FUJITSU

shaping tomorrow with you

ECTC2015/CPMT, San Diego, CA, May 28, 2015

Liquid Cooling

Challenges & Opportunities of the Technology for HPC Systems

Jie Wei

Fujitsu Advanced Technologies Limited

ECTC 2015

IEEE Electronic Components and Technology Conference

7 years ago

- **System reliability: 100X**
- **Power consumption: 0.5X**

© Fujitsu

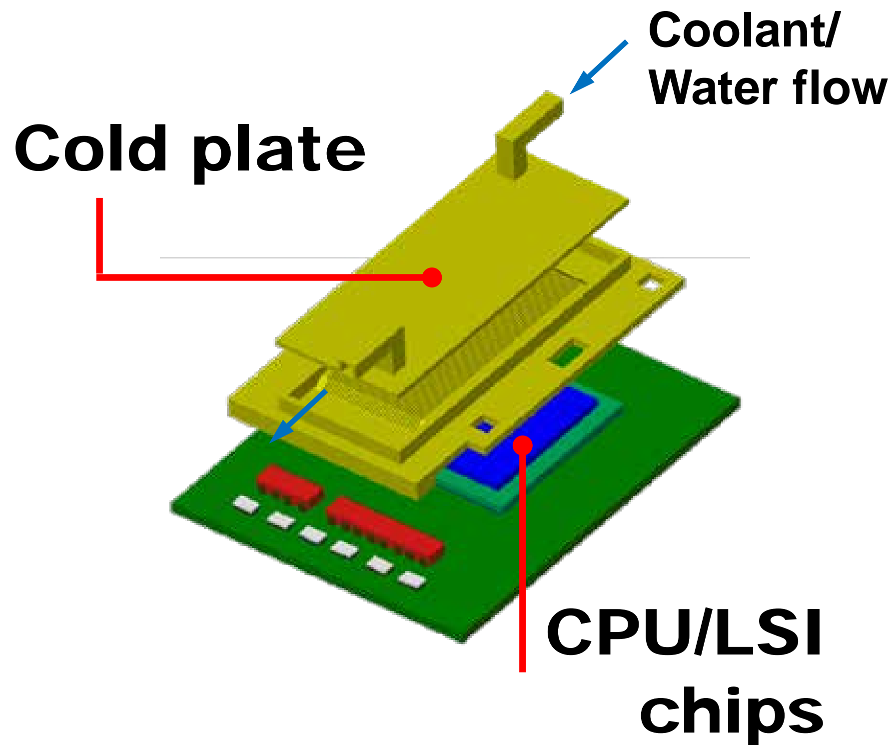
Topics

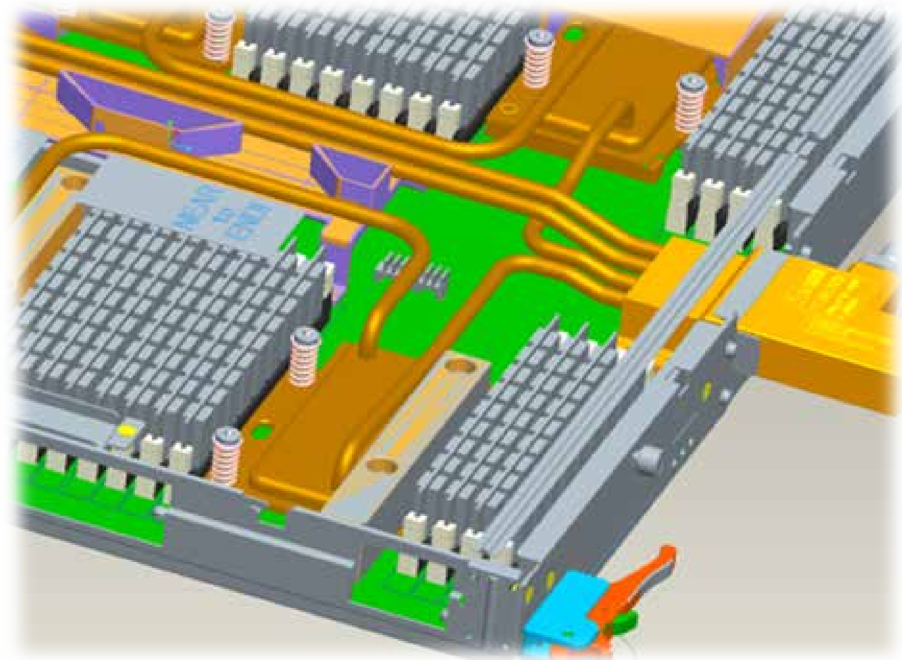
- **Liquid cooling, back to the future**
  - *the state of the art technologies*
  - *high density, toward volumetric scalability*
- **Challenges, design & implementation**
  - *packaging & thermal capability*
  - *reliability and product validation*
- **Opportunities, cooling and beyond**
  - *energy efficiency, saving, and reuse*
  - *bring ITE and facility together*

© Fujitsu

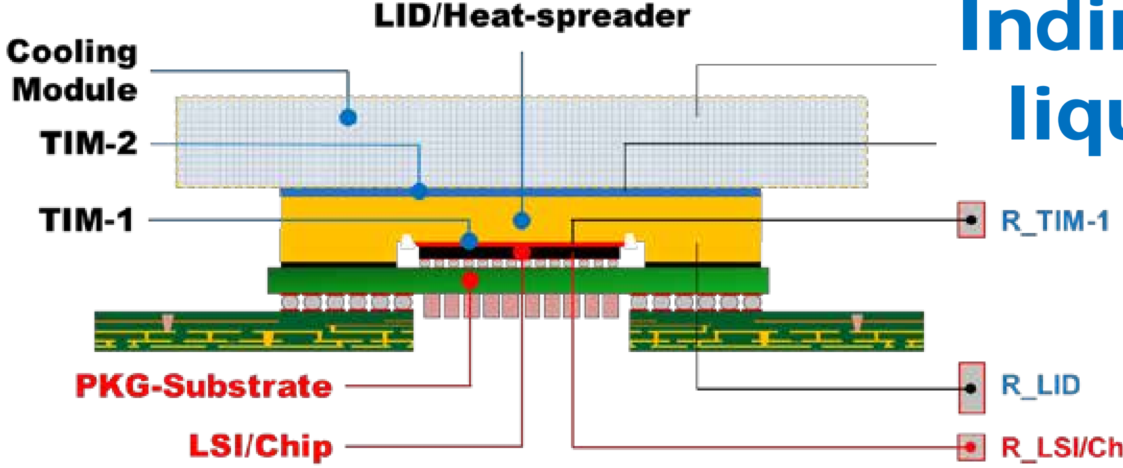
Liquid-Cooled Electronics

- Capability for high density packaging
- Energy efficiency at datacom level

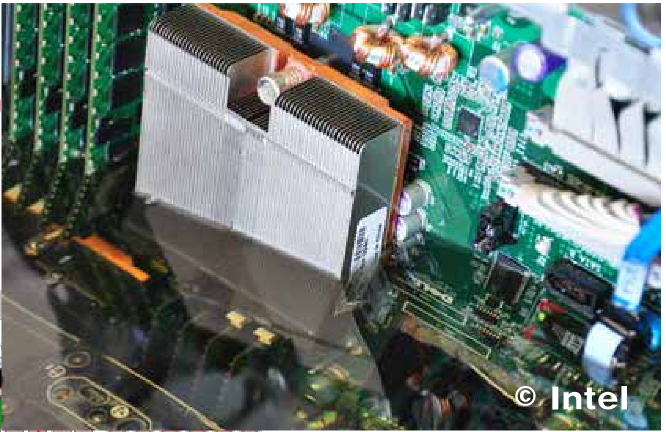




© Fujitsu



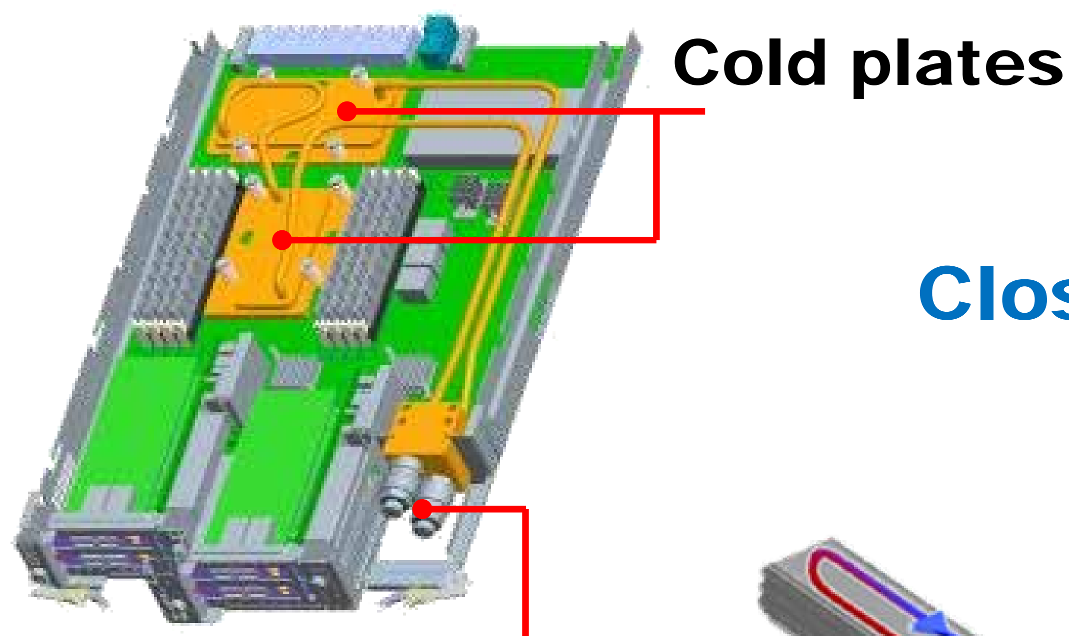
Indirect liquid cooling



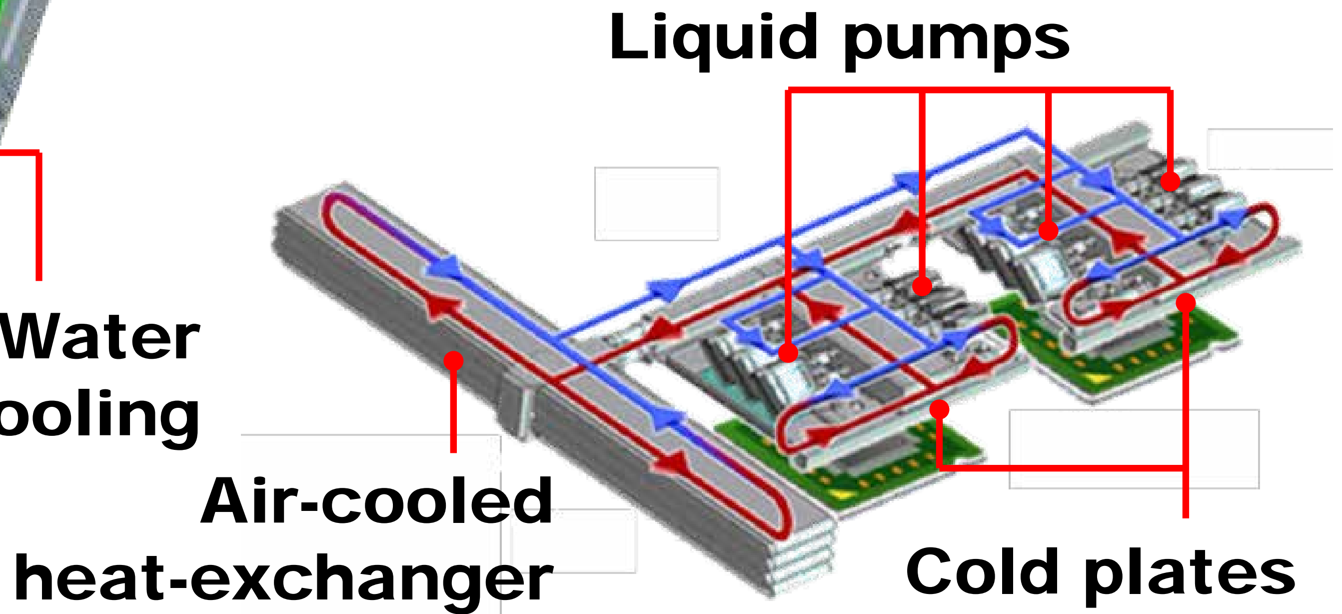
Direct liquid cooling

© Fujitsu

Open-loop to facility cooling

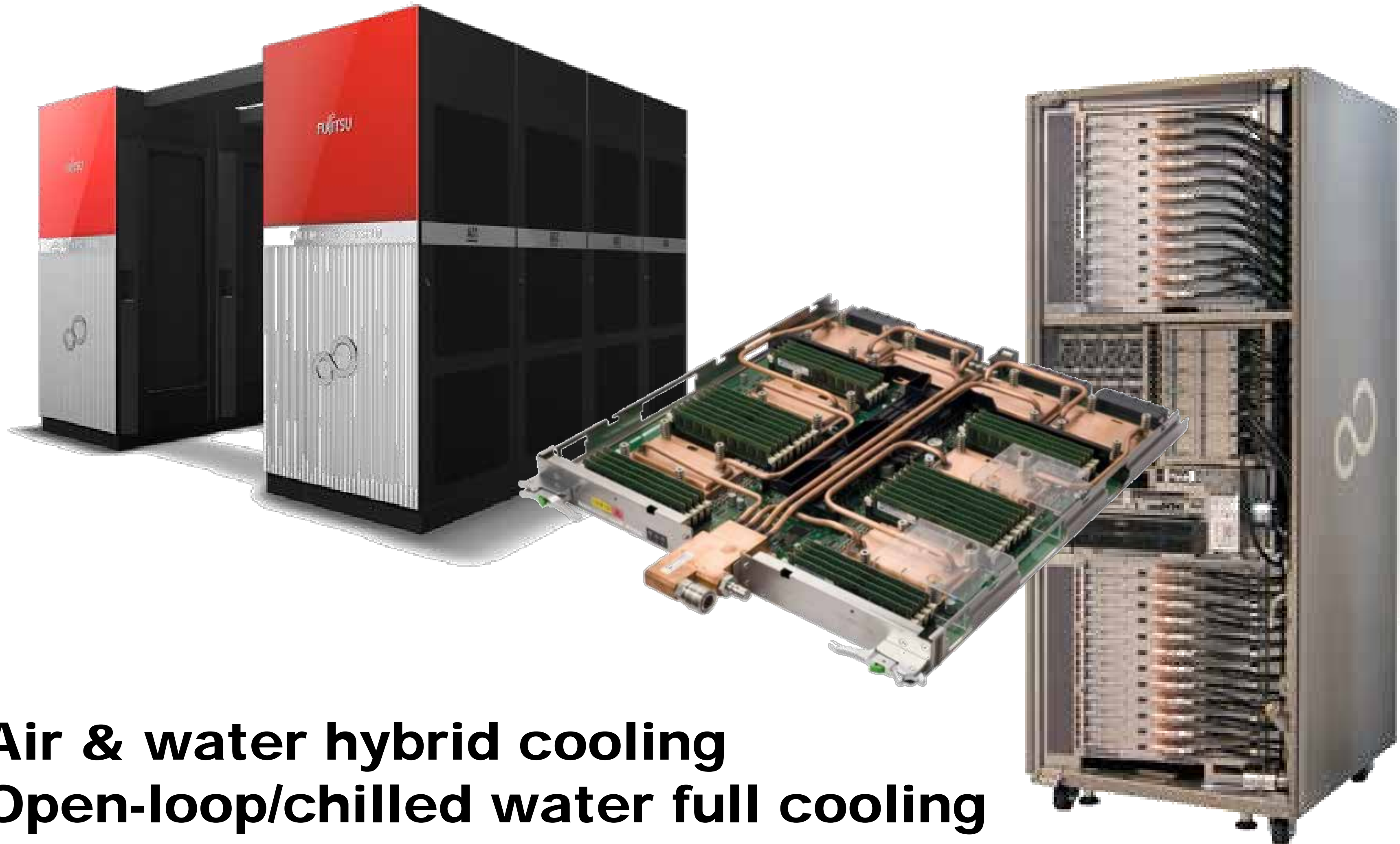


Closed-loop on board



© Fujitsu

Fujitsu PRIMEHPC FX10 (2012)



- Air & water hybrid cooling
- Open-loop/chilled water full cooling

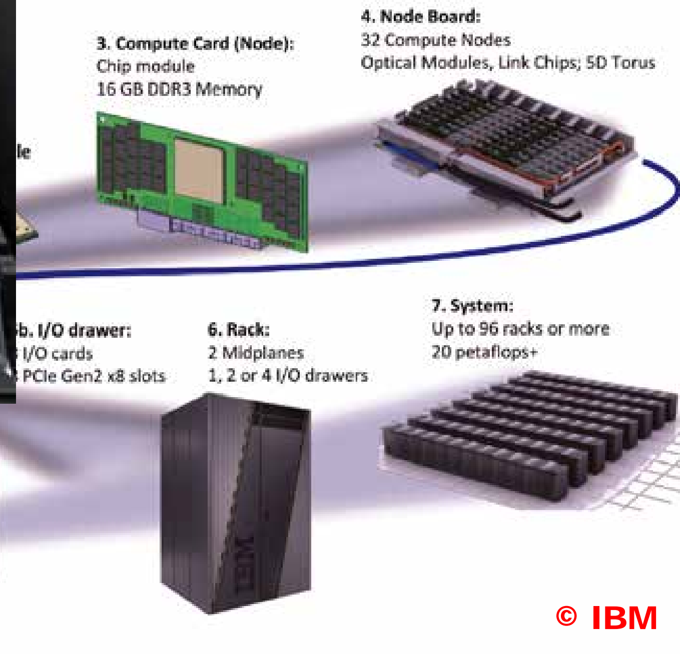
© Fujitsu

Fujitsu PRIMEHPC FX100 (2014)

- High density packaging
- Open-loop/chilled water full cooling

© Fujitsu

IBM BG/Q Sequoia (2012)



- Thermal contact structure
- Open-loop/chilled water full cooling

IBM Aquasar (2012)

Heat exchanger

Water Pump

CMOS 80°C

Heat exchanger

Direct „Waste“-Heat usage
e.g. heating

Water Out 65°C

Water In 60°C

© IBM

- Zero-emission
- Open-loop/warm water full cooling

HP Apollo 8000 (2014)

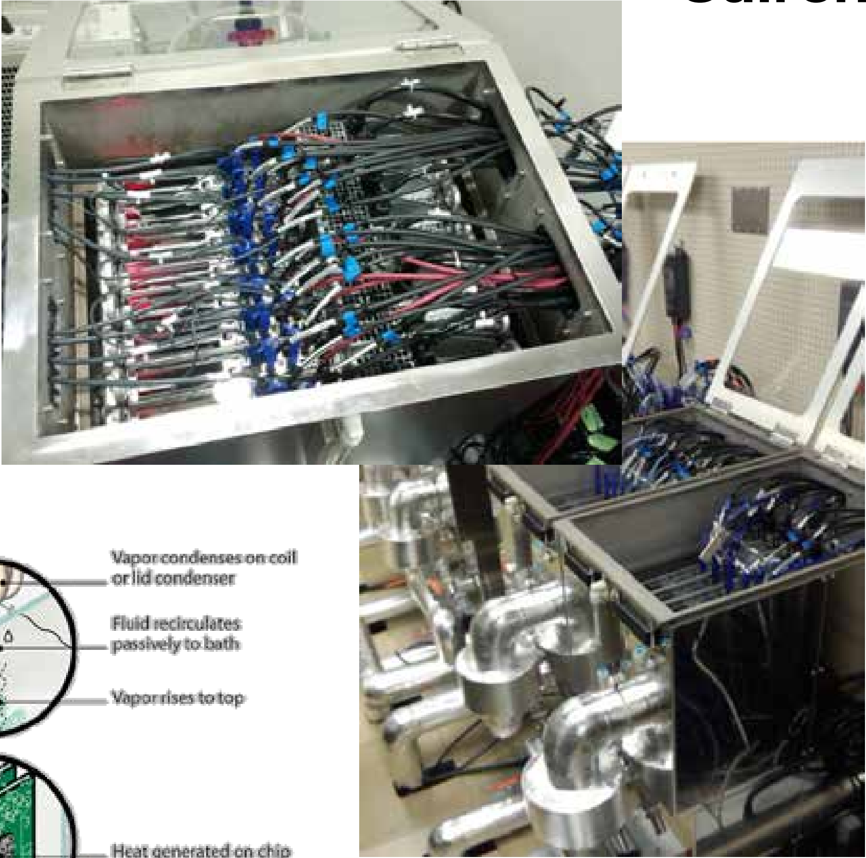
Heat-pipe dry-disconnect with rack water cooling

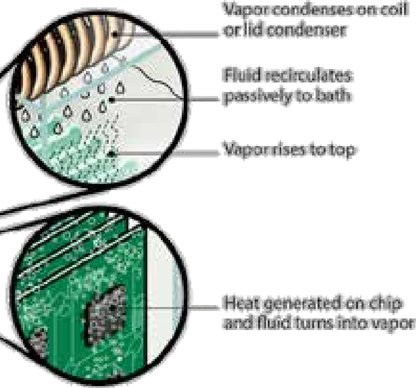
Pumped water circulation under vacuum

Immersion (2013/2014)

NEC/TIT
TSUBAME-KFC

ExaScaler/KEK
Suiren



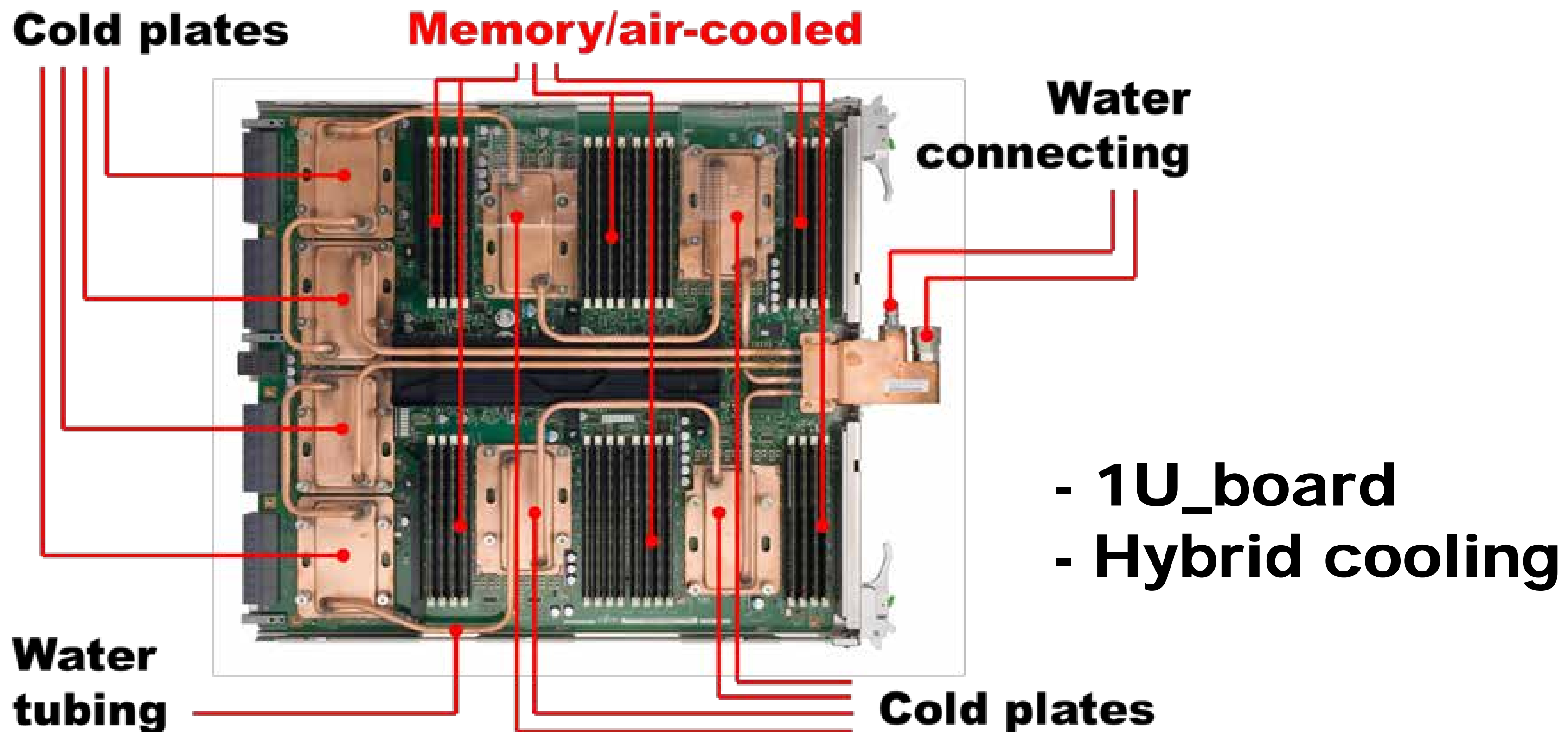


Design & Implementation of the LC Components

- Packaging/thermal capability
- Reliability and product validation

Design: packaging & cooling

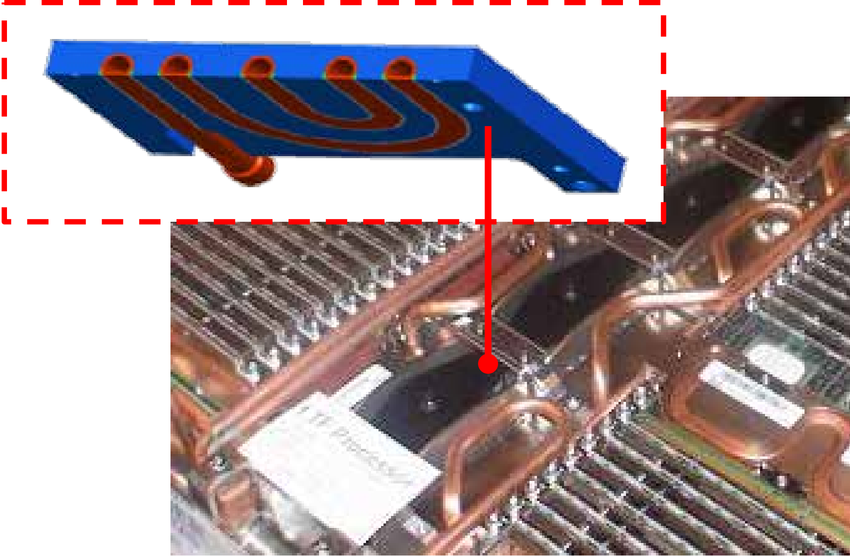
- Performance, mfg., cost, maintenance
- Materials and novel technologies



© Fujitsu

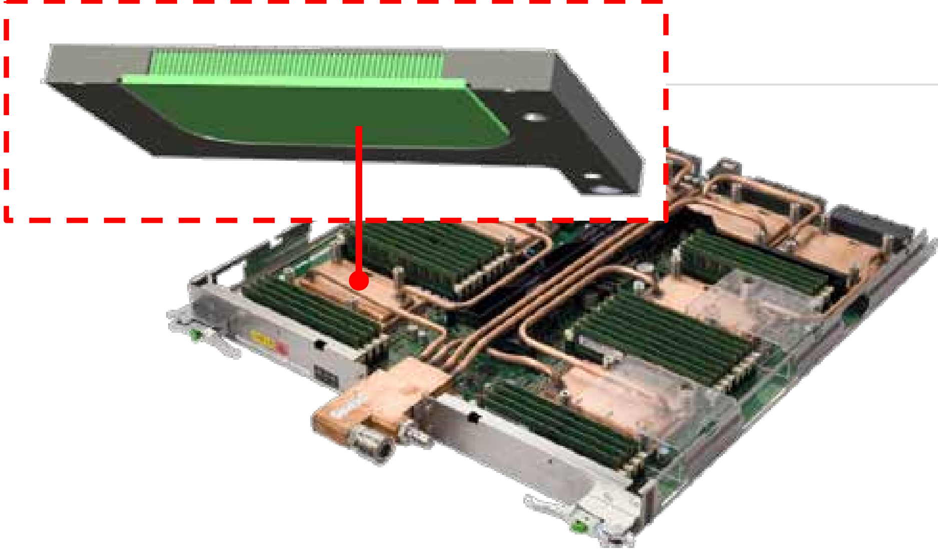
Methodology: cold plates

Cold-plate with embedded tubes



© IBM Power 775

Cold-plate with finned mini-channels

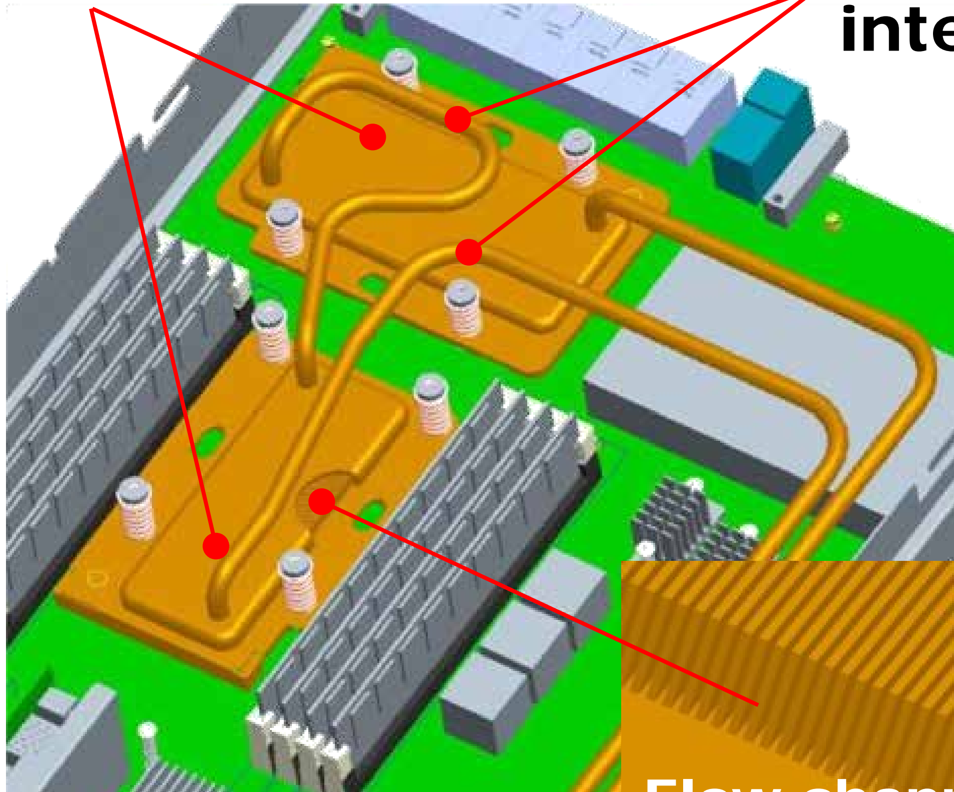


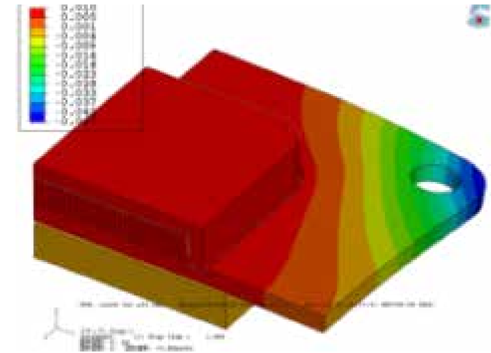
© Fujitsu FX10

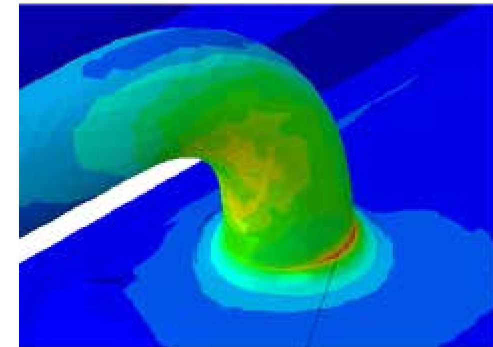
Mechanics: structure & tubing

Cold-plates

Compliant & integrated tubing

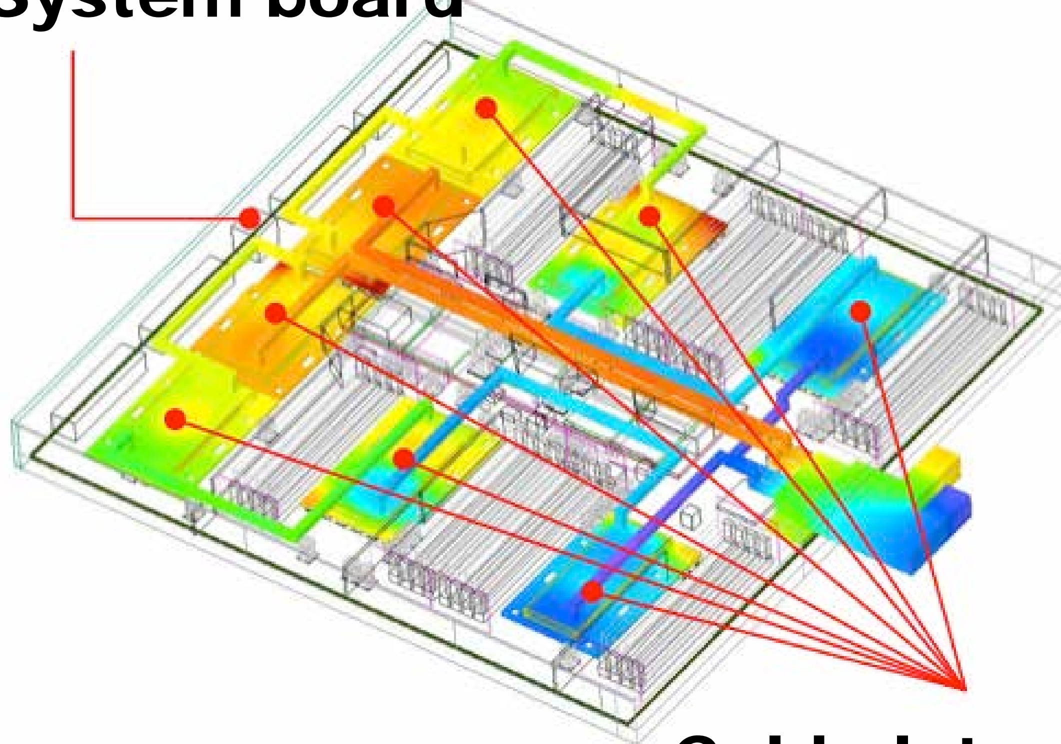


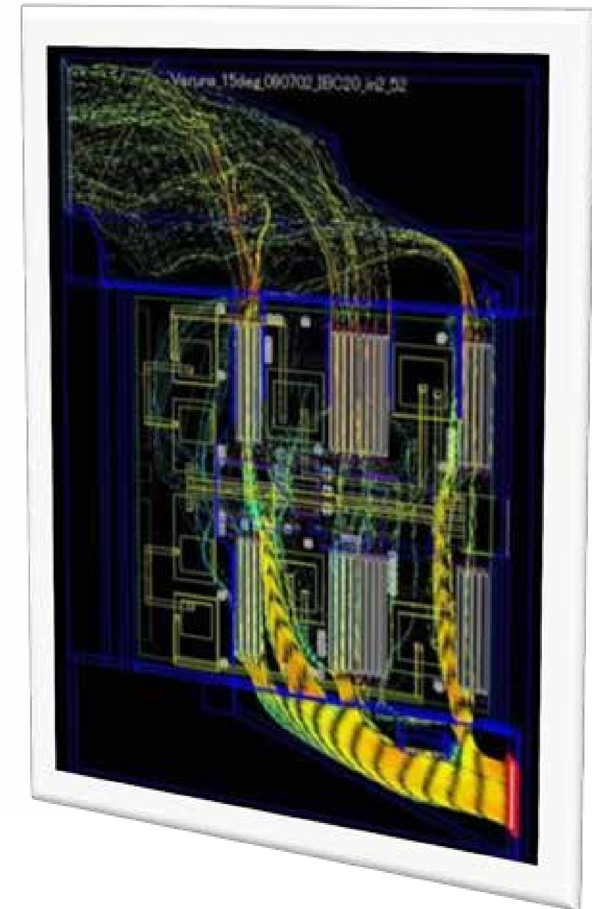




© Fujitsu

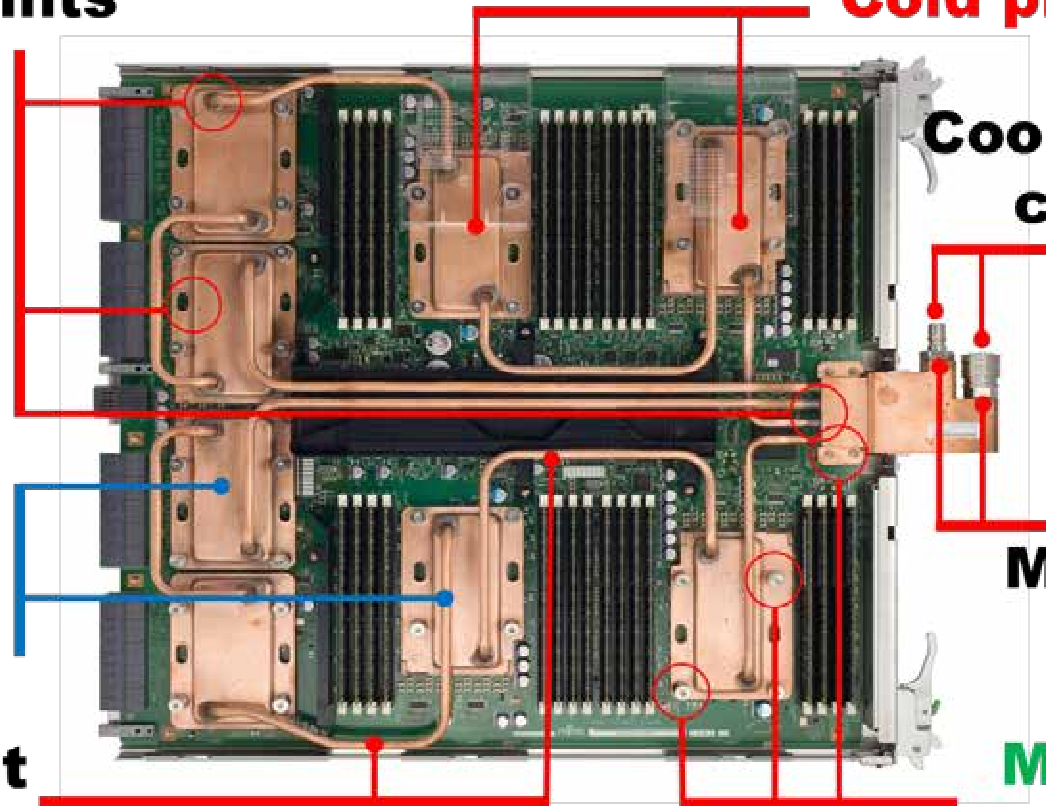
Thermal: hybrid configuration





© Fujitsu

Implementation: reliability & product validation



© Fujitsu

Reliability issues

- Electronics on thermal management
- System control, redundancy, detection
- Mechanical design & verification

Leakage Performance

© Fujitsu

Standards & specifications

ASHRAE Guidelines	• *Liquid Cooling Guidelines for Datacom Equipment Centers* • *Datacom Equipment Power Trends and Cooling Applications*
ASTM Standards	• *ASTM D1384-05 Standard Test Method for Corrosion Test of Engine Coolants in Glassware* • *ASTM D4340-96 Standard Test Method for Corrosion of Cast Aluminum Alloys in Engine Coolants Under Heat Rejecting*
UL/ANSI Standards	• *UL 1995 Heating and Cooling Equipment (includes thermal cycling, aging for gaskets, pressure, and fatigue tests)* • *109 Tube Fittings for Flammable and Combustible Fluids, Refrigeration Service and Marine USE*
RoHS Specifications	• *Directive 2002/95/EC of the European Parliament and of the Council on the restriction of the use of certain hazardous substances in electrical and electronic equipment*

© Fujitsu

Compatibility of coolants & materials

- Coolants/Fluids

- Deionized water of ASTM D1193-06, type II, grade A
- 100-1000 ppm BTA – copper corrosion inhibitor

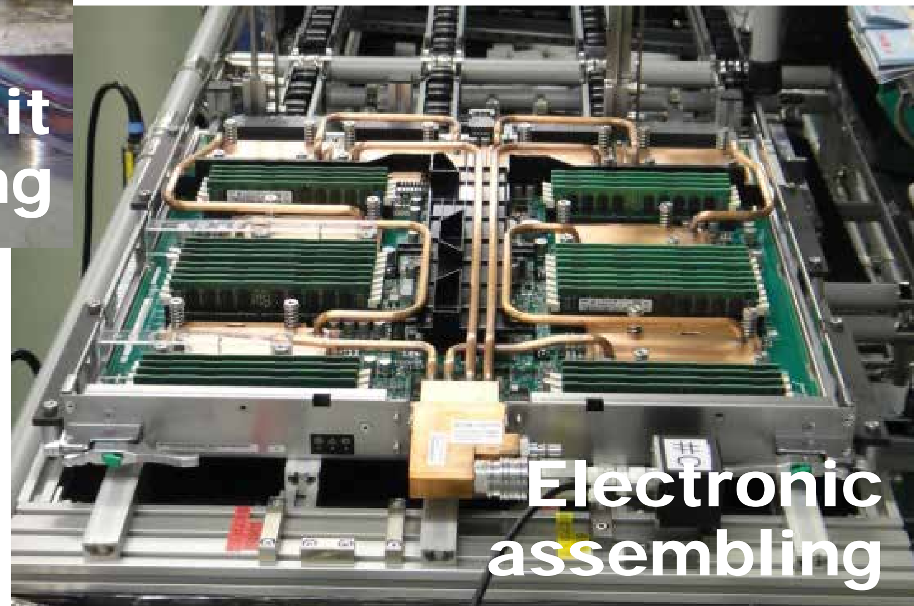
- Materials

- Copper, brasses: low zine <15%, low lead
- Stainless steel: low carbon 304, 304L, 316
  Homogenized and passivated
- Plastics / Rubber:
  Flammability with UL 94 V1 or VW1
  Geometrical stable of no swelling

© Fujitsu

Implementation & assembling

Manufacturing
Assembling & test
Inspecting & validation



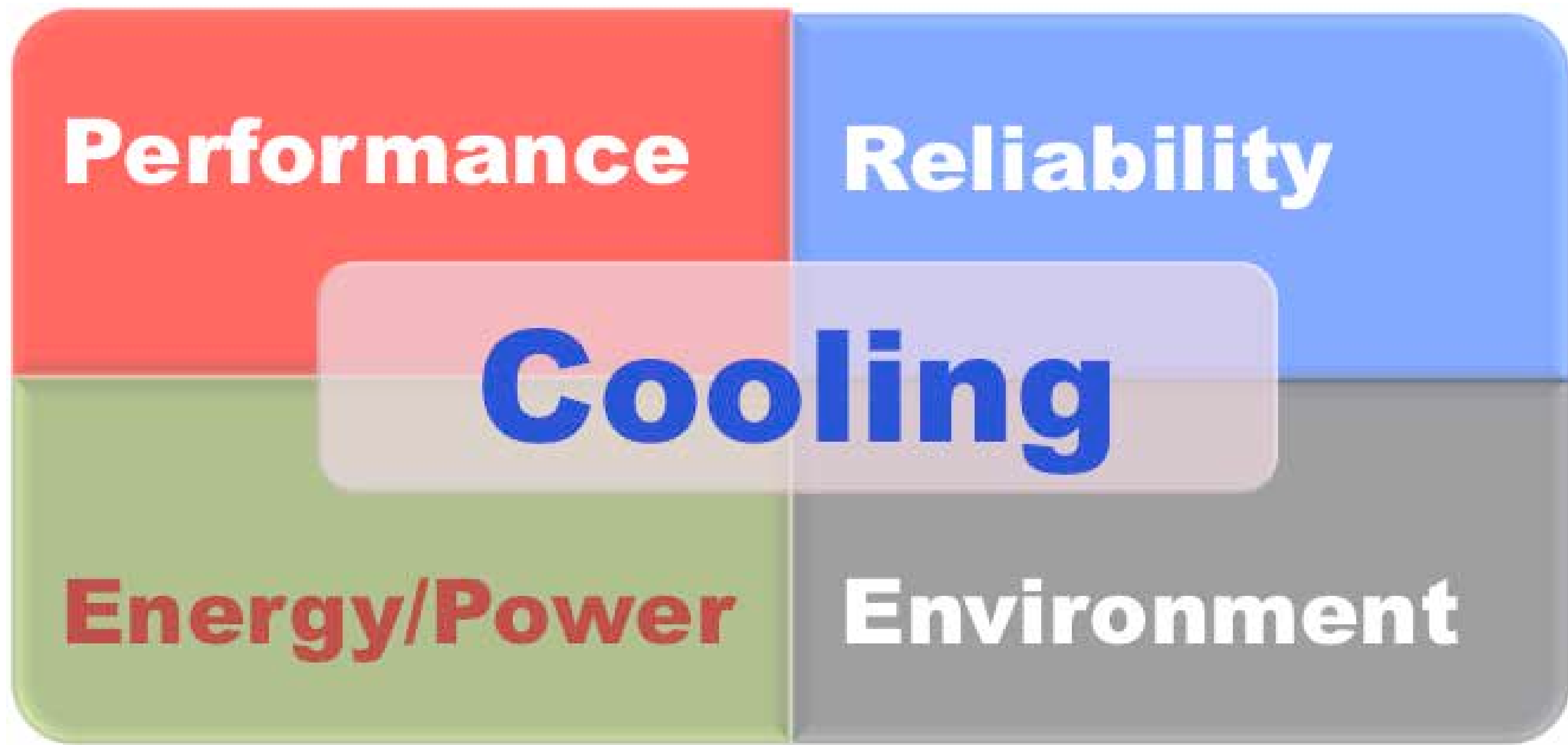
© Fujitsu

Product validation

Life Test	• *Long-term heat load testing or Accelerated life testing* *- temperature cycle, high-temperature/humidity, pressure* *- thermal/flow load testing for system performance variability*
Component/Unit Seal Validation	• *Helium leak testing, with thermal cycle testing* • *Chemical compatibility testing, Tubing permeability testing* • *Burst testing (UL1995 pressure cycle at low and high temp.)*
Coolant Lifetime Validation	• *Fluid breakdown testing (ASTM D1384/D4340)* • *System level fluid loss and/or permeation testing* • *Long-term storage testing (corrosion and fluid volume)*
Component/Unit Freeze/Thaw Test	• *Max./Min. shipping, operating, storage temperatures* • *Freezing-point validation for water-based solutions*

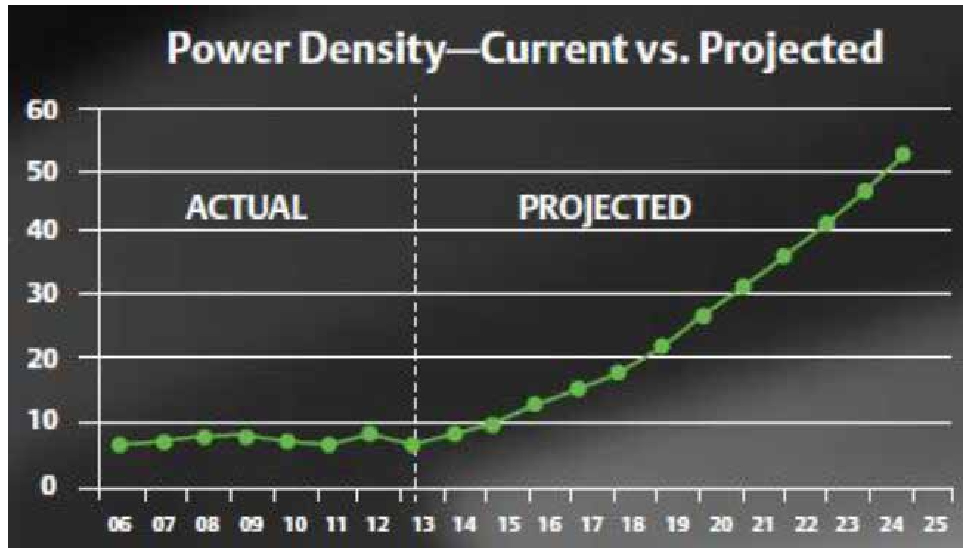
© Fujitsu

Cooling and Beyond



© Fujitsu

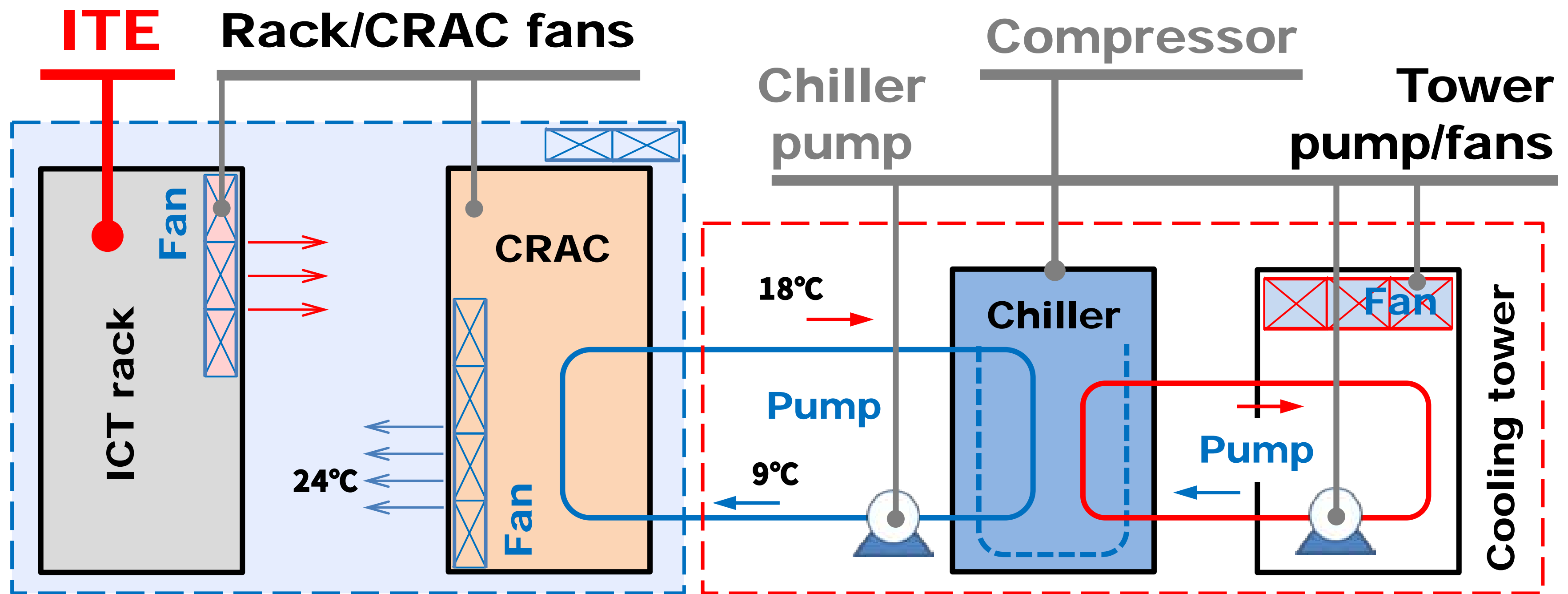
Power density & environment



Source: Emerson Network Power, "Data Center 2025"

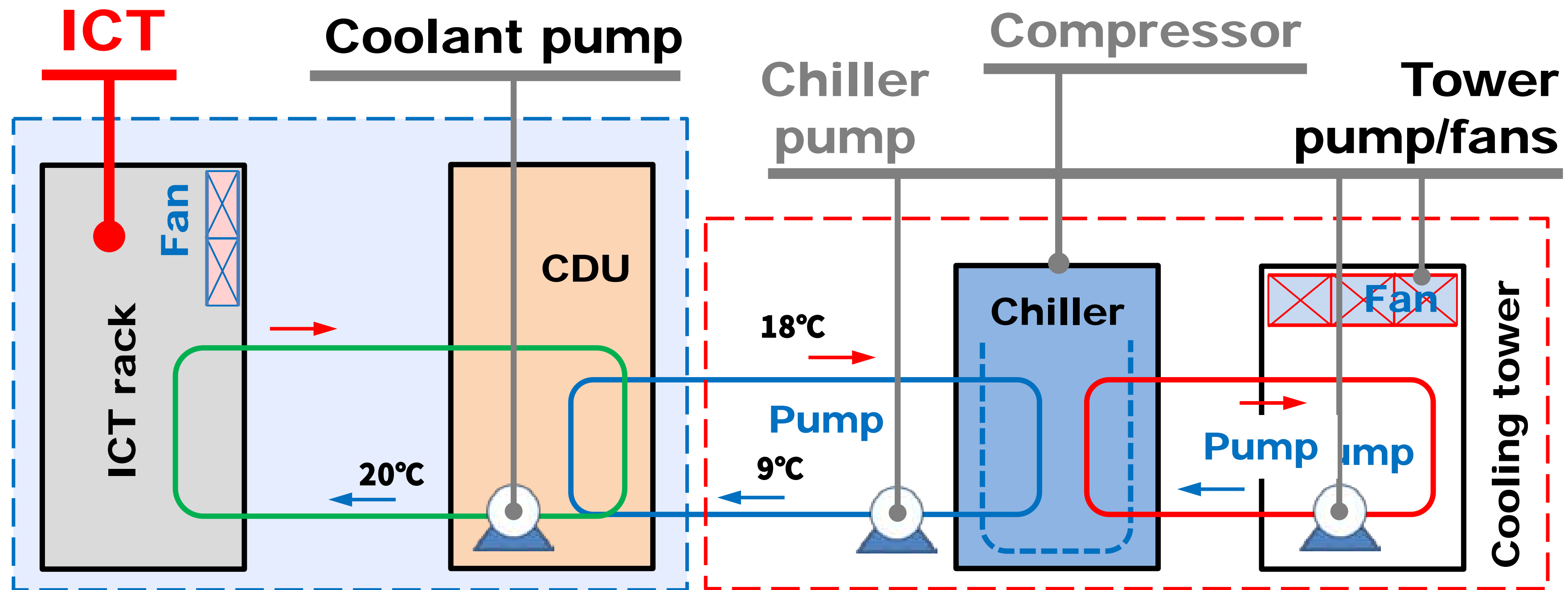
Bring ITE & facility together

Systematic optimization for
- power / space / volume densities
- energy / cooling efficiency



© Fujitsu

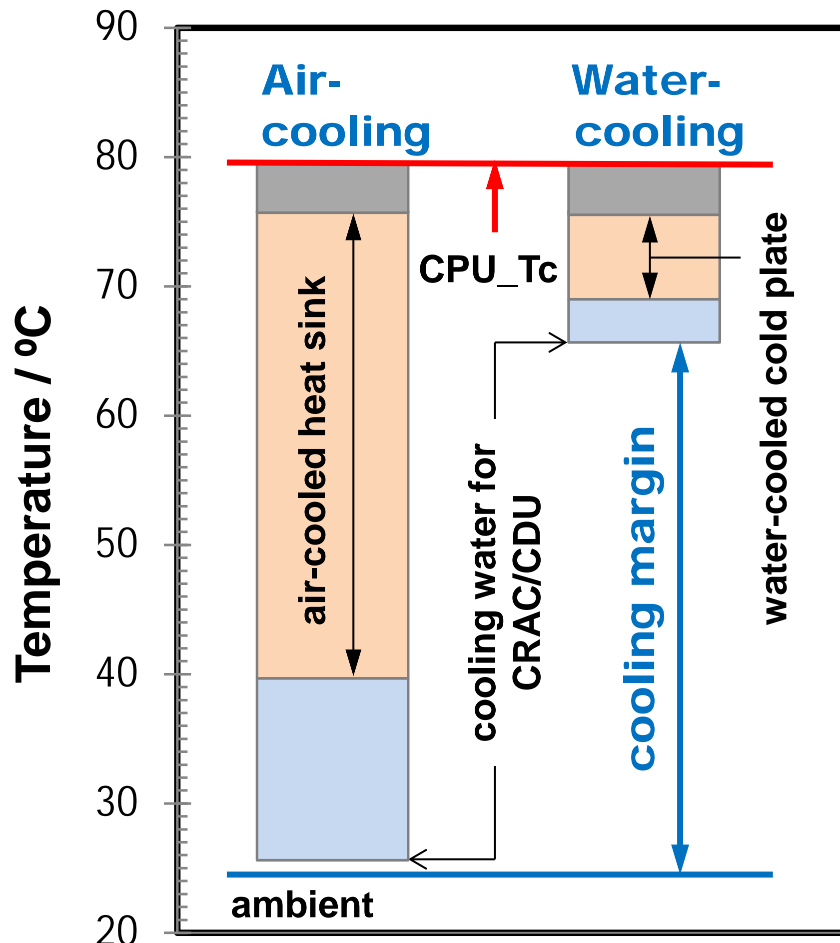
Power consumption	Rack fans	CRAC fans	CDU pumps	Chiller pumps	Refri. compressor	Tower Pumps/fans
Air convection	O	O	X	O	O	O
Liquid circulation	Ñ	X	O	O	O	O
Immersion bath	X	X	O	O	O	O



Electric required for an water-cooling DC

© Fujitsu

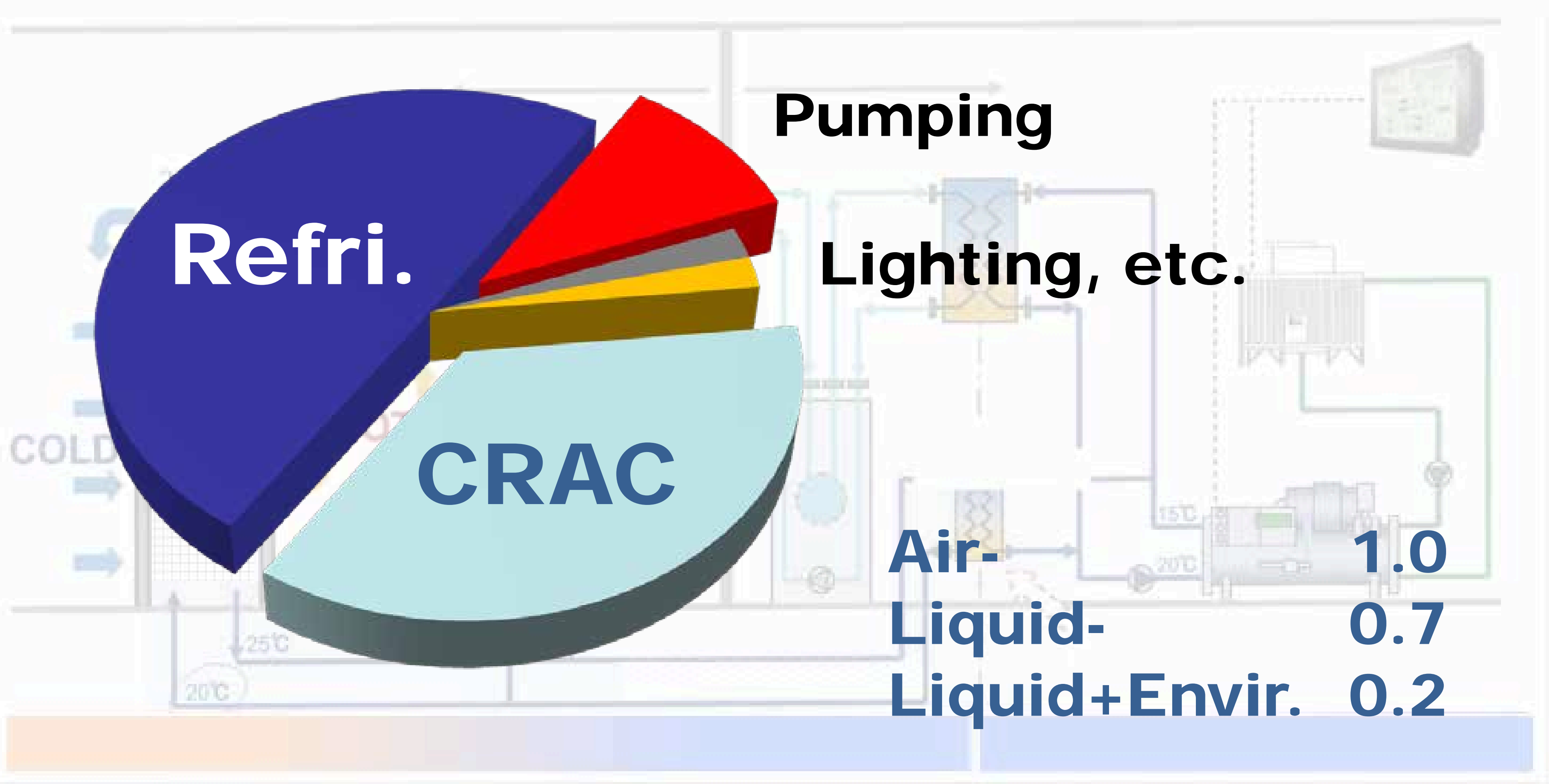
Expanded cooling margins



- CPU power: 150W
- CPU package: 1U
- cooling water required
  - air cooling: 27ºC
  - liquid cooling: 65ºC

© Fujitsu

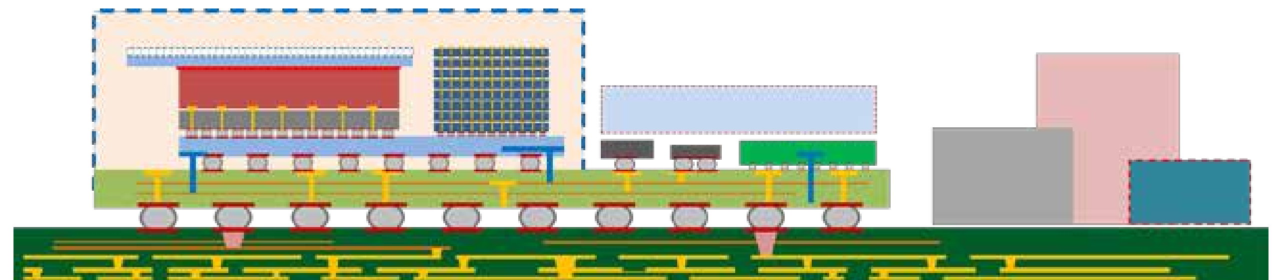
Power/Energy saving for cooling



© Fujitsu

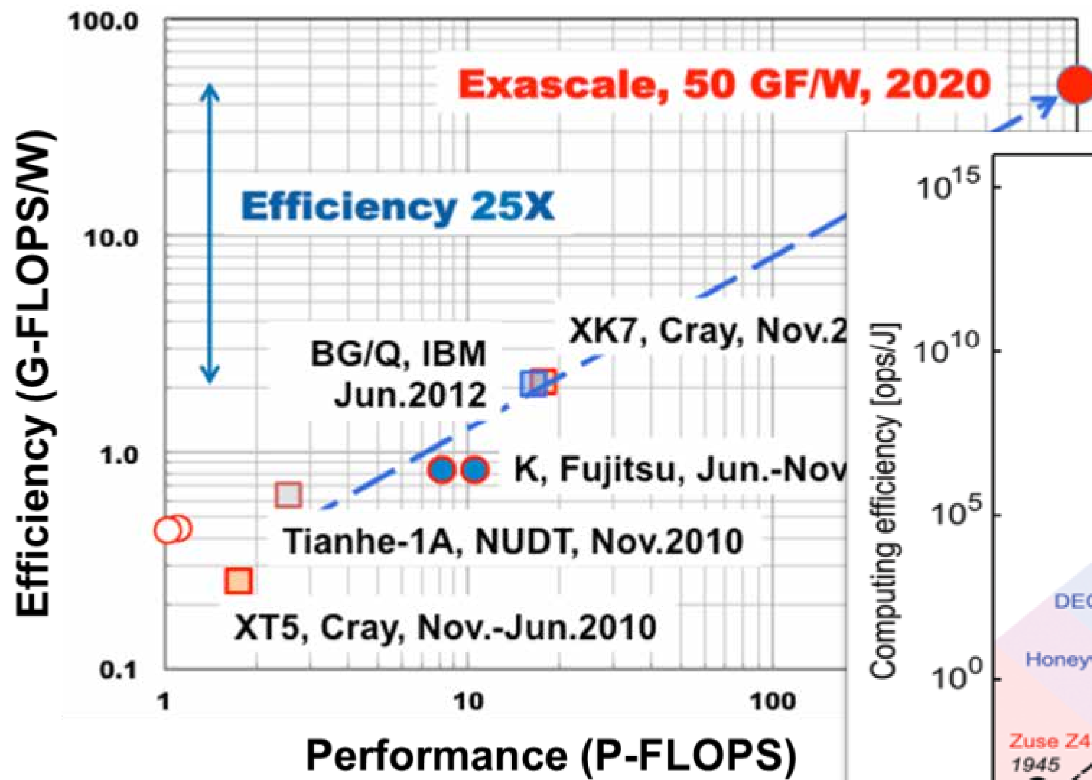
5 years later ~2020

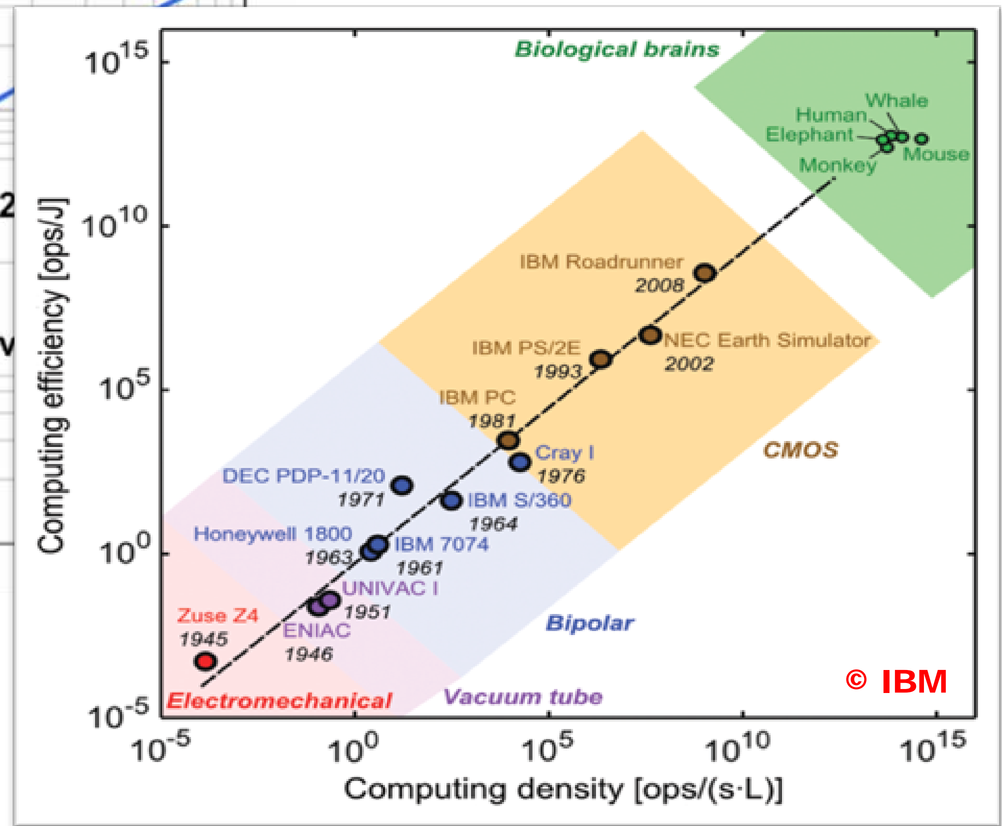
- Energy efficiency & reuse
- Density toward volumetric



© Fujitsu

Ultimate efficiency/density





© Fujitsu

Integration & innovation of the technologies for

Chip power: 50~100 W/cm^2 , 500+ W/Chip
Packaging: 2000+ W/Board

- 3D PKG/cooling: 1~3 kW/cm^3
- energy efficiency: PKG〜DC, PUE<1.1
- reuse of exhaust: PUE~1.0

© Fujitsu

In a Summary

- **Liquid cooling**
  - components, units and systems are considerably complicated and greater reliability necessitated.
  - reliability and product validation in each step of mfg./assembling process, is the most important.
- **Cooling and beyond**
  - Integration of the technologies from chip to system.
  - Co-design of the system for energy saving/reusing from chip to environment, and power-plant.

© Fujitsu

FUJITSU
shaping tomorrow with you