



Radiation Tolerant Neuromorphic Computing Platform for Mission Critical Systems

APPLICATION NOTE
October 14th, 2025



Platform Goals

Our objective is to deliver a radiation-tolerant neuromorphic compute stack that sustains deterministic, low-latency spiking inference under high-radiation environments (LEO/HEO spacecraft, defense drones, autonomous satellites). The T1C Radiation-Tolerant Neuromorphic Platform (RT-NCP) integrates spiking-neural-network (SNN) cores on radiation-tolerant FPGA/ASIC silicon, EDAC-protected memories, and self-healing firmware layers for fault-containment and secure autonomy.

Use Case

We prototype using synthetic SEU/SEL-fault-injected telemetry from satellite attitude sensors (gyro, star tracker, sun sensor). 1 kHz vectors are encoded into spike trains (Poisson or ISI) and processed by a 256-neuron LIF network running on a rad-tolerant FPGA. Outputs include corrected attitude qualifications, fault flags, and watchdog telemetry. We didn't use a public benchmark; we generated our own test logs while blasting hardware with simulated radiation and injecting faults. Each run produces time-stamped records that capture what the system experienced and how it responded. The key signals are: EDAC counters (how many single/double-bit memory errors were detected/corrected), scrub cycles (how often the FPGA/flash configuration was re-read and repaired), and error/event timestamps (exact times of SEUs, SEL trips, watchdog resets, partial reconfigures, and recoveries). Together, these signals form a synthetic radiation fault dataset, meaning the fault rates and distributions are derived from AE9/AP9/SPM and CREME96 radiation models combined with controlled fault-injection, rather than real flight telemetry.

A typical log row looks like:

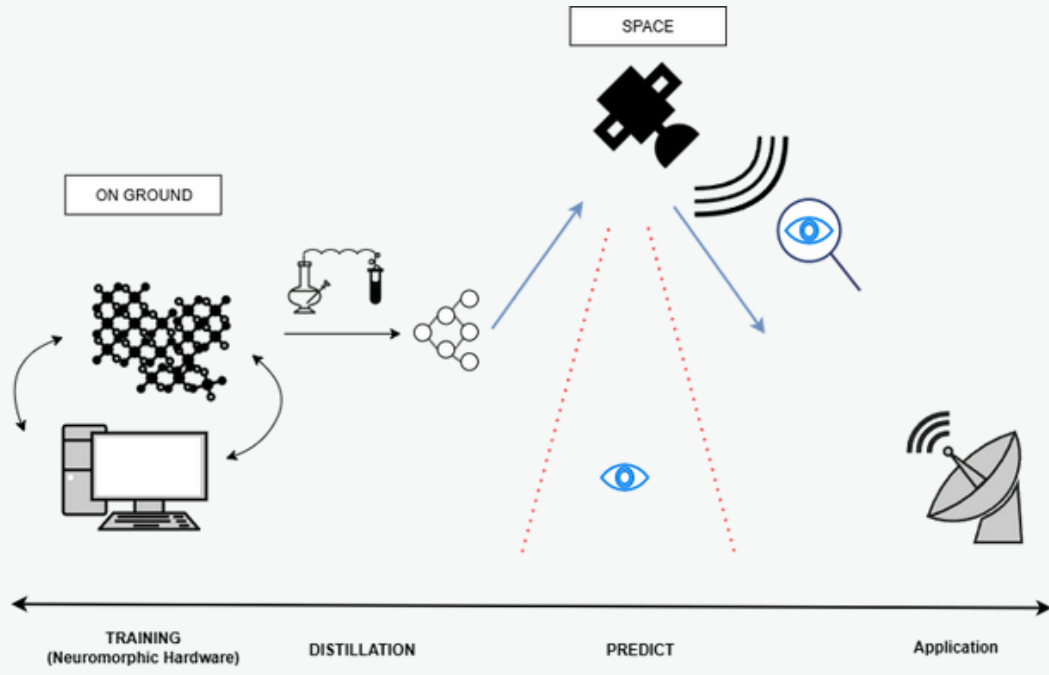
`t=372.418 s, hw=FPGA, flux=proton_25MeV, EDAC_single=3, EDAC_double=0, scrub=True, event=SEU, component=BRAM [12], action=corrected, reset=False`

From these rows we compute things like time between failure events (for MTBF), correlate fault bursts vs. scrub rate, and compare platforms.

Architecture

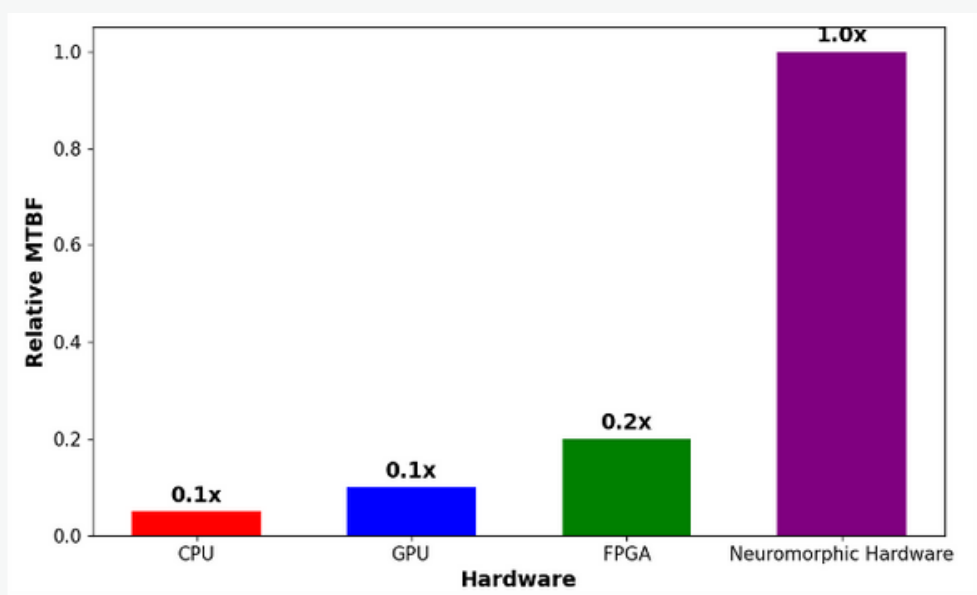
The Radiation-Tolerant Neuromorphic Platform is built around a modular neuromorphic tile that tightly integrates several hardened subsystems. At its core, the compute engine consists of a spiking neural network array implemented on a radiation-tolerant FPGA such as the RTG4 or XQRKU060, with a future migration path to a 28 nm ASIC. This core features triple-modular-redundant (TMR) neuron fabrics, an on-tile configuration scrubber, and a spike router protected by error-detection and correction (EDAC) buffers to maintain deterministic performance under single-event effects. A radiation-hardened supervisor, SoC, typically the GR740 or SAMRH71 oversees configuration scrubbing, watchdog orchestration, and secure-boot enforcement. The memory subsystem combines MRAM and ECC-protected DDR3 implementing single-error correction, double-error detection (SEC-DED), with periodic checkpointing of synaptic states to ensure data persistence during transient faults.

Power delivery relies on radiation-hardened point-of-load regulators with fast latch-up detection and current-foldback recovery for electrical protection. External interfaces include SpaceWire links for spacecraft data buses, CAN-FD for control networks, and an LVDS camera bridge for event-based sensor integration. During deployment, the SNN graph and routing tables are compiled into a T1C-compatible binary that optimizes placement to minimize inter-cluster traffic. The platform’s layered fault-tolerance combines TMR on control finite-state machines, continuous configuration scrubbing, watchdog-driven partial reconfiguration, and adaptive error-masking algorithms. Continuous telemetry provides scrubbing rates, EDAC statistics, and neuron-level firing histograms, enabling real-time health monitoring and mission assurance.



Technical Performance

The thresholds and tolerances of neuromorphic components to radiation vary depending on the component type and design. Radiation-hard devices can tolerate 100K to 1 MRad of total ionizing dose (TID), while radiation-tolerant devices can tolerate at least 30 KRad of TID. Commercial devices generally tolerate between 15 –50 KRad of TID. Our results compare various hardware systems, including CPUs, GPUs, FPGAs, and neuromorphic cores, to illustrate normalized MTBF performance under simulated radiation. The analysis presents the normalized MTBF values under simulated radiation conditions, using Neuromorphic Hardware as the reference for normalization due to its cutting-edge resistance to radiation-induced failures.



Each platform was exercised under simulated radiation profiles derived from the AE9/AP9/SPM trapped-belt model and the CREME96 solar-particle spectrum; during 10-hour accelerated runs we injected single-event upsets (SEUs) and single-event latch-ups (SELs) and logged recoveries or failures. MTBF was computed within (Total Operational Time/Number of Failure Events) and then normalized to the neuromorphic hardware baseline (1.0×). Observationally, CPUs and GPUs showed frequent SEUs and timing faults (~0.1× MTBF), FPGAs improved with partial reconfiguration and ECC (~0.2×), **while the T1C neuromorphic prototype hardened with TMR, scrubbing, and adaptive error masking achieved an order-of-magnitude longer average run time between recoverable faults.**

Roadmap

We will ship an MVP in 0–3 months: a single neuromorphic compute tile integrated with our SDA event camera, proving sub-10 ms end-to-end latency, fault-injection resilience, and basic telemetry dashboards. In 3–6 months, we scale to a multi-sensor, multi-tile configuration, release a developer SDK, and complete initial beamline screening (SEU/SEL) with automated scrubbing and watchdog recovery. By 6–9 months, we tape-out the radiation-tolerant ASIC from the FPGA prototype, build ruggedized camera-compute flight units, and enter environmental qualification (TID, TVAC, vibe). In 9–18 months, we conduct early flight demos (CubeSat/UAV), stand up design-partner deployments, and establish a production supply chain with secure OTA updates for on-orbit model refresh.

Note: This dataset is internal, generated for controlled benchmarking of reliability under radiation stress, and is not intended as a public benchmark.



hello@type1compute.com



503.810.8092



www.type1compute.com

