Revolutionizing Prosthetics 2009

April 2008

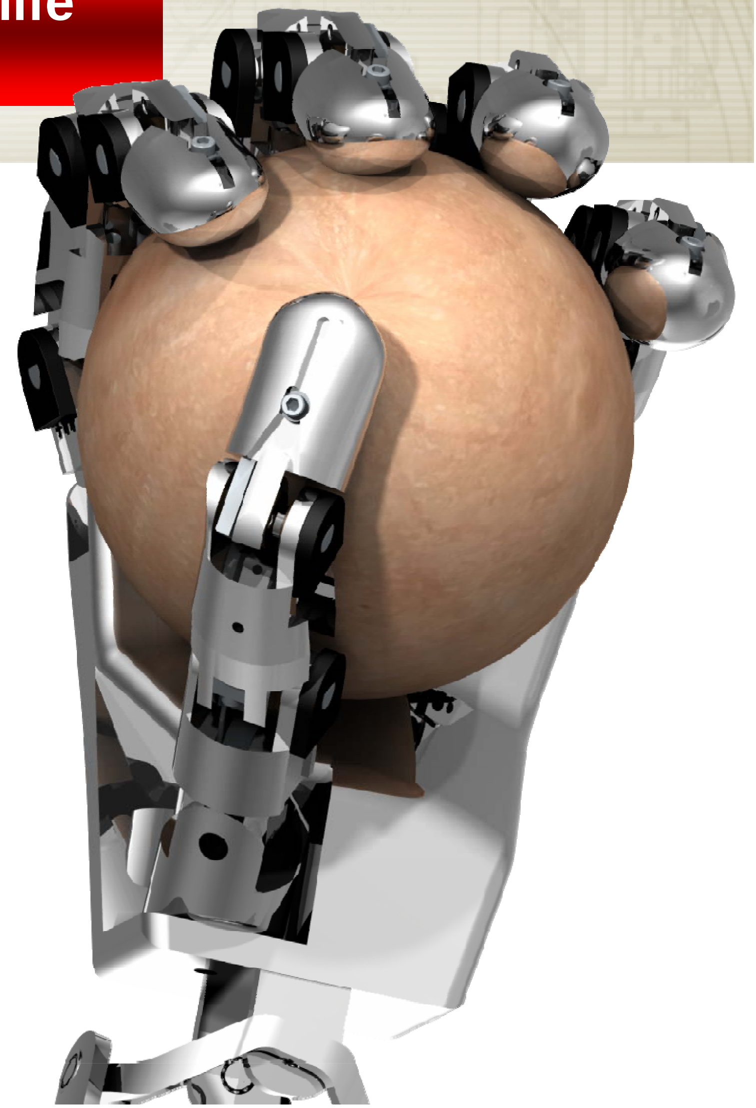
APL
The Johns Hopkins University
APPLIED PHYSICS LABORATORY

Revolutionizing Prosthetics 2009 Program

- Vision
  - Produce a fully neurally integrated upper extremity prosthetic with appropriate documentation for clinical trials, FDA approvals, and manufacturing transition.

- Mission
  - Apply an understanding of the underlying function and control of the human arm and hand when performing the basic functions of reaching, pointing, grasping, and coordinated finger movements to the design of this prosthetic.
  - Understand and address the amputees' needs to promote and enhance quality of life issues – comfort, cosmesis, natural control, integrated sensory feedback

Restoring function and improving quality of life for our injured warfighters



Modular to suit range of Upper Extremity Patients
- Suitable for Range of Injury Levels
  - (Modular Mechanical Design)

Dexterous control of 22+ degrees of freedom
- – mimics natural limb

Natural Control

Natural Performance
- Anthropomorphic, speed, dexterity, force
- Supports Activities of Daily Living

Sensory Perception of Environment
- Pressure, Force
- Temperature
- Tactile Discrimination

Proprioception

Natural Appearance

Comfortable

Durable, Reliable

Provides Suitable Function at Varying Degrees of Invasiveness

RP2009 – Some Key Partners

USC/ASU
- Cortical Control
- Learning paradigms
- Virtual Environment

JHMI
- PI for Medicine
- Human Subjects
- Brain Computer Interface

Martin Bionics
- SMART Socket System
- Haptics Patient Interface

Chicago, PT
- COBOT Actuation
- Tactor Implementation

Otto Bock
- Prosthetic Arm Components
- Control Bus Architecture
- Clinical Support

APL
- Program Management
- System Engineering & Integration
- Signal & Image processing
- Virtual Reality
- Controls

New World Associates
- Mechanical Design
- Product Development

Northwestern
- Non/Low Invasive Strategies
- Enhanced Haptics
- Mechanical Design

RIC
- Virtual Reality Environment
- Targeted Reinnervation
- Patient Needs

USC
- Virtual Reality Environment
- Biomimetic Control
- Efferent Control

U of Rochester
- Cortical Control for Hand Movement

Utah
- Peripheral Nerve Arrays
- Neural Integration
- Wireless Electronics

Vanderbilt
- Biomimetic Arm
  Gas Actuators
- Catalyst Power

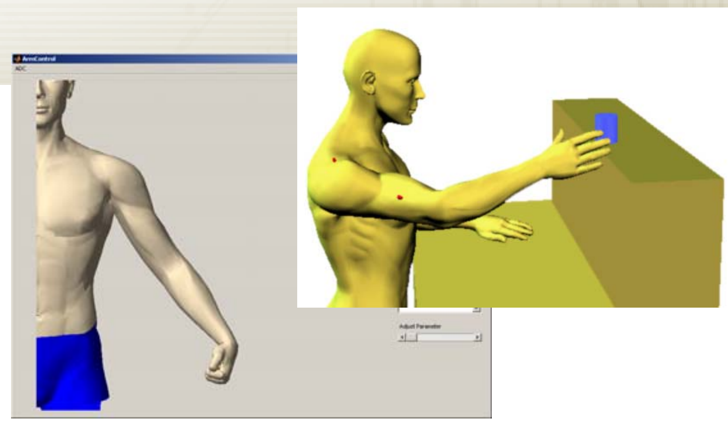
Oak Ridge
Oak Ridge National Laboratory
U.S. Department of Energy

- Biomimetic Arm
  Microscale fluidics
- Socket Technology
- Embedded Sensors

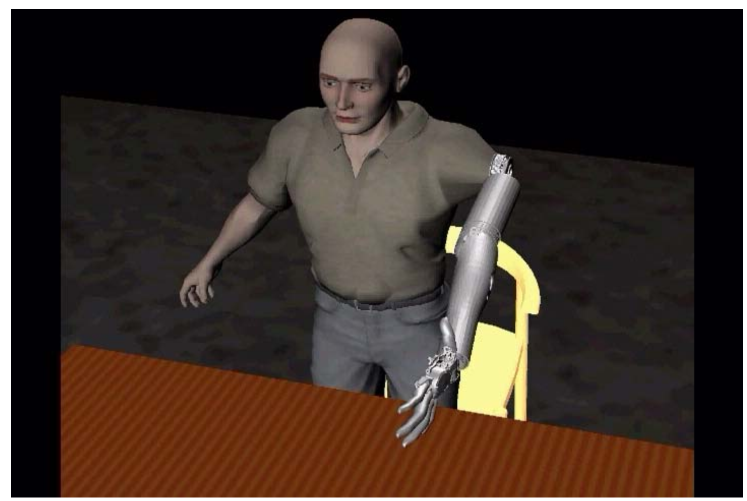
Sigenics
- IMES Implants
- Integrated Electronics

CalTech
- Higher Cortex Signal/Intent Extraction

Virtual Integration Environment



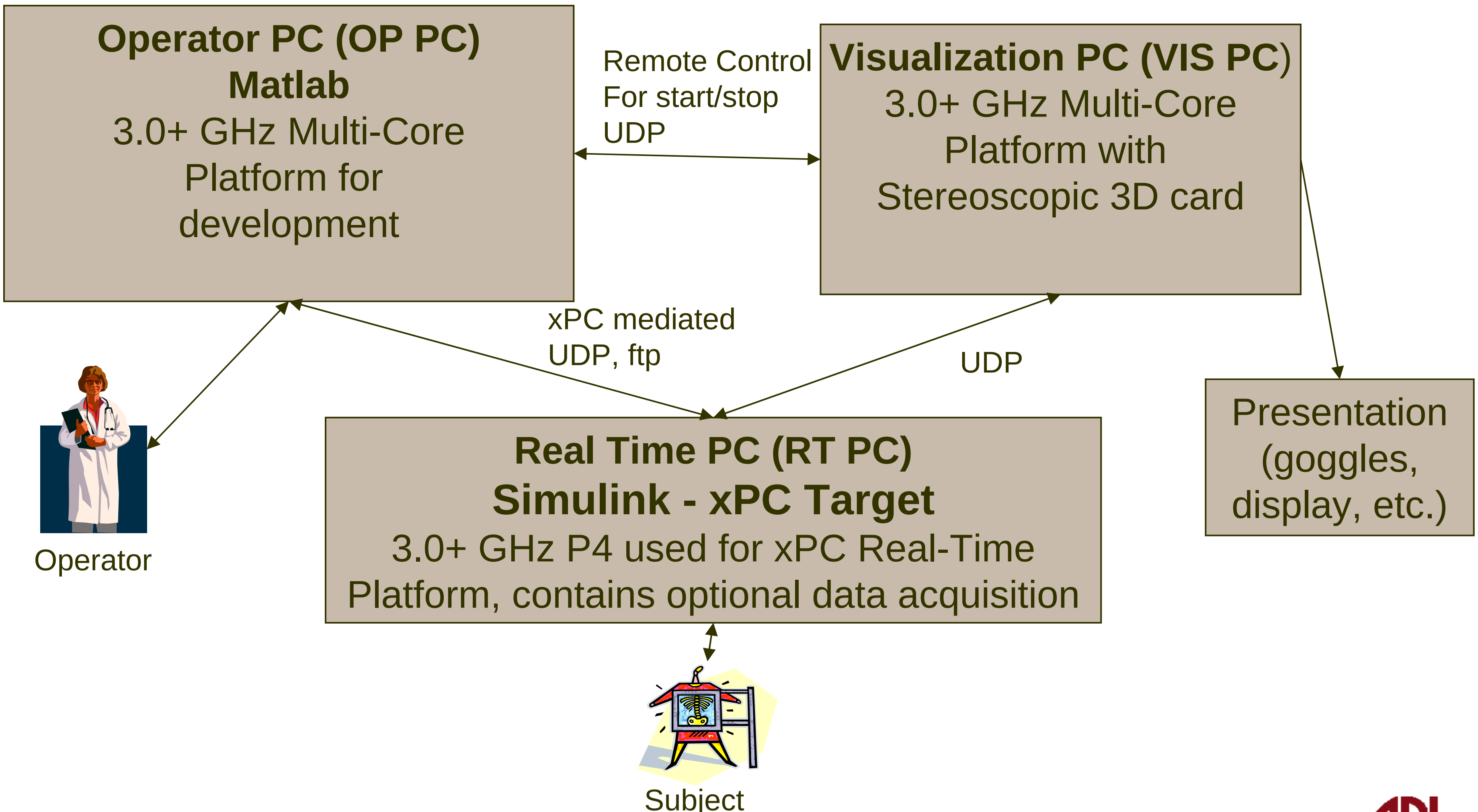
- Complete limb system simulation environment
  - Supports engineering development,
  - Neural signal acquisition
  - Algorithm development
  - Mechanical approach evaluation
  - Patient training / therapeutic applications
  - System performance validation and design compliance



- End-to-end interactive simulation
  - Acquires control signals (myoelectric, mechanical, neural, other)
  - Signal Analysis: Interprets the intention
  - Controls: Translates intention into movement of a virtual limb
  - Allows the user to interact with objects with feedback (haptics or other)

- Modular and configurable
  - Support various limb models and control algorithms
  - Engineering test bed for improvement of these designs
  - Evaluate patient interfaces for control signal extraction and sensory feedback

VIE Hardware Configuration



VIE Real Time Top Level Architecture

- For Engineering development, scientific investigation and clinical practice
- Standardized architecture
  - Top level block functions and communications are largely fixed
  - Interfaces are controlled and defined
  - Scalable and modular
  - Provides solid foundation for development
  - Common viewpoint for design and exchange of information

Prototype 1 Objectives – Year 1

Develop upper limb prosthetic with 7 independent Degrees of Freedom (DOF)

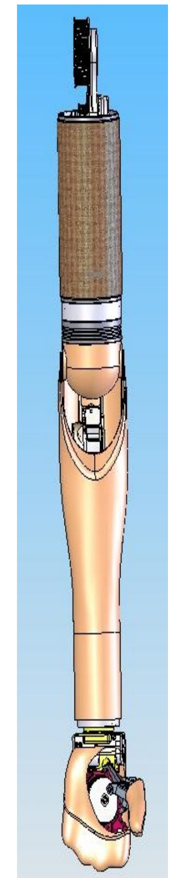
- **Purpose:**
  - **To support targeted reinnervation patients**
    - Clinical Studies
    - Take home evaluation
  - **Serves as a test bed for evaluation of haptic feedback and indirect sensory perception approaches**
  - **Demonstrates advanced prosthetic function with non-invasive and low invasive classification algorithms**
  - **Supports Neural Integration Research**
  - **Transitionable to Product**

1 DOF Shoulder
- Flexion / extension

2 DOF at Elbow
- Flexion / extension
- Humeral Rotation

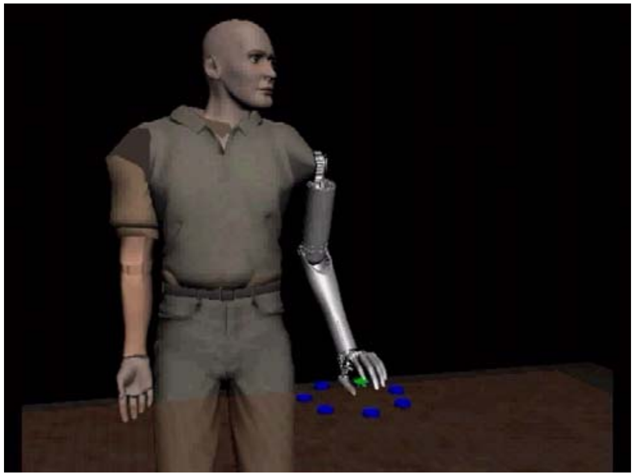
2 DOF Wrist
- Supination / Pronation
- Flexion / Extension

2 DOF Hand
- Palmar Prehension
- Lateral Prehension



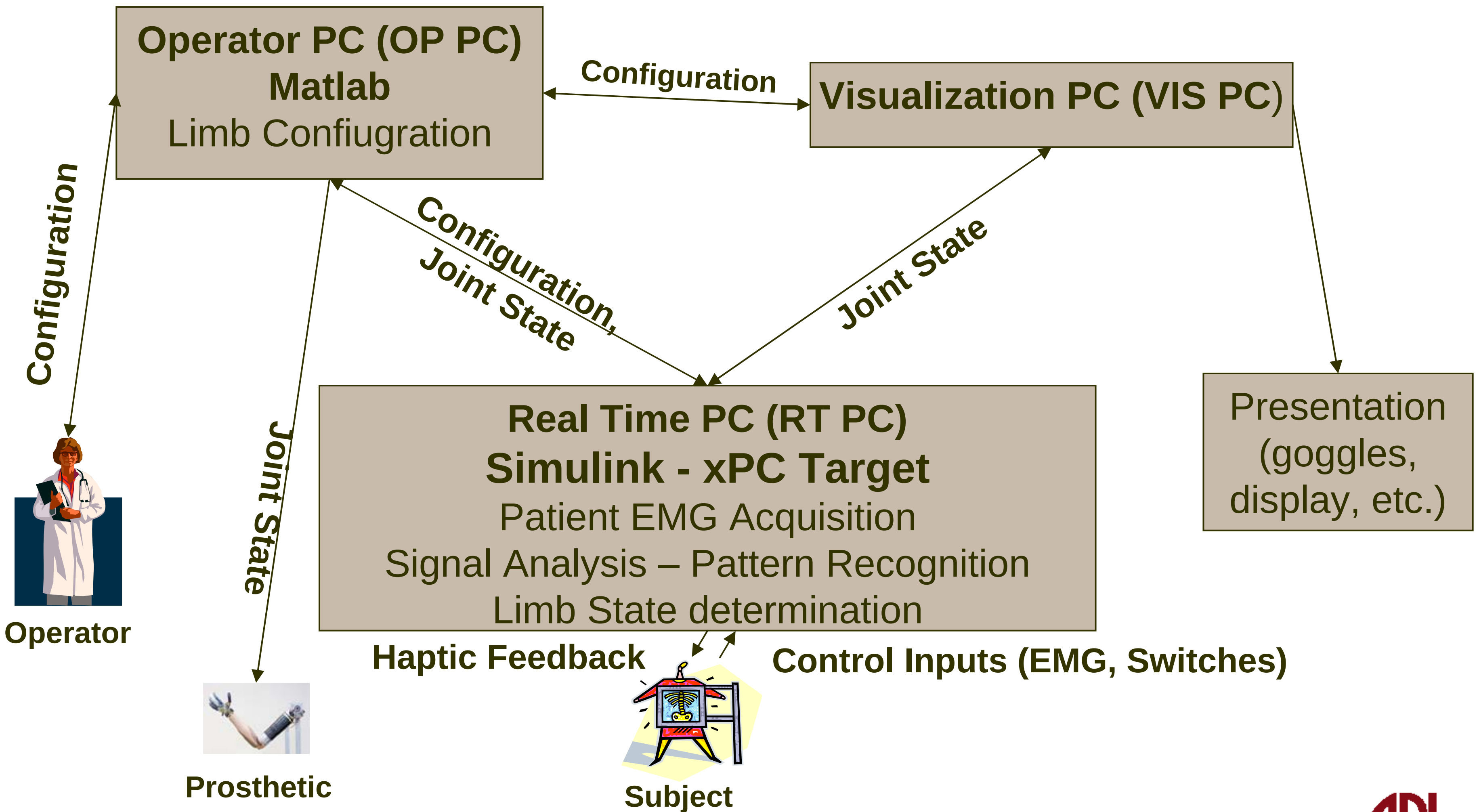
EMG TMR using Pattern Recognition and Conventional Control (UNB/ RIC)

- Input
  - Signal Source
    - Targeted Muscle Reinnervation EMG
  - Signal Type
    - EMG
    - Recording device
      - Now - Otto Bock Modified Electrodes
      - Future – Injectable Myo-Electric Sensor Systems
- Signal Analysis
  - Processing
    - LDA (pattern recognition)
    - Conventional Control

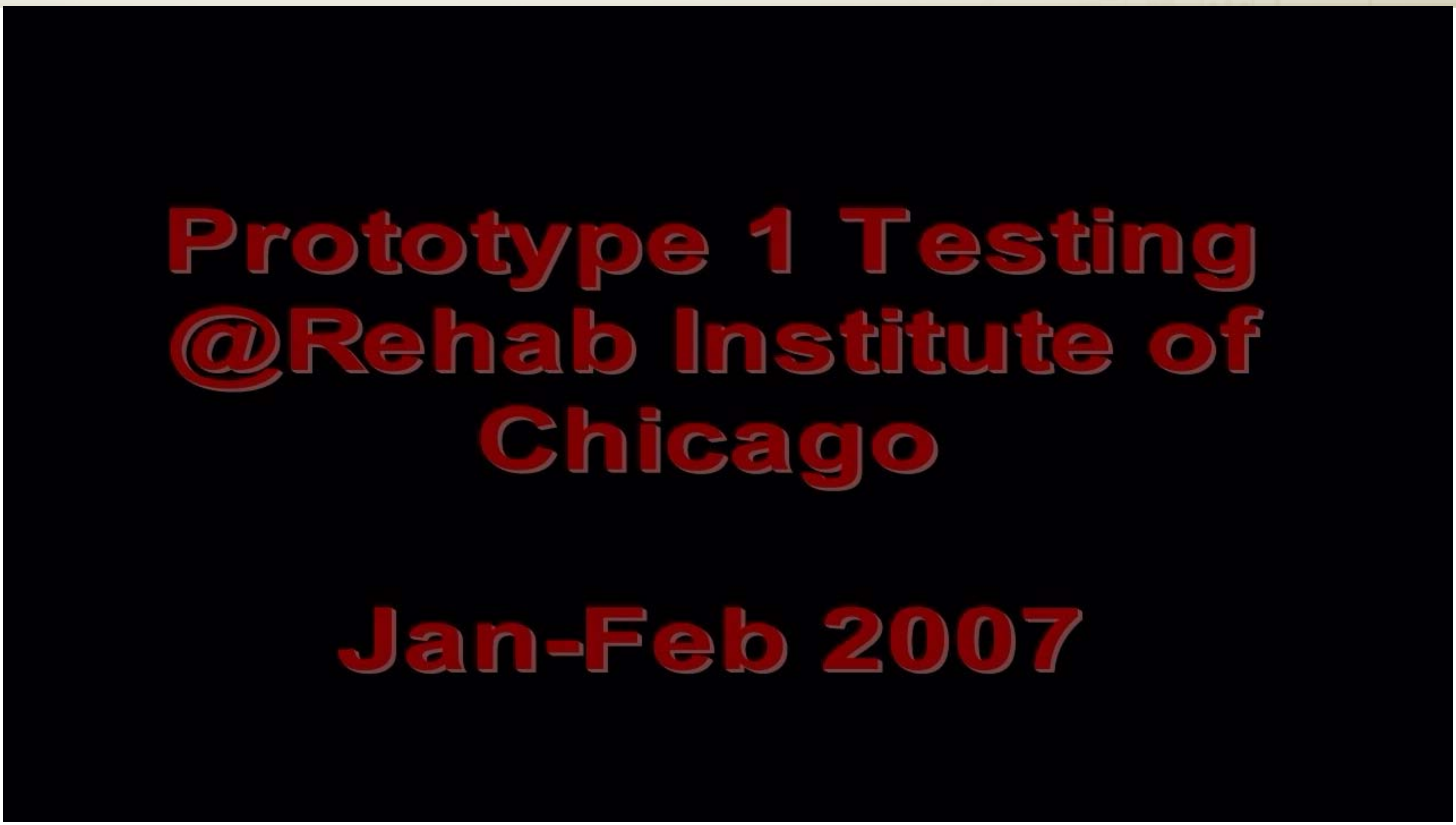


VIE reconstruction of Jesse Fitts Test using recorded signals

VIE Limb Teleoperation



Prototype 1 at RIC – January 2007



Images Courtesy of RIC Collaboration

Proto 2 Objectives

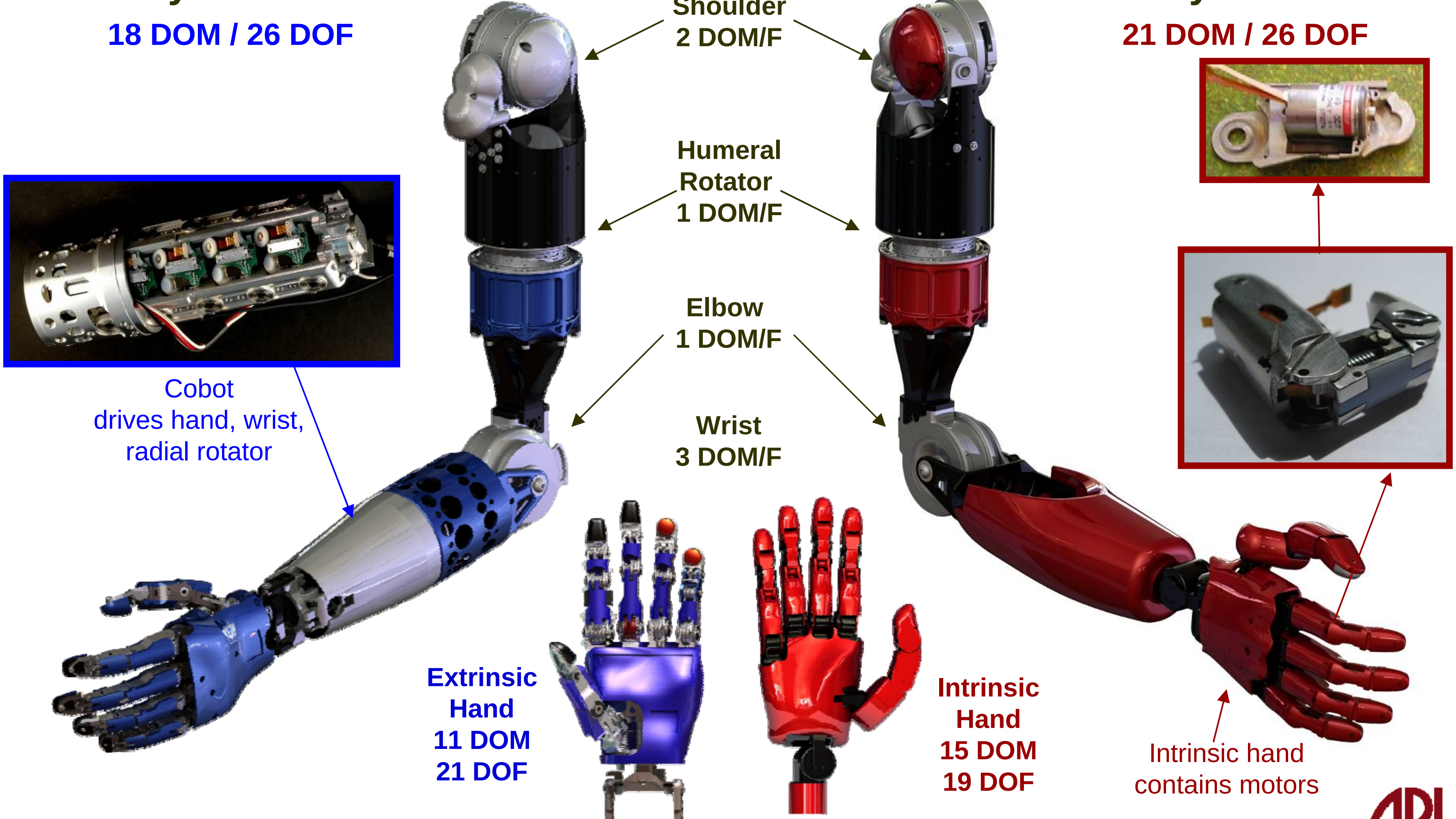
- Phase I risk reduction path to final limb
  - Electromechanical actuation
  - All degrees of freedom, speed, torque

- Platform for testing evolving neural control during Phase II
  - 27 DOF limb with supporting VIE and Controls Architectures
  - Serves as a test bed for Sensory feedback with integrated pressure, temperature, and vibration sensing

Proto 2 Arm Architectures

Extrinsically Actuated Hand

Intrinsically Actuated Hand

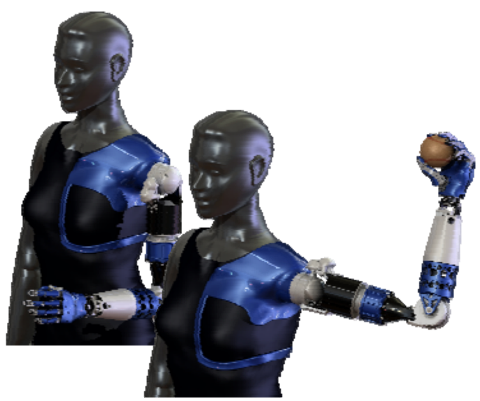


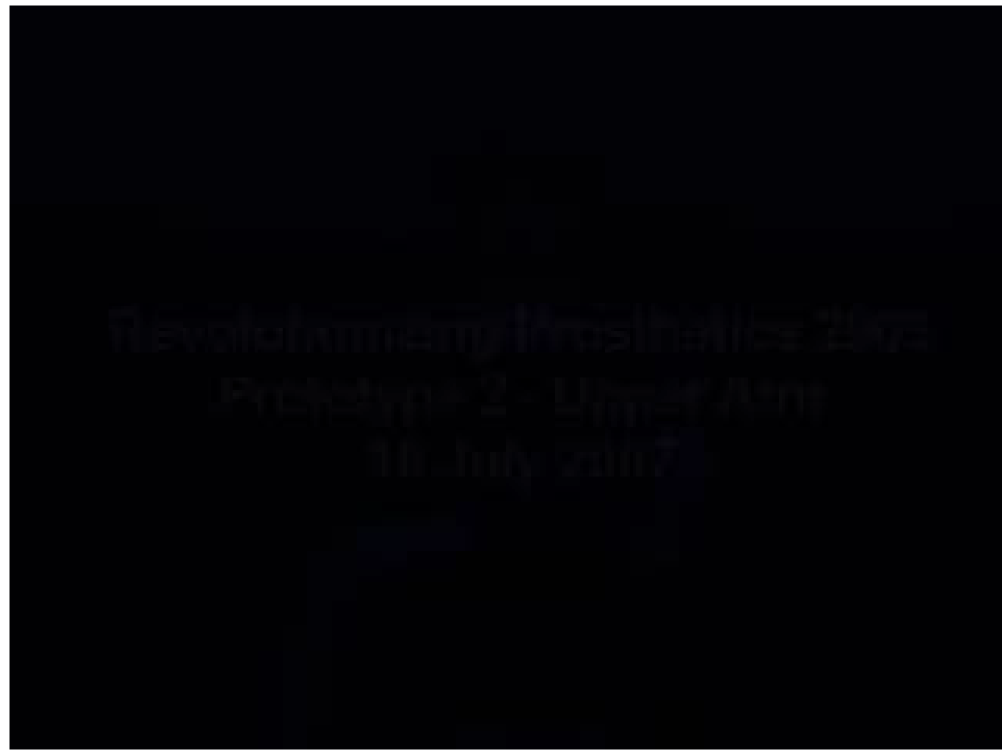
Proto 2 Upper Arm Performance

- Shoulder
  - Flex / Extend
  - Abduct / Adduct
  - Humeral Rotation
  - 45 ft-lbf, 120º/sec

- Elbow
  - Flex / Extend
  - 60 ft-lbf, 120º/sec

- Wrist
  - Flex /Extend
  - Pronate / Supinate
  - Radial / Ulnar Deviation

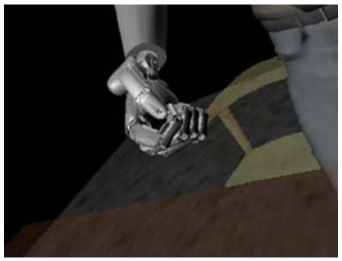


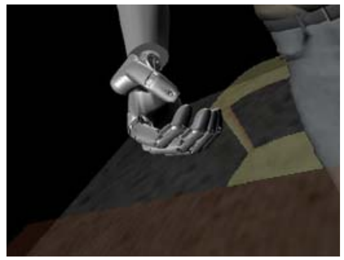


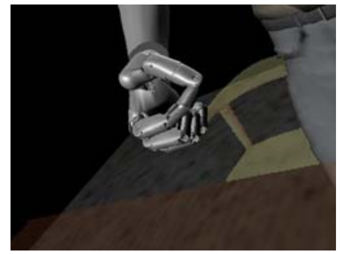
Prototype 2 Intrinsic Hand Dexterity

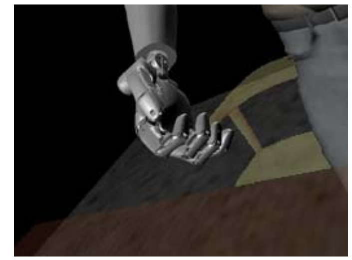
- Characteristics
  - 5 actuated and articulated fingers
  - 4 degree of freedom thumb
  - 19 degrees of freedom
    - 15 motors in hand
    - 15 actuated degrees of motion
    - 4 underactuated degrees of motion
  - 70 lbf cylindrical grasp
  - 20 lbf pinch grasp
  - 360° / sec

Prototype 2 Hand Grasps

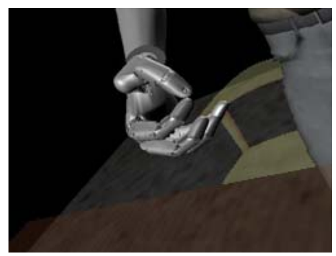

Lateral


Cylindrical

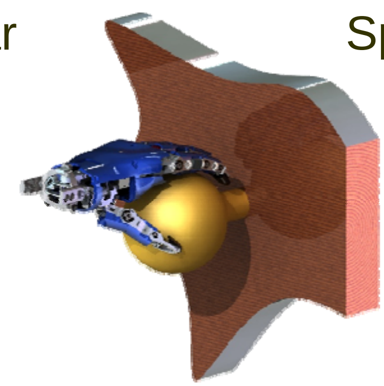

Tip


Hook

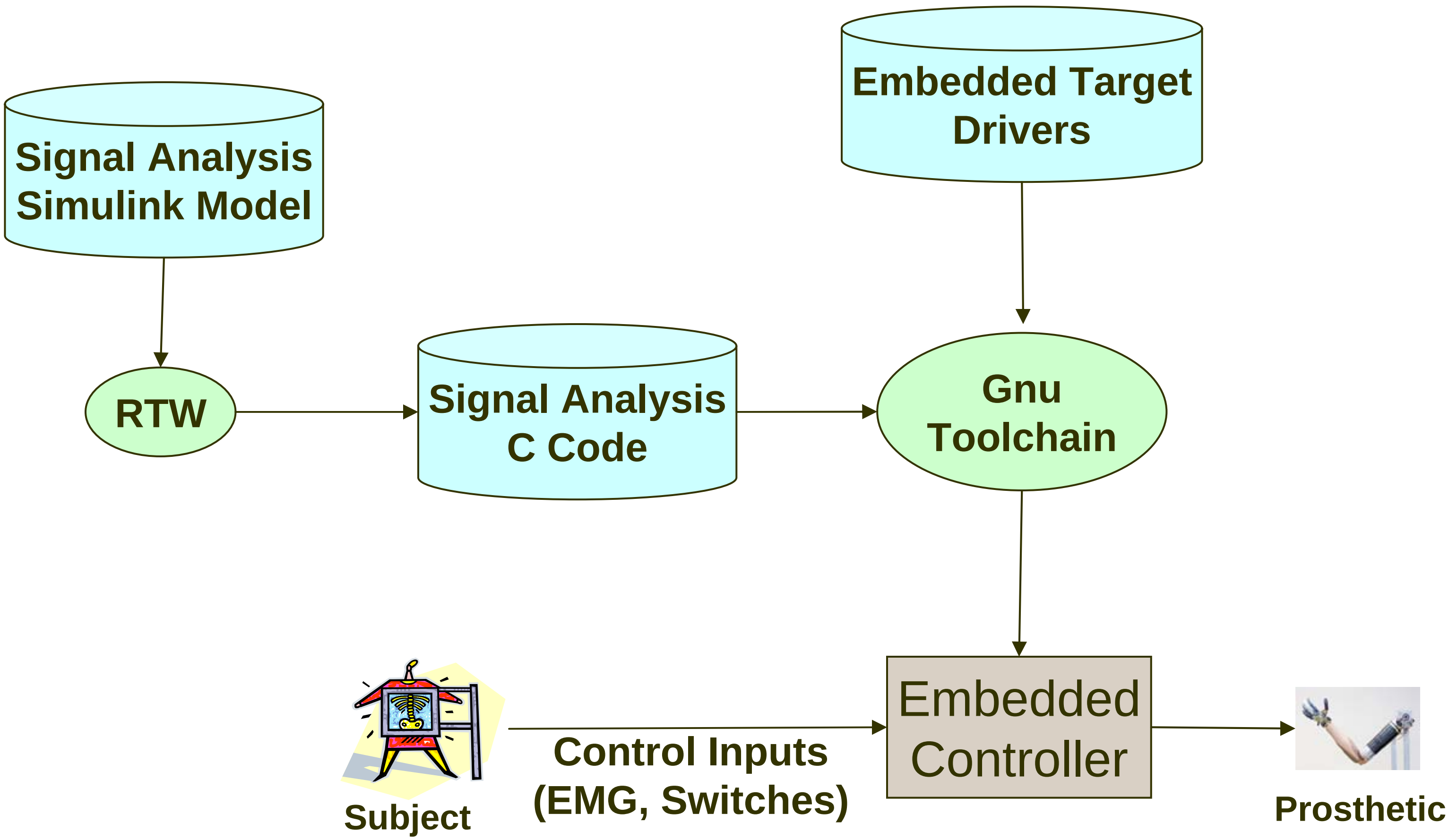

Palmar


Spherical

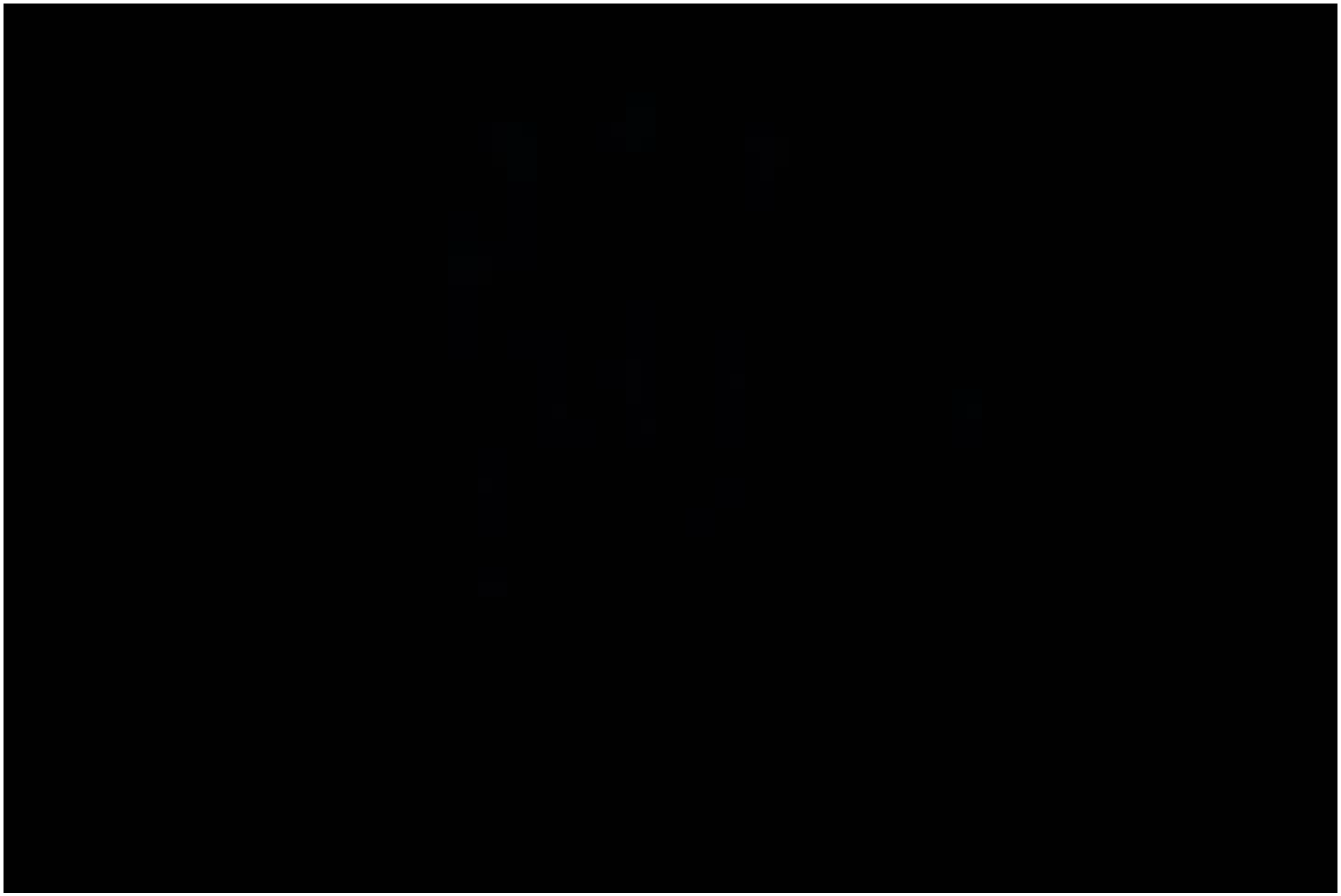

Pointer



Prototype 2 Software Embedding



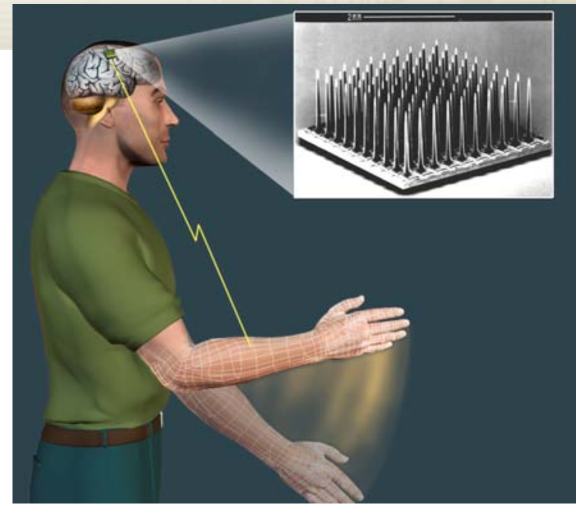
Prototype 2 Intrinsic Hand Dexterity

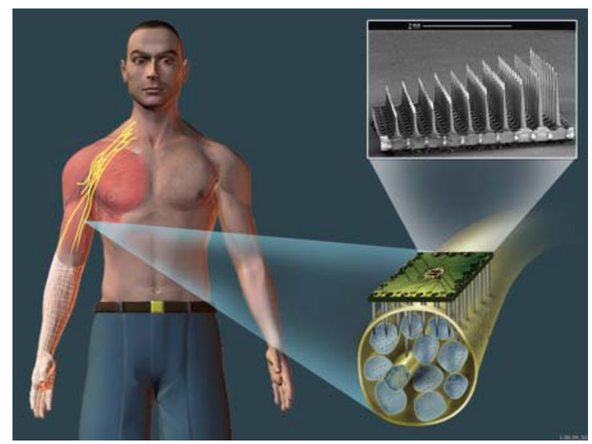


Neural Integration

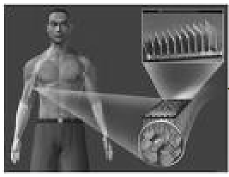
Research Components

Cal Tech	High Level Cortical, Reach Decoding and Prediction
U of Utah	Peripheral Nerve, Efferent and Afferent
ASU	Cortical, Reach and Hand Positioning
USC	Simulation Environment and Biomimetic Control
URMC	Cortical, Dexterous Digit Manipulation
NUPRL/ Sigenics	Wireless Injectable EMG Recording Methods
Zyvex*	Wireless, Direct Peripheral Nerve Interface Methods
RIRC*/UBN	Targeted Motor Reinnervation and Signal Analysis
JHU	Signal Classification, Synthesis, Simulation, and Hybrid Integration

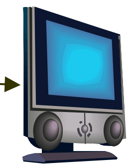




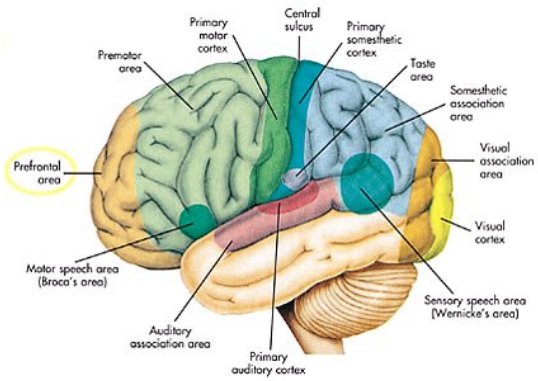
Neural Decode
End Point Goal (CalTech)



Input → **Signal Analysis** → Controls → Plant → Presentation

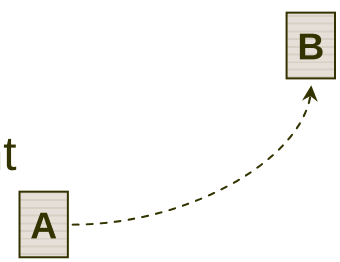


- Signal Source
  - Medial Intraparietal (MIP) and PMd (Pre-motor dorsal)



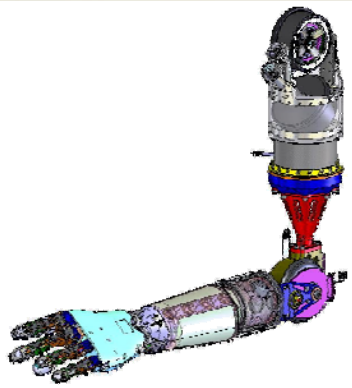
http://universe-review.ca/I10-80-prefrontal.jpg

Endpoint Goal
- Derived Intention to go to specific endpoint
- Determines macro path

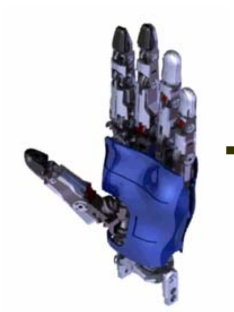


Sensory Feedback
Neural Integration Concept

Perception and User Modified Intent



Sensors

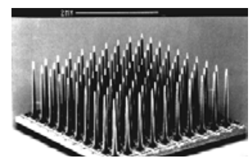


Sensors

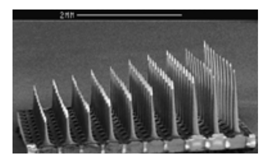
Proprioception
(position)

Tactile
(contact, pressure, temp)

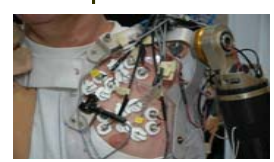
Sensory Feedback



Direct Somatosensory Stimulation



Peripheral Afferent Stimulation



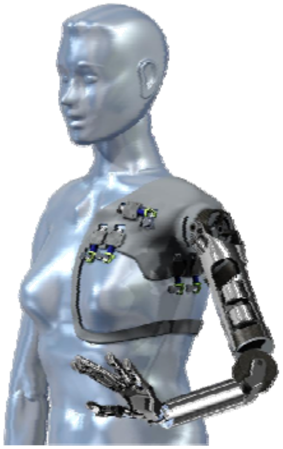
Multi-mode Haptic Displays

Embedded Intelligent Control Algorithms

Comfort & Appearance

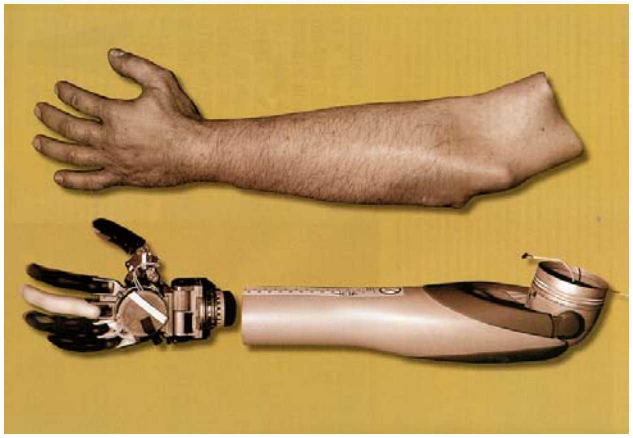
Body Attachment

- Investigating multiple volume accommodating and dynamic shape changing socket methods
  1. Pneumatic or air filled bladders
  2. Hydraulic or fluid filled bladders
  3. Vacuum attachment methods
  4. Electro-active Polymers
  5. Shape changing material structures



Cosmesis

- Exploring alternative materials and designs for reducing stress on joints
- Establishing metamerism insensitive color formula
- Testing for sensor performance (force, vibration, slip, thermal)
- Testing alternative mold designs to improve fabrication



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