Introduction of SX-Aurora TSUBASA for ISC21
-PCIe card type vector computer-

June 30th, 2021
NEC Corporation
Agenda

1. Features of SX-Aurora TSUBASA
2. World famous HPC Centers utilizing SX-Aurora TSUBASA
3. Announcement of two new functions and card business
4. Value of Vector Engine
5. Roadmap
Over 35 years experience for High Sustained Performance
Features of SX-Aurora TSUBASA

- Point 1: High Memory Bandwidth
  Vector technology makes it possible to process multiple and huge data at a time with high memory bandwidth.

- Point 2: Ease of Use
  No specialized knowledge is required, AP can be executed only after compiled. Use C/C++/Fortran to program.

- Point 3: Flexibility
  Customer can choose a system which meets their needs. From server type to card specification are all optional, NEC help customer to maximize the cost performance, to fit all market requirement.

Downsizing of super computer realized by NEC’s Technology.
Vector Engine

◆ Vector technology is packed into a PCI card.

- Vector processor (8/10 cores)
- 1.53TB/s memory bandwidth
- 48GB memory
- 2.45-3.07TF performance (double precision)
  - 4.91-6.14TF performance (single precision)
- A variety of execution modes
- Standard programming with Fortran/C/C
- Power consumption < 300 W
Architecture of SX-Aurora TSUBASA

- SX-Aurora TSUBASA = VH + VE
- Linux + standard language (Fortran/C/C++)
- Enjoy high performance with easy programming

**Software**
- Linux OS
- Fortran/C/C++ → Standard language
- Automatic vectorization compiler

**Hardware**
- VH(Standard x86 server) + Vector Engine

**Interconnect**
- InfiniBand for MPI
- VE-VE direct communication support

**Enjoy high Performance!**
Lineup of SX-Aurora TSUBASA

Vector Engine supports wide range from desk-side to large-scale Data Centers. Selling Vector Engine card was started from November, 2020.

**Data Center Model**
Huge processing in Data Centers

**Rackmount Model**
Simulation of manufacturing industry, etc.
Use of AI / big data

**Edge Model**
Simulation of mid-sized manufacturing industry, etc. Laboratory desk-side

**Vector Engine**
Application acceleration
Embedded use
Cloud service engine

Data Center Model (Water-Cooling)
8VE

Rackmount Model
4VE
8VE

Edge Model
1VE

Vector Engine
Application Set Model,
Embedded System,
Cloud service
Trusted and Chose by World Famous HPC Centers

- Weather / Climate
  - Tohoku university: Academic
  - JAMSTEC: Earth Science

- Fusion Science
  - NIFS: National Institute for Fusion Science
  - Osaka university: Academic

- Cybermedia Center

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Performance of large-scale computer system

JAMSTEC Earth Simulator is ranked in TOP10 in the latest HPCG ranking. High Byte/Flops and high performance single core $\Rightarrow$ High execution efficiency

<table>
<thead>
<tr>
<th>Rank</th>
<th>HPCG</th>
<th>HPL</th>
<th>System</th>
<th>Vendor</th>
<th>Cores</th>
<th>HPCG [TFlop/s]</th>
<th>Rpeak [TFlop/s]</th>
<th>Execution efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Fugaku</td>
<td>Fujitsu</td>
<td>7,630,848</td>
<td>16,004.50</td>
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<td>2</td>
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<td>2</td>
<td>Summit</td>
<td>IBM</td>
<td>2,414,592</td>
<td>2,925.75</td>
<td>200,794.88</td>
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<tr>
<td>3</td>
<td>5</td>
<td>5</td>
<td>Perlmutter</td>
<td>HPE</td>
<td>706,304</td>
<td>1,905.44</td>
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<td>4</td>
<td>3</td>
<td>3</td>
<td>Sierra</td>
<td>IBM / NVIDIA / Mellanox</td>
<td>1,572,480</td>
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<td>6</td>
<td>6</td>
<td>Selene</td>
<td>Nvidia</td>
<td>555,520</td>
<td>1,622.51</td>
<td>79,215.00</td>
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<td>6</td>
<td>8</td>
<td></td>
<td>JUWELS Booster Module</td>
<td>Atos</td>
<td>449,280</td>
<td>1,275.36</td>
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<td>7</td>
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<td>11</td>
<td>Dammam-7</td>
<td>HPE</td>
<td>672,520</td>
<td>881.40</td>
<td>55,423.56</td>
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<td>8</td>
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<td>9</td>
<td>HPC5</td>
<td>Dell EMC</td>
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<tr>
<td>9</td>
<td>13</td>
<td>13</td>
<td>Wisteria/BDEC-01</td>
<td>Fujitsu</td>
<td>368,640</td>
<td>817.58</td>
<td>25,952.26</td>
<td>3.15%</td>
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<tr>
<td>10</td>
<td>40</td>
<td></td>
<td>Earth Simulator -SX-Aurora TSUBASA</td>
<td>NEC</td>
<td>43,776</td>
<td>747.80</td>
<td>13,447.99</td>
<td>5.56%</td>
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<tr>
<td>11</td>
<td>25</td>
<td>25</td>
<td>TOKI-SORA</td>
<td>Fujitsu</td>
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<td>12</td>
<td>16</td>
<td>16</td>
<td>Trinity</td>
<td>Cray/HPE</td>
<td>979,072</td>
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<tr>
<td>13</td>
<td>55</td>
<td>55</td>
<td>Plasma Simulator</td>
<td>NEC</td>
<td>34,560</td>
<td>529.16</td>
<td>10,510.66</td>
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<td>14</td>
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<td>14</td>
<td>Marconi-100</td>
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<td>347,776</td>
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<tr>
<td>15</td>
<td>15</td>
<td>15</td>
<td>Piz Daint</td>
<td>Cray/HPE</td>
<td>387,872</td>
<td>496.98</td>
<td>27,154.30</td>
<td>1.83%</td>
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</tbody>
</table>
NEC Network Queuing System V(NQSV) supports Cloud Bursting

Job can be deployed on-premise and burst to the cloud computing system automatically on NQSV infrastructure when the demand for computing power spikes.

- Use the cloud resources on the same UI as on-premise as jobs are submitted to Cloud system on bursting policy
- Reduce the cost for cloud usage by allocating computing resource only as needed
- Select Cloud bursting “yes” or “no” per a job on the user side
- Enable/disable Cloud Bursting function at any time by system administrator

Select Cloud Bursting “yes” or “no” and submit a job

```
$ qsub -q OnPre -l cloud=yes
```

Decide jobs submitted to cloud system based on bursting policy

Enable/disable Cloud Bursting function at any time by system administrator
NEC LLVM-IR Vectorizer released in June, 2021

https://www.hpc.nec/forums/topic?id=pA1cPw

Add automatic vectorization feature for VE into clang/flang*1/your compilers and create assembler source file including vectorized loops.

**NEC LLVM-IR Vectorizer**

- Includes vectorizer and code generator for VE.
- Inputs LLVM-IR from memory or an IR-file and outputs an assembler source code for VE.
- Applies automatic vectorization to LLVM-IR.
- Has APIs to support compiler directive.
- Provides runtime library including vector mathematical functions (sin, cos etc.)
- Will support flang and MLIR.
- Will be enhanced to create execution file in 4Q CY21.

*1 will be supported in Q1 CY22.

- You can build your own compiler having vectorization feature for VE!
- You will enjoy vector computing power without additional SW license fee in the end of this year!
Future of NEC ‘s Vector Supercomputer Business

Develop new markets by downsizing vector supercomputers and selling Vector Engine card through partner sales.

Current Area (The HPC)
- Tsunami forecast
- Weather forecast
- Fluid analysis
- Structural analysis

Present
- AI analysis
- Chemical analysis
- Plant control
- Malware detection
- Seismic applications
- Financial risk analysis

New Business

Downsizing
- Disaster prevention and mitigation
- Production
- E-commerce
- Transportation
- Health Care
- Cyber Security

Partner Sales
Start card business

Last year NEC announced starting PCIe card selling through system integrators as NEC partners.

Value of Vector Engine

NEC’s Vector technology can invent new Social Values - as the key to accelerate HPC + AI/Big Data Analytics
Meteorology

Weather service

Power Efficiency

<table>
<thead>
<tr>
<th></th>
<th>Aladin</th>
<th>ICON-ART</th>
<th>ICON-NWP</th>
<th>COSMO</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPYC Rome 7542</td>
<td>257</td>
<td>98</td>
<td>90</td>
<td>123</td>
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<tr>
<td>SX-Aurora TSUBASA</td>
<td>597</td>
<td>412</td>
<td>486</td>
<td>889</td>
</tr>
</tbody>
</table>

Power efficiency ratio

<table>
<thead>
<tr>
<th></th>
<th>Aladin</th>
<th>ICON-ART</th>
<th>ICON-NWP</th>
<th>COSMO</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPYC Rome 7542</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>SX-Aurora TSUBASA</td>
<td>2.3</td>
<td>4.2</td>
<td>5.4</td>
<td>7.2</td>
</tr>
</tbody>
</table>

- Power supply limitation is one of the big limiting factor of each system size
- Aurora contributes to accelerate meteorology codes within the power limitation
- For the major meteorology codes, Aurora provides 2-7x higher sustained performance with same power consumption
CFD (FDL3DI, developed by US-AFRL)

The below performance evaluations were conducted at US Naval Research Lab.

- **Power consumption:** 530W/EPYC node (measured), 1,020W/(VH+2x VE10B) (measured), 530W/Xeon (assumption)
- **SX-Aurora TSUBASA** provides higher performance, and much higher power efficiency than the x86 systems
- **Customer’s satisfaction** with minimum effort for vector tuning without special program language

**Manufacturing**

- **FDL3DI:** High-Order Schemes for Navier-Stokes Equations
- **Xeon 8260:** Xeon CascadeLake 8260 24 cores/socket, 2.4GHz, 2 sockets per node
- **EPYC 7702:** EPYC Rome 7702 64 cores/socket, 2.0GHz, 2 sockets per node
- **SX-Aurora TSUBASA:** 2x VE10B / VH (dual socket Xeon)

Sustained performance on 1node and 2x VE10B

<table>
<thead>
<tr>
<th></th>
<th>Xeon 8260 2S node</th>
<th>EPYC 7702 2S node</th>
<th>SX-Aurora TSUBASA 2x VE10B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance ratio normalized to EPYC</td>
<td>0.3</td>
<td>1.0</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Power efficiency ratio on 1node and 2x VE10B

<table>
<thead>
<tr>
<th></th>
<th>Xeon 8260 2S node</th>
<th>EPYC 7702 2S node</th>
<th>SX-Aurora TSUBASA 2x VE10B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance per watt ratio normalized to EPYC</td>
<td>0.3</td>
<td>1.0</td>
<td>3.6</td>
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</tbody>
</table>
**STAC-A2™ benchmark**

https://www.staceresearch.com/news/NEC210422

Posted May 12, 2021

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**Large Greeks BM:** Computation of Greeks on American options using Longstaff-Schwartz to price the options in the presence of early exercise with large data size

**DGX A100:** 8x NVIDIA A100 SXM4 40GiB GPUs per node (https://www.staceresearch.com/news/NEC210422)

**Xeon 8380:** Xeon Platinum 8380 40 cores/socket, 2.3GHz, 2 sockets per node (https://www.staceresearch.com/INTC210315)

**Xeon 9242:** Xeon Platinum 9242 48 cores/socket, 2.3GHz, 2 sockets per node (https://www.staceresearch.com/INTC190903)

**SX-Aurora TSUBASA:** 8x VE20B / Vector Host (dual socket Xeon) (https://www.staceresearch.com/NEC210422)

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STAC-A2 is the technology benchmark standard based on financial market risk analysis.

Compared to the previous best results for single-server solutions, this (SUT ID: NEC210422) solution was:

- **79%** faster in the cold time for the large Greeks benchmark (STAC-A2.β2.GREEKS.10-100k-1260.TIME.COLD vs. SUT ID INTC210315)
- **18%** faster in the warm time for the large Greeks benchmark (STAC-A2.β2.GREEKS.10-100k-1260.TIME.WARM vs. SUT ID NVDA200909)

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*The above charts illustrate the SKUs with the best reported results from each hardware classification as of May 12, 2021.*

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**STAC-A2.GREEKS.10-100k-1260.TIME.COLD**

<table>
<thead>
<tr>
<th>SKU</th>
<th>Performance (vs. SUT ID INTC210315)</th>
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</thead>
<tbody>
<tr>
<td>DGX 8x A100 40GiB (NVDA200909)</td>
<td>x2.07</td>
</tr>
<tr>
<td>2x Platinum 8380 (INTC210315)</td>
<td>x1.79</td>
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<tr>
<td>B300-8 8x VE20B (NEC210422)</td>
<td>1.00</td>
</tr>
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</table>

**STAC-A2.GREEKS.10-100k-1260.TIME.WARM**

<table>
<thead>
<tr>
<th>SKU</th>
<th>Performance (vs. SUT ID NVDA200909)</th>
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<tr>
<td>DGX 8x A100 40GiB (NVDA200909)</td>
<td>x1.18</td>
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<tr>
<td>2x Platinum 9242 (INTC190903)</td>
<td>x2.12</td>
</tr>
<tr>
<td>B300-8 8x VE20B (NEC210422)</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Electromagnetic field analysis (OpenFDTD) [http://www.e-em.co.jp/OpenFDTD/]

Performance on 1node and 1VE

<table>
<thead>
<tr>
<th>Execution time (s)</th>
<th>Xeon Gold 6148 2S</th>
<th>Vector Engine Type 10B</th>
</tr>
</thead>
<tbody>
<tr>
<td>278.5</td>
<td>55.7</td>
<td>x5.0 faster</td>
</tr>
</tbody>
</table>

PEC* board is placed on dielectric block. Monopole antenna stands on the center of PEC board. *PEC: perfect conductor

*Simulation data provided by EEM

Telecom

- Telecom carriers simulate electromagnetic field and electromagnetic wave propagation for research and development of array antenna for 5G mobile communication. FDTD is one of method for their simulations.
- SX-Aurora TSUBASA provides 5x higher performance than Xeon on OpenFDTD simulator.
- FDTD algorithm is suitable for vector operation, SX-Aurora TSUBASA will contribute to other developments such as automotive millimeter-wave radar, wireless LAN, transmission tower, etc.

Simulation problem
- OpenFDTD: Simulator to analyze electromagnetic field with FDTD, which is provided as free software by EEM
- BM data: benchmark500 (# of cell: 500x500x500)
- Xeon 6148: Xeon Skylake 6148 24 cores/socket, 2.4GHz, 2 sockets per node
- SX-Aurora TSUBASA: VE10B x1 / VH (dual socket Xeon)
AI/ML on SX-Aurora TSUBASA

AI/ML that requires memory performance can be well accelerated.
Provide frameworks for easy utilization.
Machine Learning performance

### Linear SVM

- **CPU**: 100
- **VE**: 1.2
- **GPU**: (Memory Error)

**K-means**

- **CPU**: 100
- **VE**: 0.7
- **GPU**: 8.5

* Data: LIBSVM Data: Rcv1, Type: Sparse, Size: 1.2GB

### Logistic Regression

- **CPU**: 100
- **VE**: 0.4
- **GPU**: (Memory Error)

**Elapsed Time (Relative values, CPU=100)**

* Data: Extreme Classification-Dataset3, Type: Sparse, Size: 1.2GB

### Benchmarking environment

- **Hardware**
  - CPU: 2x Intel Xeon Gold 6126 (Skylake)
  - VE: Type 20B
  - GPU: A100 40GB

- **Software**
  - scikit-learn: 0.23.2
  - Frovedis: 0.9.8
  - RAPIDS: 0.17

* GPU BM codes were tuned for V100, and executed on A100 as is.
Frovedis supported algorithms

Implemented with Frovedis Core and Matrix Library

- Supports both dense and sparse data => Sparse data support is important in large scale machine learning

Supported algorithms:

- Linear model
  - Logistic Regression
  - Multinominal Logistic Regression
  - Linear Regression
  - Linear SVM
- ALS
- K-means
- Preprocessing
  - SVD, PCA
- Word2vec
- Factorization Machines
- Decision Tree
- Naive Byes
- DBSCAN
- Graph algorithms
  - Shortest Path, PageRank, Connected Components
- Frequent Pattern Mining
- Spectral Clustering
- Hierarchical Clustering
- Latent Dirichlet Allocation
- Random Forest
- Gradient Boosting Decision Tree (GBDT)

We will support more!
https://github.com/frovedis/frovedis
Background of multi-architecture system -towards Heterogeneous Computing-

Architecture is selected according to characteristics of each of applications. One of trends in HPC system is hybrid, composed of a variety types of processors.

Scientific calculation
- Weather forecast
- Aerodynamic analysis
- Collision analysis

Statistical processing
- Recommendation
- Demand prediction
- Fraud detection

Image recognition
- Self-driving
- Checking goods
- Cancer diagnosis

Real-time transaction
- Financial transaction
- Face recognition
- Industrial robot

Combinatorial optimization
- Financial portfolio
- Shift schedule
- Delivery planning

- Weather forecast
- Aerodynamic analysis
- Collision analysis

- Recommendation
- Demand prediction
- Fraud detection

- Self-driving
- Checking goods
- Cancer diagnosis

- Financial transaction
- Face recognition
- Industrial robot

- Financial portfolio
- Shift schedule
- Delivery planning

x86
- General

Vector Engine

GPGPU

AISC/FPGA

Quantum annealing
- Special
MPI communication on multi-architectural supercomputer

Higher performance by allocating appropriate resources with MPI communication between CPU, GPU and Vector Engine nodes.

A test benchmark execution was successful on JAMSTEC Earth Simulator!

4th generation Earth Simulator system

InfiniBand

HDR 200G, DragonFly+

Vector Engine- accelerated nodes

AMD EPYC 7742

5,472x VE 684node

CPU nodes

2x AMD EPYC 7742

1,440x CPU 720node

GPU- accelerated nodes

2x AMD EPYC 7742

64x A100 GPU 8node

File System

61PB Luster

1.3 PB all-flash Luster

Vector Engine 3.0

- Targeting the largest memory bandwidth
- Inheriting and improving VE/VH architecture
- Higher Flops per processor
- Improved memory subsystem including cache
- Accelerating short vector, and scalar operations
- Adding instructions for AI/ML
- Maintaining high power efficiency
- Heterogeneous computing enhancement
- LLVM-IR Vectorizer(C/C++, Fortran) for VE30
- Virtual machine support

<table>
<thead>
<tr>
<th>Year</th>
<th>Model</th>
<th>Cores</th>
<th>Floating Point Operations</th>
<th>Memory Bandwidth</th>
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<tbody>
<tr>
<td>2018</td>
<td>VE10</td>
<td>8C/2.45TF</td>
<td>1.22TB/s</td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td>VE10E</td>
<td>8C/2.45TF</td>
<td>1.35TB/s</td>
<td></td>
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<tr>
<td>2020</td>
<td>VE20</td>
<td>10C/3.07TF</td>
<td>1.53TB/s</td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>VE30</td>
<td>2+TB/s memory bandwidth</td>
<td></td>
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</table>

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Roadmap

Memory bandwidth / VE

VE10
8C/2.45TF
1.22TB/s memory bandwidth

VE10E
8C/2.45TF
1.35TB/s memory bandwidth

VE20
10C/3.07TF
1.5TB/s memory bandwidth

VE30
2+TB/s memory bandwidth

VE40
2++TB/s memory bandwidth

VE50

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Find more information on our website

**Aurora Web Forum**
http://www.hpc.nec

- Latest updates
- Manual, documents
- Bulletin board

**SX-Aurora TSUBASASA Website**

- Hardware and software overview
- Supported applications

**NEC ISC21 website**

- Webinar Jun 09:00 - 12:00- CEST
- Technical articles

✉️ info@hpc.jp.nec.com
Orchestrating a brighter world

NEC creates the social values of safety, security, fairness and efficiency to promote a more sustainable world where everyone has the chance to reach their full potential.