China HPC Report

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Presented to ASCAC
August 23, 2011

LLNL-PRES-492348

CHINA

A driving force in the future of global supercomputing

Trip Purpose

- Ascertain the current state of China's supercomputing capability and the application of high-performance computing to R&D

- Explore China's drive to develop clean energy technologies

Delegation

- Dr. Tomás DÍAZ de la RUBIA (Deputy Director for Science and Technology, LLNL)

- Ms. Deborah WINCE-SMITH (CEO and President of the U.S. Council on Competitiveness and LLNL ST&E Advisory Board member)

- Ms. Dona CRAWFORD (Associate Director for Computation, LLNL)

- Dr. Julio FRIEDMANN (Director for Carbon Management Program, LLNL)

- Dr. Clara SMITH (Post-doctoral Research Scientist, LLNL)

- **Accompanied by:**

  - Dr. David KAHANER (Director Asian Technology Information Program [ATIP])

  - Dr. Watson YAN (Technology Analyst, ATIP)

  - Ms. Debbie CHEN (ATIP in-country Manager)

Trip to China: June 27-July 1, 2011

- Beijing – Day 1
  - Ministry of Science and Technology (MOST)
  - Chinese Academy of Science (CAS)
  - Institute of Computing Technology (ICT) of CAS
  - Peking University
  - Institute of Process Engineering (IPE) of CAS
  - CAS Supercomputing Center

- Beijing – Day 2
  - Chinese National Offshore Oil Corporation (CNOOC)
  - US Embassy
  - China Association for the Promotion of Industrial Development (CAPID) or
  - Tsinghua University, and Clean Energy Research and Education Center
  - China Huaneng Group (state-owned power generation enterprise)

Trip to China: June 27-July 1, 2011 con't.

- **Tianjin and Langfang – Day 3**
  - Tianjin Supercomputing Center (associates from NUDT included)
  - ENN Group (clean energy company conglomerate)

- **Shanghai – Day 4**
  - GE China Research Center
  - Shanghai Supercomputing Center

- **Shenzhen – Day 5**
  - Shenzhen Institute of Advanced Technology (SIAT) of CAS
  - National Supercomputing Center
  - BGI (international genomics institute)

Lawrence Livermore National Laboratory

High-Performance Computing: China Visit
June 27–July 1, 2011

Day 1 and 2: Beijing

Day 3: Tianjin

Day 3: Langfang

Day 4: Shanghai

Changsha

Day 5: Shenzhen

Chinese have a staggering rate of growth in S&T infrastructure build-out

-including HPC and research institutes

- Aggressive campaign to recruit back to China

- Average age in organizations visited was early 30's

- Indigenous technology development and implementation

- Broad-based, balanced, HPC approach

  - Hardware

  - Software

  - Applications

  - Industrial Use

What is the U.S. position with respect to S&T leadership and its implications for National Security and Competitiveness?

Regarding HPC in China…
June 2011 Top 500, 61 systems

- **#2 (Tianhe-1A), Tianjin – Day 3**

- **#4 (Dawning Nebulae), recently moved to Shenzhen – Day 5**

- **#34 (Mole 8.5), CAS-IPE, Beijing – Day 1**

- **#41 (Magic Cube), Shanghai Supercomputer Center – Day 4**

- **#83 (DeepComp 7000), SCCAS, Beijing – Day 1**

- **#98 (Inspur TS10000), Tsinghua University, Beijing – Day 2**

- China is likely to have more submissions later in 2011

Three Domestic HPC Systems (courtesy of ATIP)

- #2 system Tianhe-1A uses Intel, nVIDIA, plus 2048 Chinese FeiTeng* processors (open SPARC based), Chinese developed interconnect & Kylin OS, located in Tianjin

- #4 system Dawning Nebulae uses Intel, nVIDIA

    Dawning 6000 (2011) **not yet ranked** will enlarge Nebulae & (initially) use 3000 Chinese Godson/Loongson processors (open MIPS based), in new center in Shenzhen

- Sunway system @ Shandong SC Center (Jinan City)

  - uses Chinese HW (Alpha-enhanced ShenWei* processor, Infiniband-like interconnect)

  - being tested (1.1PFlop peak, 738 TFlop Linpack) [~$100M (1/3 MOST, 2/3 Shandong Prov govt)].

  - Home of Inspur. Host of HPC China 2011
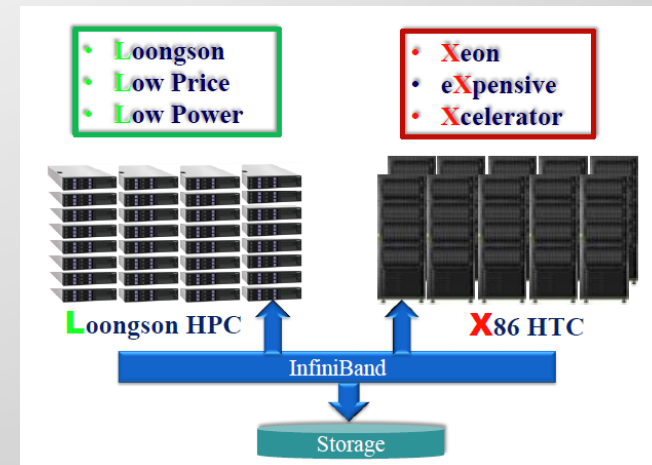
*FeiTeng & ShenWei are military developed

Beijing – Day 1
Ministry of Science and Technology (MOST)

David KAHANER, Julio FRIEDMANN, Clara SMITH, Tomas DIAZ de la RUBIA, Chaochen LI, Deborah Wince SMITH, Dona CRAWFORD
Chaochen LI, Director General MOST -> Chinese Embassy as Minister Counselor for S&T
Qiang WANG, Director Division of Americas and Oceania (not pictured)
Chunheng WANG, Department of High and new Technology Development and Industrialization (not pictured)
Zhao GANG, Director Chinese Academy of Science and Technology for Development, MOST (not pictured)

Beijing – Day 1
Chinese Academy of Science (CAS)

Zhiwei XU, CTO Institute of Computing Technology, CAS
Jinghua CAO, Deputy Director General, CAS Bureau of International Cooperation
Wei GE, Director Research, CAS Complex Systems at Institute of Process Engineering
Shizhuan ZHANG, Deputy Director, CAS Bureau of International Cooperation
Yutong LI, Professor at Institute of Physics, CAS
Qingquan ZHANG, Program Manager, CAS Bureau of International Cooperation (not pictured)
Jinghai LI, VP of CAS, President of Chinese Society of Particology and Director of State Key Laboratory of Multi-Phase
Complex Systems (not pictured)

Beijing – Day 1
Institute of Computing Technology (ICT) of CAS

Zhiwei XU – CTO/Professor Institute of Computing Technology, CAS

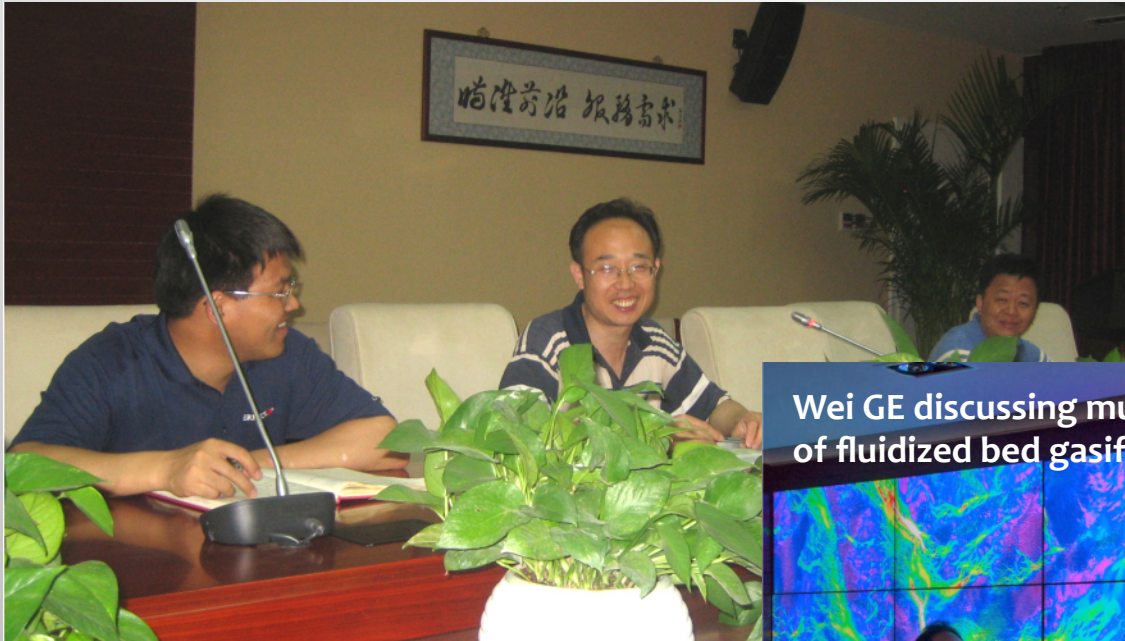# Institute of Computing Technology (ICT) of CAS

- Working on indigenous technology for
  - **Godson** (Loongson) microprocessors
  - **Dawning** HPC servers
  - **Blue-Whale** file system and storage
  - **Vega** Ling Cloud software

- Collaborating with the Europeans: EC 6th and 7th frameworks
  - OS, Manycore architectures, Semantic Web
  - New: European Commission (EC) Future Emerging Technologies (FET) Flagships

- New Challenges
  - Complexity in time, space, effort, energy, sensors dictate review of full HW/SW stack for 2015 (and beyond) computing systems
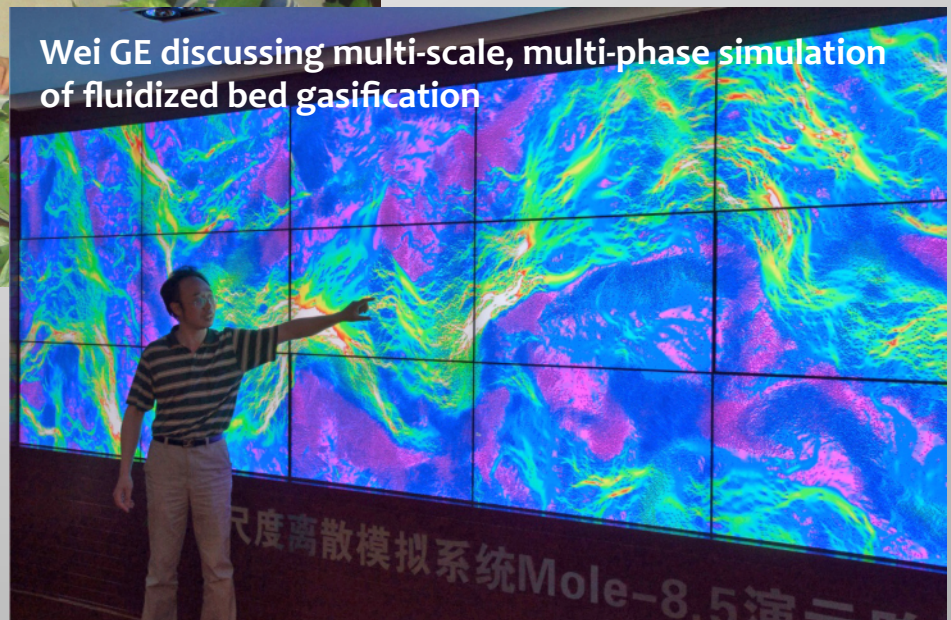
New Challenges (and Tests) – slide from ICT

- **Test 1. Rank low-carbon households in big cities automatically**
  - Automatically rank the households in Beijing and London by the best practices in terms of energy efficiency, and contrast the two cities' top 10 best practices.

- **Test 2. Use IT assets via Universal Compute Account (UCA)**
  - Even when time and space have shifted

- **Test 3. Increase datacenters efficiency by orders of magnitude**
  - Typical million-server datacenters each consume less than 100 million watts, and achieve PEE and PCE greater than 10-20%.

- **Test 4. Facilitate mass creations of value Net services**
  - A high-school student can learn to create and deploy a value Net service within a month.

- **Test 5. Enable science-based macro information policies**
  - How to price the Net to maximize 1.2 billion people's welfare?
  - A science-based messaging tax policy which could drastically reduce spam while facilitating legitimate communication.

Beijing – Day 1
Institute of Process Engineering (IPE) of CAS

Wei GE discussing multi-scale, multi-phase simulation of fluidized bed gasification

Xiaowei WANG, HPC Investigator HW
Wei GE, Director Research, CAS Complex Systems, IPE
Xianfeng HE, HPC Investigator SW

Institute of Process Engineering (IPE) of CAS

- Multi-scale simulation of complex, multi-phase systems

  - Gas-solid and gas-fluid flow; emulsions

  - Nano-microflow; biological interfaces

- Industrial applications

  - Fossil fuel combustions and conversion

  - Refining

  - Chemical fabrication and processing

  - Proof of concept using side-by-side demonstrations

- Computer System (#3 on China's Top100)

  - Mole-8.5 Cluster Xeon L55230 2.26 GHz, nVidia Tesla, Infiniband

  - Rpeak 1.1 Pf

  - Rmax 207 Tf

  - 33,120 Cores

Advanced process visarium and real-time simulator

Mole 8.5

Beijing – Day 1
Computer Network Information Center (CNIC) Supercomputing Center, CAS

Prof. Xuebin CHI, Director of Supercomputing Center and Director of Operating Management Supporting Center, China National Grid

CNGrid (con.)

CAS Supercomputing Center

- Lenovo DeepComp 7000, HS21/x3950 Cluster, Xeon QC HT 3 GHz/2.93 GHz, Infiniband (#5 on China's Top100)

  - Rpeak 146TF

  - Rmax 103TF

  - 12,216 cores

  - Total memory capacity 66TB, Bare disk array capacity 354TB

  - MPI communication bandwidth 2GB/s, delay≤3µs

  - Sustained aggregated bandwidth50GB/s

  - Uncompressed capacity of tape library 1PB, aggregated bandwidth 800MB/s.

CAS Supercomputing Center Commercial Software

Paid Software	Functional descriptions and uses
TotalView	Parallel Debugger
ParaWise	A semi-automatic tools in parallel program
PGI Compiler	PGI Compiler for Linux
Intel C/C++/ Fortran Compiler	Intel® C/C++/ Fortran Compiler for Linux
MKL	Computing science and engineering design of floating-point mathematic function library
IPP	Mathematic Function Library
VTUNE	Performance Optimization Tools
ADF	DFT calculation software
ANSYS LS-Dyna	Computational mechanics、finite element analysis software
LSF	Activity-Based Management System Software
Molpro	Quantitative calculation of the electronic structure of high-precision software
MedeA VASP	First-principles molecular dynamics calculation software
AVS，IDL，Tecplot	Visualization packages
Q-Chem，Spartan	Computational chemistry software package
Matlab	Numerical software
TurboMole	Quantum chemistry calculation software
Wien2K	Computational chemistry / Computational Materials Science Software
Materials Studio	Computational Materials Science Software
CFX，Fluent	General CFD software package, engineering computing
ANSYS	Structural calculation package

CAS Supercomputing Center
Open Source Software

Category	Open source software
Basic Parallel	PETSc、AZTEC、TAO、SUNDIALS、FFTW、LAPACK、ScalLAPACK、PARPACK、DOUG
Computational Chemistry	CPMD、DOCK6、AUTODOCK、TINKER、GAMESS、GROMACS、NAMD、polyrate、Espresso、NWChem、DL_poly
Materials Science	ALCMD、PSSP、PDIP、ABINIT、LAMMPS
Bioinformatics	NCBI Toolkit、Blast、MPI_Blast、Fasta、ClustalW、Phred-Phrap、VELVET、Blat、Emboss、Wise2、InterProScan、Cm2hmm、MEME、Weeder、Mfold、RNAfold、INFERNAL、InsPecT、Mrbayes、BEAST、Hpype
Environmental Science	MM5、WRF、REGCM3、CCSM3、ECHAM5、CAM3、HYCOM、POP、ROMS、LIS
Basic science	FPEG、Open CFD、Elmer
Visualization	ParaView、GMT
Computational Finance	QuantLib

CAS Supercomputing Center Self Developed Software

Category	Self-development Software
Grid Middleware	SCE, Scgrid Portal
Basic Parallel	PSEPS、PMDFFT、DFT、ADG
Materials Science	Getstructure、MPI-PSSP
Bioinformatics	MPI_SiClone、Para_AltSplice、Para_MEME、Para_Weeder、P_InsPecT
Environmental Science	FGOALS、RIEMS、CUACE/dust、GRAPES、IAP-AGCM、IAP-LICOM...
Computational Chemistry	GridMol、SCChem, Xian_CI 、CCSD-EOM、3D 、BDF、HONPAS
Visualization	GrADs_Web、LURR_TimeView、LURR_SpaceView、GeoModel、GlobalVis
Earth Science	MPI_LURR

Beijing – Day 1
College of Engineering(COE),Peking University

Qian WANG, Professor, Center for Computational Science and Engineering(CCSE)
Feng LIU, Professor, Dept. of Mechanics and Aerospace Engineering, COE
Xiantu HE, member of CAS, Director of Center for Applied Physics and Technology (behind Dr. CHEN in the picture)
Shiyi CHEN, Dean Graduate School and Dean COE
Guoxin CAO, Associate Professor, Dept. of Mechanics and Aerospace Engineering, COE
Zuoli XIAO, Associate Professor, Dept. of Mechanics and Aerospace Engineering, COE

Beijing – Day 2
Tsinghua University

- Computer: Inspur TS10000 HPC Server, Xeon X56xx 2.93 Ghz, QDR Infiniband (#6 on China's Top100)
  - Rpeak 107TF
  - Rmax 92TF
  - 9216 cores
- Alumni includes (since 1911):
  - >140 provincial governors,
  - >240 university presidents
  - >140 ministers
- Visited
  - Institute of Nuclear and New Energy Technology
  - Department of Thermal Engineering
  - BP Clean Energy Research and Education Center

Tianjin – Day 3
Tianjin Supercomputing Center

Xianfeng MENG

Tianjin Supercomputing Center

- Computer: NUDT TH MPP, Xeon X5670 2.93Ghz 6C, NVIDIA GPU, FT-1000 8C (#1 on China's Top100)
  - Rpeak 4.7PF
  - Rmax 2.6PF
  - 186368 cores (7168 compute nodes, 14,336Xeon CPU, 7168NVidia, 2048 FT CPUs)
  - 262TB memory
  - 2PB disk
  - Homegrown interconnect
  - Linux Kylin OS, C, C++, Fortran 77/90/95, Java, Lustre
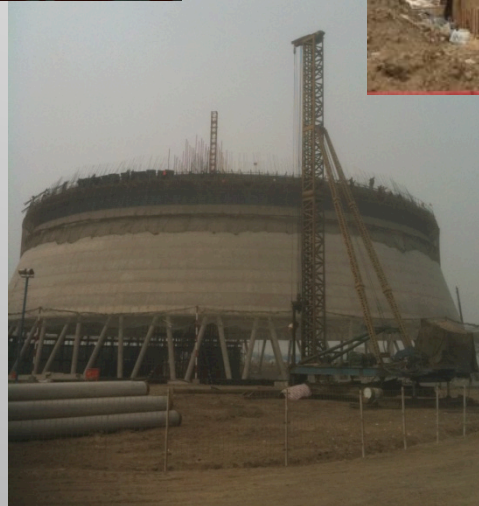
Day 3 - Tianjin
GreenGen IGCC power plant

- Major shareholders of GreenGen are China Huaneng Group (51%), 7% each to 7 other companies: 4 power companies, 2 coal companies, and 1 investment company

From: http://powerplantccs.com/blog/tag/greengen

Tianjin – Day 3
GreenGen IGCC power plant

Shanghai – Day 4
GE China Research Center

Dr. Xiangli CHEN, General Manager , GE China research center
Aoshuang XIAO, Manager Communications and Public Affairs
(not pictured)

Shanghai – Day 4
Shanghai Supercomputing Center

"Finite Computation Infinite Possibilities"

Jiancheng WU, Application Promotion Department of SSC
Genguo LI, Vice director of SSC
Dazhi KOU, Department of HPC Application & Business Development
Lijing LI, Manager HR (pictured on right)
Bo LIU, Department of HPC Application & Business Development
 (not pictured)

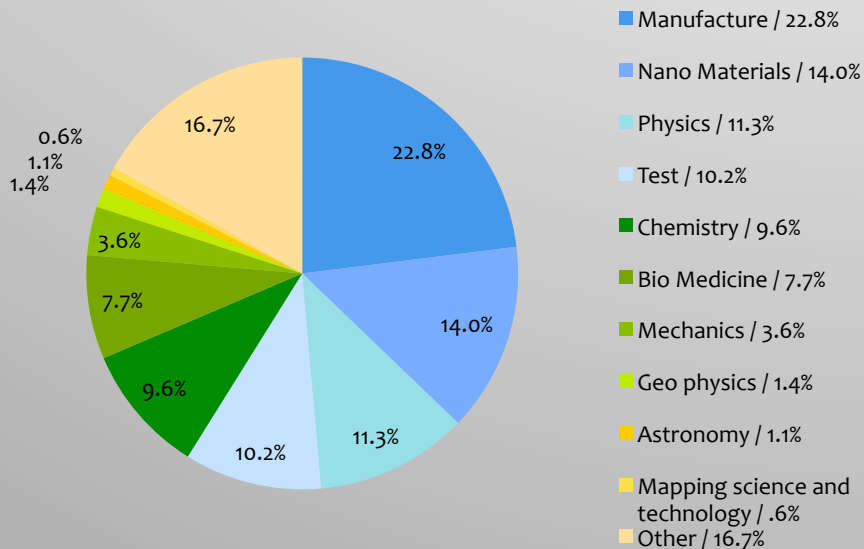# Shanghai Supercomputing Center
10th anniversary 2010

- Computer: Dawning 5000A (Magic Cube), AMD x86_64 Opteron Quad Core 1.9 Ghz, Infiniband, Windows HPC 2008 (#4 on China's Top100)

  - Rpeak 233TF

  - Rmax 181TF

  - 30,720 cores

- Doubling Scheme for advancing Magic Cube applications – 2009: 5, 2010:3 more

  - Computer Leasing, Consulting and Computing Solutions, R&D

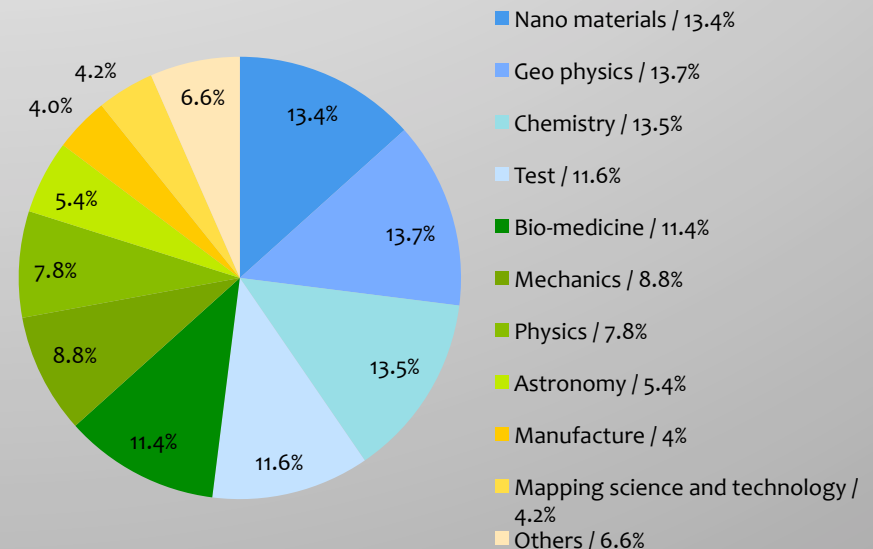- Scientific Research, Industrial Applications, Engineering Consulting

SSC R&D

- Xfinity platform software

- HPC testing environment

- CPU and GPU evaluations

- Application performance evaluation and optimizations
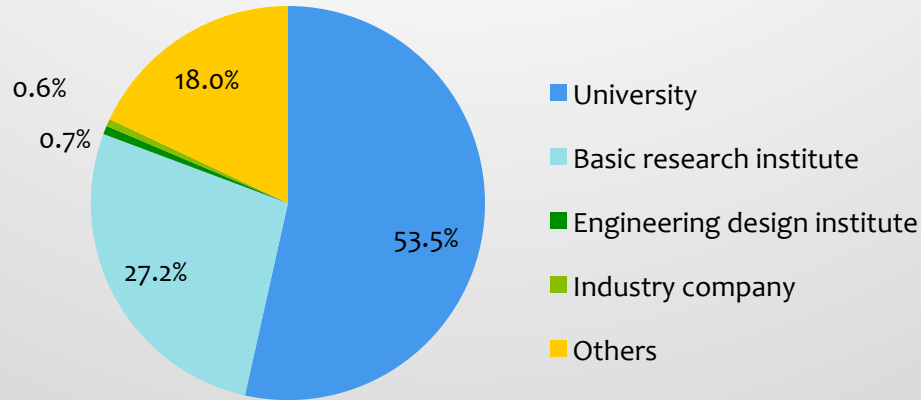
Account number by application field

- Manufacture / 22.8%
- Nano Materials / 14.0%
- Physics / 11.3%
- Test / 10.2%
- Chemistry / 9.6%
- Bio Medicine / 7.7%
- Mechanics / 3.6%
- Geo physics / 1.4%
- Astronomy / 1.1%
- Mapping science and technology / .6%
- Other / 16.7%

CPU hour by application field

- Nano materials / 13.4%
- Geo physics / 13.7%
- Chemistry / 13.5%
- Test / 11.6%
- Bio-medicine / 11.4%
- Mechanics / 8.8%
- Physics / 7.8%
- Astronomy / 5.4%
- Manufacture / 4%
- Mapping science and technology / 4.2%
- Others / 6.6%

SSC Utilization cont'd

CPU hour by user organization

- University — 53.5%
- Basic research institute — 27.2%
- Engineering design institute — 0.6%
- Industry company — 0.7%
- Others — 18.0%

Account number by user Organization

- University — 39.8%
- Basic research institute — 19.5%
- Industry company — 11.0%
- Engienering design institute — 5.5%
- Others — 24.2%

CPU hour by job scale

- 1-15 cores — 6.0%
- 16-255 cores — 53.4%
- 256-1023 cores — 26.8%
- 1024 cores and above — 13.7%
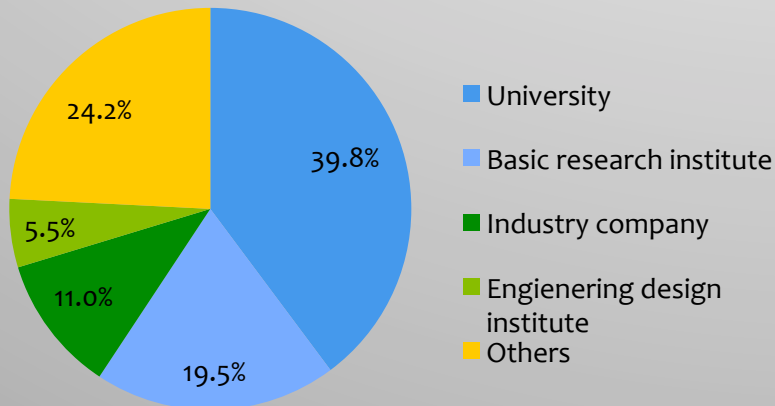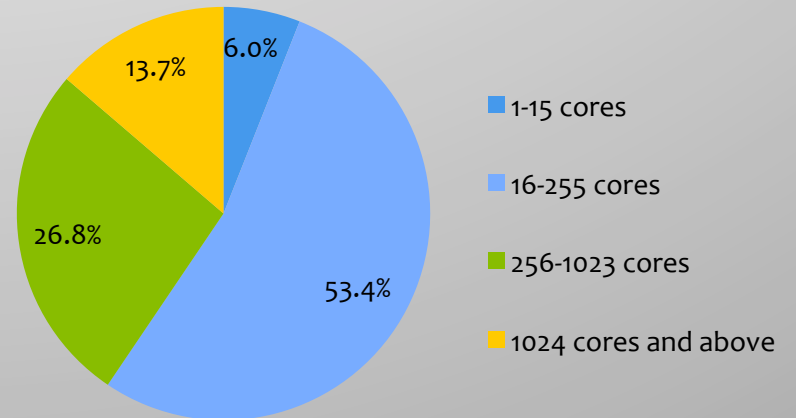
Shenzhen – Day 5
Shenzhen Institute of Advanced Technology (SIAT) of CAS

- Jointly established by Chinese Academy of Science and Shenzhen municipal government in Feb, 2006
- Knowledge-application oriented: aims to be "first-class industry research institute"; "first-class talent development place" and "first-class enterprises incubator"

ShenZhen – Day 5
Shenzhen National Supercomputing Center

(none pictured)
Zhenglu WANG, Chief Manager, Technical Cooperation Dept., NSCC-SZ
Patrick LIU, Project Manager, Technical Cooperation Dept., NSCC-SZ
Cherry Tan YE, Project Manager, NSCC-SZ

Shenzhen National Supercomputing Center

- Nebulae: Dawning TC3600 Blade, Intel X5650 2.66 GHz, NVidia Tesla C2050 GPU (#2 on China's Top100)
  - Rpeak 2.98PF
  - Rmax 1.27PF
  - 120640 cores

- Industry "clouds"
  - Healthcare, power management, disaster forecasting, smart city
  - Focused on the BIG data problem

- Recruiting trip later this year to hire 40 FTEs

ExaFlops in China (courtesy ATIP)

- Lessons China has learned from past few years

    - DO NOT be heroes.

    - Ride Moore's law.

    - Play with BIG players.

    - Cooperate with GOOD users.

- Chinese know:

    - Sustainable HPC is based on practical applications, not Linpack or peak. Unwise to blindly compete with other countries in EF race, will participate in international discussions

    - No decision about EFs yet

    - Tremendous technical challenges exist going to EFs

- "Step by step" strategy probably to be adopted; 2010-2015: 10PF, 2015-2020: EF

- If there are core technology breakthroughs, Chinese feel they may jump 2 orders of magnitude in 5 years (e.g., as China did 2006-2010 using GPUs)

CHINA
A driving force in the future of global supercomputing