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EMBEDDING INNOVATIONS

Whitepaper

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Redundant Edge Computing & Vision AI Integration

This demonstration presents a distributed control system architecture integrating Cloud-native orchestration with Safety-critical embedded systems. Using the PikeOS Edge platform, the setup shows how containerized AI applications and deterministic workloads can safely coexist across multiple Edge nodes, managed through modern Cloud orchestration workflows closer to the Edge, within a unified, secure environment suitable for next-generation Railway Cloud systems.

System Breakdown (Railway Context)

A marble run serves as a physical stand-in for Railway switch actuation, making the Safety-critical Railway control flow visible. The system showcases how modern Cloud-native technologies can be applied to strictly regulated Railway infrastructure.

Central Management: Raspberry Pi
- A Raspberry Pi acts as the Kubernetes control plane, representing a decentralized "Digital Interlocking" hub
- It enables modern DevOps workflows for Safety-critical Railway systems, allowing safe updates and lifecycle management and scalability of control software across Railway tracks

Deterministic Edge Computing Nodes
- PikeOS is running on two AMD/Xilinx UltraScale+ boards
- The two AMD Xilinx UltraScale+ boards serve as redundant Edge compute nodes, analog to object controllers in Railway systems

- PikeOS ensures strict partitioning, isolating the Vision AI (marble/train detection) from the Safety-critical control logic
- ELinOS runs the Vision AI application within a secure partition, committing the detected marble colour to the safety-critical control logic as input.
- Vision AI application is deployed and managed as a Kubernetes workload and it offloads AI inference to the FPGA via AMD Vitis AI for acceleration

Fail-Safe Execution (Voter & Actuators)
- ELinOS is running on the second Raspberry Pi
- A second Raspberry Pi acts as the voter node, demonstrating a voting pattern as used in SIL-rated Railway systems
- It validates command streams from two distinct PikeOS Kubernetes nodes, each running on an AMD/Xilinx UltraScale+ board, to prevent incorrect switch movements caused by hardware faults
- Validated commands are sent to the actuators (representing the physical Railway point machines)

Core Value Proposition

- **Workload Consolidation:** Runs AI, Linux, and real-time applications together on a single SoC
- **Strict Isolation:** Secure partitioning prevents interference between Safety-critical and non-critical tasks
- **Reliable by Design:** Software redundancy across Edge nodes ensures high availability for mission-critical use
- **Edge Intelligence:** Enables safe deployment and orchestration of containerized AI at the Edge

- **Certified Safety:** Built to meet SIL 4 (and other) functional Safety standards
- **Cloud-Native Flexibility:** Combines modern scalability with the strict requirements of Railway systems

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