A BRIEF INTRODUCTION TO
CPU DEVELOPMENT IN CHINA

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Outline

• A Brief Review of Chinese IT History

• China CPU Design Strategy

• Introduction to Loongson CPU
Chinese IT History - Three Stages

• 1950’s-1980’s: Independent Development Stage

• 1980’s-2000’s: “Open up” and Extensive Application Stage

• 2000’s-present: Independent Innovation Stage
Independent Development Stage

- 1956, identify “computer technology” as one of the “four emergent polices” of the 12-year Science & Technology plan held by Primary Minister Zhou.
  - ICT (Institute of Computer Technology) found in the same year.
- National strategic purpose use computers been developed.
- Computer science education started in ICT
  - 700 computer researchers are trained at three training classes
- By 1980's, independent IT industry for national strategy applications was set up.
“Open up” and Extensive Application Stage

- 1980’s “open up” policy in China.
  - Self developed mainframe machines such as Model-757, Model-8920, Yinhe-1, Yinhe-2 are designed at that stage.
  - The CMOS process technology of China cannot support the development of PC industry.
- 1990's all computers depended on foreign CPU and OS
  - PC Companies: Lenovo, Founder, …
  - High Performance Computers: Dawning, Yinhe, …
- Chinese IT industry on foreign technology platforms (Intel/Microsoft)
  - National security risks
  - IT industry foundation is weak
## TOP10 HPCs in 2008.11

<table>
<thead>
<tr>
<th>Rank</th>
<th>Site</th>
<th>Computer/Year Vendor</th>
<th>Cores</th>
<th>R&lt;sub&gt;max&lt;/sub&gt;</th>
<th>R&lt;sub&gt;peak&lt;/sub&gt;</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DOE/NNSA/LANL United States</td>
<td>Roadrunner - BladeCenter QS22/LS21 Cluster, PowerXCell 8i 3.2 GHz / Opteron DC 1.8 GHz, Voltaire Infiniband / 2008 IBM</td>
<td>129600</td>
<td>1105.00</td>
<td>1456.70</td>
<td>2483.47</td>
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<tr>
<td>2</td>
<td>Oak Ridge National Laboratory United States</td>
<td>Jaguar - Cray XT5 QC 2.3 GHz / 2008 Cray Inc</td>
<td>150152</td>
<td>1059.00</td>
<td>1381.40</td>
<td>6950.50</td>
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<tr>
<td>3</td>
<td>NASA/Ames Research Center/NAS United States</td>
<td>Pleiades - SGI Altix ICE 8200EX, Xeon QC 3.0/2.66 GHz / 2008 SGI</td>
<td>51200</td>
<td>487.01</td>
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<tr>
<td>4</td>
<td>DOE/NNSA/LLNL United States</td>
<td>BlueGene/L - eServer Blue Gene Solution / 2007 IBM</td>
<td>212992</td>
<td>478.20</td>
<td>596.38</td>
<td>2329.60</td>
</tr>
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<td>5</td>
<td>Argonne National Laboratory United States</td>
<td>Blue Gene/P Solution / 2007 IBM</td>
<td>163840</td>
<td>450.30</td>
<td>557.06</td>
<td>1260.00</td>
</tr>
<tr>
<td>6</td>
<td>Texas Advanced Computing Center/Univ. of Texas United States</td>
<td>Ranger - SunBlade x6420, Opteron QC 2.3 Ghz, Infiniband / 2008 Sun Microsystems</td>
<td>62976</td>
<td>433.20</td>
<td>579.38</td>
<td>2000.00</td>
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<td>7</td>
<td>NERSC/LBNL United States</td>
<td>Franklin - Cray XT4 QuadCore 2.3 GHz / 2008 Cray Inc</td>
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<td>9</td>
<td>NNSA/Sandia National Laboratories United States</td>
<td>Red Storm - Sandia, Cray Red Storm, XT3/4, 2.2/2.2 GHz dual/quad core / 2008 Cray Inc.</td>
<td>38208</td>
<td>204.20</td>
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<td>10</td>
<td>Shanghai Supercomputer Center China</td>
<td>Dawning 5000A - Dawning 5000A, QC Opteron 1.9 GHz, Infiniband, Windows HPC 2008 / 2008 Dawning</td>
<td>30720</td>
<td>180.60</td>
<td>233.47</td>
<td></td>
</tr>
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<td>1</td>
<td>Oak Ridge National Laboratory, United States</td>
<td>Jaguar - Cray XT5-HE Opteron Six Core 2.6 GHz / 2009 Cray Inc.</td>
<td>224162</td>
<td>1759.00</td>
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<td>2</td>
<td>DOE/NNSA/LANL, United States</td>
<td>Roadrunner - BladeCenter QS22/LS21 Cluster, PowerXCell 632 GHz / Opteron DC 1.8 GHz, Voltaire Infiniband / 2009 IBM</td>
<td>122400</td>
<td>1042.00</td>
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<td>3</td>
<td>National Institute for Computational Sciences/University of Tennessee, United States</td>
<td>Kraken XT5 - Cray XT5-HE Opteron Six Core 2.6 GHz / 2009 Cray Inc.</td>
<td>98628</td>
<td>831.70</td>
<td>1028.85</td>
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<tr>
<td>4</td>
<td>Forschungszentrum Juelich (FZJ), Germany</td>
<td>JUGENE - Blue Gene/P Solution / 2009 IBM</td>
<td>294912</td>
<td>825.50</td>
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<td>2268.00</td>
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<tr>
<td>5</td>
<td>National Supercomputer Center in Tianjin/NUDT, China</td>
<td>Tianhe-1 - NUDT TH-1 Cluster, Xeon E5540/E5540, ATI Radeon HD 4870 2, Infiniband / 2009 NUDT</td>
<td>71680</td>
<td>563.10</td>
<td>1206.19</td>
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<tr>
<td>6</td>
<td>NASA/Ames Research Center/NAS, United States</td>
<td>PhiLadex - SGI Altix ICE 6200EX, Xeon QC 3.0 GHz/Nehalem EP 2 93 GHz / 2009 SGI</td>
<td>56320</td>
<td>544.30</td>
<td>673.26</td>
<td>2348.00</td>
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<td>7</td>
<td>DOE/NNSA/LBNL, United States</td>
<td>BlueGene/L - eServer Blue Gene Solution / 2007 IBM</td>
<td>212092</td>
<td>478.20</td>
<td>596.38</td>
<td>2329.50</td>
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<td>8</td>
<td>Argonne National Laboratory, United States</td>
<td>Blue Gene/P Solution / 2007 IBM</td>
<td>163940</td>
<td>456.61</td>
<td>557.06</td>
<td>1260.00</td>
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<tr>
<td>9</td>
<td>Texas Advanced Computing Center/Univ. of Texas, United States</td>
<td>Ranger - SunBlade x6420, Opteron QC 2.3 Ghz, Infiniband / 2003 Sun Microsystems</td>
<td>62976</td>
<td>433.20</td>
<td>579.38</td>
<td>2000.00</td>
</tr>
<tr>
<td>10</td>
<td>Sandia National Laboratories / National Renewable Energy Laboratory, United States</td>
<td>Red Sky - Sun Blade x6275, Xeon X5560 2.93 Ghz, Infiniband / 2009 Sun Microsystems</td>
<td>41616</td>
<td>423.90</td>
<td>487.74</td>
<td></td>
</tr>
</tbody>
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## Top 10 HPCs in 2010.6

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<tr>
<th>Rank</th>
<th>Site</th>
<th>Computer/Year Vendor</th>
<th>Cores</th>
<th>$R_{\text{max}}$</th>
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<th>Power</th>
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<tr>
<td>1</td>
<td>Oak Ridge National Laboratory, United States</td>
<td>Jaguar - Cray XT5-HE Opteron 6x Core 2.6 GHz / 2009, Cray Inc.</td>
<td>224162</td>
<td>1759.00</td>
<td>2331.00</td>
<td>6950.60</td>
</tr>
<tr>
<td>2</td>
<td>National Supercomputing Centre in Shenzhen (NSCC), China</td>
<td>Nebulae - Dawning TC3600 Blade, Intel X5650, NVidia Tesla C2050 GPU / 2010, Dawning</td>
<td>120540</td>
<td>1271.00</td>
<td>2904.30</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>DOE/NNSA/LANL, United States</td>
<td>Roadrunner - BladeCenter QS22/LS21 Cluster, PowerXCell 8x 3.2 GHz / Opteron DC 1.8 GHz, Voltaire InfiniBand / 2009, IBM</td>
<td>122400</td>
<td>1042.00</td>
<td>1375.78</td>
<td>2345.50</td>
</tr>
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<td>4</td>
<td>National Institute for Computational Sciences/University of Tennessee, United States</td>
<td>Kraken XT5 - Cray XT5-HE Opteron Six Core 2.6 GHz / 2009, Cray Inc.</td>
<td>98928</td>
<td>831.70</td>
<td>1028.85</td>
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<td>JUGENE - Blue Gene/P Solution / 2009, IBM</td>
<td>294912</td>
<td>825.60</td>
<td>1002.70</td>
<td>2268.00</td>
</tr>
<tr>
<td>6</td>
<td>NASA Ames Research Center/NASA, United States</td>
<td>Pleiades - SGI Altix ICE 8200EX/8400EX, Xeon HT QC 3.0/Xeon Westmere 2.53 GHz, InfiniBand / 2010, SGI</td>
<td>81920</td>
<td>772.70</td>
<td>973.29</td>
<td>3096.00</td>
</tr>
<tr>
<td>7</td>
<td>National SuperComputer Center in Tianjin/NUDT, China</td>
<td>Tianhe-1 - NUDT TH-1 Cluster, Xeon E5540/E5550, ATI Radeon HD 4870 2, InfiniBand / 2009, NUDT</td>
<td>71560</td>
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<td>2329.60</td>
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<td>9</td>
<td>Argonne National Laboratory, United States</td>
<td>Intrepid - Blue Gene/P Solution / 2007, IBM</td>
<td>163840</td>
<td>468.61</td>
<td>557.06</td>
<td>1260.00</td>
</tr>
<tr>
<td>10</td>
<td>Sandia National Laboratories / National Renewable Energy Laboratory, United States</td>
<td>Red Sky - Sun Blade x6275, Xeon X5550x 2.93 GHz, InfiniBand / 2010, Sun Microsystems</td>
<td>42440</td>
<td>433.50</td>
<td>497.40</td>
<td></td>
</tr>
</tbody>
</table>
Independent Innovation Stage

• International trend
  • Linux reduces threshold of OS
  • EDA tools reduce threshold of CPU design
  • CMOS Foundries provide condition for production

• From 2000’s re-arrange development of CPU and OS
  • CPUs: Loongson……
  • OS/Office; Redflag, WPS, Redoffice
  • Foundries: SMIC, Grace, Huahong
Outline

• A Brief Review of Chinese IT Industry
• China CPU Design Strategy
• Introduction to Loongson CPU
Why Independent Innovation?

• For a developing country, information cost high
  • Computer purchase cost
  • Large power consumption cost
  • Computer/software upgrading cost

<table>
<thead>
<tr>
<th></th>
<th>PCs (m)</th>
<th>Population (m)</th>
<th>PC/person</th>
</tr>
</thead>
<tbody>
<tr>
<td>US</td>
<td>282</td>
<td>307</td>
<td>0.92</td>
</tr>
<tr>
<td>China</td>
<td>252</td>
<td>1340</td>
<td>0.19</td>
</tr>
</tbody>
</table>
Why Independent Innovation?

• The IT industry needs restructuring
• In 2008, GDP of China IT industry is RMB 6300 billion, net profit ~3%.
• In 2009, China produced 182 million computers, 61% of the world.

**Chinese IT industry data (Billion RMB)**

<table>
<thead>
<tr>
<th></th>
<th>output</th>
<th>profit</th>
<th>margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>1880</td>
<td>75</td>
<td>3.99%</td>
</tr>
<tr>
<td>2005</td>
<td>3840</td>
<td>130.7</td>
<td>3.4%</td>
</tr>
<tr>
<td>2009</td>
<td>5130</td>
<td>179.1</td>
<td>3%</td>
</tr>
</tbody>
</table>
Production without Innovation

- Chinese GDP contributed 8% of World GDP in 2009. Power consumption (coal) covers 45%, other resources (steel, glass, cement) covers up to 61%.
  - Count base on 8% GDP increase each year, unit GDP consumption decrease by 3%, by 2050, China power consumption will be 8 times of current figure.
- 2006, Chinese GDP resource consumption is 0.95 tce/KUSD.
  - Major Western countries figure lower than 0.3 tce/KUSD, Japan is 0.1tce/KUSD.

GDP structure (2009)
CPU Plan in China

- National “Mid-Term S&T Plan” (2006-2020)
- Design CPU&OS is part of the National S&T Major Projects

- Phase I (2001-2005)
  - Start up and key technology research
  - four-issue out-of-order Architecture, 1.0GHz

- Phase II (2006-2010)
  - From emulation to innovation, low-end to high-end, lab research to product
  - Multi-core CPU with leading performance, CPU company setup
  - Desktop, servers, HPC products based on domestic designed CPU

- Phase III (2011-2020)
  - Build a new ecosystem to support Chinese IT industry
  - Start applications from national security, education, e-government, ......

16 Major Projects, each fund USD 5-10B (2006-2020)
- CPU and OS
- VLSI process technology
- Next-generation (4G) wireless network
- High-end digital machine tool
- Advanced nuclear fission power plant
- Water pollution control and treatment
- Large aircraft
- High-resolution earth-observation system
- Manned space flight and lunar exploration
- ......
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• A Brief Review of Chinese IT Industry

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Loongson CPU Briefs

• Research milestones: started in 2001
  • The 32-bit Loongson-1 in 2002 is the first CPU in China
  • The 64-bit Loongson-2B in 2003.10
  • The 64-bit Loongson-2C in 2004.12
  • The 64-bit Loongson-2E in 2006.03
  • Each Triple the performance of its previous one
  • SPEC int2000 and SPEC fp2000 of Loongson-2E > 500

• Product Stage: started in 2008
  • Low-end: SOCs for low-cost PC and consumer electronics
  • High-end: multi-core CPUs for servers and HPCs
Loongson Technology Corporation Limited

Loongson-2F SoC

- 800MHz@90nm CMOS, 3-5W
- 51M transistors, area 43mm^2
- 64-bit MIPS III Compatible
- Four-issue, OOO
- 64KB+64KB L1 (four-way)
- 512KB L2 (four-way)
- On-Chip DDR2 controller.
- PCI/PCIX, Local IO, GPIO, etc.
- SPEC int2000 and SPEC fp2000> 500
- Volume production for low-cost PC and embedded applications

Loongson-2G SoC

- 1.0GHz@65nm CMOS, 3W
- 100M transistors, area 60mm^2
- Single GS464 cores
  - 64-bit MIPS64 Compatible
  - HW support X86 binary translation
  - Four-issue, OOO
  - 64KB+64KB L1 (four-way)
- 1MB L2
- On-chip DDR2/3 controller.
- 16-bit HT
- PCI/PCIX, LPC, GPIO,
4 core Loongson-3A

- 1.0GHz@65nm CMOS, 10W
- 425M transistors, area 174.5mm²
- Four GS464 cores
  - 64-bit MIPS64 Compatible
  - HW support for X86 binary translation
  - Four-issue, OOO
  - 64KB+64KB L1 (four-way)
- 4MB L2
- Two on-chip DDR2/3 controller.
- Two 16-bit HT
- PCI/PCIX, LPC, GPIO, etc.
- SPEC int2000 rate and SPEC fp2000 rate 25

8 core Loongson-3B

- 1.0GHz@65nm CMOS, 40W
- 583M transistors, area 300mm²
- Eight GS464V cores
  - MIPS64 Compatible, 256-bit SIMD vector
  - HW support for X86 binary translation
  - Four-issue, OOO
  - 64KB+64KB L1 (four-way)
- 4MB L2
- Two on-chip DDR2/3 controller.
- Two 16-bit HT
- PCI/PCIX, LPC, GPIO, etc.
Loongson CPU Applications

- **Commercial applications**
  - Low cost PC
  - Servers
  - High performance computers
  - Consumer electronics
  - Industry control
  - .......

- **National security applications**
  - Security computers
  - Radar and Sonar signal processing
  - Information control system
  - Network security
  - .......

Loongson Technology Corporation Limited
• Loongson low cost PC’s power consumption about 20-30W, 1/10 of average PC in market.
  • Road map for environmental concerns.

• Performance reaches 50%-60% of average PC.
  • Reaching the impoverished.

Solution to the basic computing needs for the masses of low income people in both China and the world.
THANKS!

Loongson Technology Cooperation Ltd.

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