NEPP Processor Enclave (NPE) Update

Edward J. Wyrwas
edward.j.wyrwas@nasa.gov
301-286-5213
SSAI, Inc, work performed for
NASA GSFC, NEPP

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NASA Electronic Parts and Packaging (NEPP) Program

Acronyms

- Advanced Micro Devices (AMD)
- Application Specific Integrated Circuit (ASIC)
- Artificial Intelligence (AI)
- Advanced RISC Machine (ARM)
- Automated Test Equipment (ATE)
- Board Level Adapter Plate (BLAP)
- Body of Knowledge (BOK)
- Complementary metal oxide semiconductor (CMOS)
- Commercial off-the-shelf (COTS)
- Compute Unified Device Architecture (CUDA)
- Dual Data Rate (DDR)
- Device under test (DUT)
- Electrical, Electronic and Electromechanical (EEE)
- Field programmable gate array (FPGA)
- Fin Field-effect transistor (FinFET)
- General Purpose Input / Output (GPIO)
- Graphics Processing Unit (GPU)
- High Performance Computing (HPC)
- Input / Output (IO)
- Intellectual Property (IP)
- Linear energy transfer (LET)
- Key Process Indicators (KPI)
- LINear equations software PACKage (LinPack)
- Machine Learning (ML)
- Mean time to failure (MTTF)
- Multi-Bit Upset (MBU)
- National Aeronautic and Space Administration (NASA)
- NASA Electronic Parts and Packaging (NEPP)
- NEPP Processor Enclave (NPE)
- Open Compute Language (OpenCL)
- Open Graphics Language (OpenGL)
- Operating System (OS)
- Printed Circuit Board Assembly (PCBA)
- Procurement Request (PR)
- RApid Machine-lEarned Triage (RAMjET)
- Single-Bit Upset (SBU)
- Scientific Python (SciPy)
- Single-Event Effect (SEE)
- Single-Event Functional Interrupt (SEFI)
- Single-Event Upset (SEU)
- Single-Event Upset Cross-Section (σ_{SEU})
- Simultaneous Localization And Mapping (SLAM)
- System on Chip (SOC)
- System on Module (SOM)
- Transiting Exoplanet Survey Satellite (TESS)
- Technical Operation Report (TOR)

NEPP Team Members

Ed Wyrwas	edward.j.wyrwas@nasa.gov
Carl Szabo	carl.m.szabo@nasa.gov
Scott Stansberry	scott.d.stansberry@nasa.gov
Alyson Topper	alyson.d.topper@nasa.gov
Steve Guertin*	steven.m.guertin@jpl.nasa.gov

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* JPL Caltech

NEPP Processor Enclave (NPE)

- State of the Art (SOTA) computational devices exist as individual semiconductor components yet require other devices to operate in a realistic system. While Graphics Processor Units (GPUs) are the primary technology being characterized in this NEPP subtask, the GPU is a general-purpose compute device, and its **relevant technology competitors** need to be evaluated such as Systems on Chip (SoC), microprocessors and artificial intelligence (AI)-capable devices.
- Discrete GPUs have not been available since early CY19.
  - The release cycle of 'gaming' capable GPUs is often during the summer months. Supply of these devices lessens towards year's end.
  - Cryptocurrency miners are buying GPUs internationally direct from the manufacturers making supply in the USA less than ideal. Price gouging is a consequence.
  - When the COVID quarantine started, newly found teleworkers procured the majority of computer parts. The availability of GPUs became grossly limited. Excessive lead times and price gouging are consequences.
  - Currently a GPU with MSRP of $150 is selling for $700+, limited one per customer
- The "**Processor Enclave"** is intended to be better nomenclature to categorize these types of compute devices, including compute devices that are System-In-Package (SiP), Package-On-Package (PoP), or monolithic devices which employ SOTA heterogeneous process integration to achieve the same.
  - We are exploring more low power devices, but we are primarily considering any device that can run reasonable software and that we can procure in batches of 1 to 20.

FY22: NEPP Processor Enclave

Processors and Neuromorphic Computing:

Testing includes total dose, single event and reliability. Test vehicles will include CPU, SOC and GPU devices from NVIDIA, AMD, and other vendors as available. Test vehicles will include 'simple interface' devices with USB or similar connectivity, and Single Board Computers.

- Compare to previous generations
- Investigate failure modes/compensation for increased power consumption
- Identifies viable suppliers and provide insight into product obsolescence roadmaps

Description:

- This is a task over all device topologies and processes
- The intent is to determine inherent radiation tolerance and sensitivities
- Identify challenges for future radiation hardening efforts
- Investigate new failure modes and effects
- Electrical characterization pre, during and post-rad

FY22-23 Plans:

- Deploy AI and Machine Learning test suite developed in FY20, making refinements as required
- Add new "flight project"-like AI test codes
- Update "Command Center" GUI

Collaboration:

- OGA, Industry, and NASA Center partners are asked to contribute "code" to the software repository in order to have access to it. [as permitted]
- "Code" can be their own published or CUI items since the repository is not public:
  - Science payload workflows (but not real data)
  - Flight-like applications, scripts, and source code
  - Instrumentation and monitoring frameworks

FY20-22 Hardware Roadmap

- Microprocessors
  - AMD Ryzen 3 1200, 2200G
  - Intel Core i7 6500U (Purism Librem)
  - Intel Core i7 10710U Comet Lake
- SOCs with GPUs
  - AMD Ryzen Low Power R1102G, v1202B, R1305G, R1606
  - NVIDIA Jetson TX2, TX2i, Nano
  - NVIDIA Xavier AGX, NX, JAXI, Orin
- Low Power SOCs
  - NXP i.MX 8 QuadMax, Pro
  - Edgeless EAI Series
  - Allwinner F1C200s
  - Samsung Exynos
  - Qualcomm Snapdragon
  - RISC-V
  - Raspberry Pis (*S. Guertin JPL)
- Neural Network Devices
  - Google Coral TPU (rev 1)
  - Intel VPU (Movidius/Nervana/Loihi)
  - RockChip Rk1808, Rk3399Pro
  - Nepes NM500
  - ARM Ethos-U55, U65 (NXP i.MX 8M Plus kit)
  - Sipeed Maix
  - Amlogic S905X3 (ODROID-C4 kit)
  - Gyrfalcon Lightspeeur AI
  - Xilinx Alveo
  - Texas Instruments Sitara AM57x
  - Kneron KL520, KL720
  - SimpleMachines
  - Many, many others
- Graphics Processing Units (discrete)
  - AMD Radeon e9173
  - NVIDIA GTX 1050

Red font devices were prepared for SEE testing during COVID in FY20 and FY21.
Green font indicates procurement in FY21.
Blue font indicates procurement in FY22.

Ongoing Evaluation Timelines

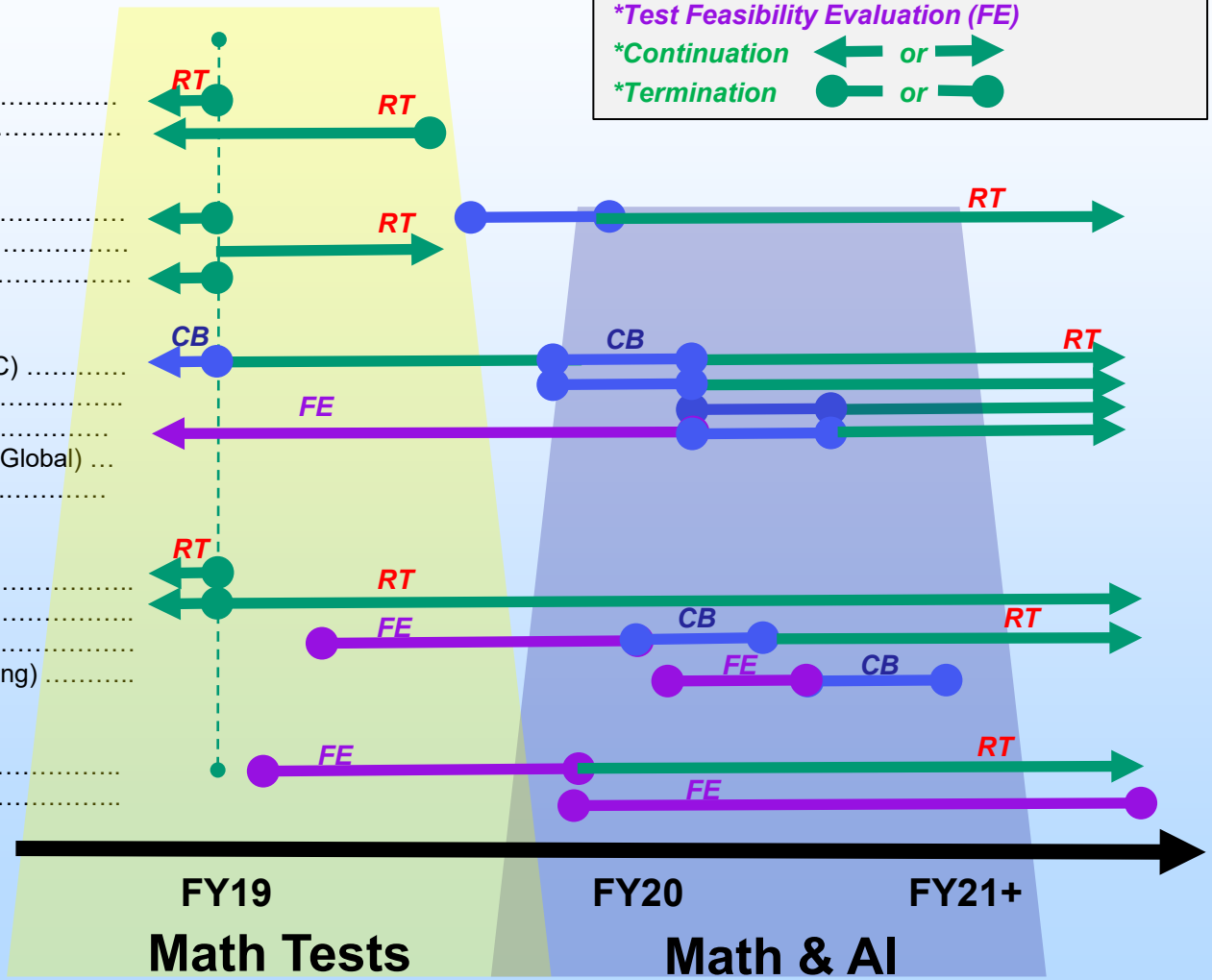
Microprocessors
- ≤14nm++ Intel (Intel) ……
- ≤10nm AMD (Global) ……

Microprocessors with embedded GPUs
- <14nm++ Intel (Intel) ……
- ≤ 10nm AMD (Global) ……
- 10nm Qualcomm (Samsung) ……

GPUs
- 14/16nm NVIDIA GTX 1050/1080 (TSMC) ……
- <7nm AMD (Global) ……
- 14nm Intel Discrete GPU (Intel) ……
- 14nm Low Power, AMD Radeon e917x (Global) …
- <7nm NVIDIA RTX (TSMC) ……

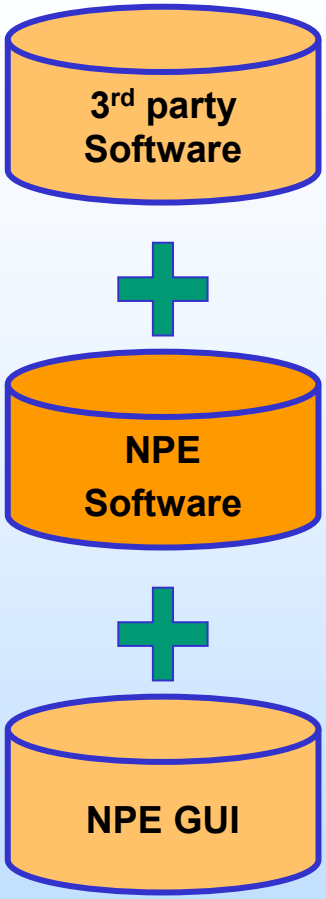
System on Chip
- 20nm NVIDIA Tegra X1 (TSMC) ……
- 16nm NVIDIA Tegra X2 (TSMC) ……
- 12nm NVIDIA Tegra Xavier (TSMC) ……
- ≤ 10nm Qualcomm Snapdragon (Samsung) ……

Neural Network Devices
- Google TPU, Intel Myriad ……
- Many, many others……



NPE Software Suite

- We utilize community-accepted Linux versions, open-source libraries, and vendor-specific development tools (as necessary)
- We try to coalesce the carrier board drivers, any required hardware initializers, and some system health prognostic tools
- Software stack from NPE is comprised of
  - 3x NVIDIA Memory Hierarchy tests (L1, L2, Registers)
  - 2x Mathematics tests (CUDA, OpenCL)
  - 1x Graphics buffer test (OpenGL)
  - 1x Linear Algebra test (LINPACK)
  - 8x Artificial Intelligence models and workflows
- The “Command Center GUI” overhaul will start Summer 2022
  - Present version coded in 2016 uses dotNet, VB, C#, and PuTTY
  - New version is being coded in Python for portability and documentation
  - Design requirements driving this framework:
    - One User-friendly portable application to control DUT operations
    - The short list is to enumerate hardware, retrieve information, collect telemetry, initiate the test sequences, and save this data package in a standard format, etc.



NPE Teams Channel

- Contains many wiki and files which cover:
  - Set up, wiring and programming instructions for various devices and single board computers
  - Troubleshooting
- We discuss SOTA device landscapes in the chat
  - New COTS devices and development kits
  - New architectures and technology demos
  - Press release announcements and solicitations
- Contact Ed Wyrwas to request access

NPE GitHub Repository

- NEPP and collaborators – authors credited
- Shared within NASA network
- So far > 80GB of content has been uploaded
  - CPU, GPU and AI Test Suites
  - Benchtop instrumentation
  - Build Guides
  - Distributable Reports
- The goal is to provide a singular source of standardized testing programs, scripts and applications for benchmarking GPUs, Microprocessors, SoC, and other devices capable of executing code

https://aetd-git.gsfc.nasa.gov/edward.j.wyrwas/nepp-processor-enclave

NPE Bi-Weekly Telecon

- **1st and 3rd Fridays** of each month at 11am Eastern
  - microprocessors, graphics processors, neuromorphic computing, Ai and ML devices, systems on chip, microcontrollers
  - test bench creation, automation and standardization,
  - Rapid prototyping, thermal cooling solutions, Additive Manufacturing (AM)
  - radiation testing and facilities discussions including collaborations and partnerships,
  - Failure Mode Effects Analysis (FMEA), Root Cause Analysis, Non-Destructive Evaluation (NDE) and Destructive Physical Analysis (DPA),
  - commercial technologies and COTS devices,
  - project-specific challenges and solutions,
  - feedback and discussions with representatives from across our community
- Processor Enclave telecon listserv as of June '22: 90
  - People from both industry and government
  - "An open forum where specifics can be taken offline in a sidebar after experts and problem solvers are identified through general discussion"
- Contact Ed Wyrwas if you would like to attend; our next meeting is Friday, July 1st

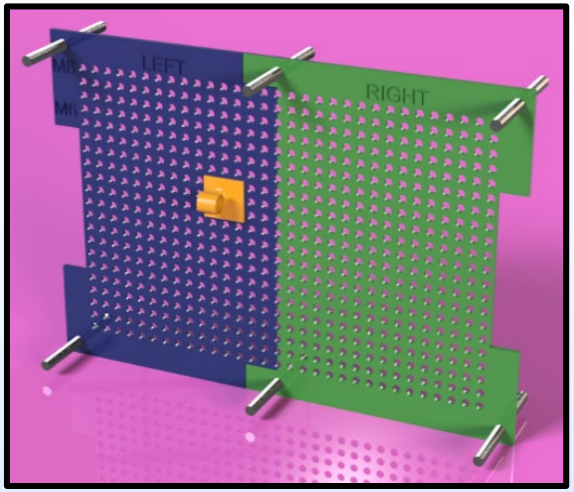
NPE Engagements

- Polaris projects with JSC - **2REDPANDAS** (Displays) and **JARVIS**/STARK (GPUs)
- GSFC **REAG -** Design and Fabrication
- **NASA** and **ASME Additive Manufacturing** (AM) Working Groups for non-metallic materials for extrusion
- **NASA Generative Design Team** (Autodesk Fusion 360 workflow support)
- **NPE Rapid Prototyping Lab** - Cooling Solutions for high power devices
- National Security Innovation Network (**NSIN**) Hacking 4 Defense (H4D) and Defense Innovation Accelerator (DIA)
- Office of Safety and Mission Assurance (**OSMA**) Physics of Failure handbook
- Aerospace Community data sharing activities: **S3VI**, **Aerospace** Corporation,
- Avionics Architecture Community of Practice (**AACoP**)
- **JPL** (Steve Guertin) is handling the ARM piece of the NPE
- **JourneyApps + RealWear** – software platform enabling standardized radiation test records

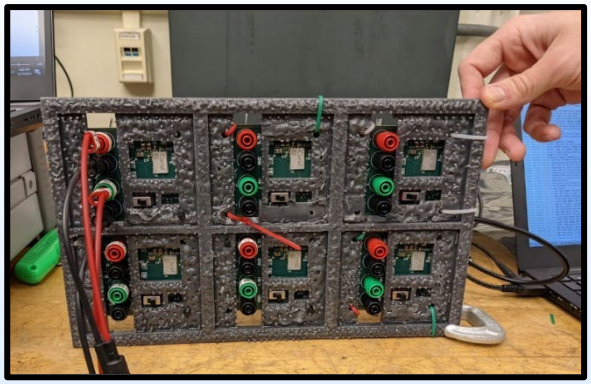
NPE Engagements

- **ARC** ISS Experiments – NVIDIA Device code, software routines and hardware
- **Cleopatra** –AI codebase porting to NVIDIA ARM SoC devices
- **CUVIS** – Google TPU test bench, procurement, DPA, sample prep, testing
- **JSC** xEMU – GPU hardware and test procedure support
- **AFRL**/Space Force – software repository deployment and testing feedback
- **SNL** – software repository support and test payload development
- **LLNL** – NVIDIA device support
- **LANL** Microprocessor Working Group – testing strategies, test post-mortems
- **JHU APL** – NVIDIA TX2i SEE Post-mortem support
- **Troxel Aerospace** – testing collaborations

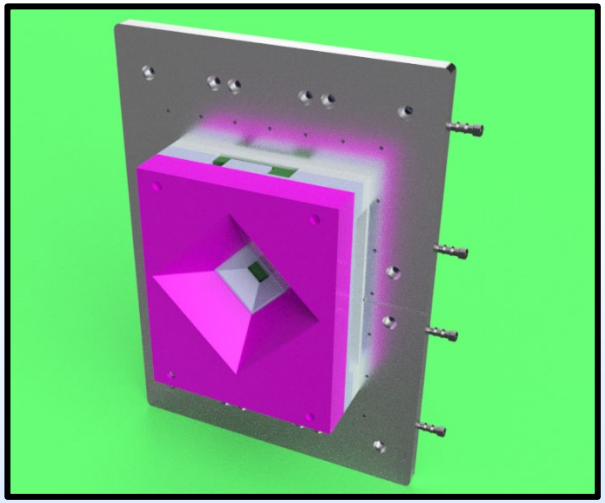
NPE Rapid Prototyping



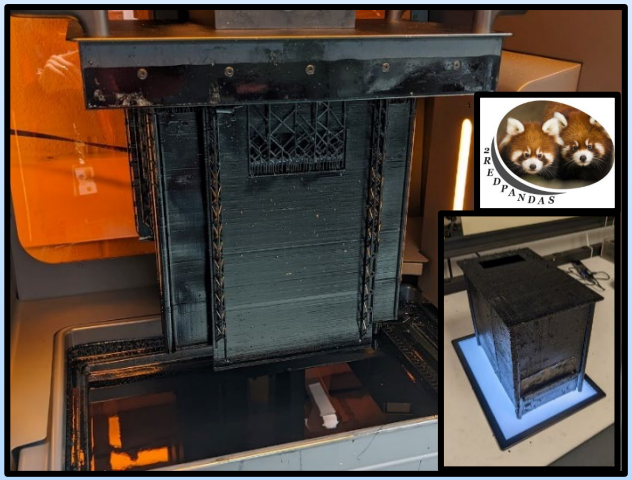
REF Dosimetry Fixture



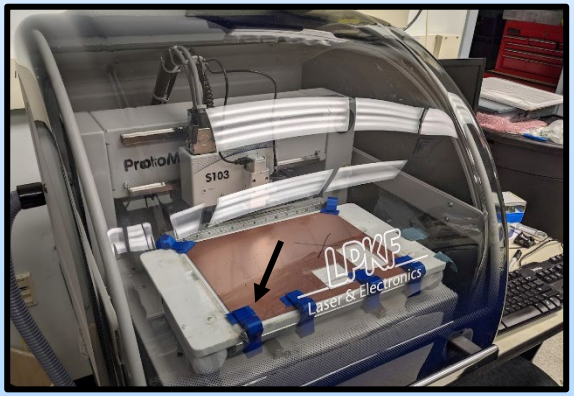
Google TPU Backplane



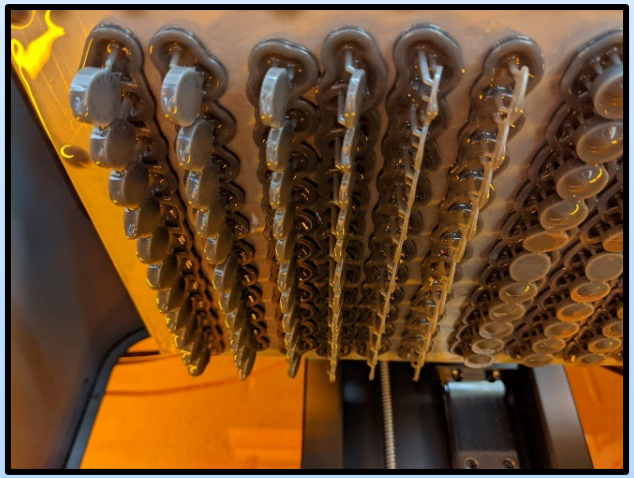
GPU Cold Plate Adapters



2REDPANDAS Photo Box



LPKF Mill Clamps



Connector Alignment Jig

NPE Workflow Publications

- **Radiation Effects and Analysis Lessons: a Scientist's Field Instruction to Explain Radiation Testing (REAL SciFI ExpRT 2022)**
  - Rad101 Presentation at NEPP ETW 2022 on Thursday, June 16th

- **Test Reports in progress with NASA Colleagues:**
  - Google Coral TPU Accelerator – TID, Heavy Ions, Protons
  - Intel Myriad X VPU NCS2 – TID, Heavy Ions, Protons
  - AMD Ryzen 1202B Microprocessor – Protons

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