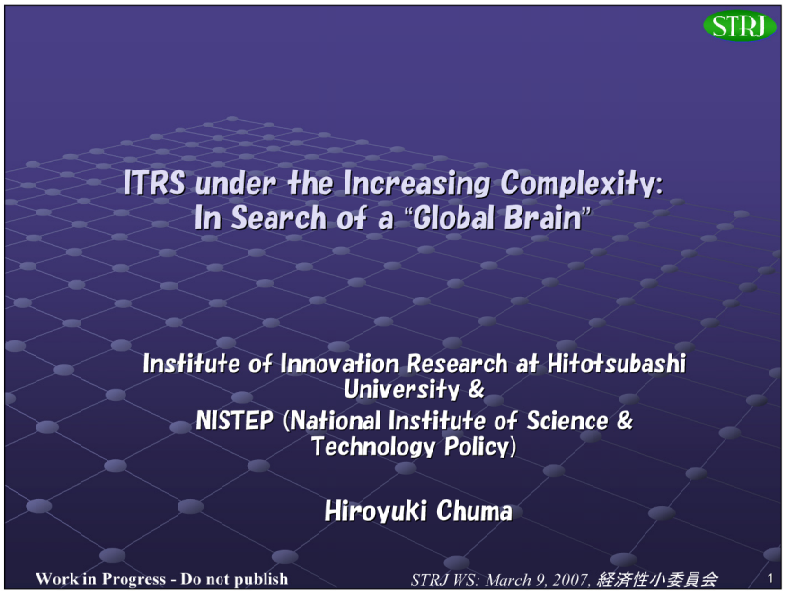
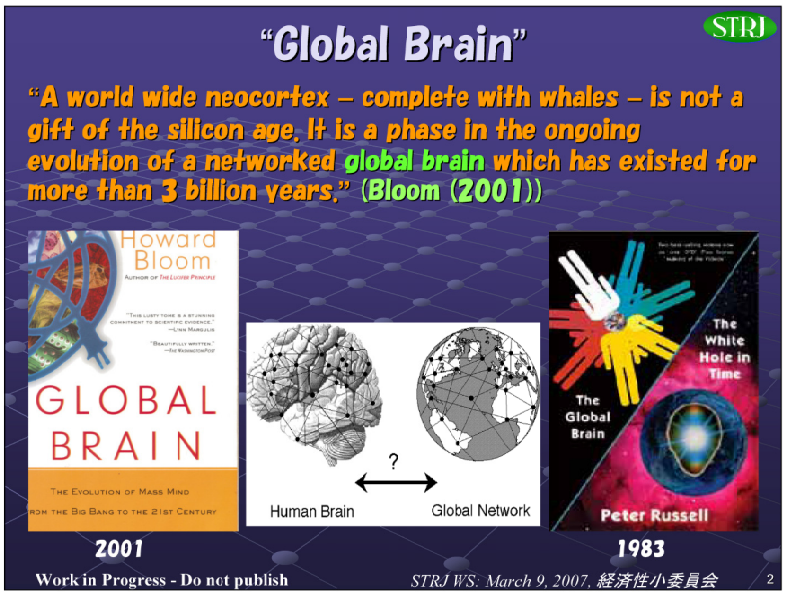
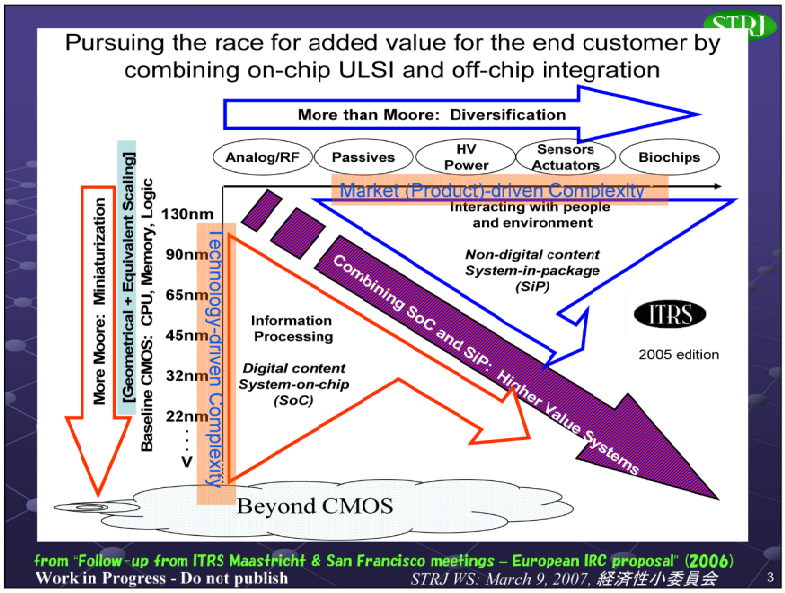
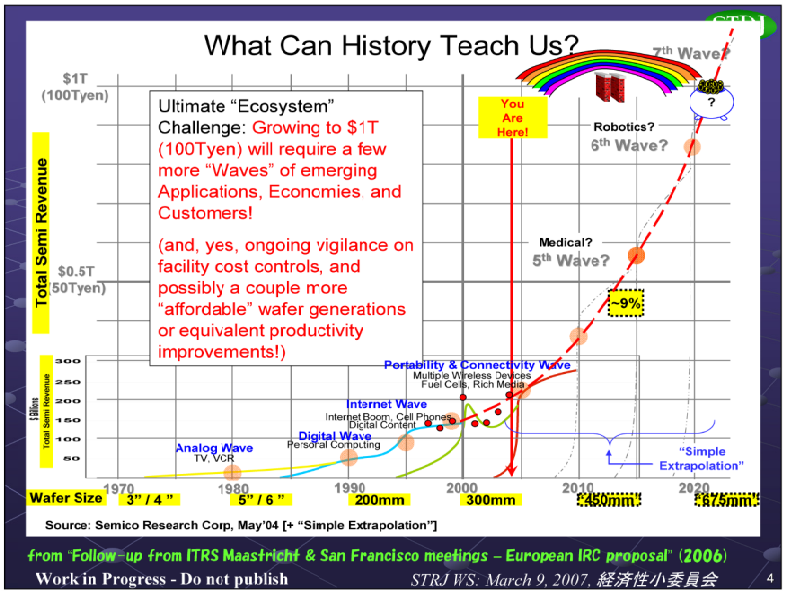
17-4 ITRS under the Increasing Complexity – In Search of a “Global Brain” –








What Can History Teach Us?
Ultimate "Ecosystem" Challenge: Growing to $1T (100Tyen) will require a few more "Waves" of emerging Applications, Economies and Customers!
(and, yes, ongoing vigilance on facility cost controls, and possibly a couple more "affordable" wafer generations or equivalent productivity improvements!)
$1T (100Tyen)
$0.5T (50Tyen)
Total Semi Revenue
You Are Here!
7th Wave?
Robotics?
6th Wave?
Medical?
5th Wave?
~9%
Portability & Connectivity Wave
Multiple Wireless Devices
Fuel Cells, Rich Media
Internet Wave
Internet Boom, Cell Phones
Digital Content
Digital Wave
Personal Computing
Analog Wave
TV, VCR
"Simple Extrapolation"
1970
1980
1990
2000
2010
2020
Wafer Size
3" / 4 "
5" / 6 "
200mm
300mm
~450mm
~675mm
Source: Semico Research Corp, May'04 [+ "Simple Extrapolation"]
from "Follow-up from ITRS Maastricht & San Francisco meetings – European IRC proposal" (2006)
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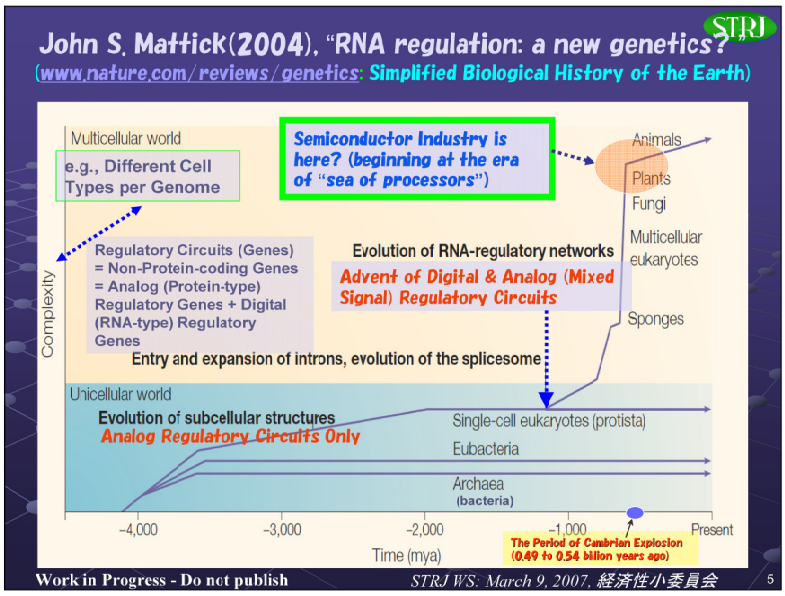
John S. Mattick(2004), "RNA regulation: a new genetics?
(www.nature.com/reviews/genetics: Simplified Biological History of the Earth)
Multicellular world
e.g., Different Cell Types per Genome
Semiconductor Industry is here? (beginning at the era of "sea of processors")
Animals
Plants
Fungi
Multicellular eukaryotes
Sponges
Regulatory Circuits (Genes) = Non-Protein-coding Genes = Analog (Protein-type) Regulatory Genes + Digital (RNA-type) Regulatory Genes
Evolution of RNA-regulatory networks
Advent of Digital & Analog (Mixed Signal) Regulatory Circuits
Complexity
Entry and expansion of introns, evolution of the splicesome
Unicellular world
Evolution of subcellular structures
Analog Regulatory Circuits Only
Single-cell eukaryotes (protista)
Eubacteria
Archaea
(bacteria)
-4,000
-3,000
-2,000
-1,000
Present
Time (mya)
The Period of Cambrian Explosion (0.49 to 0.54 billion years ago)
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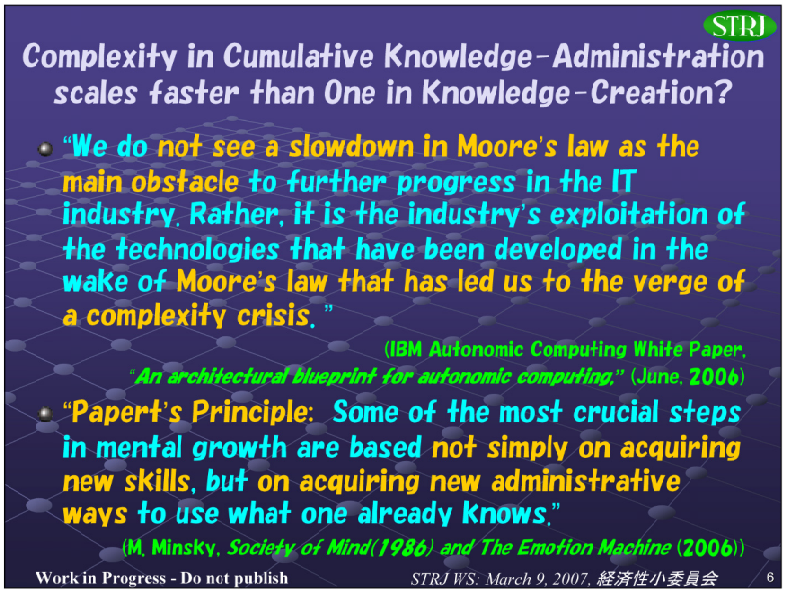
Complexity in Cumulative Knowledge-Administration scales faster than One in Knowledge-Creation?
"We do not see a slowdown in Moore's law as the main obstacle to further progress in the IT industry. Rather, it is the industry's exploitation of the technologies that have been developed in the wake of Moore's 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")

Calambos, 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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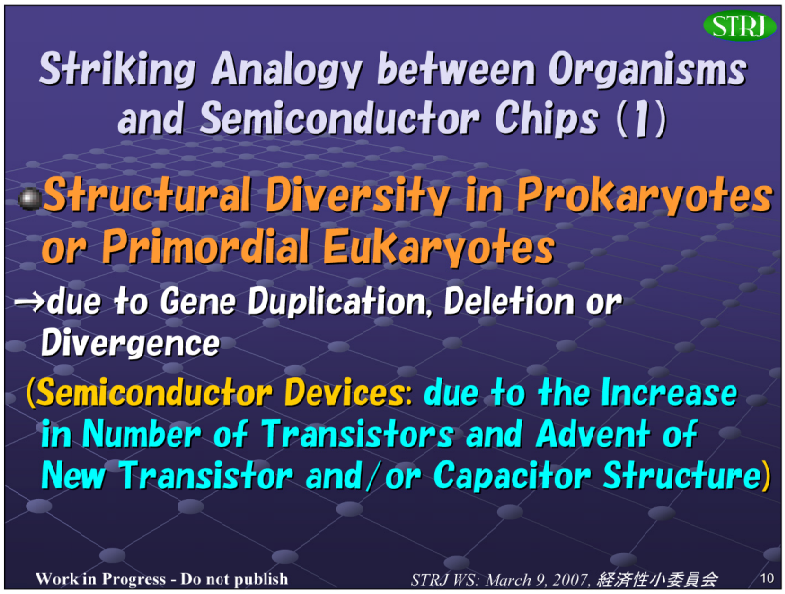
STRJ
Striking Analogy between Organisms and Semiconductor Chips (1)
Structural Diversity in Prokaryotes or Primordial Eukaryotes
→due to Gene Duplication, Deletion or Divergence
(Semiconductor Devices: due to the Increase in Number of Transistors and Advent of New Transistor and/or Capacitor Structure)
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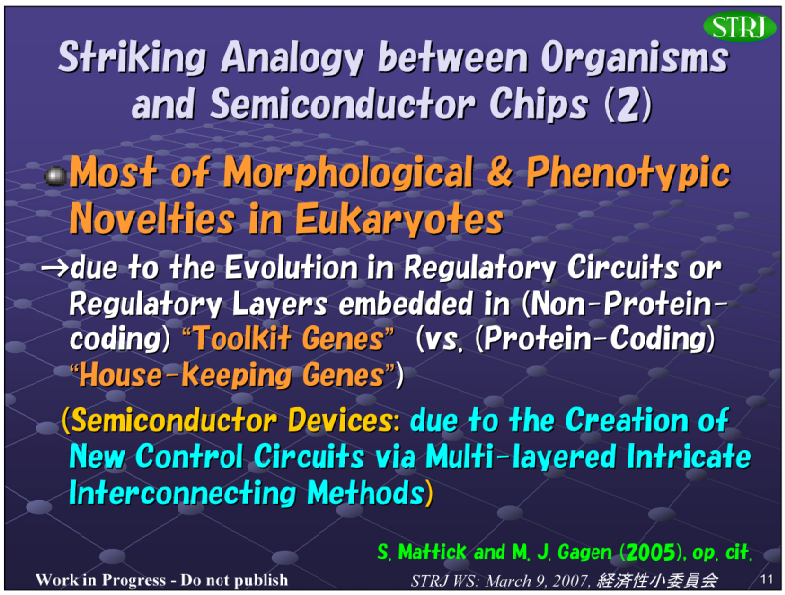
STRJ
Striking Analogy between Organisms and Semiconductor Chips (2)
Most of Morphological & Phenotypic Novelties in Eukaryotes
→due to the Evolution in Regulatory Circuits or Regulatory Layers embedded in (Non-Protein-coding) "Toolkit Genes" (vs. (Protein-Coding) "House-keeping Genes")
(Semiconductor 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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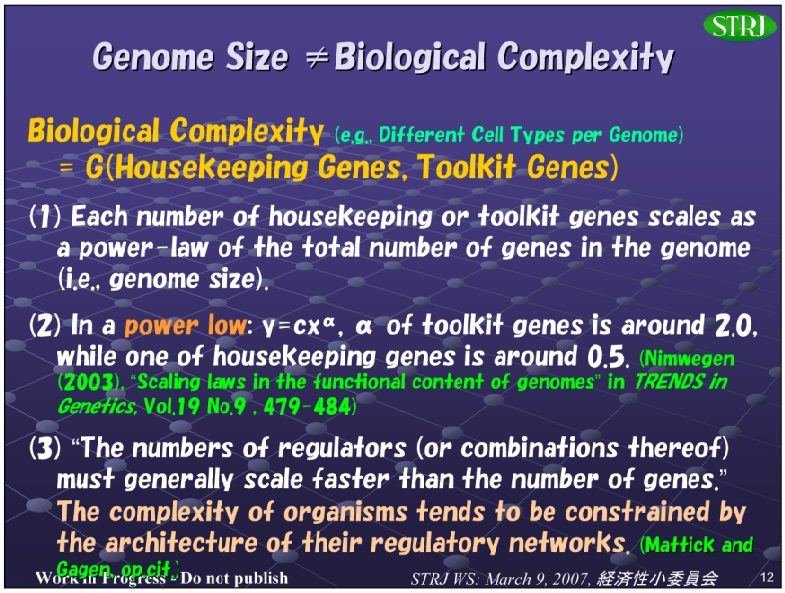
STRJ
Genome Size ≠ Biological Complexity
Biological Complexity (e.g., Different Cell Types per Genome)
= G(Housekeeping Genes, Toolkit Genes)
(1) Each number of housekeeping or toolkit genes scales as a power-law of the total number of genes in the genome (i.e., genome size).
(2) In a power low: y=cx^α, 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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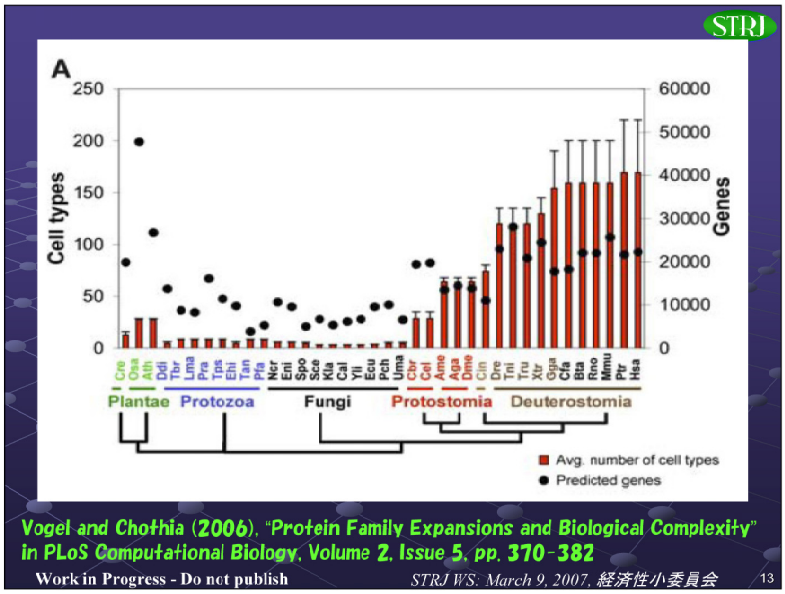
STRJ
A
Cell types
Genes
250
200
150
100
50
0
60000
50000
40000
30000
20000
10000
0
Cre Ola Ath Ddi Tha Lma Pre Tps Ehi Tan Pfa Ncr Eni Spo Sce Kla Cal Yli Ecu Pch Uma Cbr Cel Ame Aga Dme Cin Dre Tni Tru Xtr Gga Cfa Bta Rno Mmu Ptr Hsa
Plantae Protozoa Fungi Protostomia Deuterostomia
Avg. number of cell types
Predicted genes
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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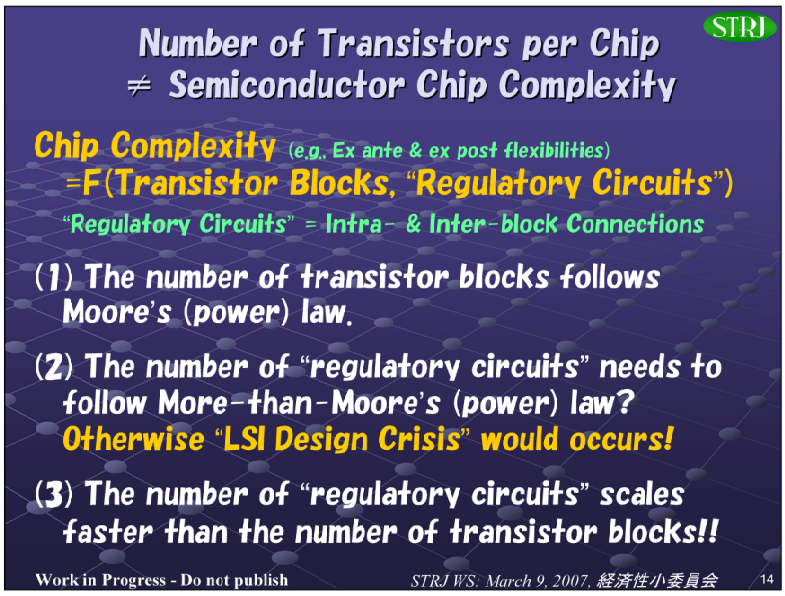
STRJ
Number of Transistors per Chip
≠ Semiconductor Chip Complexity
Chip Complexity (e.g., Ex ante & ex post flexibilities)
=F(Transistor Blocks, "Regulatory Circuits")
"Regulatory Circuits" = Intra- & Inter-block Connections
(1) The number of transistor blocks follows Moore's (power) law.
(2) The number 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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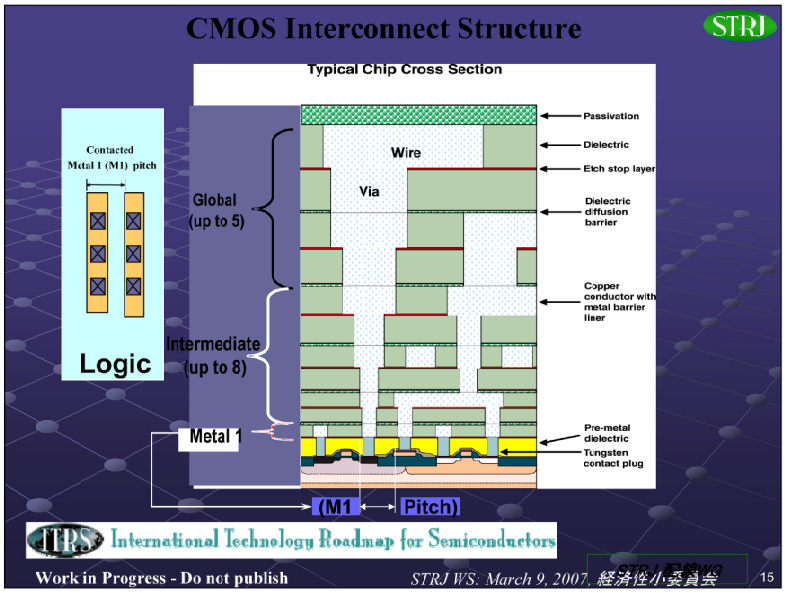
CMOS Interconnect Structure
STRJ
Typical Chip Cross Section
Contacted Metal 1 (M1) pitch
Logic
Global (up to 5)
Intermediate (up to 8)
Metal 1
Wire
Via
Passivation
Dielectric
Etch stop layer
Dielectric diffusion barrier
Copper conductor with metal barrier liner
Pre-metal dielectric
Tungsten contact plug
(M1 Pitch)
ITRS International Technology Roadmap for Semiconductors
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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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Wanted: CUSTOMERS, who breathe, eat, and live in.....

Global & Regional Political & Macro-Economic Environments

...and who BUY, based on varying levels of Purchasing Power, PRODUCTS

Customer Demand

Electronic End Equipment

Semiconductors

Semiconductor Equipment & Materials

Ecosystem or Foodchain?

Sources: NASA.gov ; SEMI

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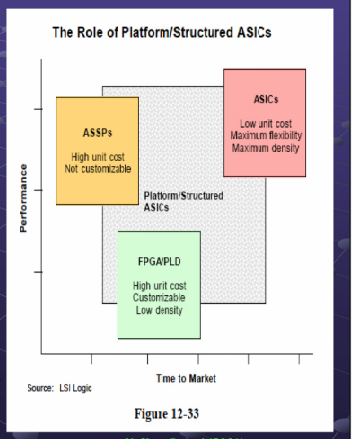
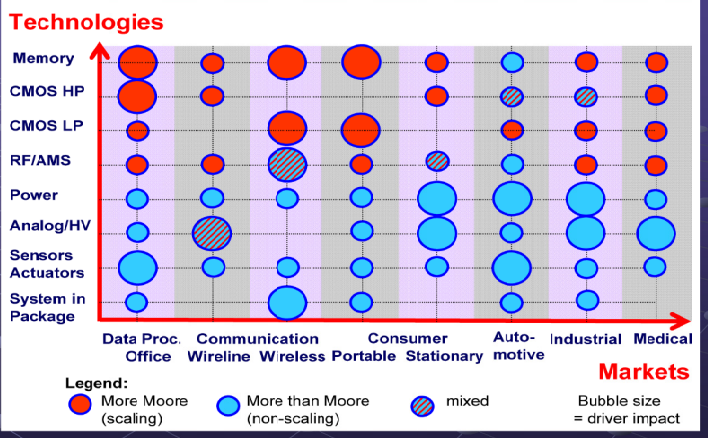
New Tendencies in the Era of "Demand Hiddenness" (2)

- *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*)



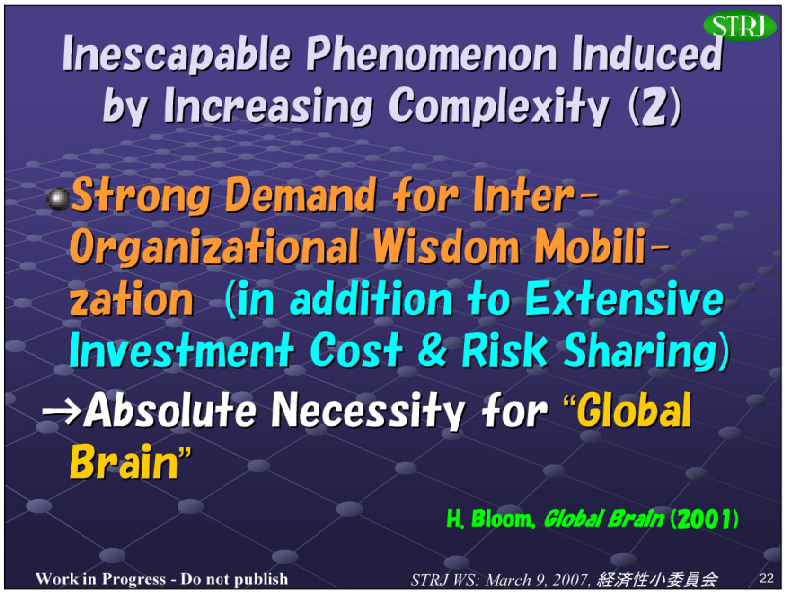
Market Drivers for Technology Roadmap



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

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!)


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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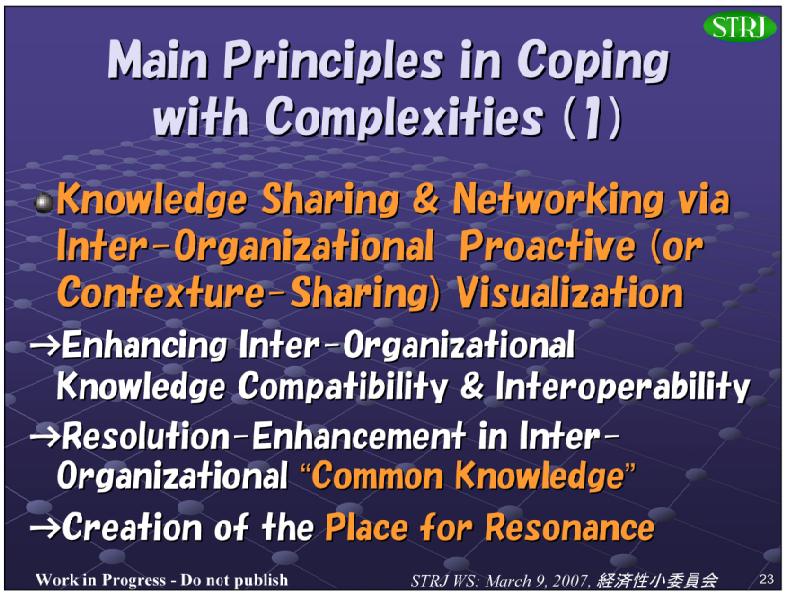
Main Principles in Coping with Complexities (1)
Knowledge Sharing & Networking via Inter-Organizational Proactive (or Contexture-Sharing) Visualization
→Enhancing Inter-Organizational Knowledge Compatibility & Interoperability
→Resolution-Enhancement in Inter-Organizational "Common Knowledge"
→Creation of the Place for Resonance
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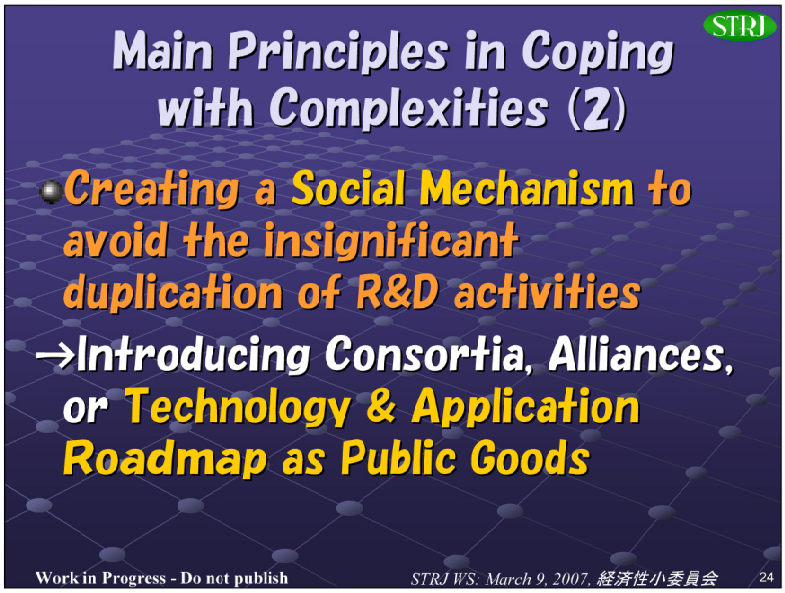
Main Principles in Coping with Complexities (2)
Creating a Social Mechanism to avoid the insignificant duplication of R&D activities
→Introducing Consortia, Alliances, or Technology & Application Roadmap as Public Goods
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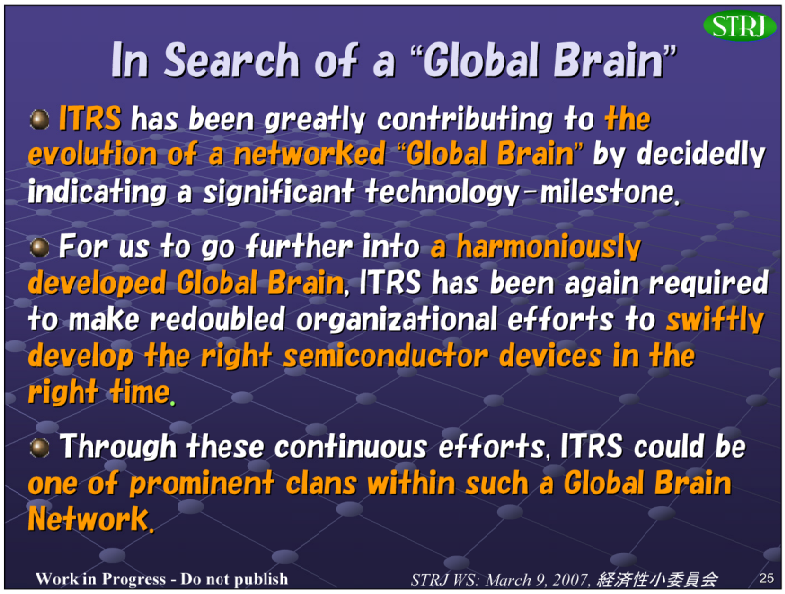
STRJ
In Search of a "Global Brain"
ITRS has been greatly contributing to the evolution of a networked "Global Brain" by decidedly indicating a significant technology-milestone.
For us to go further into a harmoniously developed Global Brain, ITRS has been again required to make redoubled organizational 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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