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INSTITUTO DE ENGENHARIA
DE SISTEMAS E COMPUTADORES,
TECNOLOGIA E CIÊNCIA

From Manifests to Orchestration

SHACL Contracts and RDF Choreographies for Federated Digital Twins

FERNANDO CASSOLA

Germany | Frankfurt (Oder), 24 march 2026

fernando.c.marques@inesctec.pt

/fernandocassola

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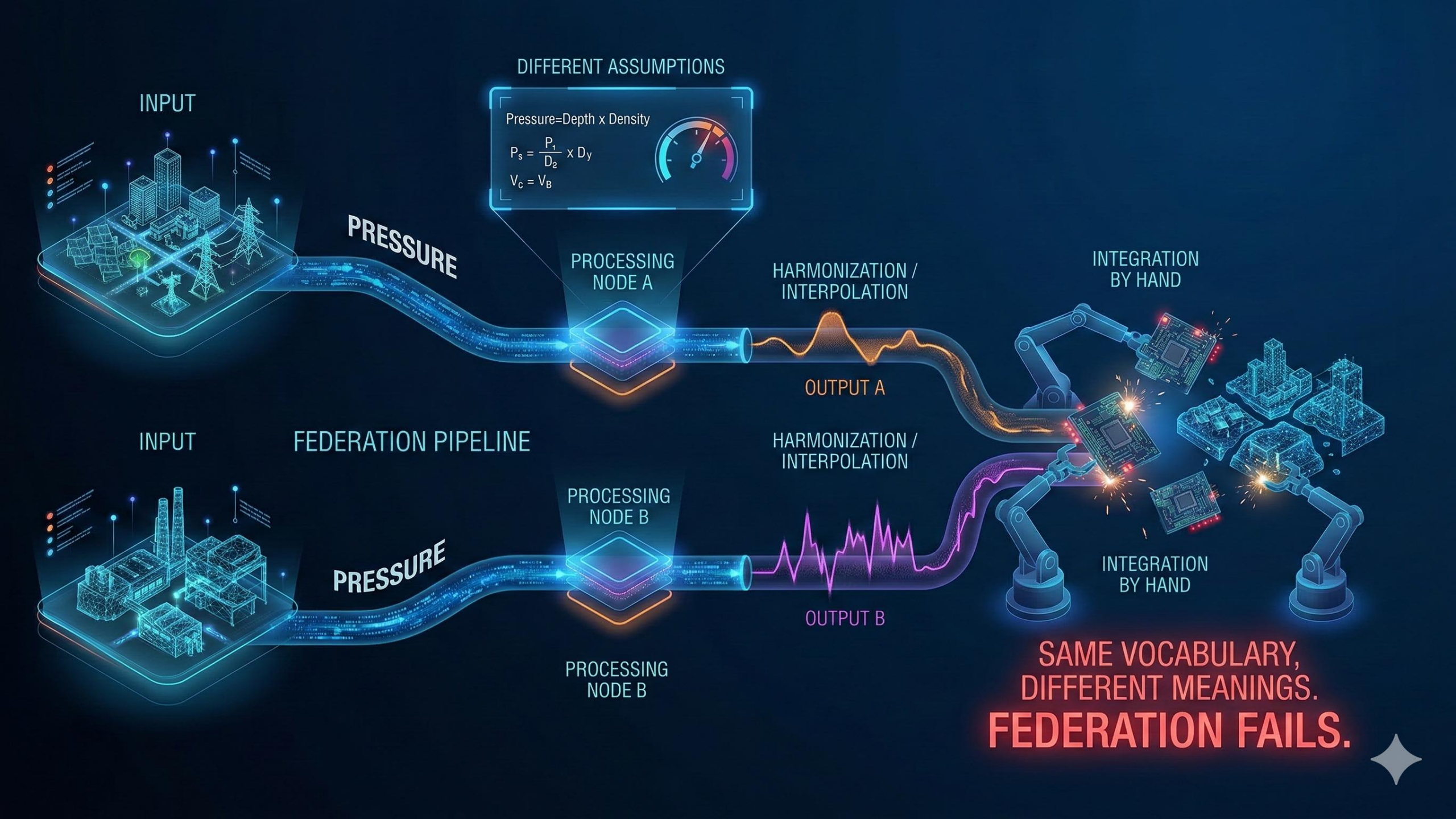
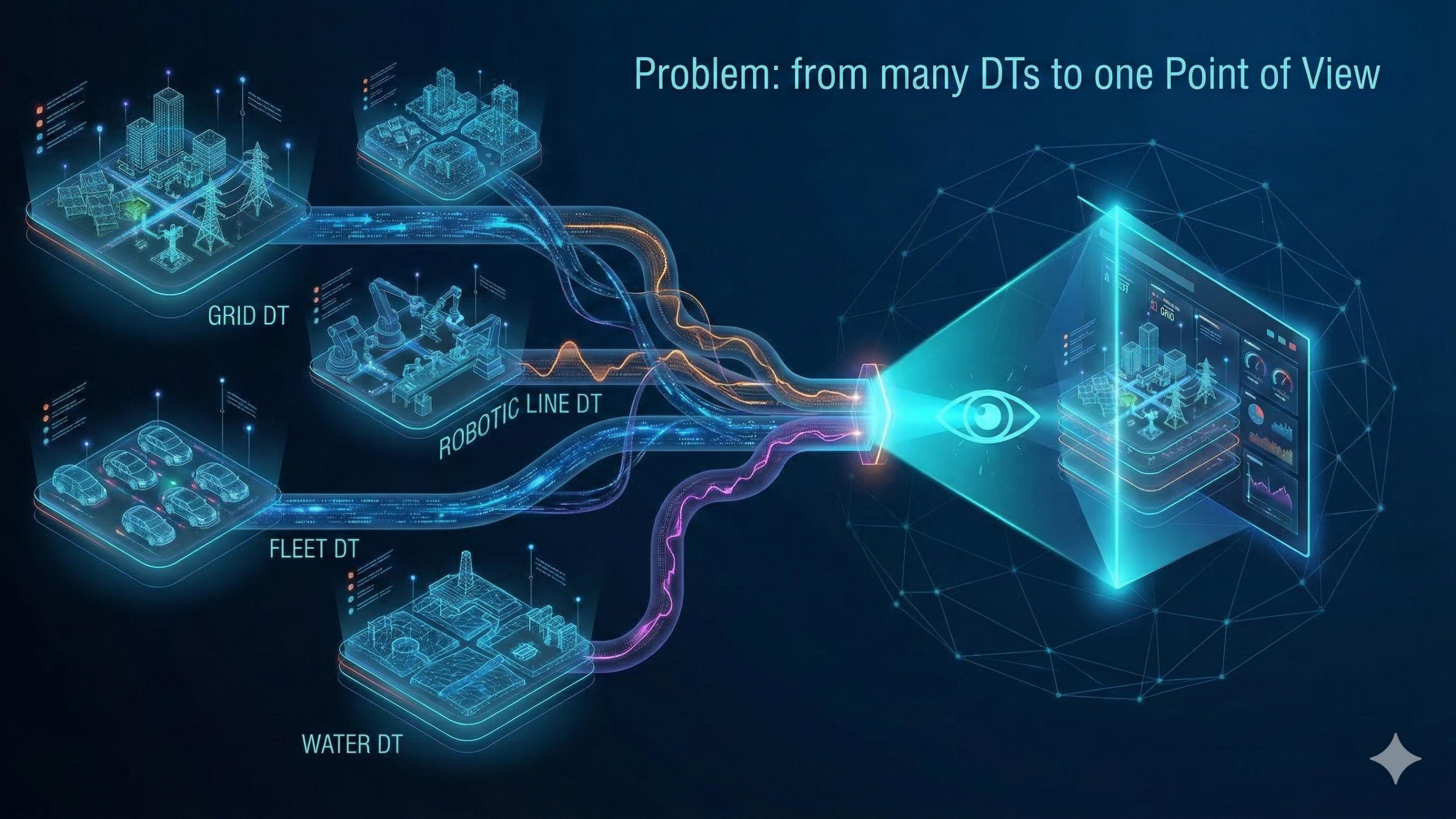

DIFFERENT ASSUMPTIONS
Pressure=Depth x Density
$P_s = \frac{P_1}{D_2} \times D_y$
$V_C = V_B$
INPUT
PRESSURE
PROCESSING NODE A
HARMONIZATION / INTERPOLATION
INTEGRATION BY HAND
OUTPUT A
INPUT
FEDERATION PIPELINE
HARMONIZATION / INTERPOLATION
PROCESSING NODE B
PRESSURE
INTEGRATION BY HAND
OUTPUT B
PROCESSING NODE B
SAME VOCABULARY, DIFFERENT MEANINGS.
FEDERATION FAILS.

Problem: from many DTs to one Point of View



Why current federation does not scale?

Interop ≠ vocabulary

Interop = contract + conformance

Vocabularies help, but are insufficient for cross-platform conformance

Contracts are often implicit → failures discovered downstream

Missing: machine-checkable contracts for data AND processes, plus orchestration validity

Core idea: Virtual Choreographies (VChor)

- Model actions and internal state as platform-independent semantic behaviors
- Compose multiple DTs into a system of systems
- Validation-first: fail early, then execute consistently

VChor = semantic behaviors + contracts + orchestration

Virtual Choreographies Definition

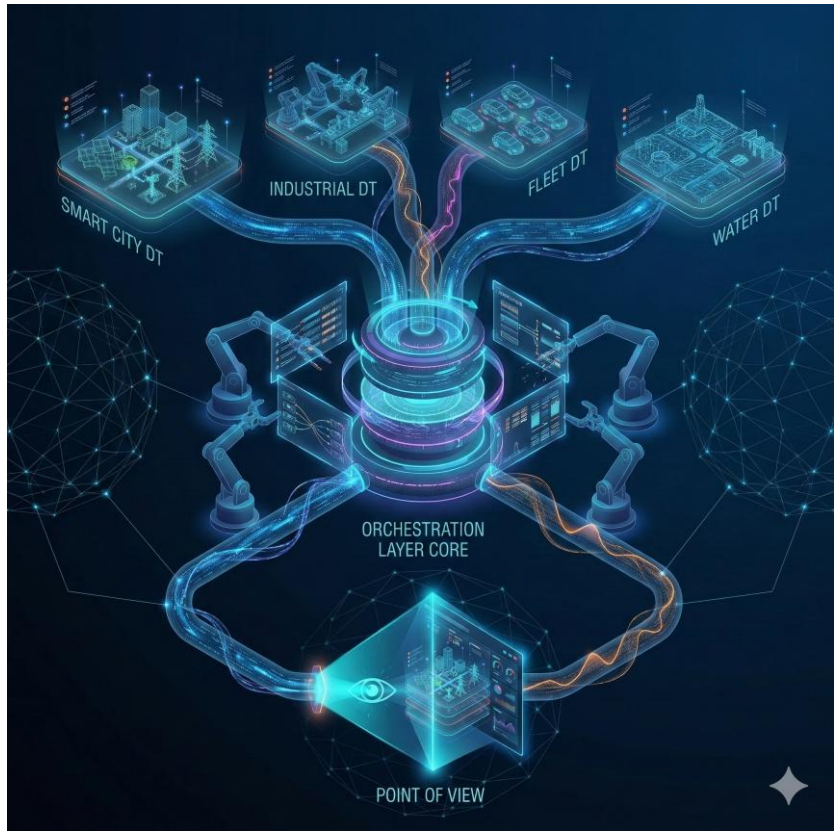
Corollary: actions and active elements are platform-independent

Choreography = set of actions (each action linked to active elements)

Actions depend on internal state (state of active elements changes through actions)

Hyperentities (e.g., goals) are also active elements (goals have state; can interact and conflict)

Theoretical approach: orchestration layer for DT federation



Use VChor to map interactions of all agents with the system

Agents can belong to different DTs; data and processes may be heterogeneous

Introduce an orchestration layer to map behaviors and ensure semantic consistency

Enable composition into a unified environment with FAIR-aligned reuse and behavior compatibility

Technical approach (high-level)

SHACL manifests = contracts

- Constraints over inputs and outputs
- Output expectations
- Expose DT processes as first-class components
- (transform - harmonize - interpolate - augment)

RDF choreography = semantic orchestration

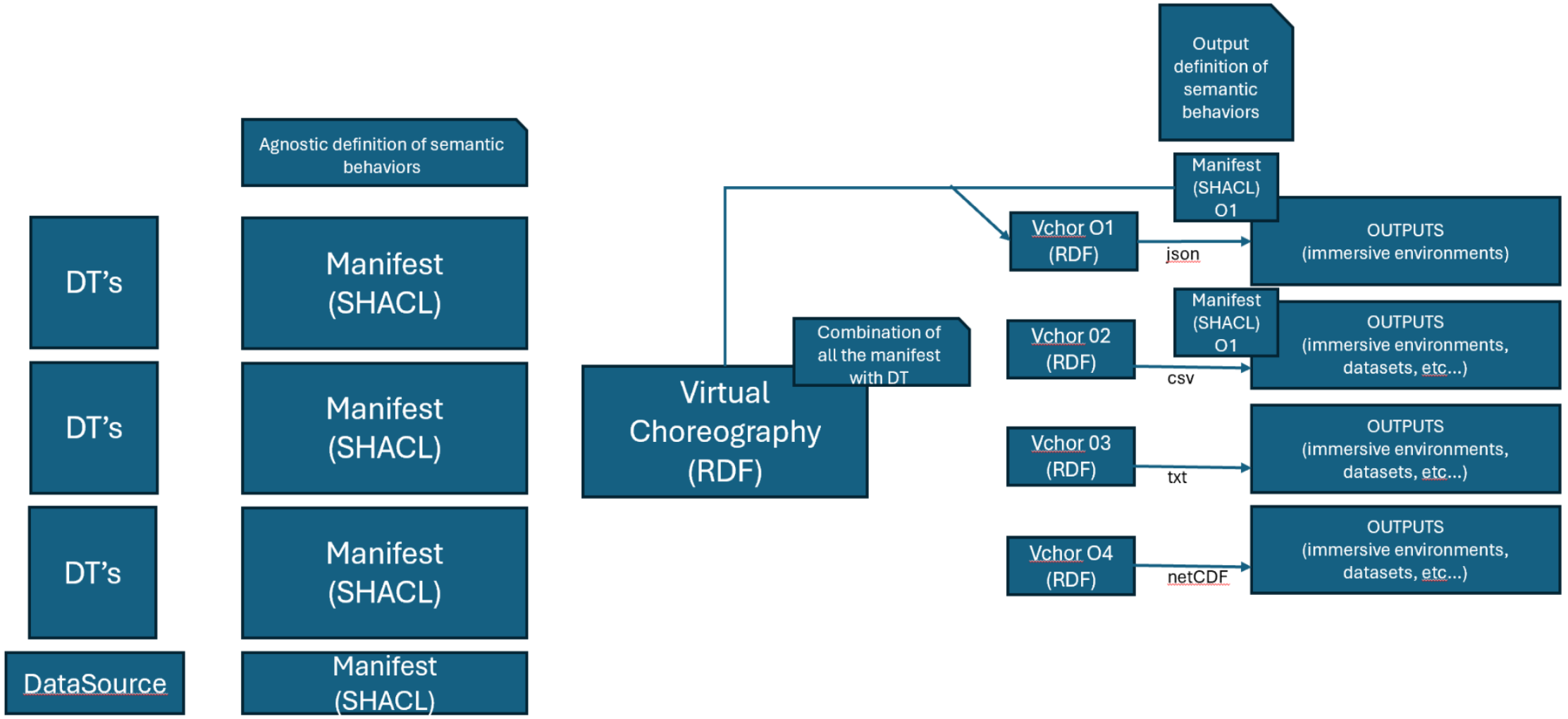
- Declares orchestration of behaviors and actors exposed by the DT manifests
- Dependencies, sequencing, conditions
- Platform-independent execution intent

Both are needed:

contracts (what exists, constraints) +

choreography (how it is composed)

From manifests to orchestration to outputs



Validation-first federation

SHACL validates

Data shape constraints (types, units, cardinalities)

Output expectations

Process I/O compatibility (signatures)

RDF choreography validates

Actor/behavior availability (from manifests)

Dependency satisfaction

Orchestration coherence (validated plan)

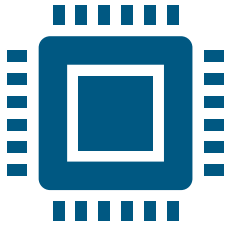
Oil Spill Use Case

GOAL:

Train stakeholders (developers, regulators, the public) using immersive environments with what-if scenarios (oil spill).

https://drive.inesctec.pt/s/zr3JbAQYzG35nt5?dir=/&editing=false&openfile=true

Outcomes & roadmap



Expected main outcomes

Combine heterogeneous DTs into one single Point of View

Interoperable federation with machine-checkable contracts

Domain-agnostic and platform-independent

Reusable and extendable across domains

Future work

AI-assisted authoring: natural language → manifest generation

AI-assisted authoring: platform-adapted choreography generation

Apply the approach to other use cases in different contexts

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QUESTIONS...

Thank you!

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