Considerations for GPU SEE Testing

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To be presented by Edward Wyrwas at the Single Event Effects (SEE) Symposium and Military and Aerospace Programmable Logic Devices (MAPLD) Workshop, La Jolla, CA, May 22-25, 2017.

Acronyms

Acronym	Definition
DUT	Device Under Test
GPU	Graphics Processing Unit
MBU	Multi-Bit Upset
NEPP	NASA Electronic Parts and Packaging
PTX	Parallel Thread Execution
RTOS	Real-time Operating System
SBU	Single-Bit Upset
SEE	Single Event Effect
SEFI	Single Event Functional Interrupt
SEU	Single Event Upset
SIMD	Single Instruction Multiple Data
SoC	System on Chip

Outline

- GPU technology
- The setup around the test setup
- Parameter considerations
- Lessons learned

Technology

- **Graphics Processing Units (GPU) & General Purpose Graphics Processing Units (GPGPU)**
  - **Are considered a compute device or coprocessor**
  - **Is not a standalone multiprocessor**
- **Using high-level languages, GPU-accelerated applications run the sequential part of their workload on the CPU – which is optimized for single-threaded performance – while accelerating parallel processing on the GPU.**

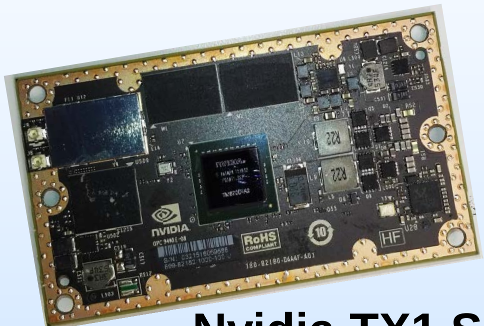
Purpose

- **GPUs are best used for single instruction-multiple data (SIMD) parallelism**
  - **Perfect for breaking apart a large data set into smaller pieces and processing those pieces in parallel**

- **Key computation pieces of mission applications can be computed using this technique**
  - **Sensor and science instrument input**
  - **Object tracking and obstacle identification**
  - **Algorithm convergence (neural network)**
  - **Image processing**
  - **Data compression algorithms**

Device Selection

- **Unfortunately, GPUs come in multiple types, acting as primary processor (SoC) and coprocessor (GPU)**



Nvidia TX1 SoC

Nvidia GTX 1050 GPU

Smart Phones

Intel Skylake Processor

AMD RX460 GPU

Device Software

- **Does it need its own operating system?**
  - **E.g. Linux, Android, RTOS**
- **Can we just push code at it?**
  - **E.g. Assembly, PTX, C**

- **Payload normalization**
  - **Can we run the same code on the previous generation and next generation of the device?**
  - **Cannot with CUDA code; can with OpenCL**

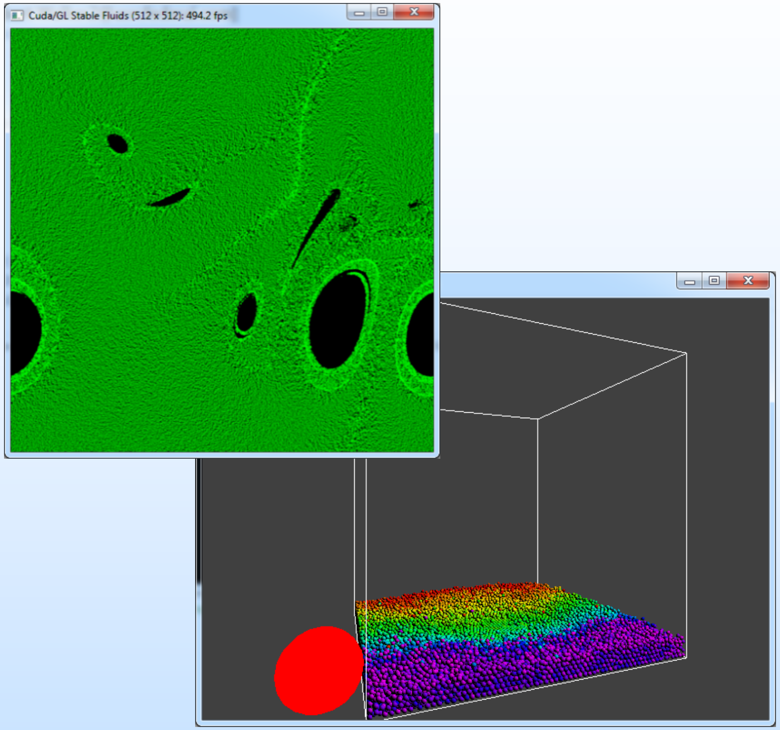
Real-time Operating System (RTOS)

Parallel Thread Execution (PTX)

CUDA is a parallel computing platform and application programming interface model created by Nvidia

Payloads

- **Visual Simulations**
  - **Sample code**
  - **Fuzzy Donut (i.e. Furmark)**
- **Sensor streams**
  - **Camera feed**
  - **Offline video feed**
- **Computational loading**
  - **Scientific computing models**
- **Easy Math**
  - **0 + 0 … wait … should = 0**



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Test Setup

- **Things to consider in the test environment**
  - **Operating system daemons**
  - **Location of payload and results**
  - **Data paths upstream/downstream**
  - **Control of electrical sources**
  - **Temperature control (i.e. heaters) in a vacuum**

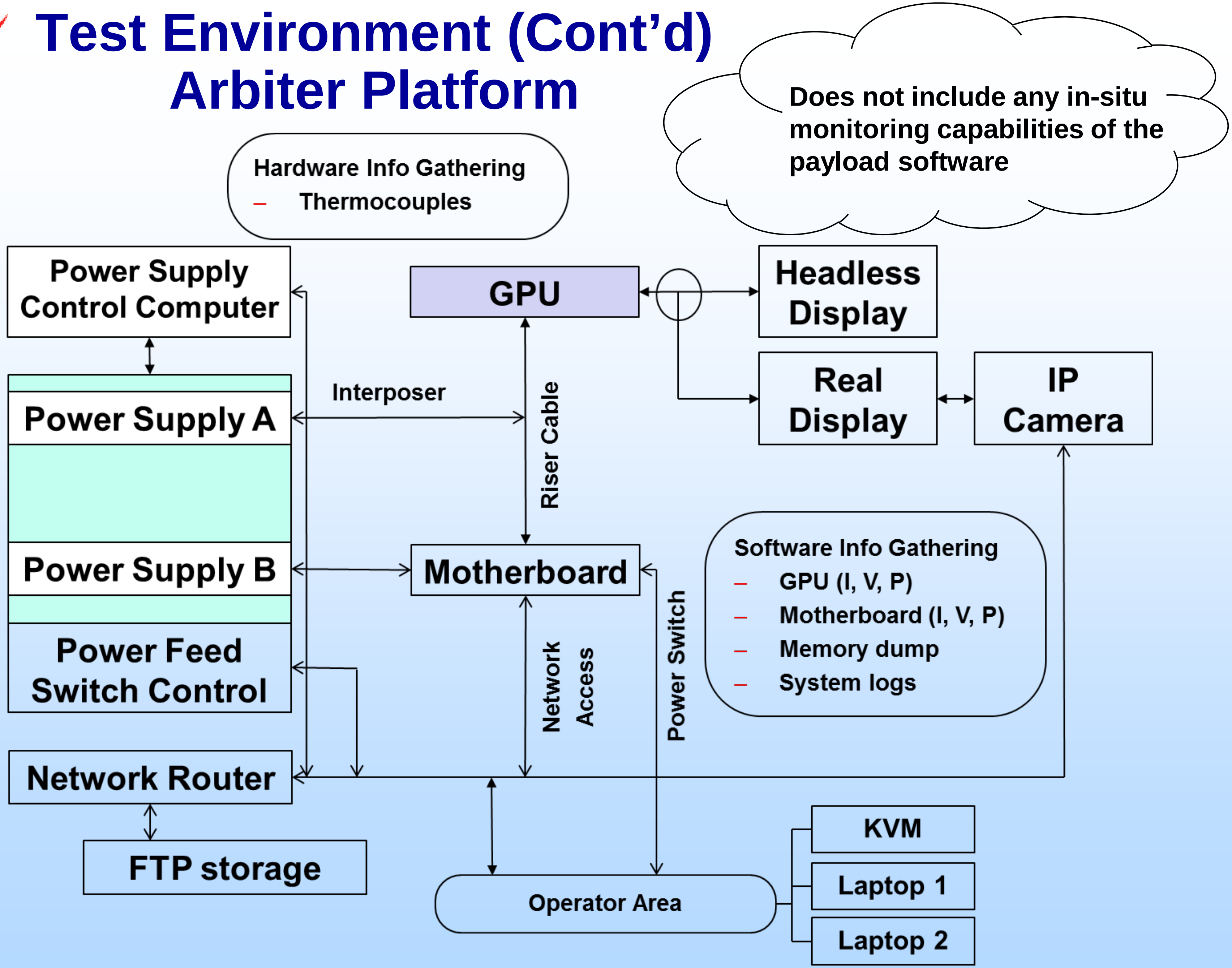
- **Things to consider in the device under test (DUT)**
  - **Is the die accessible?**
  - **What functional blocks are accessible?**
  - **Which functions are independent of each other?**
  - **Does it have proprietary or open software?**

Test Environment

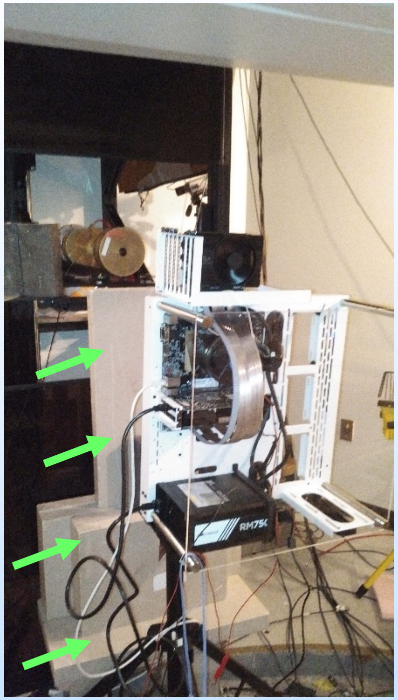
- **Beam line**
  - **DUT testing zone where collateral damage can happen**
  - **Shielding for everything non-DUT**

- **Operator Area**
  - **Cables, interconnects and extenders**
  - **Signal integrity at a distance**
  - **“Everything that was done in a lab, in front of you on a bench, now must be done from a distance…”**

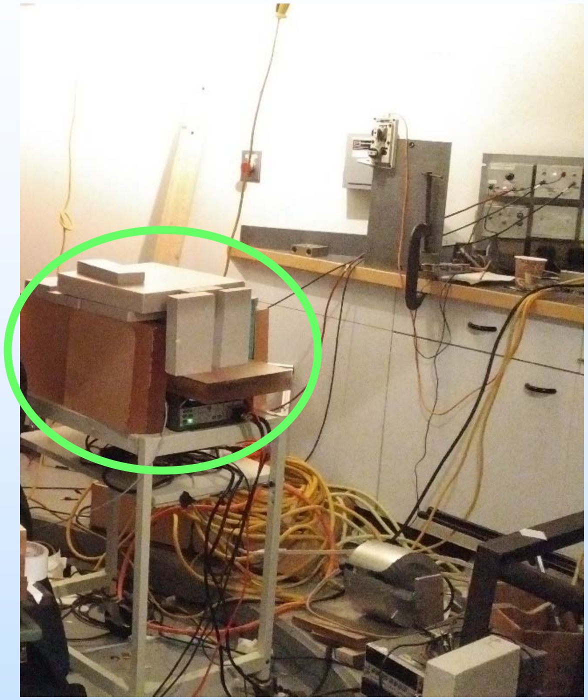
Test Environment (Cont'd)
Arbiter Platform



Test Environment (Cont'd)



Tripod and mounting

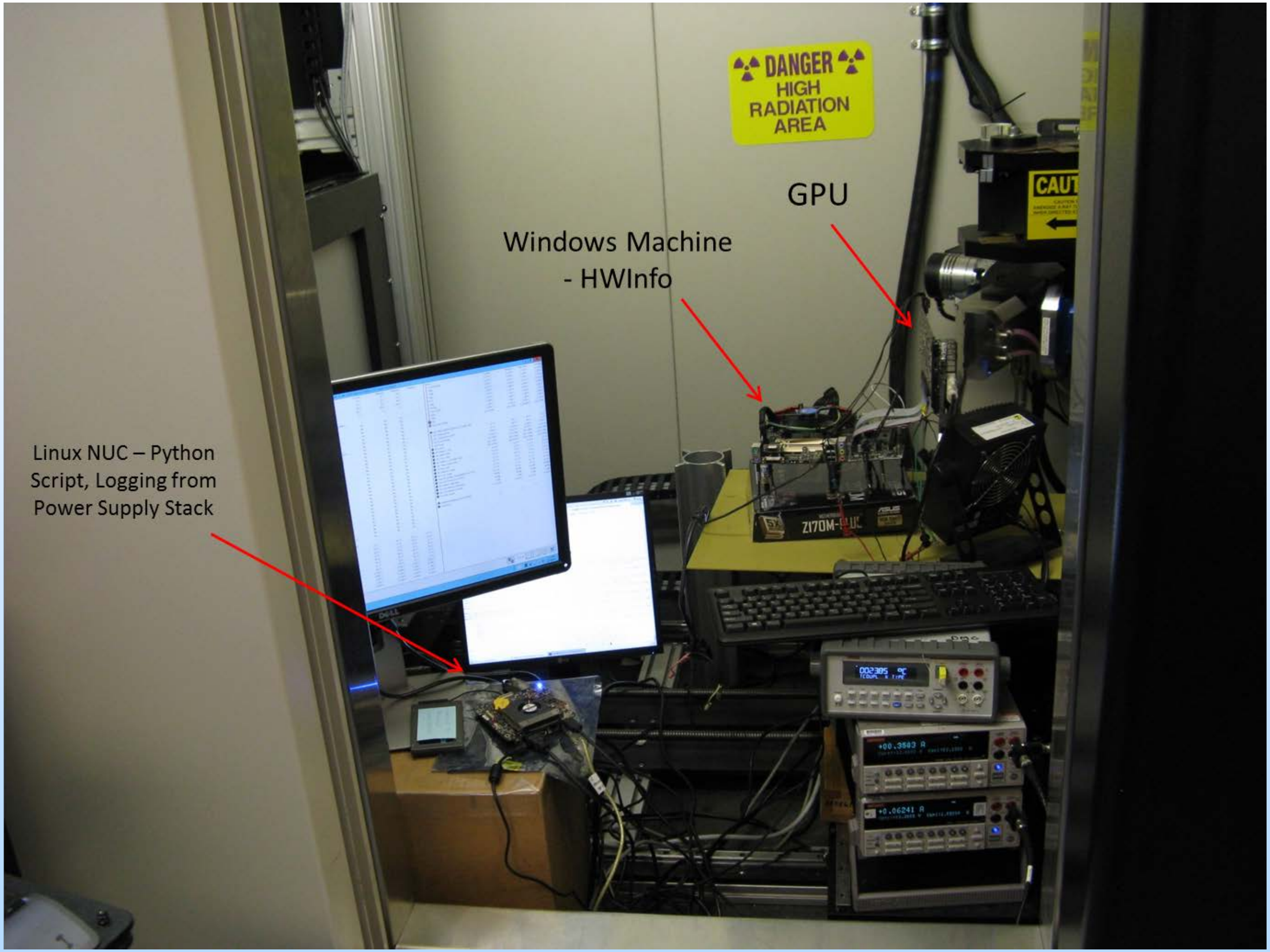


External power

Power injection

Arrows and circle mark locations
of the lead and acrylic block fortresses

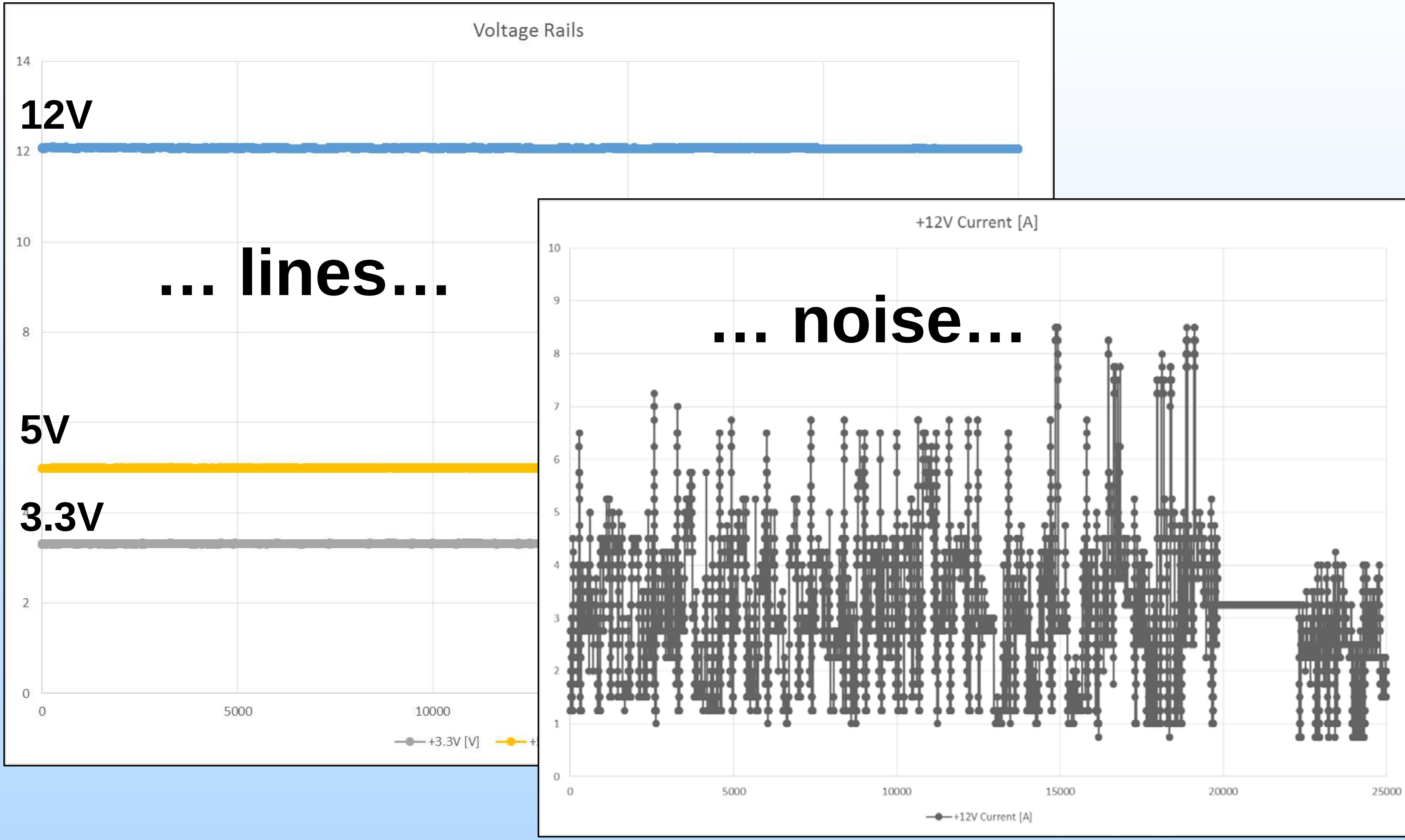
Test Environment (Cont'd)



DUT Health Status

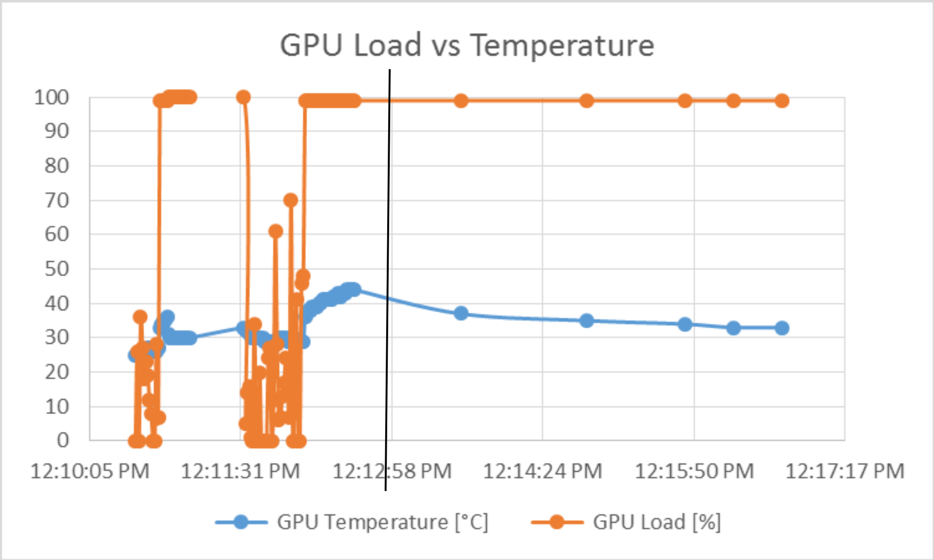
- **Accessible nodes**
  - **Network**
    - **Heart beat by inbound ping**
    - **Heart beat by timestamp upload**
  - **Peripherals response**
    - **“Num lock”**
  - **Visual check**
    - **Remote**
    - **Local**
    - **Local with remote viewing**
  - **Electrical states**

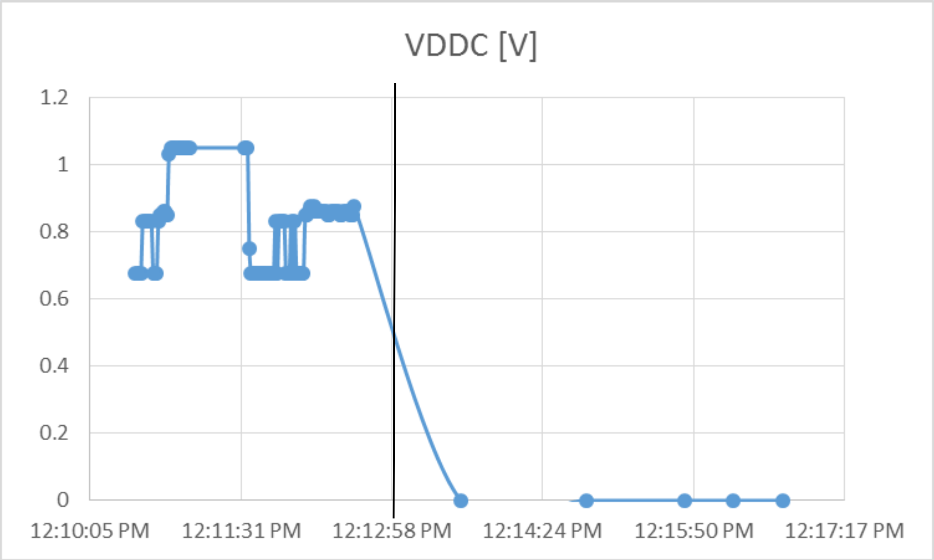
Monitoring Data



Monitoring Data (Cont’d)

- **Significant digits are important**
- **Resolution is needed for correlation**
  - **Faster sampling speed**
  - **Smaller units (µV or mV, not Volts)**





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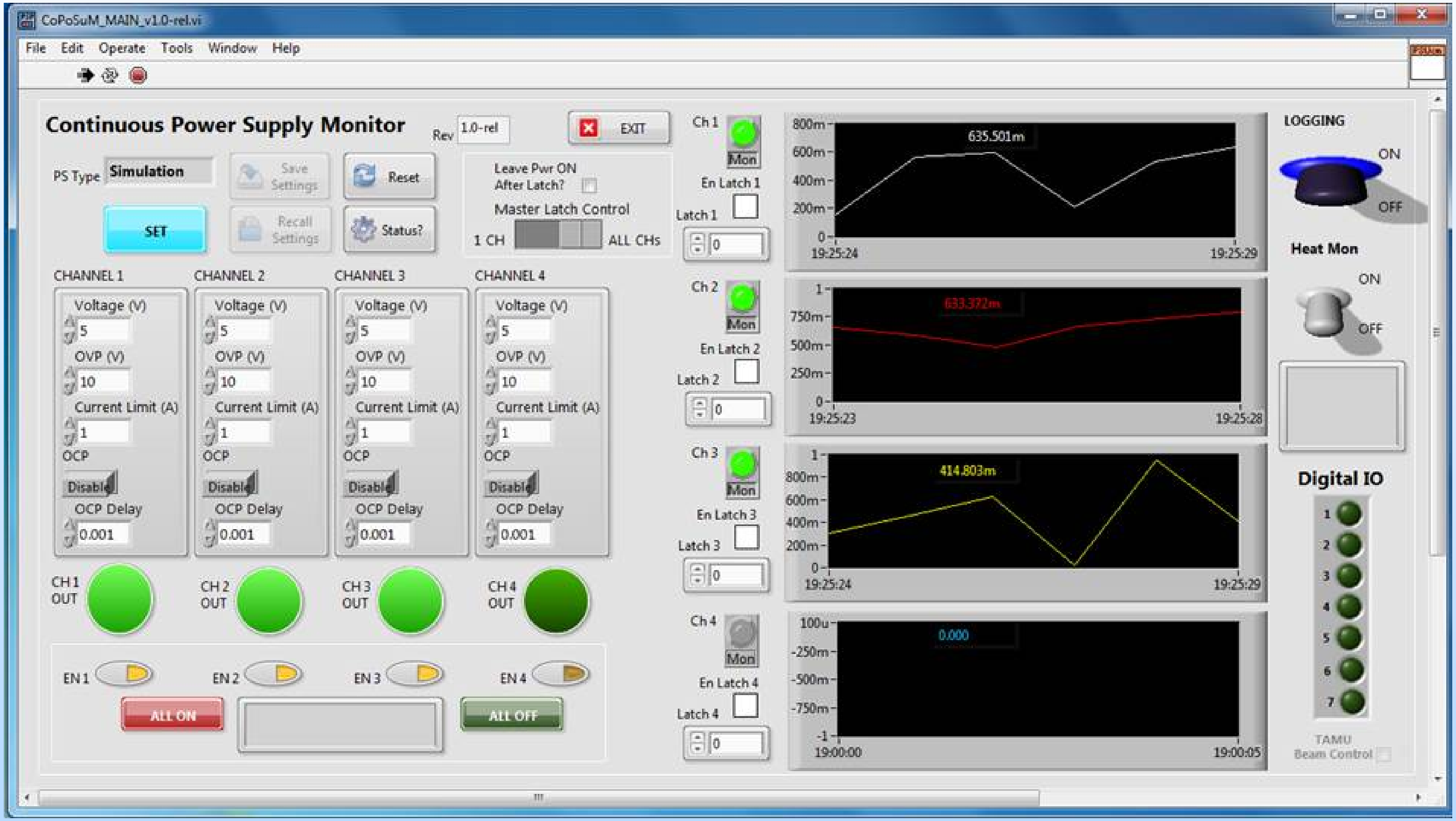
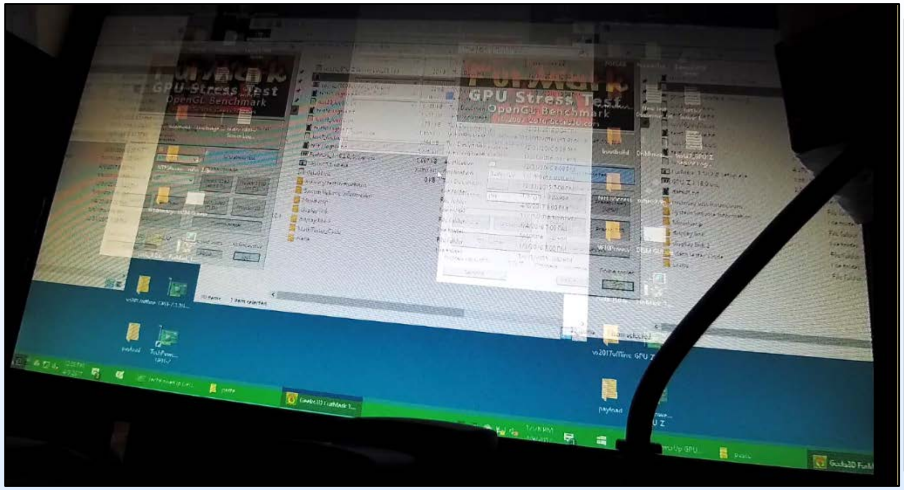
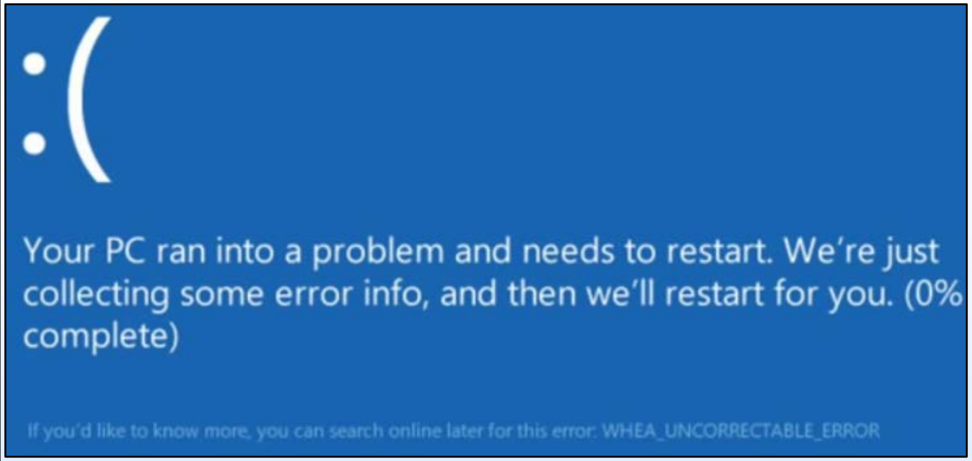
Monitoring Data (Cont'd)

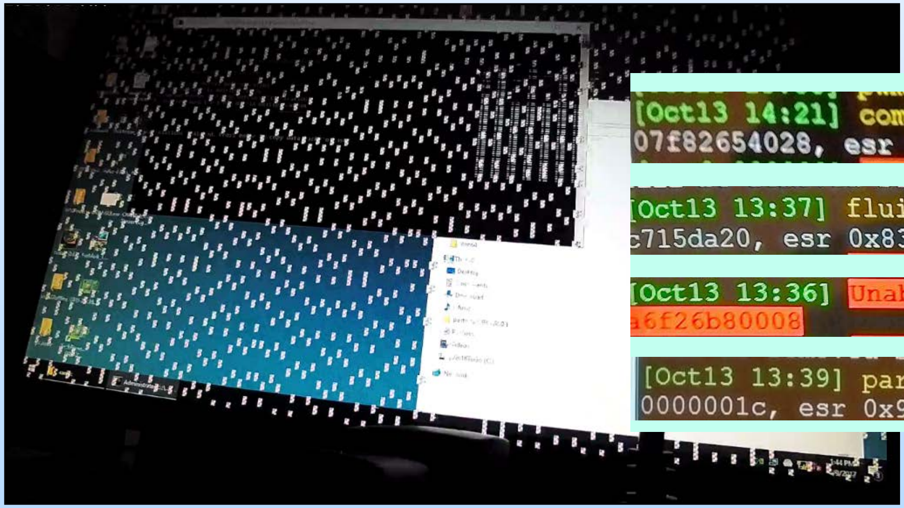
- **Even better (albeit being a mock up):**

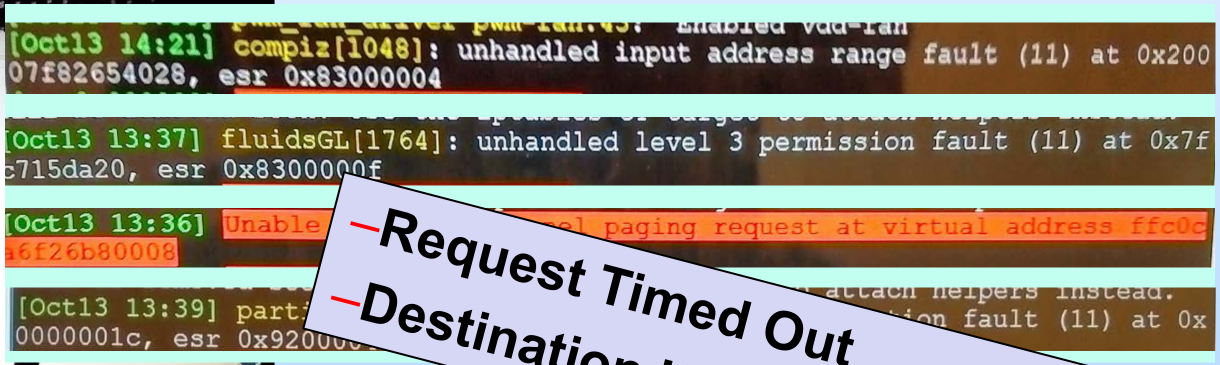


What does a failure look like?



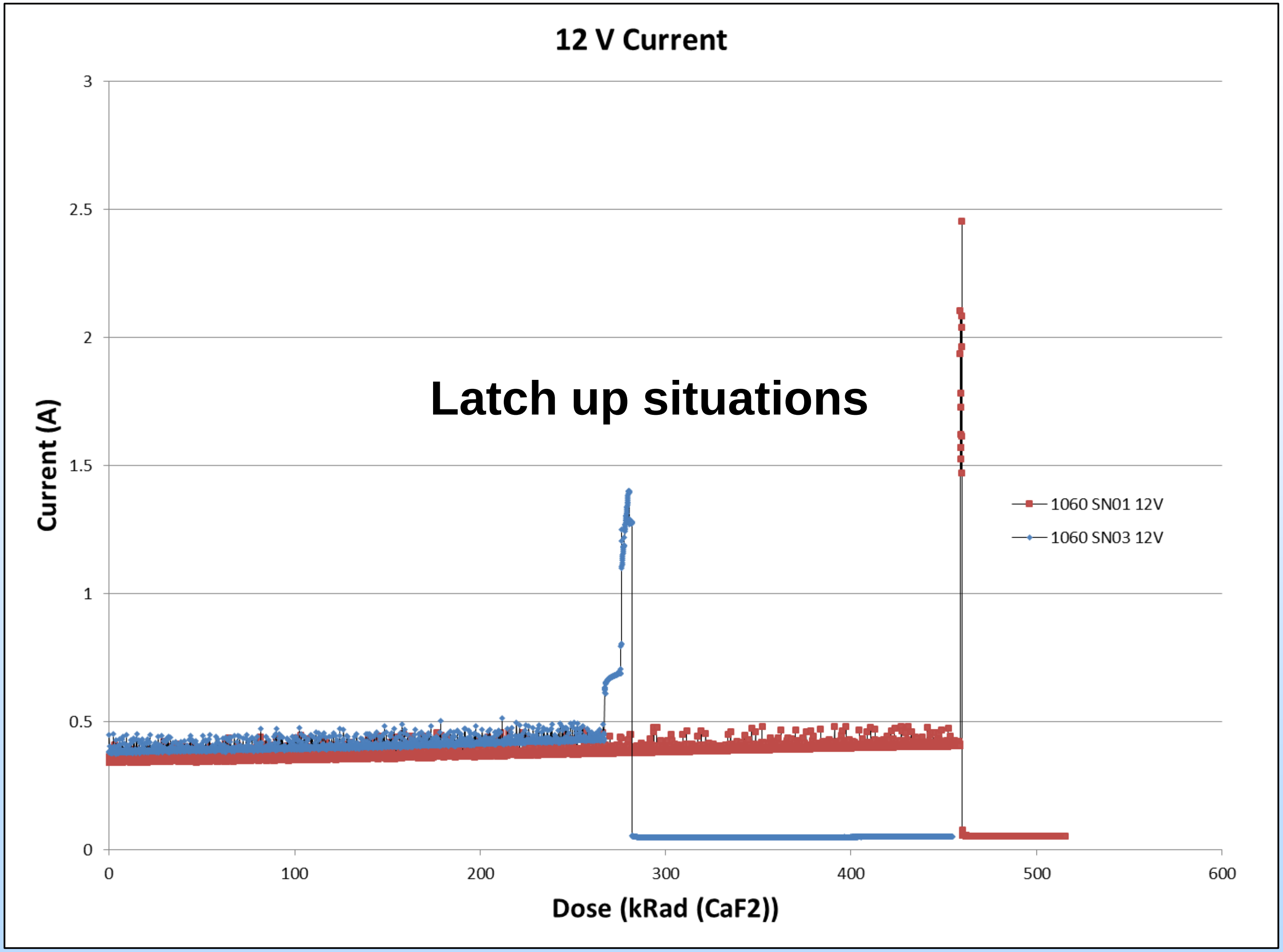






–Request Timed Out
–Destination Host Unreachable

Failures



12 V Current
Latch up situations
Current (A)
Dose (kRad (CaF2))
1060 SN01 12V
1060 SN03 12V
0
0.5
1
1.5
2
2.5
3
0
100
200
300
400
500
600

Learning Experience

- Every test is another learning experience
  - “Is the laser alignment jig in the beam path…”
  - Nuances with controllable nodes
    - DUT power switch
    - Remote power sources
    - DUT electrical isolation from test platform
    - Thermal paths
  - Improvements are always possible, but preparation time may not be as abundant
  - Prioritization during development is important
    - Software payload
    - Hardware monitoring
    - Remote troubleshooting capabilities

Conclusion

- NEPP and its partners have conducted proton, neutron and heavy ion testing on several devices
  - Have captured SEUs (SBU & MBU),
  - Have seen traceable current spikes,
  - But predominately have encountered system-based SEFIs
- GPU testing requires a complex platform to arbitrate the test vectors, monitor the DUT (in multiple ways) and record data
  - None of these should require the DUT itself to reliably perform a task outside of being exercised
- Progress has been made in proving out multiple ways to simulate and enumerate activity on the DUT
  - Narrowing down on a universal test bench
  - End goal is to make test code platform independent