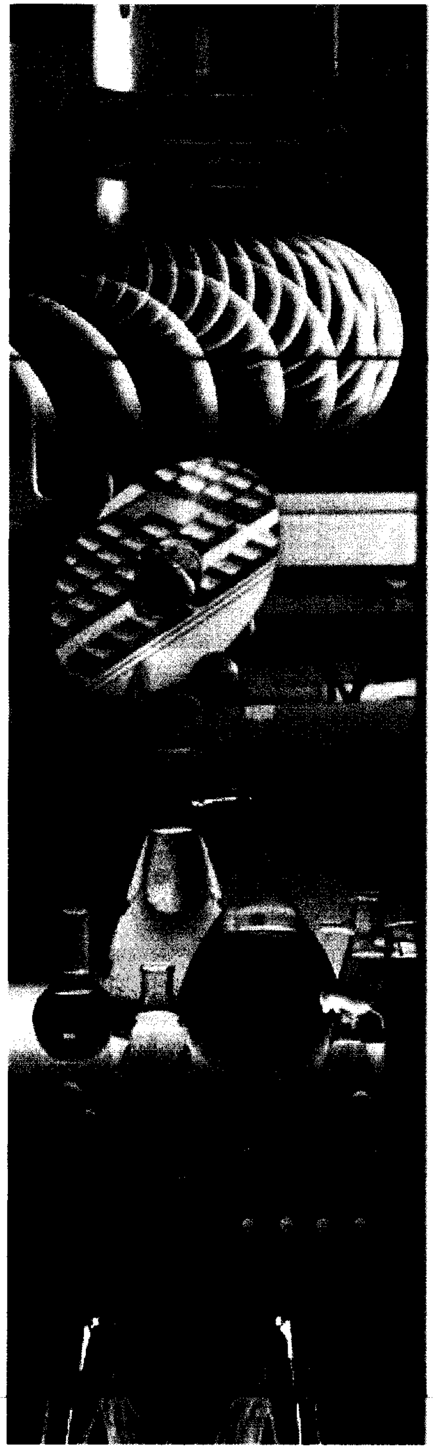


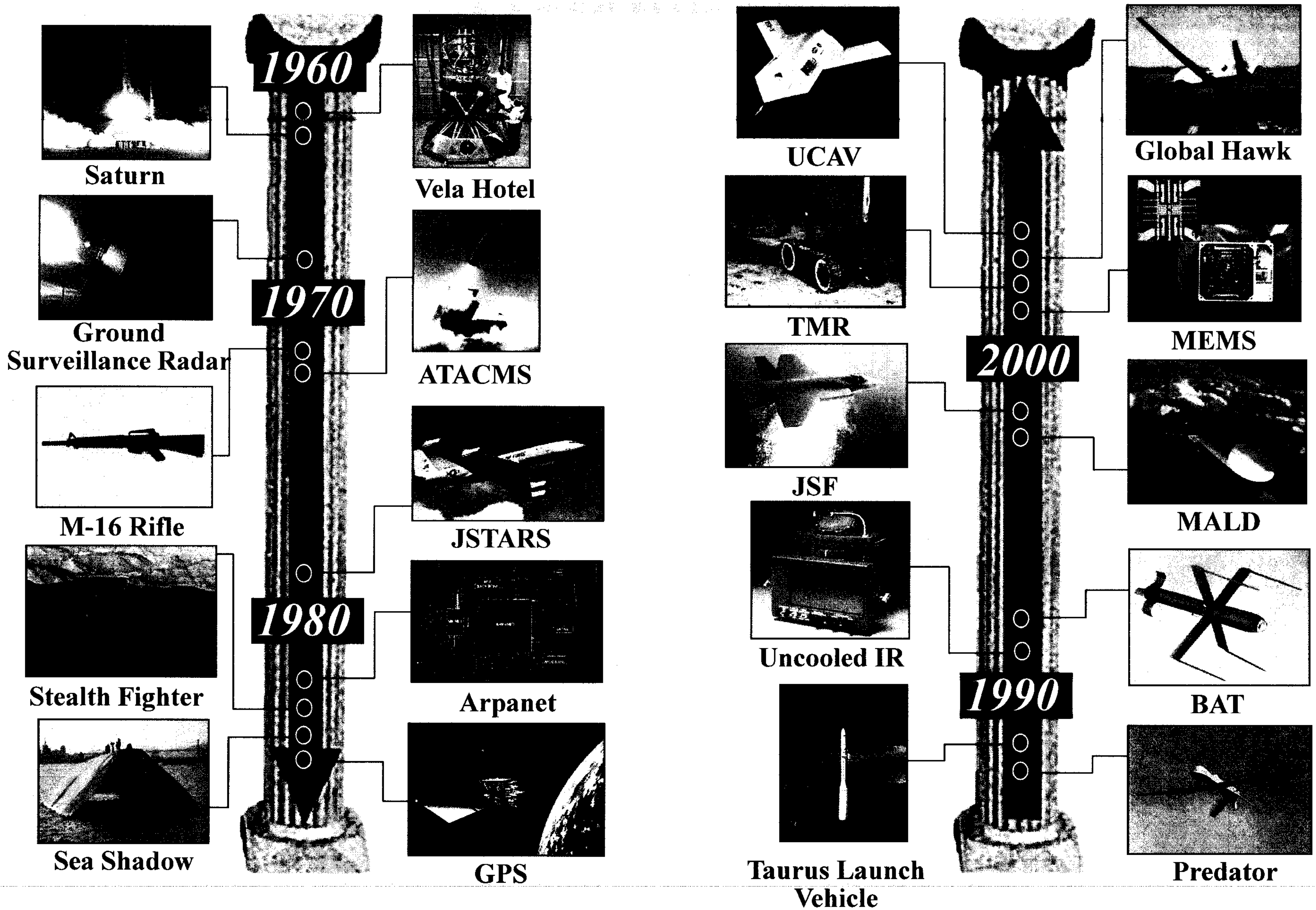
Direct Brain-Machine Interface

Eric Eisenstadt, Ph.D.
DARPA
Defense Sciences Office

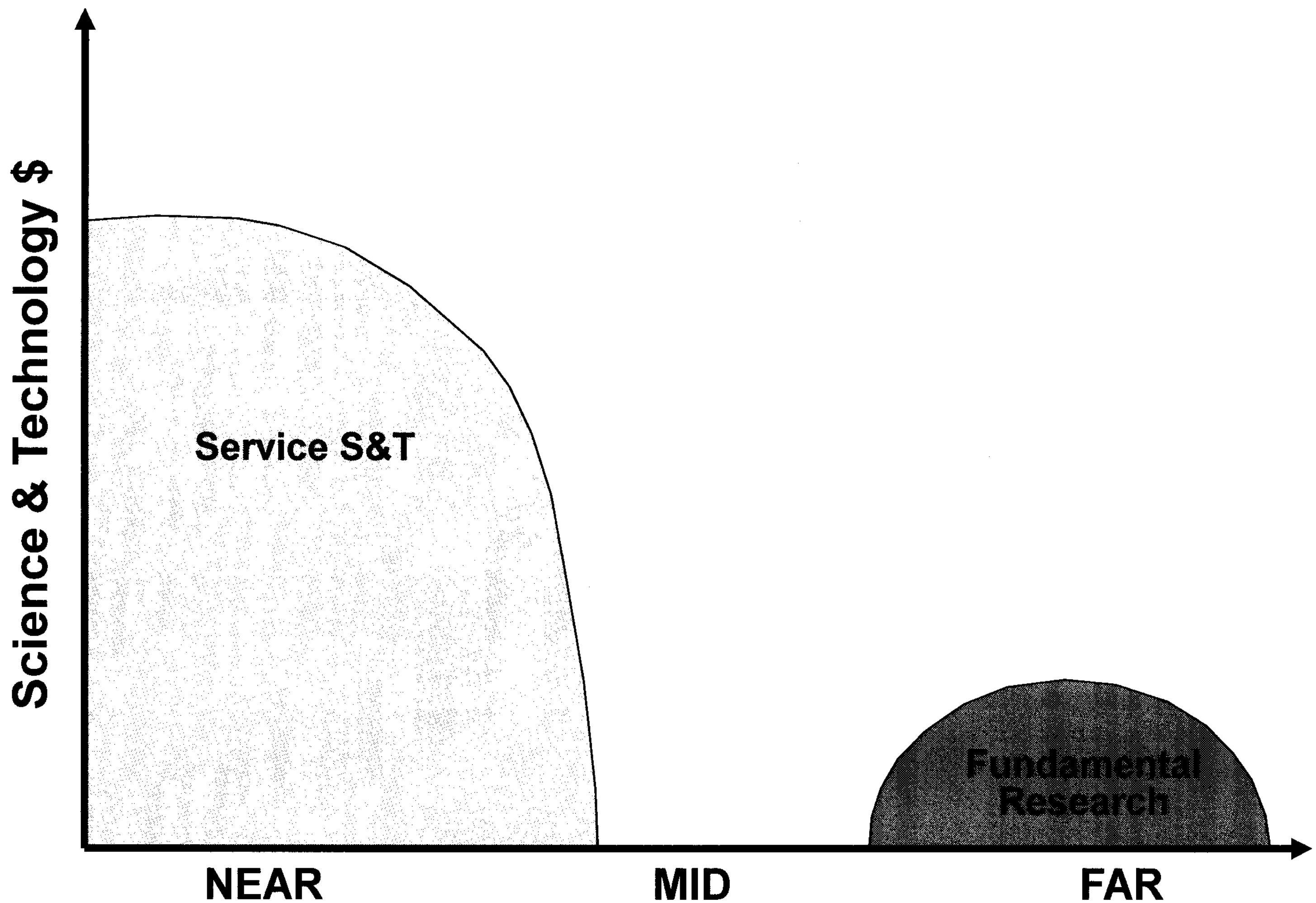
Science and Technology Symposium
21-22 April 2004

Defence Research and Development Canada
Recherche et développement pour la défense Canada

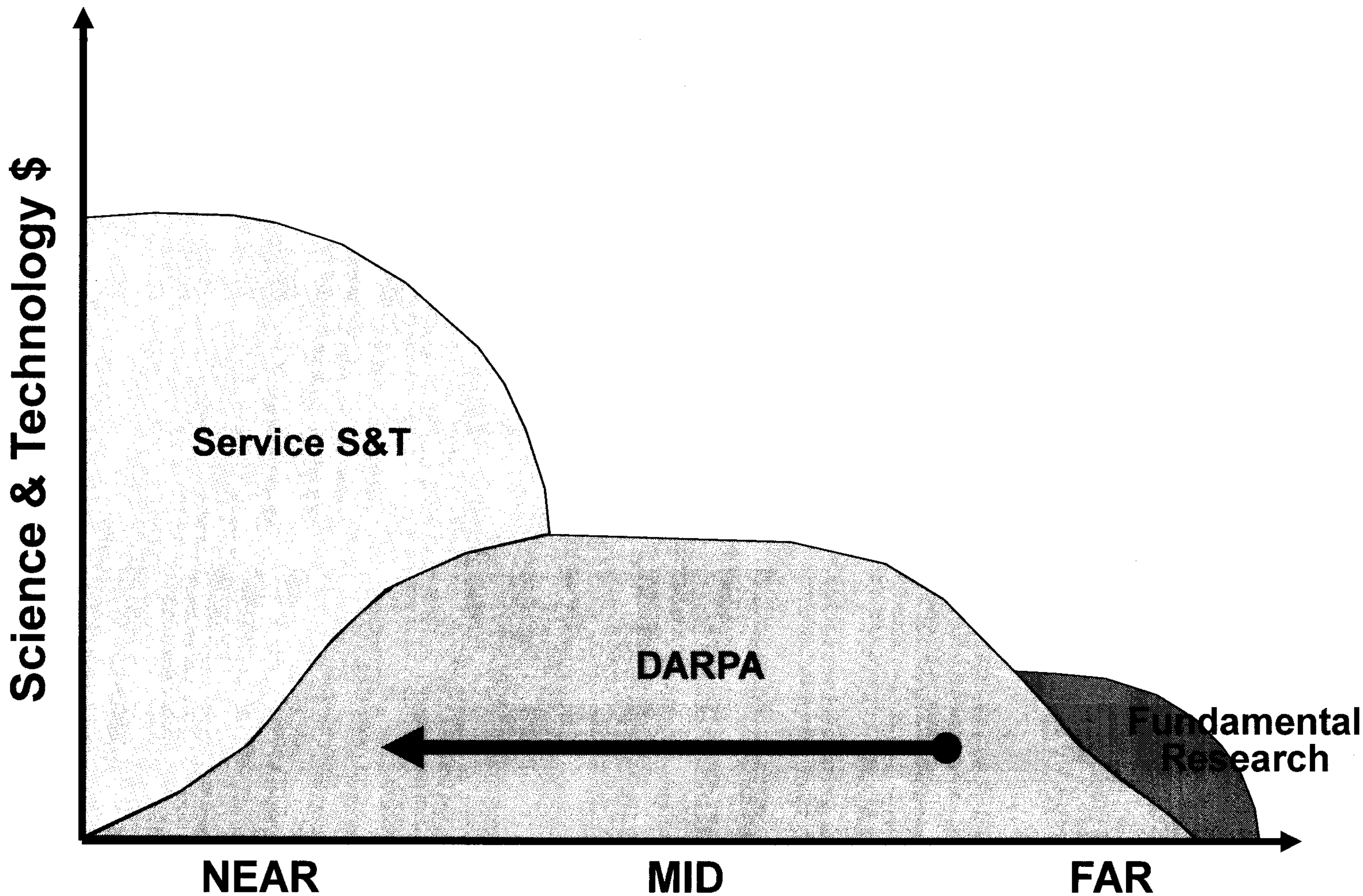
DARPA Accomplishments



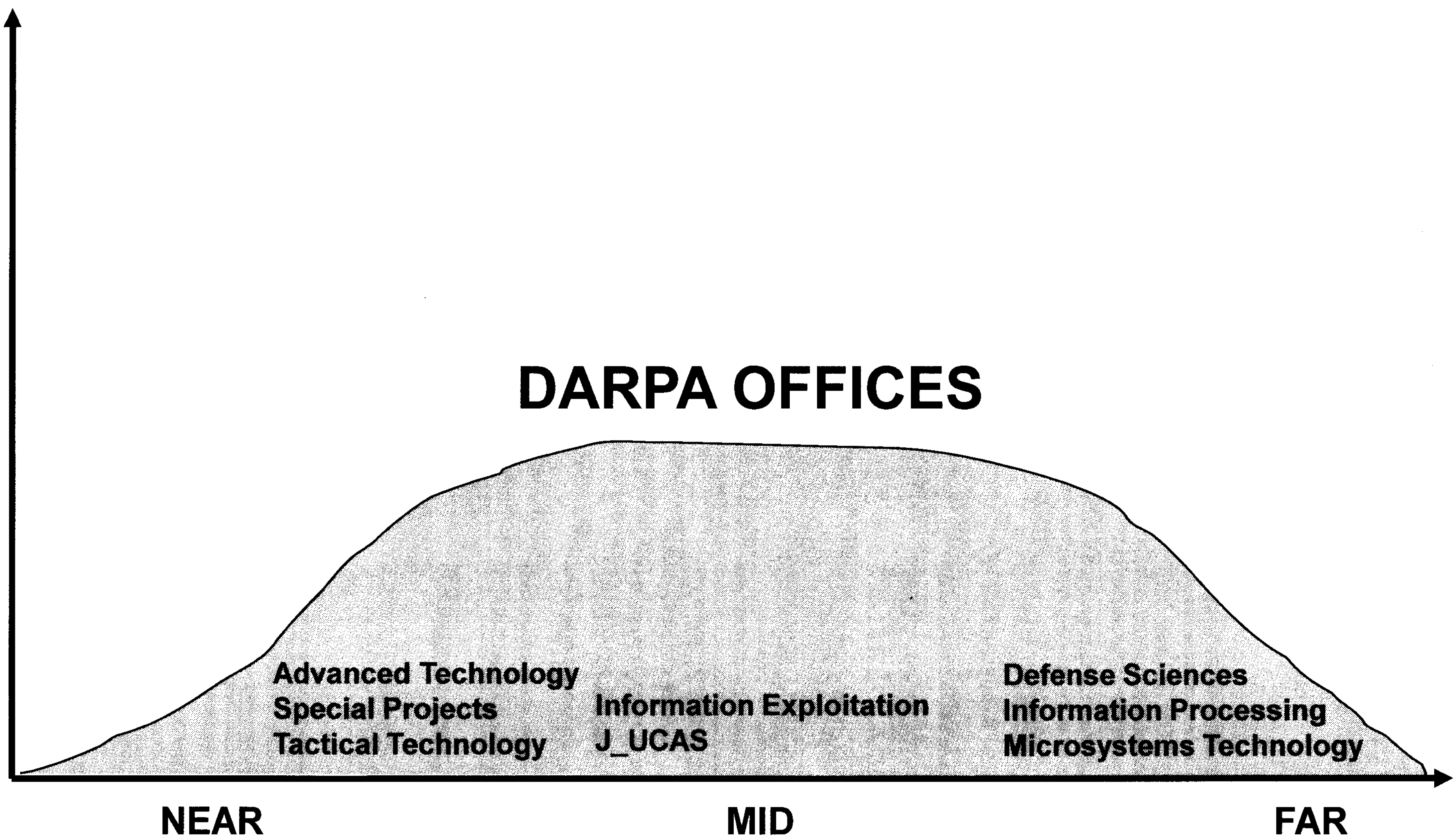
DARPA Role in Science and Technology



DARPA Role in Science and Technology



Internal Technology Flow



DARPA DSO DEFENSE SCIENCES OFFICE

DARPA Strategic Vision

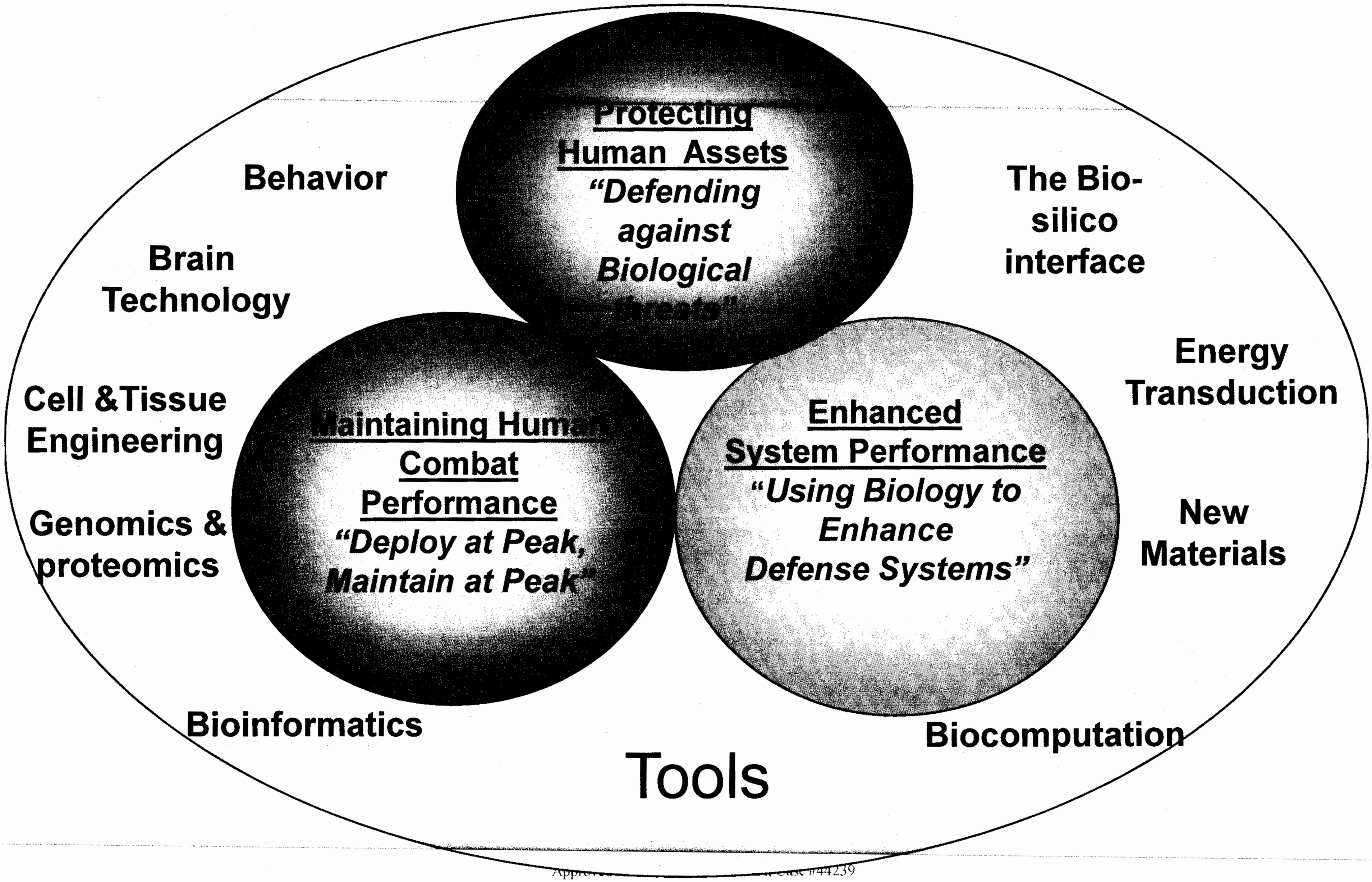
- **Strategic Thrusts**
  - **Detection, precision ID, tracking, and destruction of elusive surface targets**
  - **Location and characterization of underground structures**
  - **Force multipliers for urban area operations**
  - **Networked manned & unmanned attack operations**
  - **Assured use of space**
  - **Cognitive systems**
  - **Bio-Revolution**
  - **Robust, secure self-forming networks**
- **Enduring Foundations**
  - **Materials**
  - **Microsystems**
  - **Information Technologies**

Maintain the technological superiority of the U.S. military and prevent technological surprise …

High-payoff research that bridges the gap between fundamental discoveries and their military use.

Biology…

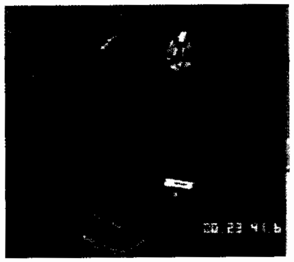
DARPA's Future Historical Strength



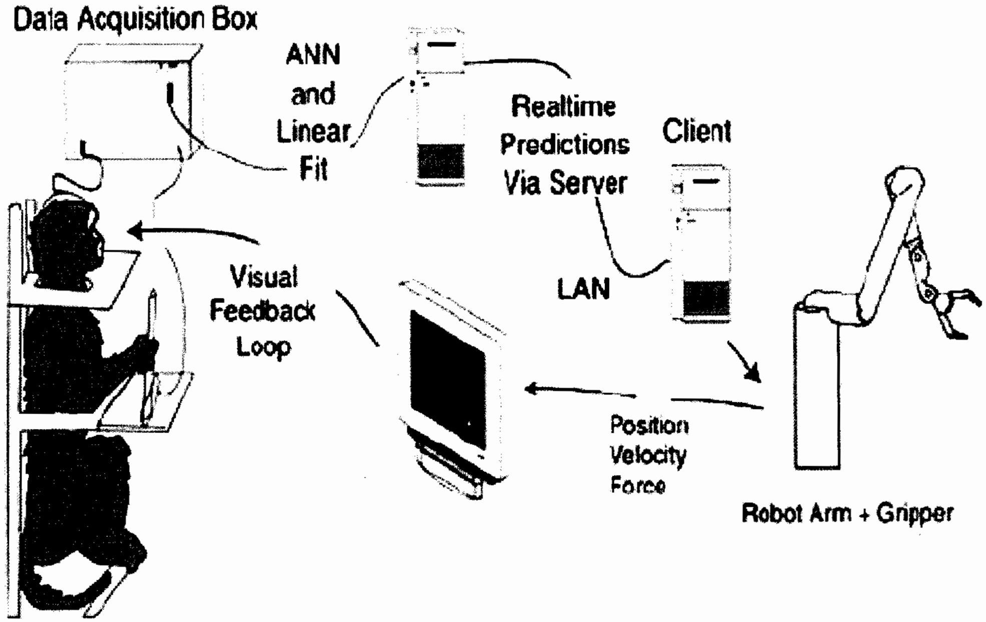
Human Assisted Neural Devices

DEFENSE SCIENCES OFFICE

Use brain activity to command, control, actuate and communicate with the world directly through brain integration with prosthetics and peripheral devices



- Closed loop demonstration of arm reach and grasp of food
- Open loop demonstration of human control of gripping force
- Long-term compatibility
- Non-invasive correlates



Human Assisted Neural Devices

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Learning to Control a Brain–Machine Interface for Reaching and Grasping by Primates

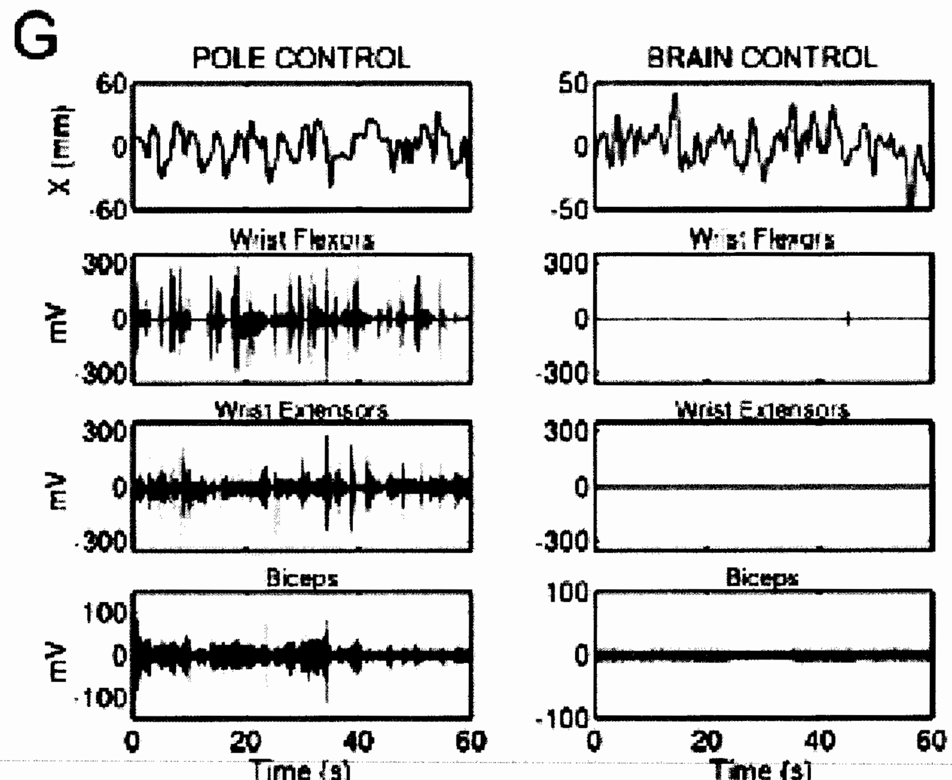
Jose M. Carmena[1,4], Mikhail A. Lebedev[1,4], Roy E. Crist[1], Joseph E. O'Doherty[2], David M. Santucci[1], Dragan F. Dimitrov[1,3], Parag G. Patil[1,3], Craig S. Henriquez[2,4], Miguel A. L. Nicolelis[1,2,4,5*]

1 Department of Neurobiology, Duke University, Durham, North Carolina, United States of America, 2 Department of Biomedical Engineering, Duke University, Durham, North Carolina, United States of America, 3 Division of Neurosurgery, Duke University, Durham, North Carolina, United States of America, 4 Center for Neuroengineering, Duke University, Durham, North Carolina, United States of America, 5 Department of Psychological and Brain Sciences, Duke University, Durham, North Carolina, United States of America

- Surface EMGs of arm muscles recorded in task 1 for pole control (left) and brain control without arm movements (right). Top plots show the X-coordinate of the cursor.

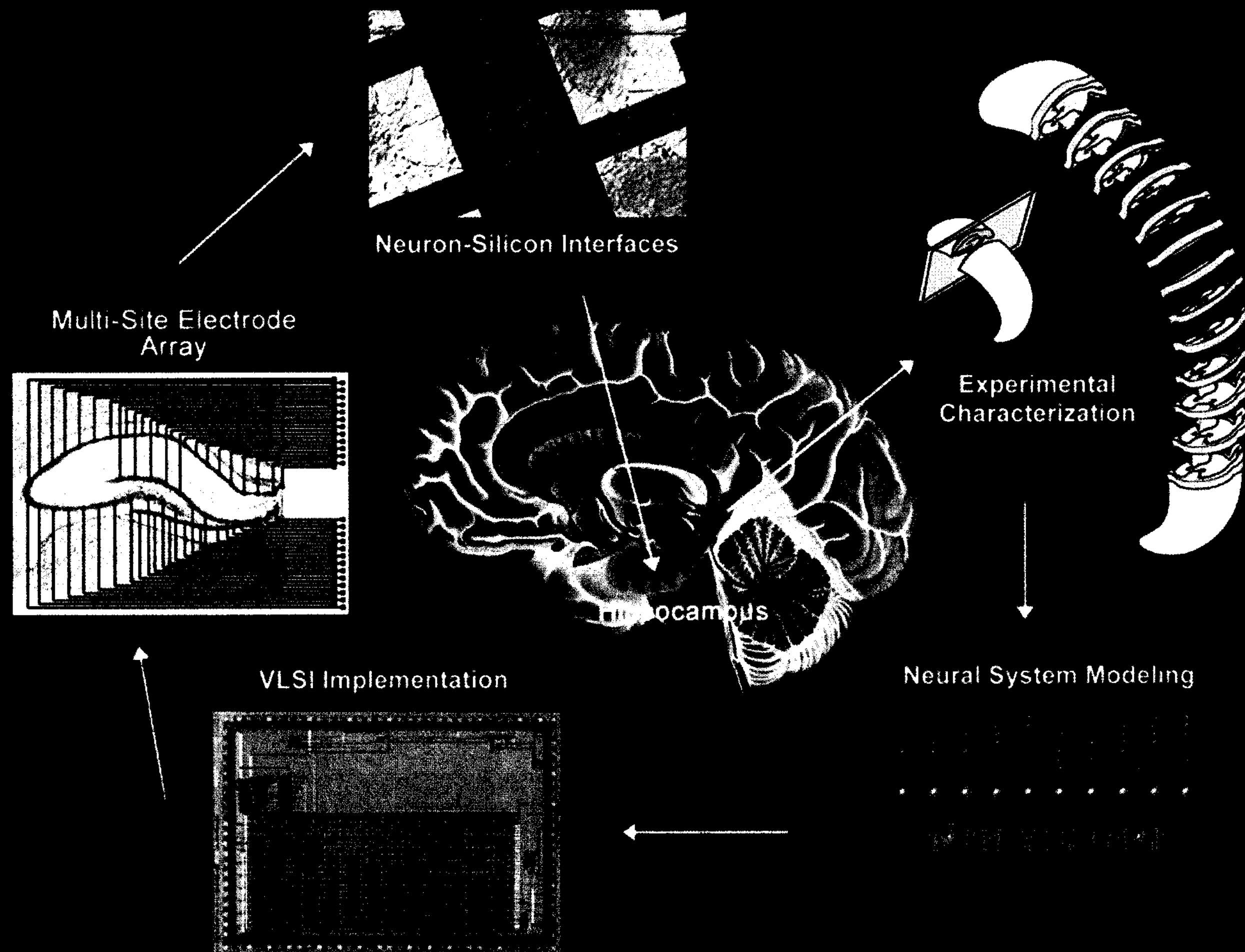
- Plots below display EMGs of wrist flexors, wrist extensors, and biceps.

- **EMG modulations were absent in brain control.**



Ap

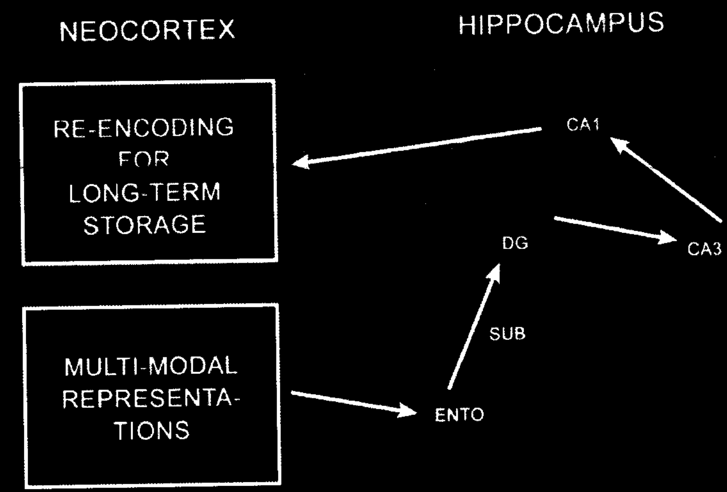
Microchip Models of Hippocampal Function as Neural Prosthetics



Cognitive Brain–Machine Interface for Hippocampus

Hippocampal Function: Encode information for long-term memory storage

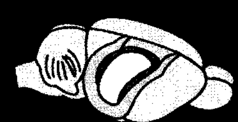
Goal: to develop a biomimetic model of the CA3 region that can interact with the brain to restore and/or augment hippocampal memory function



Stage 1
Hippocampal Slice

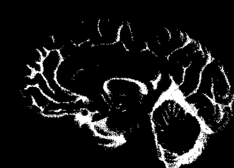
- 2-dimensions
- evoked act.
- computer-driven act.
- single I/single O
- least complex proc.

Stage 2
Behaving Rat



- 3-dimensions
- spontaneous act.
- environmentally-driven act.
- multi I/multi O
- more complex proc.

Stage 3
Behaving Monkey



- 3-dimensions
- spontaneous act.
- environmentally-driven act.
- multi I/multi O
- most complex proc.

Bio: Info: Micro Program

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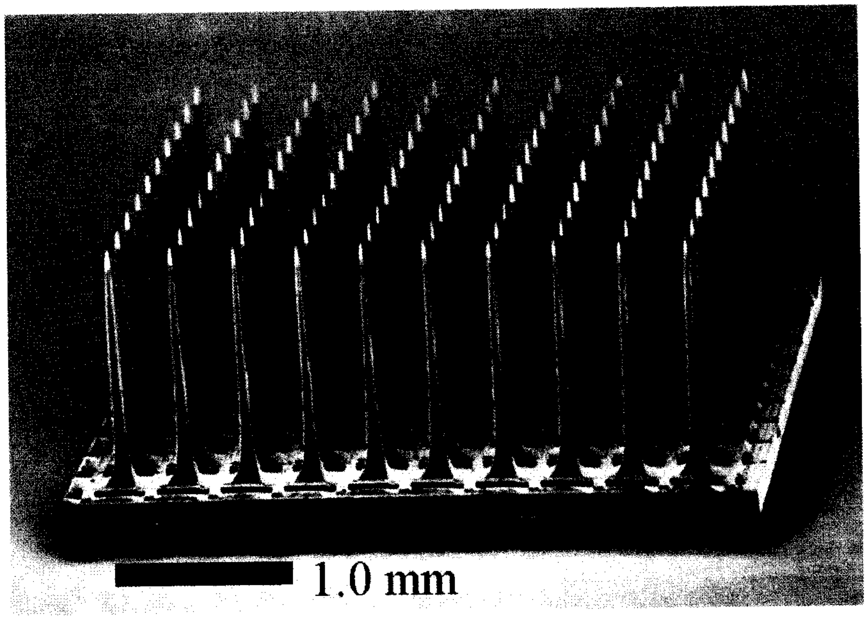
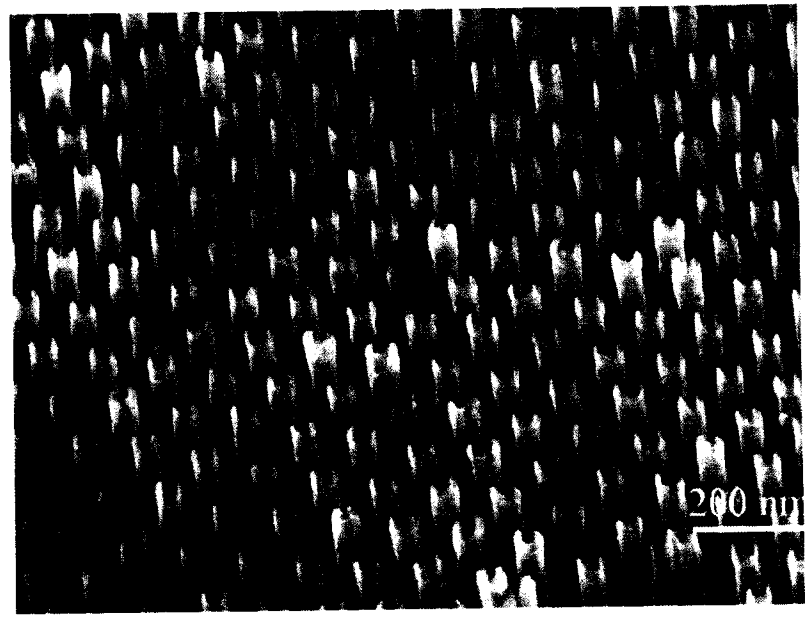
Example of extending the frontiers in multielement electrical recording of spatially extended neuronal activity





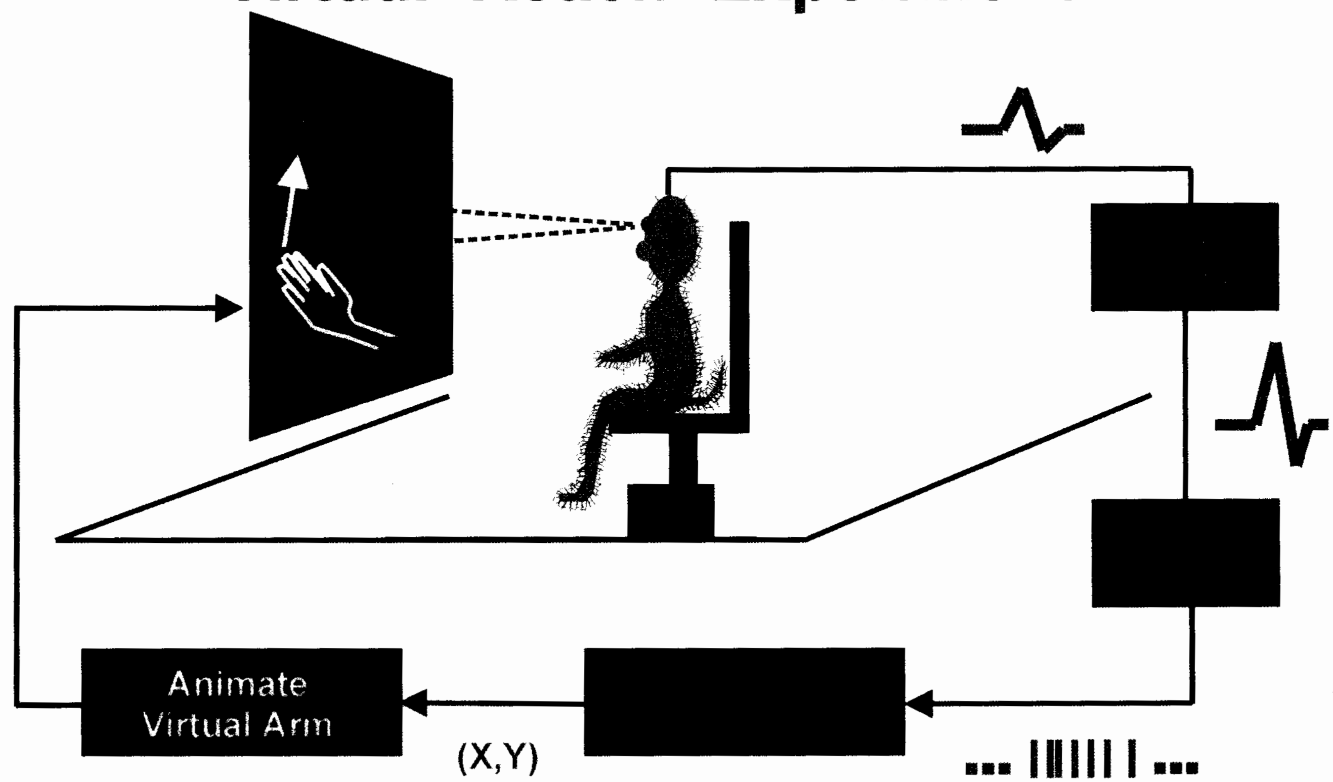
<u>Today</u>: silicon microelectrode arrays for in-vivo probing of brain cortex (J. Donoghue; Brown)

<u>Tomorrow:</u> Carbon nanotube arrays with superior spatial resolution endowed by superior electrical/mechanical properties (J. Xu, Brown)

CALTECH

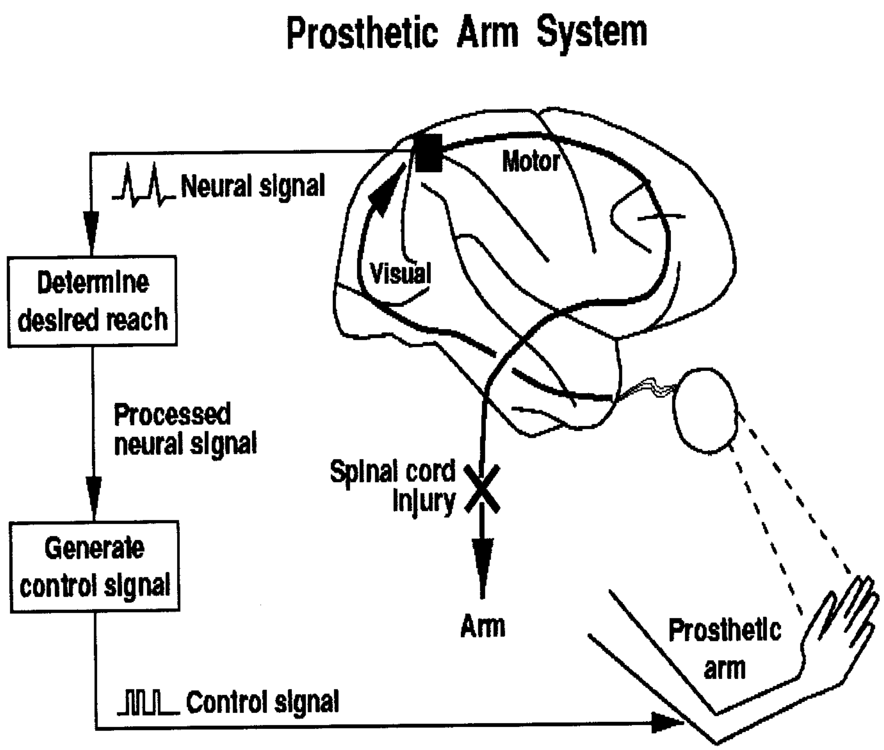
Record the intended movement activity from a reach area in the parietal cortex, decode this signal, and use it to move an animated limb on a computer screen, and later a robot limb.

Virtual Reach Experiment



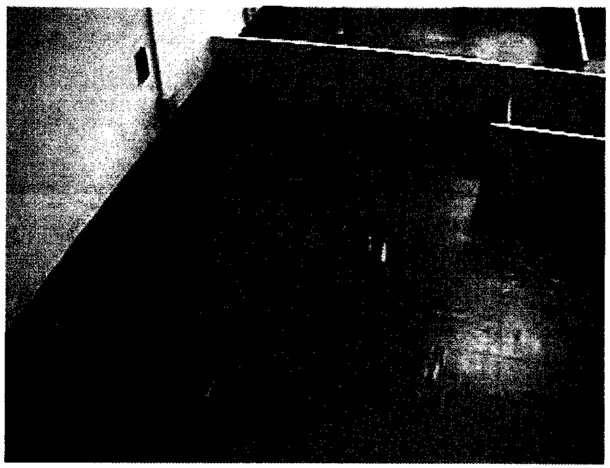
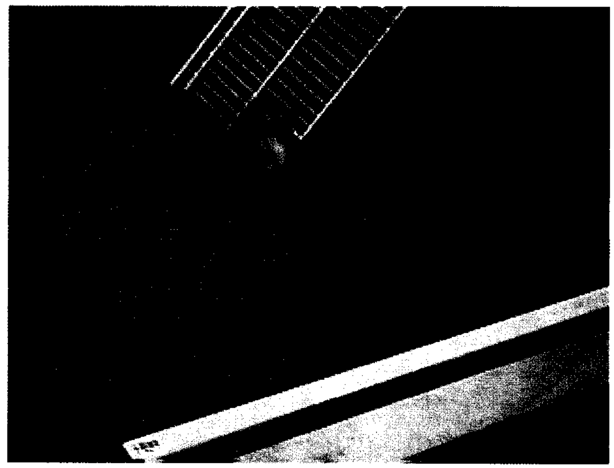
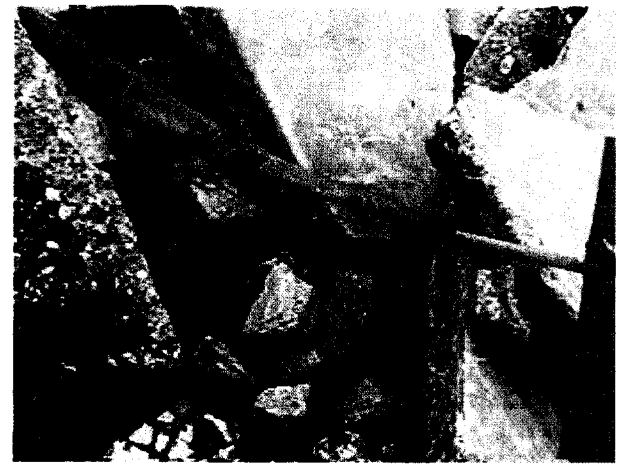
CALTECH

Using the parietal cortex rather than motor cortex is novel. Useful features of parietal cortex activity are:



- High level (cognitive) and may require fewer recordings to read out intentions.
- Visual and may show less degeneration or reorganization after spinal cord lesion.
- Plasticity, making it easier to adapt to the implant
- Spatially tuned local field potentials (LFP), which are easier to record than single cells.

Biobots: Roborat

- Electrodes in reward area (medial forebrain and somatosensory cortex)
- Trained to move forward or turn when medial forebrain is stimulated

Future activities

- Non-invasive technologies
- Sensory feedback
- Proprioception
- Integrated and multidisciplinary approach to improved prosthetic devices for amputees