The Parker Ranch installation in Hawaii

The Bump in the Road to Exaflops and Rethinking LINPACK

Bob Meisner, Director
Office of Advanced Simulation and Computing
• Actively preparing for imminent profound shift in computing architectures by making computing investments NOW in H/W and S/W
• We can’t wait for an initiative to save us
• BUT, an initiative would enable a comprehensive approach to building exascale system
• Exascale isn’t about an exaflop, but about how effectively we transition to a new era of computing
• A better correlated benchmark would help
Episodic disruption defines high-end computing

Architectural stability has made possible remarkable advances in science. But, programming model transitions are tough...and we are approaching one now....
The next disruption is NOW

New Epoch is forcing us to address issues in several broad areas:
• Exponentially growing parallelism
• Data movement management
• System complexity
• Application code evolution

Figure courtesy of Kunle Olukotun, Lance Hammond, Herb Sutter, and Burton Smith, 2004
Continuing to advance computational science will require mastering architectural complexity

- Resolution increases have led to critical scientific insights and further increases are necessary for continued progress.
- Science requirements drive the need for higher performance computers, while computational progress depends on successfully transitioning to complex architectures.

MD plasma simulation

Combustion simulation

Global climate simulation
We are in a new era of computing and need to quickly adapt our codes.

Unless we take action, our future will be keeping performance from deteriorating rather than improving.
An exascale initiative may be our long term salvation, but we need a short term life jacket as well.

- Scientific simulations must be ready for new architectures
- To prepare for the dramatic, impending changes we are pursuing:
  - Partnerships with industry to develop advanced processor, memory and interconnect technologies
  - Investments in software environments and application codes
  - Non-Recurring Engineering (NRE) investments
- We are investigating a new metric to confirm the performance of high-end computers
• Formed partnerships with multiple companies to accelerate the R&D of critical technologies needed for extreme-scale computing

• Targeted innovative new and/or accelerated R&D of technologies for productization in the 5–10 year timeframe
  • $25.4 million focusing on interconnect architectures and implementation approaches
  • $62.5M focusing on processor/memory and storage

• Future investments planned

• NRE also critical to move vendors in suitable directions
We have entered a new era in HPC architectural complexity and need to move beyond High Performance LINPACK (HPL) as a metric.
HPL: Pros

- Easy to run
- Easy to understand
- Easy to check results
- Good tool for community outreach
- “Understandable” to the outside world
- Historical database of performance information
HPL: Cons

- Has poor balance of floating point and data movement compared to modern codes
- Overall usability of a system is not measured
- Used as a marketing tool
- Can require long run times—wasting valuable resources
- Not sensitive to new architectural features
- Does not have sufficient fidelity for procurements
Promote the pros, fix the cons--
Evolving the community benchmark

- Develop a new metric that correlates with important scientific and technical apps not well represented by HPL
  - Replicate the good (enduring) features of HPL
  - Replace the outdated features

- Accurately predict rankings for a target suite of scientific applications

- Encourage vendors to focus on architectural features needed for high performance on important scientific and technical apps

- Not intended to define procurements

- PLUS--Support a historical record of performance information on existing and future systems
Proposal: HPCG for ranking scientific systems

• High Performance Conjugate Gradient (HPCG)
  – Solve $Ax = b$, $A$ large, sparse, $b$ known, $x$ computed
  – Physics-based $A$ matrix

• Contains communication patterns that are prevalent in a variety of methods for discretization and numerical solution of PDEs

• More relevant patterns of computation:
  – Dense and sparse computations
  – Dense and sparse collectives
  – Data-driven parallelism
• **HPCG Technical Specification**  
  – Jack Dongarra, Michael Heroux, Piotr Luszczek

• **Toward a New Metric for Ranking High Performance Computing Systems**  
  – Jack Dongarra and Michael Heroux
HPCG results presented at ISC 2014

<table>
<thead>
<tr>
<th>June 2014 Top 500</th>
<th>Site</th>
<th>Computer</th>
<th>Cores</th>
<th>Peak (Pflops)</th>
<th>HPL RMAX (Pflops)</th>
<th>HPCG (Pflops)</th>
<th>HPCG/R MAX</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>National Super Computer Center in Guangzhou</td>
<td>Tianhe-2 NUDT, Xeon 12C 2.2GHz + Intel Xeon Phi (57c) + Custom</td>
<td>3,120,000</td>
<td>54.90</td>
<td>33.9</td>
<td>0.58</td>
<td>1.71%</td>
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<tr>
<td>2</td>
<td>DOE / OS Oak Ridge Nat Lab</td>
<td>Titan, Cray XK7 (16C) + Nvidia Kepler GPU (14c) + Custom</td>
<td>560,640</td>
<td>27.10</td>
<td>17.6</td>
<td>0.322</td>
<td>1.83%</td>
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<tr>
<td>4</td>
<td>RIKEN Advanced Inst for Comp Sci</td>
<td>K computer Fujitsu SPARC64 VIII fx (8c) + Custom</td>
<td>705,024</td>
<td>11.30</td>
<td>10.5</td>
<td>0.426</td>
<td>4.06%</td>
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<tr>
<td>5</td>
<td>MIRA DOE / OS Argonne Nat Lab</td>
<td>BlueGene/Q, Power BQC 16C 1.60GHz, Custom</td>
<td>786,432</td>
<td>10.10</td>
<td>8.59</td>
<td>0.101</td>
<td>1.18%</td>
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<tr>
<td>6</td>
<td>Swiss CSCS</td>
<td>Piz Daint, Cray XC30, Xeon 8C + Nvidia Kepler (14c) + Custom</td>
<td>115,984</td>
<td>7.80</td>
<td>6.27</td>
<td>0.099</td>
<td>1.58%</td>
</tr>
<tr>
<td>11</td>
<td>HPC2</td>
<td>Intel Xeon 10C 2.8 GHz + Nvidia Kepler (14c) + IB</td>
<td>62,640</td>
<td>4.00</td>
<td>3</td>
<td>0.0489</td>
<td>1.63%</td>
</tr>
</tbody>
</table>

- HPCG is real and has been run on several systems
- Performance is consistent with our expectations and experience
Comments on early HPCG benchmark results

• The disparity between HPL and HPCG is not a surprise, it’s a fact of life

• The results reflect the intrinsic nature of many challenging scientific applications: climate, combustion, turbulence, etc...

• These are typical of the currently available systems for mission-critical applications

• Not all vendors have developed optimized versions
In Summary…

• The transition to the next era in high-end computing is going to affect all scientific computer users long before an exaflop system is available

• We need to take a comprehensive approach to next-gen platforms

• We are preparing for the inevitable and significant changes through
  – Hardware and software codesign efforts
  – Funded collaborations with industry to ensure that exascale architecture computers will meet our scientific computing needs
  – Application code redesign to address expected processor, memory and storage changes

• We are investigating new, more informative ways to measure performance
Thank You

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