Highlights of the 54th TOP500 List

SC19, Denver, November 19, 2019

Erich Strohmaier
SC19 TOP500 TOPICS

• Petaflops are everywhere!
• “New” TOP10
• HPCG
• Dennard Scaling and the TOP500
• Research Market vs Commercial Market
• Green500
<table>
<thead>
<tr>
<th>#</th>
<th>Site</th>
<th>Manufacturer</th>
<th>Computer</th>
<th>Country</th>
<th>Cores</th>
<th>Rmax [Pflops]</th>
<th>Power [MW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Oak Ridge National Laboratory</td>
<td>IBM</td>
<td>Summit IBM Power System, P9 22C 3.07GHz, Mellanox EDR, NVIDIA GV100</td>
<td>USA</td>
<td>2,414,592</td>
<td>148.6</td>
<td>10.1</td>
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<tr>
<td>2</td>
<td>Lawrence Livermore National Laboratory</td>
<td>IBM</td>
<td>Sierra IBM Power System, P9 22C 3.1GHz, Mellanox EDR, NVIDIA GV100</td>
<td>USA</td>
<td>1,572,480</td>
<td>94.6</td>
<td>7.4</td>
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<td>3</td>
<td>National Supercomputing Center in Wuxi</td>
<td>NRCPC</td>
<td>Sunway TaihuLight NRCPC Sunway SW26010, 260C 1.45GHz</td>
<td>China</td>
<td>10,649,600</td>
<td>93.0</td>
<td>15.4</td>
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<tr>
<td>4</td>
<td>National University of Defense Technology</td>
<td>NUDT</td>
<td>Tianhe-2A ANUDT TH-IVB-FEP, Xeon 12C 2.2GHz, Matrix-2000</td>
<td>China</td>
<td>4,981,760</td>
<td>61.4</td>
<td>18.5</td>
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<tr>
<td>5</td>
<td>Texas Advanced Computing Center / Univ. of Texas</td>
<td>Dell</td>
<td>Frontera Dell C6420, Xeon Platinum 8280 28C 2.7GHz, Mellanox HDR</td>
<td>USA</td>
<td>448,448</td>
<td>23.5</td>
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<td>Swiss National Supercomputing Centre (CSCS)</td>
<td>Cray</td>
<td>Piz Daint Cray XC50, Xeon E5 12C 2.6GHz, Aries, NVIDIA Tesla P100</td>
<td>Switzerland</td>
<td>387,872</td>
<td>21.2</td>
<td>2.38</td>
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<td>7</td>
<td>Los Alamos NL / Sandia NL</td>
<td>Cray</td>
<td>Trinity Cray XC40, Intel Xeon Phi 7250 68C 1.4GHz, Aries</td>
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<td>Fujitsu</td>
<td>AI Bridging Cloud Infrastructure (ABCI) PRIMERGY CX2550 M4, Xeon Gold 20C 2.4GHz, IB-EDR, NVIDIA V100</td>
<td>Japan</td>
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<td>Leibniz Rechenzentrum</td>
<td>Lenovo</td>
<td>SuperMUC-NG ThinkSystem SD530, Xeon Platinum 8174 24C 3.1GHz, Intel Omni-Path</td>
<td>Germany</td>
<td>305,856</td>
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<td>Lawrence Livermore National Laboratory</td>
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<td>USA</td>
<td>288,288</td>
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<td></td>
<td></td>
<td>Site</td>
<td>Manufacturer</td>
<td>Computer</td>
<td>Country</td>
<td>HPCG [Pflop/s]</td>
<td>Rmax [Pflop/s]</td>
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<td>Oak Ridge National Laboratory</td>
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<td>USA</td>
<td>0.5461</td>
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<td>Fujitsu</td>
<td>Al Bridging Cloud Infrastructre (ABCI)&lt;br&gt;PRIMERGY CX2550 M4,&lt;br&gt;Xeon Gold 20C 2.4GHz, IB-EDR, NVIDIA V100</td>
<td>Japan</td>
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<td>Piz Daint&lt;br&gt;Cray XC50,&lt;br&gt;Xeon E5 12C 2.6GHz, Aries, NVIDIA Tesla P100</td>
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<td>Nurion&lt;br&gt;Cray CS500,&lt;br&gt;Intel Xeons Phi 7250 68C 1.4 GHz, OmniPath</td>
<td>South Korea</td>
<td>0.3915</td>
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<td>JCAHPC Joint Center for Advanced HPC</td>
<td>Fujitsu</td>
<td>Oakforest-PACS&lt;br&gt;PRIMERGY CX1640 M1,&lt;br&gt;Intel Xeons Phi 7250 68C 1.4 GHz, OmniPath</td>
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<td>12</td>
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<td>Cray</td>
<td>Cori&lt;br&gt;Cray XC40,&lt;br&gt;Intel Xeons Phi 7250 68C 1.4 GHz, Aries</td>
<td>USA</td>
<td>0.3554</td>
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<td>10</td>
<td>12</td>
<td>Commissariat a l'Energie Atomique (CEA)</td>
<td>Cray</td>
<td>Tera-1000-2&lt;br&gt;Bull Sequana X1000,&lt;br&gt;Intel Xeons Phi 7250 68C 1.4 GHz, Bull BXI 1.2</td>
<td>France</td>
<td>0.3338</td>
<td>12.0</td>
</tr>
</tbody>
</table>
PERFORMANCE DEVELOPMENT

1.65 EFlop/s
149 PFlop/s
1.14 PFlop/s

June 2008
Slowdown of Dennard Scaling

SUM

N=1

N=500

1 Eflop/s
100 Pflop/s
10 Pflop/s

1 Pflop/s
100 Tflop/s
10 Tflop/s

1 Tflop/s
100 Gflop/s
10 Gflop/s

1 Gflop/s
100 Mflop/s

422 MFlop/s
.597 GFlop/s

Less incentives to upgrade systems leads to older systems
Less frequent purchases allow to increase system sizes and lead to a more top-heavy TOP500.
ANNUAL PERFORMANCE INCREASE OF THE TOP500

Less frequent purchases on steady budget leads to increases in system sizes, which temporarily keeps overall performance increase up.
COUNTRIES / PERFORMANCE SHARE

- United States: 37%
- China: 33%
- Japan: 7%
- France: 4%
- United Kingdom: 2%
- Germany: 4%
- Netherlands: 2%
- Switzerland: 4%
- Ireland: 1%
- Italy: 1%

Others: 77%; 5%
VENDORS / SYSTEM SHARE

Lenovo; 175; 35%
HPE/Cray; 73; 15%
Sugon; 71; 14%
Inspur; 66; 13%
Atos; 23; 5%
Fujitsu; 14; 3%
IBM; 17; 3%
Dell EMC; 12; 2%
Huawei; 10; 2%
Others; 28; 6%

# of systems, % of 500
VENDORS / PERFORMANCE SHARE

- Lenovo; 338; 21%
- HPE/Cray; 296; 18%
- Sugon; 119; 7%
- Atos; 65; 4%
- Inspur; 102; 6%
- Others; 240; 15%
- Dell EMC; 53; 3%
- Fujitsu; 63; 4%
- Penguin Computing; 20; 1%
- Huawei; 15; 1%

Sum of Pflop/s, % of whole list
RESEARCH / COMMERCIAL MARKETS

• Markets for scientific computing and for commercial data processing are very different.
• Extract proper sub-samples for these markets from the full TOP500 list
  – TOP100 Research and Academic installations
  – TOP100 Industry (and Vendor) installations
    • Could try to separate out Industry installations but difficult to do
  – Ignore "Government, Classified, Others" for now
  – 100 works reasonably well, more might become tricky
POSITION OF #100 ON TOP500

Research
Commercial
ENTRY LEVEL SYSTEM SIZE

1.00E-04
1.00E-03
1.00E-02
1.00E-01
1.00E+00
1.00E+01
1.00E+02
1.00E+03


TOP500 Research

Commercial

TOP500
ENTRY LEVEL SYSTEM SIZE

<table>
<thead>
<tr>
<th>Year</th>
<th>Research</th>
<th>Commercial</th>
<th>TOP500</th>
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<tbody>
<tr>
<td>2009</td>
<td>10 T flop/s</td>
<td>10 T flop/s</td>
<td>10 T flop/s</td>
</tr>
<tr>
<td>2010</td>
<td>100 T flop/s</td>
<td>1 Pflop/s</td>
<td>1 Pflop/s</td>
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<tr>
<td>2011</td>
<td>1 Pflop/s</td>
<td>10 Pflop/s</td>
<td>10 Pflop/s</td>
</tr>
<tr>
<td>2012</td>
<td>10 Pflop/s</td>
<td>100 Pflop/s</td>
<td>100 Pflop/s</td>
</tr>
<tr>
<td>2013</td>
<td>100 Pflop/s</td>
<td>1000 Pflop/s</td>
<td>1000 Pflop/s</td>
</tr>
<tr>
<td>2014</td>
<td>1000 Pflop/s</td>
<td>10000 Pflop/s</td>
<td>10000 Pflop/s</td>
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<tr>
<td>2015</td>
<td>10000 Pflop/s</td>
<td>100000 Pflop/s</td>
<td>100000 Pflop/s</td>
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<td>2016</td>
<td>100000 Pflop/s</td>
<td>1000000 Pflop/s</td>
<td>1000000 Pflop/s</td>
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<td>2017</td>
<td>1000000 Pflop/s</td>
<td>10000000 Pflop/s</td>
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<td>2018</td>
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<td>100000000 Pflop/s</td>
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<tr>
<td>2019</td>
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<td>2020</td>
<td>1000000000 Pflop/s</td>
<td>10000000000 Pflop/s</td>
<td>10000000000 Pflop/s</td>
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</table>
COUNTRIES / SYSTEM SHARE

Research
- United States: 33%
- China: 79%
- Japan: 17%
- Germany: 17%
- France: 8%
- Others: 17%

Commercial
- China: 79%
- United States: 6%
- Others: 9%
- Germany: 3%
- France: 1%
- Japan: 2%
VENDORS / SYSTEM SHARE

Research:
- Cray: 23%
- HPE: 16%
- Atos: 8%
- Fujitsu: 8%
- IBM: 9%
- Lenovo: 8%
- Sugon: 3%
- Inspur: 1%
- Others: 22%

Commercial:
- Cray: 1%
- HPE: 4%
- Atos: 2%
- IBM: 2%
- Others: 12%
- Fujitsu: 1%
- Lenovo: 31%
- Sugon: 27%
Intel; 58%

Intel/NVIDIA; 17%

Intel Phi; 11%

Power; 3%

Power/NVIDIA; 5%

Sparc; 3%

Others; 3%

Research

Commercial
SC19 TOP500 HIGHLIGHTS

• Petaflops are everywhere!

• Slow-down of Dennard’s scaling lead to longer procurement cycles which provided a 5 year delay from slowing down at the very TOP (2008-2013)
  – Don’t expect this for Moore’s Law!

• TOP100 Research System and Commercial Systems show very different markets
## MOST ENERGY EFFICIENT ARCHITECTURES

<table>
<thead>
<tr>
<th>Computer</th>
<th>Interconnect</th>
<th>Accelerator</th>
<th>Rmax/P</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A64FX Prototype, Fujitsu A64FX</strong></td>
<td>Fujitsu A64FX 48C 2GHz</td>
<td>Tofu Interconnect D -</td>
<td>16.9</td>
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<tr>
<td><strong>NA-1, ZettaScaler-2.2</strong></td>
<td>Xeon 16C 1.3GHz</td>
<td>Infiniband EDR</td>
<td>PEZY-SC2</td>
<td>16.3</td>
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<tr>
<td><strong>AiMOS, IBM Power System AC922</strong></td>
<td>POWER9 20C 3.45GHz Infiniband EDR</td>
<td>Volta GV100</td>
<td>15.8</td>
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<tr>
<td><strong>Satori, IBM Power System AC922</strong></td>
<td>POWER9 20C 2.4GHz Infiniband EDR</td>
<td>Tesla V100 SXM2</td>
<td>15.6</td>
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<td><strong>Summit, IBM Power System AC922</strong></td>
<td>POWER9 22C 3.07GHz Infiniband EDR</td>
<td>Volta GV100</td>
<td>14.7</td>
<td></td>
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<tr>
<td><strong>AI Bridging Cloud Infrastructure (ABCI), Fujitsu PRIMERGY, NVIDIA Tesla V100</strong></td>
<td>Xeon Gold 20C 2.4GHz Infiniband EDR</td>
<td>Tesla V100 SXM2</td>
<td>14.4</td>
<td></td>
</tr>
<tr>
<td><strong>MareNostrum P9 CTE, IBM Power System</strong></td>
<td>Power9 22C 3.1GHz Infiniband EDR</td>
<td>Tesla V100</td>
<td>14.1</td>
<td></td>
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<tr>
<td><strong>Tsubame 3.0, SGI ICE XA</strong></td>
<td>Xeon 14C 2.4GHz Intel Omni-Path</td>
<td>Tesla P100 SXM2</td>
<td>13.7</td>
<td></td>
</tr>
<tr>
<td><strong>PANGEA III, IBM Power System</strong></td>
<td>Power9 18C 3.45GHz Infiniband EDR</td>
<td>Volta GV100</td>
<td>13.1</td>
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<tr>
<td><strong>Sierra, IBM Power System</strong></td>
<td>Power9 22C 3.1GHz Infiniband EDR</td>
<td>Volta GV100</td>
<td>12.7</td>
<td></td>
</tr>
</tbody>
</table>

* Efficiency based on Power optimized HPL runs of equal size to TOP500 run. [Gflops/Watt]
ENERGY EFFICIENCY

Linpack/Power [Gflops/W]

0  2  4  6  8  10  12  14  16  18  20


Max-Efficiency

Fujitsu A64FX

ZettaScaler-2.2

Tsubame 3.0

DGX SaturnV

ZettaScaler-1.6 c

DGX SaturnV

Volta

AMD FirePro

Tsubame KFC

NVIDIA K20x – K80

BlueGene/Q

Cell

DGX SaturnV

TOP500 Average