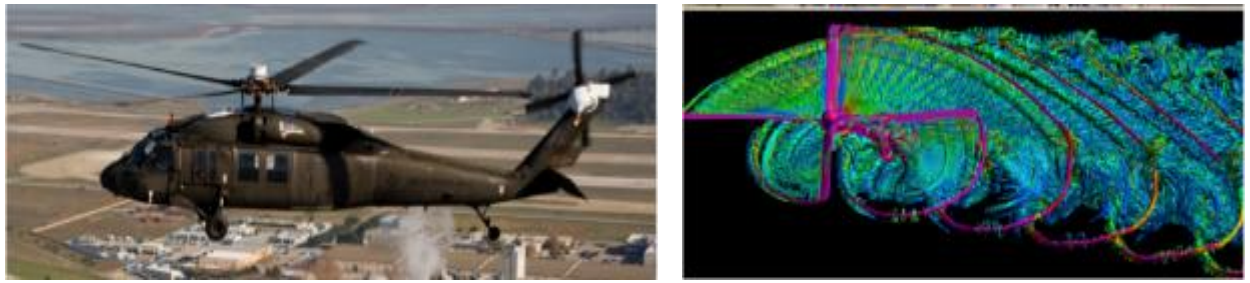
SOURCE: NASA/Ames (Dennis Jespersen) April 2016

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

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

Code: http://overflow.larc.nasa.gov/

Recipe: No code changes were required. Recompile with KNL AVX-512.



UH-60 Black Hawk helicopter and Navier-Stokes detached eddy simulation of a flexible UH-60 rotor using the OVERFLOW CFD code in forward flight.
Image Source: Neal Chaderjian and Tim Sandstrom, NASA/Ames

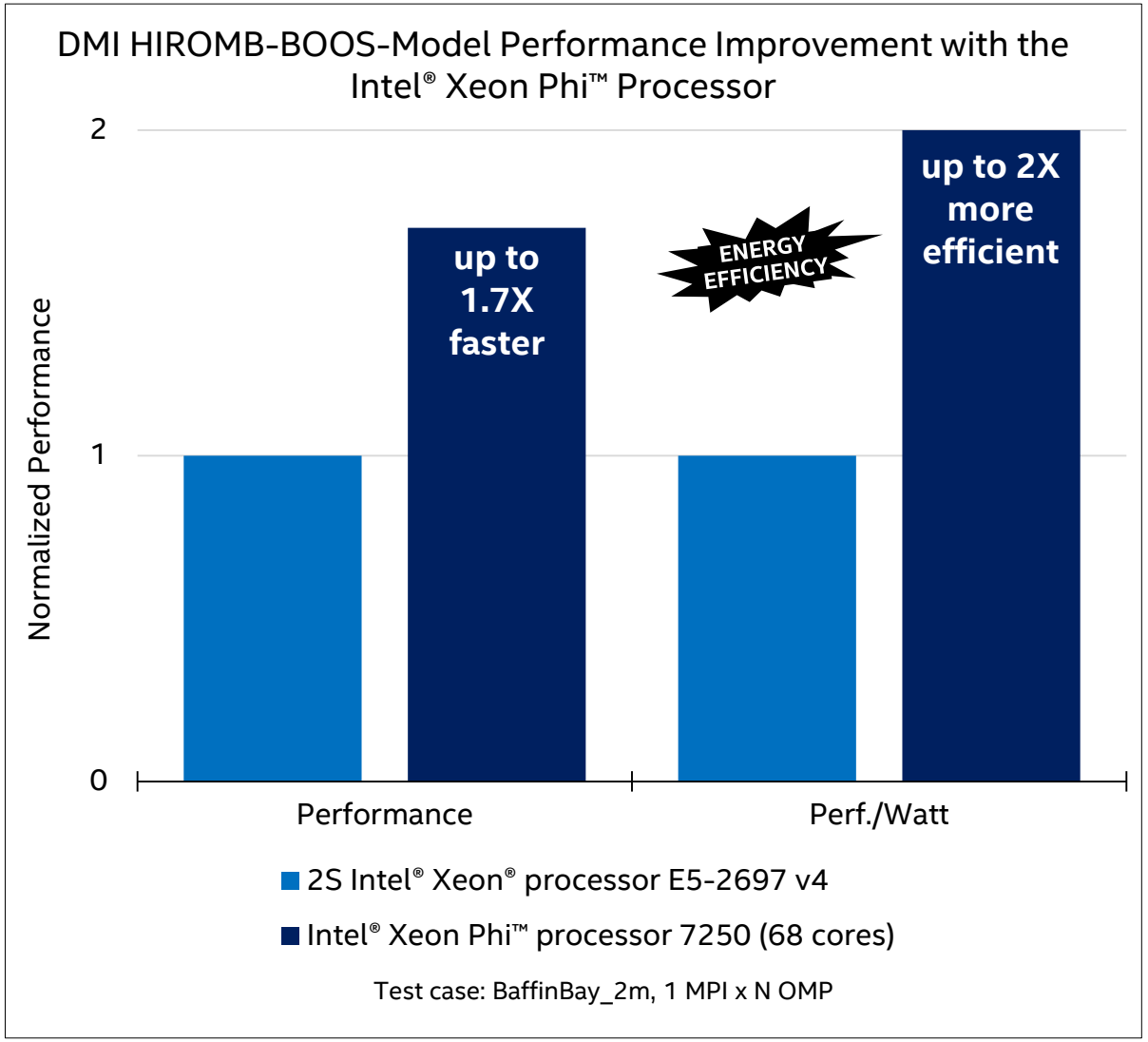
Value Proposition:

Overflow performance on KNL beats contemporary Haswell and Broadwell Architecture 2S servers. This provides better performance, performance density and better energy efficiency than today's best Intel Xeon processor based systems.

Results: Up to 1.78X performance improvement compared to the Intel® Xeon® processor E5-2680v3.

Climate & Weather

DANISH METEOROLOGICAL INSTITUTE HIROMB-BOOS-MODEL*



See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF MARCH, 2016

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

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

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

Recipe: TBD

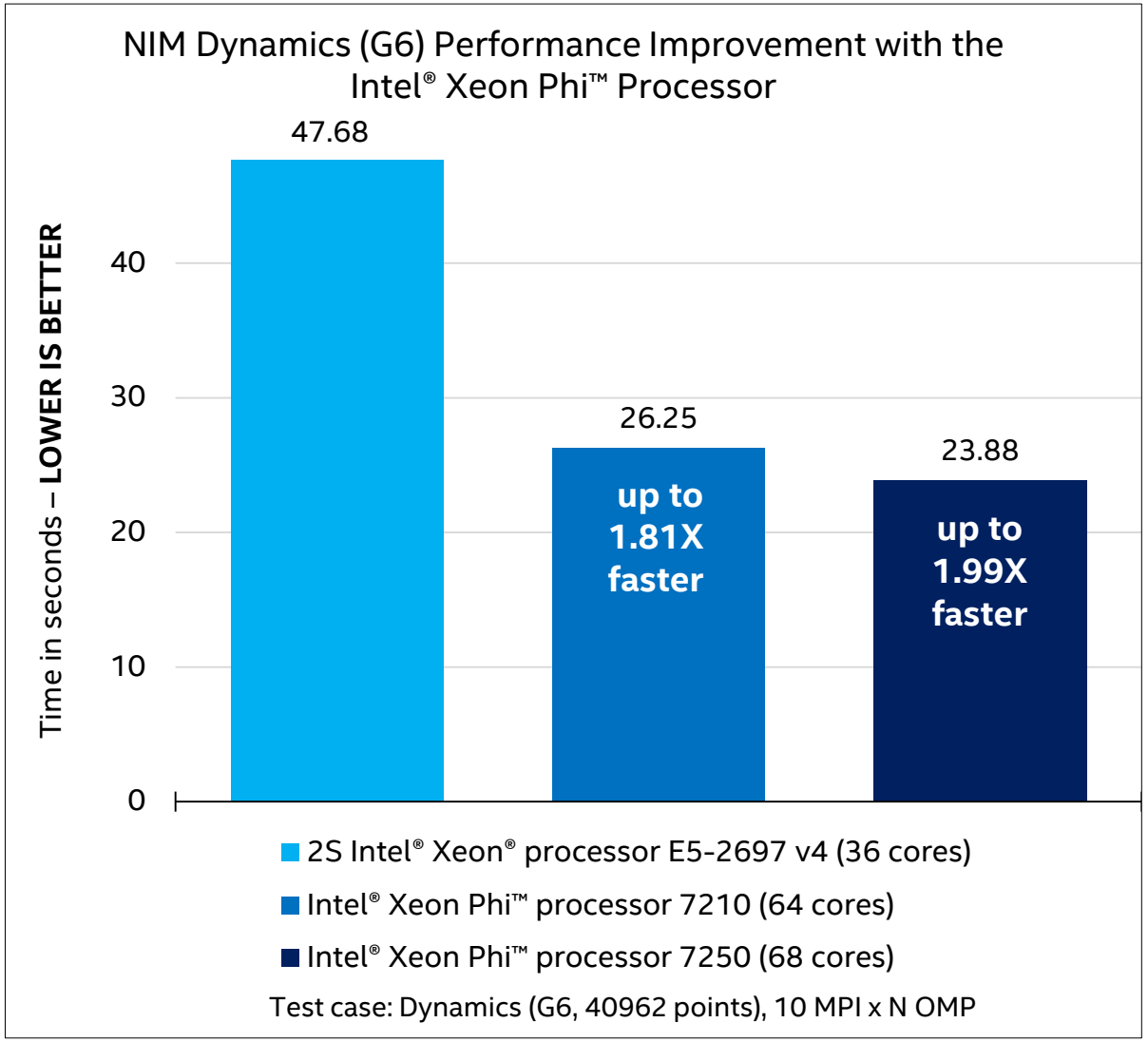
Image Source: DMI

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

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

Climate & Weather

NON-HYDROSTATIC ICOSAHEDRAL MODEL * (NIM)



See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF MARCH, 2016

Non-hydrostatic Icosahedral Model (NIM) is developed by NOAA's Earth System Research Laboratory. NIM is used for earth system modeling and weather and climate prediction. NIM is a multi-scale model designed to improve tropical convective clouds and to extend weather forecasts into intra-seasonal predictions.

Application: Non-hydrostatic Icosahedral Model

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

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

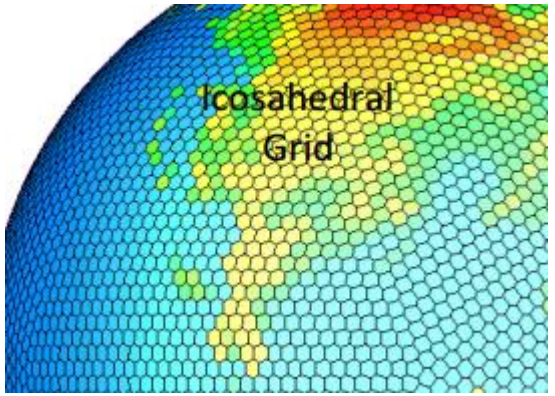


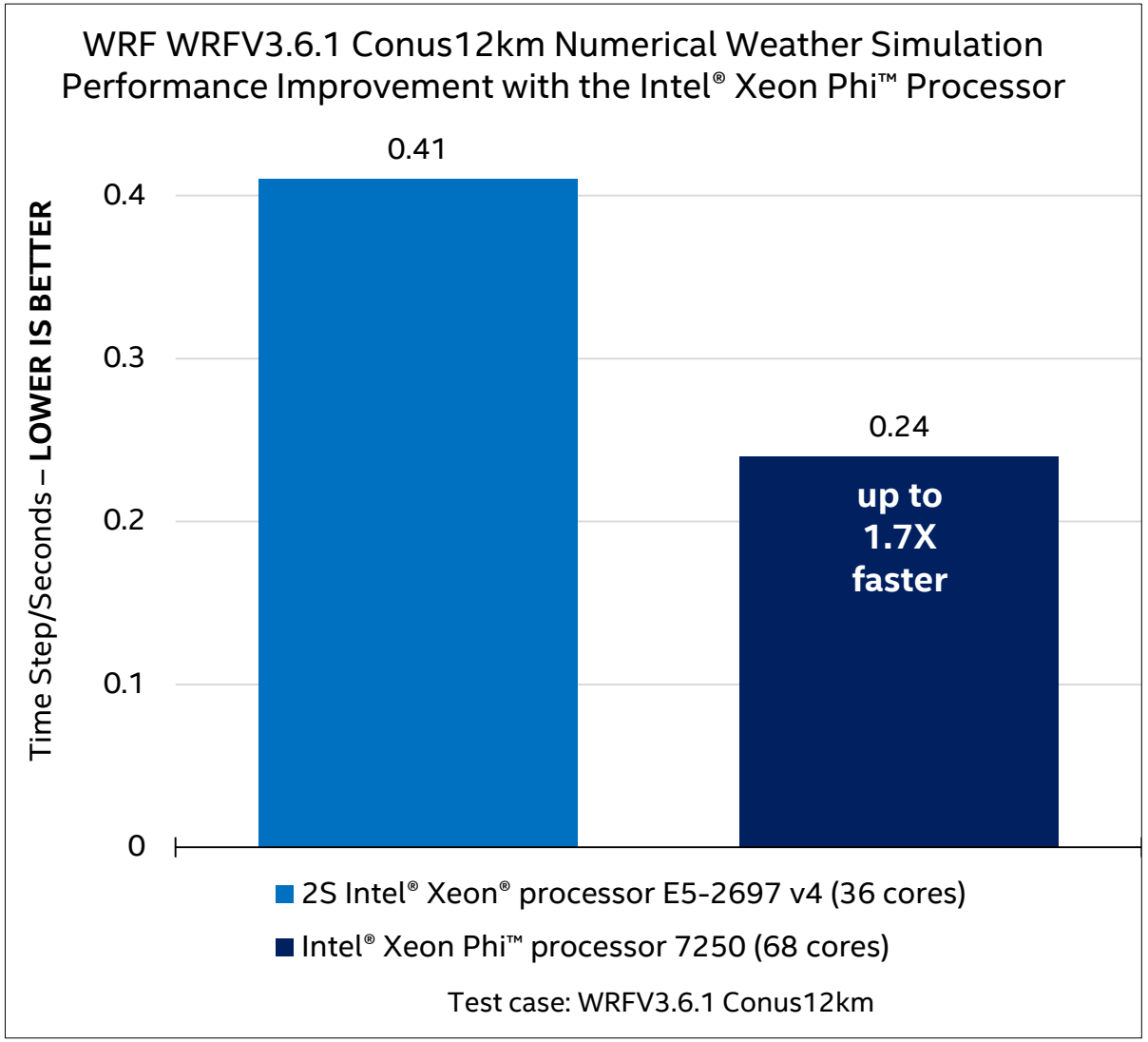
Image Source: NOAA

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

Results: Up to 1.99X performance improvement compared to the Intel® Xeon® processor E5-2697 v4.

Climate & Weather

WEATHER & RESEARCH FORECAST MODEL* NUMERICAL WEATHER SIMULATION



See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF FEBRUARY, 2016

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

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

Code: Available here. (WRF 3.6 & 3.6.1) **Recipe:** Not available.

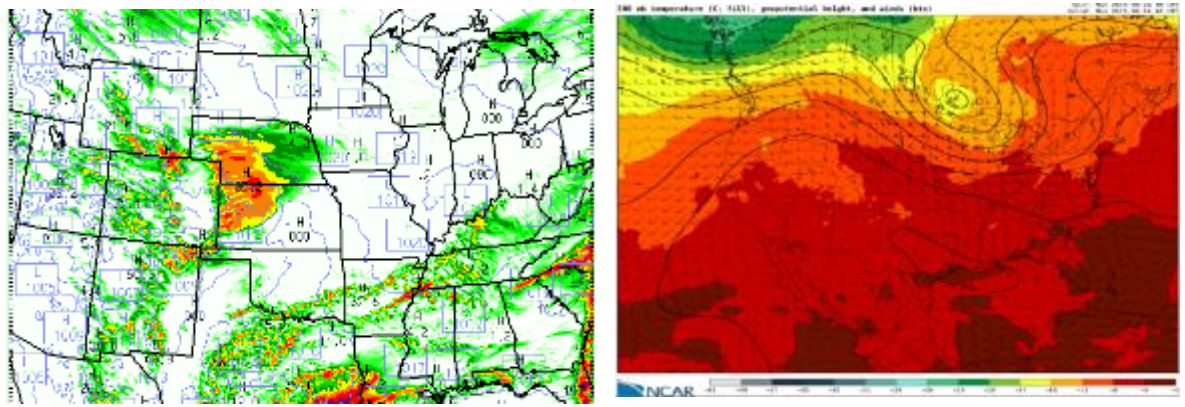


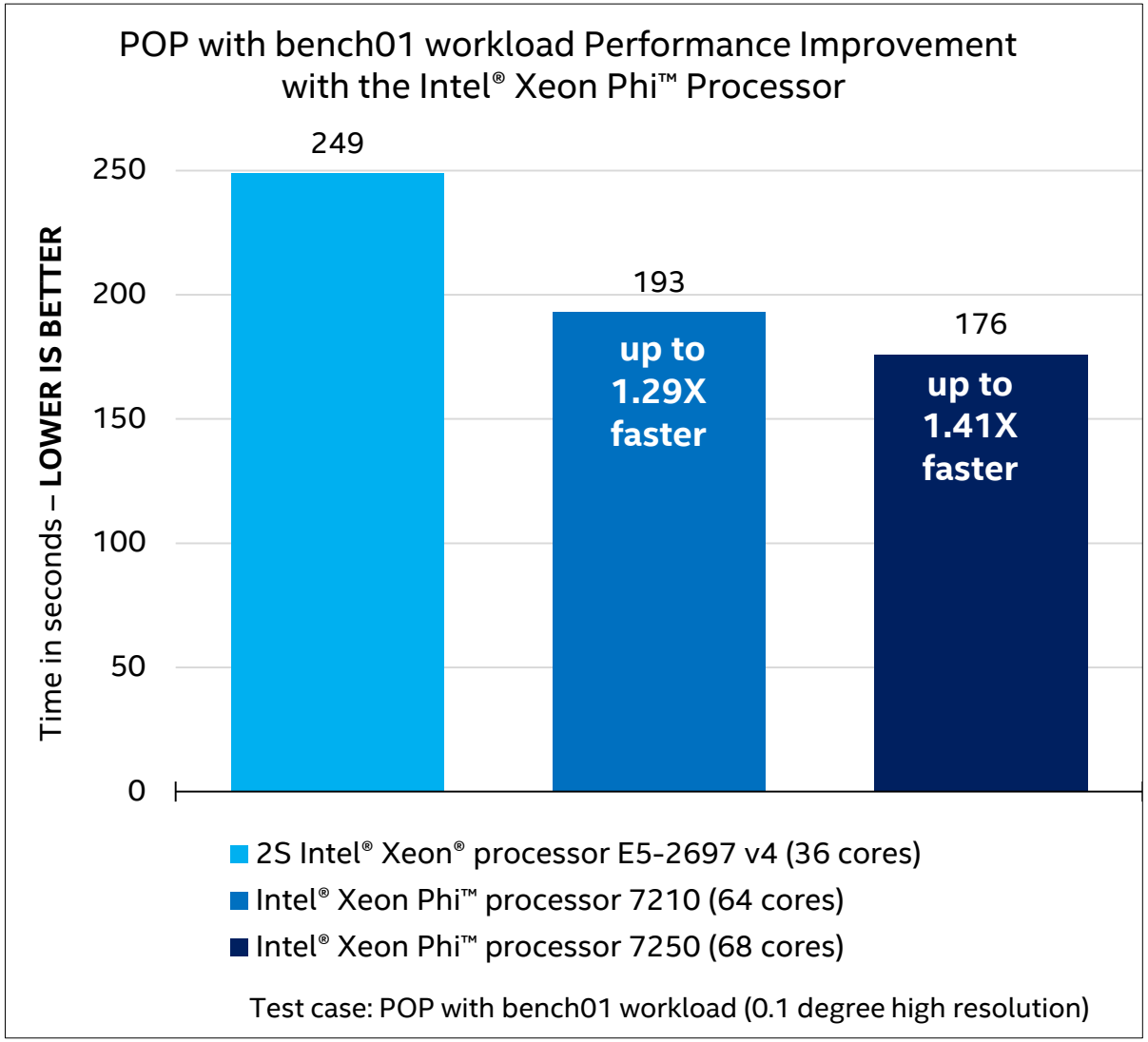
Image Source: NOAA

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

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

Climate & Weather

PARALLEL OCEAN PROGRAM*



See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF MARCH, 2016

Parallel Ocean Program (POP) is an ocean circulation model that solves the three-dimensional primitive equations for ocean dynamics. It consists of the baroclinic and barotropic solvers that solve 3-D equations explicitly and 2-D surface pressure implicitly, respectively. It is widely used for oceanography. The code is Open Source.

Application: POP (Parallel Ocean Program).

Code: http://www2.cesm.ucar.edu/

Recipe: -mcmodel=medium -O3 -ipo -xMIC-AVX512 -fp-model fast=2

Image Source: FIO, China

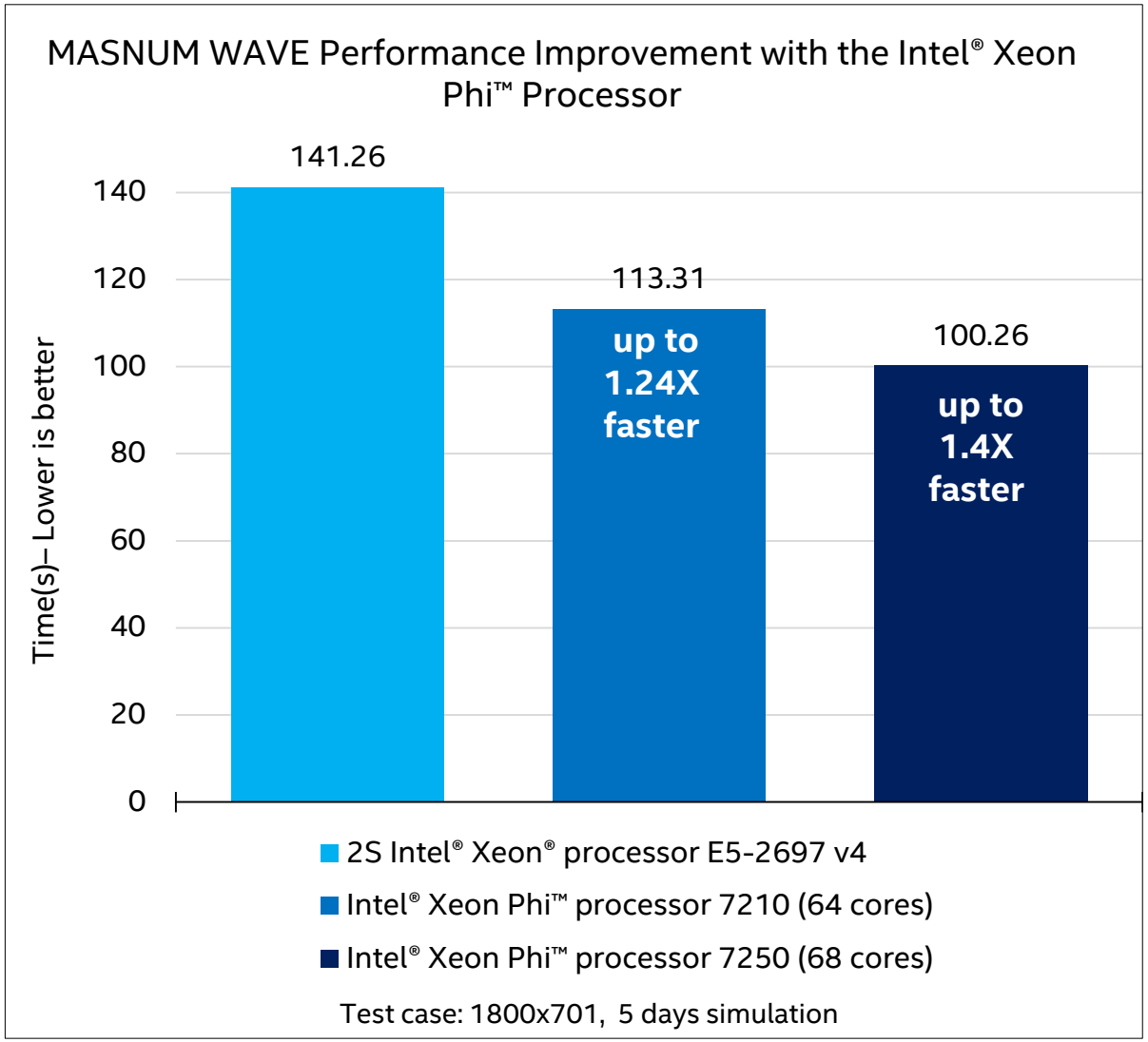
Value Proposition:

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

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

Climate & Weather

MASNUM WAVE*



See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF April,2016

MASNUM WAVE model is the 3rd generation surface wave model proposed early in 1990s in LAGFD (Laboratory of Geophysical Fluid Dynamics) from FIO. The application is used to simulate and predict the wave process by solving the wave energy spectrum balance equation and its complicated characteristic equations in wave-number space, which is written in Fortran and parallelized with MPI+OMP.

Application: MASNUM WAVE.

Code: In-house code. To get access to the code and test cases, please contact songroy@fio.org.cn, yinxq@fio.org.cn

Recipe: Please contact songroy@fio.org.cn, yinxq@fio.org.cn

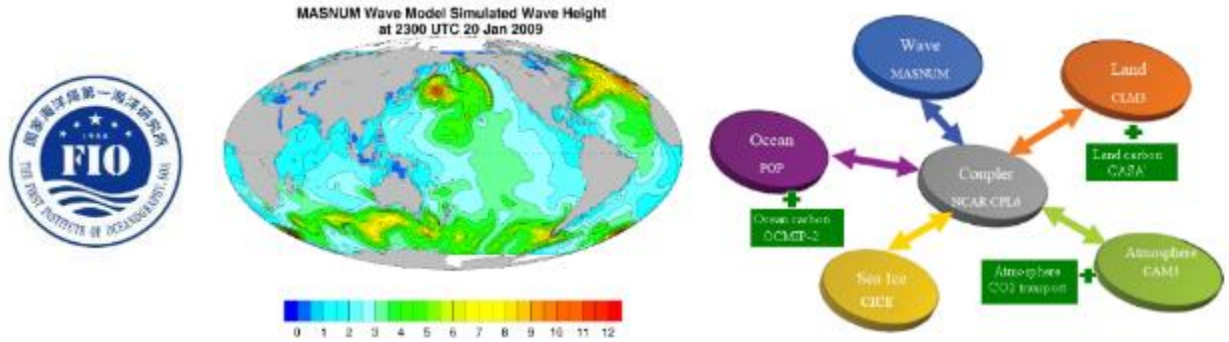


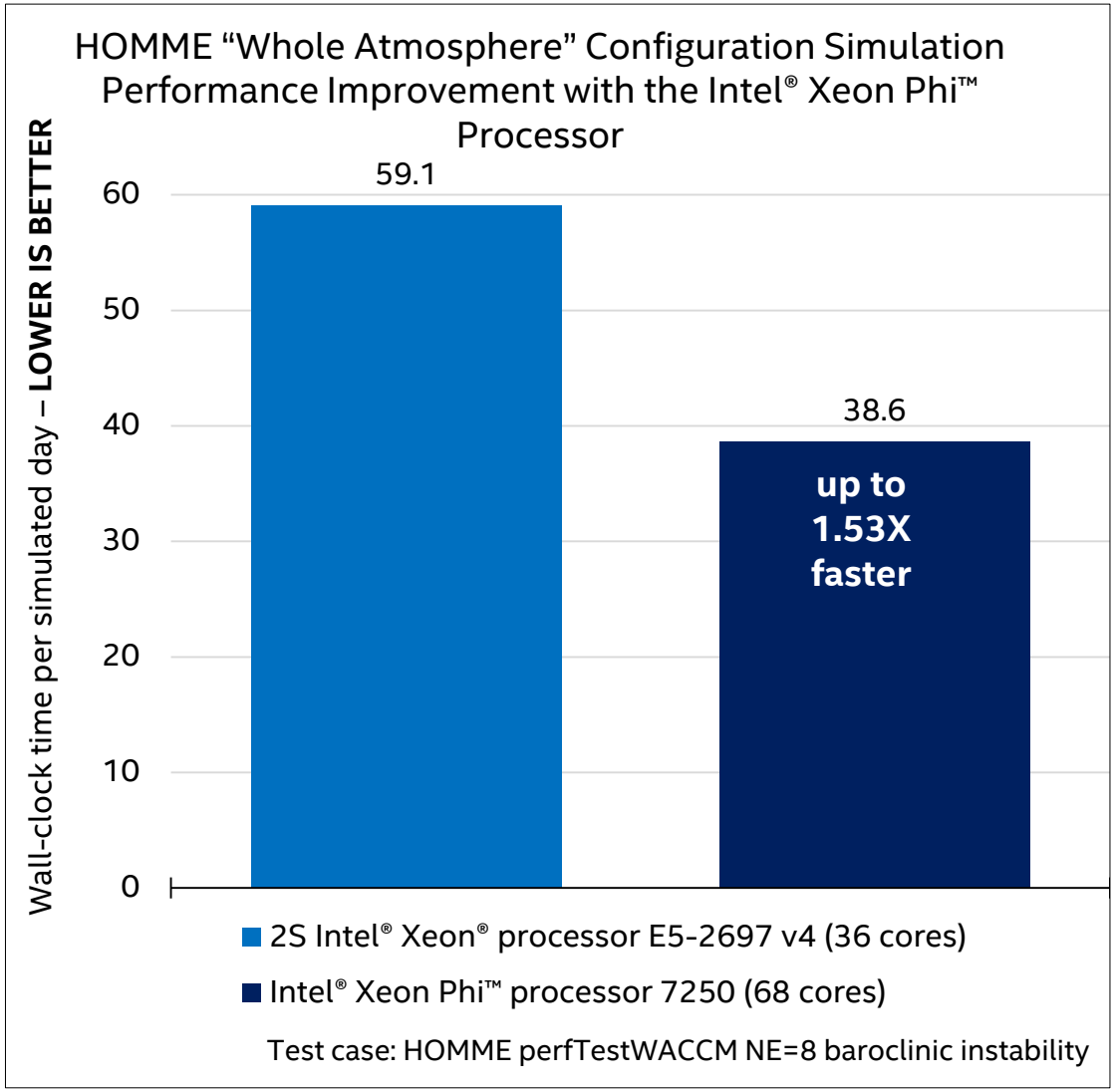
Image Source: FIO, China

Value Proposition: Performance is enhanced by Intel® AVX512.

Results: Up to 1.41X improved performance compared to the Intel® Xeon® processor E5-2697 v4.

Climate & Weather

HOMME ATMOSPHERIC DYNAMICAL CORE * NUMERICAL CLIMATE SIMULATION



See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF APRIL, 2016

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

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

Code: Request access to development branches here.

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

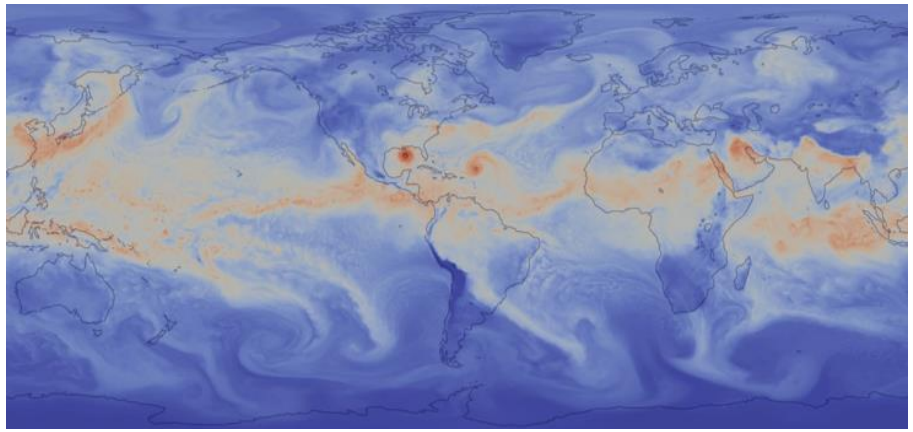


Image source: Used by permission. Global 1/8 degree simulation run using CAM5 with the HOMME spectral element dynamical core. Visualization from http://www.sdav-scidac.org/29-highlights/visualization/64-precipitable-water-vis.html.

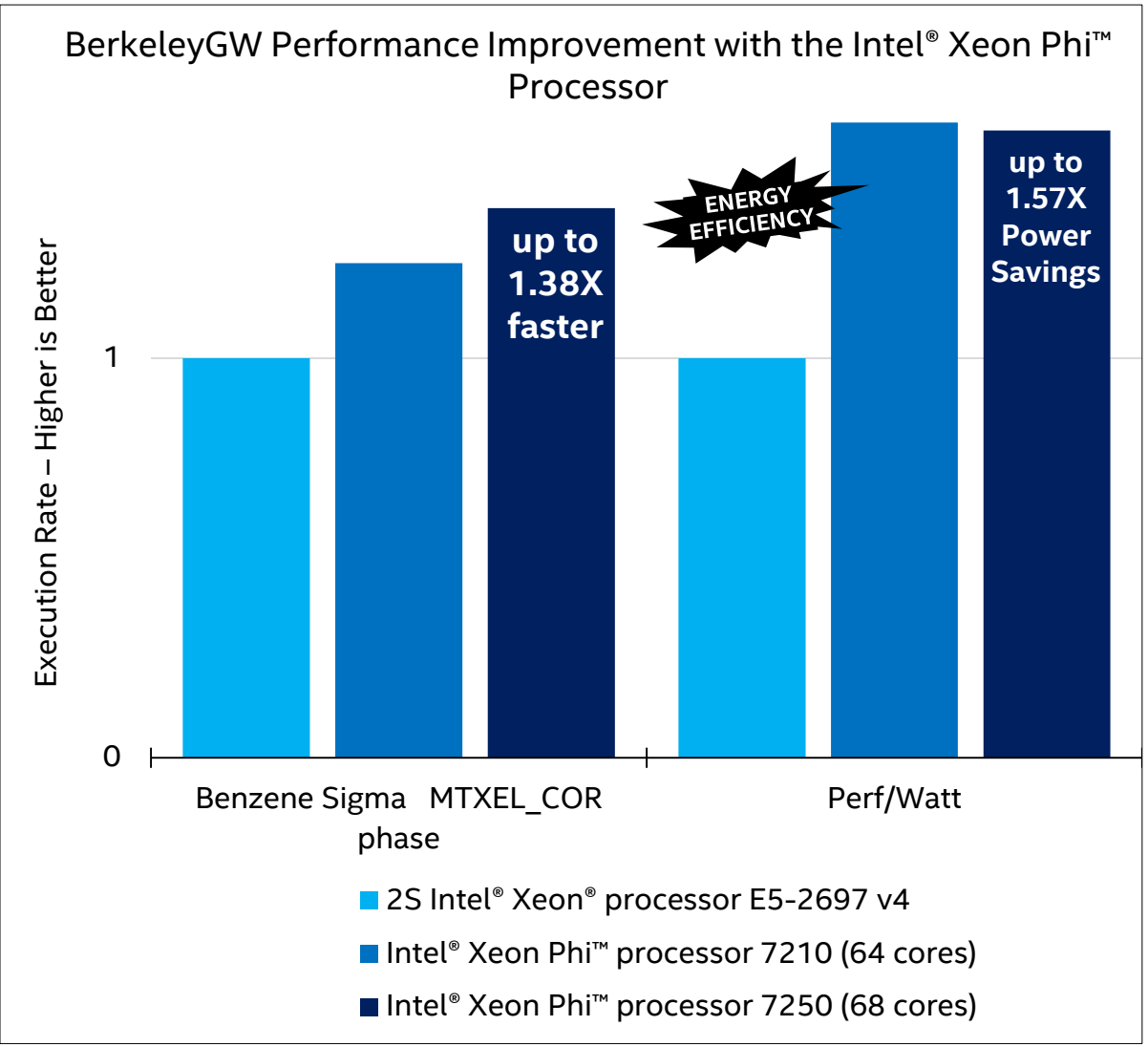
Value Proposition:

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

Results: Up to 1.53X faster compared to the Intel® Xeon® processor E5-2697 v4.

Material Sciences

BERKELEYGW*



See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF APRIL, 2016

BerkeleyGW Package is a set of computer codes that calculates the quasiparticle properties and the optical responses of a large variety of materials from bulk periodic crystals to nanostructures such as slabs, wires and molecules. It is a massively parallel computational package for electron excited state properties that is based on many-body perturbation theory employing the ab initio GW and GW plus Bethe-Salpeter equation methodology. Sigma is the second half of the GW code. It gives the quasiparticle self-energies and dispersion relation for quasielectron and quasihole states.

Application: BerkeleyGW Sigma phase of Benzene analysis

Source: http://www.berkeleygw.org

Deslippe, Jack, Georgy Samsonidze, David A. Strubbe, Manish Jain, Marvin L. Cohen, and Steven G. Louie. "BerkeleyGW: A massively parallel computer package for the calculation of the quasiparticle and optical properties of materials and nanostructures." Computer Physics Communications 183, no. 6 (2012): 1269-1289.

Recipe: -xMIC-AVX512 -Ofast –qopenmp

BerkeleyGW

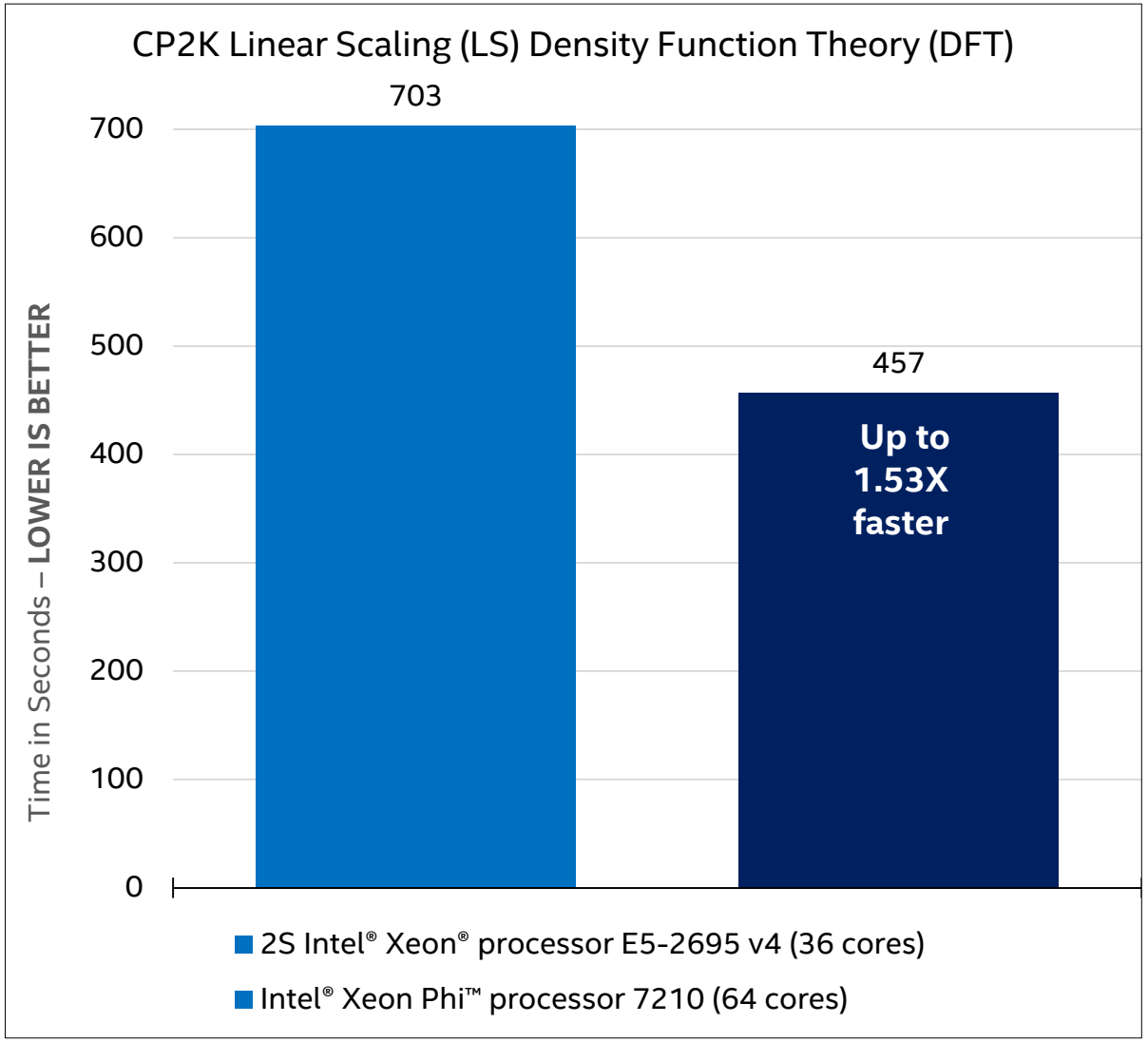
Image Source: Used with permission

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

Results: Up to 38% speedup compared to the Intel® Xeon® processor.

Material Sciences

LINEAR SCALING (LS) DENSITY FUNCTION THEORY (DFT)

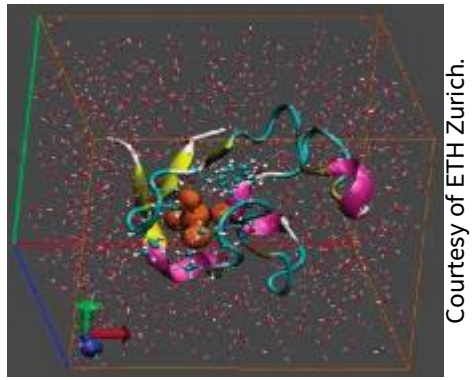


See next slide for configuration details. MEASUREMENT: University of Zurich / Intel, May 2016

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

Application: CP2K Quantum Chemistry & Solid State Physics Software Package

Code: Available here



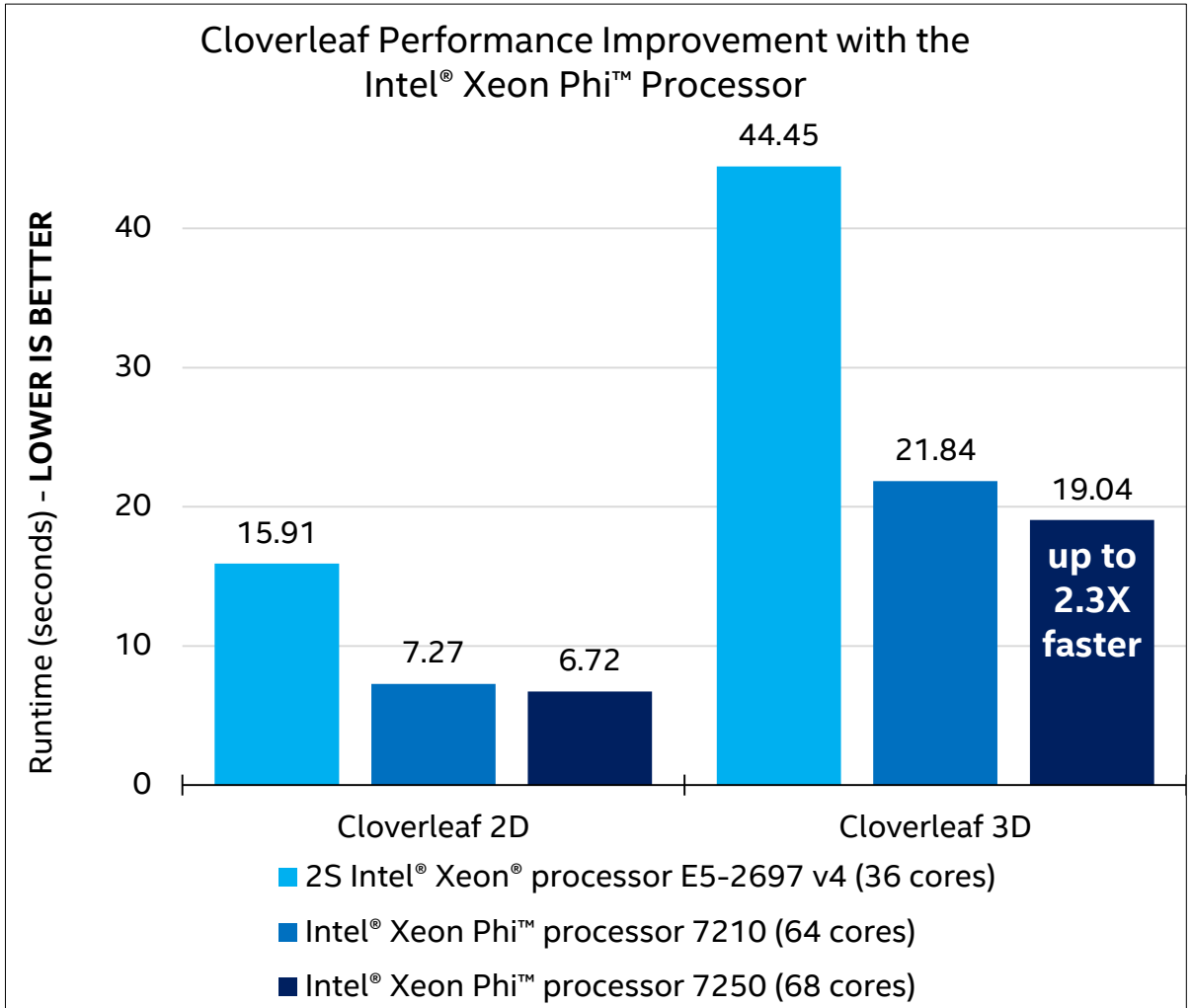
Courtesy of ETH Zurich.

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

Results: Up to 1.53X faster with the Intel® Xeon Phi™ processor 7210 when compared to the Intel® Xeon® processor E5-2695 v4.

Physics - Hydrodynamics

CLOVERLEAF*



See next slide for configuration details.

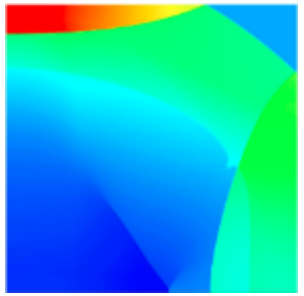
SOURCE: INTEL MEASURED RESULTS AS OF April 2016

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

Application: Cloverleaf.

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

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



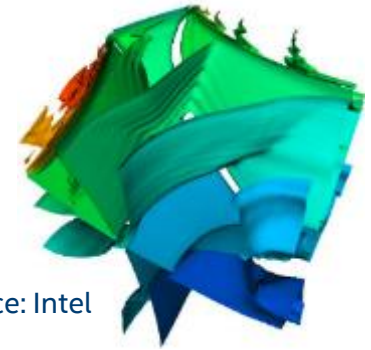


Image Source: Intel

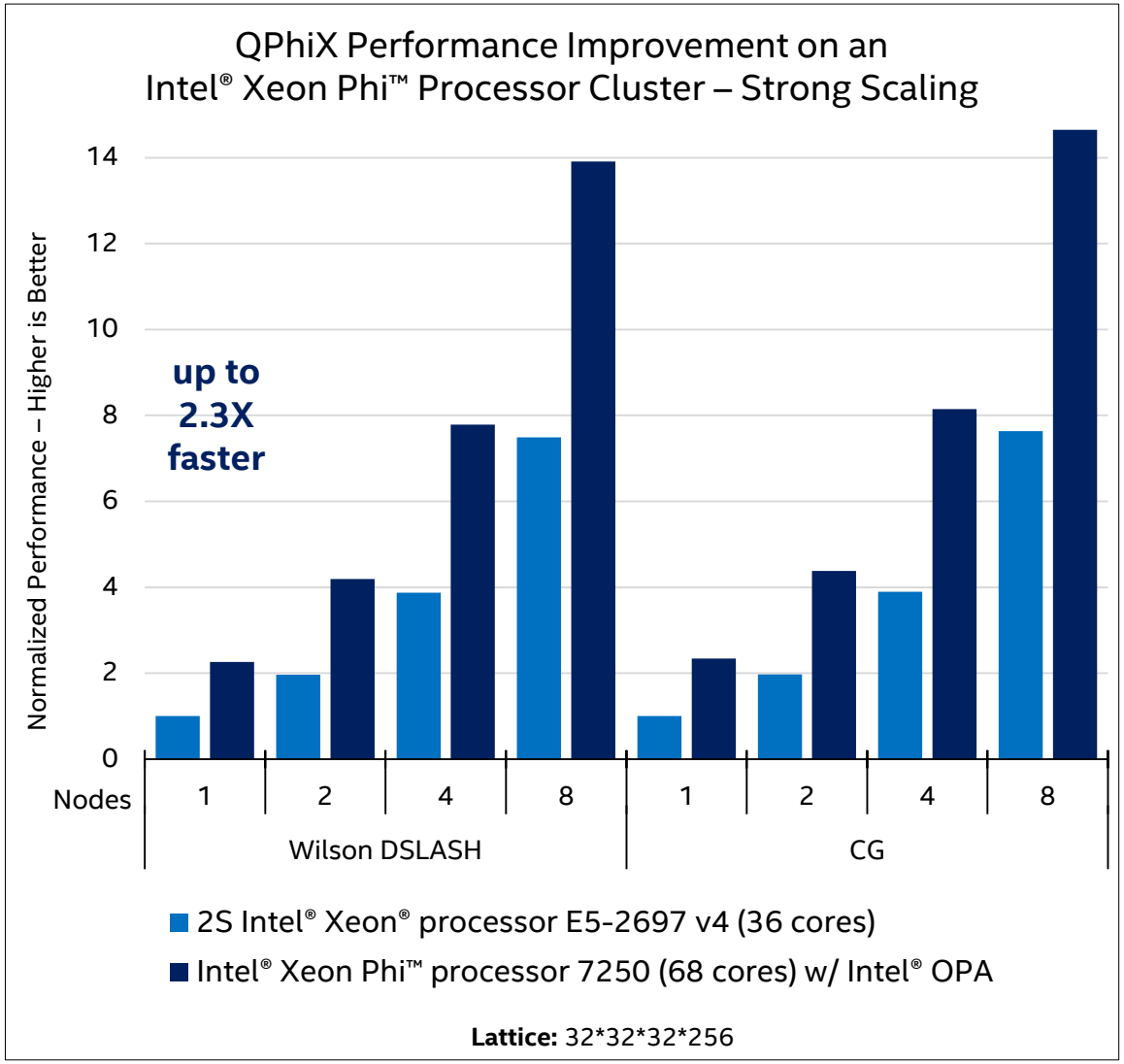
Value Proposition:

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

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

Physics - QCD

QPHIX*



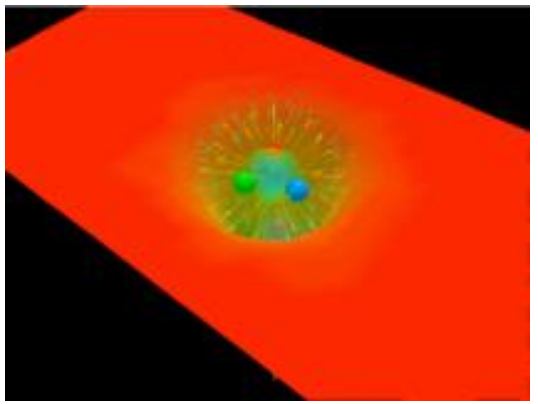
See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF MAY, 2016

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

Application: QPhiX Test Benchmark (time_dslash_noqdp)

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



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

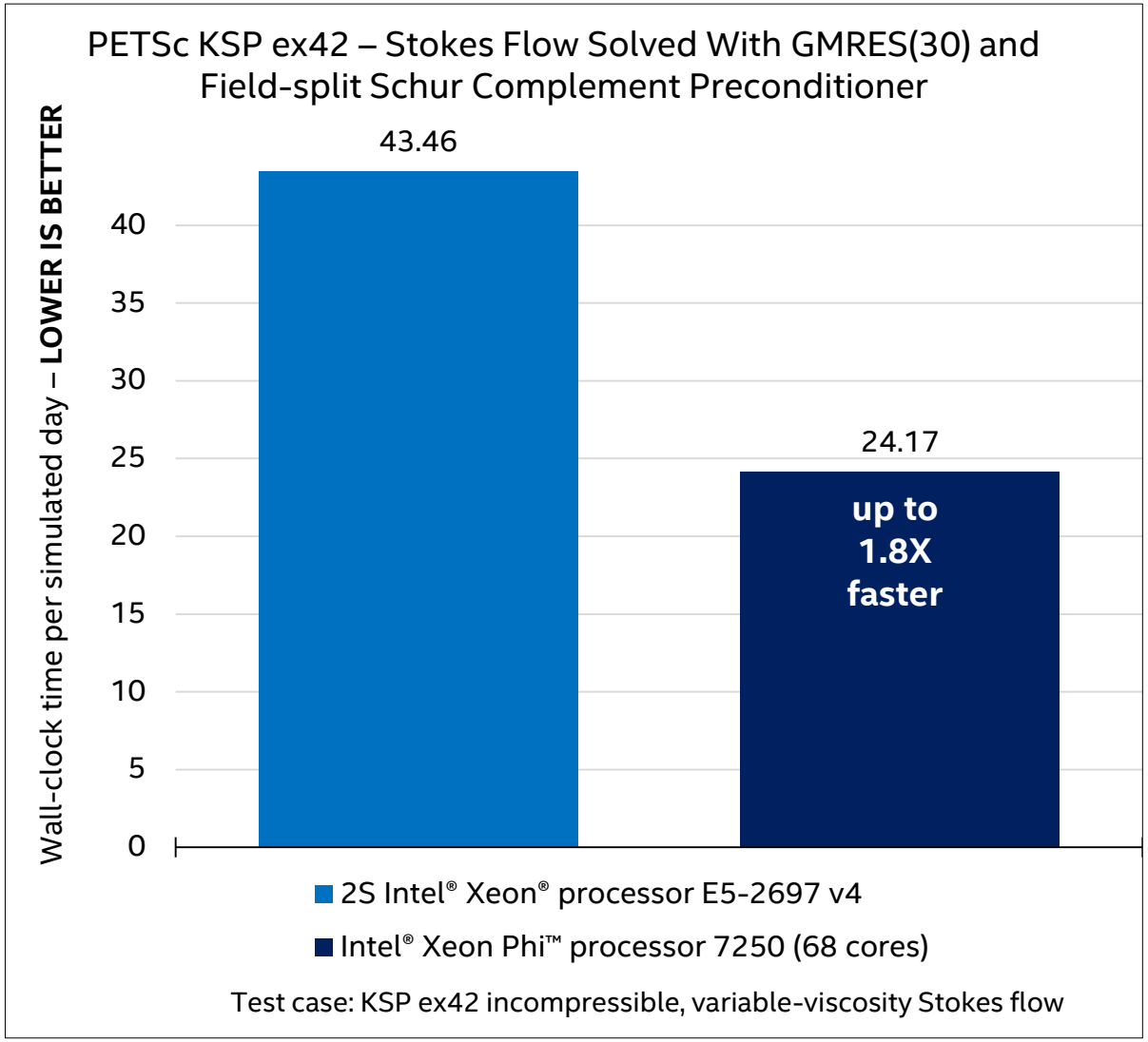
Value Proposition:

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

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

Physics

PETSC – PORTABLE, EXTENSIBLE TOOLKIT FOR SCIENTIFIC COMPUTATION



See next slide for configuration details.

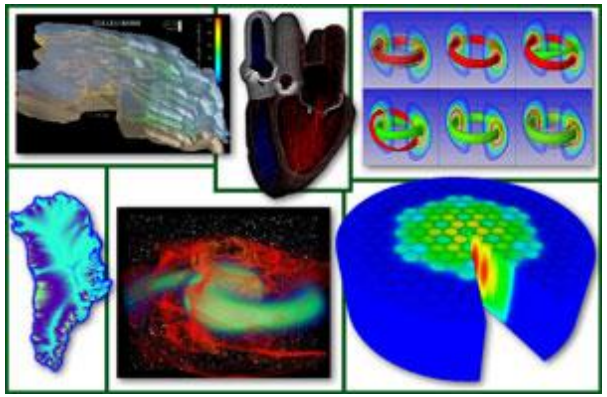
SOURCE: INTEL MEASURED RESULTS AS OF MAY 2016

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

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

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

Recipe: "-g -O3 -fp-model fast" and "-xMIC-AVX512" or "-xCORE-AVX2



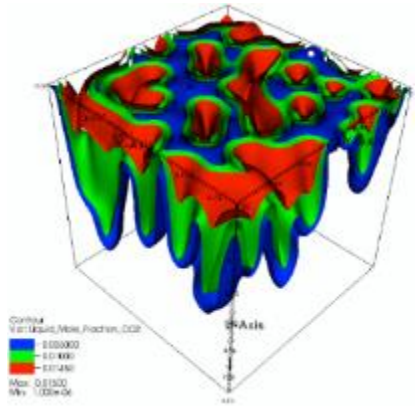


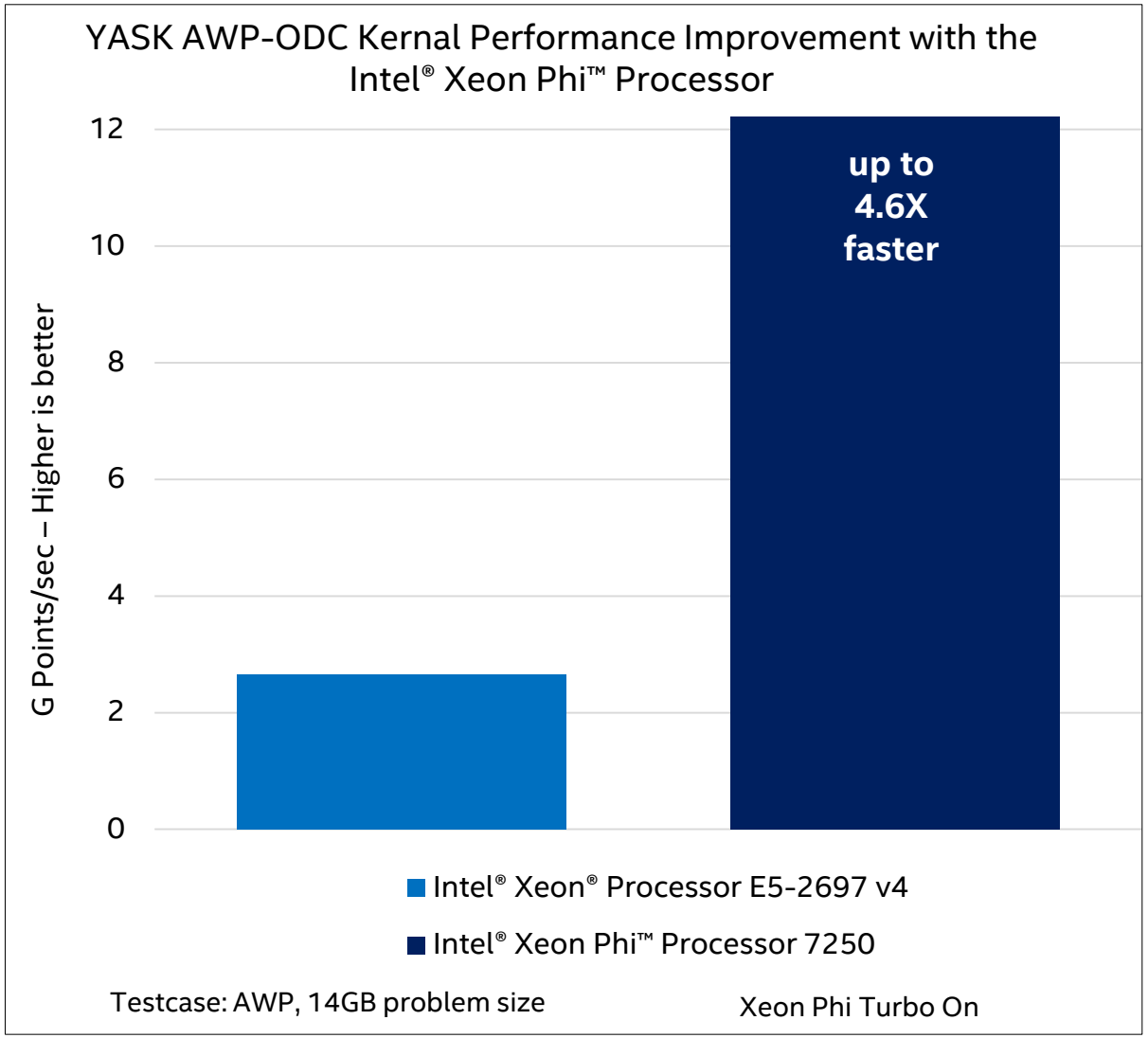
Image Source: Peter Lichtner, OFM Research

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

Results: Up to 1.8X faster with the Intel® Xeon Phi™ processor 7250 compared to the Intel® Xeon® processor E5-2697 v4.

Geophysics

YASK HPC STENCILS, AWP-ODC KERNEL



See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF MAY, 2016

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

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

Code: Available here

Recipe: 640*640*640 problem size (see command lines in next slide)

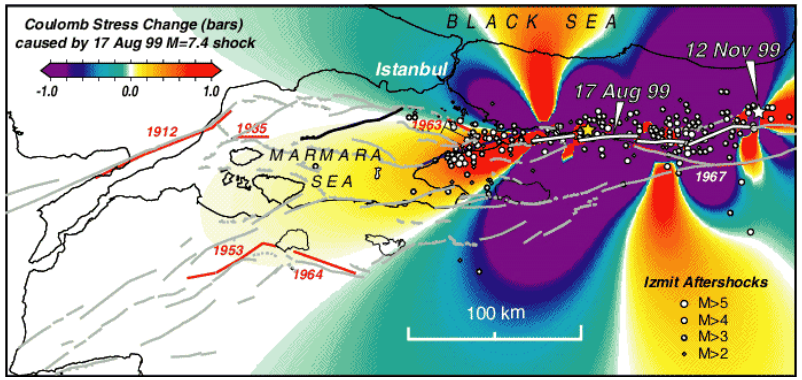


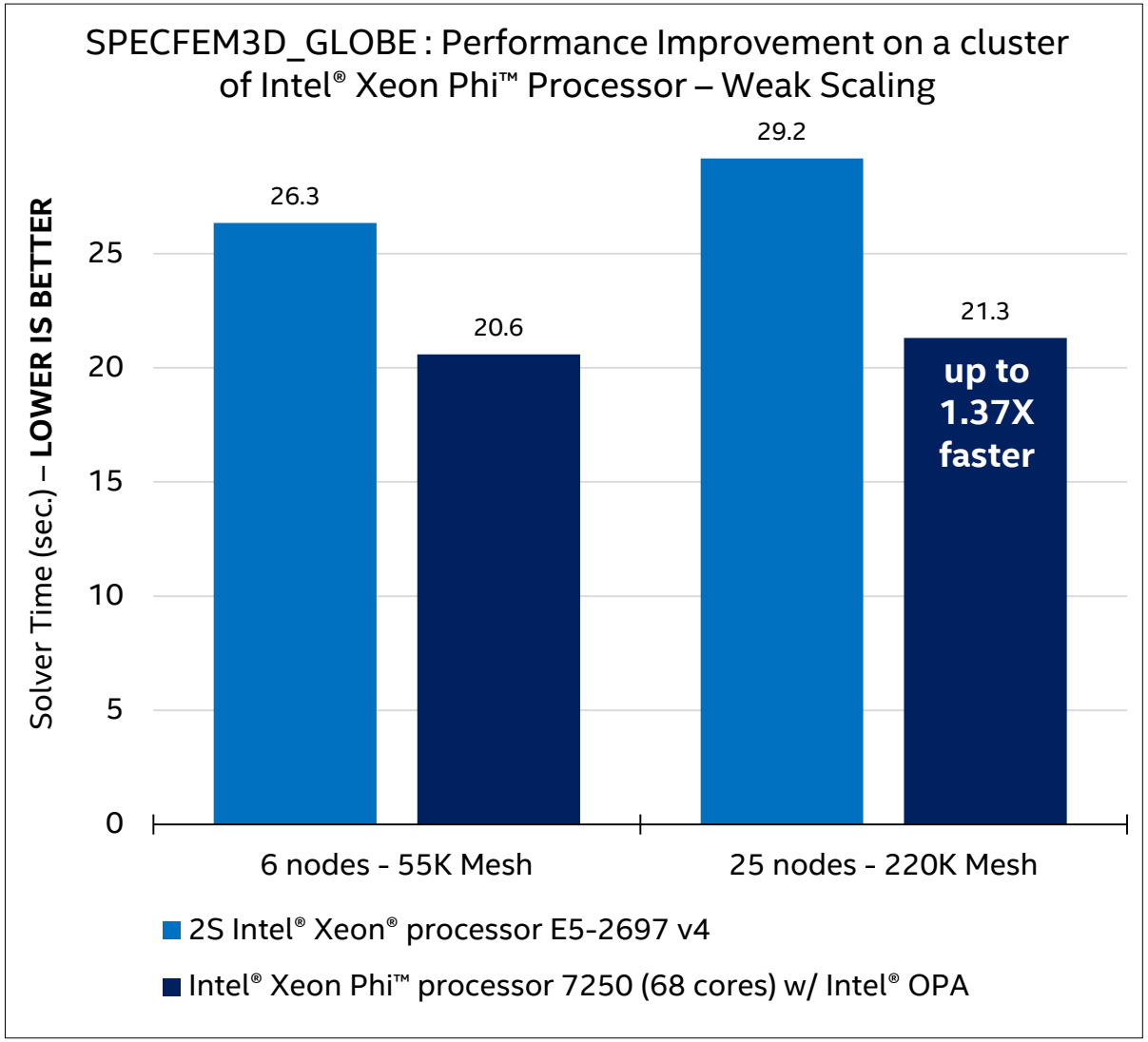
Image Source: USGS

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

Results: Up to 4.6X improved performance compared to the Intel® Xeon® processor E5-2697 v4.

Geophysics

SPECFEM3D_GLOBE*



See slide 119 for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF MAY, 2016

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

Application: specfem3D_globe

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

Optimized Code: Pending check-in. **Recipe:** Runs out-of-the-box.

Image Source: https://geodynamics.org/cig/software/specfem3d_globe/

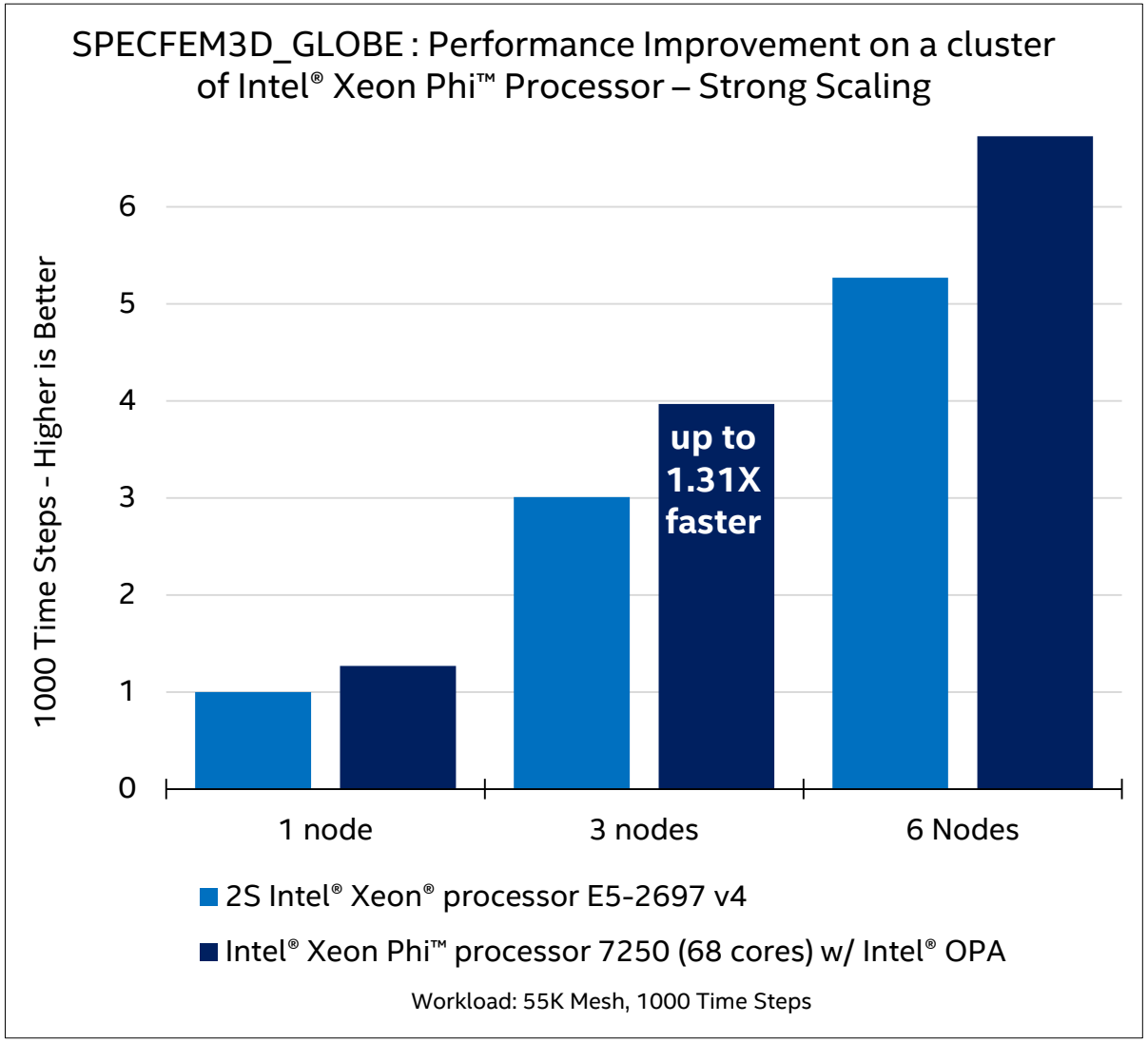
Value Proposition:

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

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

Geophysics

SPECFEM3D_GLOBE*



See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF MAY, 2016

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

Application: specfem3D_globe

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

Optimized Code: Pending check-in. **Recipe:** Runs out-of-the-box.

Image Source: https://geodynamics.org/cig/software/specfem3d_globe/

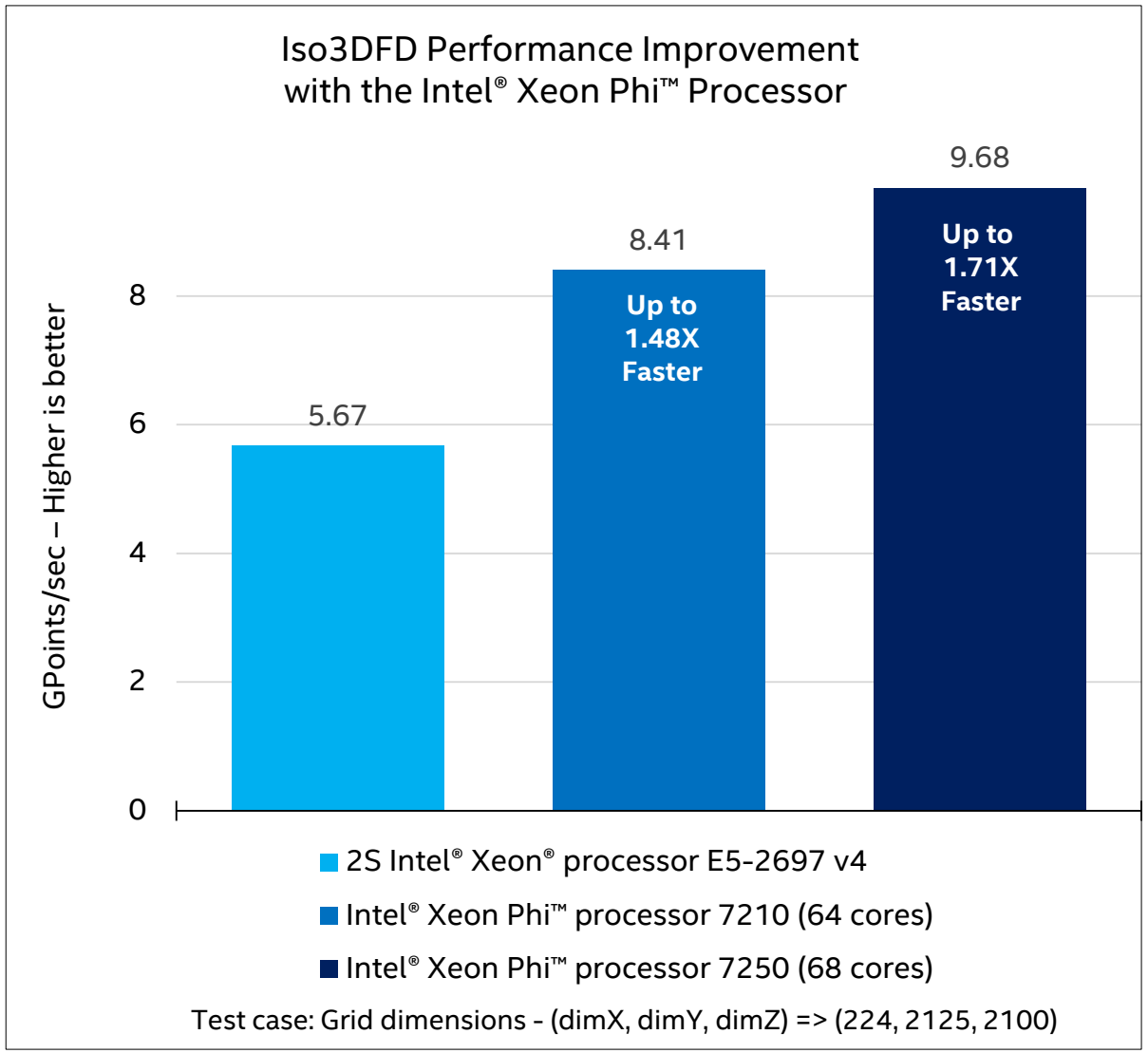
Value Proposition:

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

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

Energy Industry

ISO3DFD (3D ACOUSTIC ISOTROPIC FINITE DIFFERENCE)*



See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF MAY, 2016

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

Application: Iso3DFD (3D Acoustic Isotropic Finite Difference)

Code: Posted to Intel Developer Zone (IDZ)

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

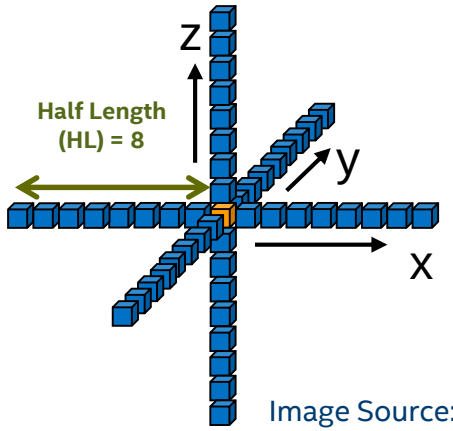


Image Source: Intel

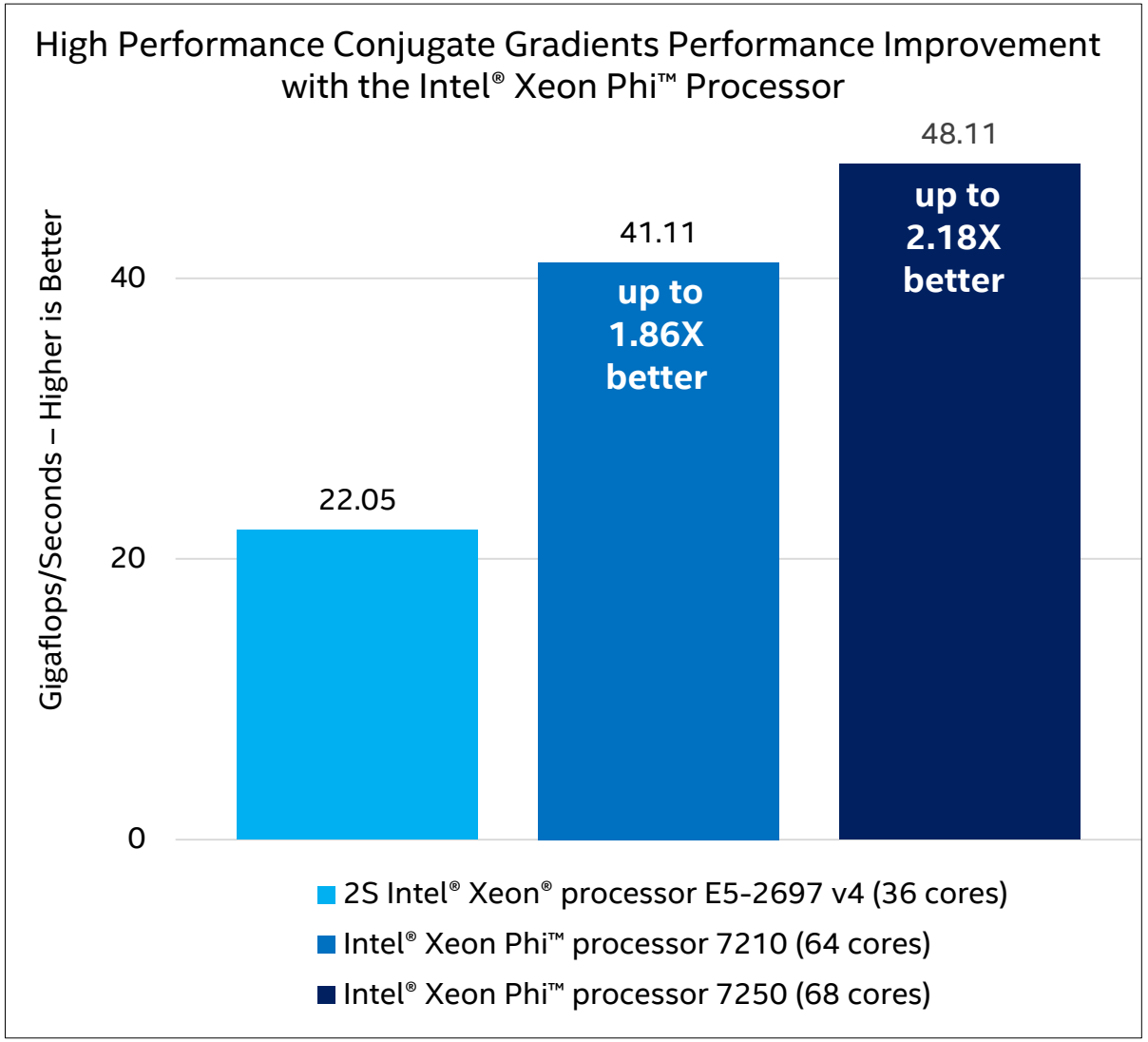
Value Proposition:

- Iso3DFD kernel makes use of Intel® AVX512 instructions and MCDRAM High Bandwidth Memory.
- Intel® Xeon Phi™ processor 7250 enables this application to significantly speedup the computation of seismic wave propagation.

Results: Up to 1.71X faster with the Intel® Xeon Phi™ processor 7250 compared to the Intel® Xeon® processor E5-2697 v4.

Performance

HIGH PERFORMANCE CONJUGATE GRADIENTS



See next slide for configuration details.

SOURCE: INTEL MEASURED RESULTS AS OF APRIL, 2016

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

Application: High Performance Conjugate Gradients

Code: Available here. **Recipe:** In development

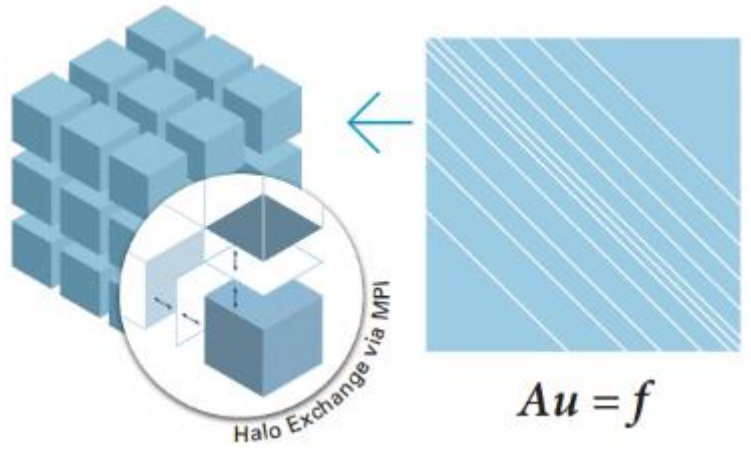


Image Source: Univ. Maryland, Baltimore Co.

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

Results: Up to 2.18X faster compared to the Intel® Xeon® processor E5-2697 v4.