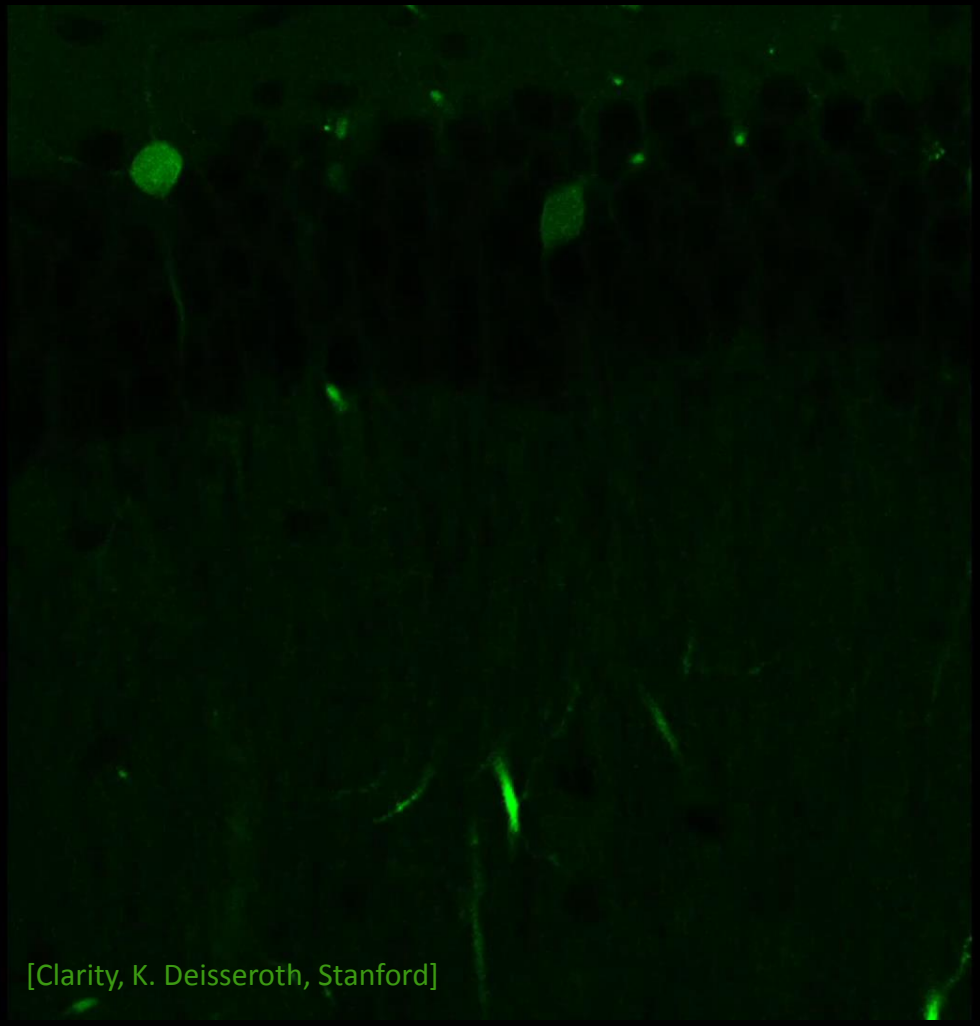
Innovation is "in" the Mind



[Clarity, K. Deisseroth, Stanford]

The Converging Trajectories of IT, Neuro and nano

Jan M. Rabaey
University of California @ Berkeley

The “Reverse Time Machine” Approach to Engineering Innovation

[* Term coined by D. Culler, UCB]

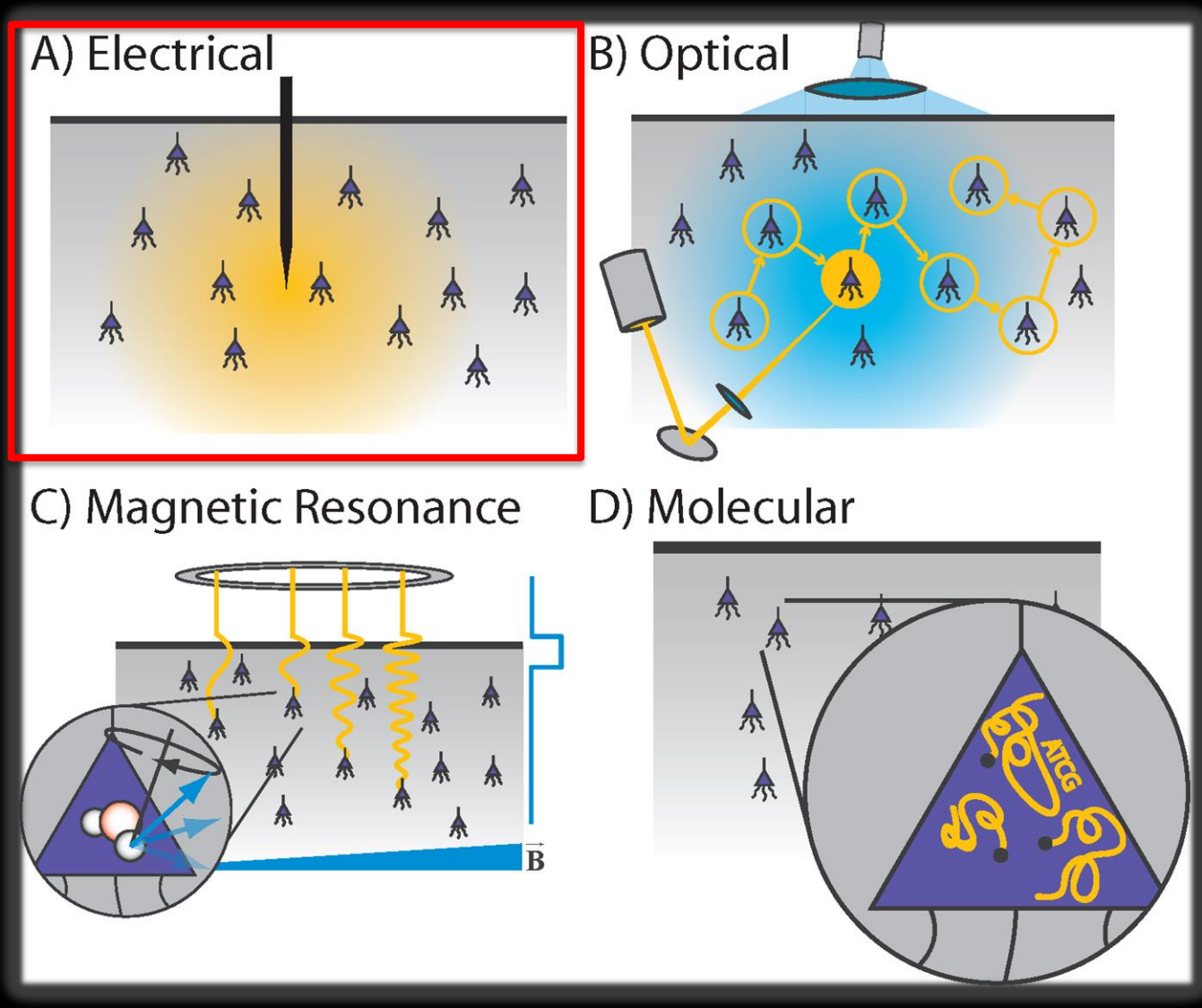
21st Century Question:

"What if electronic sensor/processor nodes approach biological cell sizes?"

Many options …
Obviously!

Just to pick a very exciting one:
Scaling the brain-cyber barrier!

Interfacing with the Brain



[Courtesy: Marblestone at el, arxiv.org 2013]

Brain-Machine Interfaces in the News

Samsung Imagines a Future With Mind-Controlled Tablets

By Jeremy Hsu
Posted 25 Apr 2013 | 15:23 GMT

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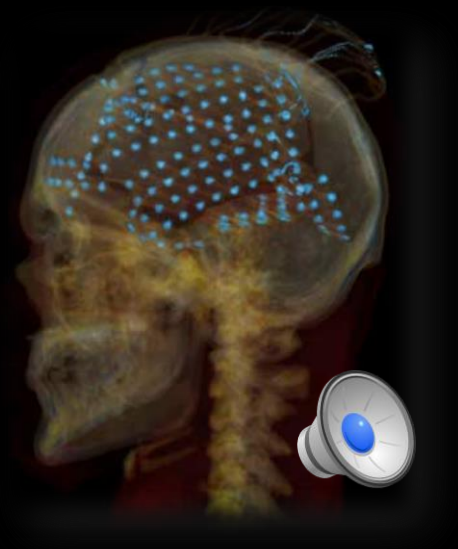
Mind over matter helps paralysed woman control robotic arm

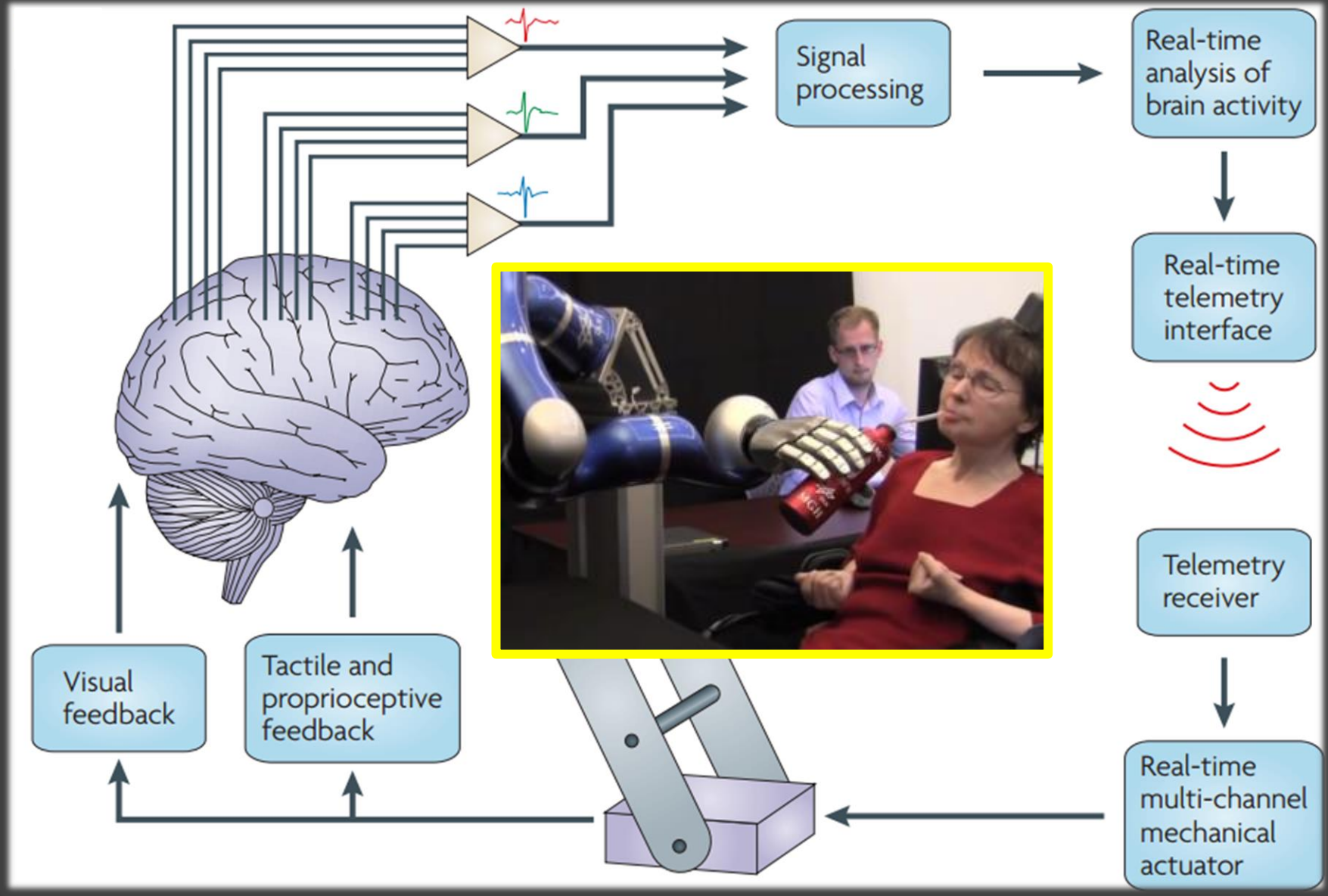
Doctors in Pittsburgh stunned at ability of patient who has reached levels of performance never seen before



Listening to the voices inside your head

"Neuroscientists may one day be able to hear the imagined speech of a patient unable to speak due to stroke or paralysis, according to University of California, Berkeley researchers." [Pasley at al, PLOS12]

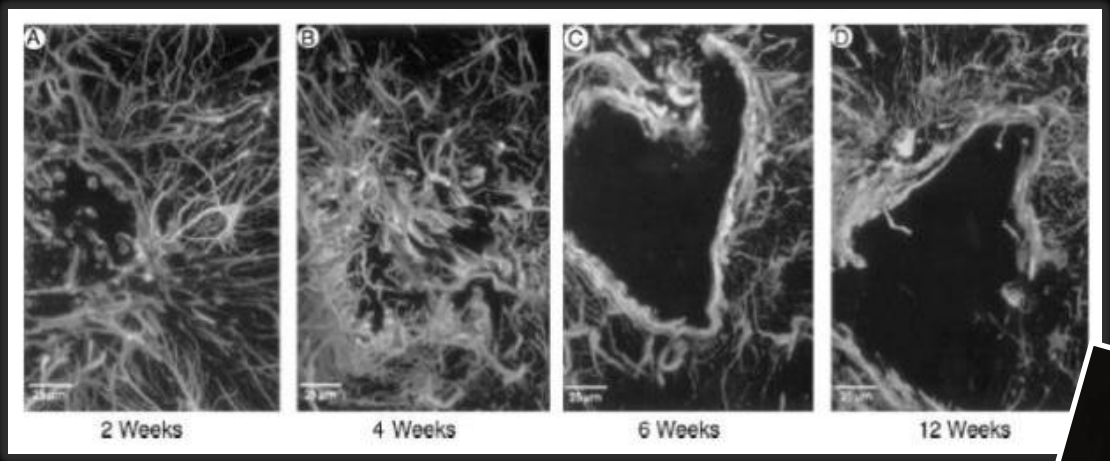
BMI Paradigm



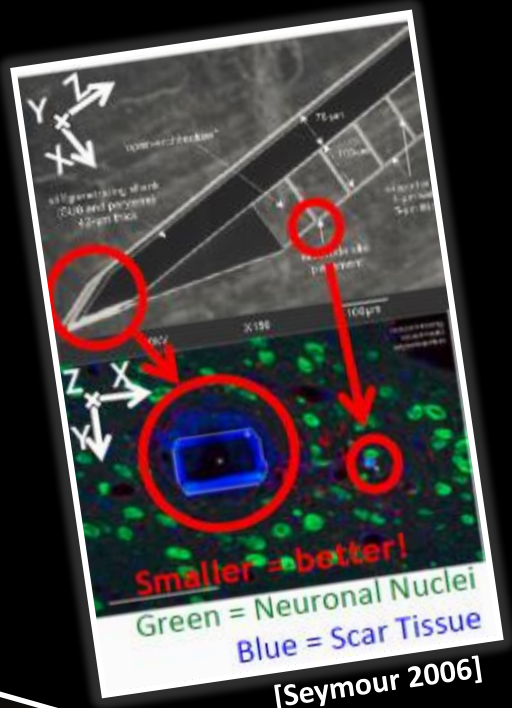
BMI Challenge: Longevity

Clinical neural implants active for at most a year

- Not sufficient for **chronic** BMI implants



[Turner 1999]

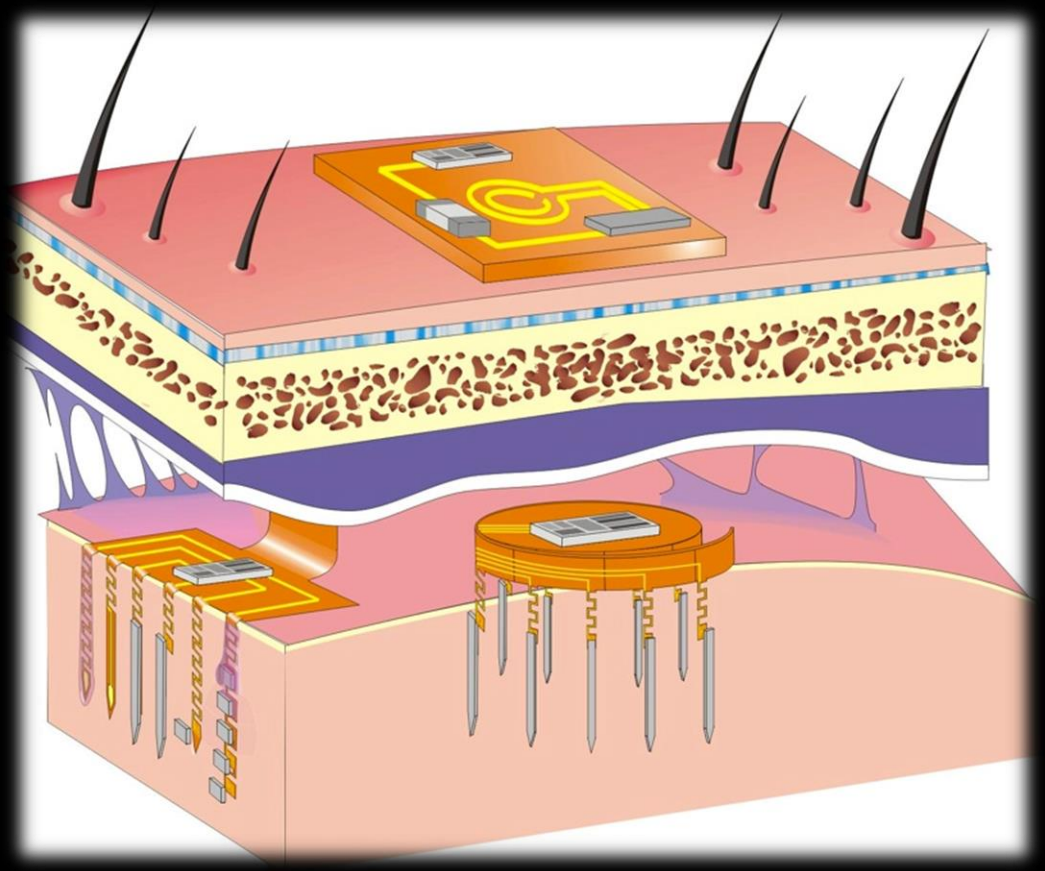


[Seymour 2006]

- Recorded signal quality is reduced by scar tissue formation
- Cables cause infection
- Packaging

[Hochberg, Nature '06]

The Berkeley Brain-Machine Interface (BMI) - Combining μECoG and "Neural Dust"



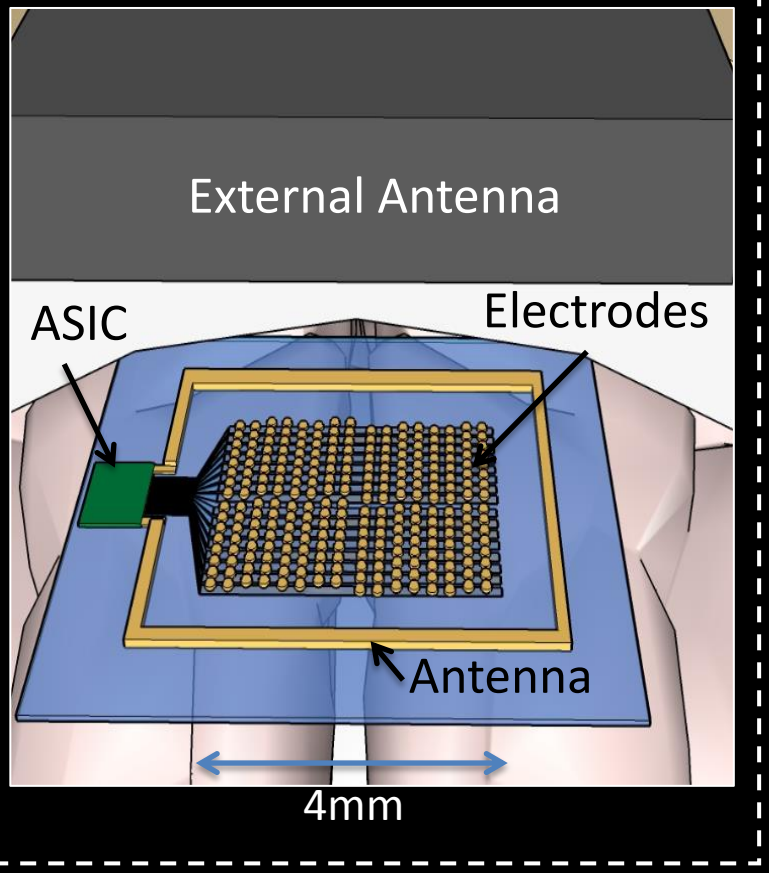
"An implanted neural interface that can provide imaging (and possibly stimulation) of neural activity at multiple scales of resolution using arrays of patterned and free-floating sensors"

Achieving reliability and longevity

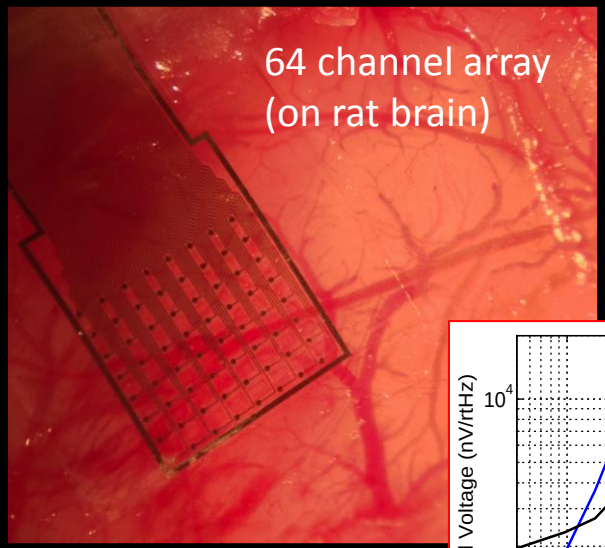
- Microscopic, compliant, and flexible (!)
- Wireless powering and data communications
- Tons of selectable channels

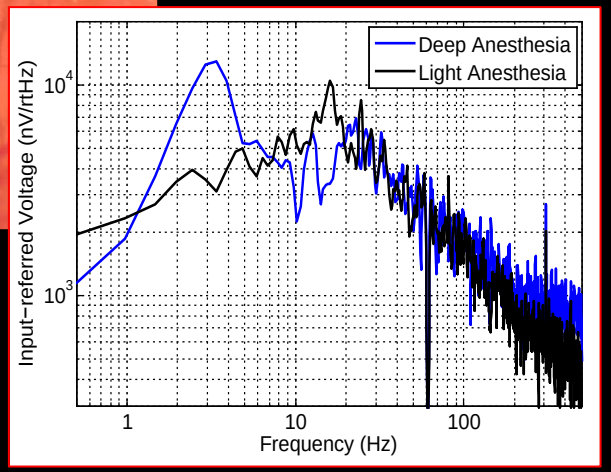
[A collaborative effort between BWRC, UCB Engineering, UCB Neuroscience, and UCSF NeuroSurgery (as part of the CNEP Center)]

A Global View with Wireless µECoG



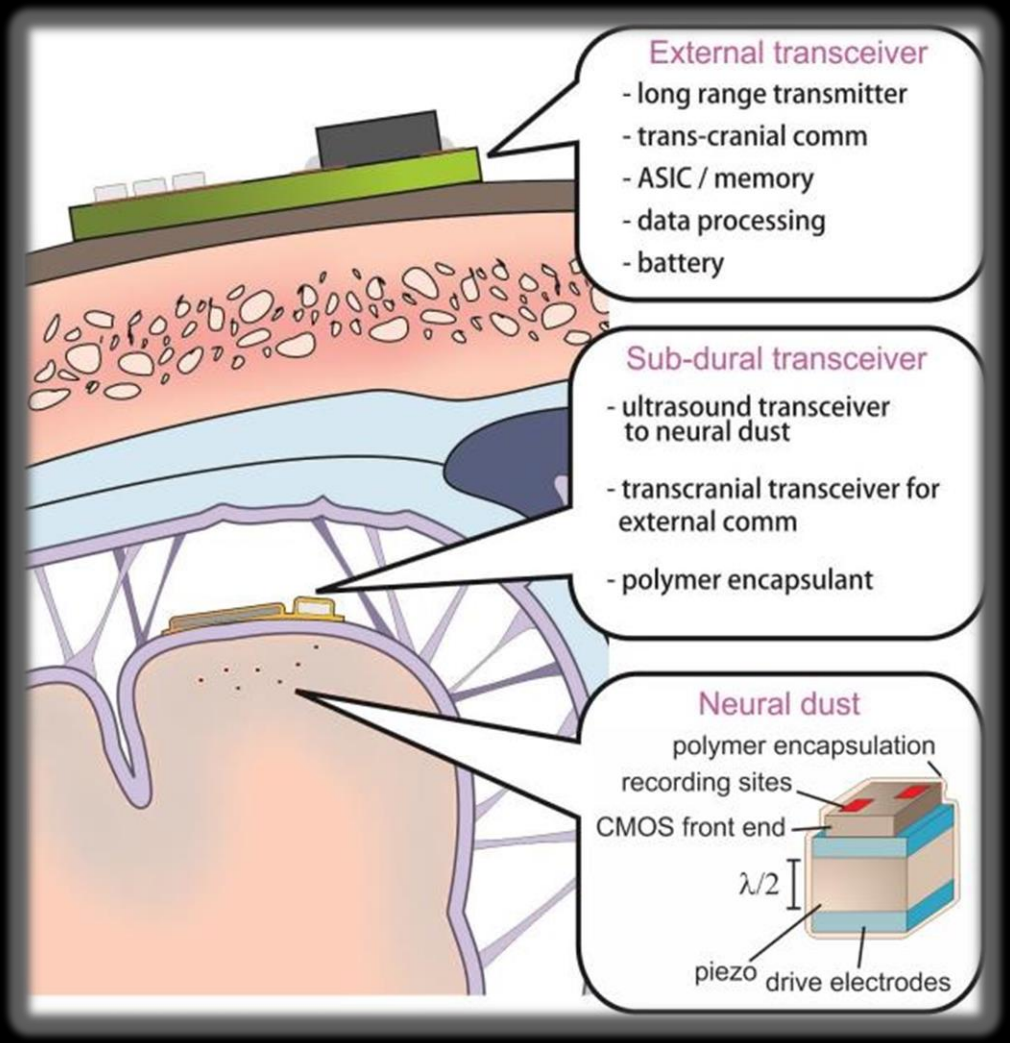
- Up to 1000 channels with pitch as low as 200 µm, providing unprecedented resolution
- Antenna + electrodes printed on parylene substrate using semiconductor-like process
- Offering huge potential for BMI (ALS, Epilepsy).





[Courtesy: P. Ledocowich, R. Muller, M. Maharbiz, J. Rabaey]

“Neural Dust” to Provide Focus



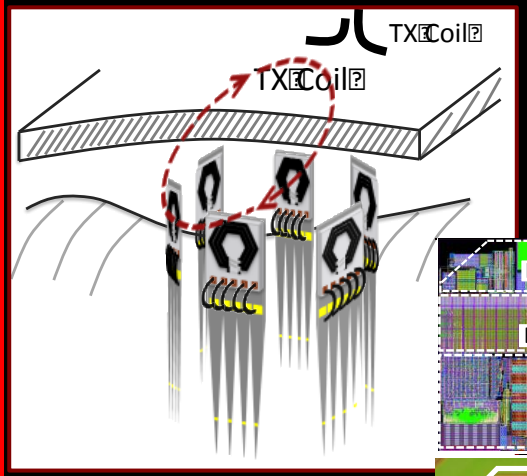
~50 µm sensor nodes embedded in cortex

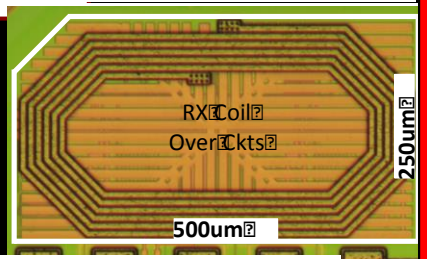
Ultrasound powering and communication to dust

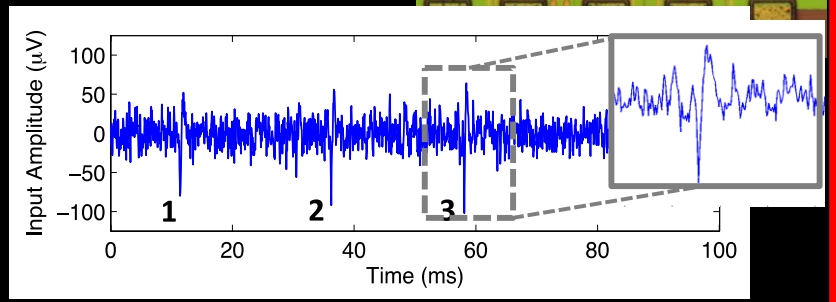
EM link from hub to external transceiver

[DJ Seo et al, Arxiv, June 2013]

Neural dust v0







[Yeager et al, VLSI, June 2012]

Some profound questions!

The opportunities are huge! So are the concerns …

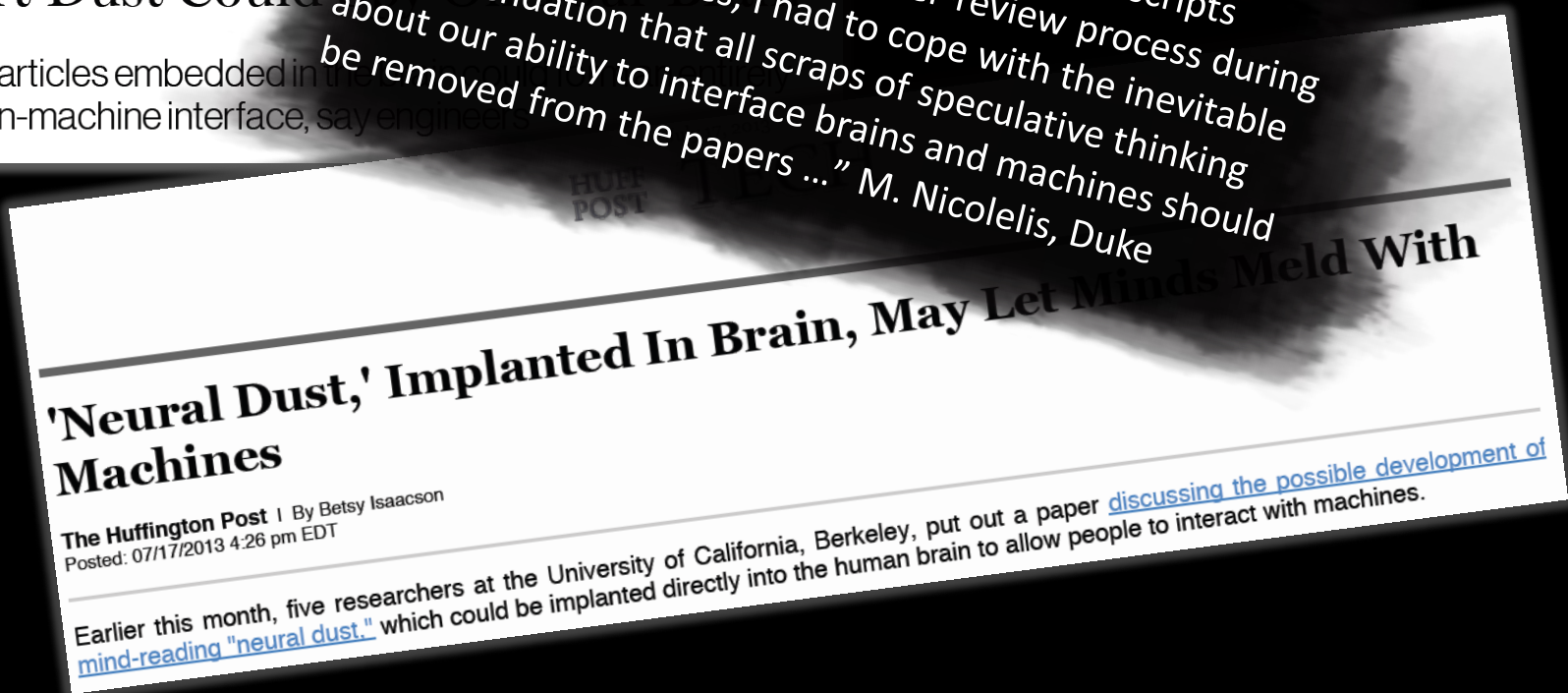

MIT Technology Review

The Physics arXiv Blog
July 16, 2013

How Smart Dust Could Spy on Your Every Move

Intelligent dust particles embedded in the body could usher in a new form of brain-machine interface, say engineers

"Almost every time one of my scientific manuscripts returned from the mandatory peer-review process during the past three decades, I had to cope with the inevitable recommendation that all scraps of speculative thinking about our ability to interface brains and machines should be removed from the papers …" M. Nicolelis, Duke


HUFF POST

'Neural Dust,' Implanted In Brain, May Let Minds Meld With Machines

The Huffington Post | By Betsy Isaacson
Posted: 07/17/2013 4:26 pm EDT

Earlier this month, five researchers at the University of California, Berkeley, put out a paper discussing the possible development of mind-reading "neural dust," which could be implanted directly into the human brain to allow people to interact with machines.

More Food for Thought …

In a First, Experiment Links Brains of Two Rats

By JAMES GORMAN
Published: February 28, 2013

In an experiment that sounds straight out of a science fiction movie, a Duke neuroscientist has connected the brains of two rats in such a way that when one moves to press a lever, the other one does, too — most of the time.

The neuroscientist, Miguel Nicolelis, known for successfully demonstrating brain-machine connections, like the one in which a monkey controlled a robotic arm with its thoughts, said this was the first time one animal's brain had been linked to another.

The question, he said, was: "Could we fool the brain? Could we make the brain process signals from another body?" The answer, he said, was yes.

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Vulcan mind meld? UW scientists connect two brains via the Internet

In what is believed to be a first, a University of Washington researcher was able to transmit signals from his brain across campus and cause a colleague's fingers to move. But some experts aren't impressed.

Back to the "Reverse Time Machine"

Observation: Energy, low signal-to-noise ratio and variability limit further scaling of semiconductor systems (end of "Moore's Law" ?)

Vision: Future abiotic computational systems that mimic biological (neural) systems to extend Moore's Law

Challenges: Neuro-inspired scalable computational paradigms based on statistical inference, massive redundancy and parallelism that embrace properties of nano-devices

The Realms of Innovation and Creativity are Endless

Acknowledgements:

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