64-bit Server Cooling Requirements

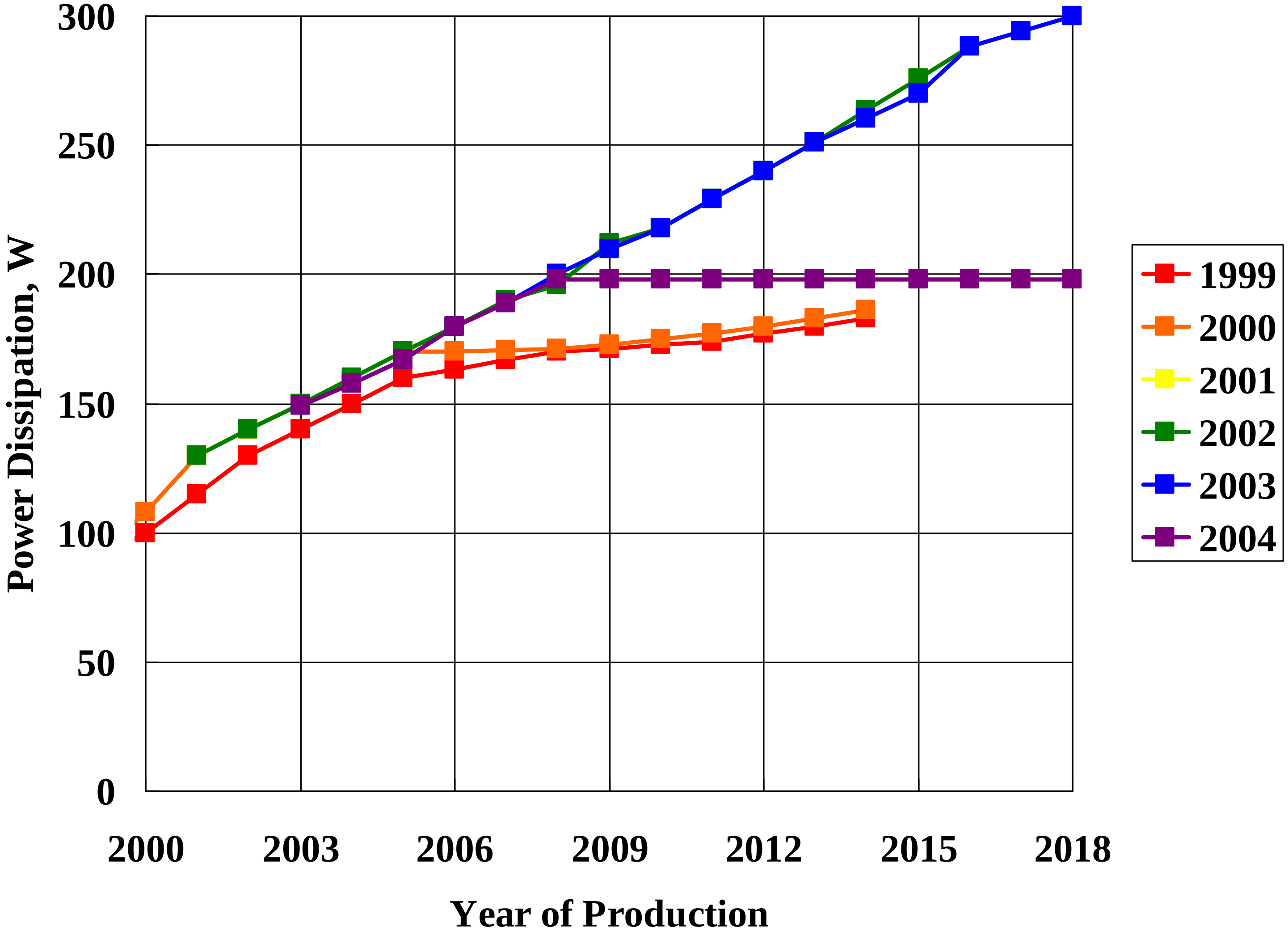
David Copeland

Fujitsu Laboratories of America

64-bit Server Cooling Requirements

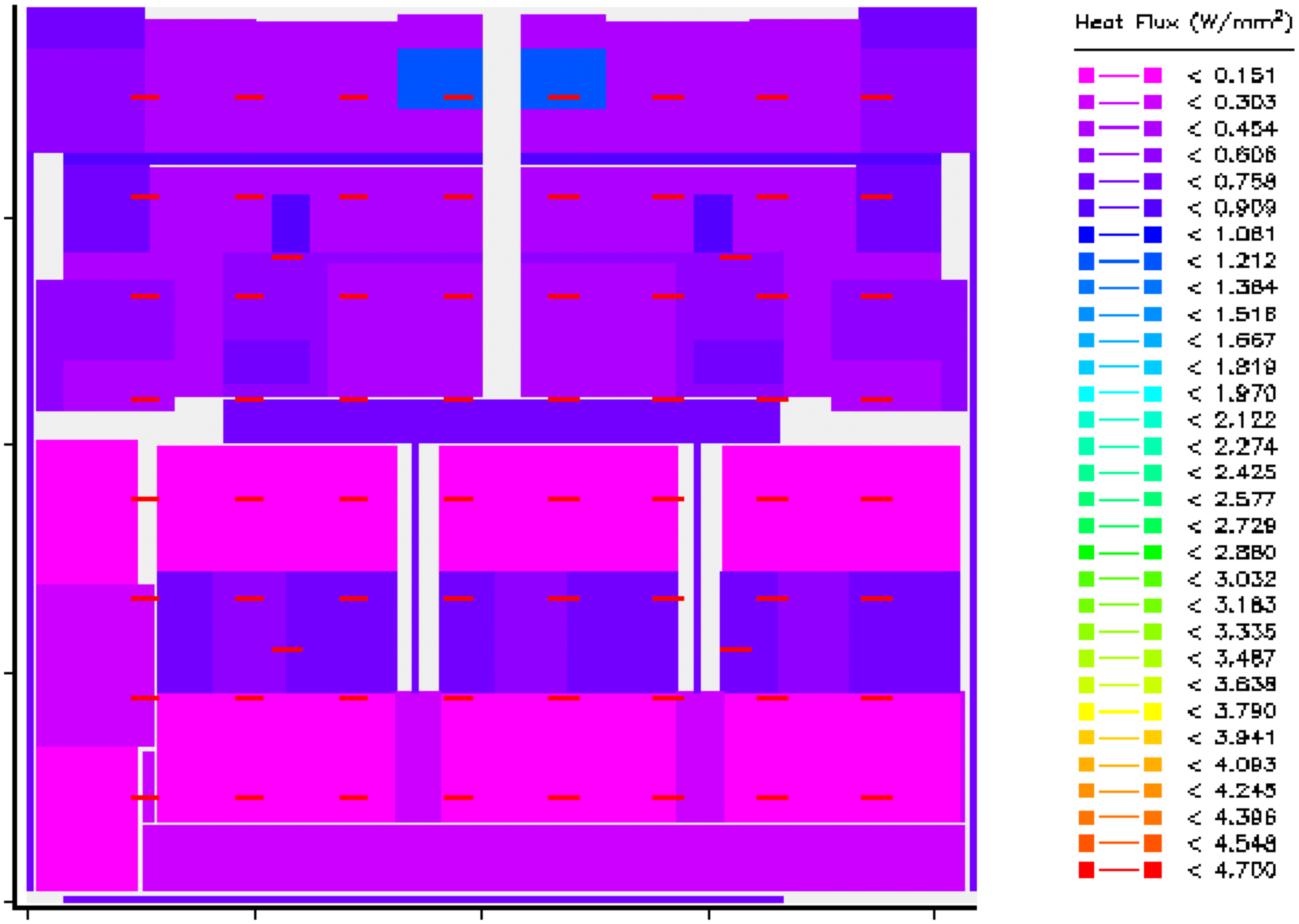
- **Power Dissipation and Distribution**
- **Temperature Dependence of Power**
- **Power Reduction by Refrigeration**
- **Air- to Water Cooling Migration**

International Technology Roadmap for Semiconductors



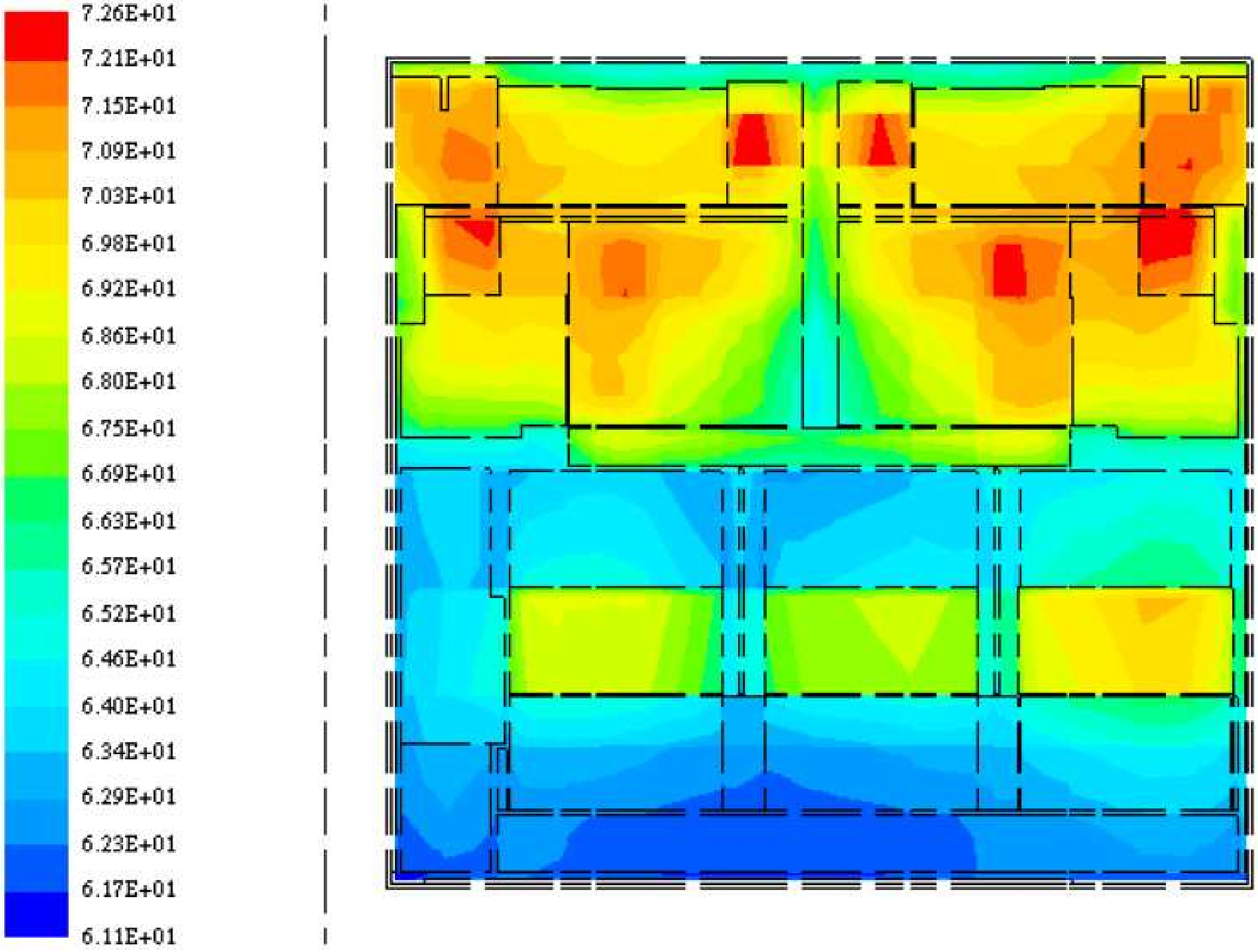
High Performance Processor Power Trend

IBM: Kang, ITherm 2000



Chip Power Map

Kang, ITherm 2000

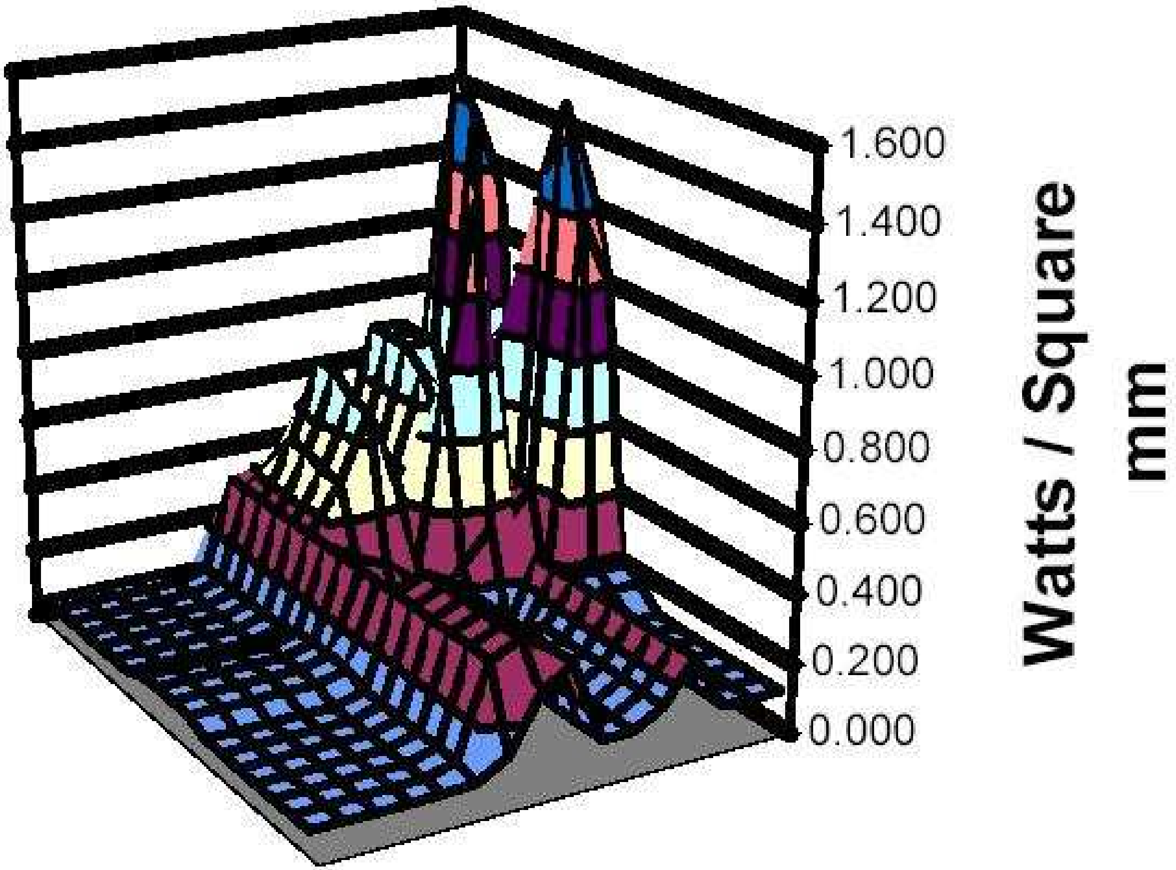


Air - Enhanced

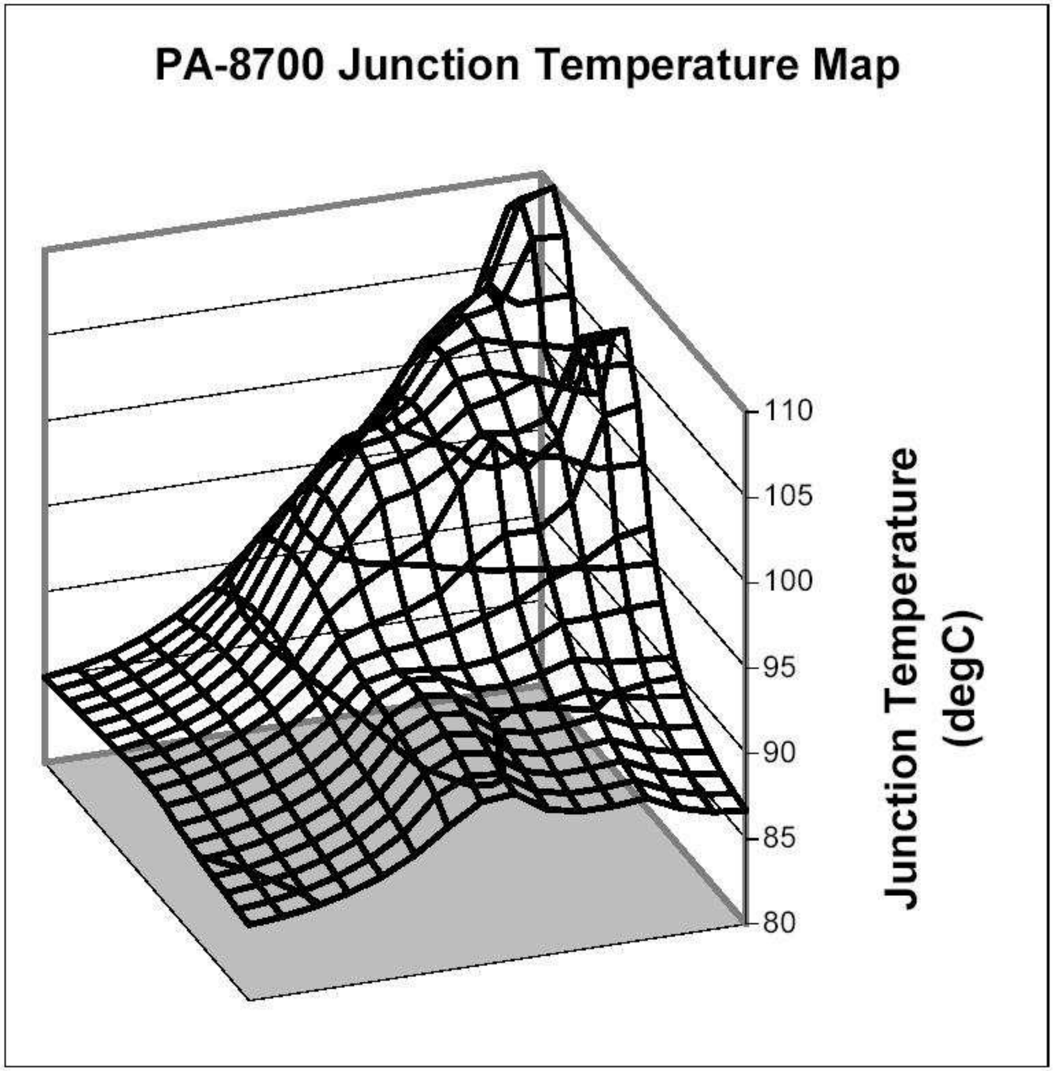
Hewlett-Packard: Deeney, IMAPS 2002

THE POSSIBILITIES ARE INFINITE FUJITSU

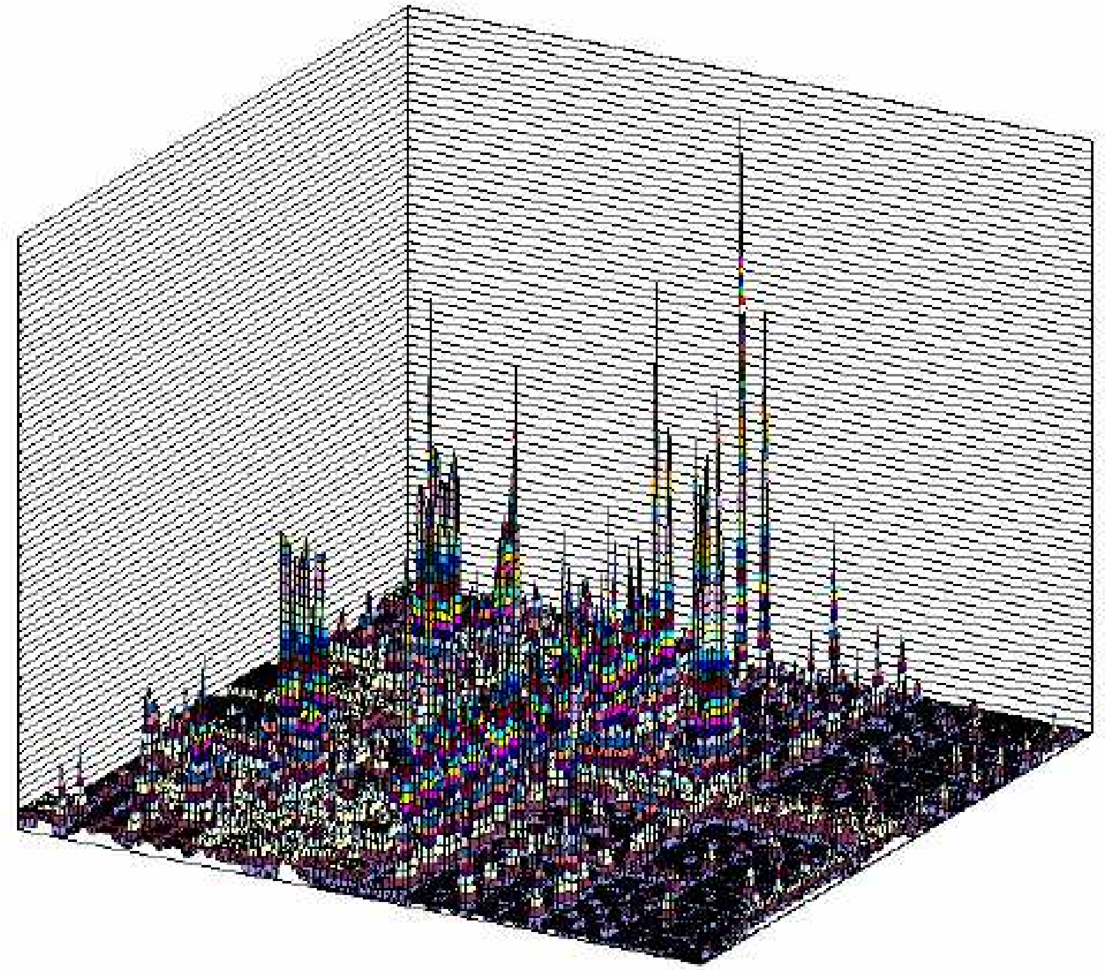
PA-8700 Power Distribution



Deeney, IMAPS 2002

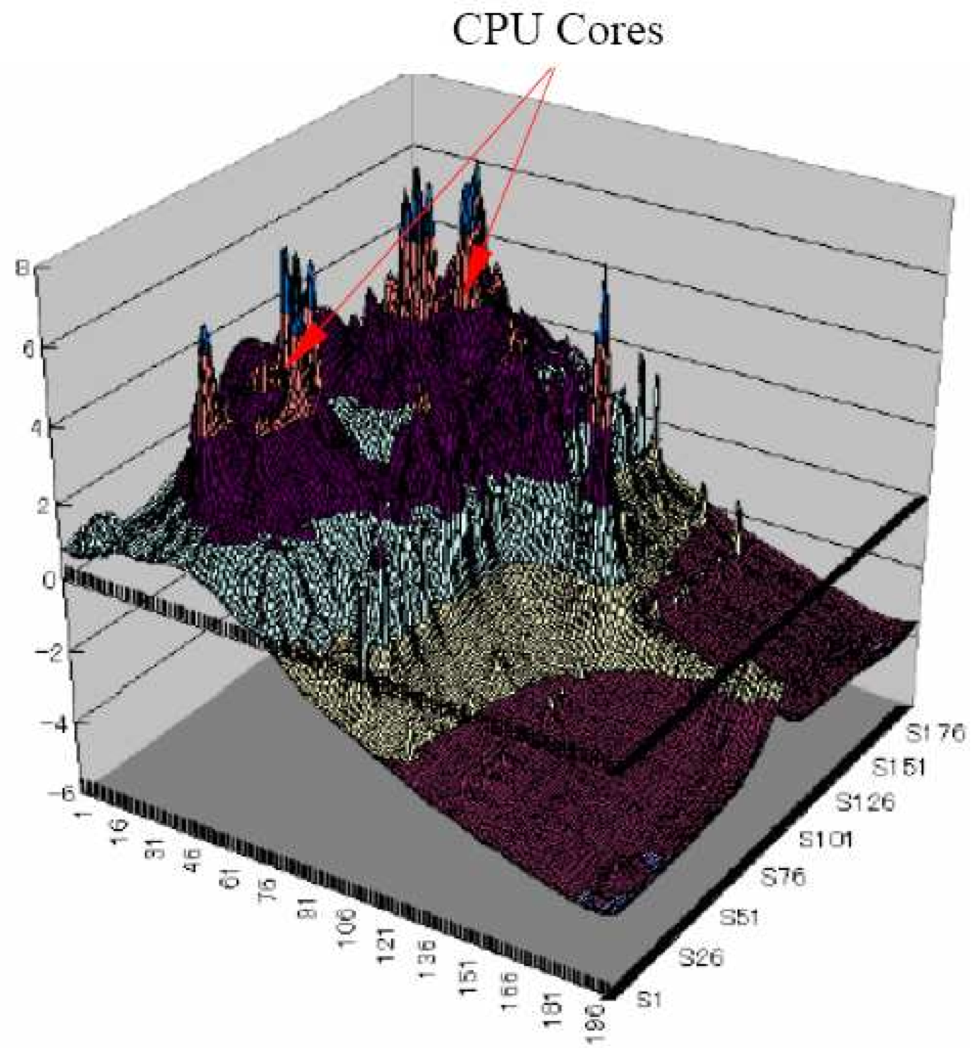


Fujitsu: Wei *et al*., International Forum on Heat Transfer 2004



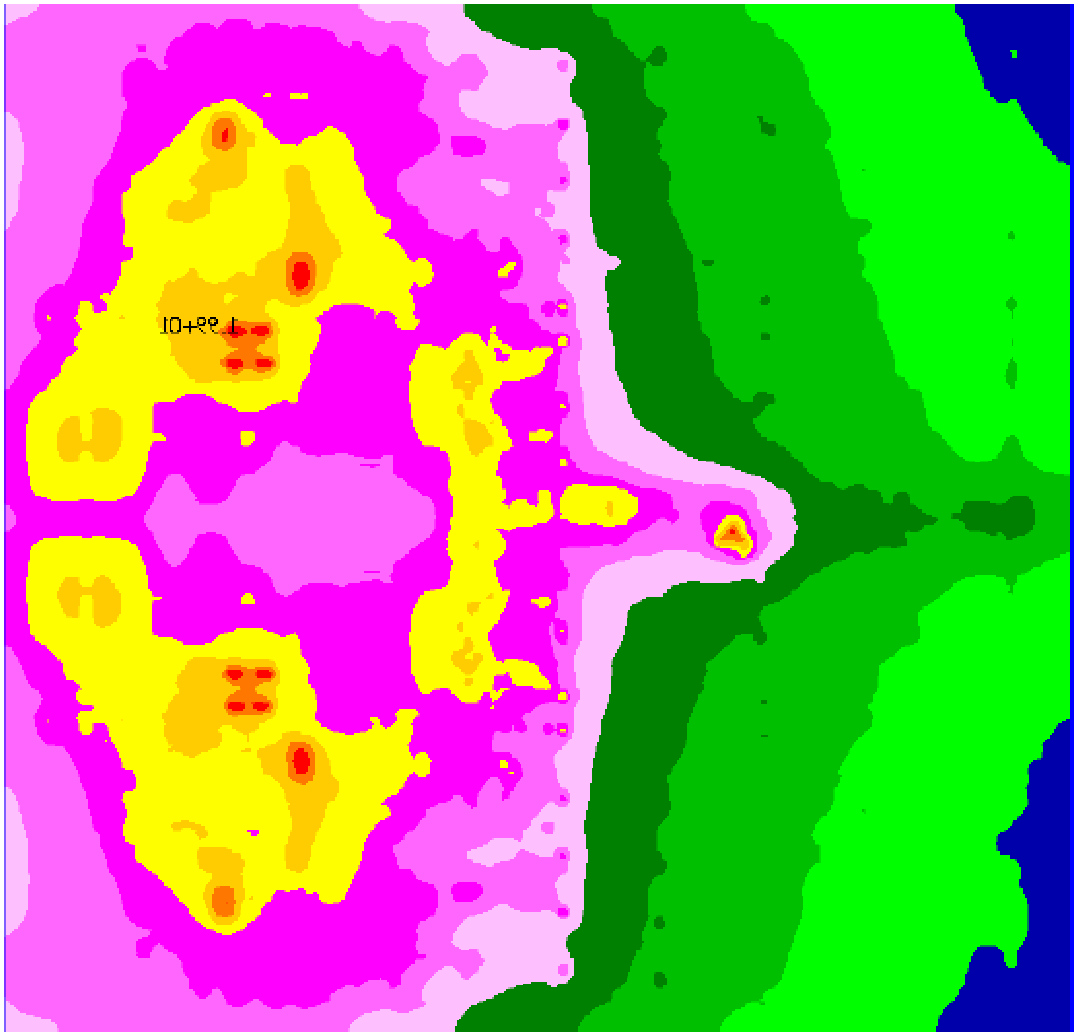
Power Distribution of the Microprocessor Design

Wei *et al.*, IFHT 2004



Temperature Distribution on Junction Surface

Wei *et al.*, IFHT 2004



Copper Heat Spreader

Fujitsu: Copeland, IMECE 2002

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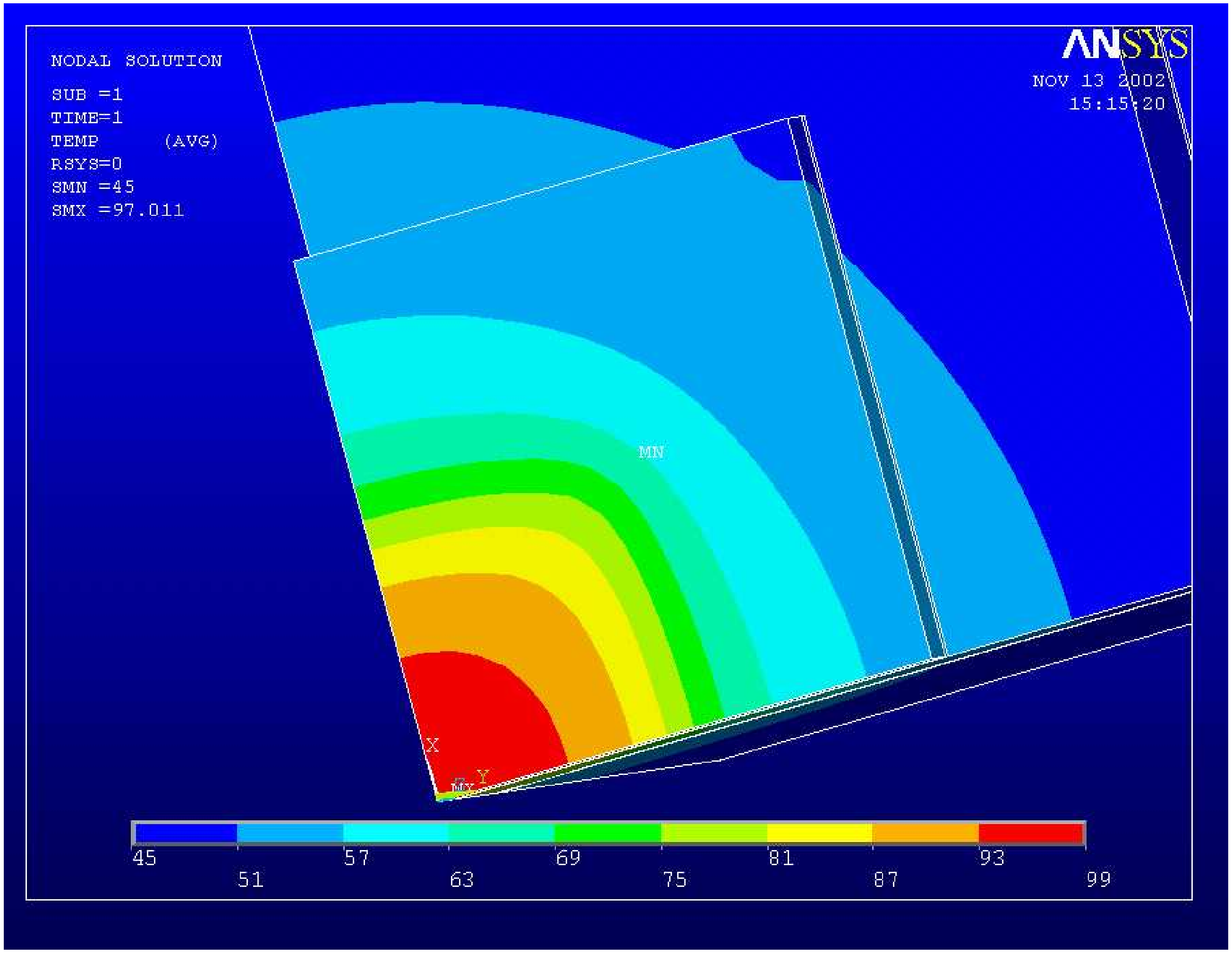
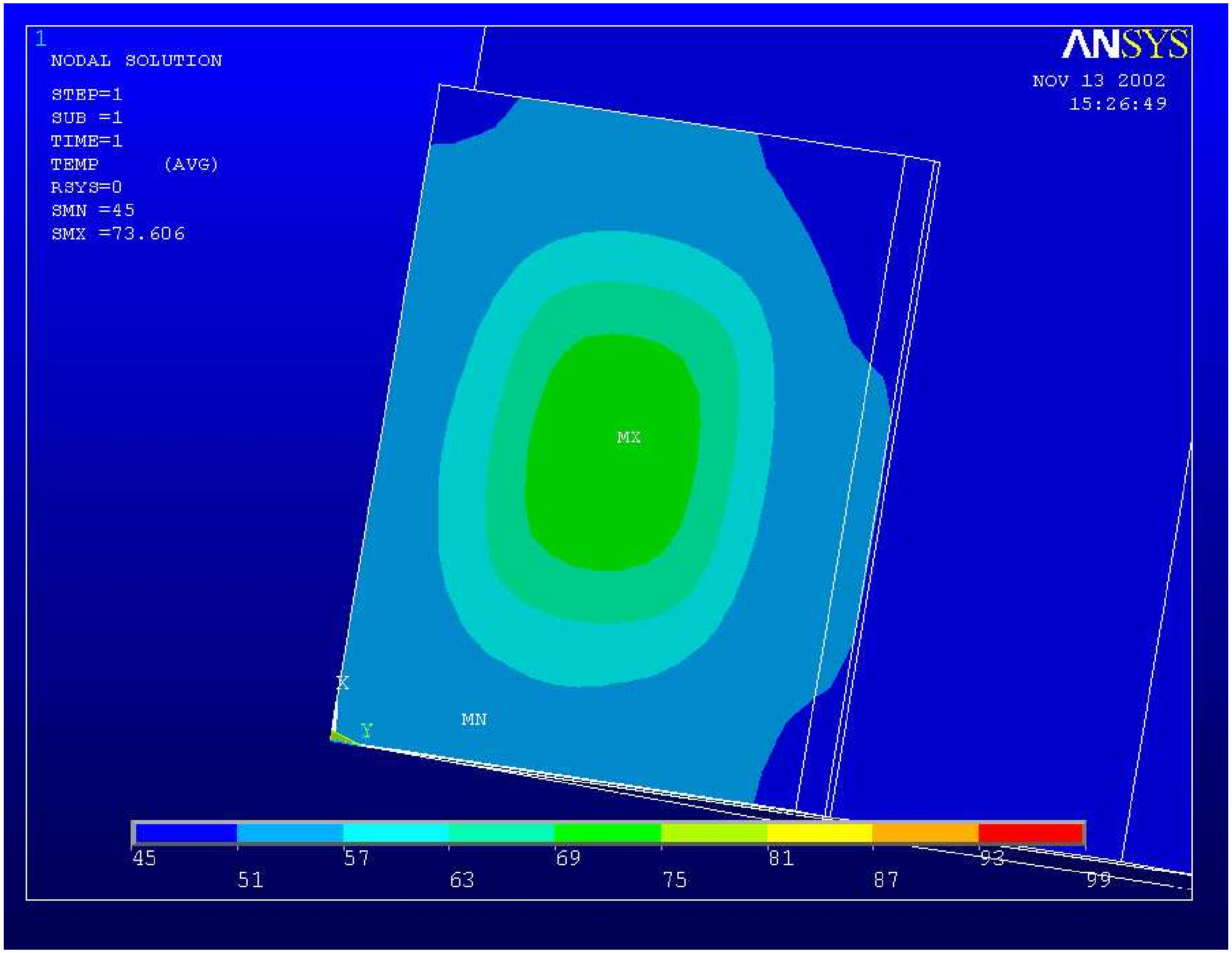


Center Core Location

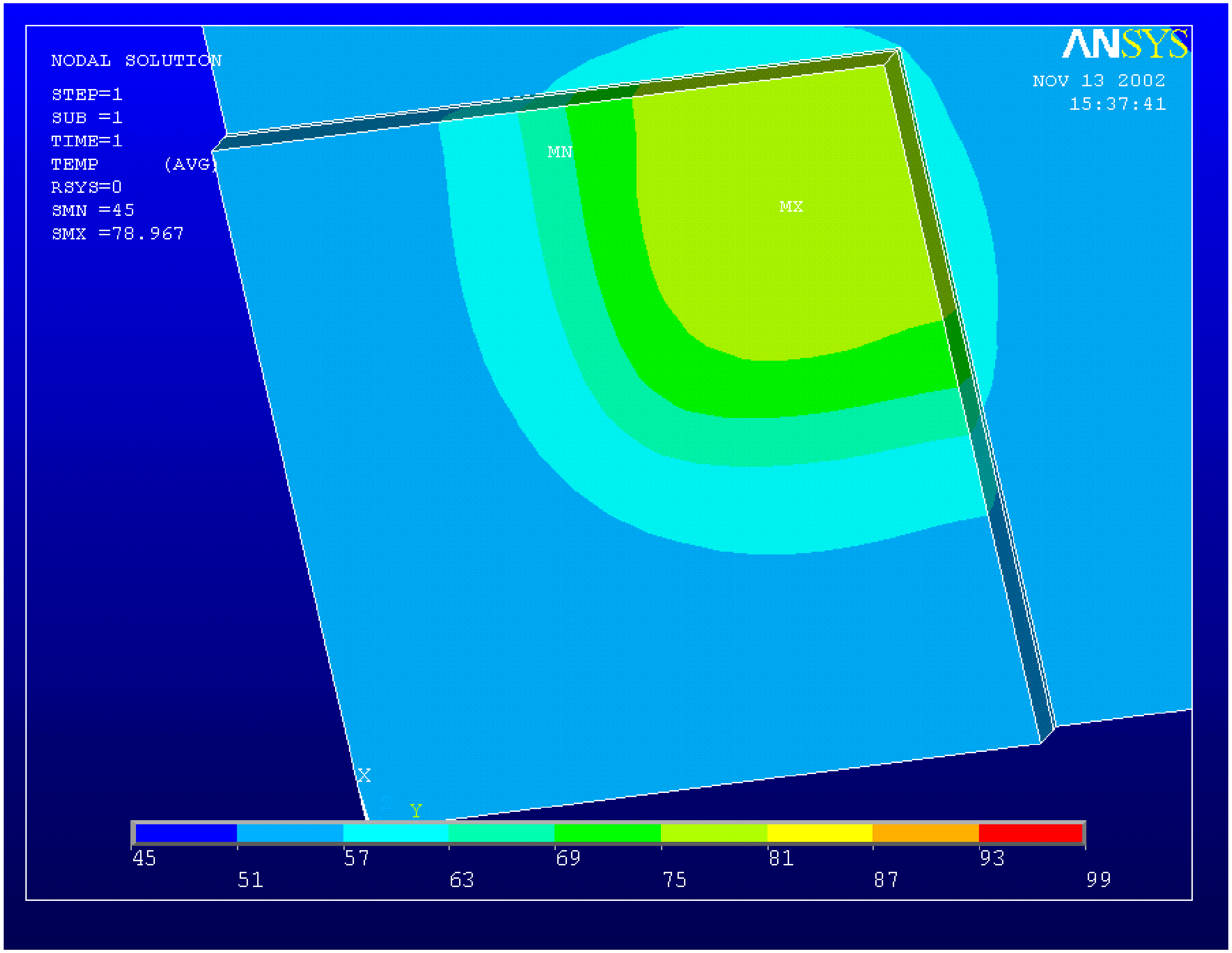
Packaging Technology Research

Fujitsu Laboratories of America



Middle Core Location

Copeland, IMECE 2002

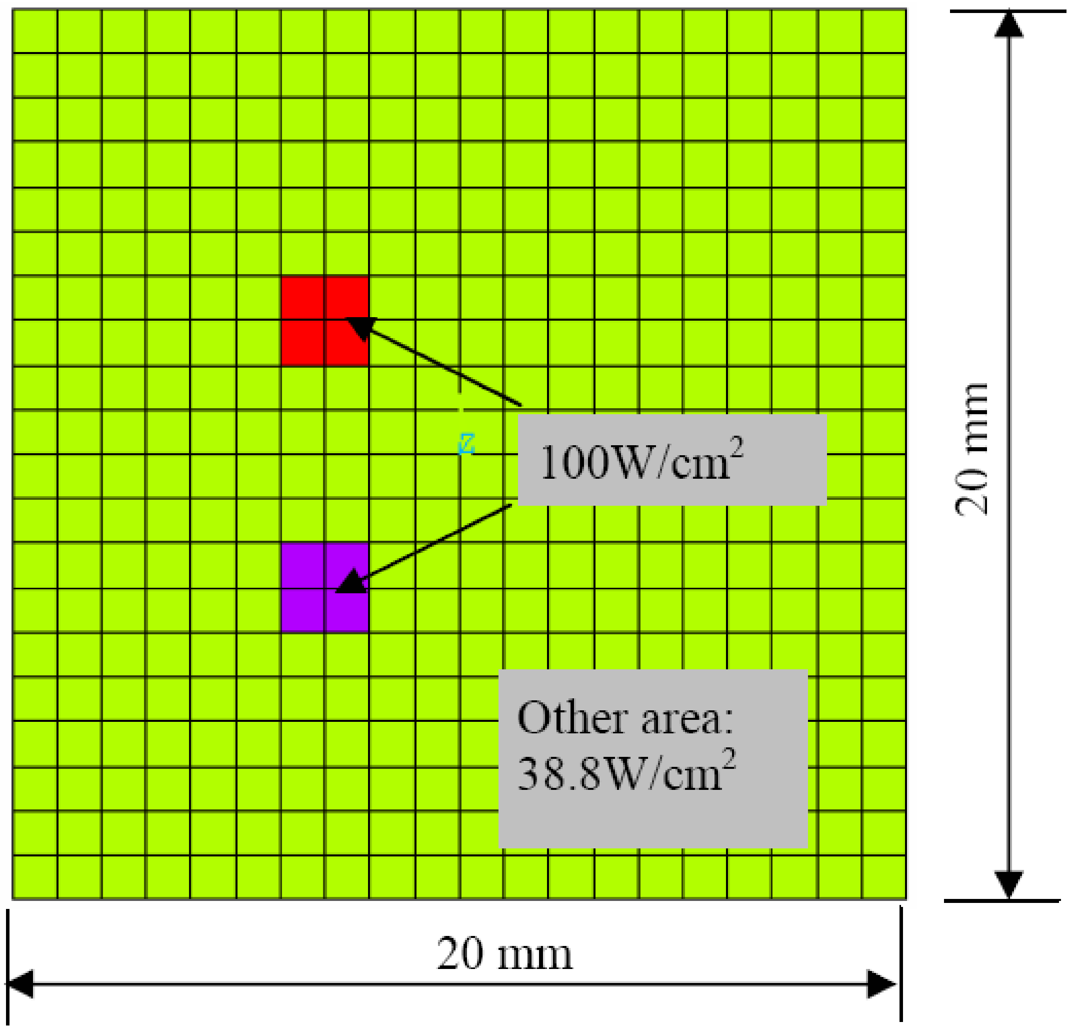


Corner Core Location

Power Multiple Core Location Results

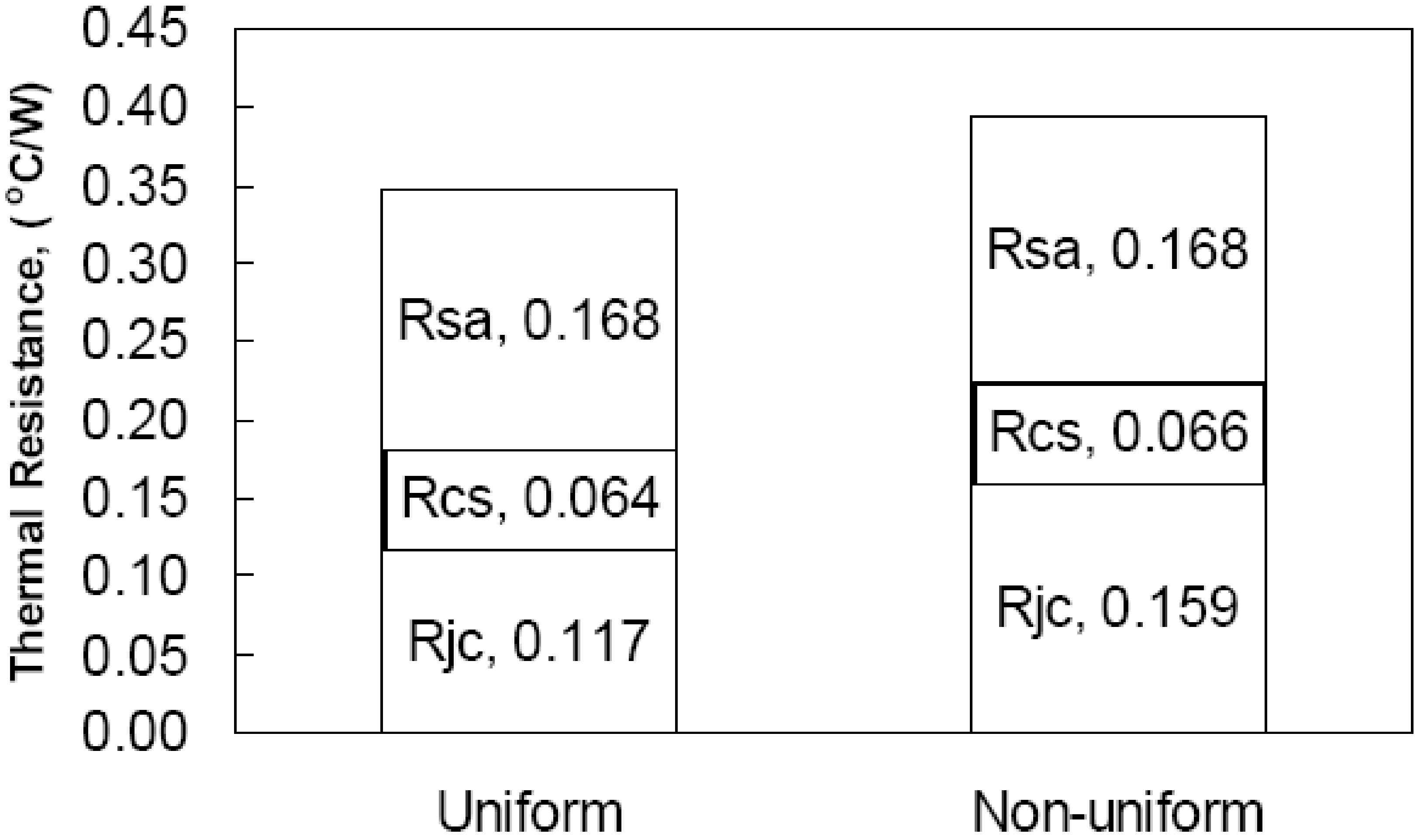
	Center	Middle	Corner
Maximum Temperature	97.0 C	73.6 C	79.0 C
Silicon heat spreading	2 sides	4 sides	2 sides
Copper heat spreading	2 sides	4 sides	4 sides

Sun: Xu et al., ITherm 2004



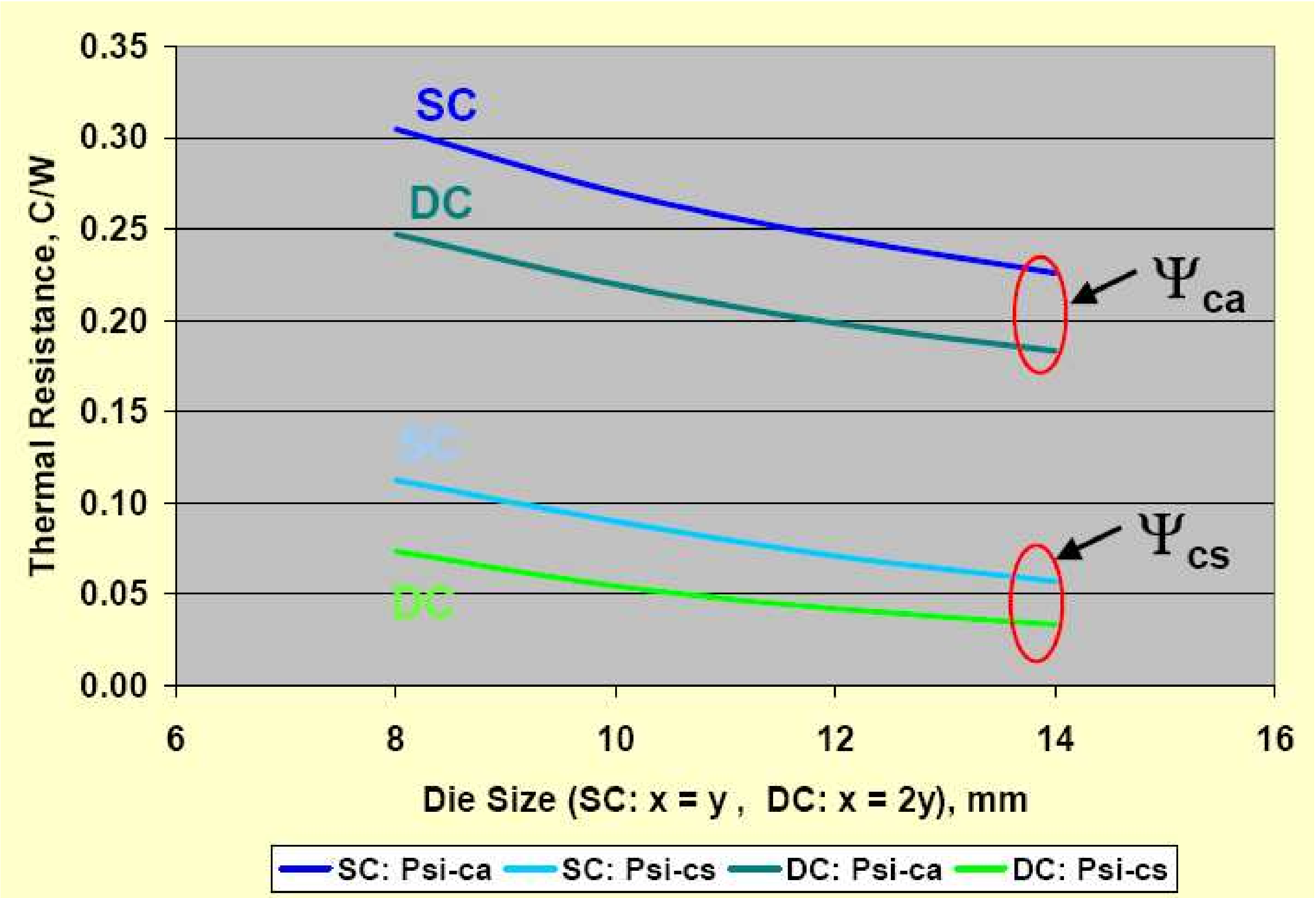
Nonuniform Power Map on the Die

Xu et al., ITherm 2004



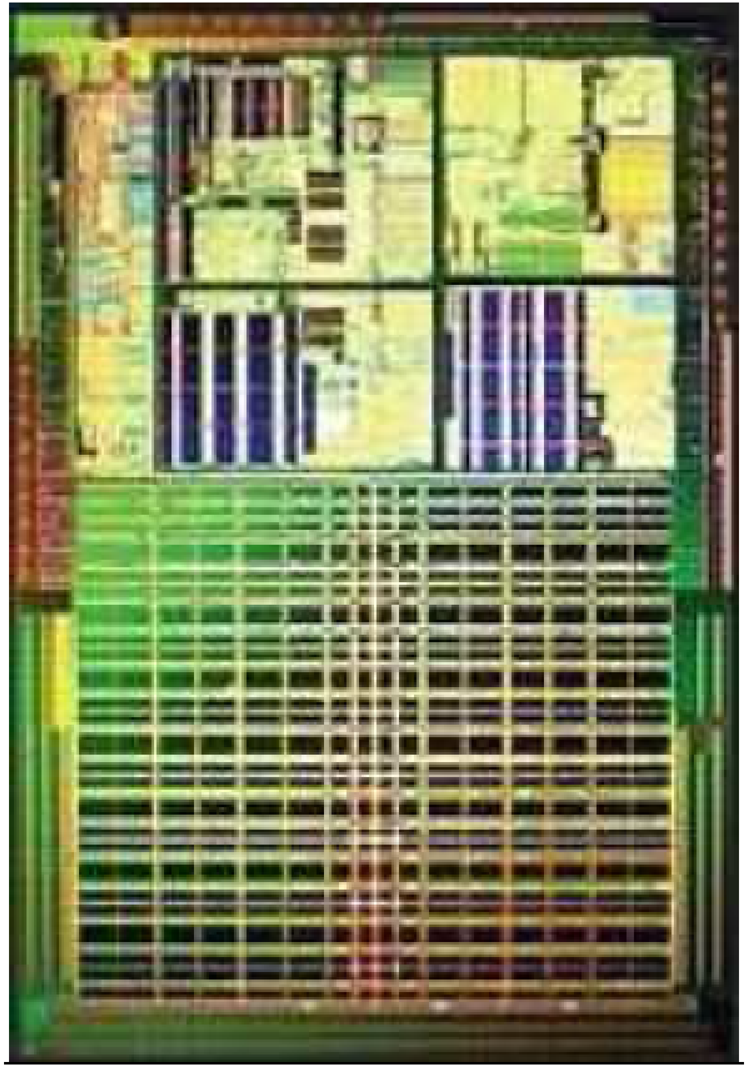
Effect of Power Distribution on the Thermal Resistance

Intel: Ahuja, Intel Technology Symposium 2004



Case to Ambient Resistance

AMD Opteron 194 mm^2



Hewlett-Packard PA-8800 365 mm^2

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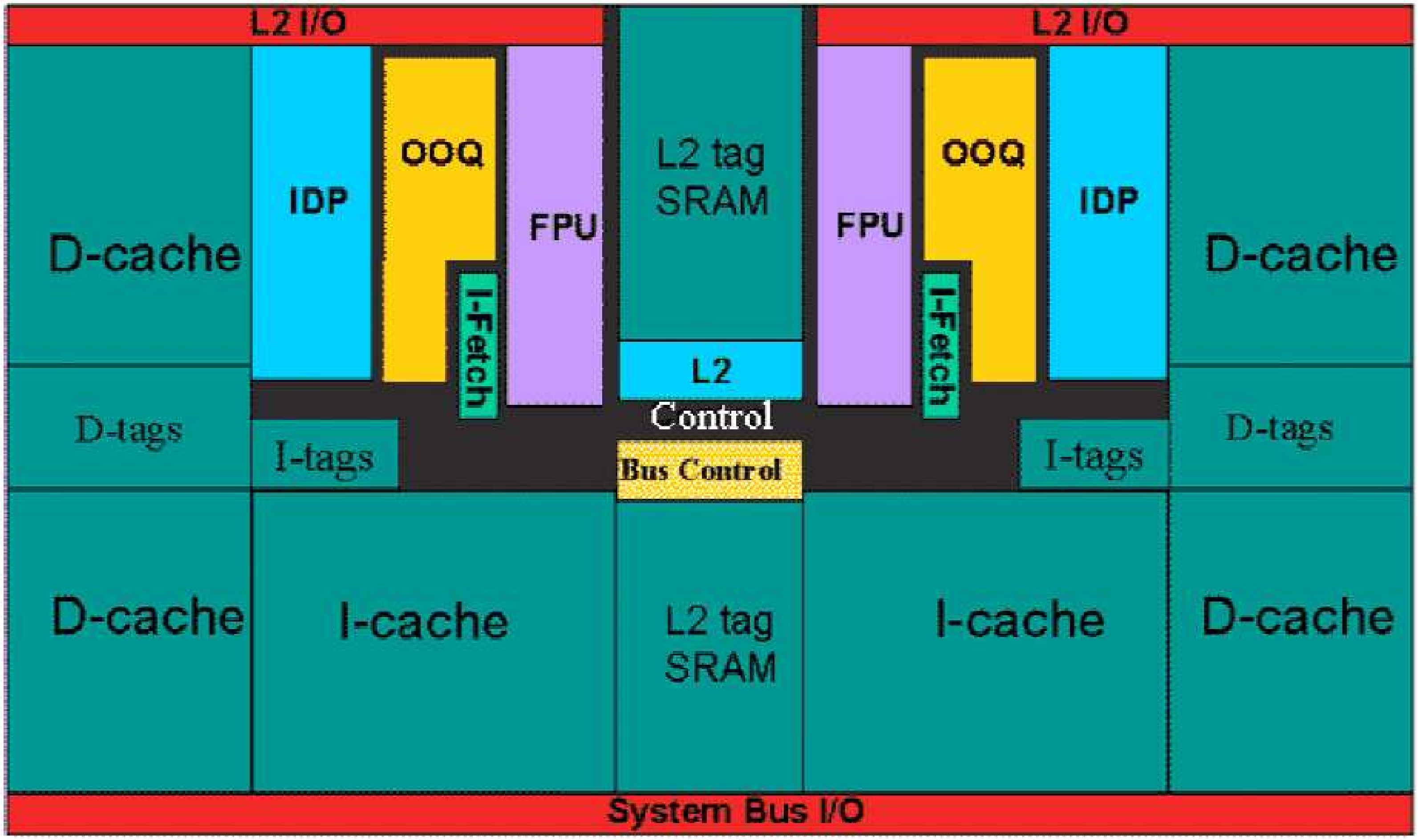
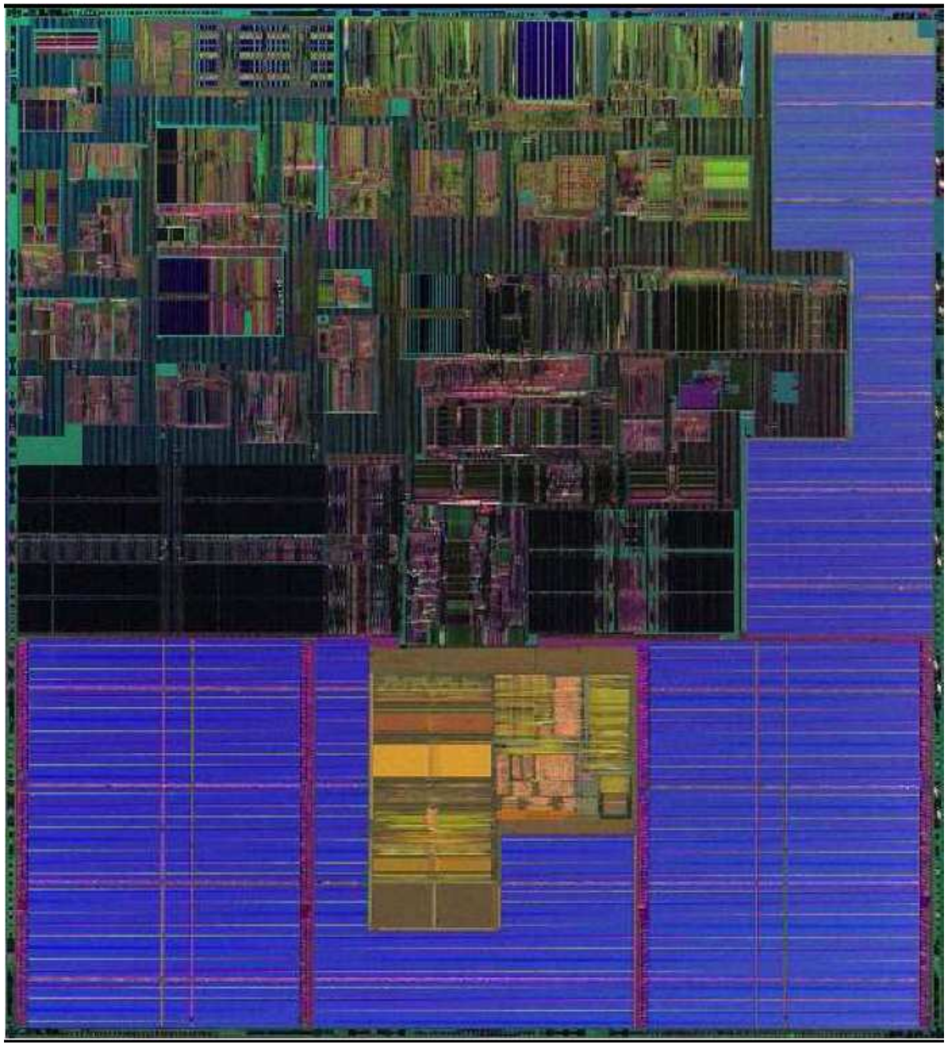
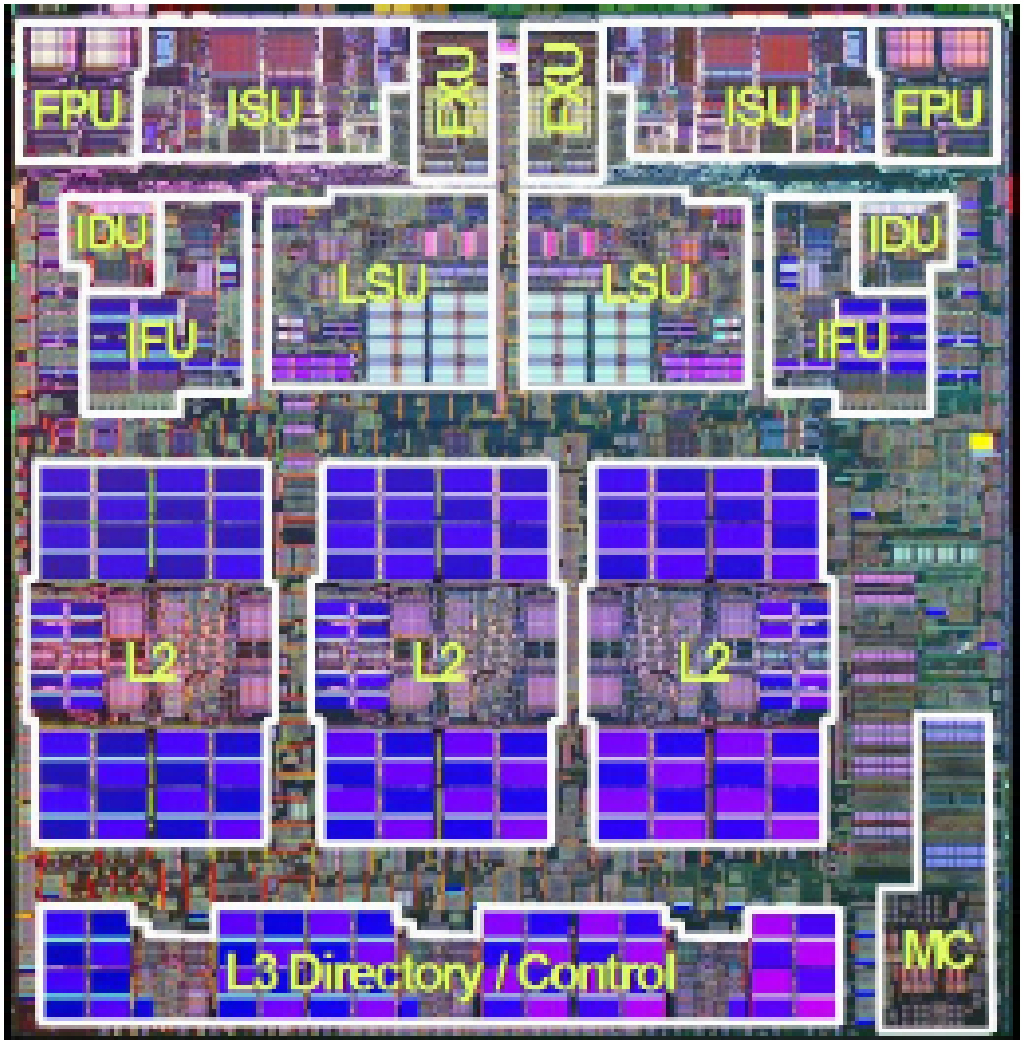


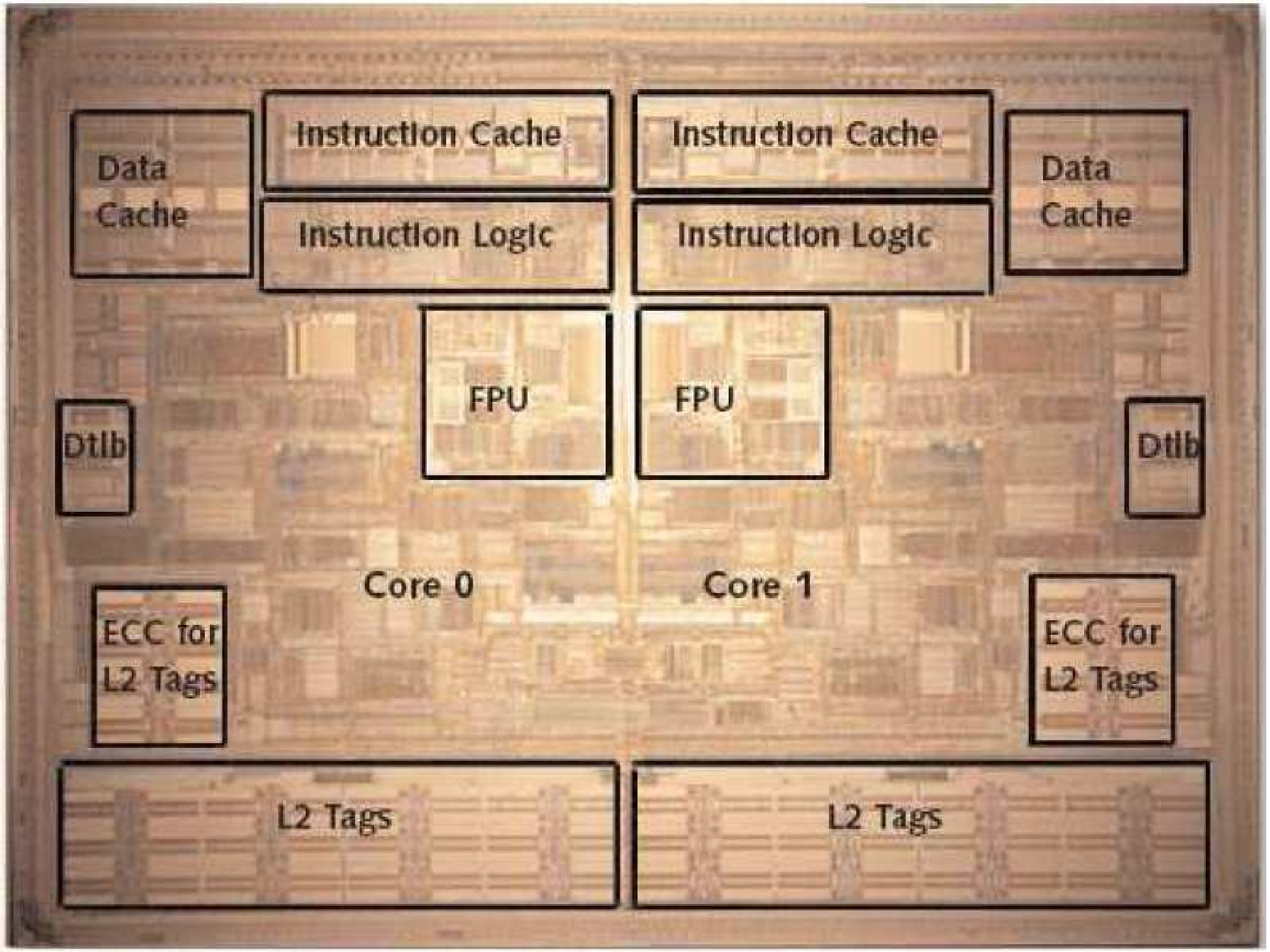
Intel Itanium 2 409 mm^2



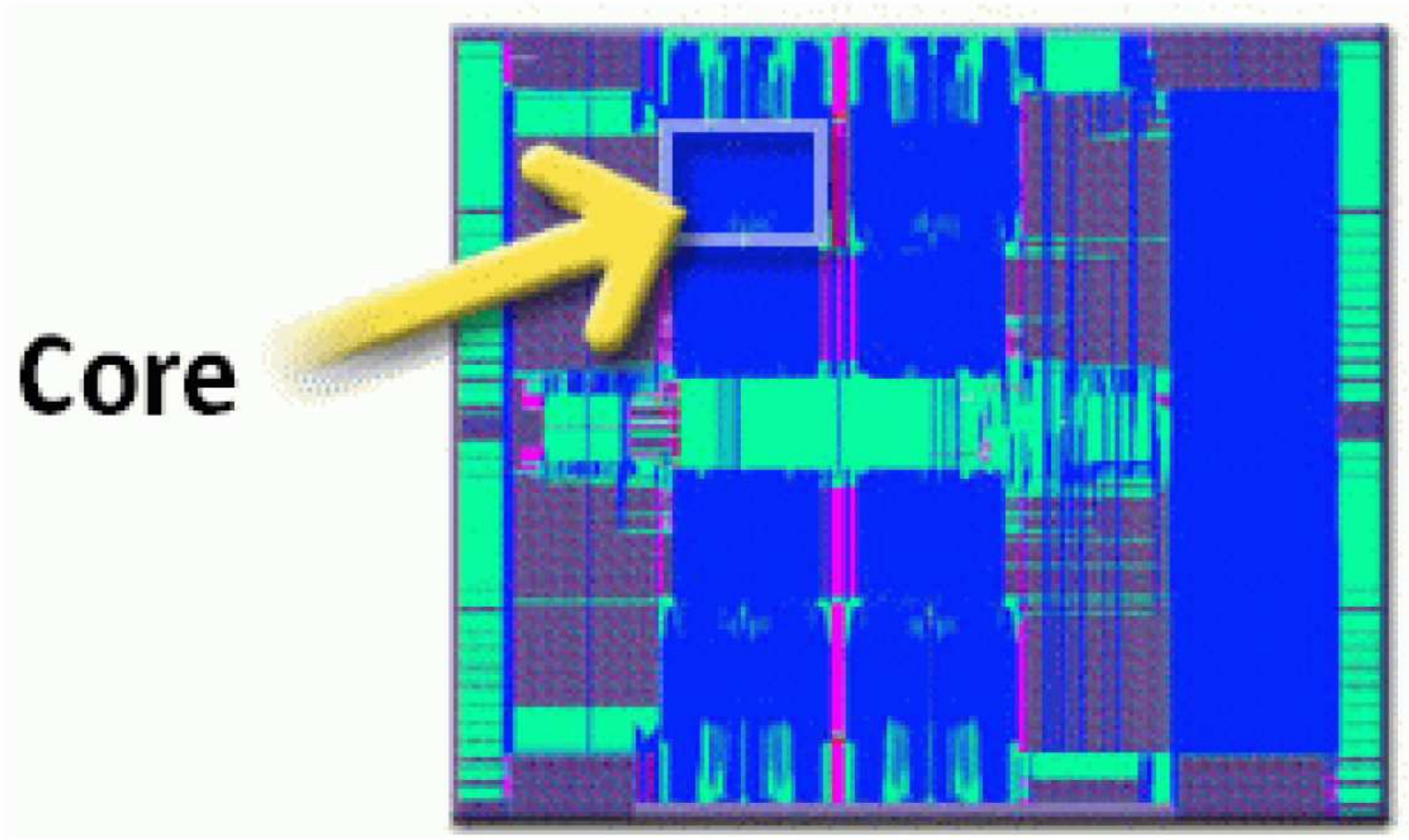
IBM Power5 389 mm^2



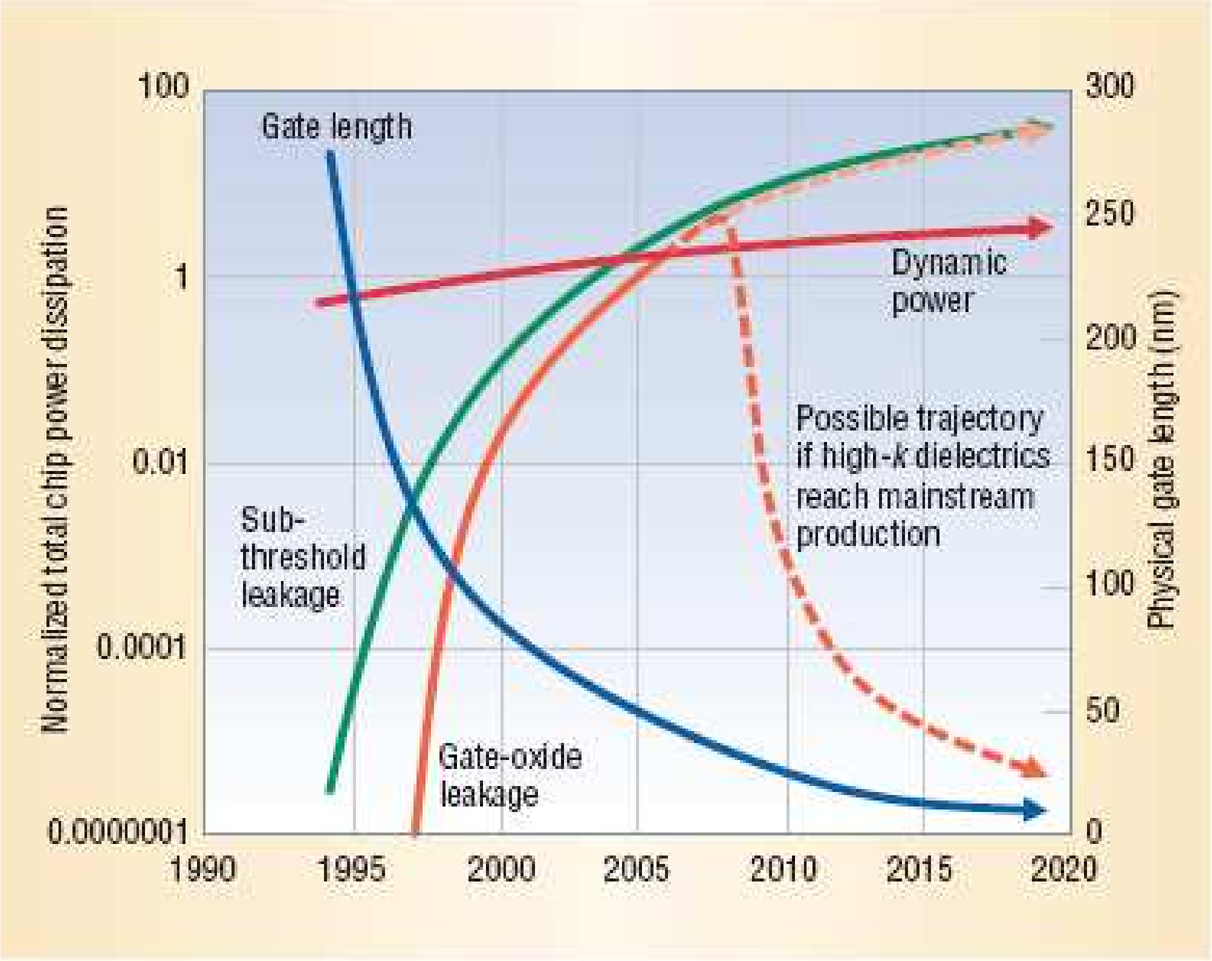
Sun UltraSPARC 4 356 mm^2



Sun Niagara ~340mm^2

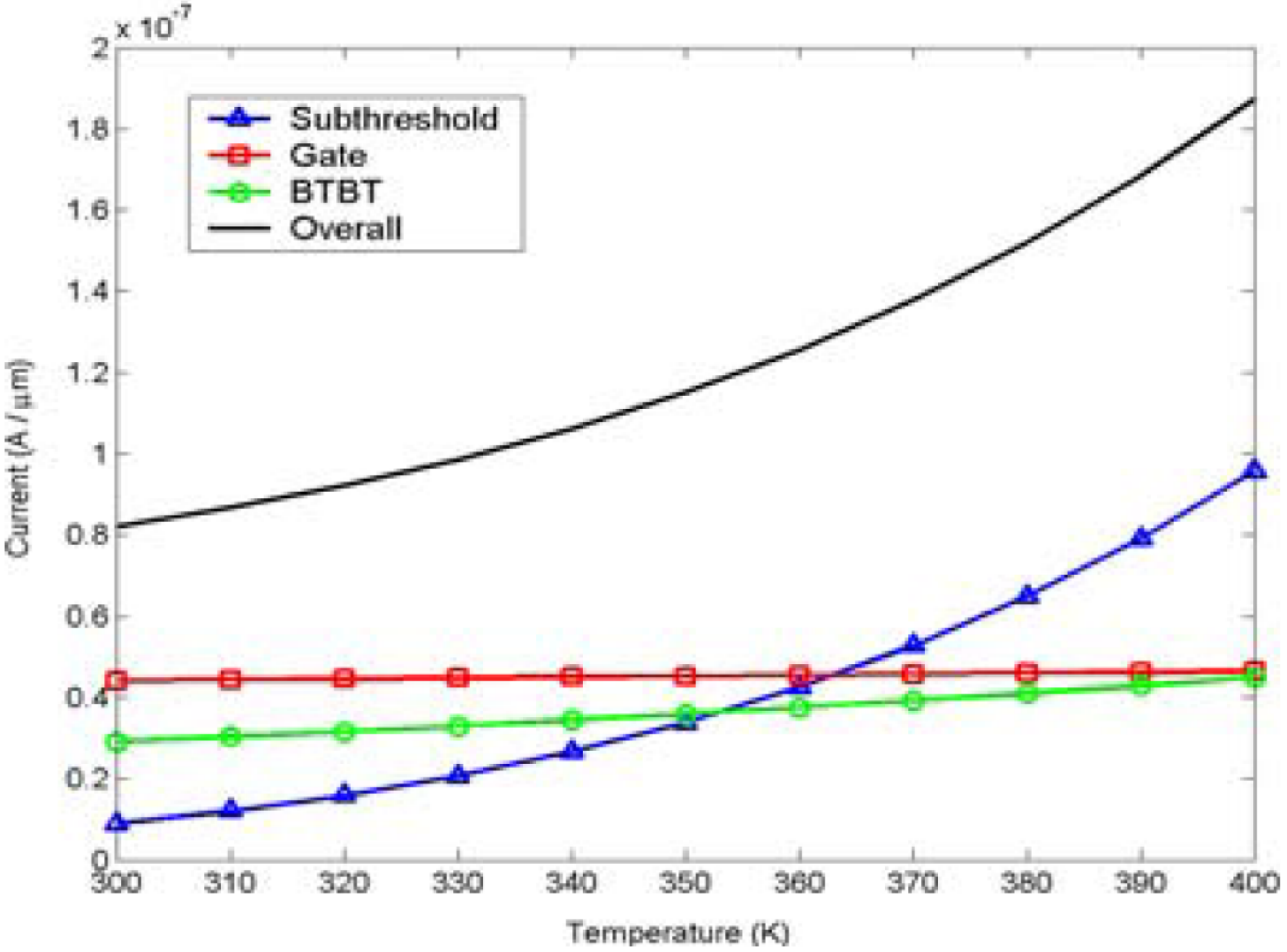


Michigan: Kim *et al*., IEEE Computer 2003



Total Chip Dynamic and Static Power Dissipation Trends Based on the ITRS

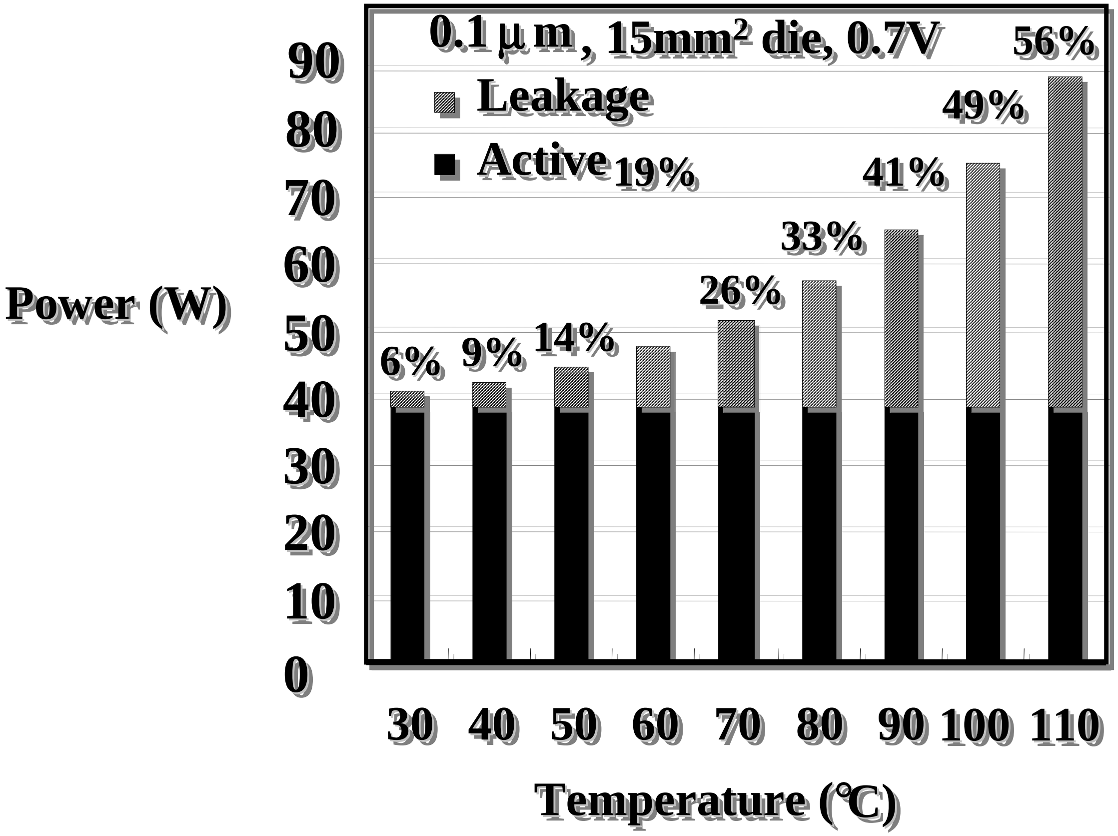
Purdue: Mukhopadhyay *et al.*, DAC 2003



Variation of Leakage Current Components with Temperature

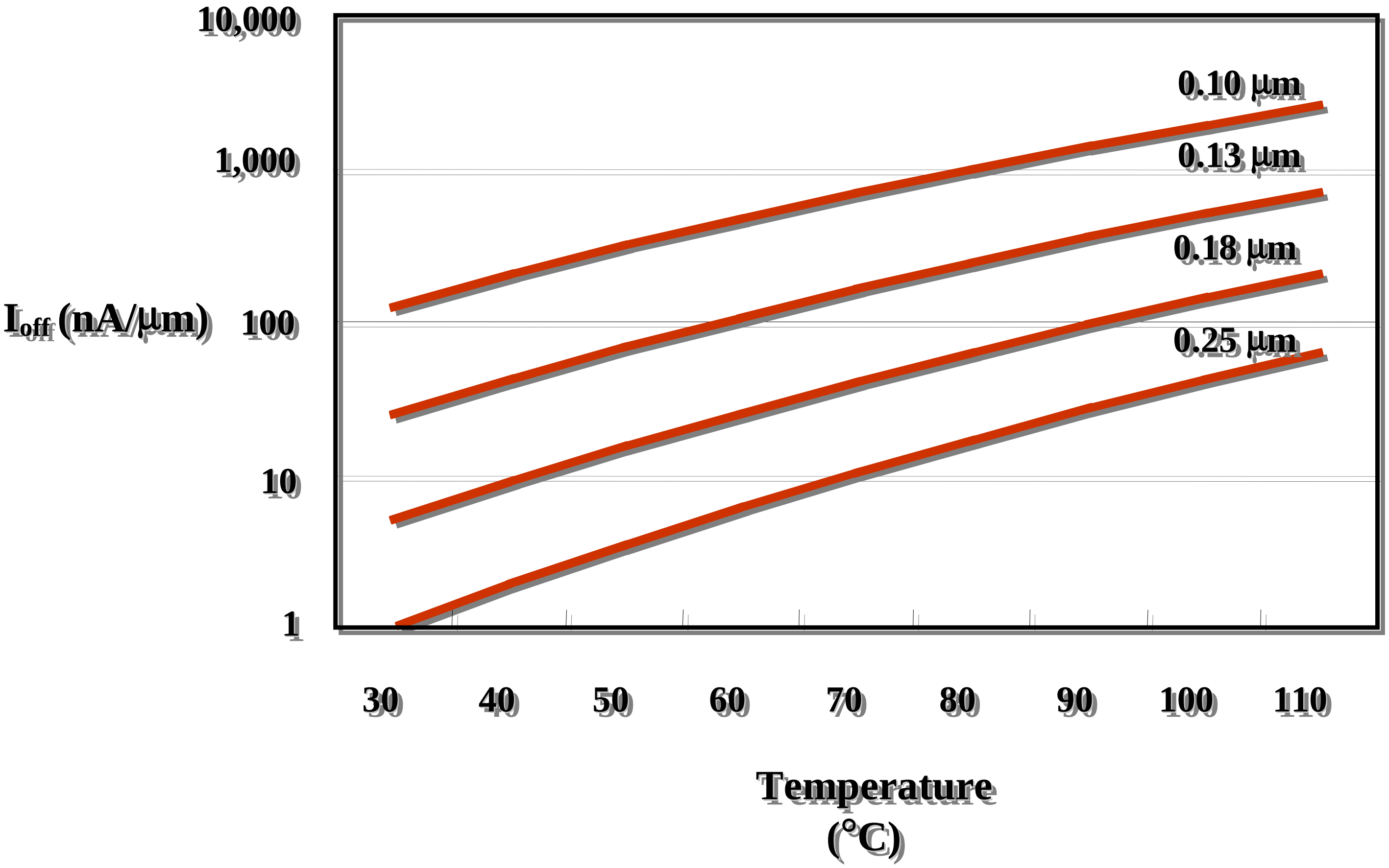
Fallah and Pedram, Power Aware Design Methodologies, 2002

Leakage Current Growth with Temperature

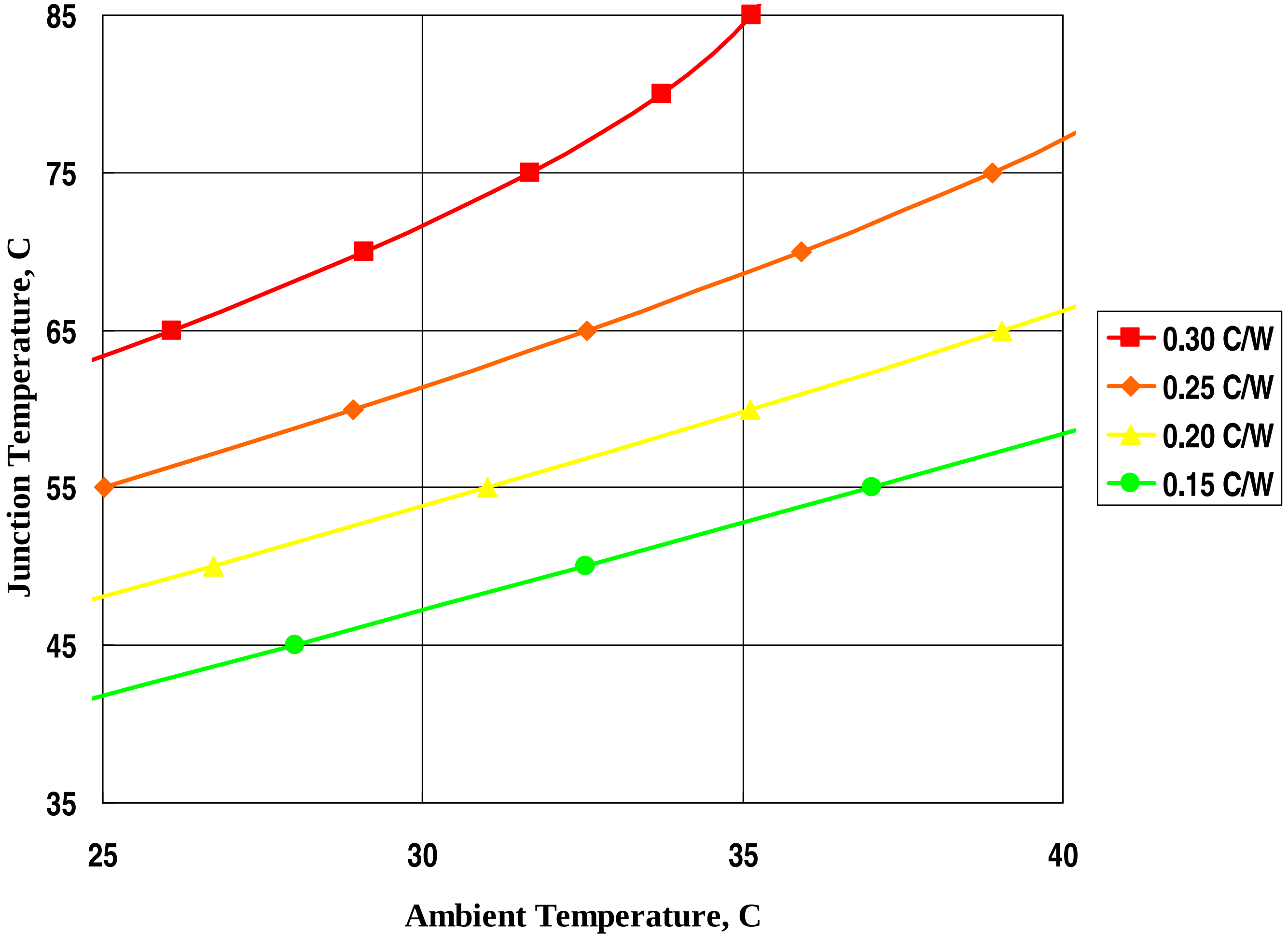


Fallah and Pedram, Power Aware Design Methodologies, 2002

Leakage Current Growth of One Transistor

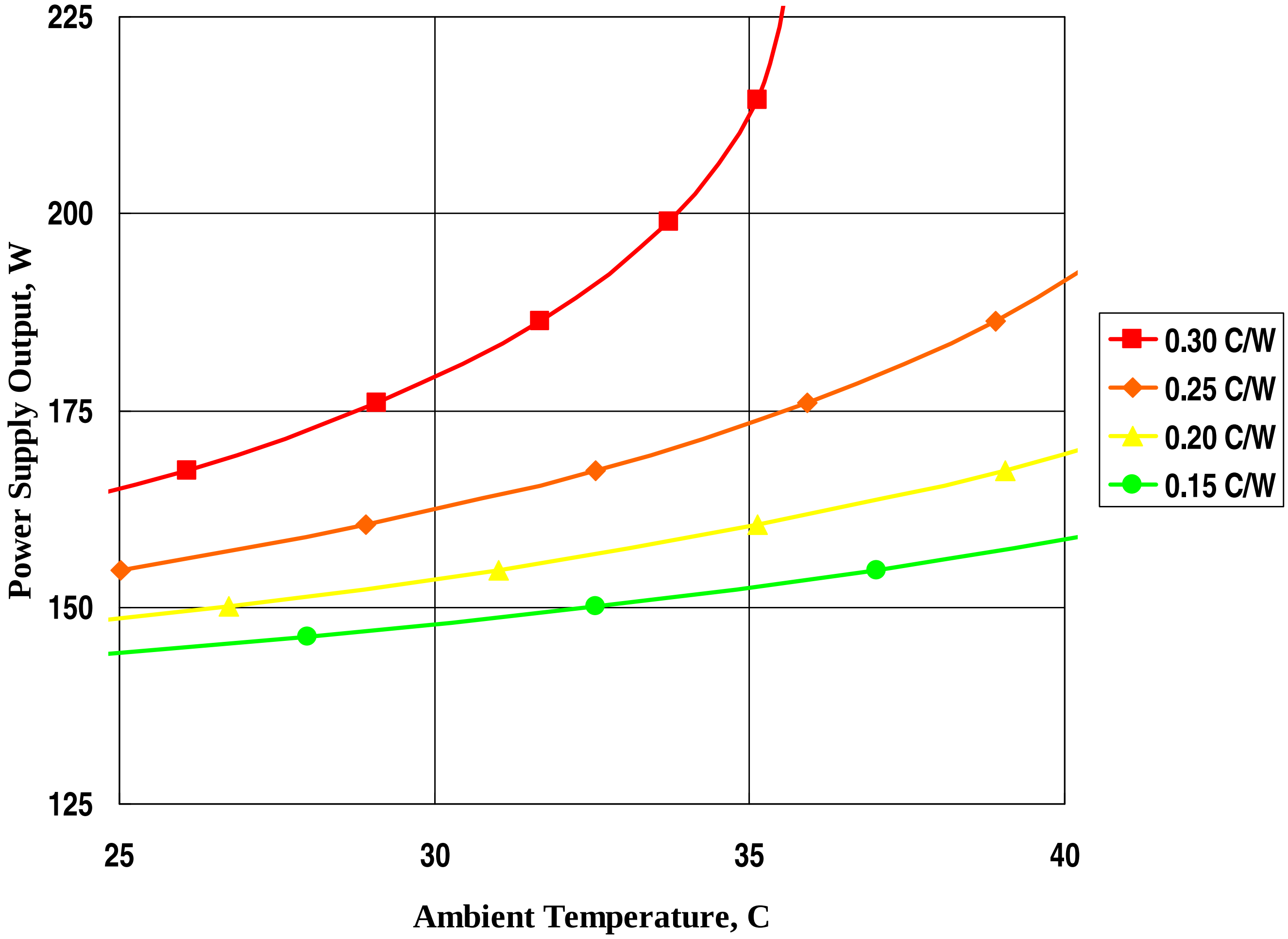


Fujitsu: Copeland and Chan, Thermal Management ATW 2003



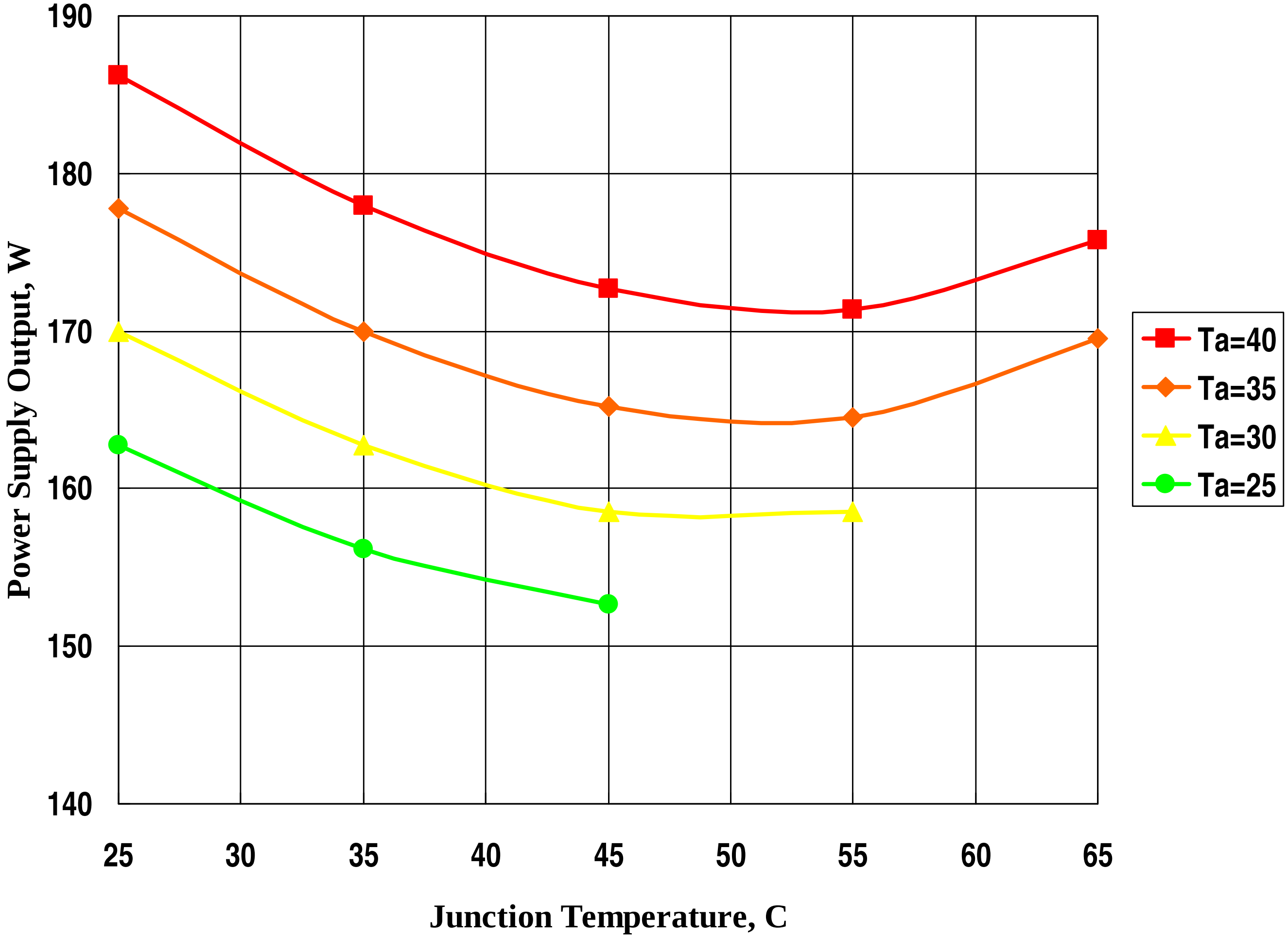
Effect of Thermal Resistance on Junction Temperature

Copeland and Chan, Thermal ATW, 2003



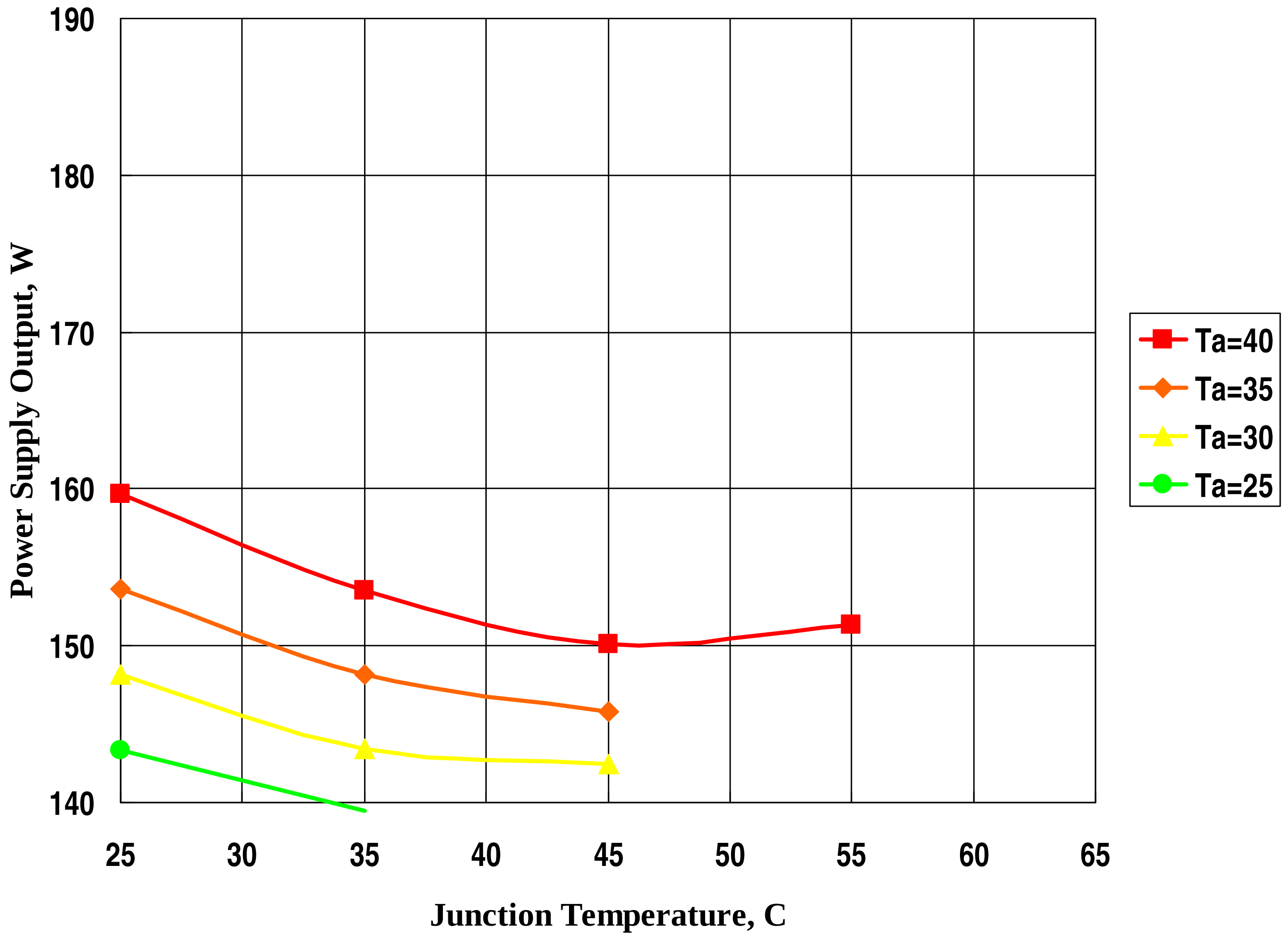
Effect of Thermal Resistance on Power Supply Output

Copeland and Chan, Thermal ATW, 2003



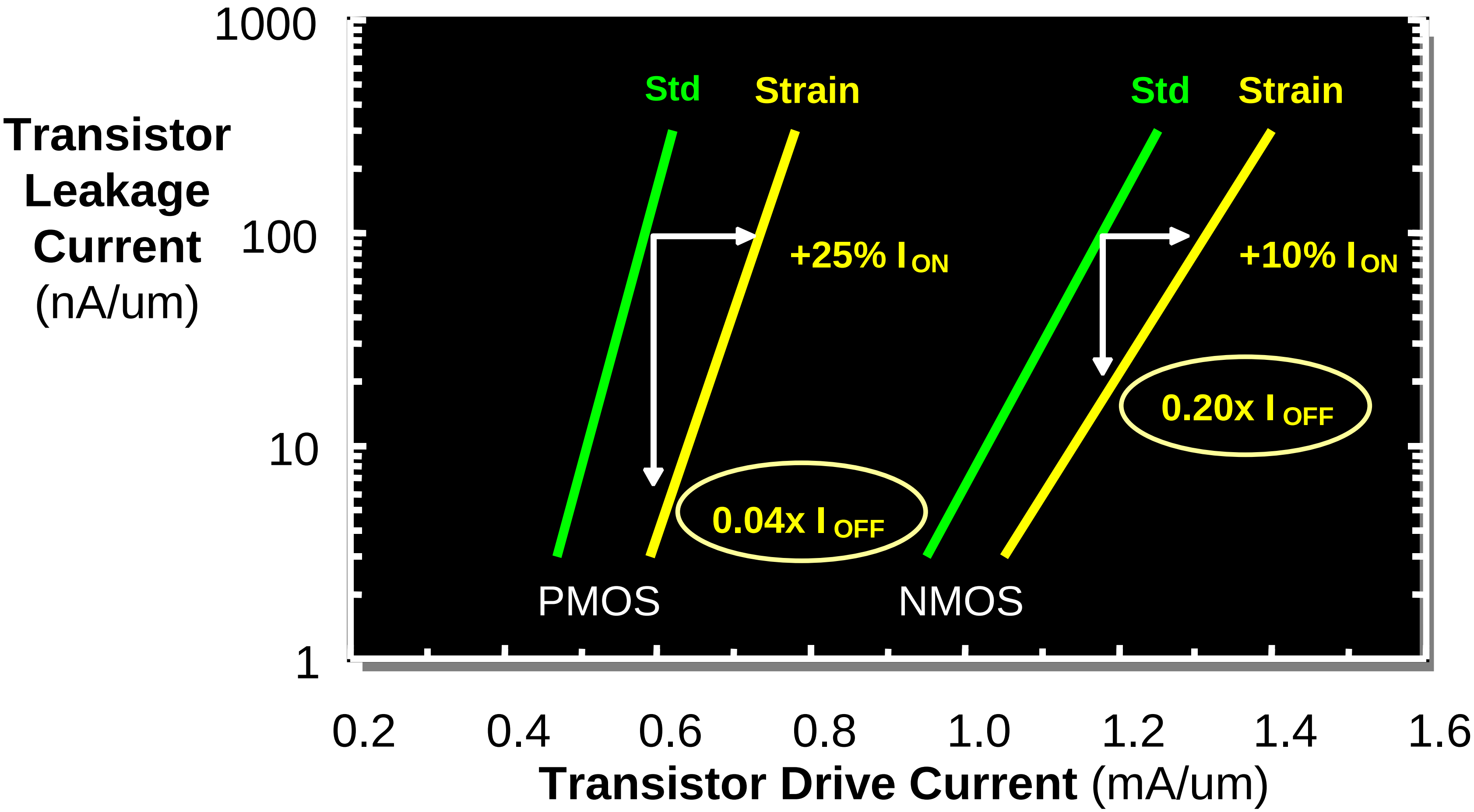
Effect of Junction and Ambient Temperatures on Power (Θ = 0.30 C/W)

Copeland and Chan, Thermal ATW, 2003



Effect of Junction and Ambient Temperatures on Power (Θ = 0.15 C/W)

Intel: Mahajan, IEPS 2004



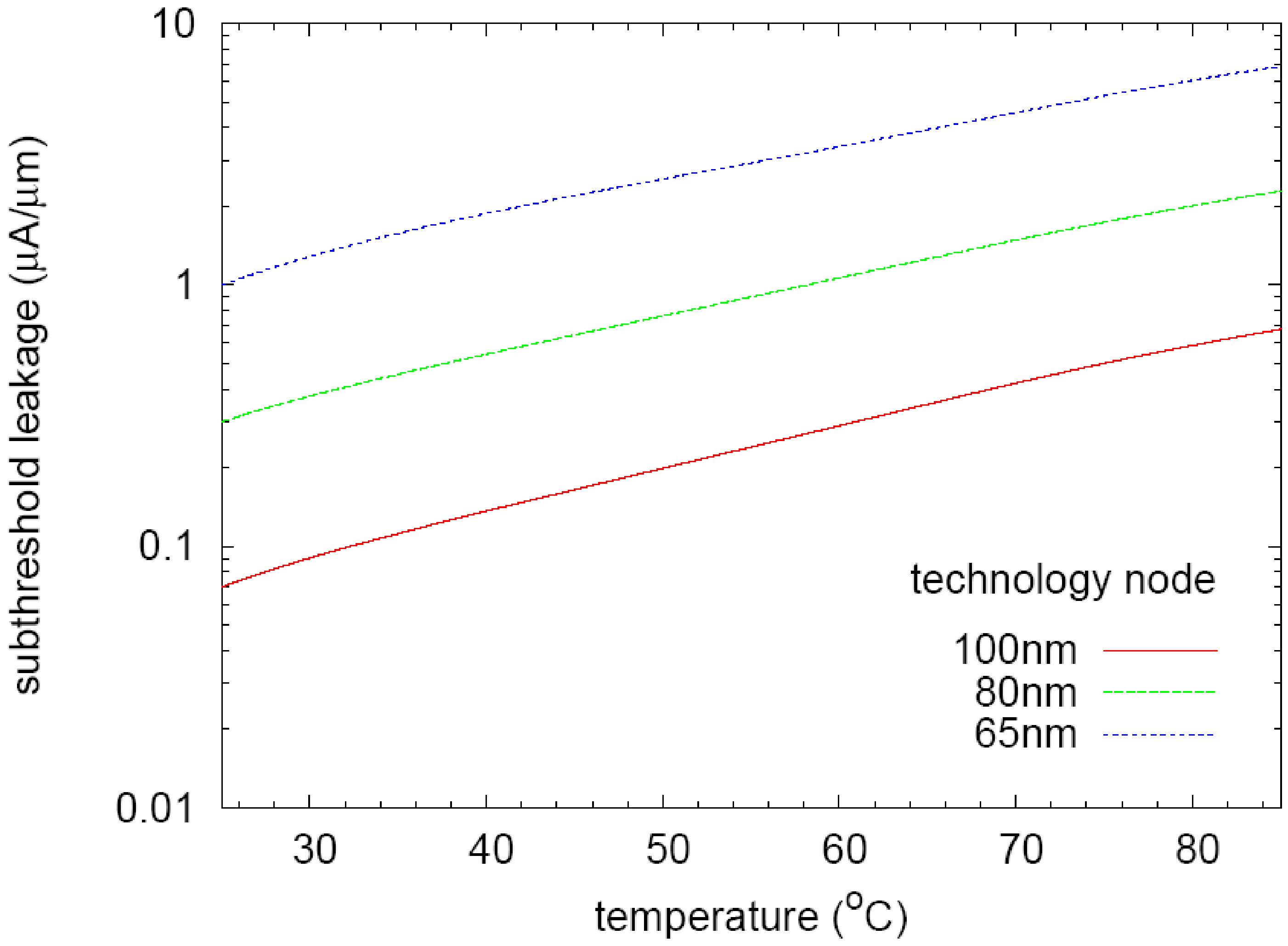
5x to 20 Reduction in Transistor Leakage Power

Fujitsu: Copeland and Chan, Itherm 2004

International Technology Roadmap for Semiconductors 64-bit microprocessors (2002 update)

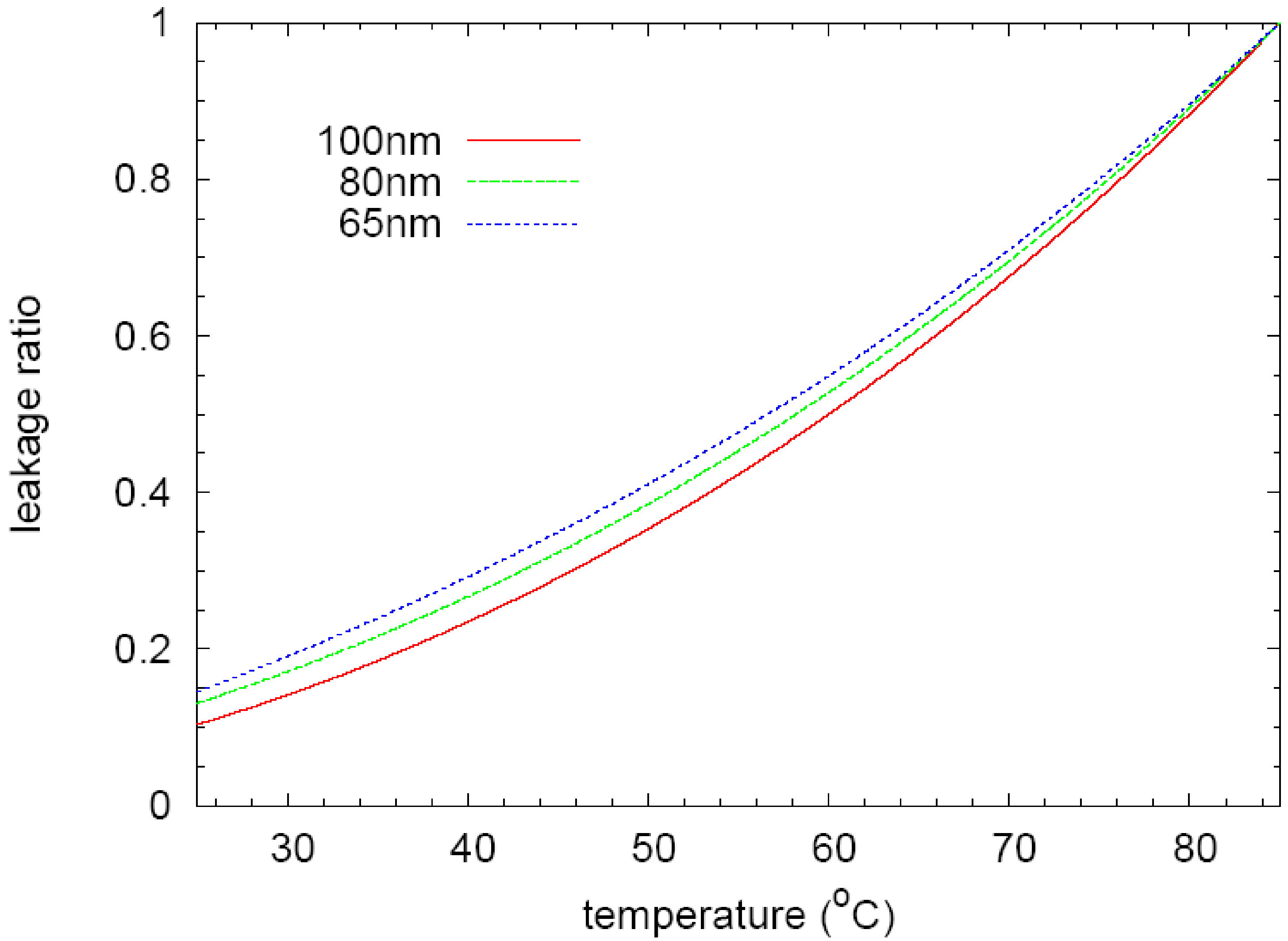
Technology	2003	2005	2007
Node (nm)	100	80	65
Die size (mm)	17.6	17.6	17.6
Power (W)	150	170	190

Copeland and Chan, Itherm 2004



Estimated Subthreshold Leakage Over the Near Term

Copeland and Chan, Itherm 2004

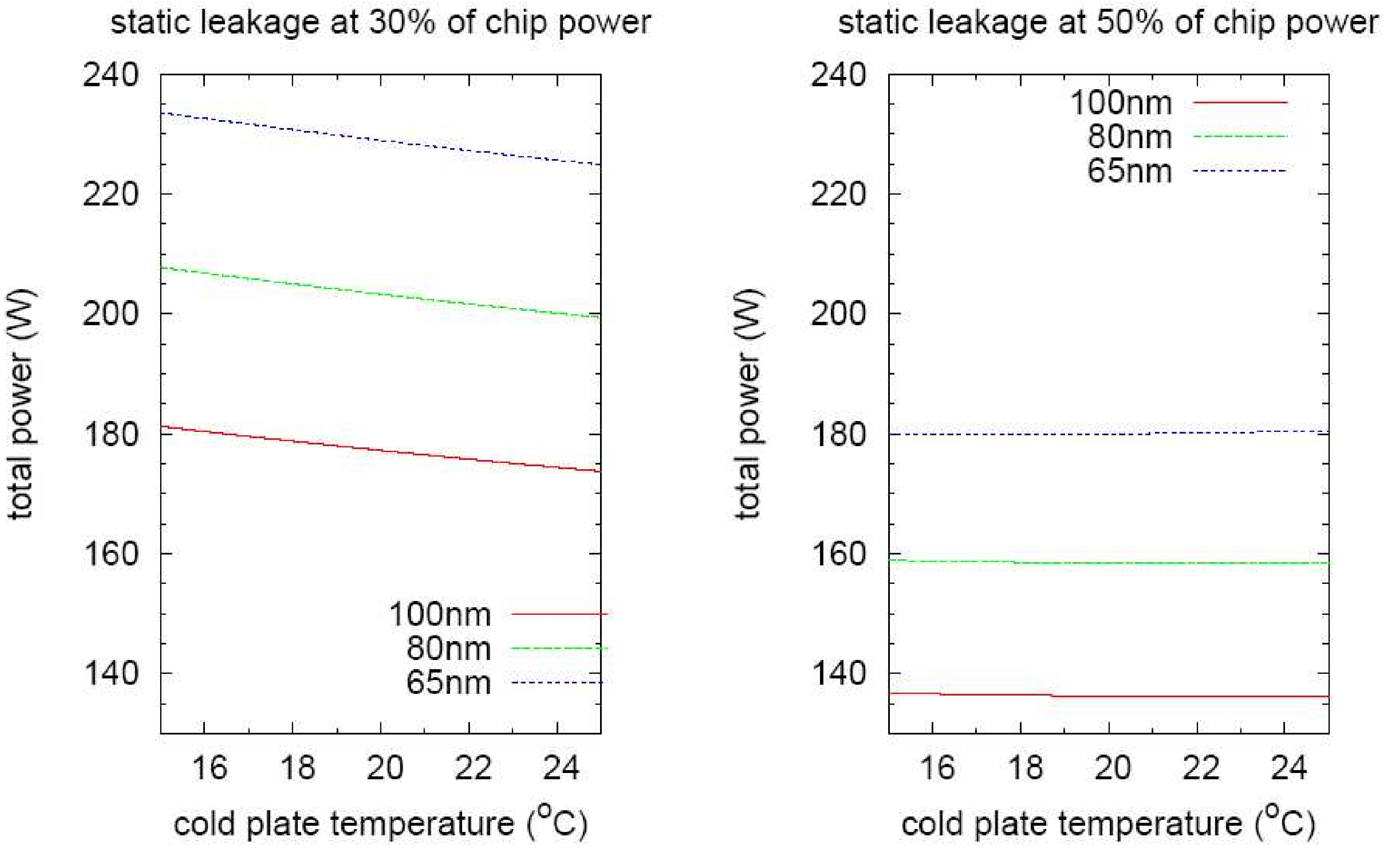


Ratio of Leakage Current Relative to 85 C

Copeland and Chan, Itherm 2004

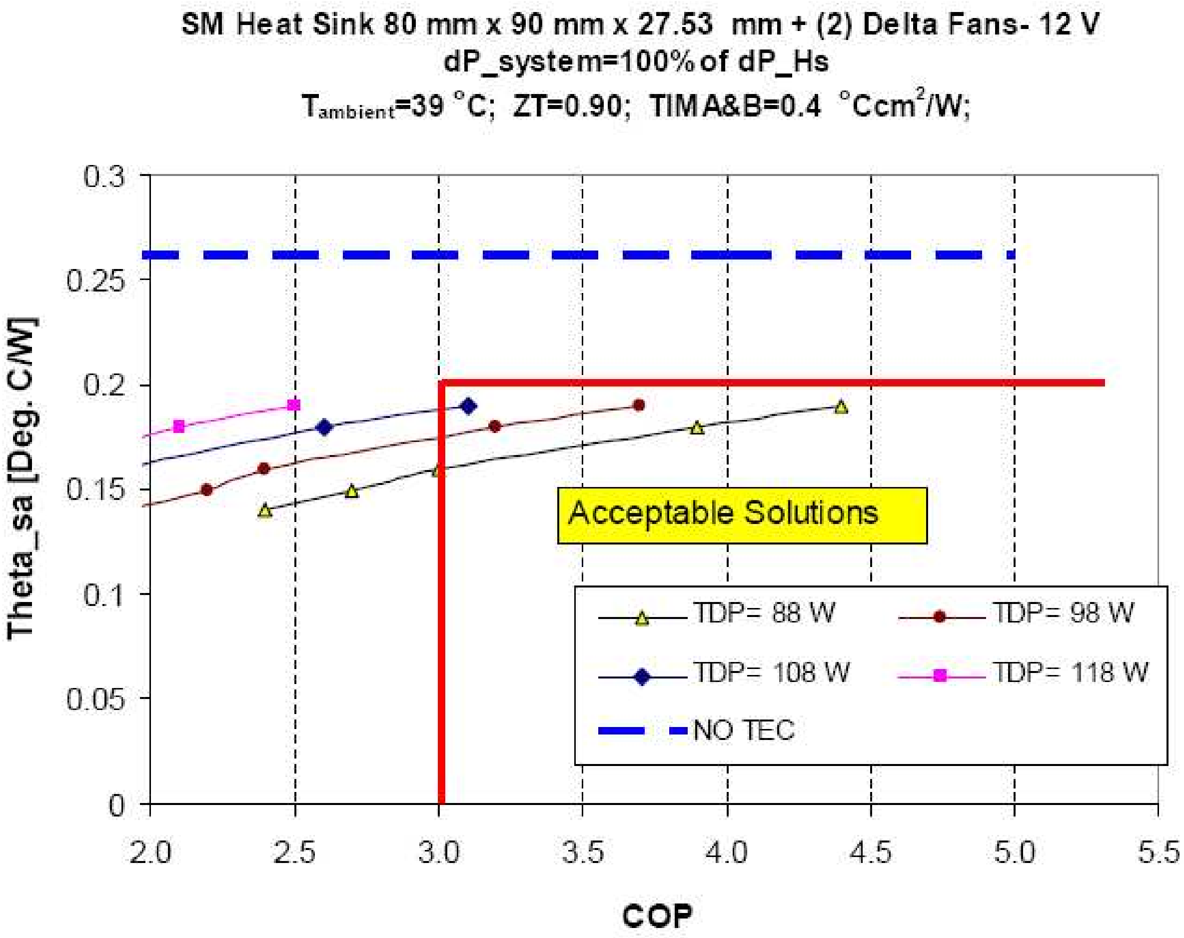
Temperature C	15	20	25
Pressure MPa	0.488	0.572	0.665
Heat kJ/kg	105.6	108.3	110.9
Work kJ/kg	28.7	25.3	22.2
COP ideal	3.68	4.28	5.00
COP actual	2.21	2.57	3.00

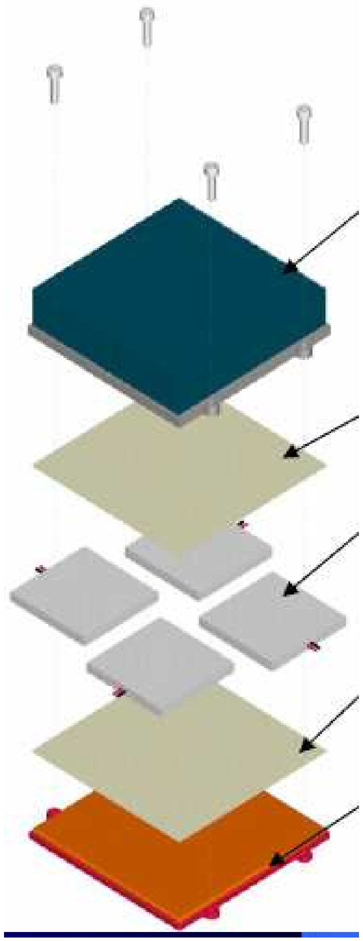
Copeland and Chan, Itherm 2004



Total Power for 30% and 50% Static Leakage Loss

Intel: Sauciuc *et al*., ITS 2004

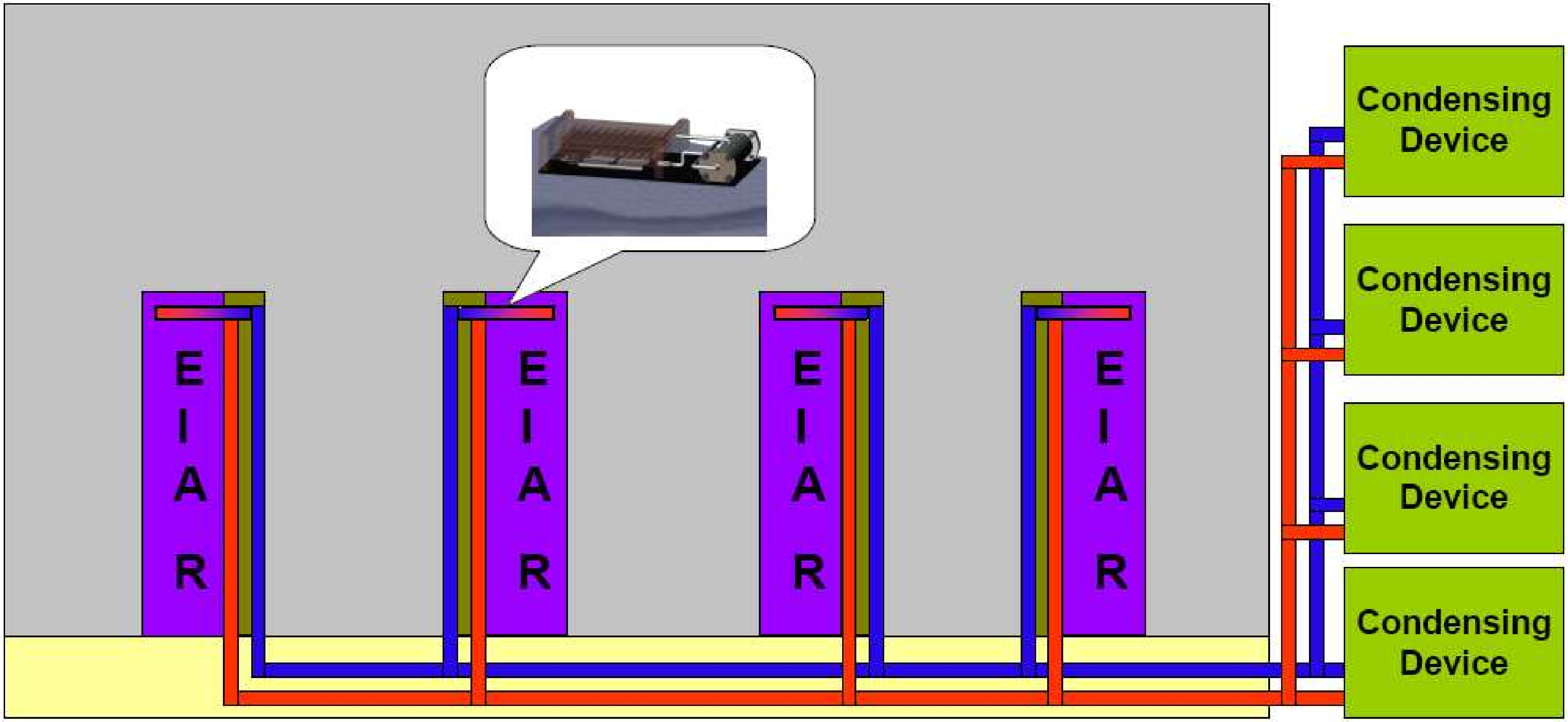




1U Thermal Performance–
Using Solid Metal Spreader and Several TECs

Sun: Gektin and Heydari, Interpack 2003

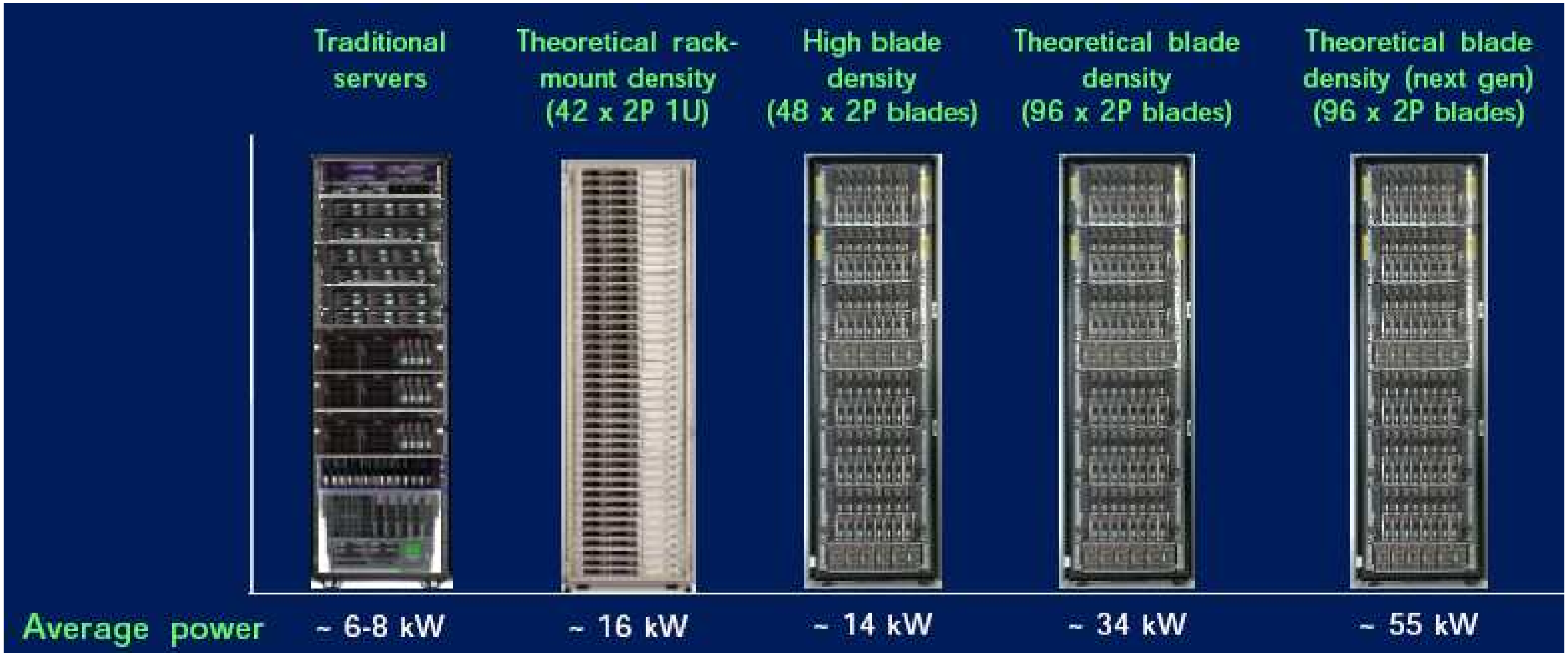
Refrigeration Cooled Module utilizing Refrigerant Cooled Heat Sinks and Remote Condensing Devices



🟦 Cold Refrigerant flow

🟥 Hot Refrigerant flow

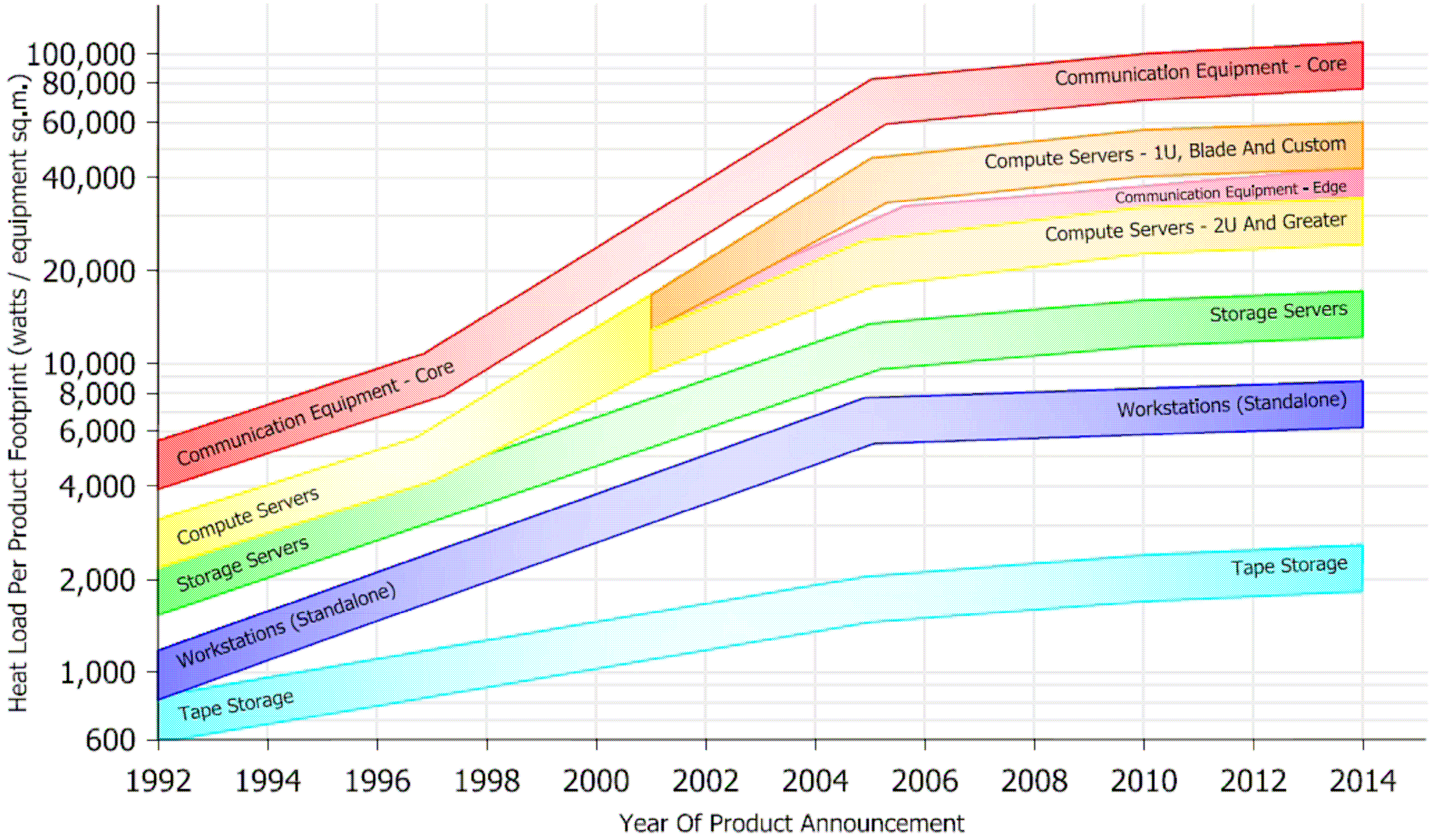
Hewlett-Packard: Mouton, Server Blade Summit 2004



	Traditional servers	Theoretical rack-mount density (42 x 2P 1U)	High blade density (48 x 2P blades)	Theoretical blade density (96 x 2P blades)	Theoretical blade density (next gen) (96 x 2P blades)
Average power	~ 6-8 kW	~ 16 kW	~ 14 kW	~ 34 kW	~ 55 kW

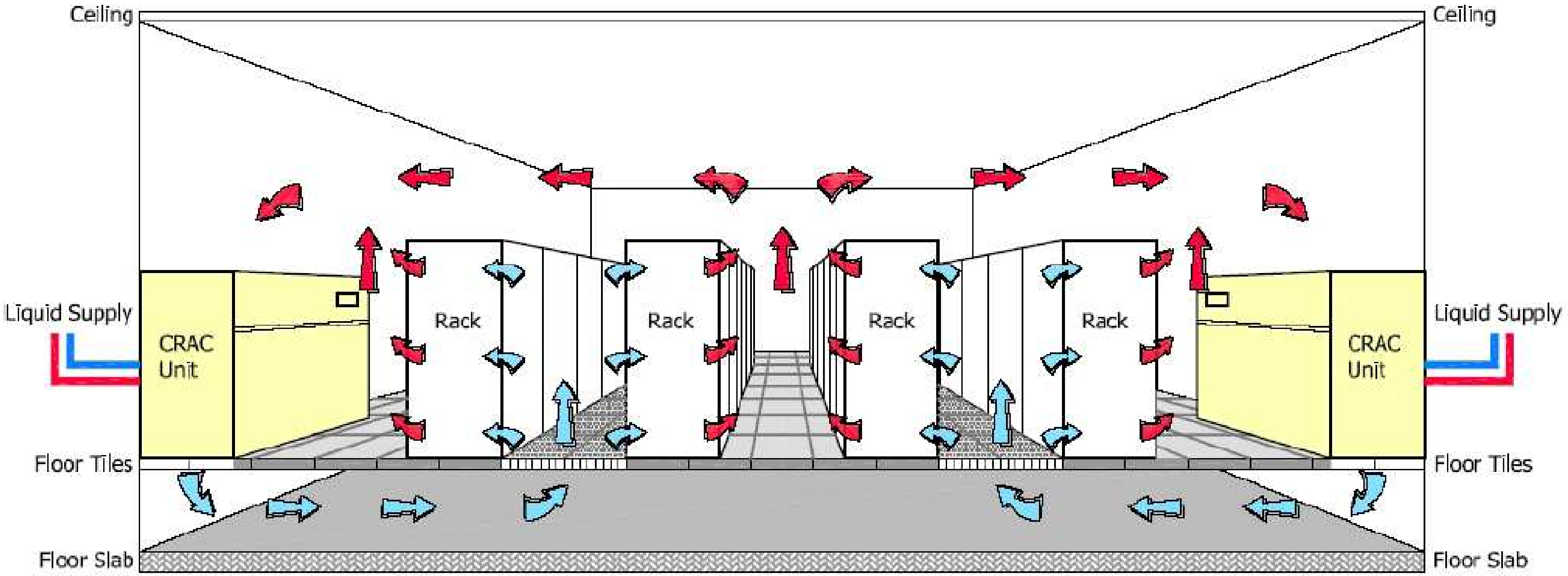
Increase in Power per Rack with Technology Advancements

Datacom Equipment Power Trends and Applications, 2004



New ASHRAE Updated and Expanded Power Trend Chart

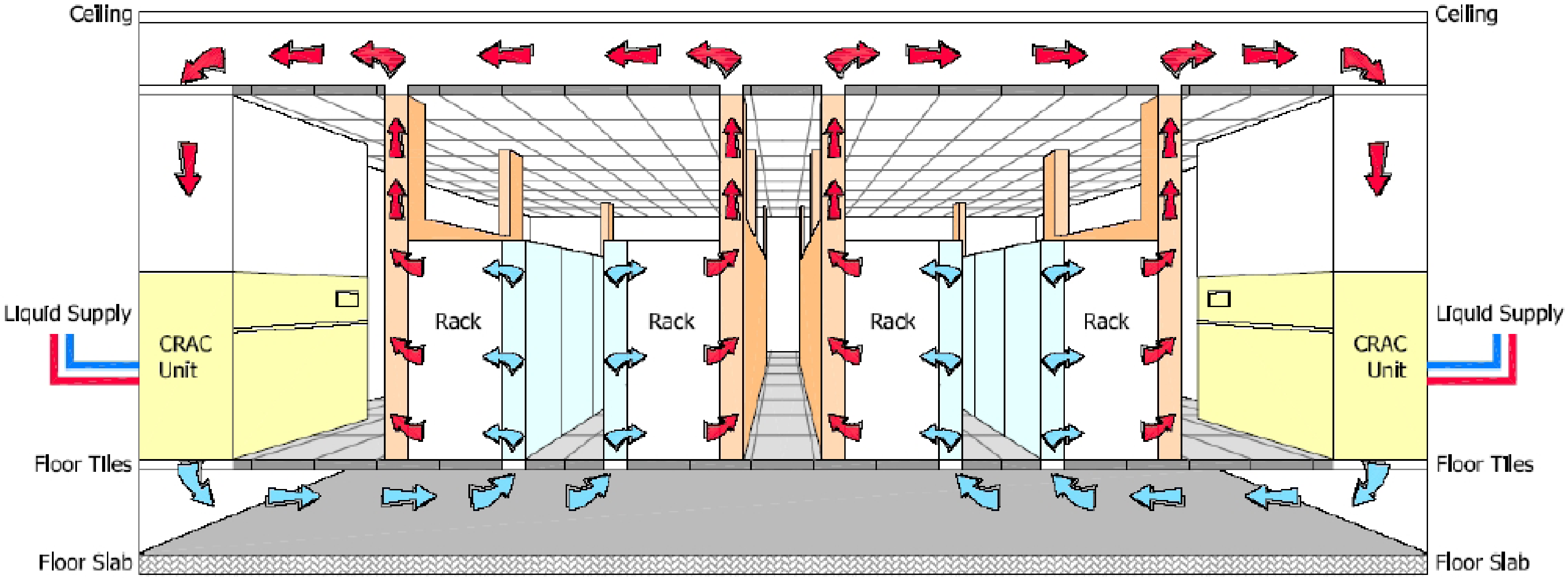
Datacom Equipment Power Trends and Applications, 2004



Raised Floor Implementation Most Commonly Found in Data Centers Today Using CRACs

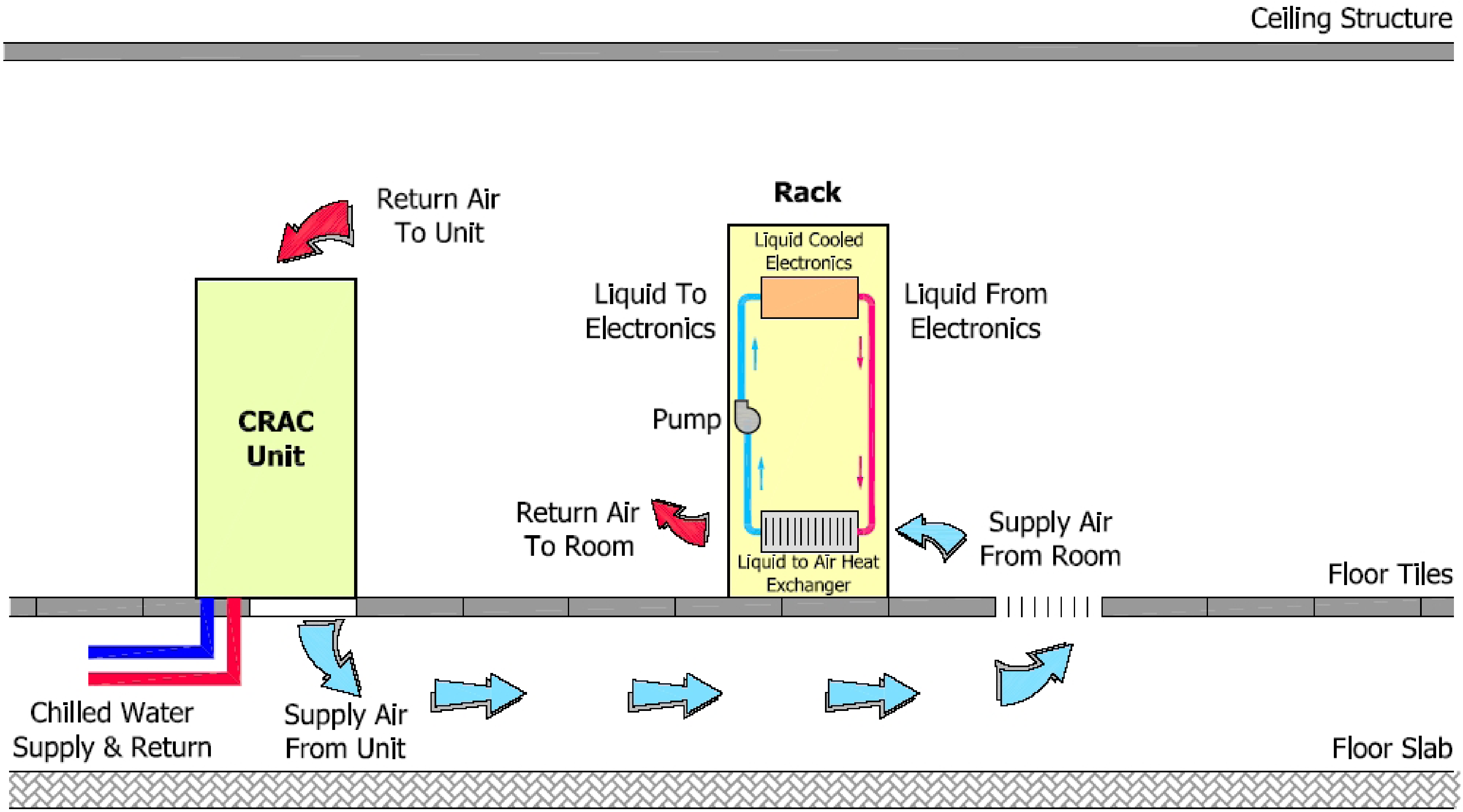
THE POSSIBILITIES ARE INFINITE

Datacom Equipment Power Trends and Applications, 2004



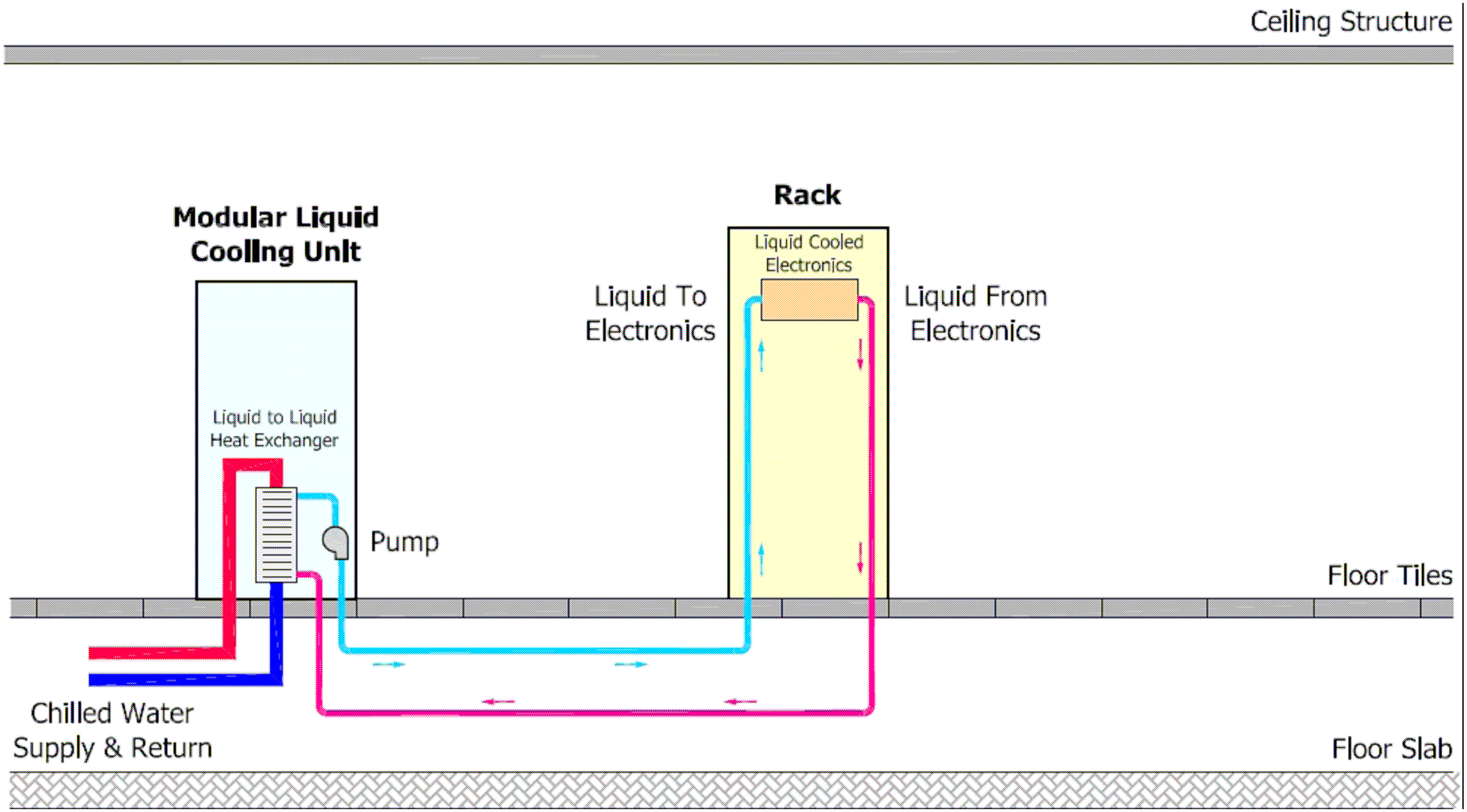
Raised Floor Implementation Using Inlet and Outlet Plenums / Ducts Integral to the Rack

Datacom Equipment Power Trends and Applications, 2004



Internal Liquid Cooling Loop Restricted to Within Rack Extents

Datacom Equipment Power Trends and Applications, 2004



Internal Liquid Cooling Loop Extended To Liquid Cooled External Modular Cooling Unit

64-bit Server Cooling Requirements

- **Power Dissipation and Distribution**
  - Multiple core processors
- **Temperature Dependence of Power**
  - Increasing leakage power
- **Power Reduction by Refrigeration**
  - Lower total power consumption
- **Air- to Water Cooling Migration**
  - More direct path to building water