2019 IEEE INTERNATIONAL SYMPOSIUM ON
ELECTROMAGNETIC COMPATIBILITY, SIGNAL & POWER INTEGRITY

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Detecting Latch-up Soft Failure Using an On-Die Sensor and Linux Kernel Log

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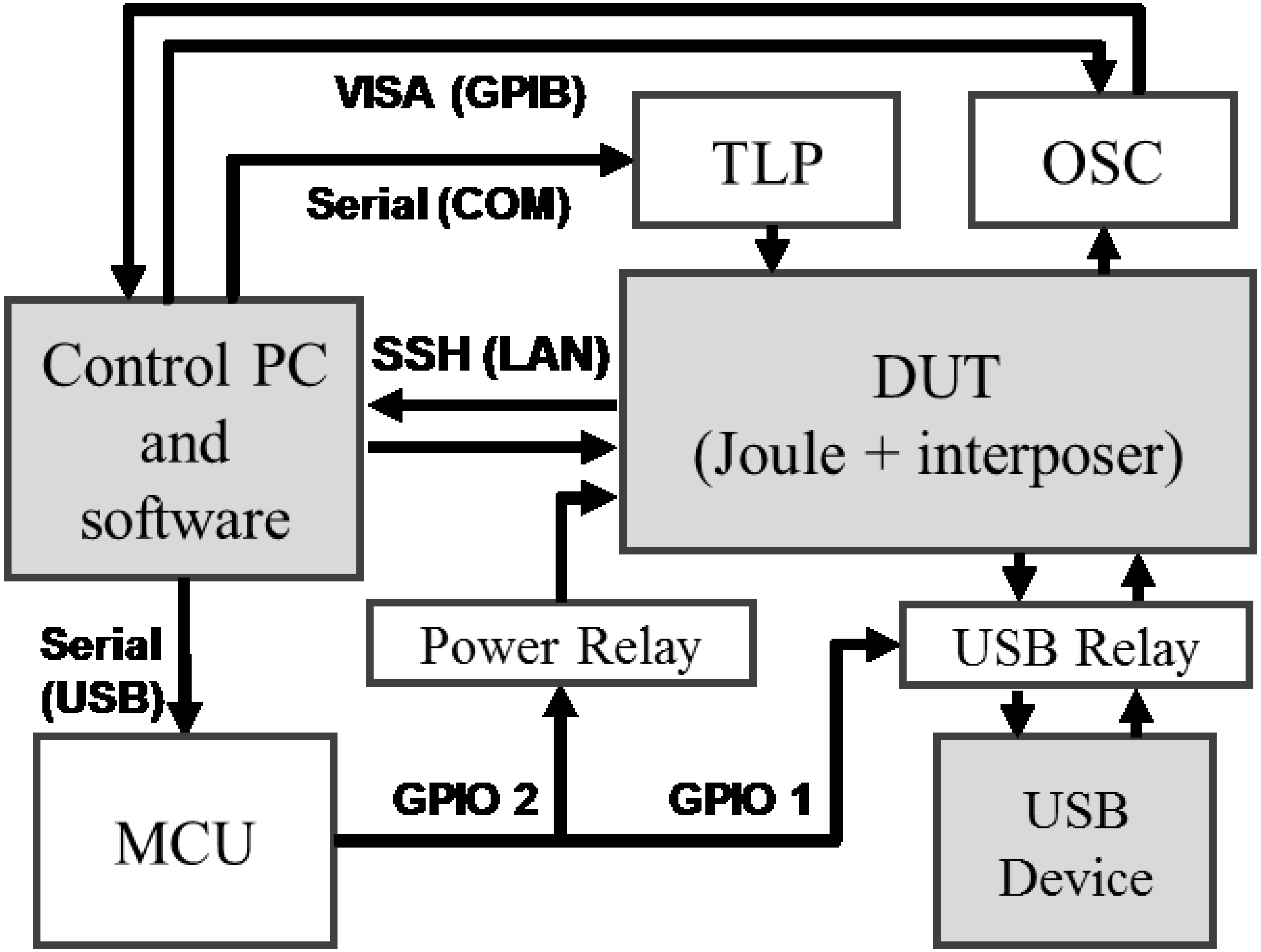
Outline

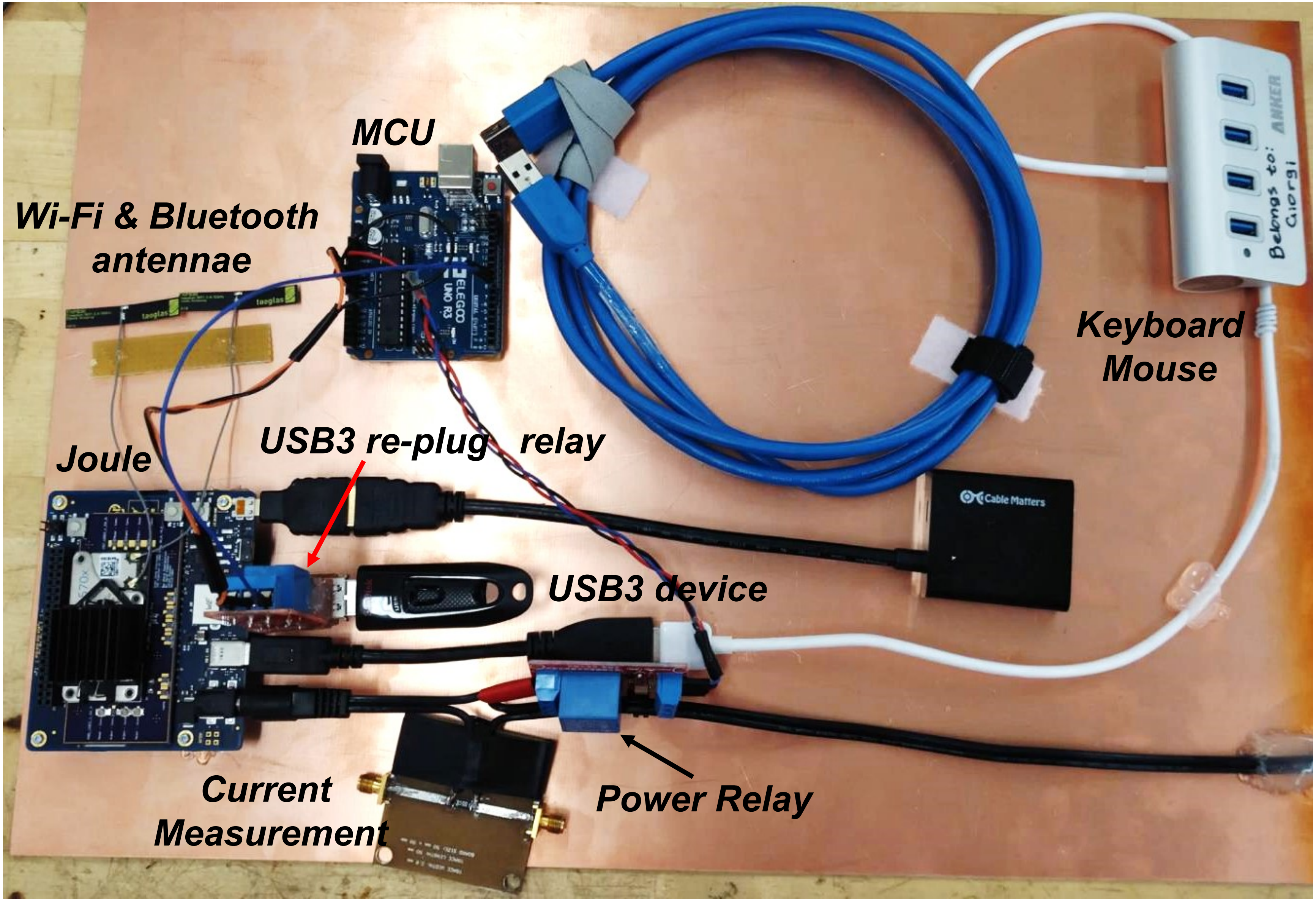
- Why is the Soft Failure Susceptibility relevant?
- The characterization process:
  - High-level overview
  - Injection / measurement setup (hardware)
  - Automation algorithm (software)
- Detection of latch-up:
  - Use existing sub-systems to detect failure
- Moving forward: what was learned?

- **Soft Failures (SF)** cause device malfunction, loss of data, etc.
- Many factors affect whether fail occurs:
  1) hardware 2) software 3) system state
- Failure occurrence is statistical by nature → 100s of tests needed

- Benefits of SF characterization:
  - **"Getting it right the first time"** - less time in development
  - **Less man-hours spent -** automation saves time
  - **Transferrable to other interfaces** with little change
  - **Risk management -** better understanding of the system

Characterization system setup



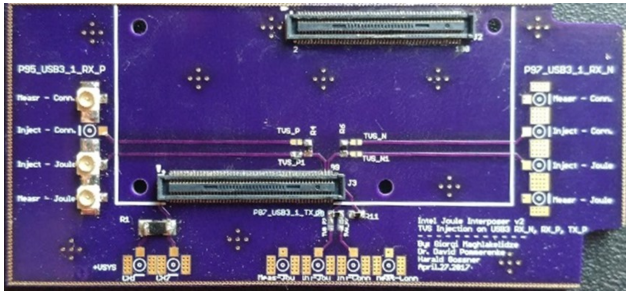

MCU
ELEGOO UNO R3
Wi-Fi & Bluetooth antennae
taoglas
Keyboard Mouse
ANKER
Belongs to: Giorgi
Joule
USB3 re-plug
relay
Cable Matters
USB3 device
Current Measurement
Power Relay

The dev platform (DUT) in 2 parts:

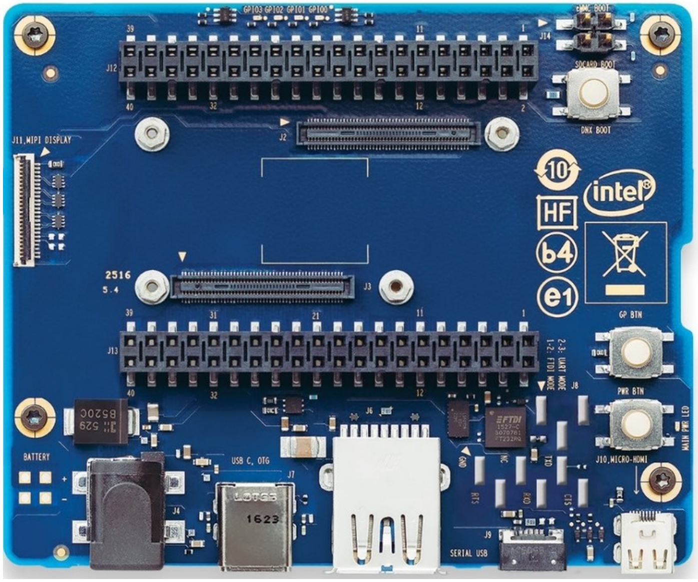
Compute module – all main ICs (CPU, RAM, eMMC, Bluetooth, WiFi)

Expansion board – power, fanout (HDMI, microSD, USB3, USB-C, GPIO)

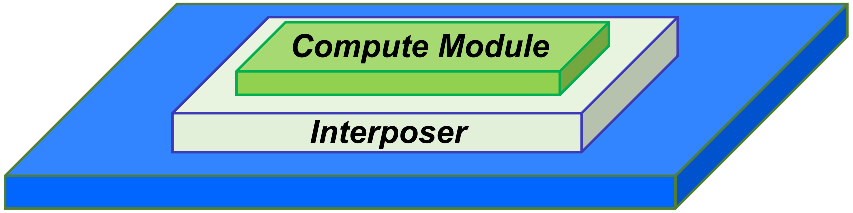
Compute Module



Interposer



Expansion Board



Expansion Board

An **interposer** goes between the boards.

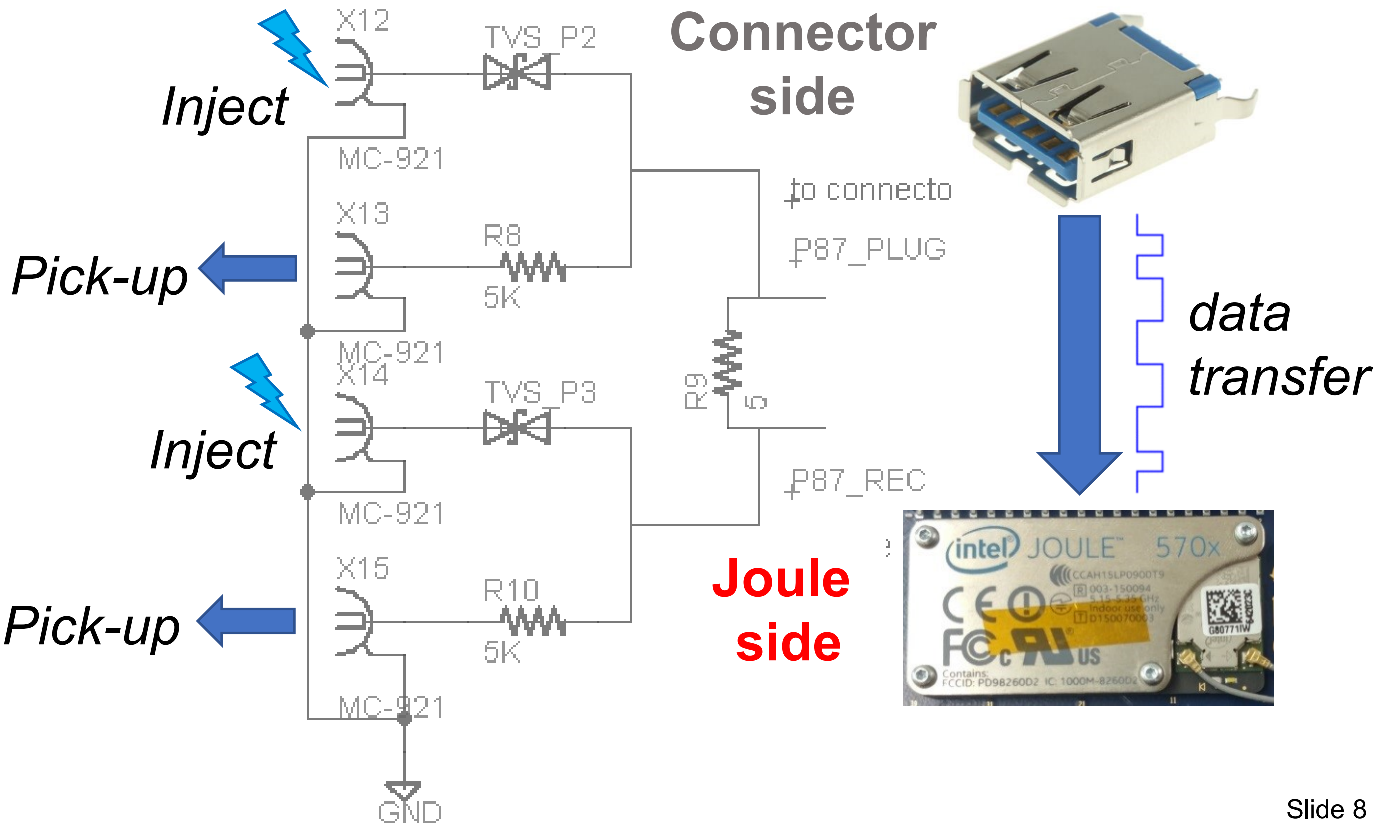
Stress injection directly into the **data** pins of **active interface.**

Not introducing SI problems (**TVS injection method** [6]).

Injection at either side of 5Ω resistor (for directionality).

Coax access → UMCC connectors (surface mount snap-in coax).

ESD injection & voltage measurement



Inject

Pick-up

Inject

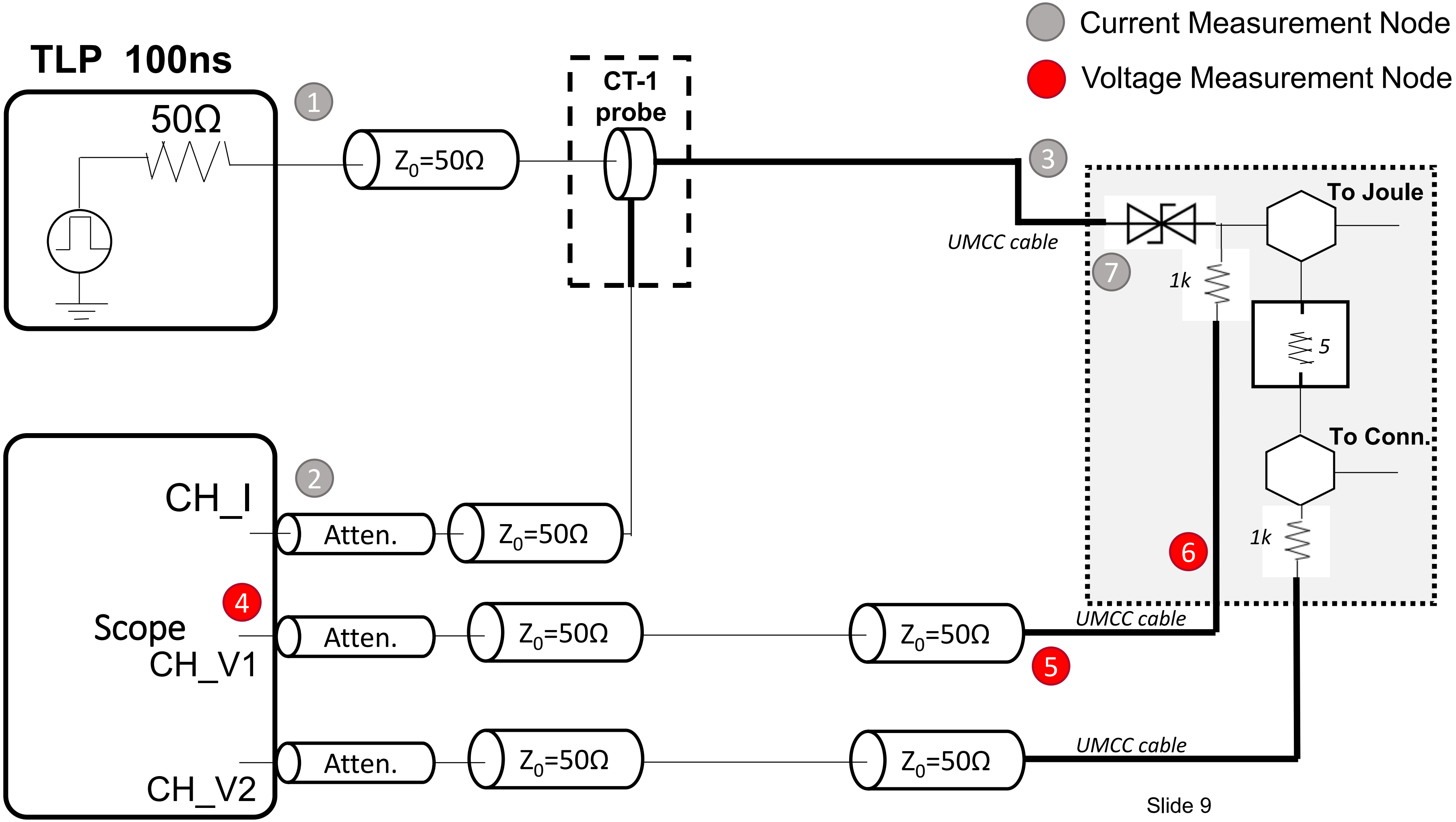
Pick-up

Connector side

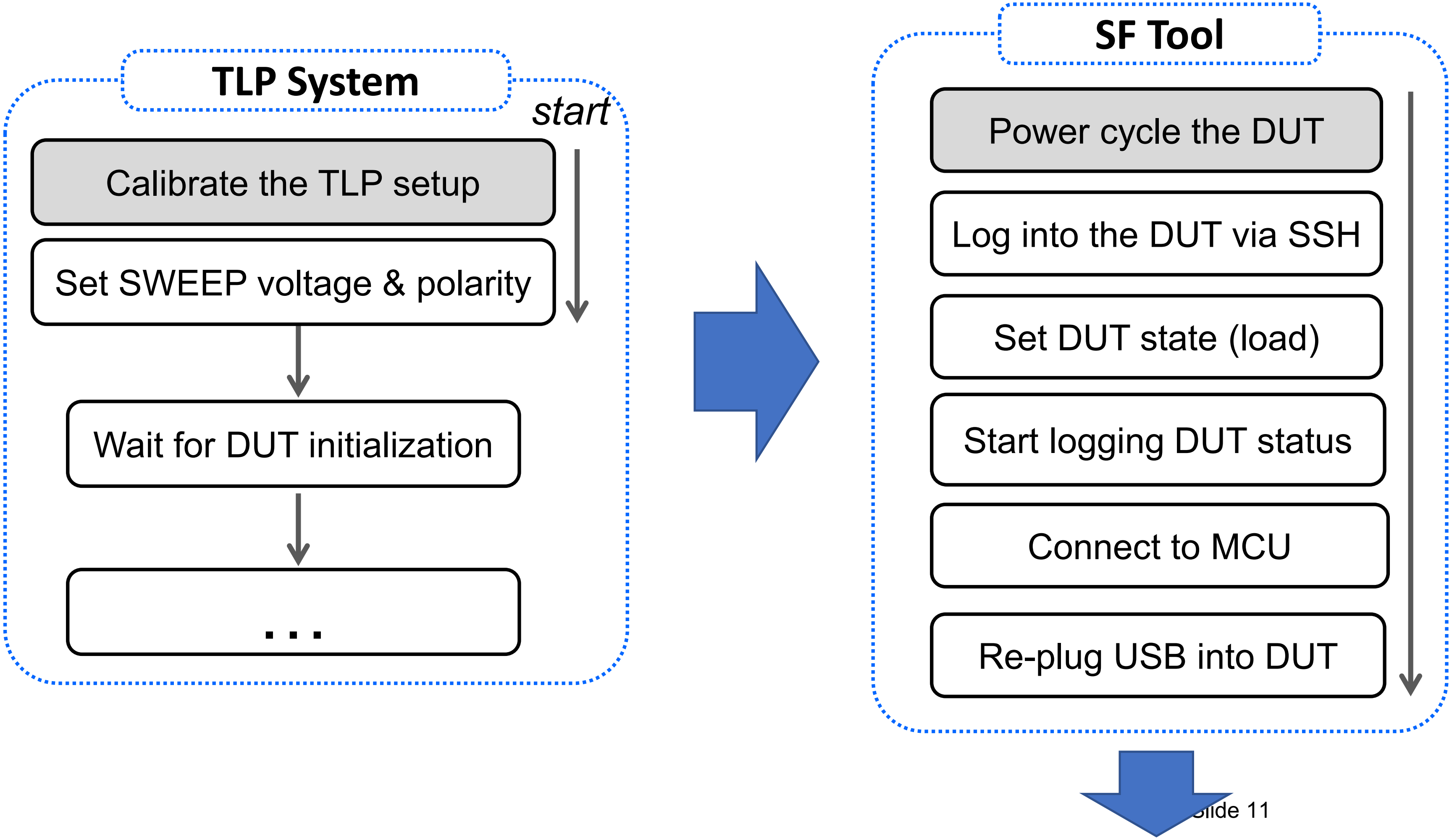
data transfer

Joule side

Stress injection setup - 100ns pulse



TLP System and DUT initialization:



TLP System

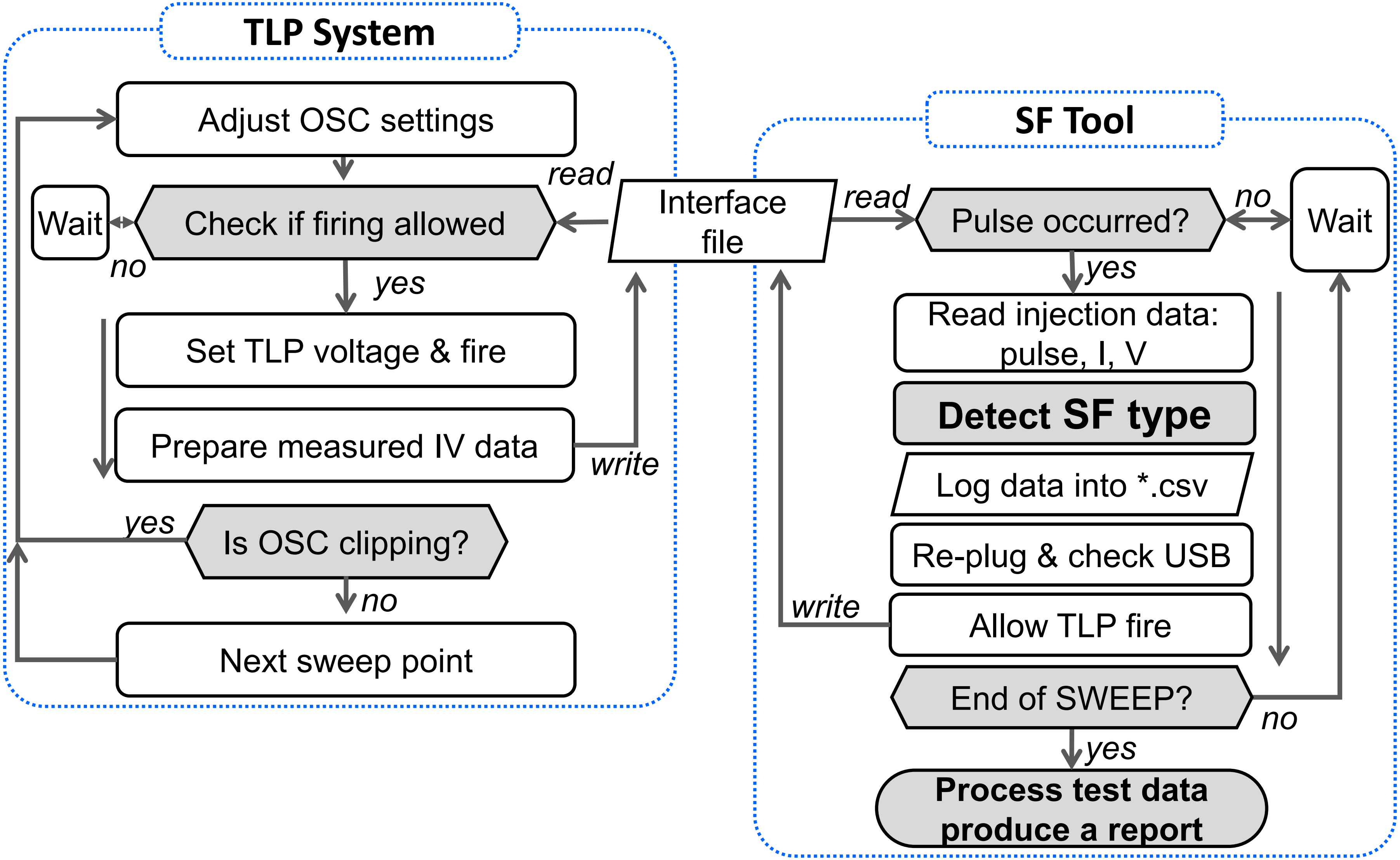
start

- Calibrate the TLP setup
- Set SWEEP voltage & polarity
- Wait for DUT initialization
- . . .

SF Tool

- Power cycle the DUT
- Log into the DUT via SSH
- Set DUT state (load)
- Start logging DUT status
- Connect to MCU
- Re-plug USB into DUT

Fully Automatic USB3 characterization flow



TLP System

Adjust OSC settings

Wait

Check if firing allowed

no

yes

read

Set TLP voltage & fire

Prepare measured IV data

write

yes

Is OSC clipping?

no

Next sweep point

Interface file

SF Tool

read

Pulse occurred?

no

Wait

yes

Read injection data: pulse, I, V

Detect SF type

Log data into *.csv

Re-plug & check USB

write

Allow TLP fire

End of SWEEP?

no

yes

Process test data produce a report

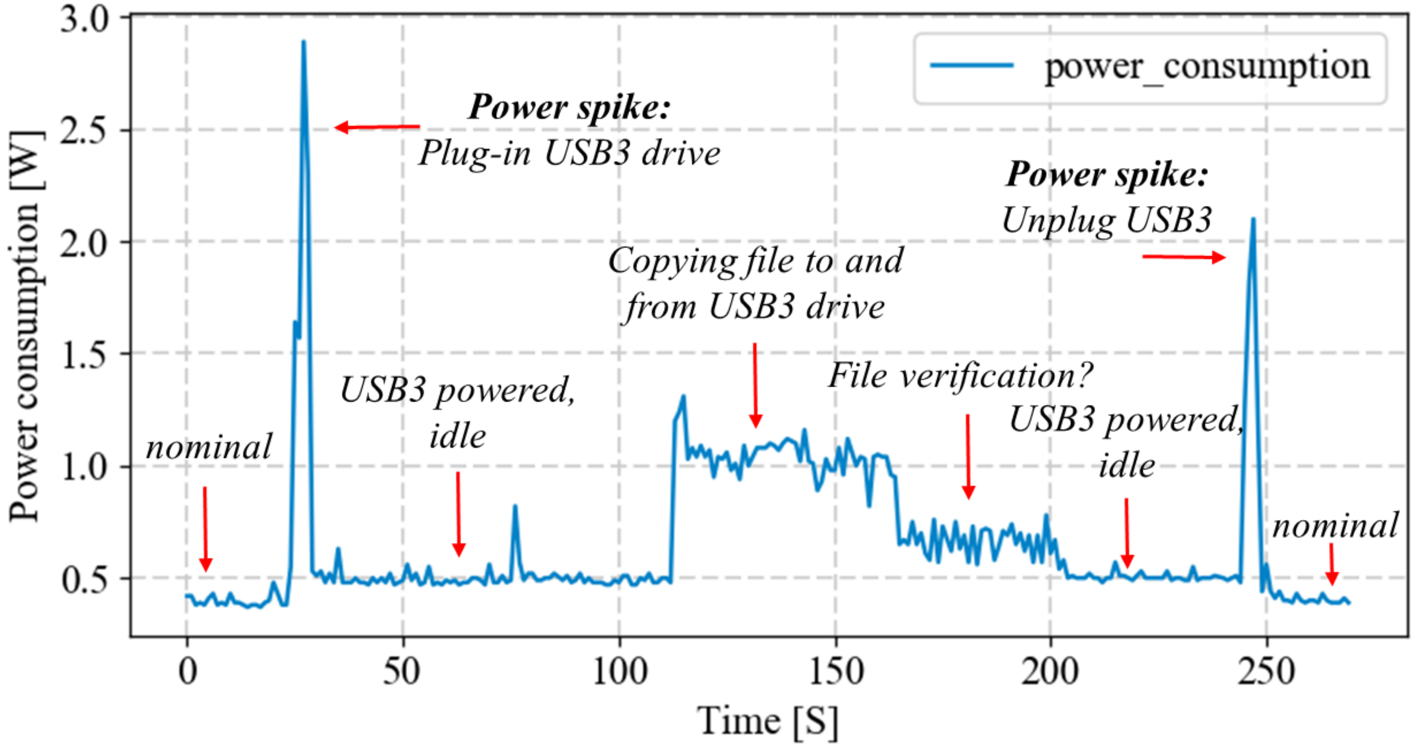
Monitoring DUT power consumption

The Run-time Average Power Limit (RAPL) sub-system of the Intel Joule CPU adjusts processor power to maintain temperature targets.

RAPL reports “energy spent by the processor in micro Joules”. The sensor polled with 1 sec interval at:

/sys/class/powercap/intel-rapl/intel-rapl:0/energy_uj

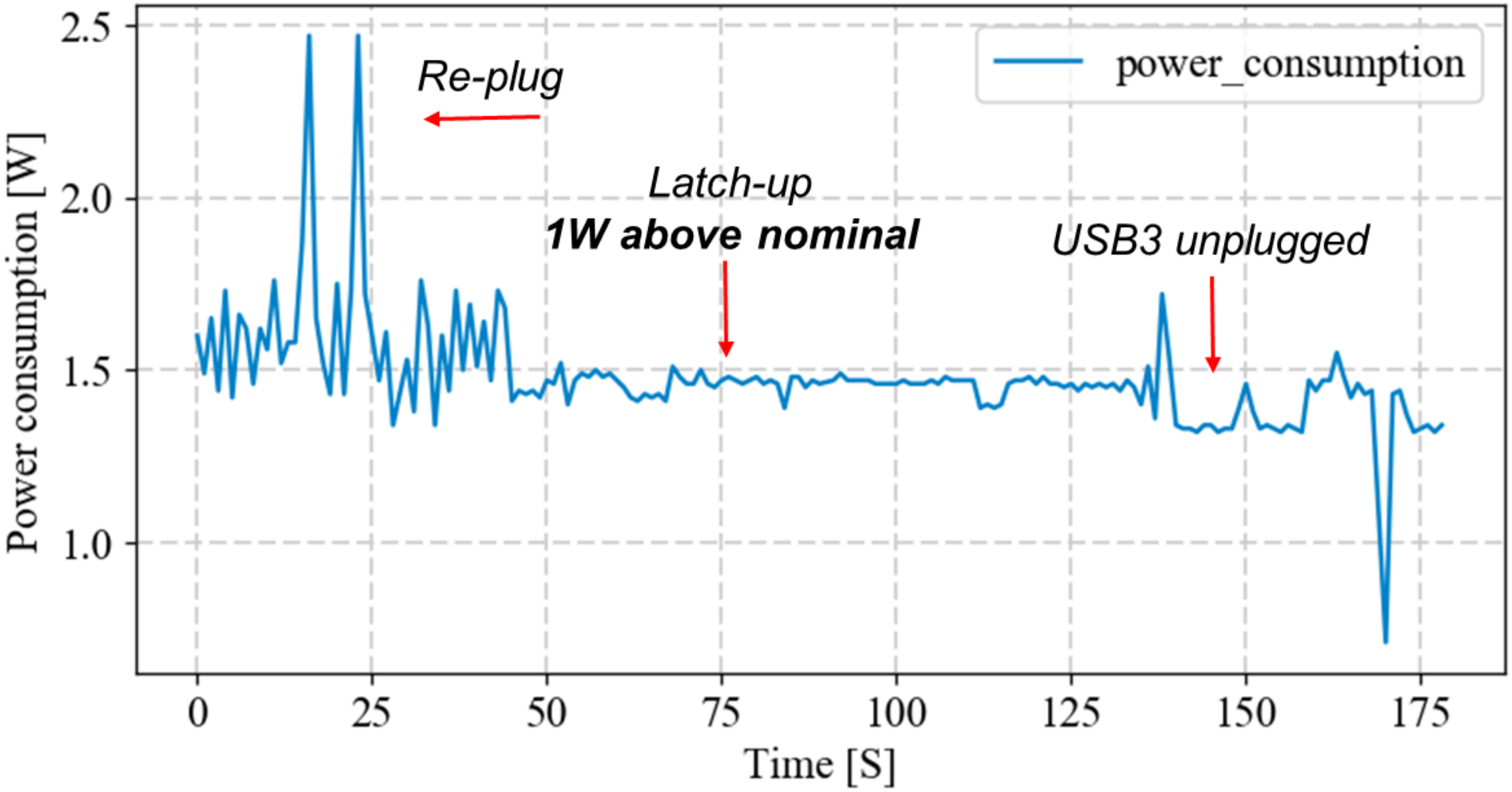
$$P_{avg} = \frac{E(t_2) - E(t_1)}{t_2 - t_1}$$



Power consumption due to Latch-up

Occurs when USB3 device is plugged in. Cannot resolve without full power cycle.

Detected without needing any external instruments.



Processing characterization data

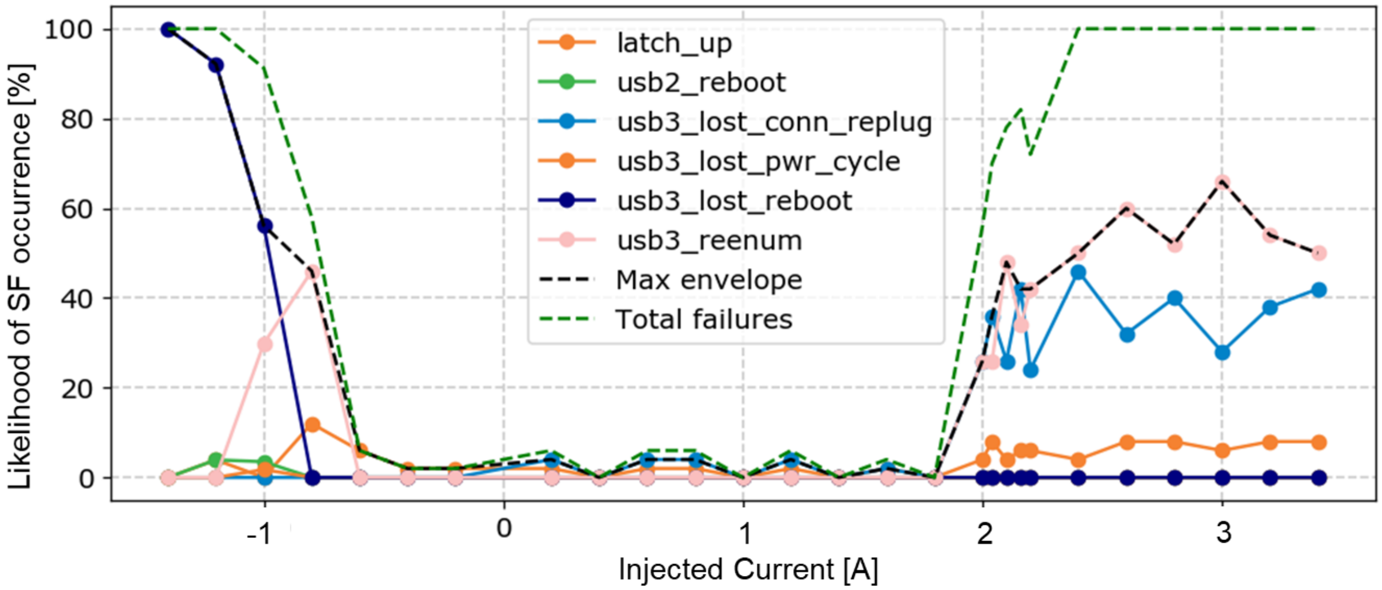
Challenge → process the results and be useful!

Python + big data tool **PANDAS** for **multivariate** analysis:

- Select and process the right data
- Generation of pivot charts and tables
- Pass/fail check w.r.t. likelihood thresholds

SF Likelihood vs… :

- TLP V_{charge}
- Measured $I_{injected}$
- Measured $V_{injected}$



Cat.	Visible	Interact	Example for USB
A	✗	✗	Bit errors; packets getting resent
B	✓	✗	Drop in data throughput; connection re-established by host
C	✓	✓	Stop of data transfer; re-plugging or power cycling required
D	✗	✓	Latch-up (power drain)

Mode	Cat.	Symptoms	Auto-resolve	Re-plug	Re-boot	Power Cycle
1	B	Drop in the data rate	✓	-	-	-
2.1	B	Client re-enumerated in USB3 mode; restored by the system	✓	-	-	-
2.2	B	Client re-enumerated in USB3 mode; GUI pop-up message appears	~	-	-	-
3	C	Client device falls back to USB2 mode	✗	✓	✓	✓
4	C	Client device disappears	✗	✓	✓	✓
5	D	Persistent power drain (latchup)	✗	✗	✗	✓
6	C	Wi-Fi functionality is lost	✗	✗	✗	✓

Conclusions

- Sometimes existing sub-systems can be used to our advantage.

- Latch-up is one of the most vicious Soft Failures for embedded and battery-powered systems.

- Automated test setups help save time and characterize DUTs for SF susceptibility

Fin.

Thank you for your time!