Fujitsu's Activities in Capability Computing

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- **Fujitsu's Renewed Interest in Capability Computing**

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- **Current Co-Design Vehicles**

- **Towards Exascale**

- **Summary**

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Fujitsu and Capability Computing

- **RIKEN and Fujitsu are jointly developing the 'K Computer'**
  - 10 PFLOP/s LINPACK
  - Installed at RIKEN's Advanced Institute for Computational Science, Kobe

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**Fujitsu Begins Shipping Japan's Next-Generation Supercomputer**

Tokyo, September 28, 2010 — Fujitsu announced that today it began shipping the computing units for Japan's Next-Generation Supercomputer, nicknamed the "K computer"

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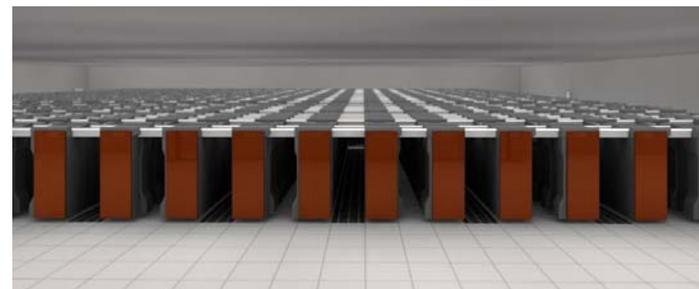
Hardware Technologies

FUJITSU

- **SPARC64™ VIIIfx: New HPC-enhanced CPU based on SPARCV9 architecture**
  - 8 cores, 2 GHz, 2.2 GFLOP/s per watt
  - Extended HPC-ACE instruction set
    - Reciprocal, trig functions, max/min, SIMD, masked SIMD
  - Enlarged number of registers (Floating:256, Int:64)
  - User-controllable sector cache

- **Tofu: 6D mesh/torus interconnect**
  - Fast node to node communication, 5 GB/s (bi-directional)
  - Integrated MPI support for collective operations and global hardware barrier
  - Scalable to 100,000s of nodes
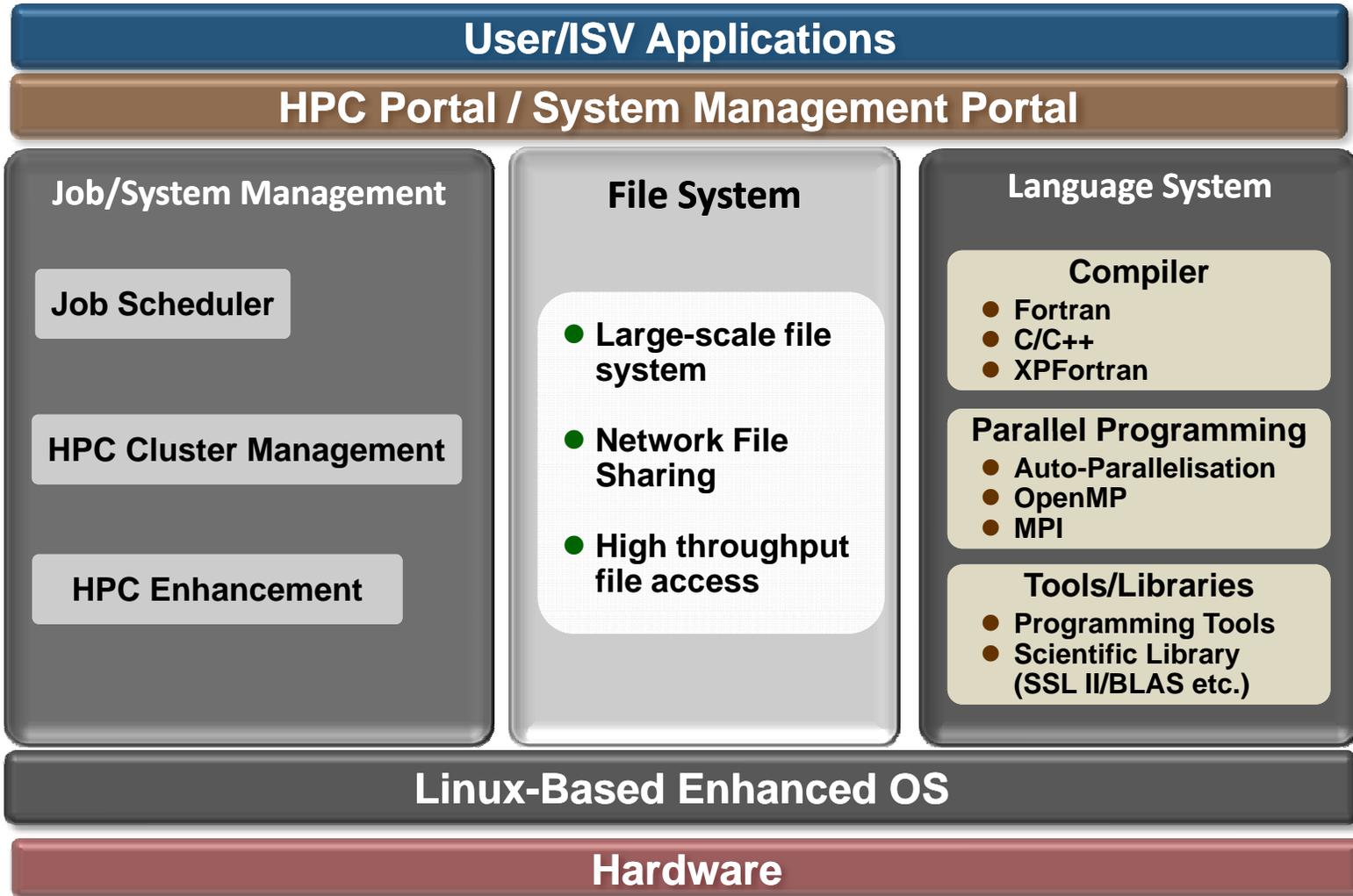
- **Direct water cooling packaging**

Node Group Unit
(12 nodes group, 2 x 3 x 2)

Node Group 3D connection
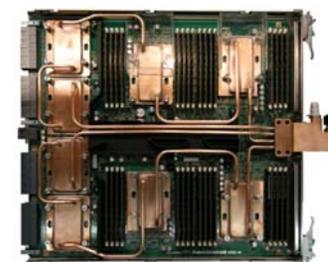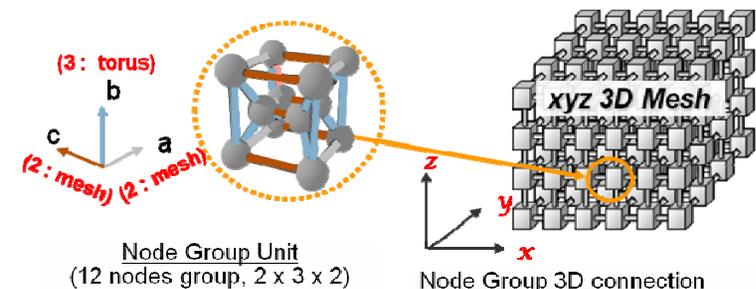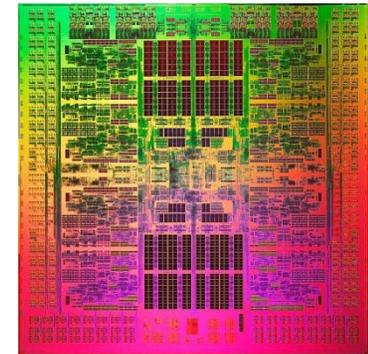
Direct water cooling System Board

System Software Stack

FUJITSU

Based on open software, standards-conforming, and built for scalability

User/ISV Applications

HPC Portal / System Management Portal

Job/System Management

- Job Scheduler

- HPC Cluster Management

- HPC Enhancement

File System

- Large-scale file system

- Network File Sharing

- High throughput file access

Language System

Compiler
- Fortran
- C/C++
- XPFortran

Parallel Programming
- Auto-Parallelisation
- OpenMP
- MPI

Tools/Libraries
- Programming Tools
- Scientific Library (SSL II/BLAS etc.)

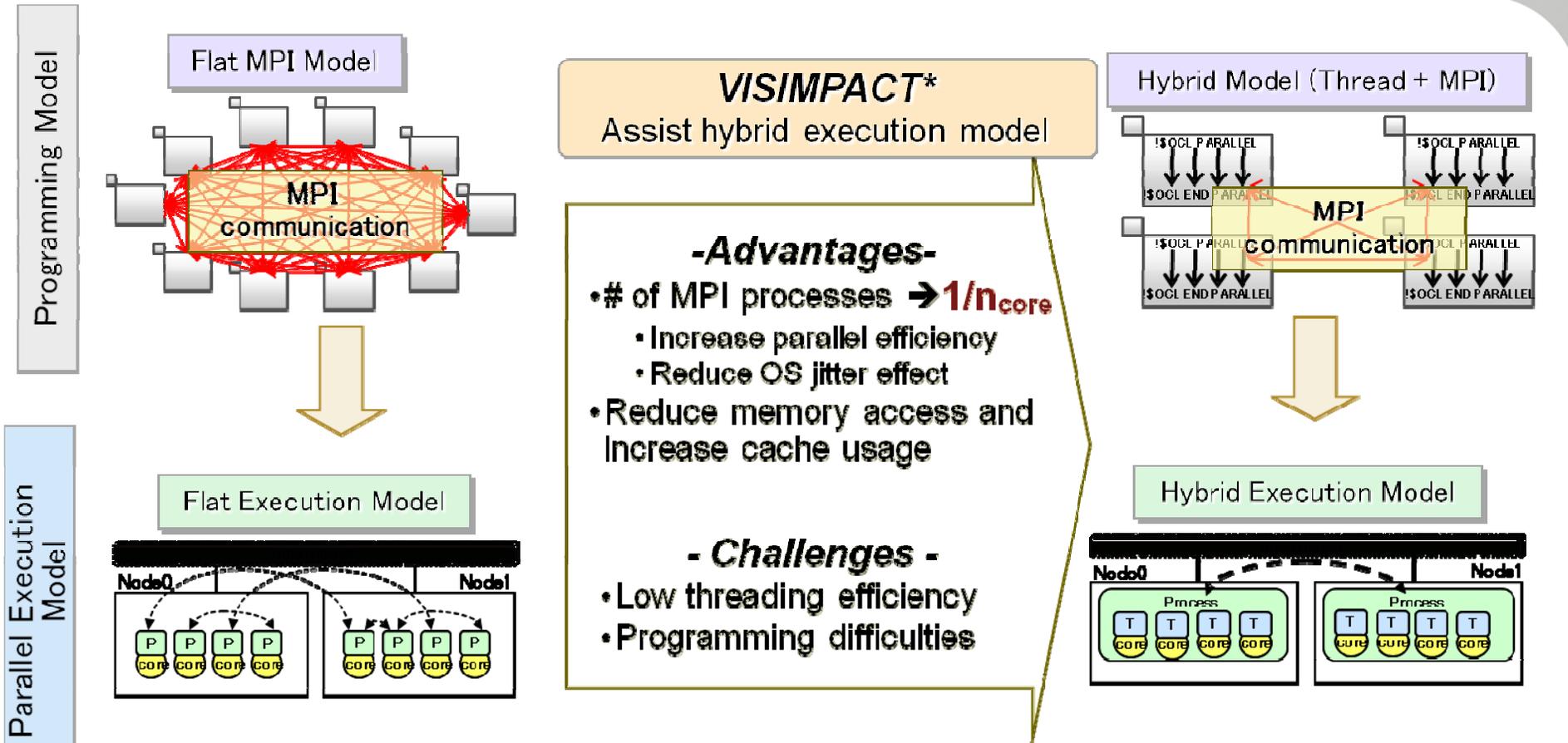| Linux-Based Enhanced OS |
| :---: |

Hardware

Programming Model

FUJITSU

- Designed for a hybrid thread/task model

- Target fine-grained innermost loop parallelisation via multithreading

  - Makes use of Fujitsu's heritage in vectorisation technology

  - Automatic parallelisation or OpenMP

- Treats a multi-core chip as a single faster CPU with high performance

  - Programmers need not think of multiple cores

  - CPU architecture is designed for fine grain parallel execution

VISIMPACT

Flat MPI Model

MPI communication

Flat Execution Model

Node0 ... Node1

VISIMPACT*
Assist hybrid execution model

-Advantages-
- # of MPI processes → $1/n_{core}$
  - Increase parallel efficiency
  - Reduce OS jitter effect
- Reduce memory access and Increase cache usage

- Challenges -
- Low threading efficiency
- Programming difficulties

Hybrid Model (Thread + MPI)

!SOCL PARALLEL   !SOCL PARALLEL
!SOCL END PARALLEL   !SOCL END PARALLEL

MPI communication

!SOCL PARALLEL   !SOCL PARALLEL
!SOCL END PARALLEL   !SOCL END PARALLEL

Hybrid Execution Model

Node0 ... Node1

Programming Model

Parallel Execution Model

* : VISIMPACT realises highly efficient threading between cores
- Hardware barrier synchronisation between cores
- Shared L2 cache memory
- Highly efficient thread parallelisation (automatic parallelisation by vectorisation technology)
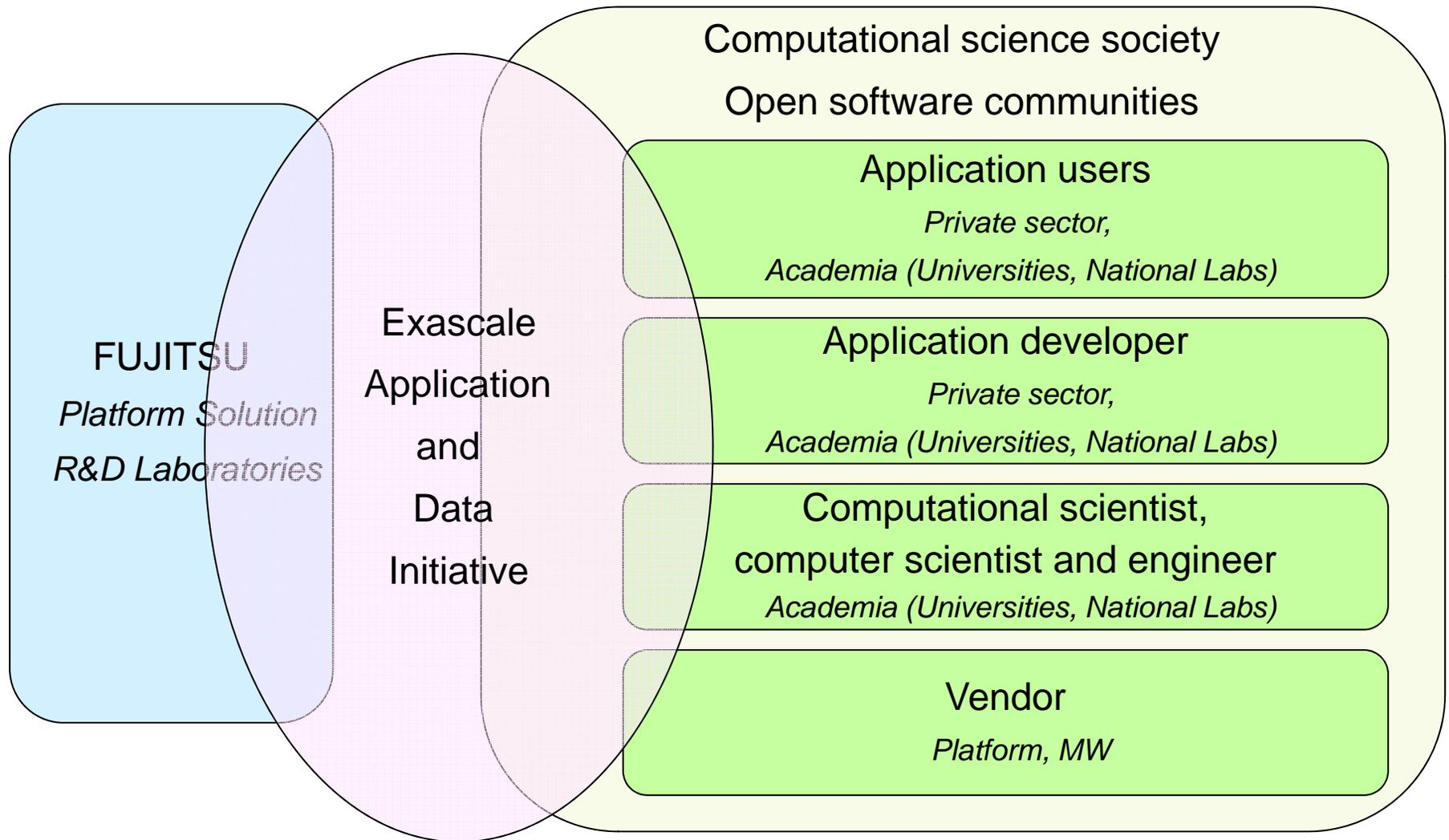
VISIMPACT

FUJITSU

- Hardware and compiler technologies designed to enhance hybrid programming model

- Highly efficient threading
  - Hardware barrier synchronisation between cores
  - Shared L2 cache
  - Automatic parallelisation via vectorisation technology

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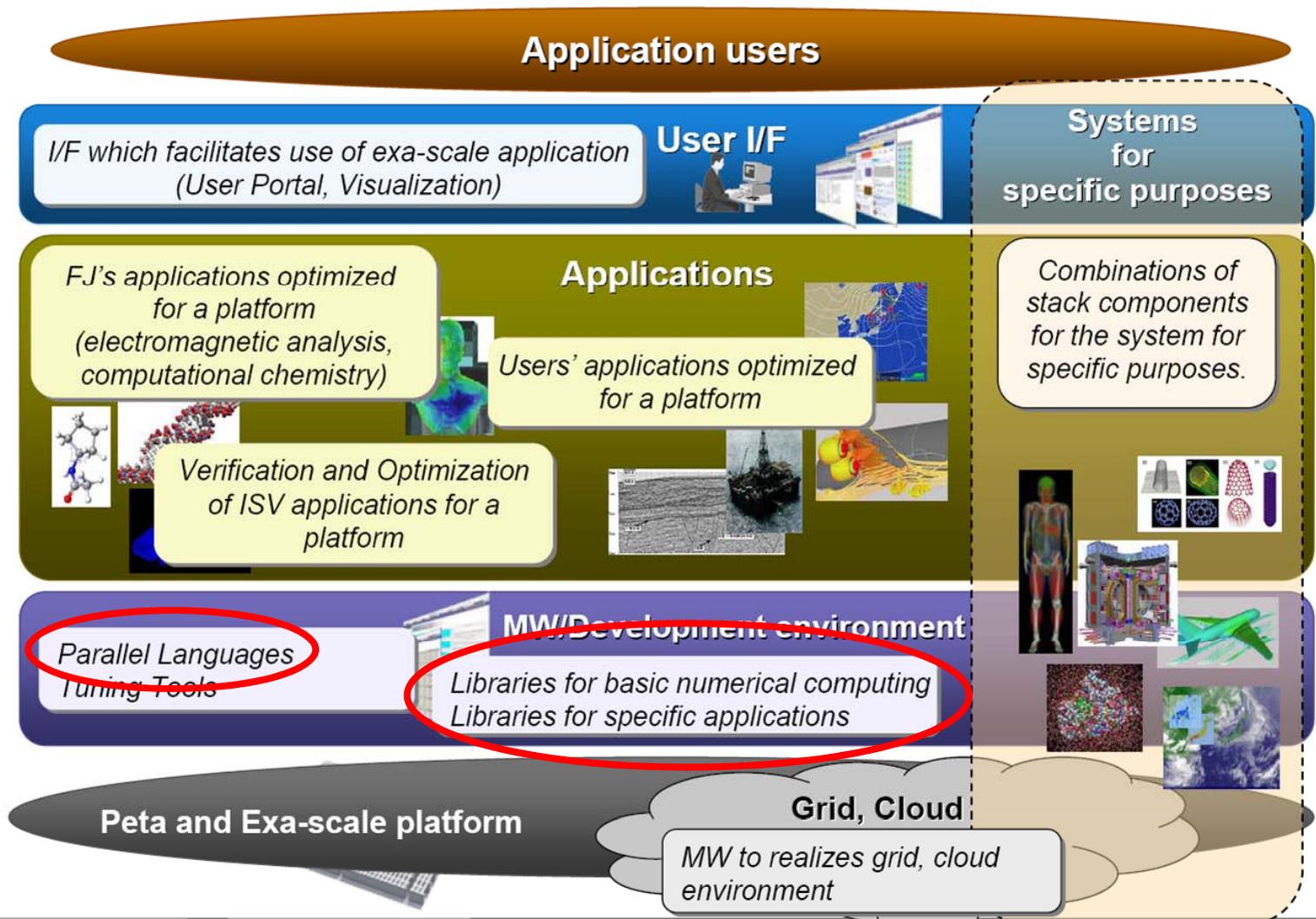- Current Co-Design Vehicles

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Exascale Application and Data Initiative

FUJITSU
Platform Solution
R&D Laboratories

Exascale
Application
and
Data
Initiative

Computational science society

Open software communities

Application users
Private sector,
Academia (Universities, National Labs)

Application developer
Private sector,
Academia (Universities, National Labs)

Computational scientist,
computer scientist and engineer
Academia (Universities, National Labs)

Vendor
Platform, MW

Exascale Application and Data Initiative

FUJITSU

Solution Stack

XcalableMP Project

- Developed by XcalableMP Specification Working Group

- A draft "petascale" parallel language for "standard" parallel programming
  - To propose the draft to the world-wide community as a standard

- Academia: U. Tsukuba, U. Tokyo, Kyusyu U., Kyoto U.

- Research Lab.: RIKEN, NIFS, JAXA, JAMSTEC

- Industry: Fujitsu, NEC, Hitachi

- This research is carried out as a part of "Seamless and Highly-Productive Parallel Programming Environment for High-Performance computing" project funded by MEXT

- Center for Computational Sciences, University of Tsukuba, is organising the XcalableMP project

XcalableMP

- A directive-based language extension that is designed to be simpler and less time-consuming than coding using MPI

- Data parallel "global view programming model" enables parallelising sequential code using simple directives like OpenMP

- Also includes a Co-Array Fortran like PGAS feature as "local view" programming

- APIs are defined for C and Fortran 95

- Execution model allows combining with explicit MPI coding for more complicated and tuned parallel codes and libraries

- OpenMP directives can be combined with XcalableMP for thread programming inside each node (under discussion)

- XcalableMP is being designed based on experiences of HPF, Fujitsu XPF (VPP Fortran) and OpenMPD

# Open Petascale Libraries Project

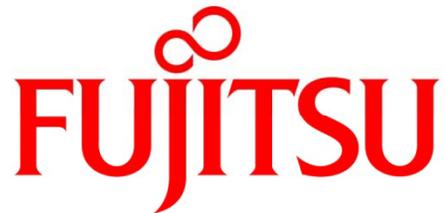**Global collaboration to develop advanced numerical software for supercomputing**

- Dedicated forum to promote the open exchange of ideas and the collaborative development of general-purpose and application-specific numerical libraries

- Targeted initially at parallel computers built from multicore processors

- All output available as open-source software

- Official launch of OPL in November

OPL: Organisation
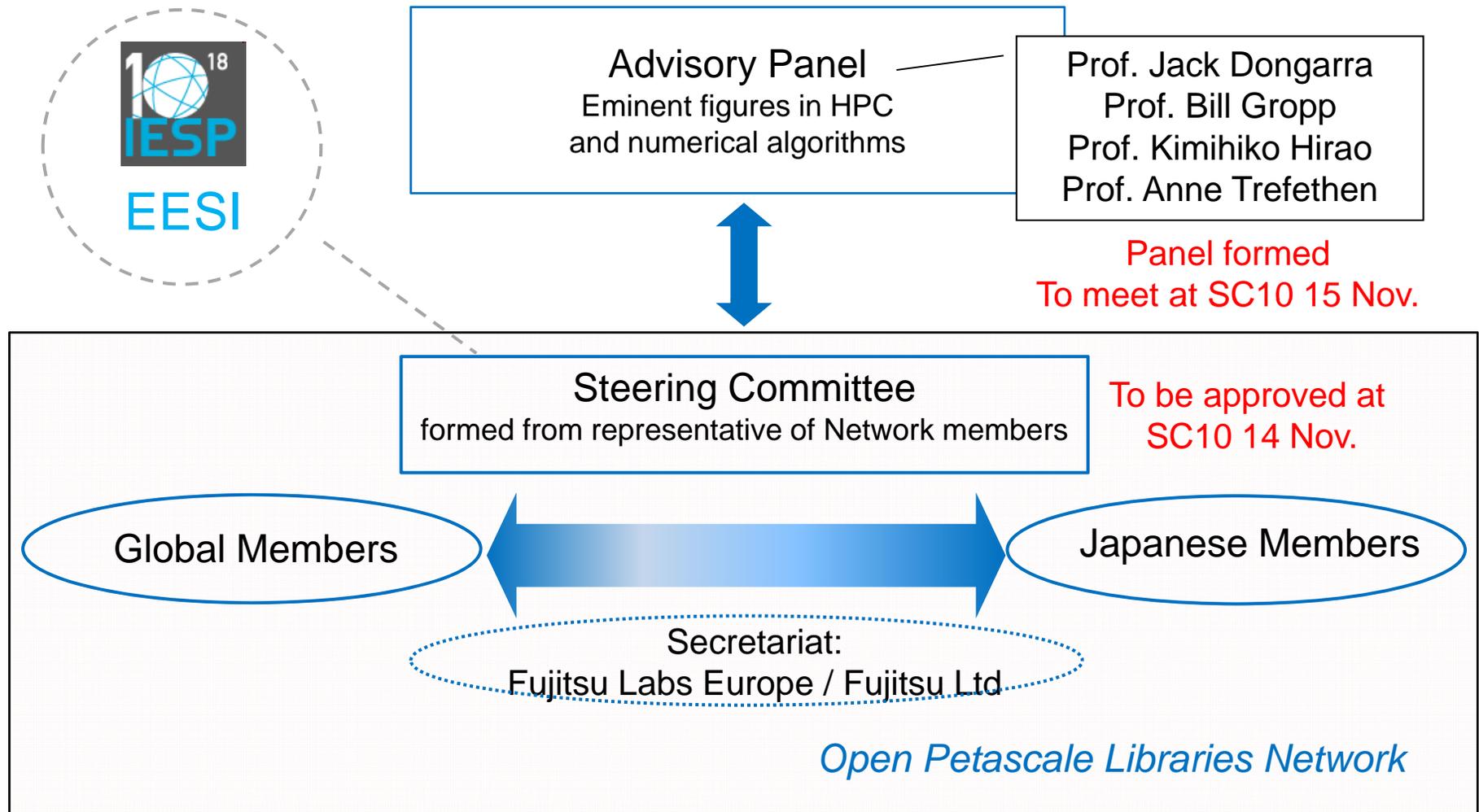
OPL: Current Global Members

OPL: Proposed Work

FUJITSU

- Survey of libraries and current research

- Application requirements

- Emerging libraries for dense linear algebra

- Enabling technologies for large-scale PDE-based simulations

- Scalable Fast Fourier Transforms

- Scalable random number generators

- Coding and documentation standards, testing and distribution of libraries

OPL: Fujitsu's Role

FUJITSU

- Set up the required administrative infrastructure

- Contribute to the project through research in its global network of R&D laboratories

- Provide an environment to support the sharing of knowledge and software

  - Organise meetings, workshops, etc.

  - Establish a dedicated project website and code repository (www.openpetascale.org)

  - Provide an open development platform
    - Housed at STFC's Daresbury Laboratory

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Co-Design Vehicles

- **Petascale software development is using CDVs**
  - Focused on reusable thread-parallel and hybrid kernels
  - Based on open-source software development
  - Environment and energy
  - Healthcare (computational physiology)
  - Computational chemistry
  - Fujitsu's in-house engineering requirements

- **More extensive use of CDVs for hardware and system software development as we move towards exascale**

Environmental Modelling

FUJITSU

- Collaboration with Imperial College London and others
- Possible involvement in two G8 projects (Arctic Ocean modelling, exascale climate simulations)
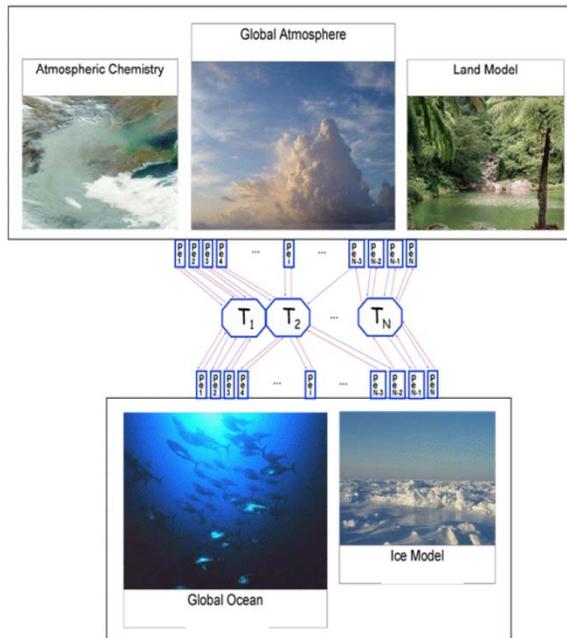
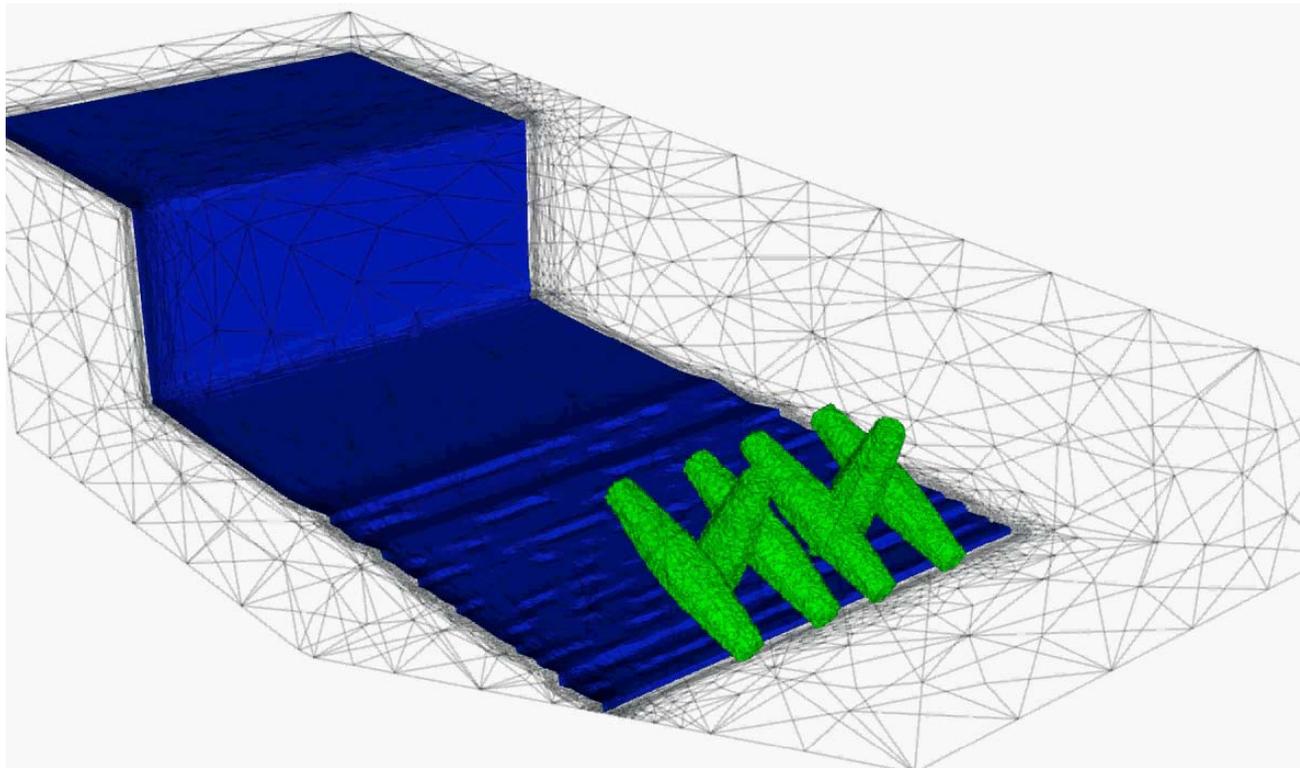**Multi-Physics**
Earth-system modelling

Multi-Application
From simulation of coastal flooding and tidal power generation to landslide-generated tsunamis and engineering applications

Technology

■ Highly parallel load-balanced FEM using anisotropic adaptive meshing and combining OpenMP with MPI

Computational Physiology

Computational Prediction of Drug Cardiac Toxicity

High-performance finite-element solver for the electrophysiology of the heart

- Three-year €4 million European project
- Targeted at the pharmaceutical industry
- Part of the Virtual Physiological Human Initiative

preDiCT

- **Improved early-stage safety testing for new drug candidates**

- **Need to streamline drug discovery process**

  - Each new drug takes 13 years and costs on average € 1 billion to develop

- **To be practical, high efficiency on petascale-class computers is essential**
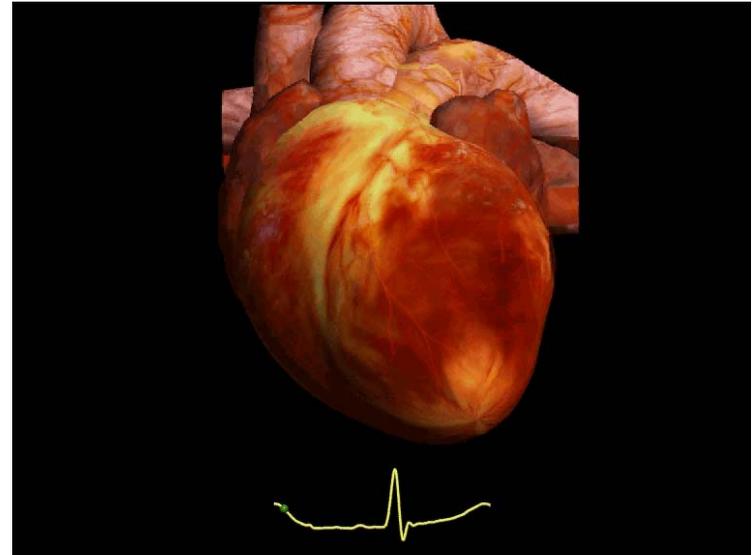
Computational Chemistry

- Lattice Boltzmann

- Molecular dynamics (GROMACS)

- Quantum chemistry (NWChem)

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Towards Exascale

FUJITSU

- **Fujitsu is undertaking future technologies research and evaluation for exascale computing**
  - Semiconductor technologies, future CPU architecture, packaging technologies, software technologies, increased memory bandwidths, high-performance and scalable interconnects

- **Which applications need exascale performance?**
  - What is the communication pattern, data size, etc.?

- **The design of the system will be deeply affected by these characteristics and needs of applications**

- **What will be the role of disruptive technologies?**

Summary

FUJITSU

- Fujitsu has returned to capability computing with renewed vigour

- Fujitsu is committed to standards, open collaborations and open-source software

- The CDV mechanism is already in use for petascale software development and will have an increased importance for the full range of exascale system development

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