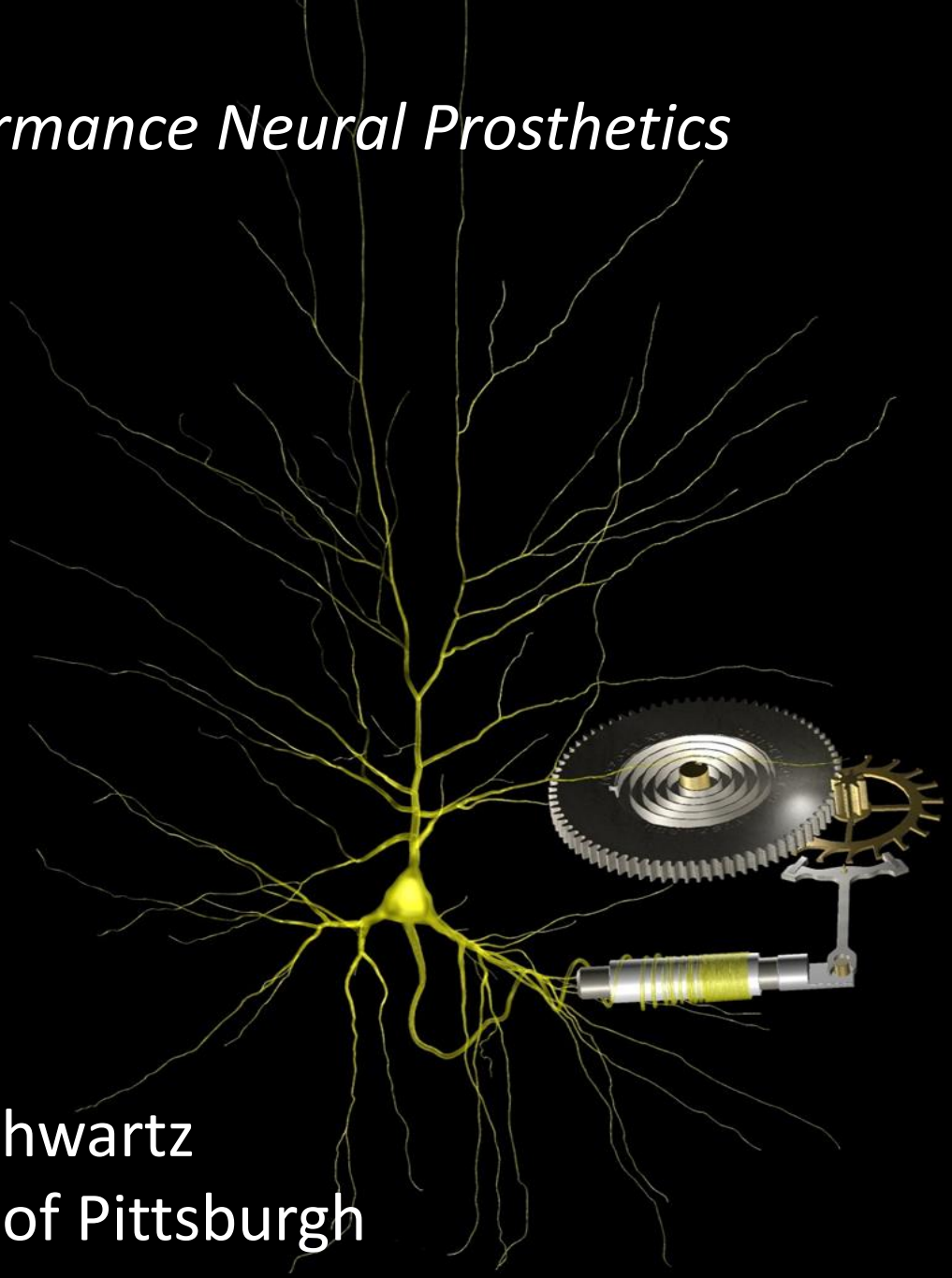
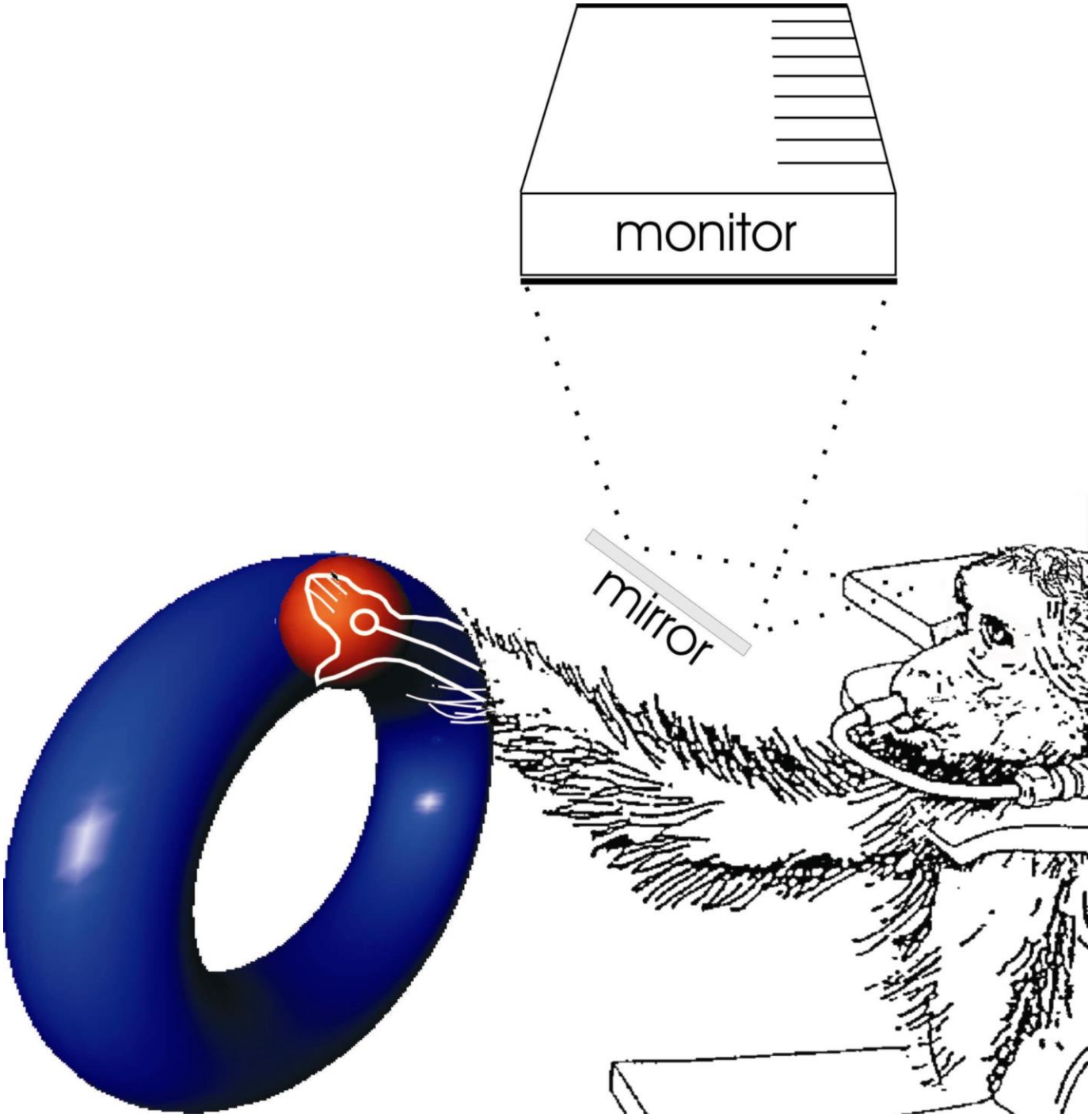
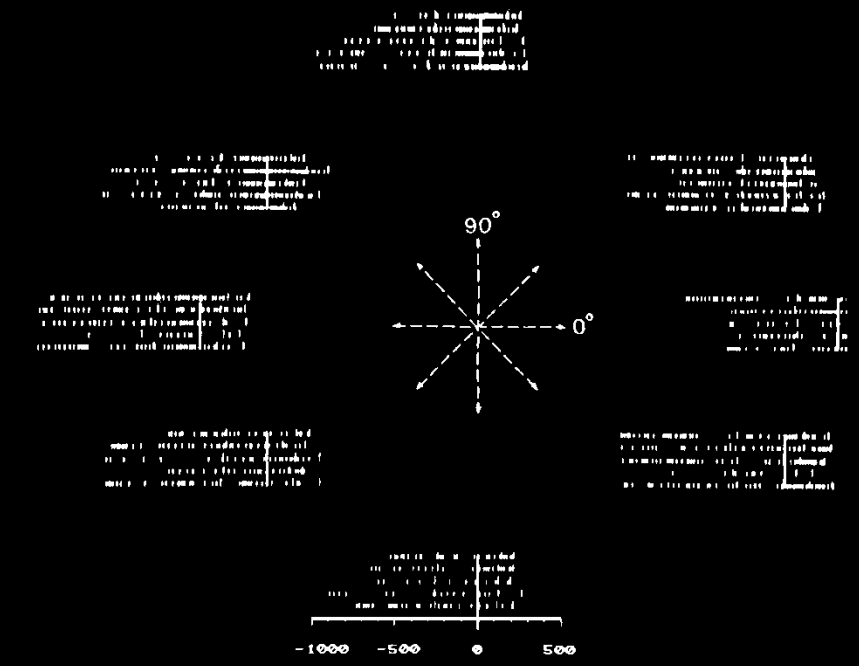
High-Performance Neural Prosthetics

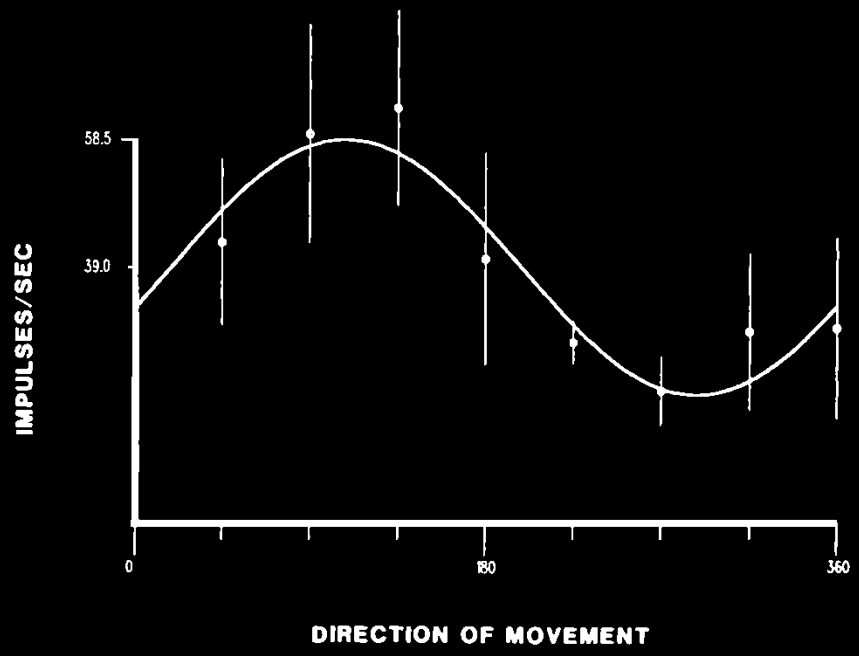


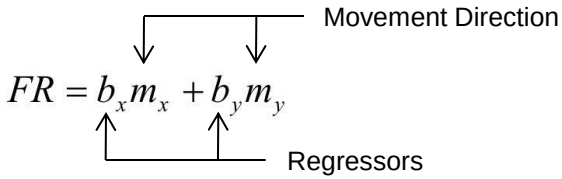
Andrew Schwartz
University of Pittsburgh

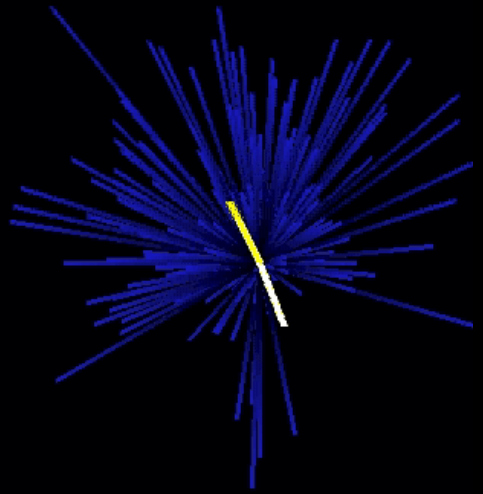

monitor
mirror

IEL Movie


90°
0°
-1000
-500
0
500


58.5
39.0
IMPULSES/SEC
0
180
360
DIRECTION OF MOVEMENT

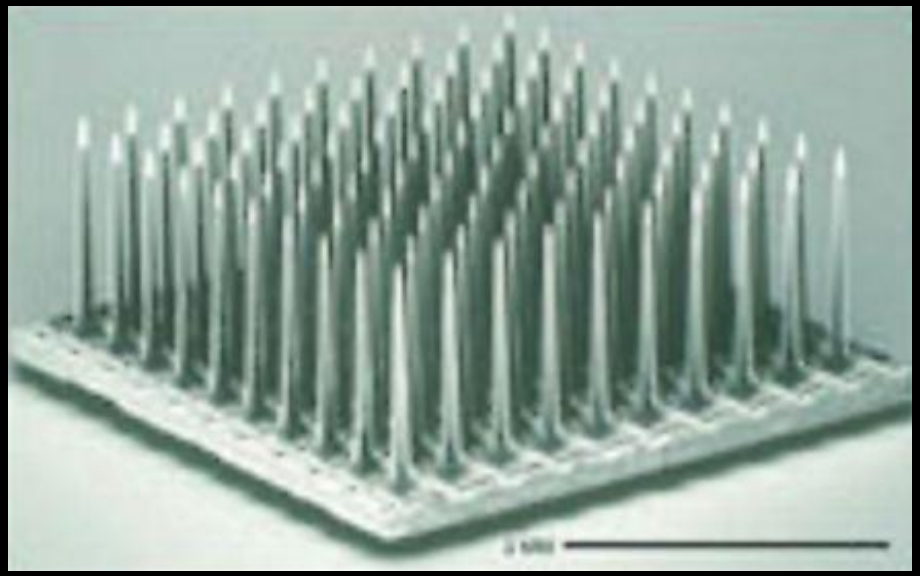

Movement Direction
$FR = b_x m_x + b_y m_y$
Regressors

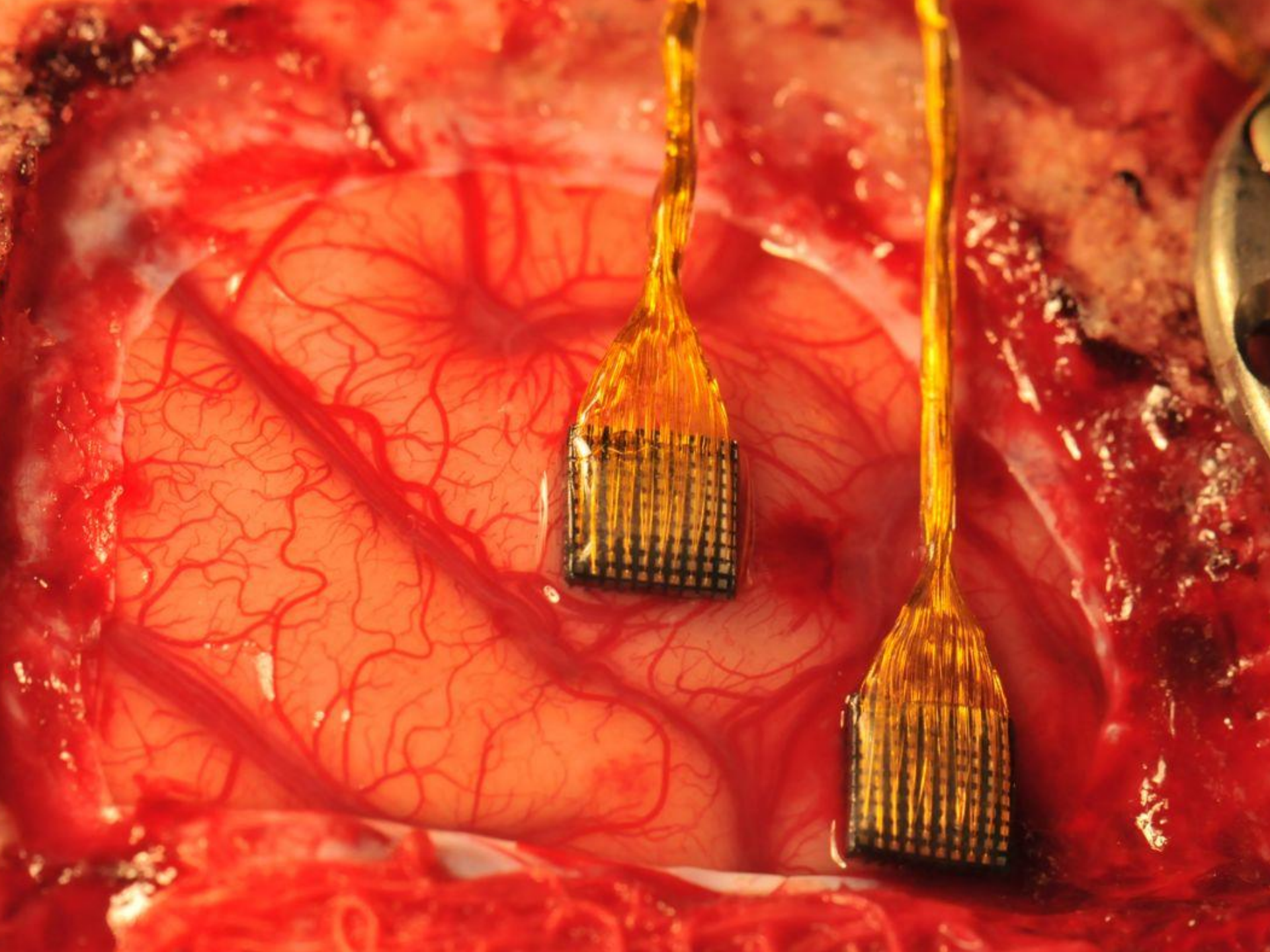


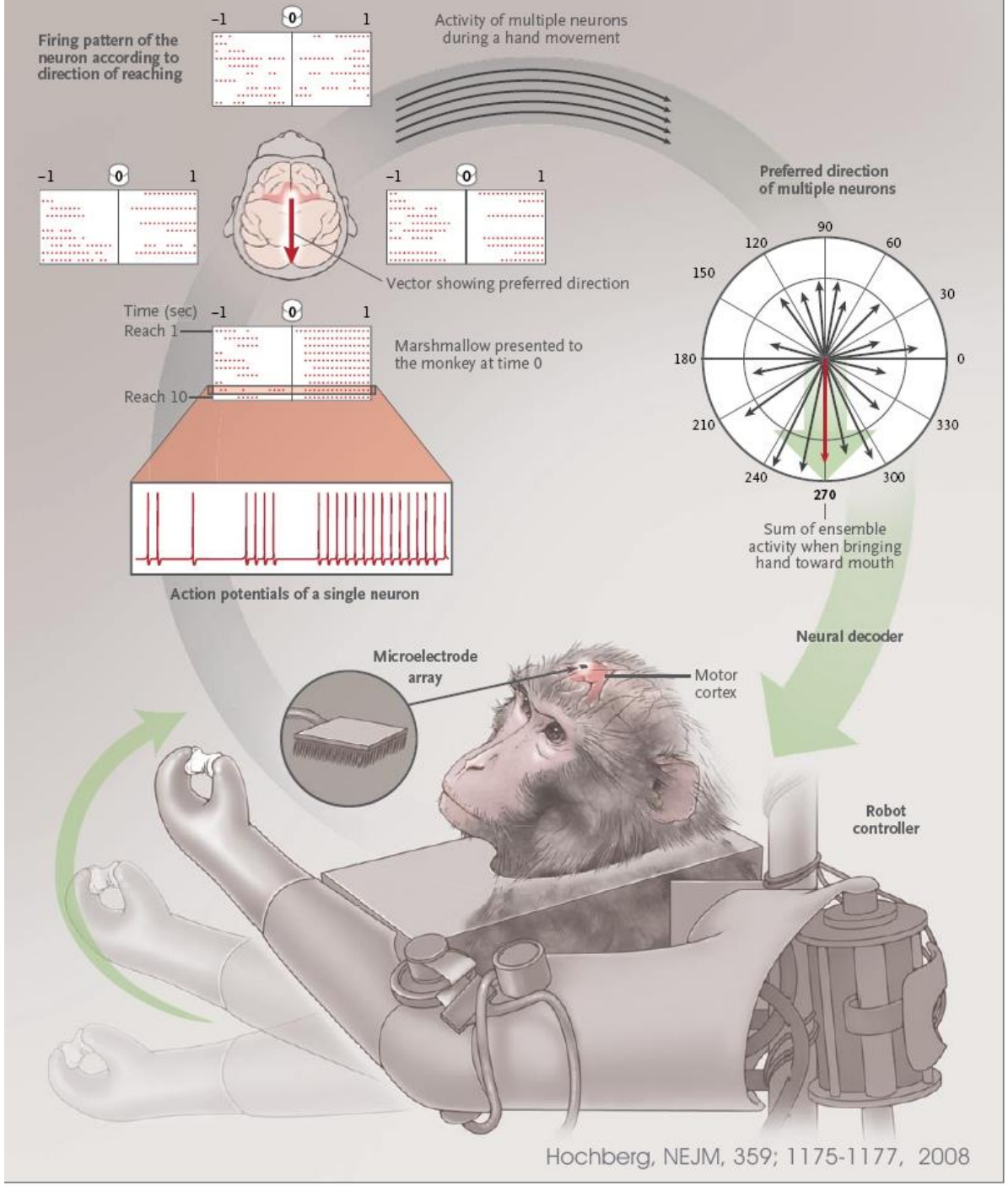
Scientific Basis

- Geometric representation of similarity
- Natural movement can be decoded based on movement direction
  - Coordinate system origin located on the moving effector
  - Continuous Coding

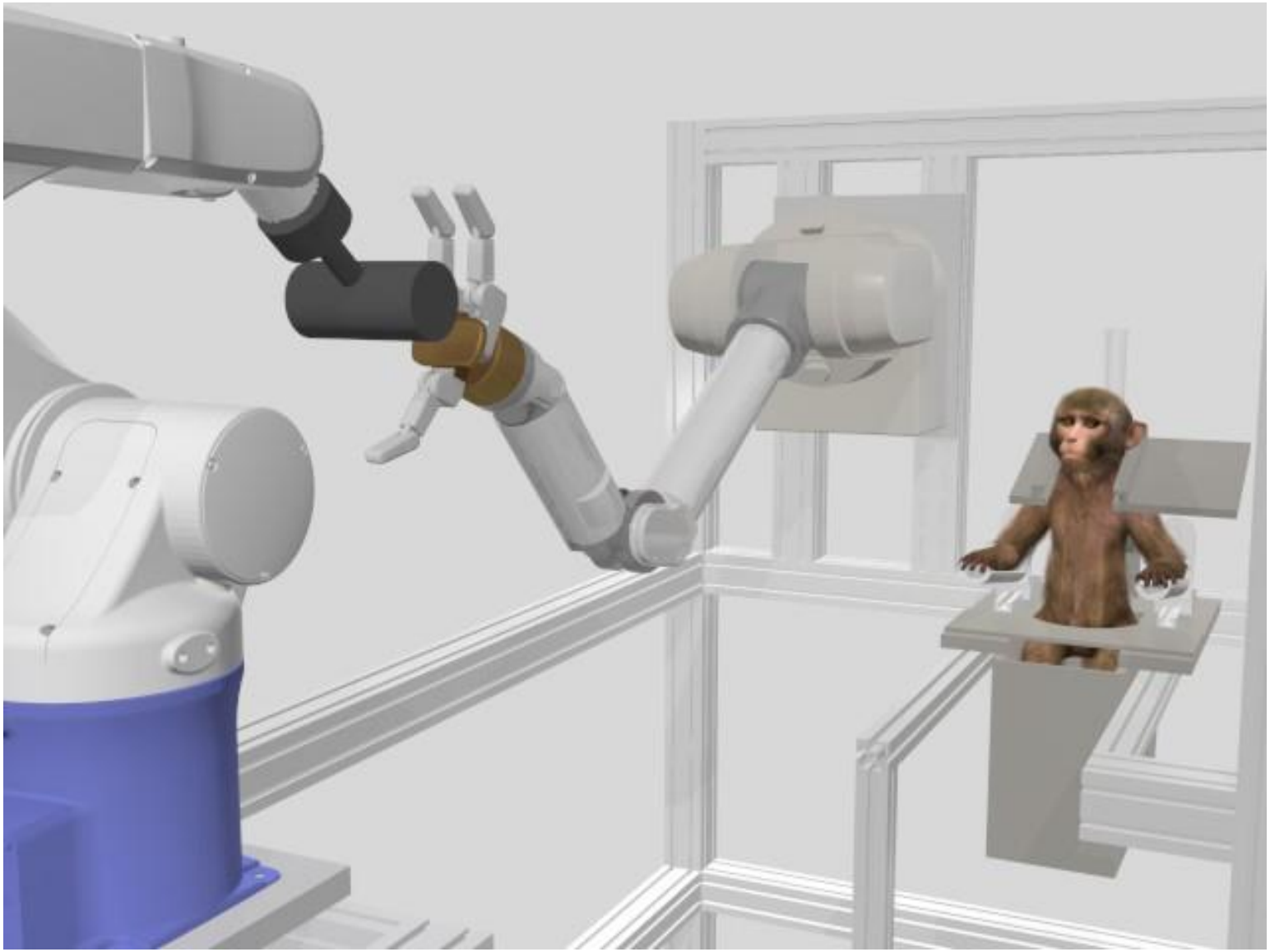
Trajectory = Behavior Output

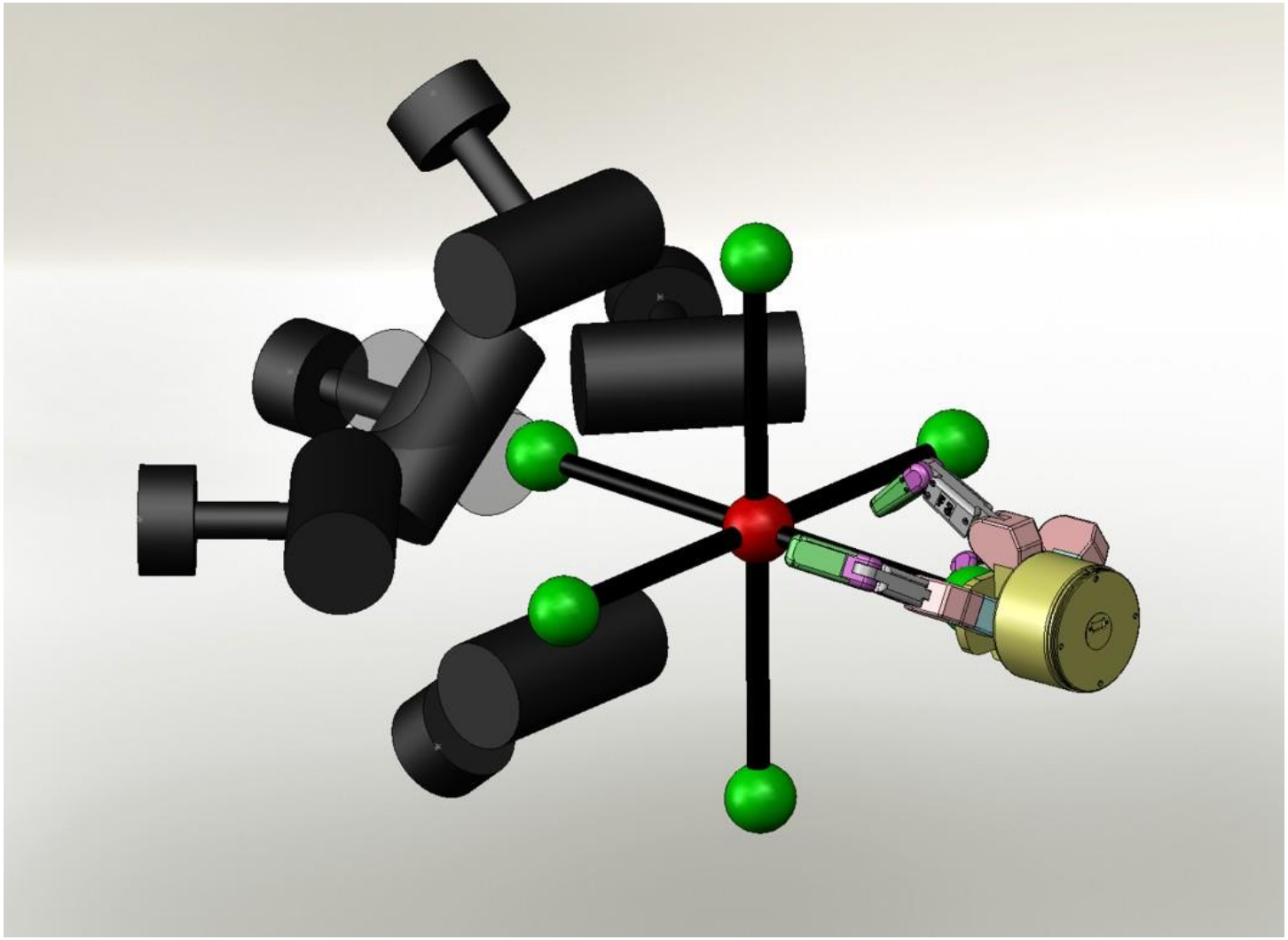





Firing pattern of the neuron according to direction of reaching
−1
0
1
Activity of multiple neurons during a hand movement
Vector showing preferred direction
Preferred direction of multiple neurons
90
120
60
150
30
180
0
210
330
240
300
270
Sum of ensemble activity when bringing hand toward mouth
Time (sec)
Reach 1
Reach 10
Marshmallow presented to the monkey at time 0
Action potentials of a single neuron
Neural decoder
Microelectrode array
Motor cortex
Robot controller
Hochberg, NEJM, 359; 1175-1177, 2008

$$\mathrm{FR} = b_0 + b_1 m_{\mathrm{x}} + b_2 m_{\mathrm{y}} + b_3 m_{\mathrm{z}} + b_4 aperture$$

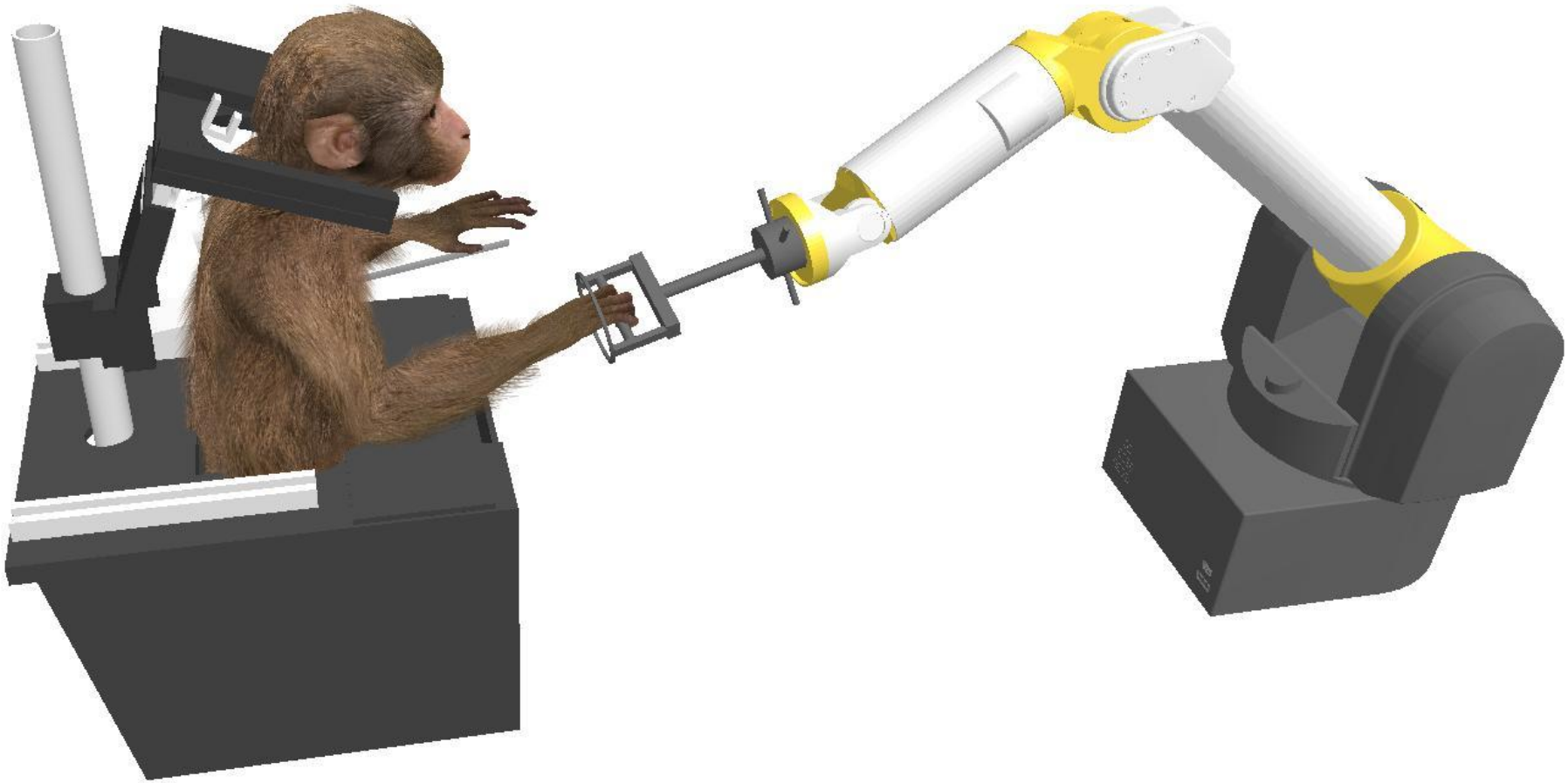




$$\mathrm{FR} = b_0 + b_1 m_{\mathrm{x}} + b_2 m_{\mathrm{y}} + b_3 m_{\mathrm{z}} + b_4 yaw + b_5 pitch + b_6 roll + b_7 aperture$$

7 DOF BCI

Tupaia
Lemur
Daubentonia
Loris
Nycticebus
Perodicticus
Galago
Tarsius
Leontocebus
Aotus
Saimiri
Cebus
Ateles
Macaca
Papio
Cercopithecus
Presbytis
Nasalis
Colobus
Hylobates
Pongo
Pan
Gorilla
Homo
A.H Schultz



Button

Small Handle

Large Handle

Small Rectangle

Large Rectangle

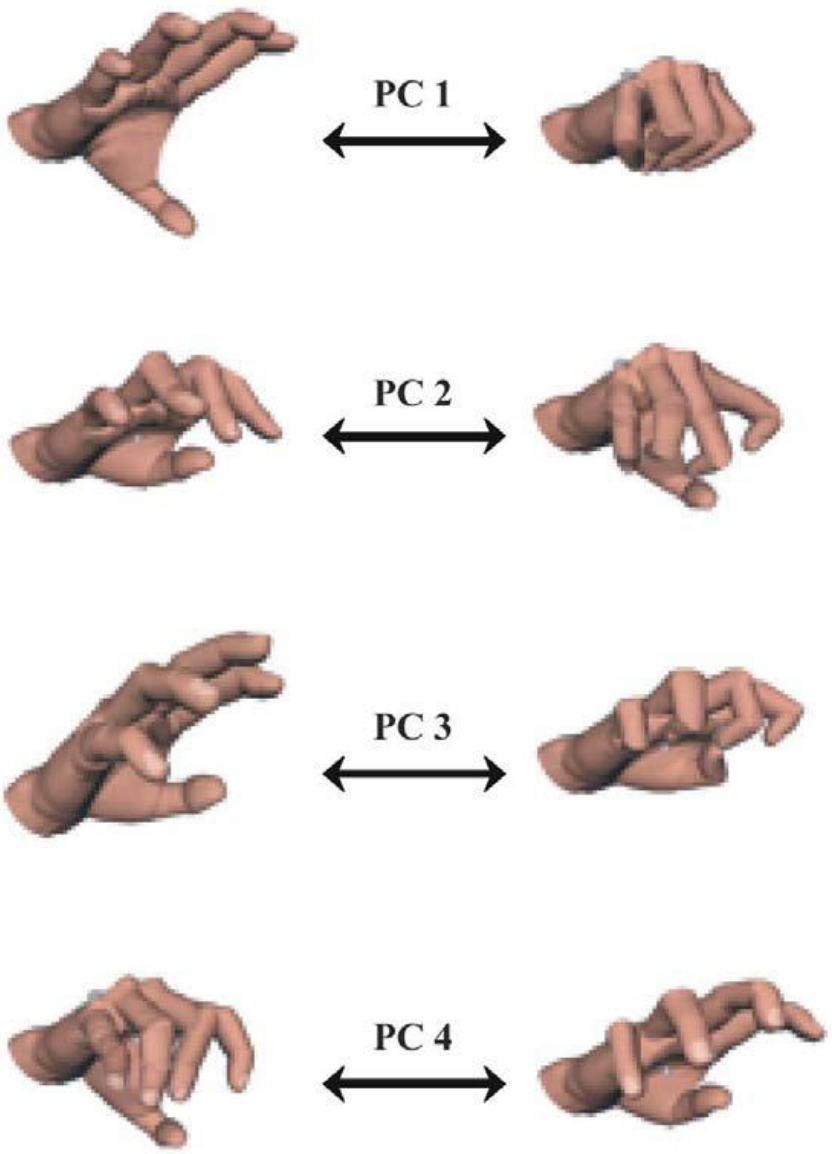
Disk

Small Precision

Large Precision

Small Cone

Large Cone


PC 1
PC 2
PC 3
PC 4

$$FR = b_0 + b_1 m_x + b_2 m_y + b_3 m_z + b_4 yaw + b_5 pitch + b_6 roll + b_7 pc_1 + b_8 pc_2 + b_9 pc_3 + b_{10} pc_4$$

Hand Shape Movie

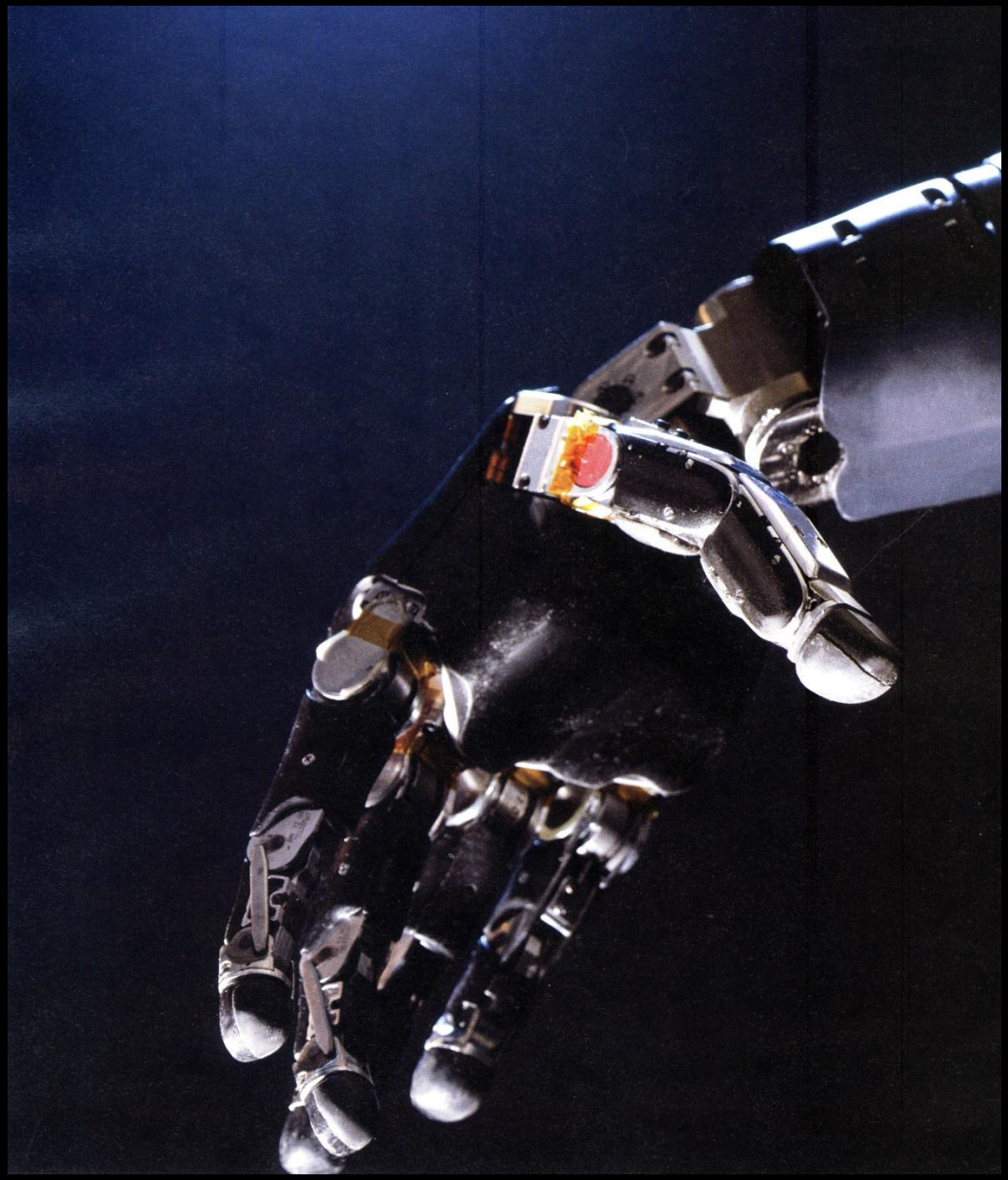
Revolutionizing Prosthetics – MPL

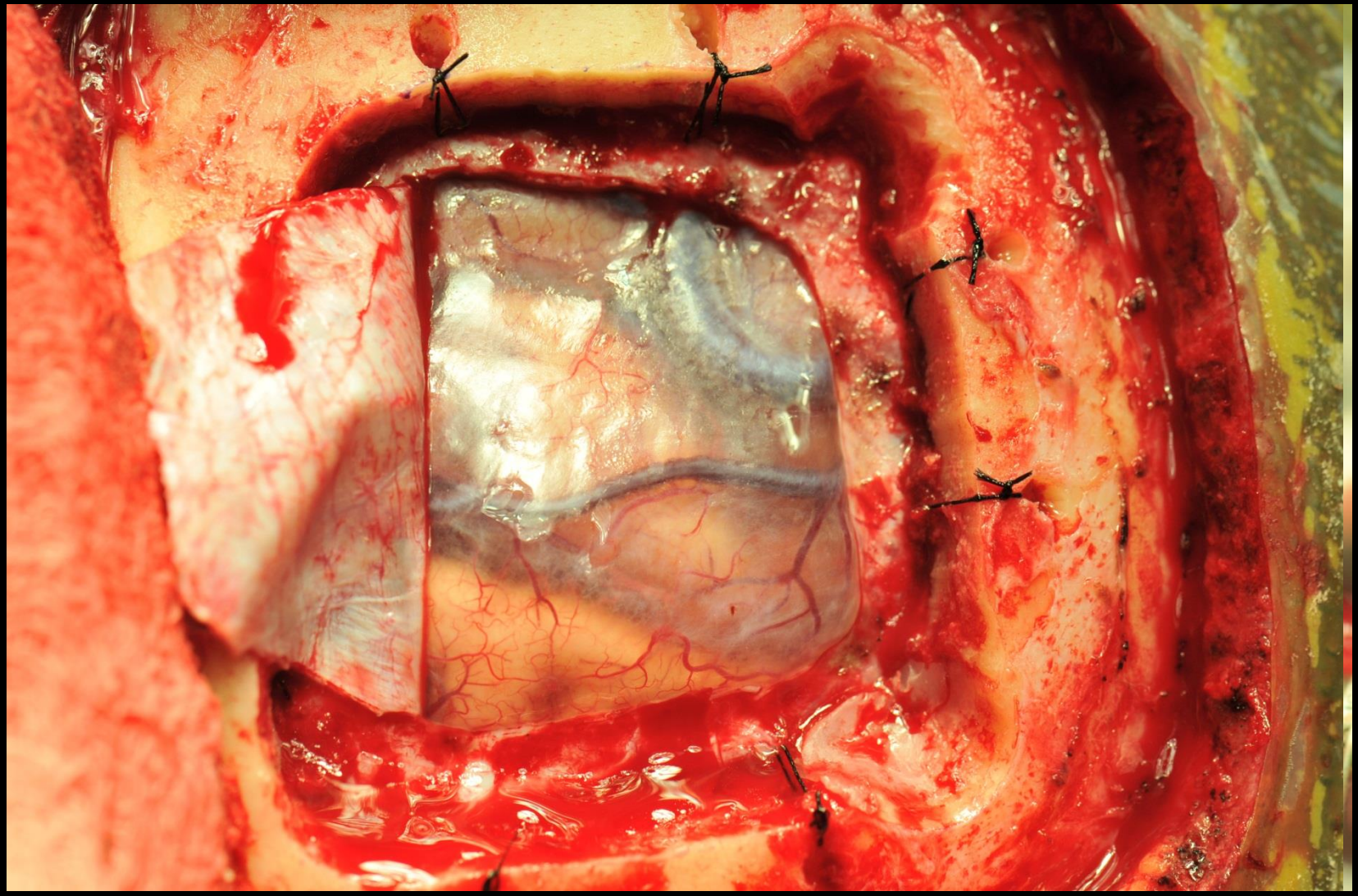
Drive	Max Vel. (deg/s)	Max Torque (N-m)
MCP PLanetary Drive (Thumb / AbAd)	450	3.4
MCP Cycloidal Drive (1 MF)	450	2.65
Wrist Flexor	120	3
Wrist Rotator	60	8
Upper Arm Drives	120	50 - 60

Nominal Voltage: 24 V
Peak Current: 40 A max, 20 A general operation
Sleep Current: < 100 mA
Weight: Approx. 10 lbs
Size: Approx. 60 cm, shoulder to center of palm

17 DOM / 26 DOF
Anthropomorphic range of motion

*2MF is 2 DOM / 3 DOF





BRAIN-COMPUTER INTERFACE RESEARCH

UPMC Rehabilitation Institute and the
University of Pittsburgh School of Medicine

Early Testing and Research clip reel

1) Initial post-surgery device tests at UPMC Mercy
2) Feb. 21, 2012 - Second day moving robotic arm
3) Feb. 28, 2012 - After one week moving robotic arm

December 2012
TRT 05:50
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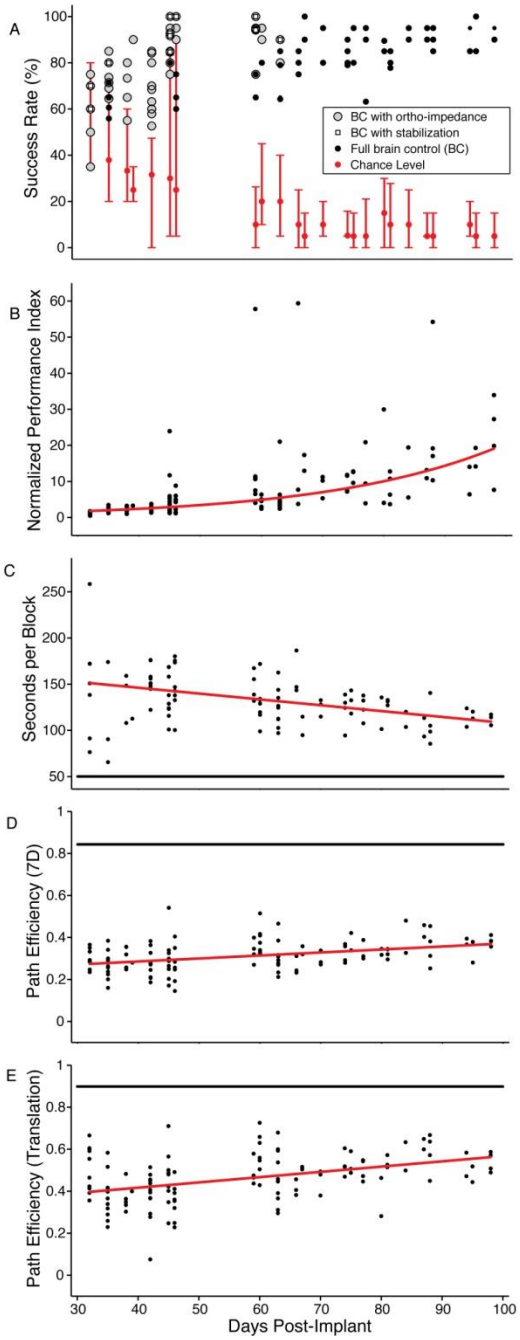
Single unit

60
MINUTES

Block ARAT

Shelf Demo

Rock ARAT


A
Success Rate (%)
BC with ortho-impedance
BC with stabilization
Full brain control (BC)
Chance Level
B
Normalized Performance Index
C
Seconds per Block
D
Path Efficiency (7D)
E
Path Efficiency (Translation)
Days Post-Implant

Rock Paper Scissors

RAIN-COMPUTER INTERFACE RESEARC

UPMC Rehabilitation Institute and the
University of Pittsburgh School of Medicine

dy participant Jan Scheuermann feeds her

1) Nov. 28, 2012 - Chocolate bar
2) Nov. 30, 2012 - Chocolate bar
3) Nov. 30, 2012 - Chocolate truffle
4) Nov. 30, 2012 - String cheese
5) Nov. 30, 2012 - Red pepper

December 2012

TRT 05:27

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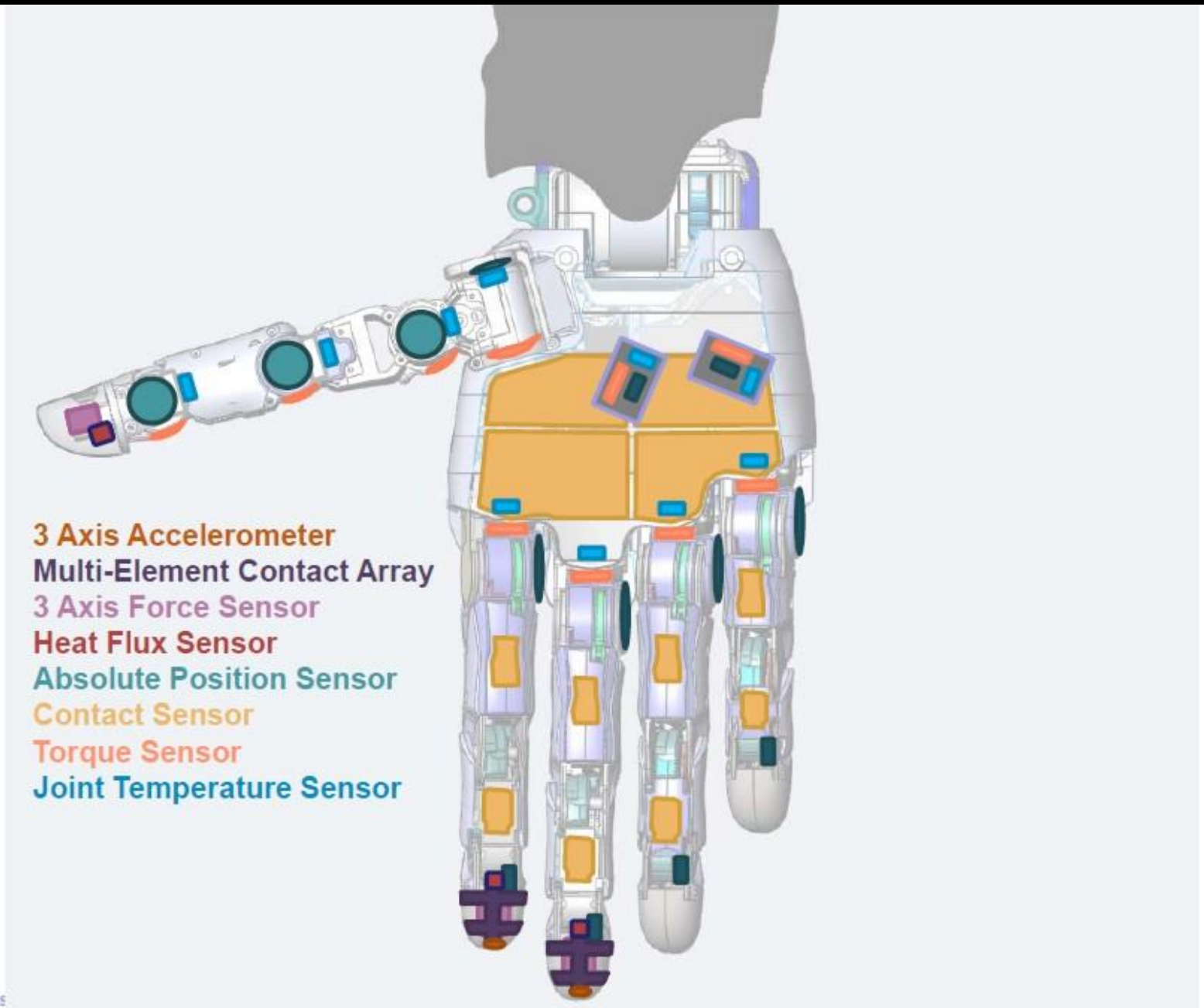
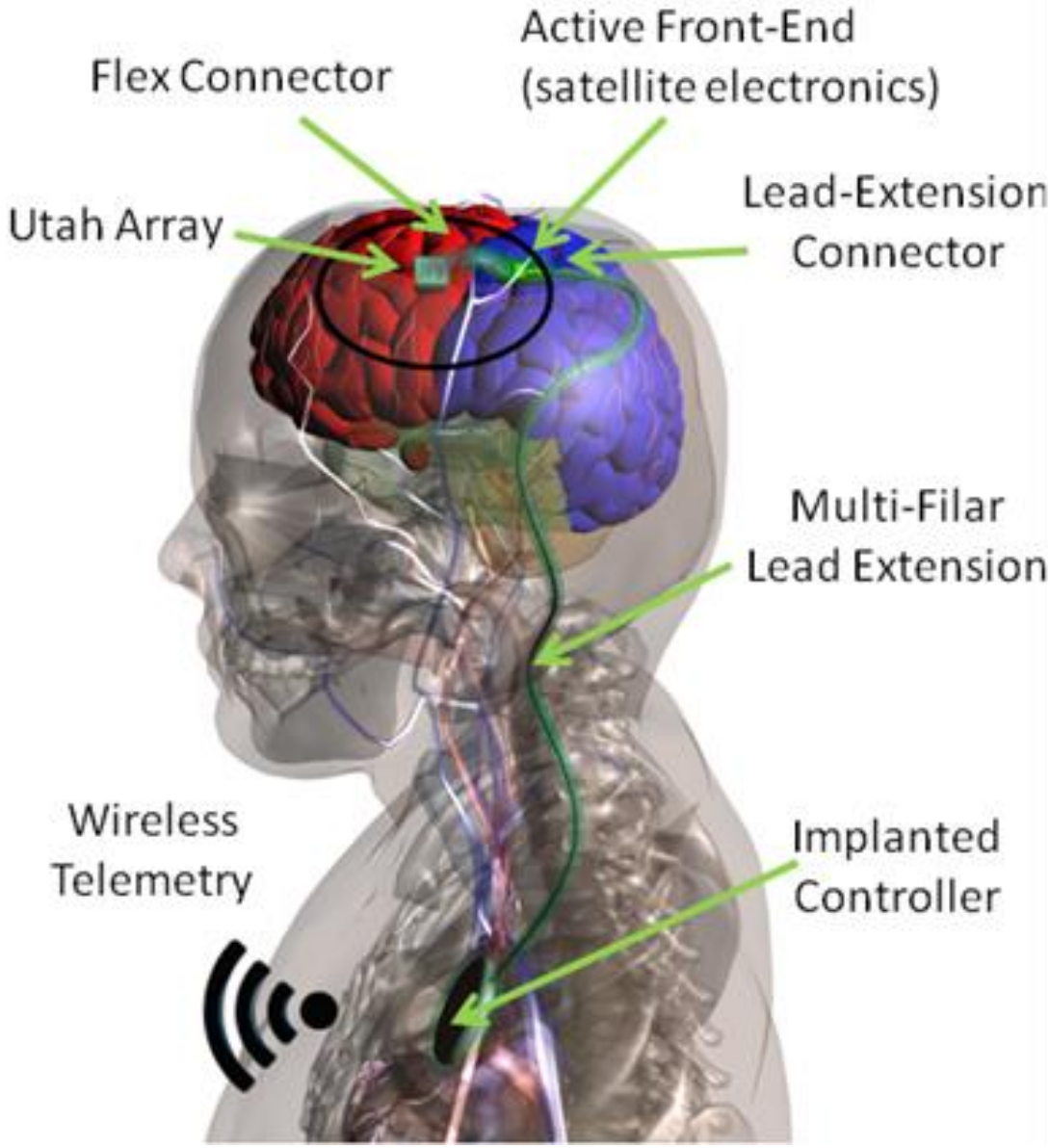

3 Axis Accelerometer
Multi-Element Contact Array
3 Axis Force Sensor
Heat Flux Sensor
Absolute Position Sensor
Contact Sensor
Torque Sensor
Joint Temperature Sensor


Flex Connector
Active Front-End
(satellite electronics)
Utah Array
Lead-Extension
Connector
Multi-Filar
Lead Extension
Wireless
Telemetry
Implanted
Controller

Arizona State
Dawn Taylor
Stephen Helms Tillery
Rob Isaacs
Peter Perepelkin
WenShan Lin
Albert Chi
Doug Weber

NSI
Dan Moran
Tony Reina
Ali Kakavand

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