M. DURANTON, **D. BLACK-SHAFFER**, S. YEHIA, K. DE BOSSCHERE

http://www.hipeac.net/roadmap

Part of the HiPEAC roadmap is required reading for AVDARK

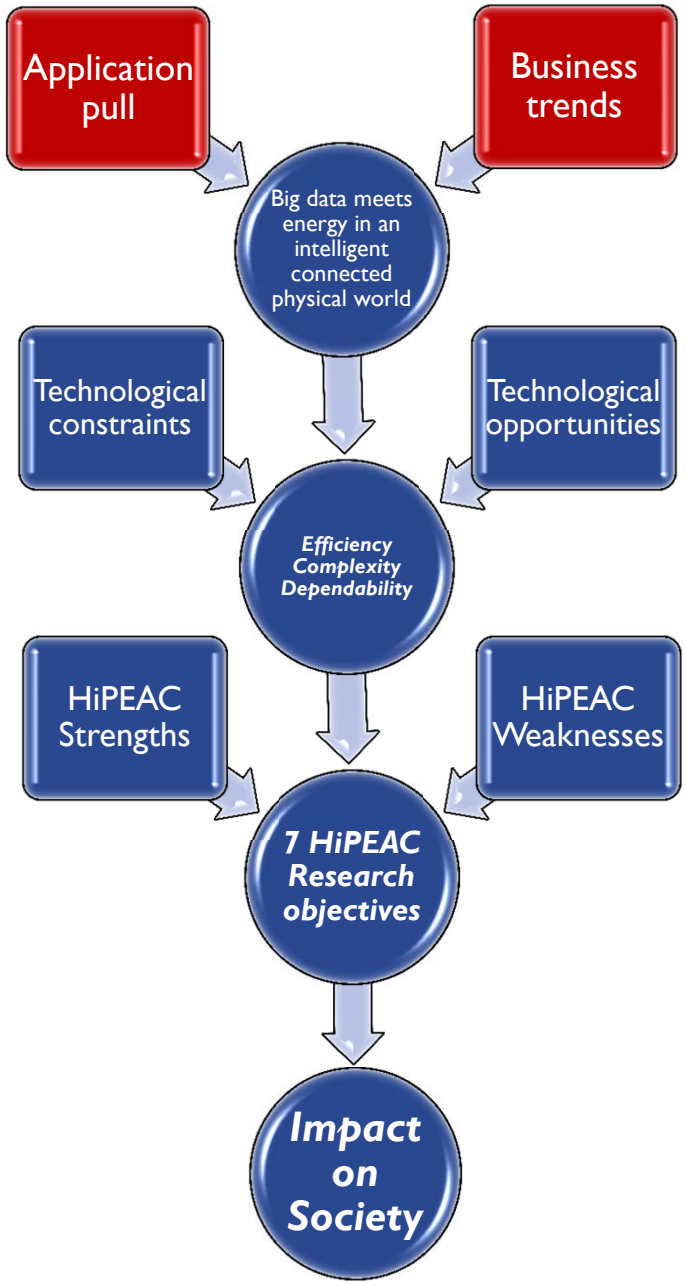
You will find it and other required reading in the ”Extra course papers” directory.

As specified in the ”Reading instructions”:

- page 2-33 are required reading
- page 34-40 read-through (RT)

http://www.hipeac.net/roadmap

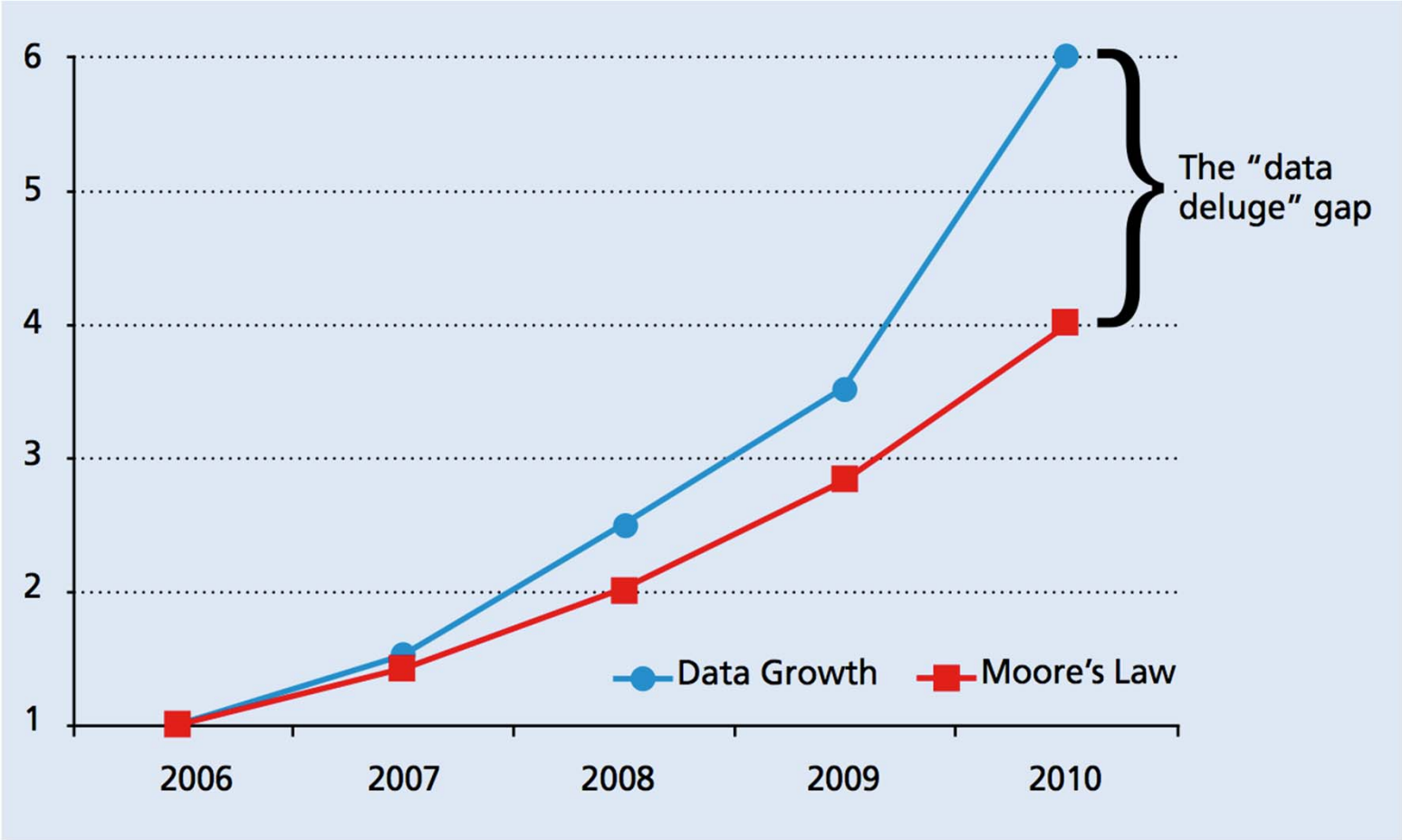
(These slides are a shortend and modified version of the official HiPEAC presentation)


Application pull
Business trends
Big data meets energy in an intelligent connected physical world
Technological constraints
Technological opportunities
Efficiency
Complexity
Dependability
HiPEAC Strengths
HiPEAC Weaknesses
7 HiPEAC Research objectives
Impact on Society

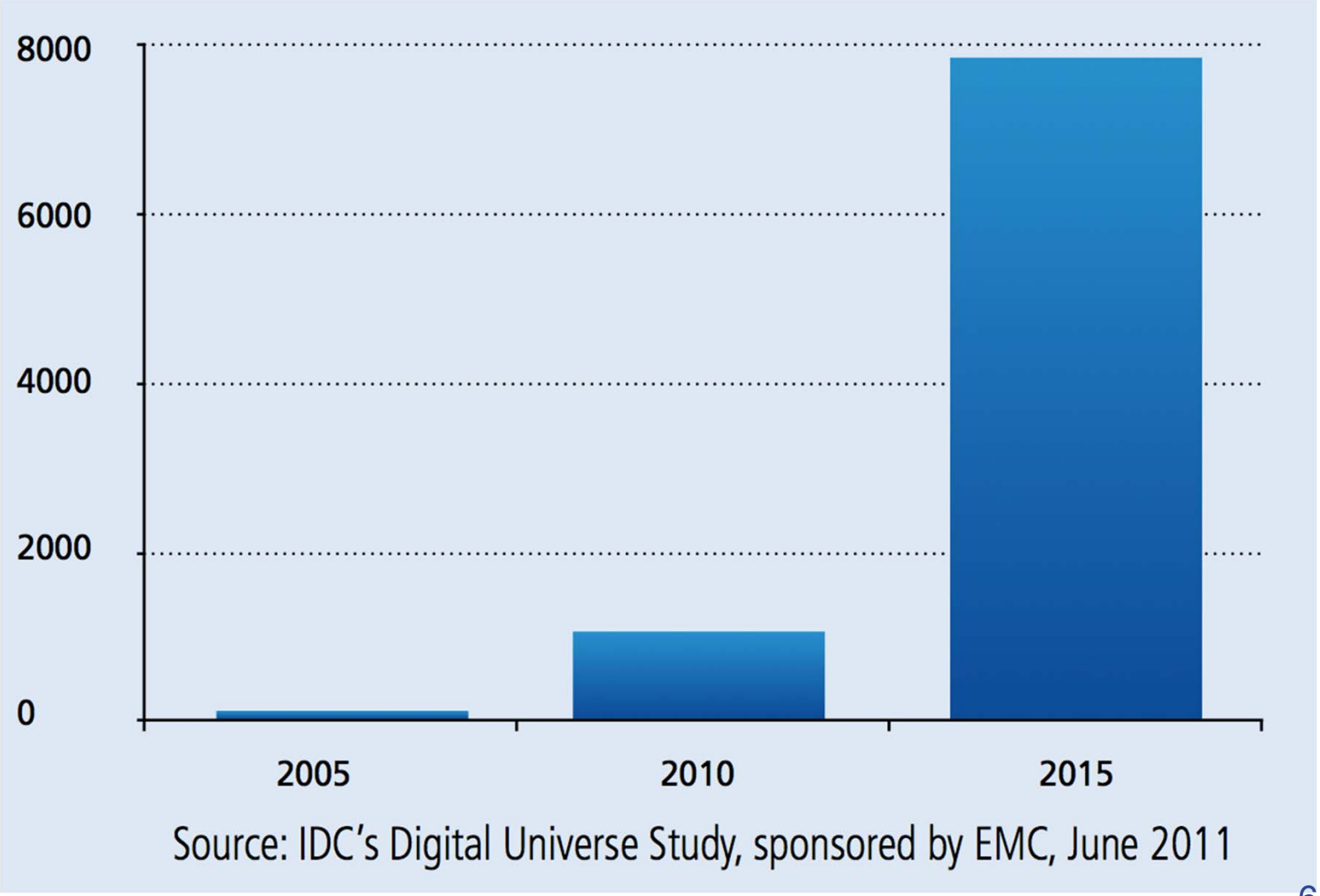
Trends influencing Computing Systems

Application Pull	Business Trends
• Data Deluge • Intelligent Processing • Ubiquitous Communication	• Convergence • Specialization • Post-PC Devices

Data Deluge


6
5
4
3
2
1
2006
2007
2008
2009
2010
The "data deluge" gap
Data Growth
Moore's Law

Growth of data storage in Exabytes



Intelligent processing of "natural" data

More and more applications are not only "number crunching"

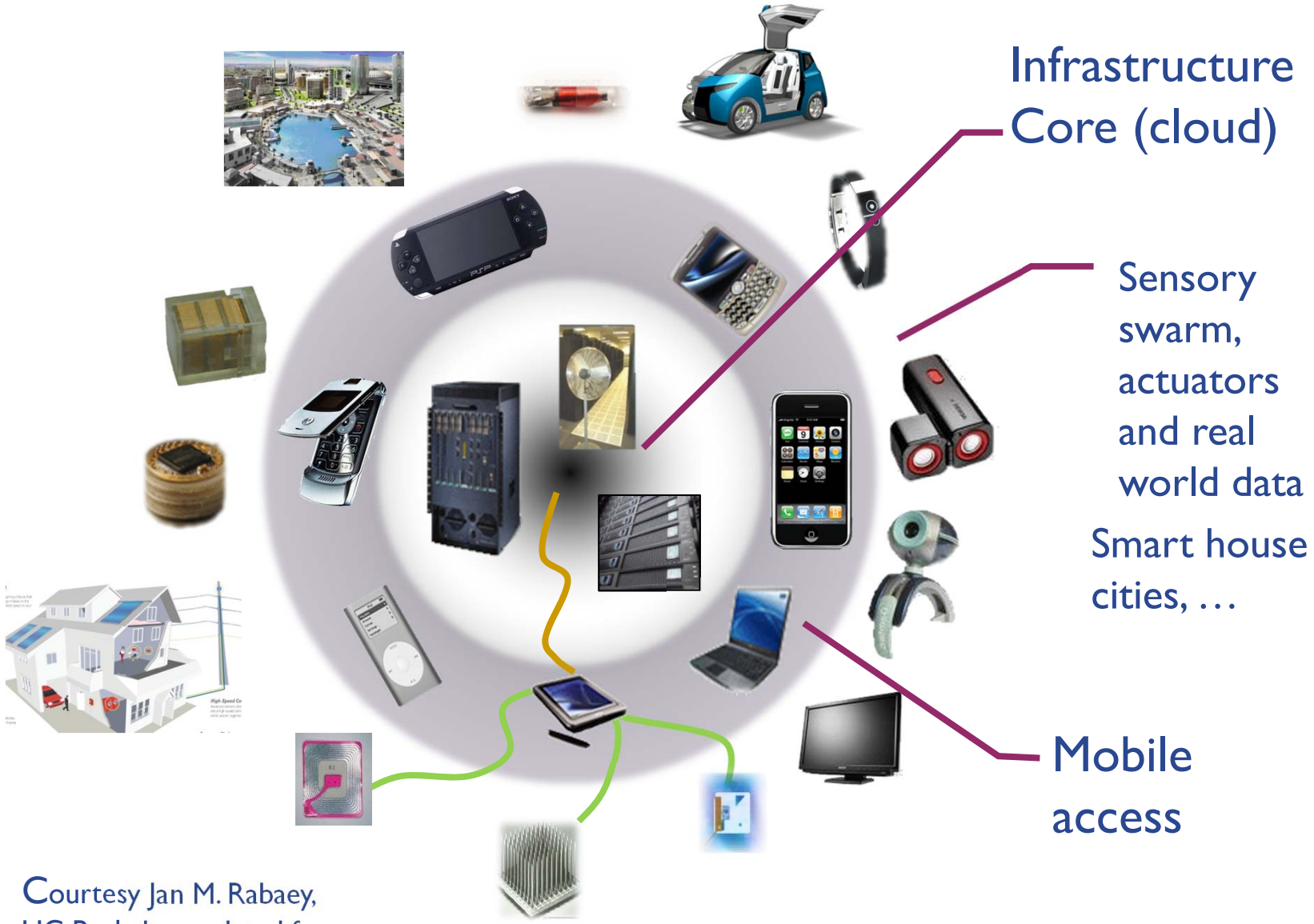
esis

Implicit and natural computing

the top of the figure, Computer Vision is classified as Recognition, Data Mining is Mining, and Rendering, Physical Simulation, and Financial Analytics are Synthesis. [Chen 2006]

Source: "The Landscape of Parallel Computing Research: A View from Berkeley" Krste Asanovic et all.

Ubiquitous computing in a connected world



Courtesy Jan M. Rabaey, UC Berkeley, updated for this HiPEAC vision

Trends influencing Computing Systems

Application Pull	Business Trends
• Data Deluge • Intelligent Processing • Ubiquitous Communication	• Convergence/standards • Specialization • Post-PC Devices

Convergence

Broadcast

IP, Internet

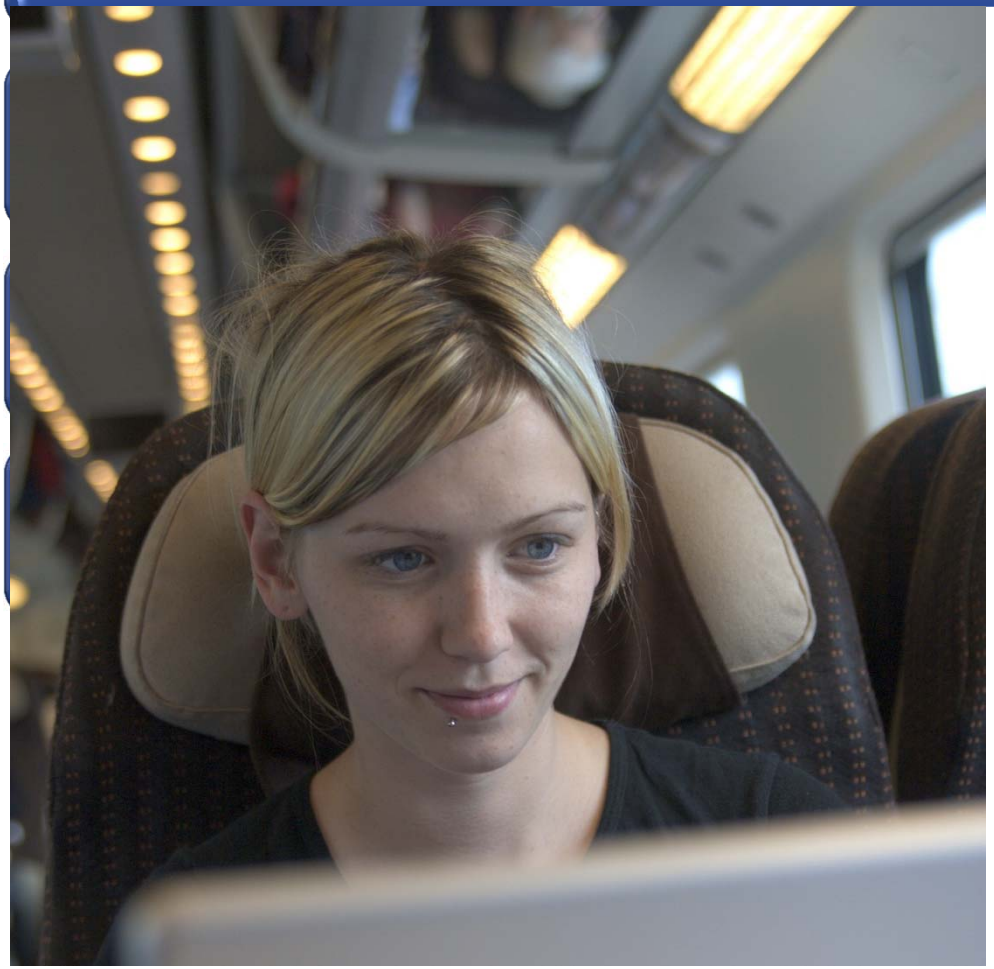
- Business models
- Standard(s)
- Interoperability
- …

Telecom

MacBook image © Jared C. Benedict
Phone, TV images © LG Electronics

Post-PC devices

Ubiquitous access



iPad image © Apple, Inc
MP3 player image © J A S P E R@flickr
iPhone image © K!T@flickr

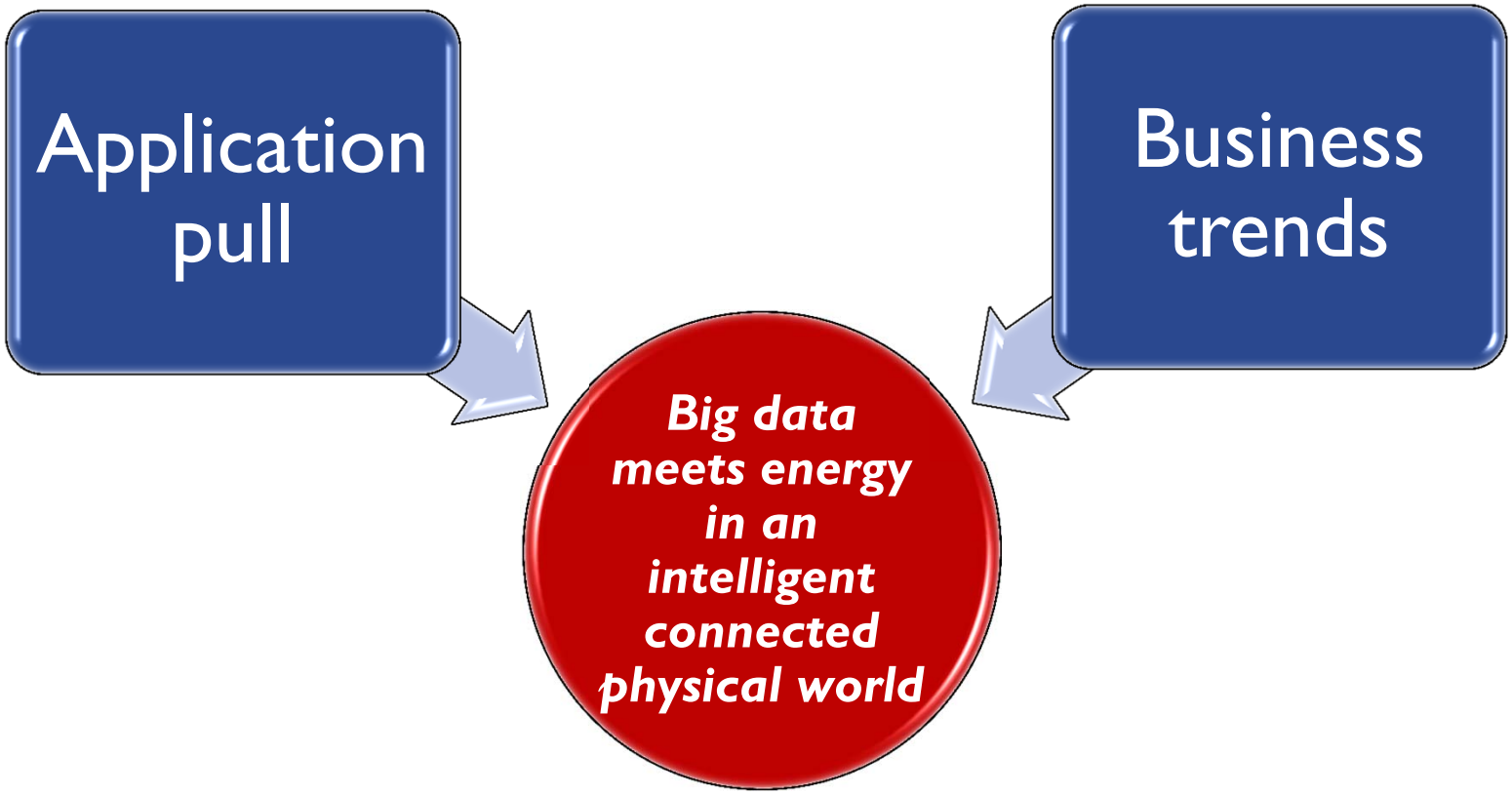
PC Market

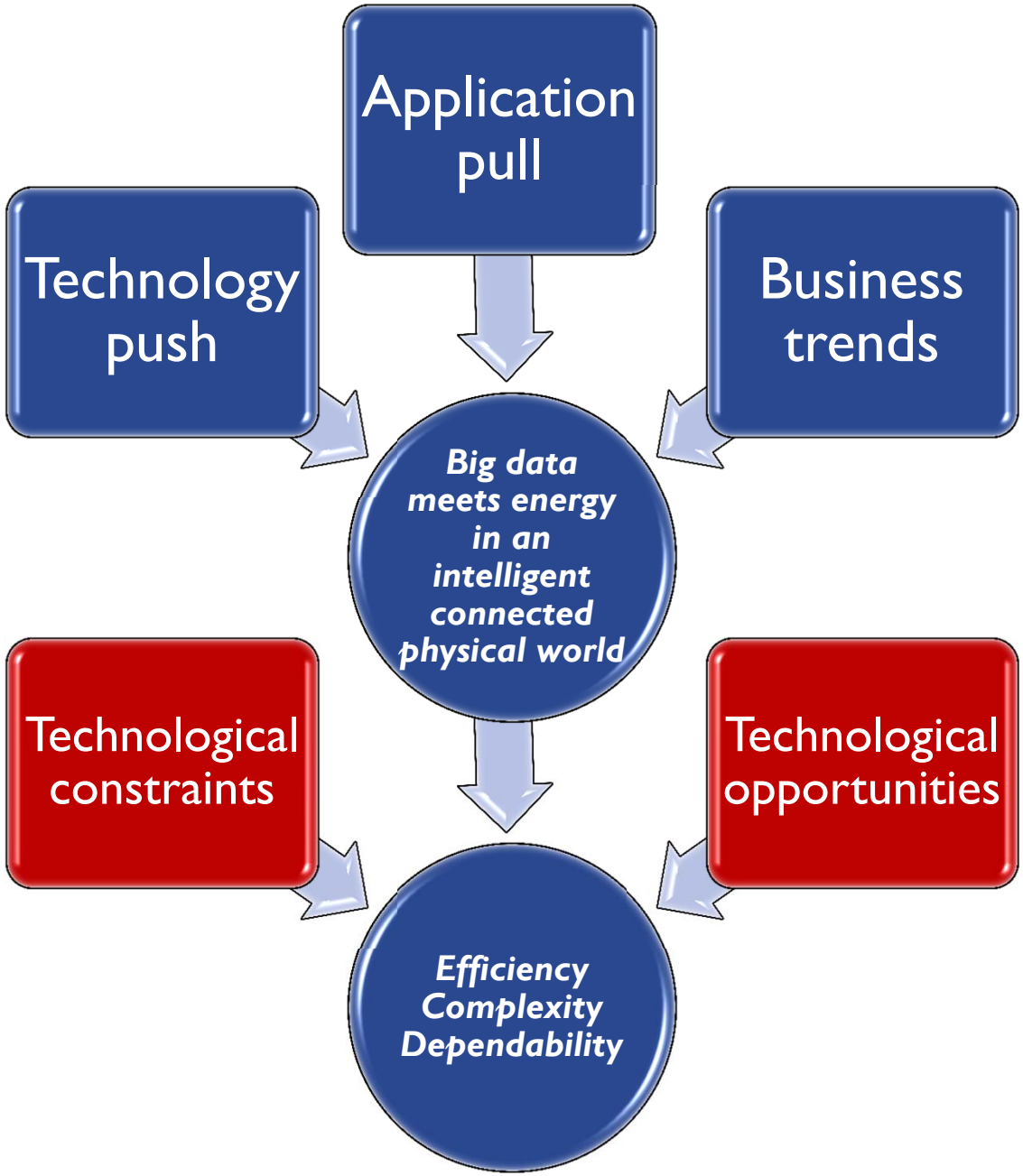
Western Europe: PC Vendor Unit Shipment Estimates for 2Q11 (Thousands of Units)

Vendor	2Q11 Shipments	2Q11 Market Share (%)	2Q10 Shipments	2Q10 Market Share (%)	2Q11-2Q10 Growth (%)
HP	3,171	25.1	3,376	21.6	-6.1
Acer Group	2,046	16.2	3,696	23.7	-44.6
Dell	1,371	10.8	1,571	10.1	-12.7
Asus	1,021	8.1	1,324	8.5	-22.9
Apple	879	7.0	875	5.6	0.5
Others	4161	32.8	4751	30.5	-12.4
Total	**12,649**	**100**	**15,593**	**100**	**-18.9**

Note: Data includes desk-based PCs and mobile PCs. Media tablets are excluded. Source: Gartner (August 2011)
(from http://www.gartner.com/it/page.jsp?id=1769215)

Computing Systems: Drivers

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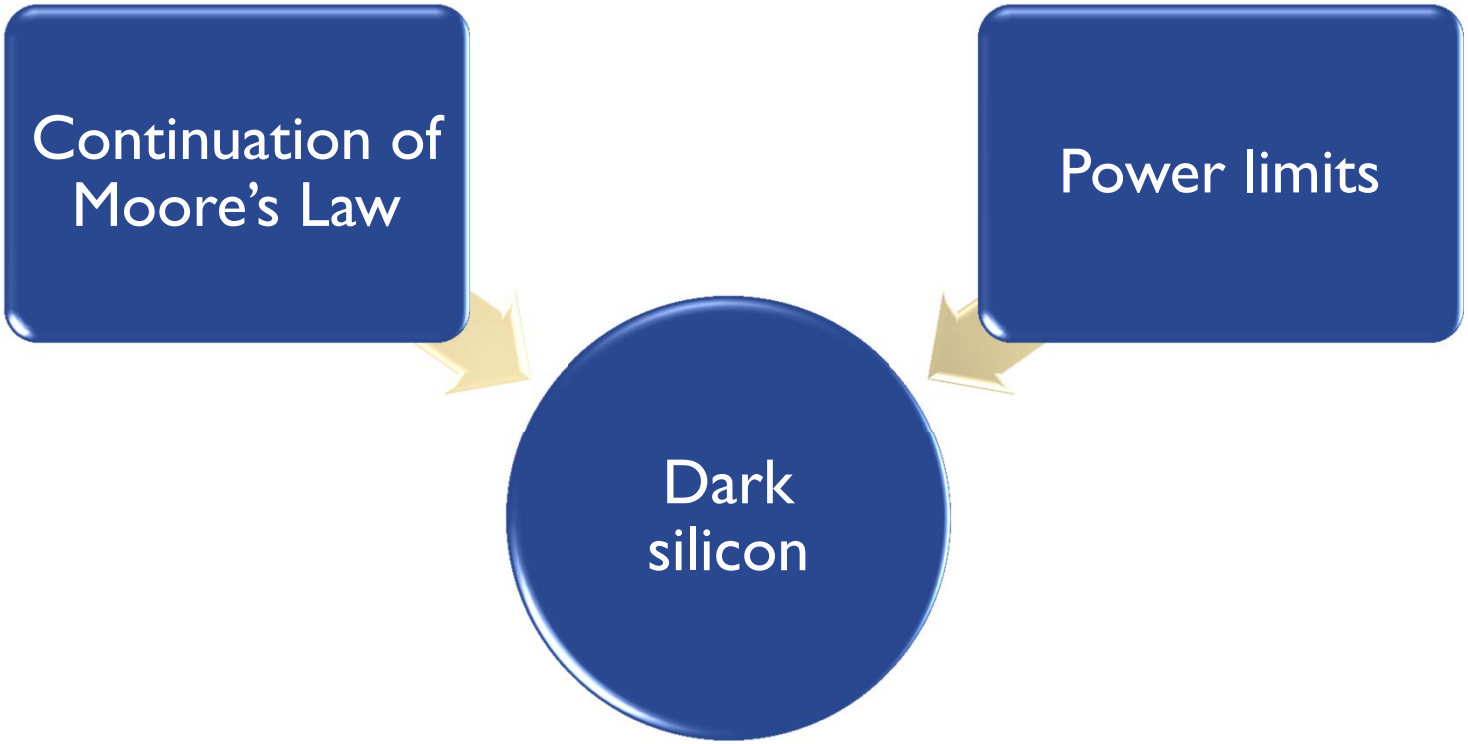
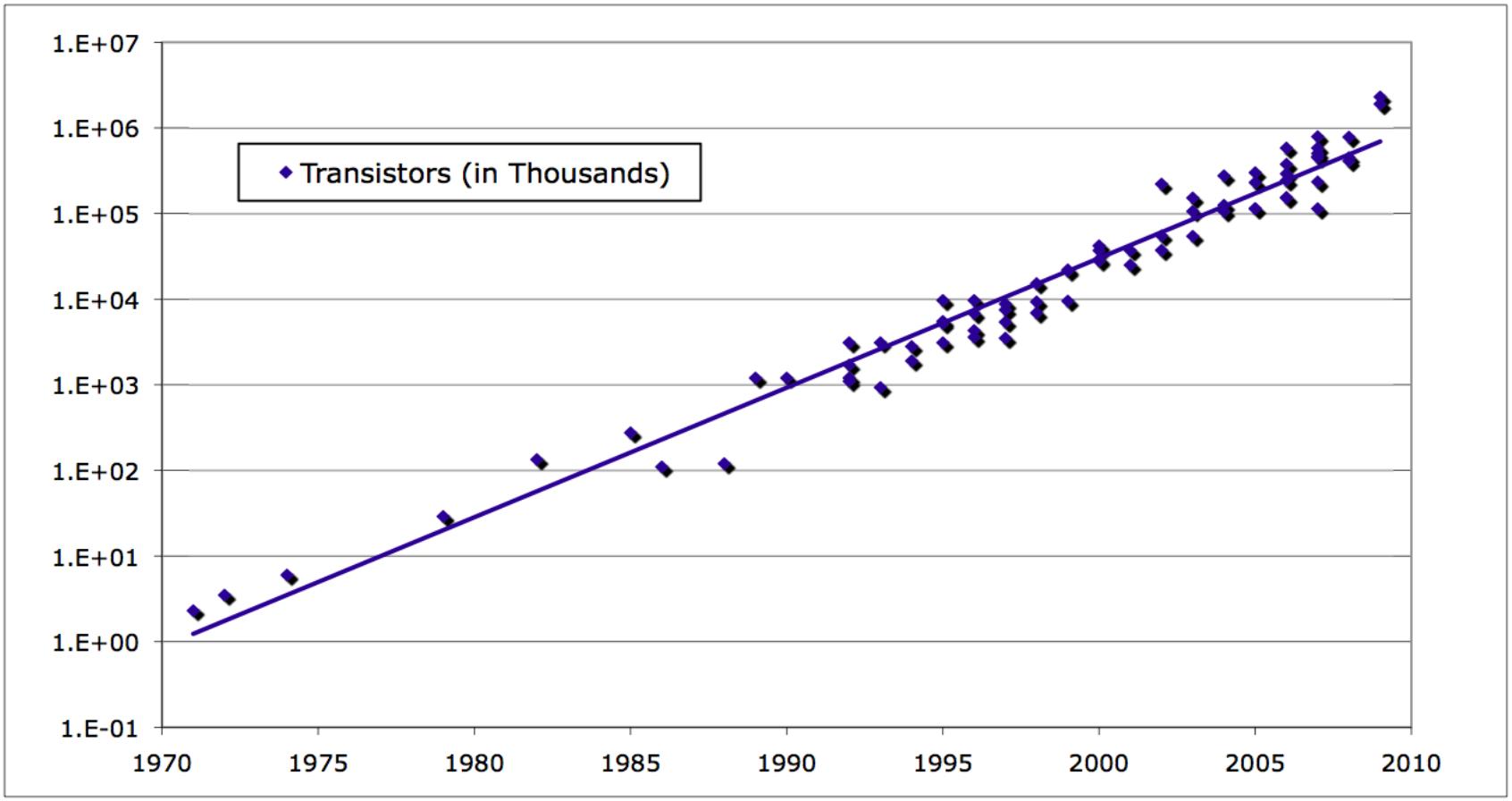
Technological trends influencing Computing Systems

Constraints	Opportunities
• Frequency Limits • Power Limits • Dark Silicon	• CMOS Phonotic • Non-volatile memories • 3D Stacking • New paradigms

Technological constraints
We are at a turning point

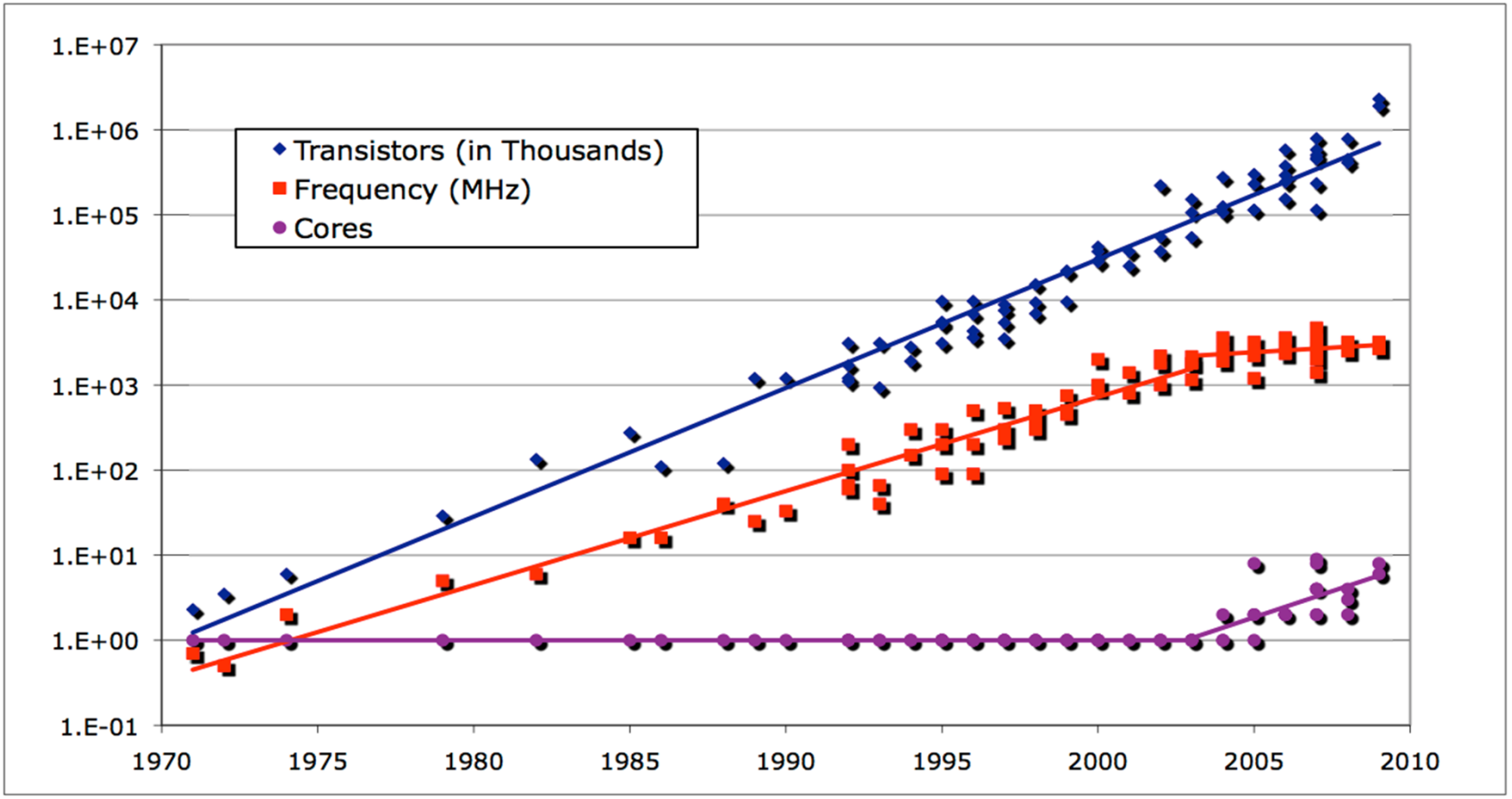


Moore's law: increase in transistor density



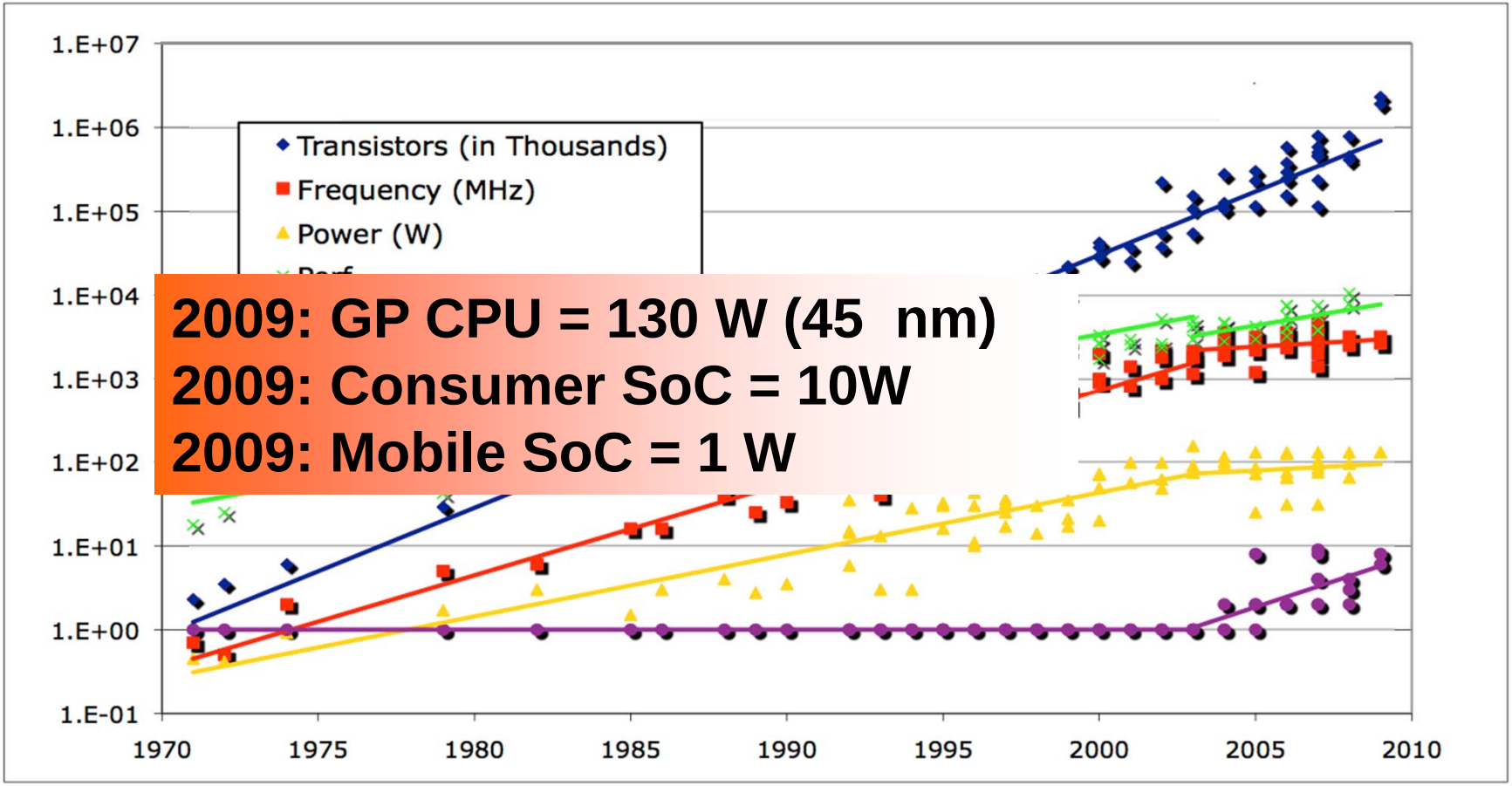
Data from Kunle Olukotun, Lance Hammond, Herb Sutter, Burton Smith, Chris Batten, and Krste Asanovic

Limited frequency increase ⇒ more cores



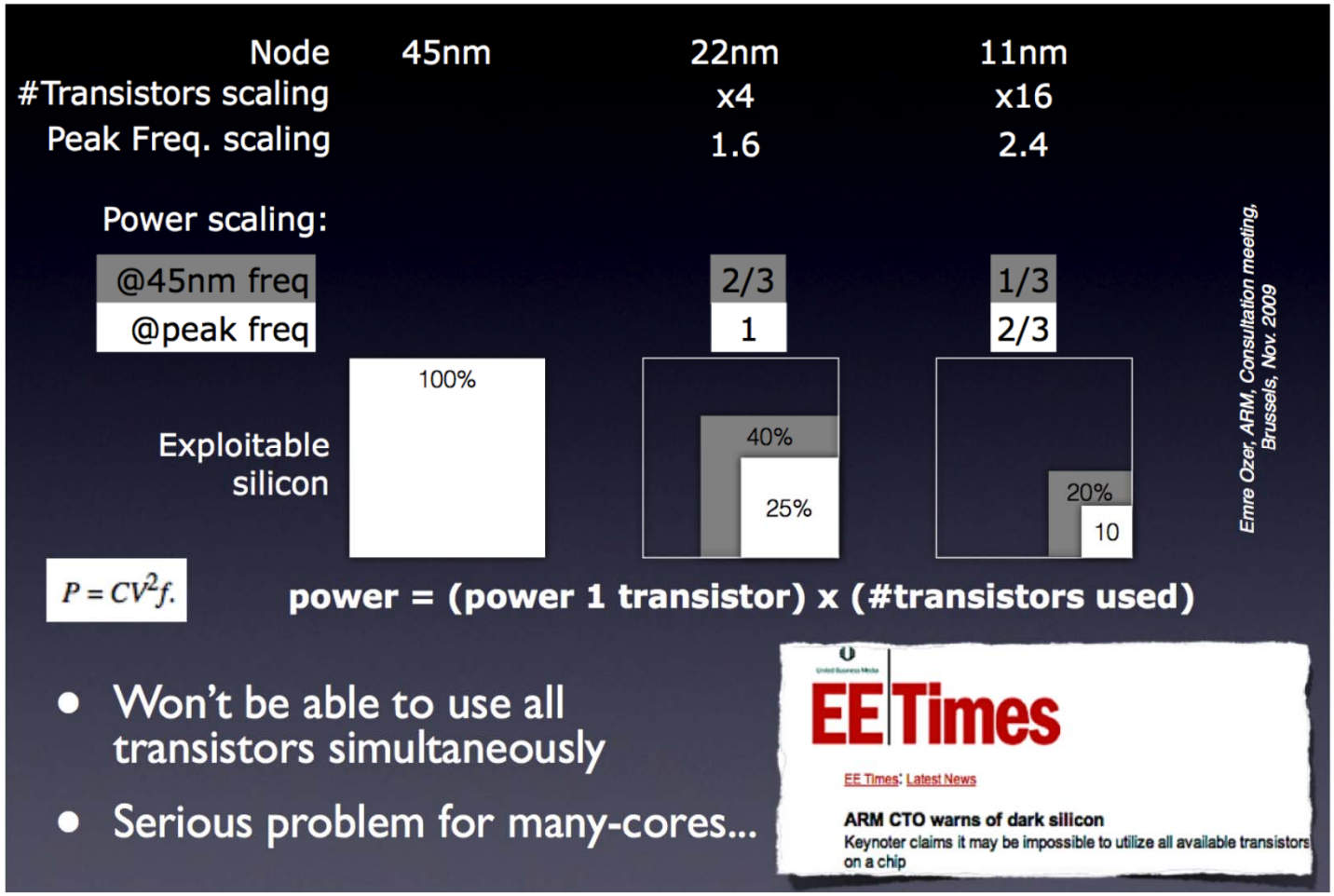
Data from Kunle Olukotun, Lance Hammond, Herb Sutter, Burton Smith, Chris Batten, and Krste Asanovic¸

Limitation by power density and dissipation



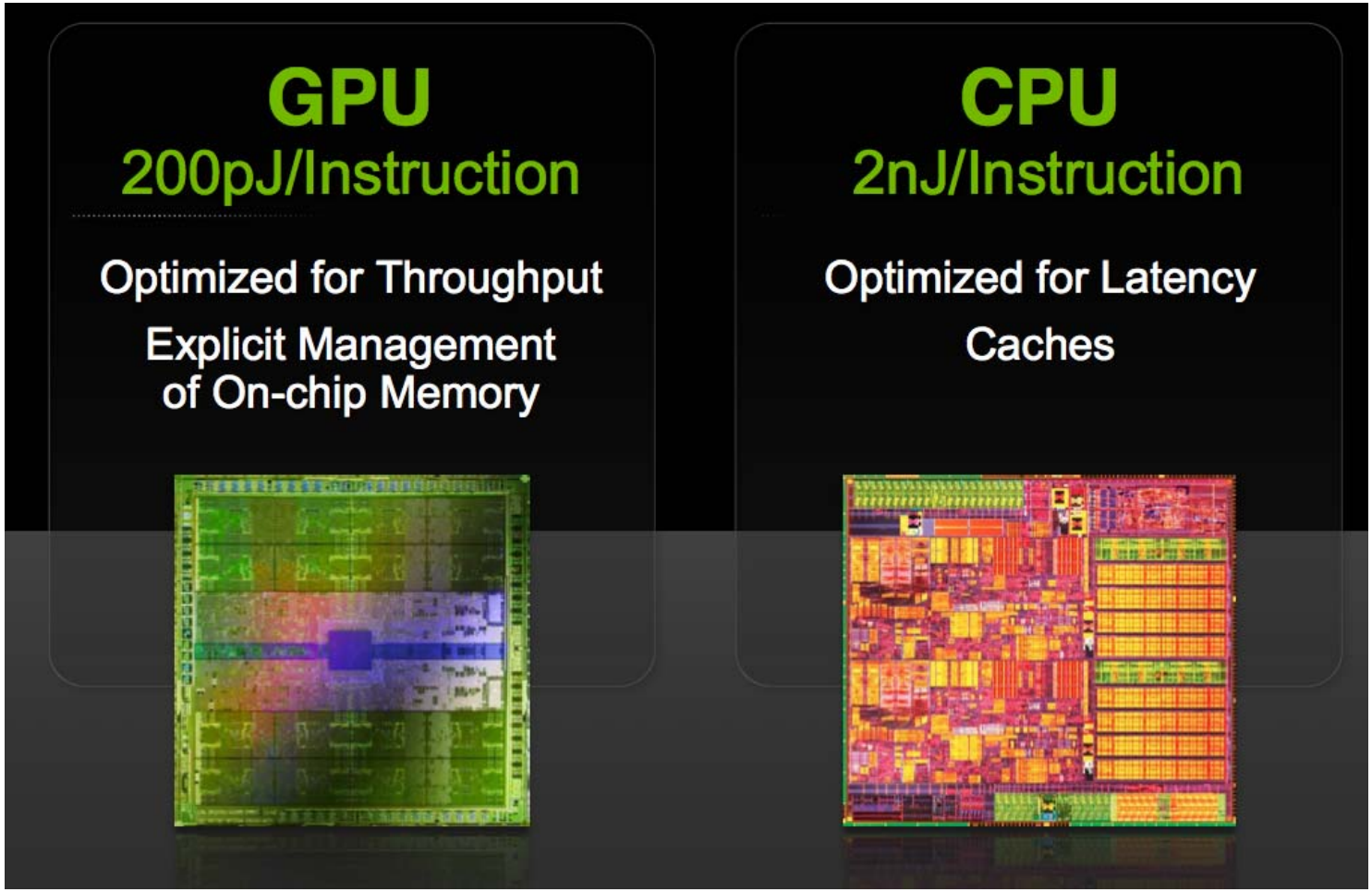
Data from Kunle Olukotun, Lance Hammond, Herb Sutter, Burton Smith, Chris Batten, and Krste Asanovic¸

Dark Silicon



Source: Krisztián Flautner "From niche to mainstream:can critical systems make the transition?"

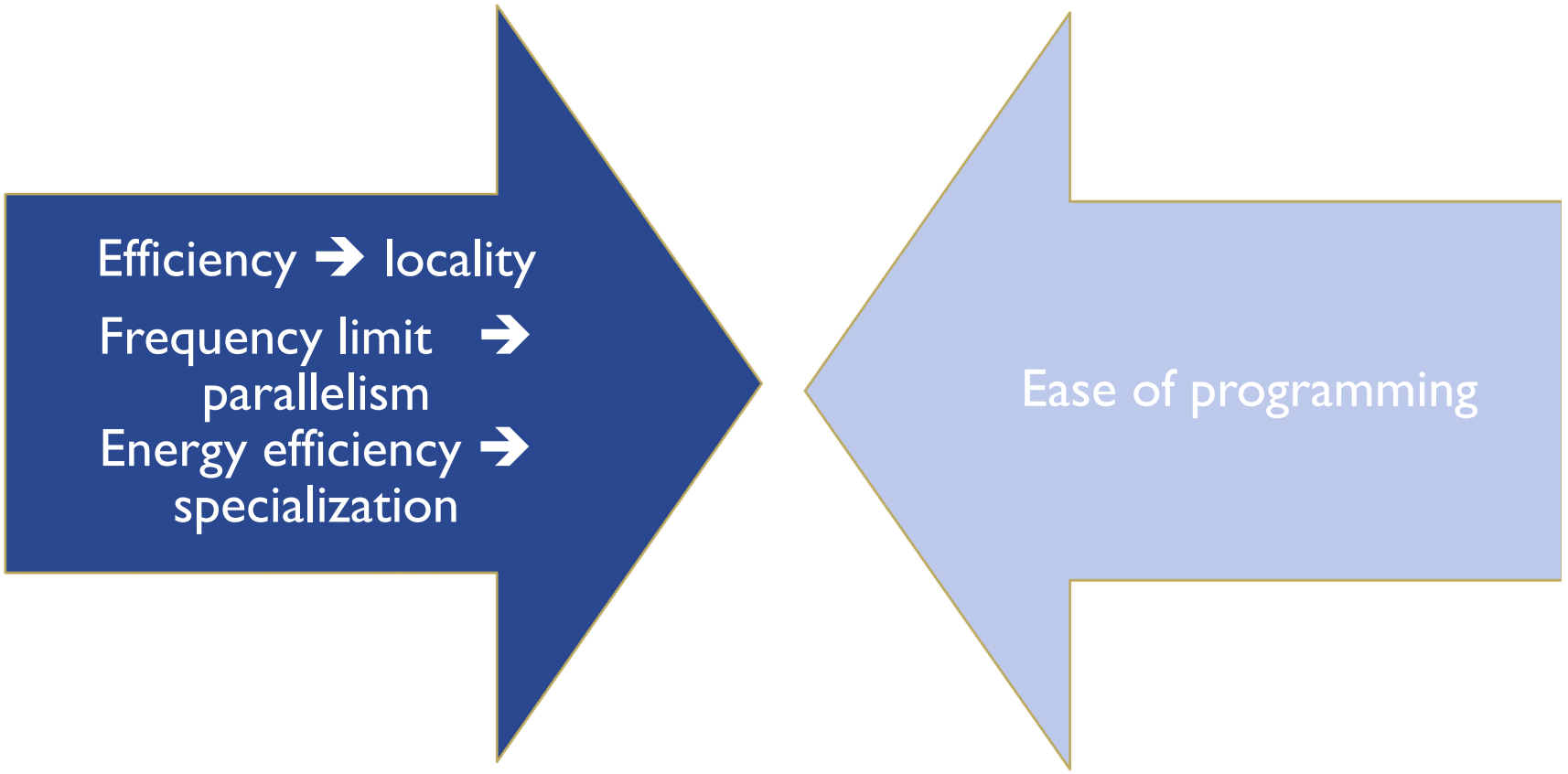
Specialization leads to more efficiency



Source: Bill Dally, « To ExaScale and Beyond »

www.nvidia.com/content/PDF/sc_2010/theater/Dally_SC10.pdf

Technological consequences



Technological trends influencing Computing Systems

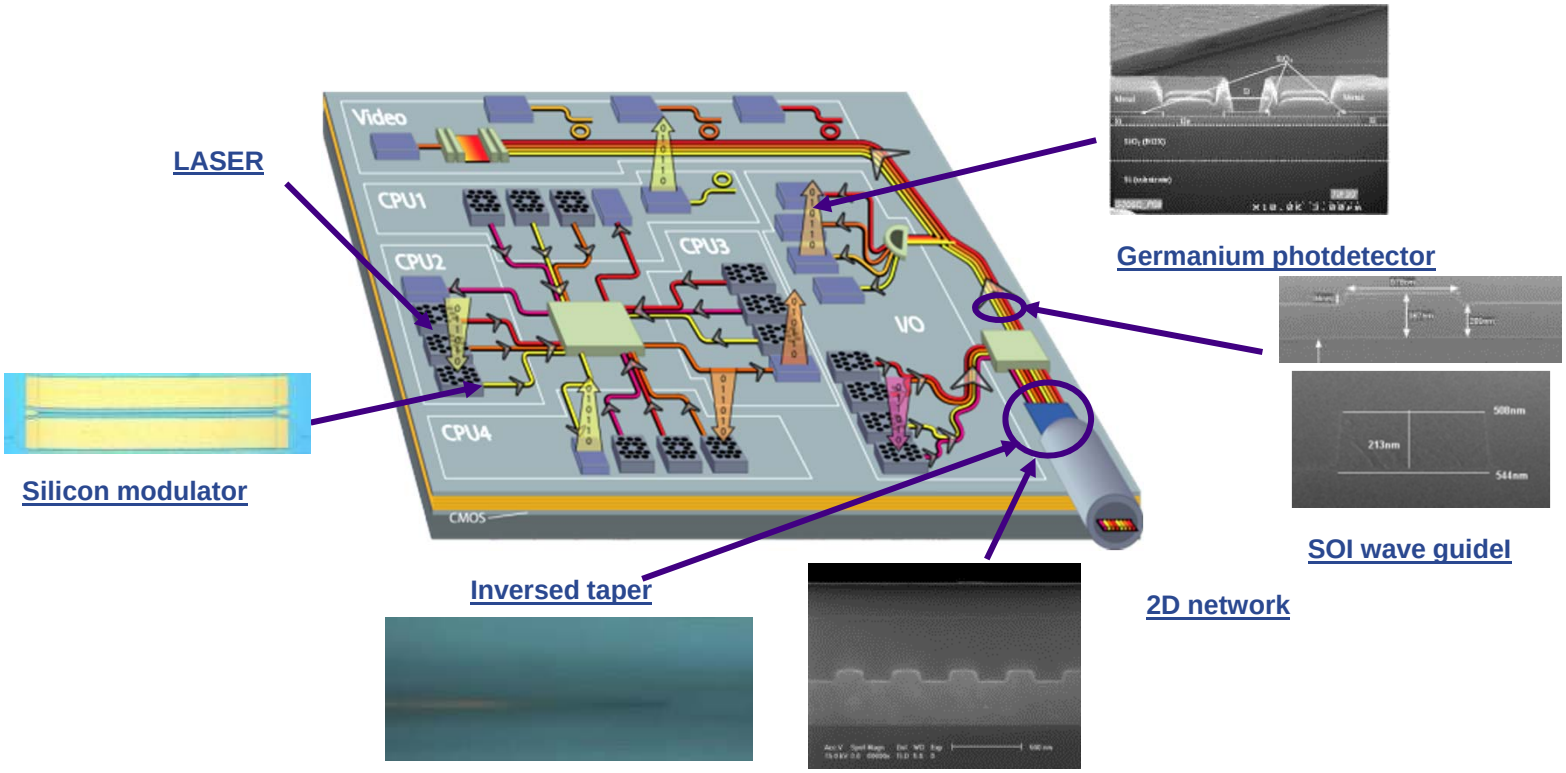
Constraints	Opportunities
• Frequency Limits • Power Limits • Dark Silicon	• CMOS Phonotic • Non-volatile memories • 3D Stacking • New paradigms

Optical interconnects

CMOS photonic is the integration of a photonic layer with an electronic circuit.

Advantages of CMOS photonic are:

- Use of standard tools and foundry, wafer scale co-integration
- **Lower energy** (~100 fJ/bit), (wire: ~1 pJ/mm)
- High bandwidth (10 Gbps), Low latency (~10 ps/mm)

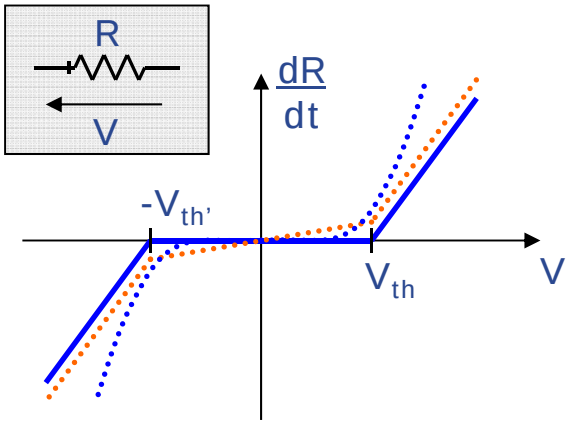


Source: CEA, Ahmed Jerraya

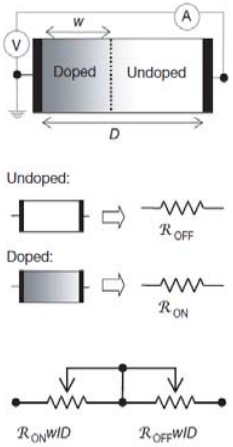
Non-volatile memories….

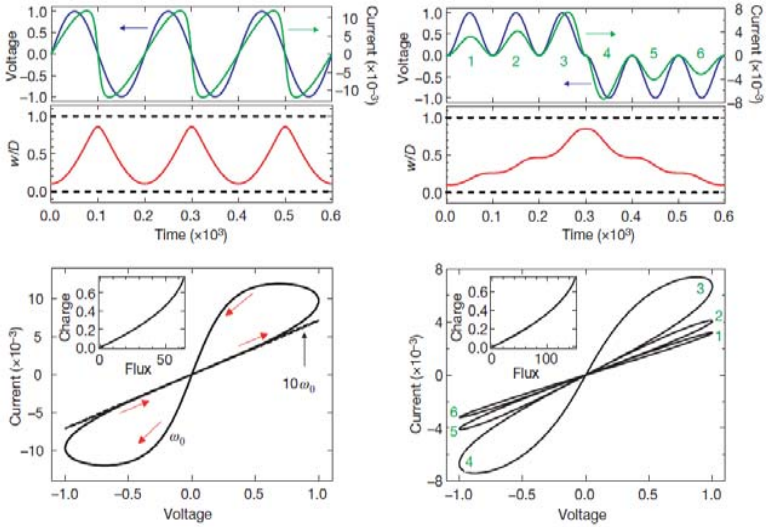
Example: Memristive Devices Principle

$$v = R(x,i).i \qquad \frac{dx}{dt} = f(x,i)$$

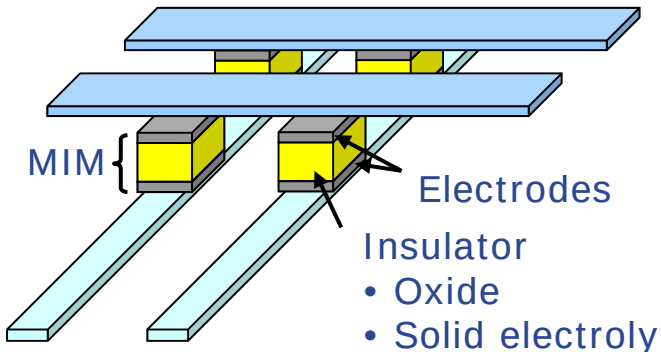


Nonlinear characteristic

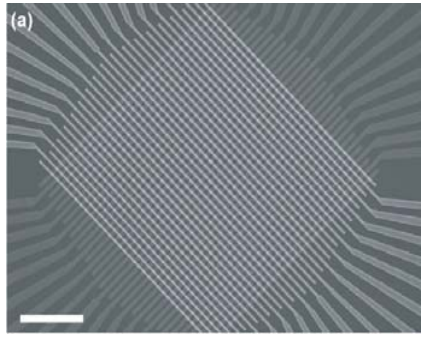




Metal (M_{x+1} layer)



Metal (M_x layer)

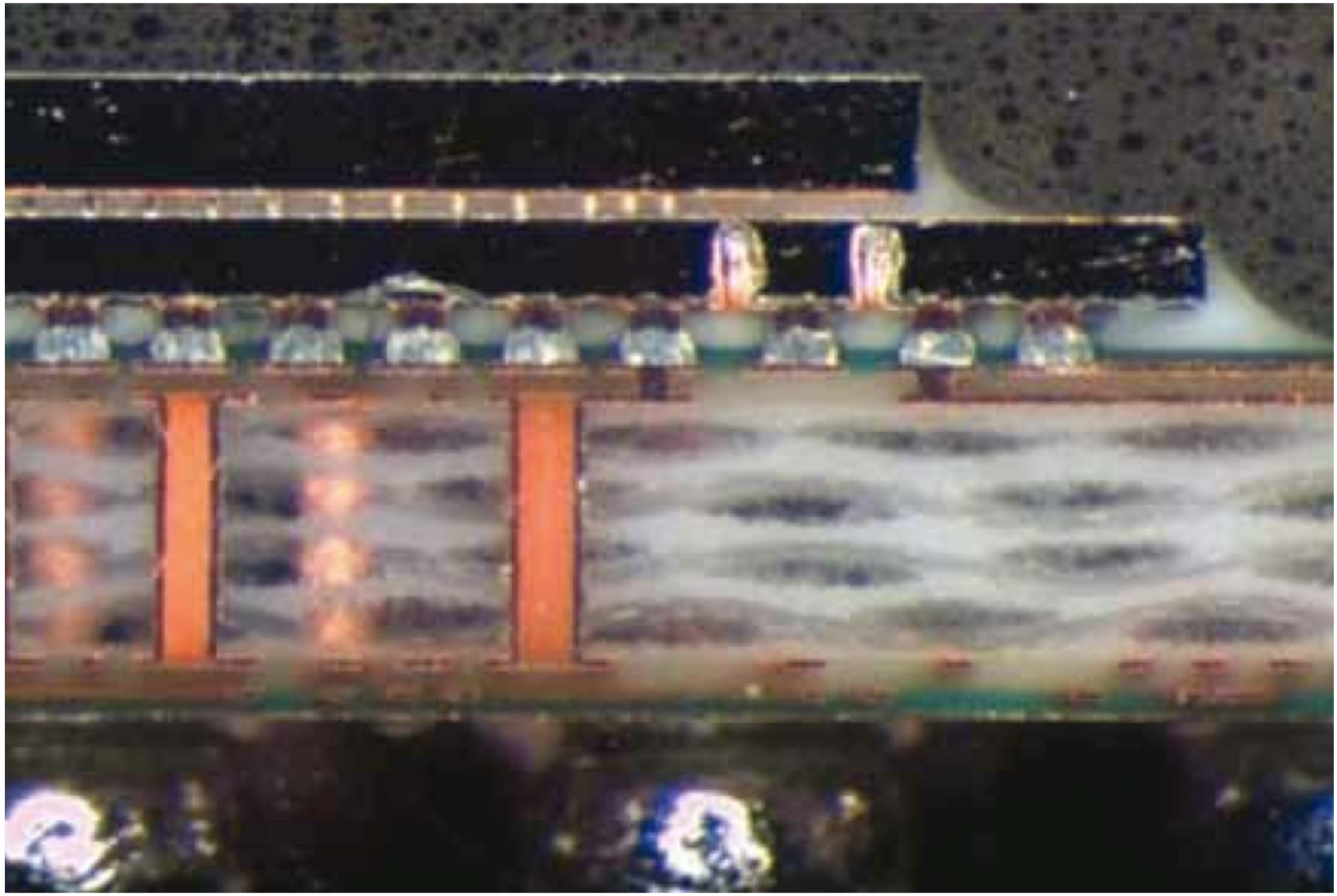


Crossbar
(University of Michigan)

Source: CEA, C. Gamrat

[1] L. Chua and S. Kang, *Proceedings of the IEEE*, 1976
[2] D. Strukov et al., *Nature*, 2008

3D stacking

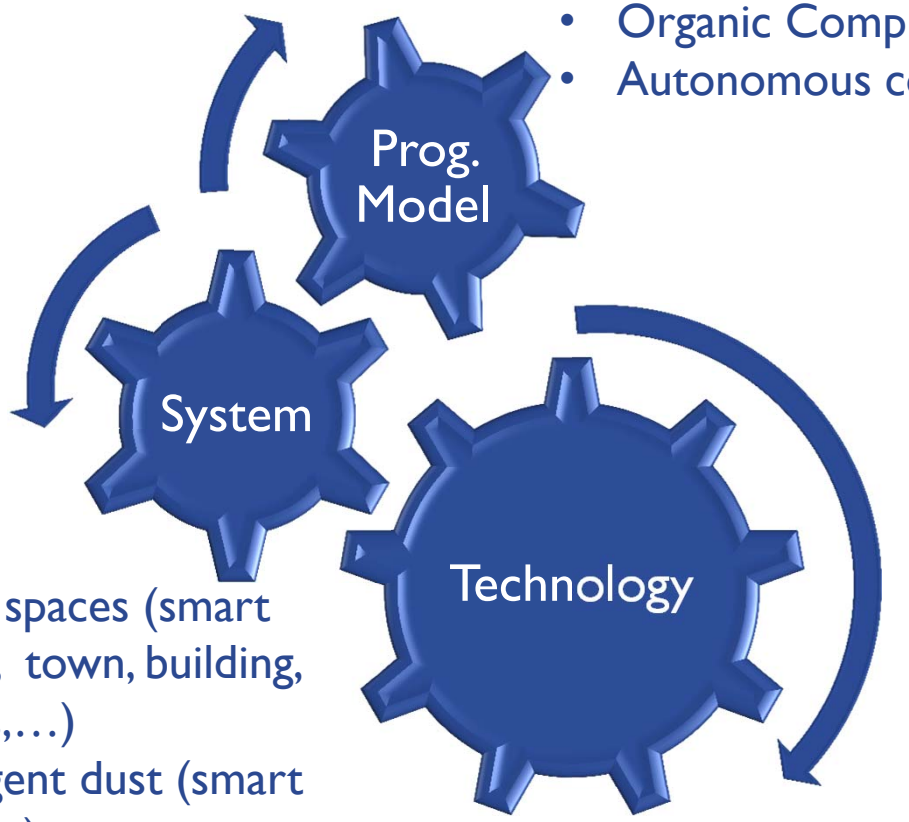


Multiple integration with 3D stacking…

Source: STMicroelectronics & CEA

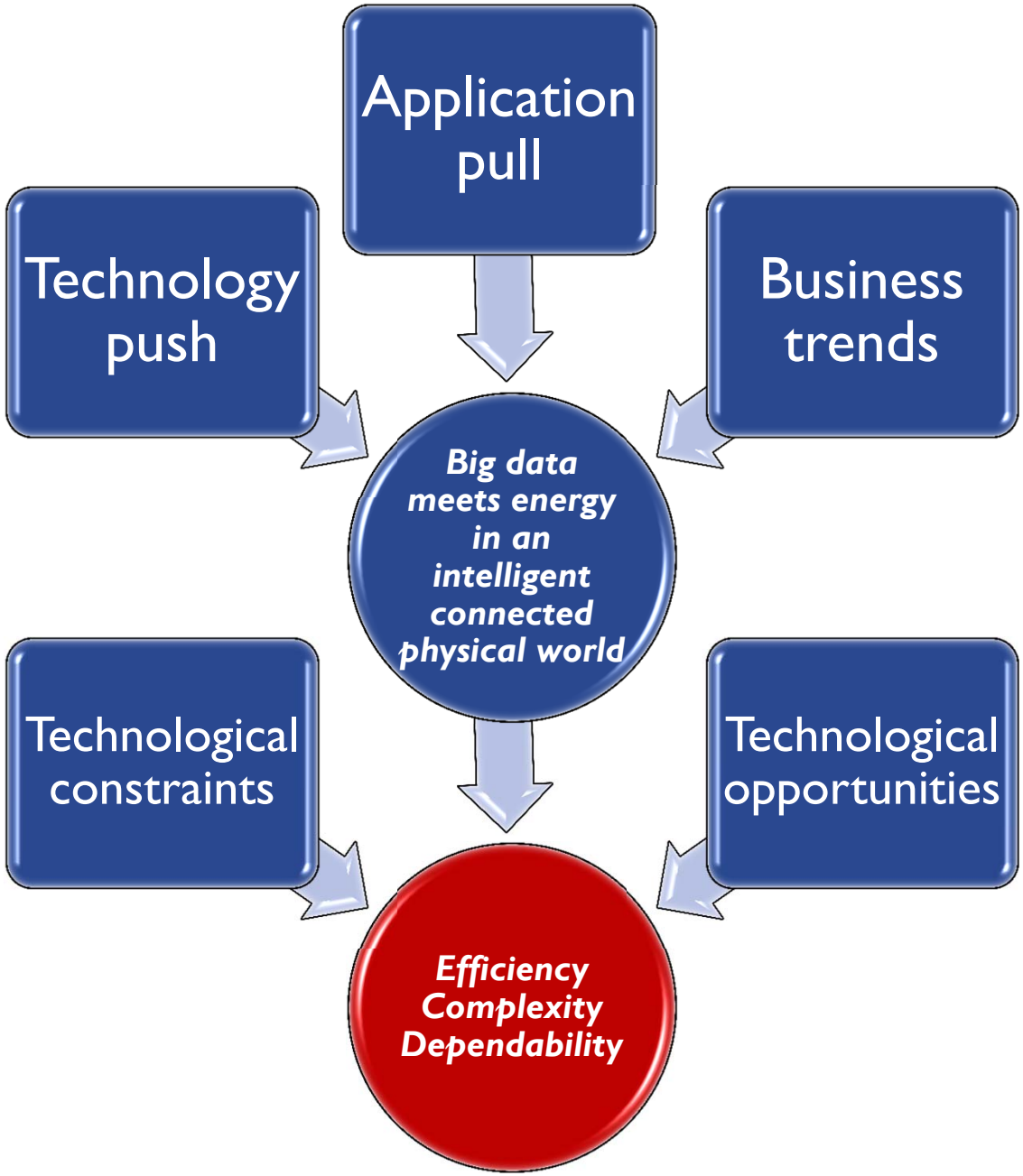
Technology also drives us to think differently…

- Stochastic computing
- Biologically inspired computing
- Organic Computing
- Autonomous computing, Self-*



- Smart spaces (smart house, town, building, rooms,…)
- Intelligent dust (smart sensors)

- 3D stacking
- Photonic interconnect
- Non-volatile memories
- Molecular computing
- More-than-Moore
- Spintronics
- Chemical computing
- Biologically inspired cells
- Memristors
- ...
- Also silicon based!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Core Computing Systems Challenges

Efficiency	Complexity	Dependability
• Power • Performance	• Parallelism • Heterogeneity	• Reliability • Privacy

Improving efficiency

- Power defines performance
- Heterogeneity and accelerators to the rescue
- More specialized hardware

Managing complexity

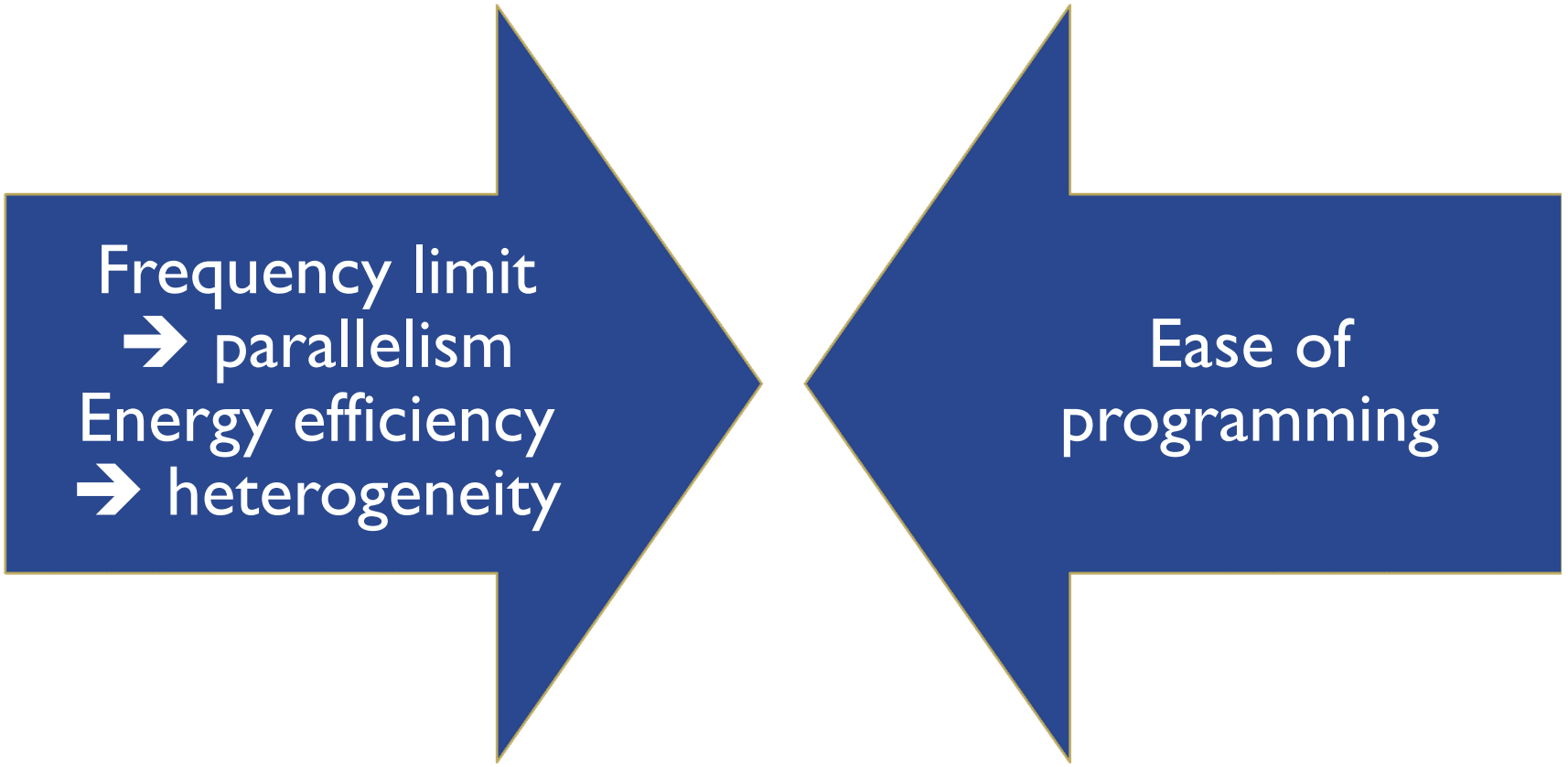
- The reign of legacy code
- Parallelism seems to be too complex for humans
- Hardware complexity

(4G is 500x more complex than 2G)

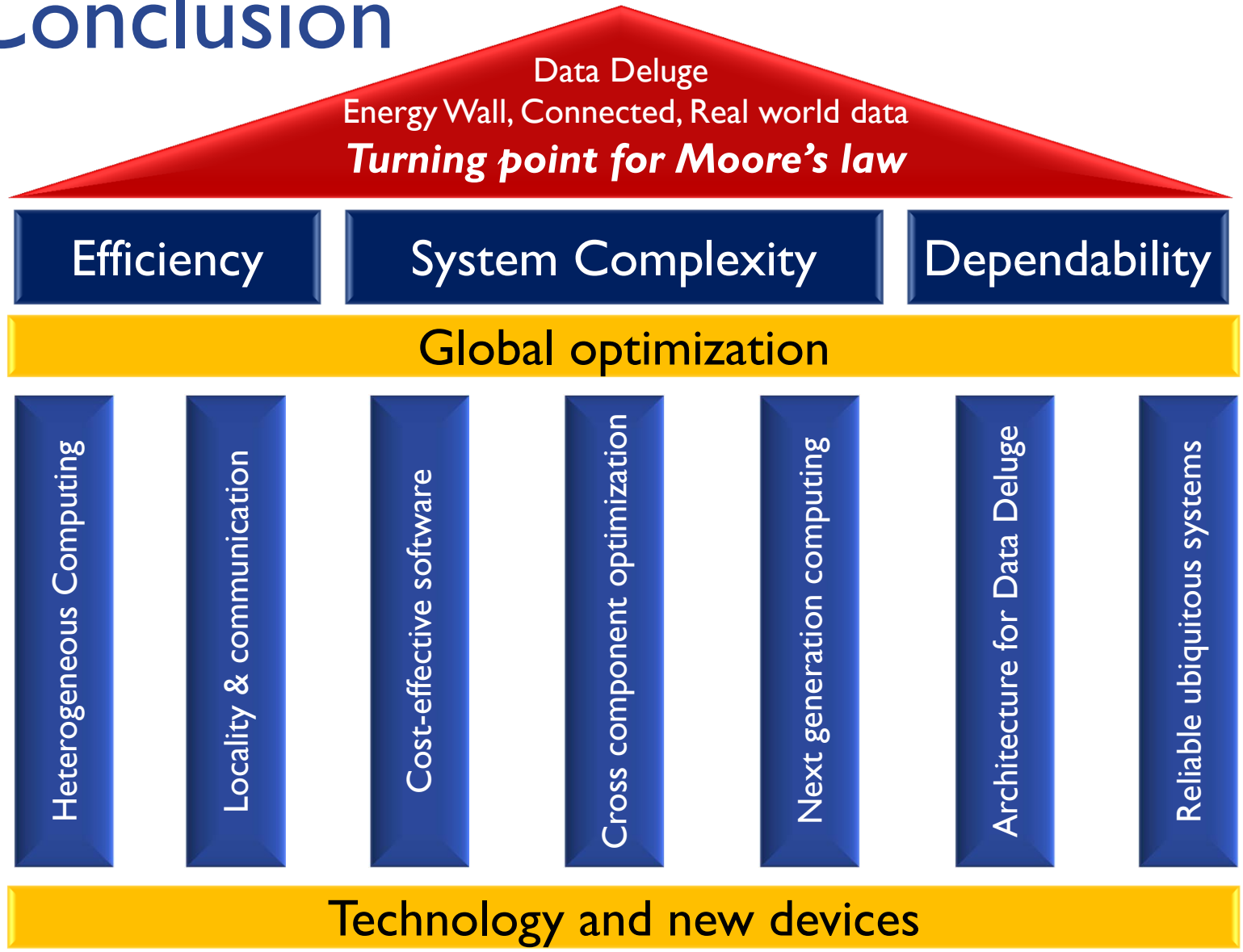
Improving dependability

- Worst case design is not an option anymore
- Systems must be built from unreliable components
- Safety and security!

Cost-effective software for heterogeneous multicores



Conclusion



Exiting new opportunities are ahead of us!