Japan HPC Programs
- The Japanese national project of the K computer -

K computer

June 28,2011

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Next-Generation Supercomputer R&D Center
RIKEN

Contents

- Outline of the Project
- System Design
- System Configuration
- Facilities for the System
- Establishment of Advanced Institute for Computational Science (AICS)
- Summary

Outline of the Project

Key Technologies of National Importance
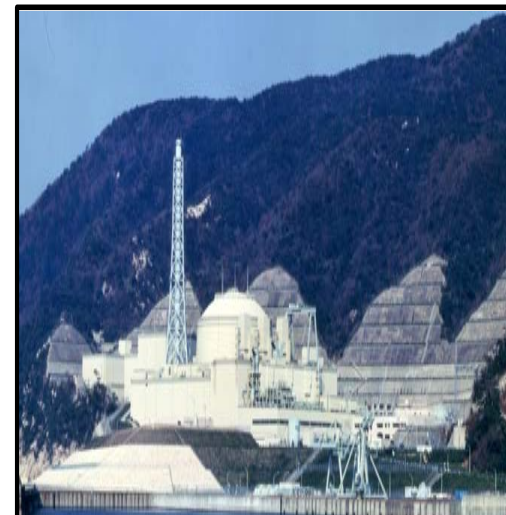

Next-Generation Supercomputer

X-ray free electron laser

Space transport system

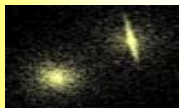
Ocean & earth exploration system

Fast breeder reactor technology

Six goals of the Japan's "Third Science and Technology Basic Plan" in FY2006 – FY2010
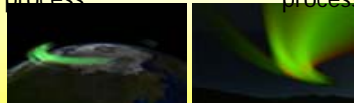
Goal One
Discovery & Creation of Knowledge toward the Future
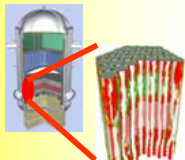
Milky Way formation process
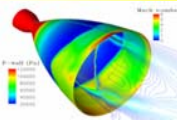
Planet formation process

Aurora outbreak process

Goal Two
Breakthroughs in Advanced Science and Technology

Nuclear reactor analysis

Rocket engine design

Goal Three
Sustainable Development
- Consistent with Economy and Environment -
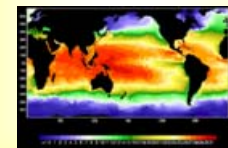
An influence prediction of El Nino phenomenon

Development and Application of the K computer

Goal Four
Innovator Japan
- Strength in Economy & Industry -

Nano technology
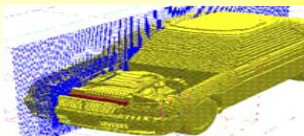
Car development

Goal Five
Good Health over Lifetime
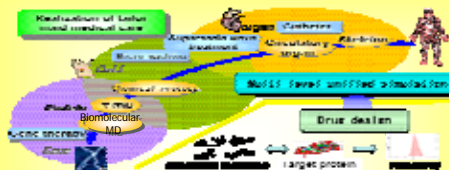
Multi-level unified simulation

Goal Six
Safe and Secure Nation
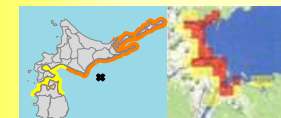
Tsunami damage prediction

Clouds analysis

Outline of the Project

- Objectives are
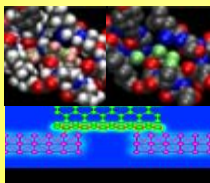 - to develop the world's most advanced and high-performance supercomputer,
  - to develop and deploy its usage technologies including application software
  - to establish the Center Of Excellence (COE) for computational science

  as one of Japan's Key Technologies of National Importance.

- Period of the project: FY2006-FY2012

High Performance Computing Infra-structure (HPCI)

SINET4: Science Information NETwork 4

Legend:
- : Core node (data center)
- : Edge node (data center)
- : Core line (40Gbps or 10Gbps)
- : Edge line (40Gbps, 10Gbps or 2.4Gbps)
- : Access line (DF+DWM) (10~40Gbps)

RIKEN AICS at Kobe
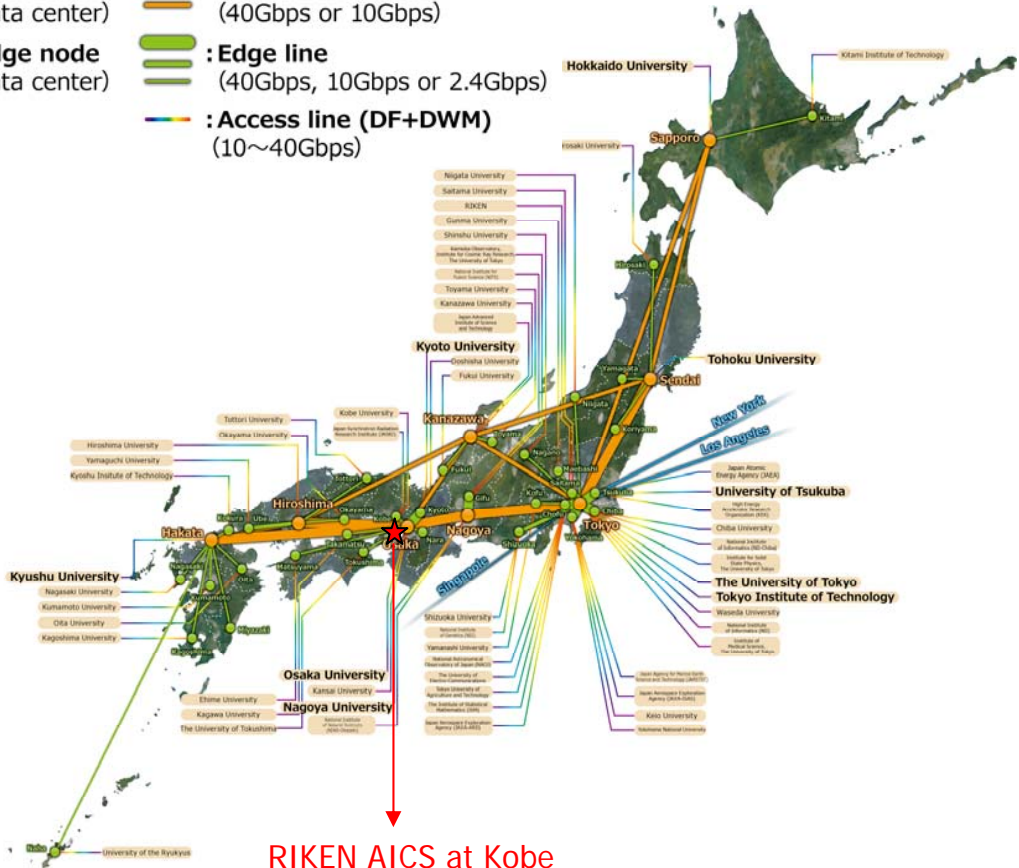
Organizations Participated in HPCI

From Resource Community
- U of Hokkaido
- U of Tohoku
- U of Tokyo
- U of Tsukuba
- Tokyo Institute of Technology (TIT)
- Institute of Molecular Science (IMS)
- RIKEN
- National Institute of Informatics (NII)
- Others
(25 organizations)

From User Community
- RIKEN
- Institute of Solid State Physics
- Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
- U of Tsukuba
- Japan Aerospace Exploration Agency (JAXA)
- Others
(13 organizations)

Manufacturing
Designing safe cars
Faster development of products

Nanotechnology
Designing new materials
Studying enzyme and
catalytic reactions

Disaster prevention
Predicting seismic waves
Predicting tsunami damage

Aerospace
Designing rocket engines
Aircraft development

Life sciences
Drug development
New technologies for medical
treatment and diagnosis

The environment
Predicting climate change
Predicting effects of
the El Niño phenomenon

Nuclear power
Analyzing whole nuclear
power plants Developing
nuclear fusion reactors

Astronomy and
astrophysics
Research on the origin of the
universe Studying the formation of
planets and galaxies

Targeted as
Grand Challenges

Five Strategic Fields Selected

Life science/Drug design

Genome
Body
Protein
Organs
Cell
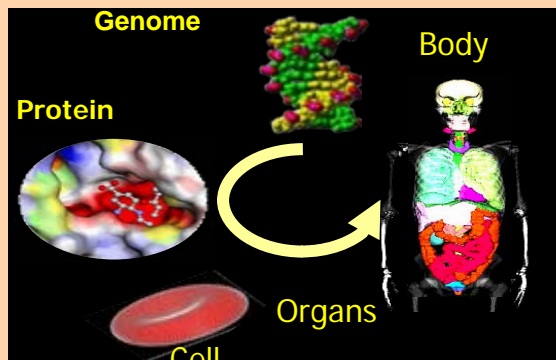
Toshio YANAGIDA
RIKEN

New materials/New energy creation

新物質創成

次世代電子デバイス

エネルギー・環境
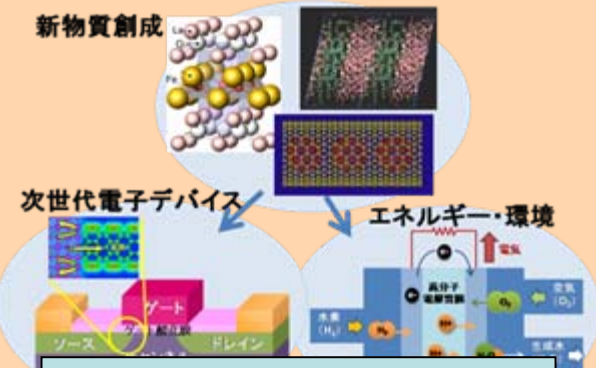
Shinji TSUNEYUKI
University of Tokyo

Global climate change prediction for disaster prevention/mitigation

Shiro IMAWAKI
JAMSTEC

MONODUKURI (Manufacturing technologies)
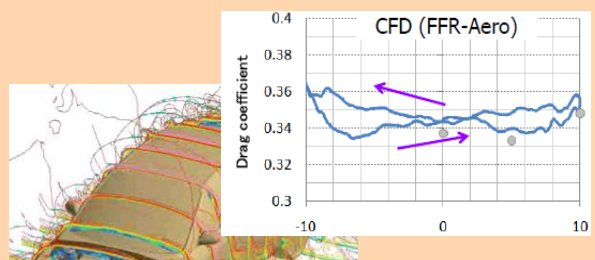
Chisachi KATO
University of Tokyo

The origin of matters and the universe
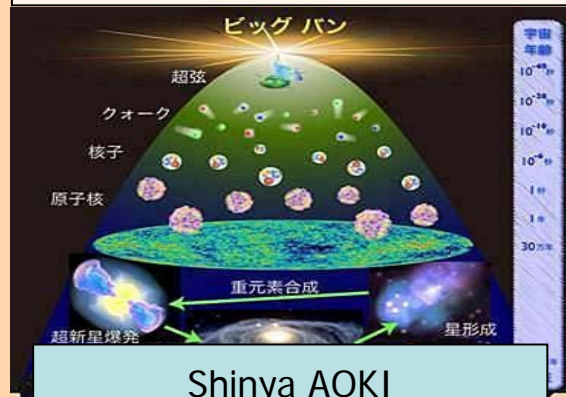
Shinya AOKI
University of Tsukuba

We are here.

	FY2006	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012
System	Conceptual design	Detailed design		Prototype, evaluation	Production, installation, and adjustment		Tuning and improvement
Applications — Next-Generation Integrated Nanoscience Simulation	Development, production, and evaluation					Verification	
Applications — Next-Generation Integrated Life Simulation		Development, production, and evaluation				Verification	
Buildings — Computer building		Design	Construction				
Buildings — Research building			Design	Construction			

9

System Design

Design Targets (2006)

- 10 peta-flops in LINPACK
- Peta-flops sustained performance in real applications
- To support a broad range of applications for computational science and engineering
- To support a huge amount of data storage
- Low power consumption system
- Highly reliable system

as a national leadership system (NLS)

National Leadership System (NLS)

National Infrastructure System (NIS)

Enterprise System

Divisional/Personal System

Requirement from Grand Challenges

Nano Sci.

Life Sci.

Others
(Engineering etc)

Requirements from Computer Centers

Power, Space

Reliability, operability

Computer center in Japan

Cost (development, manufacturing, maintenance)

Typical numerical scheme

FMO

MO

FFT

Searching algorithm

FVM

RISM

Real space density function method

Monte Carlo

FEM

Linear Solver

21 Selected Target applications

Nano Science (6)

Life Science (6)

Climate/ Geoscience (3)

Engineering. (4)

Physics/ Astro. (2)

System design

Other Projects Survey

Technology Survey

Operation & Utilization

Essential Element technologies

LSI process

Power saving SOI Low-k High-k

Light transm tech.

Software OS, compiler

Technologies of the consumer electronics

Technologies

System Configuration

- "京 (Kei)"
  - 10^{16}, or 10 peta (flops system)
  - Arch (to a new era of computational science)

Massive Parallel System to Meet Various Application Environments

- ## Sustained Peta-Flops System in Real Applications
  - High-Performance/Low Power CPU with 8 cores : 128GFlops@2GHz, 58W
  - 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℃ 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

System Configuration

Compute Nodes

Number of CPUs   >   80K
Number of cores   > 640K
Total memory capacity >   1PB

Interconnect Network
Multi-dimensional Mesh/Torus

Internet

Control Servers

System Configuration

Networks for Control and Management

Management Servers

Job & User Management

Local File System

Global I/O Networks

Frontend Servers

Global File System
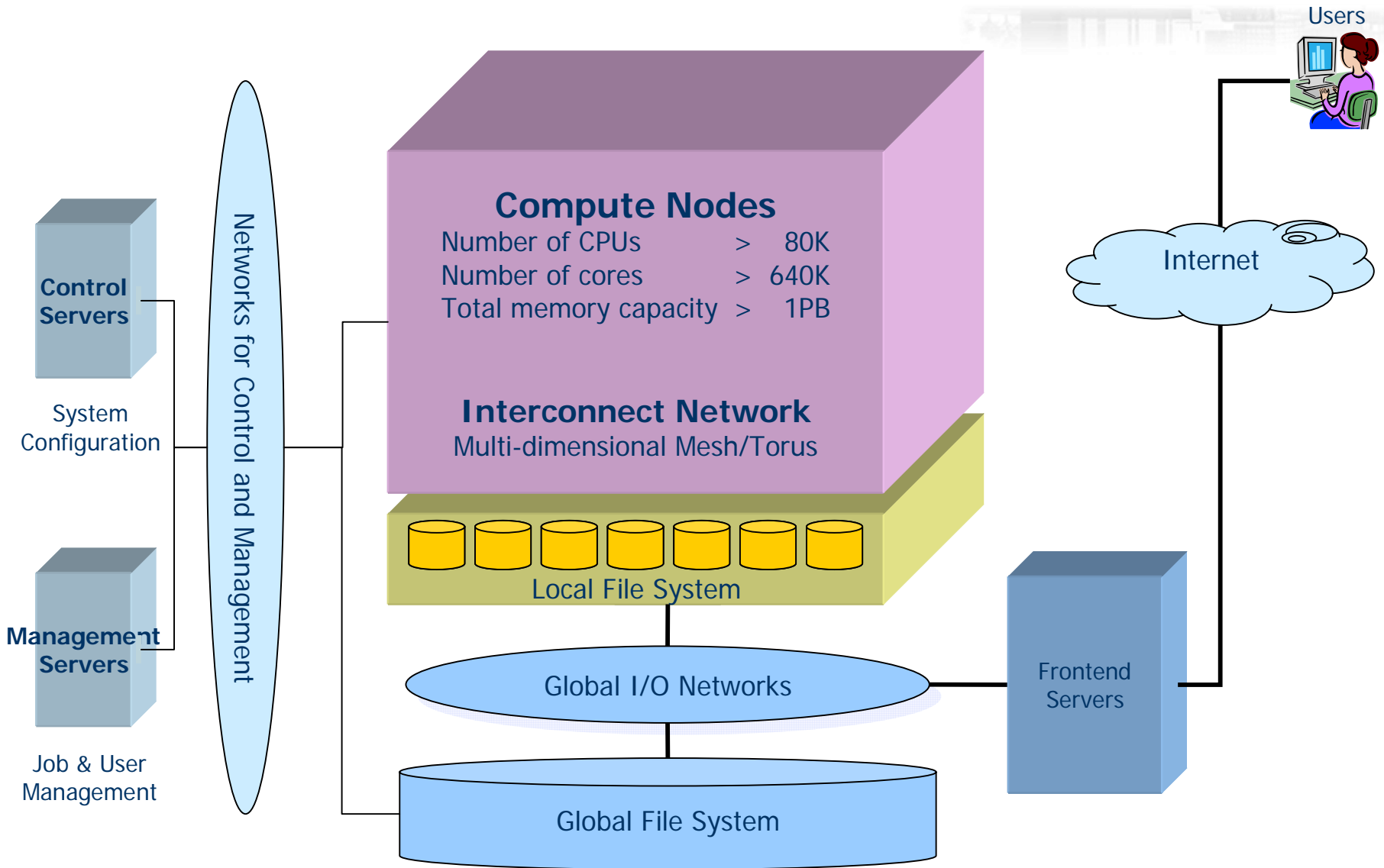
Compute nodes and network

- Compute nodes (CPUs): > 80,000
  - Number of cores: > 640,000
- Peak performance: > 10PFLOPS
- Memory: > 1PB (16GB/node)

- 6-dimensional mesh/torus network: Tofu
  - 10 connections to each adjacent node
- Peak bandwidth: 5GB/s x 2 for each connection
- Logically 3-dimensional torus network

SPARC64™ VIIIfx

Compute node

CPU: 128GFLOPS
(8cores)

Core
SIMD(4FMA)
16GFLOPS

L2$: 6MB

64GB/s

MEM: 16GB

5GB/s(peak)x 2
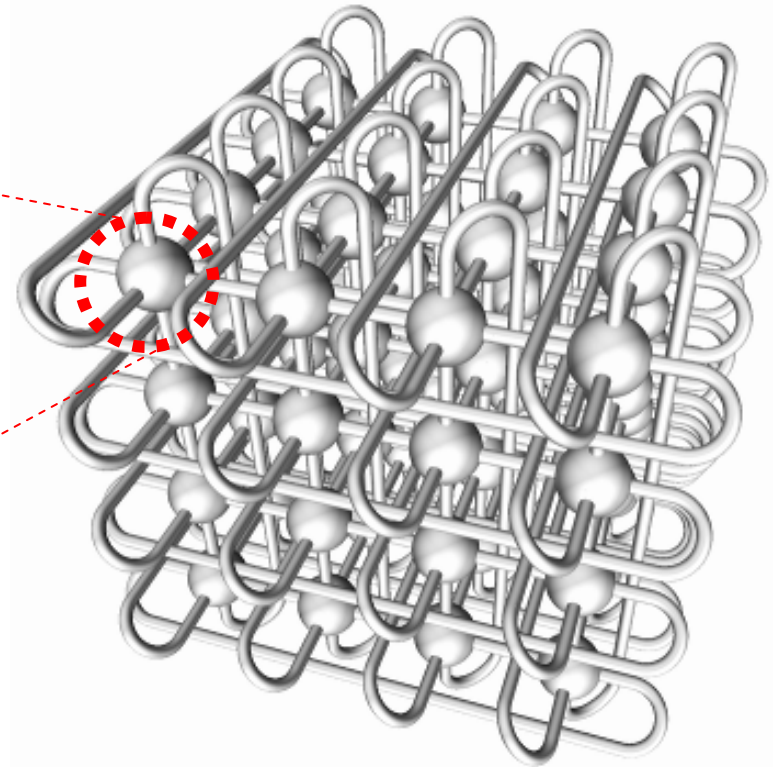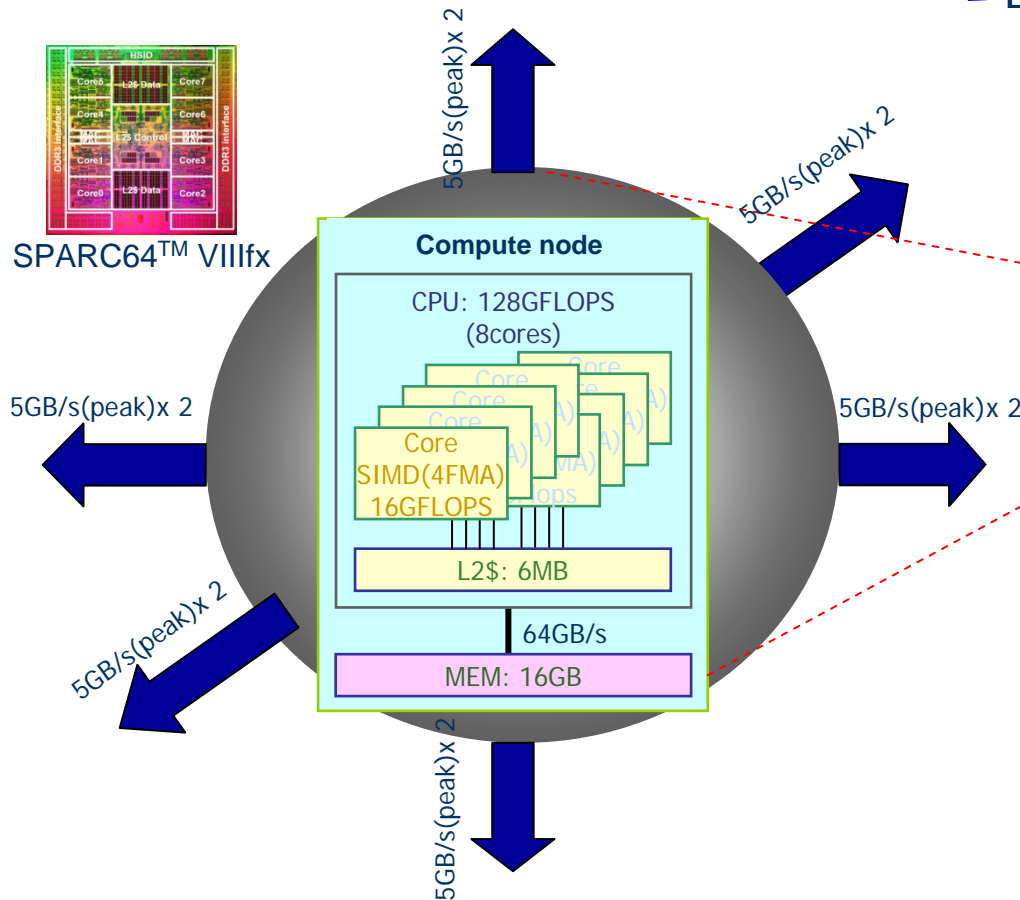
Courtesy of FUJITSU Ltd.

SPARC64™VIIIfx Chip Overview
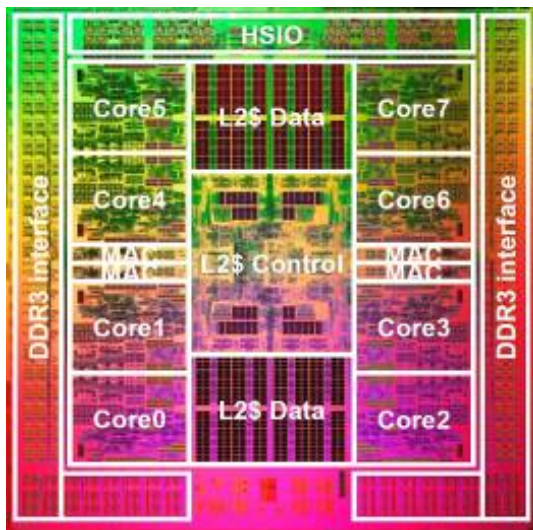
Courtesy of FUJITSU Ltd.
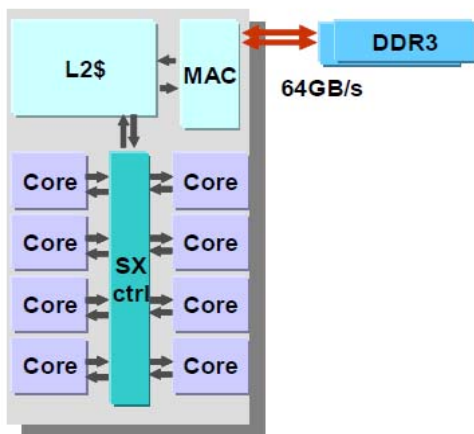
- **Architecture Features**
  - 8 cores
  - Shared 6MB L2$
  - Embedded memory controller
  - 2 GHz clock

- **Fujitsu 45nm CMOS**
  - 22.7mm x 22.6mm
  - 760 M transistors
  - 1,271 signal pins

- **Performance (peak)**
  - 128 GFlops
  - 64 GB/s memory bandwidth

- **Power**
  - 58W (typ.,@30℃)
  - Water cooling
    - Low leakage current and high reliability

Packaging of the system

- A cabinet consists of 24 system boards, power supply unit, system storage (RAID-5), and diagnostic processor.
  - A hose pipe is connected to the water loop under the floor.

CPU

ICC

LSI for interconnect

System Board

796mm

750mm

2060mm

Courtesy of FUJITSU Ltd.
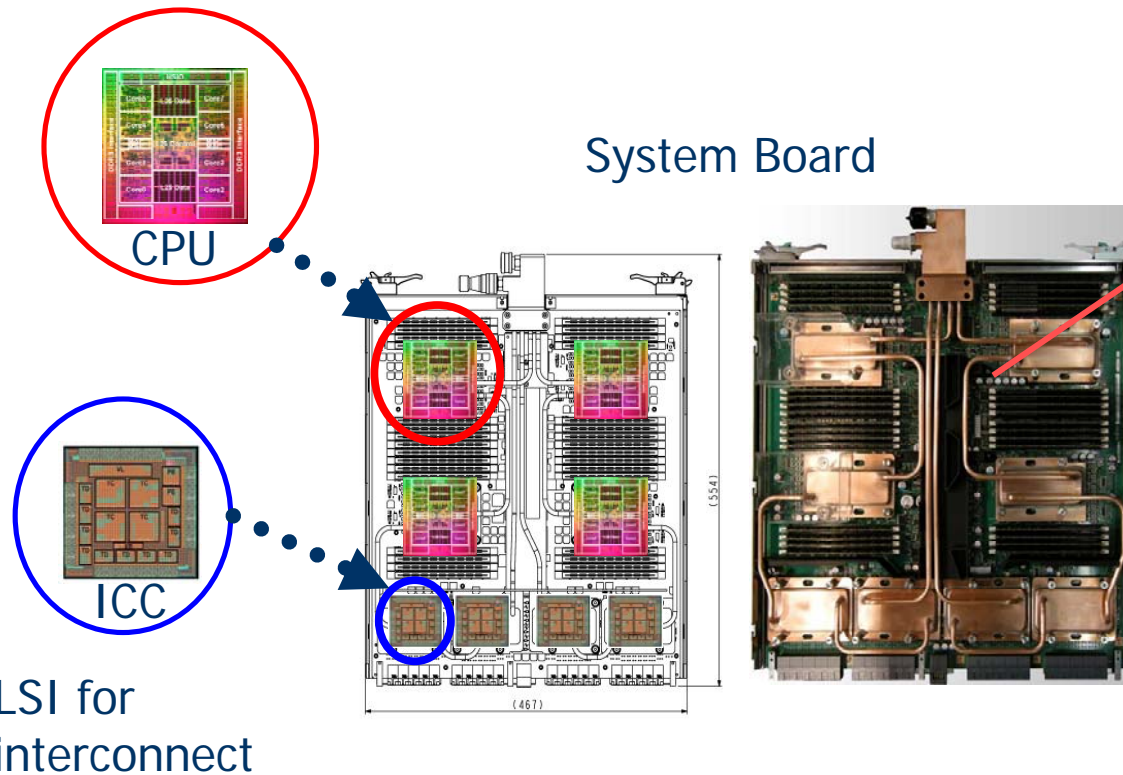
Software Configuration

Applications

HPC portal / System management portal

System operations management
-System configuration management
-System monitoring
-System installation & operation

High performance file system
- Lustre based distributed file system
- High scalability
- IO bandwidth guarantee
- High reliability & availability

Compilers (Fortran, C. C++)
- Hybrid parallel programming
- Sector cache support
- SIMD/register file extensions

MPI/Math. Libraries
- Tuned for hardware

Job operations management
-Job manager
-Job scheduler
-Resource management

Support tools
- Profiler & tuning tools
- Interactive debugger

LINUX-based enhanced Operating System
- Enhanced hardware support
- System tuning
- RAS functions

K computer

System Environments

- OS: Linux based OS on compute nodes

- Two-level large-scale distributed file system with local file system and global file system based on Lustre file system

    - Users' permanent file on the global file system

    - Staging functions
        - Files on the global file system used in a job are staged into the local file system.
        - Data generated during a job execution are moved back to the global file system after the job finished.

    - File sharing functions by using NFS-like functions
        - Users can access the file on the global file directly from frontend servers.

Applications

- Limited users started to use a part of the K computer as a trial use for the system evaluation and performance tuning since the beginning of April.
- Distribution of utilization in applications
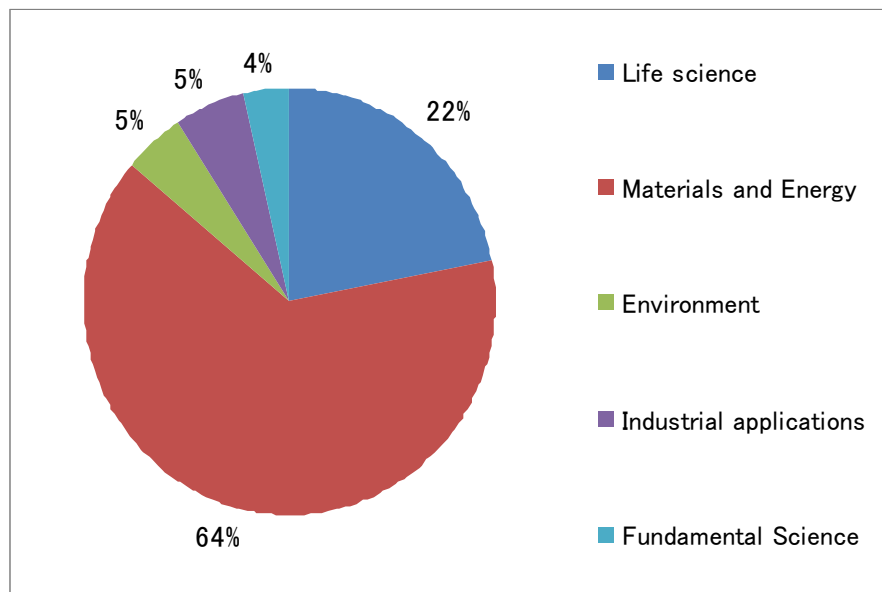
Typical Applications :
- Global Circulation Model (NICAM)
- Molecular Dynamics (Modylas/CPPMD)
- Density Function Theory (RSDFT)
- Fluid Dynamics (FFB)
- Seismic (Seism3D)
- Particle Physics (LatticeQCD)

Facilities for the System

Location of the K computer site, Kobe

Kobe

Tokyo

450km (280miles)
west from Tokyo

Mt. Rokko

Tokyo →

Shin-Kobe Sta.
Shinkansen (bullet train)

Sannomiya Sta.

Port Island

RIKEN Advanced Institute
for Computational Science

5km from Sannomiya Sta.
12 min. by a train "Portliner"

Kobe Sky Bridge

Portliner

Kobe Airport

Photo: June, 2006

Layout of the buildings

Research Building

Computer building

Chillers

Substation Supply
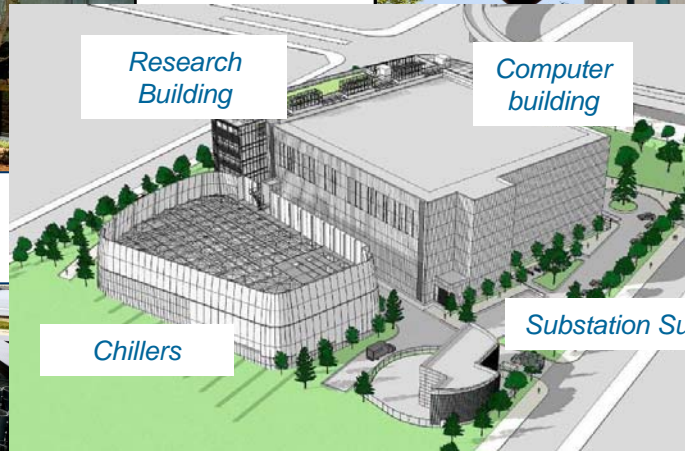
Outline of the facilities

Research Building
- six-story above ground and one below
- area : 1800 m^2

Computer Building
- Three-story above ground and one below
- Area: 4300m^2

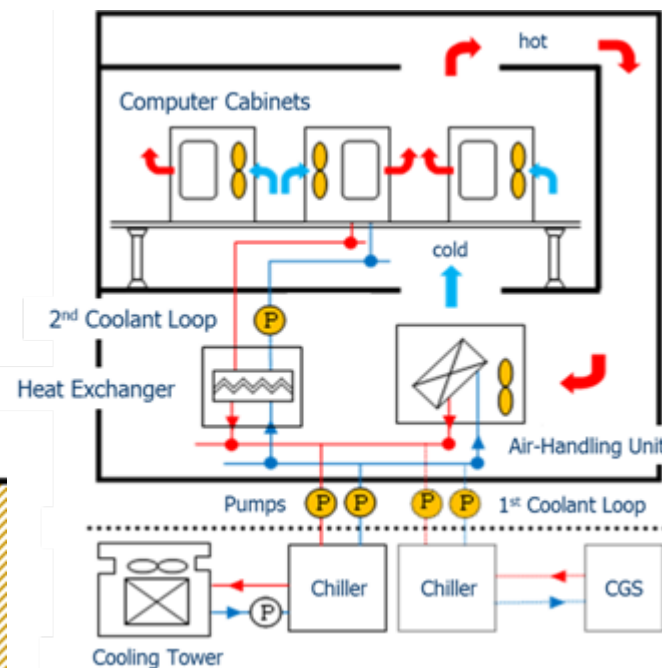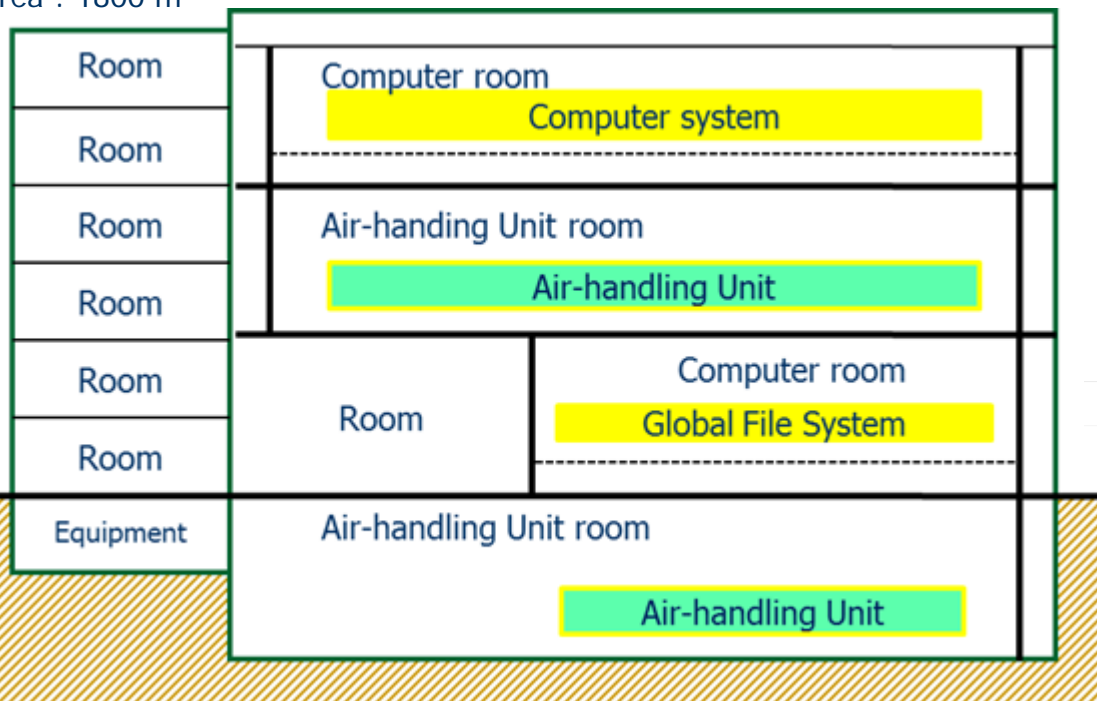|	
Room	**Computer room**
Room	Computer system
Room	**Air-handing Unit room**
Room	Air-handling Unit
Room	Room / Computer room
Room	Global File System
Equipment	**Air-handling Unit room**
	Air-handling Unit

Computer Cabinets
hot
cold
2nd Coolant Loop
Heat Exchanger
Air-Handling Unit
Pumps
1st Coolant Loop
Cooling Tower
Chiller Chiller CGS

Chillers (Area : 1900m^2)

Absorption Refrigerating Machine x 4	Centrifugal Water Chiller x 3	CGS (5MW) x 2

Substation Supply (Area: 200m^2)

77,000V(receiving) → 6,600V

Features of the facilities

- ## Preparation for the earthquake
  - Soil improvement for prevention from the liquefaction
 - Seismic isolated structure by dampers

- ## Large computer room without pillars
  - Flexible layout of computer racks and cabling
  - Average load capacity : 1 ton/m^2
  - Depth of the raised floor : 1.5m

- ## Efficient power generation and eco-system
  - Gas-turbine co-generation system (CGS) for sudden power outage
  - Absorption refrigerator using steam generated by CGS
  - Solar panels on the roof

Image of the K computer

More than 800 cabinets will be housed.
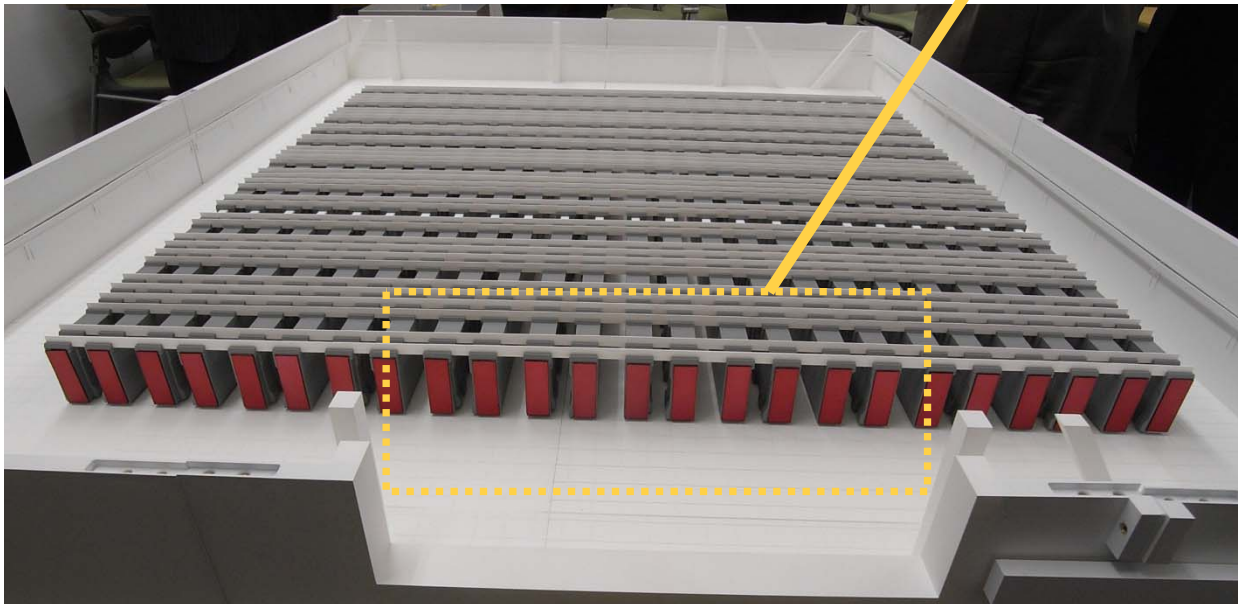
Establishment of Advanced Institute for Computational Science (AICS)

RIKEN
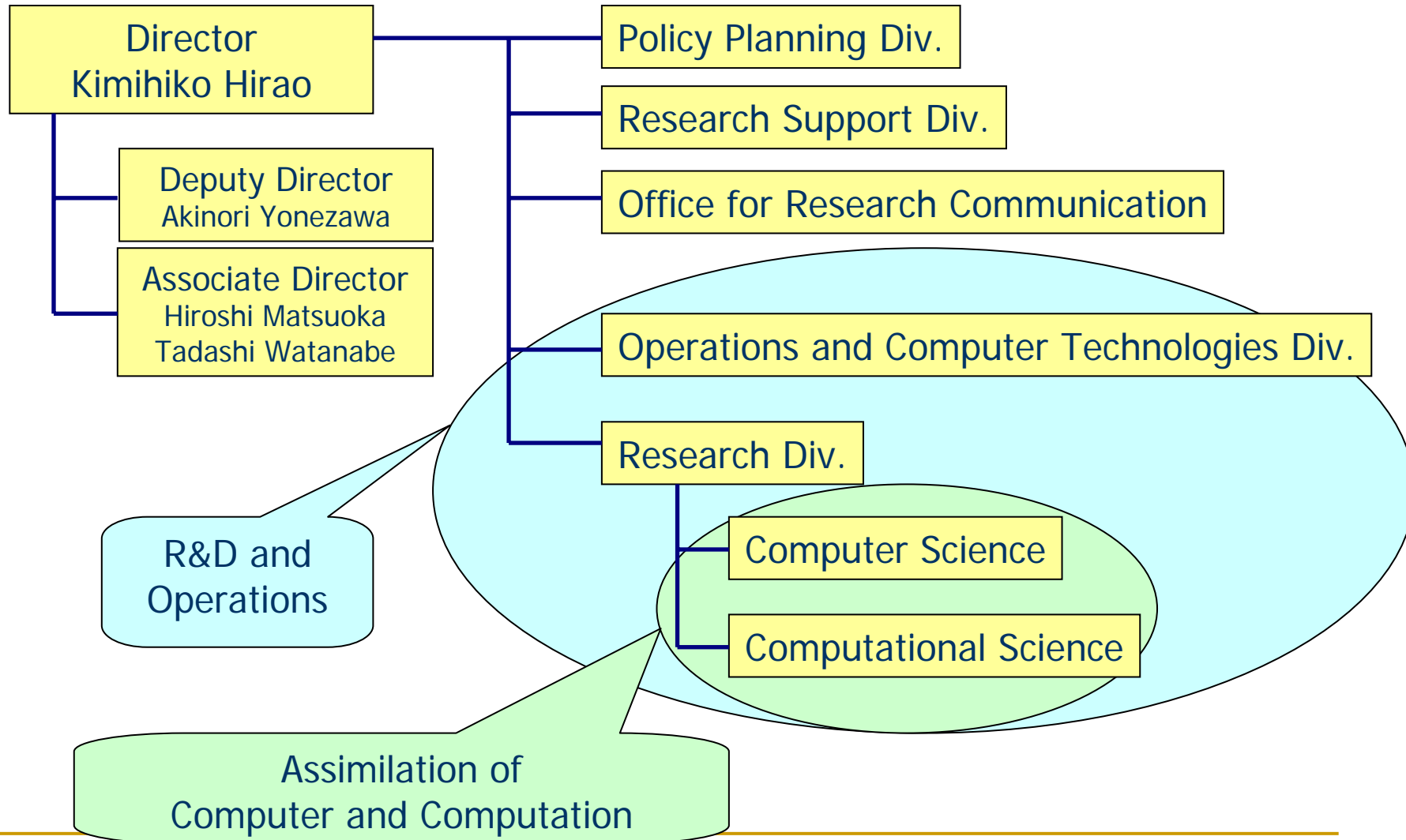# Advanced Institute for Computational Science (AICS)

An organization at Kobe Center will have roles for the full use of the K computer as the center of computational science in Japan.
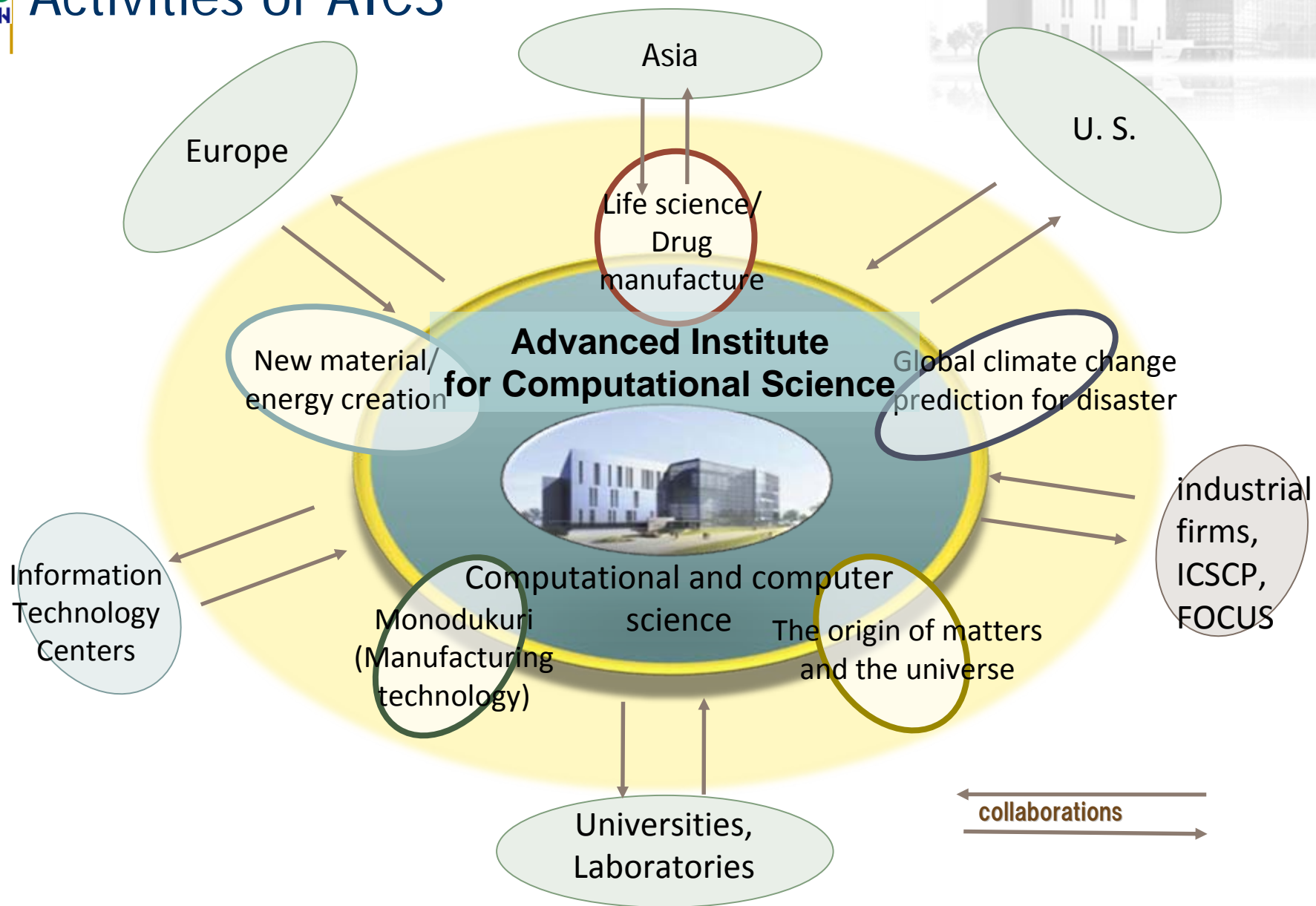
Functions :

- To operate and enhance the K computer so as to provide its resources effectively and efficiently for end-users
- To lead computational science and technology to form a world-class COE for computational science
- To develop Japan's strategy for computational science including the path to the exa-scale computing
- To provide educational opportunities by offering seminars, workshops, intensive courses, summer school, etc
- To conduct outreach program to scientists as well as the public

Organization of AICS

Asia

Europe

U. S.

Life science/
Drug manufacture

**Advanced Institute
for Computational Science**

New material/
energy creation

Global climate change
prediction for disaster

Information
Technology
Centers

Computational and computer science

Monodukuri
(Manufacturing
technology)

The origin of matters
and the universe

industrial
firms,
ICSCP,
FOCUS

Universities,
Laboratories

collaborations

Conclusion

- The system is under development
- Almost 80% of the hardware system completed
- The trial use started in April as scheduled
- A broad range of applications are already running
- The system ranked in No.1 performance in TOP500 achieving 8.16 PFlops while evaluation phase
- The system will be sure to complete by June, 2012 as planned
- The AICS of RIKEN just established to be a COE in Japan for the interdisciplinary research in computational and computer science as well as the operation of K computer

Thank you for your attention !