China’s Efforts on Supercomputing: Progress and Applications

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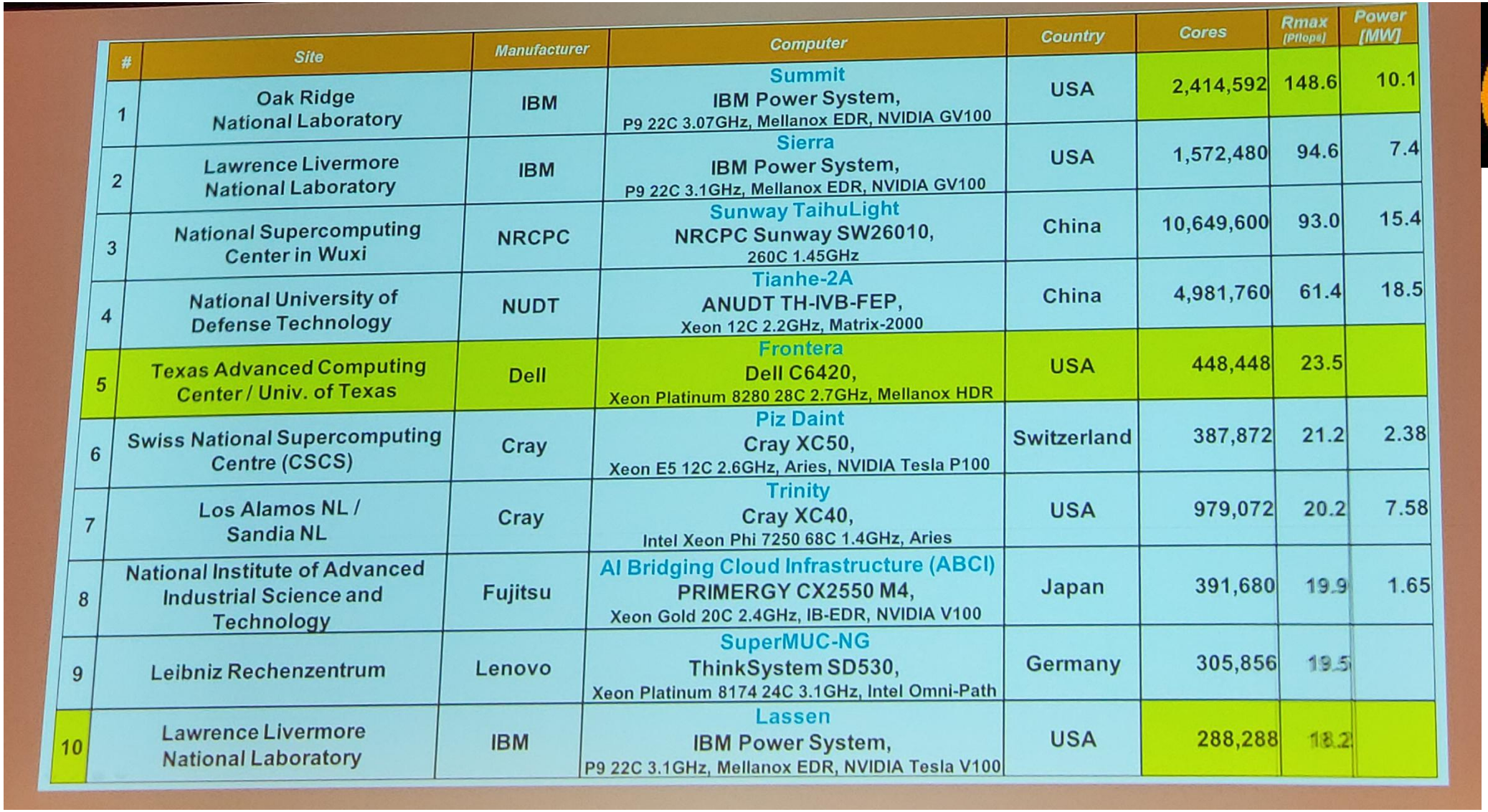
3 Exascale Supercomputer in China: From Prototype to E-System

4 Some Exploratory Work of Lattice QCD on E-prototype System

1 Global Progress in Supercomputer

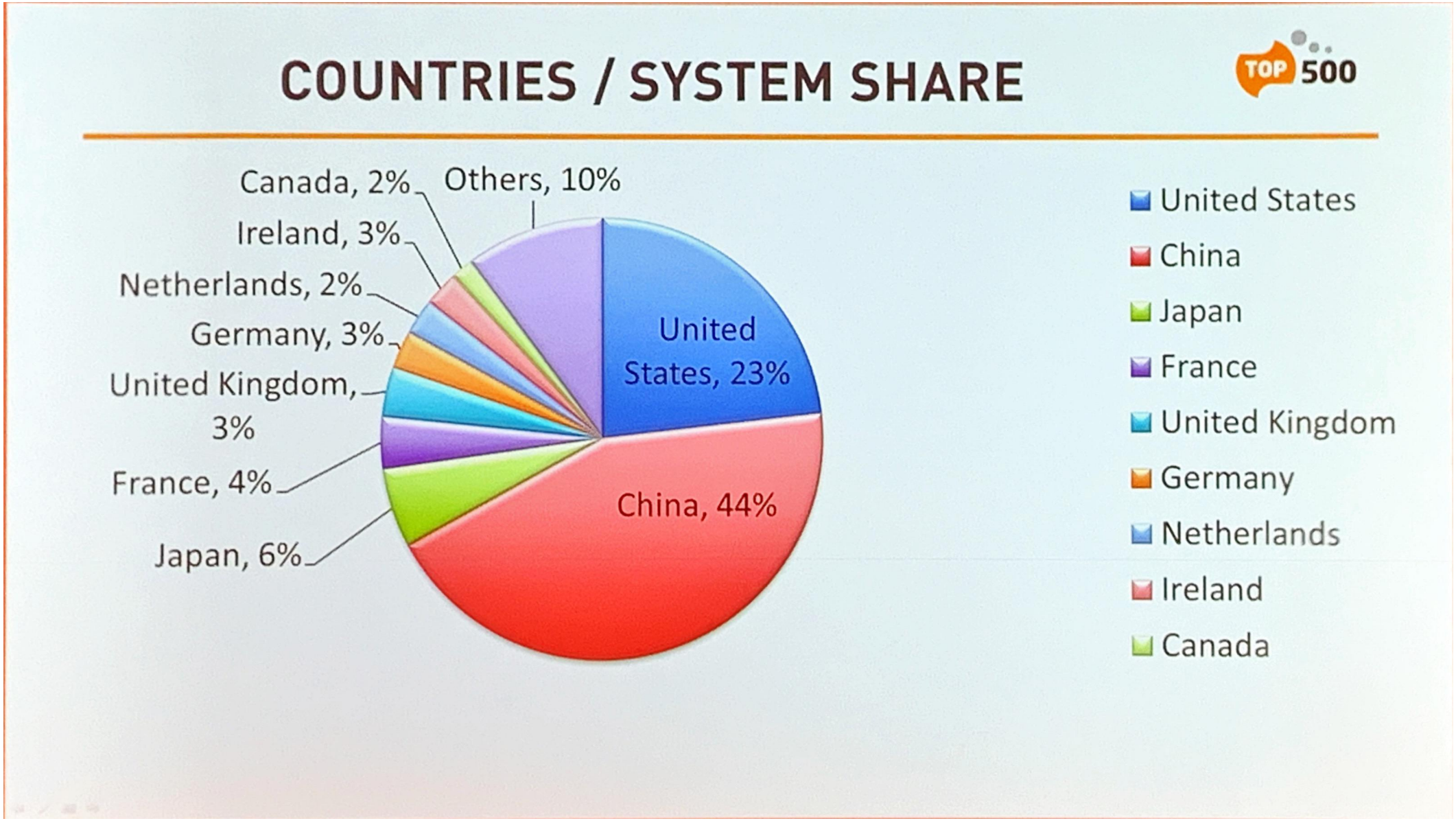
TOP500 List



#	Site	Manufacturer	Computer	Country	Cores	Rmax (Pflops)	Power (MW)
1	Oak Ridge National Laboratory	IBM	Summit IBM Power System, P9 22C 3.07GHz, Mellanox EDR, NVIDIA GV100	USA	2,414,592	148.6	10.1
2	Lawrence Livermore National Laboratory	IBM	Sierra IBM Power System, P9 22C 3.1GHz, Mellanox EDR, NVIDIA GV100	USA	1,572,480	94.6	7.4
3	National Supercomputing Center in Wuxi	NRCPC	Sunway TaihuLight NRCPC Sunway SW26010, 260C 1.45GHz	China	10,649,600	93.0	15.4
4	National University of Defense Technology	NUDT	Tianhe-2A ANUDT TH-IVB-FEP, Xeon 12C 2.2GHz, Matrix-2000	China	4,981,760	61.4	18.5
5	Texas Advanced Computing Center / Univ. of Texas	Dell	Frontera Dell C6420, Xeon Platinum 8280 28C 2.7GHz, Mellanox HDR	USA	448,448	23.5	
6	Swiss National Supercomputing Centre (CSCS)	Cray	Piz Daint Cray XC50, Xeon E5 12C 2.6GHz, Aries, NVIDIA Tesla P100	Switzerland	387,872	21.2	2.38
7	Los Alamos NL / Sandia NL	Cray	Trinity Cray XC40, Intel Xeon Phi 7250 68C 1.4GHz, Aries	USA	979,072	20.2	7.58
8	National Institute of Advanced Industrial Science and Technology	Fujitsu	AI Bridging Cloud Infrastructure (ABCI) PRIMERGY CX2550 M4, Xeon Gold 20C 2.4GHz, IB-EDR, NVIDIA V100	Japan	391,680	19.9	1.65
9	Leibniz Rechenzentrum	Lenovo	SuperMUC-NG ThinkSystem SD530, Xeon Platinum 8174 24C 3.1GHz, Intel Omni-Path	Germany	305,856	19.5	
10	Lawrence Livermore National Laboratory	IBM	Lassen IBM Power System, P9 22C 3.1GHz, Mellanox EDR, NVIDIA Tesla V100	USA	288,288	18.2	

1 Global Progress in Supercomputer

Supercomputer System Share



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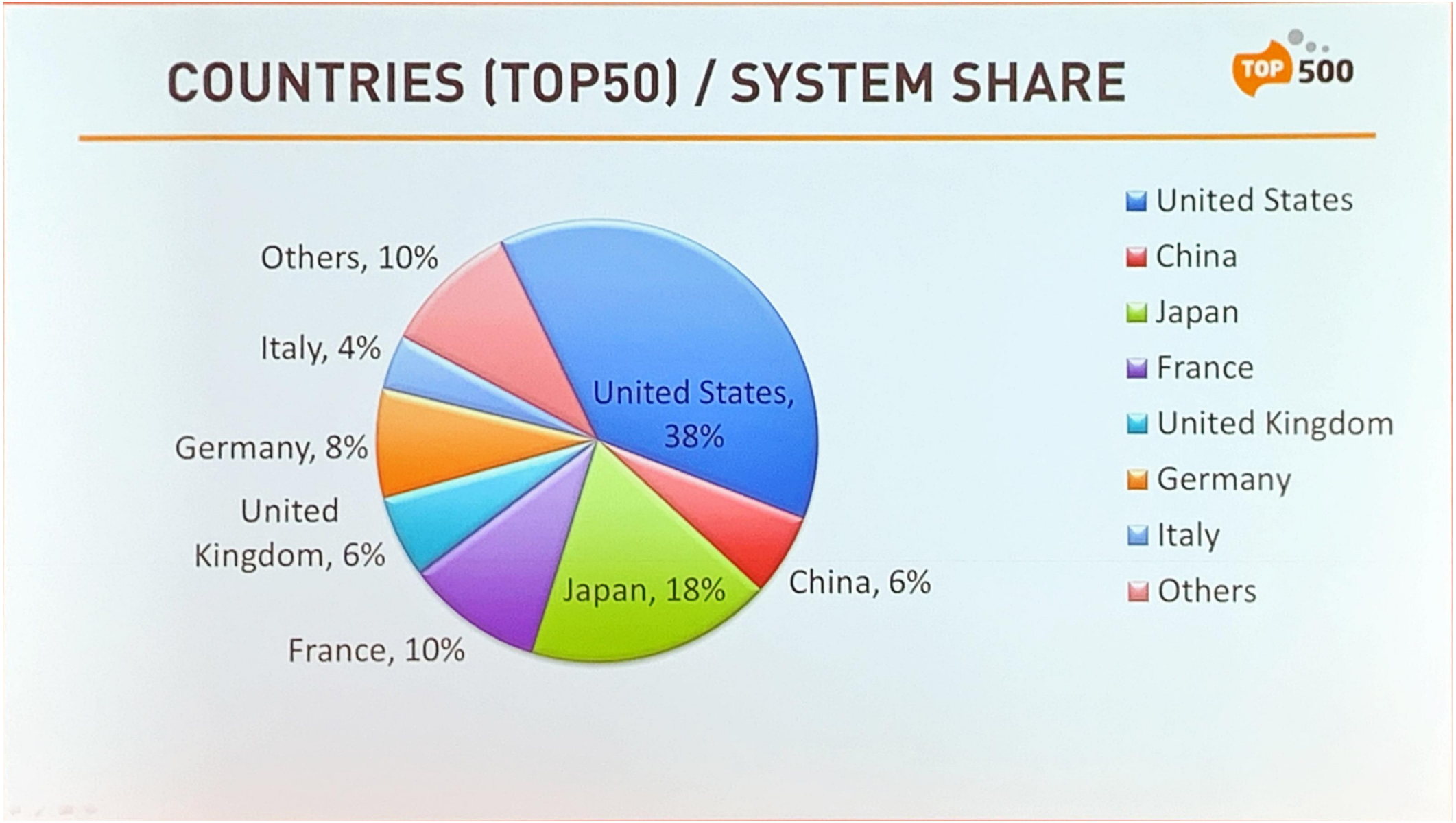
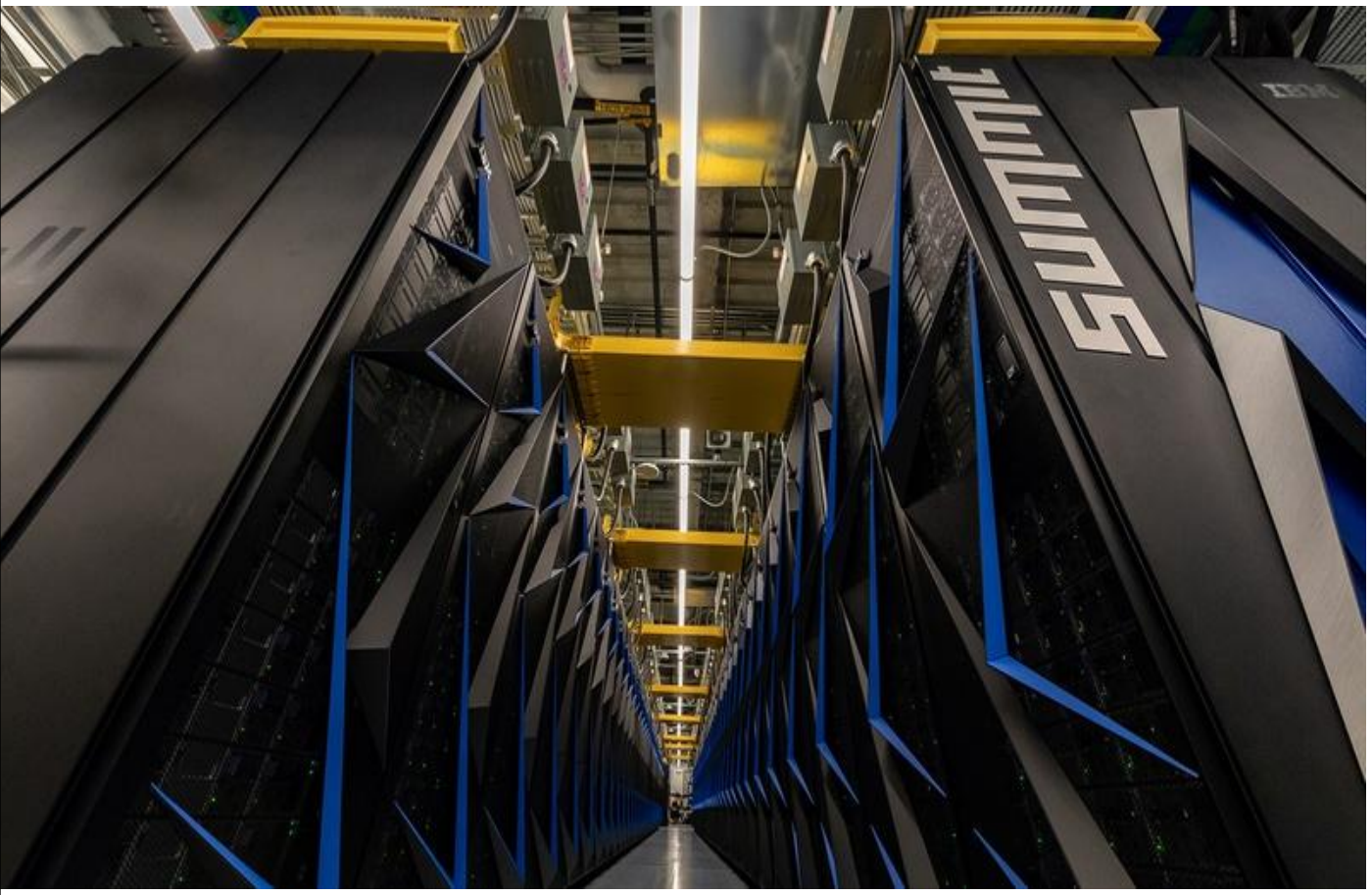
1 Global Progress in Supercomputer

TOP500 List



1 Global Progress in Supercomputer

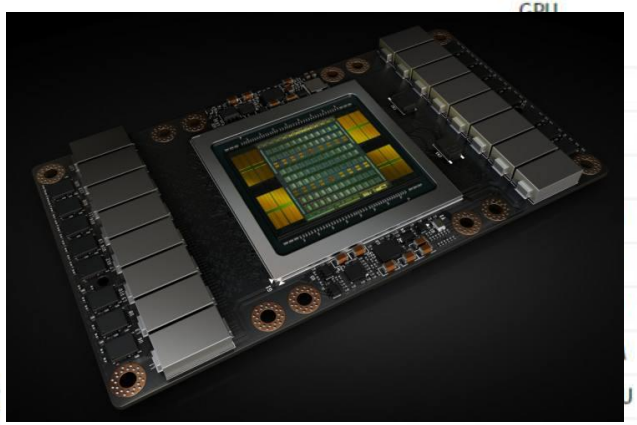
IBM SUMMIT

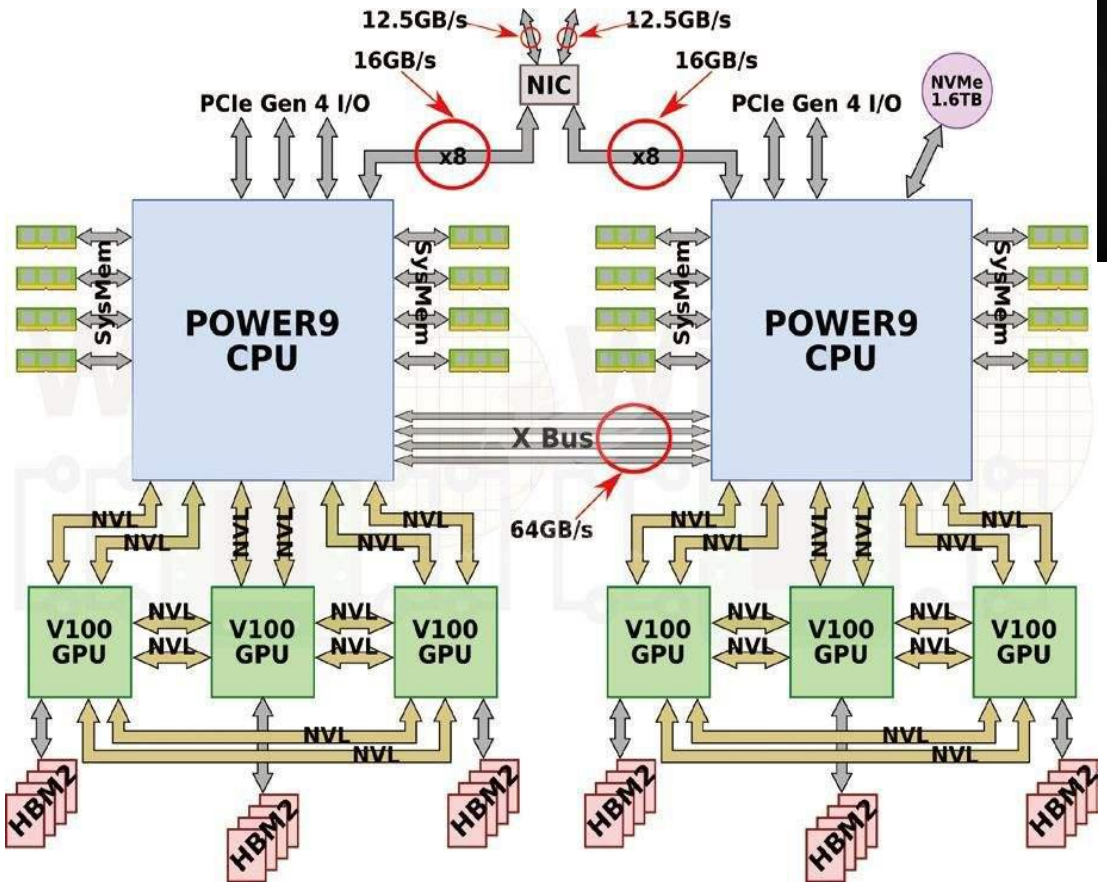


Application Performance	122 PF
Number of Nodes	4356
Node performance	42 TF
Memory per Node	512 GB DDR4 + 96 GB HBM2
NV memory per Node	1600 GB
Total System Memory	>10 PB DDR4 + HBM2 + Non-volatile
Processors	2 IBM POWER9™ 9,216 CPUs 6 NVIDIA Volta™ 27,648 GPUs
File System	250 PB, 2.5 TB/s, GPFS™
Power Consumption	8.8
Interconnect	Mellanox EDR 100G InfiniBand
Operating System	Red Hat Enterprise Linux (RHEL) version 7.4

1 Global Progress in Supercomputer

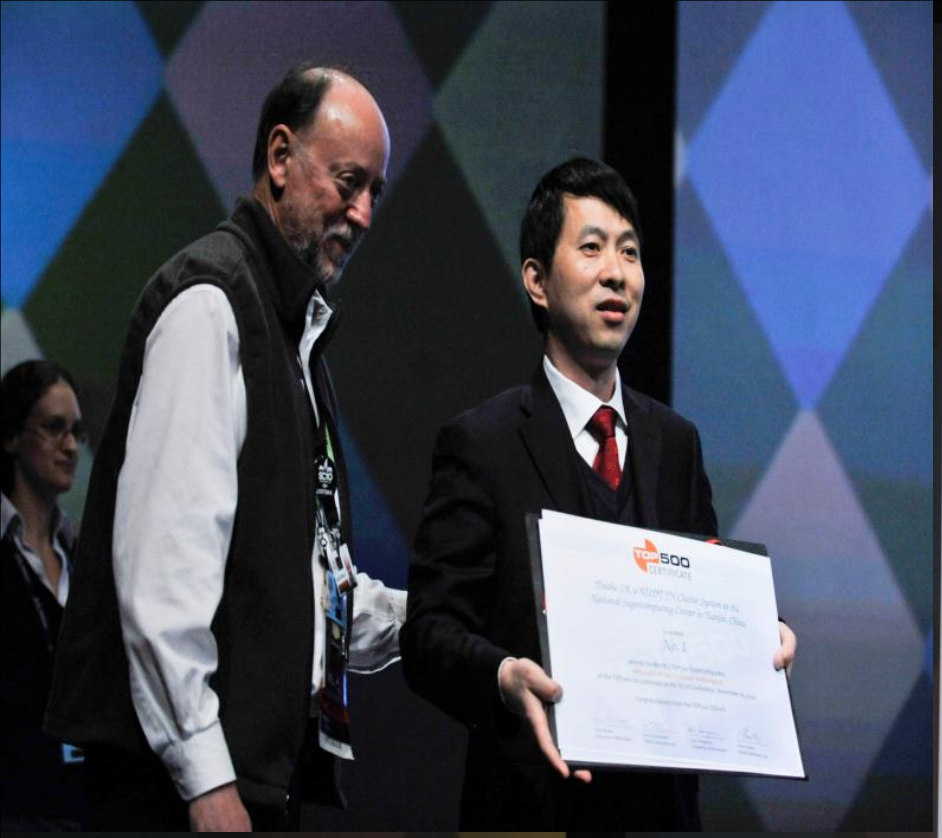
IBM SUMMIT





Tesla Product	Tesla K40	Tesla M40	Tesla P100	Tesla V100
GPU	GK180 (Kepler)	GM200 (Maxwell)	GP100 (Pascal)	GV100 (Volta)
	15	24	56	80
	15	24	28	40
	192	128	64	64
	2880	3072	3584	5120
	64	4	32	32
	960	96	1792	2560
	NA	NA	NA	8
	NA	NA	NA	640
GPU Boost Clock	810/875 MHz	1114 MHz	1480 MHz	1455 MHz
Peak FP32 TFLOP/s*	5.04	6.8	10.6	15
Peak FP64 TFLOP/s*	1.68	2.1	5.3	7.5
Peak Tensor Core TFLOP/s*	NA	NA	NA	120
Texture Units	240	192	224	320
Memory Interface	384-bit GDDR5	384-bit GDDR5	4096-bit HBM2	4096-bit HBM2
Memory Size	Up to 12 GB	Up to 24 GB	16 GB	16 GB
L2 Cache Size	1536 KB	3072 KB	4096 KB	6144 KB
Shared Memory Size / SM	16 KB/32 KB/48 KB	96 KB	64 KB	Configurable up to 96 KB
Register File Size / SM	256 KB	256 KB	256 KB	256KB
Register File Size / GPU	3840 KB	6144 KB	14336 KB	20480 KB
TDP	235 Watts	250 Watts	300 Watts	300 Watts
Transistors	7.1 billion	8 billion	15.3 billion	21.1 billion
GPU Die Size	551 mm²	601 mm²	610 mm²	815 mm²
Manufacturing Process	28 nm	28 nm	16 nm FinFET+	12 nm FFN

计算区
天河
天河
天河
能计算机系统
TH-1A Supercomputer



"TH-1A" was ranked the first on Top500 list released in Nov.2010.

36th List: The TOP10

Rank	Site	Manufacturer	Computer	Country	Cores	Rmax [Tflops]	Power [MW]
1	National SuperComputer Center in Tianjin	NUDT	Tianhe-1A NUDT YH MPP, Xeon 6C, NVidia	China	186,368	2,566	4.04
2	Oak Ridge National Laboratory	Cray	Jaguar Cray XT5, HC 2.6 GHz	USA	224,162	1,759	6.95
3	National Supercomputing Centre in Shenzhen	Dawning	Nebulae TC3600 Blade, Intel X5650, NVidia Tesla C2050 GPU	China	120,640	1,271	2.58
4	GSIC, Tokyo Institute of Technology	NEC/HP	TSUBAME-2 HP ProLiant, Xeon 6C, NVidia, Linux/Windows	Japan	73,278	1,192	1.40
5	DOE/SC/ LBNL/NERSC	Cray	Hopper Cray XE6, 6C 2.1 GHz	USA	153,408	1.054	2.91
6	Commissariat a l'Energie Atomique (CEA)	Bull	Tera 100 Bull bullx super-node S6010/S6030	France	138.368	1,050	4.59
7	DOE/NNSA/LANL	IBM	Roadrunner BladeCenter QS22/LS21	USA	122,400	1,042	2.34
8	Univ of Tenn ee	Cray	Kraken Cray XT5 HC 2.36GHz	USA	98,928	831.7	3.09
	Fo rum	IB	Jugene e Gene/P Solution	Germany	294,912	825.5	2.26
			Cielo C 2.4 GHz	USA	107,152	816.6	2.95

三大技术创新
Three technical innovations

- **CPU+GPU异构融合体系结构**
  - CPU+GPU heterogeneous architecture
- **64位多核多线程自主飞腾1000 CPU**
  - 64 bits Multi-core and Multi-thread CPU
- **自主高速互连通信技术**
  - Self-developed High-speed interconnect communication technology

国际学术界的评价
Remark from international academia

中国的“天河一号”采取的CPU与GPU融合的结构，代表了未来超级计算机的发展趋势。随着计算机规模的不断拓展，这种结构虽然不是唯一的解决方法，但目前看来是最好的。

The architecture is not the only solution, but the best so far

-- 美国斯坦福大学计算机系主任比尔•戴利

Billy Daley, Computer Science College, Stanford University

“天河一号”的运算速度比橡树岭国家实验室的要快大约40%，这是运算速率的极大提升。中国同时研制了一种互联技术，让这些处理器相互联系，这不是美国的技术，而是中国自己的技术。这是一个创举。

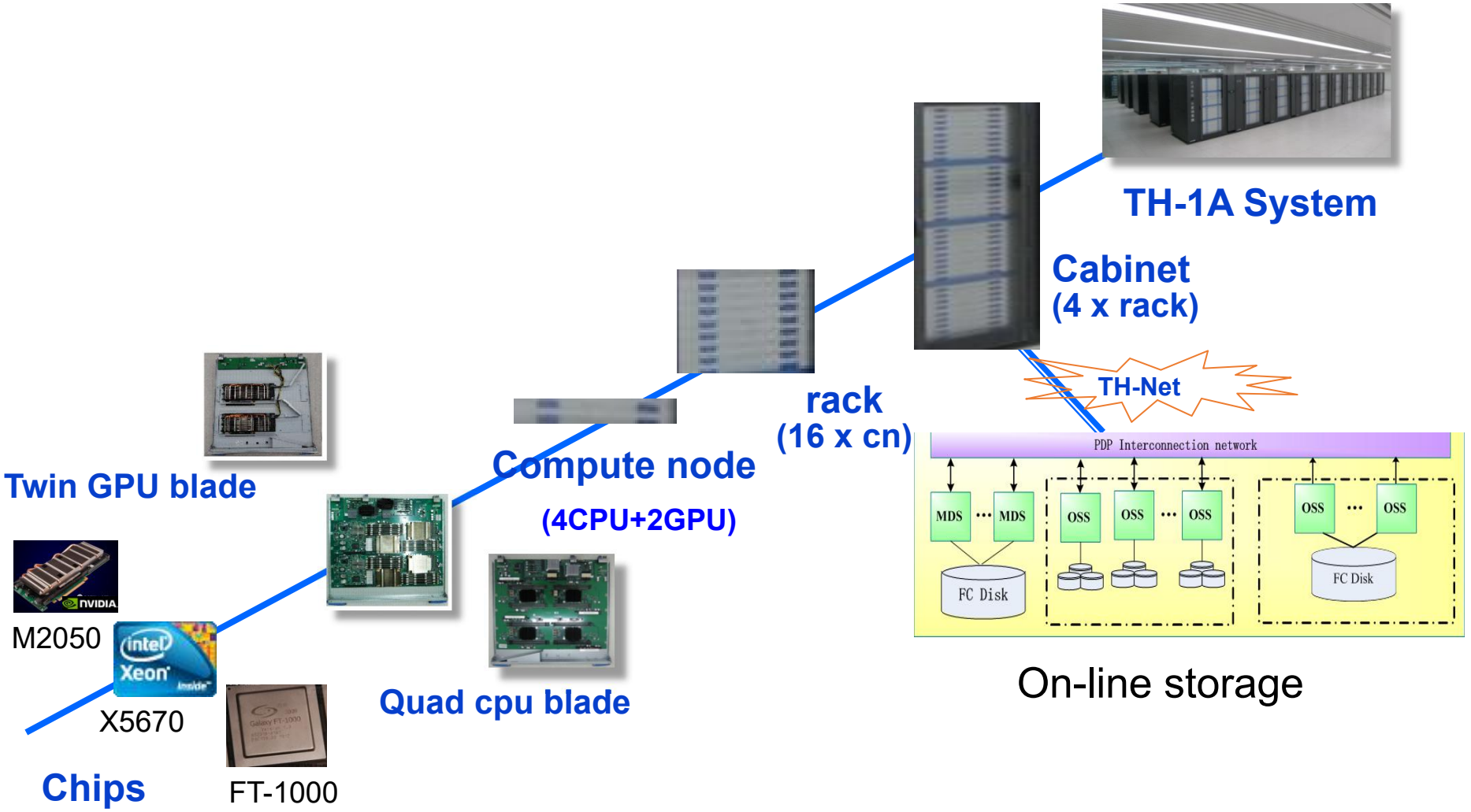
The technology belongs to China, not U.S., it's a pioneering work

-- 美国田纳西大学教授杰克•唐加拉

Prof. Jack Dongarra, Tennessee University

2 Past of Supercomputer in China

Roadmap of TH-1A



1 Global Progress in Supercomputer

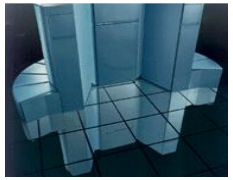
Development History

2018, summit, 187PFlops

TH-1A，2010年，
4.7PFlops

From 160MFlops to 200PFlops;
Performance improve >1000000000

走鹃，2008年，
1千万亿次



Cray-YMP
1988年，2.3Gflops

IBM红色选择
1999年，3万亿次

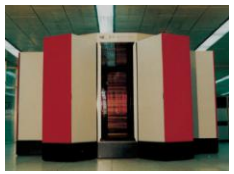
Cray-1
1976 160Mflops

The first supercomputer

日本地球模拟器
2002年，40Tflops

1 Past of Supercomputer in China

Supercomputer in China – YH & TianHe



TH－2

TH－1A

型机我国首台

1978年，由小平批准，国防科大开始研制“银河-1”

从此，开始了中国研制超级计算机的艰难和辉煌的历程

Approved by Xiao-ping DENG, the NUDT started to develop the “YH -1”.

From then on, began a difficult and glorious history of Chinese Supercomputer research.

机

台亿次巨型

型

YH－3

YH－2

YH－1

方亿次巨型

级计算

算

1983 1992 1997 2000 2006 2009 2010 2013

1 Past of Supercomputer in China

100Pflops system in China

Tianhe-2A

From 2013 to 2017，keep ten times ranked No.1

Sunway TaihuLight

1 Plan of Future of Supercomputer

MOST projects on HPC: 5 year Plan

- 高性能计算机 Supercomputer R&D
  - 建立协同研发的机制，集中优势力量，突破核心关键技术
  - Exascale Supercomputer in China （1000 Pflops)
- 高性能计算应用 HPC applications Support
  - 建立适应不同行业的国家高性能计算应用软件中心
  - 部署行业能力型重大应用软件系统的研发，构建能力型行业重大应用数值模拟软件平台
  - 部署容量型普适推广应用课题，部署于国家超算中心等，培育、吸引和稳定一批自主应用软件系统的用户
- 高性能计算环境 HPC environment Construction
  - 建立具有世界一流资源能力和服务水平的、支撑国家创新发展的国家高性能计算环境

1 Supercomputing Development in China

International Collaboration

NCSA NATIONAL CENTRE FOR SUPERCOMPUTING APPLICATIONS

JÜLICH FORSCHUNGSZENTRUM

BERKELEY LAB LAWRENCE BERKELEY NATIONAL LABORATORY

Fraunhofer SCAI

grnet

KISTI www.kisti.re.kr Korea Institute of Science and Technology Information

BSC Barcelona Supercomputing Center Centro Nacional de Supercomputación

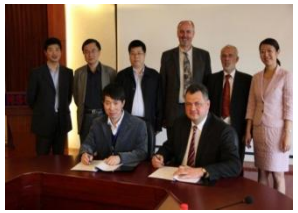
cnrs advancing the frontiers

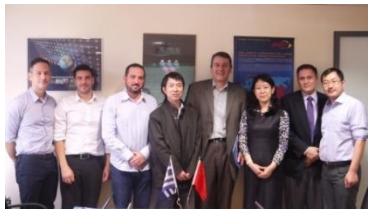
bifi

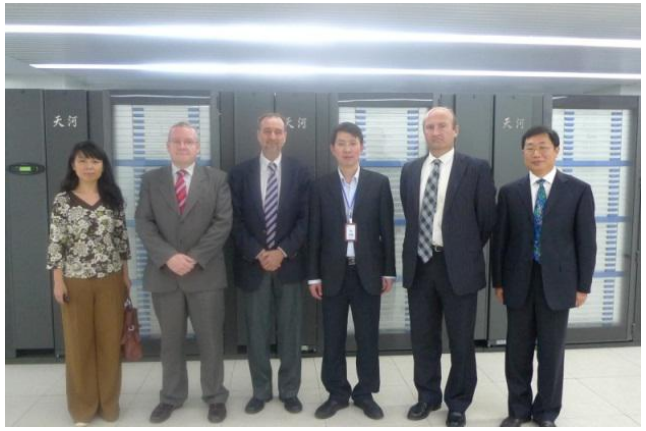
Agency for Science, Technology and Research SINGAPORE

CREATING GROWTH, ENHANCING LIVES.

OAK RIDGE NATIONAL LABORATORY Managed by UT-Battelle for the Department of Energy







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1 Development of High Performance Computing in China and Plan.

2 National Supercomputing Centers, Supercomputer Systems and Applications.

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4 Some Exploratory Work of Lattice QCD on E-prototype System

2 National Supercomputing Centers

Supercomputer System Share

天津超算中心和“天河一号”主机

National Supercomputer Center in Tianjin and “Tianhe-1A”

深圳超算中心和“曙光星云”主机

National Supercomputing Center in Shenzhen and “Dawning Nebulae”

济南超算中心和“神威蓝光”主机

ShanDong Computer Sciense Center and “Sunway BlueLight MPP”

2 National Supercomputing Centers

Supercomputer System Share

长沙超算中心和“天河一号”主机

National Supercomputing Center in Changsha and “Tianhe-1”

广州超算中心和“天河二号”主机

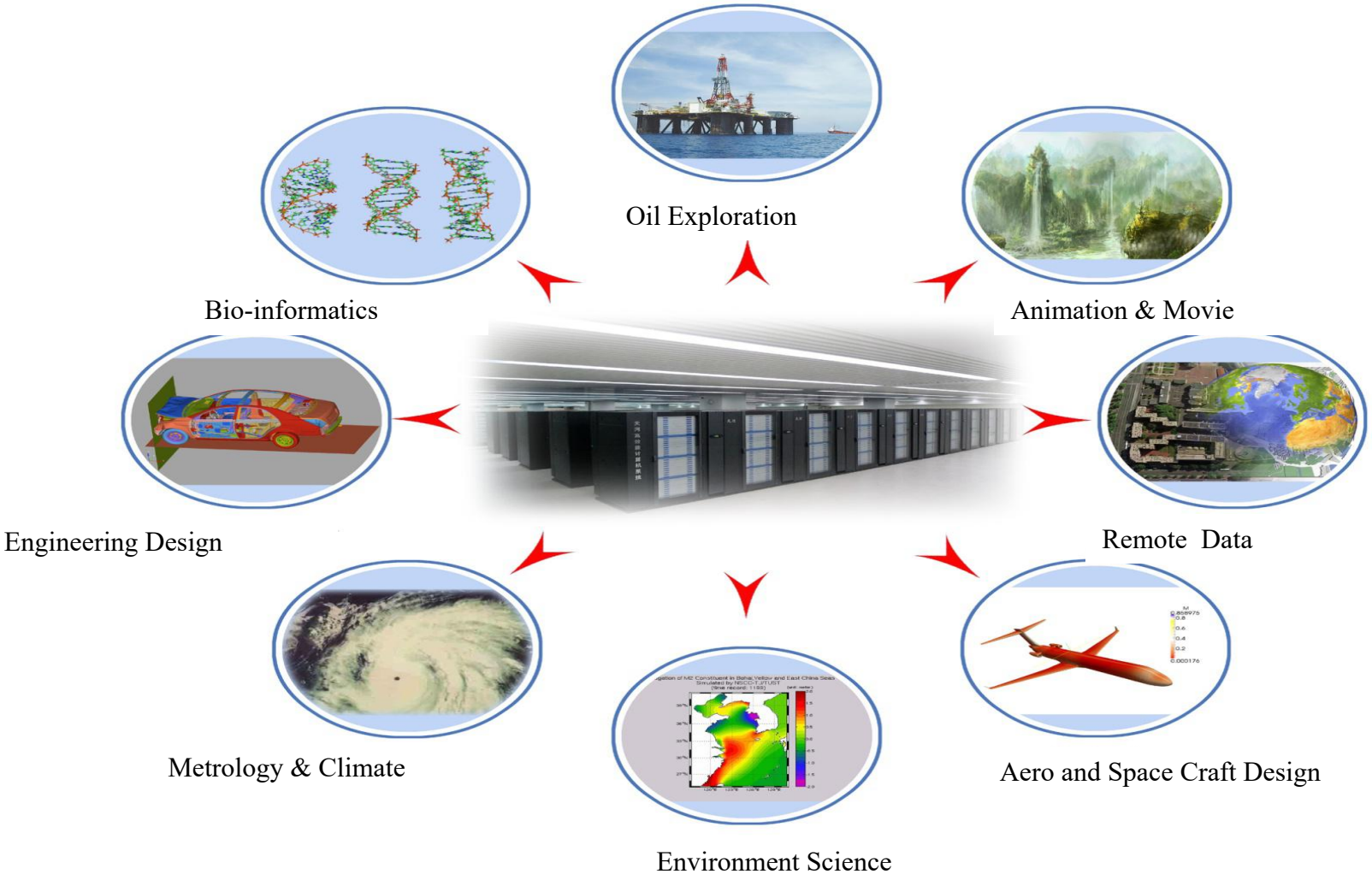
National Supercomputer Center in Guangzhou and “Tianhe-2”

无锡超算中心和“神威·太湖之光”主机

National Supercomputing Center in Wuxi and “ Sunway TaihuLight

2 Application on China's Supercomputers

Applications



2 Application on China's Supercomputers

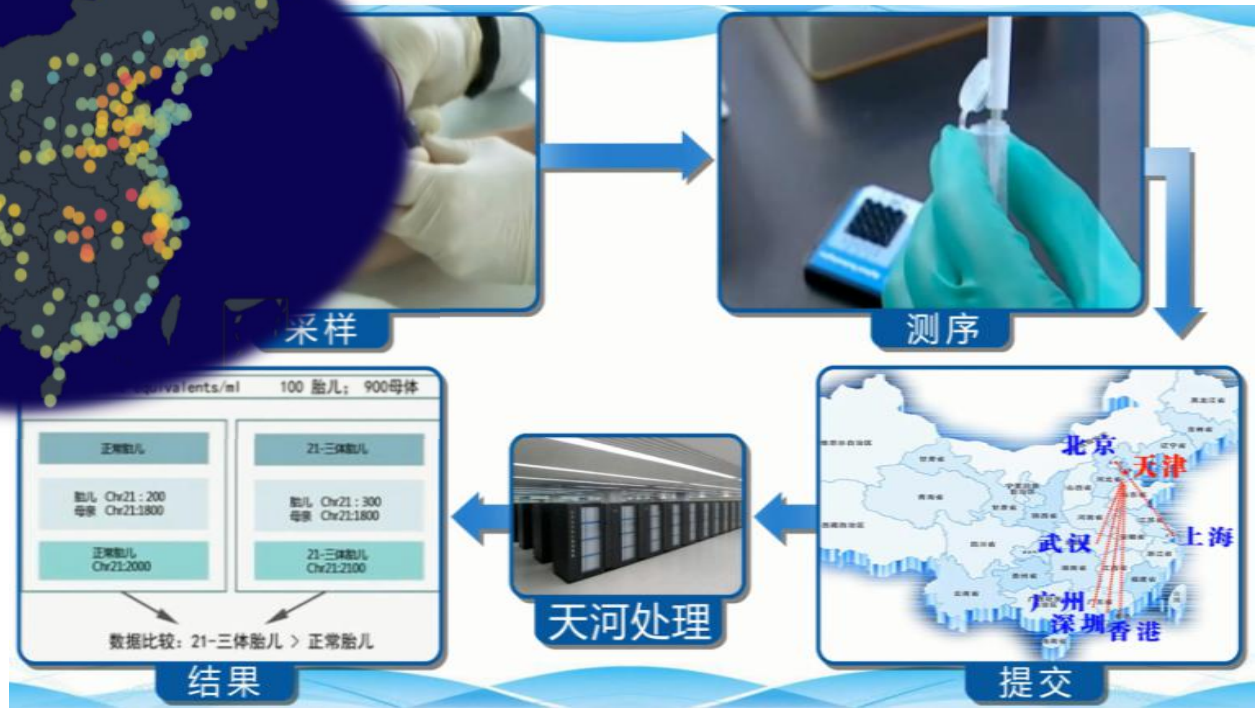
Large-Scale Computing

2 Application on China's Supercomputers

Engineering simulation and design

2 Application on China's Supercomputers

Large-Scale Data processing and analysis



2 Application on China's Supercomputers

Integrated Platform of Artificial Intelligence

Supporting Environment → Platform → Application

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3 Exascale Supercomputer in China

Exascale Supercomputer in China

Key-Technology Prototype → Exascale Supercomputer

3 Exascale Supercomputer in China

Prototype system

3 Exascale Supercomputer in China

Prototype system

- System Composition

  - 512 MT-2000+ computing nodes
  - 6 Computing Cabinets
  - Performance: 3.146PFlops

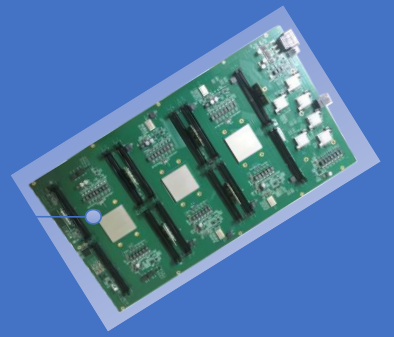
  - 128 FT-2000+nodes

System

Cabinet

200G Interconnection

ROCK



BOARD

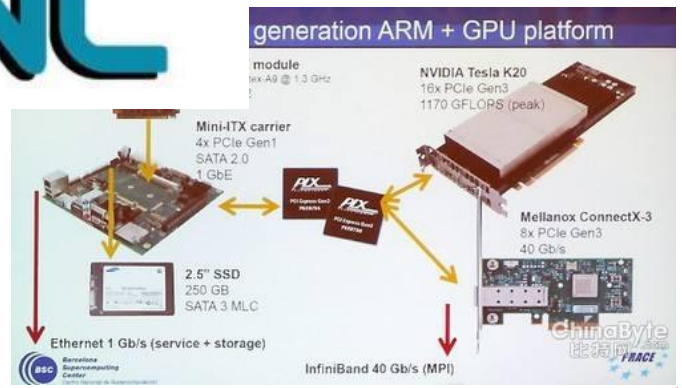
MT-2000+

4 Exascale Supercomputer in China

ARM HPC

ARM®

MONT BLANC



3 Exascale Supercomputer in China

System Architecture--Hybrid

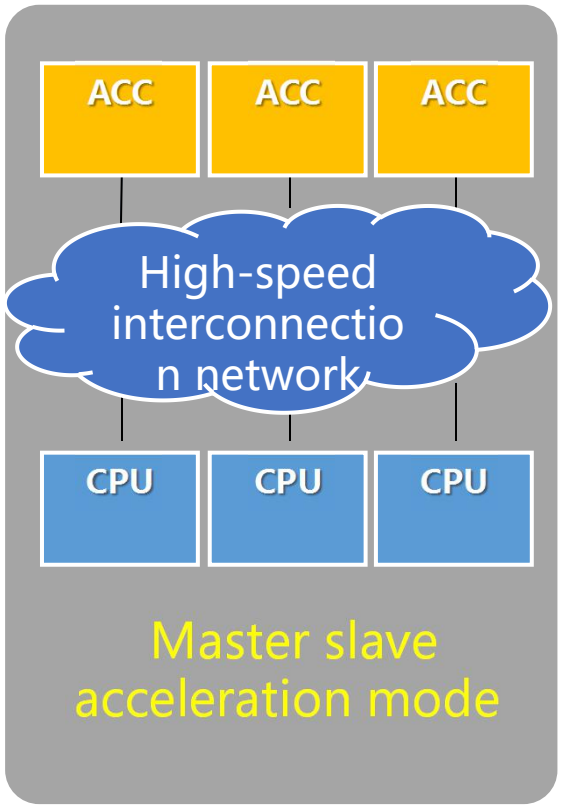
Sunway
chip level

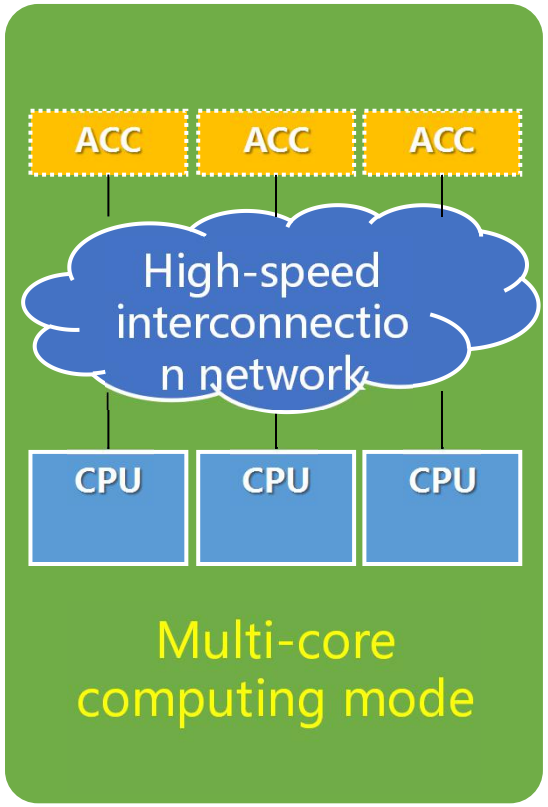
Sugon
board level

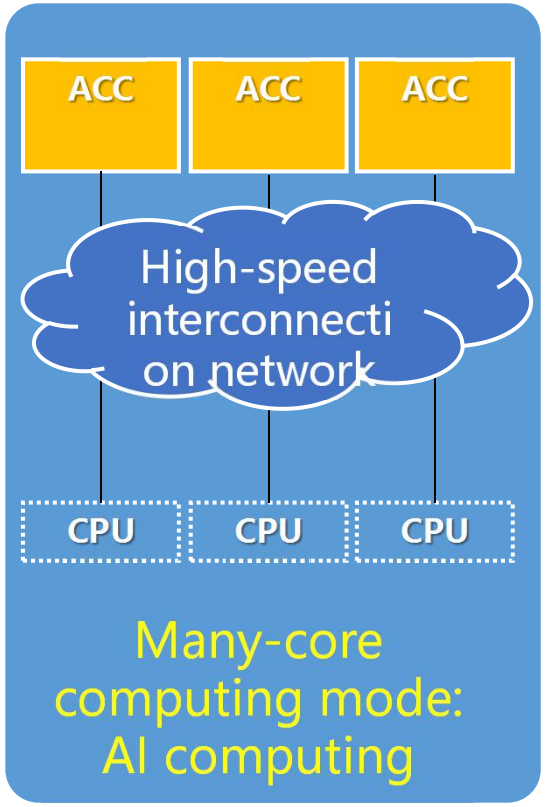
Tianhe
system level

3 Exascale Supercomputer in China

Exascale computer: Flexible architecture design

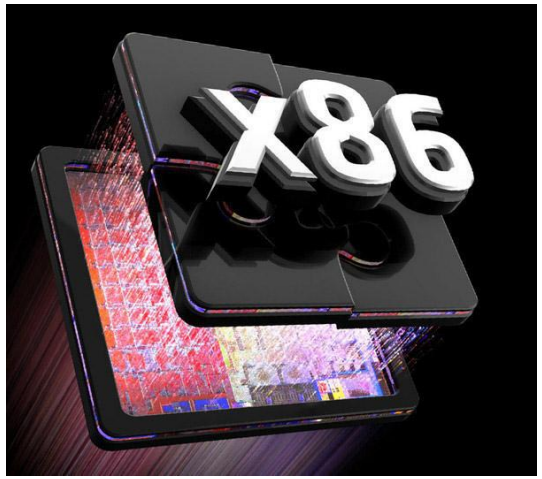


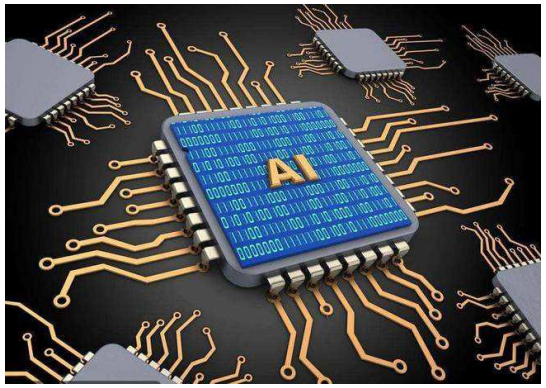


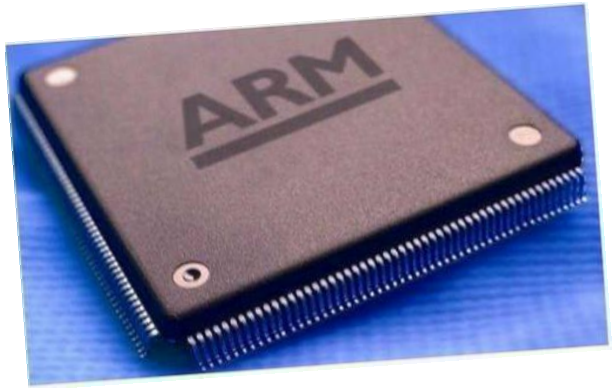


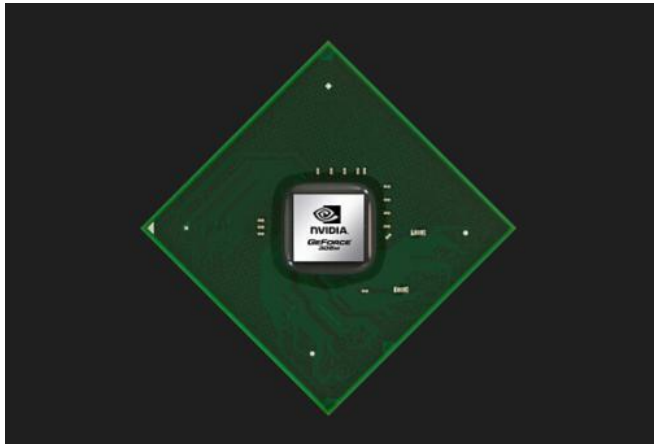
3 Exascale Supercomputer in China

Diversity Future









3 Exascale Supercomputer in China

Diversity Future

Software Definition System

cloud

Workflow

Digital twins

USER

Supercomputer

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4 Lattice QCD on E-prototype System

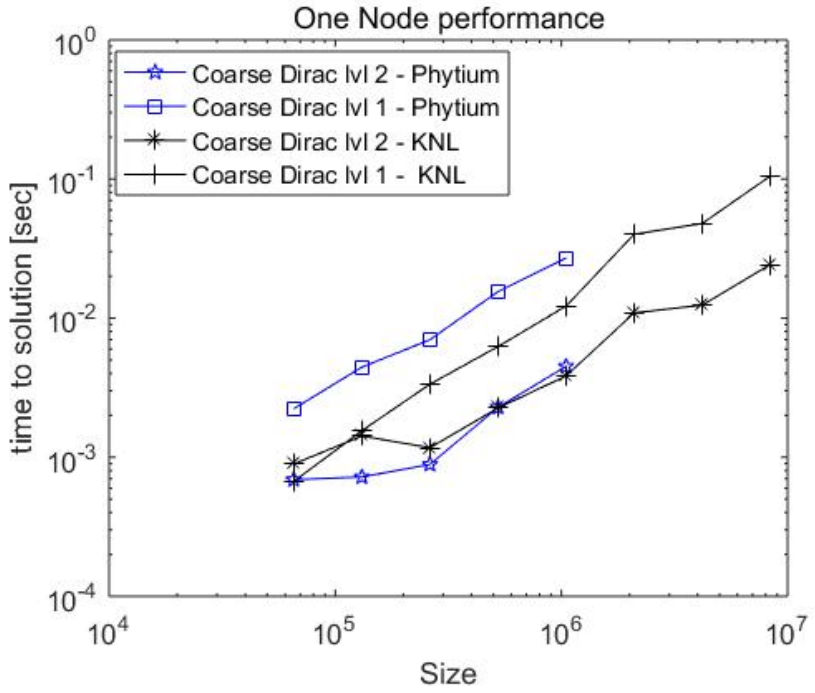
IHEP, CAS: Ming Gong, etc

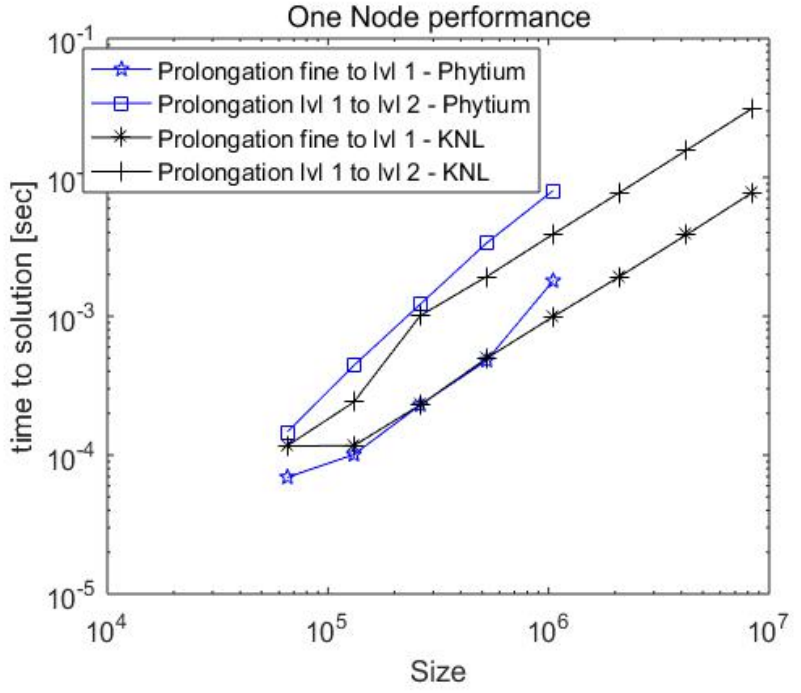
ITP, CAS : Yibo Yang

Peking University: Xu Feng, etc

4 Lattice QCD on E-prototype System

On Tianhe





The one node performance is close to the KNL(TGCC Irene).

4 Lattice QCD on E-prototype System

On Sunway

Current version :

* A D-slash function and a simple inverter for Wilson fermion.
- Two-level parallelization with MPI for MPEs and Athread for CPEs.
- Fixed-sized data partition : 16^4 lattice block on each core group.
- Compression on transferring SU(3) matrix between MPEs and CPEs.
- Fully optimized with SIMD instructions.

Working in progress :

- Adopting our "C Virtual Machine" (CVM) to achieve more FLOPs.
  - CVM is a preliminary optimization platform for Sunway architecture.
  - Gene algorithm is adopted to seek potential accelerations.
  - It is designed for lattice QCD and can be used for other applications.
- Developing an interface to QOPQDP and Chroma.

4 Lattice QCD on E-prototype System

On road

Much more work on road!

天河

Thank You ！

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