Ecosystems Technology & Design for Nanoelectronics

A European Coordination Action

www.fp7-nanotec.eu

Mart Graef

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ZEROPOWER Glasgow Workshop, 3-4 July 2012

Outline

- Objectives
- Roadmapping
- Methodology
- Results
- Conclusions

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About NANO-TEC

NANO-TEC is a European Project (Coordination Action) funded by the European Commission ICT theme to run for 30 month until February 2013 with an EU contribution of € 720.000.

Contract Nr FP7/2007-2013

Aim

- To identify the next generation of emerging device concepts and technologies for ICT, through a foresight exercise on medium and long-term requirements in nanolectronics research
- To build a joint technology-design community to coordinate research efforts in nanoelectronics by harmonising the efforts of existing and new initiatives and projects

NANO-TEC

Project partners

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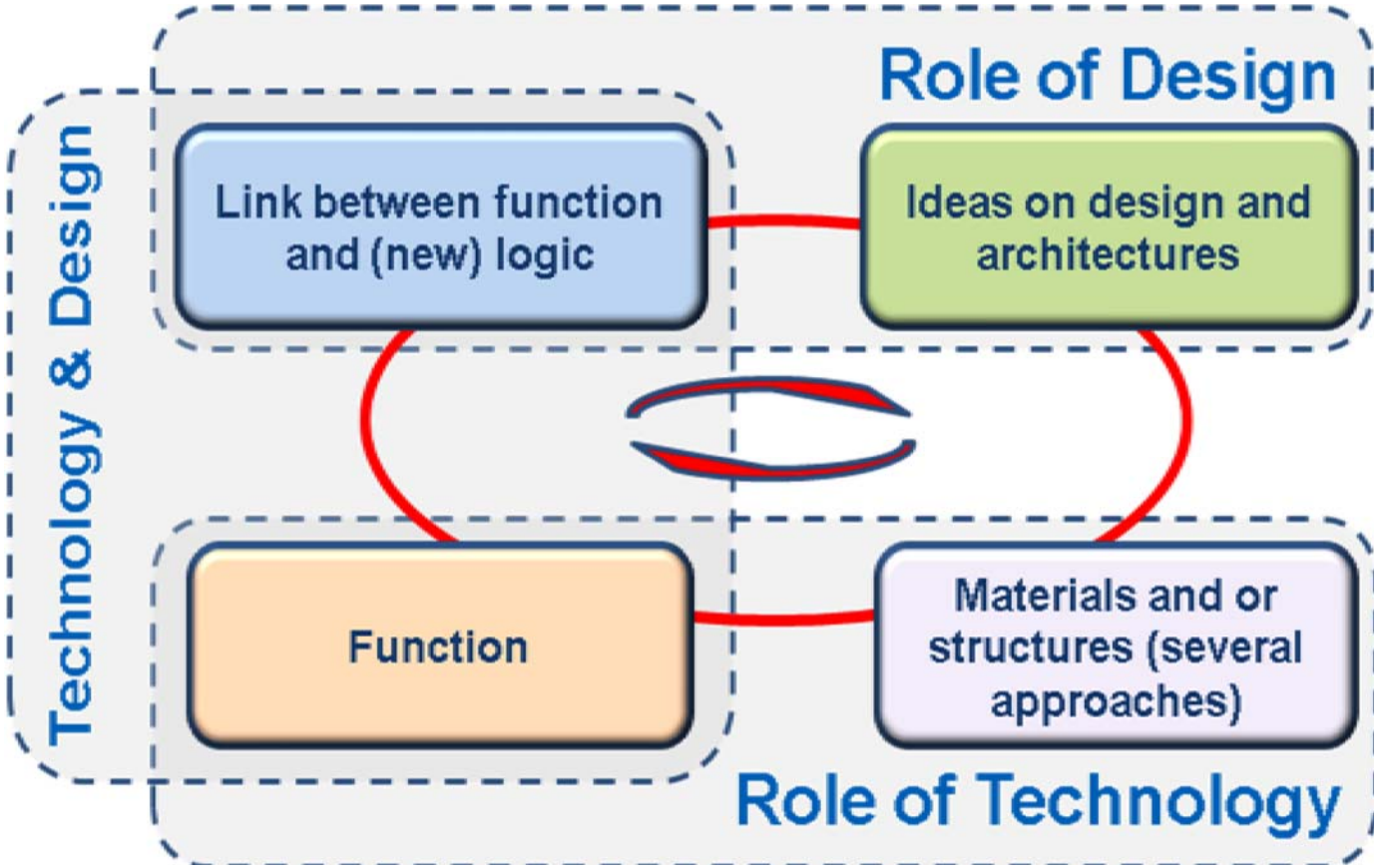
NANO-TEC Concept



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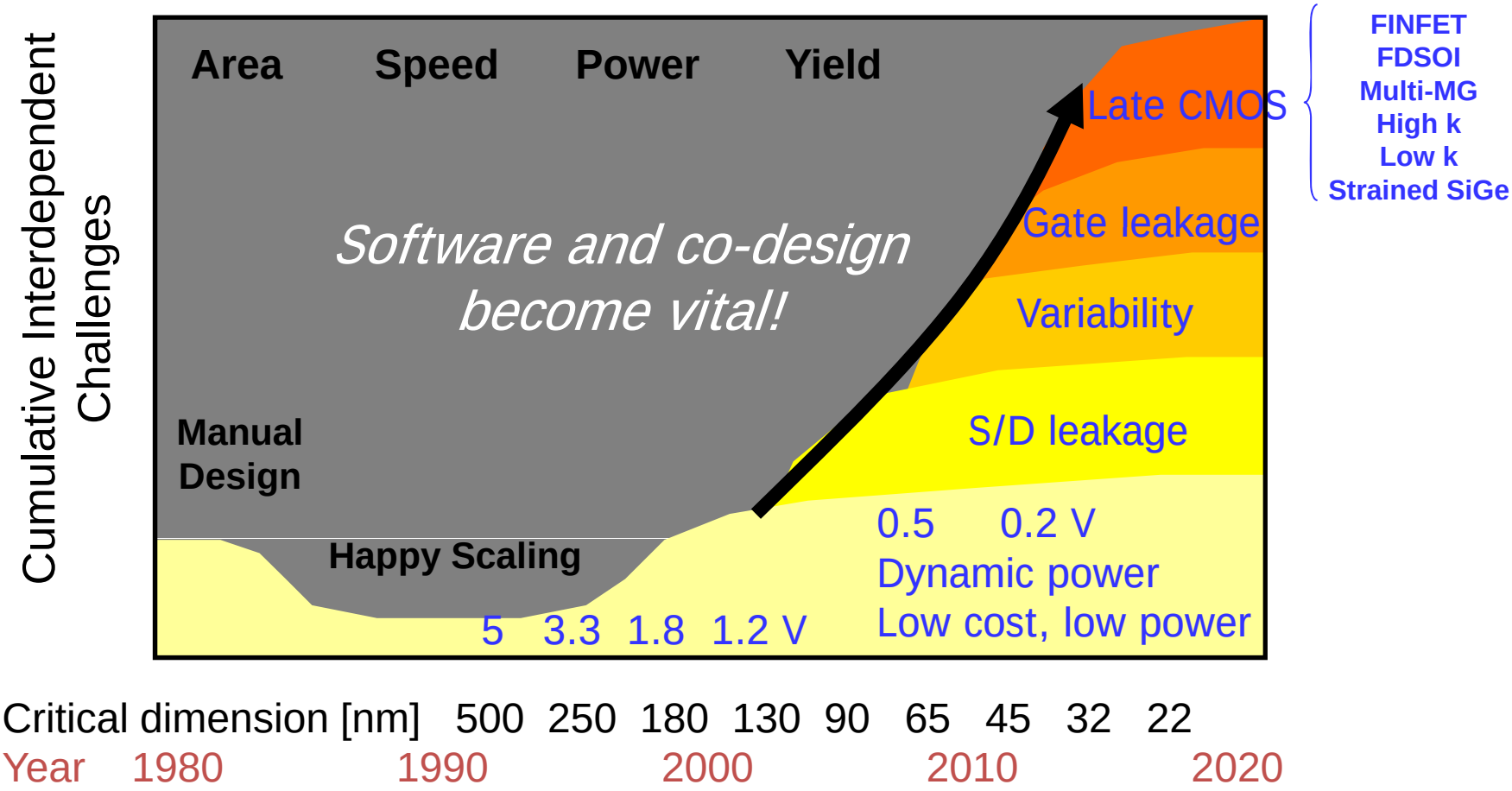
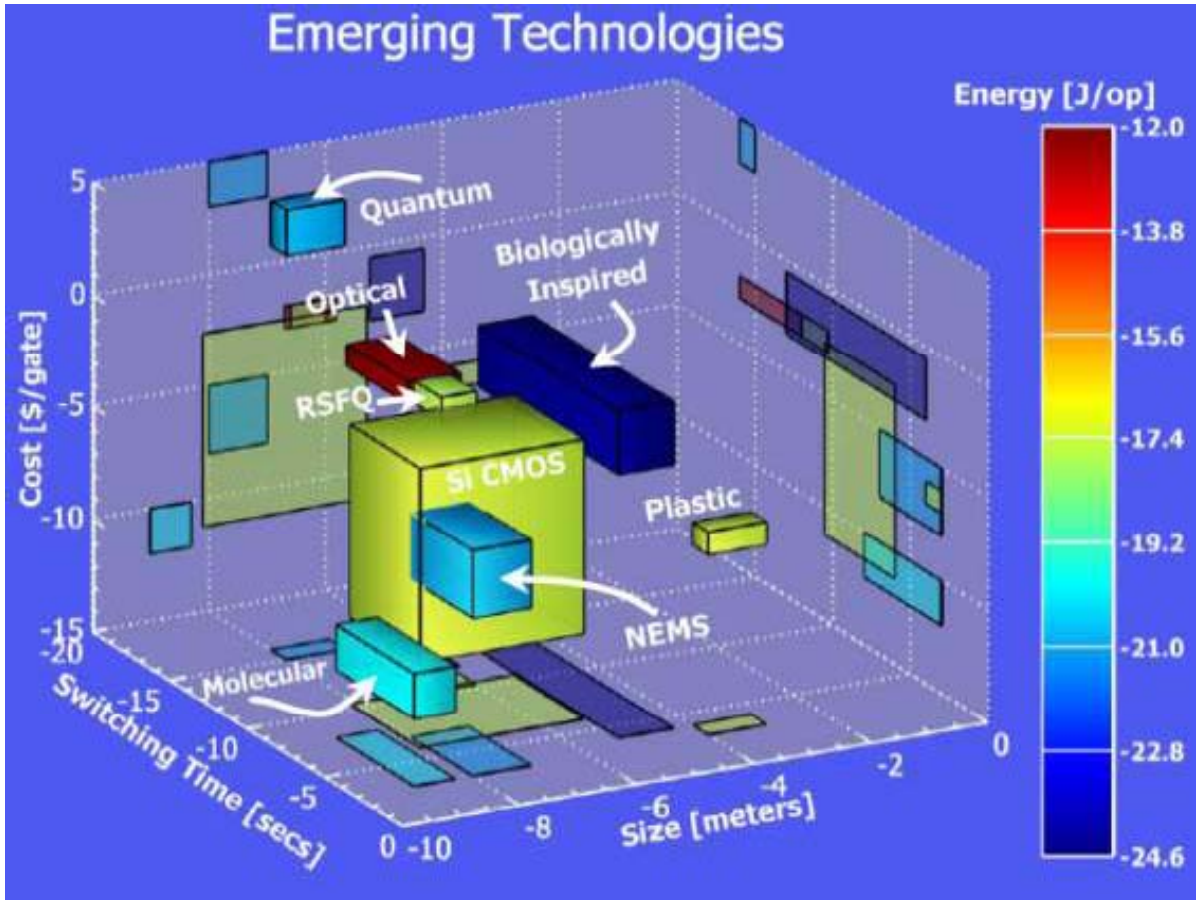
More Moore: Increasing complexity

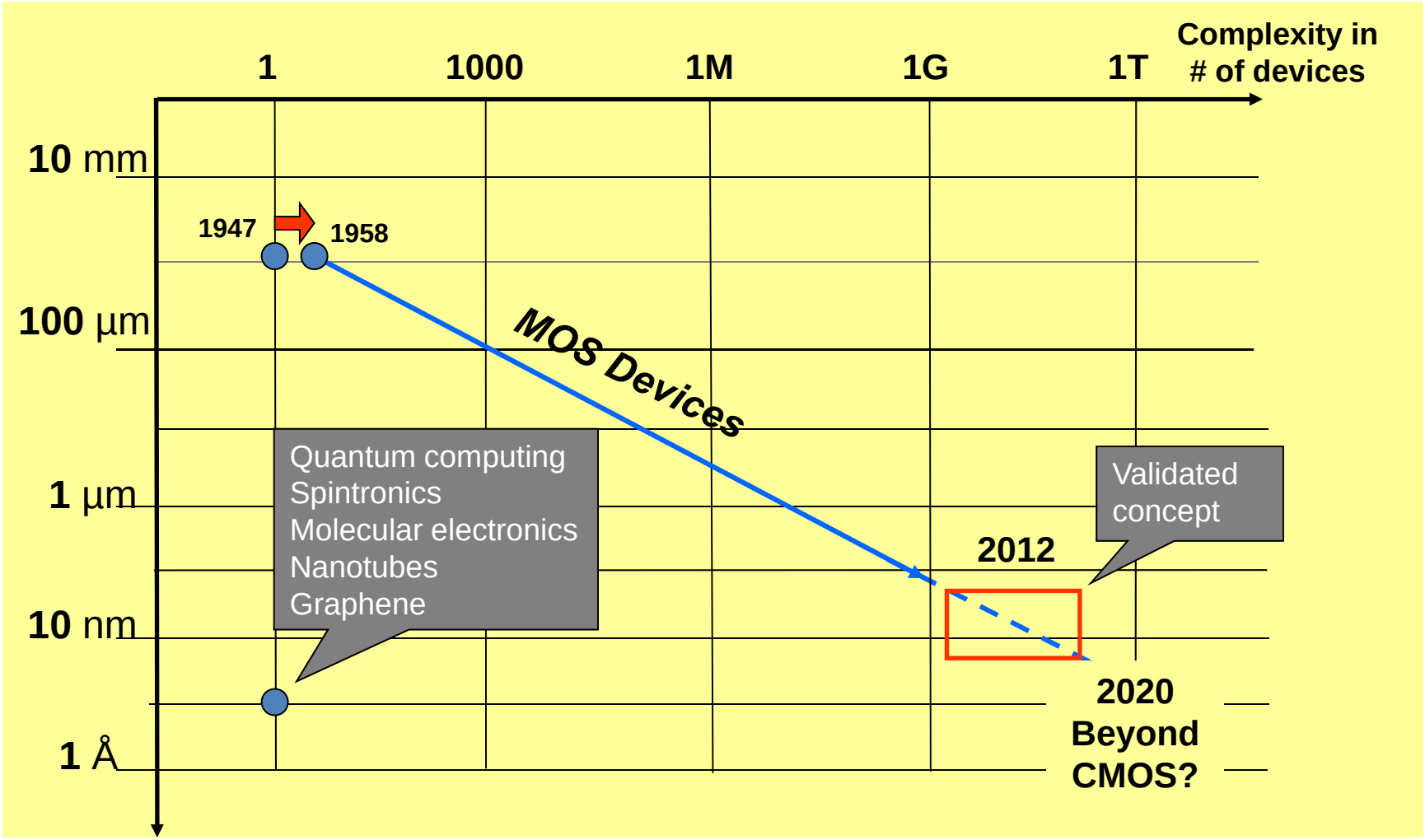


Parameterization of emerging technologies



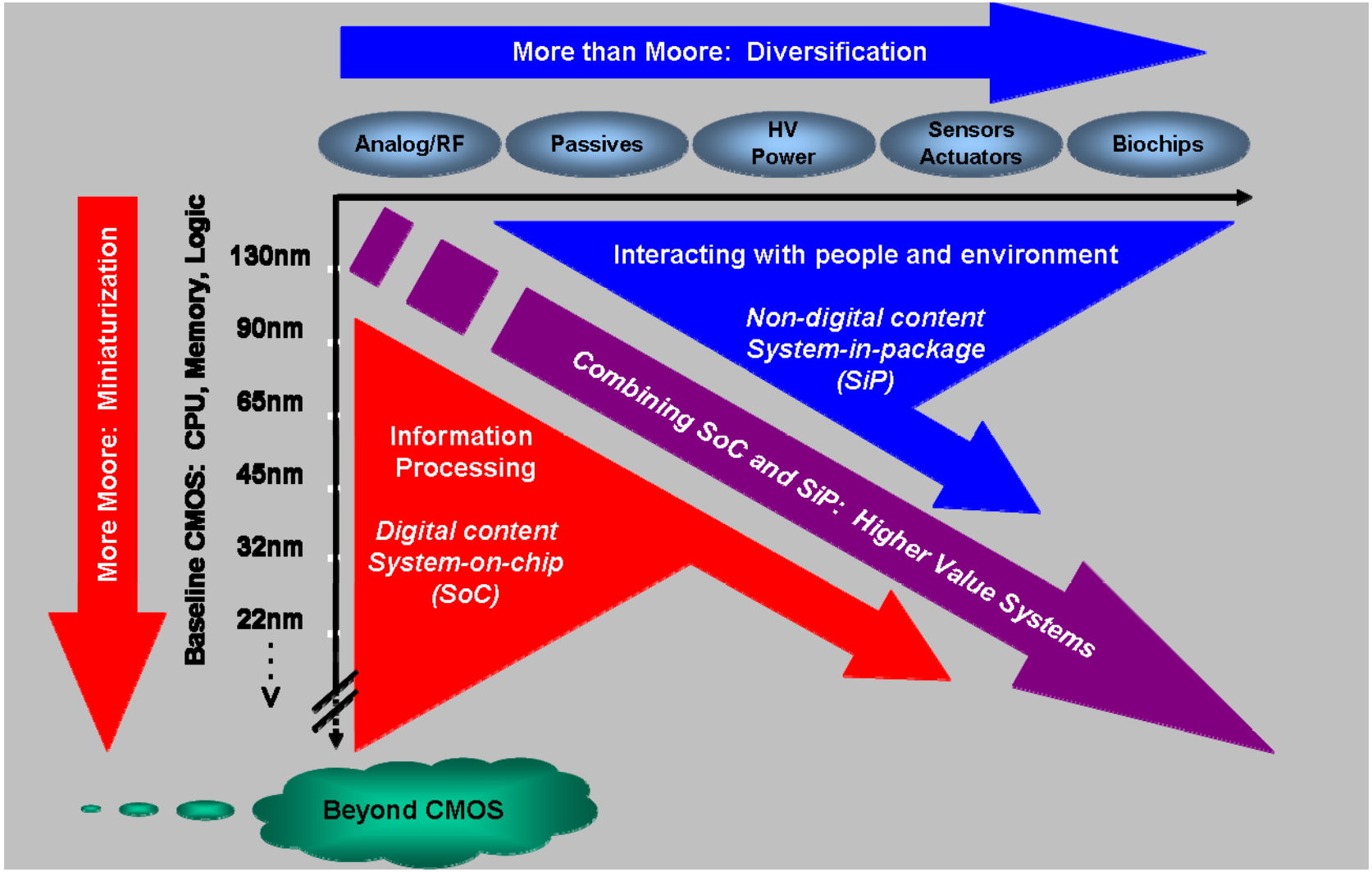
Source: ITRS

Reaching dimension/complexity limits



Source: STMicroelectronics

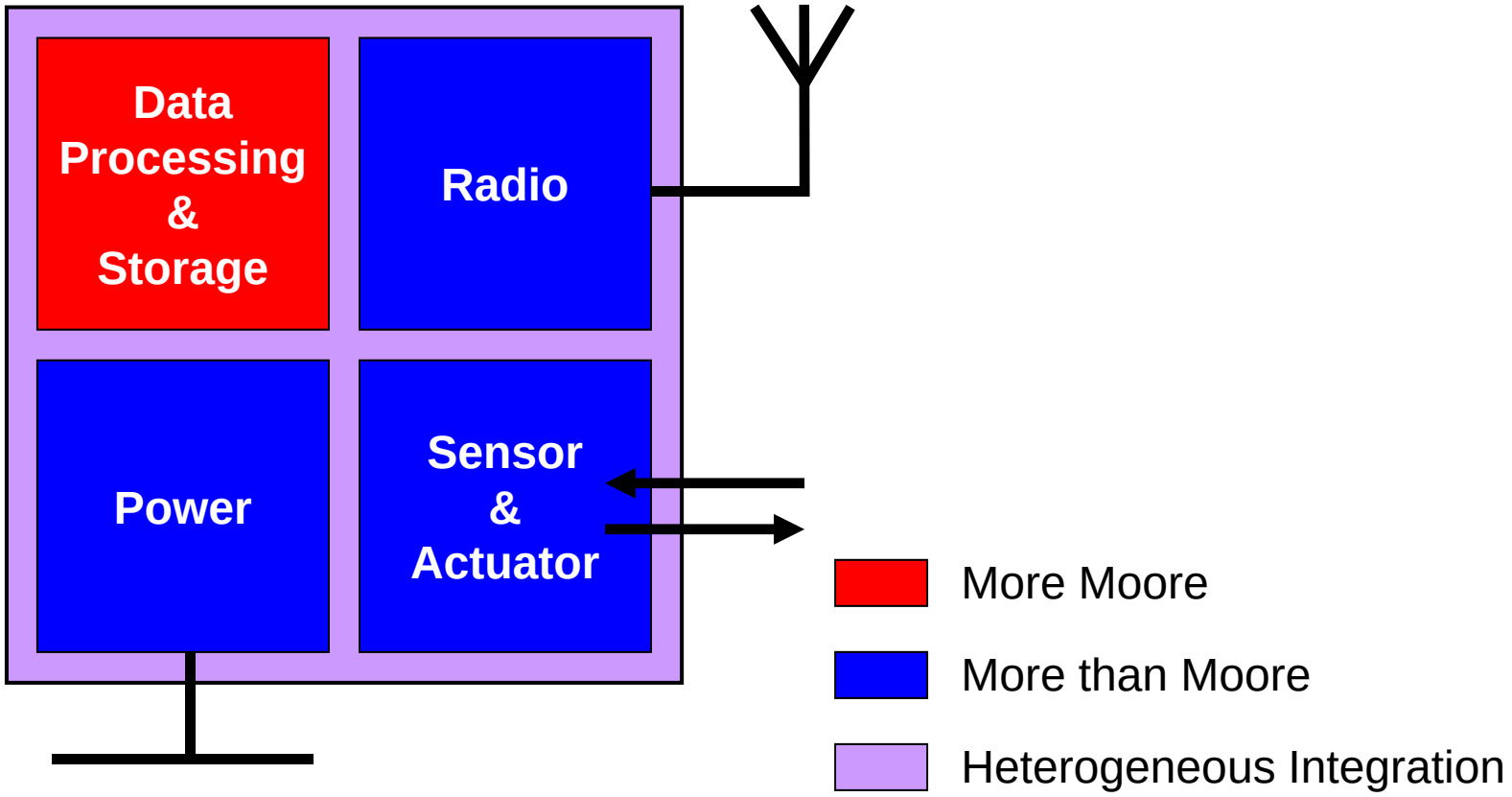
“More Moore” & “More than Moore”



Source: ITRS (2011)

Smart microsystems:

Beyond CMOS = More Moore + More than Moore



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NANO-TEC methodology

Workshop series with invited experts on 'Beyond CMOS' devices

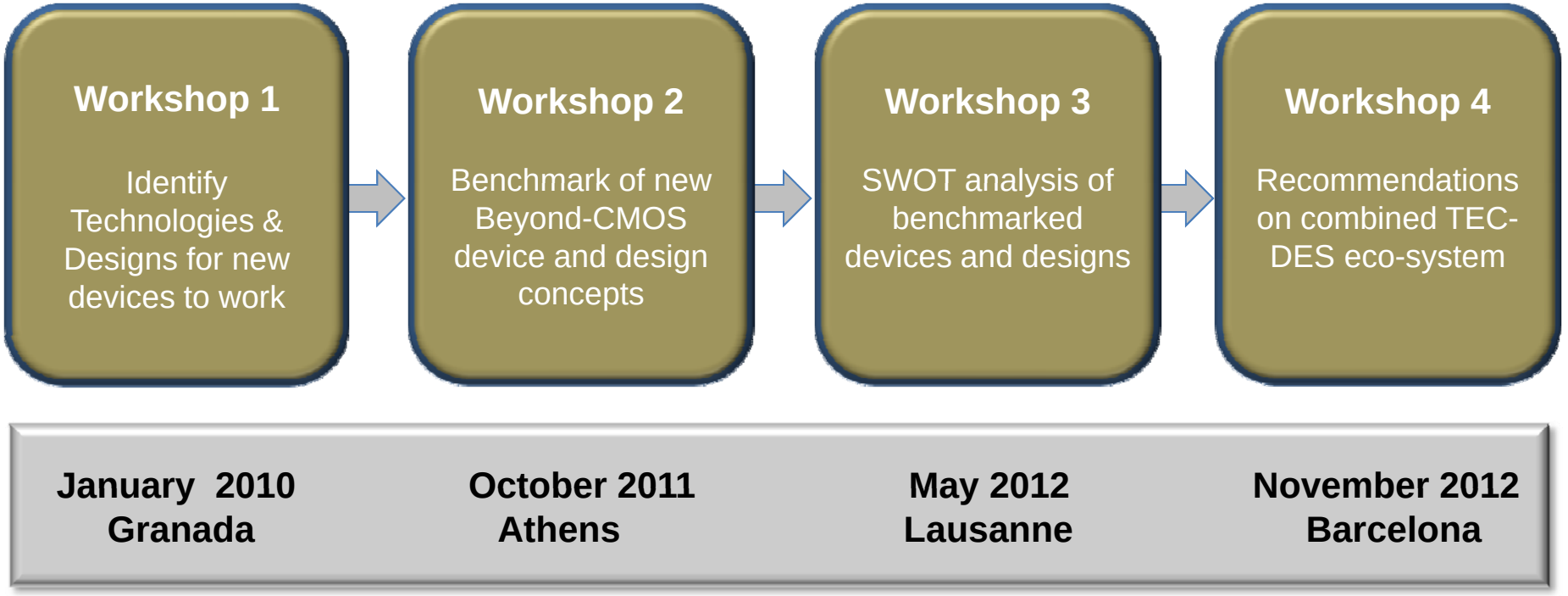
- Selection of speaker, discussants and rapporteurs from academia, institutes and industry
- Guidelines for all three groups focusing on workshop target
- Report of each Workshop building on previous one towards final recommendations

Web platform for working group discussions, communication and access to an information repository

Report on recommendations for Emerging Nanoelectronics, and the desired combined technology-design ecosystem

NANO-TEC

NANO-TEC workshops



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1st NANO-TEC WORKSHOP

Identifying Beyond CMOS devices

20-21 January 2011, Granada, Spain

Topics of WS1

- Nanotechnology trends for the next decade
- Carbon-based electronics
- Silicon-based electronics
- Compound semiconductor-based electronics
- Spintronics
- Bridge to Design
- Analogue-Mixed signal design
- Molecular Electronics/quantum computers

Recommendations of WS1

- Address *power consumption, manufacturability* and *performance* as priorities
- Strengthen research in device functionality at the nanoscale, addressing new *architectures* and *alternative concepts* to do computation
- On *Beyond CMOS design issues,* research needs include:
  - Circuits and architectures for a full exploitation of nano-components
  - Mode of operation of such devices
  - Multi-scale approach, in order to describe realistic systems

2nd NANO-TEC Workshop

Benchmarking of new Beyond CMOS device/design concepts

12-14 October 2011, Athens, Greece

Motivation for Benchmarking

- Large number of emerging 'Beyond CMOS' device concepts
- Various types of functions (data processing, computation, memory,interconnect…)
- Device fabrication/production?
- Architectures, design tools, libraries?
- Application prospects?
- Unique exercise in advancing the research of future emerging devices in Europe.

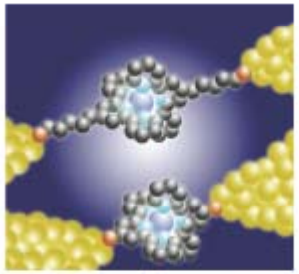
Benchmarking Beyond CMOS Devices

Technology	[Wires, graphene, MEMS etc… please insert name]
Gain **Signal/Noise ratio** **Non-linearity**	
Speed **Power consumption**	
Architecture/Integrability **(Inputs/outputs, digital, multilevel, analog, size etc.)**	
Other specific properties	
Manufacturability **(Fabrication processes needed, tolerances etc.)**	
Timeline **(When exploitable or when foreseen in production)**	

Example: Molecular electronics

D. Vuillaume (CNRS, Lille), 2nd NANO-TEC Workshop

Single molecule electronics

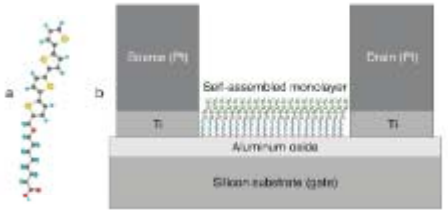


L < a few nm
t < a few nm

basic science knowledge development

no foreseen applications in a reasonable time-scale

Self-assembled molecular electronics



L ~ tens nm - µm
t < a few nm

basic science knowledge development

possible applications foreseen

Thin film molecular electronics

L > µm
t > few 10 nm

plastic electronics (OLED, OFET, OPV)

some products already commercialized

Example: Molecular electronics

Benchmarking Beyond CMOS Devices

Technology	Molecular Electronics D. Vuillaume, CNRS & University of Lille
Gain **Signal/Noise ratio** **Non-linearity**	Ok with SAMFET (to be optimized), 2-terminal junction: low current Noise not yet studied (a few publications) Molecular junctions are mainly non-linear
Speed **Power consumption**	Low Low (50 zJ/mol switching energy)
Architecture/Integrability (Inputs/outputs, digital, multilevel, analog, size etc.)	Molecule-nanoparticle 2D and 3D arrays could implement some functions (e.g. reconfigurable logic, neuro-inspired functions)
Other specific properties	Almost infinite combination of molecules, adjustable by chemistry, specific design (1 molecule = 1 function)
Manufacturability (Fabrication processes needed, tolerances etc.)	Solution processing, compatible with flexible substrate. Defect control? Large variability (but not a problem if we envision artificial neural networks)
Timeline (When exploitable or when foreseen in production)	> 5 – 10 years (if ever?)

Conclusions of WS 2

- Technology/Emerging devices ↔ Architecture/Design
  - Quite apart
- Emerging device concepts:
  Not enough data for current design tools
  - Transfer functions, memory, interconnects, tolerances, noise…
- Design tools have to develop towards multi-scale approaches
  - Physics, non-Boolean, multilevel…

3rd NANO-TEC WORKSHOP
SWOT Analysis of the Technology-Design Ecosystem

30-31 May 2012, Lausanne, Switzerland

SWOT Analysis of Beyond CMOS Devices

Strengths	**Weaknesses**
• Application perspective • Building blocks for innovation in nanoelectronics • European industrial/academic ecosystem	• Physical constraints • Compatibility issues with conventional technology • Reliability, variability
Opportunities	**Threats**
• Design of circuits and systems • 3D integration of multifunctional systems • Industrial/academic cooperation	• Gap to industrial needs? • 'CMOS competition' • Manufacturability

4th NANO-TEC WORKSHOP

Recommendations for the Technology-Design Ecosystem in Nanoeletronics

6-7 November 2012, Barcelona, Spain

Register at: https://www.fp7-nanotec.eu/registration

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Conclusions

- The identification, benchmarking and SWOT analysis of Beyond CMOS devices and technologies is well underway. This will lead to a shared vision on needs, capabilities and methodologies.

- NANO-TEC has initiated a dialogue between the technology and design communities in Europe on Beyond CMOS.

- As a result, new opportunities for collaboration on nanoelectronics between industry, institutes and academia are emerging.

Acknowledgments

The NANO-TEC consortium, in particular:

- Clivia Sotomayor Torres
- Jouni Ahopelto
- Ralf Popp