DARPA Biological Technologies Office Neurotechnology Portfolio

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Briefing prepared for

BRAIN Initiative Symposium

October 10, 2015

NEUROTECHNOLOGIES

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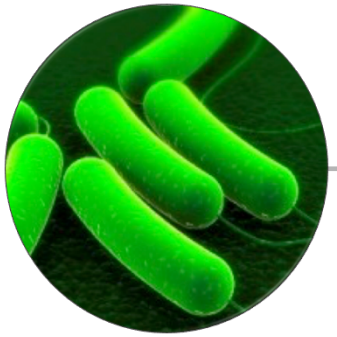
- Revolutionizing Prosthetics
- ElectR$_x$
- HAPTIX
- NeuroFAST
- RE-NET
- Restoring Active Memory
- SUBNETS

DISRUPTIVE MEDICINE

- ADEPT
- Battlefield Medicine Dialysis-Like Therapeutics In Vivo
- Nanoplatforms
- Microphysiological Systems
- Pathogen Predators
- Prophecy
- Rapid Threat Assessment
- Warrior Web



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ENGINEERING BIOLOGY

- Living Foundries
- Biochronicity
- BRICS

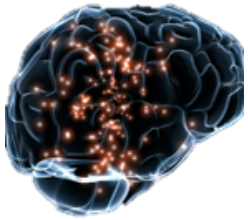
Neuroscience

Hand Proprioception and Touch Interfaces (HAPTIX)

Revolutionizing Prosthetics

Reliable Neural Interface Technology (RE-NET)

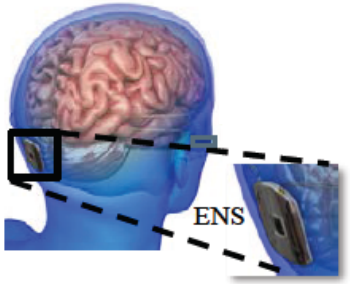
Systems-Based Neurotechnology for Emerging Therapy (SUBNETS)



Movement and Control

Behavior

Memory Recovery



Restoring Active Memory (RAM)

Opportunities:

- Physical performance
- Cognitive capabilities
- Noninvasive brain-machine integration

Revolutionizing Prosthetics

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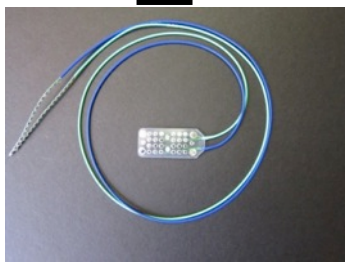
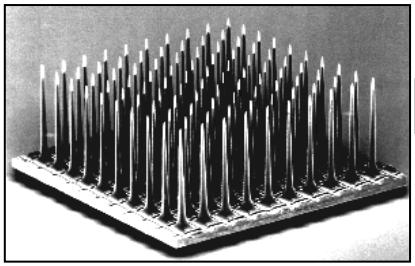
- Implantable sensors extract neural data
- Groups of firing neurons associated with intended movements
- Experiments have uncovered timing of firing neurons, intention, and attention signals
- Conditional FDA approval for sensory feedback

9 months



ECOG Array



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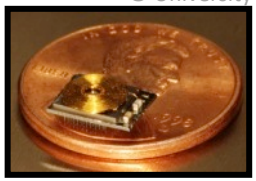

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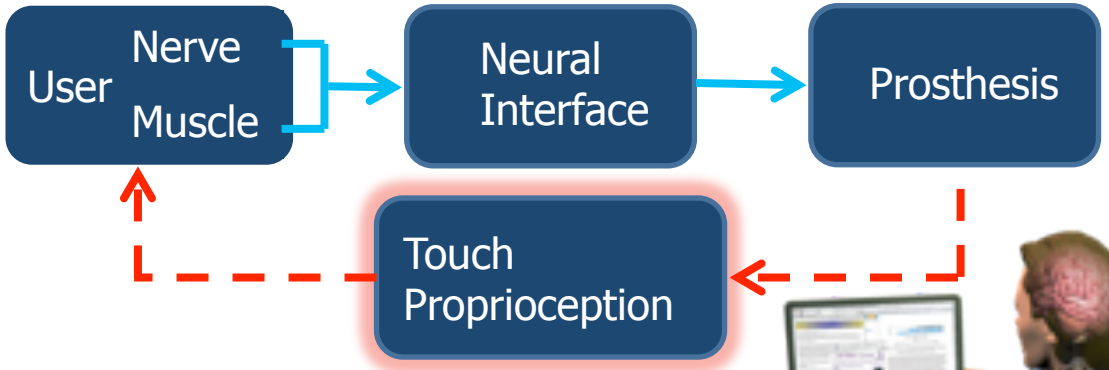
Utah Electrode Array Recording Device

© CBS 60 Minutes

Hand Proprioception and Touch Interfaces (HAPTIX)

Goal: Create a neural implant system that provides amputees with natural control and sensory functions for DARPA prosthetic hands.



Approach

1) **Develop electrodes & algorithms for communicating user intent (motor) and sensory feedback between peripheral nerves and prosthesis.**
2) **Develop in vivo electronics modules to support neural communication**
3) **Complete first-in-human trials to demonstrate capabilities of HAPTIX prosthesis.**

Program kickoff: November 2014

Restoring Active Memory (RAM)

Vision: Develop neuroprosthetics for memory recovery in human patients with brain injury or dysfunction.

Goals:

- Develop models of how neurons code for declarative memory, which is knowledge that can be consciously recalled, including events, times, places, and other event context.
- Explore new methods for analysis and decoding of neural signals in humans in order to understand how neural stimulation could be applied to facilitate recovery of memory encoding following brain injury.
- Develop and test and implantable medical device for human clinical use to restore specific types or attributes of memories to individuals with memory deficits.

REMIND Program

- Developed biomimetic model mimics functional networks of hippocampal neurons
- Implemented model in VLSI for computational speed and miniaturization

Hippocampal interface

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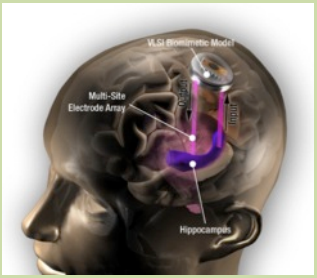
Translate to Primate and Human

RAM Program



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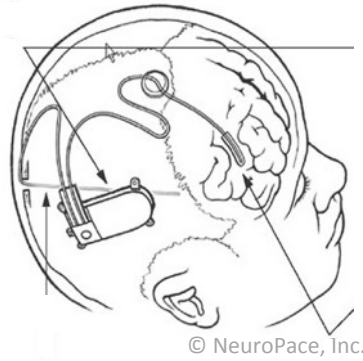
Systems-Based Neurotechnology for Emerging Therapy (SUBNETS)

Vision: Develop new neural interfaces to measure how systems disorders manifest in the brain and precisely deliver therapy in humans with neuropsychiatric and neurologic diseases.

Neuro-Psychiatric and Neurologic Disease Targets

- Major Depression
- Post-Traumatic Stress Disorder
- General Anxiety Disorder
- Borderline Personality Disorder
- Traumatic Brain Injury
- Fibromyalgia/Chronic Pain
- Substance Abuse/Addiction



10% of 22M veterans received treatment for mental health or substance abuse

Neuro Function, Activity, Structure, and Technology (Neuro-FAST)

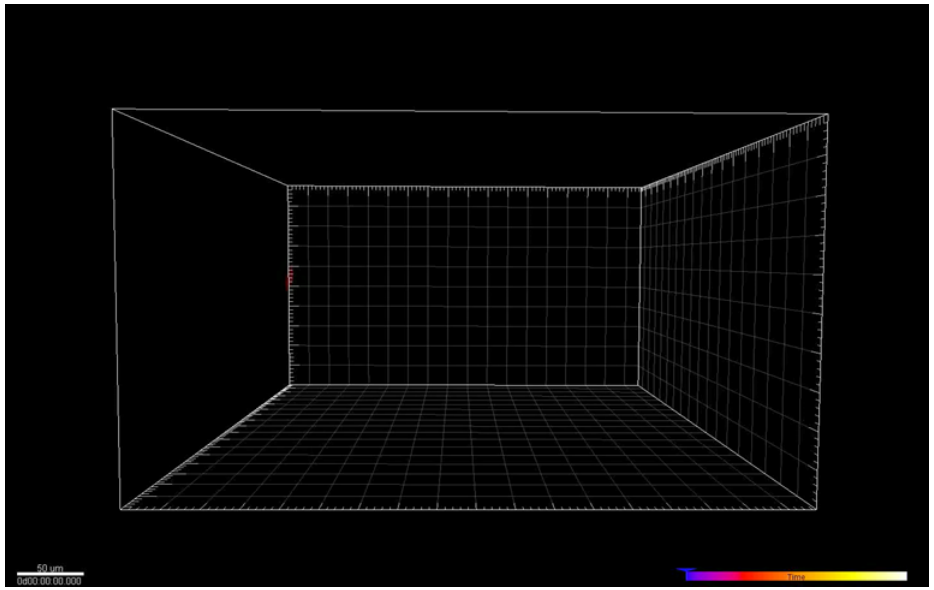
Apply novel optical methods to acquire, in real-time, brain structure, activity, and behavior

Primate Subjects

- Link optical recordings of behaving primate neurons with optical recording of post-mortem primates
- Highly parallelized recording set-up

Human Subjects:

- Registration of complete connectivity from human brain
- Potential to connect functional data with connectivity map
- Exploits primate recording set-up



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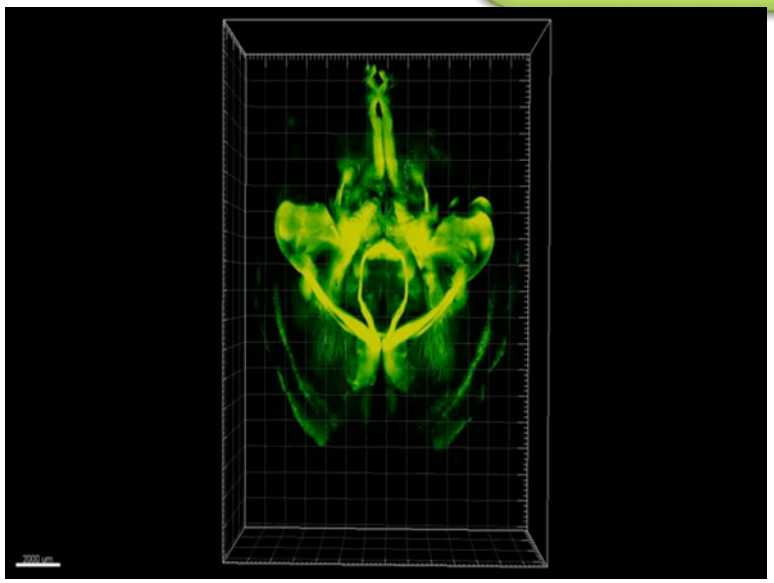

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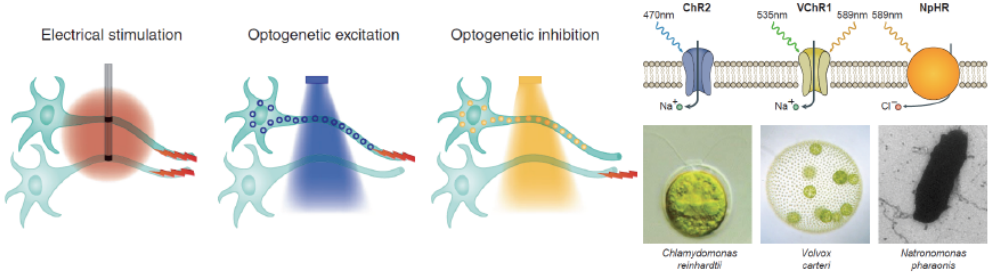
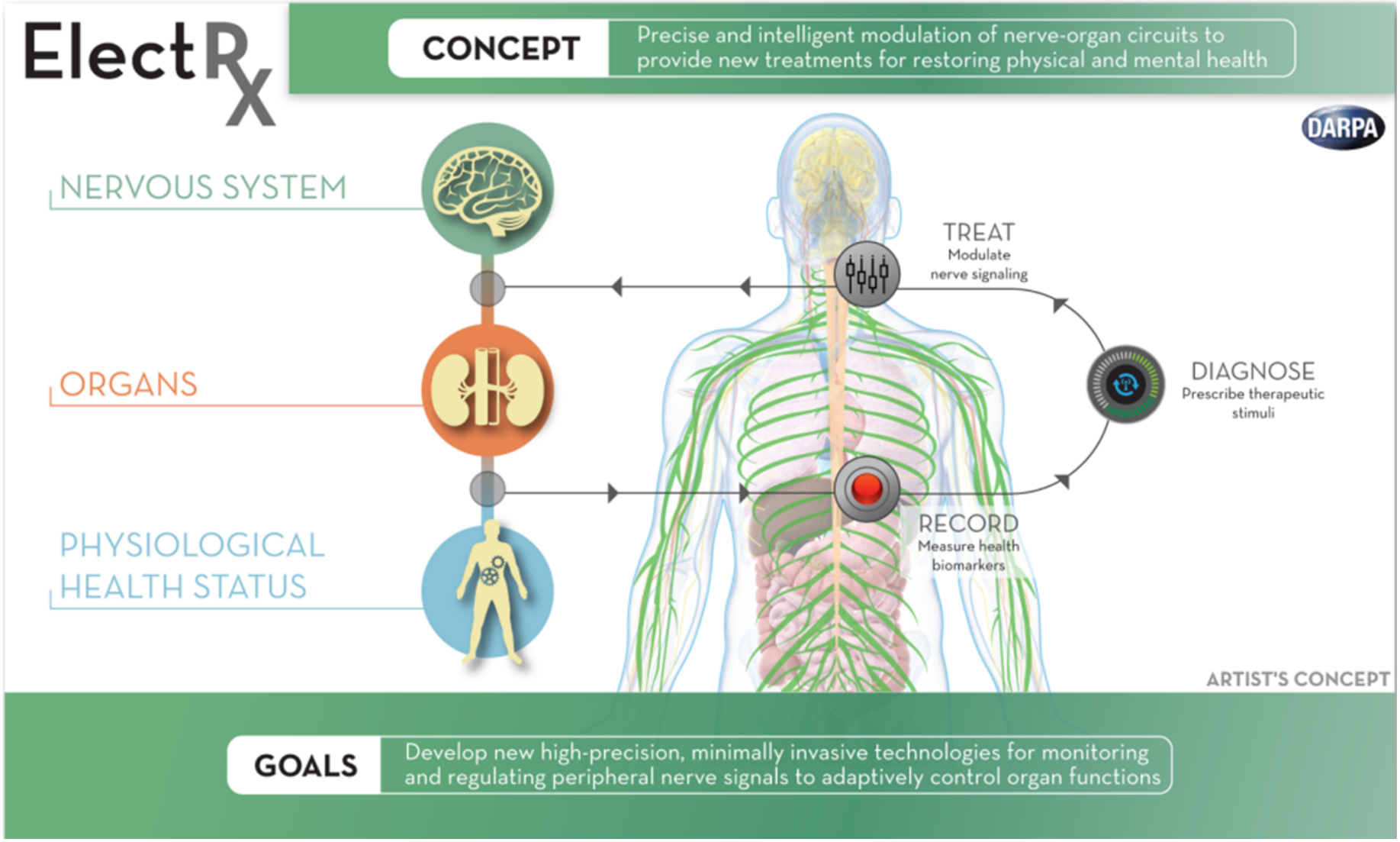


© Deisseroth, K. *et al.* J. Neurosci.

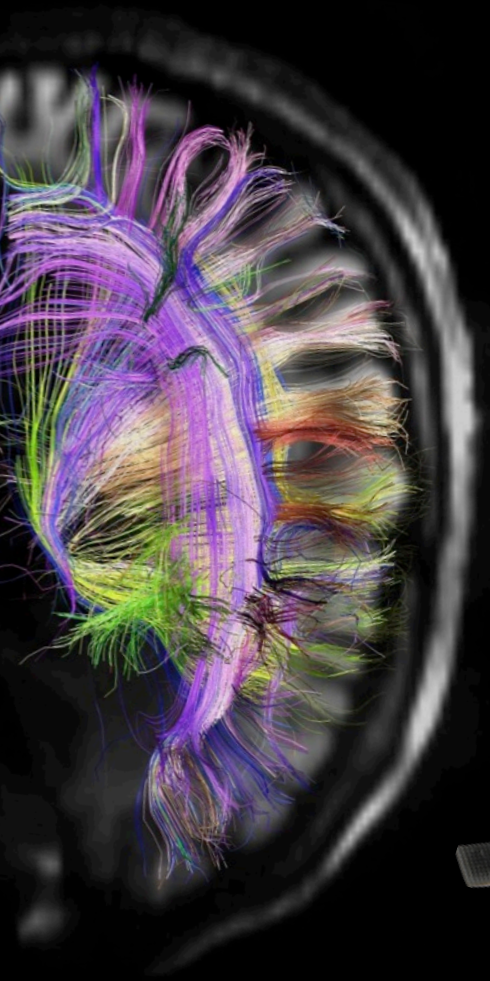
* **C**lear, **L**ipid-exchanged, **A**natomically **R**igid, **I**maging/ immunostaining compatible, **T**issue H**y**drogel

ElectRx: Control electrical state of peripheral nerves for desired cellular, organ, and immune outcomes



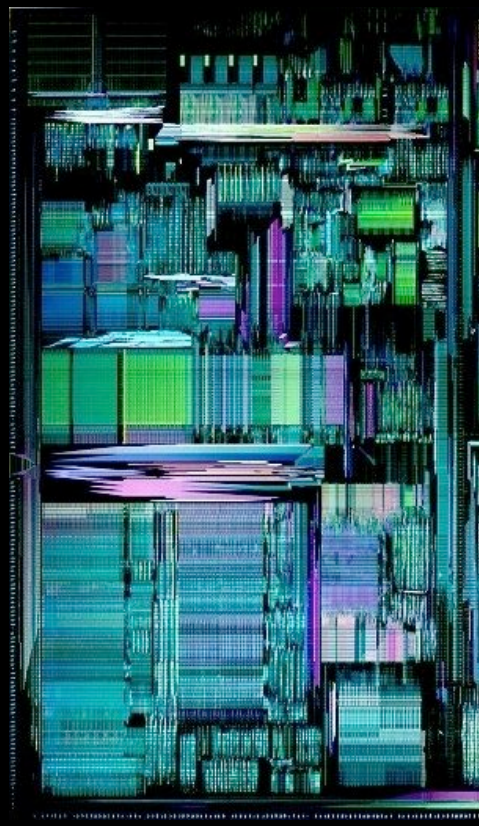
Bridging Micro-biology and Micro-electronics

Neural Modulation & De-Modulation



Cortical Modem

Electro-Chemical Impulses
to Digital Bits and back



10^{12}
Synapses

10^{12}
Transistors

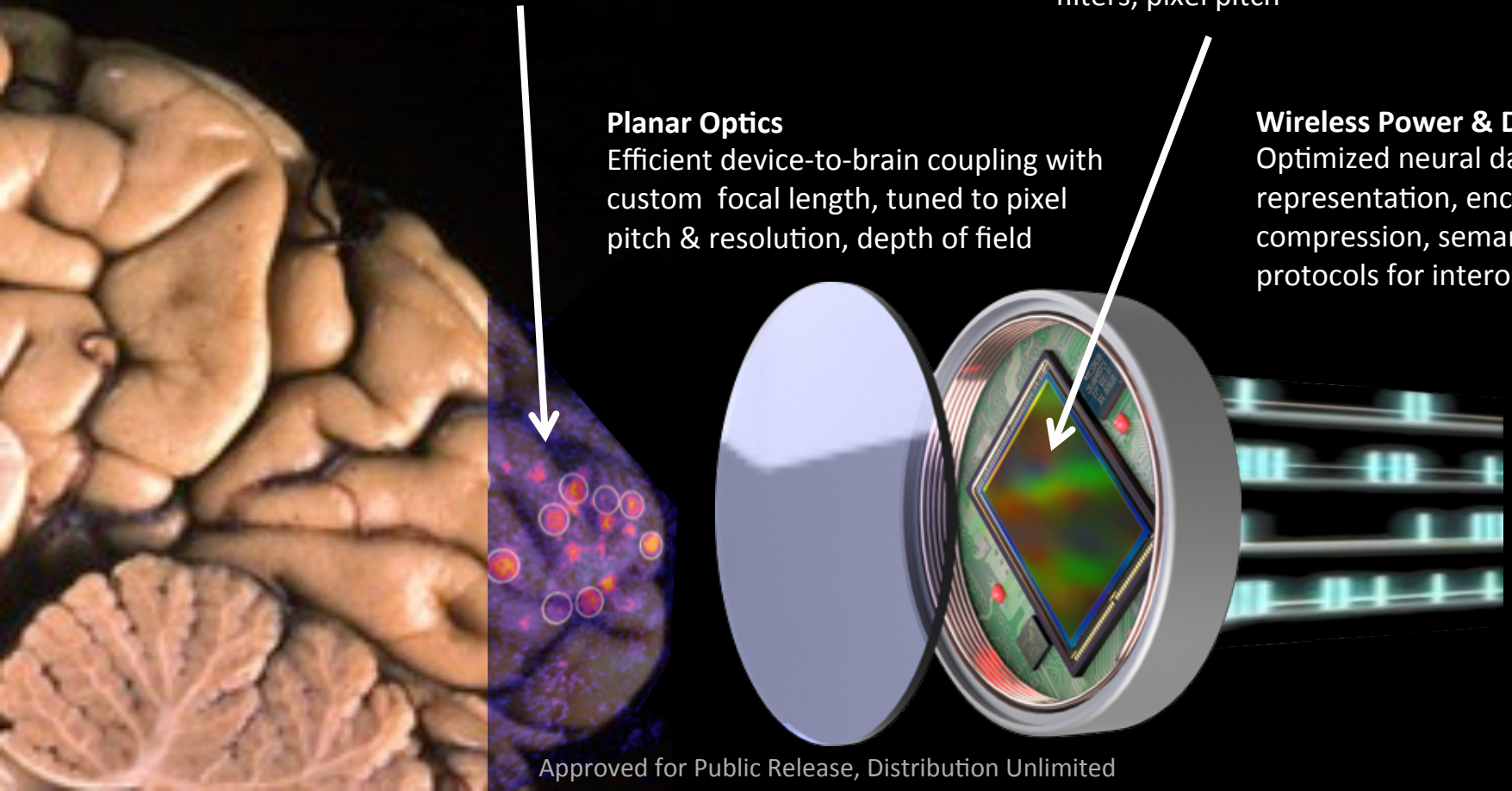
One Potential Instantiation
Opto-electronics & Optogenetics

Optogenetics
Fast kinetics, IR luminescence cell-specific targeting, transient delivery

Detector (Read)
CMOS & InGaAs imagers, dynamic range, spectral diversity, matched filters, pixel pitch

Planar Optics
Efficient device-to-brain coupling with custom focal length, tuned to pixel pitch & resolution, depth of field

Wireless Power & Data
Optimized neural data representation, encoding and compression, semantic protocols for interoperability



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