HCAS Technical Whitepaper

Human Collision Avoidance System

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Prepared for investor, grant, and pilot partner discussions. This document reflects the current HCAS prototype status and the product direction developed from the supplied HCAS technical, market, and safety-positioning materials.

Executive Summary

HCAS - Human Collision Avoidance System - is a personal active-safety platform that translates vehicle-grade collision-avoidance thinking to humans, micromobility riders, and other vulnerable road users. The system combines edge AI perception, depth sensing, IMU motion detection, GPS-tagged logging, smartphone visualization, and analytics dashboards to identify hazardous situations before they become injuries or claims.

The current prototype is an end-to-end integrated demonstrator. Jetson Nano performs RealSense depth processing and object recognition; ESP32-S3 manages IMU sensing, UART communication, Wi-Fi telemetry and event aggregation; the Expo mobile app adds GPS and exports CSV logs; the Analysion dashboard converts ride logs into safety scores, event timelines, GPS risk maps, and insurance-oriented rider profiles.

1. Problem and Opportunity

Vehicles increasingly use active safety systems such as object detection, blind-spot warnings, and advanced driver assistance. Humans, cyclists, e-bike users, scooter riders, older adults, and workers in dynamic environments typically do not have an equivalent personal safety layer. HCAS addresses that gap by treating the human as a dynamic mobility platform that can sense risk locally and generate objective risk telemetry.

- Micromobility users operate with limited physical protection in mixed traffic and shared-use environments.
- Healthcare and aging-in-place settings need proactive safety tools, not only post-fall detection.
- Insurers and fleet operators need objective near-miss and behavior data, not only claims after injury.
- Workplace environments need low-cognitive-load hazard feedback that can operate in noisy or visually complex conditions.

2. Product Positioning

The strongest positioning is not simply “AI object detection.” HCAS is better positioned as a Personal Active Safety Layer and a Vulnerable Road User Active Safety System. This framing aligns with road-safety, insurance, aging-in-place, and industrial safety language while keeping the system clearly advisory rather than autonomous.

Positioning angle	Meaning for HCAS	Primary audience
Human Collision Avoidance System	Direct, technical description of the product mission.	Investors, engineering partners, grants
Personal Active Safety Layer	Consumer-friendly framing: safety support before injury.	Care, consumer, mobility partners
VRU Active Safety System	Regulatory and road-safety framing for vulnerable road users.	Transport, municipalities, insurers
Hardware-assisted analytics platform	Commercial framing around sensor data and risk reports.	Insurers, fleets, enterprise partners

3. System Architecture

HCAS uses a distributed embedded architecture. Each node has a clear responsibility and the system avoids relying on cloud connectivity for critical active-safety functions.

Subsystem	Current role	Status
Jetson Nano + RealSense	Depth perception, object recognition, TTC/risk estimation, UART JSON event output.	Operational; object recognition verified after reboot.
ESP32-S3 + IMU	Motion event detection, sensor fusion hub, UART ingestion, Wi-Fi API, event history.	Operational.
Expo mobile app	Live telemetry UI, GPS posting, session logging, fixed CSV export.	Operational.
Analysion dashboard	CSV upload, severity timeline, GPS map, risk matrix, insurance safety grade.	Operational.
Enclosure / mounting	Integrated physical prototype for e-bike installation.	Designed; next step is field assembly and ride data collection.

Current pipeline: RealSense camera -> Jetson AI/depth processing -> UART JSON -> ESP32-S3 IMU/event hub -> Wi-Fi telemetry -> smartphone app -> CSV export -> website analytics dashboard.

4. Detection and Risk Logic

HCAS combines four categories of evidence: object recognition, depth/range, relative motion, and user motion. The current implementation supports COCO object categories such as person, bicycle, car, motorcycle, bus and truck, then maps safety-relevant objects into HCAS event logic.

- Object recognition identifies relevant safety context such as person, bike, car, truck, bus, motorcycle and obstacles.
- Depth processing estimates distance to objects and supports priority tracking.
- TTC and closing-speed logic convert raw distance changes into risk estimates.
- IMU telemetry detects impact, tilt, instability, hard braking and movement state.
- Events are serialized into a fixed CSV-aligned schema for mobile logging and analytics.

Event class	Example trigger	Current output
Collision risk	Close object with high severity or closing distance.	hazard_type=collision; severity 80-100
Near miss	Object within caution distance or moderate risk score.	hazard_type=near_miss; severity 40-79
Instability / fall risk	Tilt, IMU spike, abnormal motion.	hazard_type=instability/fall; IMU evidence fields
Blind spot / peripheral risk	Future side/rear threat logic.	roadmap item

5. Actuation and Human Factors

The HCAS actuation strategy should remain haptic-first. Haptic feedback is less dependent on visual attention and can work in noisy environments. Visual and audio channels are secondary and should support, not distract from, physical awareness.

Alert level	User experience	Example actuation
Level 1	Subtle awareness cue.	Short vibration pulse / low-severity UI event.
Level 2	Caution warning.	Directional vibration + visual indicator.
Level 3	Urgent hazard.	Strong vibration + audio + red UI warning.
Level 4	Emergency event.	Continuous alert + phone notification / emergency workflow.

Important design principle: HCAS is an advisory safety layer, not an autonomous system. It must reduce cognitive load, communicate limitations clearly, and avoid alert fatigue through adaptive thresholds and validation testing.

6. Data and Analytics Layer

The current CSV schema is strategically important because it transforms the embedded prototype into a repeatable analytics platform. Each ride session can produce a structured record that supports replay, dashboarding, insurer review, and future machine-learning refinement.

Fixed CSV fields include: session_id, event_id, phone_timestamp_iso, gps_lat, gps_lon, hazard_type, severity, object_class, confidence, distance_m, relative_speed_mps, bbox_center_x, bbox_center_y, jetson_time_ms, esp32_time_ms, source, and IMU fields.

- Dashboard outputs: KPI cards, severity timeline, hazard distribution, object frequency, distance chart, GPS map, risk matrix, behavior radar chart and insurance report narrative.
- Insurance value: timestamped and geotagged objective evidence around near misses, motion events, object context, distance and severity.
- Product value: ride history, rider coaching, route-risk mapping, fleet analytics, safety score trend and pilot-program reporting.

7. Market Strategy

HCAS should initially be sold through B2B and pilot partnerships, not only direct-to-consumer retail. The primary commercial wedge is proactive risk prevention backed by objective sensor evidence.

Segment	Why it cares	Pilot message
Micromobility fleets	Rider incidents, near misses, delivery risk, route safety.	A safety analytics layer for e-bike and scooter fleets.
Insurers / benefits providers	Falls, injuries, disability claims and mobility-related costs.	Move from reactive claims to proactive risk prevention.
Senior living / aging in place	Falls, collisions, mobility confidence and caregiver reassurance.	Before the fall. Before the collision.

Low vision / assistive mobility	Dynamic hazards may not be detected by cane or guide dog.	Directional haptic environmental awareness.
Industrial / workplace safety	Workers face vehicle, equipment and situational-awareness risks.	Reducing near-miss and collision risk in dynamic workplaces.

8. Competitive Differentiation

HCAS is differentiated by the combination of local perception, user motion context, and analytics. Many products are either camera-only, fall-only, or app-only. HCAS is a sensor-to-dashboard system.

Dimension	HCAS advantage
Perception	Depth-aware object recognition, not simple 2D object detection.
Motion context	IMU validates rider state, fall/tilt/impact and hard-brake events.
Safety architecture	Critical processing runs locally; cloud is for logging and analytics.
Commercial layer	Fixed schema supports insurance dashboards and pilot evidence.
Scalability	Same architecture can extend from e-bike prototype to fleet, wearable or workplace module.

9. Validation Roadmap

The next milestone is evidence collection. HCAS should stop feature expansion temporarily and focus on proving repeatable performance in controlled tests and e-bike field sessions.

Phase	Objective	Evidence output
Bench verification	Confirm camera, IMU, app, GPS and dashboard under repeatable scenarios.	Logs showing object labels, distances, severity and IMU events.
Controlled test	Person/car/bike approach, braking, tilt, near-miss and low-speed ride testing.	CSV datasets and dashboard screenshots.
E-bike field data	Collect multiple real ride sessions across routes and conditions.	Rider safety score history and event rates.
Pilot readiness	20-50 user or small fleet study with partner.	Pilot report, claims-prevention narrative and validation metrics.

10. Grant and Partnership Roadmap

HCAS is a strong fit for non-dilutive funding because it combines embedded AI, active safety, aging-in-place relevance, micromobility safety and applied R&D. The best near-term path is to package HCAS as a pilot-ready prototype with a clear validation plan and partner target.

Program / channel	Fit for HCAS	Recommended approach
NRC IRAP	Canadian SME R&D, productization and market-ready innovation.	Contact IRAP ITA after creating technical plan and budget.
NRC Aging in Place Challenge	AgeTech and safe aging-in-community use cases.	Pursue through living lab / care partner collaboration.

CABHI	Aging, brain health, older adults and caregiver innovation adoption.	Use senior living/home-care pilot story.
Mitacs Accelerate	University-supported applied R&D internships.	Pair with professor/student for validation, sensor fusion or data analysis.
OCI / Ontario programs	Ontario commercialization, digital health and critical technologies.	Monitor open calls and use HCAS as AI-enabled health/mobility technology.
Transport Canada ERSTPP	Road safety, ADAS, vulnerable road users and connected safety tools.	Future call or partner with municipality/road-safety organization.

11. Immediate 90-Day Action Plan

Timeline	Action	Outcome
Weeks 1-2	Finalize investor deck, executive summary, grant brief and demo narrative.	Outreach-ready package.
Weeks 3-4	Assemble e-bike prototype and run controlled tests.	First validated CSV datasets.
Weeks 5-8	Record ride data, dashboard screenshots and demo video.	Evidence package for investors/grants.
Weeks 9-12	Contact IRAP, Mitacs partner, aging-in-place/care partner and insurer contacts.	Pilot conversations and non-dilutive funding path.

References and Source Base

- HCAS Overall Update / System Business Plan and Development Phases.
- HCAS Professional System Overview and Actuation Whitepaper.
- Healthcare Applications and Market Strategy for HCAS.
- Personal Active Safety: The Human Collision Avoidance System Framework.
- Merchan-Cruz et al., Smart Safety Helmets with Integrated Vision Systems for Industrial Infrastructure Inspection, Sensors 2025.
- NRC IRAP support and financial support pages.
- NRC Aging in Place Challenge Program pages.
- CABHI program pages and Discover + Adopt program.
- Mitacs Accelerate program page.
- Ontario Centre of Innovation program pages.
- Transport Canada Enhanced Road Safety Transfer Payment Program pages.