



ESMRMB Educational track – From hardware to map Hands-on primer to imaging with a portable scanner

<https://i3m-detectors.com/mrilab>

Joseba Alonso
MRI Lab



Funded by
the European Union



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Conflicts of interest

- I am a co-founder of PhysioMRI Tech

i3M Portable Scanner



Portable
250 kg
50 k€
70 cm wide



I3M Portable Scanner - Hardware

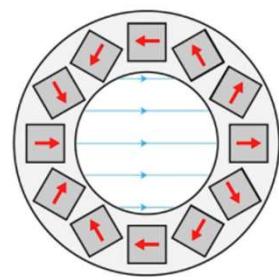
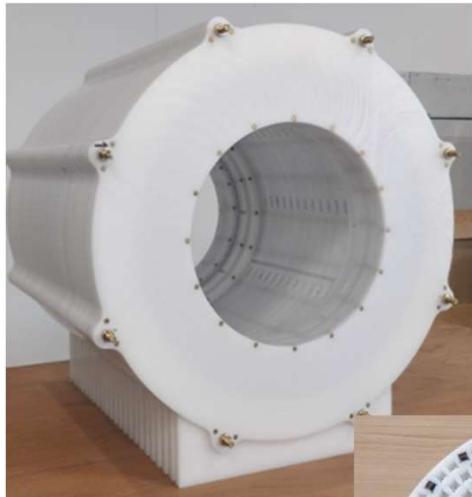
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i3M

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Halbach magnet, 72 mT



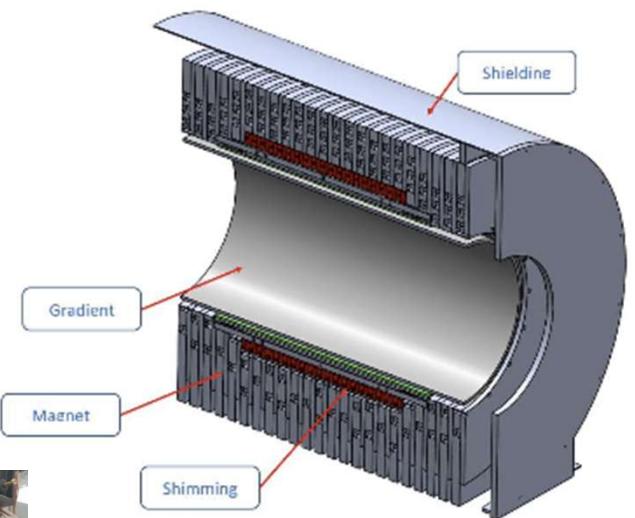
Inspired on: T. O'Reilly et al.
MRM (2020)



RF coil

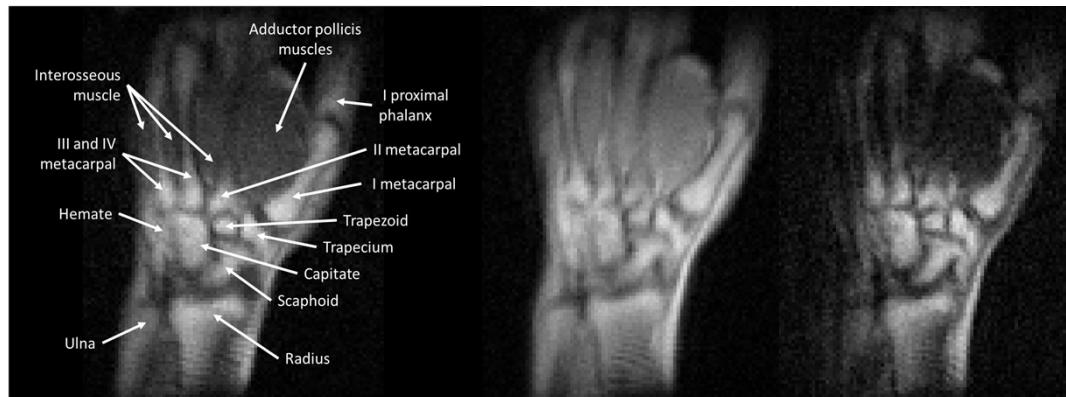
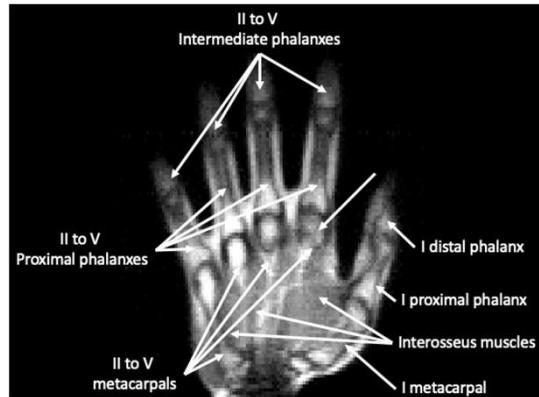


Gradient system



Scanner performance – Laboratory

3D-RARE acquisitions

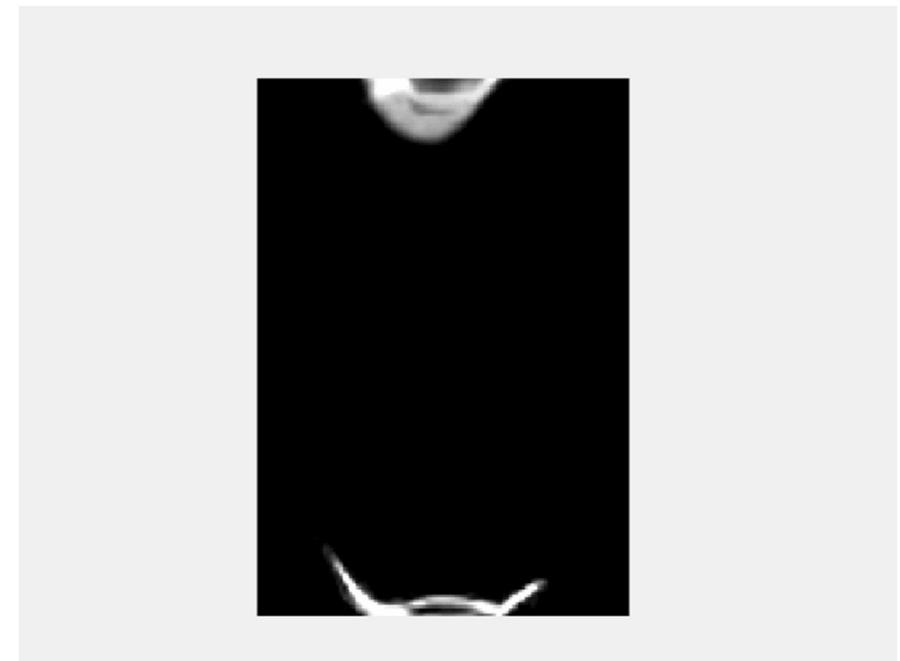


12 min acquisitions

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Isotropic knee image, BM4D-filtered
18 min acquisition

Scanner

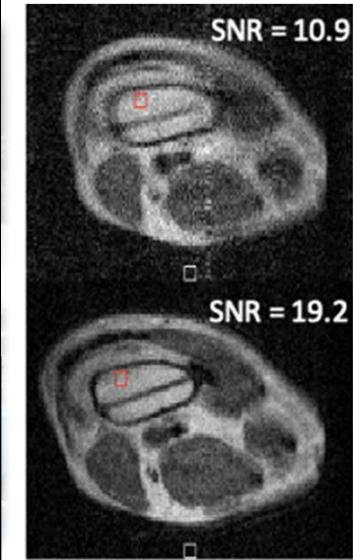
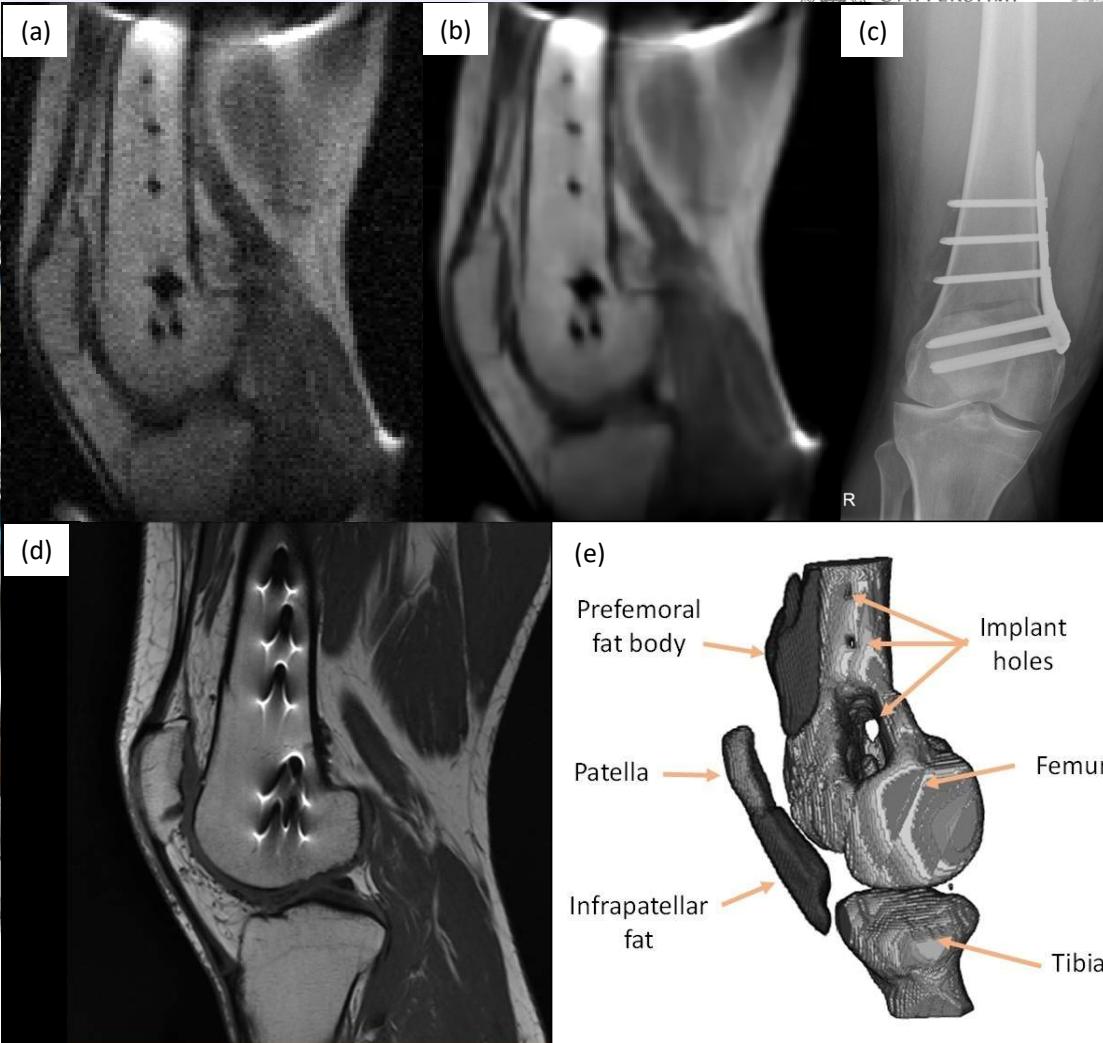
MRI physics laboratory



Office room



Outdoors (connected)



Check for updates
Magnetic resonance
imaging indoors,
at home

¹, Rubén Pellicer-Guridi^{1,2}, Fernando Galve^{2,3},
Guardo Pallís^{2,3}, José M. González¹, Juan P. Rigla¹,
J. R. Martínez-Orive¹, J. M. Gómez-Quiruelo¹,
Alvaro Marcos-Perucho¹, Joseba Alonso^{2,3,4,5} &
Vlad Negnevitsky⁶, Luis Martí-Bonmatí², Alfonso Ríos⁴, José M. Beníoch^{1,2} &
Joseba Alonso^{2,3,4,5}

Sporting events

- Valencian Motorcycle Grand Prix (Spain)

- 14 subjects – 21 acquisitions

Wrists (1 injured, 4 healthy)
Knees (6 injured, 4 healthy)
Ankles (3 injured, 3 healthy)



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PORTABLE MRI JOURNAL

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Portable MRI for major sporting events - a case study on the MotoGP World Championship

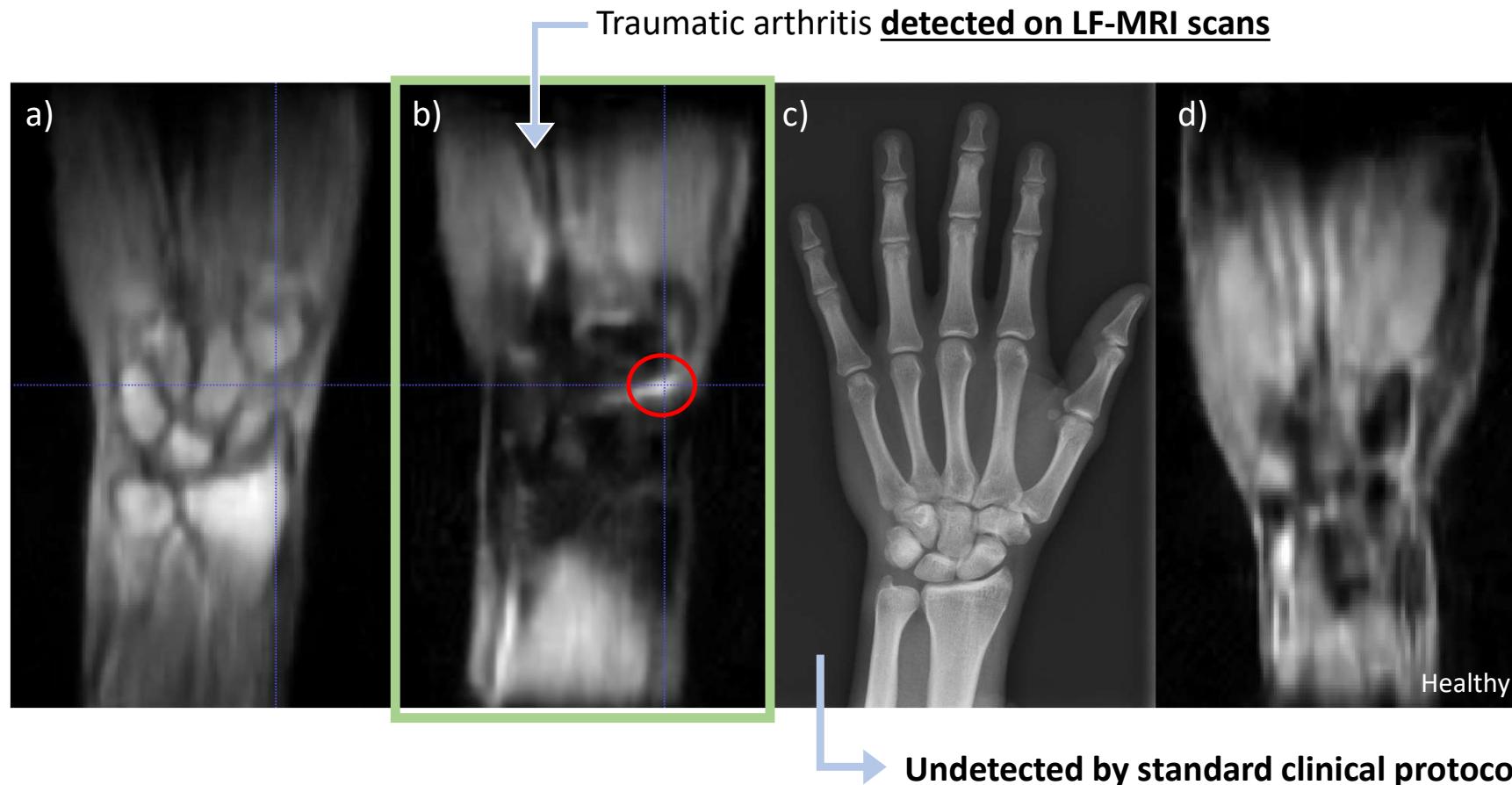
José M. Algarín *, **, Teresa Guallart-Naval *, **, Enrique Gastaldi Orquín ‡, Rubén Bosch †, Francisco Juan-Lloris §, Eduardo Pallás ‡, Juan P. Rigla †, Pablo Martínez †, José Borreguero †, Roberto Alamar ¶, Luis Martí-Bonmatí ||, José M. Benlloch *, Fernando Galve *, and Joseba Alonso *

* MRILab, Institute for Molecular Imaging and Instrumentation (i3M), Spanish National Research Council (CSIC) and Universitat Politècnica de València (UPV), 46022 Valencia, Spain

† La Salud Hospital, Department of Orthopedic Surgery, 46021 Valencia, Spain

|| Tesoro Imaging S.L., 46022 Valencia, Spain

MotoGP - Wrist

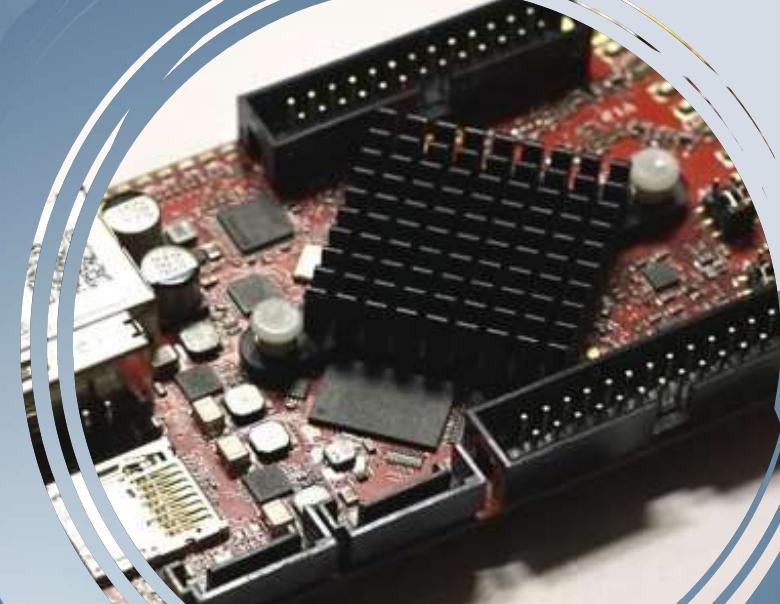


Control system

J.M. Algarín et al., JMR (2024)

V. Negnevitsky et al., JMR (2022)

T. Guallart-Naval et al., NMR in Biomed (2022)



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Tesoro Imaginario
Life resonates



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OTTO VON GUERICKE
UNIVERSITÄT
MAGDEBURG

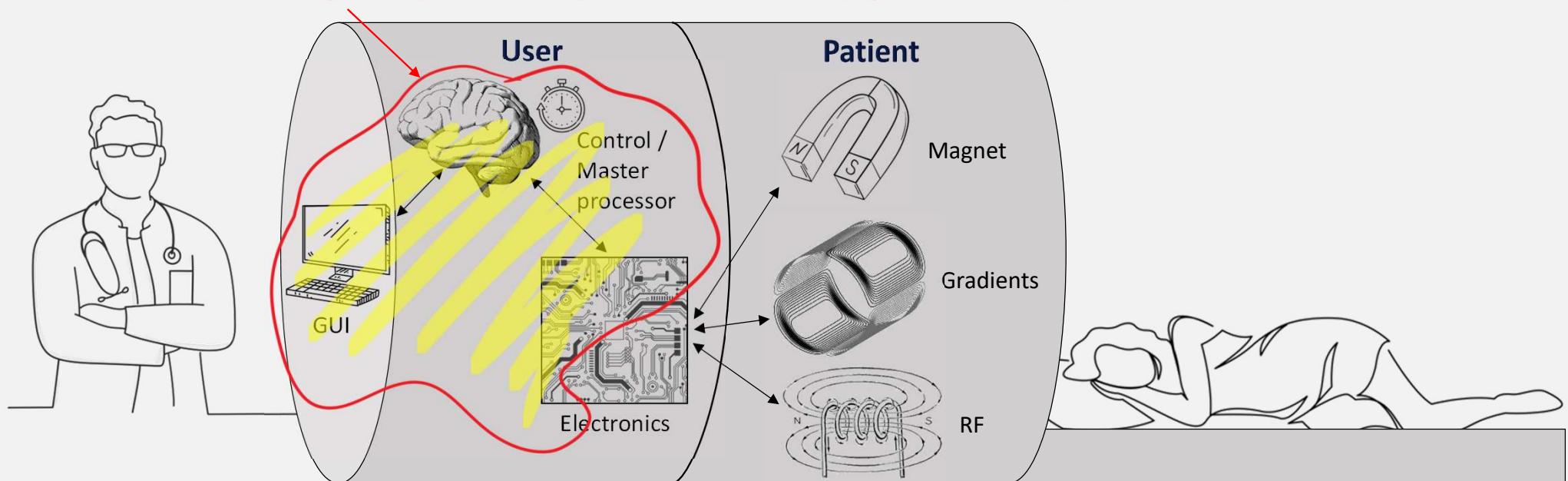


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PhysioMRI
MAGNETIC RESONANCE IMAGING

Anatomy of an MRI scanner

Control system (aka console, control electronics, spectrometer...)

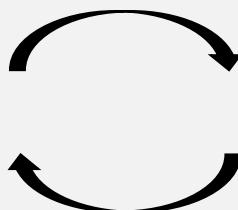


Pulse sequence design & execution

Magnetic interactions with patient

Reconstruct images

Detect signals



MRI scanner operation (non-technical interpretation)

If you're feeling low...

... the scanner embraces you and takes you in...

... it whispers to you in a unique way...

... you start sharing all your secrets, stuff that you didn't even know was part of you...

... and the scanner processes all the information so you can get cared for.

Mo^{re}THER^{esonance}

Pushing this (admittedly far-fetched) analogy...

Console: central (brain) and peripheral (sensors and actuators) nervous systems

State of the art regarding control systems

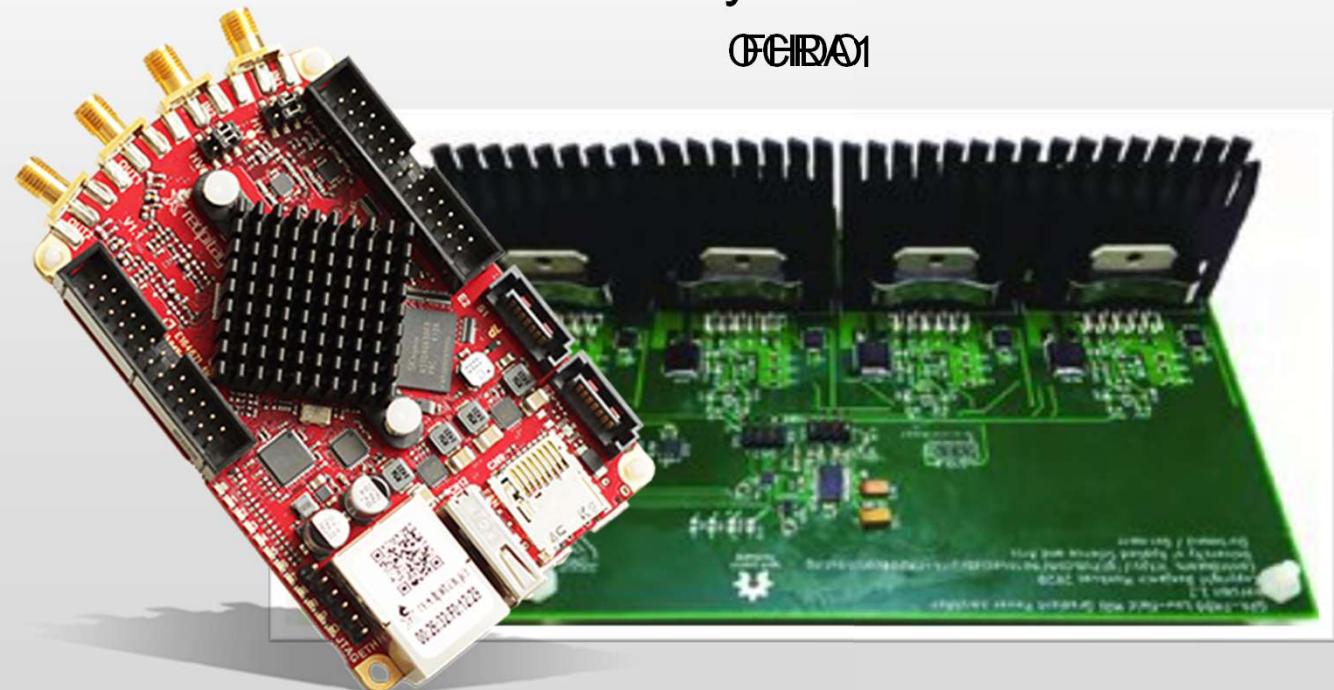
- High field: supplied by vendors
- Low field
 - Commercial systems – often rather expensive and closed (proprietary, non-interchangeable sw/hw)
 - Pure Devices (Rimpar, Germany)
 - Magritek (Wellington, New Zealand)
 - Niumag (Suzhou, China)
 - Spincore Technologies (Florida, USA)
 - Home-spun designs (e.g. OCRA, MaRCoS)
 - FPGA based
 - Some open source

Goals for MaRCoS software and firmware

- Use only open-source or off-the-shelf hardware
- Open platform, easy to reproduce/replace hardware
- Various ways of programming, including **pulseq**, to suit different users/groups
- More capable than existing inexpensive consoles
- Specific firmware goals:
 - Unlimited, timing-accurate sequence length
 - 2x RF receive channels, 2x RF transmit channels, independent frequency control
 - Up to 30 MHz burst sampling rate

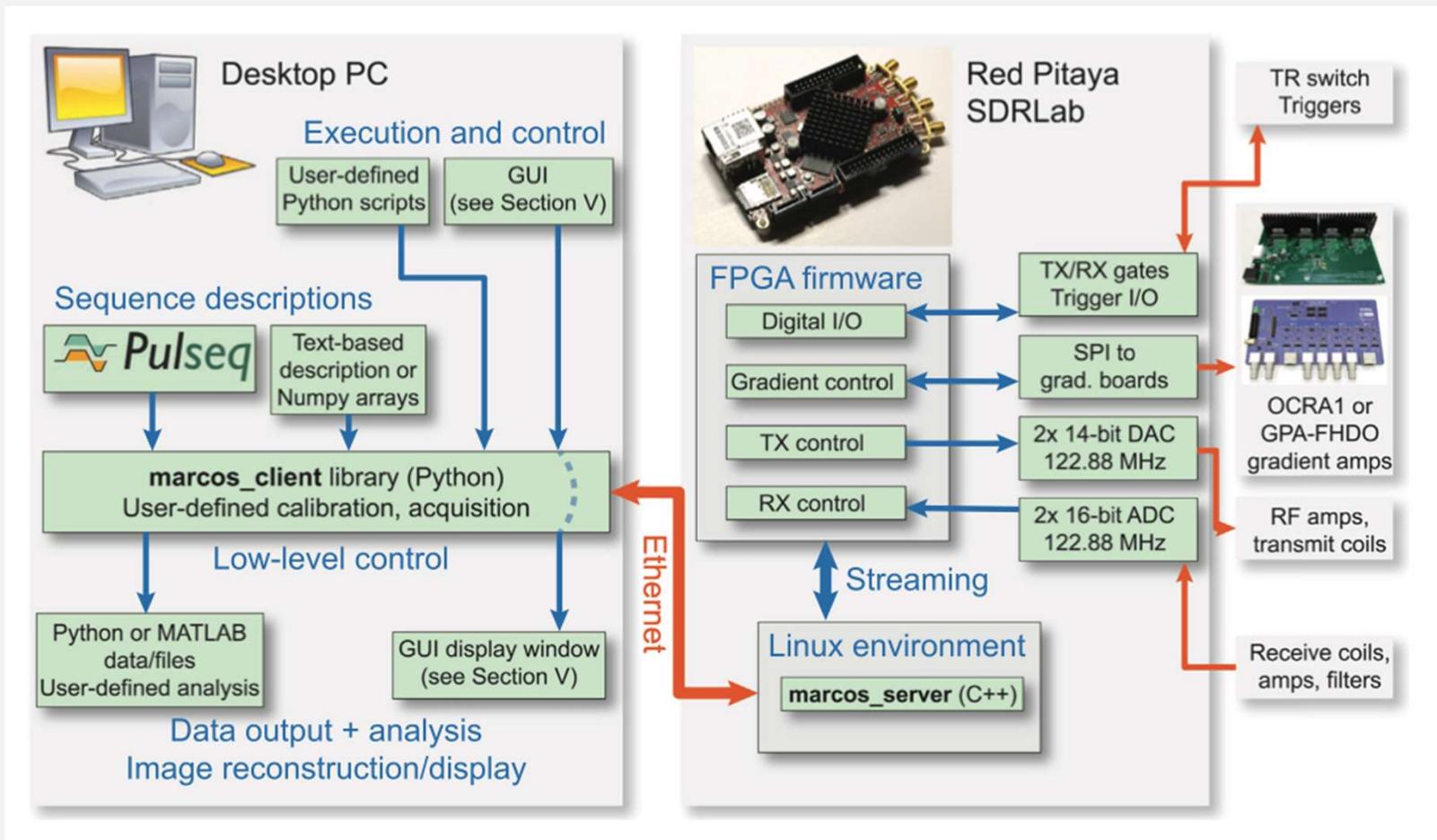
MaRCoS: Magnetic Resonance Control System

- MaRCoS is a control system based on a Red Pitaya SDRLab



OCRA1: <https://zeugmatographix.org/ocra/2020/11/27/ocra1-spi-controlled-4-channel-18bit-dac-and-rf-attenuator/>
T. Guallart et al. NMR Biomed. 36 (2022)
V. Negnevitsky et al. JMR, 350 (2023)

MaRCoS: Magnetic Resonance Control System

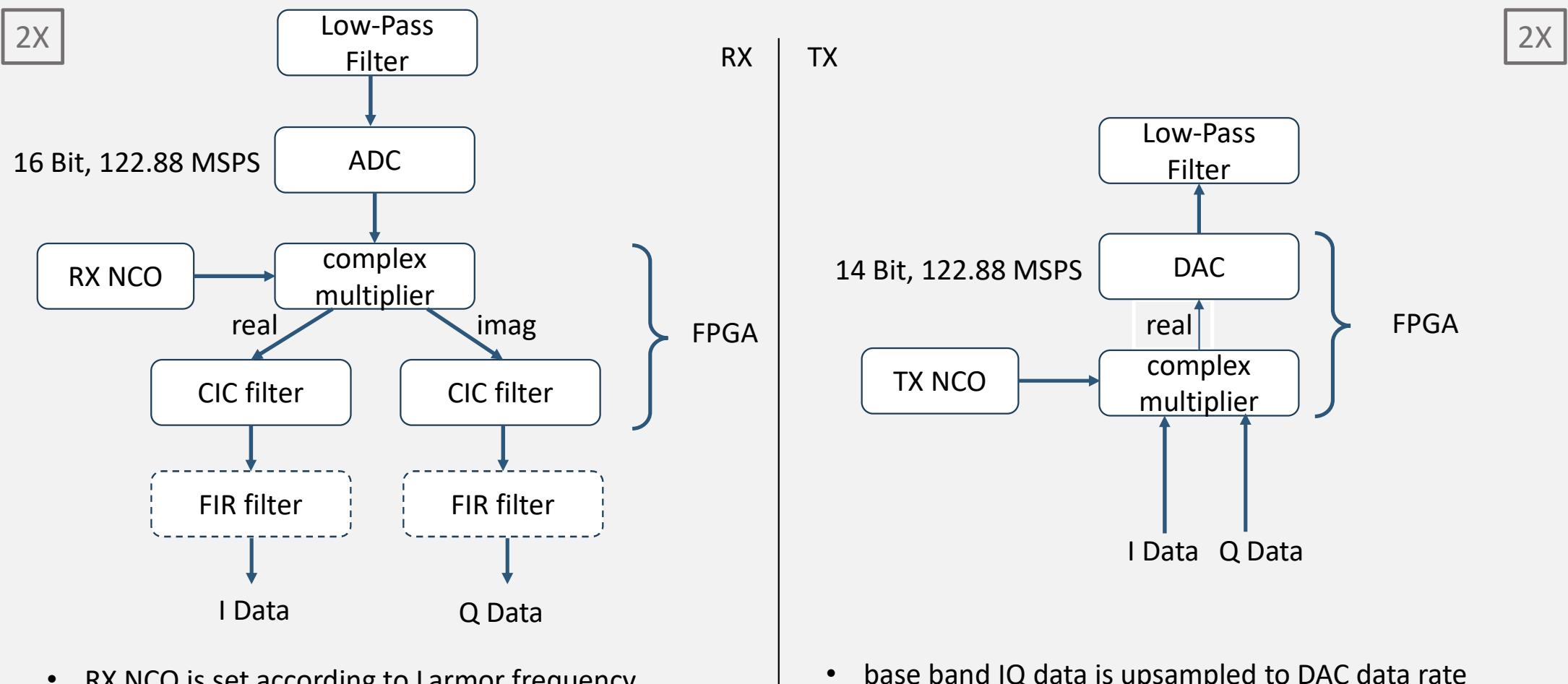


<https://github.com/marcos-mri>

T. Guallart et al. *NMR Biomed.* 36 (2022)

V. Negnevitsky et al. *JMR*, 350 (2023)

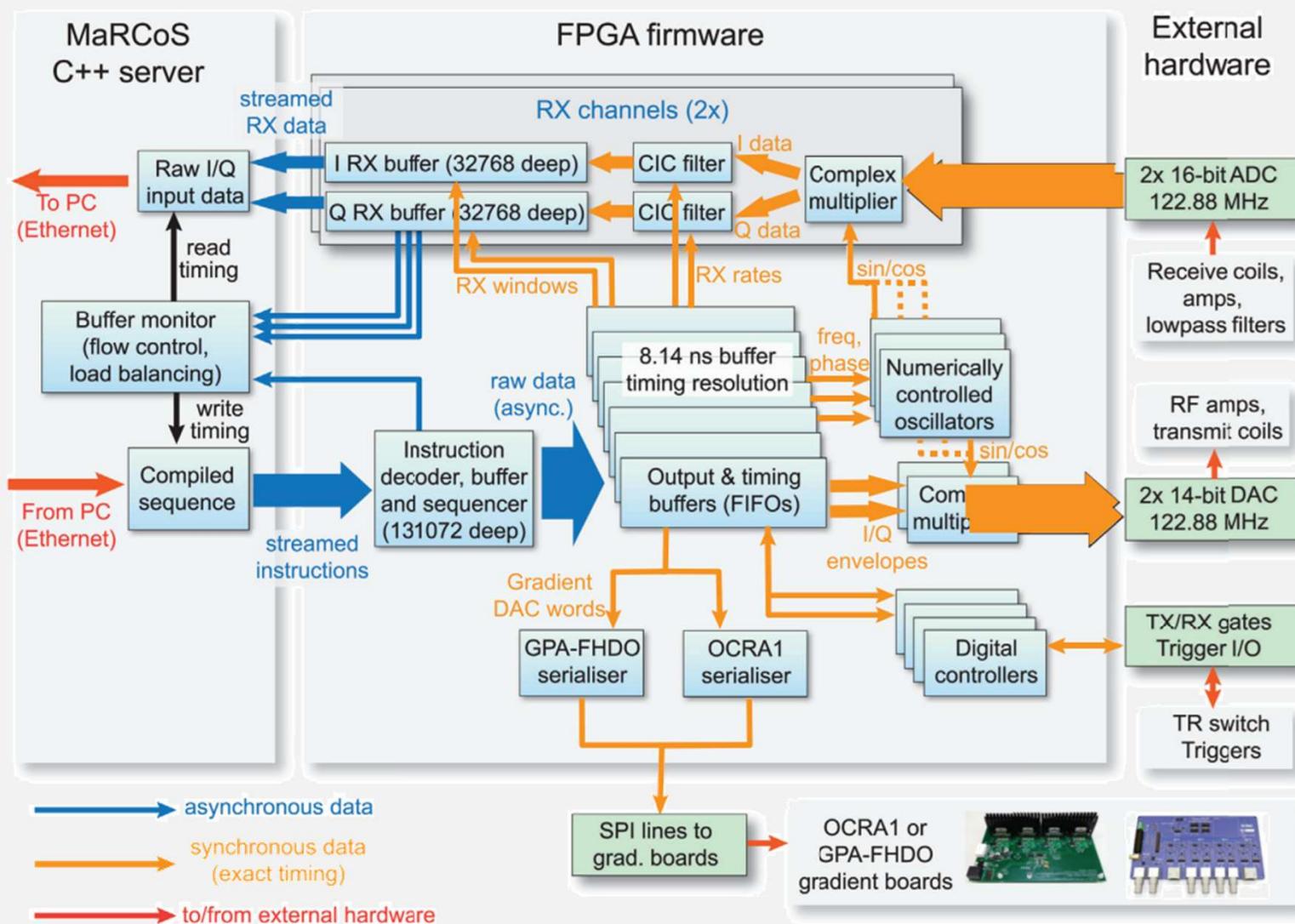
MaRGA: SDR Architecture (Marcos fpGA)



- RX NCO is set according to Larmor frequency
- CIC filters do downsampling and low-pass filtering
- FIR filters do droop correction + 2-4x downsampling

- base band IQ data is upsampled to DAC data rate
- complex multiplier mixes base band data up
- TX NCO is set according to Larmor frequency

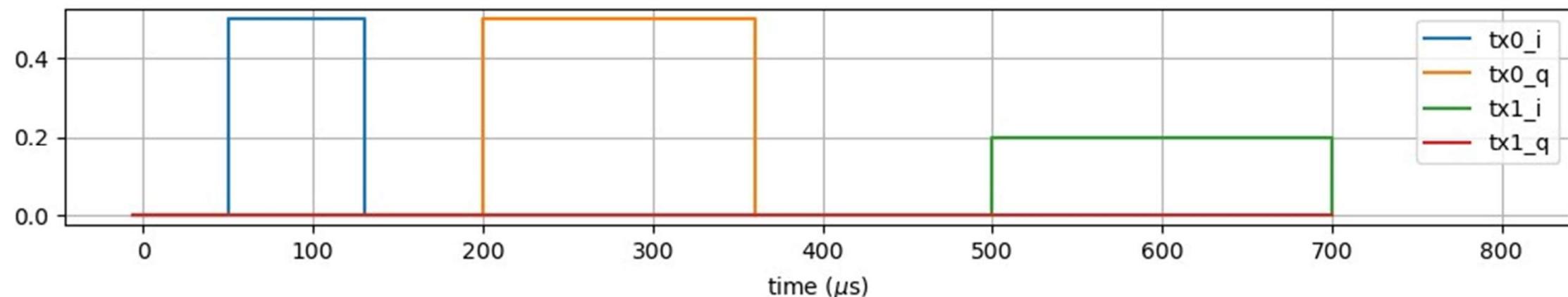
MaRCoS server + MaRGA



MaRCoS software and usage

- MaRCoS client: Python backend, hardware control + sequence compiler
 - Native format: numpy arrays
- Pulseq interpreter
 - Tested with Matlab pulseq and npulseq

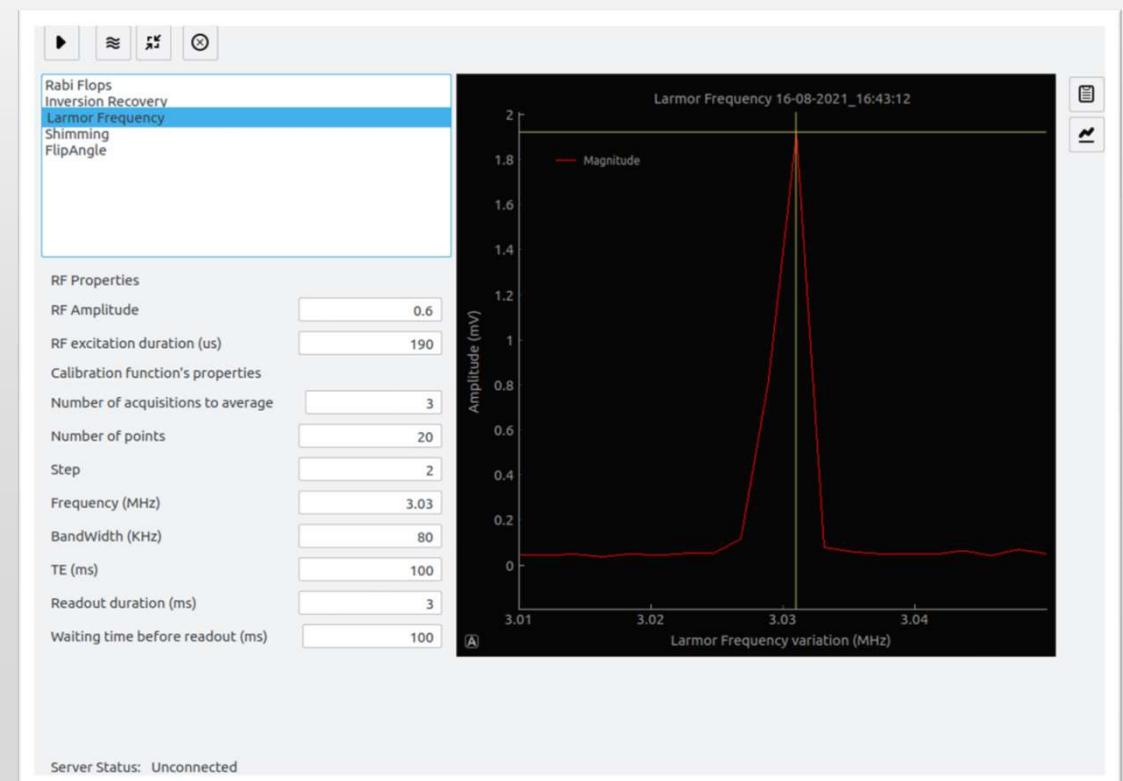
```
event_dict = {'tx0': (np.array([50, 130, 200, 360]), np.array([0.5, 0, 0.5j, 0])),  
             'tx1': (np.array([500, 700]), np.array([0.2, 0])),  
             'rx0_en': (np.array([400, 800]), np.array([1, 0])),  
             'rx1_en': (np.array([400, 800]), np.array([1, 0])) }
```



MaRGE: MARcos Graphical Environment

In previous works, rudimentary GUI was developed with strong limitations

- No communication management with MaRCos
- No session management
- Single sequence run
- No automated system calibration
- No standards like DICOM or ISMRMRD
- No image comparison
- No post-processing options

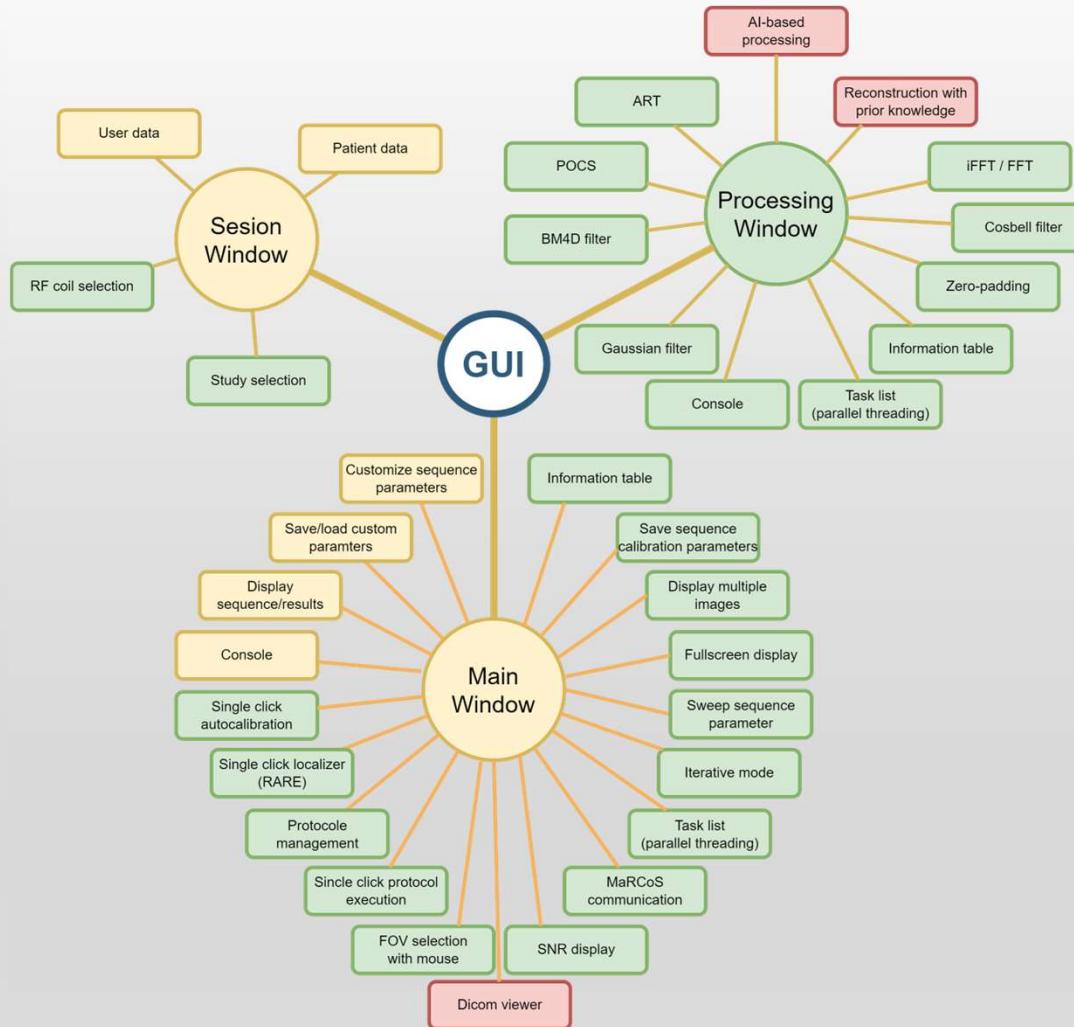


Goal

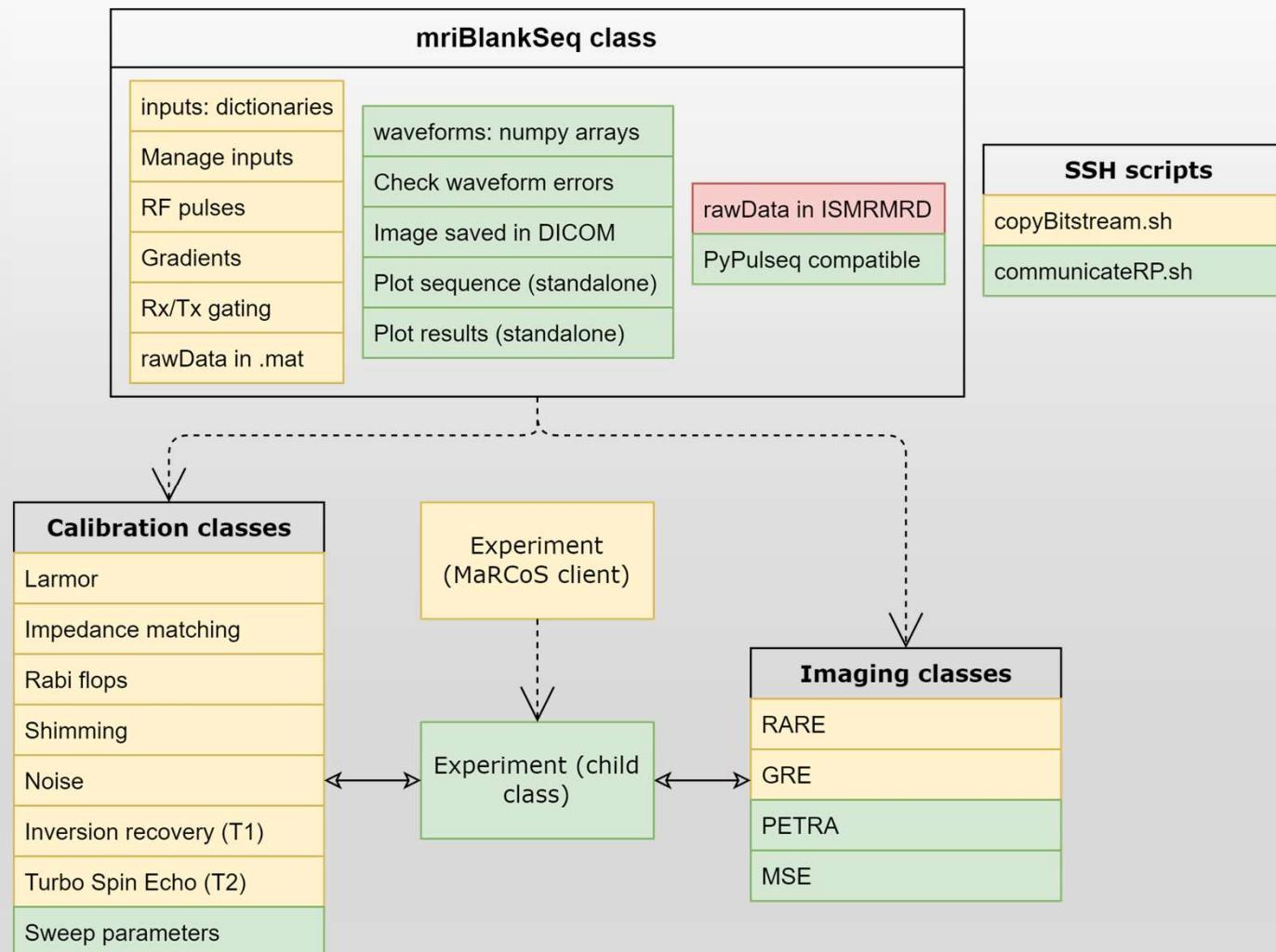
The goals behind MaRGE are three:

- To enhance user interaction with the MaRCoS system.
- To optimize the functionality of MaRCoS specifically for laboratory and medical environments.
- To provide a set of tools for image post-processing.

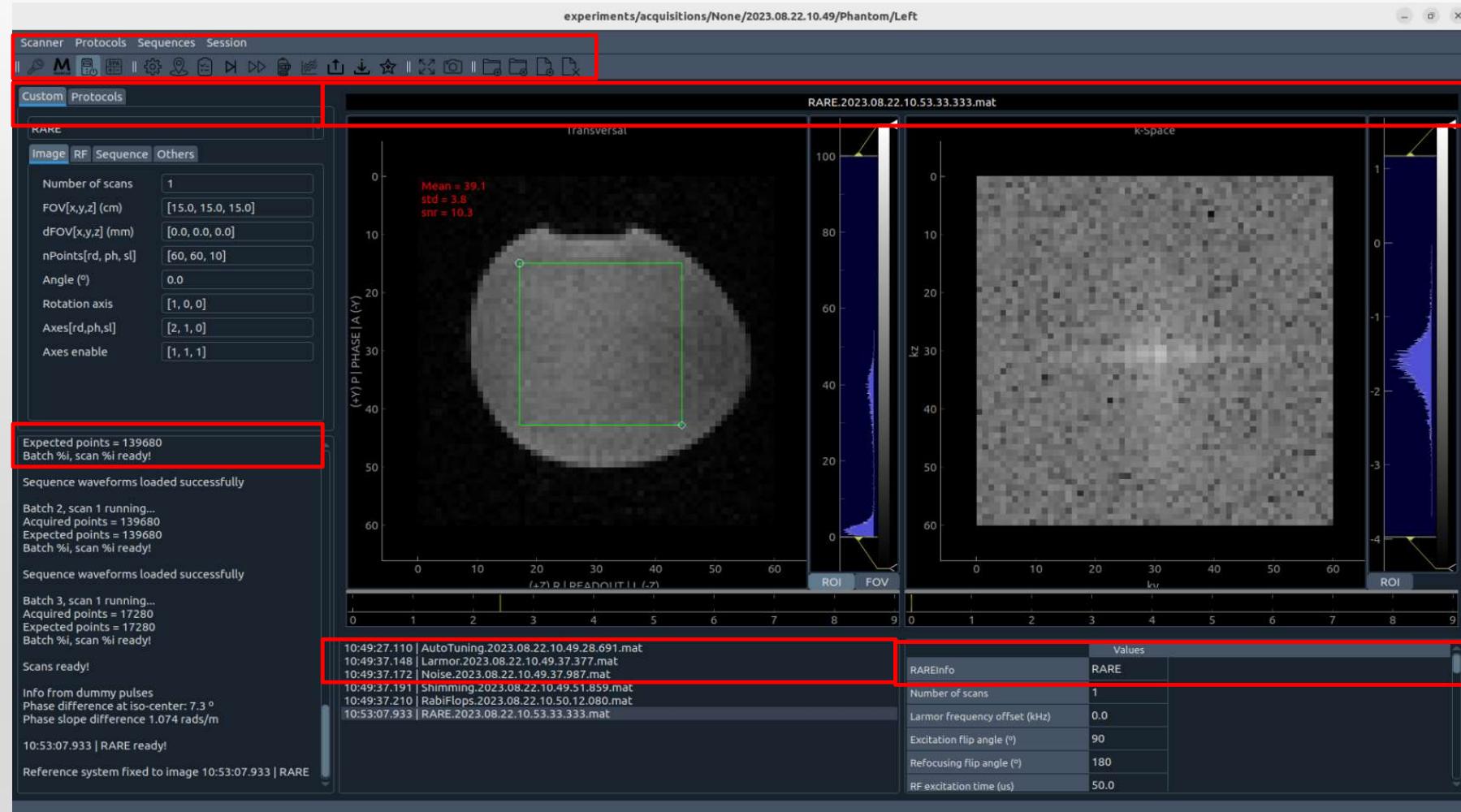
Graphical User Interface (GUI)



Application Program Interface (API)



Main window



What comes next?

- Hands-on primer to imaging with a portable scanner
- Effect of different “situations” on signals and images
 - Noise
 - Coil tuning & matching
 - Shimming
 - Acquisition bandwidth
 - Definition of FoV
 - ...
- Imaging and T2 mapping – have fun!!

MRILab

Unique scanners and techniques pushing the limits of Magnetic Resonance Imaging



Dr. F. Galve
Senior scientist



Dr. J. M. Algarín
Postdoc



E. Pallás
PhD Student



T. Guallart
PhD Student



R. Bosch
Electronics engineer



P. Borreguero
PhD Student



P. García
PhD Student



M. Fernández
Master Student



J. Conejero
Master student



Dr. J. P. Rigla
Researcher



Dr. E. Castañón
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Dr. A. González
Postdoc



M. Fernández
PhD Student



L. De Castro
PhD Student



L. Swistunow
Mechanical eng.



Dr. L. Vega
Postdoc



L. Barajas
Project admin



Prof. Dr. J. M. Benlloch
Institute director



Dr. J. Alonso
Group leader