Introduction to the K computer

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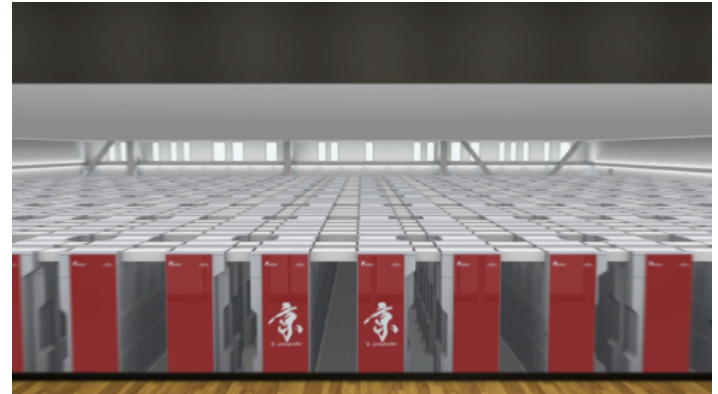RIKEN

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Outline

- ✓ Overview of the K computer

- ✓ Key technologies for the K computer

- ✓ The K computer and the others

- ✓ How to use the K computer

- ✓ Statistics
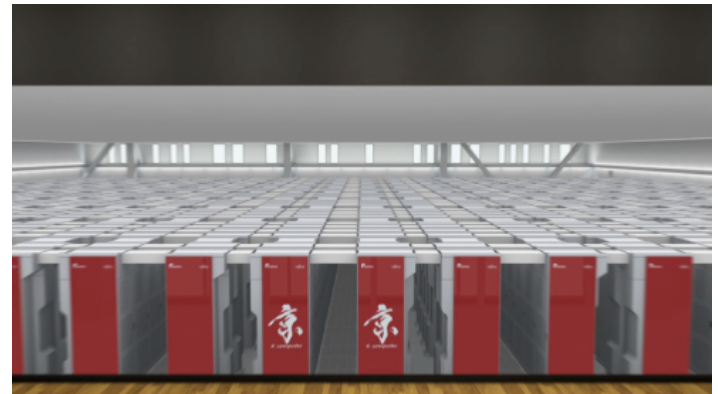
- ✓ Summary

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Design targets of the K computer

✓ **Sustained Peta-Flops System in Real Applications**

  ✓ High-Performance/Low Power CPU

  ✓ High Throughput/Low Latency Torus Network (Tofu)

  ✓ Optimized Compilers and Libraries : Fortran, C/C++,MPI,BLAS and LAPACK

✓ **Highly Reliable System**

  ✓ Low Operating Temperature in CPU/ICC : 30°C by Water Cooling

  ✓ Auto-Recovery Functions with Strict Error Detections

  ✓ Reliable Torus Network with Auto-Rerouting

  ✓ Back-up Servers and Dual Data Paths in I/O

✓ **Highly Efficient and Usable System for Diverse Work Loads**

  ✓ Distributed Parallel File System

  ✓ Hierarchical I/O System with Staging Functions

  ✓ Efficient Job Scheduler to Support 3-D Torus Network

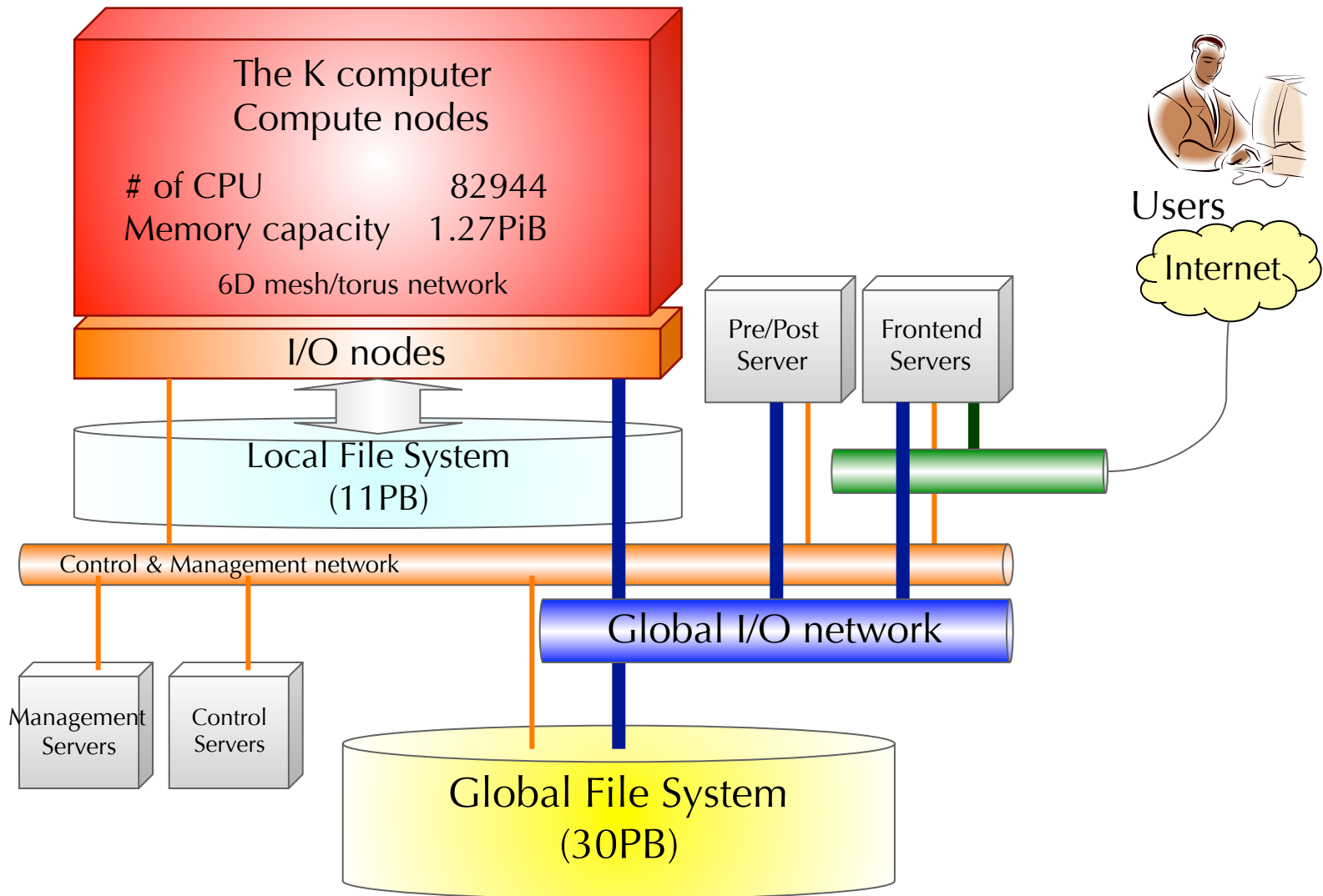 ✓ Unified Portal System to Support Application Development, File Handling, Job & Resource Monitoring, etc.

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Schedule and the history

present

	2006	2007	2008	2009	2010	2011	2012	2013
System		Conceptual Design	Detailed Design		Prototyping, evaluation	Production, Installation and ajustment		
Buildings		Design		Construction				
Operation							Early access	Regular operation

tuning and improvement

✓ 2009.7   System design fix
✓ 2010.5   Buildings complete
✓ 2010.9   Installation start
✓ 2011.6   No.1 37th on TOP500 list (8.162PF)
✓ 2011.11   No.1 38th on TOP500 list (10.51PF),
                      Gordon-Bell Prize , HPCC Awards(G-HPL, G-Random Access, G-FFT,
                      Stream triad per system)
✓ 2012.6   System complete
✓ 2012.9   Regular operation start
✓ 2012.11   Gordon-Bell Prize , PCC Awards(G-HPL, G-Random Access,
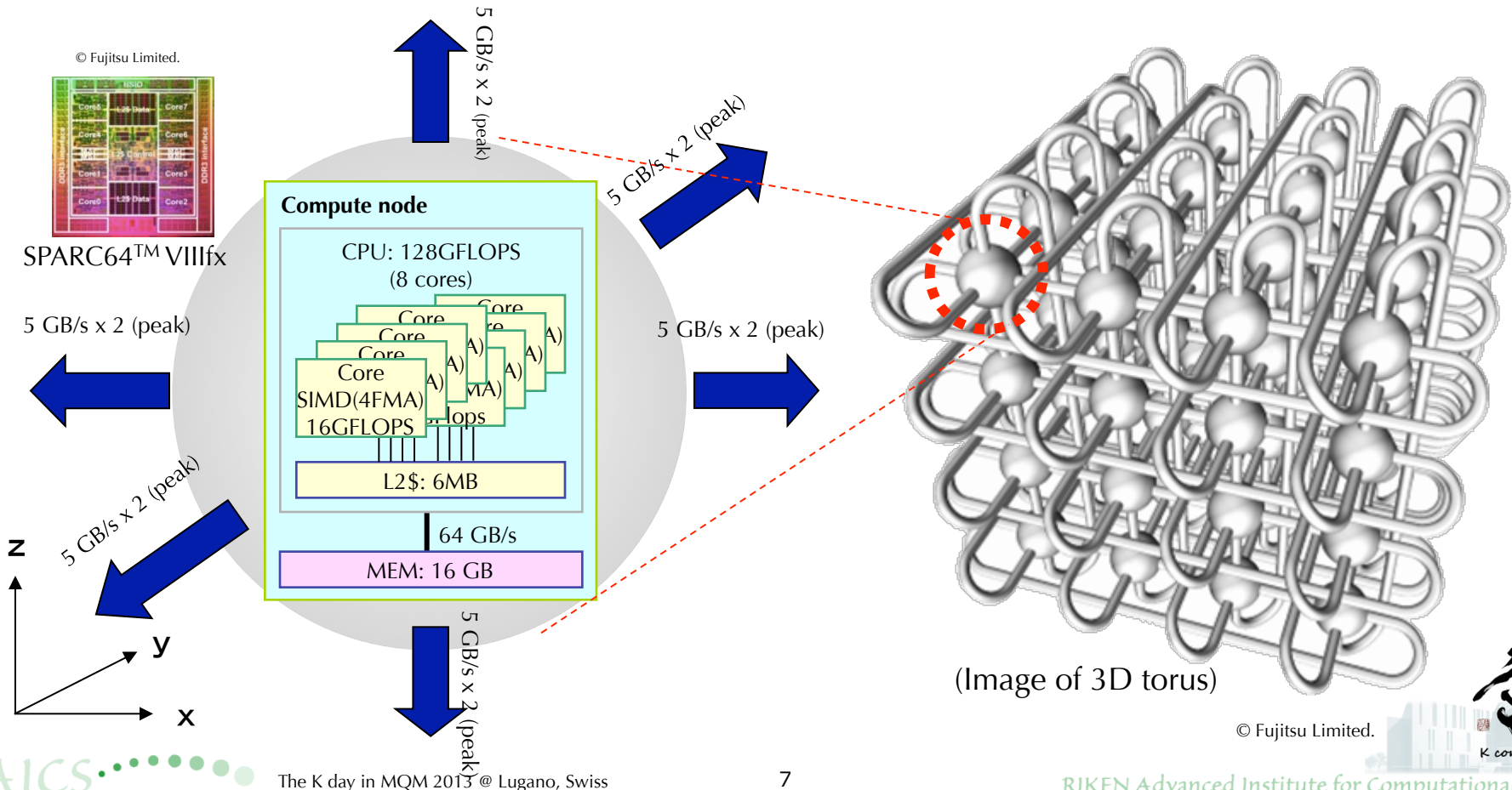   Stream triad per system)

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Overview of the K computer

The K computer
Compute nodes

# of CPU   82944
Memory capacity   1.27PiB

6D mesh/torus network

I/O nodes

Local File System
(11PB)

Control & Management network

Global I/O network

Management
Servers

Control
Servers

Global File System
(30PB)

Pre/Post
Server

Frontend
Servers

Users

Internet

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Interconnect Network

- **Network : Tofu interconnect**
  - 5 GB/s x 2 bandwidth / link
  - Logical 3D, 2D or 1D torus network from the user's point of view
  - 200K cables, total distance of about 1,000km

© Fujitsu Limited.

SPARC64™ VIIIfx

5 GB/s x 2 (peak)

5 GB/s x 2 (peak)

5 GB/s x 2 (peak)

5 GB/s x 2 (peak)

5 GB/s x 2 (peak)

Compute node

CPU: 128GFLOPS
(8 cores)

Core

Core

Core

Core

Core
SIMD(4FMA)
16GFLOPS

L2$: 6MB

64 GB/s

MEM: 16 GB

z

y

x

(Image of 3D torus)

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System Configuration of the K computer

40 m x 40 m
Full System
Compute Rack × 864

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10.6(11.3)PFLOPS
1.27(1.34)PiB

4000mm x 800mm

2 Cabinets
Compute Rack × 4
Disk Racks × 1

800mm x 800mm

Compute Rack
SB×24
IOSB×6

49.2(52.4)TFLOPS
6.00(6.38)TiB

500mm x 500mm

System Board(SB)
Node×4

Node
CPU×1
ICC×1
memory
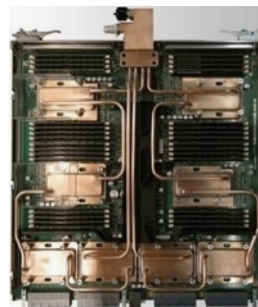
12.3(13.1)TFLOPS
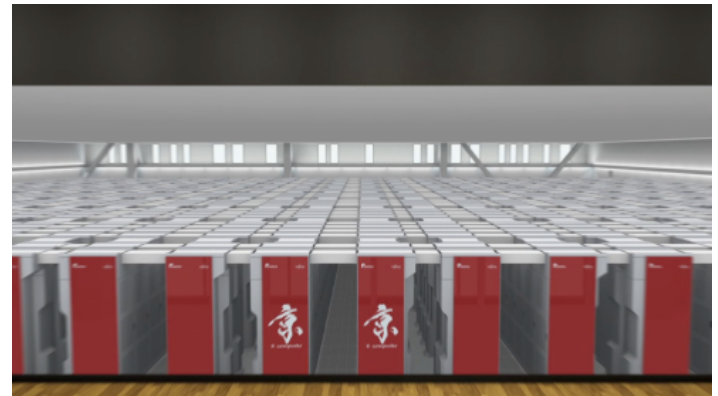**1.50(1.59)TiB**
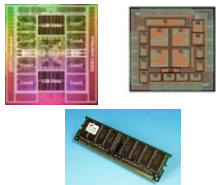
512GFLOPS
64GiB

128GFLOPS
16GiB

( )included IO node performance and memory capacity
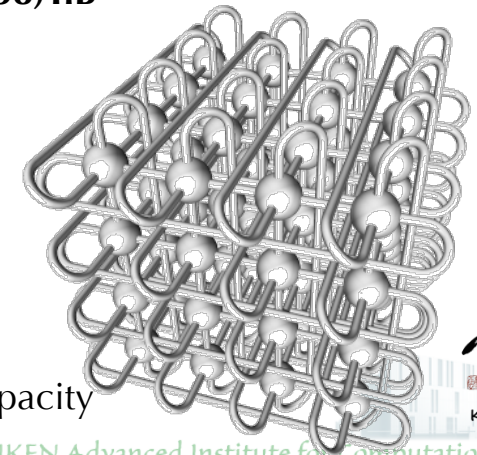
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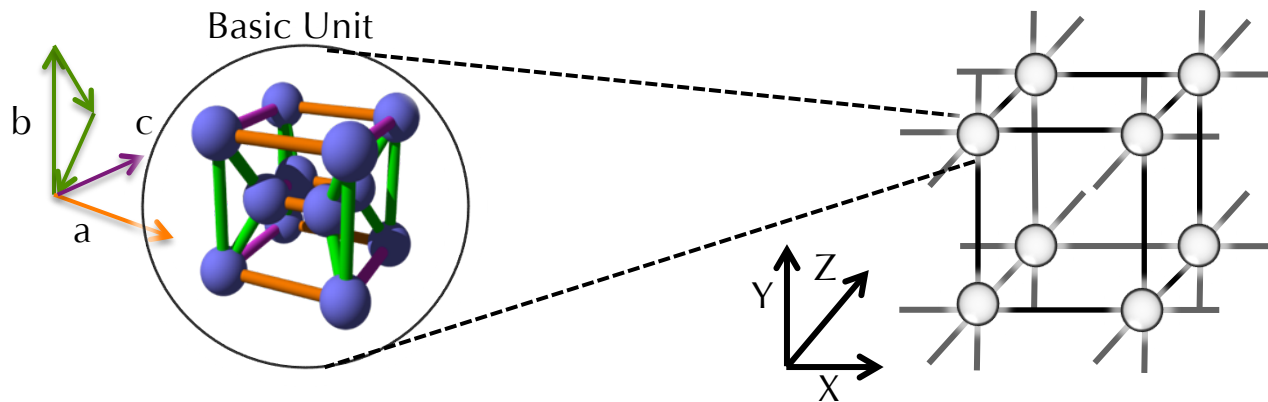
✓How to use the K computer

✓Statistics

✓Summary

Tofu Interconnect

✓ Tofu = <u>To</u>rus <u>fu</u>sion

✓ Physical view

   ✓ 6D Mesh/Torus
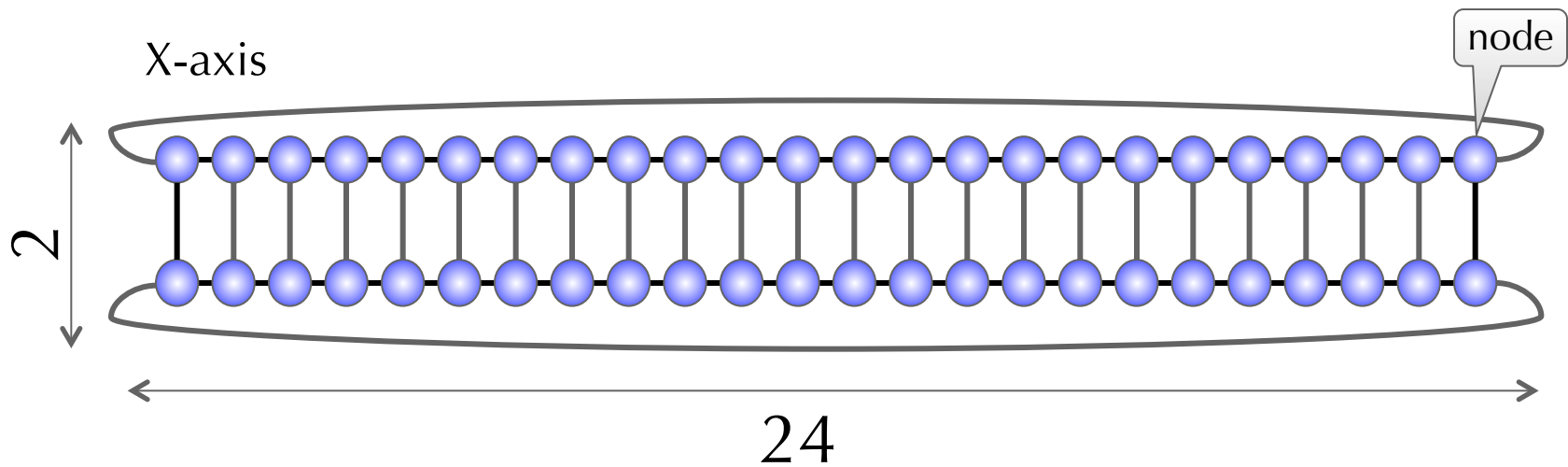
     = 3D Mesh/Torus(2x3x2) + 3D Mesh/Torus(24x18x16)

Basic Unit

b   c

a

Y   Z

X

✓ Logical view

   ✓ 3D Torus(48x54x32) w/ Redundant Links

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Tofu Interconnect(cont'd)
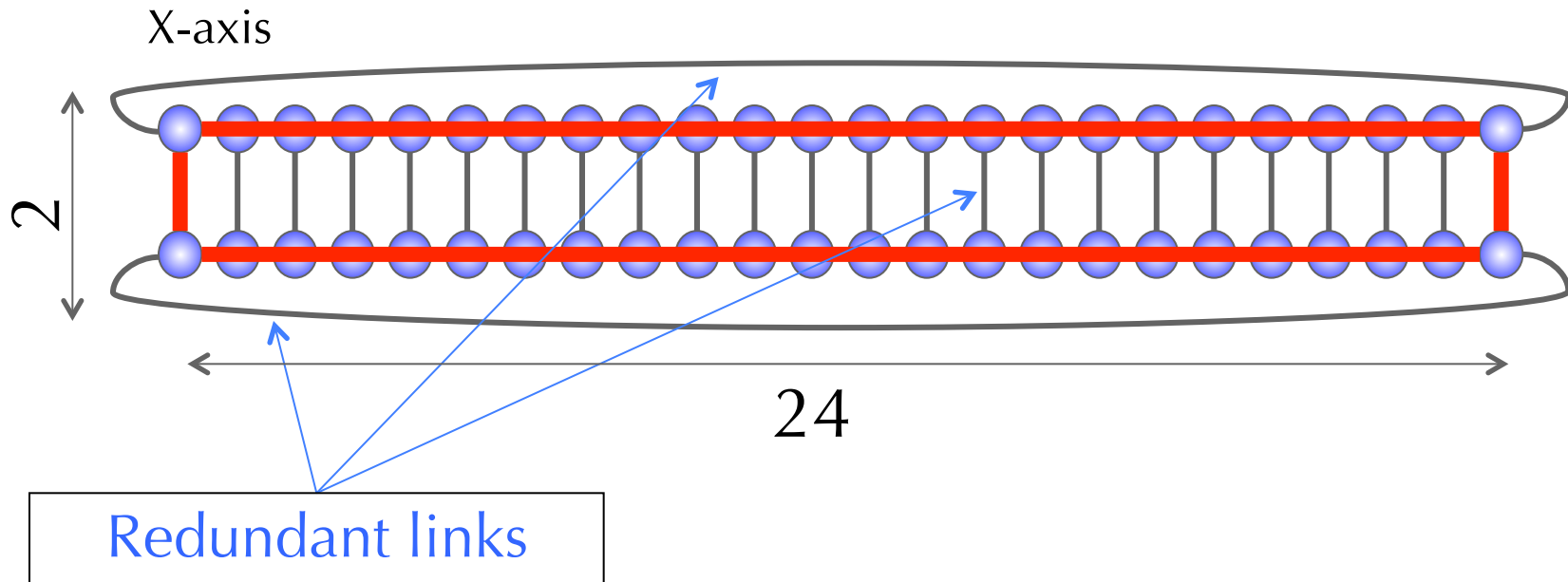
✓ Logical 3D Torus (X,Y,Z)

= (48(=2x24) , 54(=3x18) , 32(=2x16))

X-axis

node
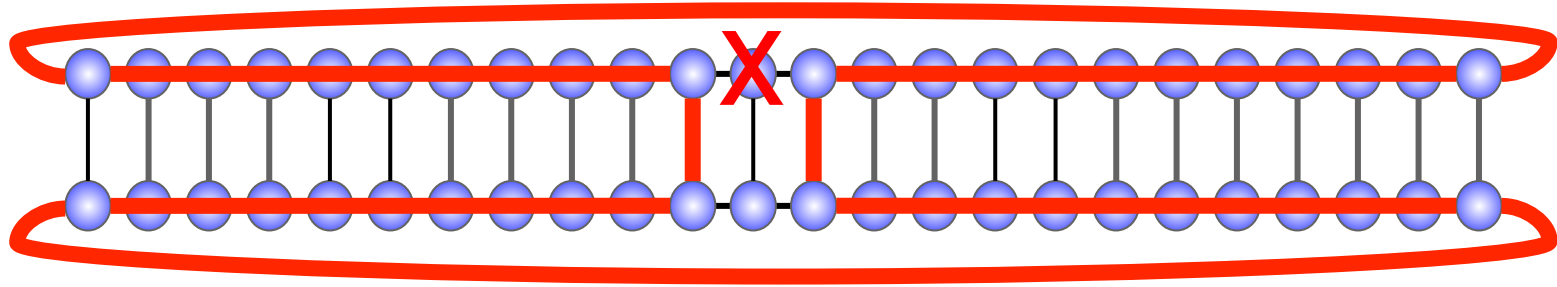
2

24

Tofu Interconnect(cont'd)

✓ Logical 3D Torus (X,Y,Z)

= (48(=2x24) , 54(=3x18) , 32(=2x16))

X-axis

2

24

Redundant links

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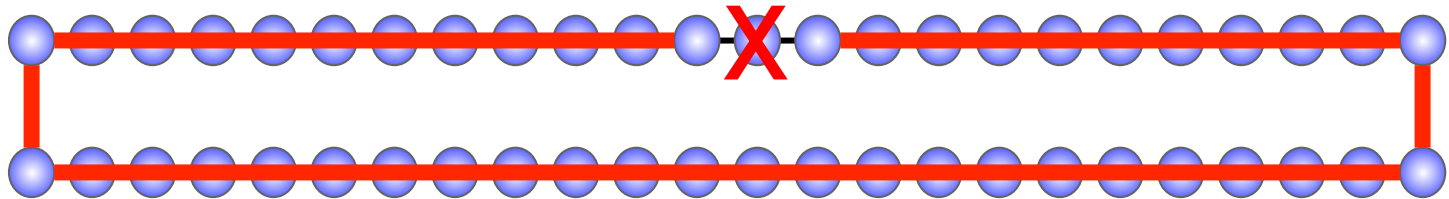RIKEN Advanced Institute for Computational Science

Tofu Interconnect(cont'd)

In Tofu case

When node down occurs, torus connection can be
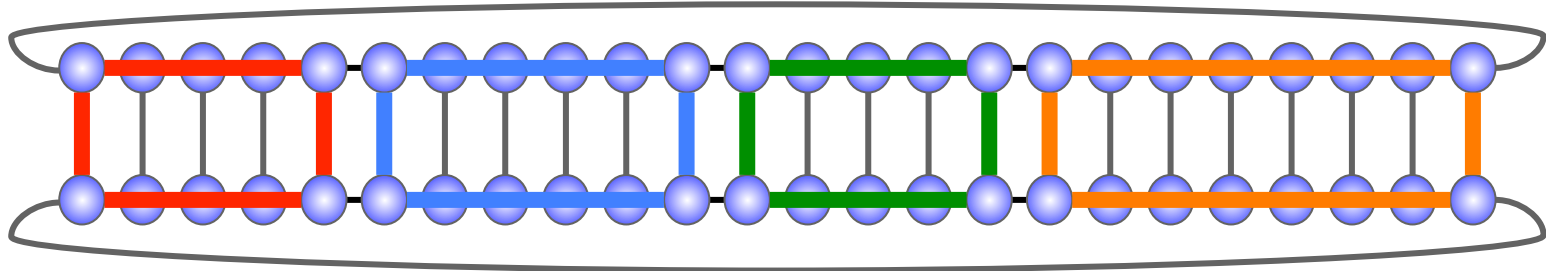kept by the redundant links.

In ordinary torus case

When node down occurs, torus connection can NOT
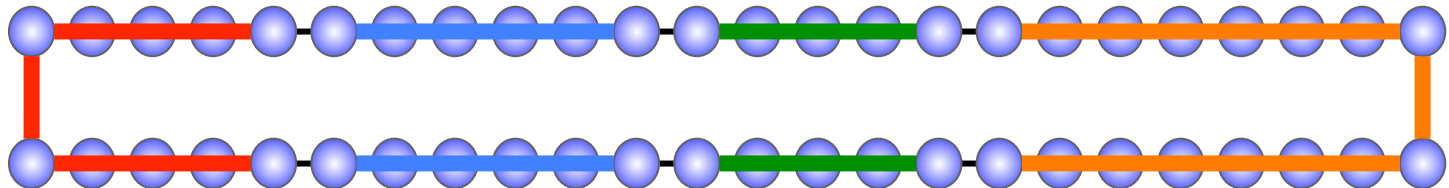be kept in ordinary torus case.

Tofu Interconnect(cont'd)

In Tofu case

Torus connection can also be kept by the redundant
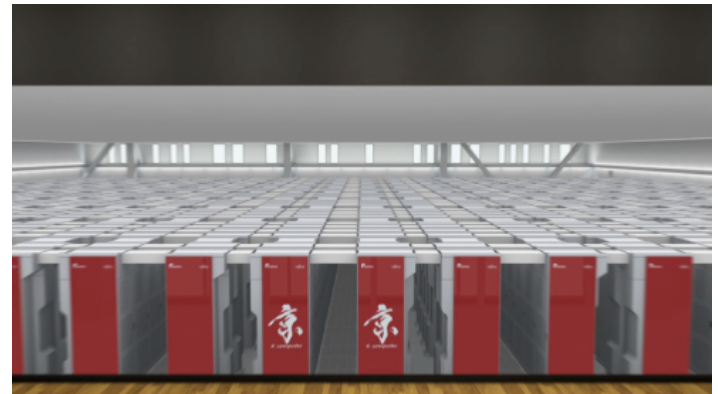links for all jobs/partitions

In ordinary torus case

Torus connection can NOT be kept in ordinary torus case

Tofu interconnect provides high reliability and flexibility

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Recent TOP5 ranking

	Jun. 2011		Nov.2011		Jun. 2012		Nov. 2012	
	System(country)	PFLOPS	System(country)	PFLOPS	System(country)	PFLOPS	System(country)	PFLOPS
1	K computer(JPN)	8.16	K computer(JPN)	10.51	Sequoia(USA)	16.32	Titan(USA)	17.59
2	Tianhe1A(CHN)	2.57	Tianhe1A(CHN)	2.57	K computer(JPN)	10.51	Sequoia(USA)	16.32
3	Jaguar(USA)	1.76	Jaguar(USA)	1.76	Mira(USA)	8.16	K computer(JPN)	10.51
4	Nebulae(CHN)	1.27	Nebulae(CHN)	1.27	SuperMUC(GER)	2.90	Mira(USA)	8.16
5	TSUBAME2.0(JPN)	1.19	TSUBAME2.0(JPN)	1.19	Tianhe1A(CHN)	2.57	JUQUEEN(GER)	4.14

The K computer has got No.1 of the TOP500 at June November 2011.
Then "K" has been caught up with supercomputers launched after the "K".
But…

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A comparison with supercomputers ranked higher

	Titan	Sequoia	K computer
latest TOP500 ranking (entry)	No.1 (Nov. 2012)	No.2 (Jun. 2012)	No.3 (Jun. 2011)
LINPACK Score（PFLOPS）	17.59	16.32	10.51
LINPACK efficiency (%)	64.8	81.1	93.2
Memory capacity / Peak performance （TB/PFLOPS）	25.7	76.3	122.1
Memory Bandwidth / Peak performance （B/FLOP）	0.2	0.2	0.5
Interconnect Bandwidth / Peak performance（B/FLOP）	0.02	0.10	0.39

A comparison with supercomputers ranked higher
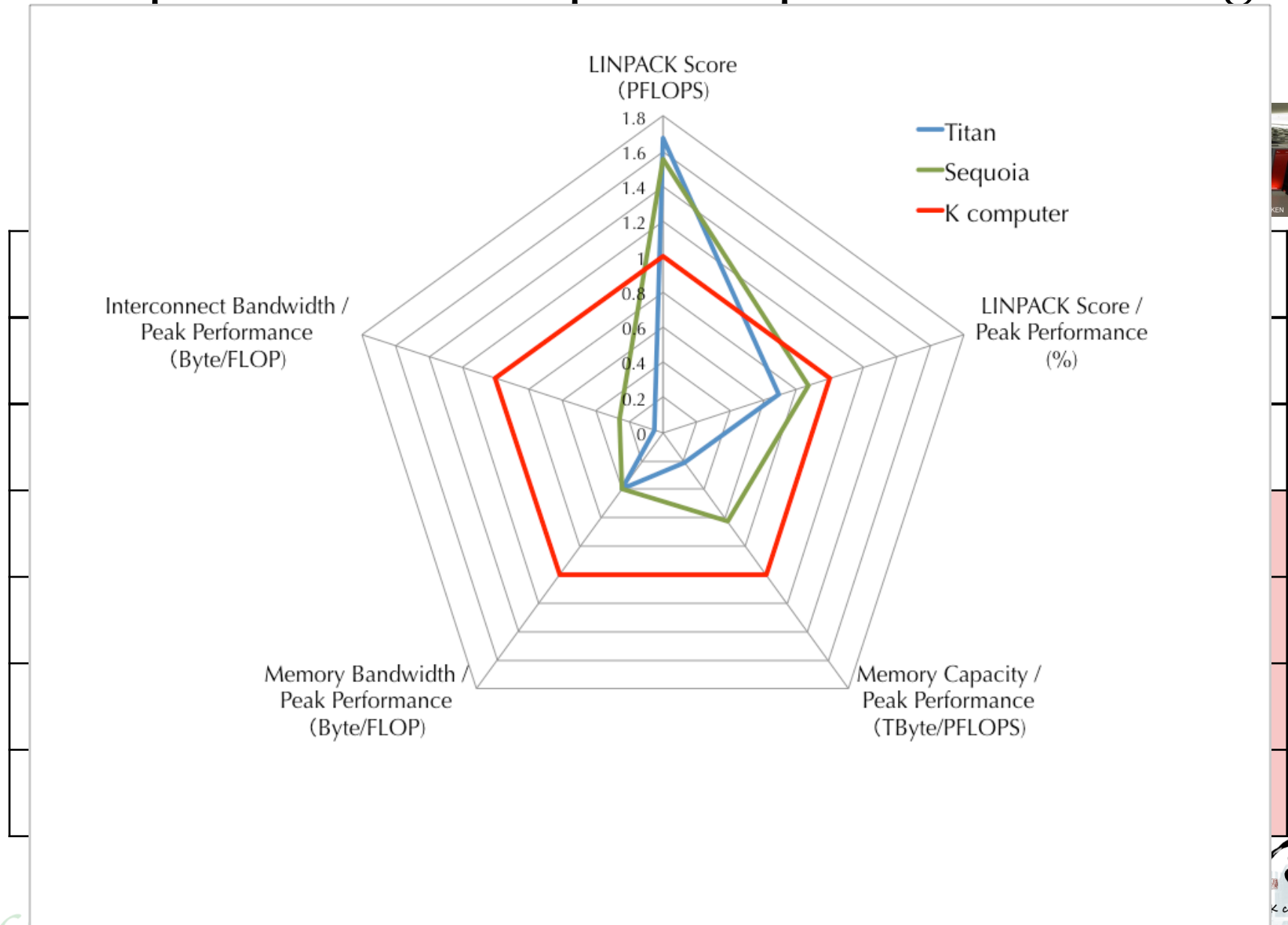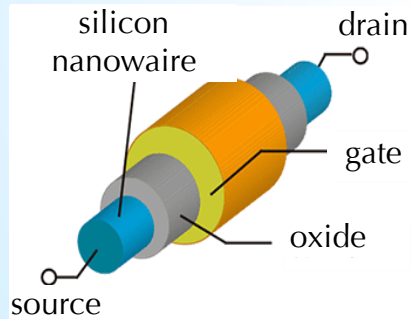
Gordon-Bell Prize

Gordon-Bell prize：

The Gordon Bell Prize is awarded each year to recognize outstanding achievement in high-performance computing.

Remarkable science outcomes from the K computer have awarded Gordon-Bell prize in 2011 and 2012.
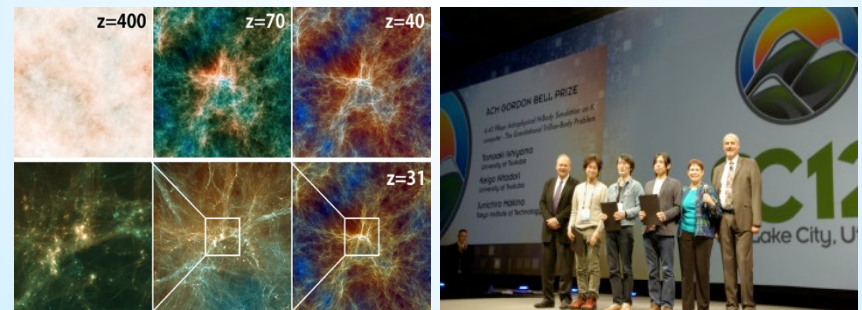
2011：

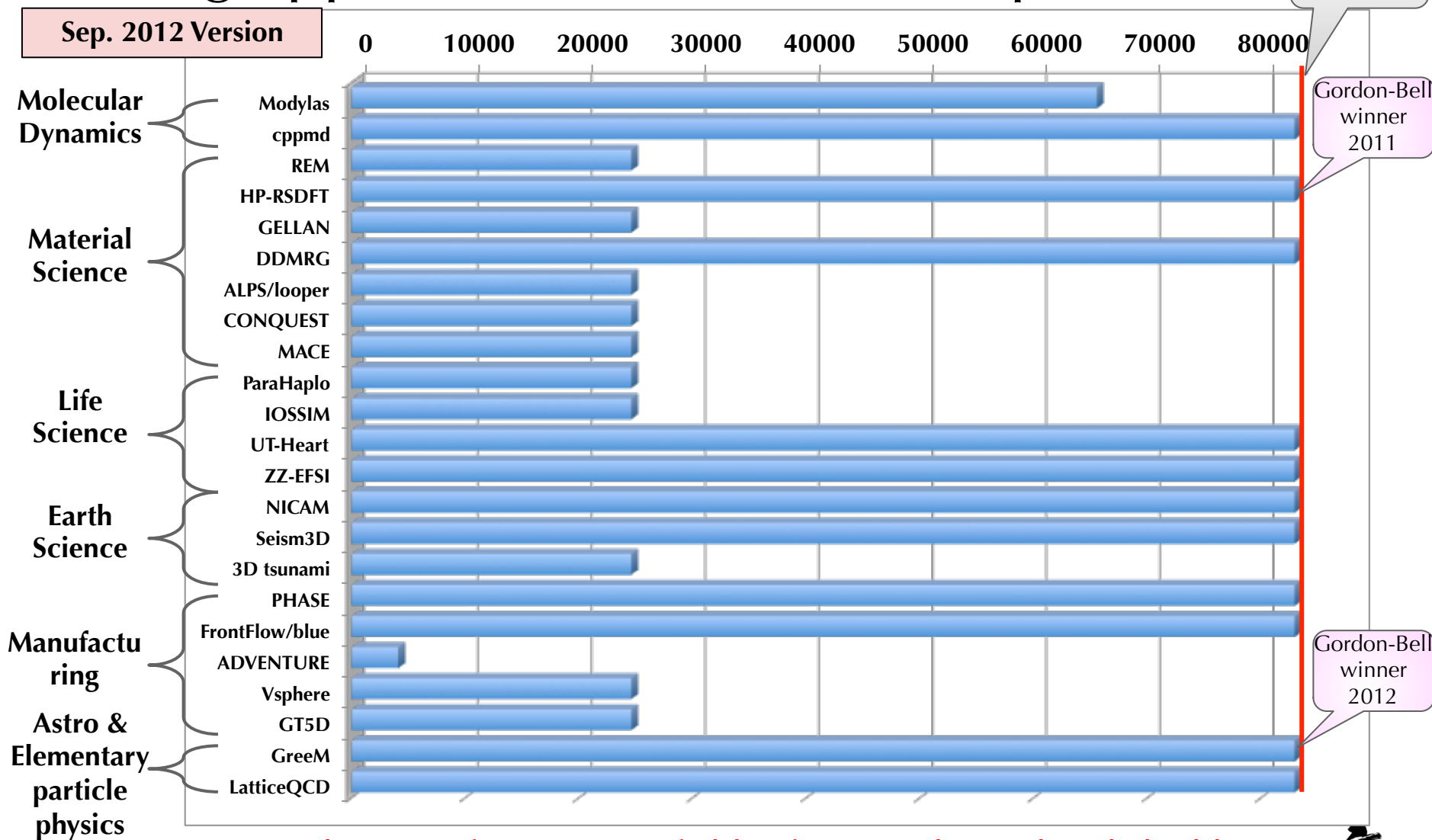"First-principles calculations of electron states of a silicon nanowire with 100,000 atoms on the K computer"

2012：

"4.45 Pflops astrophysical N-body simulation on K computer: the gravitational trillion-body problem"

Leading applications on the K computer

Sep. 2012 Version

full node

Gordon-Bell winner 2011

Gordon-Bell winner 2012

Molecular Dynamics
- Modylas
- cppmd

Material Science
- REM
- HP-RSDFT
- GELLAN
- DDMRG
- ALPS/looper
- CONQUEST
- MACE

Life Science
- ParaHaplo
- IOSSIM
- UT-Heart
- ZZ-EFSI

Earth Science
- NICAM
- Seism3D
- 3D tsunami

Manufacturing
- PHASE
- FrontFlow/blue
- ADVENTURE
- Vsphere

Astro & Elementary particle physics
- GT5D
- GreeM
- LatticeQCD

Many applications from various fields of science have already highly optimized for the K computer

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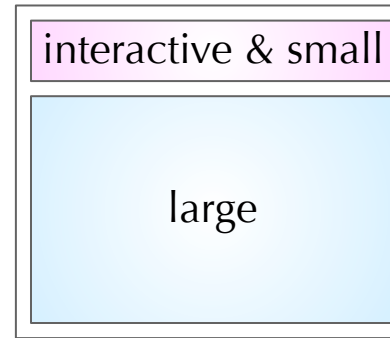
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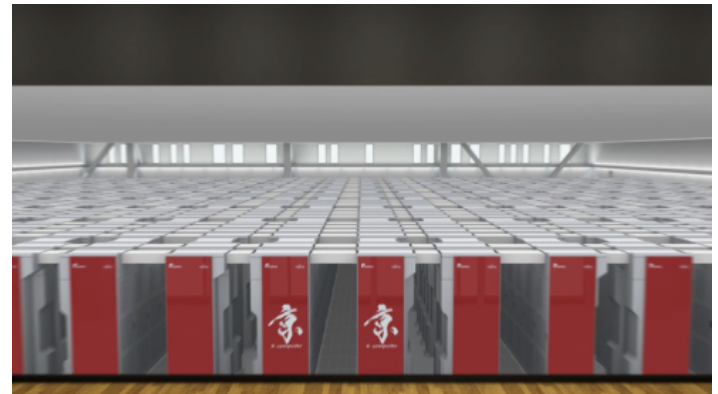
How to use the K computer

✓ Job submission

Resource Group (job queue)	node size limit	elapse time limit
interactive	1-384	1hour
small	1-384	24hours
large	385-36864	24hours
huge	36865-82944	8hours

ordinary mode

large scale job mode (2days x 2times/month)

interactive & small

large ⟺ huge

✓ Scheduling Policy

✓ FCFS(First Come First Served) + Backfill
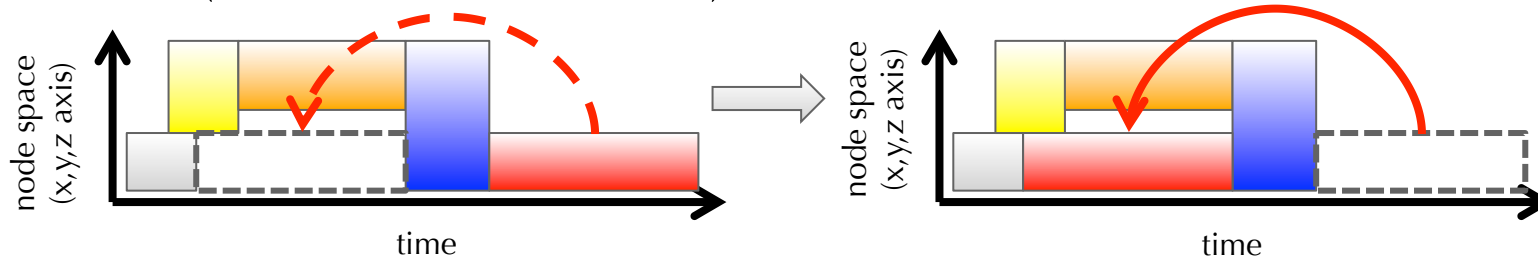
✓ A job is assigned to a node-block not in pieces.

✓ Torus connection is always guaranteed.

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How can I get the K computer's user account?

✓ Subject selection for the K computer is organized by
RIST (Research Organization for Information Science & Technology)

 ✓ See https://www.hpci-office.jp/ (English version is now under construction.)

✓ Application for use

 ✓ The application for utilization the K computer is opened for the foreign researchers.

  ✓ Some additional procedures may be necessary.(ex. security export control check, in-person authentication when you are registered as a user, etc.)

 ✓ Next application (utilization for April 2014 – March 2015) seems to be opened at Summer or Autumn of 2013 (No information on the Web).

 ✓ Acceptance ratio ~ 20% (in the previous time)

 ✓ Utilization fee

  ✓ Free (If the results can be disclosed.)

  ✓ 12.68Yen/node/hour (If the results can NOT be disclosed.)

   ✓ 25million Yen /10PF/day = $250,000 /10PF/day

Subject Selection in previous time

✓ Subject selection for utilization (Utilization period:Sep. 2012-Mar.2014) has already finished.

		# of applied	# of accepted	acceptance ratio(%)
General Use	for General	138	29[*]	21.0
	for young researchers	58	8	13.7
	for industries	31	25	80.6
	total	227	62	27.3
HPCI strategic program use			35	
total			97	

✓ ~100 subjects are using the K computer.

(*)20 proposals have been additionally selected as preparation use.

Summary

✓ **The targets of the K computer development were**

 ✓ Sustained Peta-Flops performance for various real applications
 ✓ High reliability
 ✓ High efficiency and usability for diverse work loads
 → These have been almost achieved.

✓ **The K computer is still competitive for real applications.**

 ✓ The K computer has advantages of some indexes related to usability.
  ex. Memory bandwidth, Memory capacity and Interconnect bandwidth
 ✓ Gordon-Bell Prize Winner in 2011 and 2012.

✓ **The K computer is the most productive supercomputer in the world.**

 ✓ 100 active users and 1000 jobs per day
 ✓ Peta-scale jobs are regularly running on the K computer.
 ✓ Many remarkable scientific outcomes are coming soon.

Thank you for your attention !

A photo in the early evening

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