Globalization of R & D

Changes in R&D Model Heading Toward Nanoelectronics Era

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Future R&D Model and Organization

- **Silicon-based CMOS is dominant design in the next 15 years**
- **Silicon technology R&D cost increase over revenue increase rate**
- **Need for shorter R&D cycle time**
- **Improvement need for R&D efficiency**
- **Reduction of hand-off**
- **Competition in both performance and cost**
- **Noncompetitive, precompetitive and post-competitive may be moved outside**

Open Issues

- Do we need “dedicated R&D facility”?
- How much can TCAD contribute to reduce process development cycle time
- Where should we expect to see “beyond silicon IC” research
- Where can we and how can we collaborate without “legal document”
- Plus and minus of R&D “baseline”

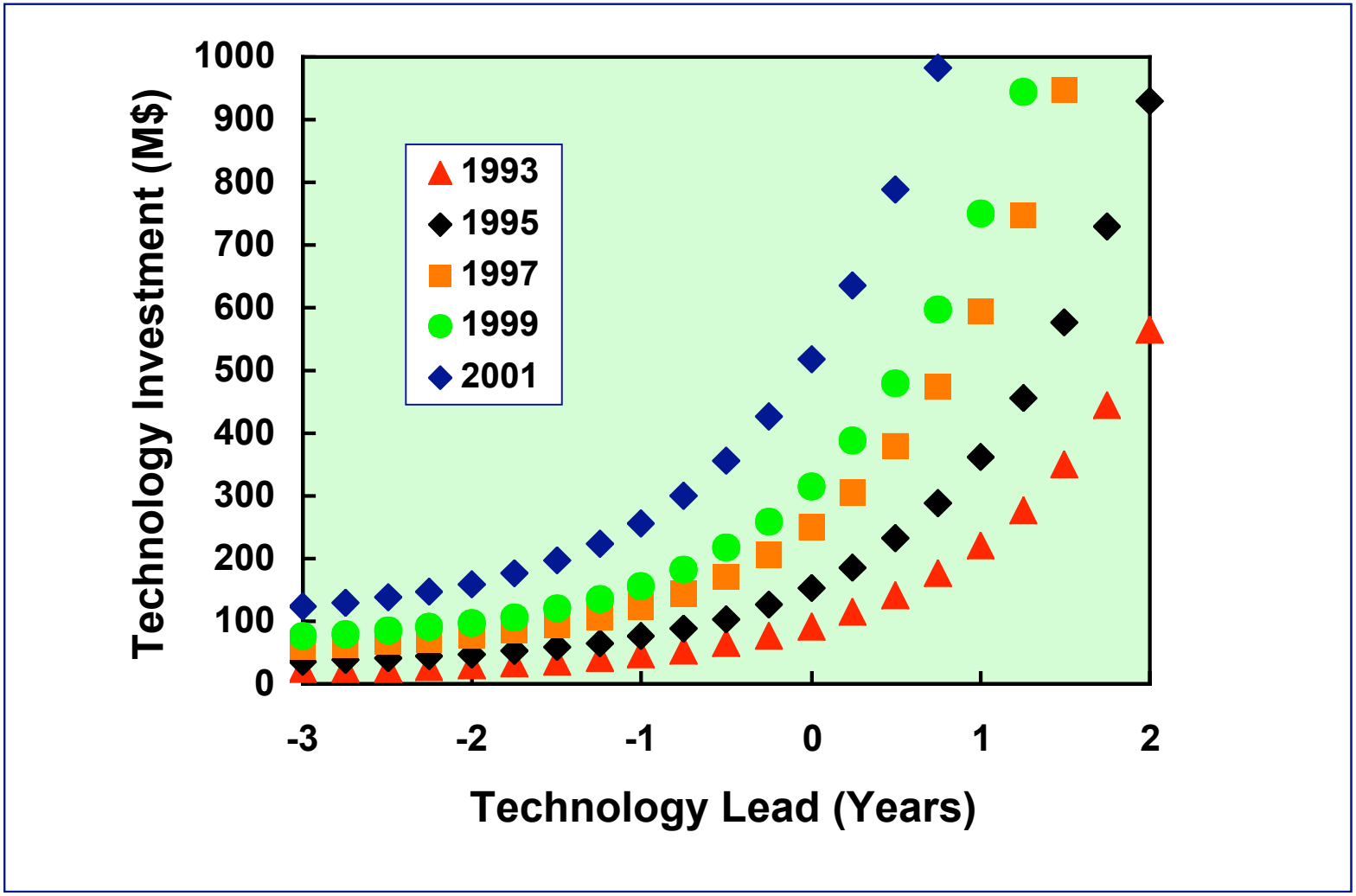
Examples in Changing R&D Model

- Toshiba in early 80's: creation of "works labs" to shorten technology transfer path
- HP in late 80's to early 90's: consolidate broadly spread R&D to create above "critical mass" for converged high performance CMOS technology
- TI in late 90's: elimination of Central Research followed by creation of Kilby Center

Results from Such Changes

- Toshiba: became #1 in DRAM with consecutive wins
- HP: Fastest CMOS based RISC Processor manufacturer
- TI: #1 DSP and Analog company with leadership silicon technology

The Right Technology at the Right Time for the Right Cost



Cost Sharing in R&D activities

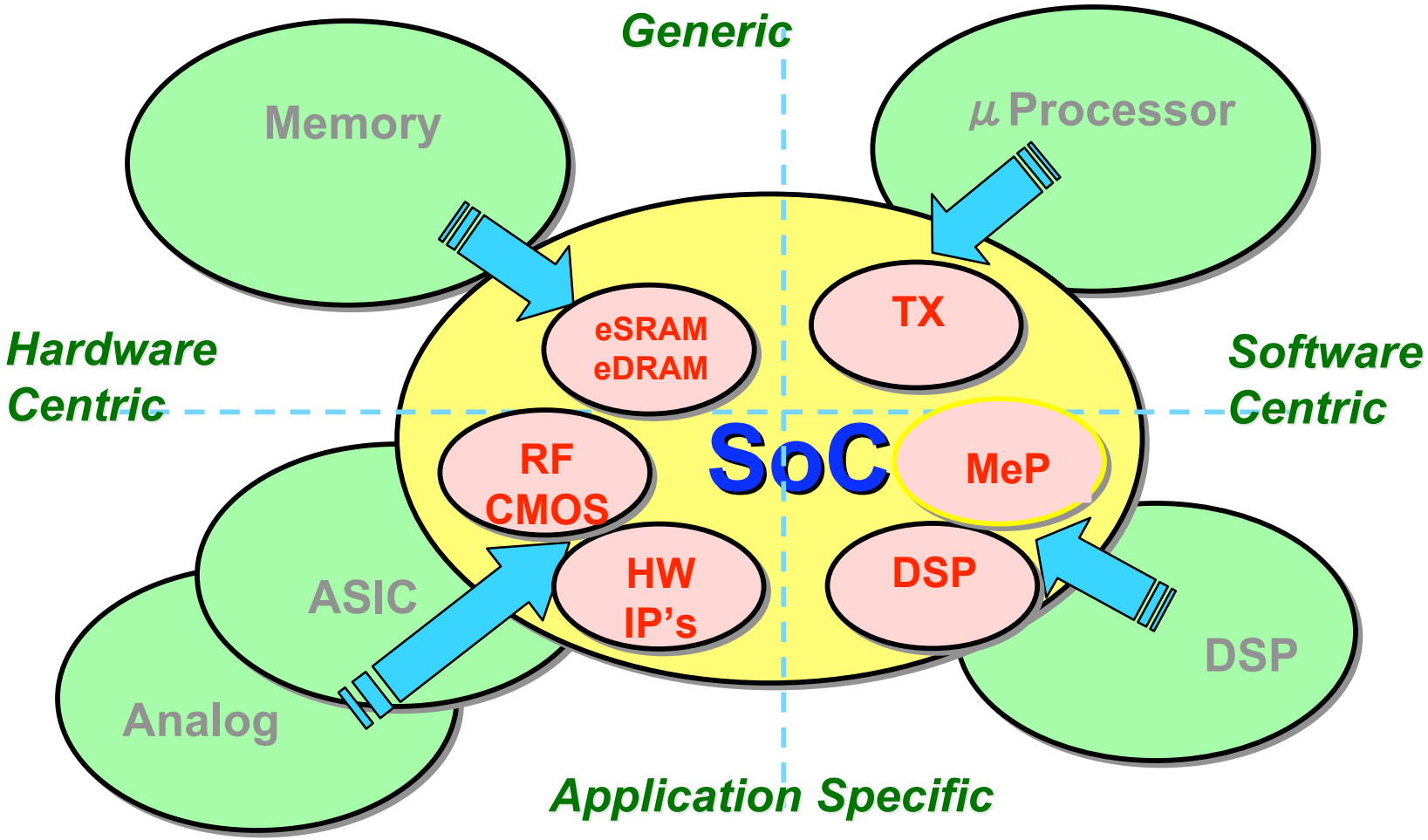
Cost / Node: > 20 M$** **> 200 M$ **> 2,000 M$**

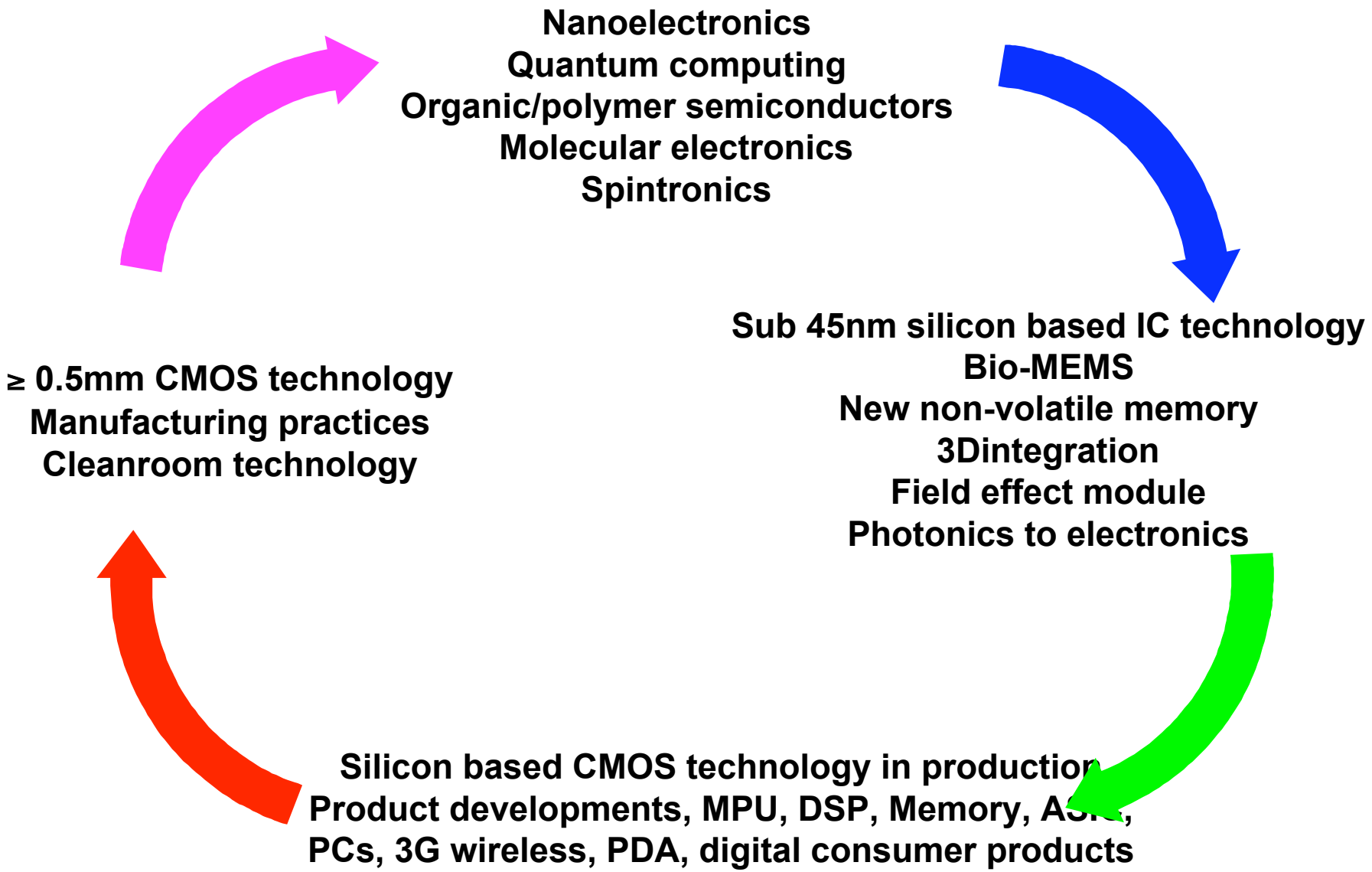
- **Unit Process and Process Module**
- **Collaboration with Universities and Consortia**

- **Full Process Integration**
- **R&D Alliance among Chip Makers**

- **Mass Production**
- **Huge Investment for 300mm Fabs**
- **Joint Venture**

SoC (System-on-Chip)




Nanoelectronics
Quantum computing
Organic/polymer semiconductors
Molecular electronics
Spintronics
Sub 45nm silicon based IC technology
Bio-MEMS
New non-volatile memory
3Dintegration
Field effect module
Photonics to electronics
Silicon based CMOS technology in production
Product developments, MPU, DSP, Memory, ASIC,
PCs, 3G wireless, PDA, digital consumer products
≥ 0.5mm CMOS technology
Manufacturing practices
Cleanroom technology

Nanotechnology

- Promising in electronics to extend Si based IC industry
- Non-volatile memory with extra density
- Energy conversion devices and applications
- Bio-MEMS/NEMS for pharmaceutical and medical applications
- New structural components
- Uncertain future for molecular electronics, spintronics for practical applications

Needs for aggressive materials research and engineering through university-industry partnership. System level breakthrough toward non-traditional use of integrated electronics

Nanoscience and Nanotechnology

- "Evolutionary" Nano (mm _ nm)
- "Revolutionary" Nano (quantum and nano devices, organic (and perhaps molecular) electronics …)
- Nanomaterials
- Biology, and Biological "Nanomachines"
- Technological Imperatives
    - Electronics: Processors and Memory
    - Biomedicine: Bioanalysis
    - National Security: Sensors, Materials

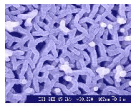
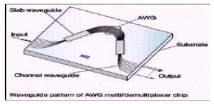
Progress on all fronts will require a mixture/portfolio of technologies: top-down lithographies, bottom-up synthesis, self-assembly, templating, bio and biomimetic!

Nanotechnology Infrastructures

- SRC: Became international in 2000
- Sematech: International in late 90's
- NNIN: Cornell, Stanford, Georgia Tech, Michigan, Minnesota, Penn State, Harvard, Howard, UT Austin, UCSB, Washington, U. New Mexico, NCSU
- Nano-foundry: U. Tokyo, Waseda U etc
- Korea: NNFC
- LETI, IMEC

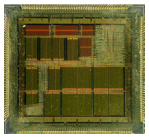
Landscape of Singapore Electronics Industry

Institute of Microelectron

Nano-ZnO on







- Nanotechnology
- Photonics
- Advanced Display
- Equipment
- Communications
- Wafer Fab
- IC Design
- PC
- EMS
- Disk Drive
- Consumer Electronics
- Precision Engineering
- IC Assembly & Test

Technology

1960s 1970s 1980s 1990s 2000 2005

Asian Semiconductor Landscape

- ***Korea***: DRAM driven development of manufacturing capability coupled with strong electronic equipment industry
- ***China***: The fastest growth in semiconductor/IC market driven by communication and consumer electronics with growing wafer manufacturing
- ***Singapore***: Comprehensive development of semiconductor IC and MEMS technology and applications for more value creation
- ***Japan***: The largest amount of efforts for R&D with transition from DRAM to digital consumer centric with SOC and massive restructuring

Needs for more globalization

- Nanotechnology/nanoelectronics require more interdisciplinary couplings
- Most of countries have promoted nanotechnology and information technology, leading to stronger regional research capability built up
- Demand for R&D resources exceed supply capability of one company, one country, or one region
- Market specific demands to products, technologies lead to R&D close to the end market