

SFR Executive Brief

Simulation Fidelity Is Not What Most People Think

1. The Problem

Simulation is widely used across:

- driver training
- vehicle development
- research and rehabilitation

However, most systems are evaluated based on:

- visual realism
- motion intensity
- specification claims

These factors do not determine whether a simulator produces correct motion or valid training.

As a result, many systems:

- introduce delayed or incorrect sensory input
- train incorrect timing and response patterns
- create a false sense of realism

The industry lacks a consistent standard for determining whether a system is structurally valid.

2. What Actually Defines Fidelity

Simulation fidelity is not defined by how much a system moves.

It is defined by whether the system reproduces:

- correct rotational behavior
- correct timing of motion
- correct sensory alignment

Three conditions must exist:

1. Motion originates from the vehicle's center of mass
2. Rotational axes are independent
3. Motion is driven by real-time physics

If these conditions are not met, the system cannot reproduce vehicle behavior accurately.

3. The Role of the Human System

The brain does not rely on visuals first.

The vestibular system detects motion before it is seen.

This means:

- yaw is perceived before visual confirmation
- timing determines reaction
- early cues drive control decisions

If a simulator delays motion, distorts rotational cues, or misaligns sensory inputs, it trains delayed and incorrect responses.

Training outcome is determined by timing, not appearance.

4. Why Most Systems Fail

Common structural limitations include:

- mechanically coupled motion systems
- motion applied away from the center of mass
- position-based movement instead of physics-driven motion
- visual environments disconnected from motion

These systems may appear realistic and feel active, but do not reproduce actual vehicle dynamics.

Perceived realism does not equal structural validity.

5. The SFR Framework

The Simulation Fidelity Rating (SFR) framework evaluates systems based on:

- motion structure
- vestibular alignment
- system synchronization
- unified behavior

Core model:

$$SFR = DOF + Vestibular Load + Sync + Unified Feel$$

Optional validation layer:

$$Total Fidelity = SFR \times G \times (1 + NA)$$

Where: G = measured G-force output | NA = neurological accuracy

The framework provides:

- a consistent classification system
- a method for comparing architectures
- a pathway for evaluation and validation

6. Structural Classification Matters

Not all simulators operate the same way. System architecture determines capability.

Examples:

- Static systems: no vestibular input
- Seat movers: motion applied away from the center of mass
- Stewart platforms: mechanically coupled motion
- 4-post systems: vertically driven motion that approximates pitch and roll without true rotational dynamics at the center of mass
- True CoM systems: physics-driven, independent rotational motion

Each category produces different training outcomes. Without classification, comparison is meaningless.

7. Why This Matters

Simulation directly influences:

- reaction timing
- motor learning
- decision-making

If motion is incorrect:

- reaction timing is delayed
- corrections become excessive
- neural patterns degrade

This applies to: motorsports, aviation, rehabilitation, and athletic performance.

Incorrect simulation does not just fail to help. It can train the wrong behavior.

8. The Direction Forward

Simulation requires:

- clear structural standards
- defined evaluation protocols

- measurable thresholds

Without this: terminology becomes misleading, systems are misapplied, and outcomes are misunderstood.

The SFR framework establishes:

- a basis for evaluation
- a method for classification
- a pathway toward certification

Final Statement

*Simulation is not defined by how it looks or how much it moves.
It is defined by whether it behaves correctly.*

Apply the Framework



