# Transport and Communication: matter, information and consciousness

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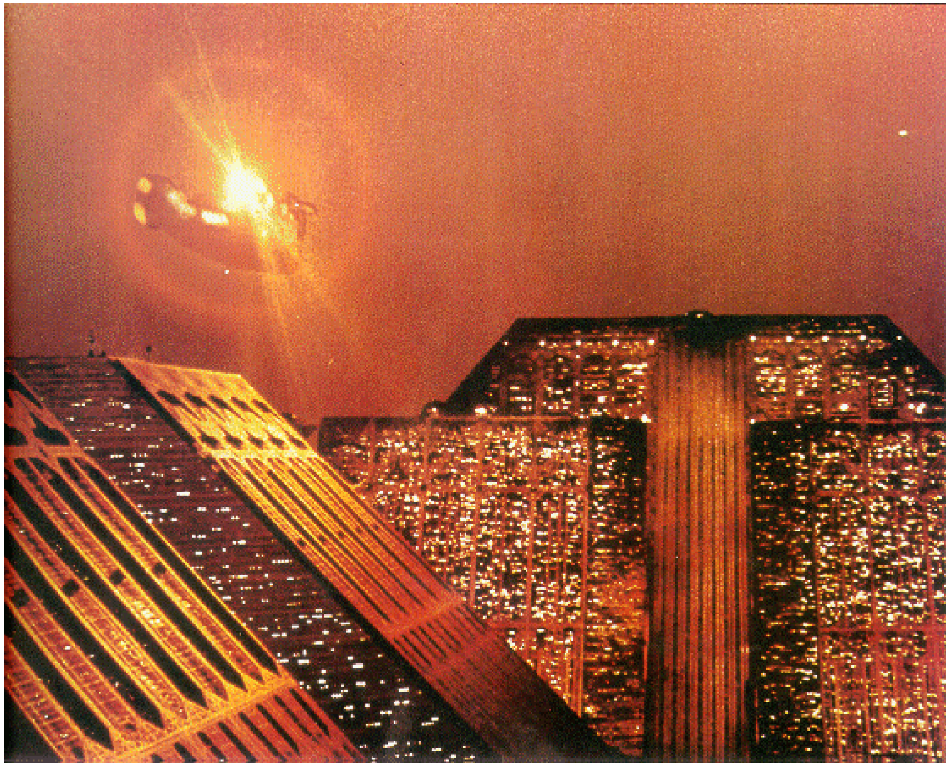
# 2050 and Beyond

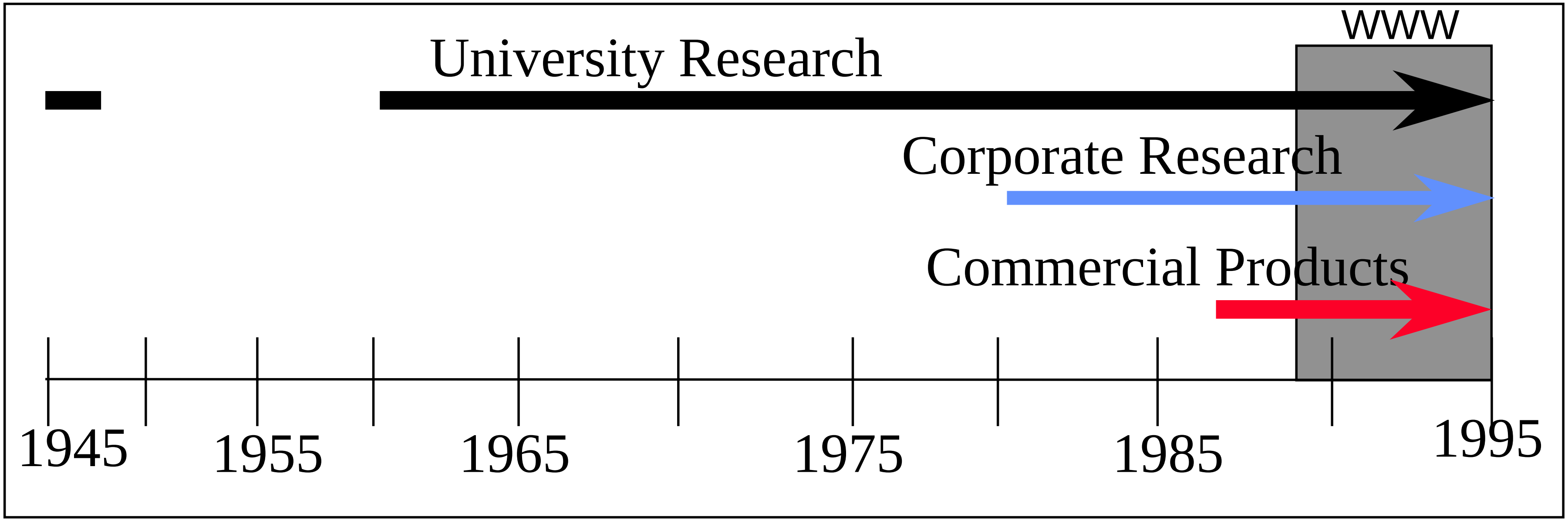
We transport objects (matter) to communicate information in order to achieve our purposes (consciousness)

What will the technologies of these three be in 2050 ?

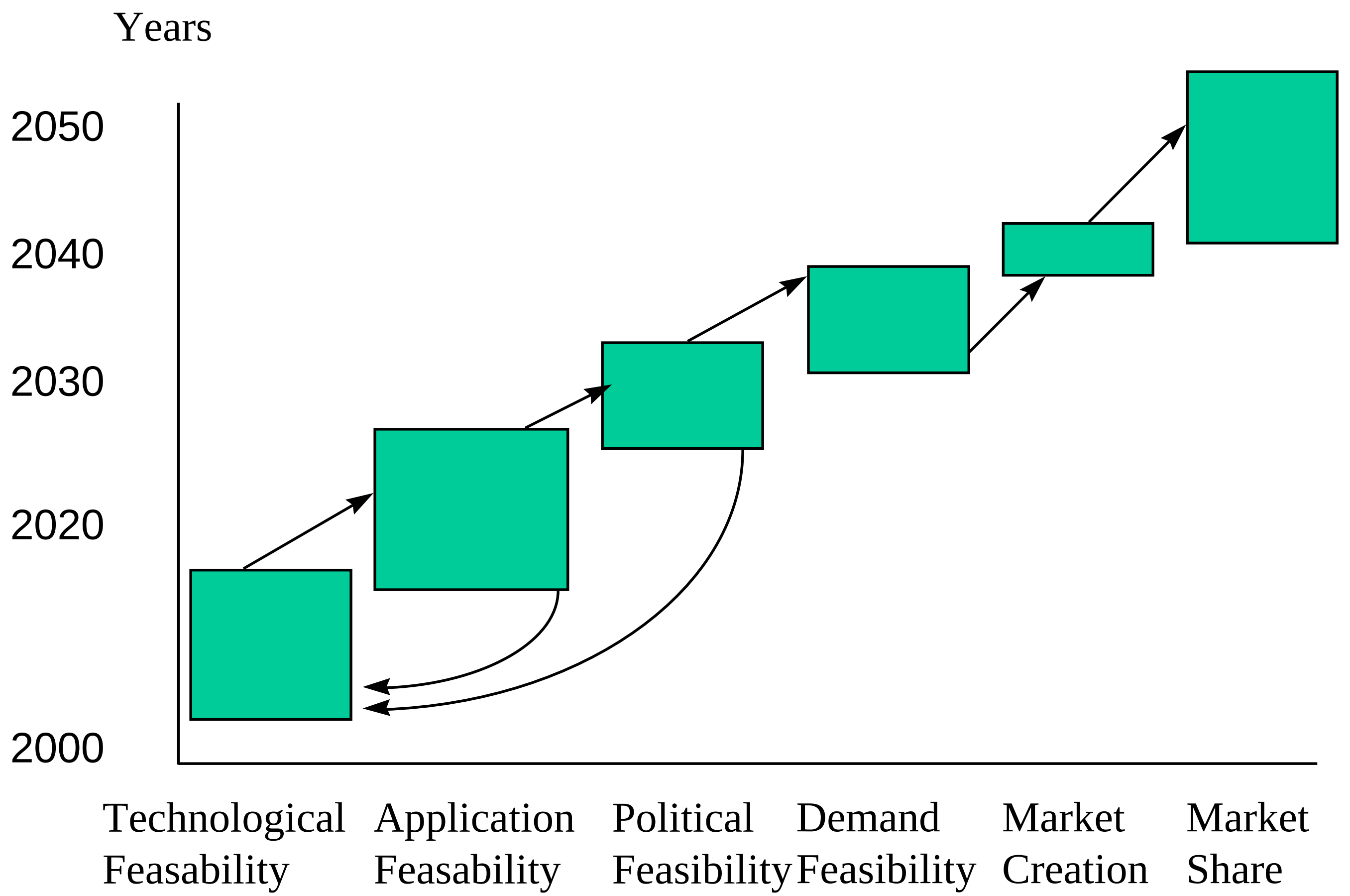


# Technology Timescales

## Hypertext: from conception to 10% of UK population using WWW



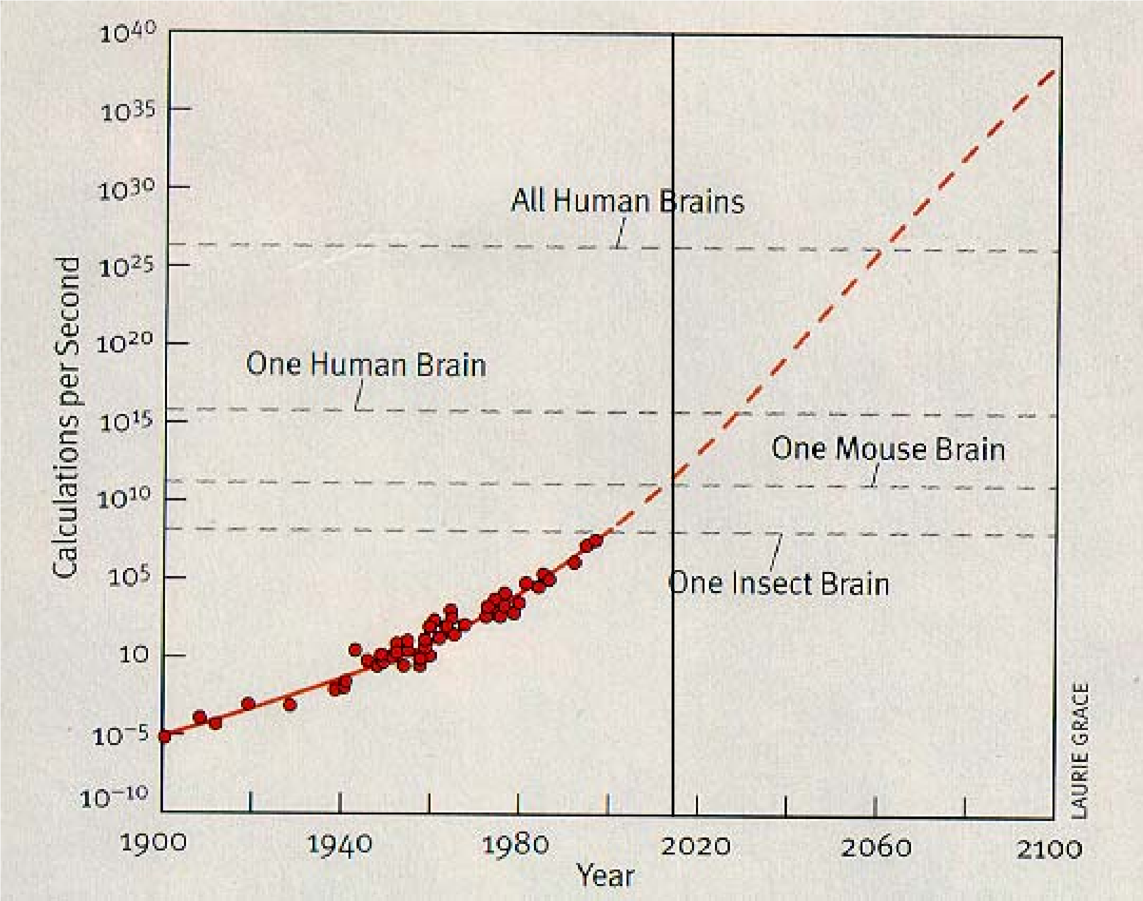
# Technology Lifecycle Activities



# Matter

- Transportation of Matter
- Quantum Teleportation
- Today we can transport the state of individual atoms a few kilometres
- The transport of molecules can be expected within 20 years
- Transportation of complex matter – maybe ?

# Computing Power

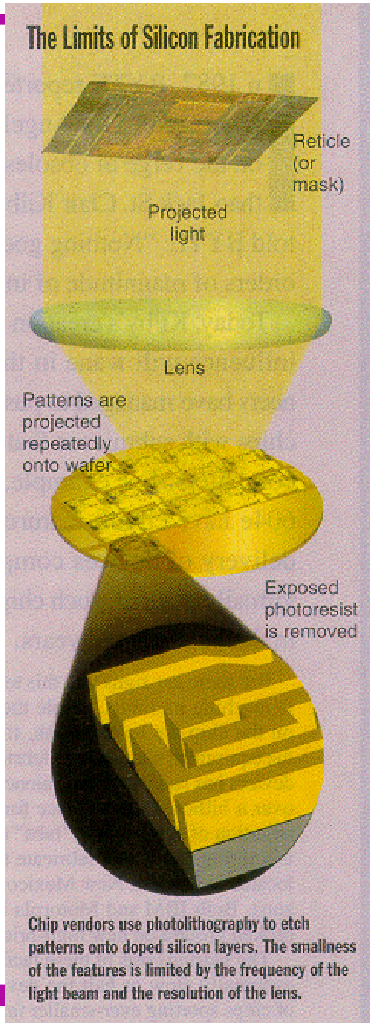



Growth of computing power available for $1000

Current technology extrapolation stops in 2015

# Silicon Chip limits

- Current computing processor chips double in power every 18 months.
- This will continue while silicon chip masks can reduce the size of components – otherwise they will overheat.
- Present technology will only do this for another 15 years.



# Quantum Computing

- Use the quantum properties of particles to compute
- Use entanglement to transmit the data instantly - faster than the speed of light
- A 3 bit register holds only 1 of 8 numbers at once
- A 3-qubit register holds all 8 simultaneously - superposition

• Particles can be held in ion traps and programmed by pulsed lasers

or

• Liquids can be programmed by pulsed Nuclear Magnetic Resonance

# Benefits and Limitations

- Modelling the evolution of 40 particles would take :
  - $10^{24}$ digital operations or 31,709 years on a TOP computer
  - 100 quantum interactions of 40 ions (qubits)
- Coherence - Qubits must interact strongly together,
- Decoherence - but not with the environment (e.g. thermal vibrations of trap)
- The NIST ion trap XOR gate looses coherence after 20 operations, the MIT/IBM liquid XOR gate 1000
- The number of qubits in a liquid is limited to the number of atoms in the molecule employed = 10 for current NMR

# Quantum progress

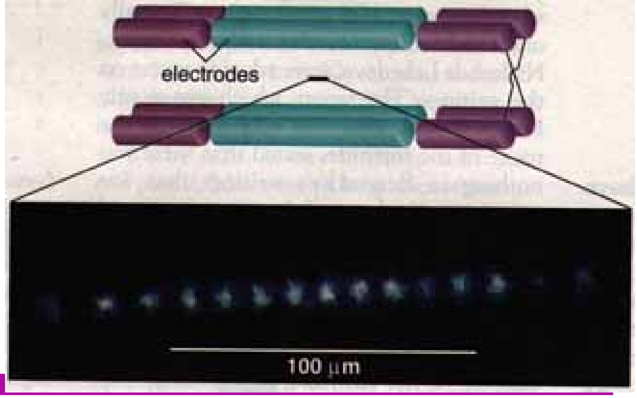
**1982-** Richard Feynman speculated on the idea

**1985 –** David Deutsch at Oxford described a universal quantum computer

**1993** – Seth Lloyd at Los Alamos showed many systems could act as quantum computers (e.g salt)

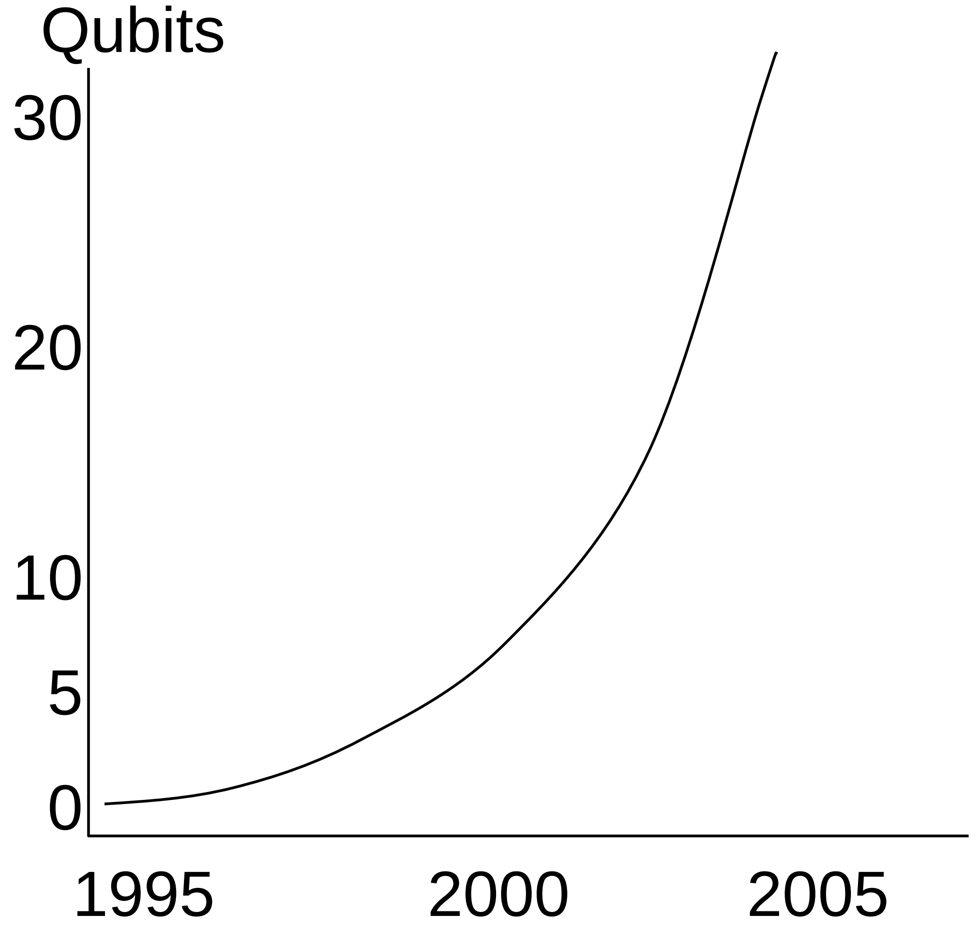
**1994 -** Peter Shor at AT&T's Bell Labs devised the first quantum algorithm, to perform efficient factorisation

**1998** – Gershenfeld & Chuang at MIT & IBM - loading data and reading out a result from a solution of chloroform molecules at normal temperatures.



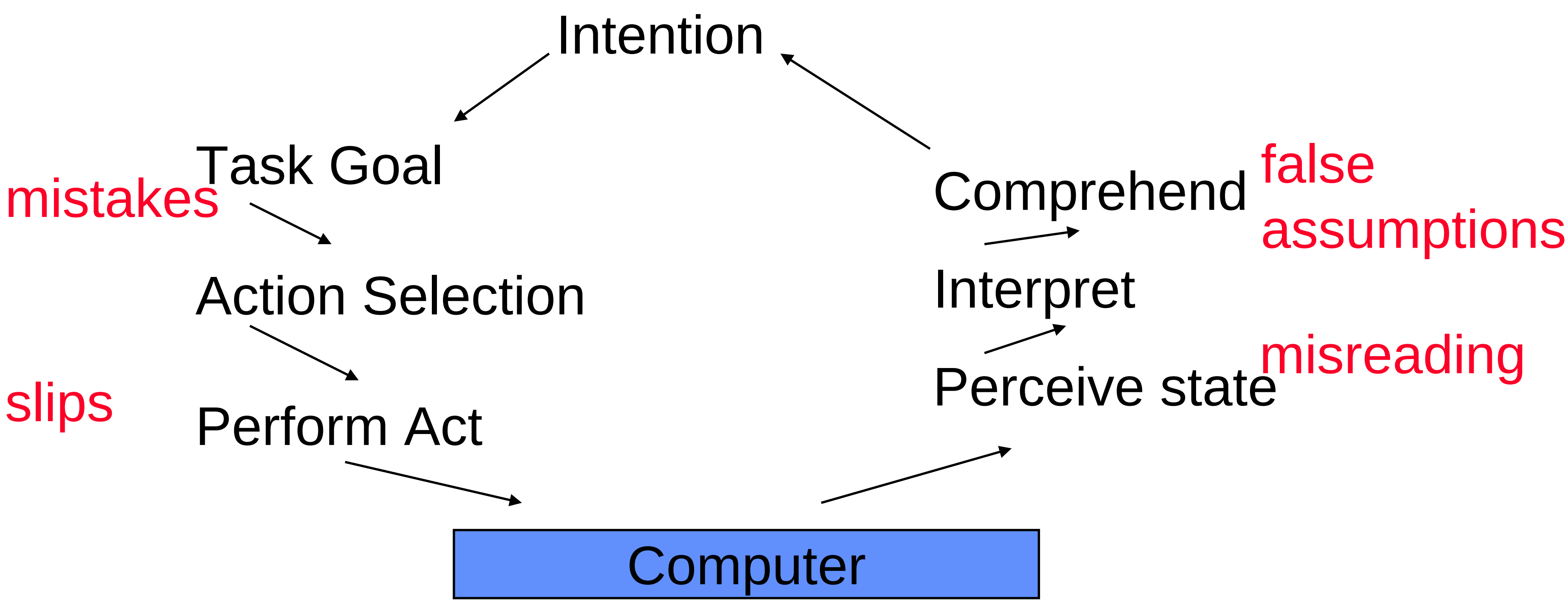
# Projected Progress in Quantum Computing

- Growth follows Moore's Law
- 7 Qubits achieved Apr. 2000
- Similar state to digital computing in the 1940's



# User Computer Interaction

Using computers to achieve our intentions, with errors.



# Today's UI Research

- We have computers that speak & understand NL
- We have computers which hear, touch, even smell.

•We have computers that understand and express emotion.

# Neural Interfaces

- science-fiction movie *Forbidden Planet, 1956*
- Direct interfaces between the human nervous system and the computer could avoid the comprehension and execution errors.
- Non-Invasive neural interfaces
  - Electro-muscular
  - EEG
- Invasive neural interfaces
  - Peripheral Nerves
  - Central Nervous System

neural_interface.avi

# Electro-muscular

- 1970's - sensors detect muscle impulses through the skin to control prostheses - electromyographic signal, or EMG
- 1991- a general-purpose interface between a computer and the body's various electrical signals - Biomuse. Hugh Lusted and Benjamin Knapp Stanford Univ.

Useful for control by the handicapped – but won't scale up to thought recognition, supports development of IO technology

# Non-Invasive neural interfaces


- EEG – brain waves
- Aim - assemble a suite of EEG signatures that users can control simultaneously
- Most people can easily learn to manipulate several biosignal signatures one at a time.
- The tricky part is learning to control *multiple* EEG patterns at once

# Single Signal EEG Control

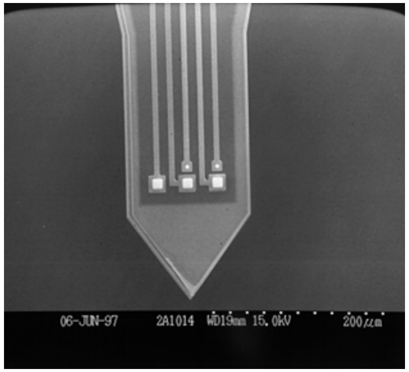
- Grant McMillan, Wright-Patterson Air force Base, 1996
- Place two electrodes on either side of the back of the head and attach ground and reference electrodes.
- A differential EEG signal, produced by subtracting a person's left hemisphere signal from that of the right hemisphere
- amplified and displayed to the user, who uses the feedback to help control the amplitude

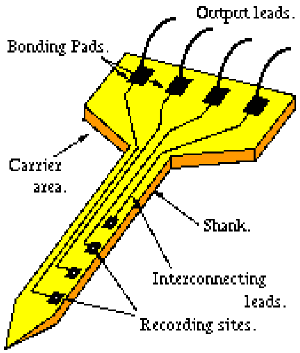
# Multiple Signal EEG Control

- Andrew Junker Cyberlink Mind Systems, Yellow Springs, Ohio, 1998
- break down the EEG spectrum into 10 *brainfingers*.
- Each finger is a narrow-band filter of the EEG spectrum up to 3,000 Hz.
- three brainfingers in the theta band, three in alpha, and four in beta.
- Could EEG scale up through positional and bandwidth sensitivity to thought recognition - unlikely

# Peripheral Nerve Interfaces

- Microprobes inserted into the peripheral nerves can read and write nerve signals – 1995 Danny Banks, Surrey Univ.
- Support for finer prosthesis control, and limb control after spinal break
- Proof of technology, but thought does not go to the Peripheral Nervous System



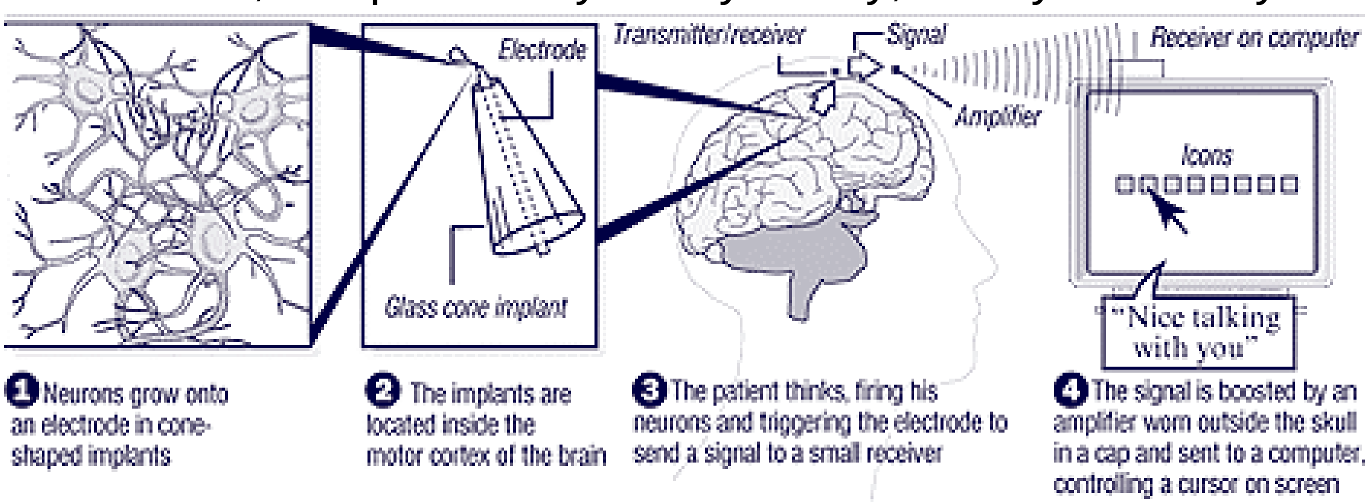



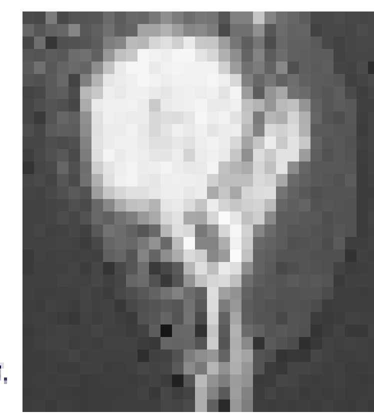

Sketch of a typical microprobe.

# Central Nervous System Interfaces

- Connect Motor Cortex to 2 electrode cones.
- Electrode cone to a small transmitter-receiver
- PC receives signal.
- 4 Patient users control cursors – horizontal & vertical

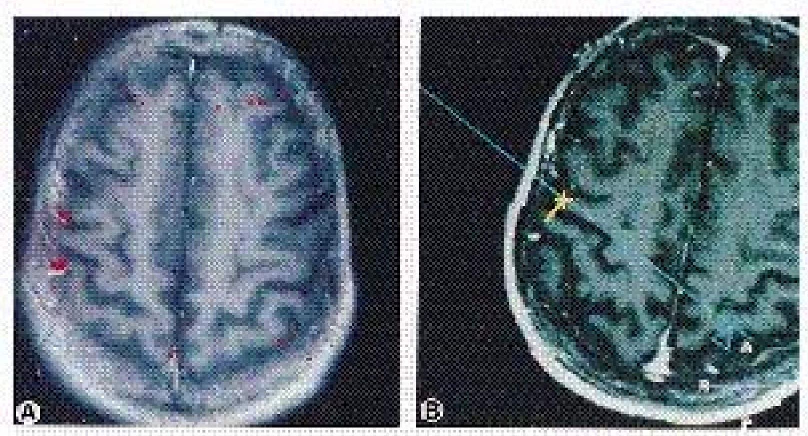
Oct '98, Philip Kennedy & Roy Bakay, Emory University Atlanta



# Thought Recognition

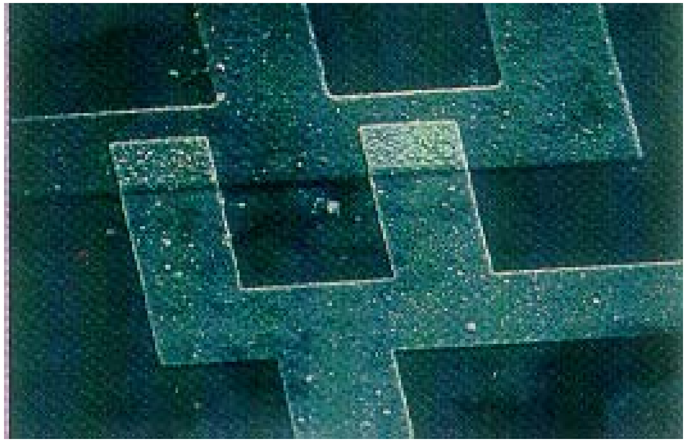
- the ultimate computer interface
- the ultimate communication device




- CNS write as well as read required
- Move from Motor Cortex only to Intention and Consciousness centres required
- Requires brain science research to identify Intention and Consciousness centres and their neural codes – post genome project global research topic

# A word of caution – the Josephson Junction

- 1962 - Supercooled superconductors separated by thin insulating layer allows current flow through insulator



- Magnetic and electric fields switch current on/off very fast – Potentially ultrafast logic gates

•Too expensive to cool, speeds too slow, circuits tore apart when cooled in liquid helium –270 C

•They are used as noninvasive medical sensors

# Conclusion

- Predicting 50 years ahead is very risky
  - technology development takes a long time
  - intermediate stages in technology require their own justification/markets
- Electrophysiological communication and control of computers is currently possible in very limited cases
- There are markets to justify continuing these developments (e.g. disability) to solve many intermediate technical problems
- The expected change in computing architecture after 2015 justifies research in quantum computing
- Massively parallel computing architectures such as quantum computing may match the massively parallel computing architecture of the brain
- By 2050 direct thought control of quantum computers may be possible
- If not (recall the Josephson junction) these two lines of research will probably each produce something else significant for computing and communication