Hazard & Constraint Taxonomy

Shared Path Safety for Drone–Human Reasoning

This taxonomy defines how the agent classifies **hazards and physical constraints** in egocentric video, and how those signals are combined to determine whether a **locally observed path** is:

- Safe for both drone and human
- Safe for the drone but unsafe for a human
- Unsafe for both

The taxonomy is intentionally **coarse, interpretable, and finishable by Feb 26**.
It avoids control, medical inference, planning, or speculative semantics, and focuses strictly on **physical traversability and shared safety reasoning**.

> **Exit awareness does not introduce new hazard classes.**
> Exits are treated as **directional intent**, evaluated *only after* path safety classification.

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1. Hazard Categories (What exists in the scene)

Hazards are scene elements detected or inferred from egocentric video using **Cosmos Reason 2**.
Each hazard is evaluated **independently**, before being filtered through agent-specific constraints.

H1. Structural Obstacles

Physical objects that block or constrain motion.

Examples

- Walls, columns, beams
- Collapsed structures
- Fences, railings
- Low ceilings or overhangs

Key property: spatial obstruction

H2. Terrain & Surface Conditions

Ground or surface properties relevant to **human traversal**.

Examples

- Uneven rubble
- Slopes or stairs
- Loose gravel
- Mud, ice, water-covered ground

Key property: stability and foot support

H3. Gaps & Vertical Discontinuities

Absence of continuous support.

Examples

- Holes in floors
- Drop-offs
- Trenches
- Broken staircases

Key property: continuity of support

H4. Narrow Passages & Clearances

Constrained spaces affecting body or payload clearance.

Examples

- Tight corridors
- Partially blocked doorways
- Debris-restricted paths

Key property: minimum clearance vs agent body envelope

H5. Environmental Hazards

Non-solid hazards affecting physical safety.

Examples

- Smoke or dust clouds
- Debris fall zones
- Chemical or gas plumes *(treated strictly as spatial exclusion zones)*

Key property: exposure risk
(No health diagnosis or physiological inference)

H6. Dynamic or Uncertain Hazards

Hazards with temporal instability.

Examples

- Moving debris
- Swinging cables
- Collapsing structures
- Crowds or moving humans

Key property: unpredictability

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2. Agent-Specific Physical Constraints (Who can traverse)

Each detected hazard is evaluated differently for the drone and the human based on **physically grounded traversal constraints**.

Drone Constraints (Aerial Agent)

- Can fly over gaps and discontinuities
- Can tolerate uneven ground below
- Requires clearance for propellers
- Sensitive to narrow lateral spacing
- Limited by visibility and obstacle proximity

Human Constraints (Ground Agent)

- Requires continuous ground support
- Sensitive to uneven or unstable terrain
- Limited by body width and balance

- Cannot traverse gaps or vertical drops
- Sensitive to cluttered, debris-filled paths

These constraints are encoded in:

`risk/human_vs_drone_constraints.py`

and enforced via the **Physical Plausibility Filter**.

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3. Constraint–Hazard Interaction Matrix (Core distinction)

This matrix is the **heart of shared-path reasoning** and makes the project immediately legible to judges.

Hazard Type	Drone Traversal	Human Traversal
Open gap / hole	✅ Fly over	❌ Unsafe
Uneven terrain	✅ Safe	⚠️ Risk
Narrow passage	⚠️ Possible	❌ Unsafe
Debris field	✅ Fly over	⚠️ / ❌
Low ceiling	❌ Unsafe	⚠️ Possible
Smoke / plume	⚠️ Caution	❌ Unsafe
Dynamic debris	❌ Unsafe	❌ Unsafe

Legend:
✅ Safe ⚠️ Caution ❌ Unsafe

This table **directly supports explainable outcomes** and avoids black-box scoring.

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4. Path Safety Classification Logic (Judge-readable)

After hazards are detected and filtered through constraints, the agent assigns one of three **path-level safety classes**.

> **Exit awareness does not change class assignment.**
> It only biases decisions *after* classification among already-safe options.

Class A — Safe for Drone and Human

Conditions

- No hazards violate human constraints
- Terrain is stable and continuous
- Clearance sufficient for both agents

Example explanation

> "The corridor is clear of obstacles, the ground is even, and clearance is sufficient for both aerial navigation and human walking."

Class B — Safe for Drone, Unsafe for Human *(Signature class)*

Conditions

- One or more hazards violate **human-only constraints**
- Drone traversal remains physically plausible

Typical triggers

- Gaps or drop-offs
- Narrow passages
- Uneven or unstable ground

Example explanation

> “The drone can safely fly over the damaged floor section, but the lack of continuous ground support makes the path unsafe for a human to follow.”

This class is the **core contribution** of the project.

Class C — Unsafe for Both

Conditions

- Hazards violate drone constraints **or**
- High uncertainty / dynamic instability
- Physical plausibility check fails

Typical triggers

- Collapsing structures
- Dense dynamic debris
- Extremely tight clearances

Example explanation

> “Falling debris and limited clearance create an unsafe environment for both aerial navigation and human traversal.”

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5. Relationship to Exit Awareness (Clarification)

- Exit awareness is **directional and abstract**
- It does **not override** hazard classifications
- An exit located along a **Class B or Class C path is treated as invalid for guidance**

This ensures the agent **never leads a human toward an unsafe exit**, even if it is visible.

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6. Why This Taxonomy Scores Well with Judges

Quality of Idea

- Separates **affordances**, not just hazards
- Explicitly models **shared human–robot safety**

Technical Implementation

- Maps directly to existing modules
- No new data requirements
- Deterministic, reproducible logic

Design Clarity

- Table-driven reasoning
- Human-readable explanations
- No hidden heuristics

Impact

- Addresses a real failure mode in robotics:
  robots guiding humans through unsafe paths

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7. What This Enables Next (Optional, Low-Risk)

If time allows (not required):

- Add 5–7 labeled scenarios in `evaluation/scenarios.md`

- Each scenario maps cleanly to **Class A / B / C**
- Judges can instantly validate correctness

One-line summary for judges

The hazard taxonomy explicitly distinguishes between drone-only and human-traversable affordances, enabling exit-aware but non-planning shared-path safety decisions rather than robot-only navigation.