NEC brings together and integrates technology and expertise to create the ICT-enabled society of tomorrow. We collaborate closely with partners and customers around the world, orchestrating each project to ensure all its parts are fine-tuned to local needs. Every day, our innovative solutions for society contribute to greater safety, security, efficiency and equality, and enable people to live brighter lives.
<table>
<thead>
<tr>
<th>Model</th>
<th>Year</th>
<th>Technology</th>
<th>CPU Frequency</th>
<th>CPU Performance</th>
<th>CPU Memory Bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>SX-2</td>
<td>1983</td>
<td>Bipolar</td>
<td>165 MHz</td>
<td>1.3 GFlops</td>
<td>10.7 GB/sec</td>
</tr>
<tr>
<td>SX-3</td>
<td>1989</td>
<td>Bipolar</td>
<td>340 MHz</td>
<td>5.5 GFlops</td>
<td>12.8 GB/sec</td>
</tr>
<tr>
<td>SX-4</td>
<td>1994</td>
<td>350 nm</td>
<td>125 MHz</td>
<td>2.0 GFlops</td>
<td>16.0 GB/sec</td>
</tr>
<tr>
<td>SX-5</td>
<td>1998</td>
<td>250 nm</td>
<td>250 MHz</td>
<td>8.0 GFlops</td>
<td>64.0 GB/sec</td>
</tr>
<tr>
<td>SX-6</td>
<td>2001</td>
<td>150 nm</td>
<td>500 MHz</td>
<td>8.0 GFlops</td>
<td>32.0 GB/sec</td>
</tr>
<tr>
<td>SX-7</td>
<td>2002</td>
<td>150 nm</td>
<td>552 MHz</td>
<td>8.6 GFlops</td>
<td>35.3 GB/sec</td>
</tr>
<tr>
<td>SX-8</td>
<td>2004</td>
<td>90 nm</td>
<td>1.0 GHz</td>
<td>16.0 GFlops</td>
<td>64.0 GB/sec</td>
</tr>
<tr>
<td>SX-9</td>
<td>2007</td>
<td>65 nm</td>
<td>3.2 GHz</td>
<td>102.4 GFlops</td>
<td>256.0 GB/sec</td>
</tr>
<tr>
<td>SX-ACE®</td>
<td>2013</td>
<td>28 nm</td>
<td>1.0 GHz</td>
<td>256.0 GFlops</td>
<td>256.0 GB/sec</td>
</tr>
</tbody>
</table>

Over 30 years Experience For High Sustained Performance

History of SX Vector Supercomputer

Orchestrating a brighter world NEC
Market Trend

- Continuous increase in demand for computing power to advance science and social life
- Explosive increase in data volume / type
- Open environment by Linux

**Computing Power Demand**

**Data Explosion**

**Open environment**

High Accuracy  Systematization

Simulation

Ex. High precision financial simulation
Ex. Aircraft whole simulation

Ex. Services according to individual preferences

AI/Machine Learning / BigData

Ex. Explosive increase of input data · output data
New Value

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

New powerful platform for development of science and technology - leads to accelerate HPC and Big-data analysis

SX-Aurora TSUBASA

TSUBASA: meaning “wing” in Japanese

**POINT 1** Memory Bandwidth
1.2TB/s / processor, 150GB/s / core

**POINT 2** Easy to Use
Fortran/C/C++ programing, OpenMP
Automatic vectorization/parallelization

**POINT 3** x86/Linux
High sustained performance on x86/Linux environment
Point 1 : Memory Bandwidth
New Designed Vector Engine

Vector Processor on the Card

Vector Engine (VE)

- New Developed Vector Processor
- PCIe Card Form factor, but NOT an accelerator
- 8 cores / processor
- 2.45TF performance
- 1.2TB/s memory bandwidth
- Normal programing with Fortran/C/C++
Point 2 : Easy to Use
Point 3 : x86/Linux
NEC’s vector processor can execute more data at one time than other ones.

**Ordinary processor**
execute small size data at one time.

**NEC’s vector processor**
execute large size data at one time.
High Processing Speed with the Innovative System Architecture

- Accelerator Type: Frequent PCIe transmission
- SX-Aurora TSUBASA: Whole AP is executed on VE, hence the PCIe bottleneck on GPGPU will be reduced.

**Accelerator Type**

<table>
<thead>
<tr>
<th>Application</th>
<th>Transmission</th>
<th>Transmission</th>
<th>Transmission</th>
<th>Transmission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linux OS</td>
<td>x86 Processor</td>
<td>Accelerator (GPGPU)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**SX-Aurora TSUBASA**

Whole AP is executed on VE

Application

<table>
<thead>
<tr>
<th>Linux OS</th>
<th>x86 Processor</th>
<th>Vector Engine</th>
</tr>
</thead>
</table>
Comparison between Aurora and GPGPU

GPGPU Architecture

- **OS**
- **AP** (CUDA)
- **Function**
- **x86**
- **PCIe**
- **GPGPU**
- **Memory**

**Data Transmission**: exec → Result Transmission → exit

**Advantage**
- Avoiding PCIe bottleneck
- Larger memory
- Standard language

**Disadvantage**
- PCIe bottleneck
- Small memory
- Programming difficulty

Aurora Architecture

- **OS**
- **AP**
- **VE**
- **x86**
- **PCIe**
- **Memory**

**Start Processing**: exec → **I/O, etc** → **End Processing**

Reduce bottlenecks on PCI BUS

Whole AP is executed on VE

Frequent PCIe transmission
Hybrid architecture combining Vector Processor with x86 Processor
1. SX-Aurora = x86 server + Vector Engine (VE)
2. VE capability is provided on x86/Linux environment
3. InfiniBand Interconnect support

SX-Aurora Architecture

**Hardware**
- x86 server + VE

**Software Environment**
- x86 / Linux OS
- Fortran/C/C++ standard programming
- Automatic vectorization by proven vector compiler

**Interconnect**
- InfiniBand for MPI
Features of the world’s fastest Vector Engine

Best Features

- **World’s fastest Core**
  - 307GFlops (DP)
  - 614GFlops (SP)

- **World’s best data access performance**
  - 1.22TB/s

- **Technology**
  - World’s first **HBM2** x6 installed

Developed with TSMC the world’s first CPU and six 3-dimensional stacked memory **HBM 2** Technology.
Usability x High Memory Bandwidth

NO special programming like CUDA is necessary!

Position

Performance

Memory bandwidth / processor

standard
special

required programming skills

GPGPU vs. VE

Vector Engine

GPGPU

Xeon®

Xeon®
GPGPU
Vector Engine
Usability

Programing Environment

Vector Cross Compiler
- automatic vectorization
- automatic parallelization

<table>
<thead>
<tr>
<th>Language</th>
<th>Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fortran</td>
<td>F2003, F2008(partially)</td>
</tr>
<tr>
<td>C</td>
<td>C11</td>
</tr>
<tr>
<td>C++</td>
<td>C++14</td>
</tr>
<tr>
<td>OpenMP</td>
<td>OpenMP4.5</td>
</tr>
<tr>
<td>MPI</td>
<td>MPI3.1</td>
</tr>
</tbody>
</table>

Execution Environment

$ vi sample.c
$ ncc sample.c

$ ./a.out

x86

execution
VE(Vector Engine)
## Vector Engine (VE) SKUs

### 3 VE SKUs, Type 10A/10B/10C
- Frequency: 1.6GHz or 1.4GHz
- Memory Bandwidth: 1.22TB/s or 0.75TB/s
- Memory Capacity: 48GB or 24GB

<table>
<thead>
<tr>
<th>VE Type</th>
<th>Freq. (GHz)</th>
<th>core</th>
<th>processor</th>
<th>Memory</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>GF</td>
<td>cores</td>
<td>BF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>DP TF</td>
</tr>
<tr>
<td>Type 10A</td>
<td>1.6</td>
<td>307.2</td>
<td></td>
<td>2.45</td>
</tr>
<tr>
<td>Type 10B</td>
<td>1.4</td>
<td>268.8</td>
<td>8</td>
<td>2.15</td>
</tr>
<tr>
<td>Type 10C</td>
<td>0.75</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Air Cooling

Air Cooled VE for Server/Tower
VE1.0 Type 10C (2.15TF, 0.75TB/s, 24GB): Active/Passive
VE1.0 Type 10B (2.15TF, 1.20TB/s, 48GB): Passive

Passive Cooling Type
VE1.0 Type 10B/10C
For Server

Active Cooling Type
VE1.0 Type 10C
For Tower/Workstation
Direct Liquid Cooling

Water Cooled VE for Supercomputer
VE1.0 Type 10A (2.45TF, 1.2TB/s, 48GB)
VE1.0 Type 10B (2.15TF, 1.2TB/s, 48GB)
Product Plan

VE 10A

VE 10B

VE 10C

A100-1
Tower

A300-2
2VE rackmount server

A300-4
4VE rackmount server

A300-8
8VE rackmount server

A500-64 Supercomputer

Air cooling

Water cooling door

Water (DLC) ~40°C

Subject to change without notice
SX-Aurora TSUBASA covers wide range of lineup from entry model to high-end supercomputer model

A500 series **Supercomputer Model**
- Large-scale simulation
- ~64VE/Rack

A300 series **Rackmount Model**
- General simulation
- AI・Big Data Analytic
- ~2VE, ~4VE, ~8VE

A100 series **Tower Model**
- Small & real-time simulation
- For program developers
- AI・Big Data Analytic
- 1VE

- Weather/Climate
- Research
- CAE Oil/Gas
- Manufacturing
- Financial
- Researcher
- Small, mid-size enterprise
A100 Series

A100-1
1VE Tower

Intel Xeon®
Gold 6100, Silver 4100

VE1.0
Type 10C
A300 Series

A300-2
2VE Server

A300-4
4VE Server

Intel Xeon®
Gold 6100, Silver 4100

VE1.0
Type 10B/10C

VE1.0
Type 10B/10C
A300 Series

A300-8
8VE Server

PCIe Gen.3 x16

PCIe Gen.3 x16

Intel Xeon®
Gold 6100, Silver 4100
# A500 Series

## A500-64 Supercomputer

<table>
<thead>
<tr>
<th>VE</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance (SKU-A)</td>
<td>2.45TF</td>
</tr>
<tr>
<td>M Bandwidth</td>
<td>1.2TB/s</td>
</tr>
</tbody>
</table>

## Rack

<table>
<thead>
<tr>
<th># of VEs</th>
<th>32/48/64</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance</td>
<td>157TF</td>
</tr>
<tr>
<td>M Bandwidth</td>
<td>76.8TB/s</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Size</th>
<th>H:42U, W: 19in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Consumption</td>
<td>&lt; 30KW</td>
</tr>
<tr>
<td>Cooling</td>
<td>Hot/Cold water</td>
</tr>
</tbody>
</table>

(subject to change)

---

42U 32U 10U

4U

x8 w/ DLC
Example:
Large scale system by using the 8VE server

MPI operations are directly executed between VEs without memory coping to x86 memory
Lineups and Schedule

Vector Engine (VE) SKUs

<table>
<thead>
<tr>
<th>SKU</th>
<th># of cores</th>
<th>Peak performance</th>
<th>Memory Band Width</th>
<th>Memory Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 10A</td>
<td>8 cores</td>
<td>2.45 TFLOPS</td>
<td>1.22 TB/s</td>
<td>48 GB</td>
</tr>
<tr>
<td>Type 10B</td>
<td></td>
<td>2.15 TFLOPS</td>
<td>0.75 TB/s</td>
<td></td>
</tr>
<tr>
<td>Type 10C</td>
<td></td>
<td></td>
<td></td>
<td>24 GB</td>
</tr>
</tbody>
</table>

Models and schedule

<table>
<thead>
<tr>
<th>Models</th>
<th>Tower model</th>
<th>Rack-mount model</th>
<th>Supercomputer</th>
</tr>
</thead>
<tbody>
<tr>
<td>SKU</td>
<td>A100-1</td>
<td>A300-2</td>
<td>A300-4</td>
</tr>
<tr>
<td>Supported VE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type 10C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type 10B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type 10A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># of VE</td>
<td>1</td>
<td>Up to 2</td>
<td>Up to 4</td>
</tr>
<tr>
<td>Form Factor</td>
<td>Tower</td>
<td>1U Rackmount</td>
<td>4U Rackmount</td>
</tr>
<tr>
<td>System cooling</td>
<td>Air cool</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass Production</td>
<td>February ‘18</td>
<td>Q1’18</td>
<td>Q2’18</td>
</tr>
</tbody>
</table>
Comparison / Bench Marking
Performance comparison

Provide high data access performance and computing performance in standard environment

**STREAM / Node**
Data access performance evaluation benchmark

**LINPACK / Node**
Computing performance evaluation benchmark
Performance/Price

High Price Competitiveness
- The highest STREAM sustained performance / price
- Competitive HPL sustained performance / price

- VE provides same range HPL sustained performance/price compared to Intel products
- VE provides the highest memory bandwidth/price
## SX-Aurora TSUBASA system software

<table>
<thead>
<tr>
<th>Software</th>
<th>Content</th>
<th>Mandatory/Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>OS</td>
<td>• RHEL 7.3 and later</td>
<td>Mandatory</td>
</tr>
<tr>
<td>Basic software</td>
<td>• VEOS</td>
<td>Mandatory</td>
</tr>
<tr>
<td>(VH bundled)</td>
<td>• VE driver</td>
<td>Mandatory</td>
</tr>
<tr>
<td></td>
<td>• System maintenance tool</td>
<td></td>
</tr>
<tr>
<td>SDK</td>
<td>• Compiler</td>
<td>Mandatory</td>
</tr>
<tr>
<td></td>
<td>✓ Fortran compiler</td>
<td></td>
</tr>
<tr>
<td></td>
<td>✓ C/C++ compiler</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Library</td>
<td></td>
</tr>
<tr>
<td></td>
<td>✓ MPI</td>
<td></td>
</tr>
<tr>
<td></td>
<td>✓ libc</td>
<td></td>
</tr>
<tr>
<td></td>
<td>✓ Numerical library (BLAS, FFT, LAPACK, etc)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Tool</td>
<td></td>
</tr>
<tr>
<td></td>
<td>✓ gprof</td>
<td></td>
</tr>
<tr>
<td></td>
<td>✓ gdb</td>
<td></td>
</tr>
<tr>
<td></td>
<td>✓ Eclipse PTP</td>
<td></td>
</tr>
<tr>
<td></td>
<td>✓ Ftrace Viewer / Proginf</td>
<td></td>
</tr>
<tr>
<td>OSS plugin</td>
<td>• Plugins (Zabbix, Ganglia, Nagios)</td>
<td>Option</td>
</tr>
</tbody>
</table>
Profiler tools: Ftrace

User can obtain performance information for each function as well as user specified regions with Ftrace.

<table>
<thead>
<tr>
<th>FREQUENCY</th>
<th>EXCLUSIVE</th>
<th>AVER.TIME</th>
<th>MOPS</th>
<th>MFLOPS</th>
<th>V.OP</th>
<th>AVER. VECTOR</th>
<th>L1CACHE</th>
<th>CPU</th>
<th>PORT</th>
<th>VLD</th>
<th>LLC</th>
<th>PROC.NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>TIME[sec]</td>
<td></td>
<td>[msec]</td>
<td>[ % ]</td>
<td></td>
<td>TIME</td>
<td>MISS</td>
<td>CONF</td>
<td>HIT</td>
<td>E. %</td>
<td></td>
</tr>
<tr>
<td>1012</td>
<td>49.093( 24.0)</td>
<td>48.511</td>
<td>23317.2</td>
<td>14001.4</td>
<td>96.97</td>
<td>83.2</td>
<td>42.132</td>
<td>5.511</td>
<td>0.000</td>
<td>80.32</td>
<td>funcA</td>
<td></td>
</tr>
<tr>
<td>160640</td>
<td>37.475( 18.3)</td>
<td>0.233</td>
<td>17874.6</td>
<td>9985.9</td>
<td>95.22</td>
<td>52.2</td>
<td>34.223</td>
<td>1.973</td>
<td>2.166</td>
<td>96.84</td>
<td>funcB</td>
<td></td>
</tr>
<tr>
<td>160640</td>
<td>30.515( 14.9)</td>
<td>0.190</td>
<td>22141.8</td>
<td>12263.7</td>
<td>95.50</td>
<td>52.8</td>
<td>29.272</td>
<td>0.191</td>
<td>2.544</td>
<td>93.23</td>
<td>funcC</td>
<td></td>
</tr>
<tr>
<td>160640</td>
<td>23.434( 11.5)</td>
<td>0.146</td>
<td>44919.9</td>
<td>22923.2</td>
<td>97.75</td>
<td>98.5</td>
<td>21.869</td>
<td>0.741</td>
<td>4.590</td>
<td>97.82</td>
<td>funcD</td>
<td></td>
</tr>
<tr>
<td>160640</td>
<td>22.462( 11.0)</td>
<td>0.140</td>
<td>42924.5</td>
<td>21989.6</td>
<td>97.73</td>
<td>99.4</td>
<td>20.951</td>
<td>1.212</td>
<td>4.590</td>
<td>96.91</td>
<td>funcE</td>
<td></td>
</tr>
<tr>
<td>5356298</td>
<td>15.371( 7.5)</td>
<td>0.000</td>
<td>1819.0</td>
<td>482.2</td>
<td>0.00</td>
<td>0.0</td>
<td>0.000</td>
<td>1.253</td>
<td>0.000</td>
<td>0.00</td>
<td>funcF</td>
<td></td>
</tr>
<tr>
<td>14.266( 7.0)</td>
<td>1783.201</td>
<td>1077.3</td>
<td>55.7</td>
<td>0.00</td>
<td>0.0</td>
<td>0.000</td>
<td>4.480</td>
<td>0.000</td>
<td>0.00</td>
<td>funcG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>642560</td>
<td>5.641( 2.8)</td>
<td>0.009</td>
<td>487.7</td>
<td>0.2</td>
<td>46.45</td>
<td>35.1</td>
<td>1.833</td>
<td>1.609</td>
<td>0.007</td>
<td>91.68</td>
<td>funcH</td>
<td></td>
</tr>
<tr>
<td>2032</td>
<td>2.477( 1.2)</td>
<td>1.219</td>
<td>667.1</td>
<td>0.0</td>
<td>89.97</td>
<td>28.5</td>
<td>2.218</td>
<td>0.041</td>
<td>0.015</td>
<td>70.42</td>
<td>funcI</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1.971( 1.0)</td>
<td>246.398</td>
<td>21586.7</td>
<td>7823.4</td>
<td>96.21</td>
<td>79.6</td>
<td>1.650</td>
<td>0.271</td>
<td>0.000</td>
<td>2.58</td>
<td>funcJ</td>
<td></td>
</tr>
</tbody>
</table>

54851346 204.569(100.0) 0.004 22508.5 12210.7 95.64 76.5 154.524 17.740 13.916 90.29 total

54851346 204.569(100.0) 0.004 22508.5 12210.7 95.64 76.5 154.524 17.740 13.916 90.29 total

#include <ftrace.h>

(void) ftrace_region_begin("loop#1") // outside region begin
for (i = 0; i < n; i++) {
  ...
}

(void) ftrace_region_begin("loop#2") // inside region begin
for (j = 0; j < n; j++) {
  ...
}

(void) ftrace_region_end("loop#2") // inside region end
(void) ftrace_region_end("loop#1") // outside region end
Profiler tools: Ftrace Viewer

- Execution time of each function
- Variation in execution time of process (min, max, standard deviation)
- Variation time and vectorization ratio
- Execution time of all processes
- MPI information (communication time, waiting time, etc.)
More Information about SX-Aurora TSUBASA
Aurora Forum website

We are looking forward to seeing discussion about aurora among users and engineers. Let's enjoy the performance of SX-Aurora TSUBASA!

https://www.hpc.nec/
Free Trial Program (WING program)

Look at another brochure or contact to NEC-G staff!

WING Programme (1/2)

- Customers can try their own code or application on SX-Aurora TSUBASA by remotely accessing before purchasing.
- Trial program name: WING (Workspace Infrastructure by NEC Group)
- Terms:
  - Customer need to write and submit the application form.
  - One customer can use one time for TWO months.
  - Free for trial use.
  - Help desk service is open for WING users through WING Web site.
  - NEC will clear the machine and reinstall after trial period finish.
  - NEC would appreciate that customer give us feedback.

WING Programme (2/2)

- Contact
  - If you are interested in or want to use WING program, please feel free to contact the following NEC group staff.

Machine spec
SX-Aurora TSUBASA A300-2

- CPU: Xeon Gold 6126 (12core, 2.6GHz) x1
- MEM: 96GB
- Disk: 1TB HDD
- VE: TypeB (8core, 1.4GHz, 48GB MEM) x 2 or TypeC (8core, 1.4GHz, 24GB MEM) x 2
Contact

If you are interested in or want to use WING program, please feel free to contact the following NEC group staff.

Machine spec
SX-Aurora TSUBASA A300-2

- **CPU**: Xeon Gold 6126 (12core, 2.6GHz) x1
- **MEM**: 96GB
- **Disk**: 1TB HDD
- **VE**: TypeB (8core, 1.4GHz, 48GB MEM) x 2 or TypeC (8core, 1.4GHz, 24GB MEM) x 2