open ephys

Open-source tools for electrophysiology

Neuro Open Science Workshop
January 15-16 2019, ICM Paris

Jakob Voigts
jvoigts@mit.edu

McGOVERN INSTITUTE
FOR BRAIN RESEARCH AT MIT

open ephys

We are a nonprofit organization

We organize the development and distribution of open-source tools for neuroscience

Focus on extracellular electrophysiology during behavior

Started in ~2010 at MIT by Josh Siegle and Jakob Voigts, now in the hands of **many contributors**.

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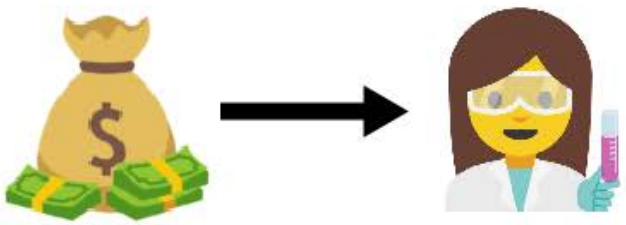
Wanted a **cheap,** and **hackable** system,
many channels & closed-loop capable.

Started by organizing group purchases, roll out from a few capable labs,
transitioned to commercial-ish distribution via oeps (Filipe Carvalho)

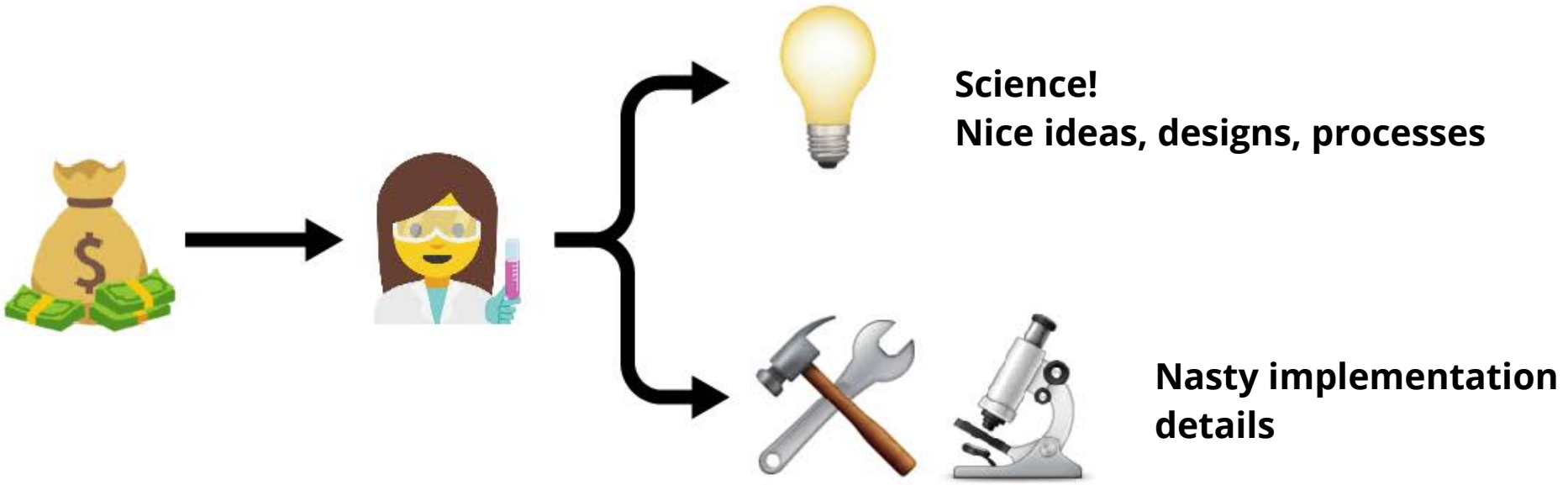
Users & Developers

Australia: Florey Institute of Neuroscience and Mental Health, Monash University
Belgium: NERF, IMEC, KU Leuven, Université Libre de Bruxelles
Brazil: University of São Paulo, Federal University of Rio Grande do Norte (Natal), Conselho Nacional de Desenvolvimento Científico e Tecnológico, Universidade Federal do ABC, Universidade Federal de Minas Gerais, Universidade Federal de Sao Joao del Rey
Canada: McGill University, University of Waterloo, University of Lethbridge, University of Montreal, University of Ottawa, CHU Sainte-Justine, Dalhousie University, University of Toronto, Western University
Chile: Universidad de Chile
China: Huazhong University of Science and Technology, Tsinghua University, Shanghai Institutes for Biological Sciences, Sanjiang University
Denmark: Aarhus University
Finland: University of Eastern Finland
France: CRICM, University Paris 6, INSERM, CNRS
Germany: Tübingen, Oldenburg, Freiburg, Köln, MPI for Brain Research, MPI for Biological Cybernetics, DZNE, LMU Munich, TU München, Charite Berlin, Bremen, Göttingen
Hong Kong: City University of Hong Kong
Hungary: Hungarian Academy of Sciences, Institute of Experimental Medicine
India: National Centre for Biological Sciences, Tata Institute of Fundamental Research
Israel: Tel Aviv University, Weizmann Institute
Italy: Instituto Italiano di Tecnologia, Neurofarba
Japan: Doshisha University, University of Fukui, Nagoya University, Physio-tech Ltd., RIKEN Brain Science Institute, University of Toyama
Kazakhstan: Nazarbayev University
Korea: Korean Institute for Basic Science
Mexico: UNAM, Universidad Autónoma Metropolitana
Netherlands: Donders Institute, Erasmus MC, Radboud Universiteit, University of Amsterdam
Norway: University of Oslo
Poland: Nencki Institute of Experimental Biology
Portugal: Champalimaud Institute, Universidade do Minho
Russia: Lomonosow State University
Slovakia: AXON Neuroscience SE
South Africa: University of Cape Town
Spain: Alicante Neuroscience Institute, Cajal Institute, Fundacio IMIM, IDIBAPS (Barcelona), UPV/EHU
Sweden: Karolinska Institute, Uppsala University
Switzerland: University of Geneva
United Kingdom: Francis Crick Institute, Imperial College London, Newcastle University, Oxford University, University College London, University of Bristol, University of Edinburgh, University of Exeter, University of Leicester
United States: Allen Institute, Baylor College of Medicine, Boston University, Brandeis, Brown University, Caltech, Case Western, Columbia University, Cold Spring Harbor Laboratory, Dartmouth College, Duke University, Georgia Tech, Harvard University, Indiana University, Janelia Research Campus, Johns Hopkins University, MIT, Mayo Clinic, Medical University of South Carolina, Michigan State University, NYU, Princeton University, Research Foundation for Mental Hygiene, Rice University, Rockefeller University, Salk Institute, Stanford University, Stevens Institute of Technology, Stony Brook University, UC Davis, UCSD, UMass Amherst, University of Buffalo, UCSF, University of Eastern Michigan, University of Idaho, University of Missouri, University of Oregon, University of Pittsburgh, USC, UT Austin, Virginia Tech, University of Washington, Washington University
Uruguay: Universidad de la República

Dissemination



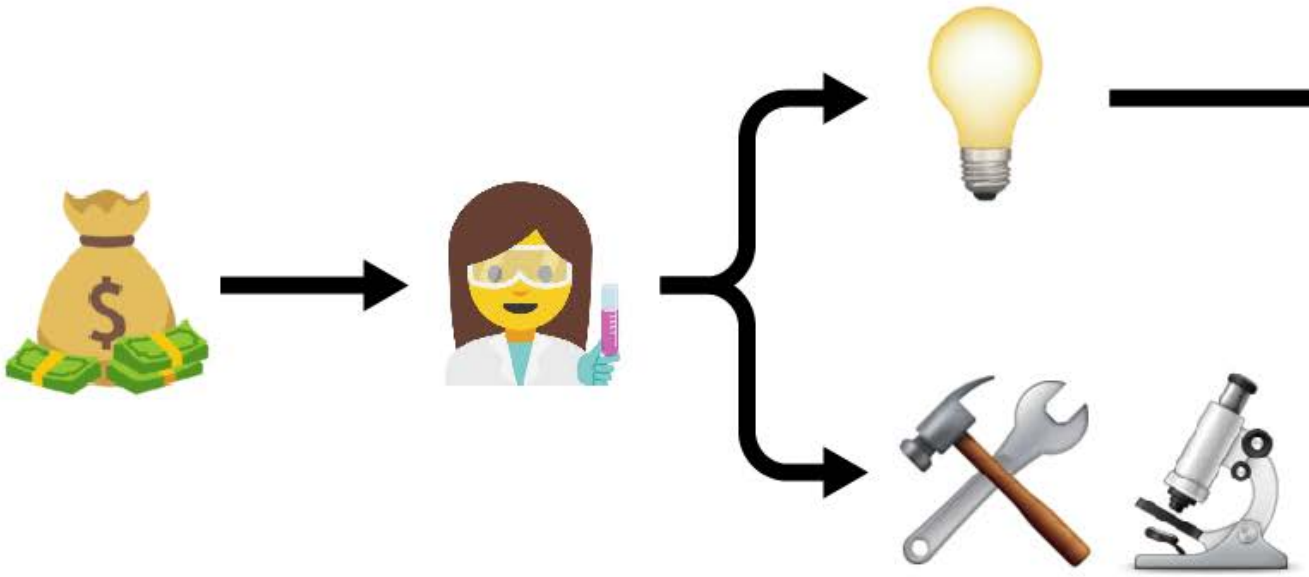
Dissemination



Science!
Nice ideas, designs, processes

Nasty implementation details

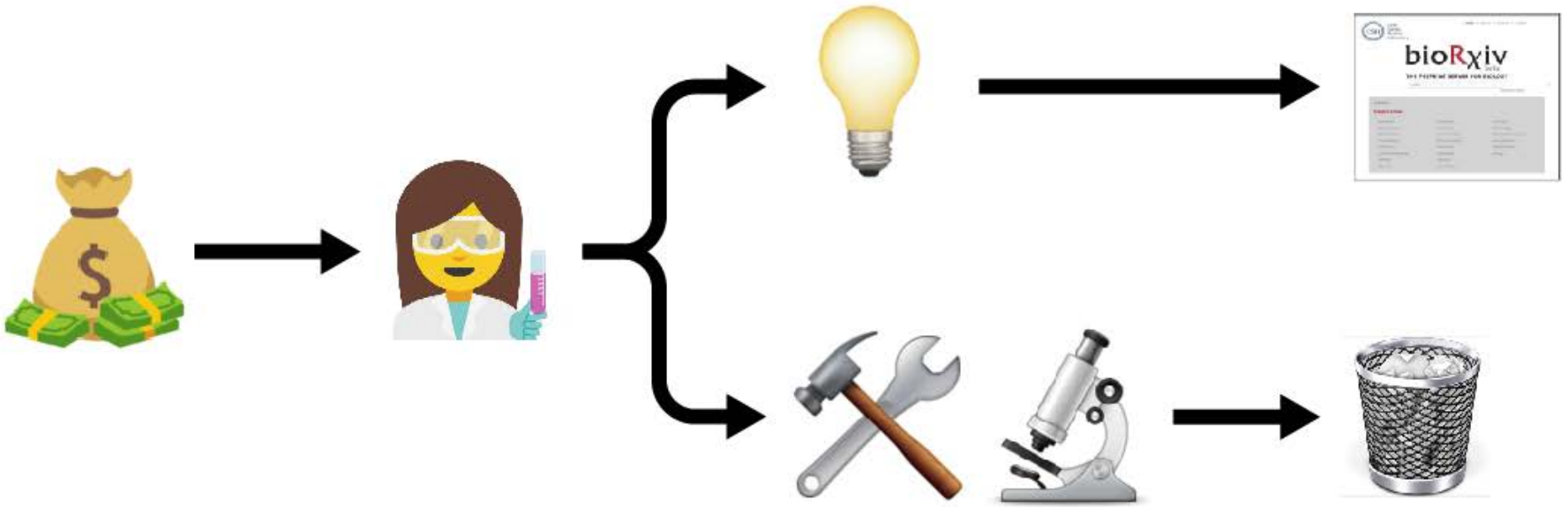
Dissemination



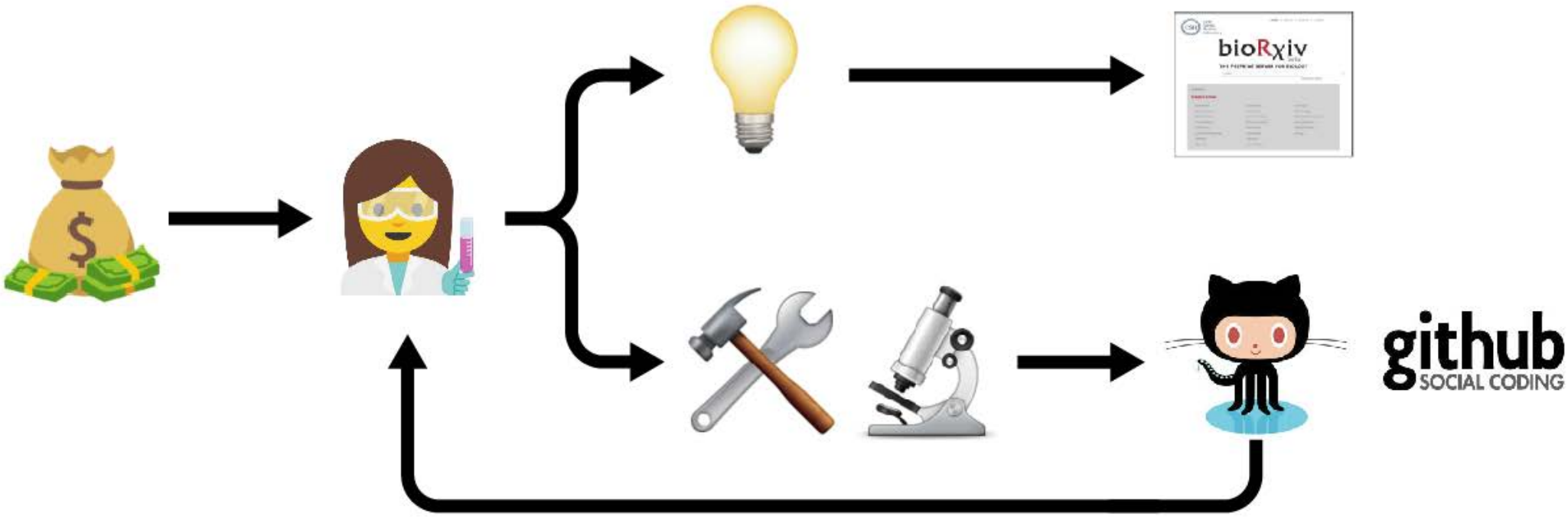
Scientific or Methods paper

Nasty implementation details

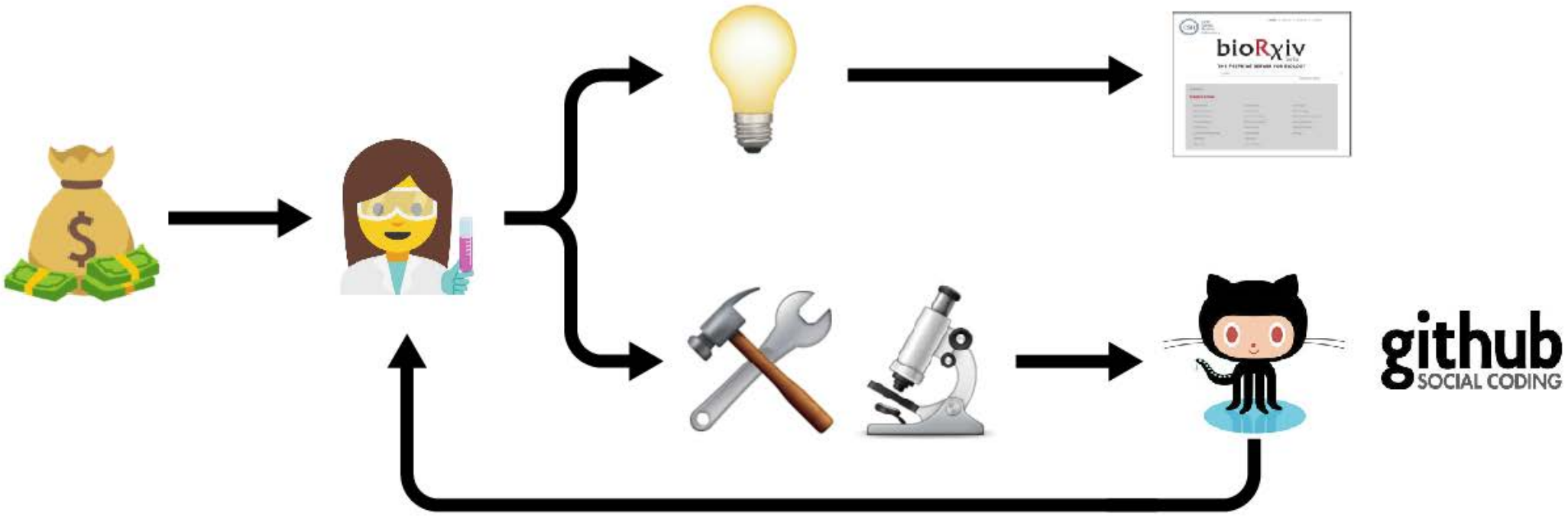
Dissemination



Dissemination

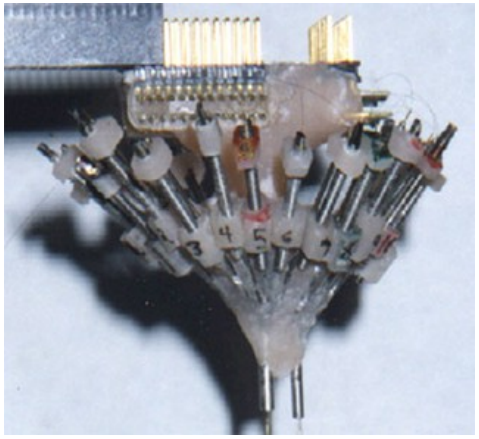


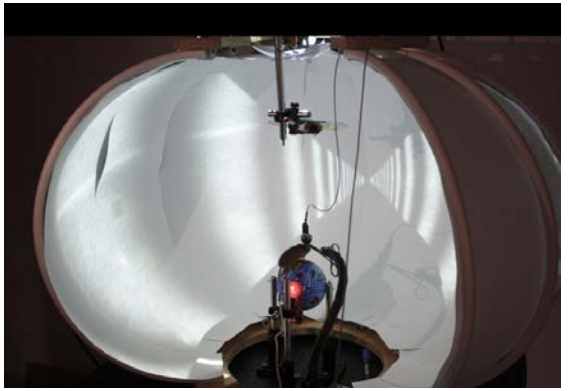
Dissemination

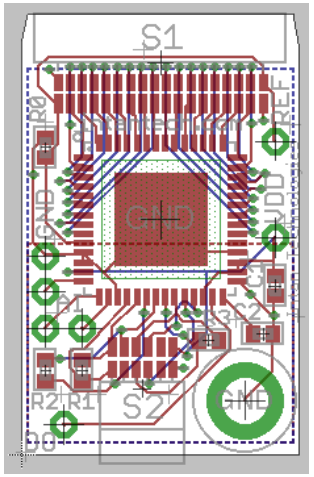


Active, continuous effort
Documentation, Licensing,
Distribution, Training, Support

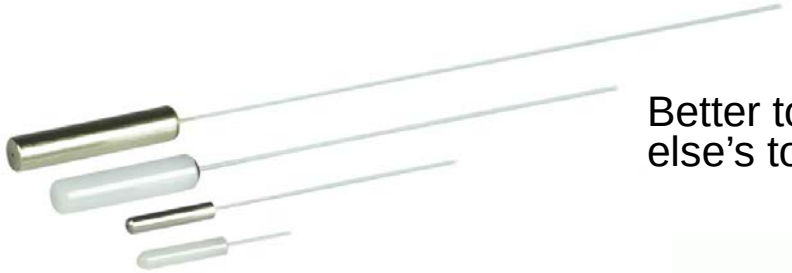
Dissemination



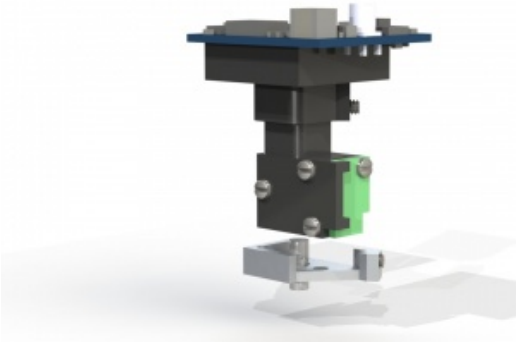




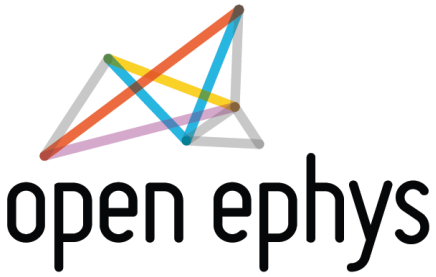
The small details matter, and spending a bit of extra effort is required to actually share something. **This effort is worth it.**



Better to re-learn and re-use someone else's tool than to make another one-off.



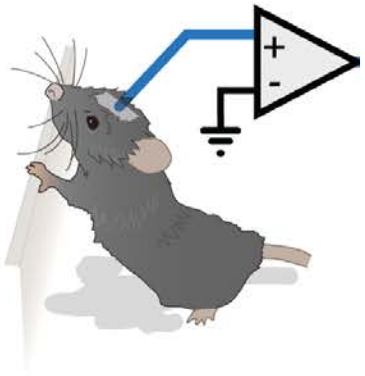
Development

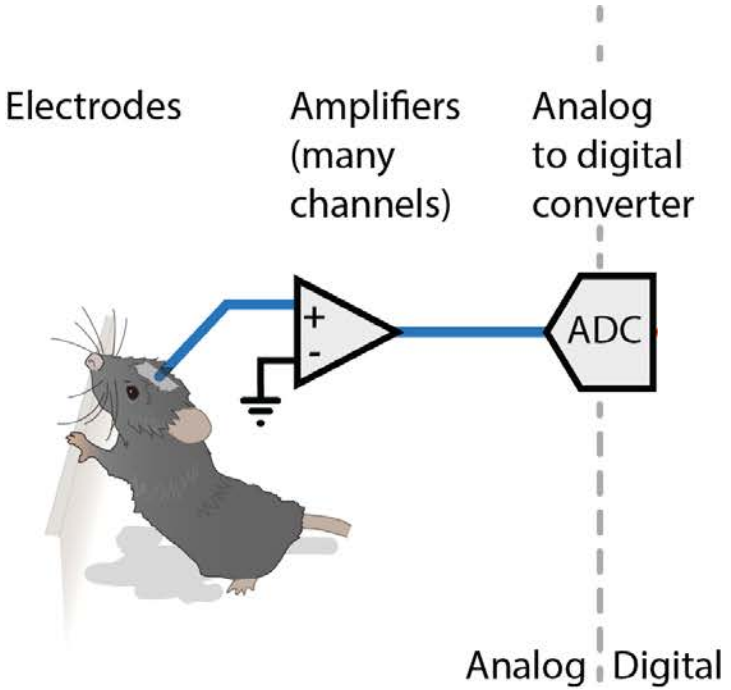


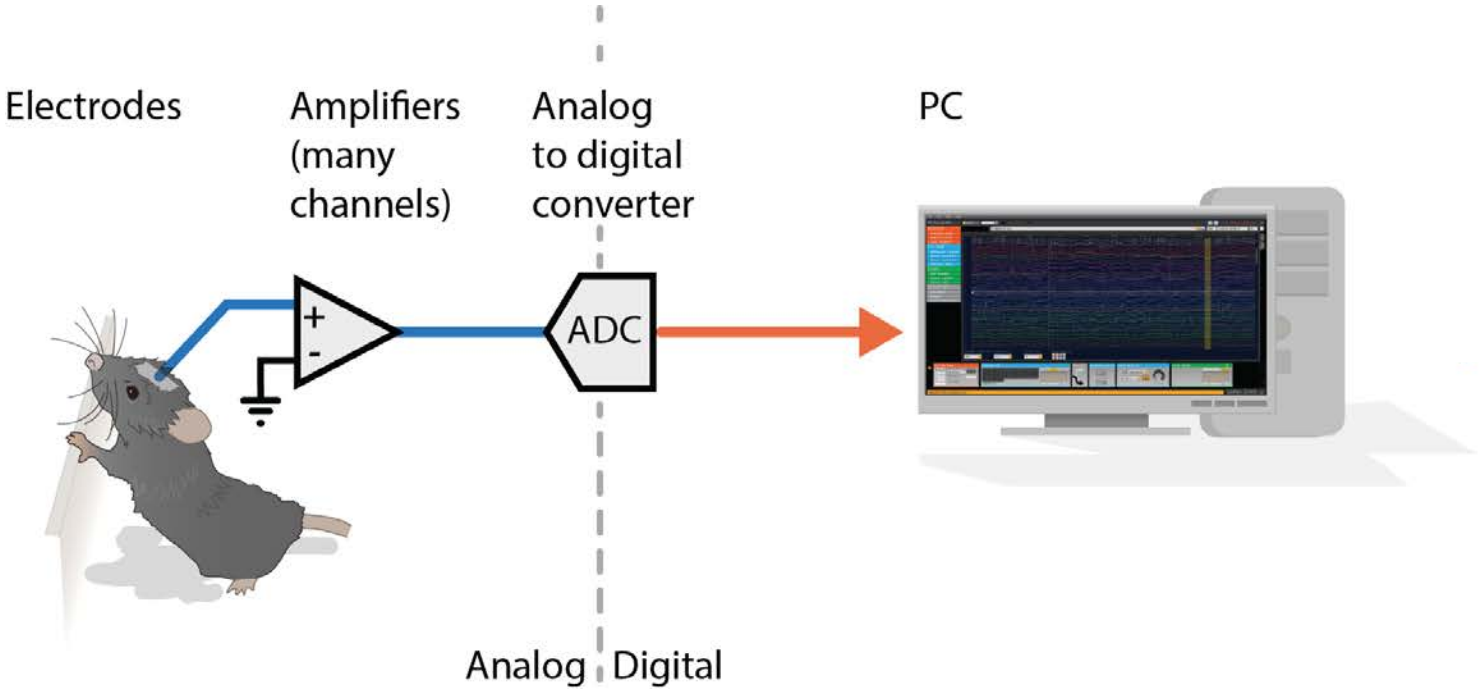
Current projects & tools

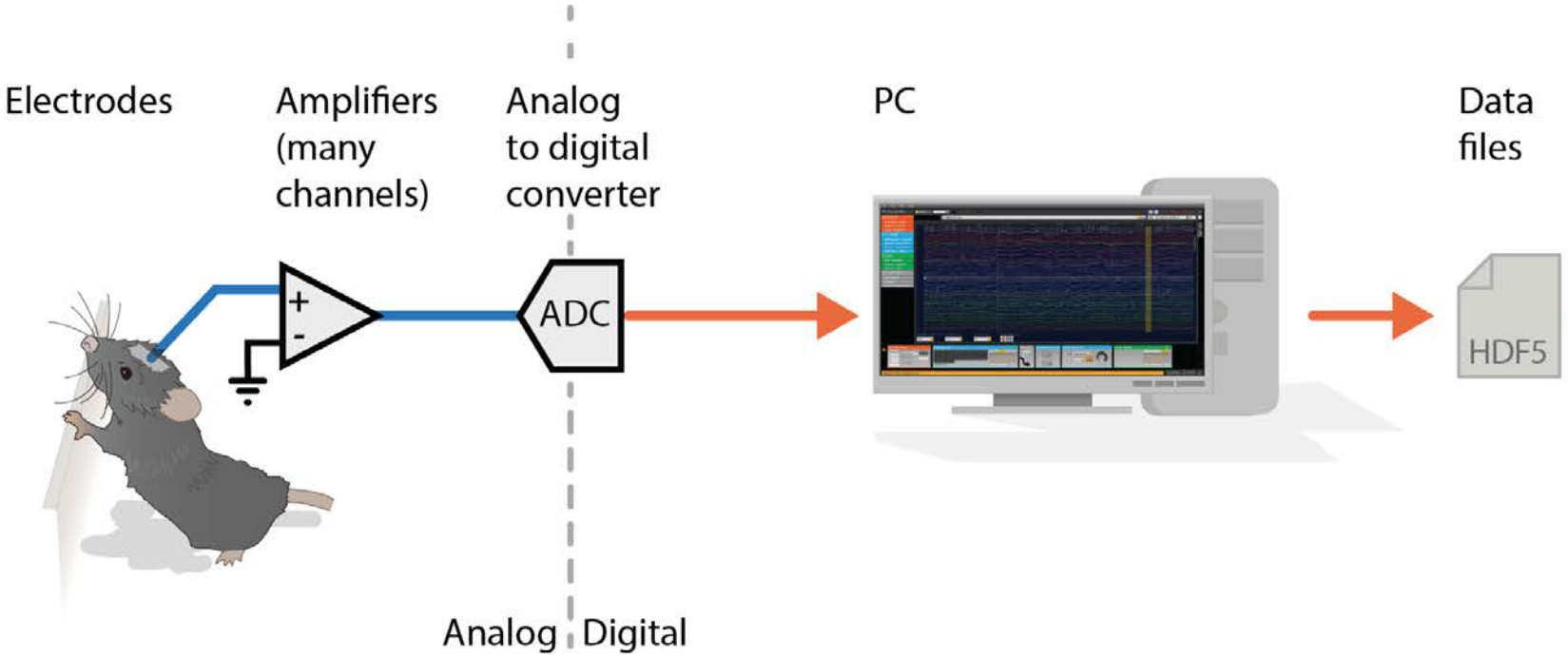
Electrodes

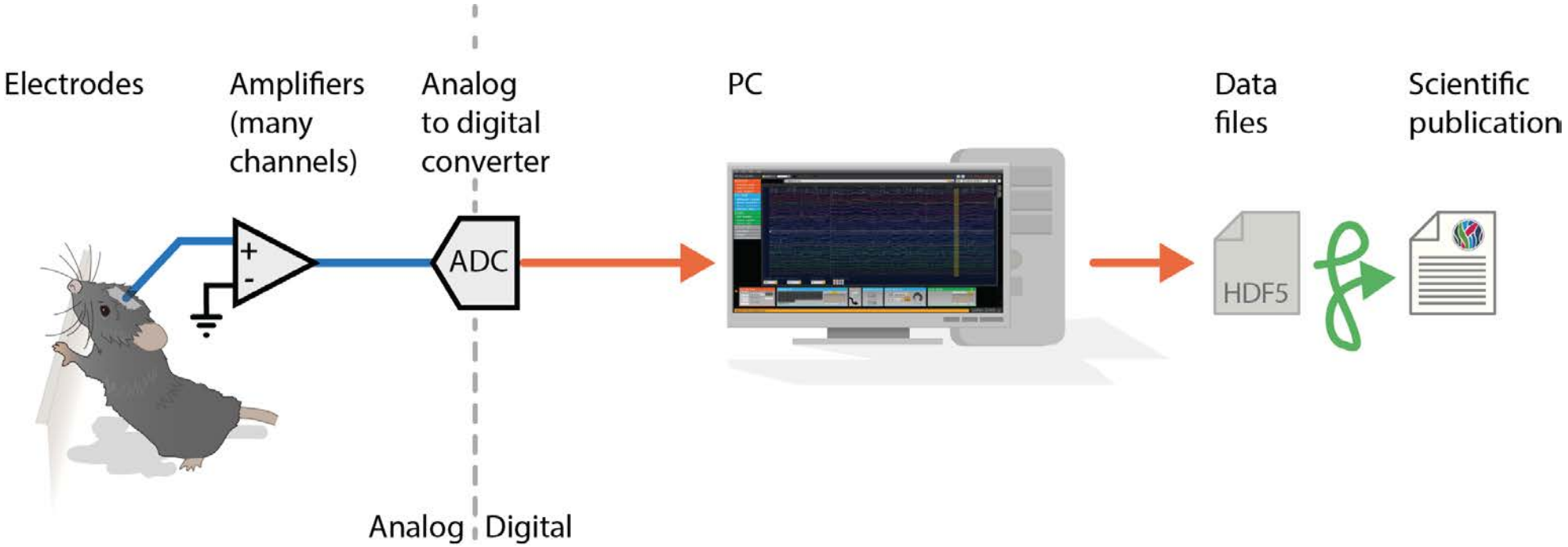
Amplifiers (many channels)

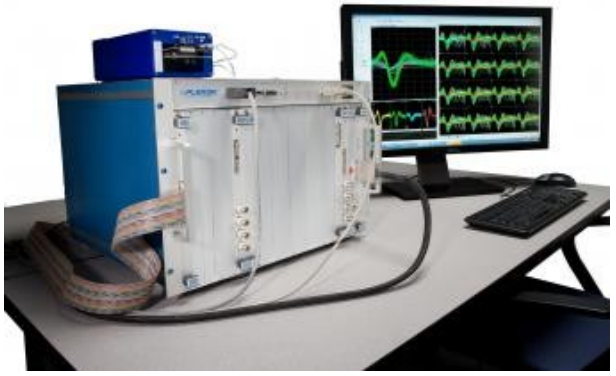



Electrodes
Amplifiers (many channels)
Analog to digital converter
+
-
ADC
Analog
Digital


Electrodes
Amplifiers (many channels)
Analog to digital converter
PC
+
-
ADC
Analog
Digital

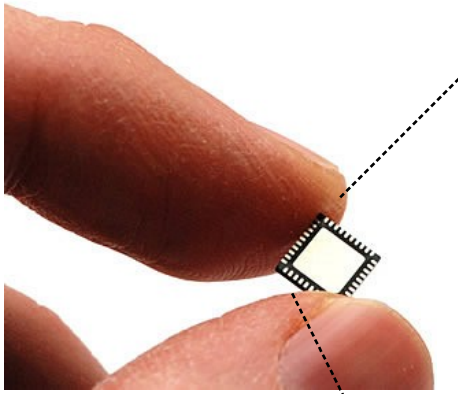

Electrodes
Amplifiers (many channels)
Analog to digital converter
PC
Data files
+
-
ADC
HDF5
Analog
Digital


Electrodes
Amplifiers (many channels)
Analog to digital converter
PC
Data files
Scientific publication
+
-
ADC
HDF5
Analog
Digital



Plexon, Neuralynx, Tucker Davis Tech.

Intan amplifier chips

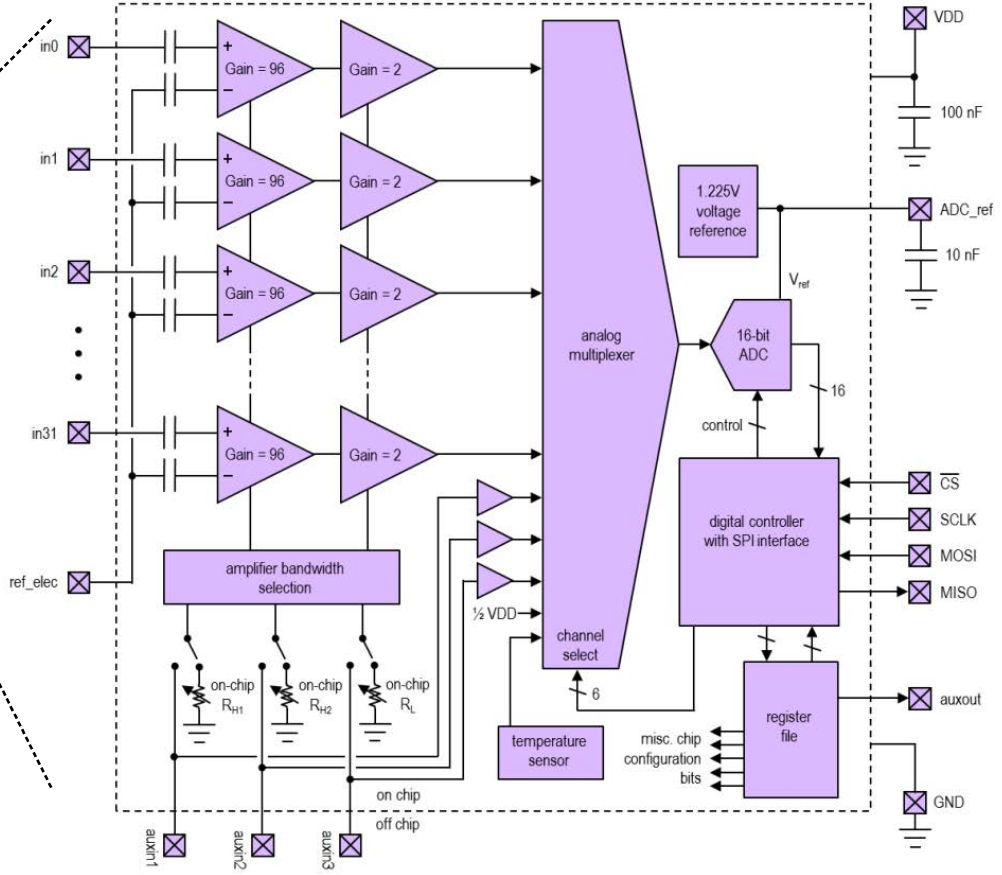


Reid Harrison,
Intan Technologies

32-64 Channels, 30KHz rate
Bandpass 0.1Hz-15KHz
±5mV input range
2.4 µV rms noise floor

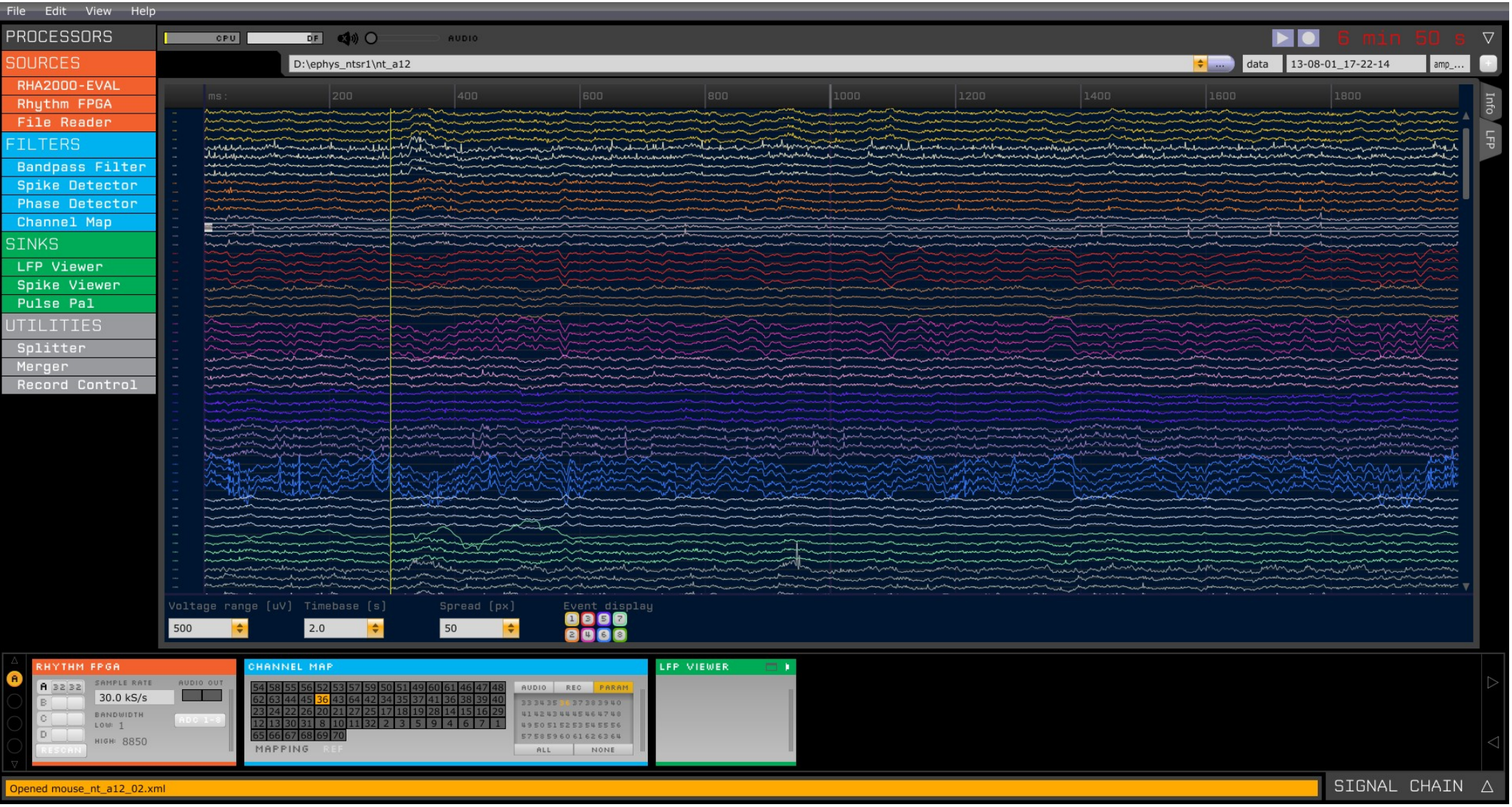
Standardized digital
SPI interface

$425 for 64ch BGA chip

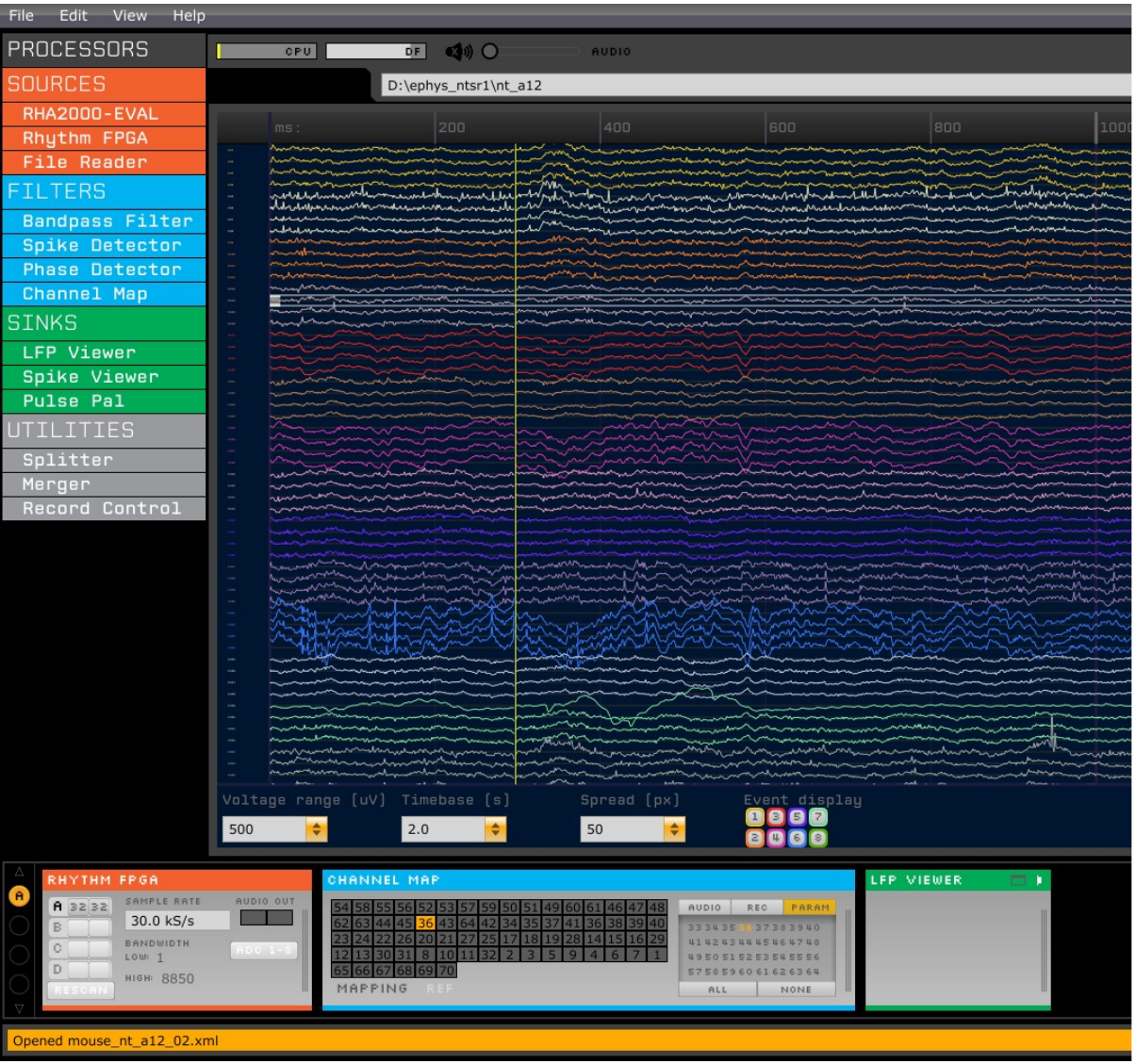


Current extracellular data acquisition system

GUI Plugins


File
Edit
View
Help
PROCESSORS
SOURCES
RHA2000-EVAL
Rhythm FPGA
File Reader
FILTERS
Bandpass Filter
Spike Detector
Phase Detector
Channel Map
SINKS
LFP Viewer
Spike Viewer
Pulse Pal
UTILITIES
Splitter
Merger
Record Control
CPU
DF
AUDIO
6 min 50 s
D:\ephys_ntsr1\nt_a12
data
13-08-01_17-22-14
ms:
200
400
600
800
1000
1200
1400
1600
1800
Info
LFP
Voltage range [uV]
Timebase [s]
Spread [px]
Event display
500
2.0
50
RHYTHM FPGA
SAMPLE RATE
AUDIO OUT
30.0 kS/s
BANDWIDTH
LOW: 1
HIGH: 8850
RESCAN
CHANNEL MAP
AUDIO
REC
PARAM
MAPPING
REF
ALL
NONE
LFP VIEWER
Opened mouse_nt_a12_02.xml
SIGNAL CHAIN

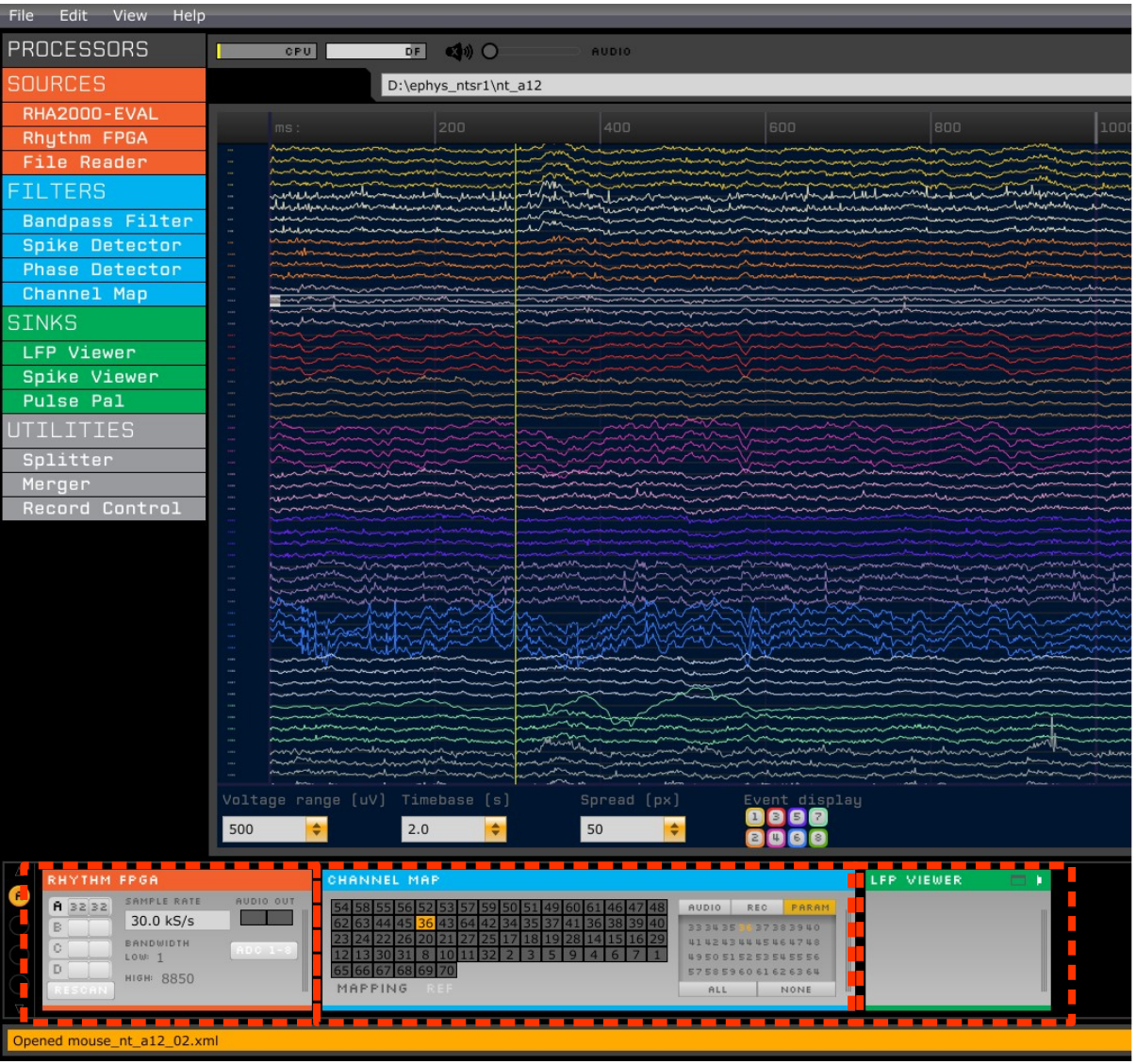
GUI Plugins



Josh Siegle, Aarón Cuevas López

Kirill Abramov, Jakob Voigts, Clayton Barnes, Christopher Stawarz, Jon Newman, Vincent Prevosto, Ronny Eichler, Ethan Blackwood, and many others

GUI Plugins

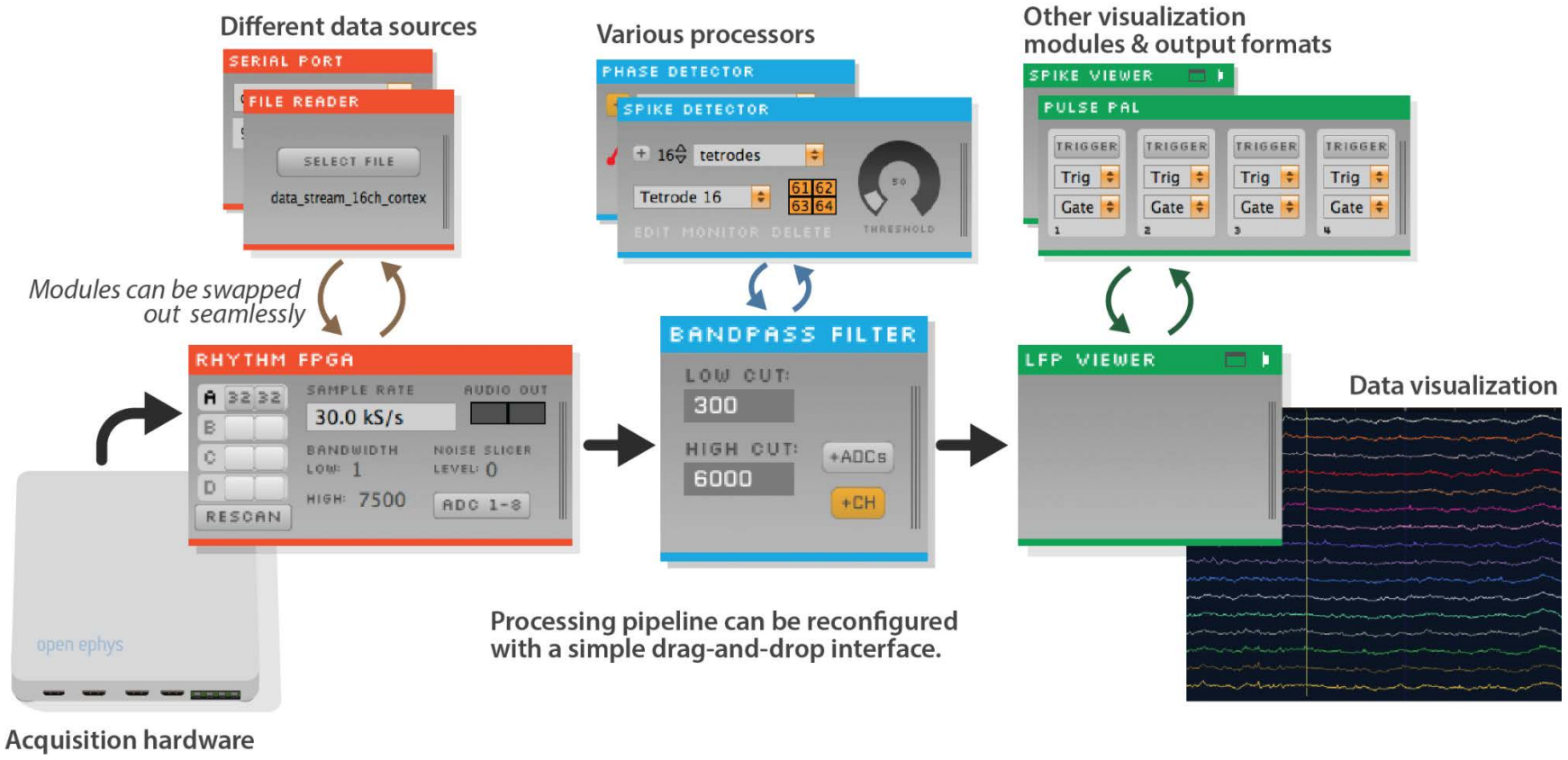


Individually Compiled plugins

Josh Siegle, Aarón Cuevas López

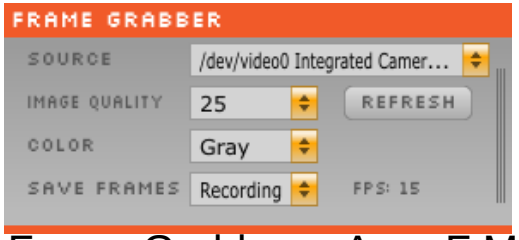
Kirill Abramov, Jakob Voigts, Clayton Barnes, Christopher Stawarz, Jon Newman, Vincent Prevosto, Ronny Eichler, Ethan Blackwood, and many others

GUI Plugins

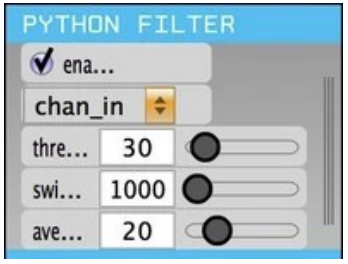

Different data sources
SERIAL PORT
FILE READER
SELECT FILE
data_stream_16ch_cortex
Various processors
PHASE DETECTOR
SPIKE DETECTOR
16 tetrodes
Tetrode 16
61 62
63 64
EDIT MONITOR DELETE
THRESHOLD
Other visualization
modules & output formats
SPIKE VIEWER
PULSE PAL
TRIGGER
Trig
Gate
Modules can be swapped
out seamlessly
RHYTHM FPGA
A 32 32
B
C
D
RESCAN
SAMPLE RATE
30.0 kS/s
AUDIO OUT
BANDWIDTH
LOW: 1
HIGH: 7500
NOISE SLICER
LEVEL: 0
ADC 1-8
BANDPASS FILTER
LOW CUT:
300
HIGH CUT:
6000
+ADCs
+CH
LFP VIEWER
Data visualization
open ephys
Acquisition hardware
Processing pipeline can be reconfigured
with a simple drag-and-drop interface.

GUI Plugins

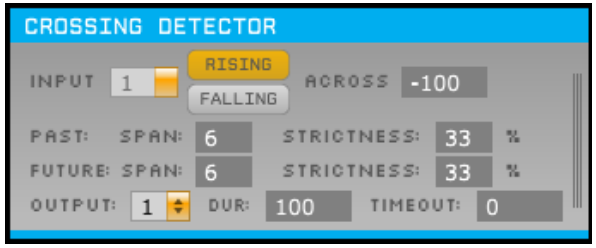
Arduino I/O – Chris Black



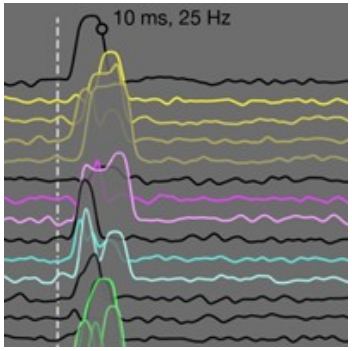
Frame Grabber – Arne F Meyer



Python interface – Battaglia Lab



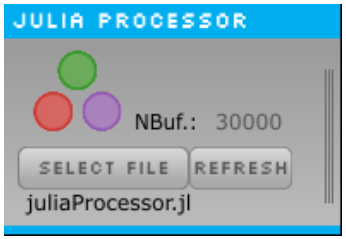
Threshold>events – Ethan Blackwood



Triggered average – Clayton Barnes

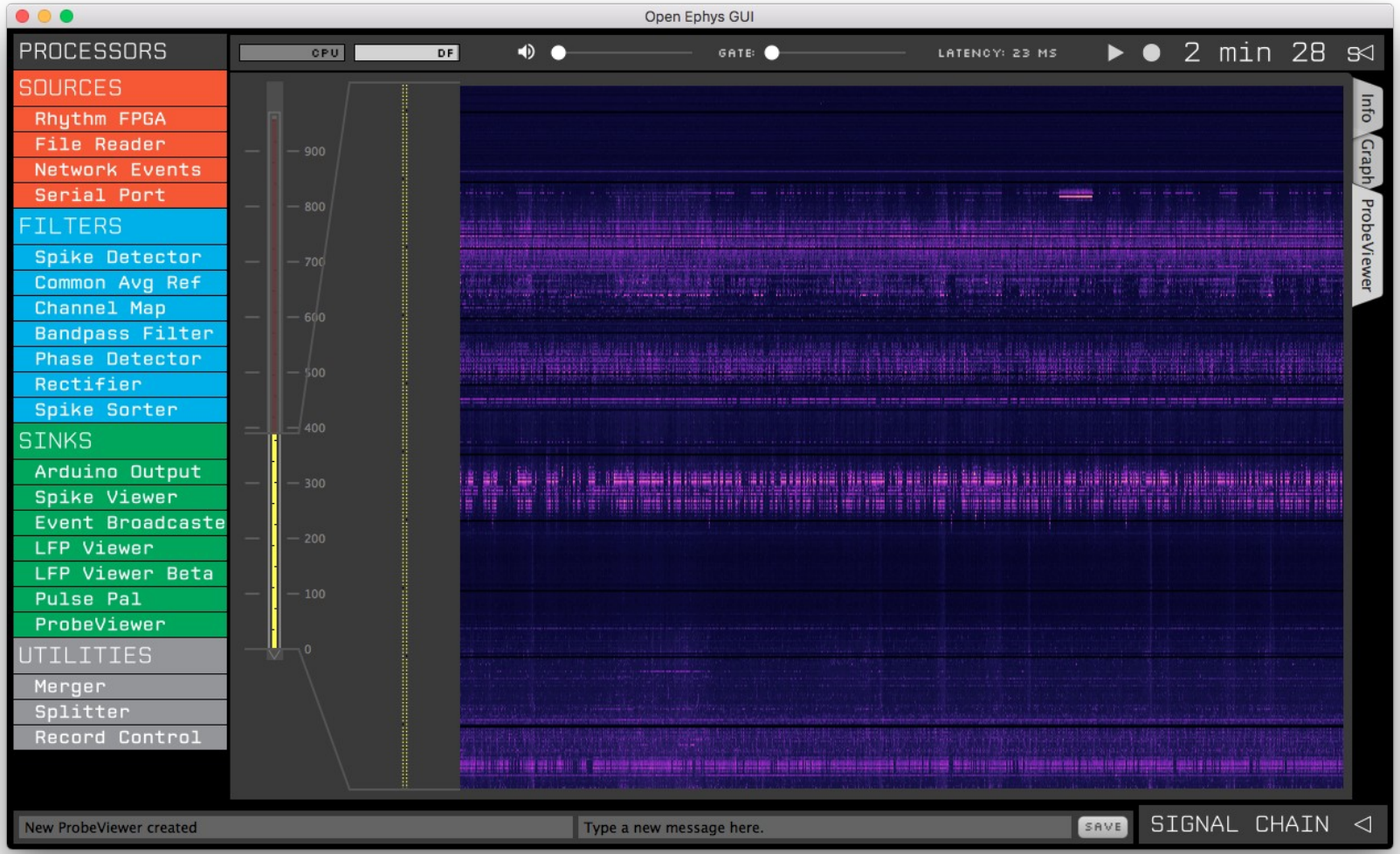
Arf Format – Michal Badura,
Mworks interface – Christopher Stawarz,
Serial Data Input – FlorianFranzen

Dynamic Spike Threshold – Camilo Gordillo



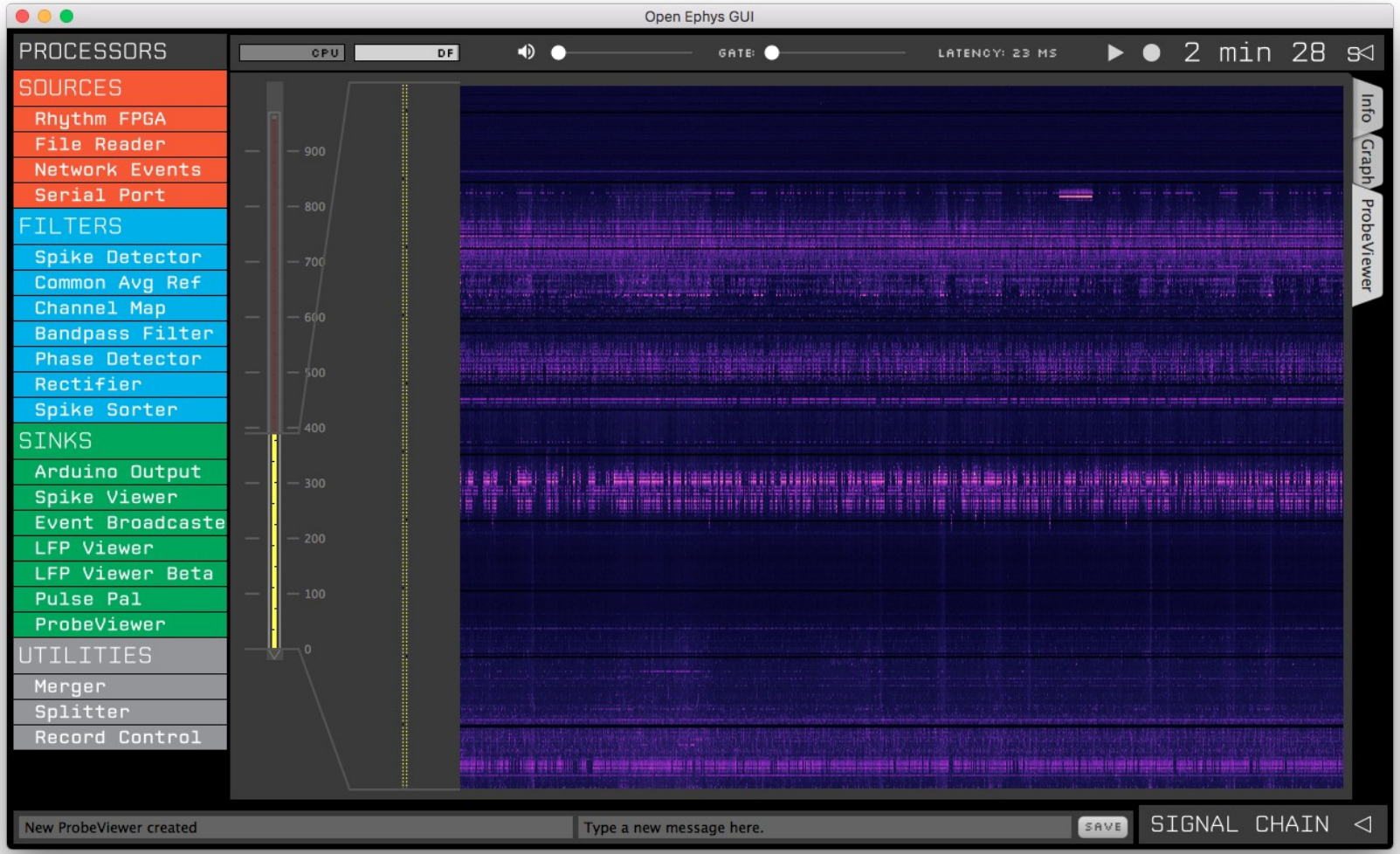
Julia Processor – Jakob Voigts

Neuropixels support



Josh Siegle, K. Michael Fox at Allen Institute

Neuropixels support



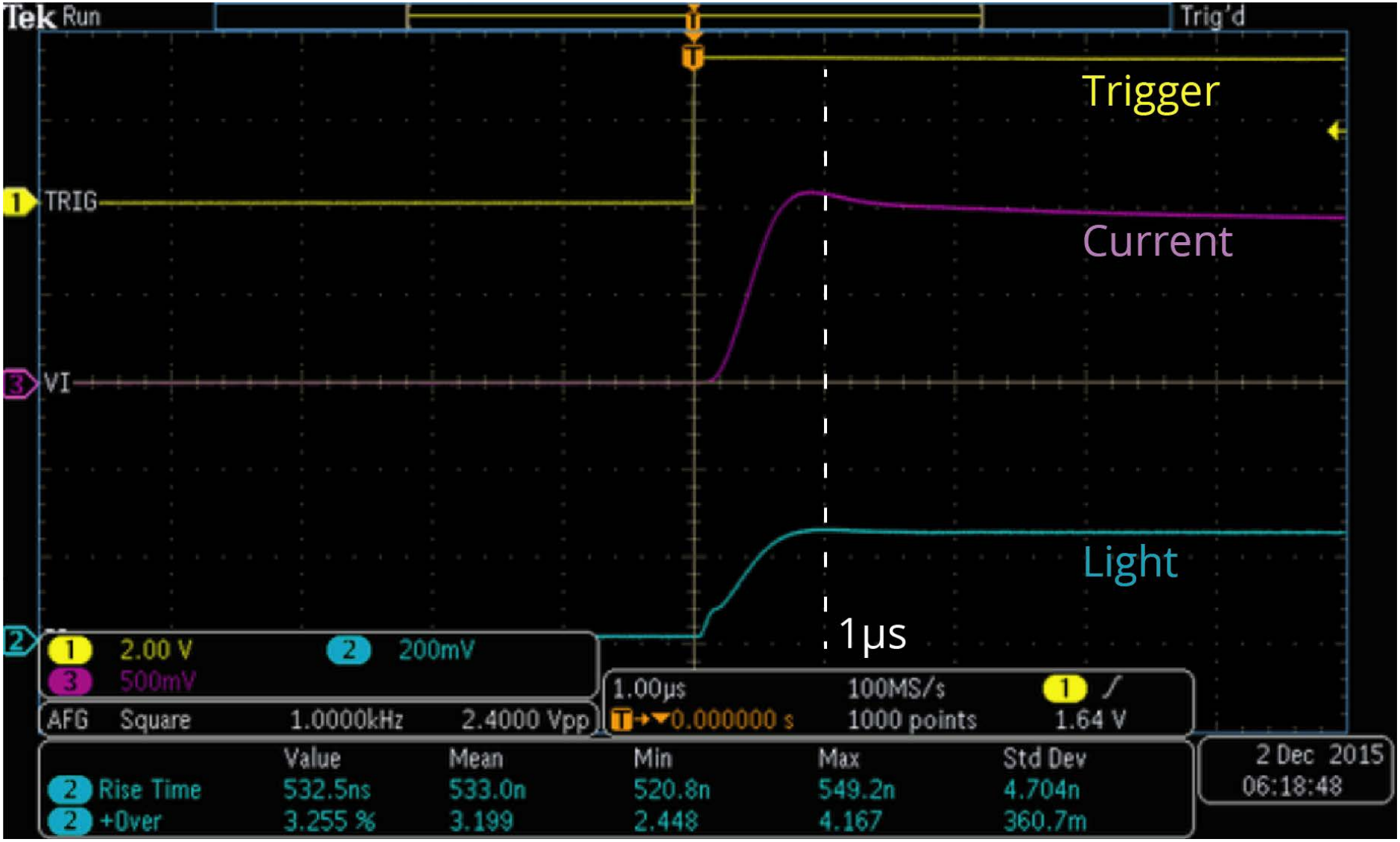
Josh Siegle, K. Michael Fox at Allen Institute

2 open positions for software devs.!

Cyclops LED/Laser driver

Jonathan P. Newman
github.com/jonnew/cyclops

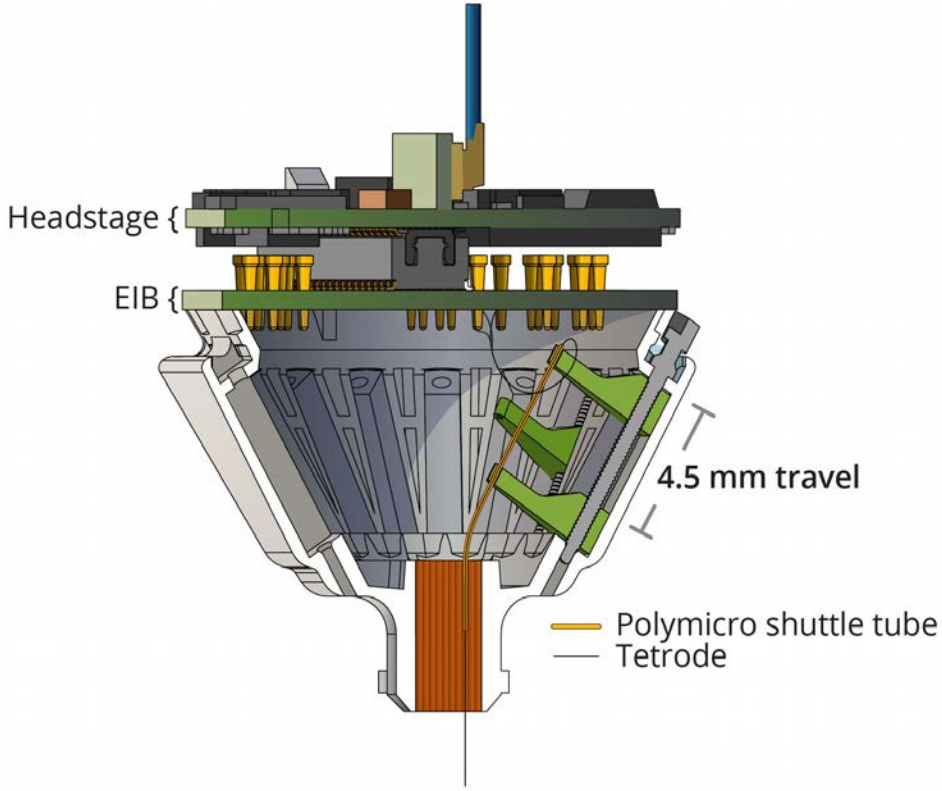
Cyclops LED/Laser driver



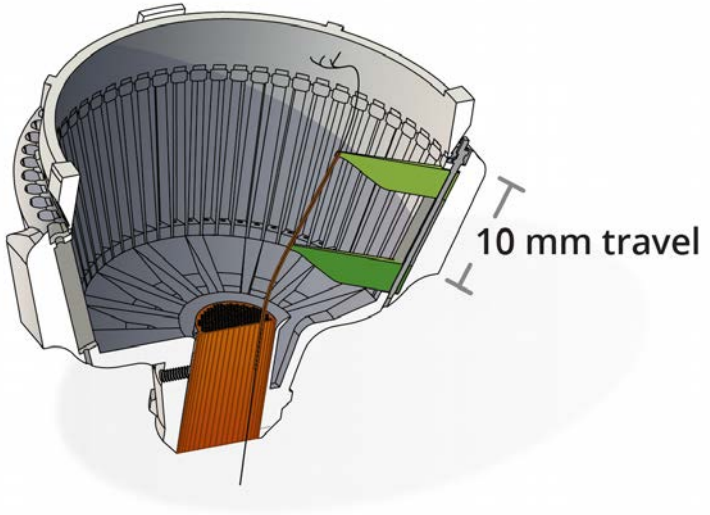
Cyclops LED Driver by Jonathan P. Newman
https://github.com/jonnew/cyclops

Next generation drive implant

Mouse: 16 drives

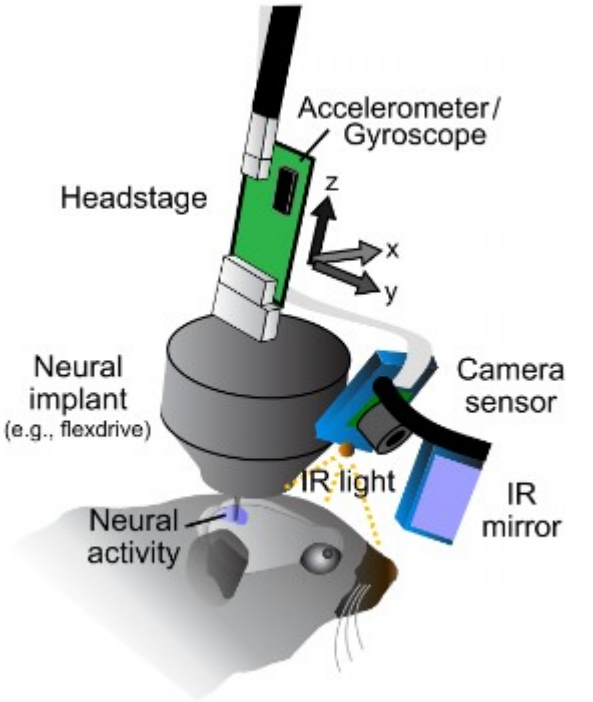


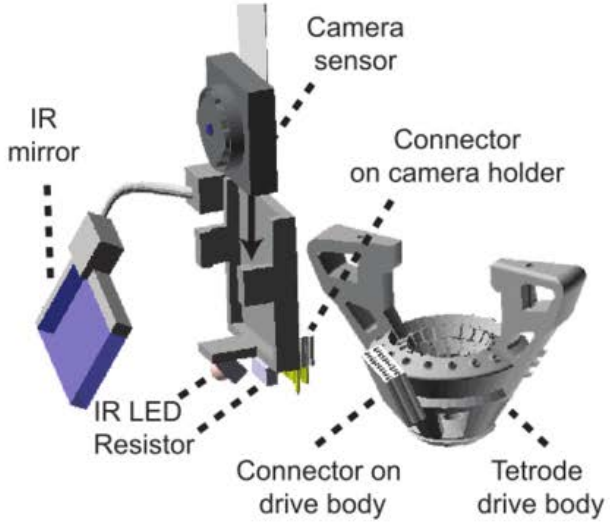
Rat/Shrew/Lemur: 64 drives

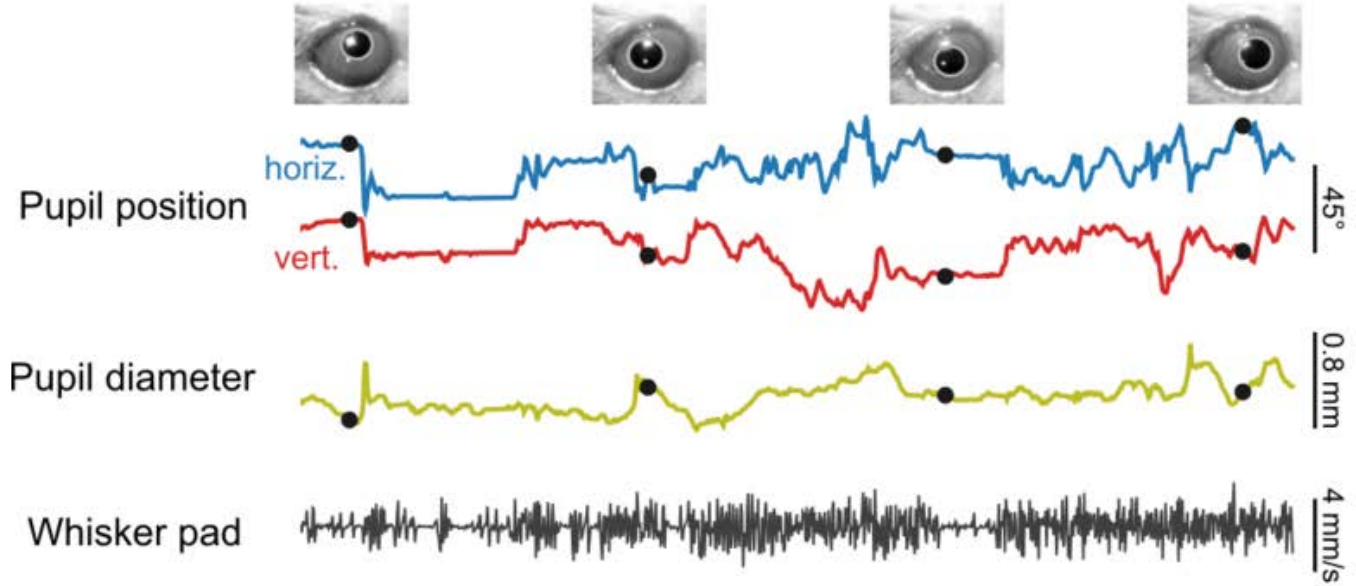


Available via open ephys soon, get in touch to be added to email list.

Mousecam







AF Meyer, J Poort, J O'Keefe, M Sahani, and JF Linden: A head-mounted camera system integrates detailed behavioral monitoring with multichannel electrophysiology in freely moving mice, Neuron, Volume 100, p46-60, 2018.

Why did we go with open-source
Instead of commercial marketing and distribution?

Why did we go with open-source
Instead of commercial marketing and distribution?

- Promoting the development of tools ≠ developing tools
  Keeping a constant influx of new ideas from scientists/developers keeps the tools current

- Promoting tools developed by others requires an impartial, non-profit(ish) organization.
  Credit & recognition needs to go to individual developers

Why did we go with open-source
~~Instead of~~ commercial marketing and distribution?

- Selling **and supporting** open-source tools can be profitable
  An open source tool is just a tool with some important benefits and can be sold as such

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- Tools don't need to be *fully* open, good interfaces, APIs etc. solve many problems

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- Tools don't need to be *fully* open, good interfaces, APIs etc. solve many problems

  - Standardized interfaces help removing redundant efforts

Why did we go with open-source
~~Instead of~~ commercial marketing and distribution?

- Selling **and supporting** open-source tools can be profitable
  An open source tool is just a tool with some important benefits and can be sold as such

- Tools don't need to be *fully* open, good interfaces, APIs etc. solve many problems

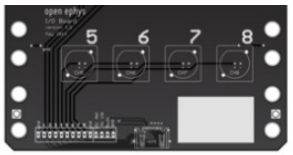
  - Standardized interfaces help removing redundant efforts

    - Spending money on consulting & support
      for open-source can be well worth the cost.

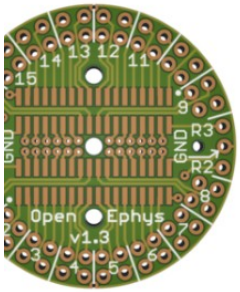
Commercial dissemination

OEPS
Filipe Carvalho
'Official' manufacturing agreement – pays support salary

Starter Kit
€5,400.00



I/O Board
from €12.50



64-channel EIB
from €10.00

SOLD OUT

Cyclops LED Driver
from €450.00

Open Science Brasil
Cleiton Lopes Aguiar,
Luis Lucca

Independent NeuroScience Services
Bruno Pichler, Dale Elgar

Labmaker
York Winter

Electronic Interface Board - up to 64-channels - pack of 8 PCBs
$46.00 USD

$334.00 USD

Feeding Experimentation Device - F.E.D.
$368.00 USD

Miniscope - DAQ PCB
$374.00 USD

Sale

Multichannel Electrophysiology Acquisition Board

Two major gaps in the current (commercial) landscape:

Production

Open source tools can be hard to acquire. Requires group orders, collecting parts from multiple sources etc.

Support

Open source tools can be tricky to operate and there are fewer guarantees that they will keep working.

But open source tools are often technologically superior, and allow researchers to do more creative, flexible, and reproducible work.

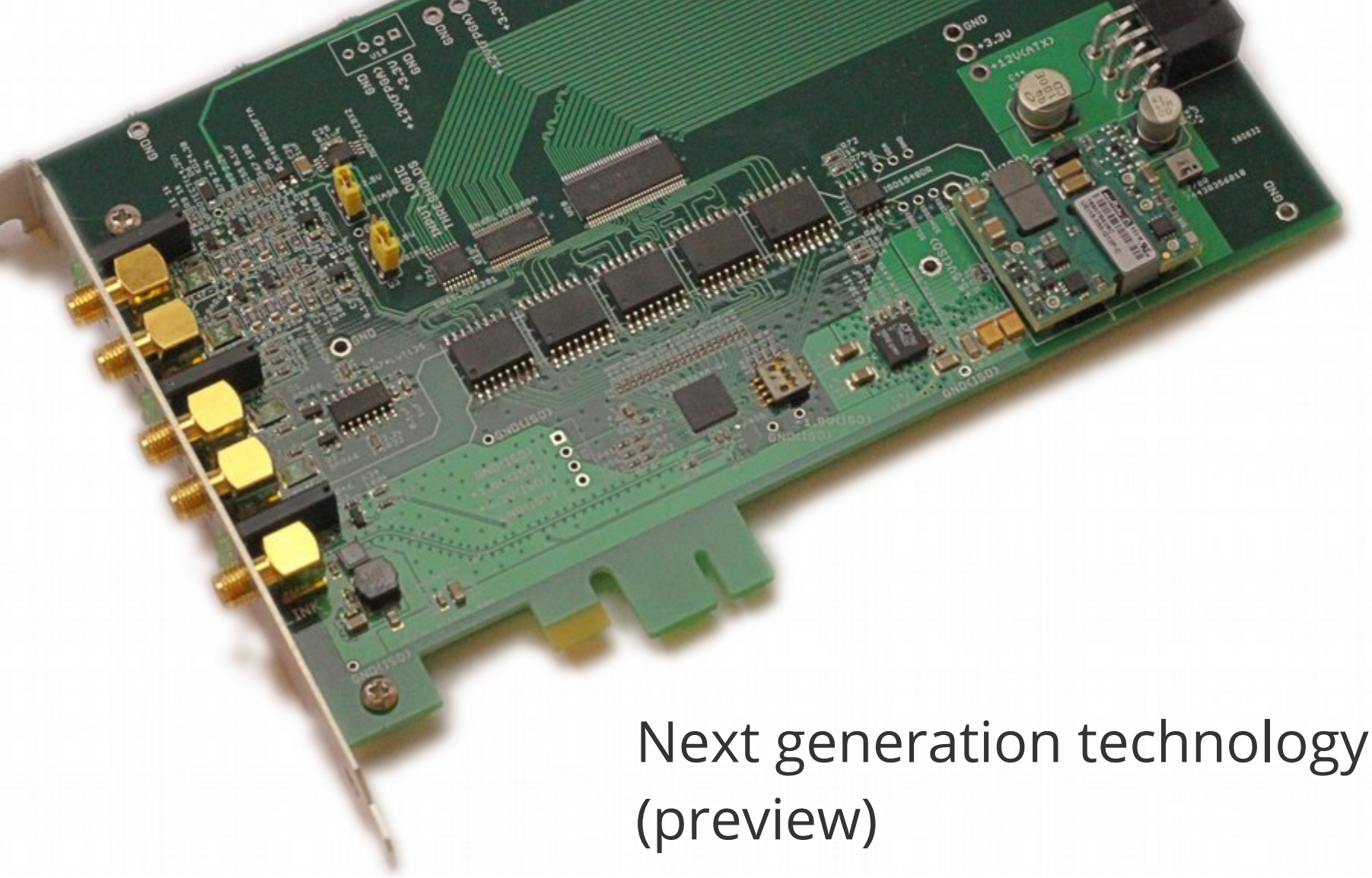
Two major gaps in the current (commercial) landscape:

Sale of open-source tools

- No IP monopoly, relatively low margins, but also low costs
- Can provide cutting-edge technology
- Support / replacements etc could be charged separately

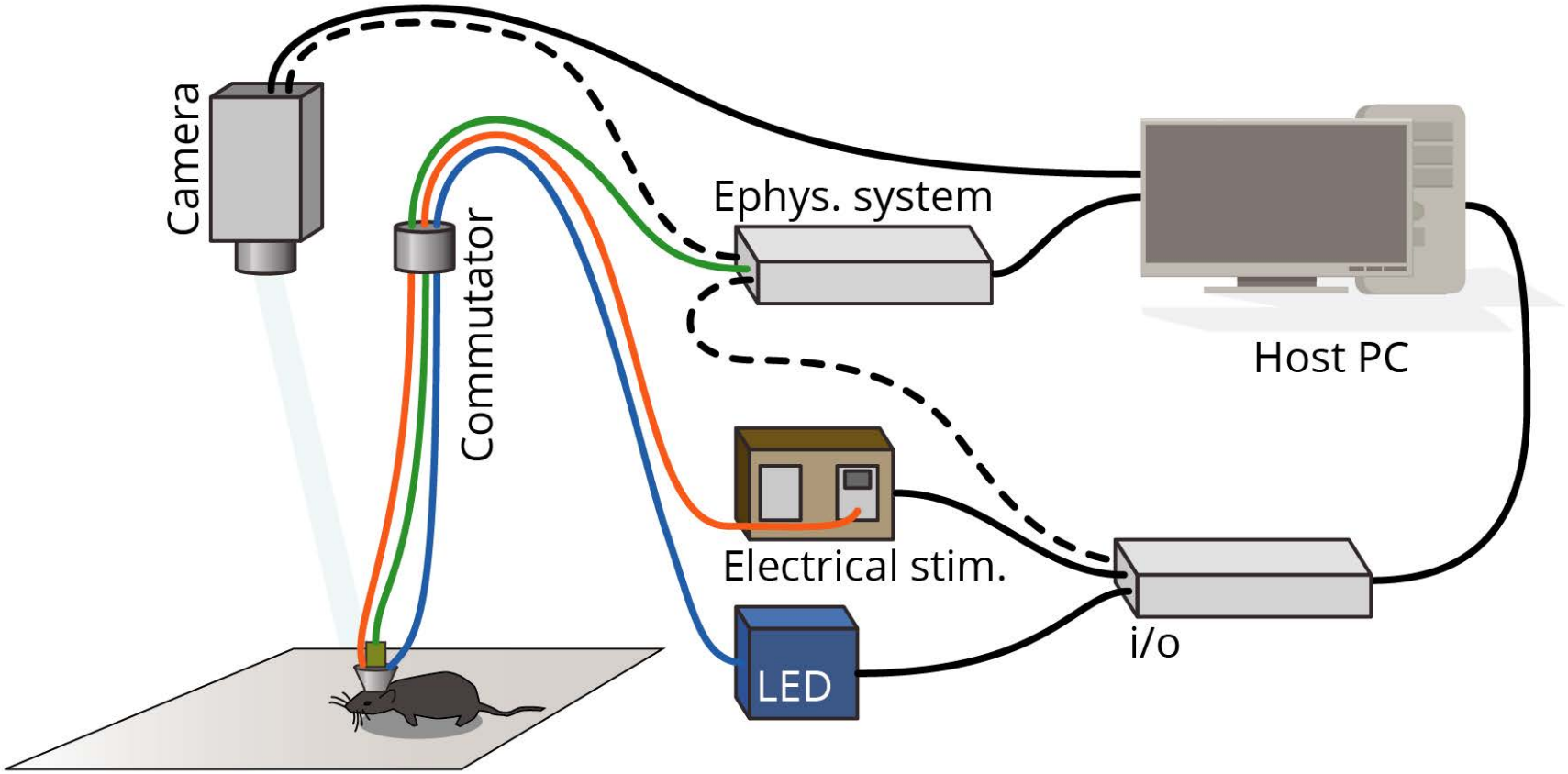
Training, Support & Consulting

- Currently almost completely absent, only served incidentally through support of commercial products
- Will require some change in funding landscape
- Large potential for overall productivity gains

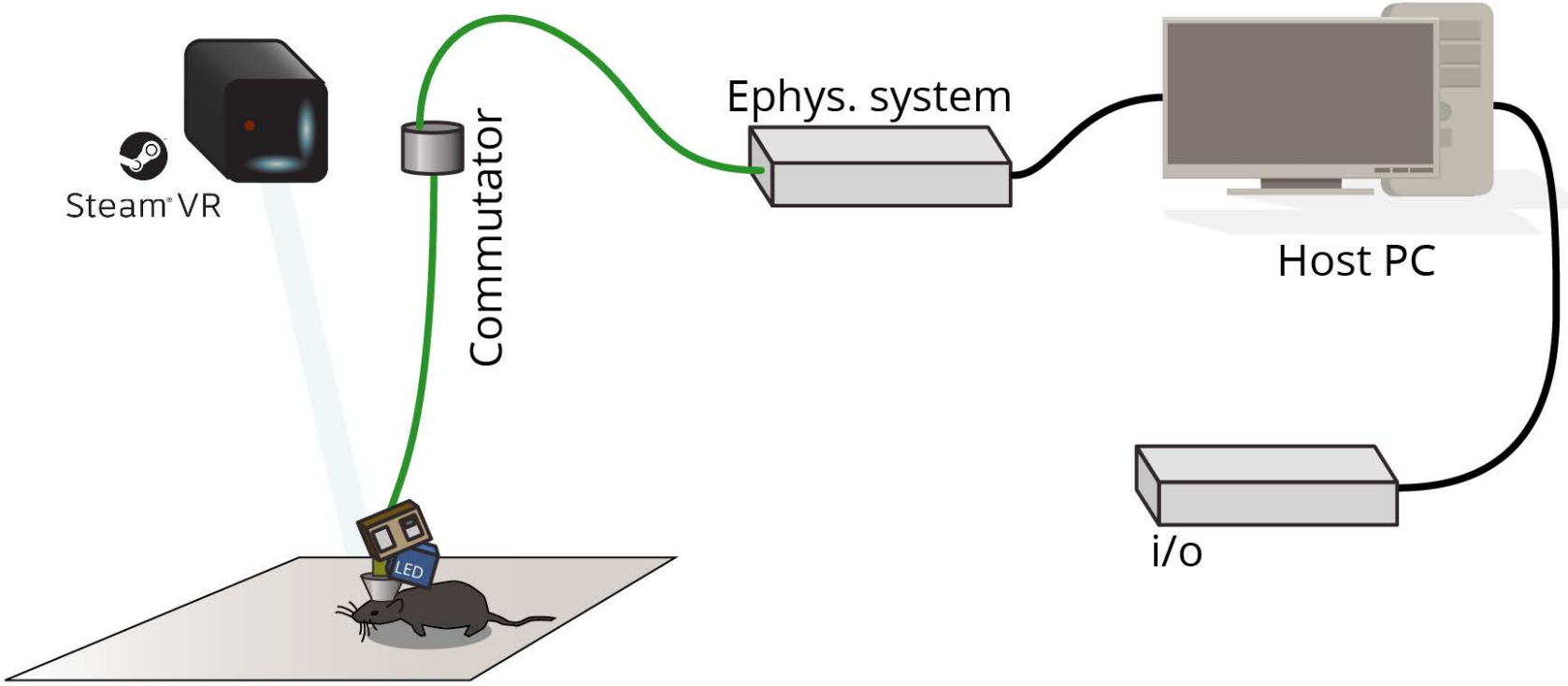


Next generation technology (preview)

Next-generation free behaving animal ephys system



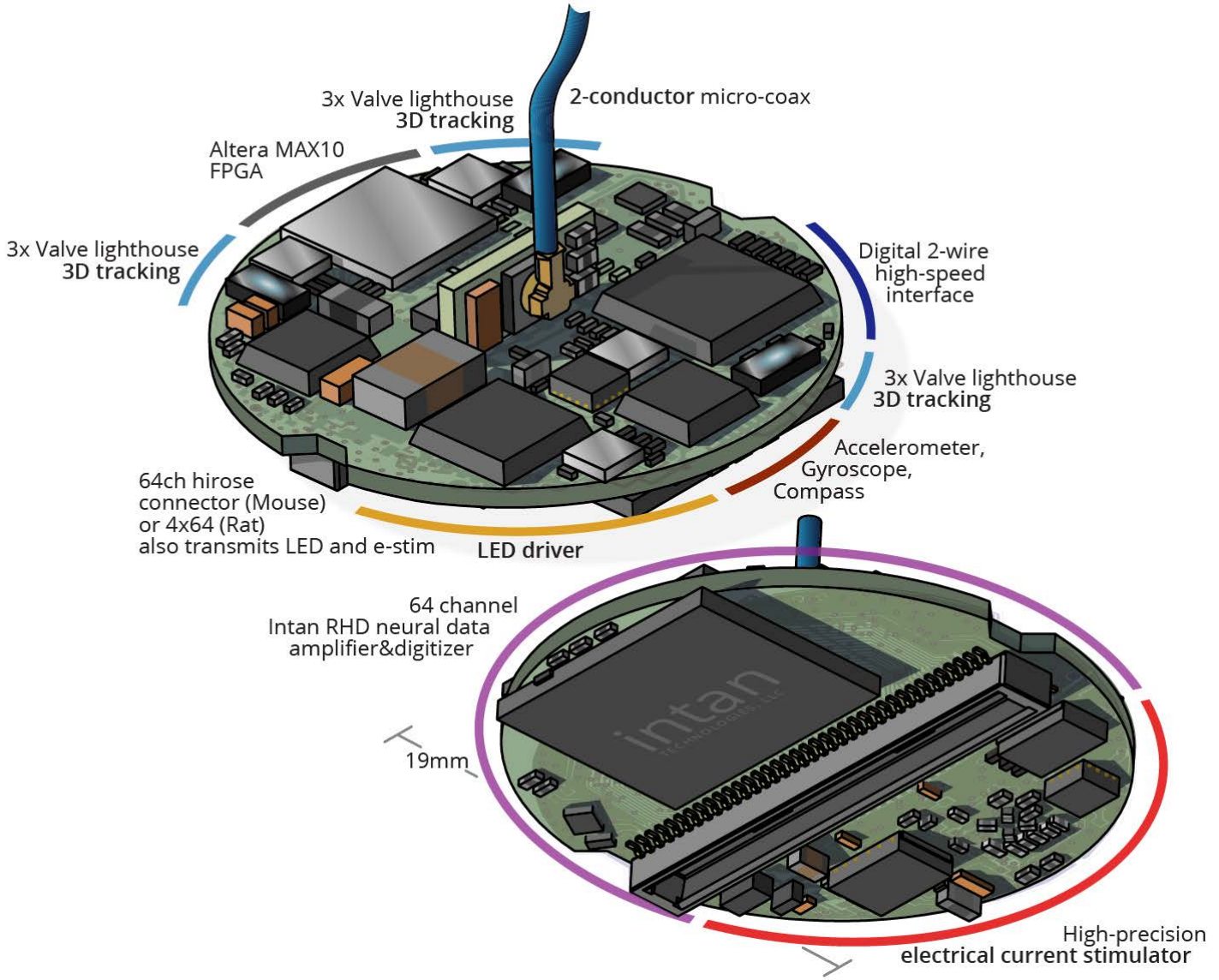
Next-generation free behaving animal ephys system



Jonathan P. Newman

Jack Zhang

Next-generation free behaving animal ephys system



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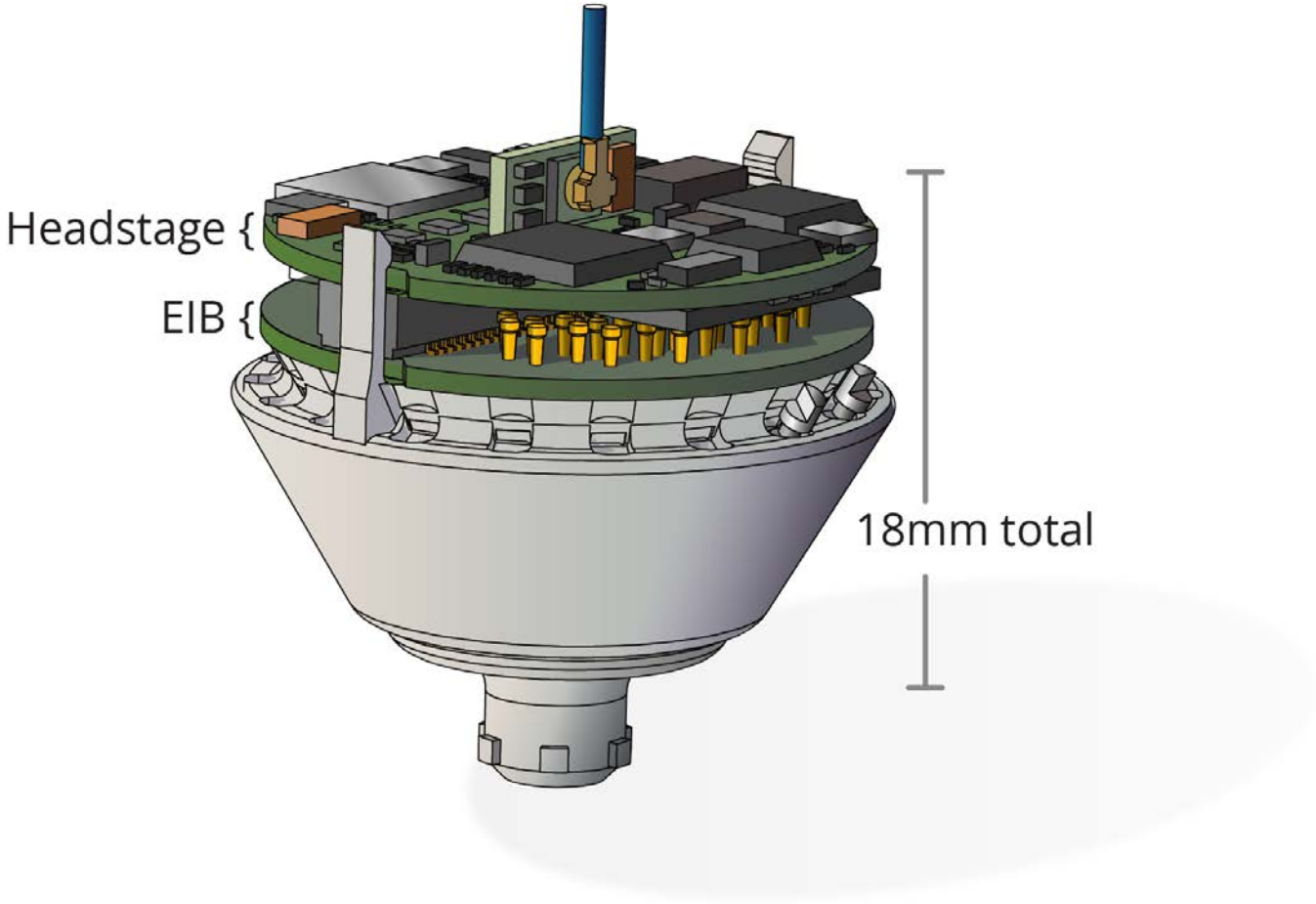

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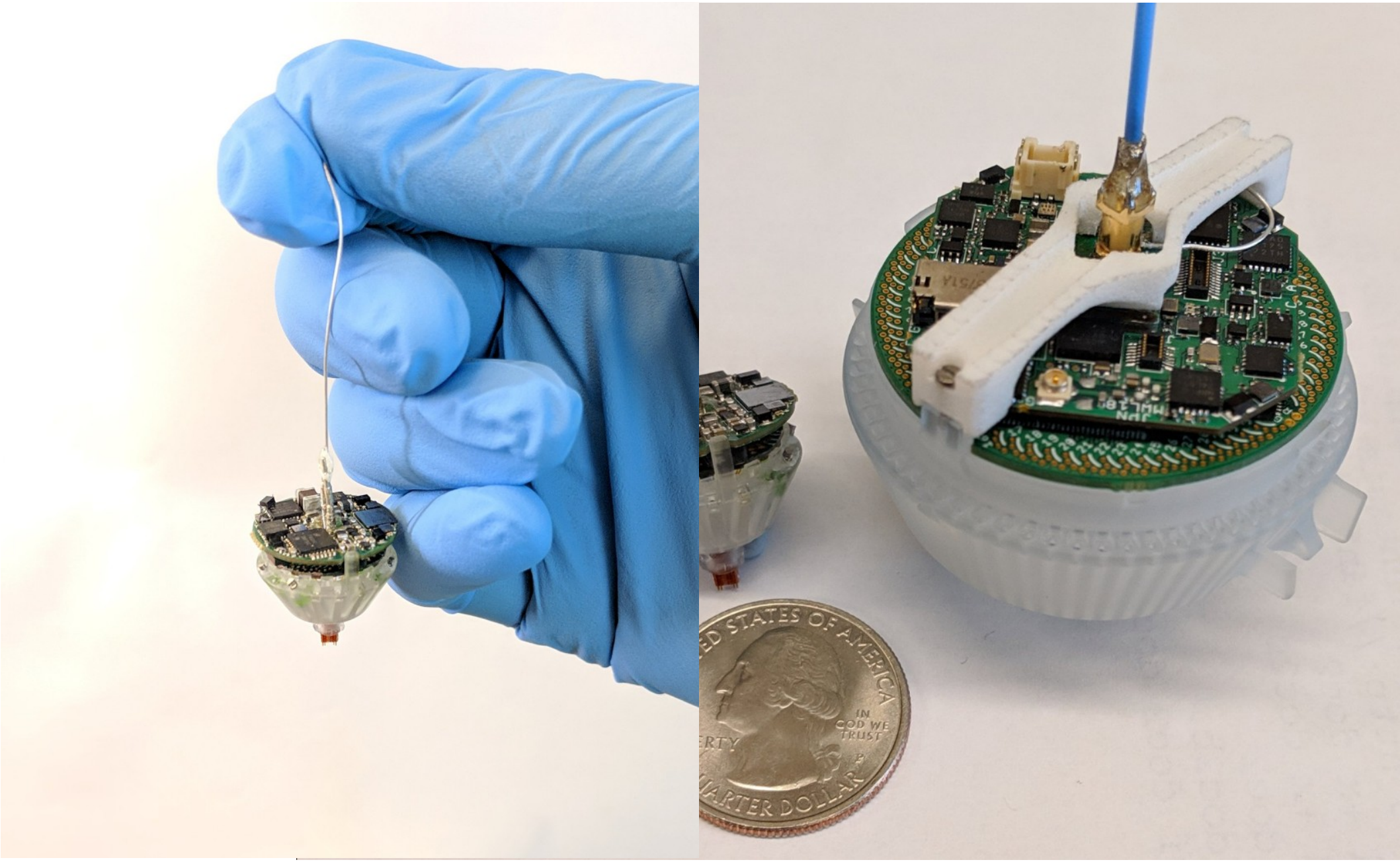

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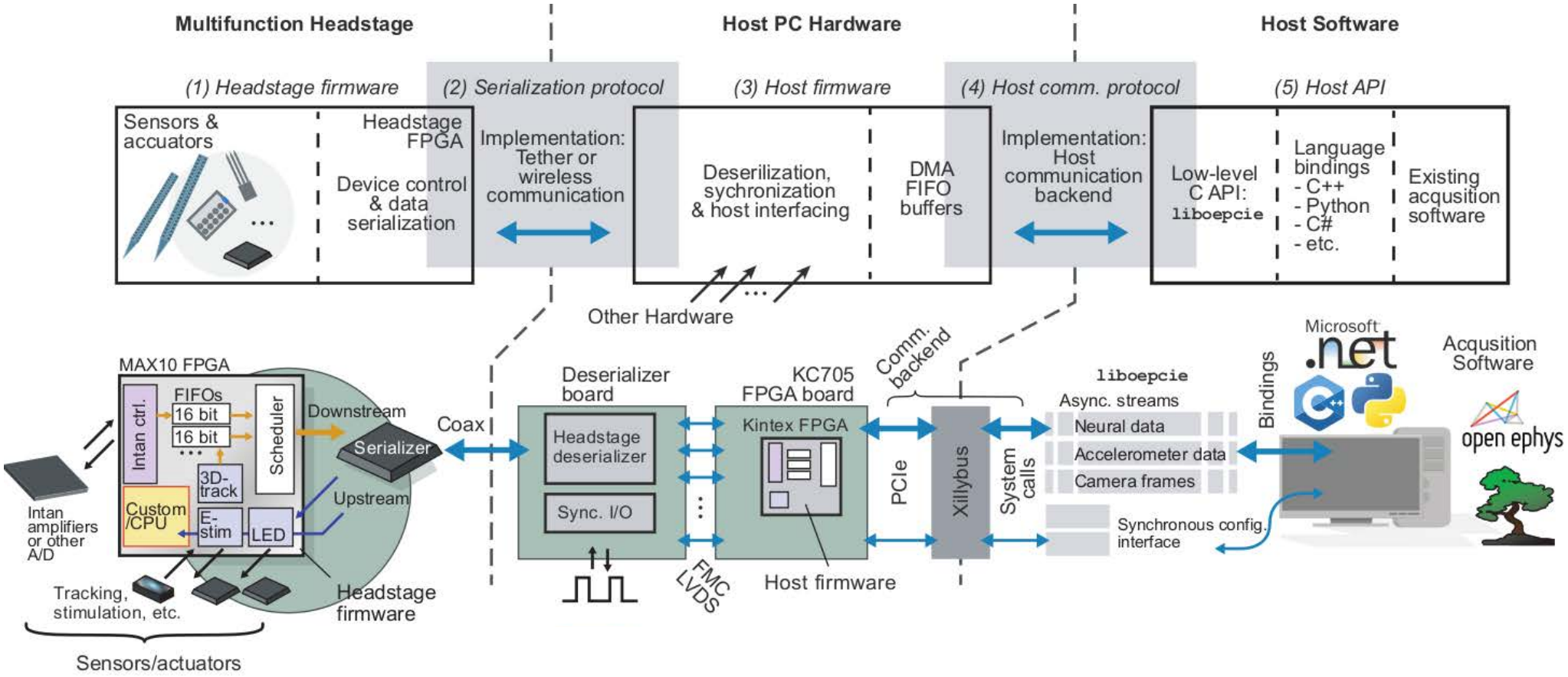

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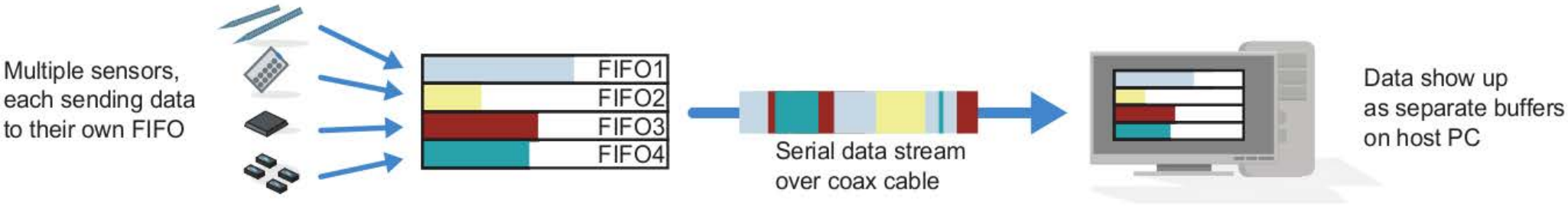

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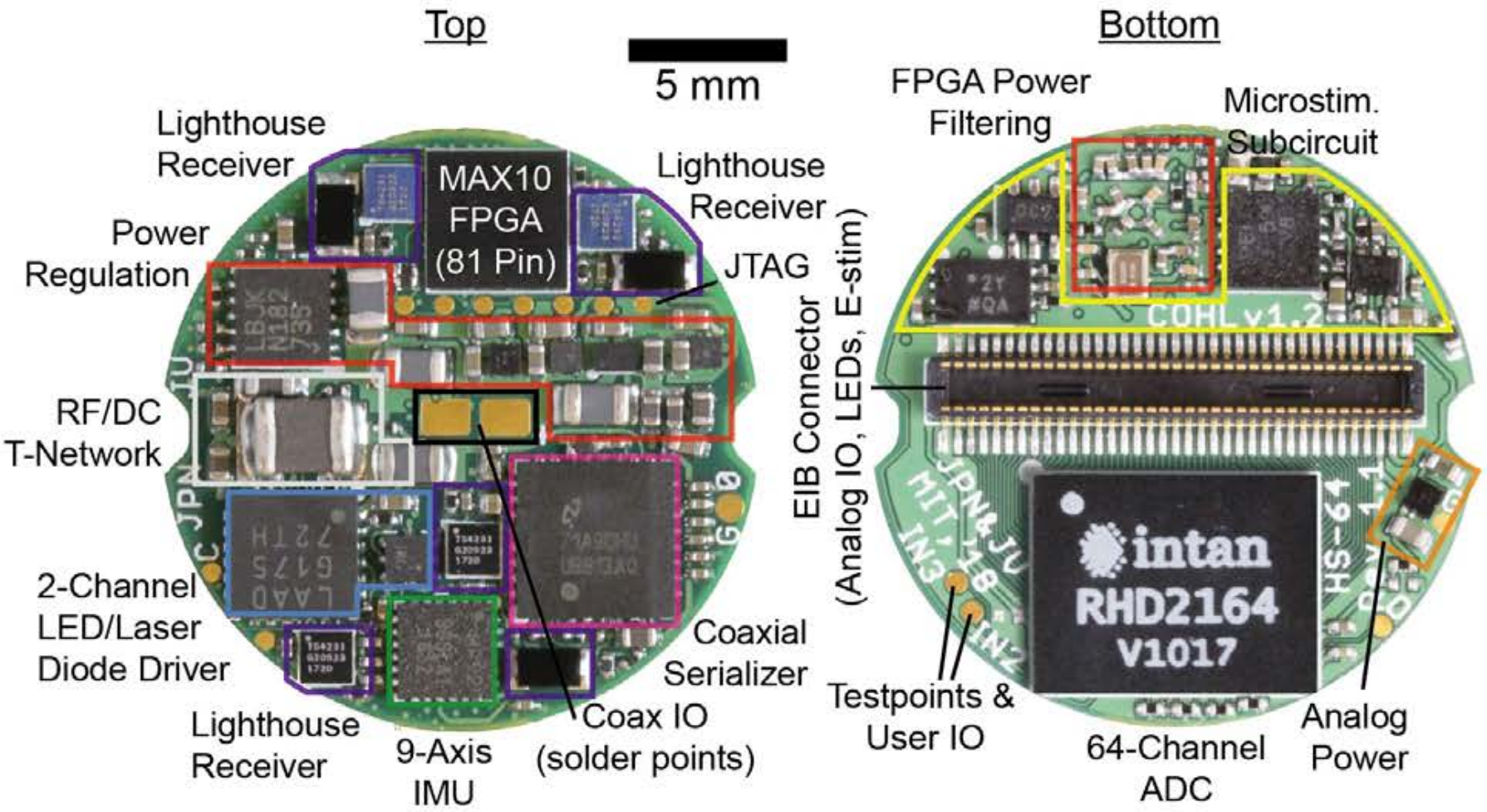

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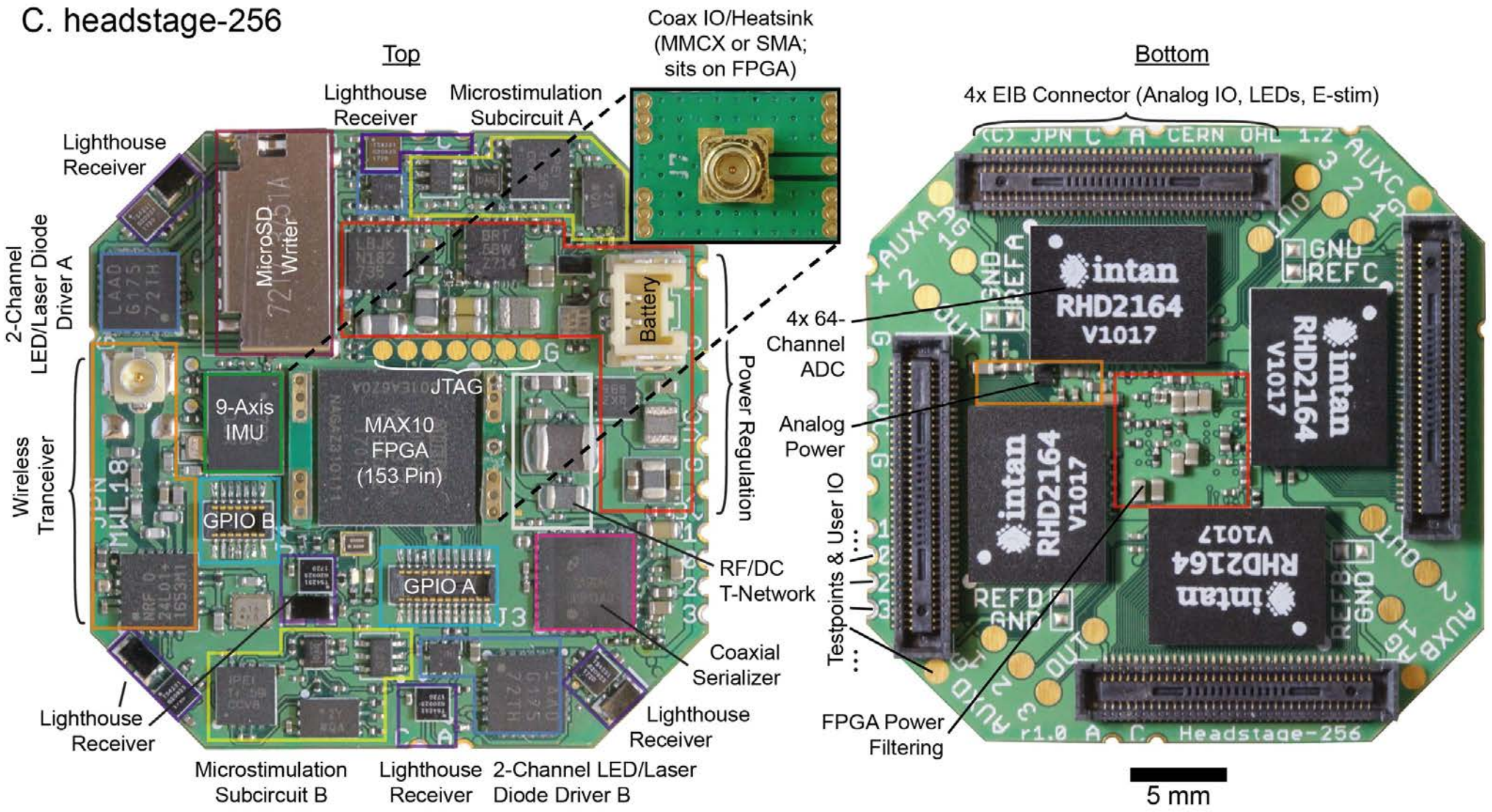

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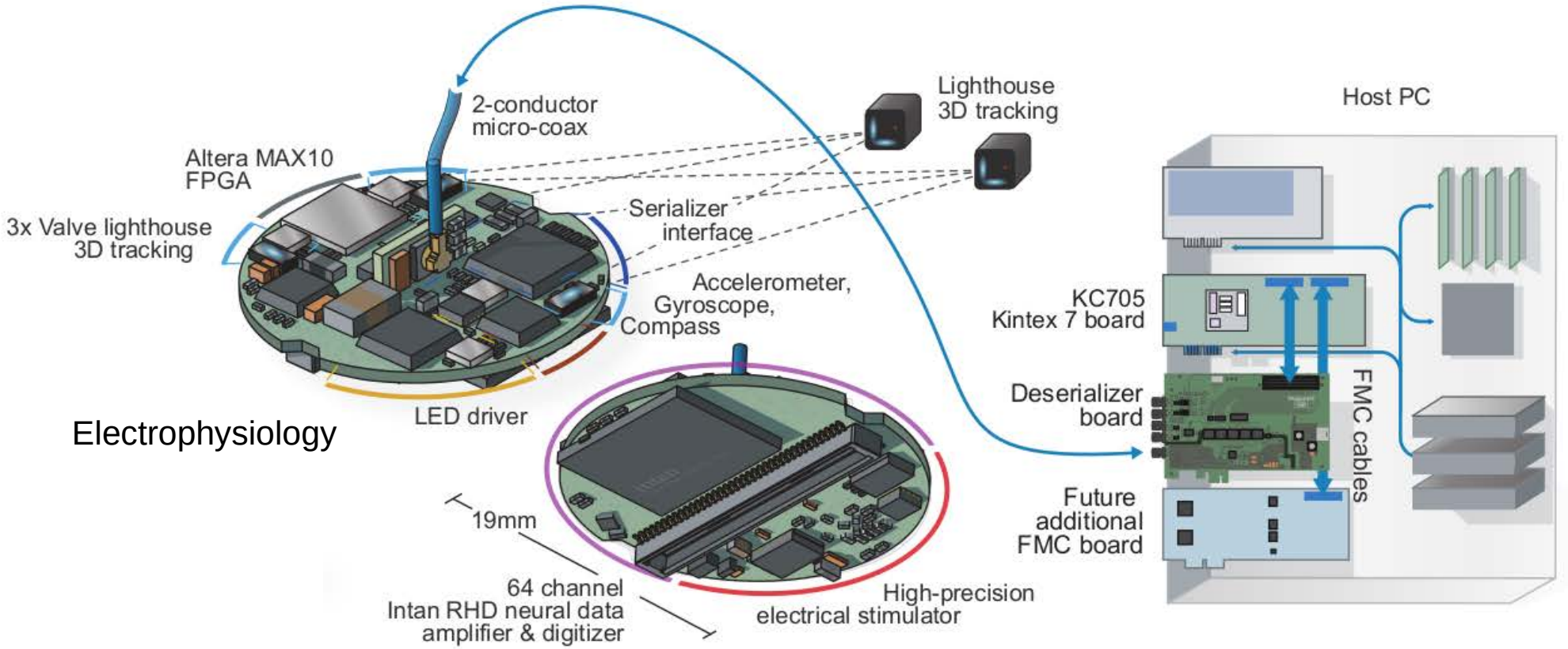

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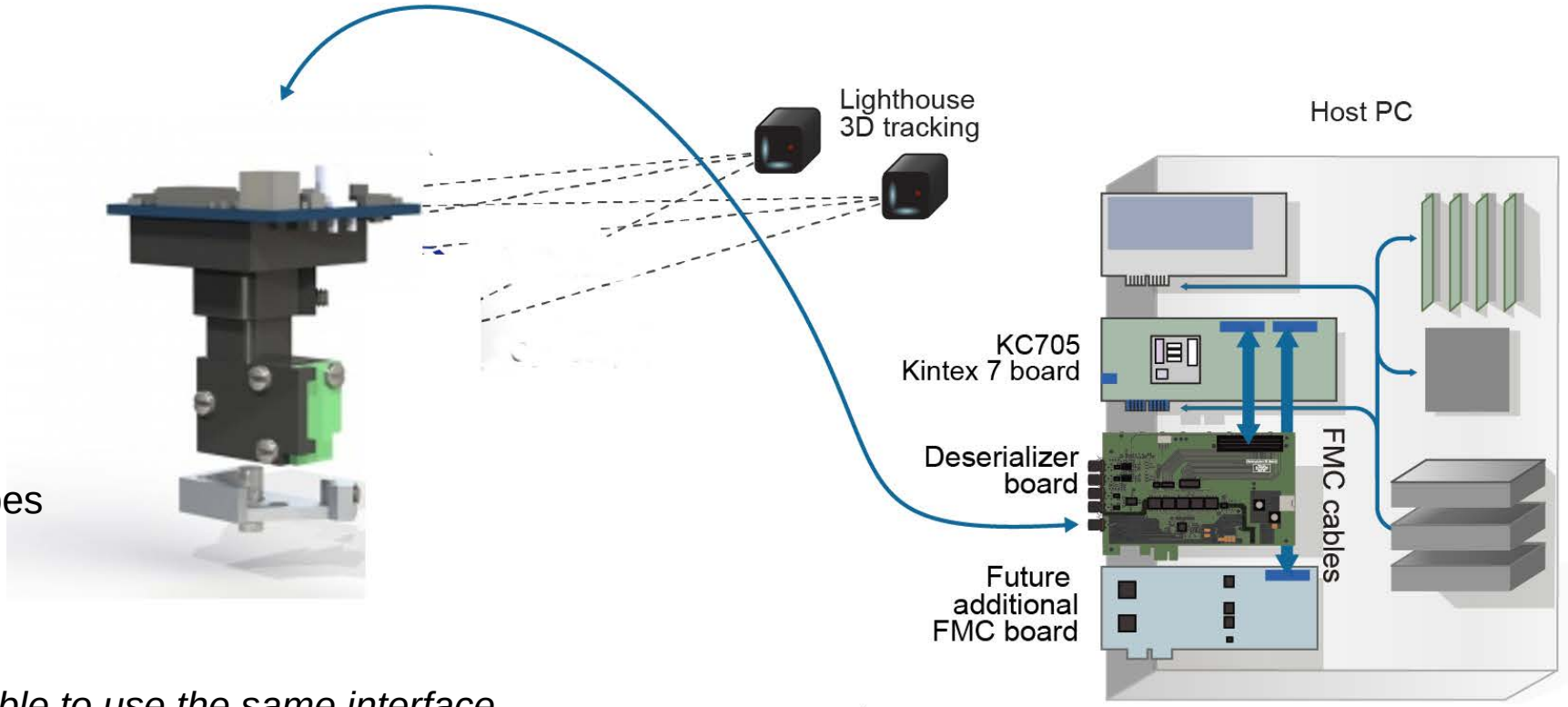
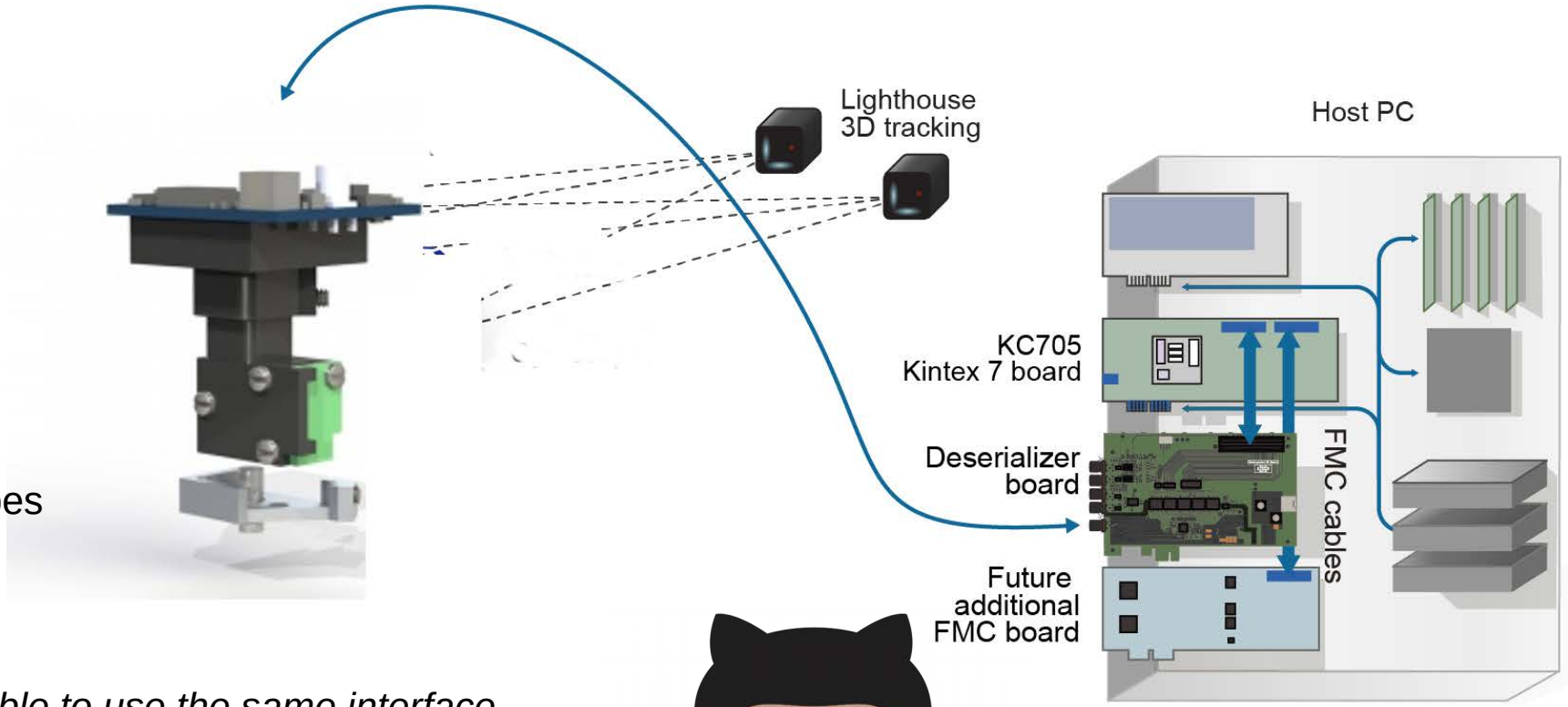


Miniscopes

Will be able to use the same interface.

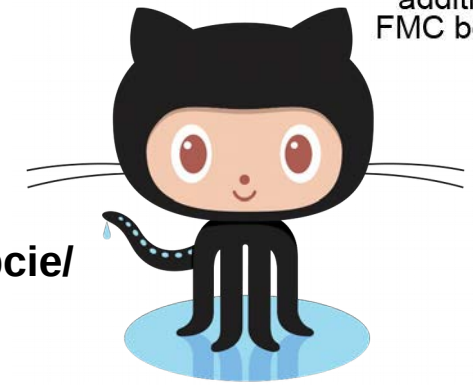
Next-generation free behaving animal ephys system



Miniscopes

Will be able to use the same interface.

https://github.com/jonnew/open-ephys-pcie/



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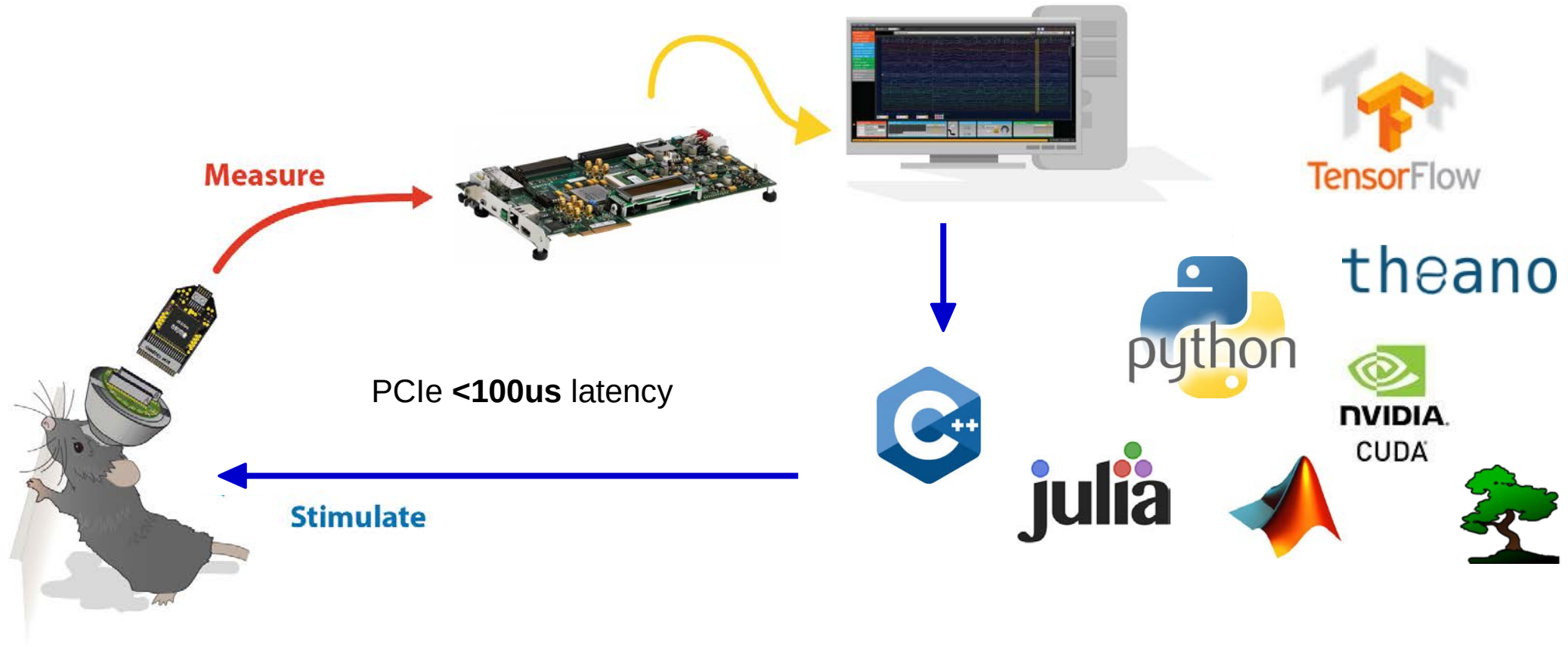

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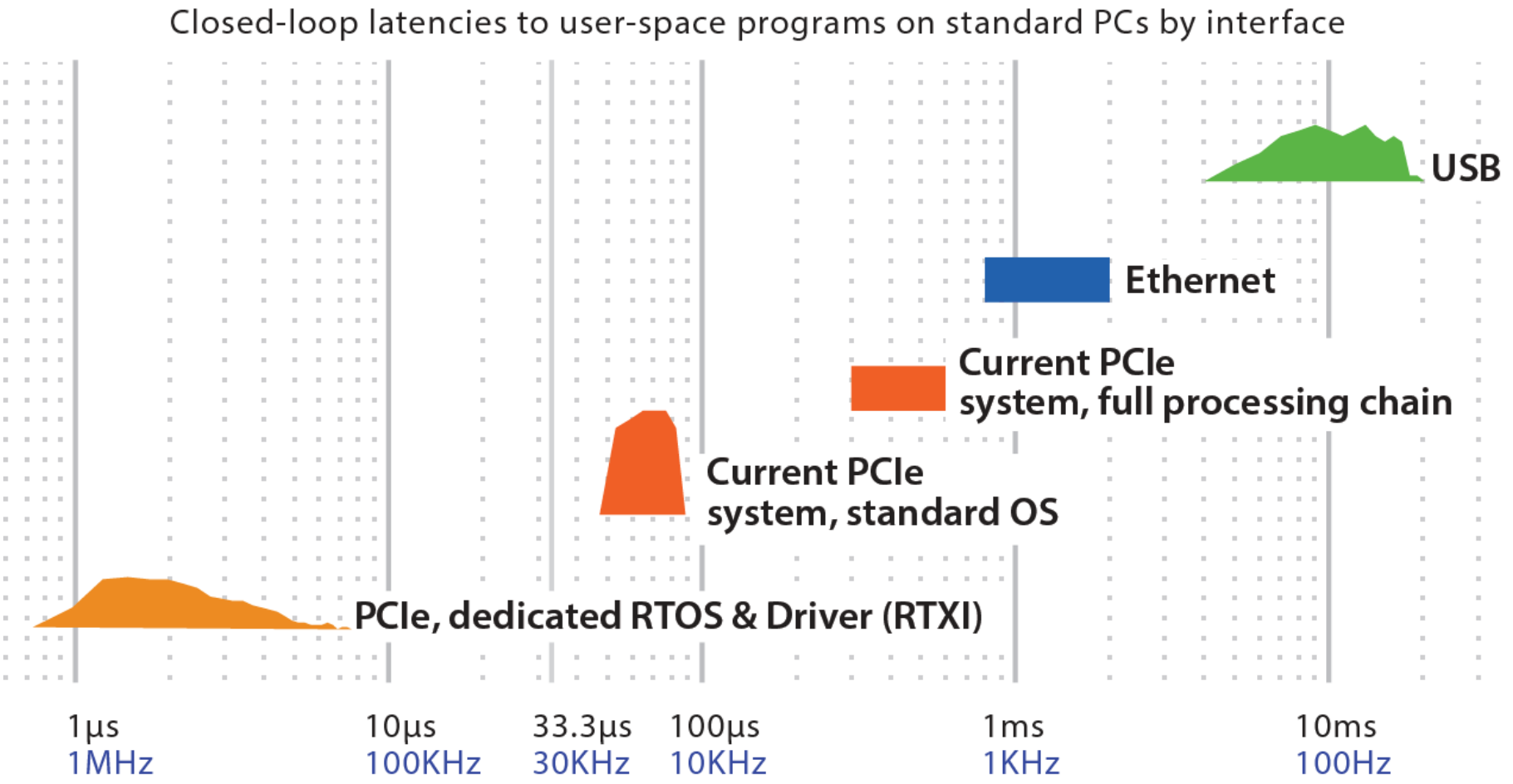

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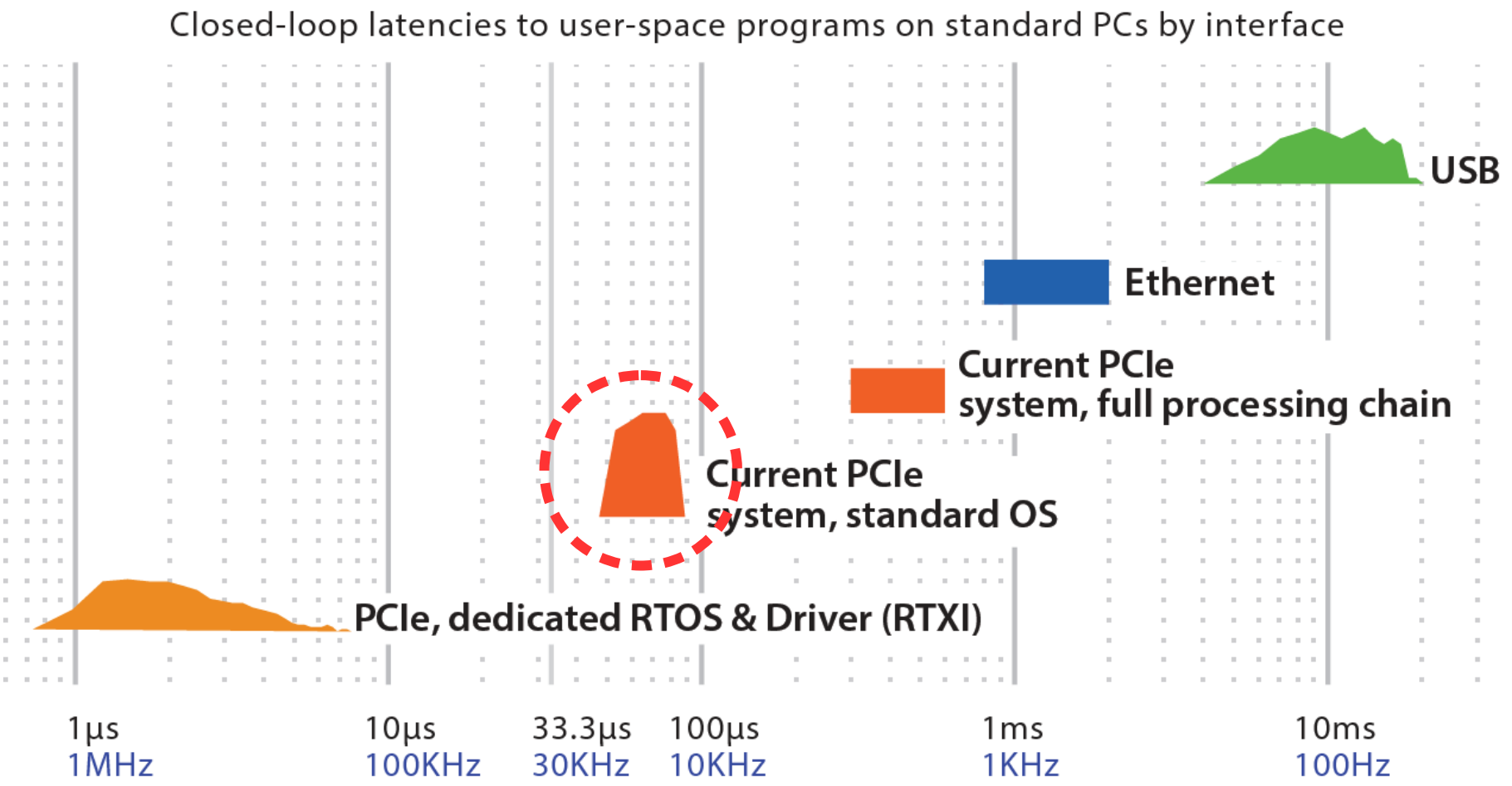

Thanks to everyone who contributed!

@OpenEphys