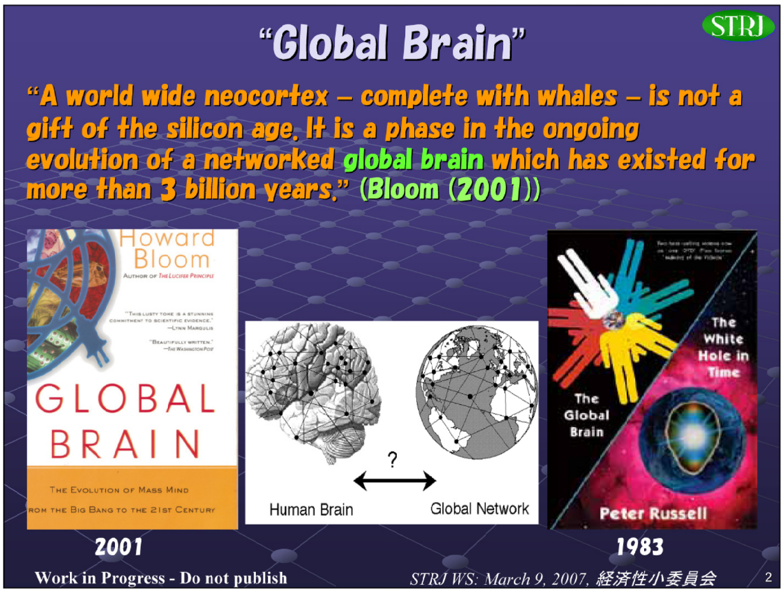
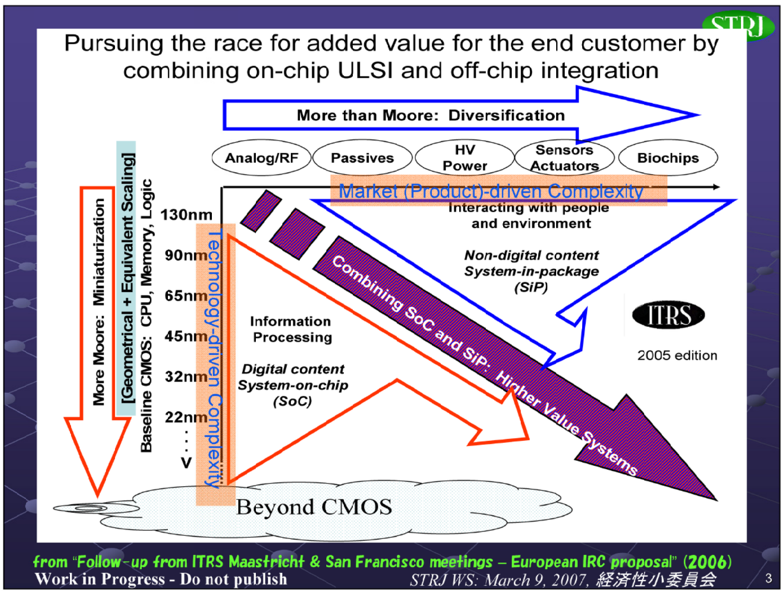
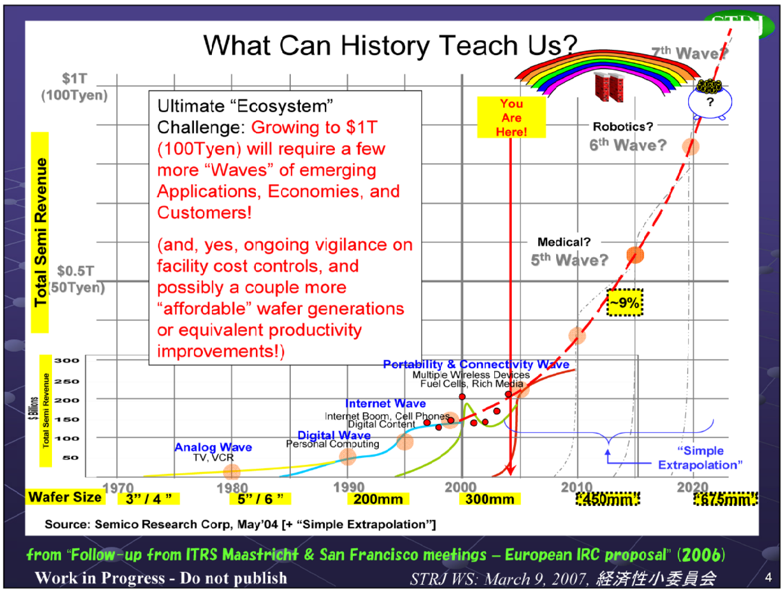
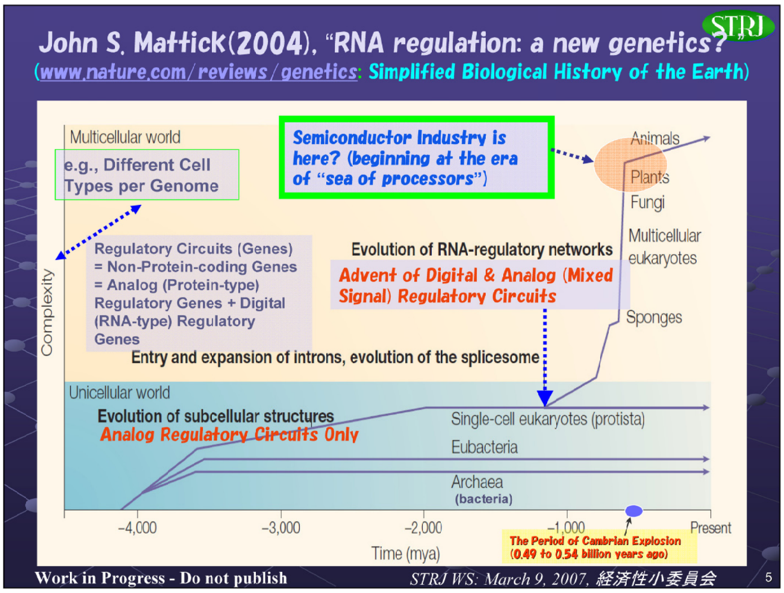
17-4 ITRS under the Increasing Complexity – In Search of a “Global Brain” –









Complexity in Cumulative Knowledge-Administration scales faster than One in Knowledge-Creation?

- "We do not see a slowdown in Moore's law as the main obstacle to further progress in the IT industry. Rather, it is the industry's exploitation of the technologies that have been developed in the wake of Moore's law that has led us to the verge of a complexity crisis."

  (IBM Autonomic Computing White Paper, "*An architectural blueprint for autonomic computing,*" (June, 2006)

- "Papert's Principle: Some of the most crucial steps in mental growth are based not simply on acquiring new skills, but on acquiring new administrative ways to use what one already knows."

  (M. Minsky, *Society of Mind*(1986) and *The Emotion Machine* (2006))

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パパートの原理（Papert’s Principle）

パパートの原理:「精神的な成長の最も重要な段階では、新しい技能・技術を獲得することだけではなく、既に獲得した技能・技術を新しい方法で活用するための方法を獲得することが（さらなる成長のための）土台となる。」

M. Minsky, *Society of Mind(1986) and The Emotion Machine* (2006)

⇔創造された発見・発明の数（ n ）の増大が、それらの活用方法数 の“組合せ爆発”現象（ $n(n-1)/2 \fallingdotseq n^2$ $(n \to \infty)$）によっても制約されるようになる。

John S. Mattick(2004), “RNA regulation: a new genetics? ”

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Complexity in Semiconductor Markets: Cause-and-Effect (1)

- Globalization of Various Markets and Consumers’ Diversified & Upgraded Preferences

→Emergence of Thick & Wide Global Markets

→Increasing Comparative Advantage of Pure-Play Firms (due to the increasing necessity for inter-organizational corroboration)

→Increasing Difficulty in Managing Vertically Integrated Firms (due to the explosive expansion of “range of optimization”)

Galambos, L.(2005), “Recasting the organizational synthesis: structure and process in the twentieth and twenty-first centuries,” Business History Review vol.79.

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Complexity in Semiconductor Markets: Cause-and-Effect (2)

- Advent of the Structural Similarity between Semiconductor Markets & Devices (as an effective counter-measure for the complexity in market & technology)

→Small-World Property (due to Loose but Intricate Connectedness)

→Scale-Freeness (due to Modularity)

Note: Newman, Barabasi, and Watts (2006), *The Structure And Dynamics of Networks*

→”Accelerating-Network” Property (due to the fact that the total number of connections between nodes scales faster than the total node number) Note: S. Mattick and M. J. Gagen (2005), “MATHEMATICS/COMPUTATION: Accelerating Networks,” in *Science*, Vol. 307, no. 5711, pp. 856-858

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Striking Analogy between Organisms and Semiconductor Chips (1)

- **Structural Diversity in Prokaryotes or Primordial Eukaryotes**

→due to Gene Duplication, Deletion or Divergence

(Semiconductor Devices: due to the Increase in Number of Transistors and Advent of New Transistor and/or Capacitor Structure)

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Striking Analogy between Organisms and Semiconductor Chips (2)

- **Most of Morphological & Phenotypic Novelties in Eukaryotes**

→due to the Evolution in Regulatory Circuits or Regulatory Layers embedded in (Non-Protein-coding) "Toolkit Genes" (vs. (Protein-Coding) "House-Keeping Genes")

(Semiconductor Devices: due to the Creation of New Control Circuits via Multi-layered Intricate Interconnecting Methods)

S. Mattick and M. J. Gagen (2005), op. cit.

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Genome Size ≠ Biological Complexity

Biological Complexity (e.g., Different Cell Types per Genome)
= G(Housekeeping Genes, Toolkit Genes)

(1) Each number of housekeeping or toolkit genes scales as a power-law of the total number of genes in the genome (i.e., genome size).

(2) In a power low: $y=cx^{\alpha}$, α of toolkit genes is around 2.0, while one of housekeeping genes is around 0.5. (Nimwegen (2003), "Scaling laws in the functional content of genomes" in *TRENDS in Genetics*, Vol.19 No.9, 479-484)

(3) "The numbers of regulators (or combinations thereof) must generally scale faster than the number of genes." The complexity of organisms tends to be constrained by the architecture of their regulatory networks. (Mattick and Gagen, op.cit.)

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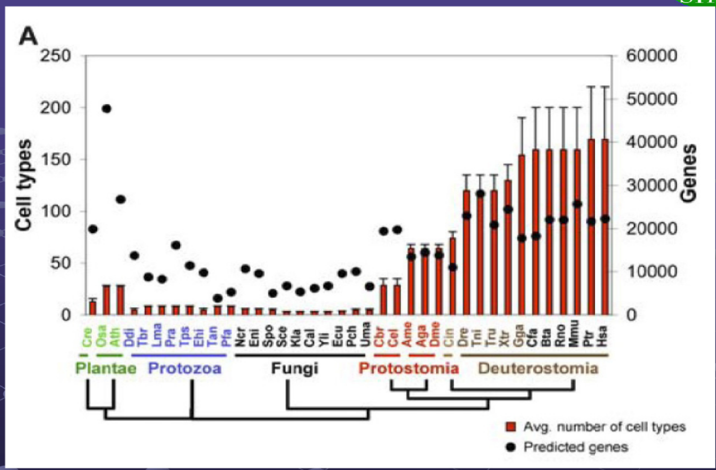

Vogel and Chothia (2006), "Protein Family Expansions and Biological Complexity" in PLoS Computational Biology, Volume 2, Issue 5, pp. 370-382

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Number of Transistors per Chip ≠ Semiconductor Chip Complexity

Chip Complexity (e.g., Ex ante & ex post flexibilities)
=F(Transistor Blocks, "Regulatory Circuits")
"Regulatory Circuits" = Intra- & Inter-block Connections

(1) The number of transistor blocks follows Moore's (power) law.

(2) The number of "regulatory circuits" needs to follow More-than-Moore's (power) law?
Otherwise "LSI Design Crisis" would occurs!

(3) The number of "regulatory circuits" scales faster than the number of transistor blocks!!

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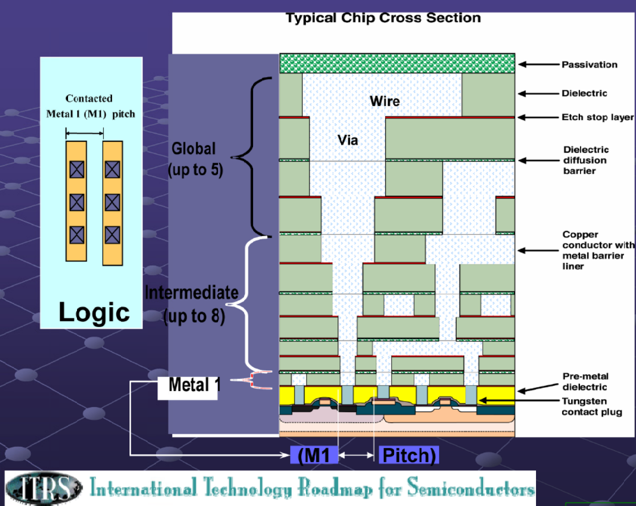
CMOS Interconnect Structure



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"Demand Hiddenness" in the Era of More-Than-Moore

- Facing the boundlessly diversified & uncharted landscape,

→Suppliers puzzled by consumers' widely diversified and Kaleidoscopic preferences

→Consumers (customers) plagued by their incontrollable revealed preferences

→Emergence of "Demand Hiddenness"

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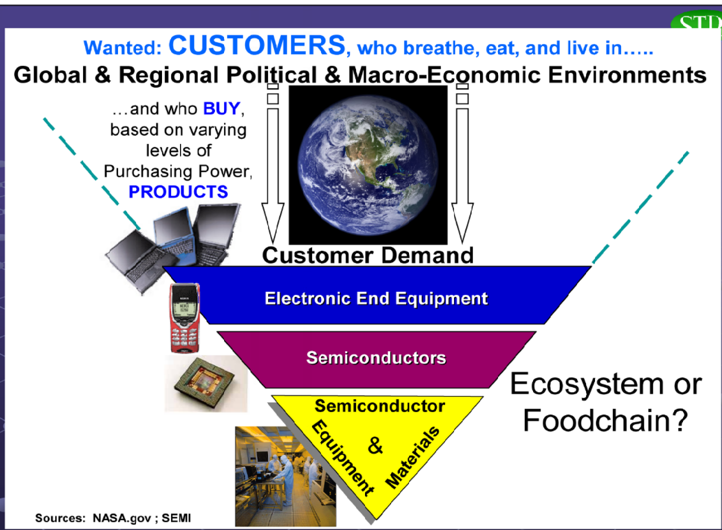

from "Follow-up from ITRS Maastricht & San Francisco meetings – European IRC proposal" (2006)

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New Tendencies in the Era of "Demand Hiddenness" (1)

- From "Stereotype Marketing" to "(Jungian) Archetype Marketing"

(G. Zaltman (2003), *How Customers Think*)

→Arm-in-arm information exchange & sharing between suppliers and consumers (or customers)

→Era of Application-driven as well as Technology-driven Roadmap

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New Tendencies in the Era of "Demand Hiddenness" (2)

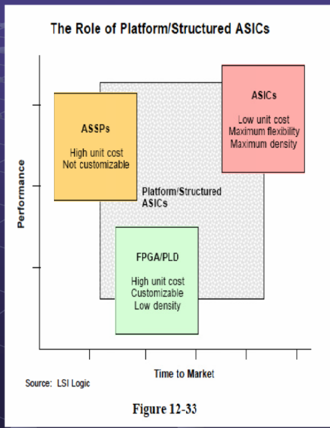
- *Ex ante* and *ex post* nimbleness (resiliency) as a core source of competitiveness

→FPGA/PLD (but still very sensitive to interconnect delay)

→ASSP or SOC with (gate-centric) hard-wired blocks

→ASSP or SOC with programmable blocks having application specific processors

(C. Rowen (2004), *Engineering the Complex SOC: Fast, Flexible Design with Configurable Processors*)



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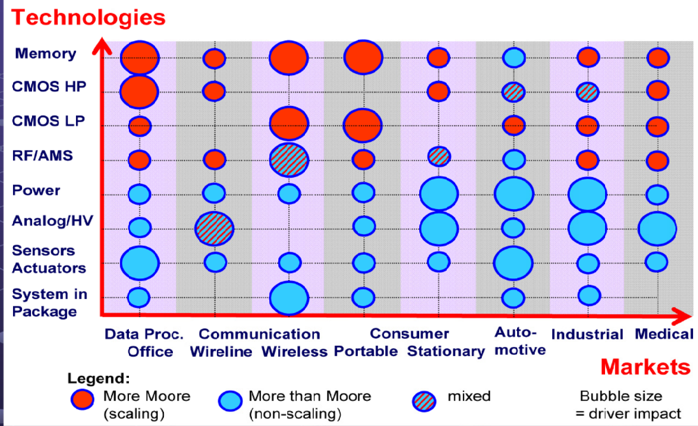
Market Drivers for Technology Roadmap



from "Follow-up from ITRS Maastricht & San Francisco meetings – European IRC proposal" (2006)

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Inescapable Phenomenon Induced by Increasing Complexity (1)

- Sub-systemization of Various Existing Systems at a splitting pace

→Increasing incapability to make a self-contained market evaluation of own products as well as R&D performance (Hiddenness Everywhere!)

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Inescapable Phenomenon Induced by Increasing Complexity (2)

- Strong Demand for Inter-Organizational Wisdom Mobilization (in addition to Extensive Investment Cost & Risk Sharing)

→Absolute Necessity for "Global Brain"

H. Bloom, *Global Brain* (2001)

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Main Principles in Coping with Complexities (1)

- Knowledge Sharing & Networking via Inter-Organizational Proactive (or Contexture-Sharing) Visualization

→Enhancing Inter-Organizational Knowledge Compatibility & Interoperability

→Resolution-Enhancement in Inter-Organizational "Common Knowledge"

→Creation of the Place for Resonance

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Main Principles in Coping with Complexities (2)

- Creating a Social Mechanism to avoid the insignificant duplication of R&D activities

→Introducing Consortia, Alliances, or Technology & Application Roadmap as Public Goods

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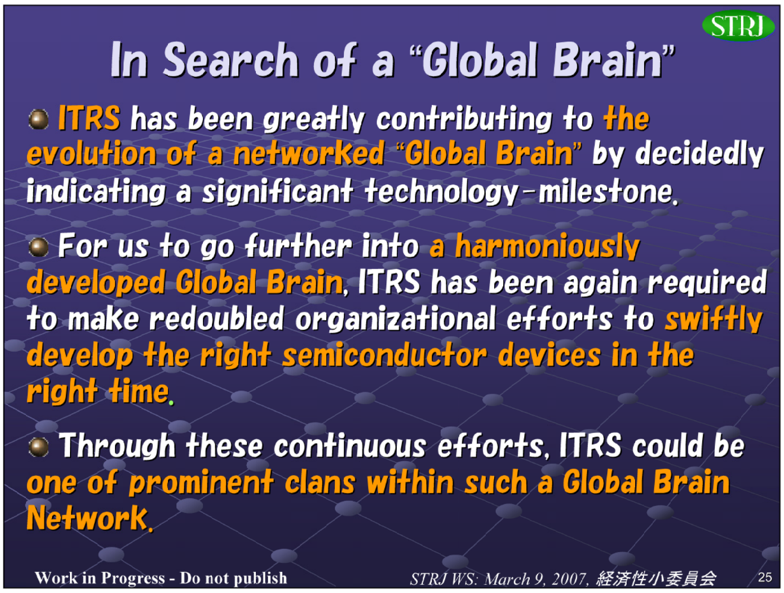
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In Search of a "Global Brain"
ITRS has been greatly contributing to the evolution of a networked "Global Brain" by decidedly indicating a significant technology-milestone.
For us to go further into a harmoniously developed Global Brain, ITRS has been again required to make redoubled organizational efforts to swiftly develop the right semiconductor devices in the right time.
Through these continuous efforts, ITRS could be one of prominent clans within such a Global Brain Network.
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