Direct Brain-Machine Interface

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DARPA Accomplishments

- **1960**
  - Saturn
  - Vela Hotel

- **1970**
  - Ground Surveillance Radar
  - ATACMS

- **1980**
  - M-16 Rifle
  - Stealth Fighter
  - JSTARS
  - Arpanet

- **1990**
  - Uncooled IR
  - GPS
  - Taurus Launch Vehicle

- **2000**
  - UCAV
  - TMR
  - JSF
  - MEMS
  - MALD
  - Uncooled IR
  - BAT
  - Predator

Global Hawk
DARPA Role in Science and Technology

Science & Technology $\uparrow$

Service S&T

NEAR  MID  FAR

Fundamental Research
DARPA Role in Science and Technology
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

Protecting Human Assets
"Defending against Biological threats"

The Bio-silico interface

Energy Transduction

New Materials

Enhanced System Performance
"Using Biology to Enhance Defense Systems"

Maintaining Human Combat Performance
"Deploy at Peak, Maintain at Peak"

Tools

Bioinformatics

Biocomputation

Brain Technology

Cell & Tissue Engineering

Genomics & proteomics

Behavior

"Deploy at Peak, Maintain at Peak"

Enhanced System Performance
"Using Biology to Enhance Defense Systems"

Tools

Bioinformatics

Biocomputation

Brain Technology

Cell & Tissue Engineering

Genomics & proteomics

Behavior

"Deploy at Peak, Maintain at Peak"
Human Assisted Neural Devices

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

Jose M. Carmena, Mikhail A. Lebedev, Roy E. Crist, Joseph E. O'Doherty, David M. Santucci, Dragan F. Dimitrov, Parag G. Patil, Craig S. Henriquez, Miguel A. L. Nicolelis

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- 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.
Microchip Models of Hippocampal Function as Neural Prosthetics

Neuron-Silicon Interfaces

Multi-Site Electrode Array

VLSI Implementation

Experimental Characterization

Hippocampus

Neural System Modeling
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 l/single O
- least complex proc.

Stage 2
Behaving Rat
- 3 dimensions
- spontaneous act.
- environmentally-driven act.
- multi l/multi O
- more complex proc.

Stage 3
Behaving Monkey
- 3 dimensions
- spontaneous act.
- environmentally-driven act.
- multi l/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

**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)
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.
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