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RFSoC 2x2 Project

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FPGA21 RFSoC PYNQ Tutorial

The RFSoC 2x2 Project

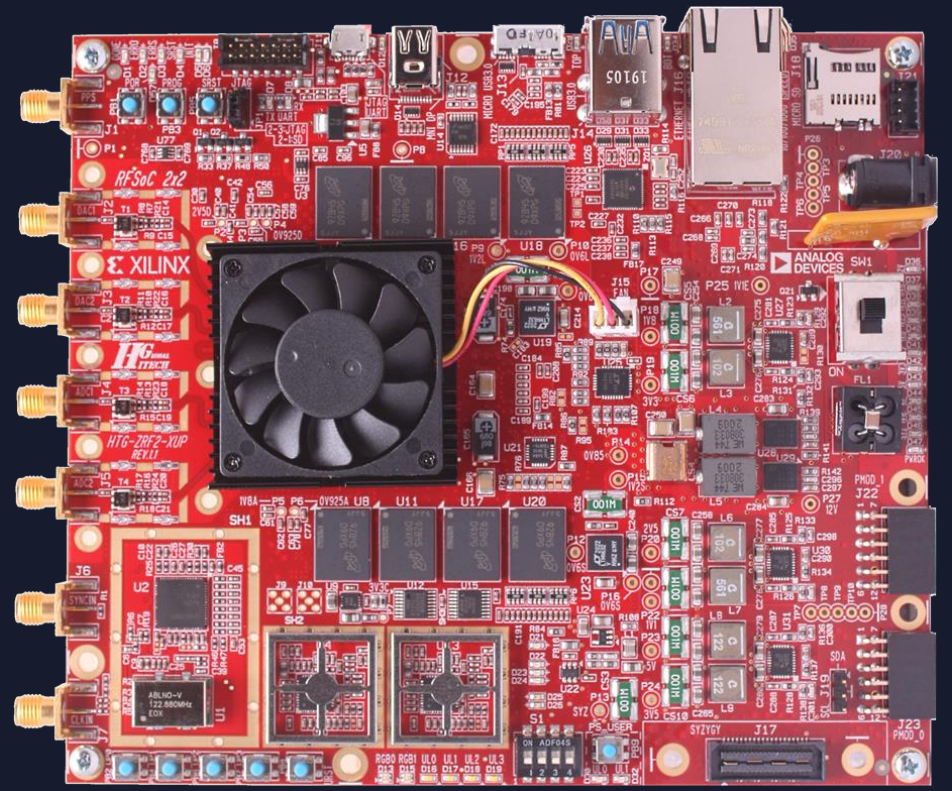
- Affordable RFSoC 2x2 kit price of $1,899 available only to academics
- Includes RFSoC 2x2 board with 2 RF DAC and 2 RF ADC channels
- PYNQ framework with JupyterLab IDE for exceptional ease-of-use
- Open-source resources including:
  - Tutorial materials
  - Executable notebooks
  - Design examples

The RFSoC 2x2 Project Continued

ZYNQ RFSoC

- Complete end-to-end reference designs including:
  - Spectrum analyzers
  - Software defined radios
- Dedicated project web site at rfsoc-pynq.io
- GitHub-hosted repositories of all project materials
- Online community support forum

RFSoC 2x2 Board Overview



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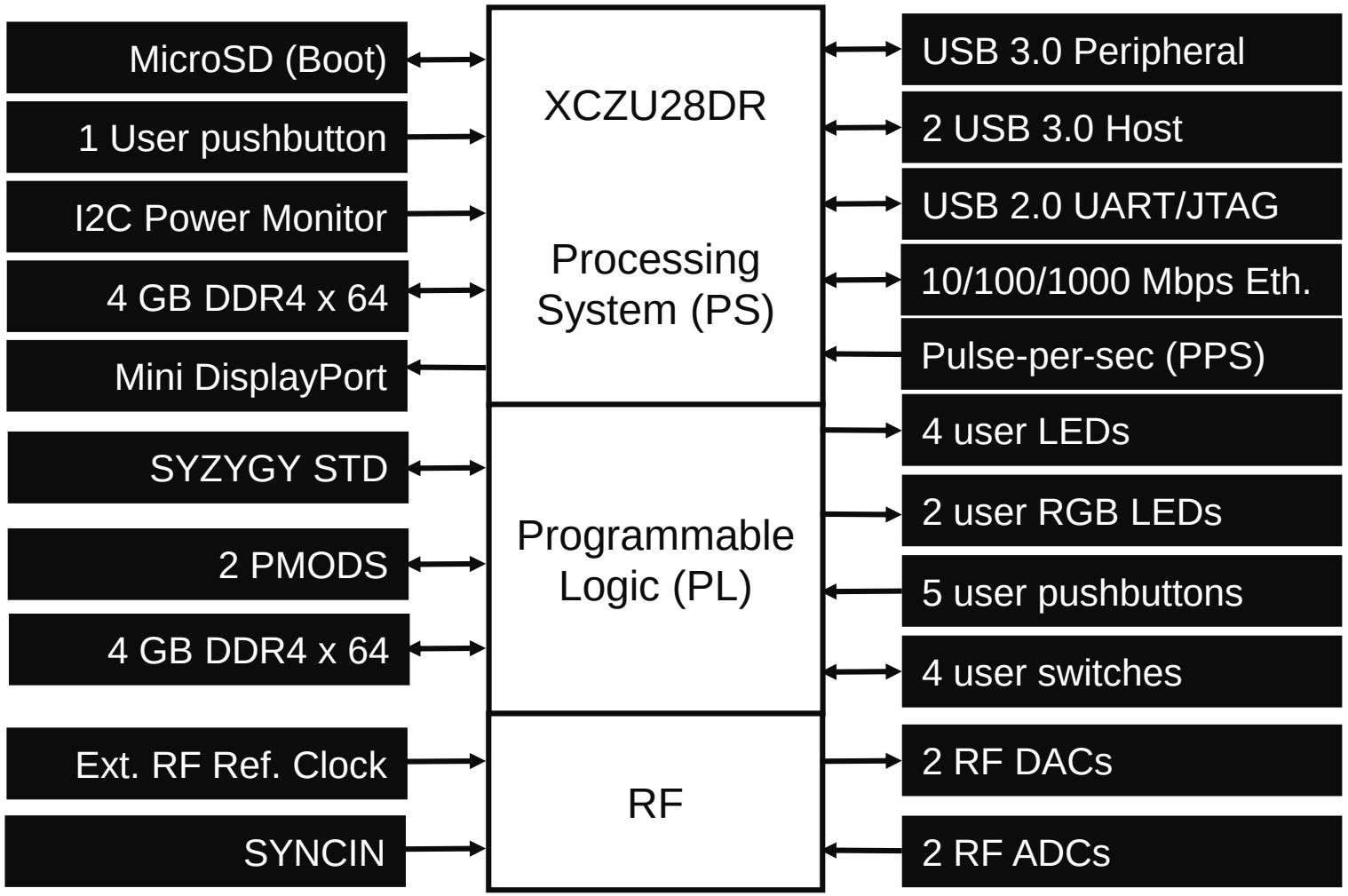
RFSoC 2x2 Block Diagram



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RF DACs and RF ADCs

- 2 RF ADCs:
  - 12-bits resolution
  - 4.096 GSPS max
  - Single-ended, 2V peak-to-peak
- 2 RF DACs:
  - 14-bits resolution
  - 6.554 GSPS max
  - Single-ended, 2V peak-to-peak
- RF converter voltage ranges can be re-programmed by the user up to 6V peak-to-peak max if converter tile IOs are reprogrammed

RFSoC 2x2 Board Anatomy #1

PPS

RF DAC 1

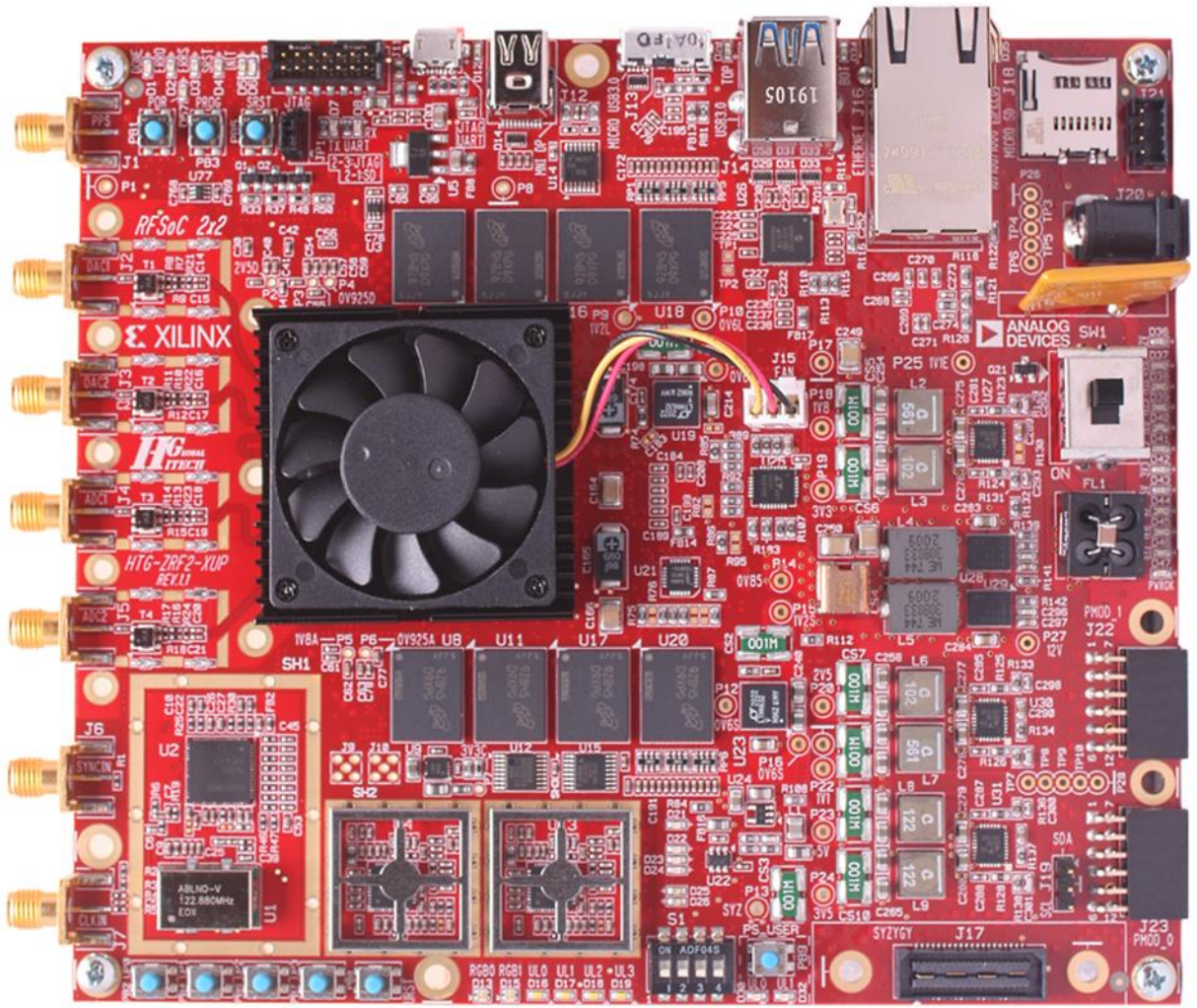
RF DAC 2

RF ADC 1

RF ADC 2

SYNCIN

Ext CLKIN



PMBus

12V Power

EFuse

Power switch

Power rail status LEDs

PMOD 1

PMOD 2

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RFSoC 2x2 Board Anatomy #2

5 user PL Pushbuttons

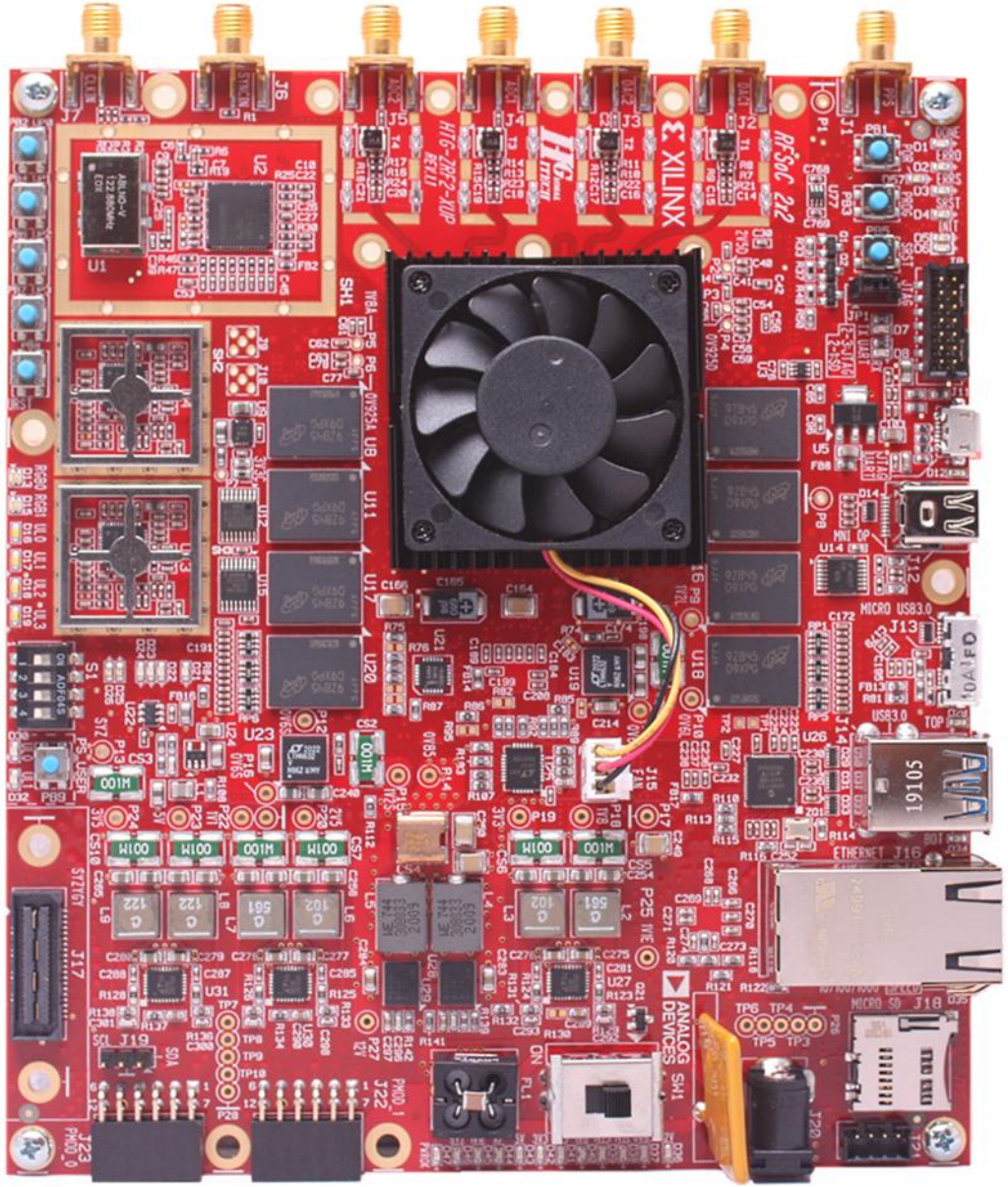
2 user PL RGB LEDs

4 user PL LEDs

4 user PL switches

1 user PS Pushbutton

SYZYGY STD



INIT & DONE LEDs
RESET Pushbuttons & LEDs

JTAG

USB 2.0 UART/JTAG

Mini DisplayPort

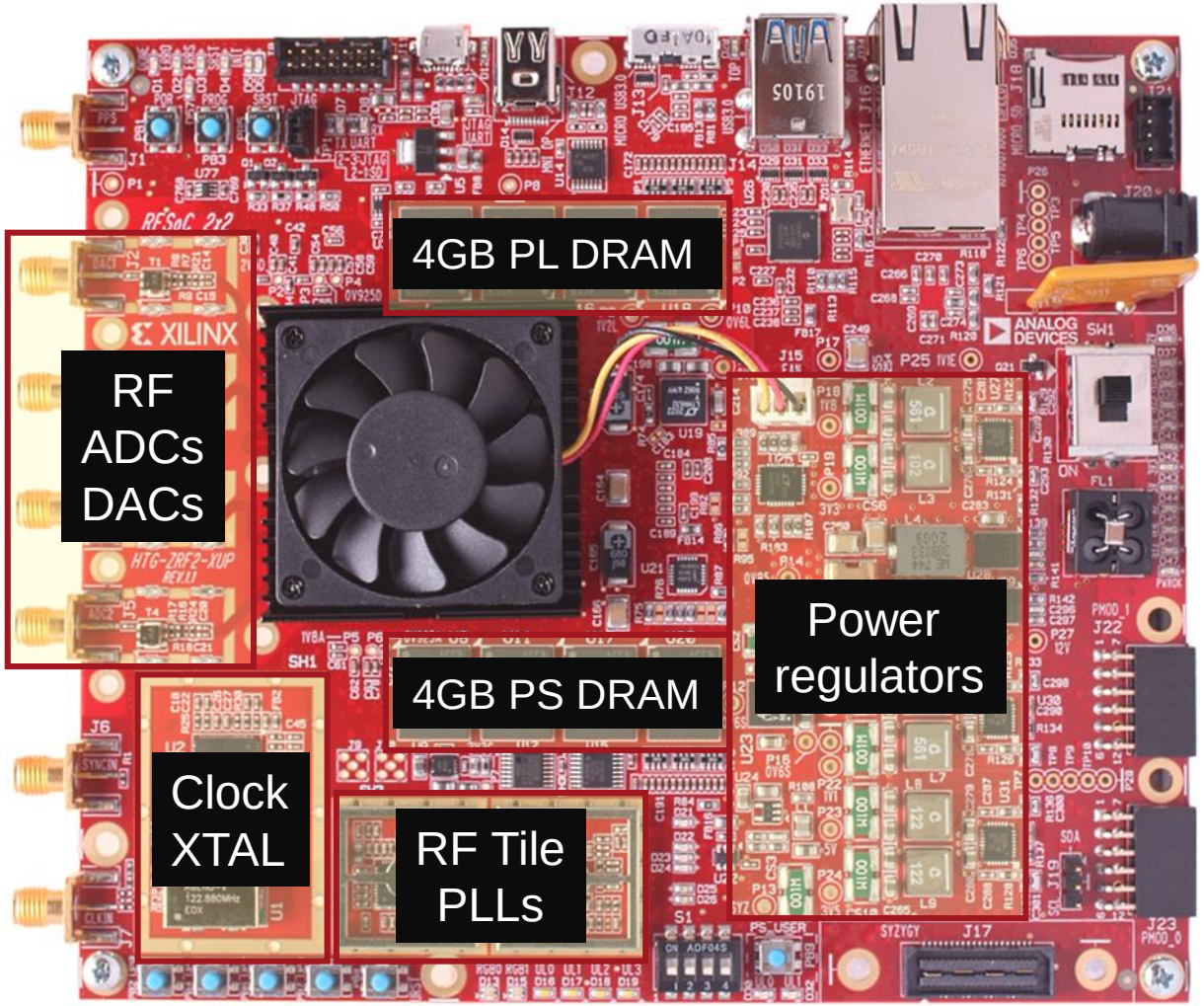
1 USB 3.0 Peripheral

2 USB 3.0 Host

10/100/1000 Mbps Ethernet

Micro SD Reader

RFSoC 2x2 Board Anatomy #3



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Additional RFSoC 2x2 Features

- Built-in I^2C current and voltage monitoring on 10 power rails
  - Python API and notebook examples
- ”USB Gadget API”
  - IP over USB 3.0 A to Micro B Cable
  - Enables RFSoC 2x2 as Ethernet, mass storage, and serial device over USB
- Extensive suite of self-test for IO peripherals
  - Full set of Python notebooks
- Programmable RF clock jitter and PLL/VCO chips

RFSoC 2x2 Kit Contents

- RFSoC 2x2 Board
- 12V, 72W power supply unit
- USB 3.0 A to Micro B Cable
- 2 RF cables with SMA connectors
- 16 GB MicroSD card with pre-loaded Linux and PYNQ image

IPython Notebooks, JupyterLab and …

PYNQ™

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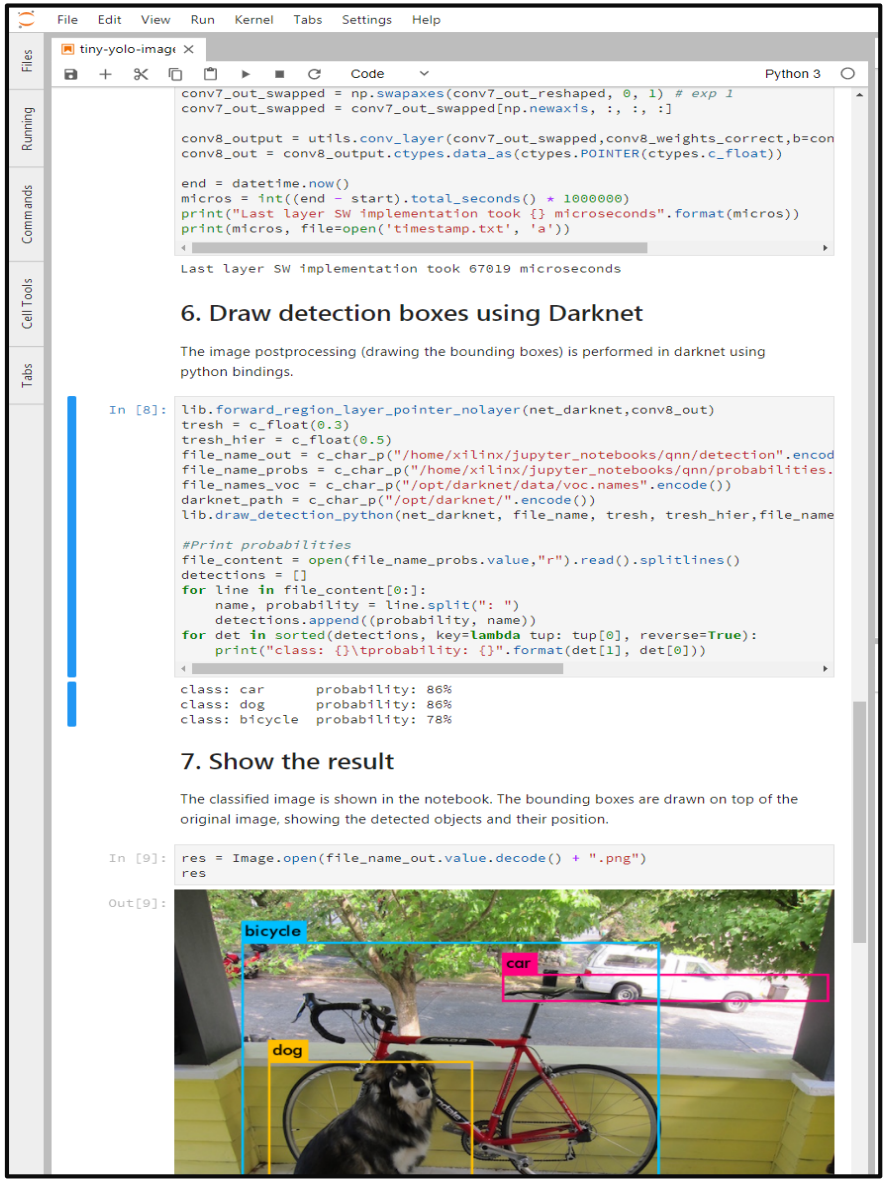
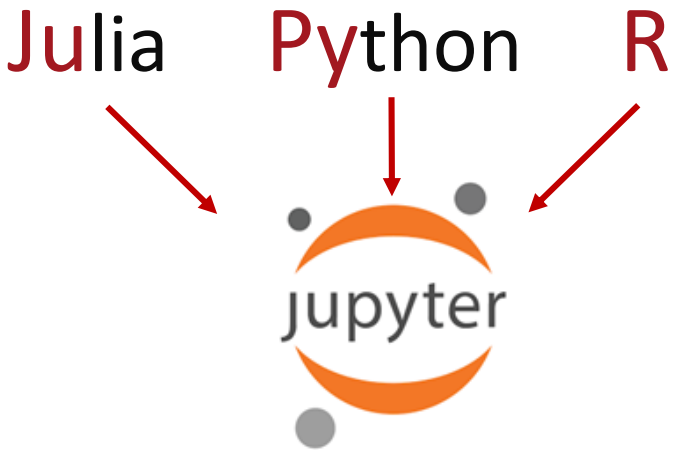
IPython Notebooks to Jupyter Notebooks





Displays source code, results, text, math, images and other rich media

Default engine of data science, machine learning and AI

Taught to 100,000's of college students every semester

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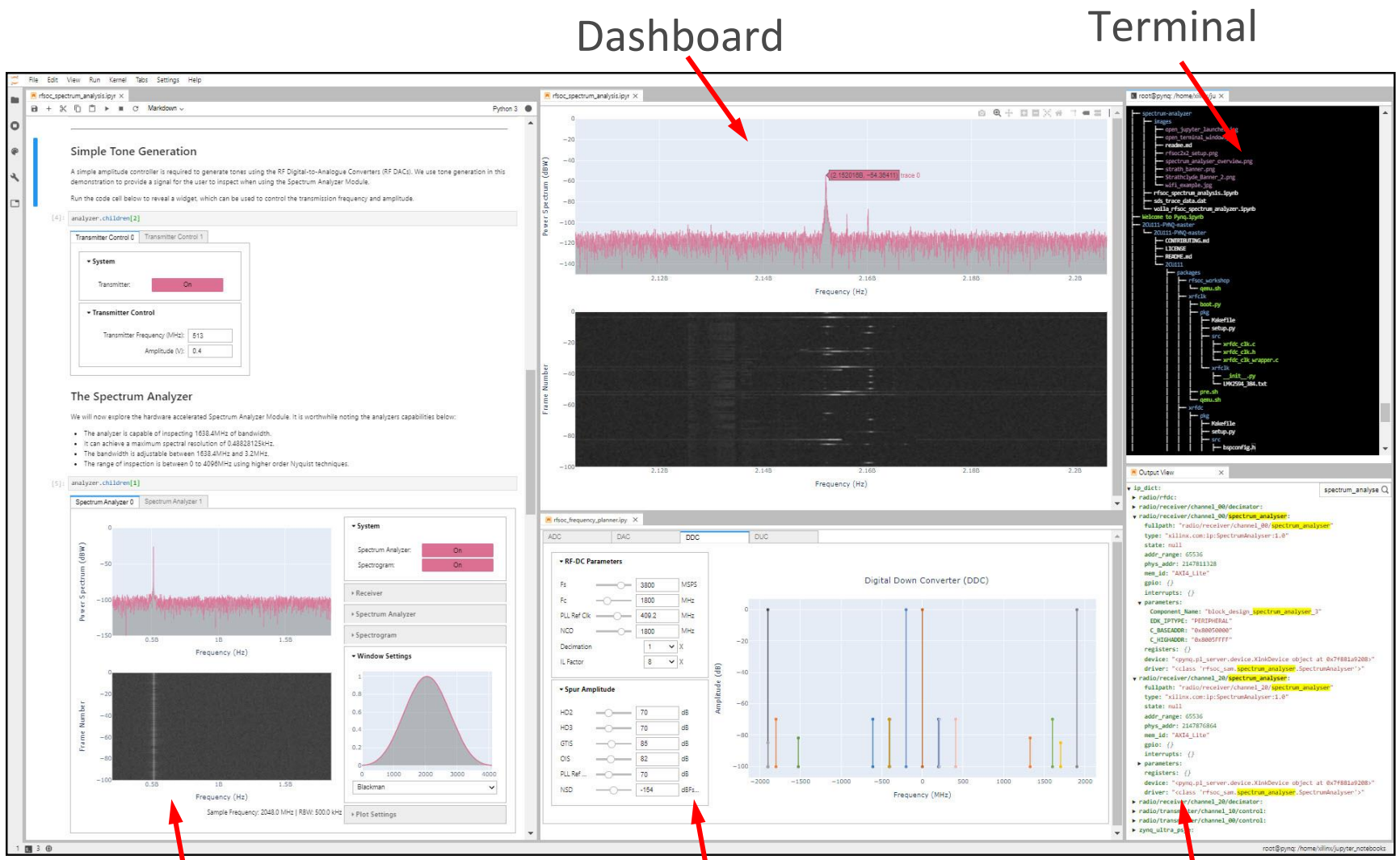
Jupyter Notebooks to JupyterLab IDE



Next-generation IDE

Browser-based GUI

Multiple re-sizable frames in one browser window

Completely extensible

Jupyter Notebooks are one of many plug-ins available in JupyterLab

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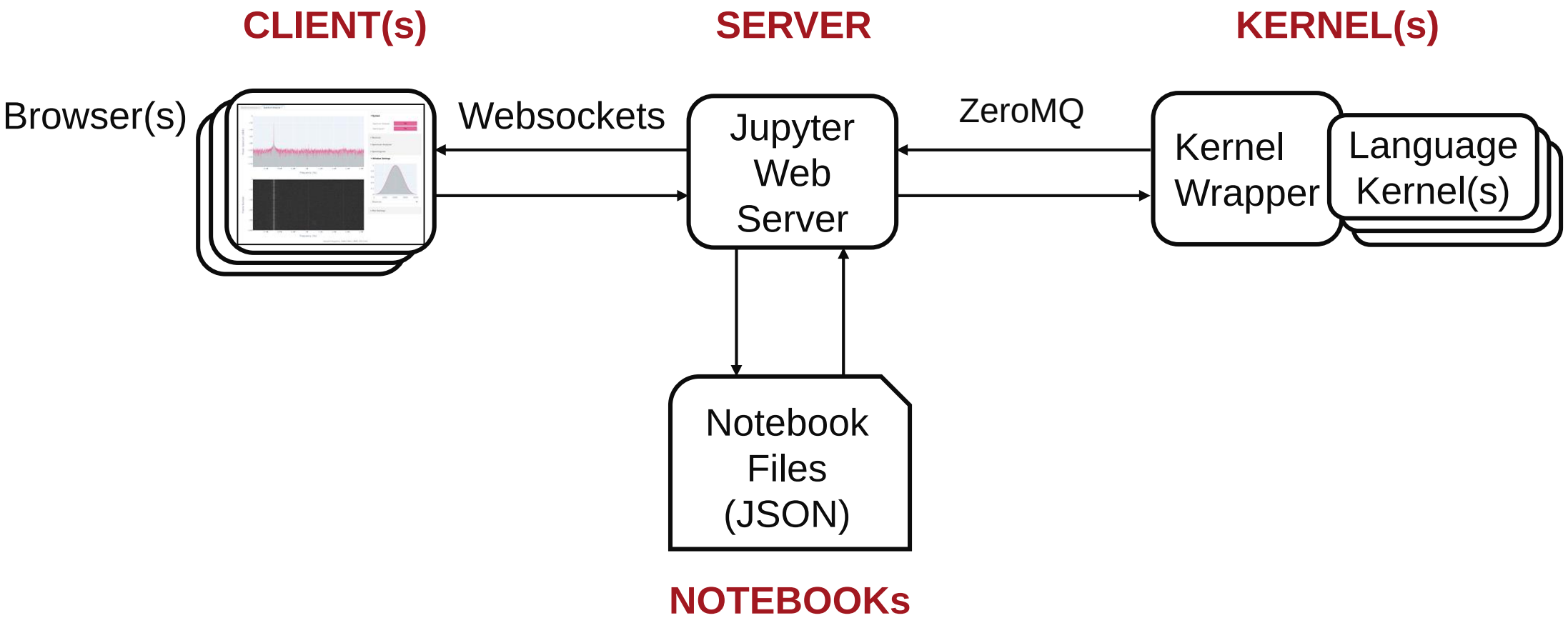
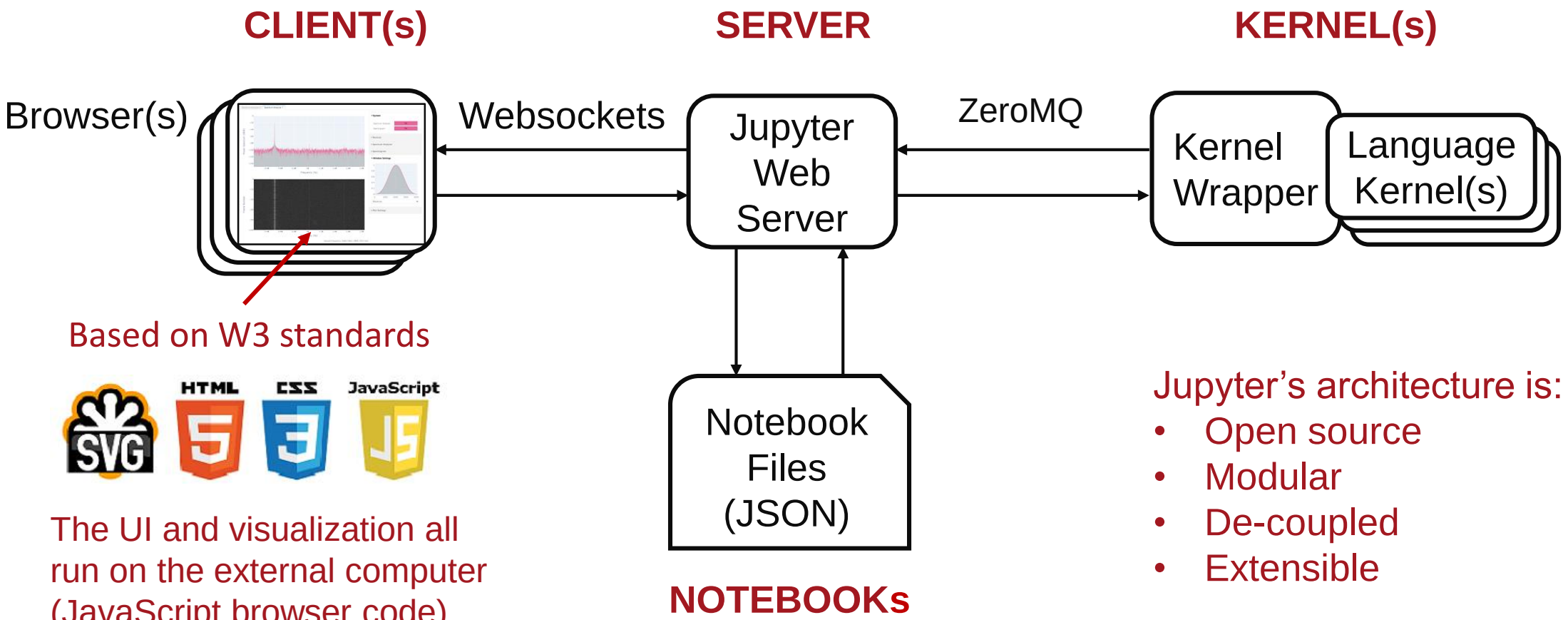
Jupyter's Client-Server-Kernel-Notebook Architecture



Browser is the de facto Platform for Data Visualization



The UI and visualization all run on the external computer (JavaScript browser code)

Jupyter's architecture is:

- Open source
- Modular
- De-coupled
- Extensible

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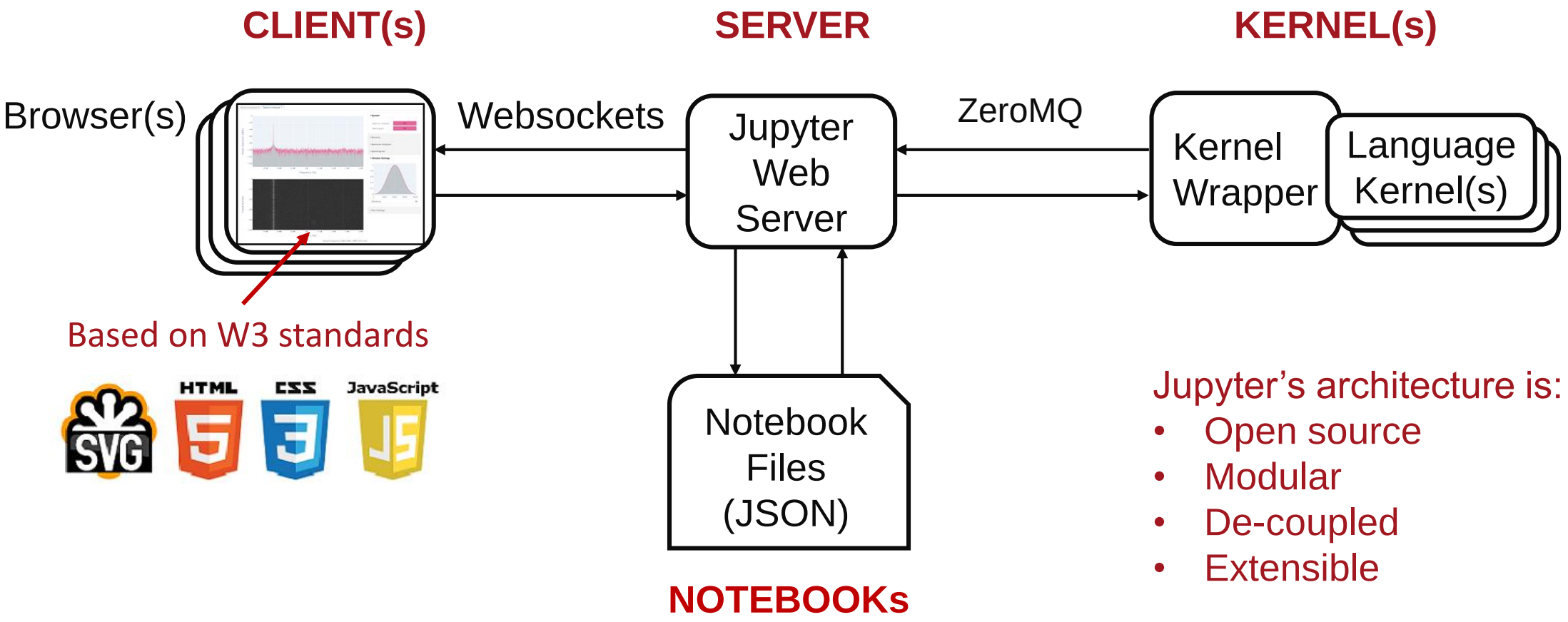
Winner of the 2017 ACM System Software Award



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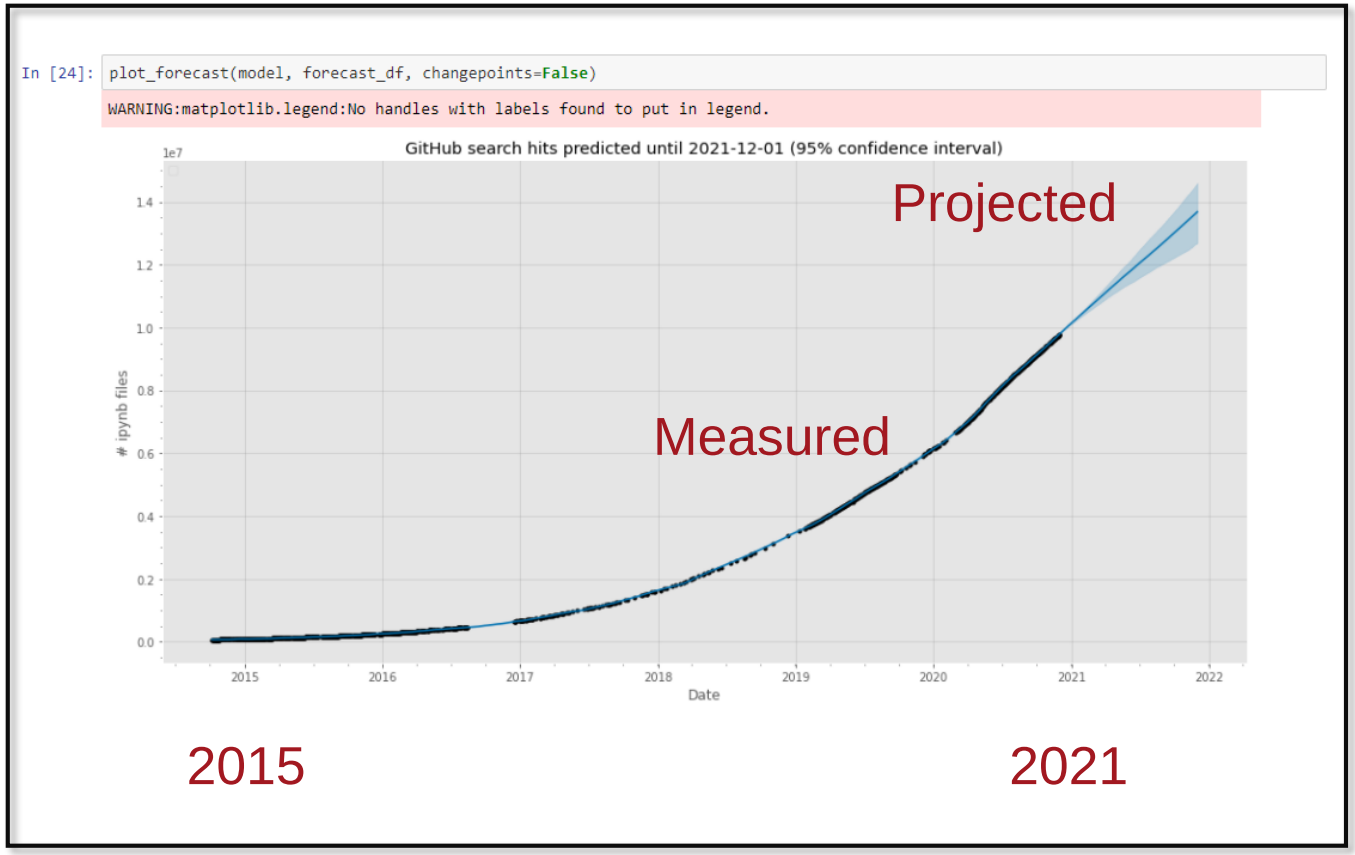
Exponential Rise in Adoption of Jupyter Notebooks

Notebooks on GitHub



12 million notebooks in approximately 6 years (as of Feb 2021)

https://nbviewer.jupyter.org/github/parente/nbestimate/blob/master/estimate.ipynb

Accessed on 24 Feb 21

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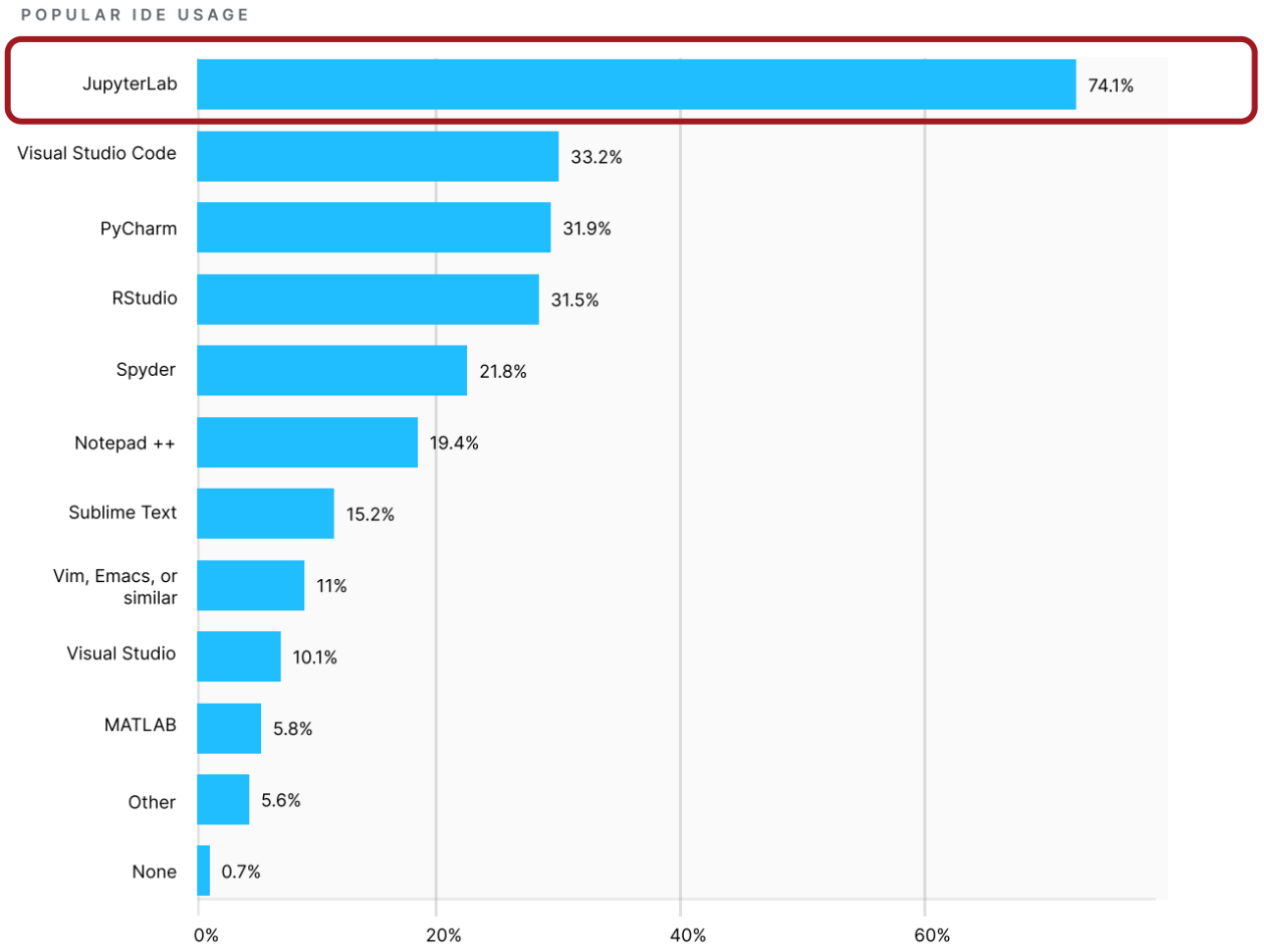
Popular IDE Usage among Data Scientists



https://www.kaggle.com/kaggle-survey-2020

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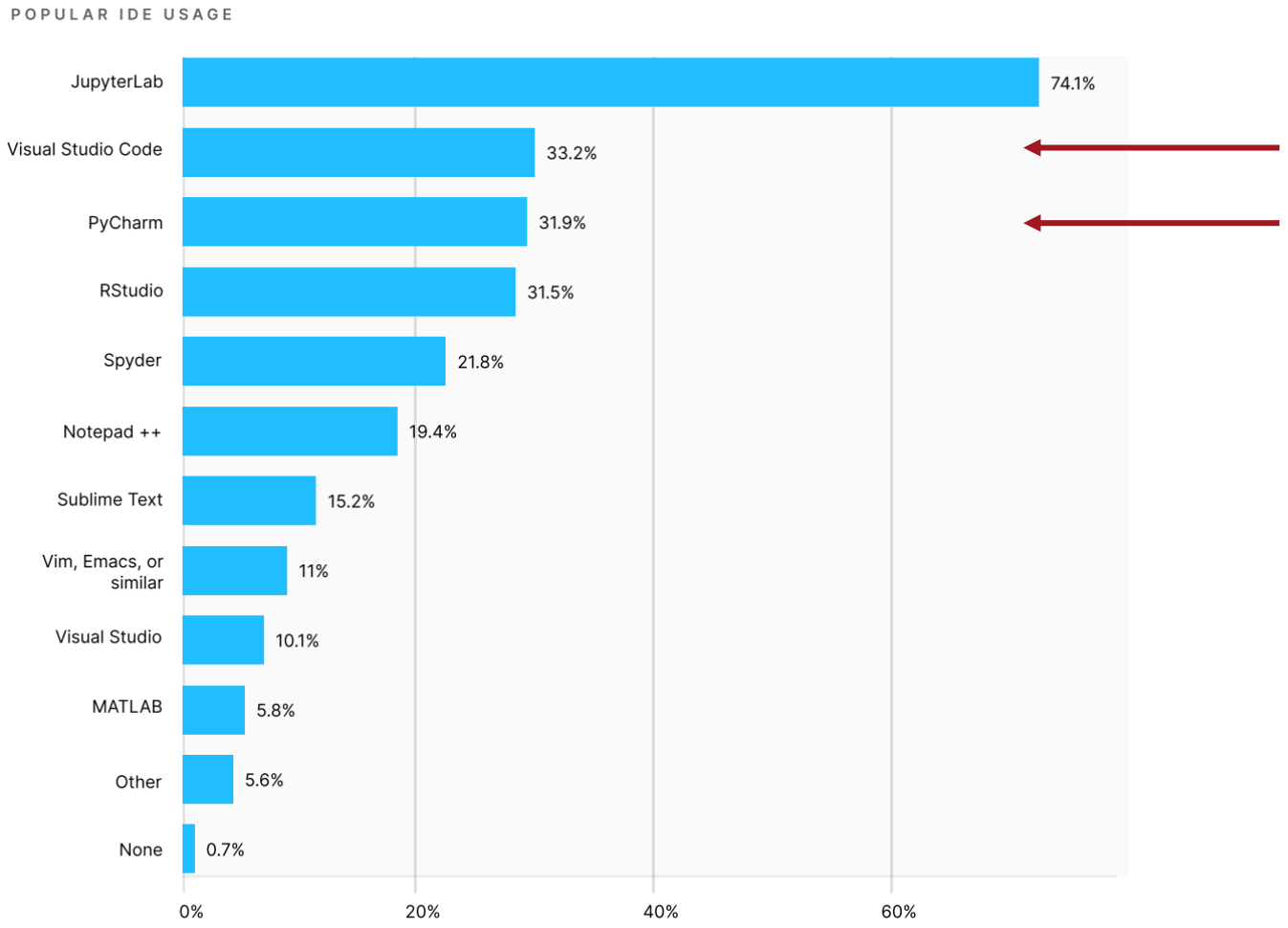
IDEs and Notebooks are Synergistic



Visual Studio and PyCharm both include support for Notebooks

Science and engineering are increasingly (big) data-driven

This applies also to high-performance, embedded-computing applications such as SDR with RFSoC

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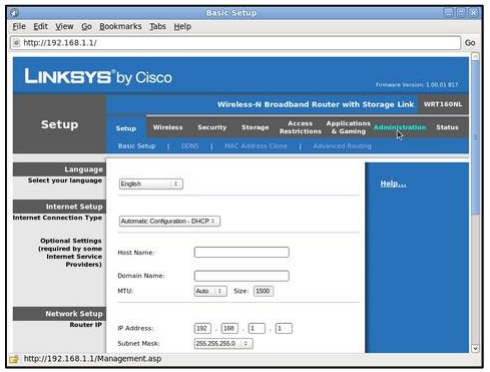
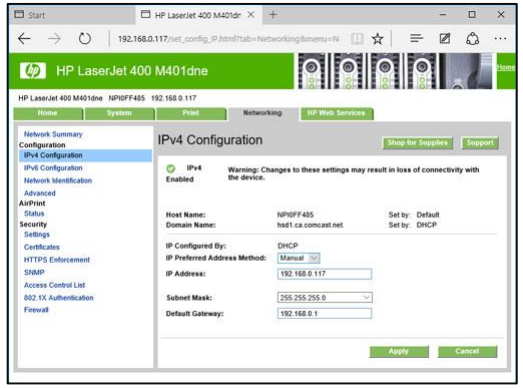
Embedded Web Portals





We are familiar with embedded servers hosting browser interfaces for product configuration

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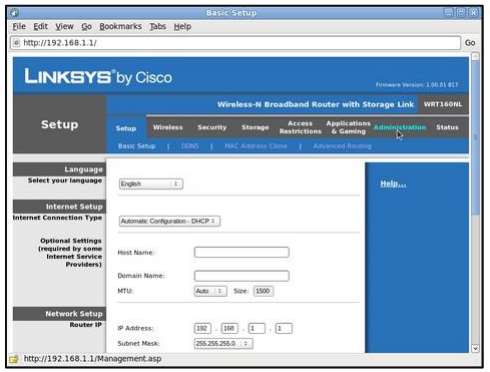
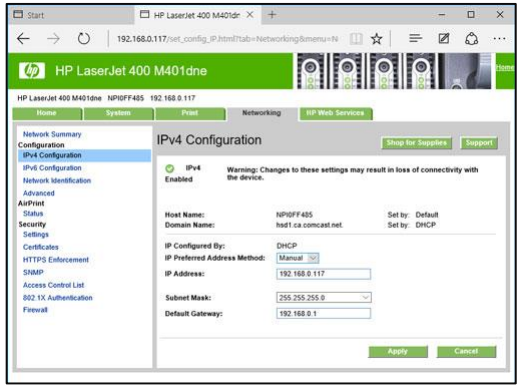
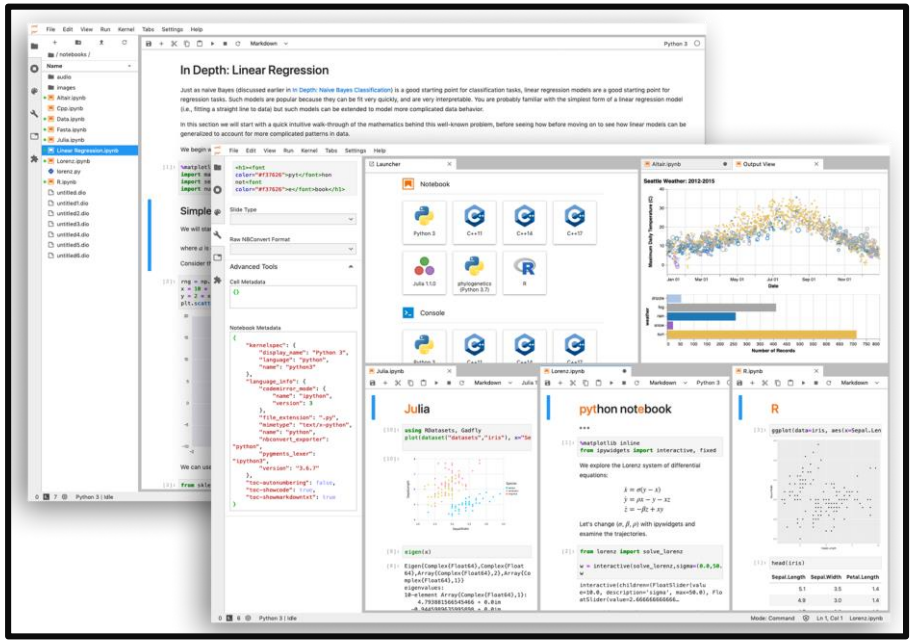
Embedded Web Portals … to Web-server IDEs







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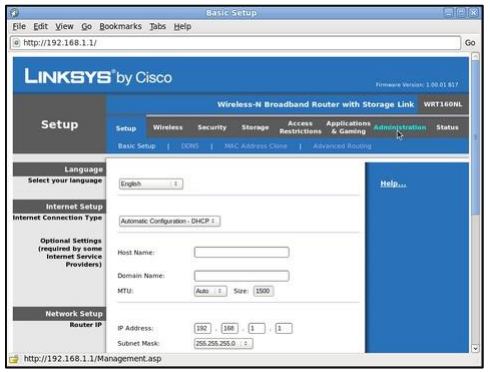
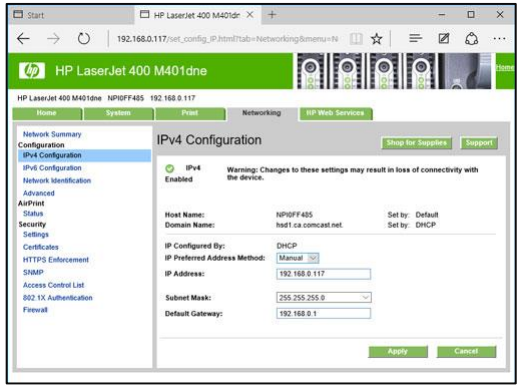
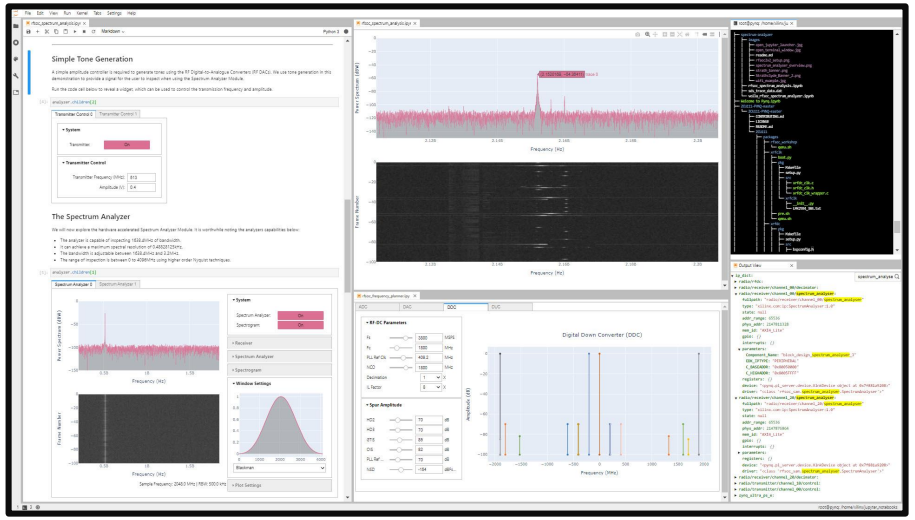
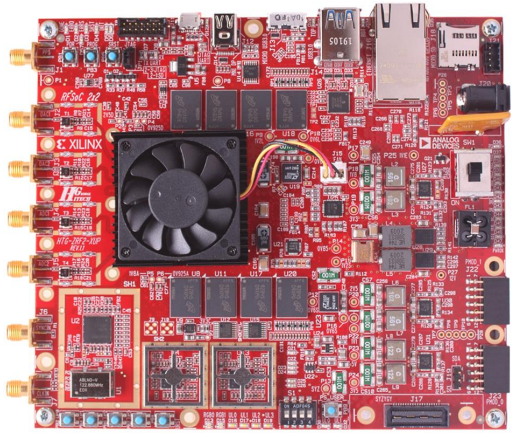
Embedded Web Portals … to Embedded IDEs





RFSoC-PYNQ uses JupyterLab to host an IDE on the RFSoC's ARM CPUs





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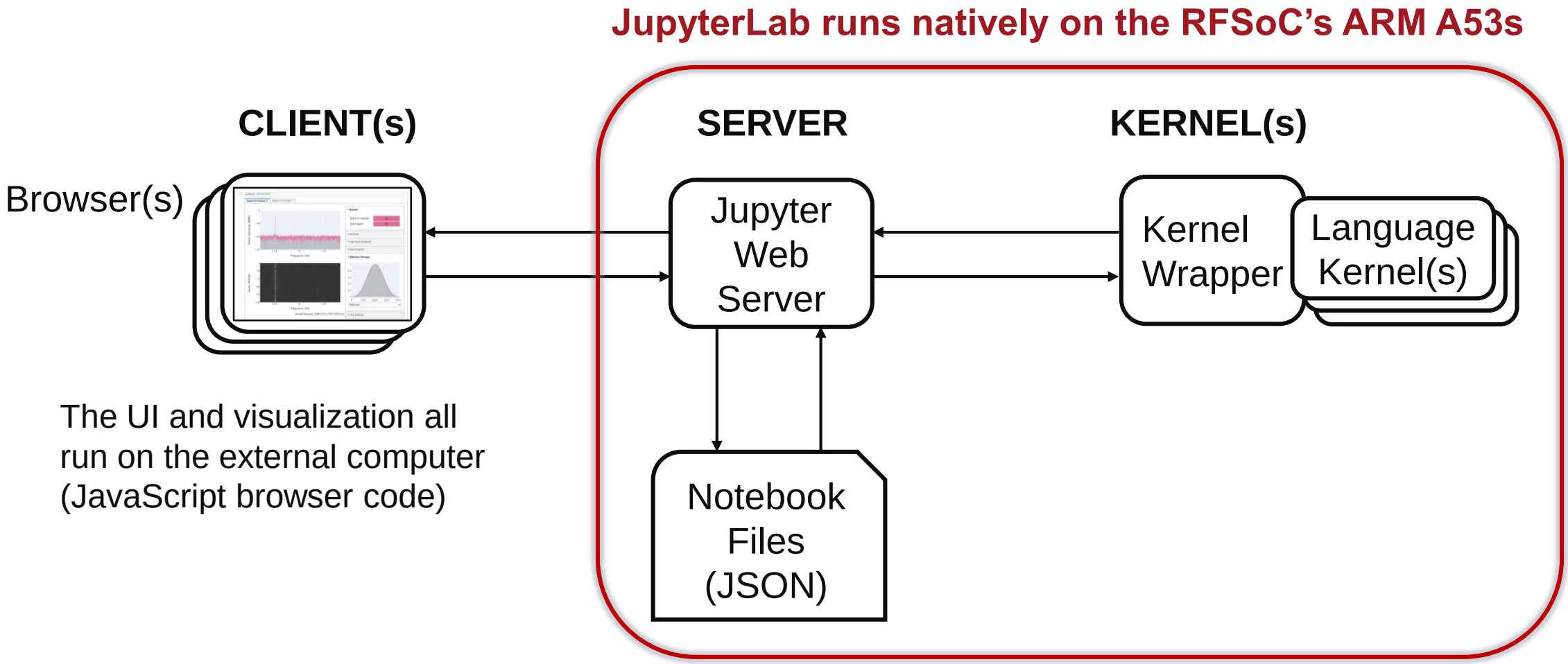
PYNQ = Embedded Jupyter Lab



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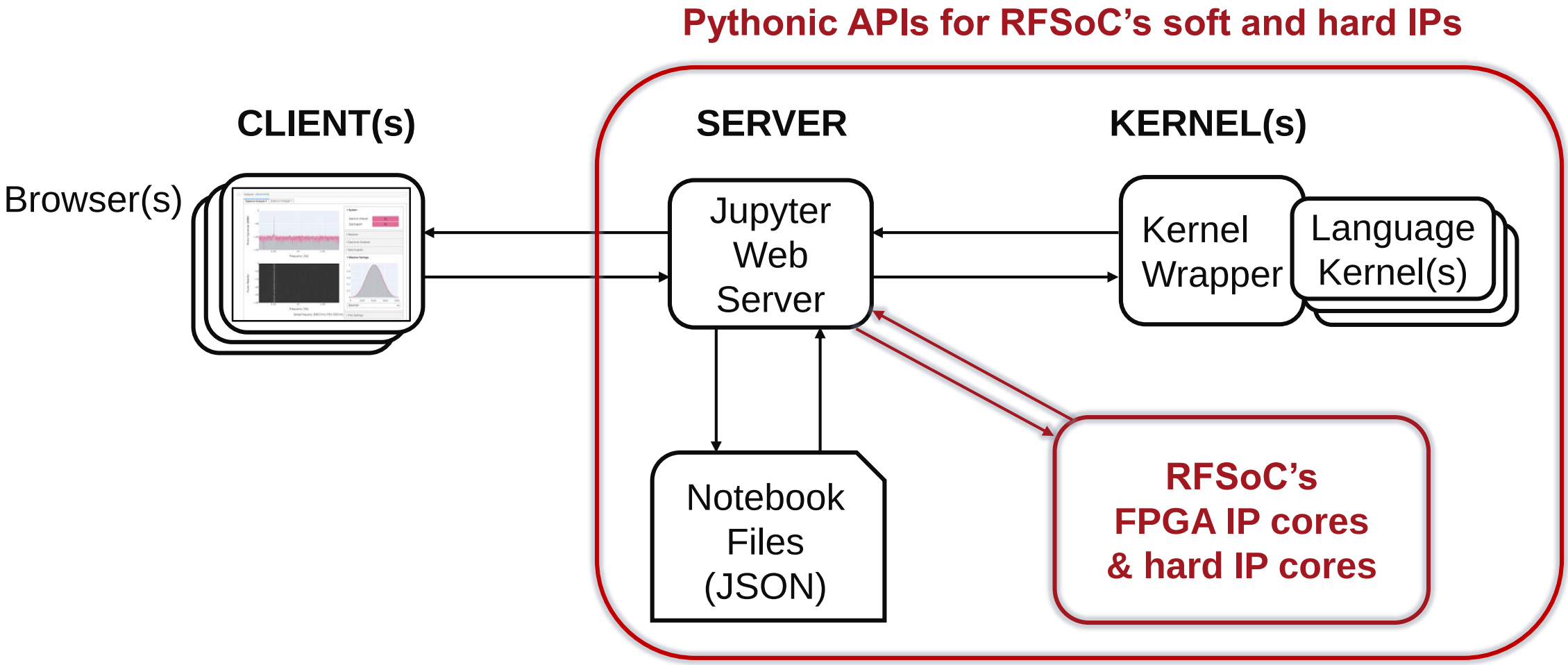
PYNQ = Embedded JupyterLab

+ Pythonic Integration of FPGA & Hard IPs



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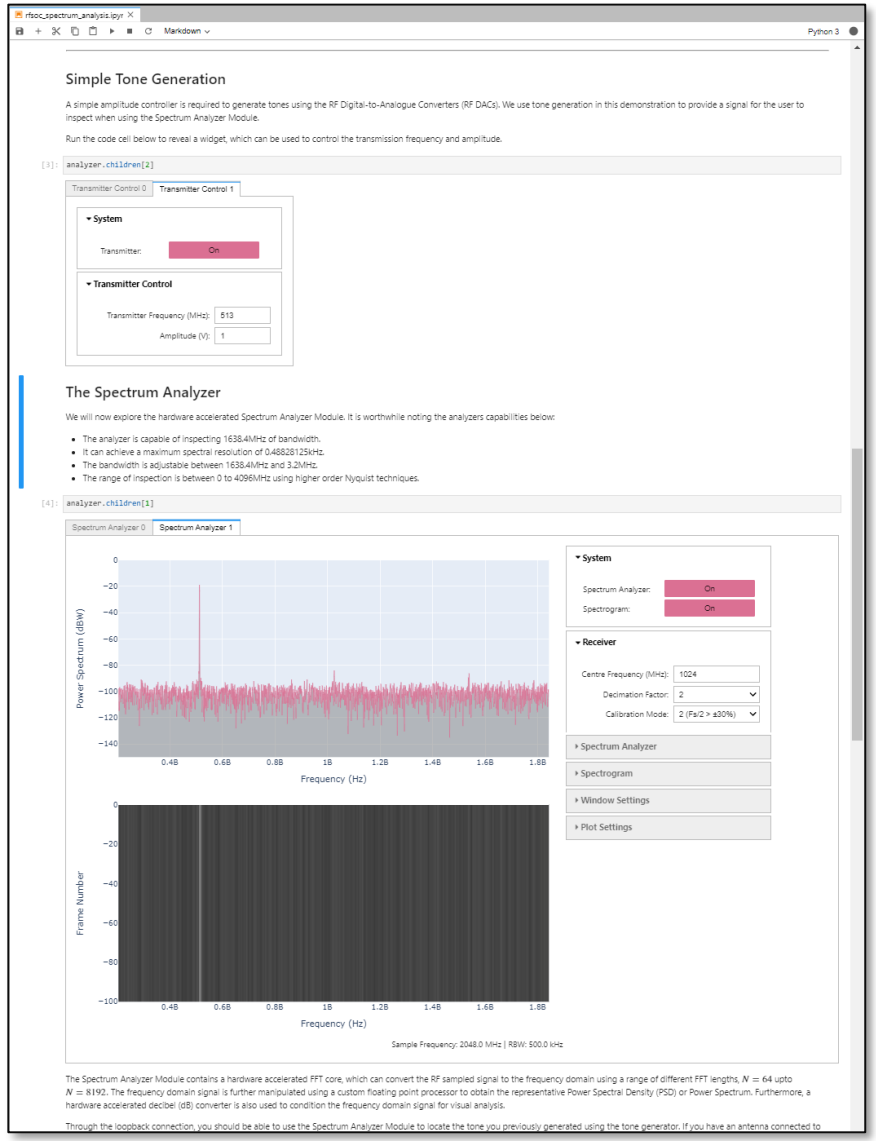
PYNQ = Productivity = Ease-of-Use + Ease-of-Reuse

- Reproducibility via executable notebooks
- Python APIs to RFSoC IPs
- Optimized CPU-FPGA data transfer using Python/NumPy buffer protocol
- Widgets for interactive visualization and dashboards for standalone GUIs
- PIP packaging of design software & bitstreams in fat binaries
- Open-source packages in GitHub repositories

Spectrum Analyzer as Jupyter Notebook



The notebook is an excellent interactive environment for development, research and learning

We can mix interactive controls and visualization to explore our algorithms and data and for documentation

There are times, however, when we want to share work without all the notebook details

This is where dashboards come in …

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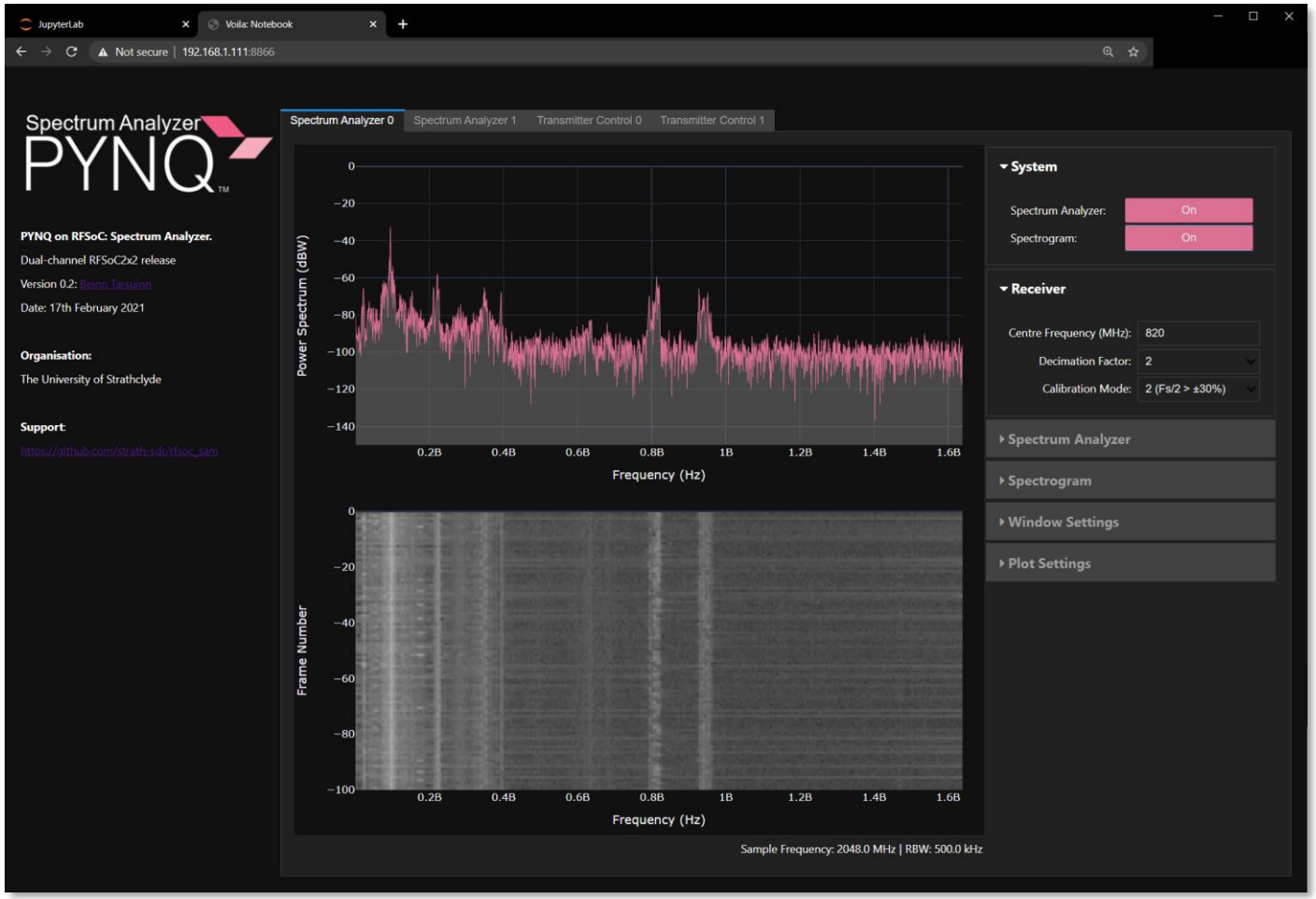
Spectrum Analyzer as Voila Dashboard



Voila dashboards allow us to deploy our spectrum analyzer without exposing the Jupyter notebook interface

This is great for:

- **research demonstrators**
- **interactive teaching exercises**
- **collaboration with specialists from other disciplines**

Easy transition from notebook to dashboard allows rapid GUI generation for deployment

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Thank You

Xilinx Mission

Building the Adaptable, Intelligent World