FOR EVALUATION DOC TORUS-BRIEF-001 REV 2026-07 PacketFive

TORUS • UNATTENDED FACILITY SENSING PLATFORM

# Detection begins at the perimeter.

FOR EVALUATION

TORUS-BRIEF-001

A passive sensing platform for AI/HPC data center facilities: ground, visual, and drone/UAS domains, fused into one validated facility picture.

TORUS is an Unattended Facility Sensing platform for AI/HPC data centers. It protects campus perimeters, data halls, and utility yards by sensing across ground, visual, and drone/UAS domains, classifying security events at the edge with on-device AI, and driving facility response actuation under safety interlock where remote power or network access is limited. PacketFive Design Services can adapt TORUS for other customer requirements.

| Zero-miss | Layered | Passive | Cued response | AI-enabled |
|---|---|---|---|---|
| alarm pipeline | ground / visual / drone | low-signature sensing | transducer interlock | edge to operations |

## 1 Operational need - the perimeter is the problem

AI/HPC data center facilities need continuous awareness across campus perimeters, service yards, data hall approaches, substations, and cooling plant areas. These zones often have constrained power, network, and staffing. Fixed cameras see a cone; guard rounds see a moment; fences report only contact.

TORUS monitors those approaches continuously and passively. It detects intrusion in more than one physical domain, correlates the cues, and gives operators a validated track with location and confidence, not a raw alarm.

| | |
|---|---|
| **Design goal** | No event is missed. Every security event is captured, sequenced, and delivered. Coverage gaps are detected, not discovered after the fact. |
| **Posture** | Passive & low-signature sensing emits nothing to find. The only active element is a response node, and it actuates only through an interlock. |
| **Autonomy** | Facility-ready unattended operation covers battery and solar operation, long-range radio, and months between visits. |
| **Assurance** | Auditable by design. Every detection and every command is timestamped and logged for post-incident review. |

## 2 Layered detection - three sensing domains, one picture

TORUS covers campus perimeter and facility approaches from below, at eye level, and overhead. Each domain matures on its own track, so the ground layer deploys today and the system extends without replacing installed assets.

| Domain | Status | Detail |
|---|---|---|
| Ground | FIELDED | Seismic and acoustic detection on unattended battery nodes reporting over long-range radio. Pre-production hardware complete. (TORUS-SN) |
| Visual | IN DEVELOPMENT | Long-range thermal cores and LiDAR on a mast, cued by ground detections to identify and track at standoff, day or night. (Thermal LWIR + LiDAR + long-range optics) |
| Drone/UAS | R&D | Radar-class RF detection of drones and UAS over the facility. An active research track: long-range drone detection demands higher transmit power and dedicated RF front ends. |

## 3 Sensor node variants - one protocol, four node classes

A deployment mixes node classes to match cost, alarm profile, and facility constraints. All classes report on the same event contract, so the CCISRT layer treats a mixed facility field as one sensor network.

| # | Class | Link / RF | Mat. | Role & trade-off |
|---|---|---|---|---|
| 1 | Fixed Wireless | LoRa 433 MHz | FIELDED | Lowest cost per node; the default perimeter element for wide, dense rings. |
| 2 | Programmable Wireless | SDR (AD9371/AD9363) + LoRa failsafe | R&D | Software-defined RF for experimental, R&D, and high-assurance facility segments; where LoRa alone suffices, class 1 is the cheaper choice. |
| 3 | Wired Optical | Optical fibre | R&D | Emanation-quiet, tamper-resistant wired transport for the highest-assurance segments. |

| # | Class | Link / RF | Mat. | Role & trade-off |
|---|---|---|---|---|
| 4 | Transducer | per host node | CONCEPT | Response node. On a validated cue it actuates a facility response through a mandatory safety interlock (activate, safety-validate, then trigger). |

*See the TORUS-SN Node Variants datasheet (TORUS-SNV-DS-001) for the full comparison.*

## 4 Ground sensing payload - what is on the node

Every sensing channel on the TORUS-SN ground node is a named, datasheet-backed component selected for low standby power and facility serviceability.

| Channel | Detail | Parts |
|---|---|---|
| Seismic | 4.5 Hz vertical geophone into a low-noise front end with 128-step digital gain and a hardware wake comparator that trips with the processor asleep. Signatures include footfall, vehicles, and digging. | R.T. Clark, OPA2134, MCP4017, LM393 |
| Acoustic | Two 24-bit I2S microphones give a stereo field for on-device classification. Audio is classified at the node; raw audio never leaves it. | 2× INMP441 |
| Radio & position | LoRa 433 MHz uplink, GNSS scanning, and passive Wi-Fi-scan positioning from one device. A relocated node reports its own new position. | LR1110, 32 MHz TCXO |
| Compute & autonomy | Dual-core edge MCU with on-device ML, temperature-compensated timekeeping, single-cell Li-ion with USB-C charging, and three independently gated sensing rails. | ESP32-S3, DS3231, TP4056, 3× TPS22918 |

## 5 Security-event processing - zero-miss, priority-preemptive

The runtime guarantee is a reliability property, not a slogan. Every event is captured, ordered, and delivered, and the highest-priority event is never queued behind noise.

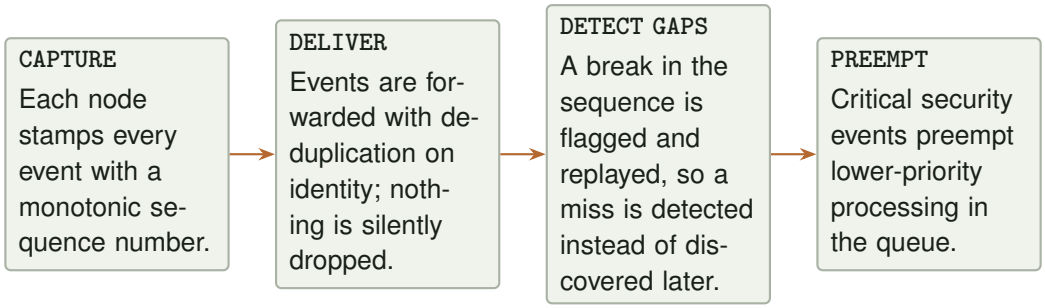


Figure 1: The zero-miss security-event pipeline.

**On complexity, stated correctly**

The runtime is a hard-real-time, zero-miss pipeline. The genuinely NP-hard problem in TORUS is optimal sensor placement for complete coverage (a set-cover / art-gallery problem). That is why the deployment is rehearsed in simulation first: the coverage problem is approximated off-line, then zero-miss processing is guaranteed on-line.

## 6 Deployment and coverage - a ring around data center assets

A representative data center deployment uses ground nodes on the campus perimeter, visual masts for service-yard and data-hall approaches, an experimental drone/UAS layer over the facility, and a gateway linked to facility operations.

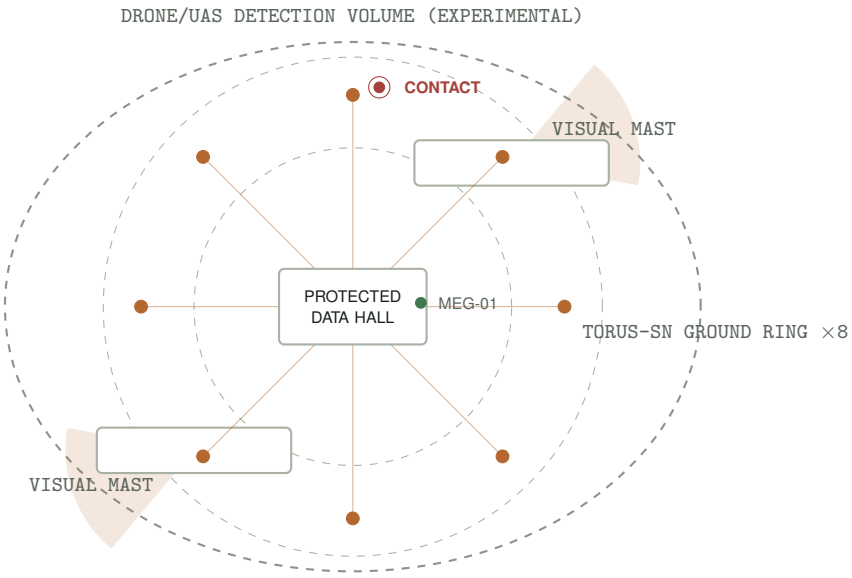


Figure 2: Representative TORUS data center deployment: ground ring, visual masts, drone/UAS volume, and gateway.

## 7 Deployment rehearsal - rehearse the facility before rollout

AI/HPC campuses are expensive to survey twice. A deployment is rehearsed as a cyber-physical twin in NVIDIA Isaac Sim with terrain reconstructed from mapping data, the full system placed virtually, and unauthorized-entry scenarios run against it. The figure below is real output from the open-source planner.

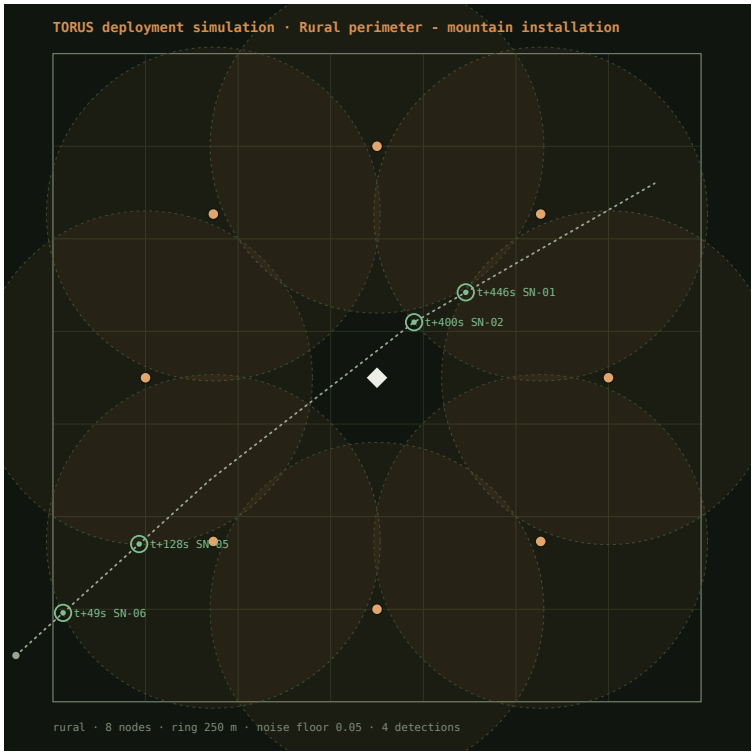


Figure 3: Real output from `torus-isaac-sim`: sample perimeter, 8 nodes, ring 250 m, first contact t+49 s at node SN-06, 4 nodes triggered along the track.

**Data center campus deployments**

In data center campus deployments the twin helps twice. The local noise floor is simulated first, so seismic thresholds and acoustic classifiers arrive on site pre-tuned against cooling plant, generator, and traffic background instead of by trial and error.

## 8 System architecture - facility sensor network, gateway, operations

| Layer | Element | Role |
|---|---|---|
| Edge | TORUS-SN nodes | Mixed node classes sense passively and classify at the edge, reporting compact events over LoRa, SDR, or optical. *AI at the edge.* |

| Layer | Element | Role |
|---|---|---|
| Aggregation | TORUS-MEG gateway | Receives the facility field, fuses and timestamps events on a Jetson-class edge computer, and forwards over flexible backhaul. Cluster-aware gateways chain and federate across distances for high availability. |
| Facility operations | TORUS-CCISRT | The operator layer provides one live common operating picture for the room and facility teams, with facility response actuation under transducer safety interlock. *AI at facility operations.* |

## 9 CCISRT layer - one picture, two vantage points

Command, Control, Infrastructure, Security, Response, and Tier. The operations room and facility team share a single fused picture; each sees it in the form the job needs, and response nodes actuate only through the interlock.

### Operations room

Map wall with live node, gateway, and mast state; fused, prioritised alerts; triage and escalation; thermal/video cued from the masts; timeline replay; deployment planning with the Isaac rehearsal link; northbound REST API and webhooks for PSIM, DCIM, BMS, VMS, SIEM, Redfish, BACnet, ONVIF, and MQTT adapters.

*See `TORUS-CCISRT-DS-001` and `TORUS-AI-001` for detail.*

### Facility team

Handheld map with own position and the node ring; prioritised alerts with bearing and distance; cue a sensor or mast; confirm or reclassify on site; offline-tolerant sync over the gateway.

## 10 Assurance - built to be trusted with the response

| Property | Detail |
|---|---|
| Interlock | No trigger without validation. A transducer walks arm, safety-validate, then trigger. The trigger is refused until validation passes. |
| Audit | Every command logged. Who armed, validated, or triggered what, and when, is recorded for post-incident review. |
| Deployment | On-prem / private cloud. The CCISRT layer runs on-premises or private cloud, with an offline option for controlled data center environments aligned to TIA-942 and OCP operational expectations. |

# 11 Documentation and source

| Type | Title | Reference |
|---|---|---|
| Datasheet | TORUS-SN node | TORUS-SN-DS-001: ground sensing node, in detail |
| Datasheet | Node variants | TORUS-SNV-DS-001: the four node classes and their trade-offs |
| Datasheet | TORUS-MEG gateway | TORUS-MEG-DS-001: aggregation, fusion, backhaul |
| Datasheet | TORUS-CCISRT | TORUS-CCISRT-DS-001: the CCISRT layer |
| Brochure | AI/ML Engine | TORUS-AI-001: intelligence at the edge, gateway, and facility operations |
| Document | Programme status | TORUS-PROG-001: what is built, and the roadmap |
| Repository | TORUS platform | https://github.com/PacketFive/TORUS: open-source hardware, firmware, design data |
| Repository | TORUS Isaac Sim | https://github.com/PacketFive/torus-isaac-sim: deployment rehearsal |

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