



# **Testing the Tester: Lessons Learned During the Testing of a State-of-the-Art Commercial 14nm Processor Under Proton Irradiation**

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# Acronyms

- **Basic Input/Output System (BIOS)**
- **Device Under Test (DUT)**
- **Graphical Processing Unit (GPU)**
- **Goddard Space Flight Center (GSFC)**
- **High Definition Multimedia Interface (HDMI)**
- **Massachusetts General Hospital (MGH)**
- **National Aeronautics and Space Administration (NASA)**
- **NASA Electronic Parts and Packaging (NEPP) Program**
- **Random Access Memory (RAM)**
- **Solid State Disk (SSD)**
- **single event effect (SEE)**
- **Thermal Design Power (TDP)**
- **Universal Serial Bus (USB)**

# Background



*Circa 1986, playing with an Atari 1040ST*

- **Lifelong Computer Hobbyist and Enthusiast**
  - Unconventional Training and Skill Set
- **System Administrator supporting GSFC since 2002**
  - Duties often require flexibility and out of the box thinking to solve unplanned problems / handle unexpected events
- **Introduced to Radiation Effects ~2012**
  - “Person Under Test”

# Device Under Test



- **Intel core i5-6600K “Skylake” Microprocessor**
  - ASUS Z170M-Plus Motherboard, 8GB RAM, 750W Power Supply, SSD, USB and HDMI over Ethernet control
  - Microsoft Windows Server 2012R2 OS, HWiNFO System Monitoring, Linpack, FurMark, Prime95 Stress, Batch File Control
  - In-situ, “System Level” Best Effort Approach
- **Proton Testing via**
  - TRIUMF 105 MeV Beam Line (November 2015)
  - MGH 200 MeV Beam Line (October 2016)



# What Happened

- **Hard failure event observed during TRIUMF visit**
  - Device appeared to lose integrated GPU functionality during irradiation
    - Failure occurred during “Full” test (Linpack + FurMark) with only 1 CPU core active
  - Results were difficult to explain at the time of testing
- **Subsequent testing at MGH yielded no functional failures after 60+ test runs!**
  - How??
- **Next day at MGH, re-tested board used during TRIUMF tests**
  - Processors began to fail!

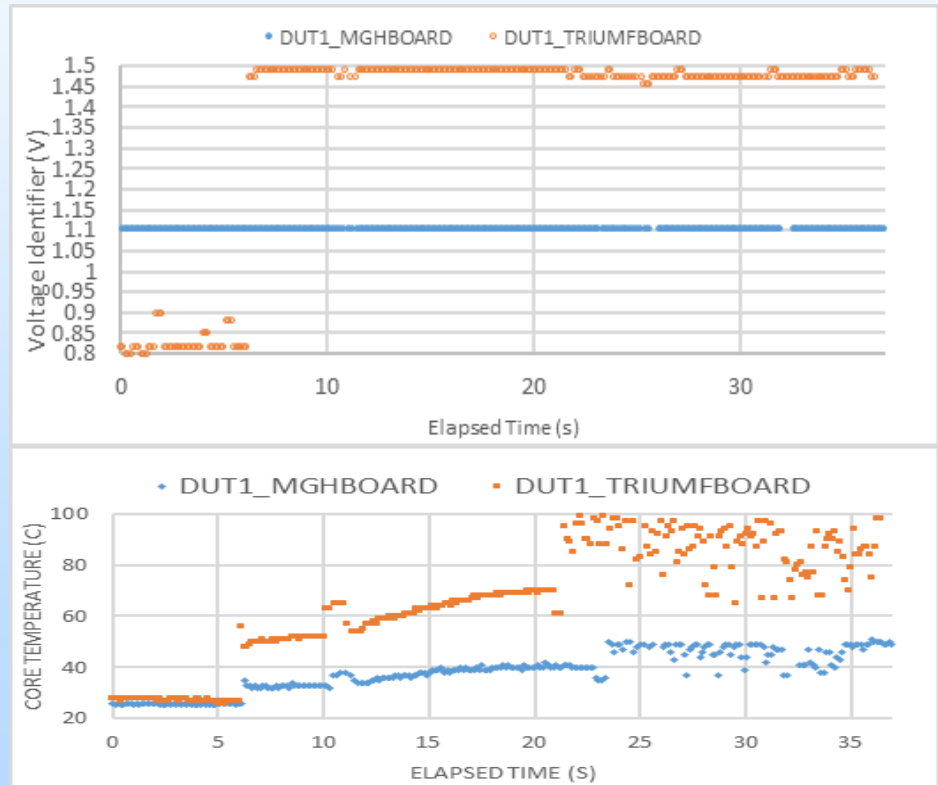
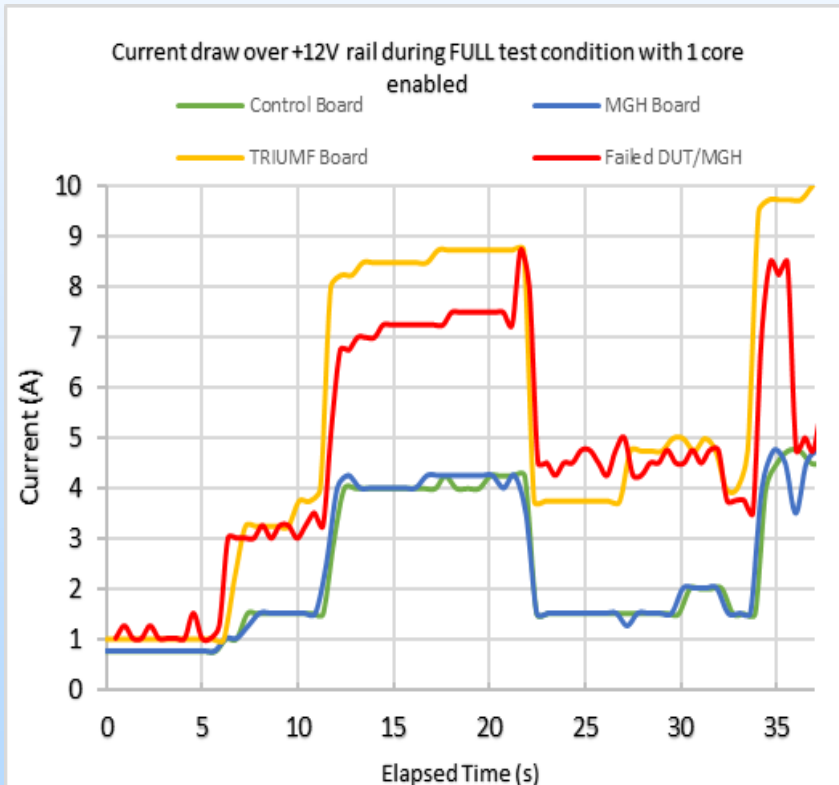


# Troubleshooting 1/3

- **Product was new and period of testing was short**
  - First setup featured early release hardware
  - Public discovers flaws (Prime95 lockup issue)
- **Test setup evolved as the device technology matured**
  - Later procured motherboards featured updates
    - BIOS revision of board used at MGH operated DUT differently than board and BIOS version used at TRIUMF
  - Supporting hardware and software enabled enhanced data collection
    - Accurate data
  - Evolution of test setup allowed insight that was not possible in early testing
  - Retesting on the MGH and TRIUMF-tested boards showed same behaviors with fresh processors

# Troubleshooting 2/3

- Large differences in functional parameters
  - Failures only occurred during exposure to protons
  - These differences would likely be transparent to regular users



# Troubleshooting 3/3

- **Motherboard used at TRIUMF operated DUT in excess of rated 91 Watt TDP!**
  - Only 1 processing core active
  - Degradation of performance after 18 hour extreme stress test
    - Failed Linpack tests
    - Could not reproduce GPU functional failure
- **Motherboard used at MGH operated DUT more efficiently**
  - Lower temperature operation
  - Fewer changes in voltage
  - Slightly better performance
- **Control Motherboard (latest BIOS available as of Sep. 2017)**
  - Behavior largely the same as MGH motherboard





# Conclusion

- **Early hardware and software is imperfect**
  - Perform updates BIOS, microcode, hardware and software
- **Up-to-date hardware and software leads to**
  - Increased data
  - Accurate data
    - Correctable / Uncorrectable Error Reporting
- **However, current product cycle is changing quickly**
  - How feasible to characterize?
    - Limited time begets limited reliability data
  - Flight project cannot tolerate lack of supply + reliability data, nor frequent updates