Nanoelectronics: Scientific and Research Challenges

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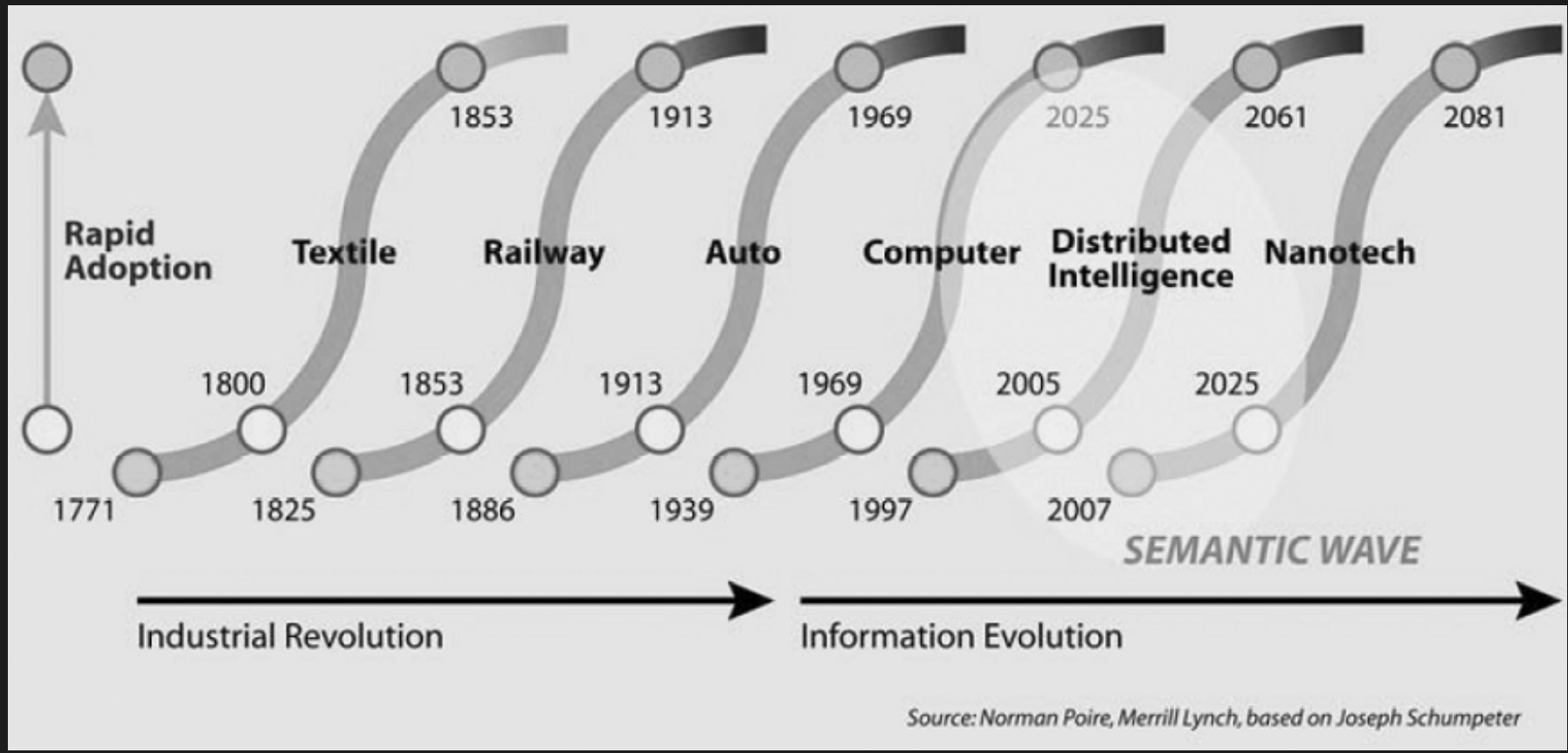
Outline

- Nano(electronics):
  why embracing the ultra-small?
- Research and scientific challenges
- Europe: building on strengths
- Future: investing in nanoelectronics research, infrastructures and education
- Conclusion

Nano: embracing the ultra-small

Nano as next semantic wave



Nano: serving society needs

Water

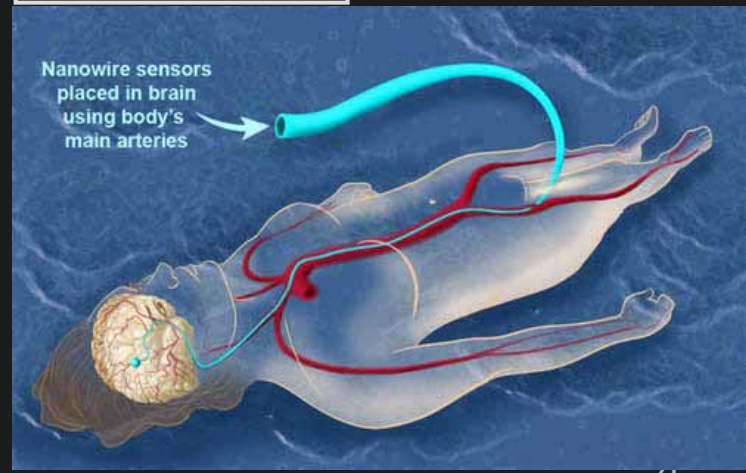
NANOELECTRONICS

Space exploration

Environment

Energy

Health



Nano everywhere

- Nano-technology - creation of useful materials, devices and systems through manipulation of matter on the nanometer scale and exploitation of novel phenomena and properties
- Nano-electronics - nanoscale electronics (<100nm) manufacturing of ever-smaller and higher performance of existing semiconductor devices and advances in molecular electronics
- Nano-architectonics – the science of creating large systems composed of nanometer-sized components
- Nano-mechanics - building devices with features that are nanometers in size, working on sensing/positioning things that are smaller than an atom
- Nanophotonics – studying the quantum behavior of light on length scales of a few hundred nanometers
- Nano-bio-info-cogno – interaction between Information and Communication Technologies and Life Sciences

Nano(electronics) = atoms-to-systems

Nanoelectronics is about engineering

- People do not buy technology, they buy products

- In a global, knowledge-driven economy, technological innovation - the transformation of knowledge into products, processes, and services - is critical to competitiveness, long-term productivity growth, and the generation of wealth. Preeminence in technological innovation requires leadership in all aspects of engineering: engineering research to bridge scientific discovery and practical applications; engineering education…; and the engineering profession and practice to translate knowledge into innovative, competitive products and services.

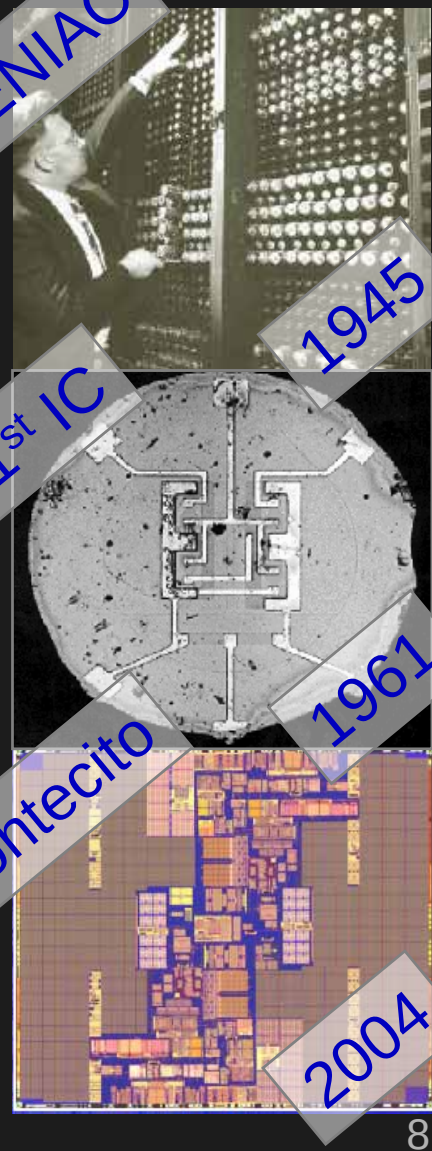
From Engineering Research and America's Future: Meeting the Challenges of a Global Economy (2005)

Research and scientific challenges

Future of computing: CMOS-like?

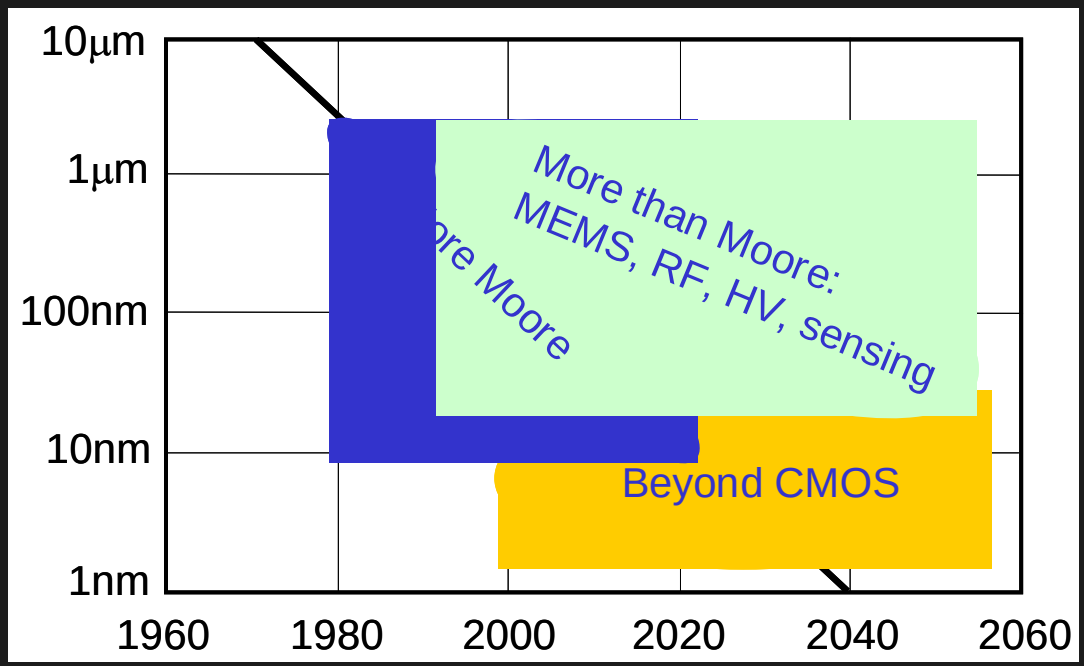
Key questions:

- Is CMOS or its metamorphosis still the future of computing?
- Is low power a better focus than high speed (next driver)?
- Is nano the future of computing?
- What else is important for the future of computing? Logic? Biology?



Today true computing is CMOS

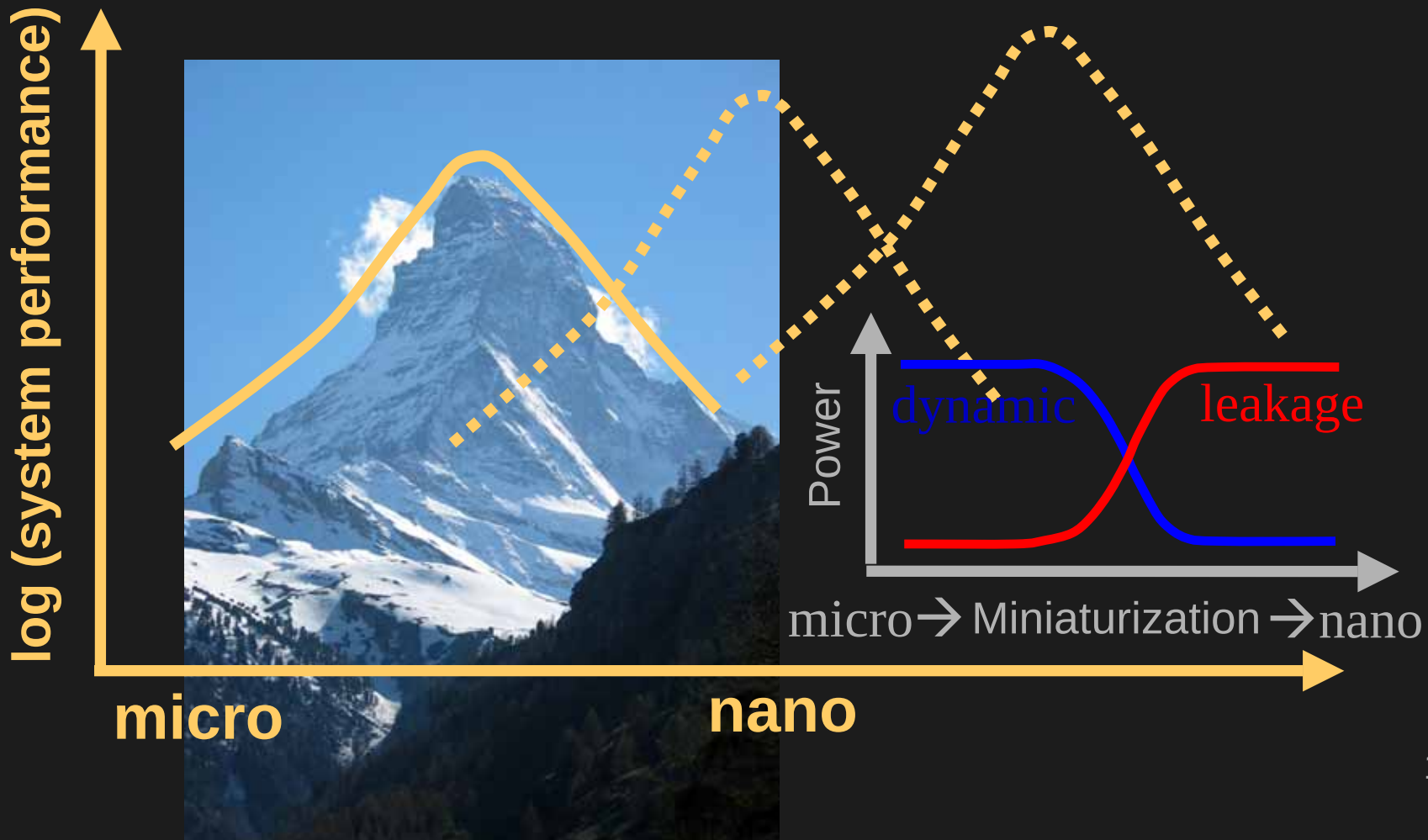
- Moore's law is alive and well. So, what's wrong?
- Why talking about:
  More Moore, Beyond CMOS and More than Moore?



> 1B transistors

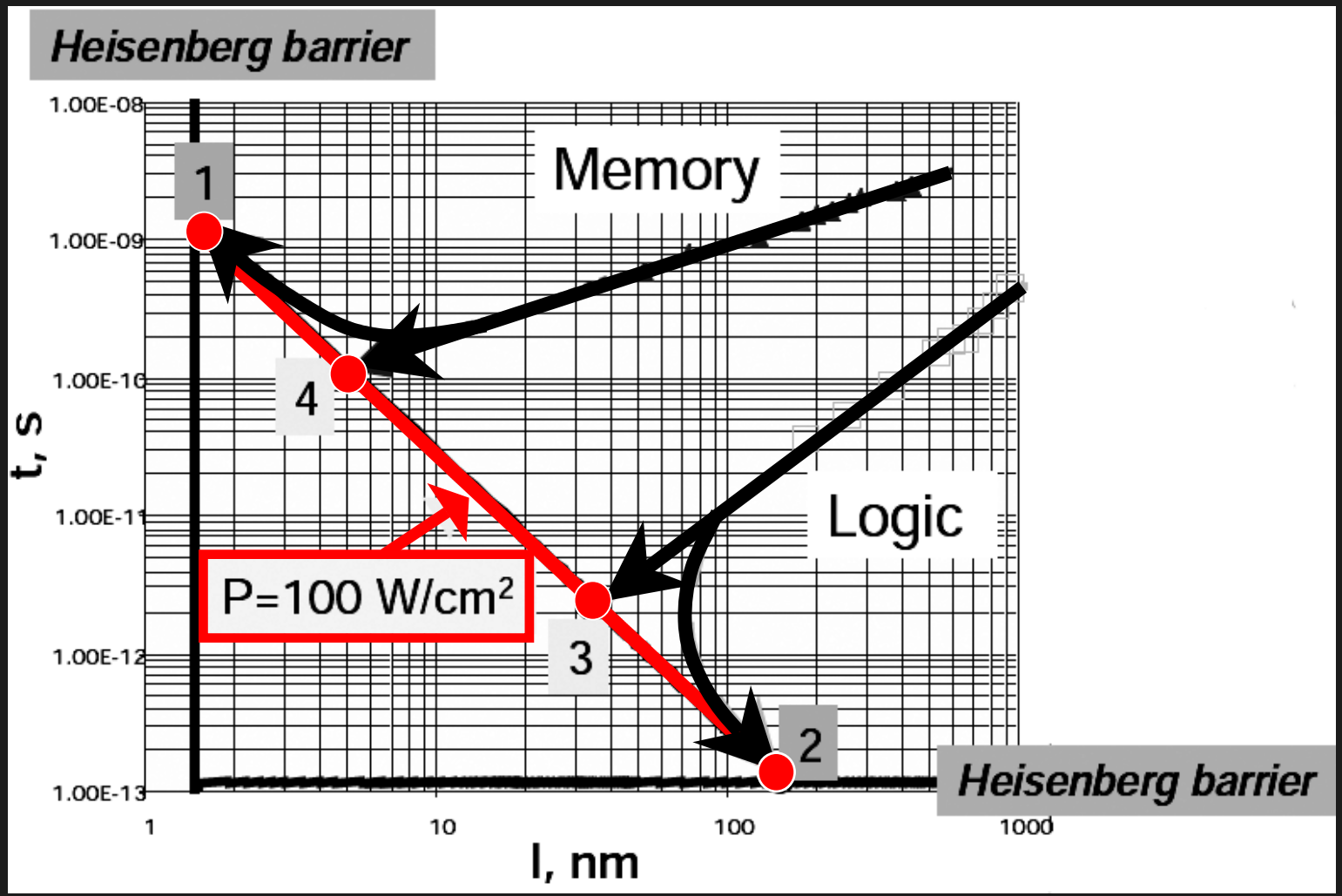
More Moore: end of traditional scaling

CMOS: end-of-additive-strategy, need of system optimization



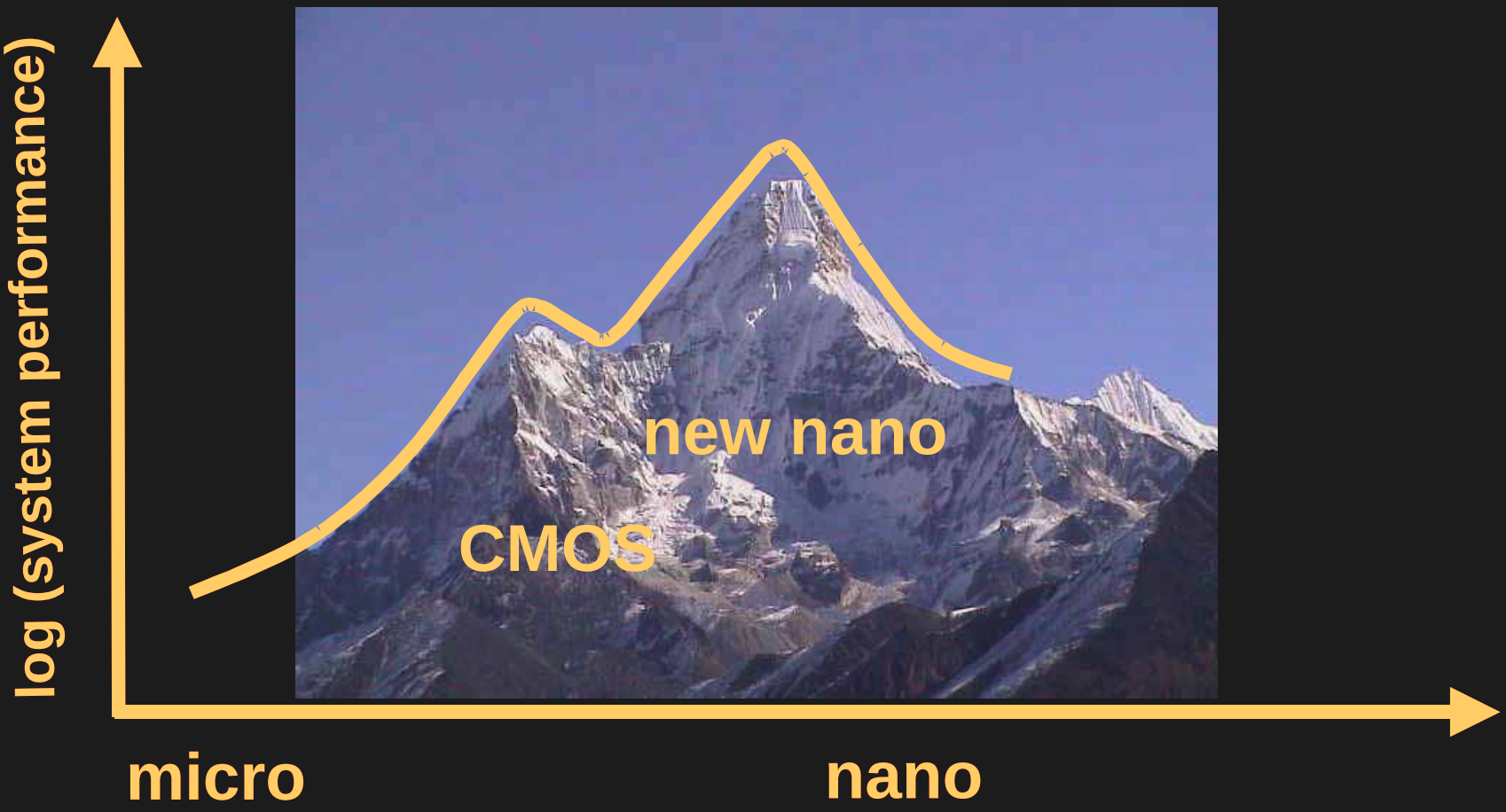
Power density barrier

- not addressed today!



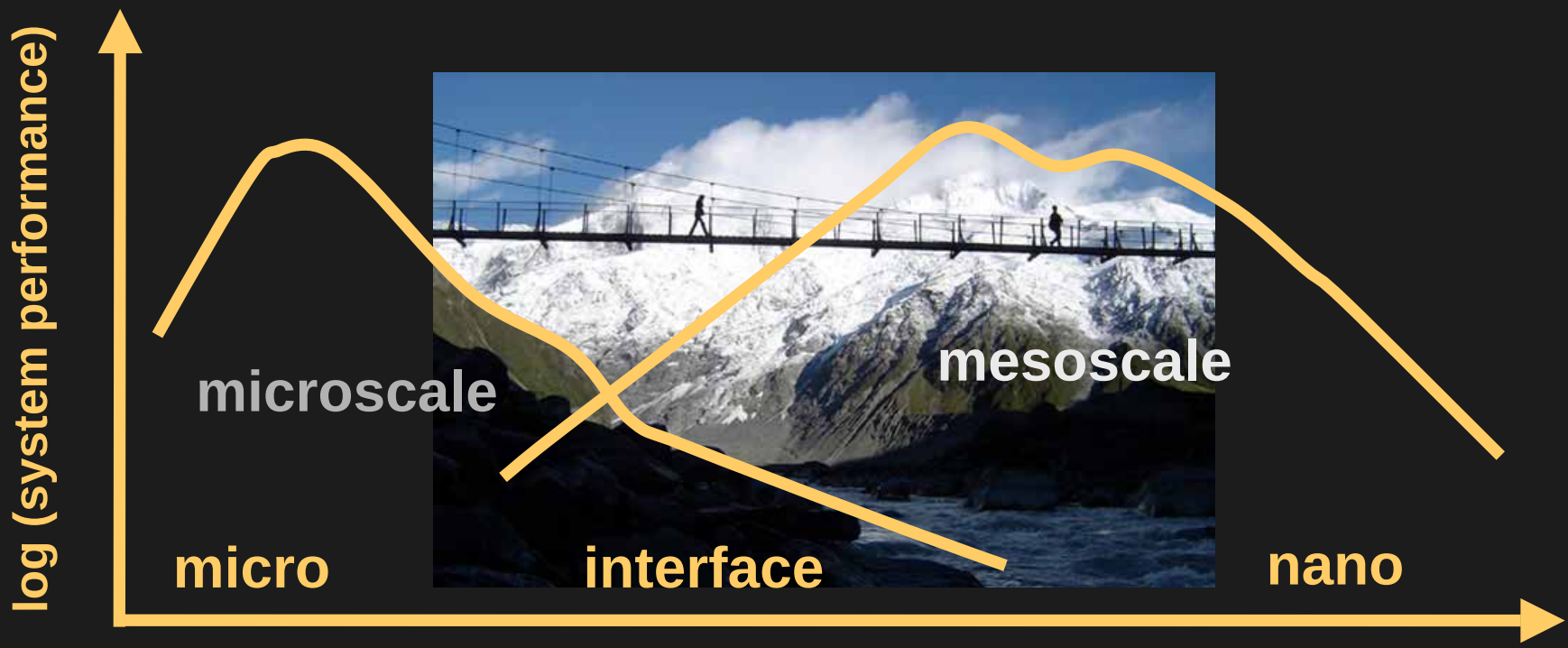
The smooth transition

Future hybrid platforms = combining More Moore, More-than-Moore and Beyond CMOS

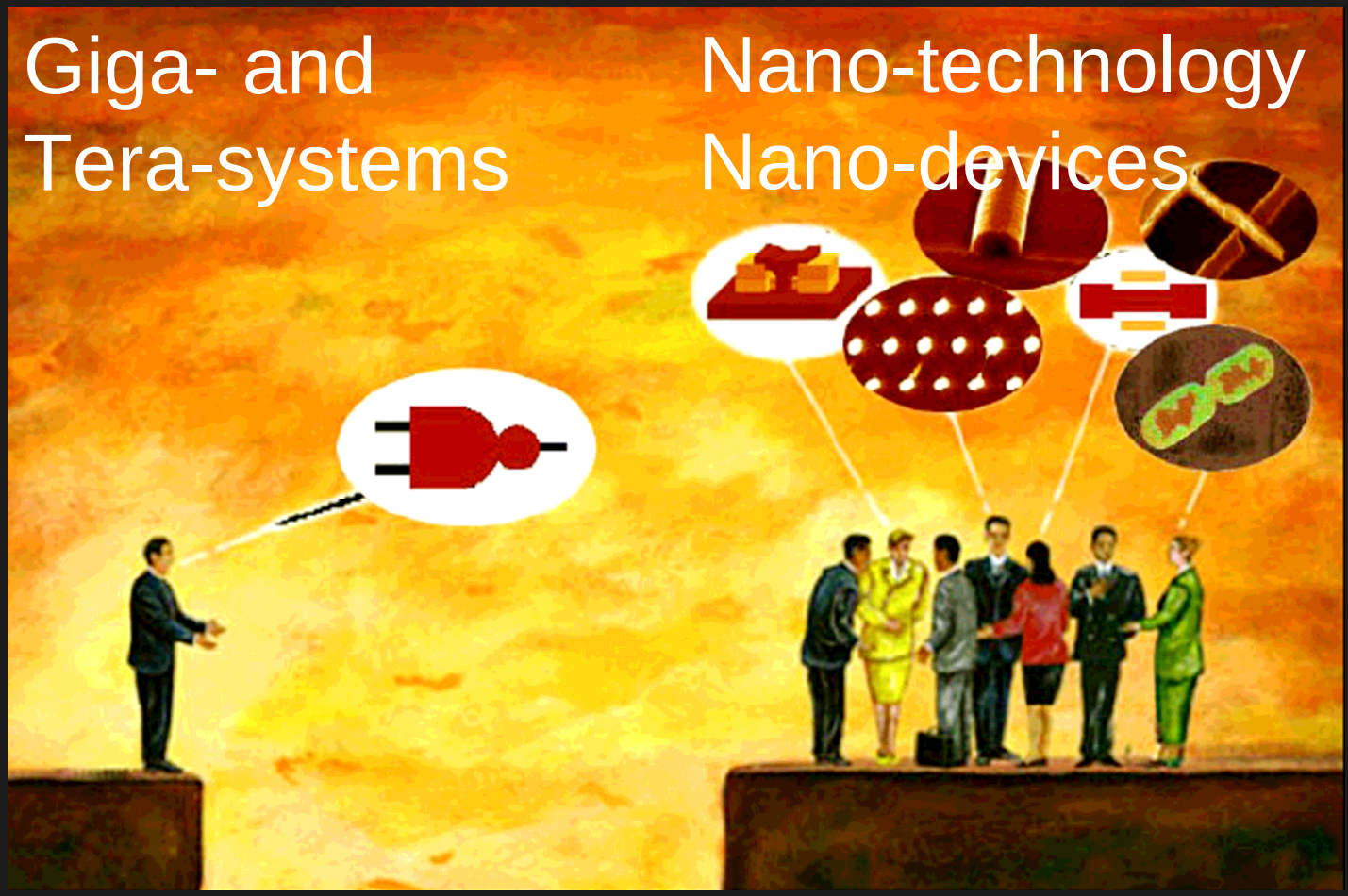


Micro-nano interface design

• Monumental challenge: communication between the micro and the nano: generic issue of nanotechnology!
• Need for interfacing the nano with the real world: analog electronic interfaces for detecting very weak signal/noise, detection of nm motions in NEMS, etc.



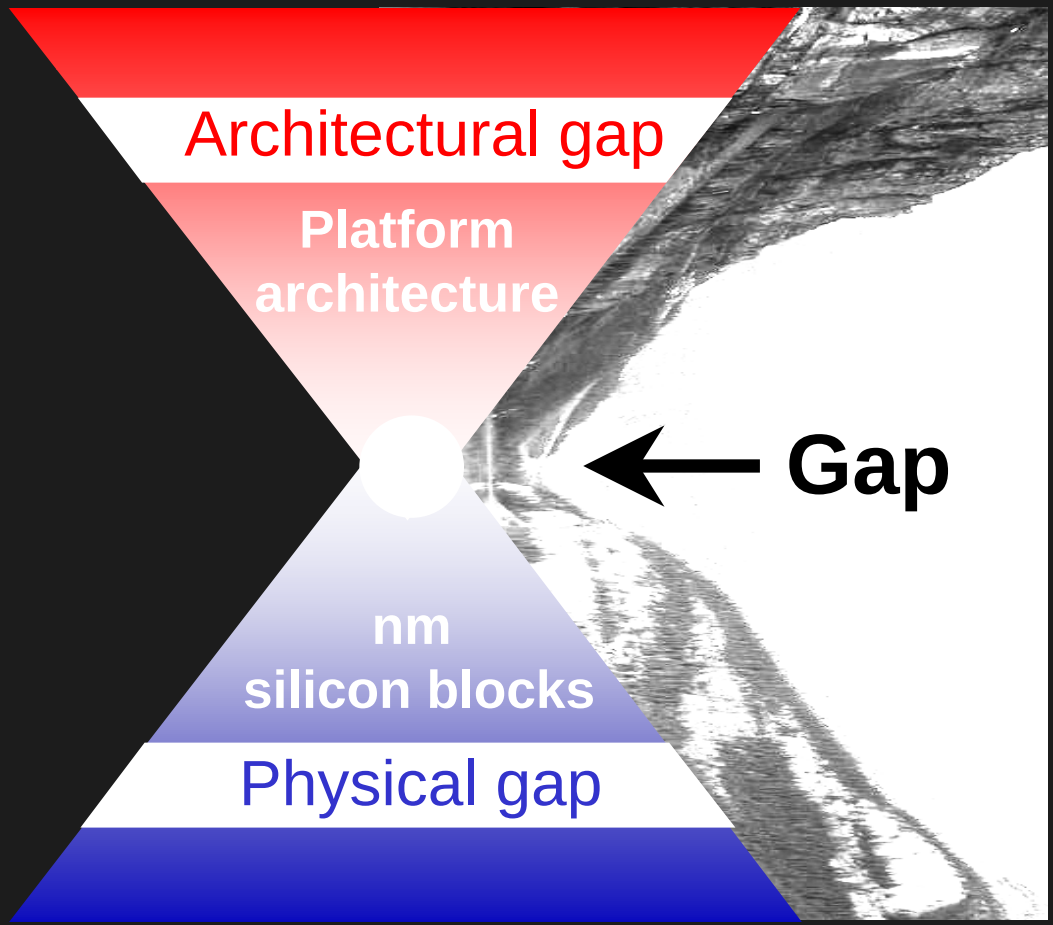
Gaps in nanoelectronic research



Report: Medea+ Scientific Working Group ('06):
Towards and Beyond 2015: technology, devices, circuits and systems

Growing gap: too little focus in the middle

Embedded Software Systems



Hw/e-Sw
Power-Leakage-Variability
Resilient Multi-Core
Architectures
Compatible with
Nano-devices

Nanoscale physics

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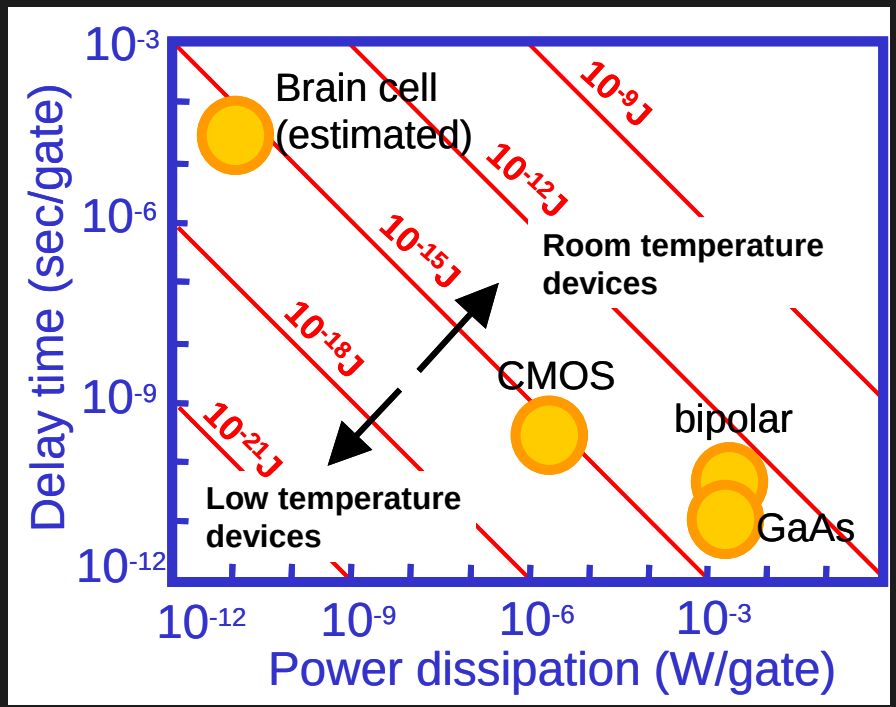
Future trends in nanoelectronics (1)

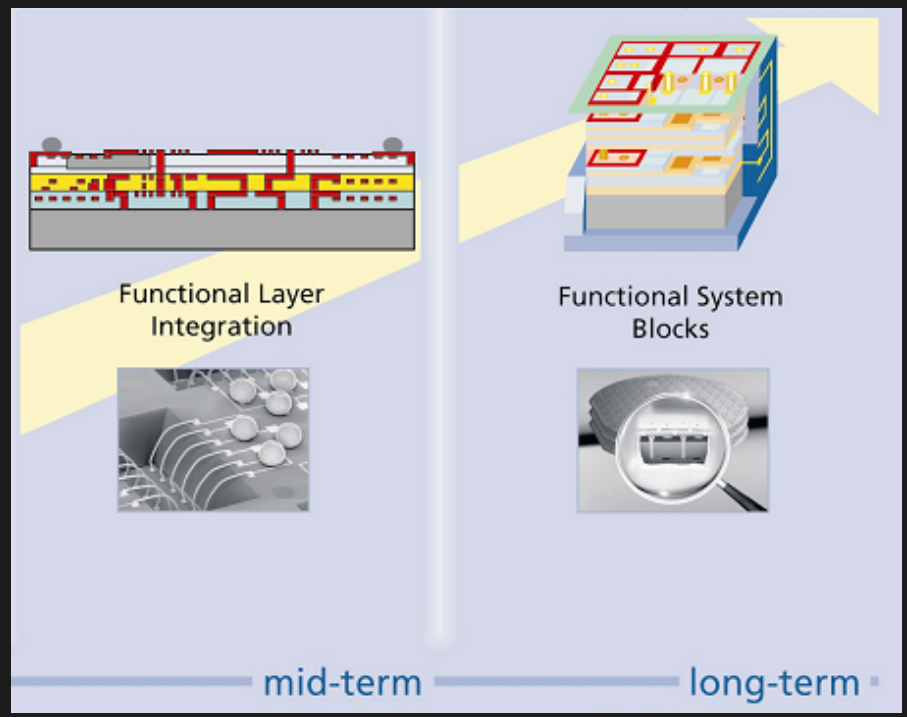
- Key future topics in nanoelectronics:
  - Power-speed trade-off
  - Interconnects & 3D system architectures

Biology vs. logic



Source: E. Takeda.

3D road-map



Source: ENIAC SRA 2007

Future trends in nanoelectronics (2)

- Hybrid CMOS/nano platforms
- Combination of top-down and bottom-up (self-assembly in applications on hybrid platforms)
- Heat removal/reduction technologies
- Eliminating the need for transistors (new system architectures, possibly cross-bar like)
- Computational state vectors other than electronic charge (spin, molecular state)
- Non-equilibrium systems

Continuity

System-able nanotechnology

Disruption

Strong interaction needed between:

- technology/device and circuit/system communities
- experimentalists, theorists and metrologists:
  - What modeling to understand and exploit device/material potential?
  - What experiment to constitute proof of concept of new theory?
  - How to measure parameters bridging experiments and theory?

Europe: building on strengths

Europe strengths and ENIAC

- strength of the European electronics industry in systems (SoC, SiP), calls for long-term research associated with More-than-Moore and exploitation of opportunities in Beyond CMOS
- ambient intelligence concepts are natural areas of development for the systems - other platforms than silicon (plastic, paper, textile substrate, etc) may develop either to accompany AmI or satisfy other markets.
- nano-bio-info-cogno (NBIC) convergence

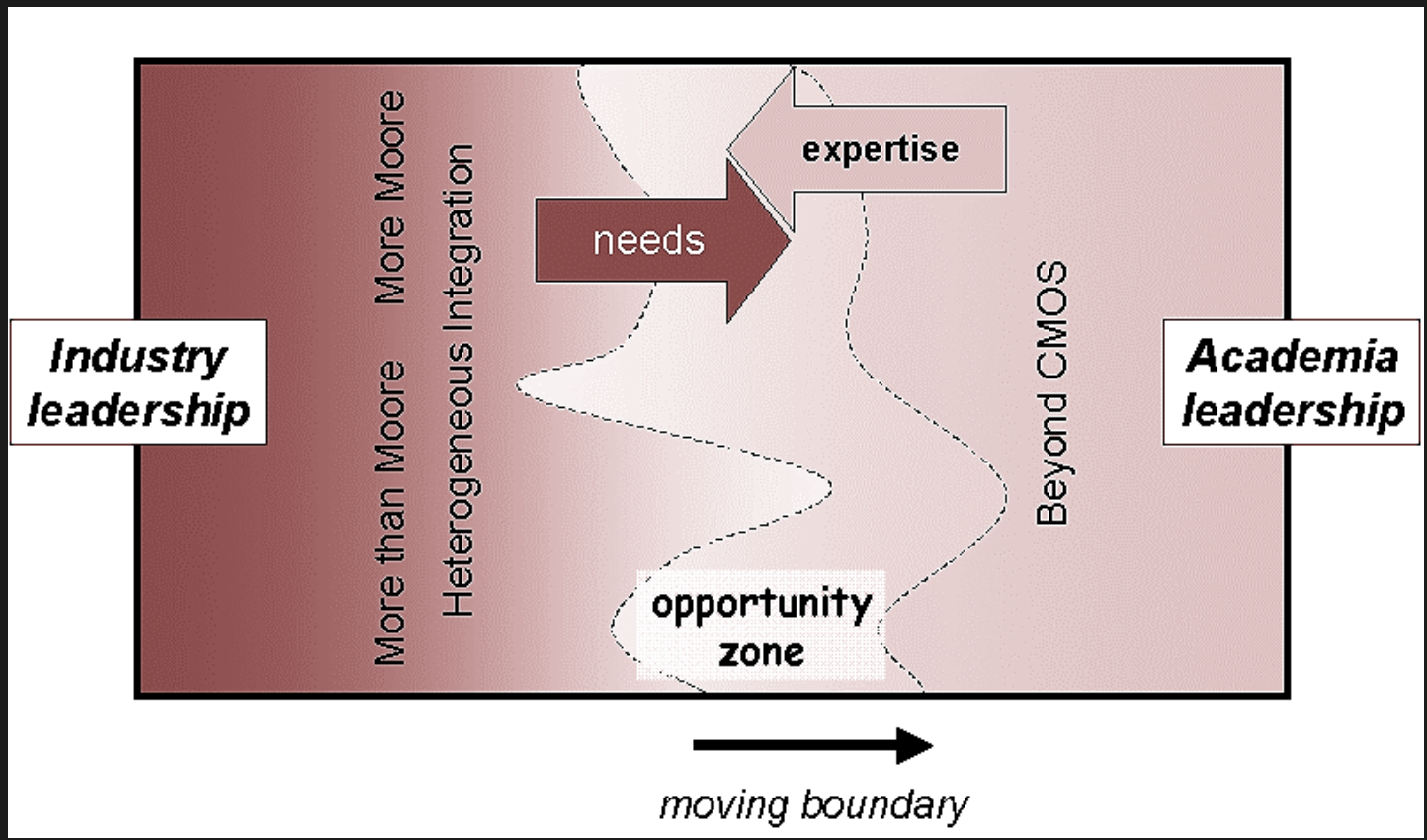
Key role of ENIAC = a vision on future of nanoelectronics towards Europe 2020 – from academic research to industrial opportunities and new markets (strategic research agenda)

ENIAC Strategic Research Agenda domains

- More Moore:
  advanced nano-CMOS: logic & memory
- More than Moore:
  set of technologies that enable non-digital micro/nanoelectronic functions
- Heterogeneous Integration:
  integration of multi-functional components into SiP
- Beyond CMOS:
  disruptive functions complementing or replacing CMOS
- Design Methods and Tools:
  added values of products by the design process itself
- Equipment and Materials:
  from global to small niche innovative companies

Domain interactions

- Continuous and moving boundary between classical approaches in MM, MtM and HI domains and the disruptive technologies Beyond CMOS.
- Significant opportunities for emerging markets where R&D organisations, SMEs/start-ups, together with large companies, will play a significant role.



Future: investing in nanoelectronics research, infrastructures and education

Investing in nanoelectronics research

New I-RO-AC research models should trigger sizable European investments in nanoelectronics – key condition for maintaining leadership and competitiveness

- Elaborate European-specific collaboration models for I, RO and AC and an associated funding scheme capable of implementing the complete innovation pipeline (ENIAC, ARTEMIS, EPOSS)
- Elaborate and accept by I, RI and AC, a broad vision about what Europe wants to achieve with nanoelectronics research
- Sizable investment should be made at the European level to set up a nanoelectronics ERA with the main industrial players, the research institutes, and academia, coordinating national and European level funding sources.

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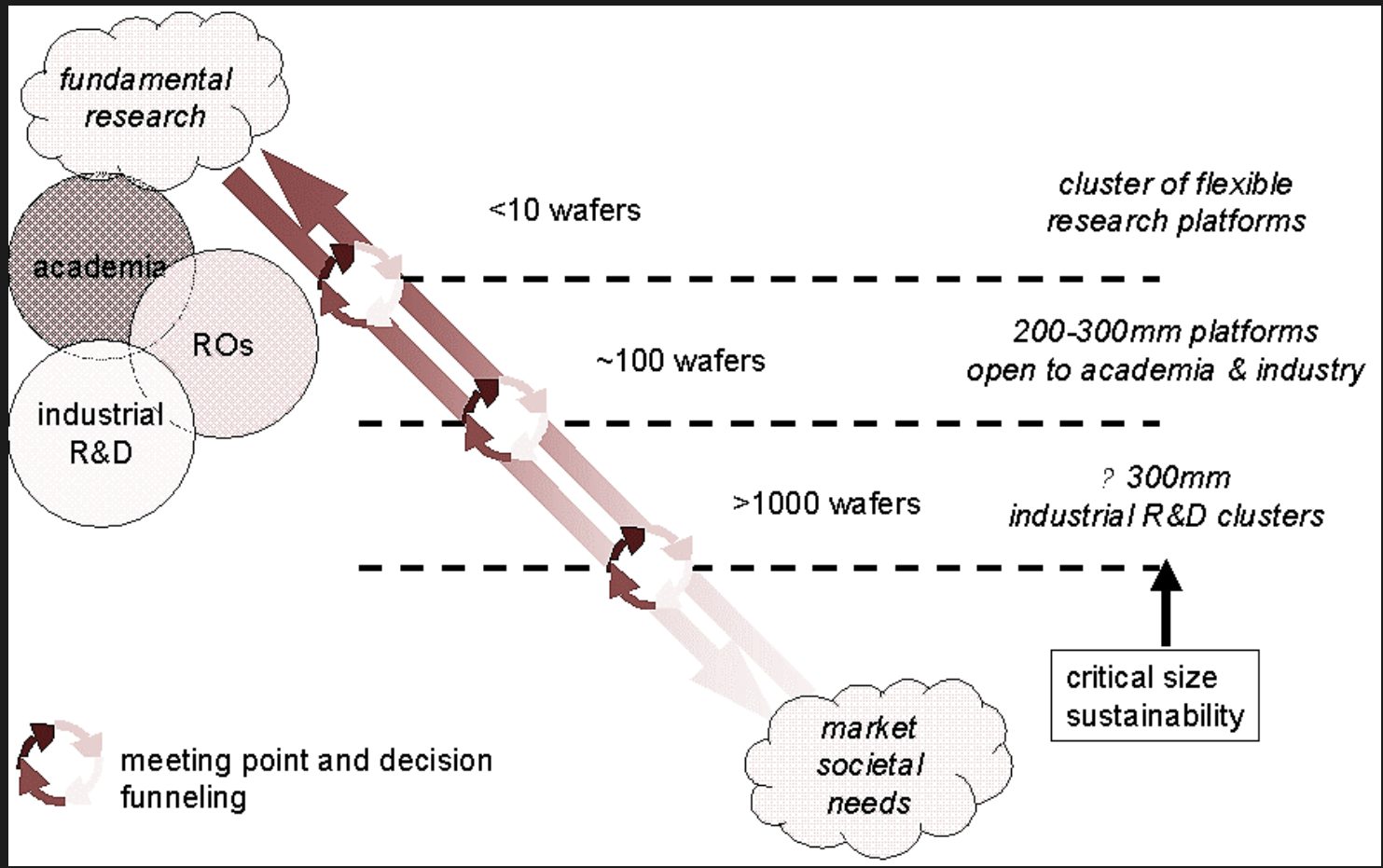
Access to fabrication platforms

- support the creation of flexible academic/RO platforms
- support the development of few advanced platforms @ RO



Source: ENIAC SRA 2007

Get inspiration from pragmatic models

PARTNERSHIP BETWEEN THE GOVERNMENT, INDUSTRY AND ACADEMIA CONSIDERED CRUCIAL TO NANOELECTRONICS RESEARCH in US!

FEDERAL GOVERNMENT

- Commitment to funding long-range research for national interest
- Deep expertise in fundamental, basic research projects
- "Beyond CMOS" projects in areas such as spintronics, molecular electronics, and quantum computing

Nanoelectronics Challenge

ACADEMIA

- World's pre-eminent research universities and professors
- Most diverse and brightest graduate student population
- "Out-of-the-box" thinking and wealth of ideas

SEMICONDUCTOR INDUSTRY

- Knowledge of technology transfer and path to commercialization
- Experience in multi-entity, mission-oriented research programs
- Expertise in "roadmapping" technology challenges

SIA SEMICONDUCTOR INDUSTRY ASSOCIATION

See also: Report: Medea+ Scientific Working Group ('06): Towards and Beyond 2015: technology, devices, circuits and systems

Investing in education

• Develop multi-disciplinary education and new training schemes covering the More-Moore, More-Than-Moore and beyond CMOS domains – **ENGINEERING SKILLS!**

• Create greater public awareness of the societal benefits of advanced nanoelectronics research and industry in Europe

Conclusion

- Nanoelectronics is strategic research and application field for the society
- ENIAC SRA is encompassing definition and execution of R&D in nanoelectronics in Europe for all players (industry, academia, and public authorities) and all mechanisms for public-private partnership (national, transnational, and EC). Make it happen!
- Nanoelectronics institutes, regional competence clusters and academia in Europe must actively work together on strengthening the total research infrastructure
- Address the human capital for nanoelectronics in Europe, by attracting and motivating young scientists and preparing education programs that deliver new skills

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