

Power Technology Roadmap for Microprocessor Voltage Regulators

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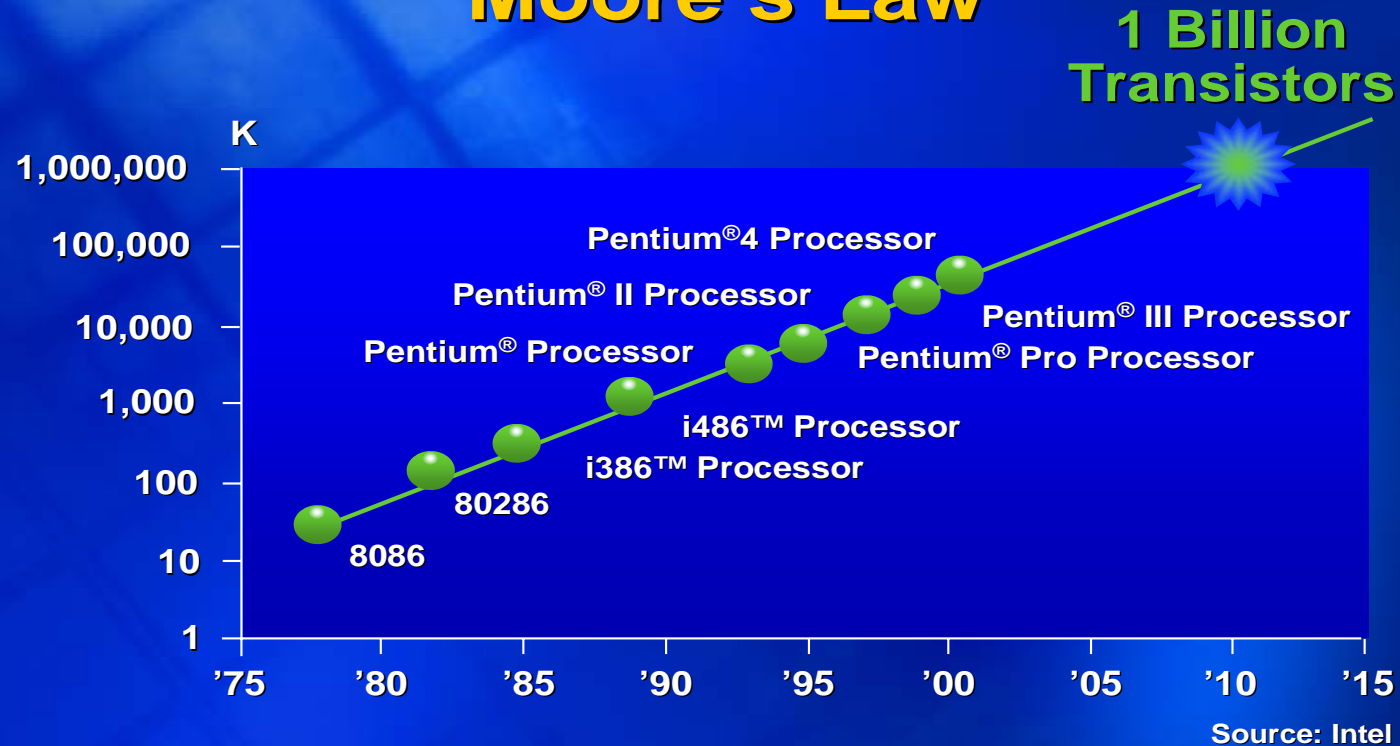
Outline

1. Introduction
2. CPU Power Road Map
 - Power & Thermals
 - Current & Voltage scaling
 - Voltage regulator Impedance
3. VR Technology drivers
4. System Level Power Supply trends
 - System chassis shrinking
 - Power Supply Density
5. Conclusions

Increasing complexity...

Voltage Regulator Technology for
Microprocessor Power Delivery

Moore's Law

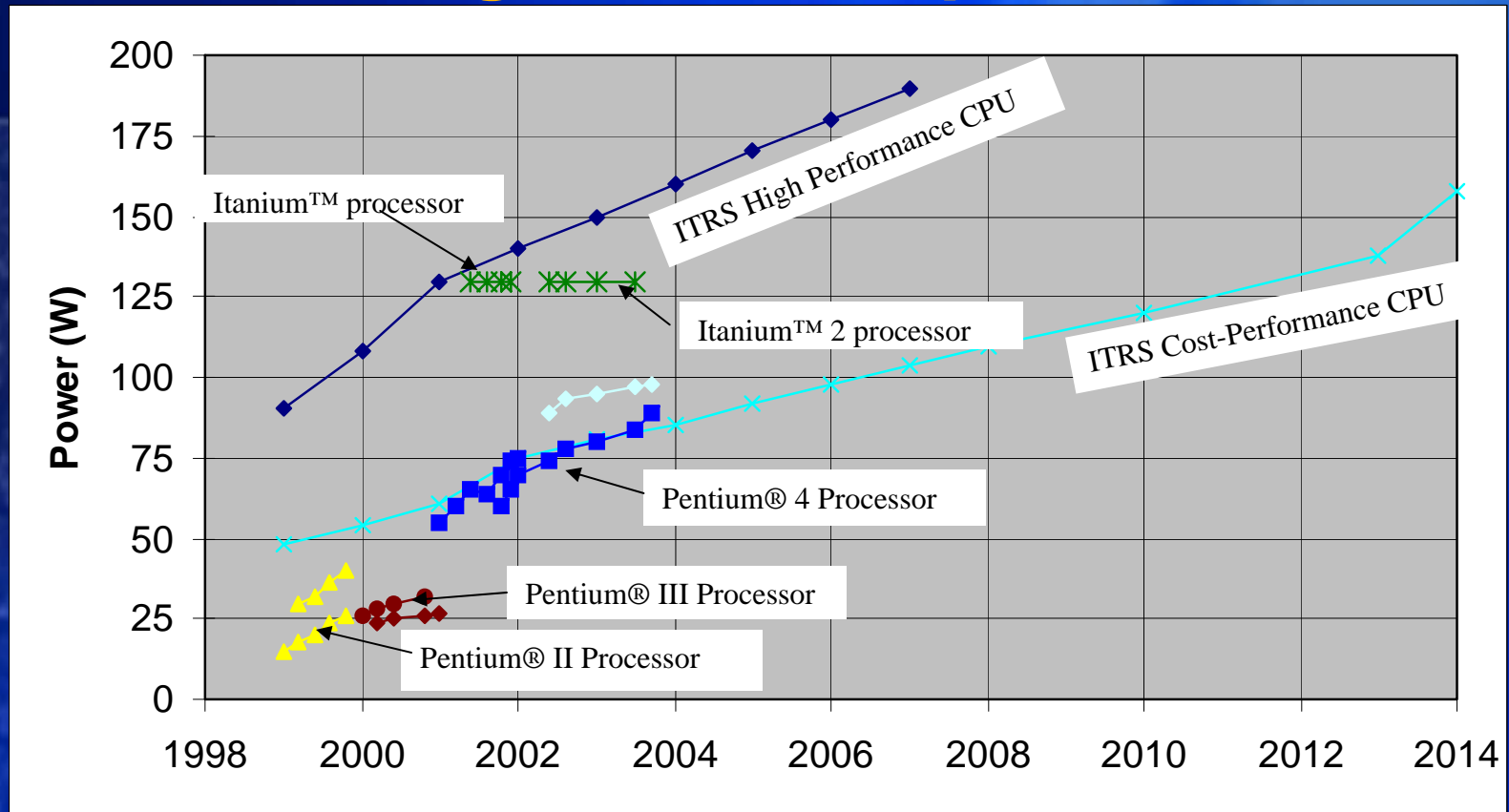


***The Number of Transistors Per Chip
Will Double Every 18 Months***

intel.

intel.

... Increasing Power Requirements



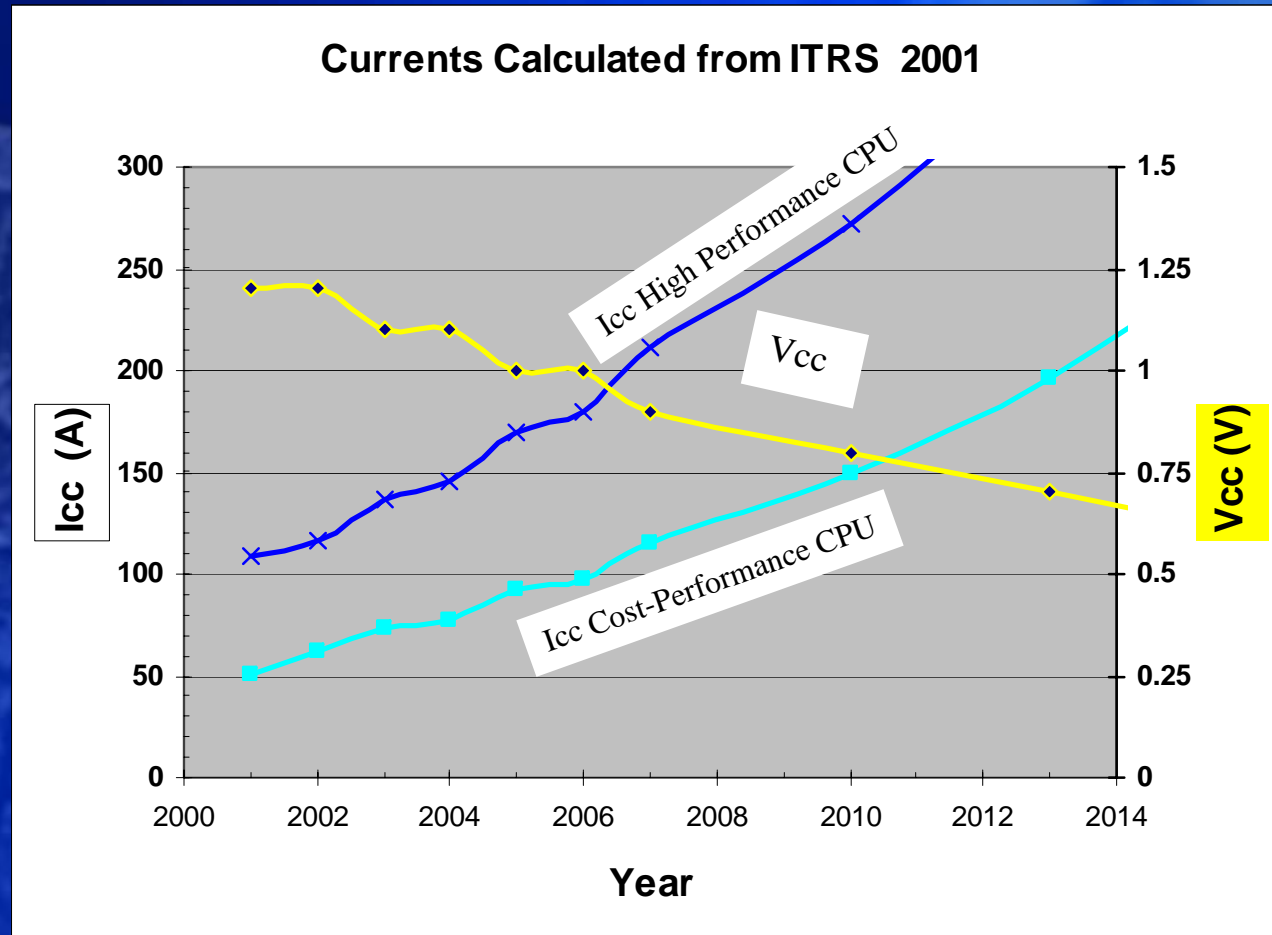
- Intel processors fall within the TRS power road map window.
- 100 W+ processors in 2006.

Source : Intel and 2001 International Technology Roadmap for Semiconductors (ITRS)



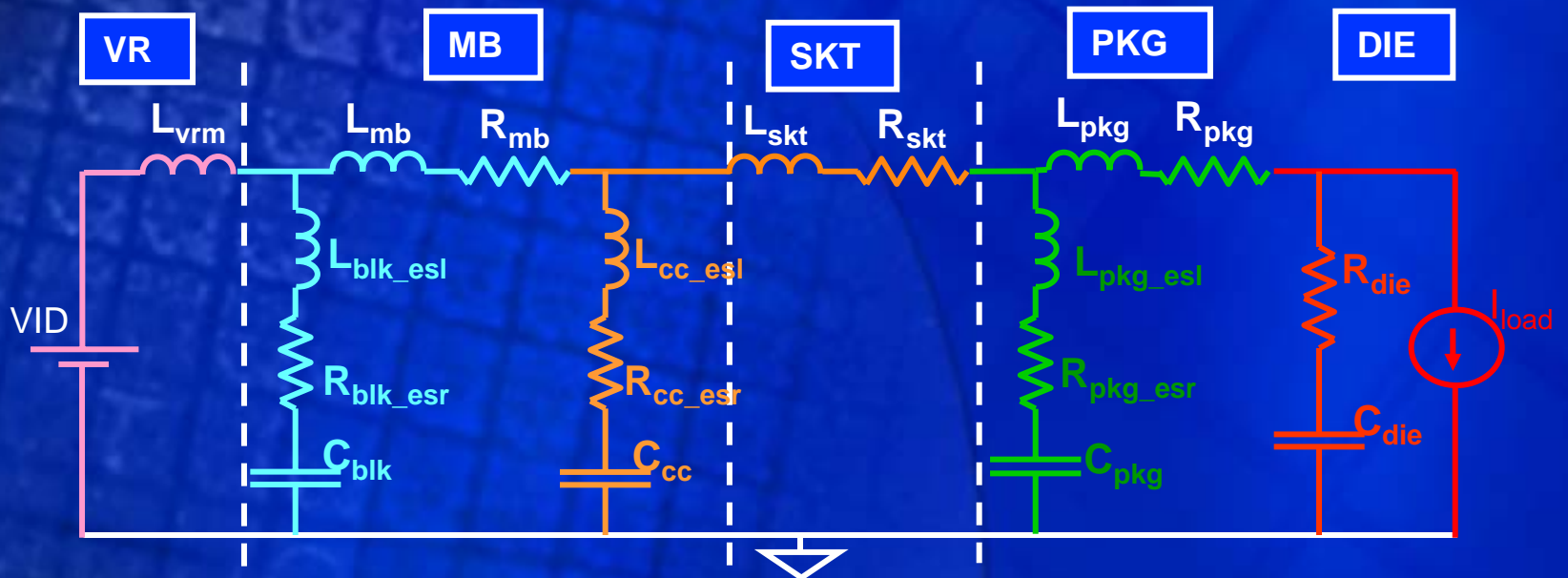
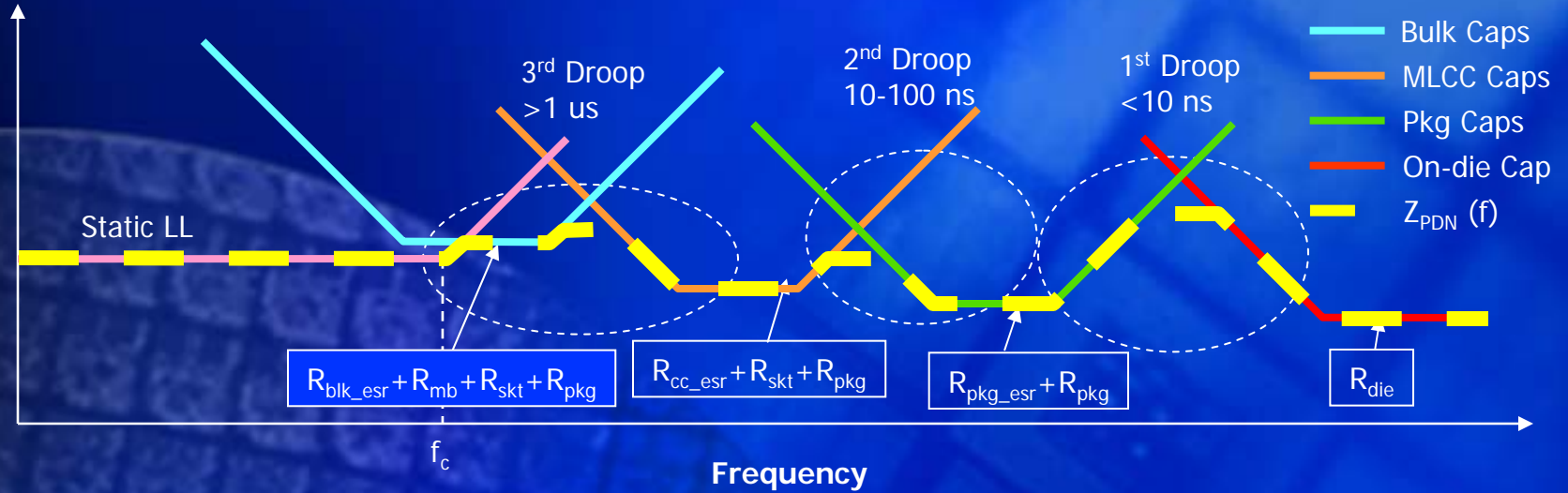
Higher Currents, Lower Voltages...

Voltage Regulator Technology for Microprocessor Power Delivery



- Voltage scaling ~ 1 V by 2006
- Currents scaling to 100-175 A ~ 2006-2009
- Power Delivery System Impedance dropping below 1 m Ω ~2008

VR Impedance & Load Line definition



Voltage Regulator Technology for
Microprocessor Power Delivery

Output Current & Impedance Drive VR technology

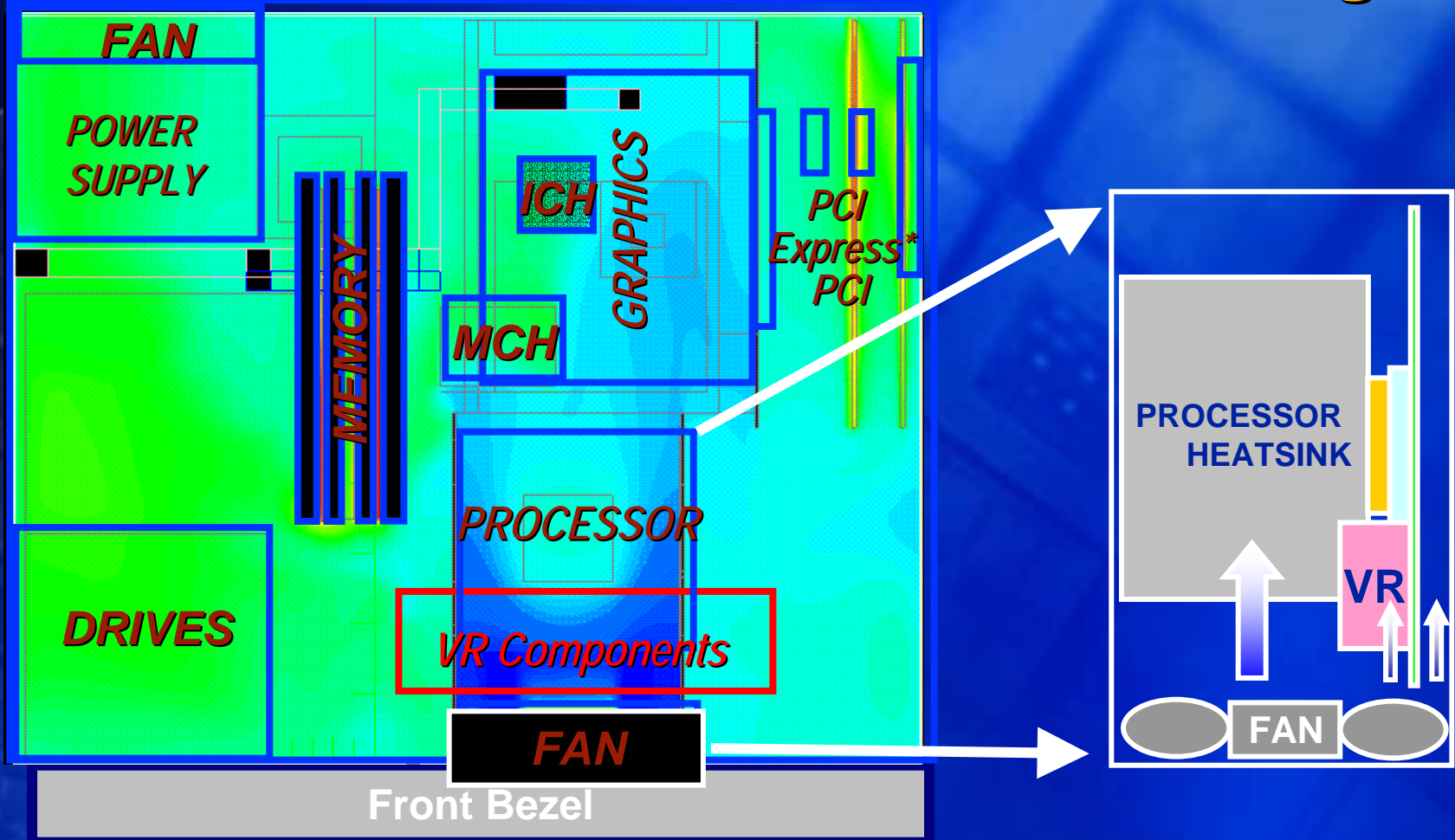
- Impedance is determined by
 - Capacitor technology (ESR, ESL, C)
 - Layout & socket parasitics
 - VR loop bandwidth & response time
 - Switching Frequency
 - Control Techniques
 - Cost effective designs balance capacitor vs. silicon technologies
- High currents & total power drive
 - Optimize gate drive voltages – small changes in drive voltage (IE from 12 V to 8 V) can change efficiency 2-4%
 - Different MOSFETs, different frequencies require optimization
 - Advanced, low loss MOSFETS ($1 \text{ m}\Omega$ R_{dson} , $<20 \text{ nQ}$ Q_{g})
 - New topologies or input voltage changes will be required for $> 150\text{W}$

VR Cooling

- **Optimize # Phases**
 - Paralleling more than 3 MOSFETs may not be the answer
 - Driver cannot drive high C loads & slows down, creating more loss
 - Layout parasitics, R_{gate} tolerance create current imbalance FETS don't current share
 - Lower current per phase, smaller & lower cost inductors can be used
- **Lowest R_{DSon}, SMD packages (Direct FET*, BGA FET*, etc.) require heat sinks & airflow to be effective**
- **New chassis & board form factors help direct airflow across VR components**

BTX Form Factor improves VR Cooling

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- BTX allows for effective airflow & temperature distribution
- See WWW.formfactors.org

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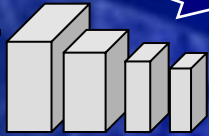
intel.

...Smaller System Chassis, Higher Density Power Supply

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Desktop

Smaller



Higher Performance
(75W+ graphic cards)

7-20 Liters



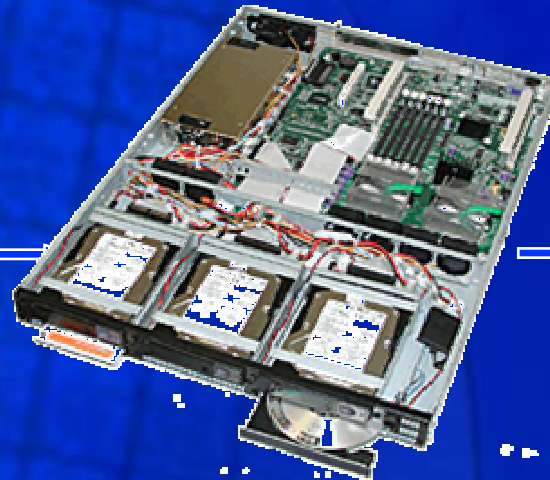
Optimized



for small size
& max airflow

Server

Space reduction
Redundant
Higher
Performance



Rack mount

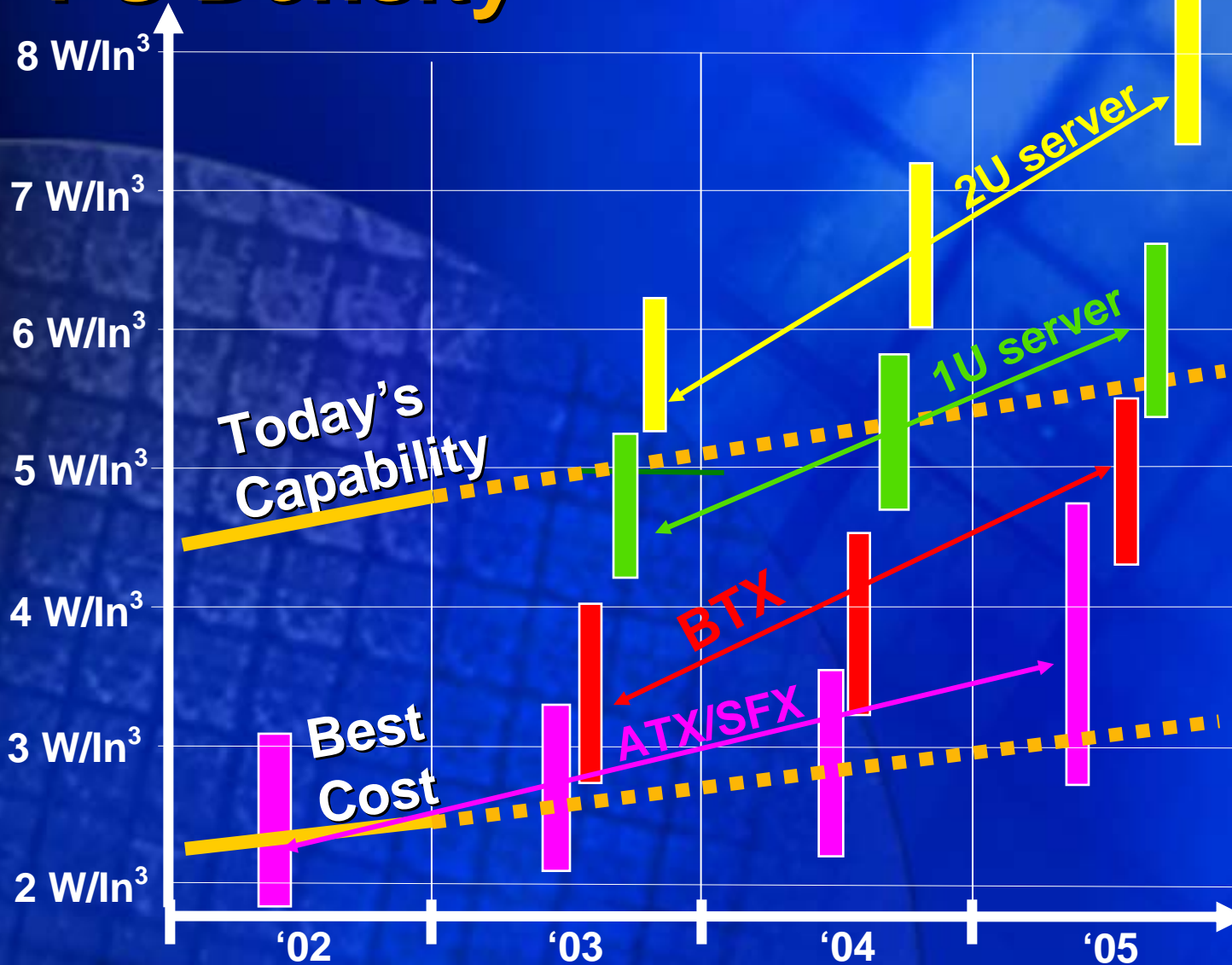


1U and 2U



PS Density

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1U & 2U servers exceed capability projections by 1-2.5 W/ln³



High Density PSU Drive

- Low loss boost diodes (SiC, etc.) for PFC
- > 150KHz boost PFC for smaller chokes
- High density bulk caps (>20uF/cc, 450V)
- Topology change from forward to half bridge, full bridge, or resonant to improve efficiency, lower power loss
- Synchronous rectifiers on output stage
- High density is in tension with low cost targets

Conclusions

- **100+ A Currents & 1 m Ω impedance drive both VR Silicon technology and capacitor technology**
- **Smaller chassis, higher power CPU and Graphics cards drive power supply density & efficiency**