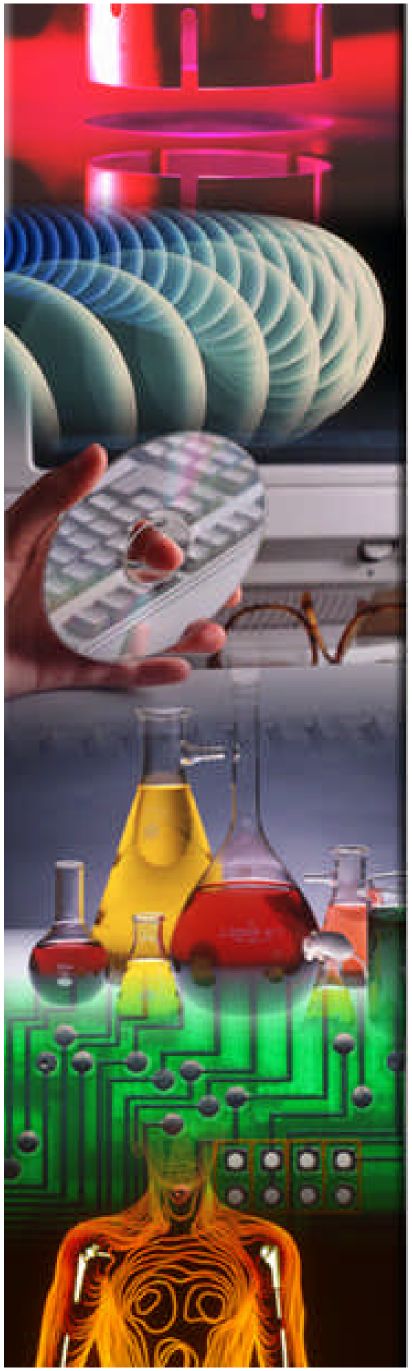


Direct Brain-Machine Interface

Eric Eisenstadt, Ph.D.

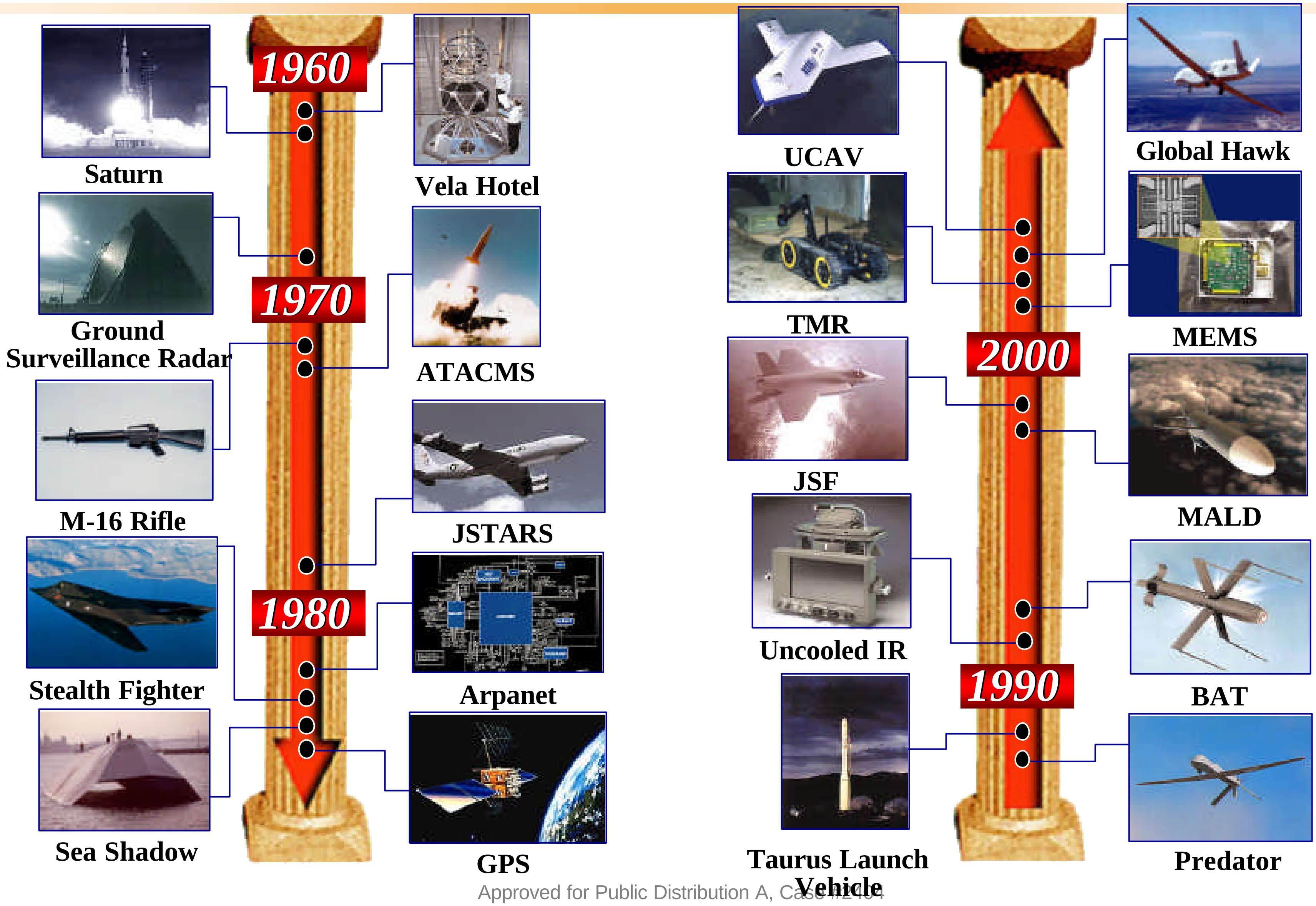
DARPA

Defense Sciences Office

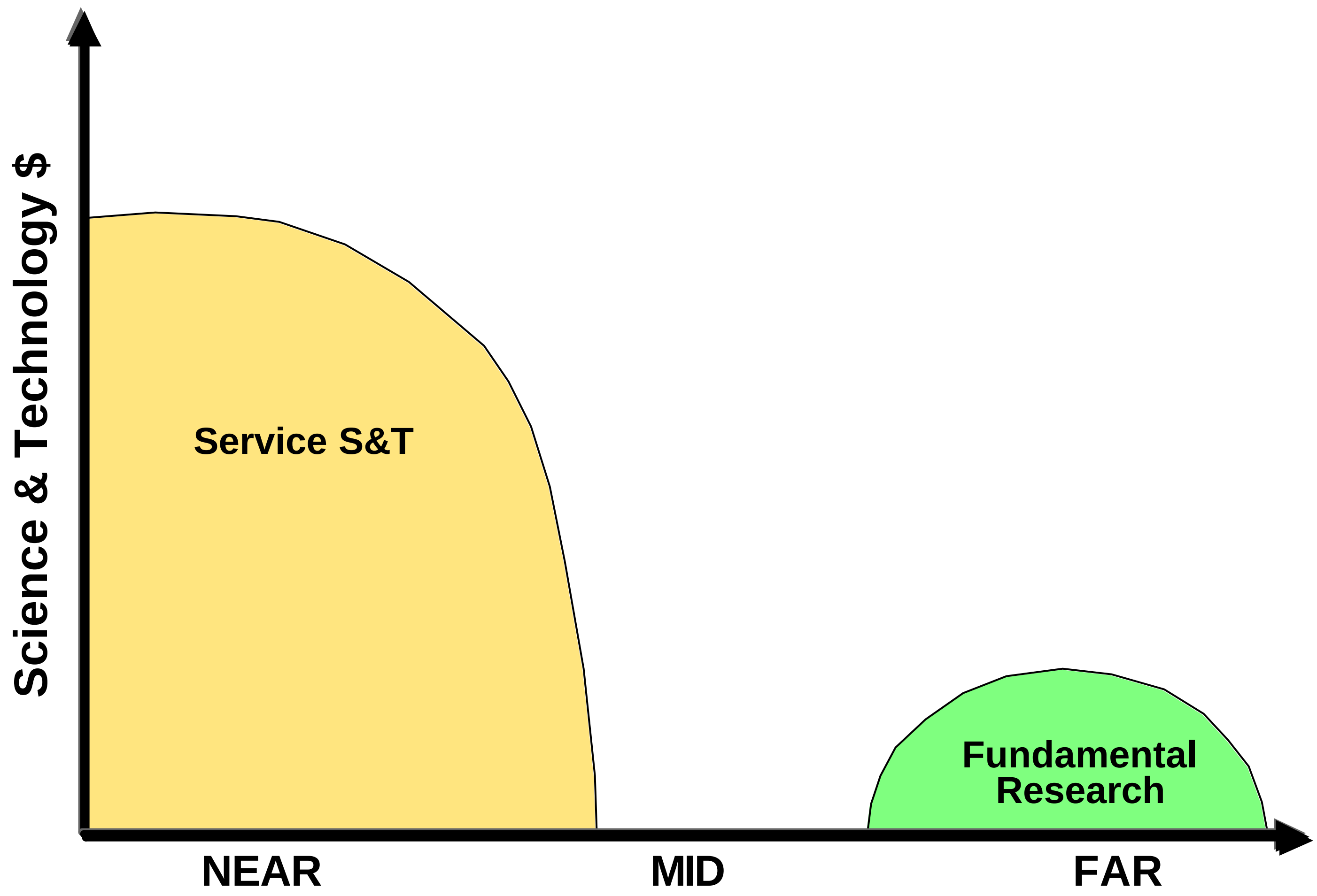
Science and Technology Symposium
21-22 April 2004

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

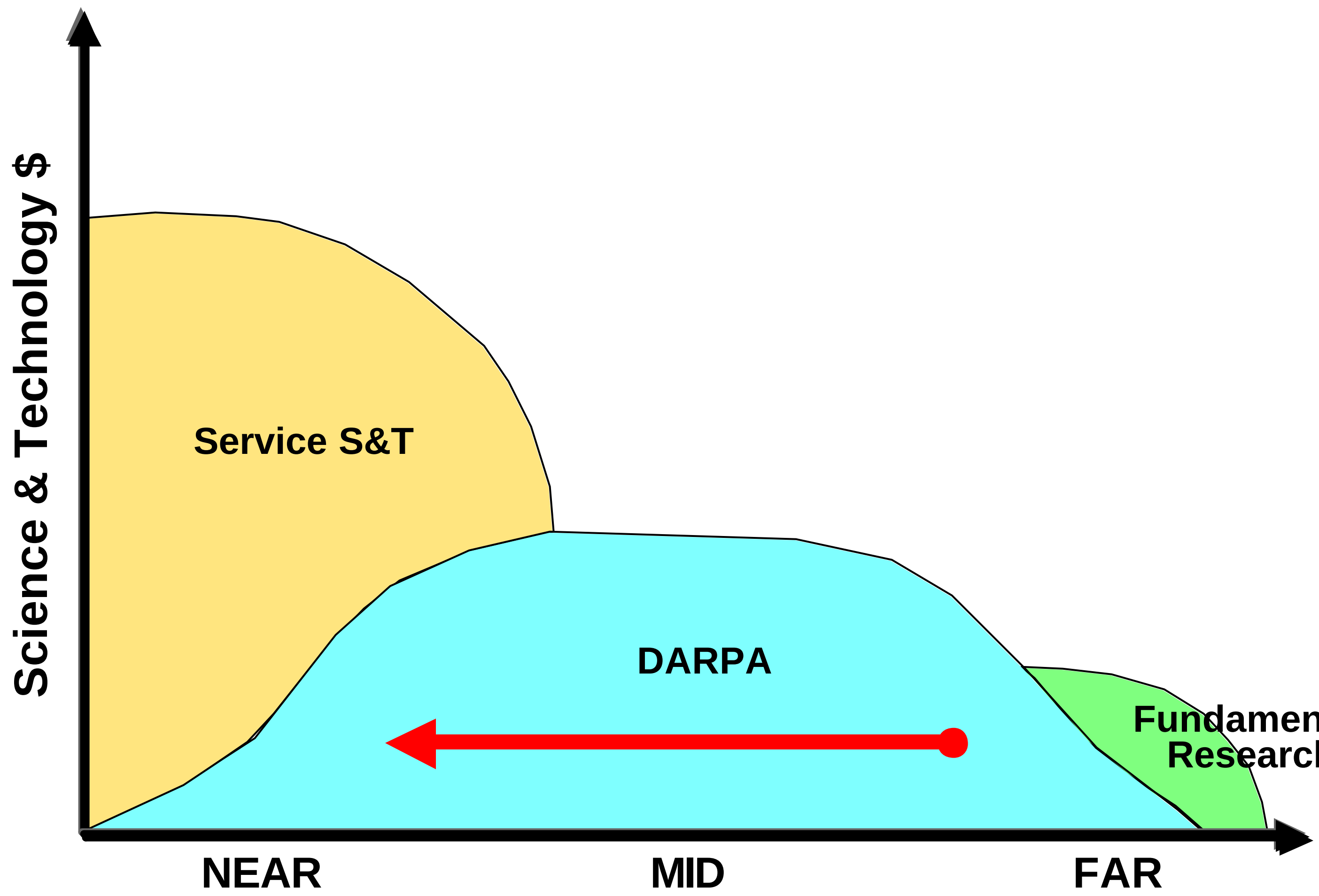
DARPA Accomplishments



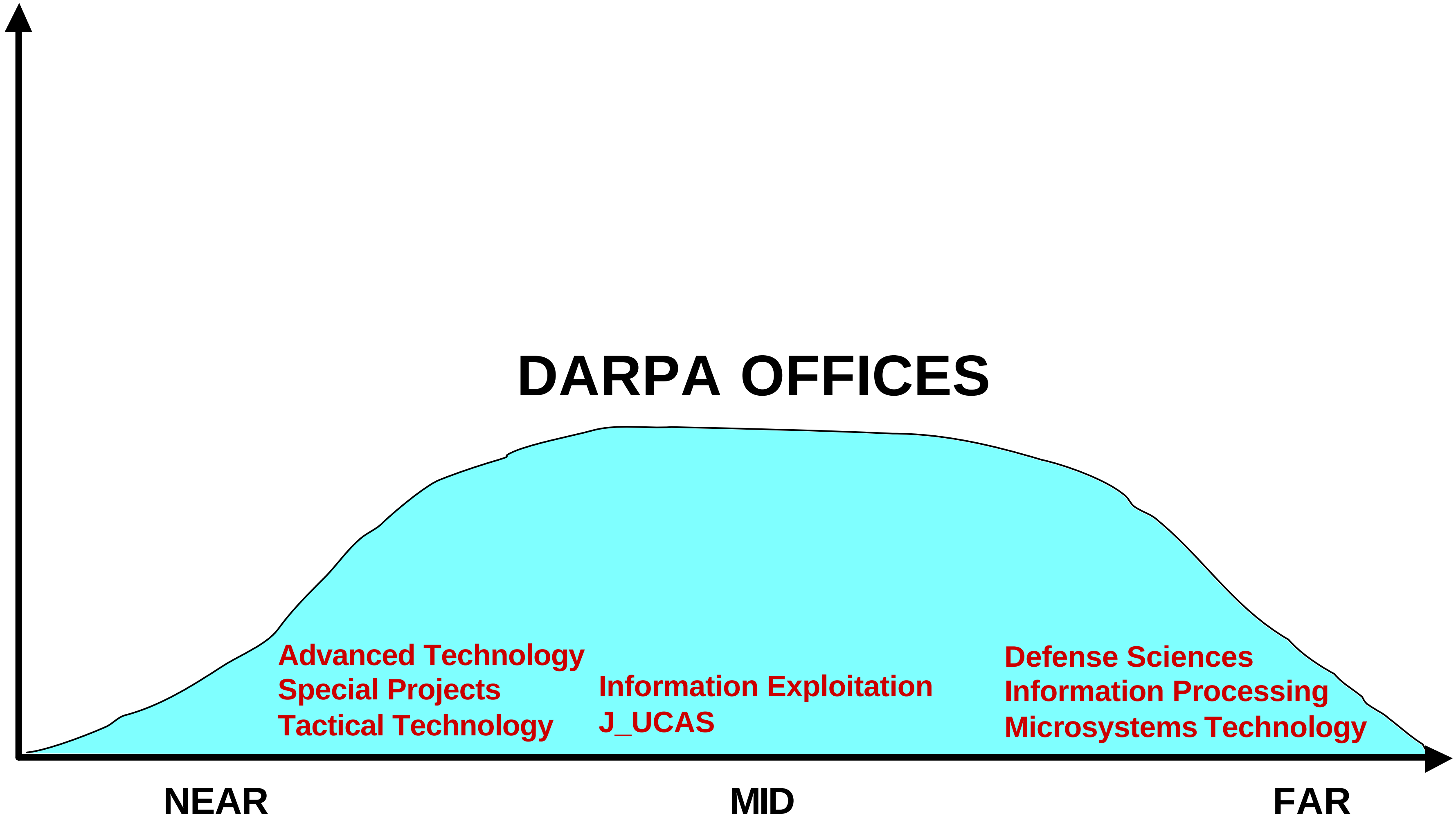
DARPA Role in Science and Technology



DARPA Role in Science and Technology



Internal Technology Flow



DARPA Organization

Director, Tony Tether
Deputy Director, Bob Leheny

Information Exploitation
Ted Bially
Bob Popp/Robert Tenney

- Sensors
- Exploitation Systems
- Command & Control

Tactical Technology
Art Morrish
Stephen Welby

- Air/Space/Land Platforms
- Unmanned Systems
- Space Operations
- Laser Systems
- Future Combat Systems
- Planning / Logistics

Special Projects
Amy Alving
Joe Guerci

- Chem/Bio Def Systems
- Counter Underground Facilities
- Space Sensors/Structures
- Navigation/Sensors/ Signal Processing

Advanced Technology
Dave Honey
Larry Stotts

- Assured C3ISR
- Maritime
- Early Entry/Special Forces

Joint Unmanned Combat Air Systems
Mike Francis

- Common Systems & Technologies
  - X-45 System
  - X-47 System

Defense Sciences
Steven Wax
Brett Giroir

- Bio Warfare Defense Technologies
- Biology
- Materials & Devices
- Mathematics

Information Processing Technology
Ron Brachman
Barbara Yoon

- Cognitive Systems
- Computational - Perception
- Representation & Reasoning
- Learning
- Natural Communication

MicrosystemsTechnology
Zach Lemnios
John Zolper

- Electronics
- Optoelectronics
- MEMS
- Combined Microsystems

DARPA Strategic Vision

DEFENSE SCIENCES OFFICE

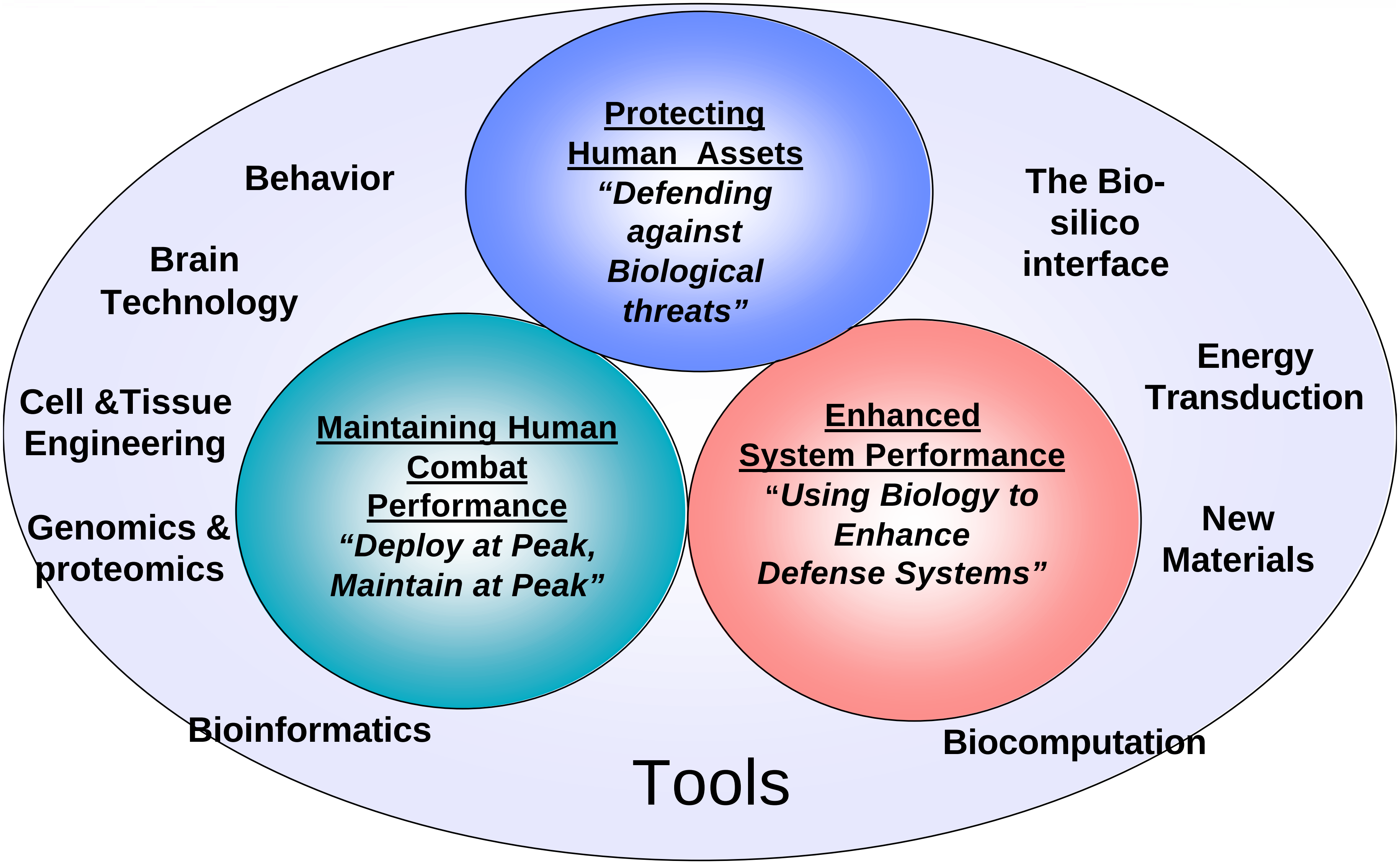
- **Strategic Thrusts**
  - **Detection, precision ID, tracking, and destruction of elusive surface targets**
  - **Location and characterization of underground structures**
  - **Force multipliers for urban area operations**
  - **Networked manned & unmanned attack operations**
  - **Assured use of 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



DSO – Technical Personnel

DEFENSE SCIENCES OFFICE

Dr. Steven G. Wax, Dir
Dr. Brett Giroir, Dep Dir

Materials, Mathematics and Devices

Dr. Valerie Browning
Dr. Leonard Buckley
Dr. Leo Christodoulou
Dr. William Coblenz
Dr. Douglas Cochran
Dr. John Lowell (Maj, USAF)
Dr. John Main
Dr. Carey Schwartz
Dr. Terrence Weisshaar
Dr. Stuart Wolf

Advanced Biological and Medical Technologies

Dr. Joseph Bielitzki
Dr. Ralph Chatham
Dr. Mildred Donlon
Dr. Eric Eisenstadt
Dr. Neurosurgeon (LT Col, USA)
Dr. Anantha Krishnan
Dr. Rick Satava
Dr. Morley Stone

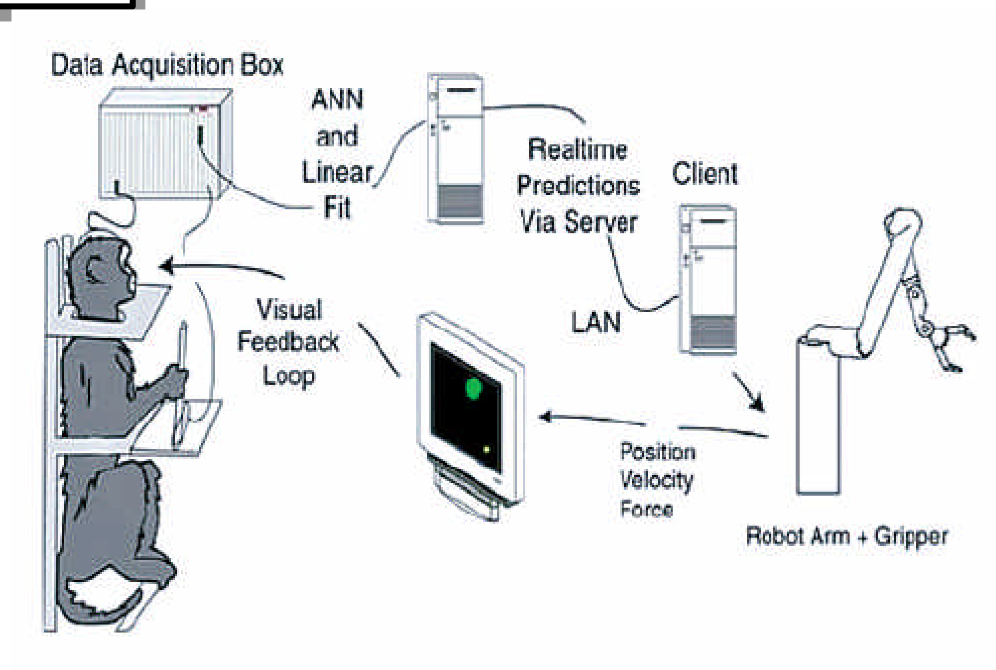
AAAS Fellows:
Dr. Rosemarie Szostak, Dr. Stephen Ho

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

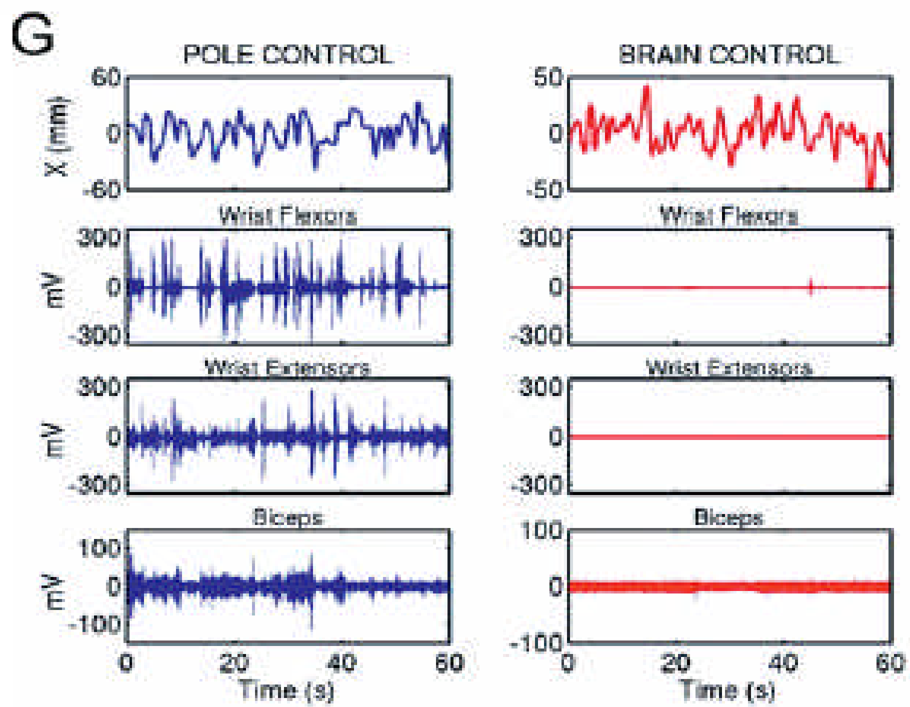
DEFENSE SCIENCES OFFICE

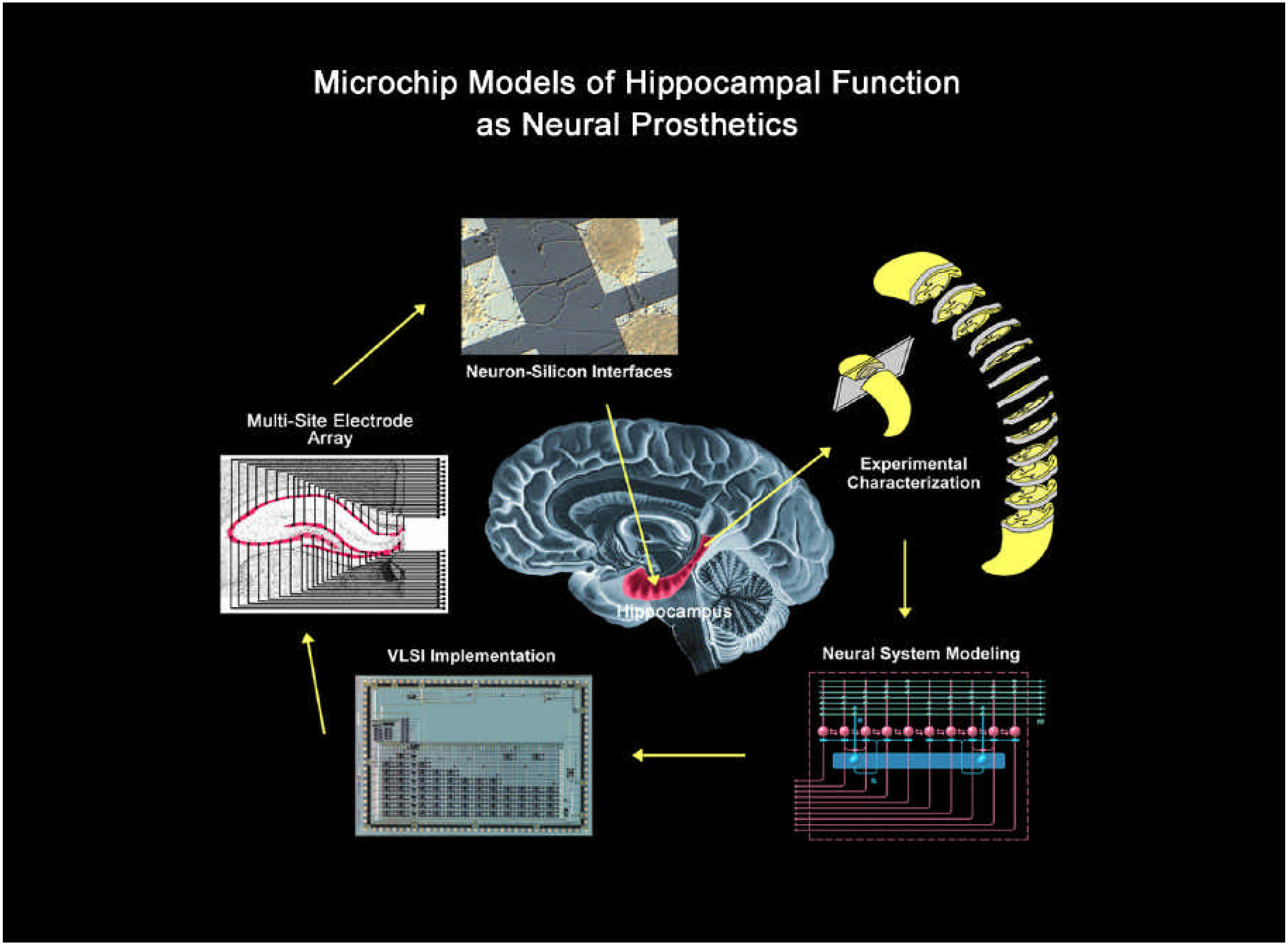
Learning to Control a Brain–Machine Interface for Reaching and Grasping by Primates

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.**





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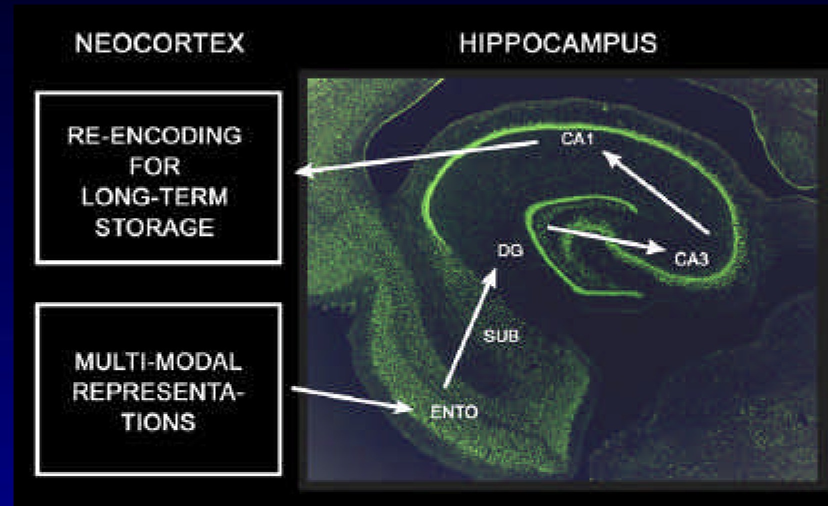
Cognitive Brain-Machine Interface for Hippocampus

Hippocampal Function: Encode information for long-term memory storage

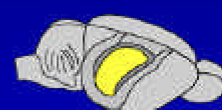
Goal: to develop a biomimetic model of the CA3 region that can interact with the brain to restore and/or augment hippocampal memory function



Stage 1
Hippocampal Slice

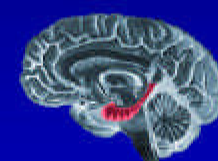
- 2-dimensions
- evoked act.
- computer-driven act.
- single I/single O
- least complex proc.

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.

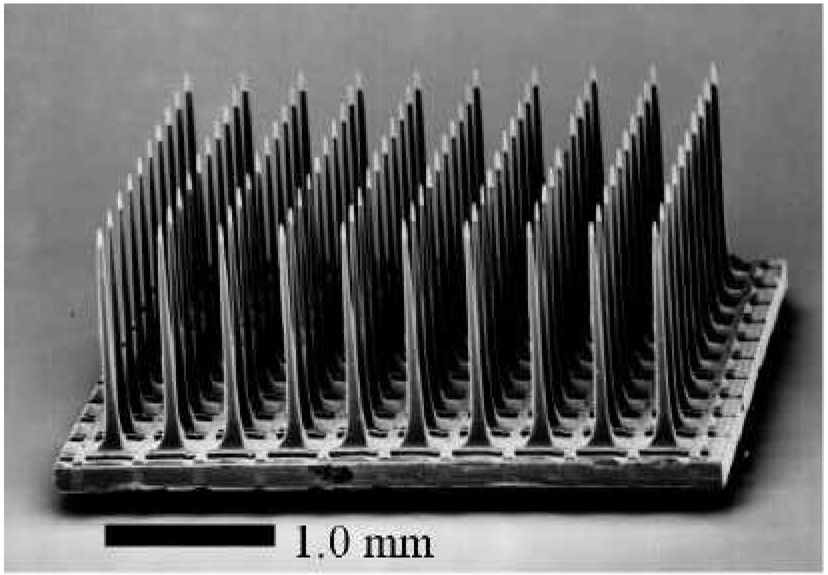
Bio: Info: Micro Program

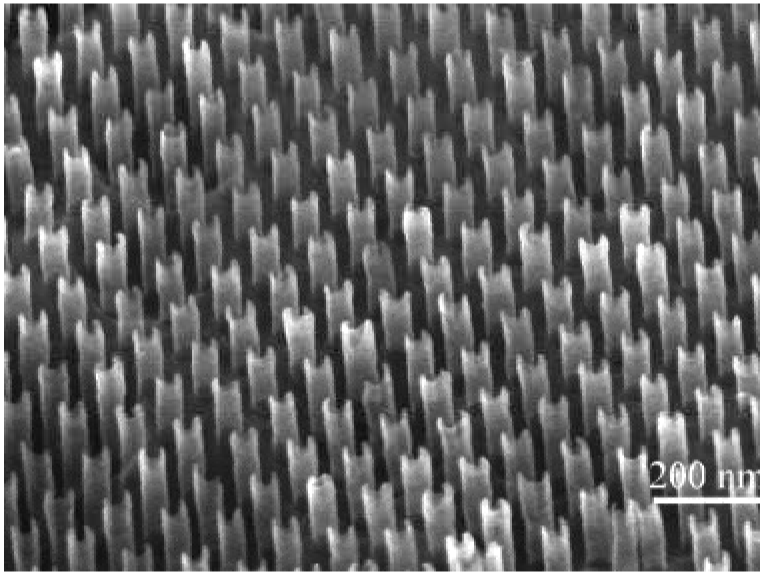
Dr. Eric Eisenstadt - DSO
eeisenstadt@darpa.mil
Phone: (703) 696-2322
Fax: (703) 696-3999

Dr. Douglas Gage - IPTO
dgage@darpa.mil
Phone: (703) 696-1122
Fax: (703) 696-4534

Dr. Mike Krihak - DSO
mkrihak@darpa.mil
Phone: (571) 218-4246
Fax: (571) 218-4553

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



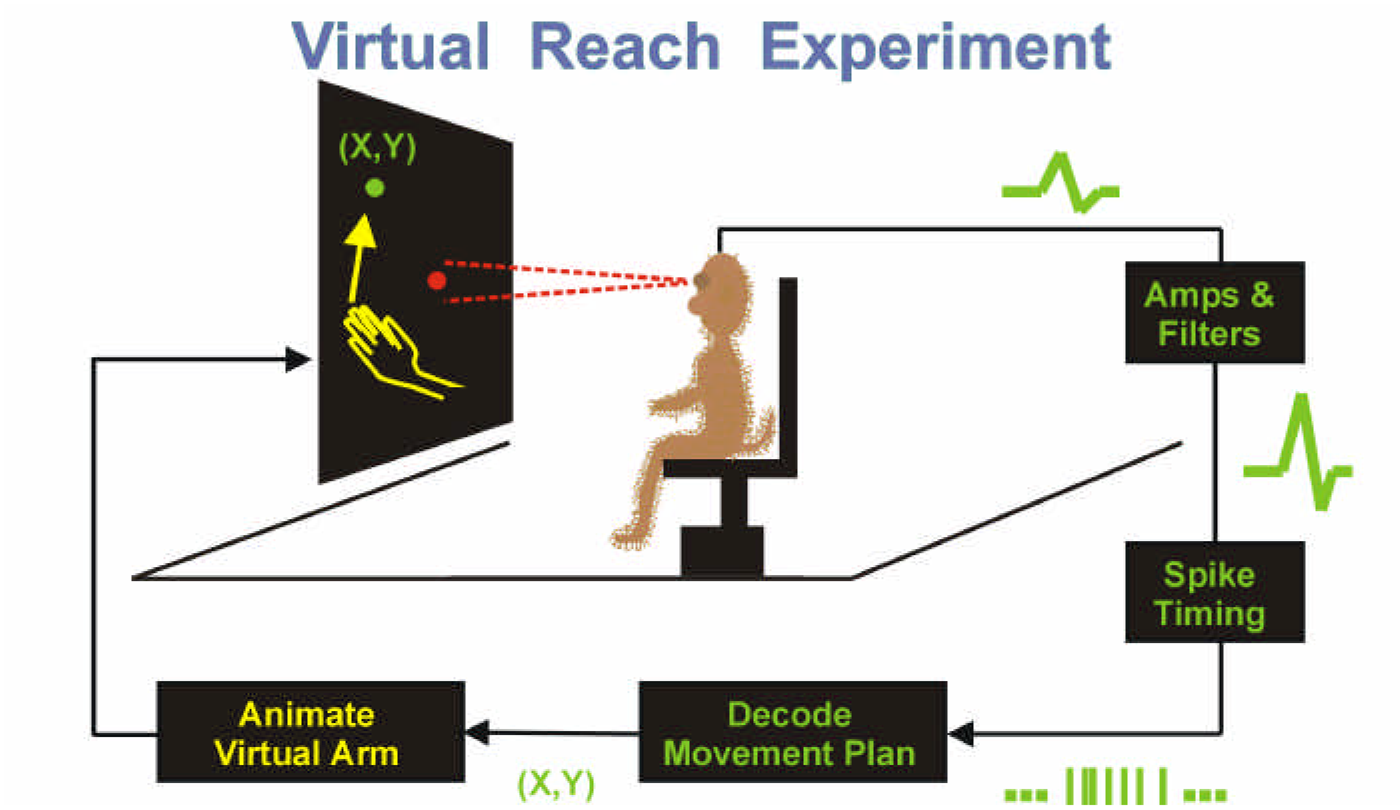


Today: silicon microelectrode arrays for in-vivo probing of brain cortex (J. Donoghue; Brown)

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

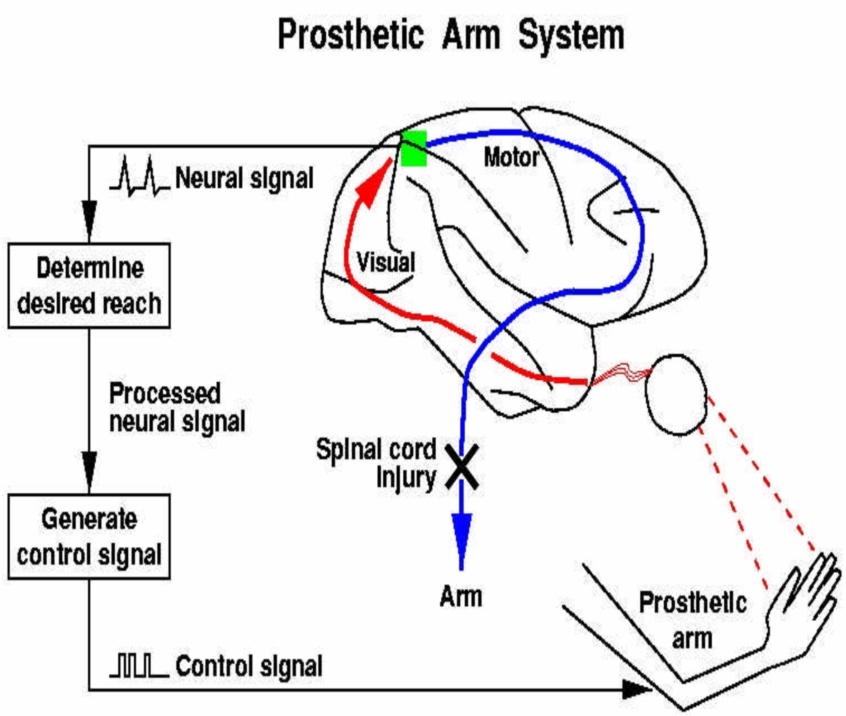
CALTECH

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.



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

Defense Advanced Research Projects Agency

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Highlights

- DARPA conducted its first Grand Challenge, a field test of autonomous ground vehicles, March 8 to 13, 2004. Its purpose was to encourage the accelerated development of autonomous vehicle technologies that could be applied to military requirements.
- The 23rd DARPA Systems and Technology Symposium (DARPATech) was held in Anaheim, California, March 9 to 11, 2004. Downloadable presentations are available at http://www.darpa.mil/DARPATech2004/proceedings.html.
- DARPA has been granted **Experimental Personnel Hiring Authority** for eminent scientists and engineers from outside government service to term appointments with our agency. This authority significantly streamlines and accelerates the hiring process. For additional information regarding this