

Implantable Telemetry

Robert Sobot

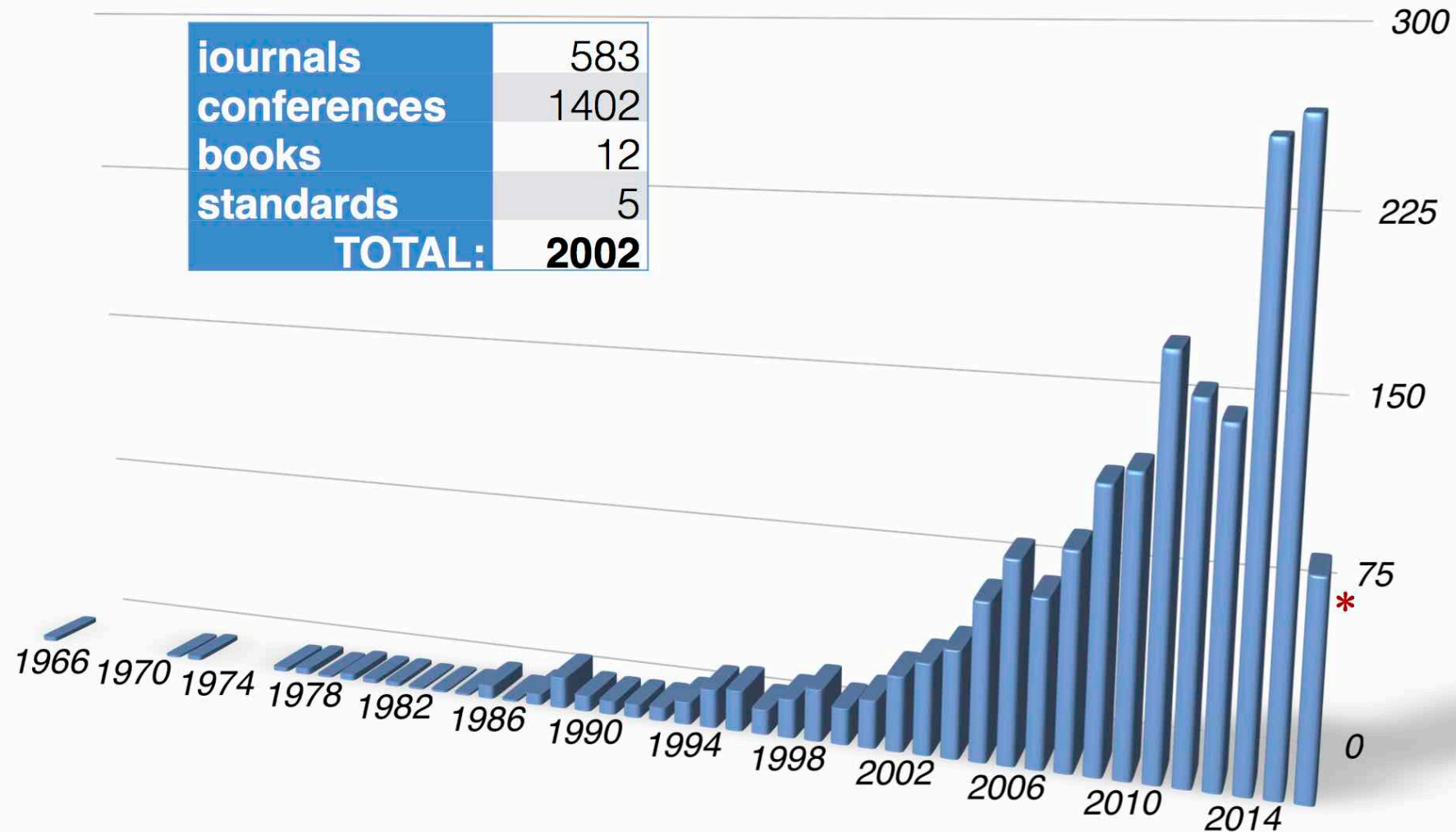
Professeur des universités, ETIS/ENSEA/CNRS/UMR 8051, France

Adjunct Professor, Western University, Canada

Synopsis

- Short history of technology
- Implantable devices
- Design case : PV cardiac monitoring system

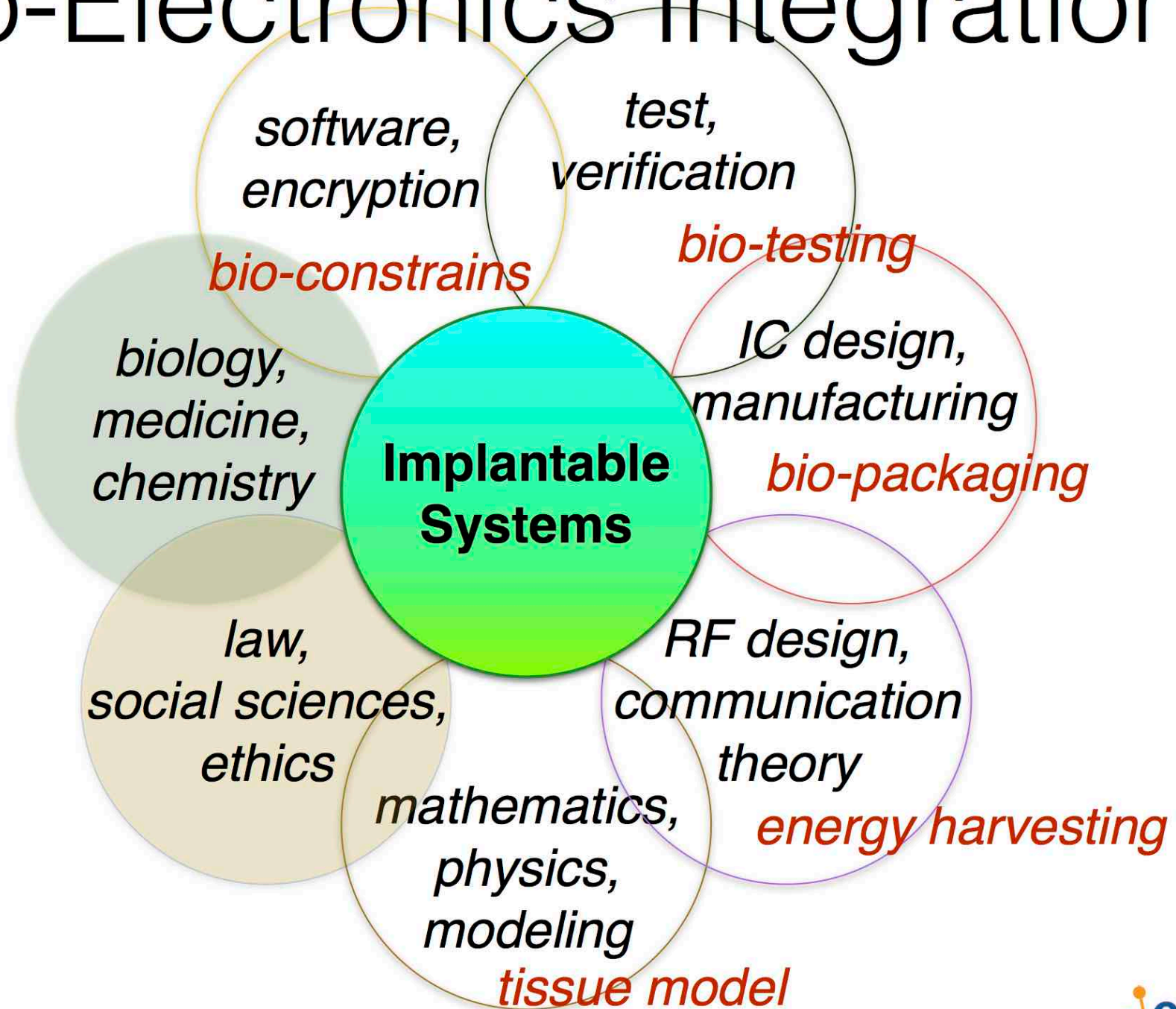
Implantable biomedical devices



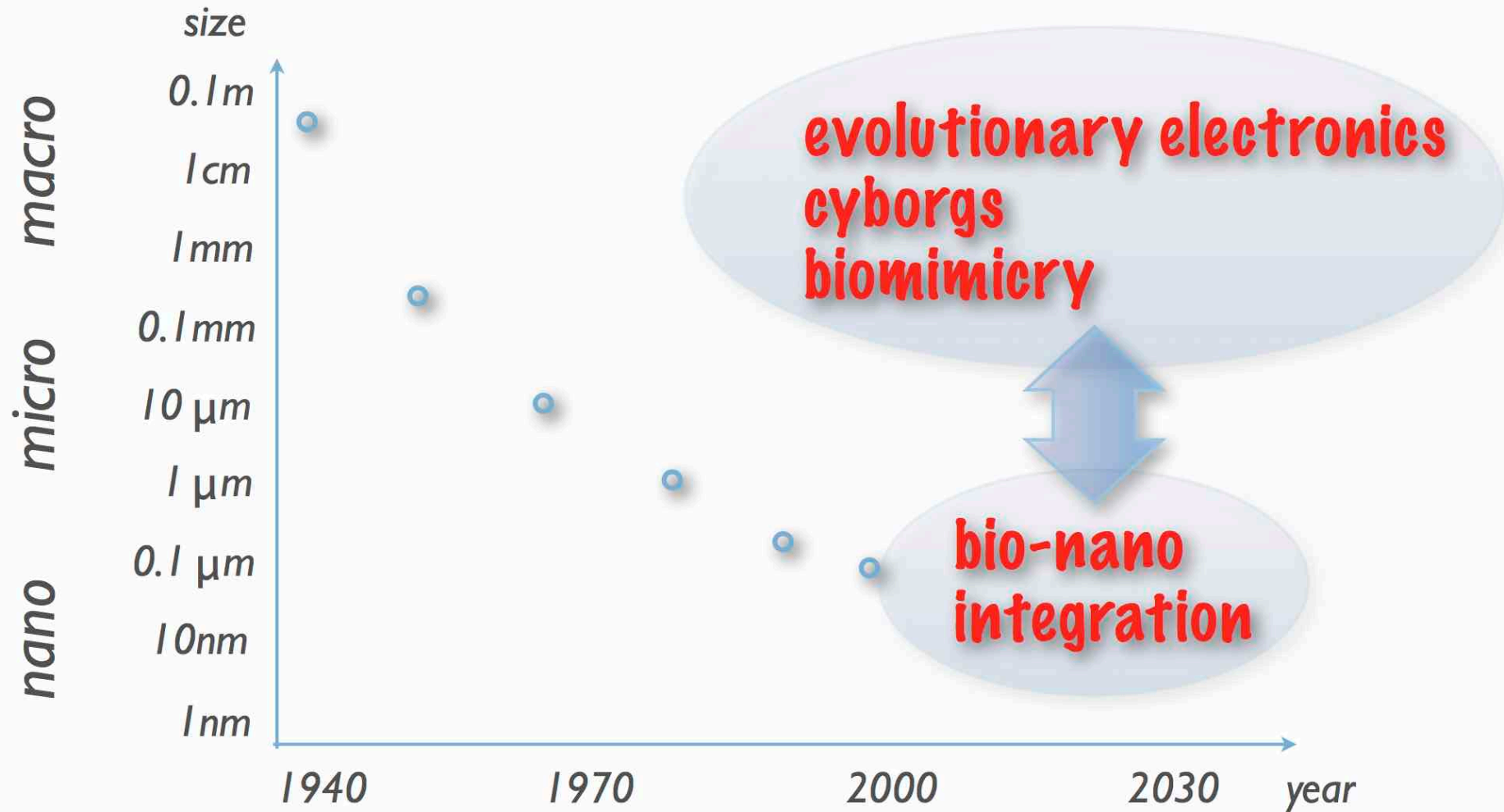
Source: IEEE Xplore - search on "implantable devices" (july 01, 2016)

* 2016 (partial data)

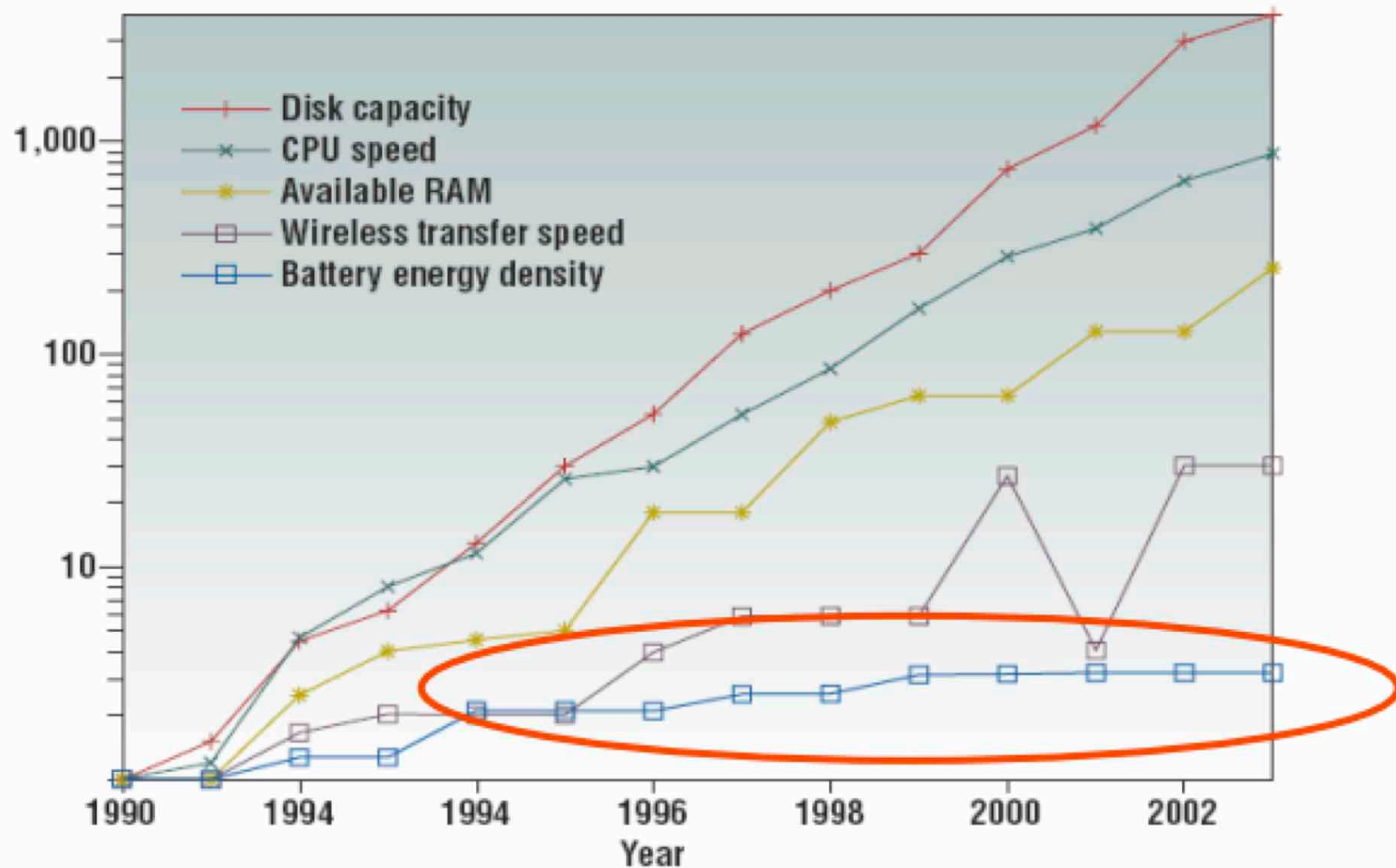
Bio-Electronics Integration



Bio-Electronics Integration

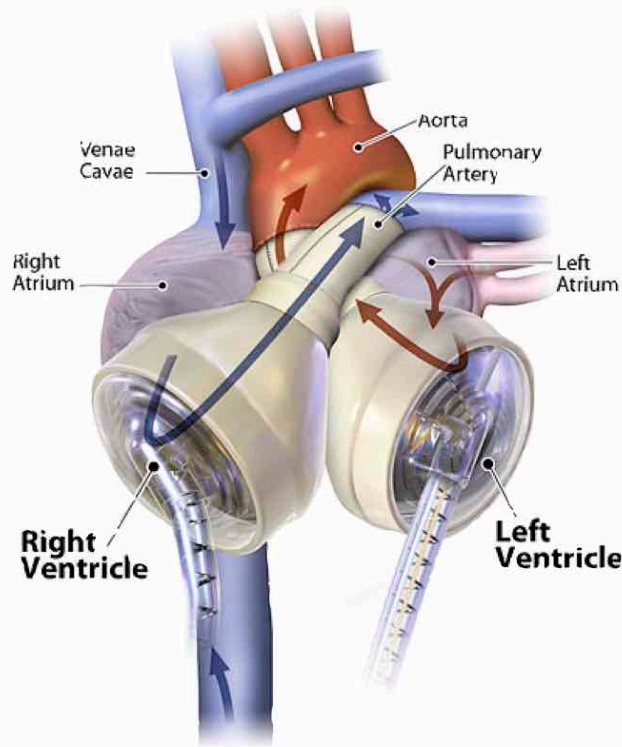


Moore's Law

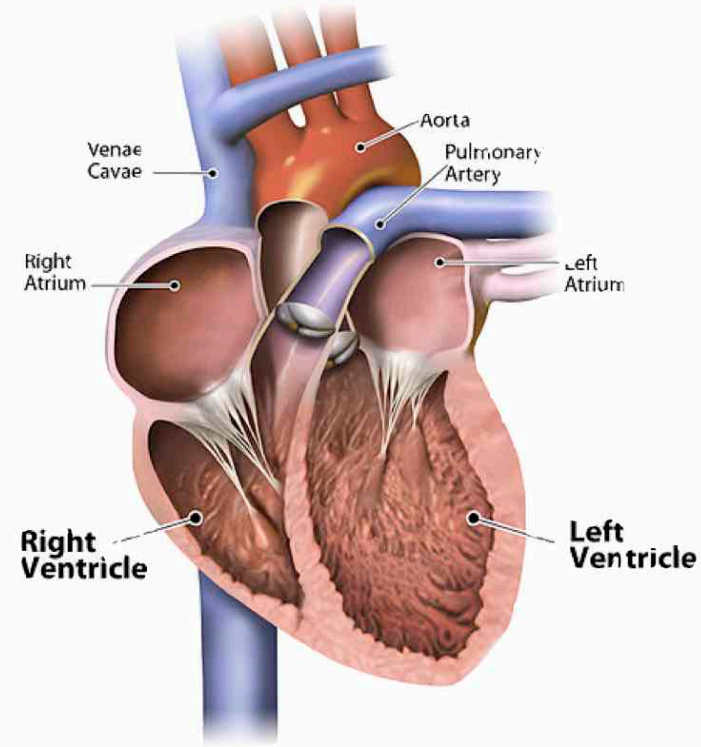


Mobile Computing Improvement – Paradiso, et al. Pervasive Computing, IEEE, 2005.

Why bio-nano integration ?



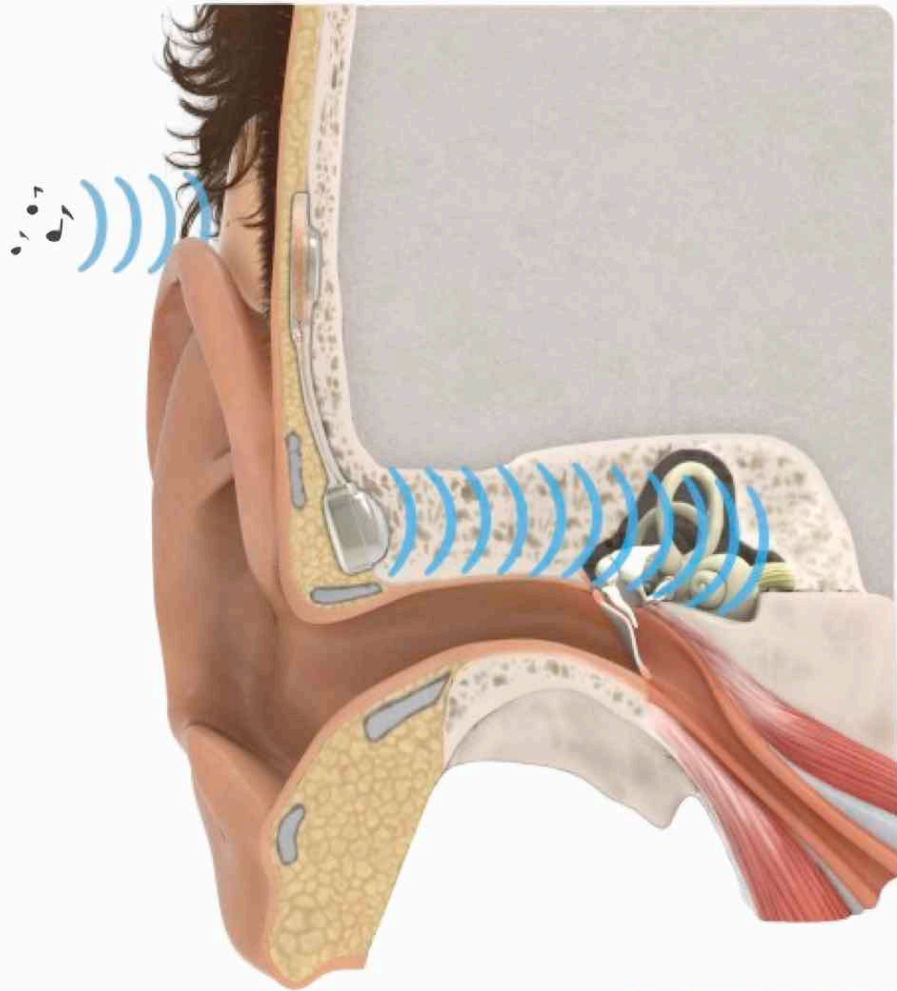
Total Artificial Heart



Human Heart

File source: wikipedia.org

Why bio-nano integration ?



File source: wikipedia.org

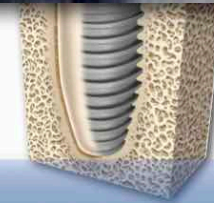
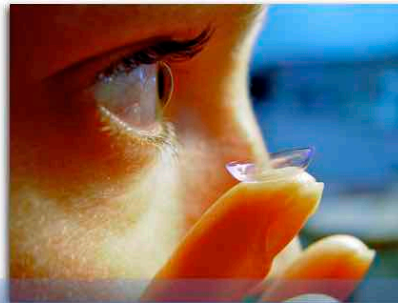
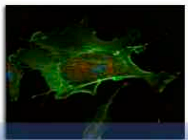
Artificial Hearing

- ☑ Humans are living longer
- ☑ We need medical care
- ☑ Technology integration with the human body is inevitable (maybe only as a transition phase, but still...)

Living to non-living interface

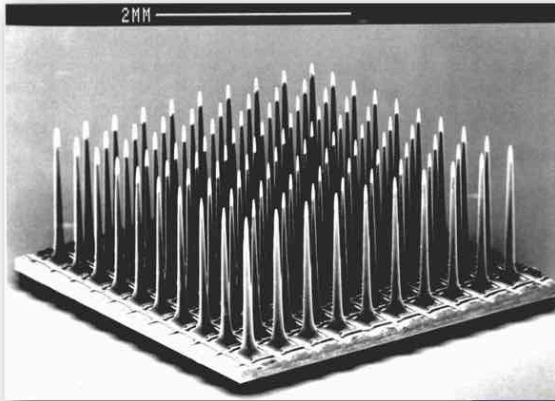
Body to technology distance :

- infinite
- external (shared)
- external (personal)
- internal (temporary)
- internal (permanent)
- iCyborg ?

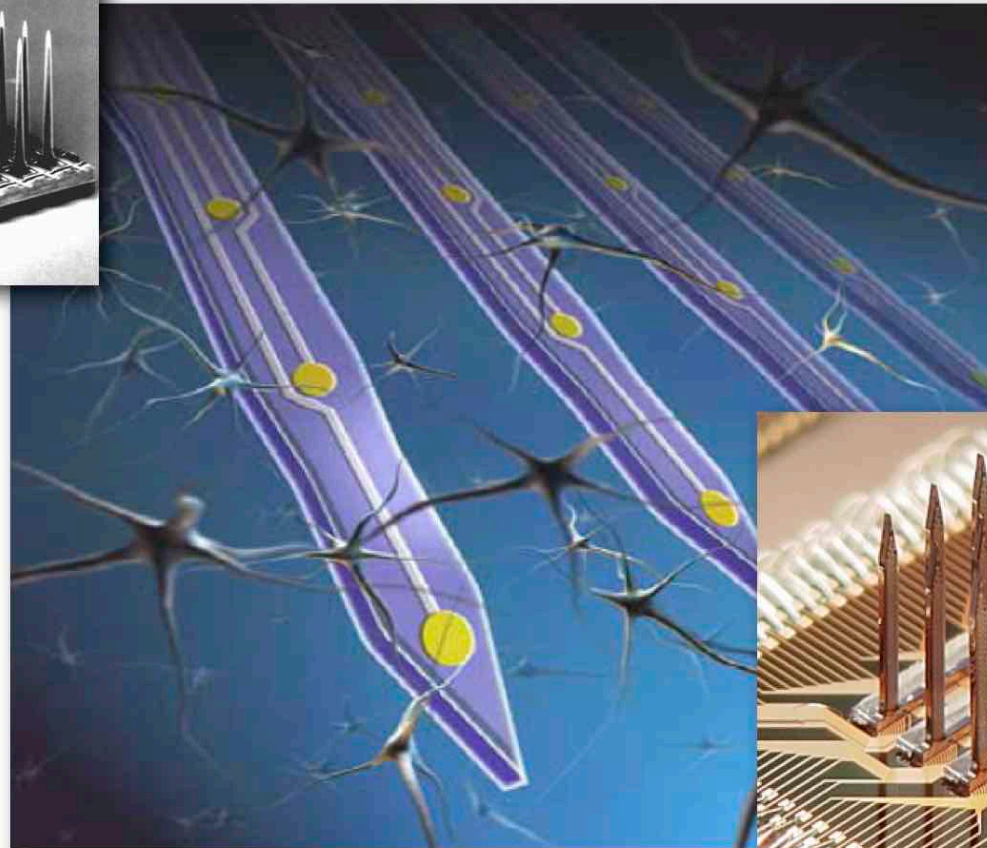


time

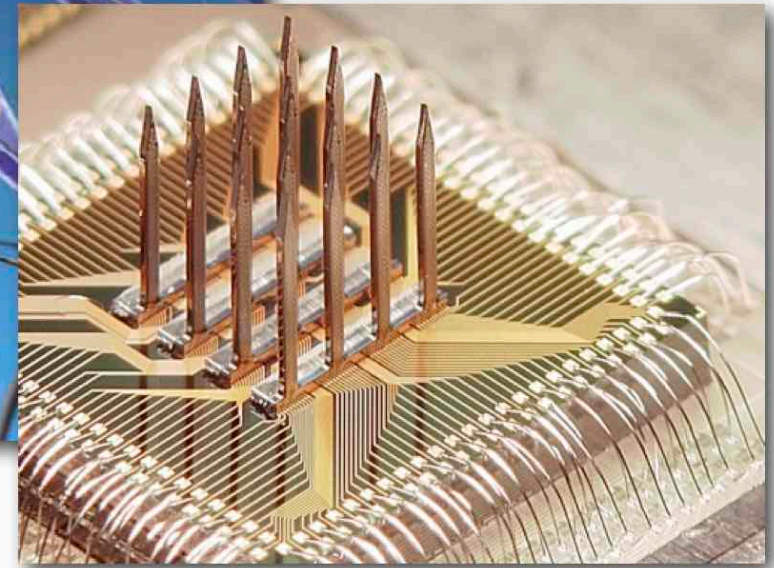
Living to non-living interface



Utah microarray



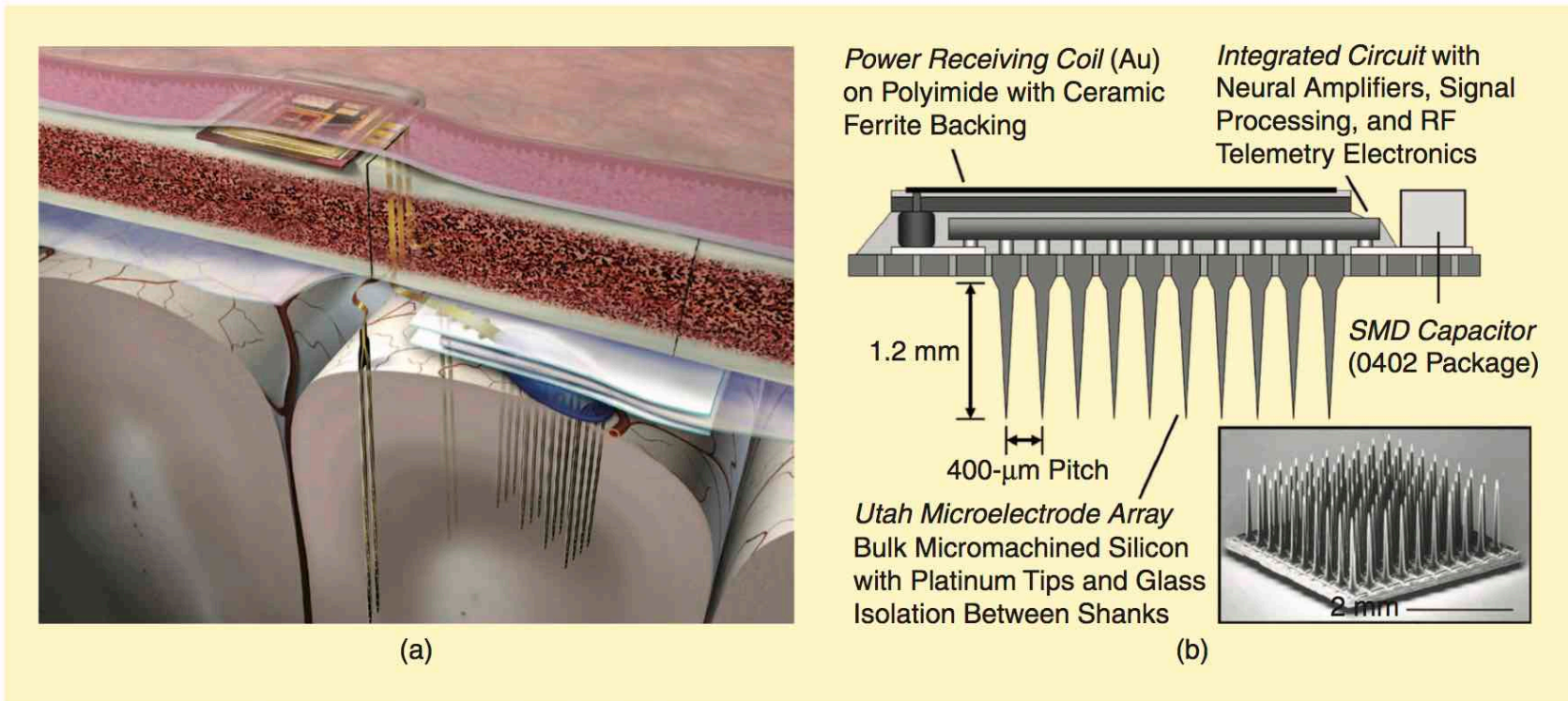
NeuroNexus Technologies



Living to non-living interface

Brain Computer Interface (BMI)

- 256 micro-electrodes interface, $\sim 15\text{mW}$, $\sim 30\text{mm}^2$ IC
- 4-8MHz inductive power link, 70-200MHz data link, 2Mb/s data rate

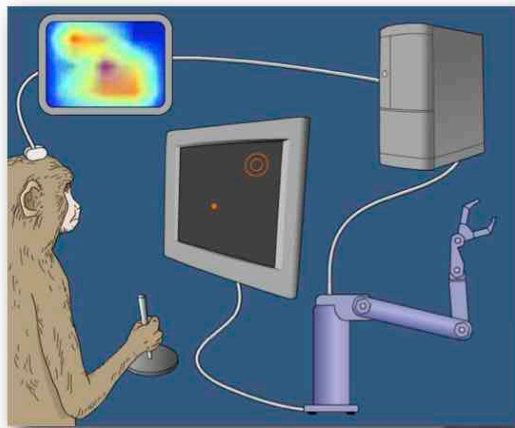


R. Bashirullah, Wireless Implants, IEEE Microwave Magazine, December 2010

Living to non-living interface

Brain Computer Interface (BMI) :

Magic of “mind control”



Prof. Miguel Nicolelis, Duke University



*Mr. Jessie Sullivan, Prof. Todd Kuiken,
Northwestern Medical School, Chicago*

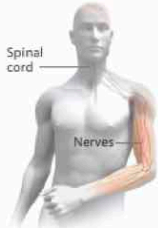
Bionic idea

“Enhanced human”


Closing in on a Lifelike Limb Close X

THE ABILITIES OF TODAY'S PROTO 1 BIONIC ARM WILL TRIPLE IN THE NEXT PROTOTYPE.


HUMAN ARM
22+ MOVEMENTS
From the shoulder to a finger's last joint, an arm has at least 22 points of movement. Nerves carry the brain's instructions from the spinal cord to the muscles.



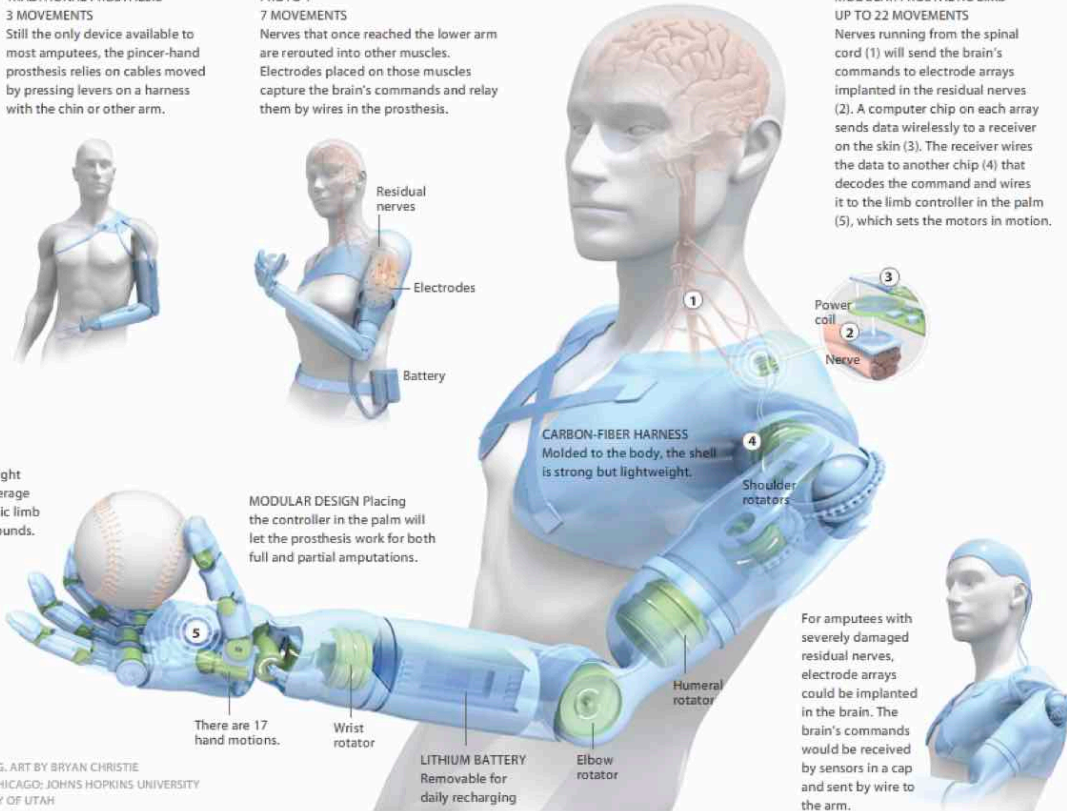
TRADITIONAL PROSTHESIS
3 MOVEMENTS
Still the only device available to most amputees, the pincer-hand prosthesis relies on cables moved by pressing levers on a harness with the chin or other arm.



PROTO 1
7 MOVEMENTS
Nerves that once reached the lower arm are rerouted into other muscles. Electrodes placed on those muscles capture the brain's commands and relay them by wires in the prosthesis.



MODULAR PROSTHETIC LIMB
UP TO 22 MOVEMENTS
Nerves running from the spinal cord (1) will send the brain's commands to electrode arrays implanted in the residual nerves (2). A computer chip on each array sends data wirelessly to a receiver on the skin (3). The receiver wires the data to another chip (4) that decodes the command and wires it to the limb controller in the palm (5), which sets the motors in motion.



WEIGHT Seven to eight pounds, like the average adult arm. The bionic limb can curl up to 60 pounds.

SENSORY DATA
Fingertip nodes will detect pressure, vibration, and temperature. The data will be sent wirelessly to the electrode arrays, then back through the nerves to the brain.

MODULAR DESIGN Placing the controller in the palm will let the prosthesis work for both full and partial amputations.

There are 17 hand motions.

LITHIUM BATTERY
Removable for daily recharging

Wrist rotator

Elbow rotator

Humeral rotator

Shoulder rotators

CARBON-FIBER HARNESS
Molded to the body, the shell is strong but lightweight.

Power coil

Nerve

For amputees with severely damaged residual nerves, electrode arrays could be implanted in the brain. The brain's commands would be received by sensors in a cap and sent by wire to the arm.

HIRAM HENRIQUEZ, NG STAFF; JENNY WANG, ART BY BRYAN CHRISTIE
SOURCES: REHABILITATION INSTITUTE OF CHICAGO; JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY; UNIVERSITY OF UTAH


NOI.com: Shawn Greene, Greg Harris, Paul Holtzel, Sabi Chawla, Stefan Estrada

Bionic idea


“Enhanced human”

The Bionic Body

Roll over the points and click on the icons at right to view information



An electrode array tacked to the retina circumvents damaged light-receptor cells and sends visual stimuli to the optic nerve.

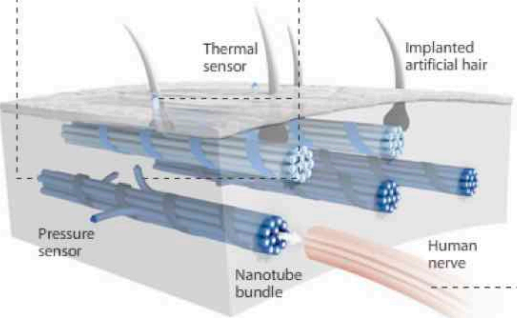


New Vision **Bionic Skin** **Lifelike Limb**

Engineering Bionic Skin

WITHIN 20 YEARS, ARTIFICIAL LIMBS COULD HAVE SKIN THAT SENSES TEMPERATURE AND TOUCH.

- 1 CARBON NANOTUBES are dispersed in a flexible polymer composite skin.
- 2 SENSORS distinguish between temperature and pressure.
- 3 SENSATIONS are picked up by the active endings of living nerves.



- Carbon nanotubes—1/10,000 as thick as a human hair—are the most efficient thermal and electrical conductors known.
- Nanotechnology will be used to create the water-resistant skin composite, shaped by lasers to be lifelike.
- FILMskin, a joint project of Oak Ridge National Laboratory and NASA, may also benefit burn victims.

ART BY BRYAN CHRISTIE
SOURCES: OAK RIDGE NATIONAL LABORATORY; NASA

Active Bionics (Multiple functions) **Passive Bionics** (Single function such as artificial replacements)


NGM.com: Shawn Greene, Greg Harris, Paul Heltzel, Sabi Chawla, Stefan Estrada

Bionic idea

“Enhanced human”

The Bionic Body

Roll over the points and click on the icons at right to view information



New Vision

- 1 VIDEO CAMERA sends images to a computer worn on a belt. The computer converts the video to a simplified signal.
- 2 TRANSMITTER sends the signal wirelessly to an implant in the eye.
- 3 RECEIVER sends the signal to the electrode array to stimulate the retina.
- 4 OPTIC NERVE carries the signal from retina to brain, which perceives visual patterns corresponding to the electrodes stimulated.

Patients learn to interpret the visual patterns produced.


Power and data processing provided by belt computer.

ART BY BRYAN CHRISTIE
SOURCES: SECOND SIGHT
MEDICAL PRODUCTS;
DOHENY EYE INSTITUTE

Active Bionics
(Multiple functions)

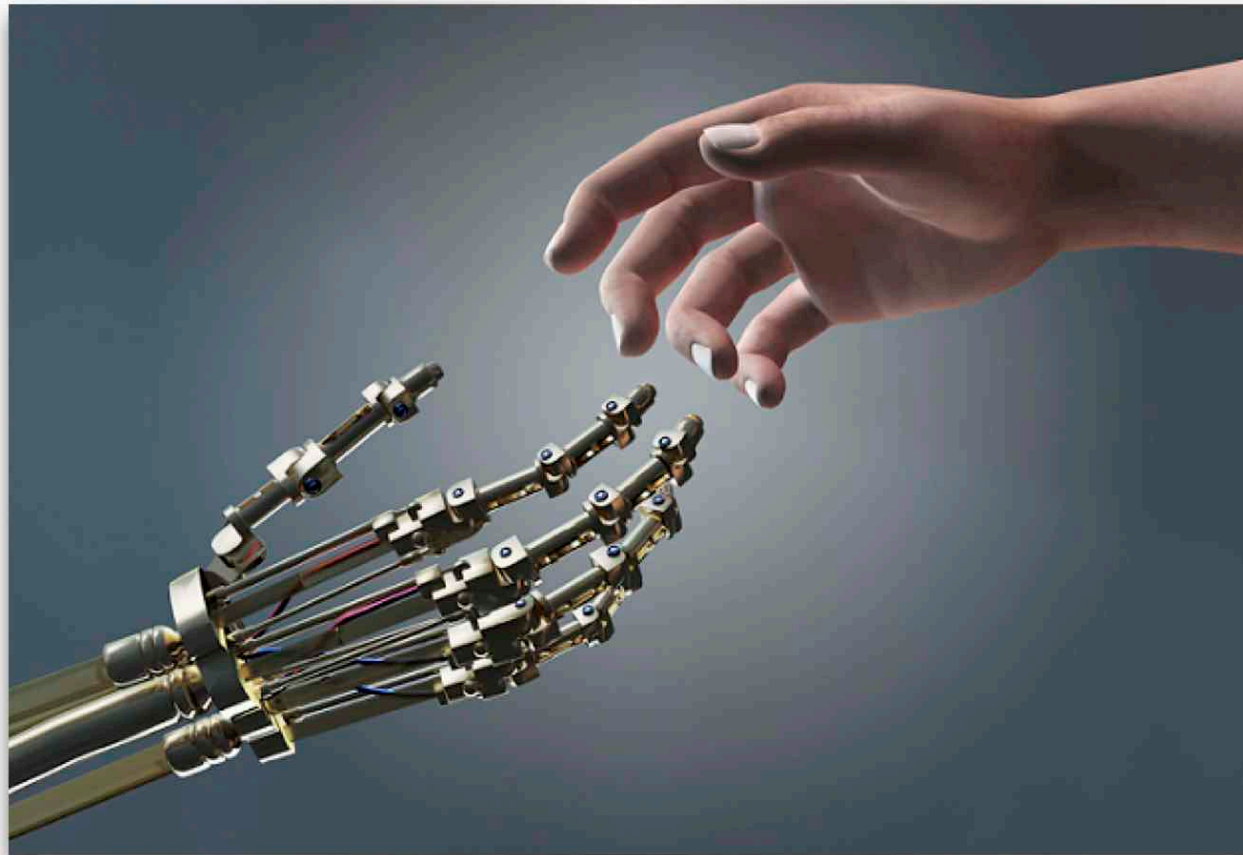
Passive Bionics
(Single function such as artificial replacements)

NGM.com: Shawn Greene, Greg Harris, Paul Heltzel, Sabi Chawla, Stefan Estrada



Living to non-living interface

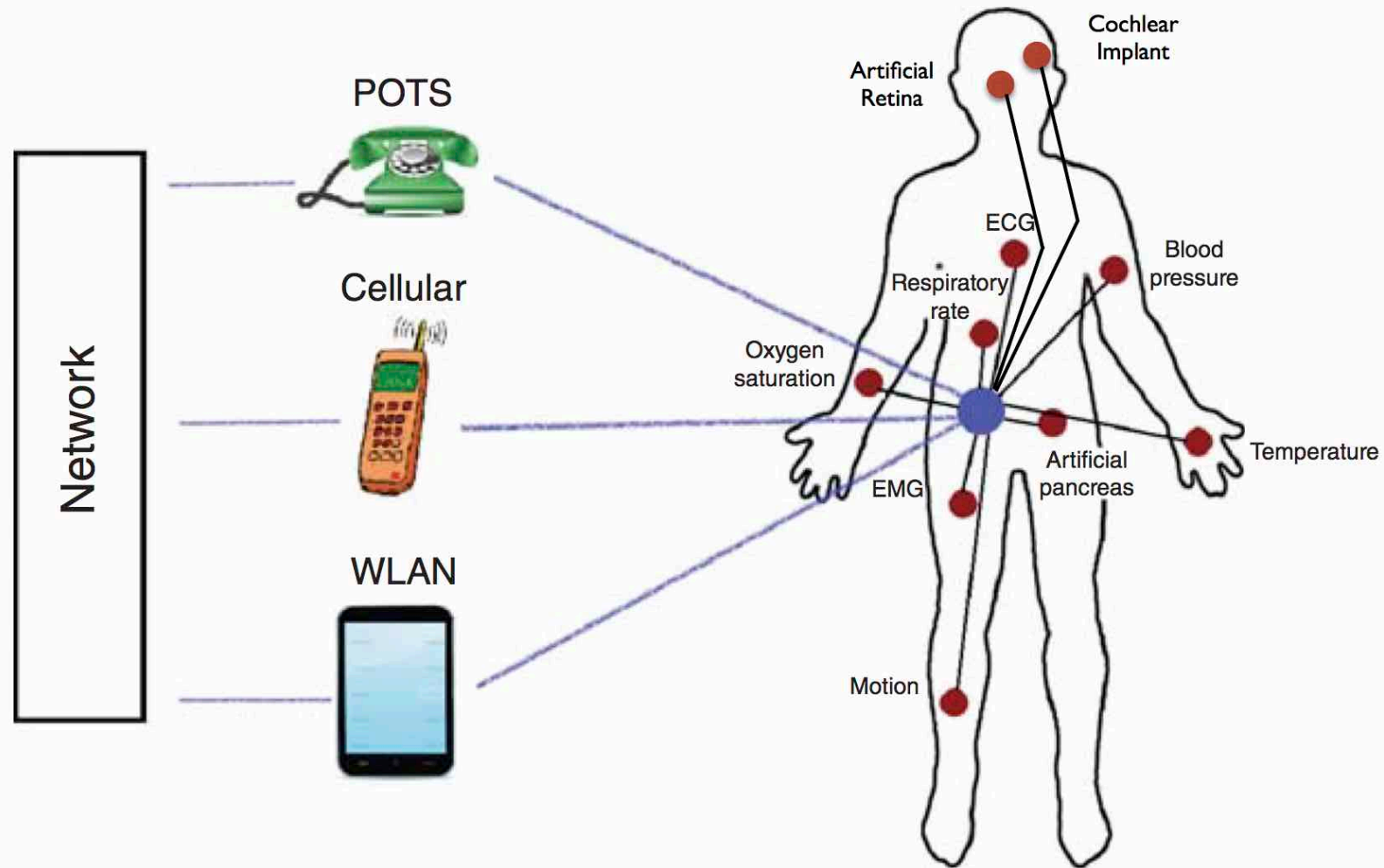
“Missing links” : where is the border between the human and the machine ?



<http://www.watchdocumentary.tv/future-human-2-the-cyborg-revolution-documentary/>

Implantable Technology Today

Telemetry systems :



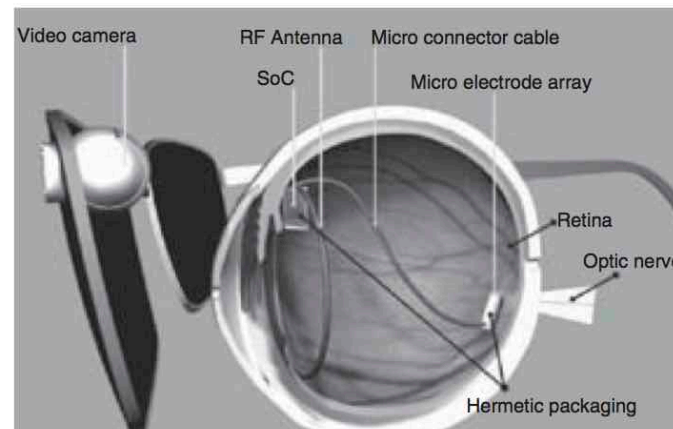
K.S. Nikita, ed.

Handbook of Biomedical Telemetry, First Edition © 2014 John Wiley & Sons, Inc.

Implantable biomedical devices

Categories :

- Wearable devices
- Implantable devices
- Ingestible devices

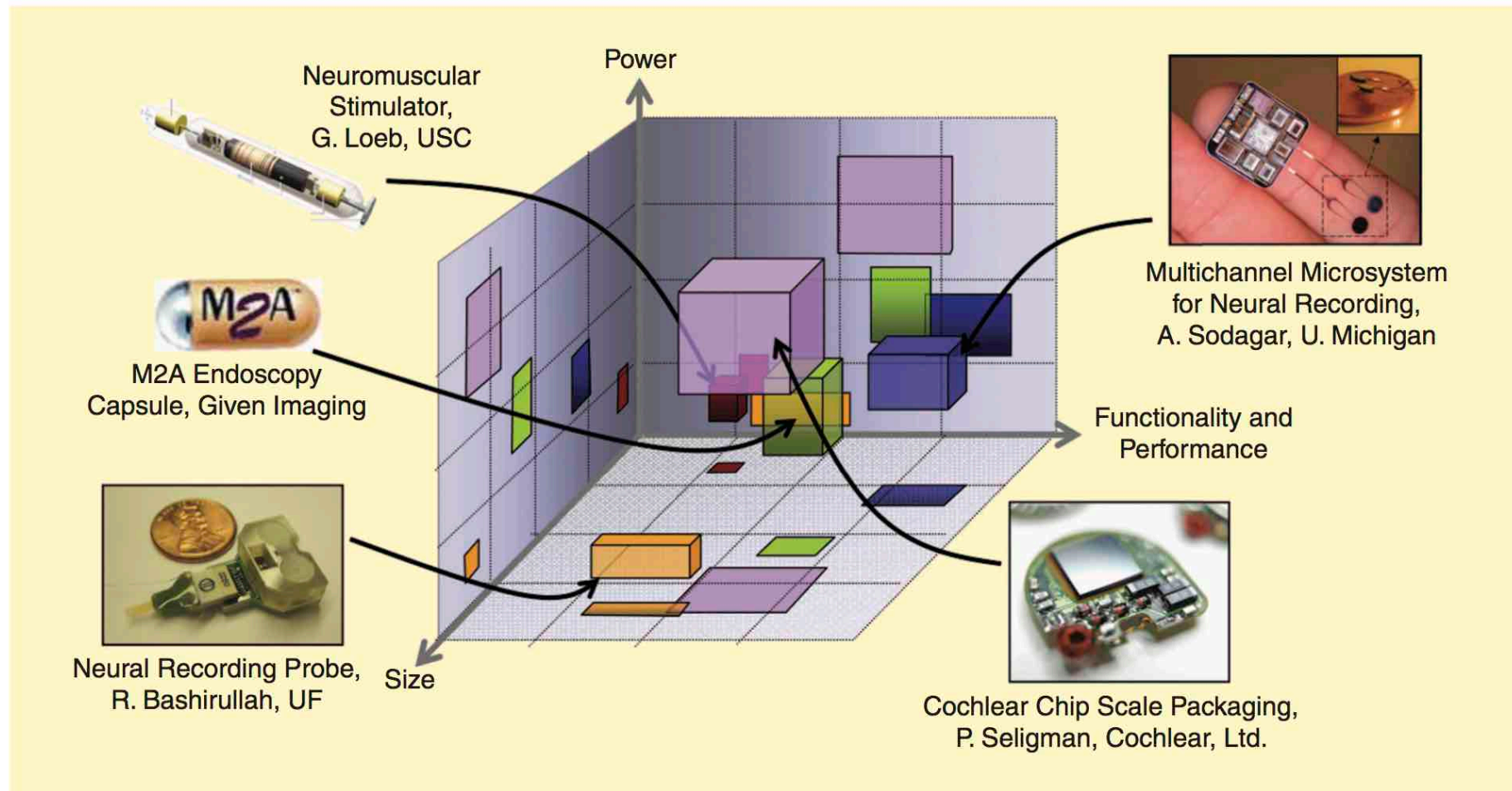


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Implantable biomedical devices

System's parameter space :



R. Bashirullah, Wireless Implants, IEEE Microwave Magazine, December 2010

Implantable biomedical devices

Applications and power requirements :

Device	Power	Life-Time	Energy Source
Biomonitoring System	<100 μ W	NA	Primary Battery
Pacemaker	<100 μ W	10 Years	Primary Battery
Cardioverter-Defibrillator	Cont: <100 μ W Peak: 5–10 W	10 Years	Primary Battery
Cochlear Processor	200 μ W	1 Week	Rechargeable Battery
Hearing Aid	100–2,000 μ W	1 Week	Rechargeable Battery
Retinal Implant	40–250 mW	NA	Inductive Power
Neural Recorder/Stimulator	1–100 mW	NA	Inductive Power
Artificial Heart	10–100 W	NA	Inductive Power

R. Ritter, J. Handwerker, T. Liu, M. Ortmanns

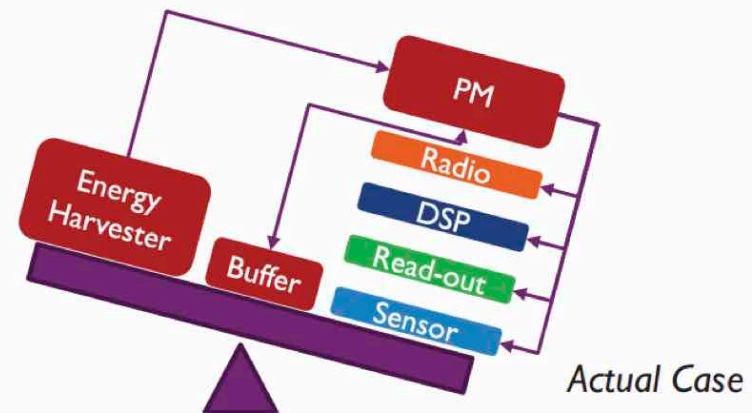
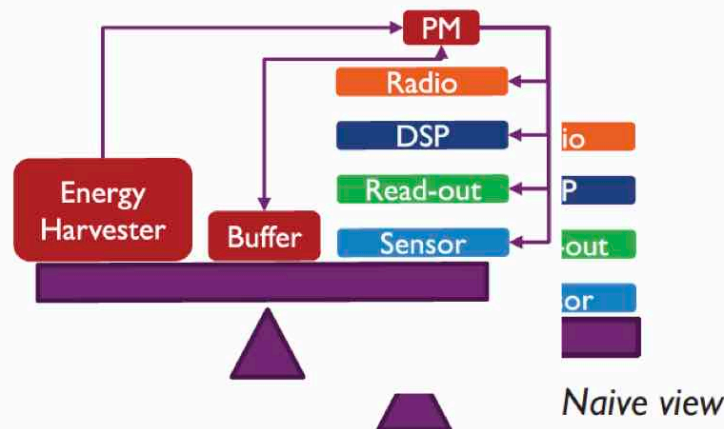
Telemetry for Implantable Medical Devices : Part 1–Media Properties and Standards

IEEE SOLID-STATE CIRCUITS MAGAZINE, Spring 2014, p.47–51

Implantable biomedical devices

Power management

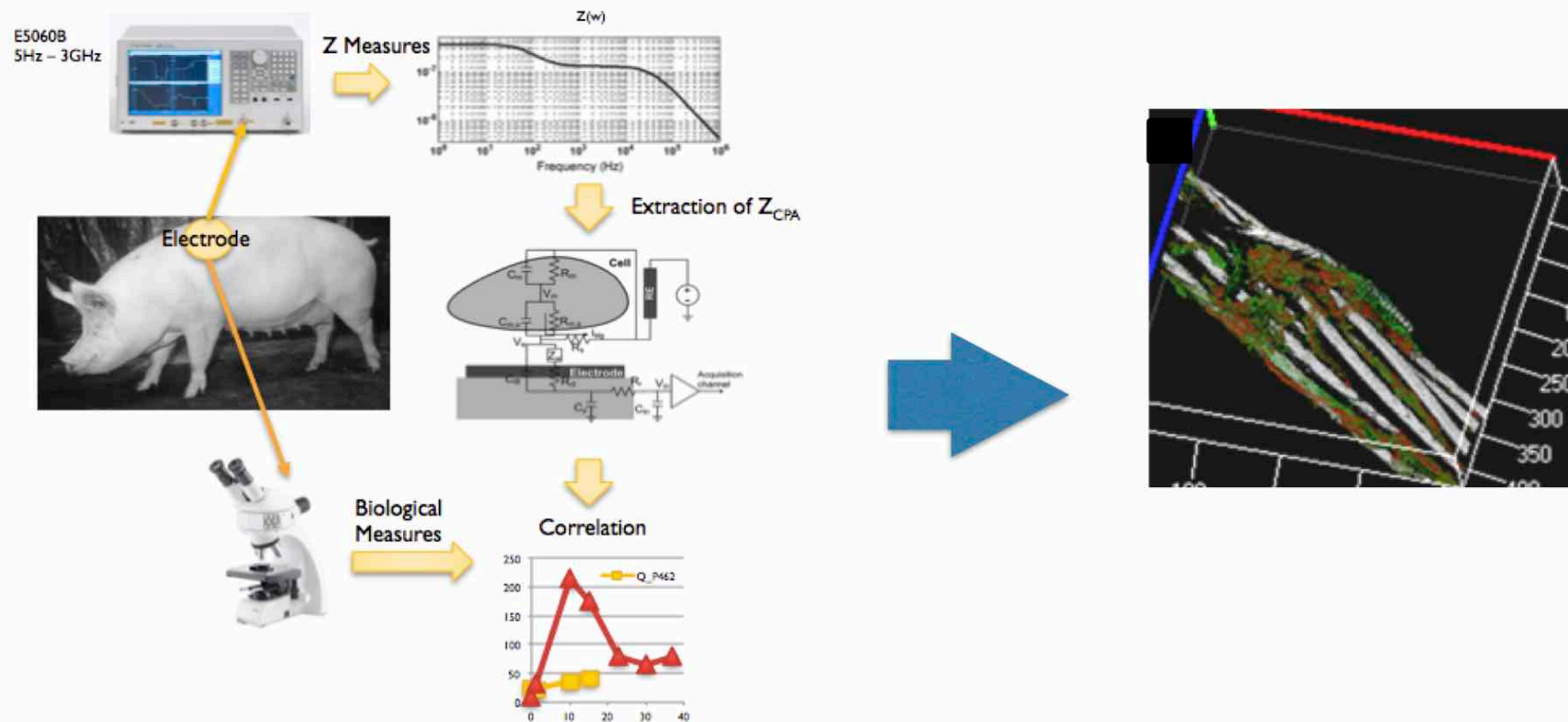
- power usage must be minimized
- application specific IC design
- must increase the overall efficiency



Implantable biomedical devices

Fibrosis issues :

- long term implantable devices induce fibrosis



N. Lewis et al. Study of fibrosis induced by an implanted medical device

Implantable biomedical devices

Possible attacks :

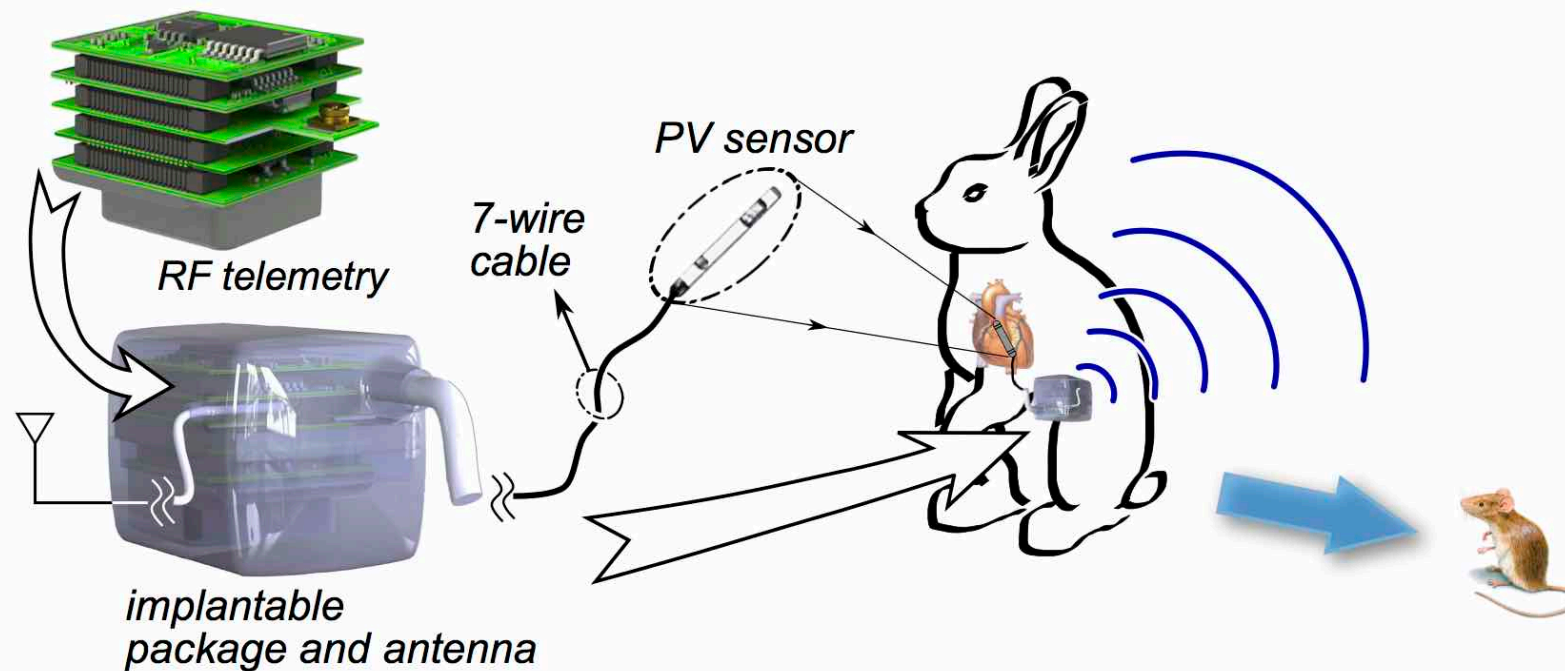
- Data harvesting
- Cloning
- Relay attack
- Physical compromise

Countermeasures :

- Limit the amount of data
- Distance measurement
- Blocking (using second tag)
- Authenticate readers
- Minimalistic cryptography

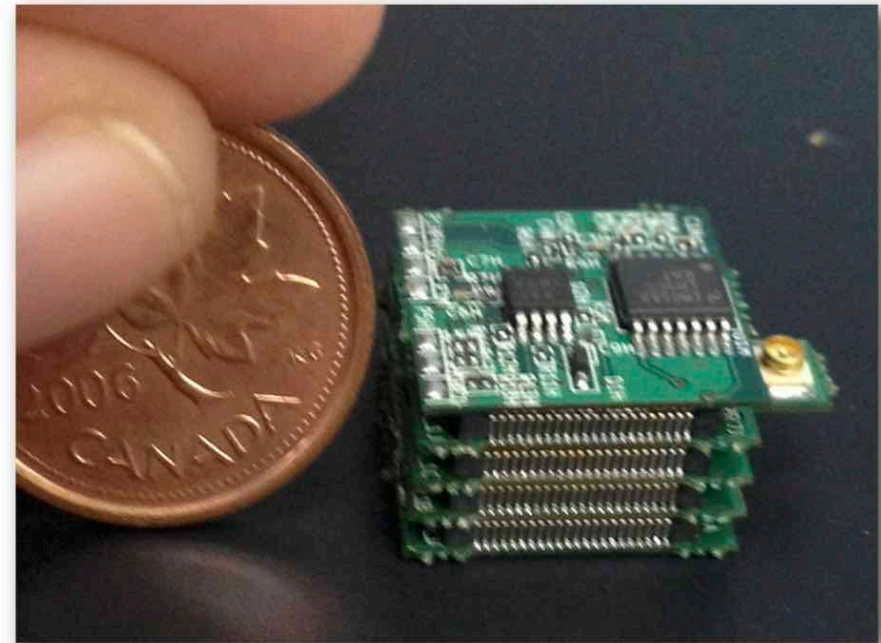
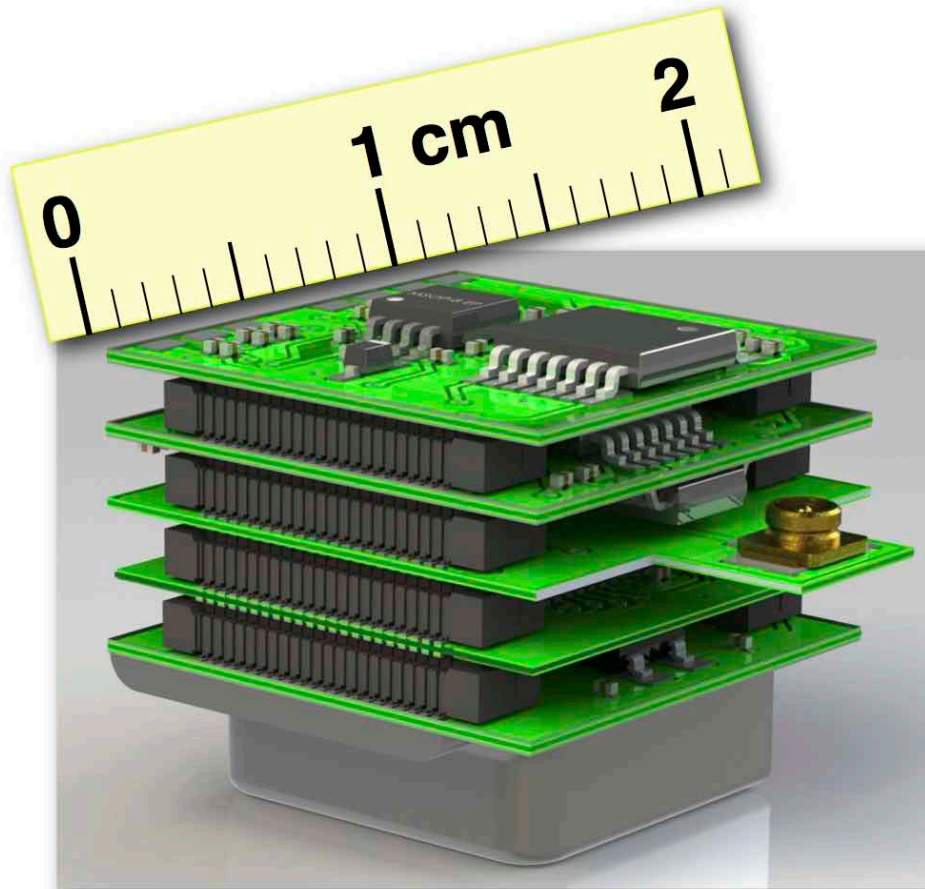
Implantable telemetry

Design case : PV cardiac monitoring



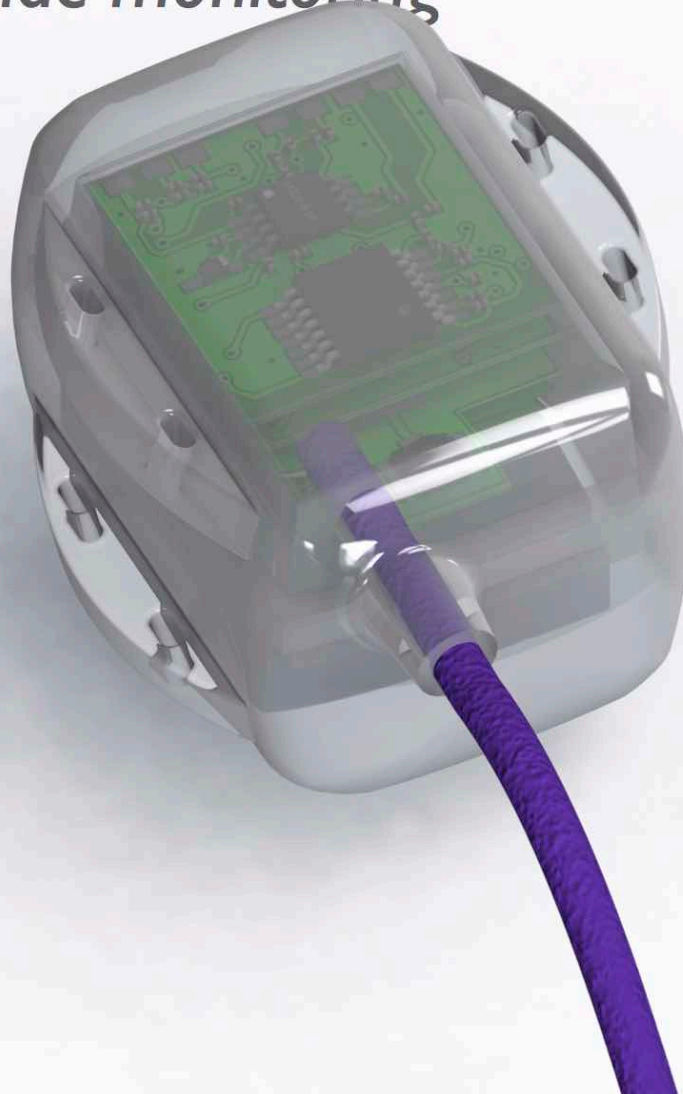
Implantable telemetry

Design case : PV cardiac monitoring



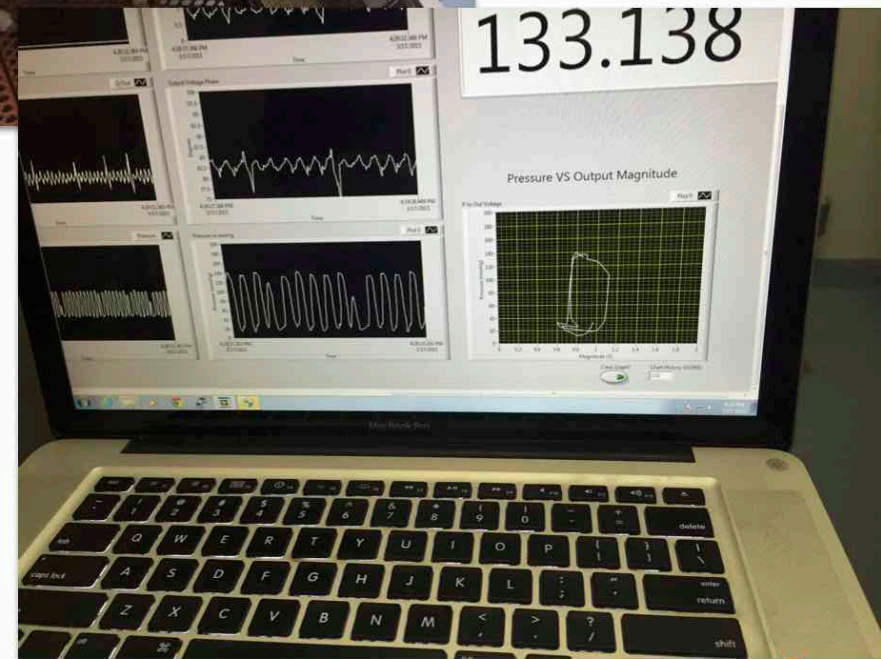
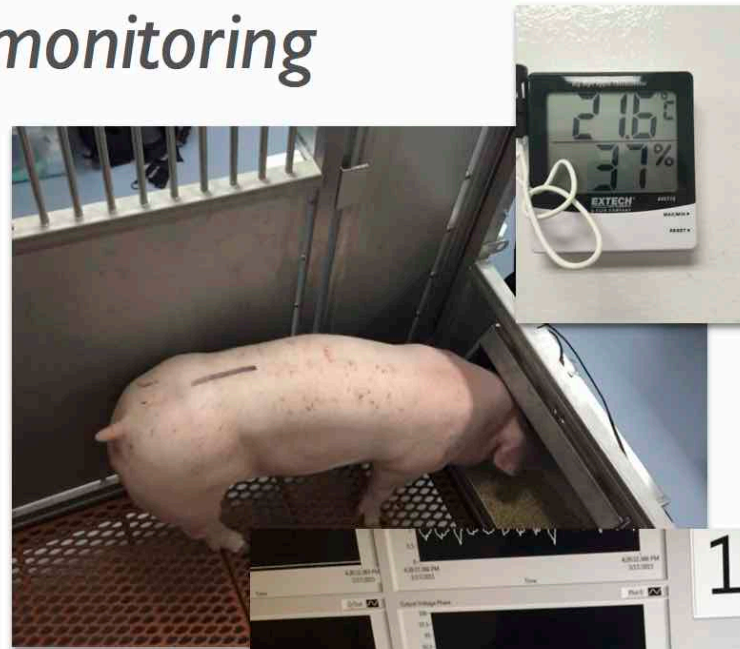
Implantable telemetry

Design case : PV cardiac monitoring



Implantable telemetry

Design case : PV cardiac monitoring



Multidisciplinary research

- medicine: cardiology, genetics, ...
- physics: biophysics, sensors...
- mixed-signal processing
- electronics, analog IC design
- communication theory, RF circuits
- semiconductor technology and manufacturing
- IC and biomedical test and characterization
- software tools IT support, cadence, EM solvers,...
- ... and, of course, ...

