The Constructed Brain:

Comments on Chapter 7 of the EU's Neuro-IT Roadmap
Brussels / 3 December 2003

Doug DeGroot

Digital Life Technologies Group

Computer Science

Leiden University, The Netherlands

degroot@acm.org

Outline of Discussion

- My Biases and Background
- My Comments on the "Constructed Brain" Program
- My Opportunity List (Just some "seed" thoughts)
- My Comments on Magnet Centers

Digital Life Technologies Group

Leiden Inst. Of Advanced Computer Science, University of Leiden

Our Interests & Activities Include:

- Computational Consciousness & Emotions
- Robotic Companions and Pets
- Emergent Phenomena & Artificial Life
- High-Performance Computing
- Bio-Inspired, Evolutionary Hardware
- Digital Immortality

Experience Includes:

- Industry R&D
  - IBM T.J. Watson Research and Texas Instruments R&D Center
- Academia (US & Europe)
- Entrepreneuring
  - Silicon Valley; Venture Capital
- Large-Scale DARPA funding
- Technology & Innovation Strategy Development

Accordingly, I am going to address some innovation and tech-transfer issues more than you might wish.

Neuro-IT Related Projects at DLT:

- Computational Consciousness & Emotions
- Robotic Companions and Pets
- Visual Brain Tool
- reLife: Reverse Evolution of Emergent Computations
- KBOT Radio: Virtual Internet Radio DJs

Science and Reductionism

> **“One of the most highly developed skills in contemporary Western civilization is dissection: the splitting-up of problems into their smallest possible components.**
>
> **We are good at it.**
>
> **So good, we often forget to put the pieces back together again.”**

Alvin Toffler, 1984
foreword to *Order Out of Chaos*

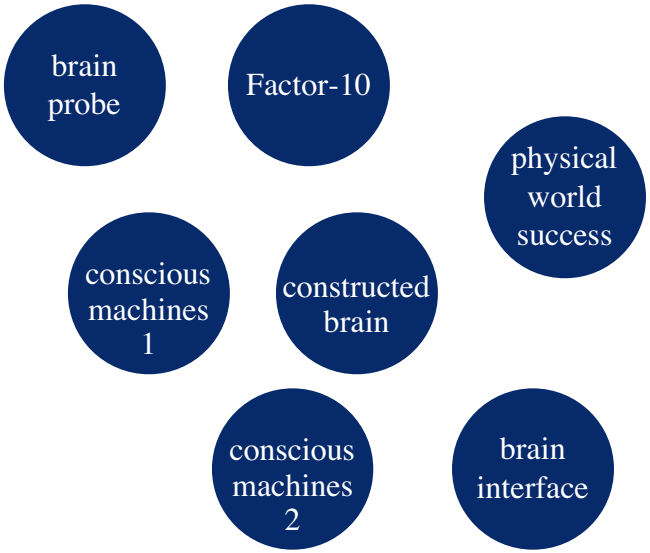
Attempting to put the pieces together… is at the heart* of the Constructed Brain project.

- Comprehensive views of brain processes
  - The brain as framework, system, and subsystem
- Systematic engineering principles for bio-inspired HW & SW.
  - Extended sensory capabilities
    - Synergistic R&D infrastructures
- Reusable, plug-and-play systems, theories, databases, devices
  - … and many more.

* sic

Neuro-IT's Strategic Thrusts

- Machine & SW System Interfaces to the Human Central Nervous System
- Conscious, Intelligent Machines
- Complete & Integrative Cognitive Engineering Frameworks
- Tools for Neuroscience
- Embodied, virtual, constructed brain
- And more …



Common to all of these is the overwhelming degree of complexity of the subject matter - the Human Brain.

If we're not careful, this complexity will continue to force us

to overly abstract,
to over-simplify,
to know but not understand,
to predict but fail to explain.

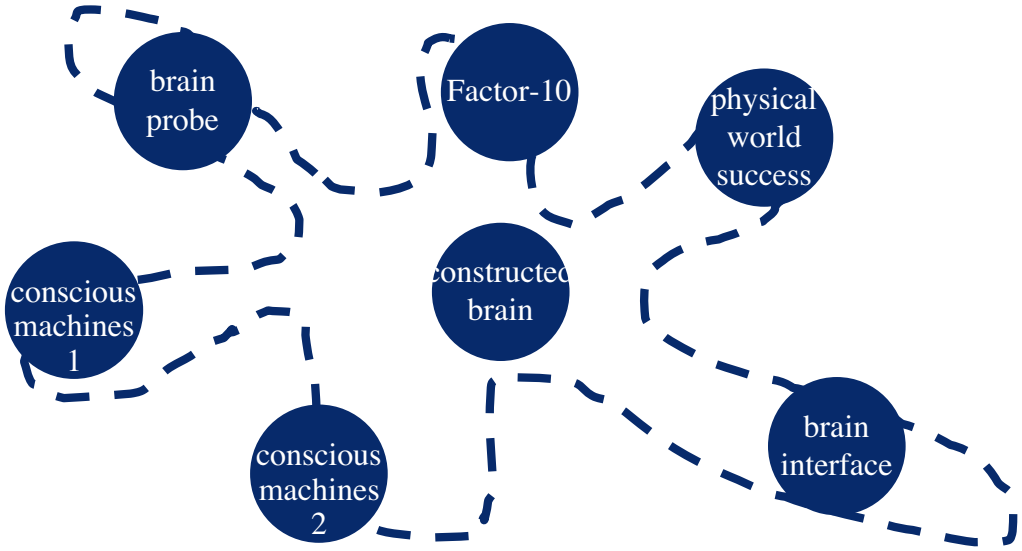
… as we currently do.

One could argue that today's desktop computer paradigm is partially to blame.

Within the Neuro-IT Scientific Disciplines:

- **Current desktop software, modeling tools, visualization packages, and the like are quite slow, by any reasonable measure.**
- **Hopes of performing actual experiments often forces researchers to:**
  - **Scale the problem to the smallest unit of complexity and then extrapolate to the entire structure or process.**
  - **Abstract away critical details.**
  - **Perform sub-critical numbers of experiments.**
  - **Simulate rather than emulate, build, and deploy.**
- **Coupled with the inherent complexity of the domain …**
  - **we will continue to suffer from the lack of a comprehensive Theory of the Brain.**

Neuro-IT's Strategic Thrusts Need Power



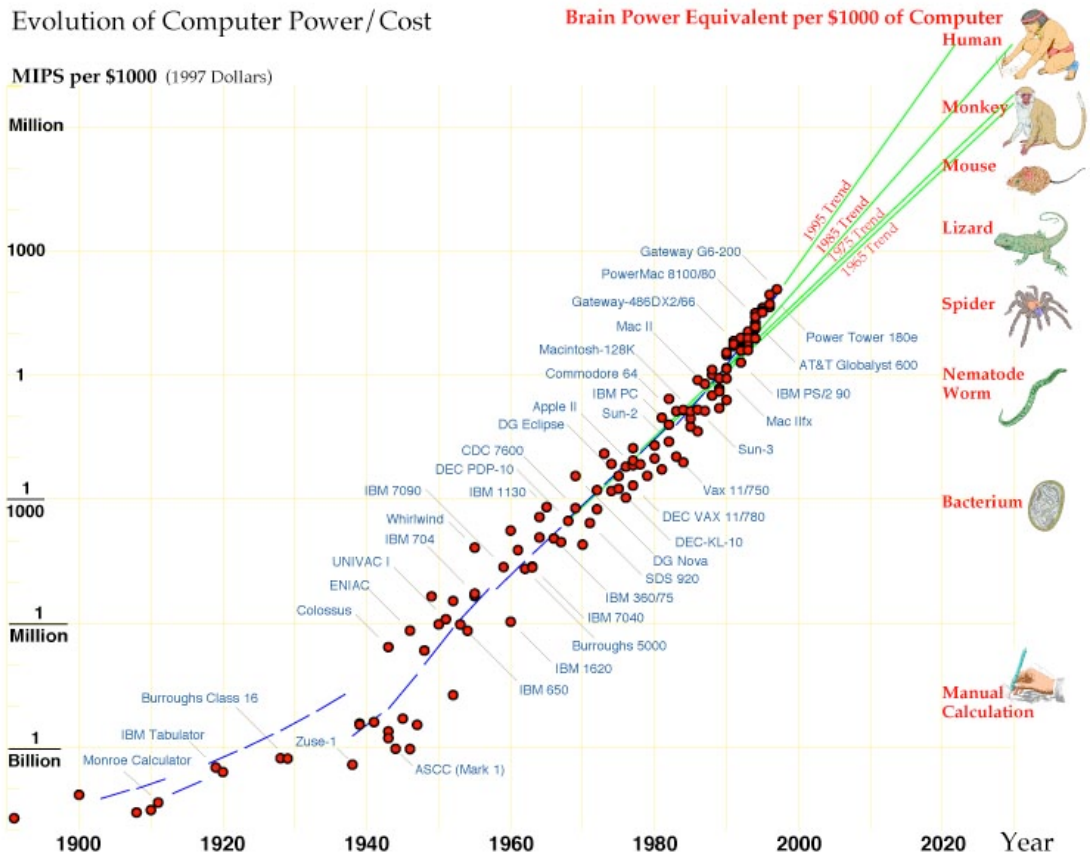
- **High-performance computing could prove to be strategic to nearly all of our programs.**
  - **Problem size, turn-around time, level of detail, number of experiments, confidence intervals, visualizations, etc.**
- **Perhaps the "Constructed Brain" effort could serve as:**
  - **a key integration project**
  - **a potential EU-test bed, shared platform**
  - **encourages interoperability, common data/object framework, emphasis on protocols**

There's good news, and there's bad news.

- **Good news:**
  - Moore's law predicts a continued performance-doubling of processor speeds every 12-18 months.
  - Thus each 10 years, computer processors increase in power roughly 1000-fold.
  - A mere 20 years from now, processors will be 1-million times faster than they currently are.

- **Bad news:**
  - Software technology is not keeping up.
  - And it's not clear why.

Moore's Law contains a couple of startling implications.



Hans Moravec, Carnegie Mellon University

Computational Capacity of Single Computer Chips:

- 2020 - equal to the human brain
- 2050± - equal to the entire human race

But that prediction was for chips. What about *computers*, and in particular, *Supercomputers*?

WIRED NEWS

This Is Your Computer on Brains Go to this Story

Change gallery: All Images Go

Supercomputer makers strive to top the processing power of the human brain.
Photo: IBM Corp.

“ Supercomputer makers strive to top the processing power of the human brain. ”

Wired Magazine News

Thus:

Brain-scale *chips* in 2020.

Brain-scale *machines* now.

Consider IBM's BlueGene/L Supercomputer:

IBM's Deep Blue	**1997**	**1**	**200 Million Chess Moves/sec**
ASCI Blue			**3.8 teraFLOPs**
ASCI White	**2000**	**1000 X**	**12.3 teraFLOPs**
ASCI Purple			
BlueGene/L	**2003**	**30,0000 X**	**367 teraFLOPs**

A teraFLOP is one trillion (10^{12}) floating-point operations per second.

The Human Brain:

One estimated data point: ~100 teraFLOPs

Various types of arguments can be made about this number.

What about storage capacity equivalences?

Or vision, hearing, and other capabilities?

Yeah, I know. I have mixed planned and actual, peak and mean, etc.
But I don't really care, as there are worse problems with this page, anyway..

Implications?

“It will be analogous to having access to the *first electron microscope*, while everyone else in the world still makes observations with optical microscopes.”

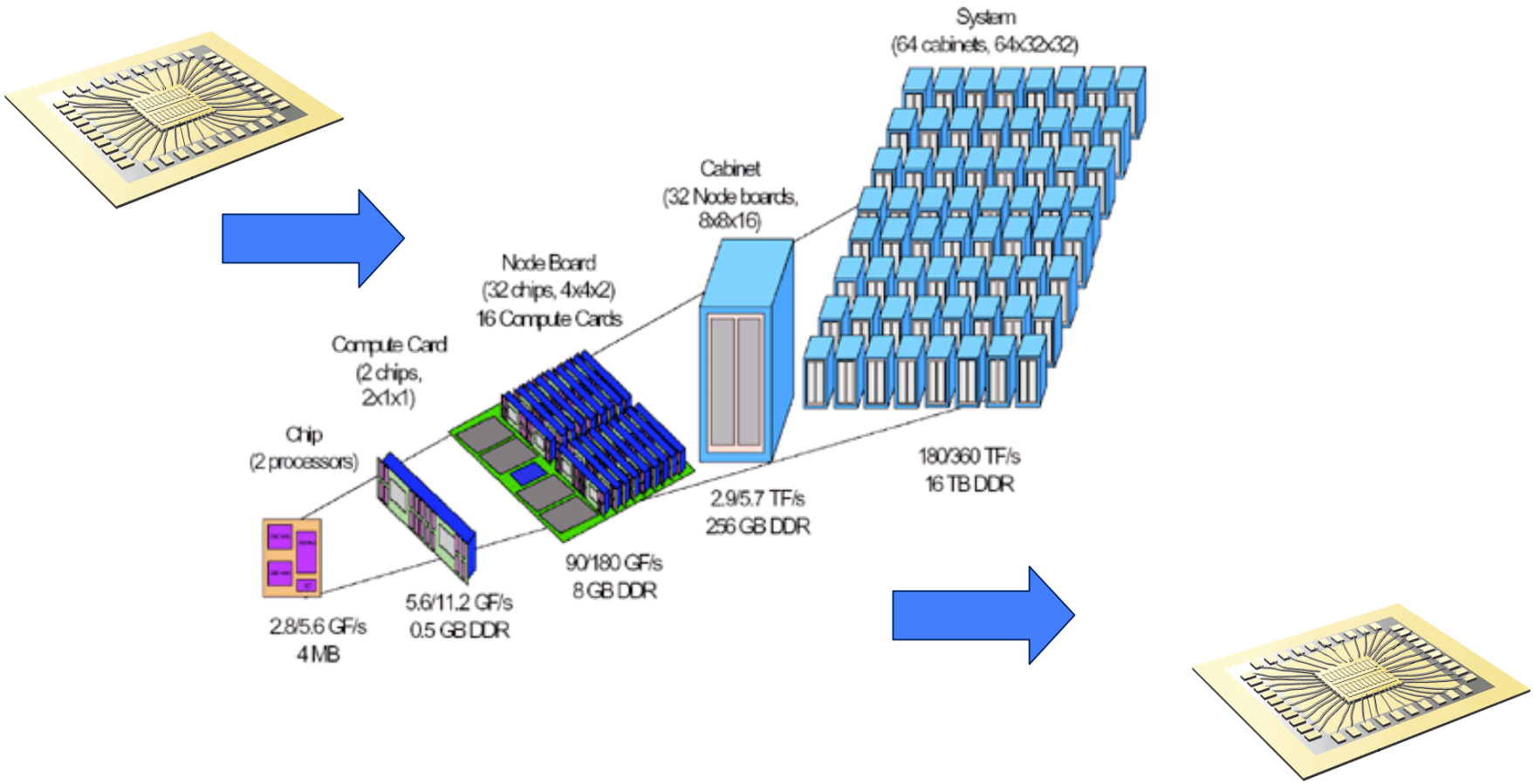
“It will relieve some of the *intense demand* for access to ASCI Purple.” *

ASCI brochure
Facts on BlueGene/L
Supercomputing 2002

Massively Parallel Supercomputers may be evolving at a rate that exceeds that of Moore’s law.

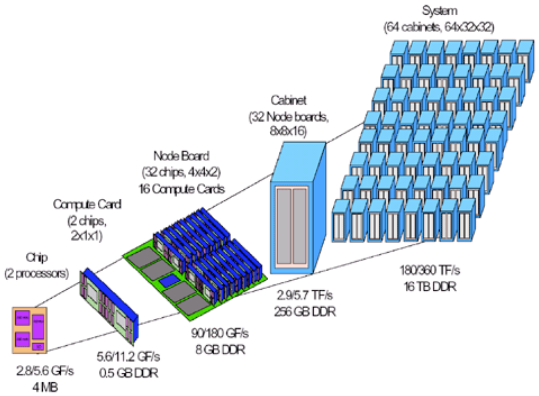
* Italics are mine.

The significance of this illustration can be seen two ways - simply by changing directions!

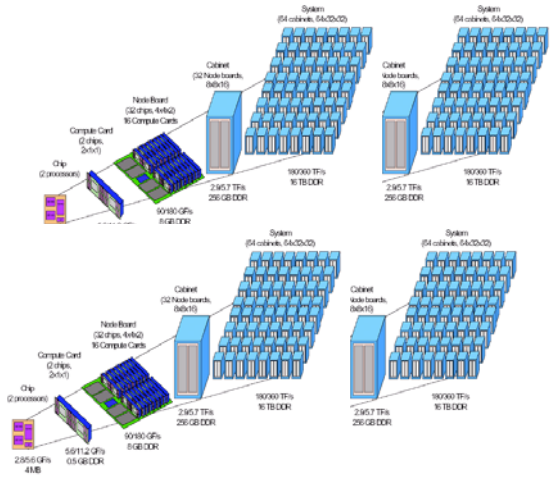


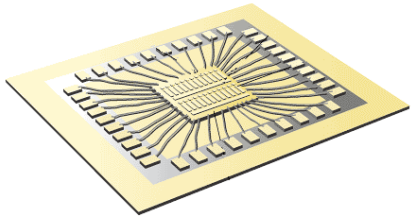
2020 will be here shortly.

"Time flies like an arrow."



Note: There are really two significant paths here.





2003 ——————————————————— 2020

You are Here

What should be done throughout here, concerning this "brains on a desk" era?

- Wait, think, plan?
- Begin?
- Innovate?

Brain-Scale Parallel Supercomputers

- **Supercomputers**
  - homogeneous processors
  - homogeneous interconnection networks
  - regularity of computation processes
  - non-embedded, non-real-time
  - minimalistic I/O
- **Brains**
  - non-homogeneous structures
  - irregular and non-homogeneous communications
  - distributed, irregular computations
  - embedded, situated
  - massive I/O

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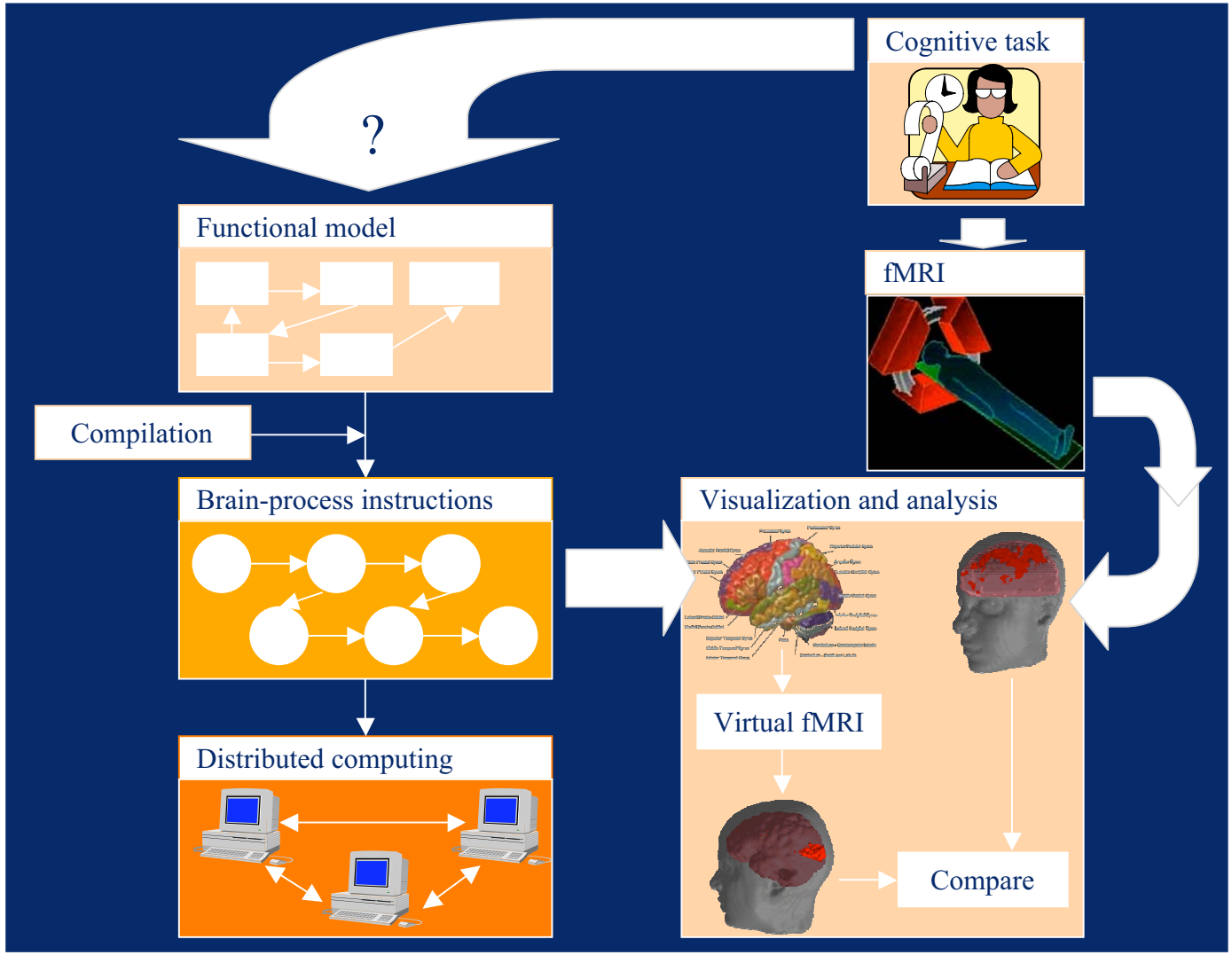
- **Will Brain-Scale Supercomputers / Parallel Processors differ from the current architectural approaches?**
- **Will evolvable hardware and interconnects be key?**
- **Will application mapping, debugging, performance measurements differ substantially?**
- **How will human sensory devices integrate with the data networks?**
- **How will the whole SW process change?**

DLT's "Visual Brain Tool" Project



We are in the initial stages of a significant technological and scientific discontinuity for Brain Sciences.

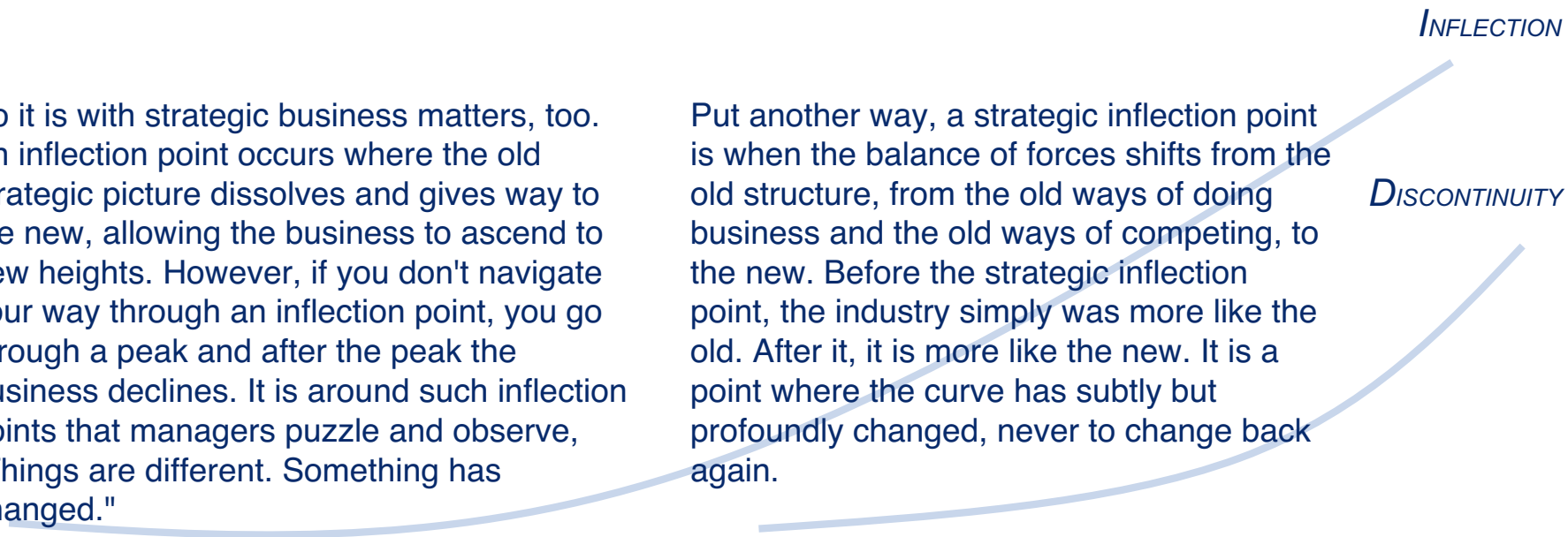
Addressing this Challenge/Opportunity very early on is one of the key potential values of the "Constructed Brain" proposal.

- **Key Enabler for Science**
  - Faster
  - Cheaper
  - Sooner
  - More thorough
  - More _____, _____, _____, …
  - Integrated (w)hole for all pegs
  - New disciplines

- **But also a major Discontinuity**
  - large-scale paradigm shifts
  - New & Discarded theories/approaches
  - Significant shifts to experimental, computational methodologies likely.
  - Much unlearning
  - System-level thinking is often difficult
  - True, integrative multidisciplinarians
  - Multiple, large-scale collaborations required

Discontinuities and Inflection Points

- **Strategic Inflection Points**
  - **Occur when multiple, significantly different technologies converge.**
  - **Enable radically new and different products and services.**
  - **Can create whole new markets and industries.**



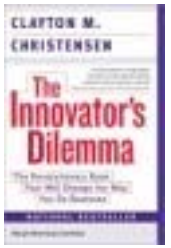
So it is with strategic business matters, too. An inflection point occurs where the old strategic picture dissolves and gives way to the new, allowing the business to ascend to new heights. However, if you don't navigate your way through an inflection point, you go through a peak and after the peak the business declines. It is around such inflection points that managers puzzle and observe, "Things are different. Something has changed."

Put another way, a strategic inflection point is when the balance of forces shifts from the old structure, from the old ways of doing business and the old ways of competing, to the new. Before the strategic inflection point, the industry simply was more like the old. After it, it is more like the new. It is a point where the curve has subtly but profoundly changed, never to change back again.

Andy Grove, CEO, Intel
Only the Paranoid Survive

Much more is known about this process and phenomenon.

- **Hamel & Prahalad**
  - *Competing for the Future*
  - *Leading the Revolution: How to Thrive in Turbulent Times by Making Innovation a Way of Life*
- **Clayton M. Christensen**
  - *The Innovator's Dilemma*
  - *The Innovator's Solution*
- **Peter Schwartz**
  - *Art of the Long View: Planning for the Future in an Uncertain World*

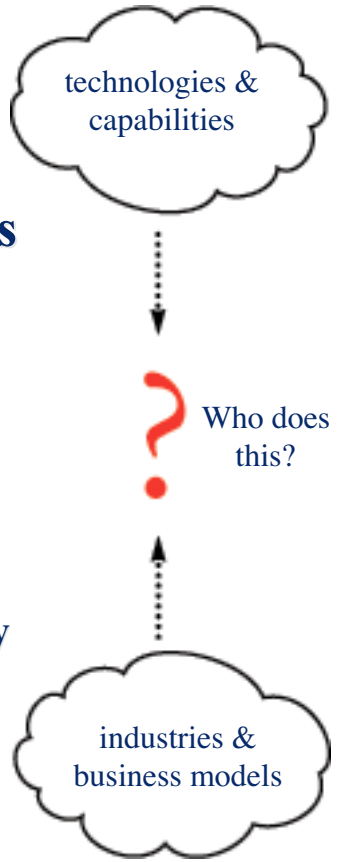


for only a few examples.

For both Science and Industry, discontinuities and inflection points can be bad and/or good.

cf: Digital Convergence

- **Exploiting the opportunity space can lead to whole new**
  - **Industries, Markets, Scientific Advances, Scientific Disciplines**
  - **As well as Economies, Societal Benefits, etc.**
- **But believe it or not, Innovation is often fought by companies and industries.**
  - **And it is often the best run companies that fight the most.**
- **Innovation can be risky, costly, and hard work.**
- **Planned, integrative Technology Transfer can be key.**
  - **But industry has a hard time doing this on its own.**
  - **Yet academics and government labs generally eschew any responsibility for this.**
  - **(and even corporate R&D centers often do so, too.)**

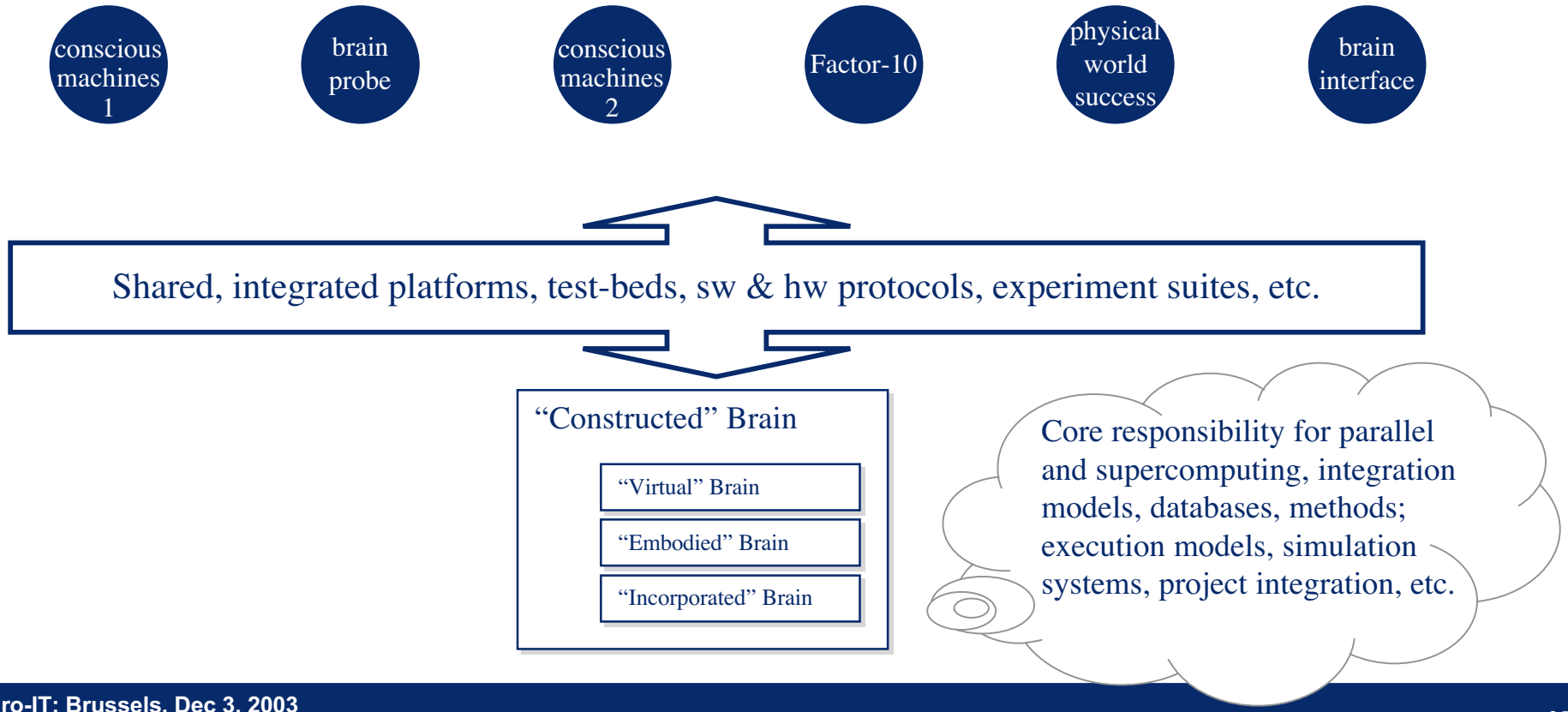


The Nature of the Neuro-IT program will create numerous opportunities for high-value cross-fertilization between academia and industry. Exploiting the opportunities will not be easy or familiar - for either side.

Some Questions concerning Vision-Based Innovation and Tech-Transfer

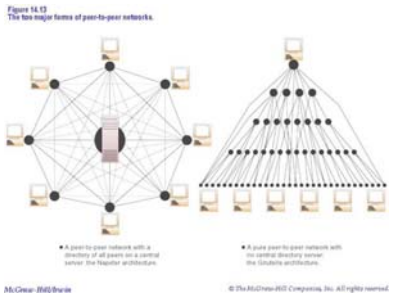
- What roles and responsibilities can we foresee for the Scientific Members involved in Neuro-IT?
- Should we and and how can we maximally ensure institutionalized innovation practices?
- What can Neuro-IT members do to assist the rapid adoption and smooth commercialization of their combined scientific advancements and breakthroughs?

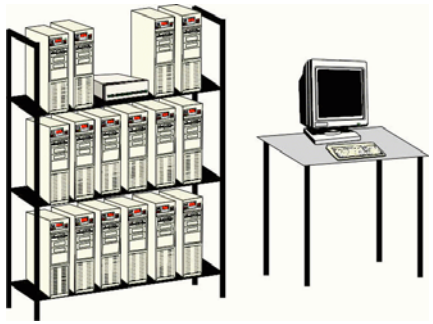
Should we establish the "Constructed Brain" program as an overarching strategic platform for Neuro-IT?

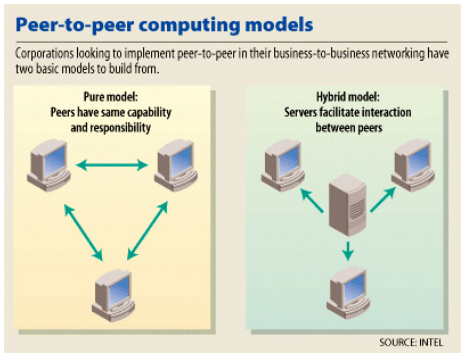


BTW, thinking about Supercomputers…

We don't have to wait for the availability of Supercomputers to begin capitalizing on the promises of Supercomputers.







- **P2P (peer-to-peer)**
  - distributed computing
  - very loosely coupled
  - cf: SETI at home volunteers
- **Beowulf Systems**
  - tightly coupled execution
  - commodity hardware
  - open software
- **Technology Grids**
  - full-scale Advanced Computational Infrastructures
  - super-infrastructures vs. supercomputers

Magnet Centers

- Super-infrastructure Hubs
- Domain and Enabler Specialists
- EU-wide resources (both for amortization and access)
- Training, tools, resources, hands-on, etc.
- "Science Center" model (e.g., Leiden's Lorentz Center)

- Tech-transfer awareness, competence, endorsement
- Integration test-bed and platform centers
  - Engineering support as well
- Industry-Academia cross-fertilization centers.

The Role of Patents in FP6 Efforts

- **What is the situation with University-level patents in Europe?**

  "Not only would most European professors not be interested in patenting, they would probably even think it beneath them."

  a friend

- **Is(n't) this something to be overcome?**
  - **If so, the whole academic reward structure needs to be modified.**
- **How about an FP6/EU program to grant Scientific Awards for EU patents initiated by Professors.**
  - **Or even just Neuro-IT, perhaps, as a place to start?**
- **Starting Endowed Chairs for Innovation in Neuro-IT?**
- **Replicate the Leuven R&D Model?**

Selected References and Pointers

- **Neuro-IT**
  http://www.neuro-it.net
- **The Human Brain Project**
  http://www.nimh.nih.gov/neuroinformatics/index.cfm
- **This is Your Computer on Brains (re: IBM's BlueGene)**
  http://www.wired.com/news/infostructure/0,1377,56459,00.html
- **Digital Life Technologies Group (Leiden, DeGroot)**
  http://www.liacs.nl/research/dlt
- **XtremWeb**
  Computer Science Laboratory, Paris XI University, France
  http://www.lri.fr/~fedak/XtremWeb/
- **Australia National University's Bunyip Beowulf Project**
  http://tux.anu.edu.au/Projects/Beowulf/
- **David Hanson & H.E.R.**
  http://www.utdallas.edu/dept/ah/prospective_students/spring2003.html
- ***Only the Paranoid Survive***
  Andrew S. Grove, March 1999.
- **Honda ASIMO Robot**
  http://world.honda.com/ASIMO/

The End

to contact:

Doug DeGroot
degroot@acm.org