Overview of Supercomputer Systems

Supercomputing Division
Information Technology Center
The University of Tokyo

Supercomputers at ITC, U. of Tokyo

Oakleaf-fx
(Fujitsu PRIMEHPC FX10)

Total Peak performance	: 1.13 PFLOPS
Total number of nodes	: 4800
Total memory	: 150 TB
Peak performance / node	: 236.5 GFLOPS
Main memory per node	: 32 GB
Disk capacity	: 1.1 PB + 2.1 PB
SPARC64 Ixfx 1.84GHz	

T2K-Todai
（Hitachi HA8000-tc/RS425 ）

Total Peak performance	: 140 TFLOPS
Total number of nodes	: 952
Total memory	: 32000 GB
Peak performance / node	: 147.2 GFLOPS
Main memory per node	: 32 GB, 128 GB
Disk capacity	: 1 PB
AMD Quad Core Opteron 2.3GHz	

Yayoi
(Hitachi SR16000/M1)

Total Peak performance	: 54.9 TFLOPS
Total number of nodes	: 56
Total memory	: 11200 GB
Peak performance / node	: 980.48 GFLOPS
Main memory per node	: 200 GB
Disk capacity	: 556 TB
IBM POWER 7 3.83GHz	

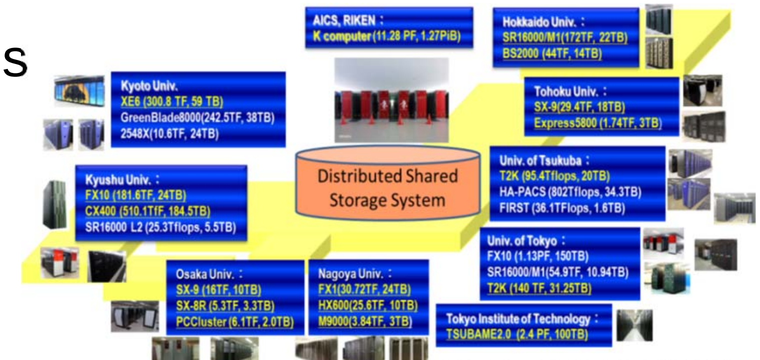
Total Users > 2,000

- HPCI
- Supercomputer Systems in SCD/ITC/UT
- Overview of Fujitsu FX10 (Oakleaf-FX)

- Post T2K System

Innovative High Performance Computing Infrastructure (HPCI)

- HPCI
  - Seamless access to K computer, supercomputers, and user's machines
  - Distributed shared storage system
- HPCI Consortium
  - Providing proposals/suggestions to the government and related organizations
    - Plan and operation of HPCI system
    - Promotion of computational sciences
    - Future supercomputing
  - 38 organizations
  - Operations started in Fall 2012
    - https://www.hpci-office.jp/



11.28 PF + 0.757496 PF + 2.21248 PF

SPIRE/HPCI

Strategic Programs for Innovative Research

- Objectives
  - – Scientific results as soon as K computer starts its operation
  - – Establishment of several core institutes for comp. science
- Overview
  - – Selection of the five strategic research fields which will contribute to finding solutions to scientific and social Issues
    - Field 1: Life science/Drug manufacture
    - Field 2: New material/energy creation
    - Field 3: Global change prediction for disaster prevention/mitigation
    - Field 4: *Mono-zukuri* (Manufacturing technology)
    - Field 5: The origin of matters and the universe
  - – A nation wide research group is formed by centering the core organization of each research area designated by MEXT.
  - – The groups are to promote R&D using K computer and to construct research structures for their own area

HPCI戦略プログラム
Strategic Programs for Innovative Research

予測する生命科学・医療および創薬基盤

予測医療と革新的創薬

臓器レベルでの疾患を再現する階層統合シミュレーションを実現し、予測医療に貢献。また、標的タンパク質に強く結合する薬の候補化合物の設計を行い、創薬プロセスを加速。

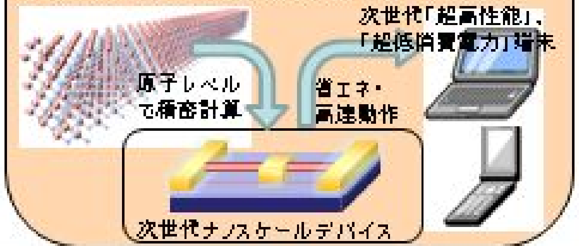
血栓成長による血管閉塞シミュレーション

薬候補のタンパク質への結合シミュレーション

新物質・エネルギー創成

世界に先駆けた次世代デバイスを提唱

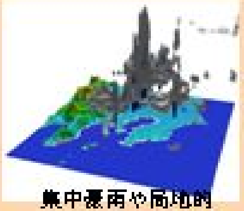
ナノスケールデバイスをまるごとシミュレーションし、機能・材料特性予測を実現することで、次世代デバイスの設計手法を提唱、超高性能・超低消費電力端末等の実現に貢献する。



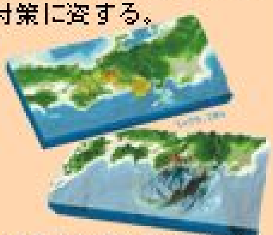
防災・減災に資する地球変動予測

集中豪雨や地震の予測

雲解像モデル、強震動モデル等を駆使して、集中豪雨の位置や地震の被害規模を高精度に予測し、防災・減災対策に資する。



集中豪雨や局地的大雨の予測

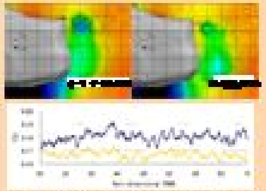


地震波伝播計算と津波発生伝播の連成シミュレーション

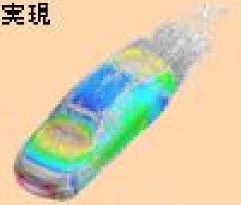
次世代ものづくり

設計プロセスの革新

熱流動の物理メカニズム理解に基づいた高度な設計制御技術を確立することで、環境(CO 2,NOx)と製品性能のバランスを目指した将来の製品競争力強化に資する革新的ものづくりを実現



車体後部周りの超精緻解析による最適形状の究明



非定常空力・振動連成解析による、低空気抵抗、低振動車の開発

物質と宇宙の起源と構造

大質量星の超新星爆発の解明

超新星爆発の3次元シミュレーション

爆発時の密度分布

磁場増幅、ニュートリノ輻射輸送などを考慮した3次元シミュレーションを、次世代スパコンを用いることで世界に先駆けて実行し、大質量星が重力崩壊から超新星爆発に至る過程を解明する。

＞17.5PFLOPS

As of June 2012

AICS, RIKEN：
K computer (11.28 PF, 1.27PiB)

Hokkaido Univ.：
SR16000/M1(172TF, 22TB)
BS2000 (44TF, 14TB)

Tohoku Univ.：
SX-9(29.4TF, 18TB)
Express5800 (1.74TF,
3TB)

Kyoto Univ.
XE6 (300.8 TF, 59 TB)
GreenBlade8000(242.5TF, 38TB)
2548X(10.6TF, 24TB)

Univ. of Tsukuba：
T2K (95.4Tflops, 20TB)
HA-PACS (802Tflops,
34.3TB)
FIRST (36.1TFlops, 1.6TB)

Osaka Univ.：
SX-9 (16TF, 10TB)
SX-8R (5.3TF, 3.3TB)
PCCluster (6.1TF, 2.0TB)

Univ. of Tokyo：
FX10 (1.13PF, 150TB)
SR16000/M1(54.9TF, 10.94TB)
T2K (75.36TF,16TB/140 TF, 31.25TB)
EastHubPCCluster(10TF,5.71TB/13TF,8.15
GPU Cluster(CPU 4.5TF, GPU 16.48TF,1.5
WestHubPCCluster(12.37TF,8.25TB)
RENKEI-VPE:VM Hosting

Kyushu Univ.：
FX10 (181.6TF, 24TB)
CX400 (510.1TfF, 184.5TB)
SR16000 L2 (25.3Tflops, 5.5TB)

Nagoya Univ.：
FX1(30.72TF, 24TB)
HX600(25.6TF, 10TB)
M9000(3.84TF, 3TB)

Tokyo Institute of
Technology：
TSUBAME2.0 (2.4 PF, 100TB)

- HPCI
- **Supercomputer Systems in SCD/ITC/UT**
- Overview of Fujitsu FX10 (Oakleaf-FX)

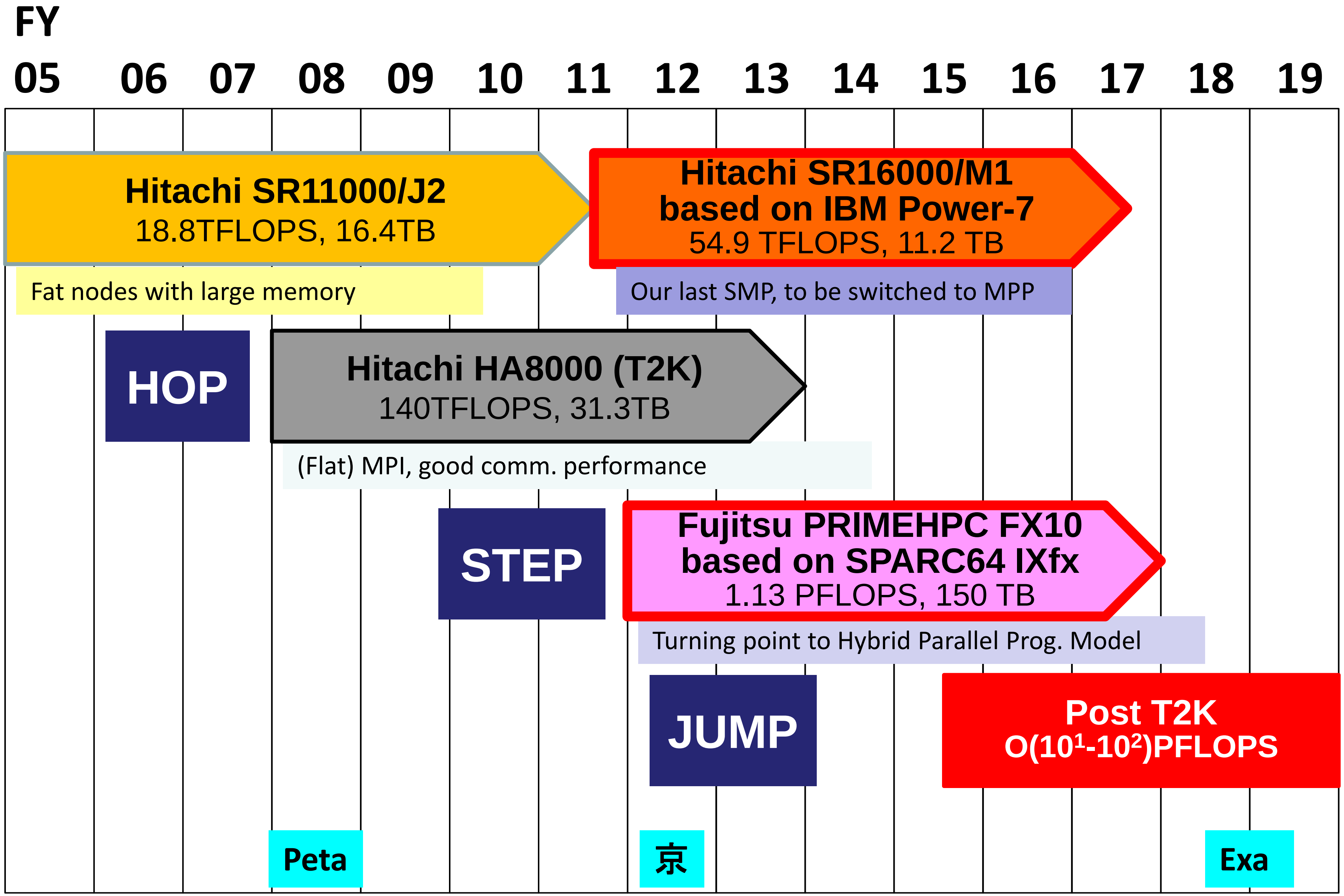
- Post T2K System

Current Supercomputer Systems University of Tokyo

- Total number of users ~ 2,000
- Hitachi HA8000 Cluster System (T2K/Tokyo) (2008.6-)
  - Cluster based on AMD Quad-Core Opteron (Barcelona)
  - 140.1 TFLOPS
- Hitachi SR16000/M1 (Yayoi) (2011.10-)
  - Power 7 based SMP with 200 GB/node
  - 54.9 TFLOPS
- Fujitsu PRIMEHPC FX10 (Oakleaf-FX) (2012.04-)
  - SPARC64 IXfx
  - Commercial version of K computer
  - 1.13 PFLOPS (1.043 PFLOPS for LINPACK, 21st in 40th TOP500)

	HA8000 (T2K)	SMP (Yayoi) SR16000/M1	FX10 (Oakleaf-FX) PRIMEHPC FX10
CPU	AMD Quad Core Opteron 2.3GHz	IBM Power7 3.83GHz	FUJITSU SPARC64IXfx 1.8GHz
Total # of core	15232	1792	76800
Total Peak FLOPS	140 TFLOPS	54.9 TFLOPS	1.13 PFLOPS
Total # of nodes	952	56	4800
Total Memory	32 TB	11200 GB	150 TB
# of core / node	16	32	16
Perk FLOPS / node	147.2 GFLOPS	980.5 GFLOPS	236.5 GFLOPS
Memory / node	32 GB, 128 GB	200 GB	32 GB
Network	Myrinet 10G Full-bisection	Hierarchical Full-bisection	Tofu 6D Mesh/Torus
Storage	1 PB	556 TB	1.1PB + 2.1 PB

Supercomputers in U.Tokyo



FY

05 06 07 08 09 10 11 12 13 14 15 16 17 18 19

Hitachi SR11000/J2
18.8TFLOPS, 16.4TB

Fat nodes with large memory

Hitachi SR16000/M1 based on IBM Power-7
54.9 TFLOPS, 11.2 TB

Our last SMP, to be switched to MPP

HOP

Hitachi HA8000 (T2K)
140TFLOPS, 31.3TB

(Flat) MPI, good comm. performance

STEP

Fujitsu PRIMEHPC FX10 based on SPARC64 IXfx
1.13 PFLOPS, 150 TB

Turning point to Hybrid Parallel Prog. Model

JUMP

Post T2K
O(10^1-10^2)PFLOPS

Peta

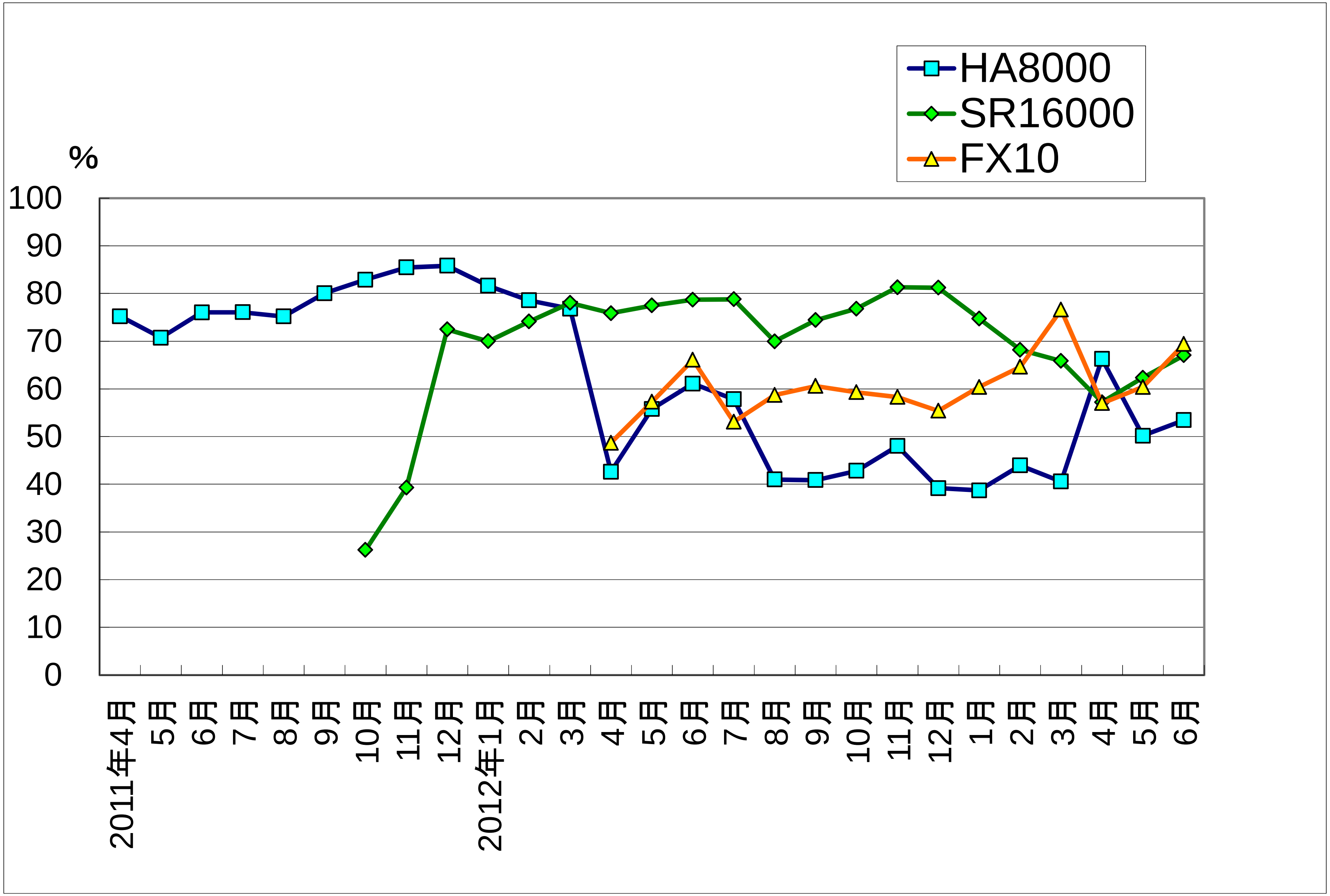
京

Exa

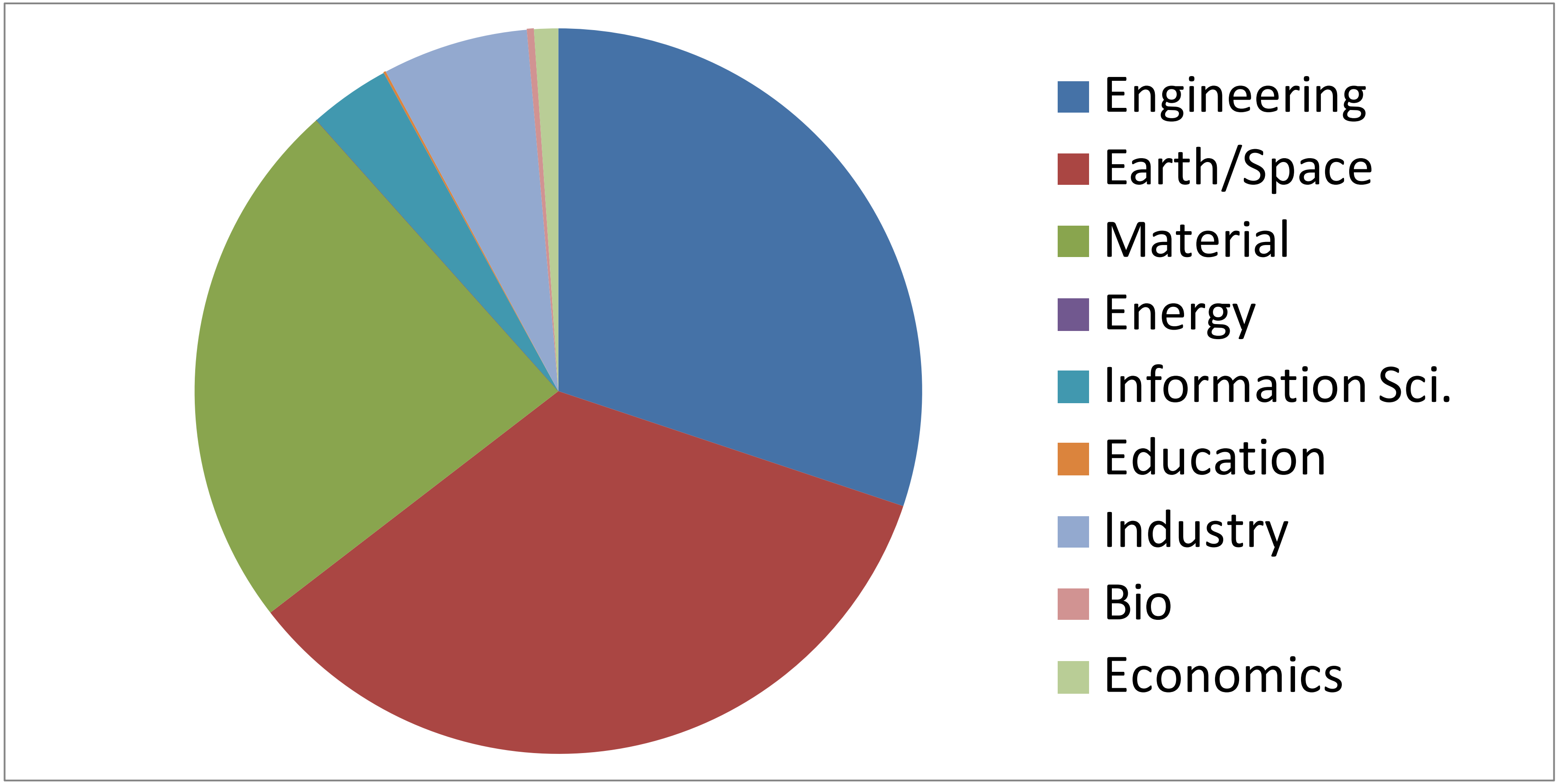
Status of FX10

- Hop
  - HA8000（T2K）, Homogeneous Compute Nodes
  - O(10^{-1}) PFLOPS
  - Flat MPI
- Step
  - FX10 (Oakleaf-FX), Homogeneous
  - O(10^{0}) PFLOPS
  - MPI + OpenMP, Flat MPI is also fast
- Jump
  - Post T2K, Heterogeneous
    - Efficient Power/Memory: Heterogeneous Compute Node
  - O(10^{1}-10^{2}) PFLOPS
  - MPI + X（OpenMP, CUDA, OpenCL … OpenACC）
- Exascale system is beyond that …

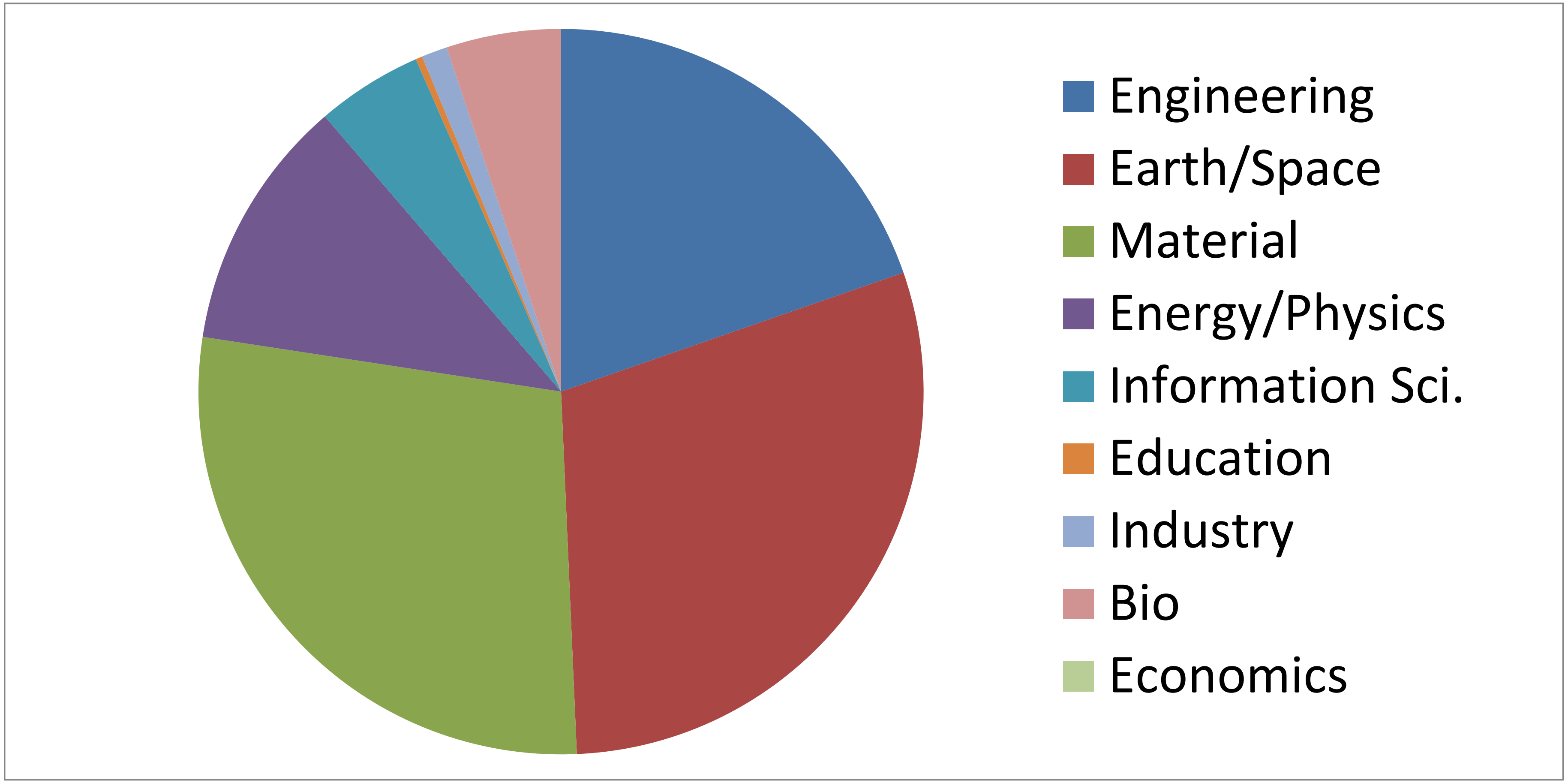
History of Work Ratio



Research Area based on CPU Hours HA8000 (T2K) in FY.2011 (~2012.01E)



Research Area based on CPU Hours FX10 in FY.2012 (2012.4~2013.3E)



Service Fee

- Not FREE
- Service Fee = Cost for Electricity (System+A/C)
  - 2M USD for Oakleaf-FX (2 MW)
  - 1M USD for T2K (1 MW)

Services for Industry

- Originally, only academic users have been allowed to access our supercomputer systems.
- Since FY.2008, we started services for industry
  - mainly for spread of large-scale parallel computing
  - not compete with private data centers, cloud services …
  - basically, results should be opened to public
  - up to 10% of total computational resource is open for usage by industry
  - special qualification processes are needed
- Currently only Oakleaf-FX is open for industry
  - Normal usage (more expensive than academic users)
  - Trial usage with discount rate
  - Research collaboration
  - 7 groups (2 normal, 5 trial)

Education

- Oakleaf-FX only
- 2-Day “Hands-on” Tutorials for Parallel Programming by Faculty Members of SCD/ITC (Free)
  - Fundamental MPI (3 times per year)
  - Advanced MPI (2 times per year)
  - OpenMP for Multicore Architectures (2 times per year)
  - Participants from industry are accepted.
- Graduate/Undergraduate Classes with Supercomputer System (Free)
  - We encourage to faculty members to introduce hands-on tutorial of supercomputer system into graduate/undergraduate classes.
  - Up to 12 nodes of Oakleaf-FX
  - Proposal
  - Not limited to Classes of the University of Tokyo

HPC Challenge

- Proposal-based Research Project
- Each group with accepted proposal can use full-system of Oakleaf-FX with 4,800 nodes for 24 hours
- Once per month
- Open to public

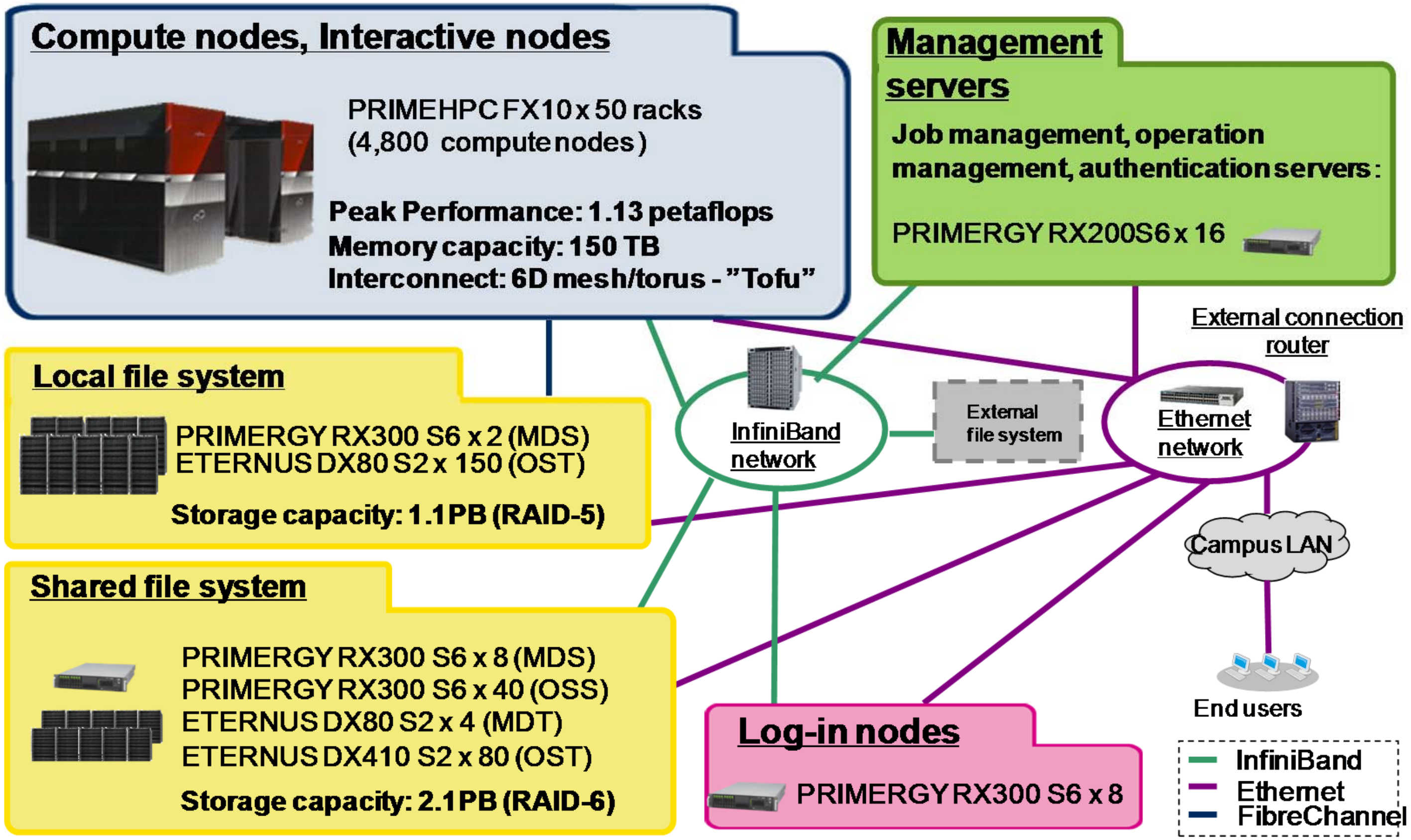
- HPCI
- Supercomputer Systems in SCD/ITC/UT
- **Overview of Fujitsu FX10 (Oakleaf-FX)**

- Post T2K System

Features of FX10 (Oakleaf-FX)

- Well-Balanced System
  - 1.13 PFLOPS for Peak Performance
  - Max. Power Consumption < 1.40 MW
    - < 2.00MW including A/C
- 6-Dim. Mesh/Torus Interconnect
  - Highly Scalable Tofu Interconnect
  - 5.0x2 GB/sec/link, 6 TB/sec for Bi-Section Bandwidth
- High-Performance File System
  - FEFS (Fujitsu Exabyte File System) based on Lustre
- Flexible Switching between Full/Partial Operation
- K compatible !
- Open-Source Libraries/Applications
- Highly Scalable for both of Flat MPI and Hybrid

FX10 System (Oakleaf-FX)



Compute nodes, Interactive nodes

PRIMEHPC FX10 x 50 racks
(4,800 compute nodes)

Peak Performance: 1.13 petaflops
Memory capacity: 150 TB
Interconnect: 6D mesh/torus - "Tofu"

Management servers

Job management, operation management, authentication servers:

PRIMERGY RX200S6 x 16

Local file system

PRIMERGY RX300 S6 x 2 (MDS)
ETERNUS DX80 S2 x 150 (OST)

Storage capacity: 1.1PB (RAID-5)

Shared file system

PRIMERGY RX300 S6 x 8 (MDS)
PRIMERGY RX300 S6 x 40 (OSS)
ETERNUS DX80 S2 x 4 (MDT)
ETERNUS DX410 S2 x 80 (OST)

Storage capacity: 2.1PB (RAID-6)

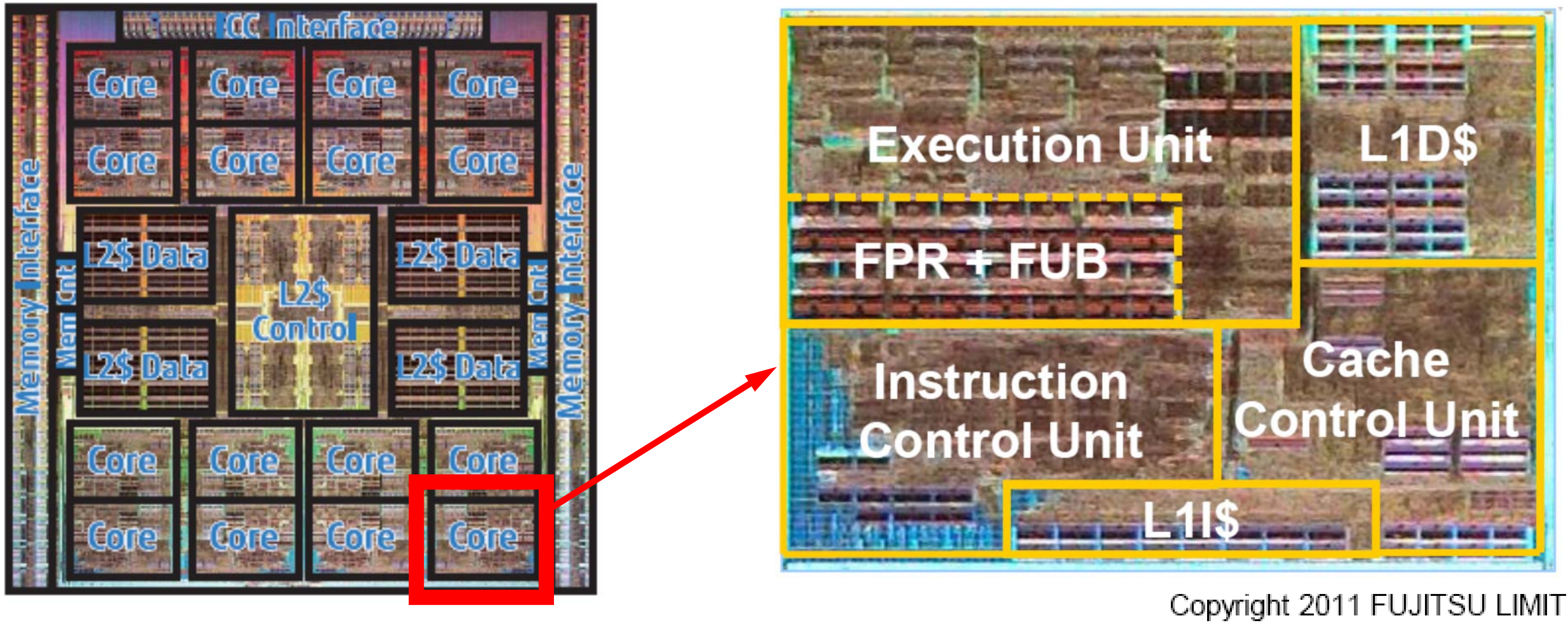
Log-in nodes

PRIMERGY RX300 S6 x 8

🟩 InfiniBand
🟪 Ethernet
🟦 FibreChannel

- Aggregate memory bandwidth: 398 TB/sec.
- Local file system for staging with 1.1 PB of capacity and 131 GB/sec of aggregate I/O performance (for staging)
- Shared file system for storing data with 2.1 PB and 136 GB/sec.
- External file system: 3.6 PB

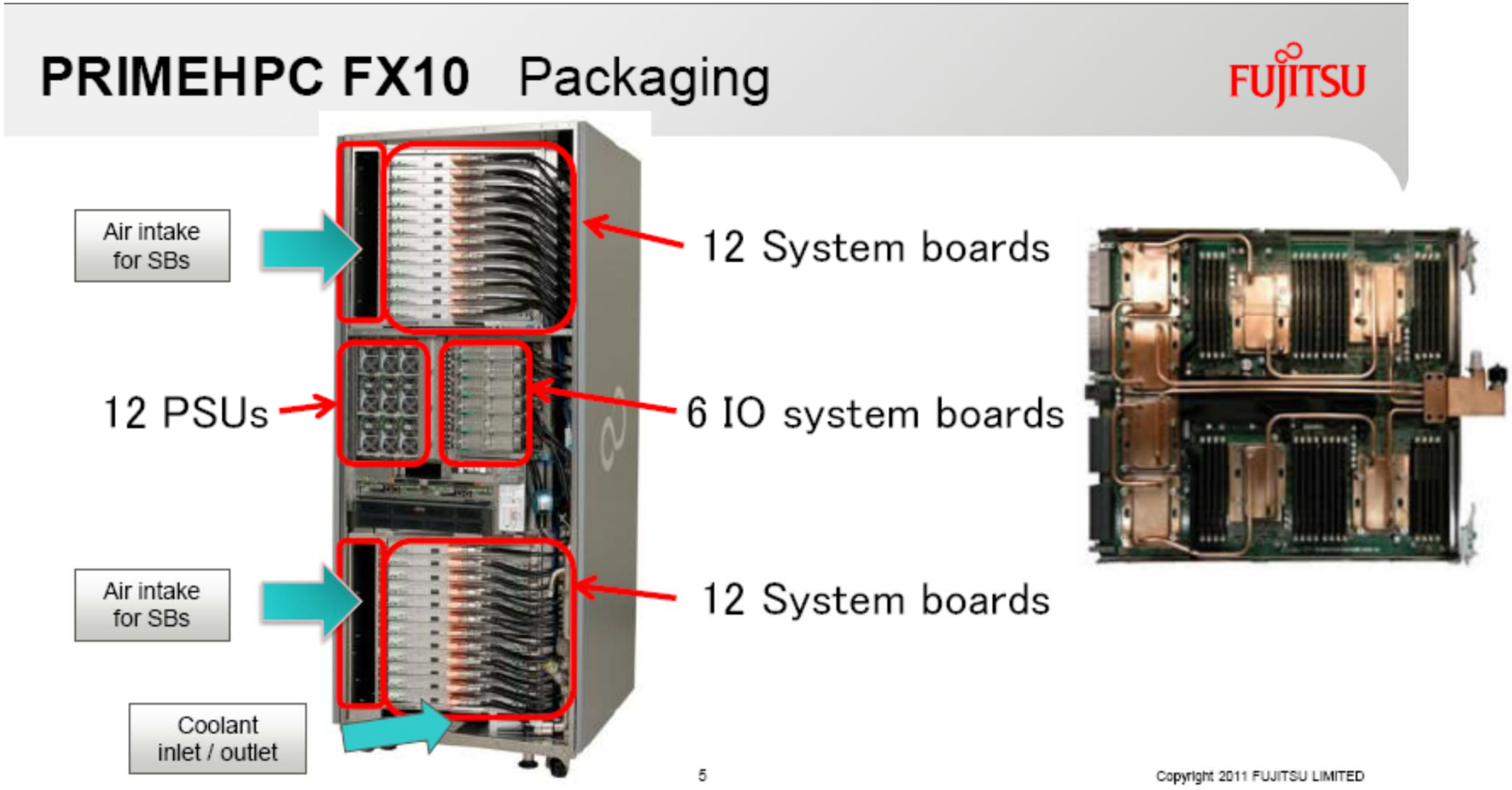
SPARC64^{TM} IXfx



CPU	SPARC64™ IXfx 1.848 GHz	SPARC64™ VIIIfx 2.000 GHz
Number of Cores/Node	16	8
Size of L2 Cache/Node	12 MB	6 MB
Peak Performance/Node	236.5 GFLOPS	128.0 GFLOPS
Memory/Node	32 GB	16 GB
Memory Bandwidth/Node	85 GB/sec (DDR3-1333)	64 GB/sec (DDR3-1000)

Racks

- A “System Board” with 4 nodes
- A “Rack” with 24 system boards (= 96 nodes)
- Full System with 50 Racks, 4,800 nodes



PRIMEHPC FX10 Packaging

FUJITSU

Air intake for SBs

12 System boards

12 PSUs

6 IO system boards

Air intake for SBs

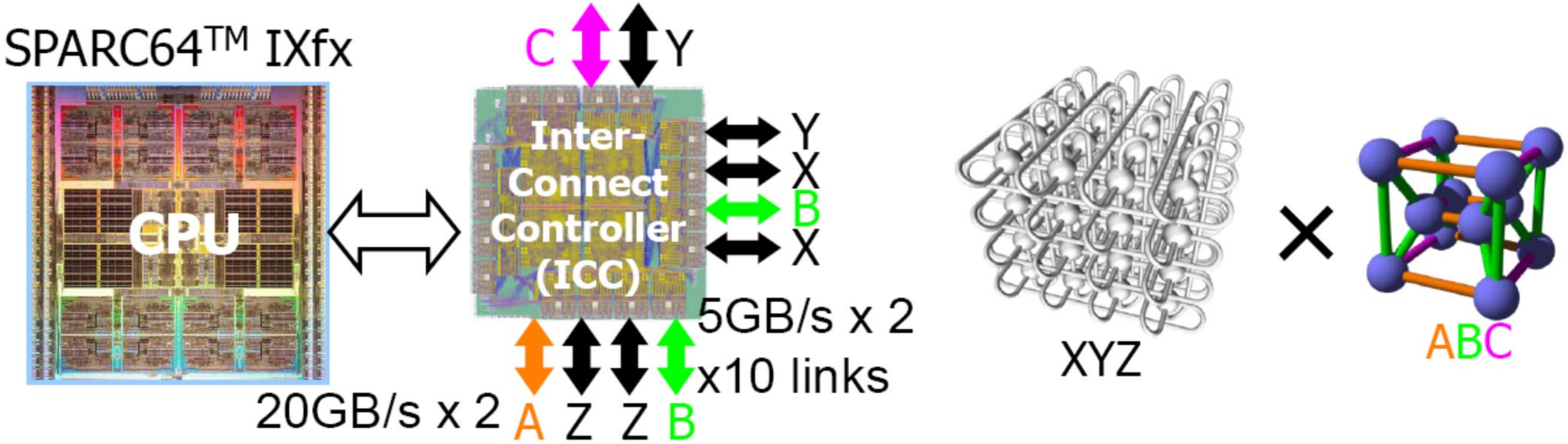
12 System boards

Coolant inlet / outlet

5

Tofu Interconnect

- Node Group
  - 12 nodes
  - A/C-axis: on system board, B-axis: 3 system boards
- 6D：（X,Y,Z,A,B,C）
  - ABC 3D Mesh: connects 12 nodes of each node group
  - XYZ 3D Mesh： connects “ABC 3D Mesh” group



Software of FX10

	Computing/Interactive Nodes	Login Nodes
OS	Special OS（XTCOS）	Red Hat Enterprise Linux
Compiler	Fujitsu Fortran 77/90 C／C++ GNU GCC，g95	Fujitsu (Cross Compiler) Fortran 77/90 C／C++ GNU (Cross Compiler) GCC，g95
Library	Fujitsu SSL II (Scientific Subroutine Library II)，C-SSL II，SSL II/MPI Open Source BLAS，LAPACK，ScaLAPACK，FFTW，SuperLU，PETSc，MeTiS，SuperLU_DIST，Parallel NetCDF	
Applications	OpenFOAM，ABINIT-MP，PHASE， FrontFlow/blue FrontSTR，REVOCAP	
File System	FEFS (based on Lustre)	
Free Software	bash, tcsh, zsh, emacs, autoconf, automake, bzip2, cvs, gawk, gmake, gzip, make, less, sed, tar, vim etc.	

- HPCI
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- Overview of Fujitsu FX10 (Oakleaf-FX)

- **Post T2K System**

Post T2K System

- Will be installed FY.2014-2015, O(10^1-10^2) PFLOPS
  - under collaboration with U. Tsukuba
- Heterogeneous computing node will be adopted
  - best performance and well balanced memory-computation under limited power consumption.
- Multi-core CPU+GPU, Multi-core CPU+Many-core（e.g. Intel MIC/Xeon Phi）
  - TSUBAME 2.0 (Tokyo Tech)
  - HA-PACS (U.Tsukuba)
  - We are mainly thinking about MIC/Xeon-Phi-based system.
- Programming is difficult
  - (MPI+OpenMP) is already difficult
    - Explicit method is rather easier
  - OpenACC, CUDA, OpenCL