

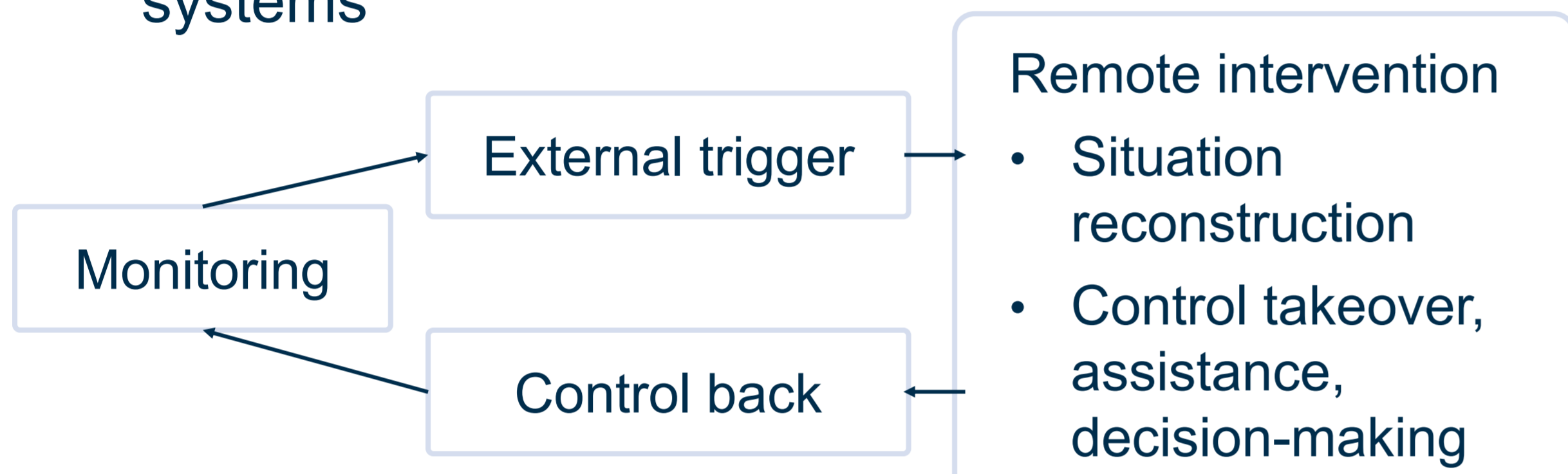
How should we design rail teleoperation if it is event-driven rather than continuous monitoring?



Why Rail Teleoperation Is Different

System states

- **Externally triggered, time-critical** engagement [1]
- Infrastructure-constrained operations (signaling, fixed routes) & network-level interdependencies [2]
- **Multi-role** operator functions (supervision, control, coordination) [3]
- Safety-critical accountability in public transport systems



Cognitive Challenges in Event-Based Rail Teleoperation

Situation entry

- Late situation construction
- Authority transfer & temporal constraints [4,5]

Support: rapid state integration & projection

Abrupt workload transitions

- Extended monitoring phases, high-stakes intervention demands [6]

Critical attentional reallocation & transition support

Context switching

- Switching between vehicles, control levels & organizational layers [1,3]

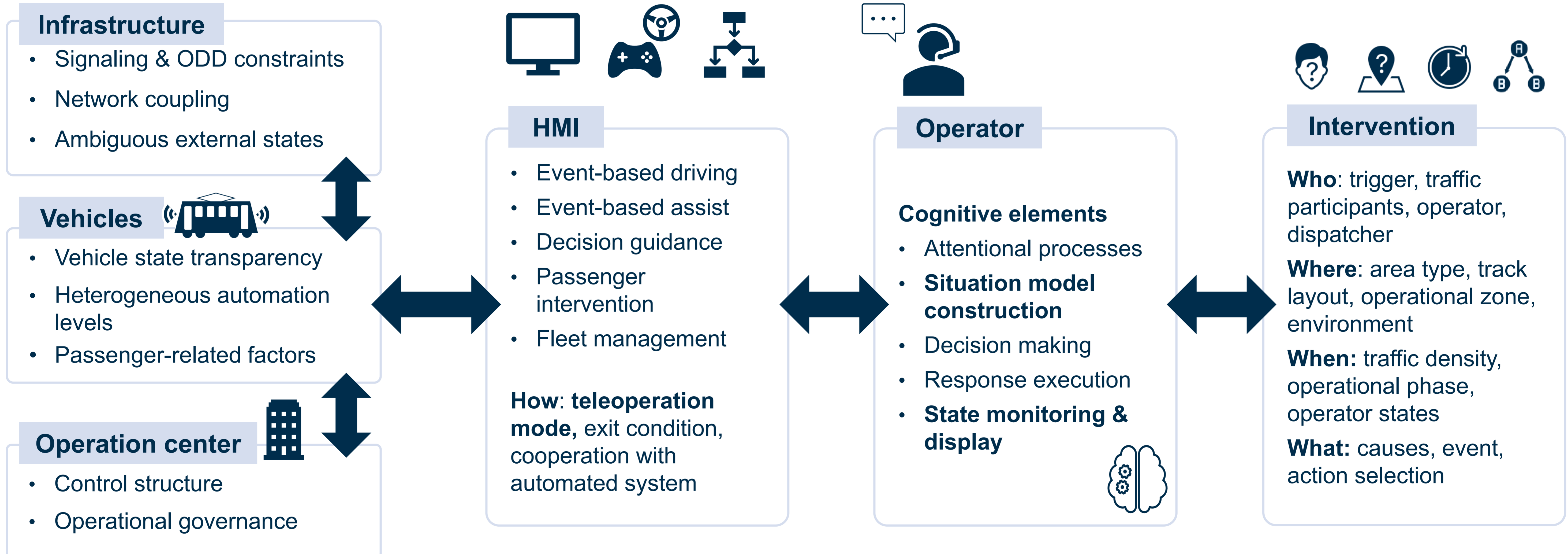
Support: prioritization & task structures

Decision-making under uncertainty

- **Incomplete** symbolic, abstract, sensor representations

Cues for transparency & uncertainty

Socio-Technical System Model



Research Roadmap

Conceptual framework:

How to **model** based teleoperation?

Cognitive task analysis:

What are the key cognitive demands?

Simulation studies: How do system conditions affect **performance & workload**?

Experimental evaluation: Which design improve performance, **safety & user experience** and why?

Interface design: How to design & evaluate **adaptive HMI**s?

Workplace Design Implications

Situation awareness support

- High-quality, multi-perspective video
- Integrated maps & system status
- **Signal & infrastructure awareness**

Information & interaction design

- Information prioritization
- **Mode & authority clarity** (disclosure & delegation)
- Real-time system transparency

Safety-critical interaction

- Emergency functions & redundancy
- Human error protection
- **Reliable multimodal feedback**

Ergonomic & adaptive workplace

- Screen placement & input-device fit
- Adjustable seating & anti-glare setup
- **Operator state monitoring** (fatigue, workload, distraction)