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Evaluating the performance of the NEC Vector Engine and Cavium Thunder X2 on NCAR kernels

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Motivation

- Impact of compiler choice on Cavium Thunder X2 performance
- Identify areas of potential collaboration to strengthen ARM software ecosystem
- Evaluate the durability of Intel Xeon and Xeon Phi optimizations
- Explore use of the NEC Vector Engine

Acknowledgements

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  - Tim Miller
  - Randy Pidhayny
- Cavium/ARM
  - Larry Wikelius and team
  - Ashok Bhat and Team
  - Srinath Vadlamani

Approach

- STREAM2
- Elemental function (exp,log,pwr,sqrt)
- NCAR Kernels

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Platforms

- 2 x Intel Xeon E5-2697v4 Broadwell
  - 2.3 Ghz
  - 45 MB L3 cache
  - 36 cores
  - 64 GB, 2400 Mhz DDR4
- NEC VE 10-B
  - 1.4 Ghz
  - 16 MB L3 cache
  - 8 cores
  - 48 GB, HBM2
- 2 x Cavium Thunder X2
  - 2.2 Ghz
  - 32 MB L3 cache
  - 64 cores
- 2 x Intel Xeon Skylake Gold 6148
  - 2.4 Ghz
  - 27.5 MB L3 cache
  - 40 cores

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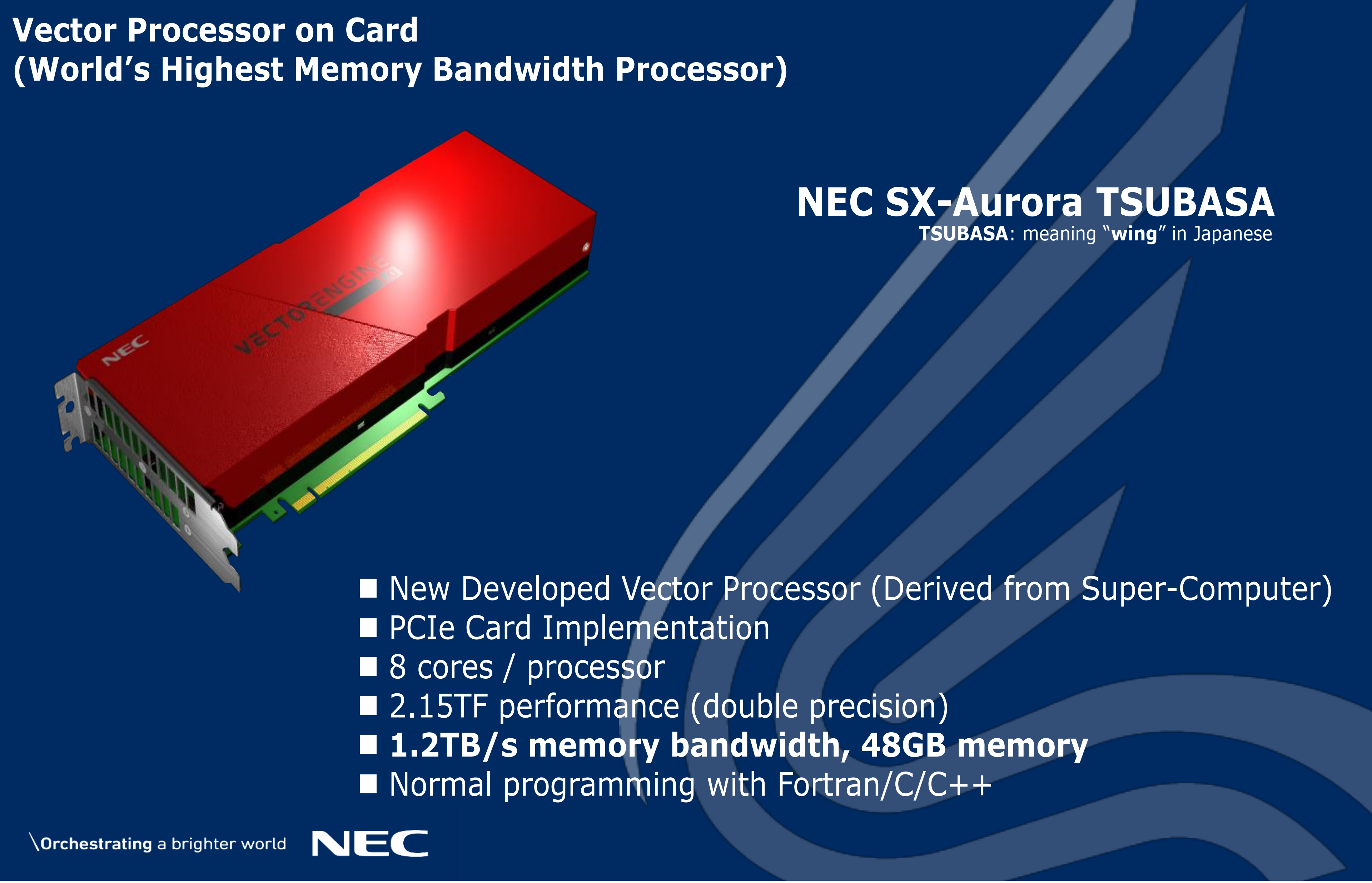

Vector Processor on Card
(World’s Highest Memory Bandwidth Processor)

NEC SX-Aurora TSUBASA

TSUBASA: meaning “**wing**” in Japanese

- New Developed Vector Processor (Derived from Super-Computer)
- PCIe Card Implementation
- 8 cores / processor
- 2.15TF performance (double precision)
- **1.2TB/s memory bandwidth, 48GB memory**
- Normal programming with Fortran/C/C++

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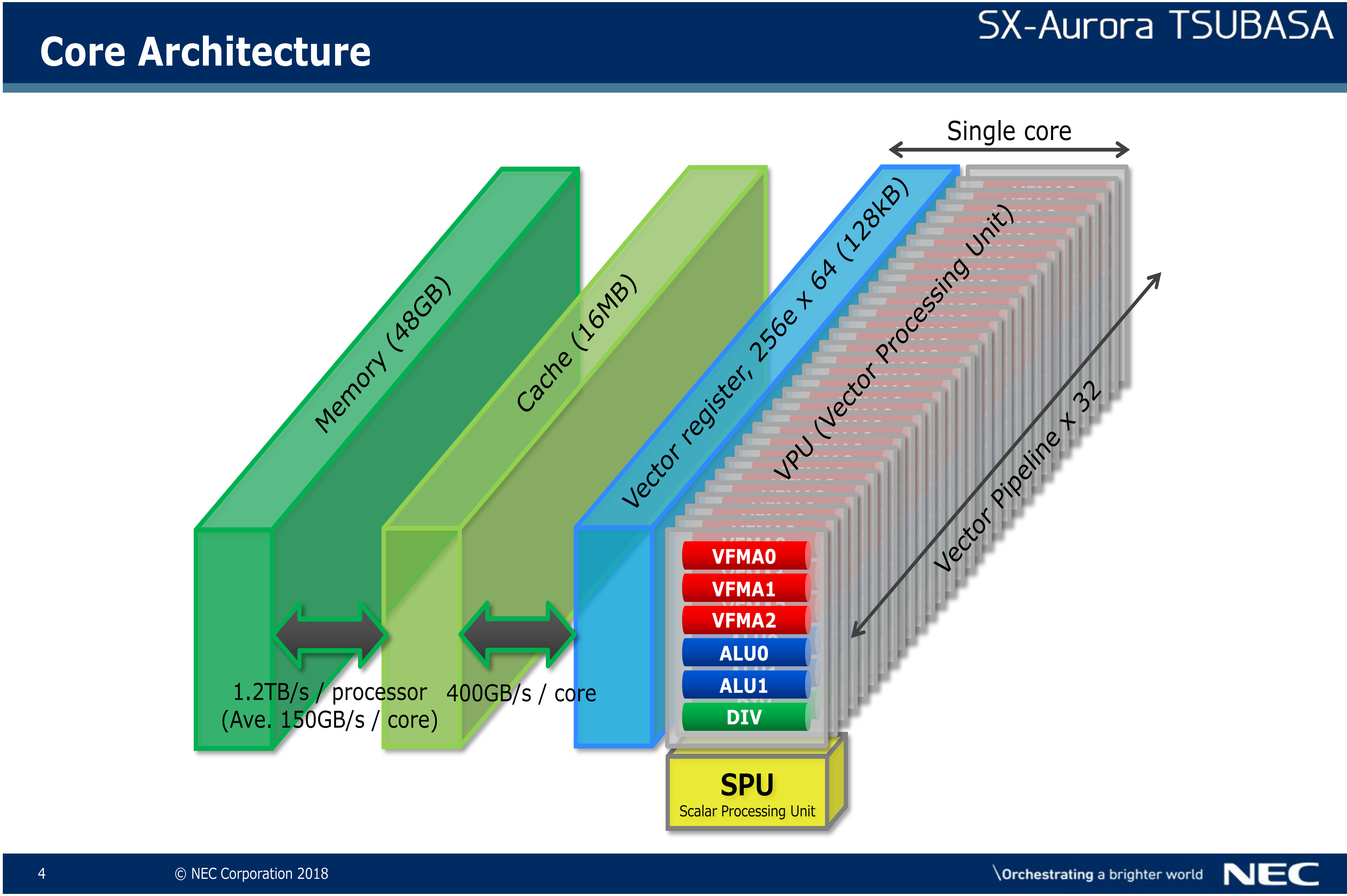
Image from NEC_SX_Aurora_TSUBASA\(WING\)_QuickStartGuide_20180713.pdf



SX-Aurora TSUBASA

Core Architecture

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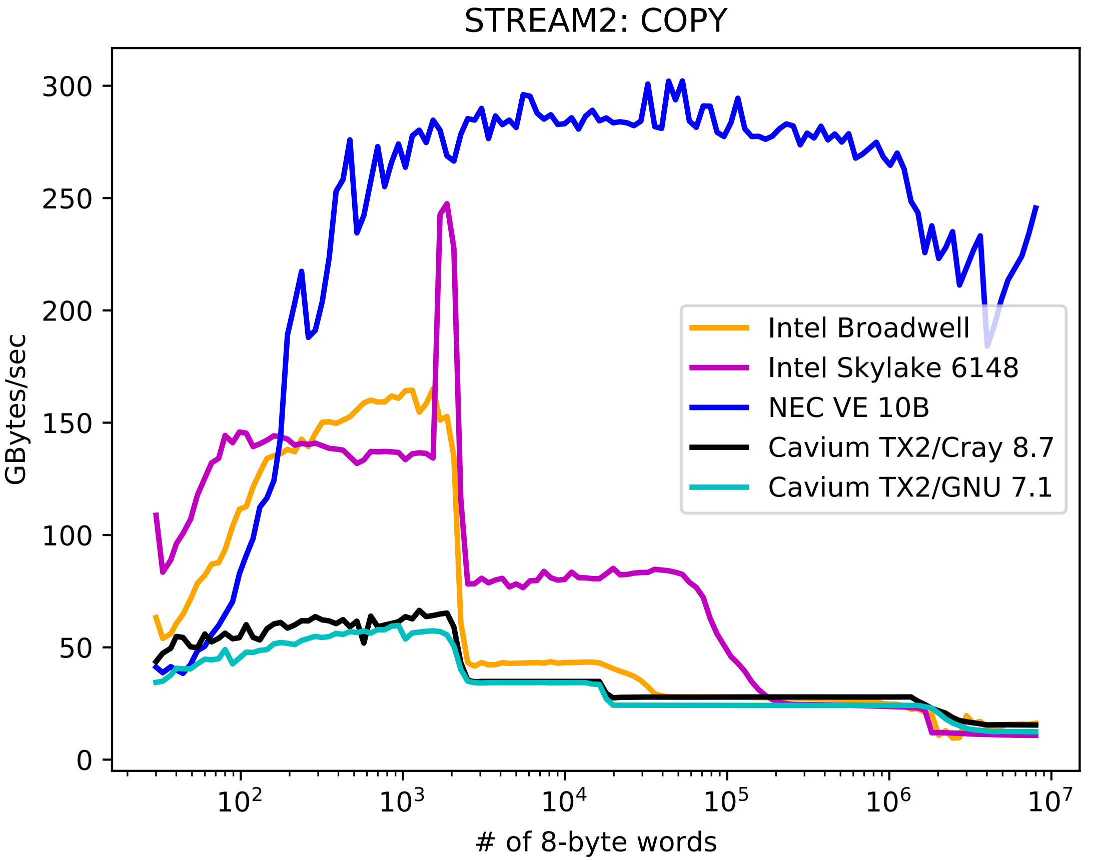
Image from NEC_SX_Aurora_TSUBASA\(WING\)_QuickStartGuide_20180713.pdf

STREAM2: COPY (single core)



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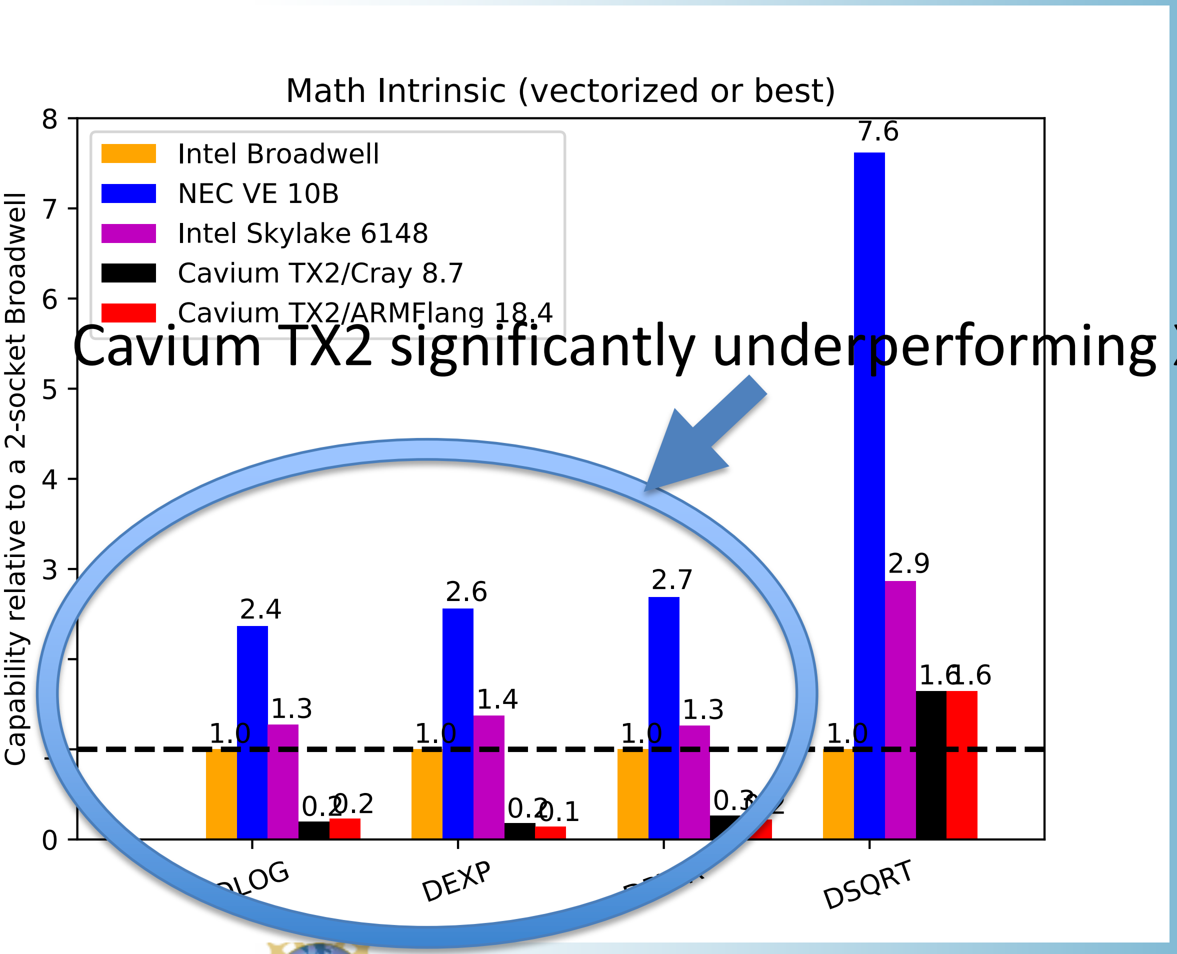
Elemental function performance (elefunt)

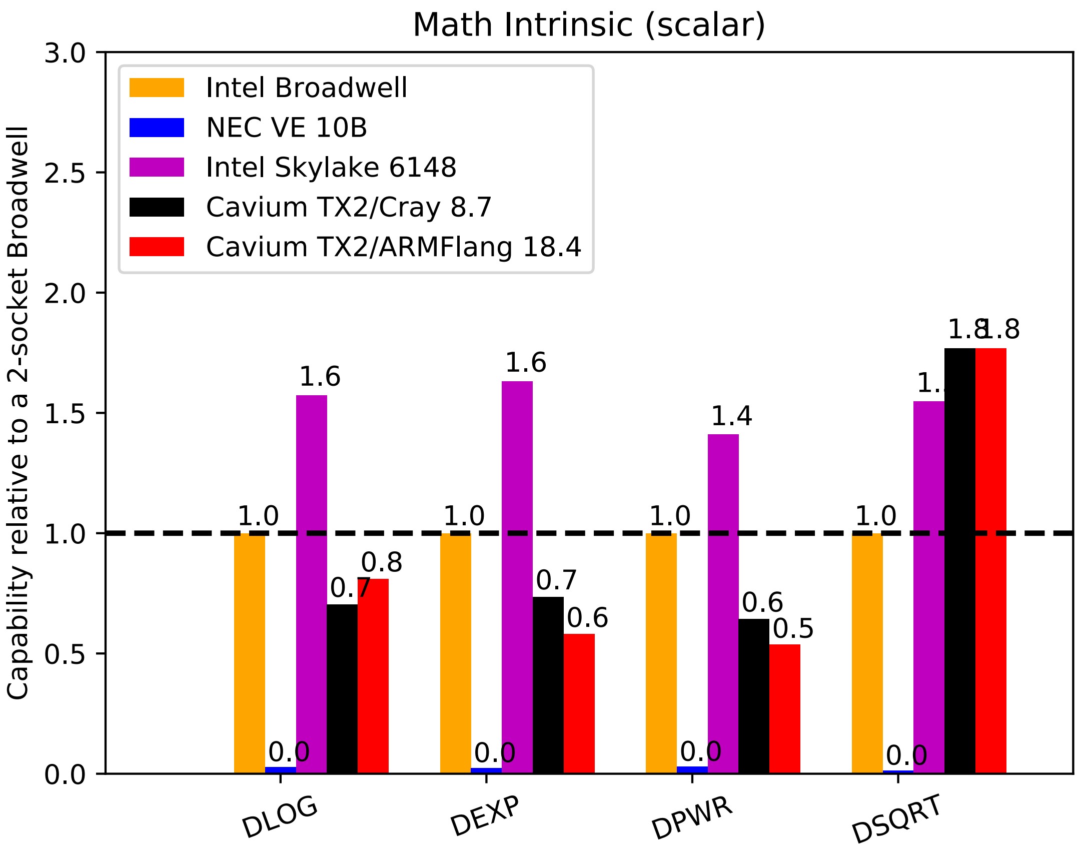
- CESM physics code utilizes large number of elemental function calls
- Poorly performing math intrinsics can negatively impact overall CESM
  - Simple way for vendors to improve performance

Elemental math function rate



Cavium TX2 significantly underperforming Xeon

Elemental math function rate (scalar)



Vectorization on VE is critical!

Description of NCAR Kernels

- Selection of kernels extracted from NCAR applications (https://github.com/NCAR/kernelOptimization)
  - Created using KGEN (https://github.com/NCAR/KGen)
  - Expensive sections of computational code
  - Representative input data
  - Built in verification testing

Description of NCAR Kernels

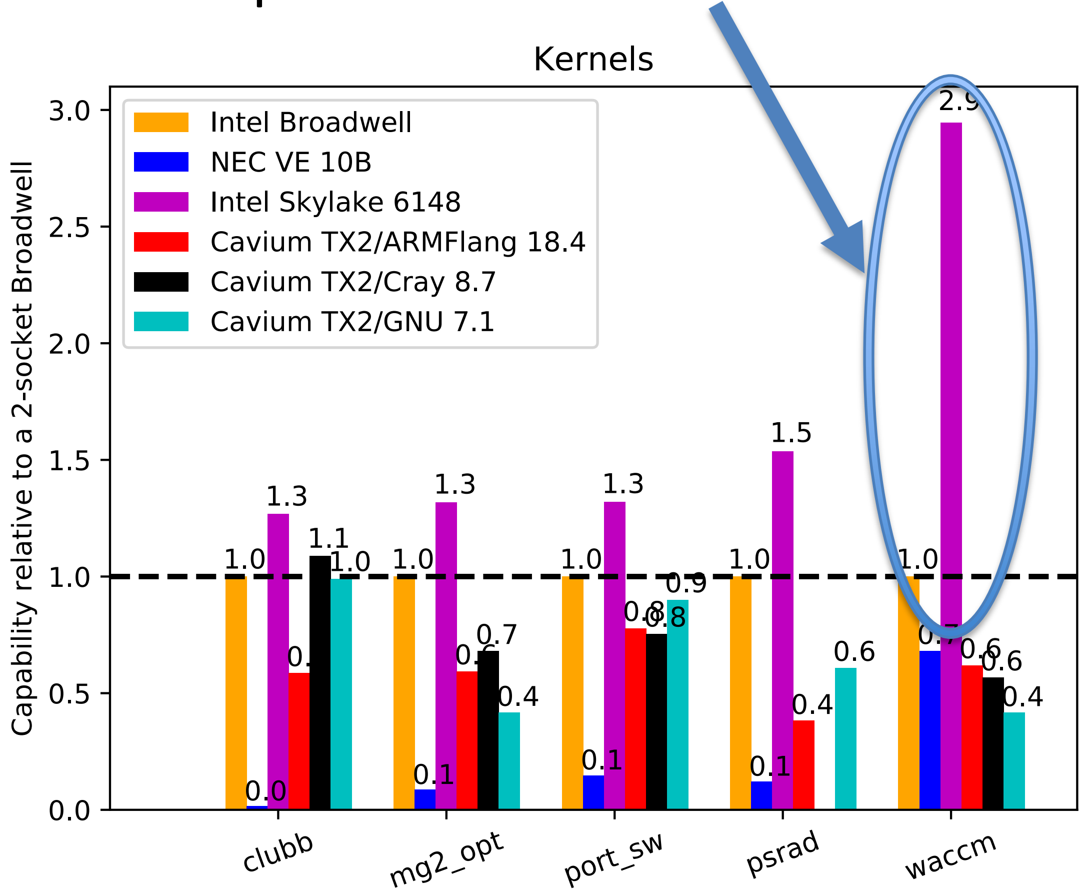
- CLUBB:
  - Cloud macrophysics and turbulence
  - Status: straight from scientists
  - Single column abstraction ☹
- MG2_opt:
  - Version 2 of the Morrison Gettleman microphysics
  - Status: Extensive optimization for Intel Xeon & Xeon Phi [MC5]
  - Math intrinsic performance sensitive
- PORT_SW:
  - Short-wavelength radiation from RRTMG
  - Status: Original pre-optimized code
- PSRAD:
  - Long-wavelength radiation from RRTMG
  - Status: Optimization for Intel Xeon & Xeon Phi [MC5]

Description of NCAR Kernels

- WACCM:
  - Chemistry solver from the Whole Atmosphere Climate Community Model
  - Status: Extensive optimizations for Intel Xeon & Xeon Phi
  - **Adjustable inner-loop dimension**
- CESM2_MG2
  - Version 2 of the Morrison Gettleman microphysics
  - Status: **Extensive optimization for NEC Vector Engine** [MC8]
  - Math intrinsic performance sensitive

NCAR Kernels (normalized to 2-socket Broadwell)

Combined impact of AVX512 and L2 cache



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WACCM

- Auto-generated linear solver from chemical specification
- Resurrected version of auto-generator from 1990’s to support the creation of vector version
- 99.8% vectorized (NEC VE)
- Very demanding of L2 cache

Can MG2 be refactored to be long vector ready?

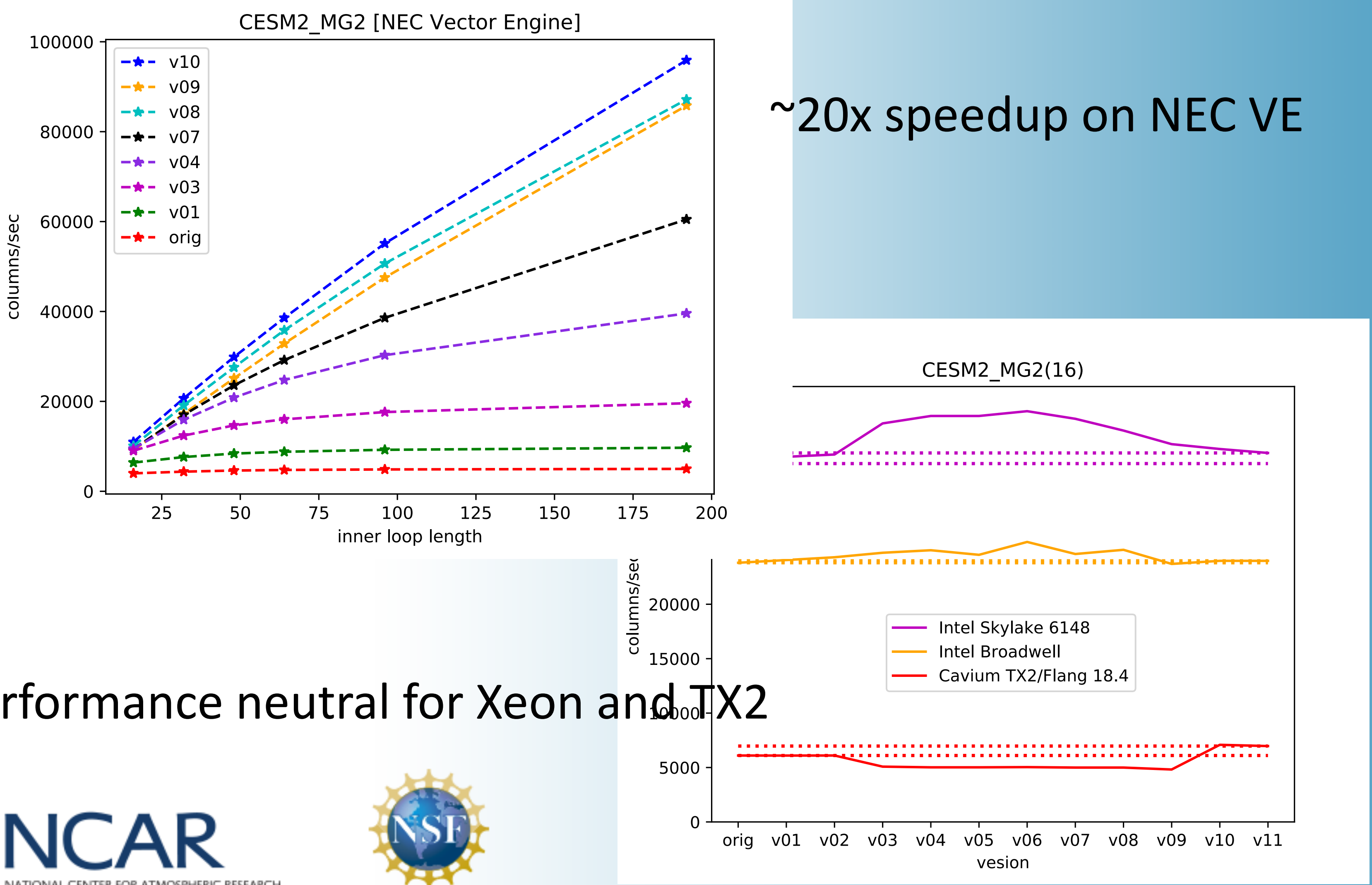
Refactor the MG2 kernel

- MG2_opt:
  - Extensively optimized for Xeon & Xeon Phi 2.3x speedup
  - Minimize code changes
- CESM2_MG2:
  - Part of CESM2 release code
  - Initial version: NEC VE achieves 3.7% of Broadwell node ☹
  - Address several key questions
    - How difficult to refactor to support long vector length for NEC VE?
    - Impact on Intel Xeon, Cavium Thunder X2 performance?

Refactoring CESM2_MG2

- Used vendor supplied GAMMA function
  - Single use of __NEC__ cpp ifdef
- Vectorize nearly all subroutines
- Calculate everywhere and mask out results
  - Did not check for vector occupancy
- Inline functions
- Input datasets with various lengths of inner loops (16,32,48,64,96, and 192)
- Currently 96% vectorized

Performance evolution of CESM2_MG2 kernel



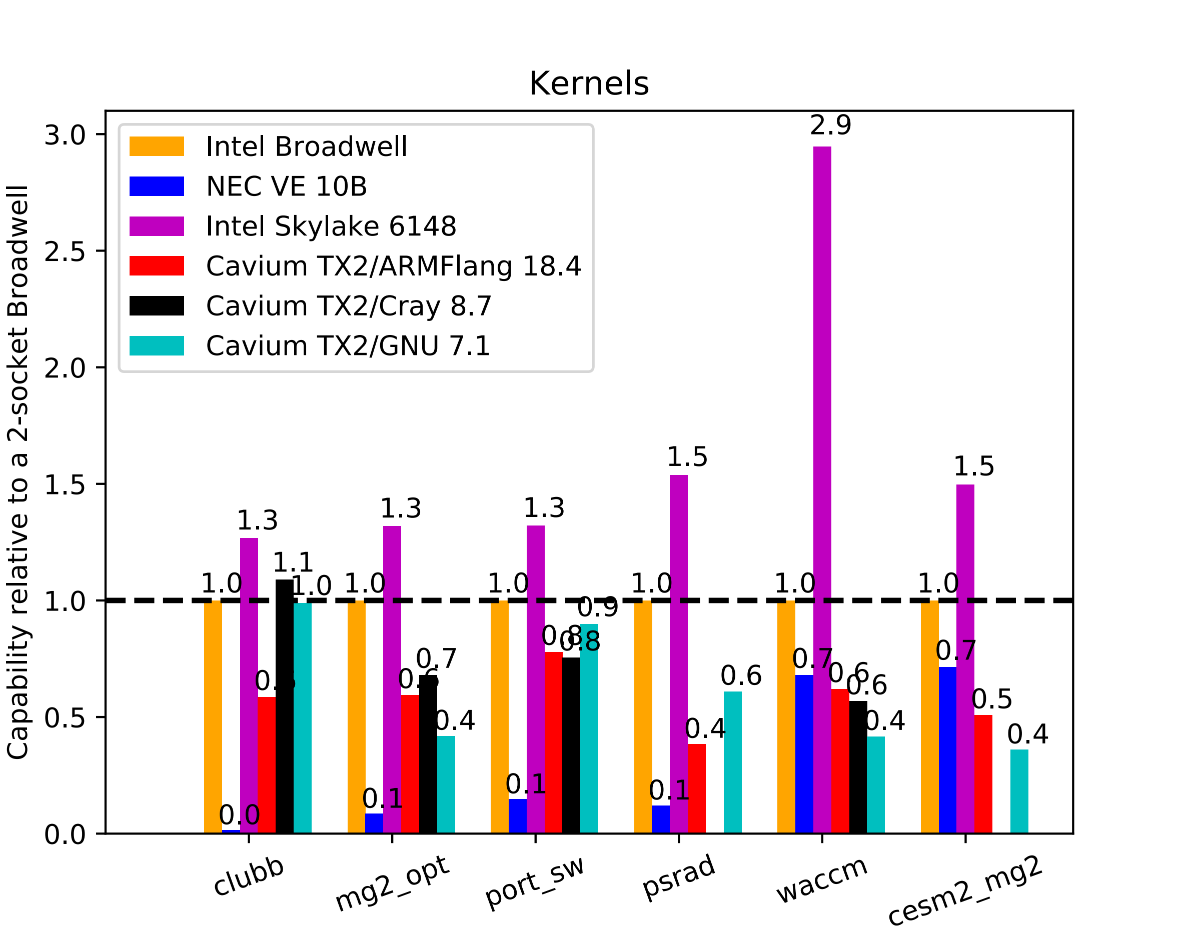
~20x speedup on NEC VE

Performance neutral for Xeon and TX2

Code optimization on the NEC VE

- Ftrace capability
  - Good
    - Augmented gprof capability
    - Very easy to use
    - Provides % vectorization, vector length, LLC efficiency, etc
  - Bad
    - Cost of built-in Fortran get lost (TRIM, scalar LOG)
- Compiler reports
  - Simple, easy to use
  - Look for “Unvectorized loop”
  - Good concordance between compiler report, ftrace report and runtime

NCAR Kernels (normalized to 2-socket Broadwell)



Conclusions

- Cavium Thunder X2
  - 40-110% of capability of Broadwell node on multiple kernels
  - Improvement to math intrinsics should help significantly (October 2018 compiler release)
- NEC Vector Engine
  - 7-70% of capability of Broadwell node on multiple kernels
  - Sufficiently long vector length is critical to performance
  - Only a single kernel was long vector length ready
  - Robust easy to use performance optimization environment
- Long vector length ready code basis of reduced precision versions

Questions?

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