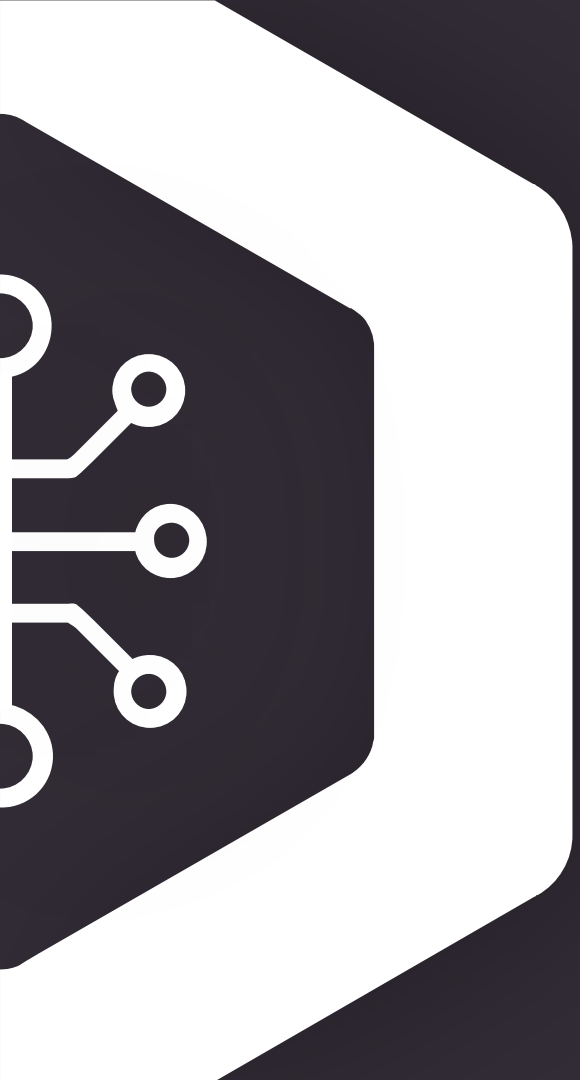

From Zephyr's structured data to traceable and testable open hardware

Zephyr Developer Summit, Mountain View, 2022-06-08

Michael Gielda, mgielda@antmicro.com

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> "Our electrical and firmware engineering teams remain hard at work designing, developing and validating **19 new variants of controllers** in response to ongoing semiconductor shortages."

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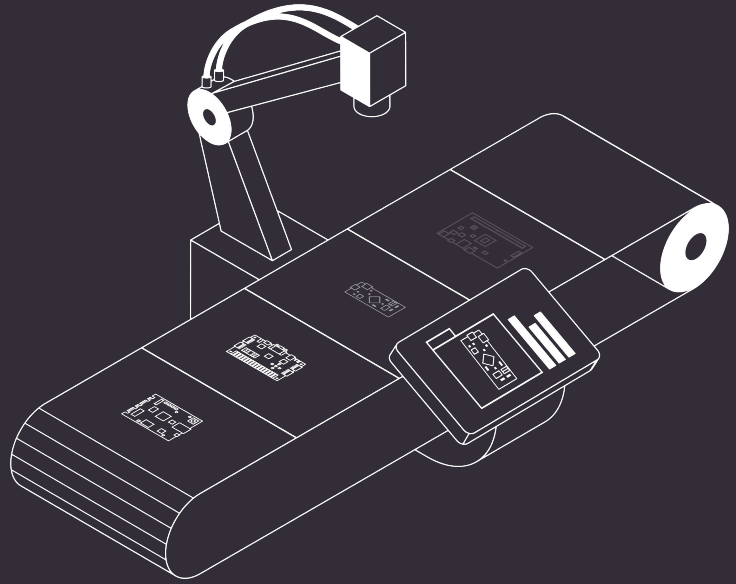
HOW TO DEAL WITH UNCERTAINTY

- Flexibility/portability
  (to react to supply chain issues)
- Software-first development
  (to cut development cycles)
- Transparency
  (to mitigate growing complexity,
  bad actors, security threats)
- Understanding
  (to improve quality and speed of iteration)



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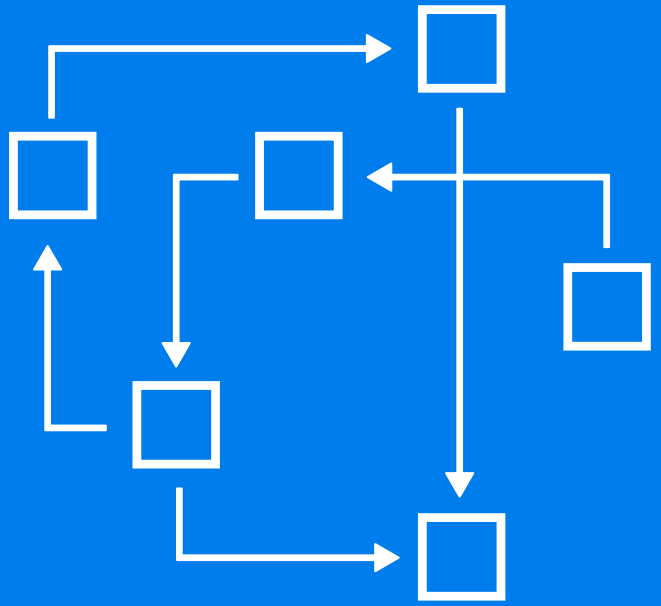
FINDING YOUR WAY AROUND HARDWARE

- The hardware landscape is vast and unevenly documented, full of vaporware and not easily quantifiable
- How to tell if my software will work on a specific board?
  - Connect the board and check?
- What about checking tens, hundreds of potential targets?
- How to learn about the ecosystem, its capabilities and limitations in a structured way?

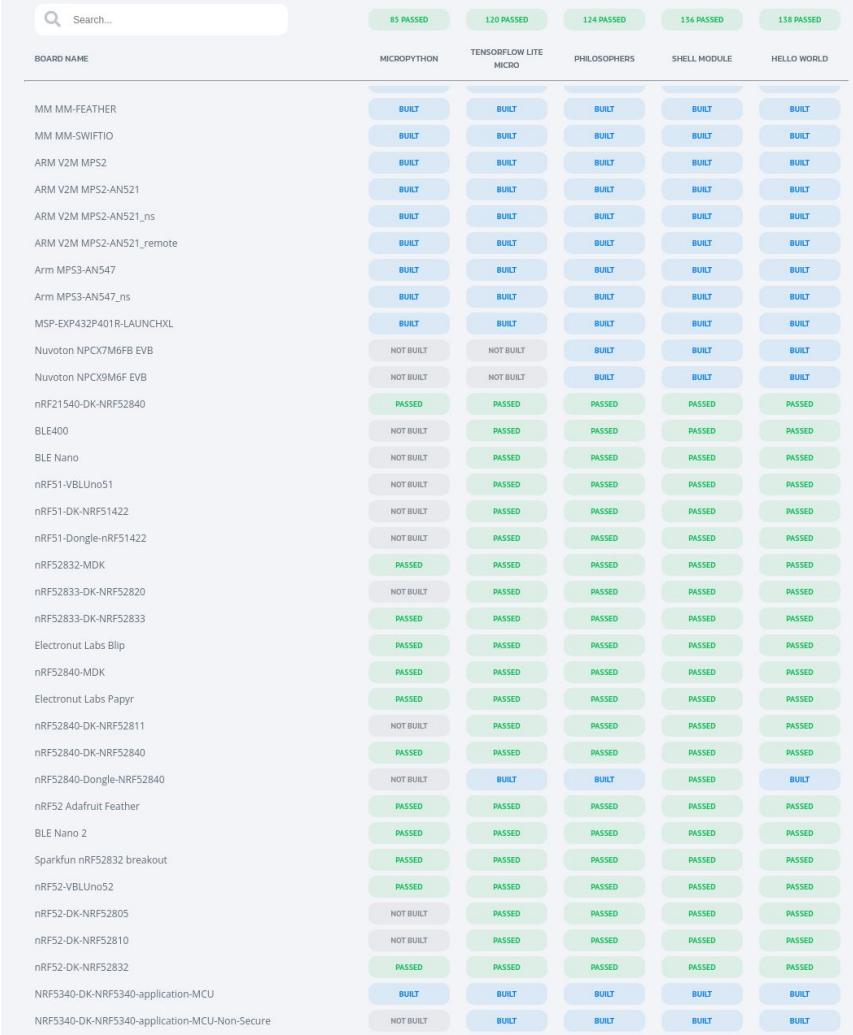


ZEPHYR AS AN UNIQUE SOLUTION

- Strongly focuses on order and structure, not "hacking things together"
- Spans vendors, archs (resulting in fairly good abstraction and not over-specialization)
- Provides structured data
  - yamls
  - device trees
  - repo organization
- Tools to work with the data
- Focuses on ecosystem aspect

WHAT ZEPHYR ENABLES

- Data is power: using it you can do things like testing virtually every Zephyr target in simulation, over a range of scenarios
- **>170 boards with software tested in Renode**
- See talk tomorrow at 9.00 AM PDT
- Testing is important, but can we do more?



Search...

BOARD NAME	MICROPYTHON	TENSORFLOW LITE MICRO	PHILOSOPHERS	SHELL MODULE	HELLO WORLD
	85 PASSED	120 PASSED	124 PASSED	136 PASSED	138 PASSED
MM MM-FEATHER	BUILT	BUILT	BUILT	BUILT	BUILT
MM MM-SWIFTIO	BUILT	BUILT	BUILT	BUILT	BUILT
ARM V2M MPS2	BUILT	BUILT	BUILT	BUILT	BUILT
ARM V2M MPS2-AN521	BUILT	BUILT	BUILT	BUILT	BUILT
ARM V2M MPS2-AN521_ns	BUILT	BUILT	BUILT	BUILT	BUILT
ARM V2M MPS2-AN521_remote	BUILT	BUILT	BUILT	BUILT	BUILT
Arm MPS3-AN547	BUILT	BUILT	BUILT	BUILT	BUILT
Arm MPS3-AN547_ns	BUILT	BUILT	BUILT	BUILT	BUILT
MSP-EXP432P401R-LAUNCHXL	BUILT	BUILT	BUILT	BUILT	BUILT
Nuvoton NPCX7M6FB EVB	NOT BUILT	NOT BUILT	BUILT	BUILT	BUILT
Nuvoton NPCX9M6F EVB	NOT BUILT	NOT BUILT	BUILT	BUILT	BUILT
nRF21540-DK-NRF52840	PASSED	PASSED	PASSED	PASSED	PASSED
BLE400	NOT BUILT	PASSED	PASSED	PASSED	PASSED
BLE Nano	NOT BUILT	PASSED	PASSED	PASSED	PASSED
nRF51-VBLUno51	NOT BUILT	PASSED	PASSED	PASSED	PASSED
nRF51-DK-NRF51422	NOT BUILT	PASSED	PASSED	PASSED	PASSED
nRF51-Dongle-nRF51422	NOT BUILT	PASSED	PASSED	PASSED	PASSED
nRF52832-MDK	PASSED	PASSED	PASSED	PASSED	PASSED
nRF52833-DK-NRF52820	NOT BUILT	PASSED	PASSED	PASSED	PASSED
nRF52833-DK-NRF52833	PASSED	PASSED	PASSED	PASSED	PASSED
Electronut Labs Blip	PASSED	PASSED	PASSED	PASSED	PASSED
nRF52840-MDK	PASSED	PASSED	PASSED	PASSED	PASSED
Electronut Labs Papyr	PASSED	PASSED	PASSED	PASSED	PASSED
nRF52840-DK-NRF52811	NOT BUILT	PASSED	PASSED	PASSED	PASSED
nRF52840-DK-NRF52840	PASSED	PASSED	PASSED	PASSED	PASSED
nRF52840-Dongle-NRF52840	NOT BUILT	BUILT	BUILT	PASSED	BUILT
nRF52 Adafruit Feather	PASSED	PASSED	PASSED	PASSED	PASSED
BLE Nano 2	PASSED	PASSED	PASSED	PASSED	PASSED
Sparkfun nRF52832 breakout	PASSED	PASSED	PASSED	PASSED	PASSED
nRF52-VBLUno52	PASSED	PASSED	PASSED	PASSED	PASSED
nRF52-DK-NRF52805	NOT BUILT	PASSED	PASSED	PASSED	PASSED
nRF52-DK-NRF52810	NOT BUILT	PASSED	PASSED	PASSED	PASSED
nRF52-DK-NRF52832	PASSED	PASSED	PASSED	PASSED	PASSED
NRF5340-DK-NRF5340-application-MCU	BUILT	BUILT	BUILT	BUILT	BUILT
NRF5340-DK-NRF5340-application-MCU-Non-Secure	NOT BUILT	BUILT	BUILT	BUILT	BUILT

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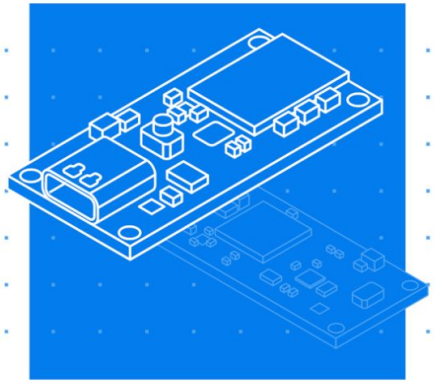
ENTER RENODEPEDIA



BOARDS

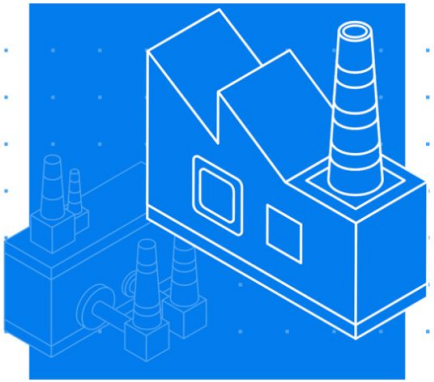
Choose hardware for your next project amongst 391 boards and see real software in action.

BROWSE BOARDS

SOCS

Select a System on Chip from 256 options and see their structure, Renode models, drivers and available hardware.

BROWSE SOCS



VENDORS

Click below to browse vendors in Renodepedia.

BROWSE VENDORS

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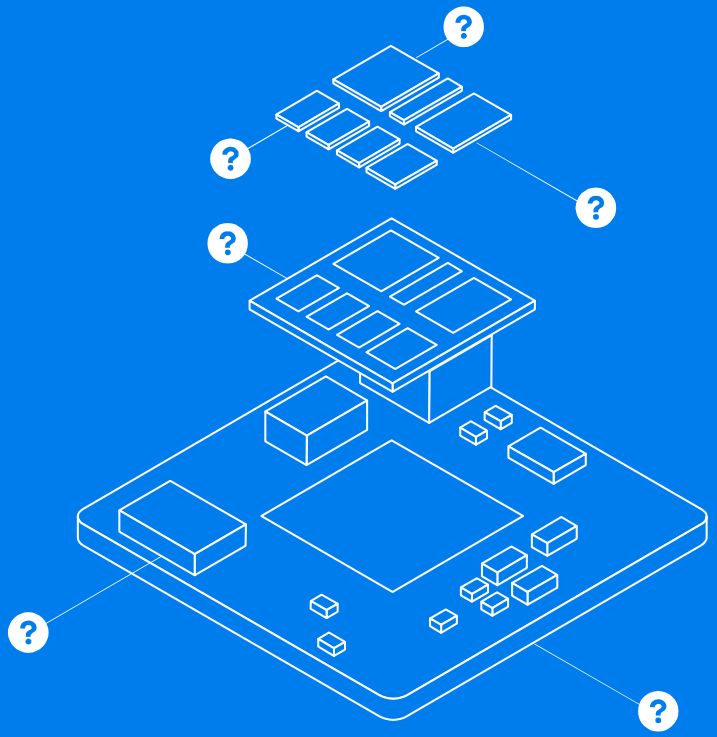
RENODEPEDIA - MOTIVATION

- Hardware is out of necessity modular in nature
- There is a lot of reuse (due to cost of verifying new things), and a lot of underlying structure in terms of variants, register maps, IPs used
- But: this is communicated very inconsistently to the SW world (both between vendors but even in a single vendor's case)
- However, this structure is to some extent captured by Zephyr's device tree data



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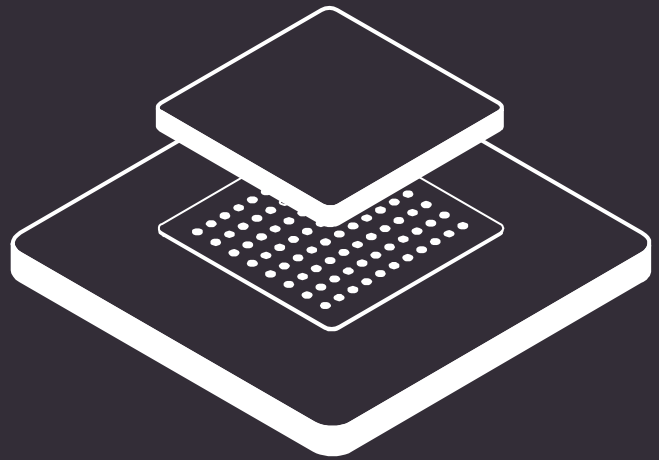
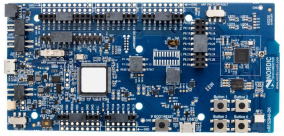
RENODEPEDIA - GOALS

- Catalogue the extracted HW-related data
- Present it in a consistent way
- Make it all-connected, navigable
  - Discover connections between components
  - Navigate dependencies of elements
- Show commonalities and SW porting options
  - Use Renode to prove it actually works!

Make it all automatic!





nRF52840-DK-NRF52840

NRF52840
System on Chip

Nordic
Vendor

Software | Hardware

Samples

Hello World
A simple sample that prints "Hello World"

TensorFlow Lite Micro
Sample application replicating sine function

Philosophers
Solution to the Dining Philosophers problem

Shell Module
Zephyr shell interface demonstration

Micropython
MicroPython Zephyr port demonstration

Supported software

Zephyr RTOS

Hello World

A simple sample that prints "Hello World" to the console.

Run locally

You can run the Micropython demo on the nRF52840-DK-NRF52840 board by following the instructions below:

Assuming you have Python 3 and pip installed on your Linux machine, run the following commands to download Renode and the prebuilt binaries for this demo, and the run the simulation on your own machine.

```
pip3 install --user --upgrade git+https://github.com/antmicro/renode-run.git
renode-run demo -b nrf52840dk_nrf52840 hello_world
```

Run in Colab

You can run this demo instantly on a cloud server in Google Colab by clicking the button below.

Colab
Run nrf52840dk_nrf52840 hello_world demo in Google Colab.

UART output

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ENABLING APPLICATION DEVELOPMENT

- Run libraries/middlewares like TF Lite, MicroPython, micro-ROS (soon) across a wide range of hardware
- Quickstart for application developers
- Showcase for the ecosystem aspect of Zephyr

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RUN LOCALLY

```
pip3 install --user --upgrade \
    git+https://github.com/antmicro/renode-run.git

renode-run demo -b nrf52840dk_nrf52840 hello_world
```

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RENODE RUN

- Get & run Renode demos with a single command
  - Downloads Renode (if needed)
  - Grabs and unpacks artifacts from the dashboard
- Open source: github.com/antmicro/renode-run

INTERACTIVE RENODE COLABS

- Google Colab offers free cloud machines which Allows you to run arbitrary scripts and share the results online
- We have pre-made Colabs to run your device virtually in Renode in the browser without any installation
- Working with GCP to enable real cloud deployment in native GCP machines
- Great for presentation/education purposes, popular among students and academics

RENODE™

RUN IN GOOGLE COLAB | VIEW IPYNB SOURCE | VIEW PYTHON SOURCE

Install requirements

```
[1] ! pip install -q git+https://github.com/antmicro/renode-colab-tools.git
    ! pip install -q git+https://github.com/antmicro/renode-run.git@new-features
    ! pip install -q git+https://github.com/antmicro/pyrenode.git@renode-run-experiments
    ! pip install -q robotframework==4.0.1
    ! renode-run download
```

Start Renode

[ ] 1 cell hidden

Setup a script

[ ] 1 cell hidden

Run the sample

```
[5] ExecuteCommand("include @script.resc")
    CreateTerminalTester("sysbus.uart7", timeout=5)
    StartEmulation()

    WaitForLineOnUart("Hello World! 96b_aerocore2")
    print(ExecuteCommand("sysbus.uart7 DumpHistoryBuffer"))

    ResetEmulation()
```

```
*** Booting Zephyr OS build v3.0.0-rc1-106-ge83b07412854  ***

Hello World! 96b_aerocore2
```

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ARTIFACTS

- Dynamic UART output with Asciinema
- Artifacts
  - Prebuilt binaries
  - Pregenerated scripts
  - Test results in Robot
- SBOM data

UART output

```
Philosopher 0 [P: 3]   EATING  [  325 ms ]
Philosopher 1 [P: 2]  THINKING [  625 ms ]
Philosopher 2 [P: 1]  THINKING [  625 ms ]
Philosopher 3 [P: 0]   EATING  [  425 ms ]
Philosopher 4 [C:-1]  THINKING [  725 ms ]
Philosopher 5 [C:-2]  THINKING [  775 ms ]




Demo Description
----------------
An implementation of a solution to the Dining Philosophers
problem (a classic multi-thread synchronization problem).
This particular implementation demonstrates the usage of multiple
preemptible and cooperative threads of differing priorities, as
well as dynamic mutexes and thread sleeping.
```

Download

Build artifacts
Download binaries, Renode scripts and other artifacts for the Philosophers demo

SBOM data
Download Software Bill of Materials data for the Philosophers demo

Robot Test Suite Log
See Robot test results for the Philosophers demo

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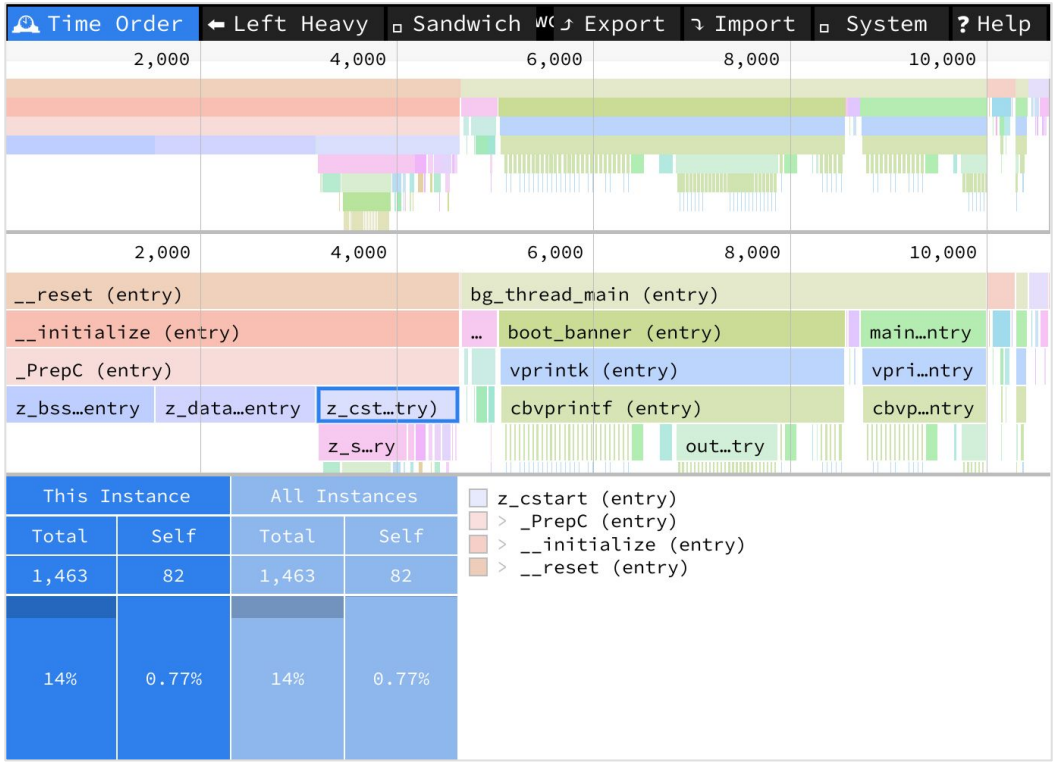
RUNTIME DATA

- See data about execution runs to understand what is going on
- speedscope.app format, working on perfetto traces



EXPLORING SOC DATA

- This is in a way the central part of Renodepedia - boards are good to get started, but most people will end up designing a new PCB / product based on an SoC
- Mapping onto types and Renode peripherals
- Links to Renode models
- (future) map to Zephyr drivers with links
- See boards with this SoC

stm32f446zet6

ST
Vendor

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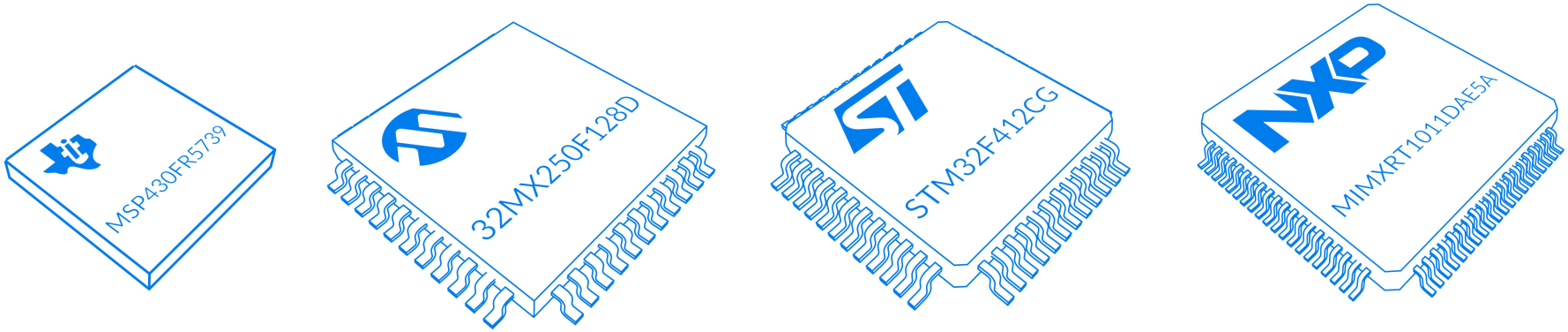
Peripherals | Boards

ADDRESS SPACE	PERIPHERAL	TYPE
0x08000000 - 0x08080000	flash0	mtd
0x40000000 - 0x40000400	timers2	timer
0x40000400 - 0x40000800	timers3	timer
0x40000800 - 0x40000c00	timers4	timer
0x40000c00 - 0x40001000	timers5	timer
0x40002800 - 0x40002c00	rtc	rtc
0x40002c00 - 0x40003000	wwdg	watchdog
0x40003000 - 0x40003400	iwdg	watchdog
0x40003800 - 0x40003c00	spi2	spi
0x40003800 - 0x40003c00	i2s2	i2s
0x40003c00 - 0x40004000	spi3	spi
0x40003c00 - 0x40004000	i2s3	i2s

AUTOMATED SOC MODEL GENERATION



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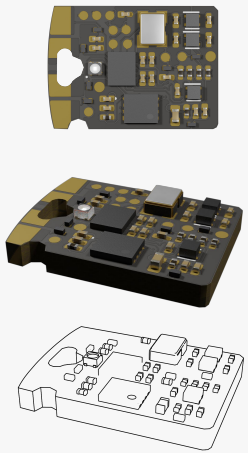
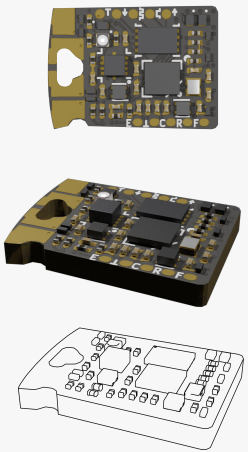
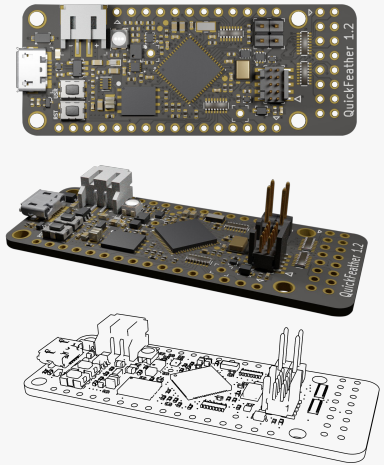
OPEN SOURCE HARDWARE - BOARDS

- We're building up an open PCB component database and rendering flow to fix the "where do I find a good board image" problem
- Generate a photorealistic straight from KiCad (or Gerbers)
- Create interactive, animatable boards







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OPEN SOURCE HARDWARE - CHIPS

- Taking this vision further, we should be looking at how to enable configurable, self-describing hardware which would enable us to do what we're doing even more efficiently
- We're working in RISC-V and CHIPS alliance to make the vision of open source SoCs composed of open source blocks a reality
- This is also important from the security/transparency perspective (HBOM etc)
- Working with partners like Google on open source ASIC PDK, ASIC verification tools and IP cores (memory controllers, CAN, PCIe, ETH...)

RISC-V

CHIPS ALLIANCE

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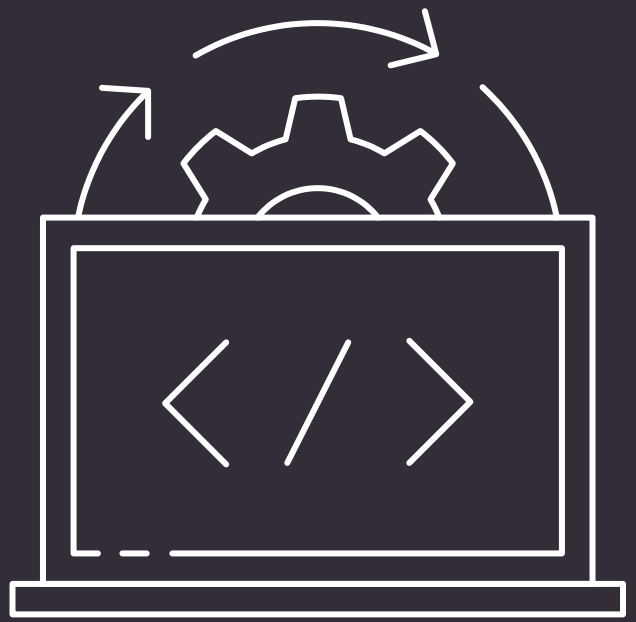
SUMMARY: SW-FIRST DEVELOPMENT

- what we want to achieve is software driving hardware choice and development, less waterfall, more intertwined
- HW/SW co-design is a rapidly growing area for us, working with Google, Microchip but also end user product companies
- ML practically requires this
- Zephyr enables this!



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ACTION ITEMS

- If you are trying to convince people internally why Zephyr is the superior choice, hopefully this talk provided some arguments
- If you're already all in on Zephyr, we're happy to get your thoughts on how we could help improve the open source HW and SW ecosystem with Renodepedia!
- We'd love to work with you to improve the data, coverage and features
- https://zephyr-dashboard.renode.io/renodepedia

THANK YOU
FOR YOUR ATTENTION!