Intellectual Property Computing After the End of Semiconductor Scaling

ICT 2008

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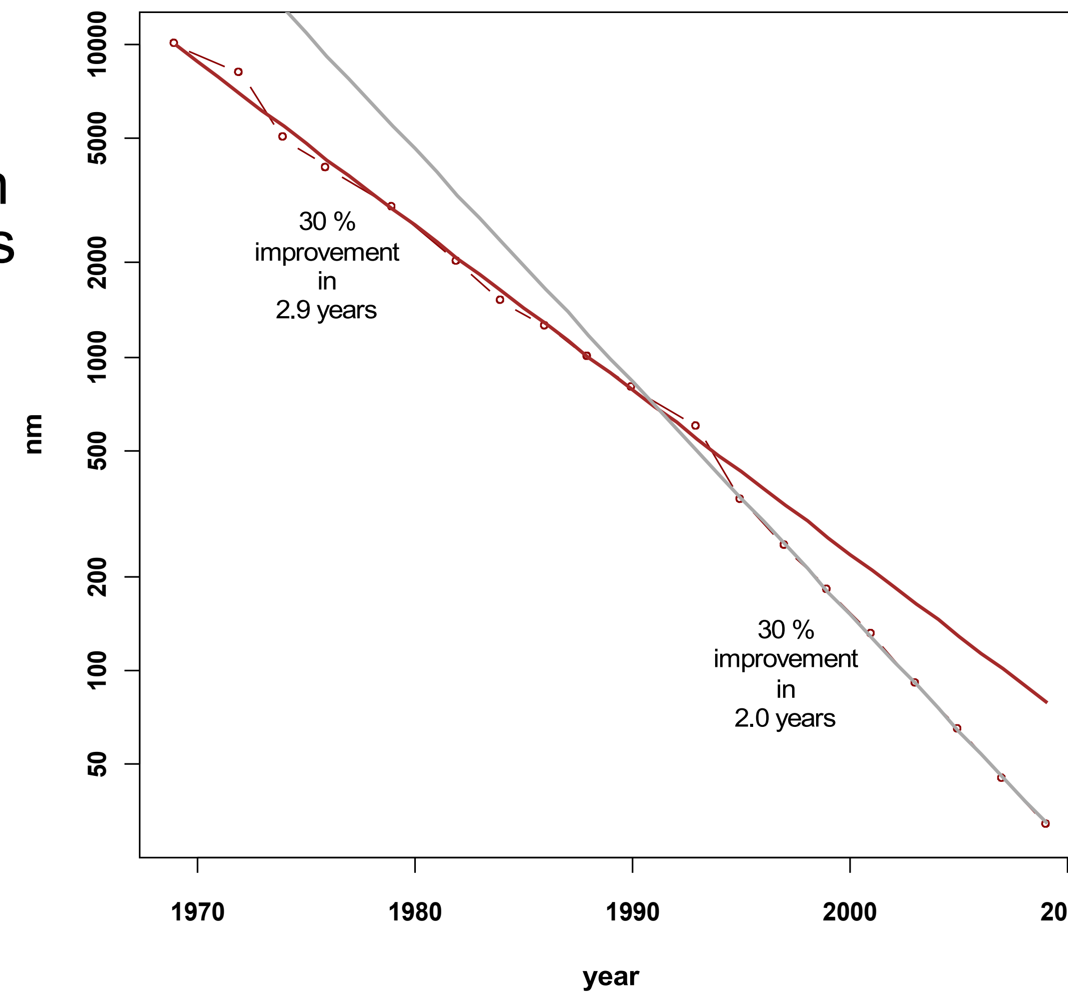
Themes

- Semiconductor scaling is about to end
- This creates one of the biggest technology disruptions we have ever known
  - new business models, key knowledge, and geographic distribution of economic activity emerge
- What will be the new business models? What will happen to ICT, after the end of semiconductor scaling?

Semiconductor Scaling

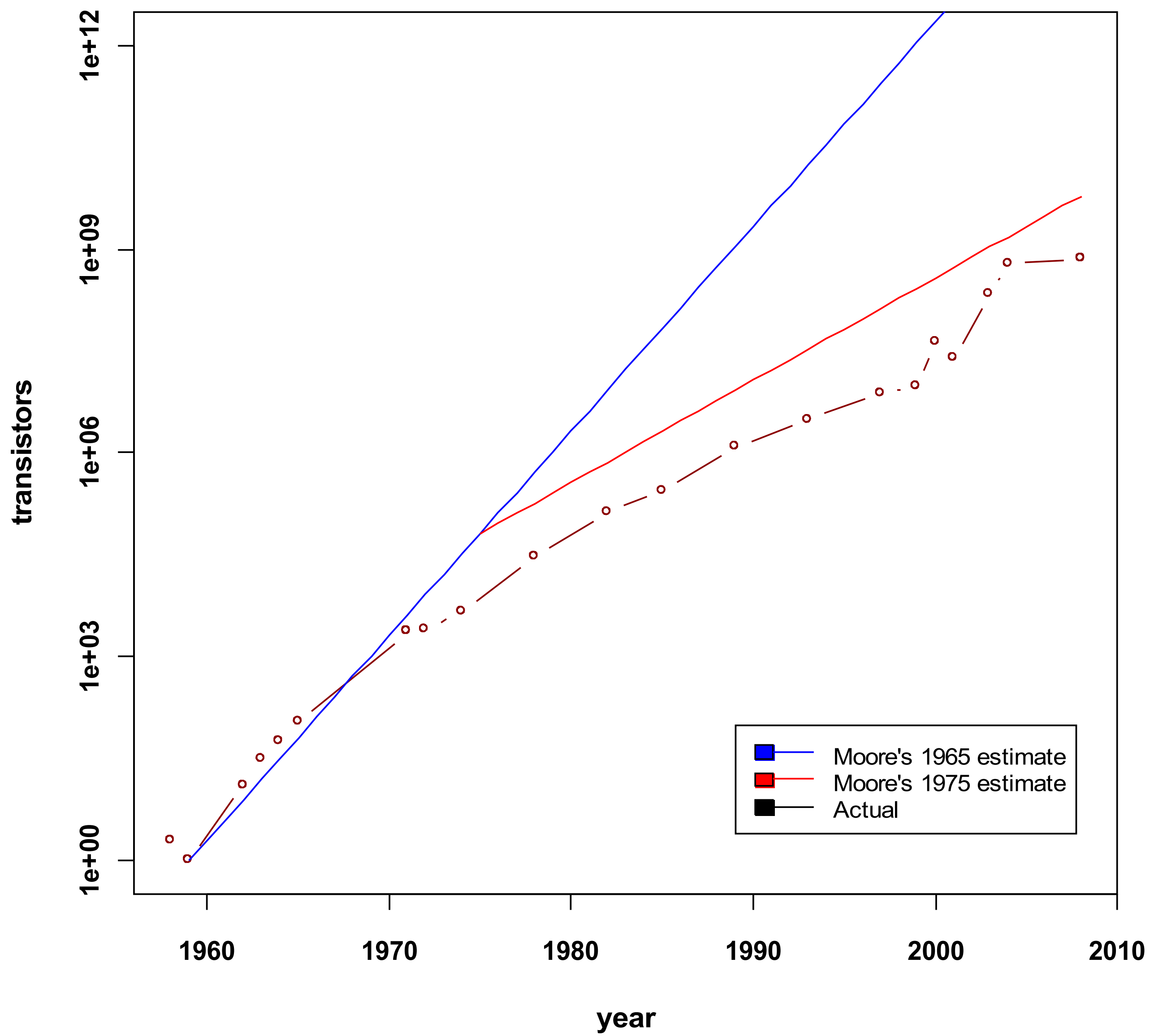
- Since 1958, the ICT revolution has been driven by continuous miniaturization



Lithography process nodes: first year of large-scale use

Source: Tuomi, I. (2008) The future of semiconductor intellectual property blocks and architectures in Europe. Luxembourg, European Commission, (final draft).

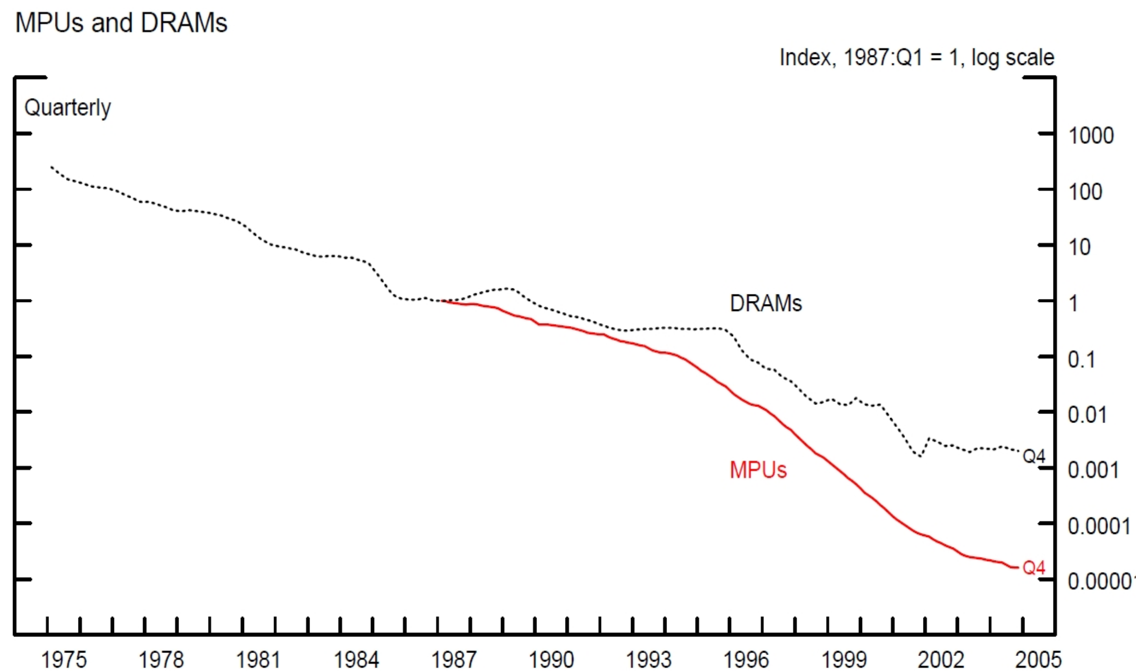
...known as Moore's Law



Source: Tuomi, I. (2008) The future of semiconductor intellectual property blocks and architectures in Europe. Luxembourg, European Commission, (final draft).

The Impact of Scaling

- **All** positive benefits bundled together
  - Reduced component cost
  - Increased functionality
  - Higher performance
  - Reduced component size
  - Smaller energy consumption



Quality-adjusted price of semiconductors

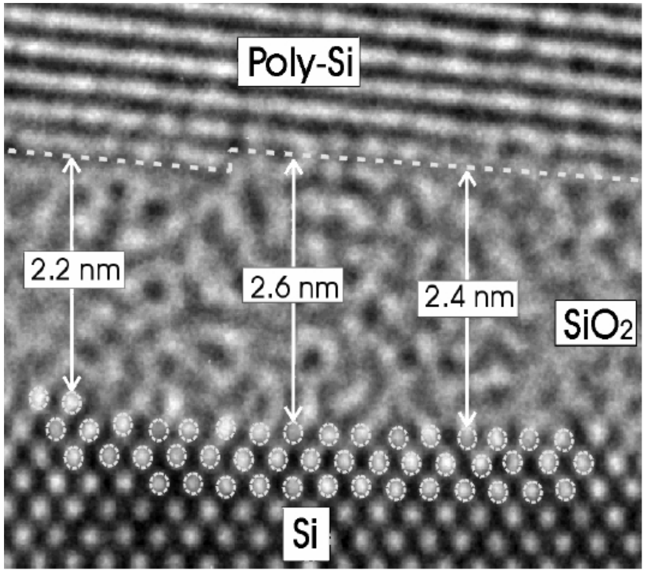
Source: Aizcorbe, Oliner, Sichel (2006): Shifting trends in semiconductor prices and the pace of technical progress. Finance and Economics Discussion Series, Federal Reserve Board, Washington, D.C.

The Consequences of Scaling

- The Information Revolution
  - Rapid expansion of the use of integrated circuits in all products and services
  - Wide penetration of digital technologies in all areas of society and economy
- Expectations of extremely fast technical improvement combined with price declines
- “Fall-forward” business models, and industry mind-sets based on incremental innovation
- Rapid growth of macroeconomic labor productivity

Except...
The End of Scaling

- Rapidly increasing capital expenditure
  - Rock's Law: the cost of leading-edge plant doubles every three years (now at 3-4 billion USD)
- Rapidly increasing manufacturing costs
  - Total costs for creating a bleeding-edge chip ~ 40 – 80 million USD
  - Optical masks @ 32nm: 6-8 million USD
- And physics
  - Insulator thickness now < 5 molecular layers
  - Increasing variability at atomic component sizes; increasing complexity of verification and testing
  - Decreasing reliability and life-time

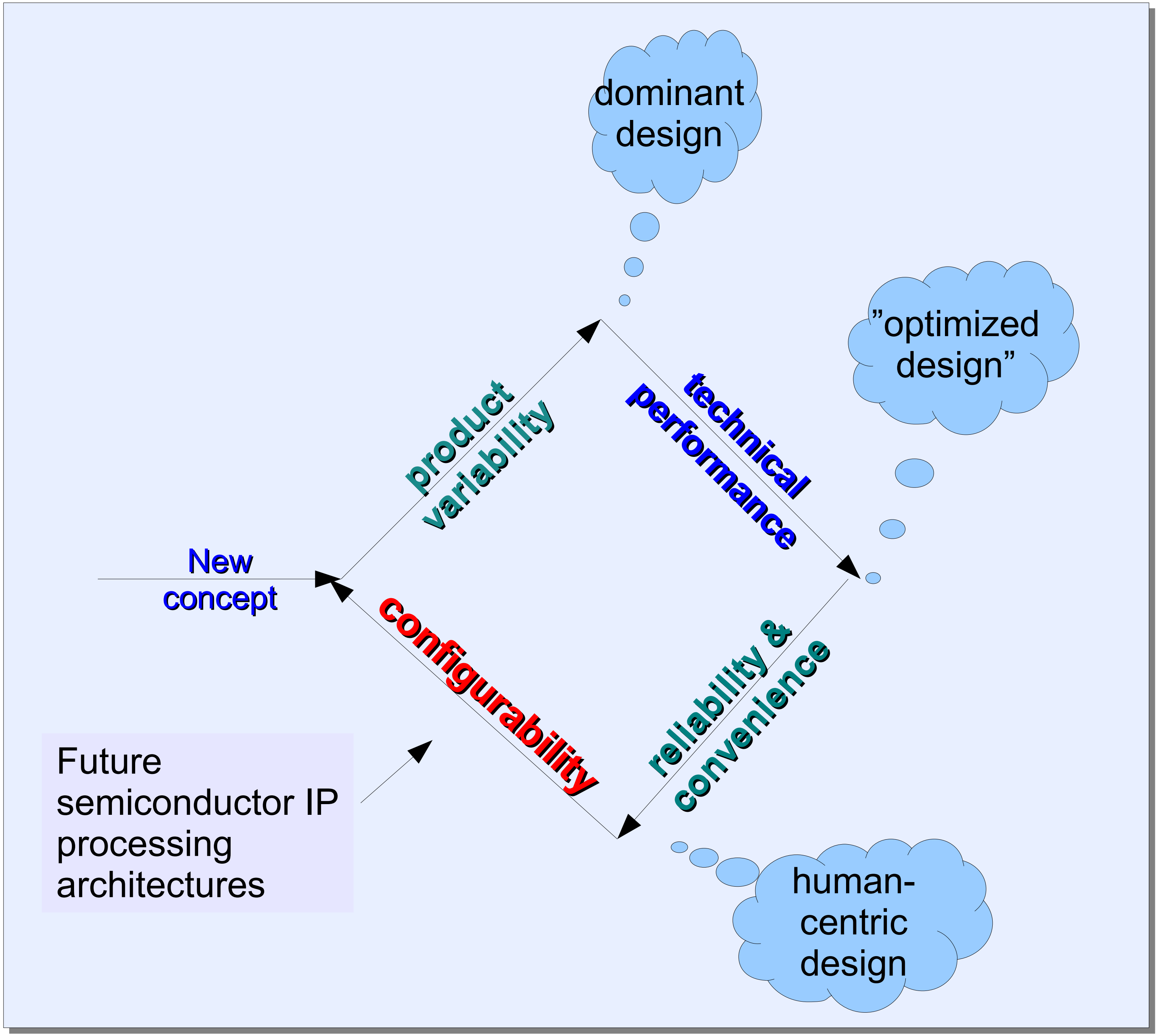


Great Technology: No Demand

"Because everything in her home is waterproof, the housewife of 2000 can do her daily cleaning with a hose."

"Miracles You'll See In The Next Fifty Years," Popular Mechanics, 1950

Life-Cycles of General-Purpose Technologies

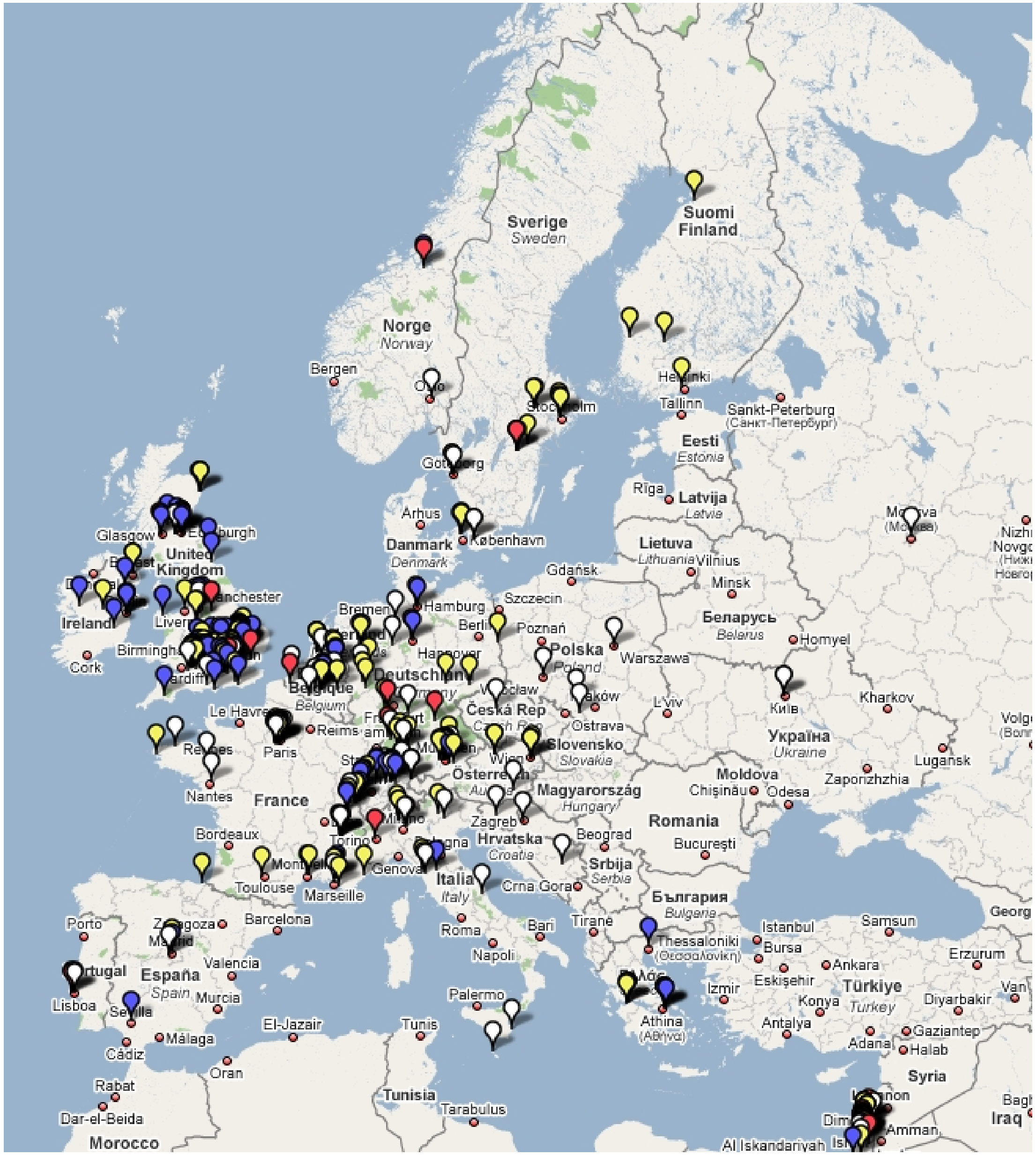


The Basic Idea of Semiconductor Intellectual Property (IP) Business

- Create and sell re-usable designs that can be embedded into integrated circuits
- Give the customers the opportunity to rapidly build new ICs using pre-designed IP blocks
- High value-added: pure knowledge
- Low entry cost: “a designer, workstation, and a garage”
- Revenues from licensing and royalties

- Also known as the “chipless semiconductor firm”

Over 150 IP Vendors in EU



Some Existing Success Stories

- Few outstanding success stories in Europe
  - Products from the leading vendor were embedded in about a quarter of all digital devices sold in 2007
  - The leading European vendor shipped about **one billion** IP processors in Q2/08

The Root Cause for Success: Fast-Growth Innovation Ecosystems

- Key ecosystem characteristics
  - Distributed innovation and competence development
  - Low entry costs
  - Shared shaping view
  - Flexible dynamic capabilities
- Examples
  - Linux
  - YouTube, Facebook, ...
  - ARM Connected Community (356 partners in 11/08)

The Last Wave of Semiconductor Scaling?

- The current IP success stories reflect profound changes in the semiconductor industry
  - Complex circuits are very expensive to develop and test
    - Outsourcing and design reuse are necessary
  - Consumer products have become the industry driver
    - Product versions are created in the UI, by software and branding
    - Product life-cycles are short
    - Profit windows are measured in months
  - Portable and embedded computing requires good performance with low power consumption
    - RISC processors are easy for programmers

- The **emerging** IP success stories will reflect the **new** reality

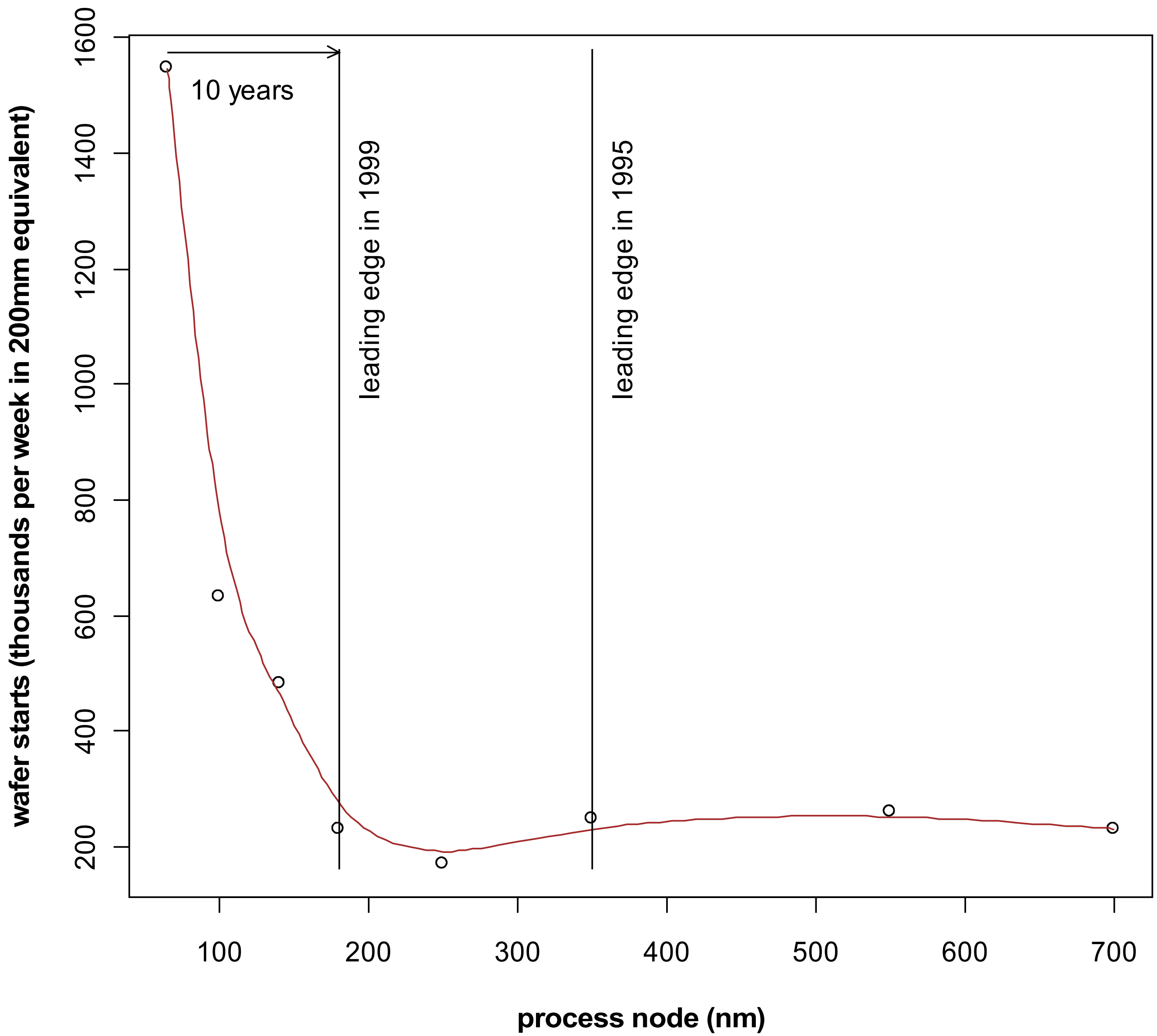
Beyond the Last Wave: The New Concept of Computation

- The end of scaling will make it clear that we need new concepts for computing
  - ... the digital era was a historically unique period
    - when we thought that more **transistors** on a chip means progress
    - when we thought that more **processors** on a chip mean progress
    - when we thought that meaning can be computed from information
- Current architectures use abstractions that do not match with the real world
  - Embedded systems require interaction in continuous time and space
  - Algorithmic systems have a fundamental limitation in the way they can address context; this is one of the reasons why they can not bridge the gap between syntax and meaning
  - The new fast-growing application domains (e.g., embedded systems, ambient intelligence / ubicomp, social computing) require rethinking of the principles of information processing
  - Combined with the end of scaling, this further leads to better understanding of why and where digital computation is useful

Back to the Future

- Imagine a world where you could create processor hardware architectures on-demand, or in a mass-customized way:
  - What opportunities did we miss by focusing on the "leading edge"?
  - Why, indeed, did we call it the "leading edge"?
- For most digital applications, low-cost, reliable and configurable technologies are the best
  - There is abundance of excess capacity at old CMOS process nodes
  - Many interesting functions do not scale easily (e.g. analog & RF, sensors, ...)
  - Abundant cheap design labor will be available for second- and third-tier technologies
  - New low-complexity technologies (e.g., printed electronics) are becoming practical

The Long Tail of Technology
Semiconductor Wafer Starts in 1H/2008



The New Low-Cost Computing Paradigm

- Today, low-cost semiconductors are **very**, **very** expensive
  - A cheap transistor in a bleeding-edge chip costs over **50 million USD**
  - These “low-cost” transistors can **only** be used in very high-volume products that can be copied millions of times (PC, mobile phone, MP3, smart card, + n other products)
  - There are **very limited opportunities** to create such products from scratch, or by SMEs
  - That's why the current expansion is on **software applications** that rely on rapid continuing decline of memory, processor and network costs (i.e., a dead-end)

- Real low-cost semiconductors mean **massive expansion of opportunities** for IP-based business models
  - The influx of new designs and architectures will create many new products and services
  - Configurable and reconfigurable processor architectures will be the key
  - The current distinction between software and hardware will blur: when low-cost computing becomes possible, many designs will be compiled and configured to silicon as this leads to optimal performance

What It Takes?

- Low-cost production infrastructure (small-volume, on-demand and mass-customized chips)
- Open ecosystems for design tool development
- Configurable processing and system architectures
- New models of information processing and programming that work in the real world

- ...and the very simple observation:
  - the concept of *leading edge* assumes a linear model of progress; it used to be a good approximation in integrated circuit technology; this 50-year line of technology evolution is, however, soon to become extinct

Thank You!