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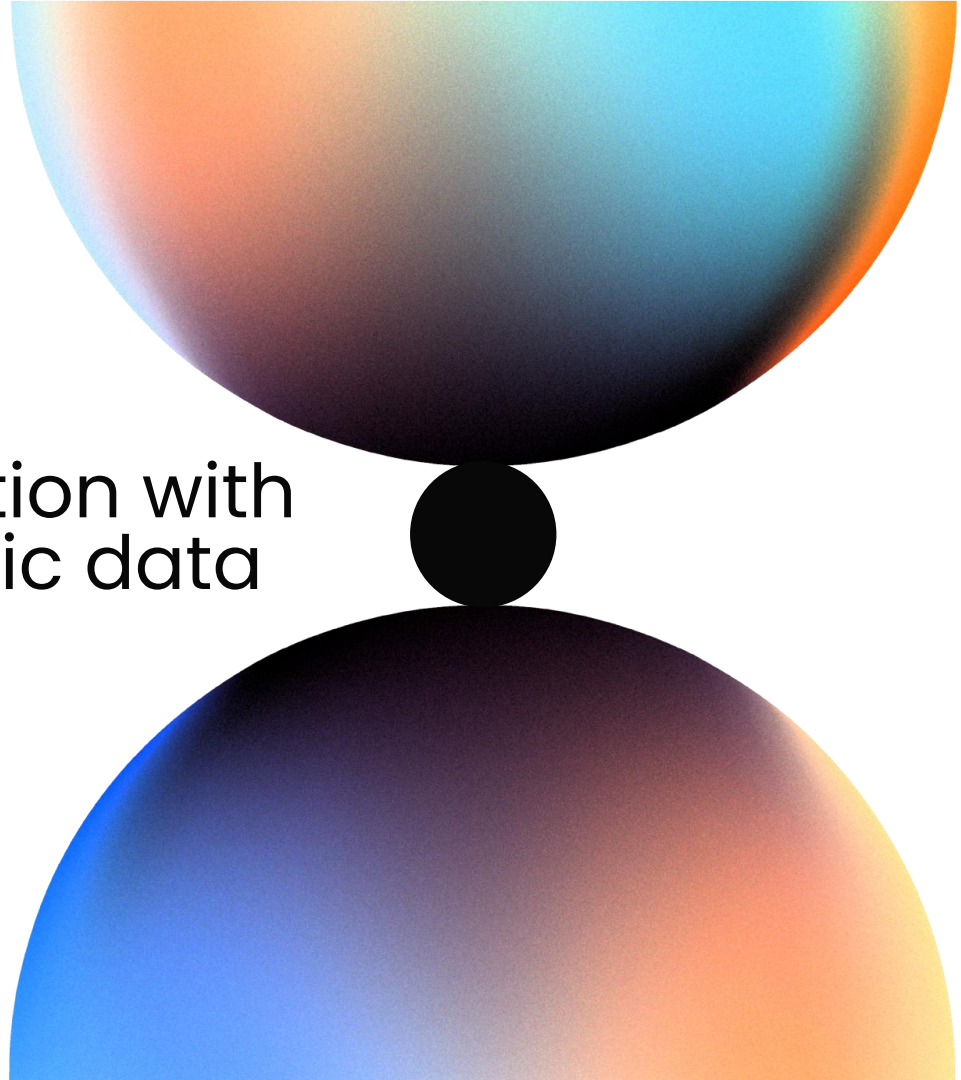
AI-first transformation with streaming, semantic data products



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Living with complexity

Successfully responding to today's unpredictable VUCA world, adaptation is king – "The one most adaptable to change is the one that survives". Then, how to enable adaptability?

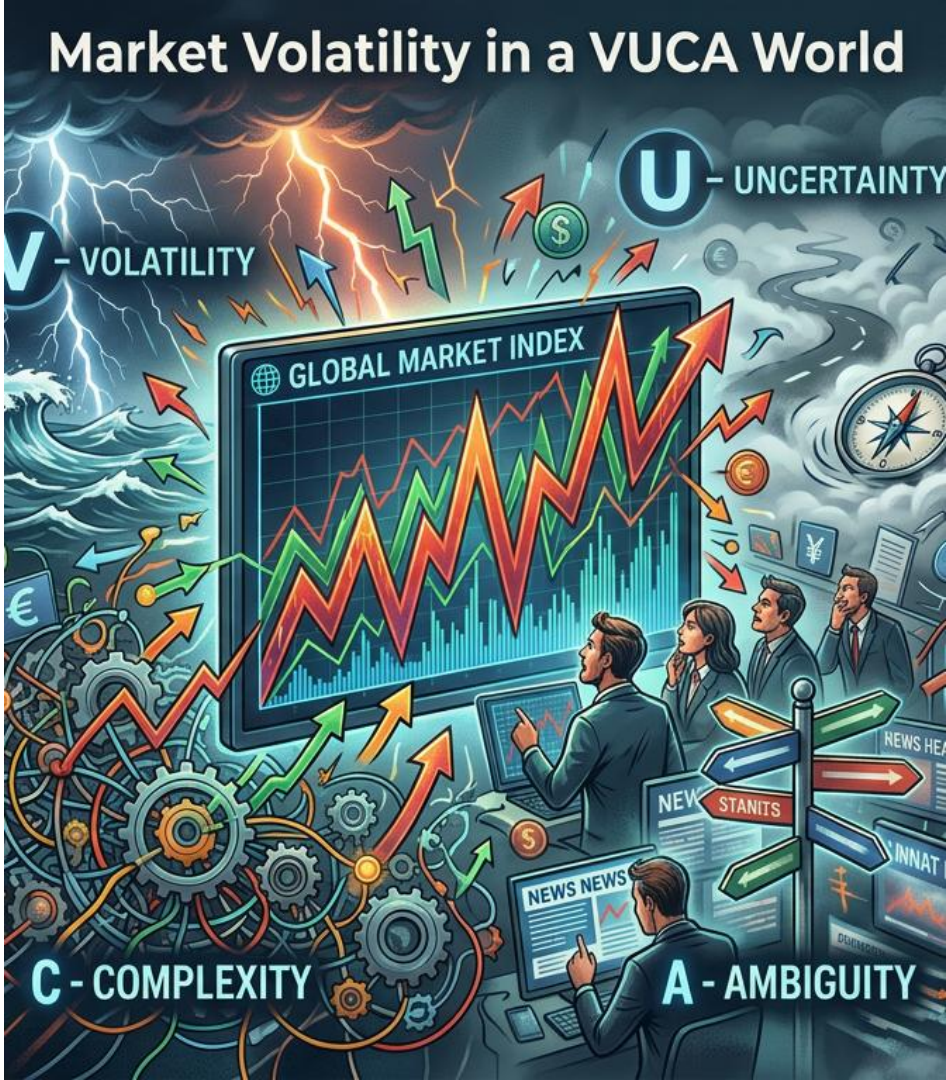
Continuously adaptive company

Organization that operates as a **living ecosystem**, organically balancing continuity and change across its operations, organization, and finance to thrive amid disruption.

Future-focused companies transform itself from enduring disruption to utilizing disruptions proactively to create their future

Success in VUCA world requires systems thinking approach to understand and take a leap towards real data-centric operations transformation which is required for effective, scalable and resilient agentic AI era OT operations

Continuous adaptation: Why organizations must think beyond 'resilience' and 'agility'– weforum.org



The Evolution of Enterprise Architecture – IT/OT convergence

	Industry 3.0	**Industry 4.0 so far**	**Industry 5.0 in the future**
Enterprise Architecture	Monolithic	Composable	Agentic AI
Architecture	Single, integrated	Modular, reusable	Autonomous agents
Flexibility	Low	Moderate	Very High
Scalability	Low	High	Highly scalable
Agility	Low	Moderate	Extremely agile
Decision making	Human-driven	Human-driven/assisted	AI driven (human-on-the-loop)
Efficiency	Low	Medium	High
OT data strategy	"wired"	"collect data"	"semantic information streams"

AI-first: Systemic organizational and operational transformation

“Business management should examine the whole system **systematically**, broadly and with a long-term perspective. Companies must strengthen their ability to perceive **complexity** and understand how different actions and decisions are **interconnected**. It is essential to build **continuous** innovation and foresight” – Sitra 12/2025

Thinking must change

"We cannot solve our problems with the same thinking we used when we created them“ – Albert Einstein

Embrace the complexity - Information resolution is the new currency

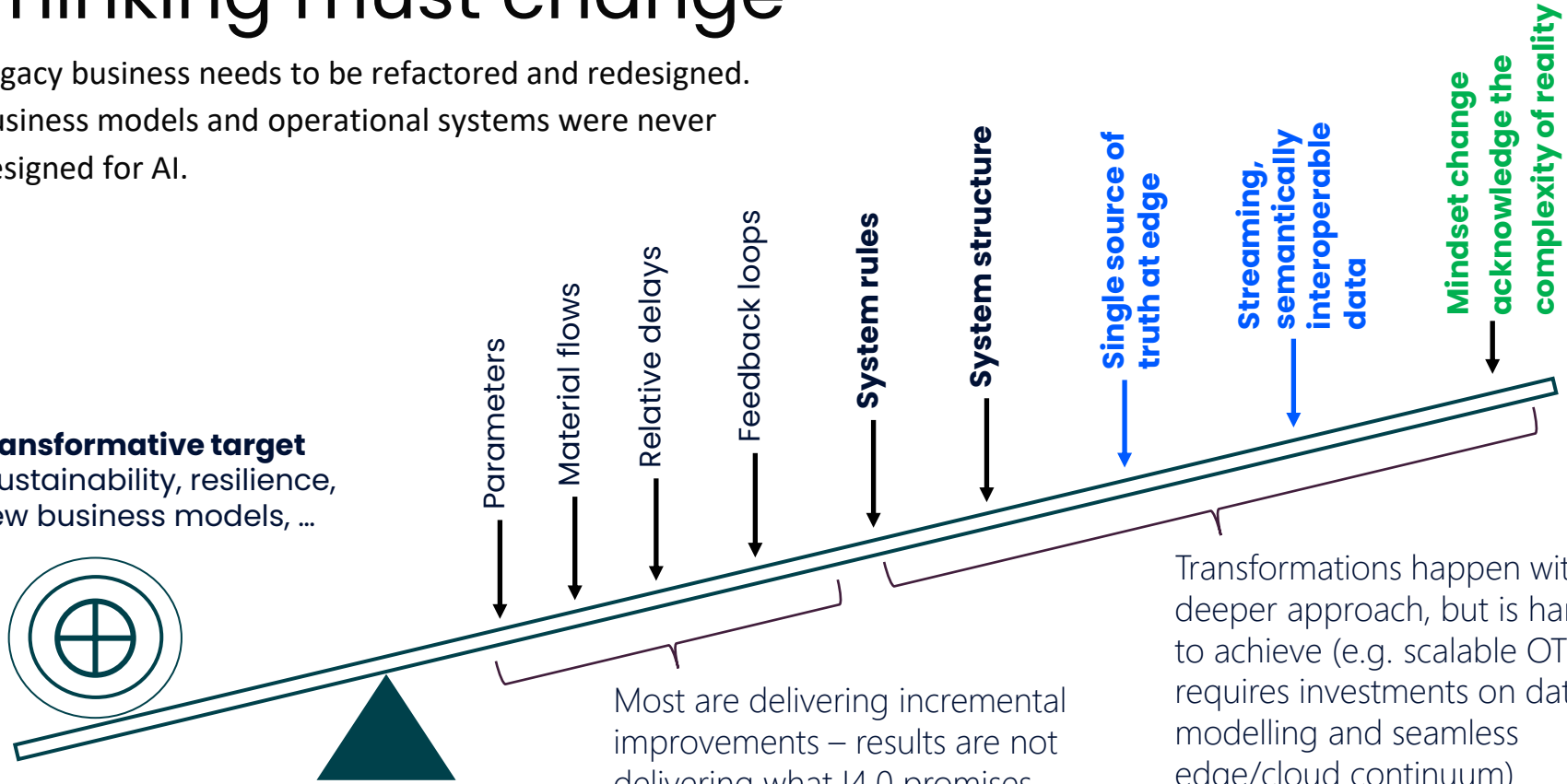
The KISS principle is replaced by RICH (Relational, Integrated, Contextual, High-definition) - **Let go of old rules of thumbs !**

The Business Imperative - Why Act Now

Real productivity gains with AI (and carbon-neutral circular economy) demands **systemic approach** with business and operational model redesign

Thinking must change

Legacy business needs to be refactored and redesigned. Business models and operational systems were never designed for AI.

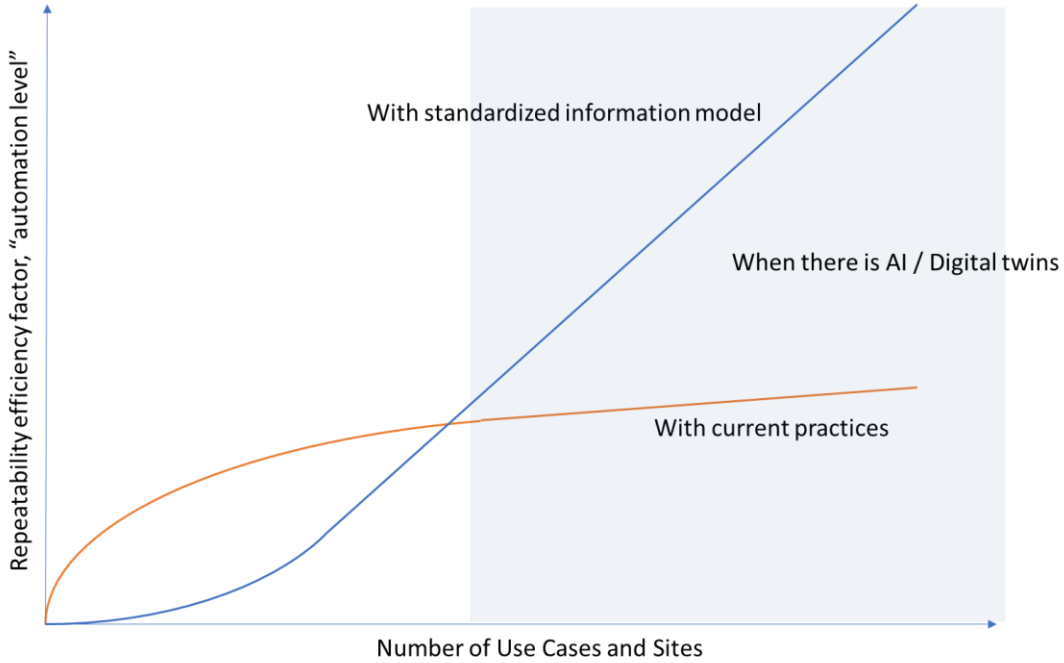


Transformative target (sustainability, resilience, new business models, …

Most are delivering incremental improvements – results are not delivering what I4.0 promises

Transformations happen with deeper approach, but is harder to achieve (e.g. scalable OT AI requires investments on data modelling and seamless edge/cloud continuum)

Productivity growth with AI starts with semantic data products



Emerging enterprise data architectures

- Data Fabric, Data Mesh, Edge/Industrial DataOps - "connective tissue"
- Distributed execution, centralized management (supporting also European collaborative computing continuum)
- Semantic layer (spine) - mandatory by 2030 for Intelligence / Agentic AI (Gartner 2026)
- Employee self-service engagement, domain ownership – Letting power to people

Emerging OT architectures

- Open Industry 4.0 Alliance, OPAF, NAMUR NOA, …

Thinking must change for AI-first

Sixty years of wisdom can be a mental prison. “Good. Fast. Cheap. Pick two“ - The room nods. Sixty years of wisdom.

Revolution is happening in data and AI

Advanced teams deliver higher quality results faster with lower costs.

They made the "right way" also the "fast way.“

Good AND fast AND cheap becomes reality.

Through constraint dissolution (biggest constraint currently is human)

Traditional thinking traps you on a fixed curve.

Transformational organizations shift the entire curve.

By understanding exponential power of systemic approach and semantic interoperability.

The Investment Secret: The Platform Paradox

Organizations that invest heavily upfront in proper abstractions initially appear to violate the Iron Triangle by choosing expensive and slow approaches.

Yet these same organizations eventually deliver capabilities that are simultaneously faster, cheaper, AND higher quality.

The Three Foundations:

Reusable Building Blocks

Simplified technology components that eliminate repetitive work

Self-Service Infrastructure

Teams access resources without bottlenecks

Computational Governance

Compliance rules embedded in automated systems

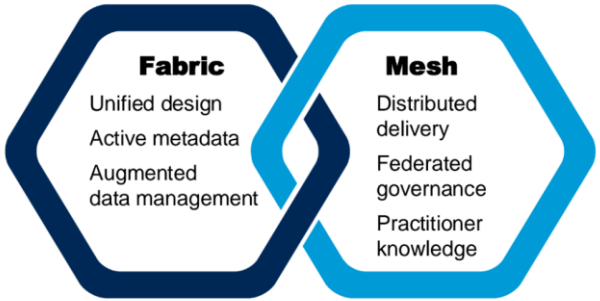
The platform investment doesn't just improve efficiency—it fundamentally changes the nature of work itself.

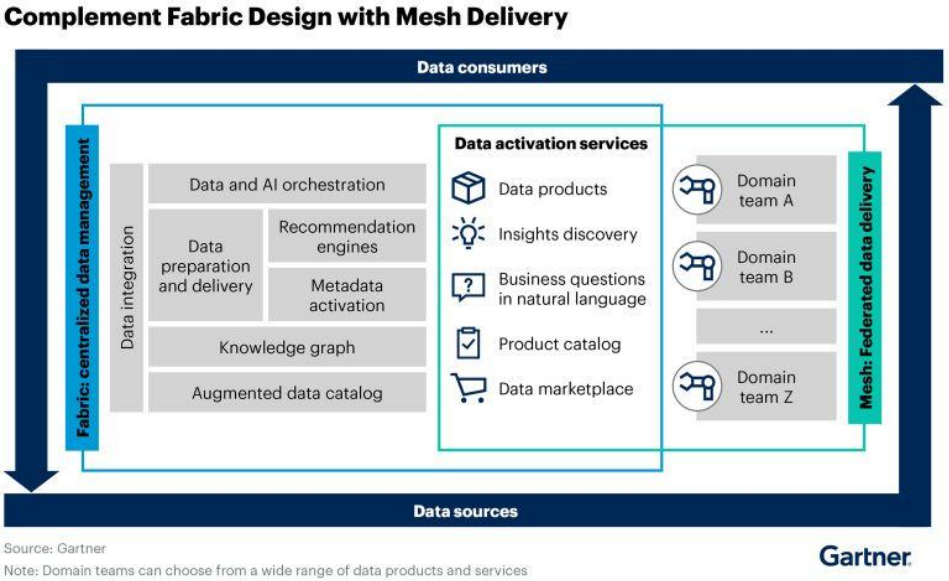
Journey towards Enterprise Architecture 4.0

Complement Data Fabric Design with Mesh Delivery

"By 2028, 80% of autonomous data products supporting "AI-ready data" use cases will emerge from a fabric and mesh complementary architecture"

Semantic data products are perfectly suited for a hybrid Data Fabric/Data Mesh approach.





Data Fabric / Mesh & Unified Data Layer - towards Semantic Layer

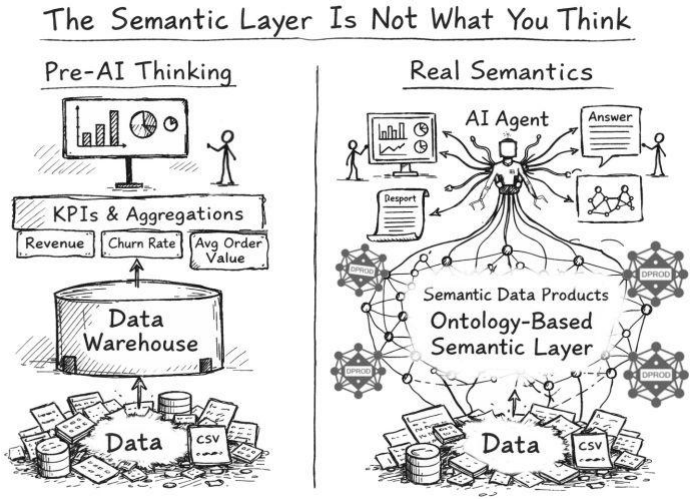
Unified Data Layer is strategic abstraction layer that connects, cleanses, and harmonizes disparate data sources on-premises or across multi-cloud environments into a single, trusted "source of truth" for analytics, AI, and operational systems – ***for Semantic Layer***

Data Fabric: Data Fabric is a broader architectural concept that includes a UDL as a major component (using metadata to enable integration)

Data Mesh: Data Mesh is an organizational strategy (decentralized domains), whereas a UDL is a technical implementation that can be used *within* a Data Mesh to provide consistent federated governance

Data Lake/Warehouse: A UDL sits *above* these physical stores. It is the logical layer that makes a Lakehouse, Warehouse, or Lake accessible, whereas Lakehouses are primarily about storage.

Edge DataOps: In “mesh” part of Industrial DataOps approach, abstracts site/ plant/production line complexity of assets and protocols and offers tools to map data to ***semantic data products with data contracts (“shift left” – Data as Code)***



Gartner: Semantic Layer a "non-negotiable foundation" for AI.

Industrial Data Products & Contracts

Use Edge DataOps and a Data Mesh approach to transform OT data to valuable, trusted data products right where it is generated – "shift-left" approach moves data contextualization, cleansing, and governance from the central cloud/lakehouse to the shop floor

Semantic Data Product: Reusable, standards-based and self-contained unit of curated data, packaged for consumption by AI or analytics, and managed by a production domain team

Domain Ownership: The production line or plant manager who owns the assets takes responsibility for the quality and availability of the data produced

Edge DataOps: Transforms and contextualizes data into meaningful, semantic data products (e.g., normalized "Vibration Level" rather than "PLC_Tag_AI03").

- **Data Asset:** Curated, cleaned data (high-quality, real-time stream).
- **Protocol:** Standards-based access points (PC UA PubSub, CESMII i3X).
- **Metadata:** Documented semantic definitions and lineage

Data Contract: Acts as the "handshake" between the Edge (Mesh) and the Cloud (Fabric). It defines:

Payload Schema: The exact structure of the data (e.g., conforming to the OPC UA Companion Specification).

Hierarchy: Where the data lives in the **Unified Namespace (UNS)** (e.g., site/area/line/cell/asset – part of ISA-95).

Quality Requirements: The expected update frequency (e.g., 1Hz) and the assurance that metadata (like Asset ID) is always present.

Data products and data contracts are foundational to data governance and compliance automation

Industrial data contract - .NodeSet2.xml

Using an OPC UA NodeSet (.NodeSet2.xml format) as a data contract is a best practice for ensuring semantic interoperability between industrial systems, devices, and cloud applications

Key Aspects of NodeSet as a Data Contract

- **Formal Definition:** Nodeset files (defined in OPC UA Part 6, Annex B) serve as the normative contract for information models.
- **Semantic Structure:** It is a graph-based structure connecting typed nodes (e.g., ObjectType, VariableType) rather than just a flat list of tags.
- **Interoperability:** It enables vendor-independent communication, allowing different systems to agree on data structure ahead of time, which is critical for Industry 4.0.
- **Machine-Readable:** The XML format allows clients to ingest the model automatically to configure data ingestion (e.g., in Python or SCADA systems).
- **Versioned Contracts:** Similar to API versioning, NodeSets can be versioned to manage changes in data structures over time.

Components of the Data Contract

A NodeSet file defines the following essential aspects of the contract:

- **Data Types:** Defines the structure of data points (e.g., TemperatureSensor, MotorType).
- **Nodes:** Defines specific instances of objects and variables.
- **References:** Defines the relationships between nodes (e.g., HasComponent, Organizes), providing context.
- **Namespace URI:** A unique identifier that ensures data model consistency across different manufacturers

Semantics – mandatory for scalable I4.0

"When you bind that data product to your ontology, it becomes SEMANTIC and that makes the data AI Ready" – Tony Seale

Enterprise ontology vs. subdomain (segment/vertical) ontologies

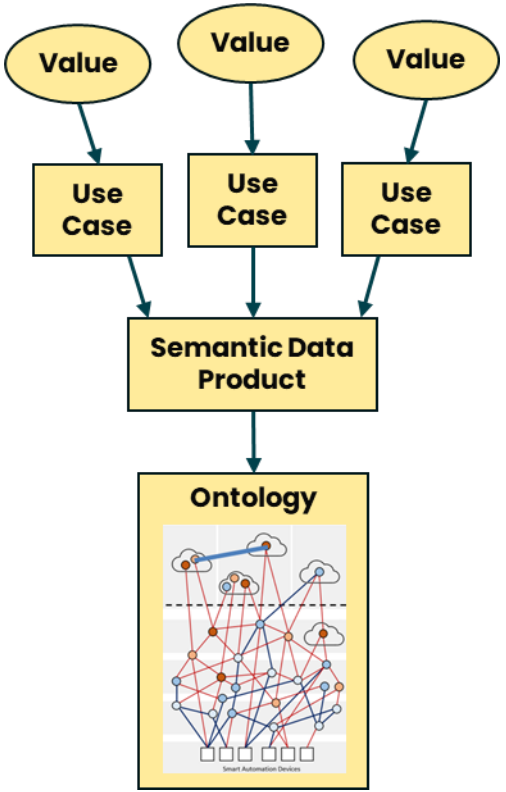
OPC UA Companion Specifications (e.g. ISA-95) are ***"real-world operational technology (OT) ontology implementations" for specific industrial verticals*** like the process industry, manufacturing, mines - practical, standardized implementation of semantic data models

In business level, ontologies align siloed data (e.g. via Knowledge Graphs), making it easier to retrieve insights for decision-making.

Model what you can prove you need. Let the use case lead.

The Strangler Fig pattern is an incremental, low-risk approach to migrating legacy monolithic applications to microservices, and modular data architectures.

➔ ***"Shift left" and start value- and use case-driven, iterative I4.0 data architecture modernization with immediate business value.***



Data architecture terminology

Concept	The Strategic Purpose	McKinsey / Gartner "consultant jargon"	Nervous System Analogy	Role in the Ecosystem
Semantic Data Product	Treating data like a "Product" with its own lifecycle and "Customer" (the business).	Domain-Specific (Data) Assets	**The Nerve Impulse (Signal)**	A discrete, complete packet of meaning delivered from an organ to the rest of the body.
Data Contract	Creating "Marriage settlement" between data producers and consumers to stop breaking pipelines	Governance-as-Code	**The Synapse (The Gap)**	The "handshake" protocol ensuring the signal is transmitted correctly and safely between neurons.
Edge DataOps	Processing data at the source to enable "Zero-Latency" decisions and "shift-left"	Physical AI / Edge Convergence	**The Senses, Reflexes and Filtering**	Processing data at the "fingertips" (sensors/devices). Enables instant local action before the signal reaches the brain.
Data Mesh	Moving responsibility to the people who know the data (e.g., Manufacturing owns Manufacturing data), not a central IT bottleneck.	Decentralized Data Ownership	**The Organs**	Decentralized parts i.e. organs that function independently but as part of the whole.
Data Fabric	Using AI to "stitch together" different data sources automatically, rather than manual ETL.	Active Metadata / AI-Driven Integration	**The Nervous System**	The physical and automated connections that transport signals across the body.
Unified Data Layer	A logical (not always physical) layer that prevents data fragmentation.	Single Source of Truth (SSOT) 2.0	**The Brain's Logic**	The central place where signals are interpreted and unified into a single conscious reality.
Semantic Layer	Ensuring "Profit" means the same thing to a Python script, a PowerBI dashboard, and a CEO.	Universal Business Language	**Language & Cognition**	The ability to turn neural signals into meaningful thoughts and concepts (e.g., "Success" or "Risk").

Key takeaways

"By 2030, universal semantic layers will be treated as critical infrastructure, alongside data platforms and cybersecurity." - *Gartner Data & Analytics Summit 2026*

A semantic data product is a machine-readable contract that guarantees the standardized meaning and quality of data, enabling automation of governance at the data creation.

Resilience and strategic adaptability require a systemic approach. In the corporate world, those who get stuck in point-based experiments without a broader systemic understanding will be left behind when the rules of the game change.

For OT data, it means transforming from silos and point-like integrations **towards liquid semantic information flow if form of semantic data products and data contracts**

Conversation around AI shifted. For two years, we've been talking about models. We are now talking about infrastructure.

Cybersecurity is critical infrastructure. Gartner signals that the semantic layer has reached that same tipping point.

European Industry 4.0 insiders have known this already a long time – OPC UA Nodesets are core of industrial operations subdomain for enterprise semantic layer

Industrial semantic data products and data contracts are derived directly from OPC UA Nodesets, enabling IT/OT convergence, data pipeline automation and governance automation

Productivity leap occurs when the technical layer (semantic network) and the human layer (servant leadership and learning) meet.

25 years of Semantic Web (backbone of Industry 4.0 thinking)

Henrik von Scheel - from automation to intelligence

From vision to reality

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End game towards autonomous operations?

Knowledge, focusing on meaning, context and reasoning as foundation for decision-centric approach

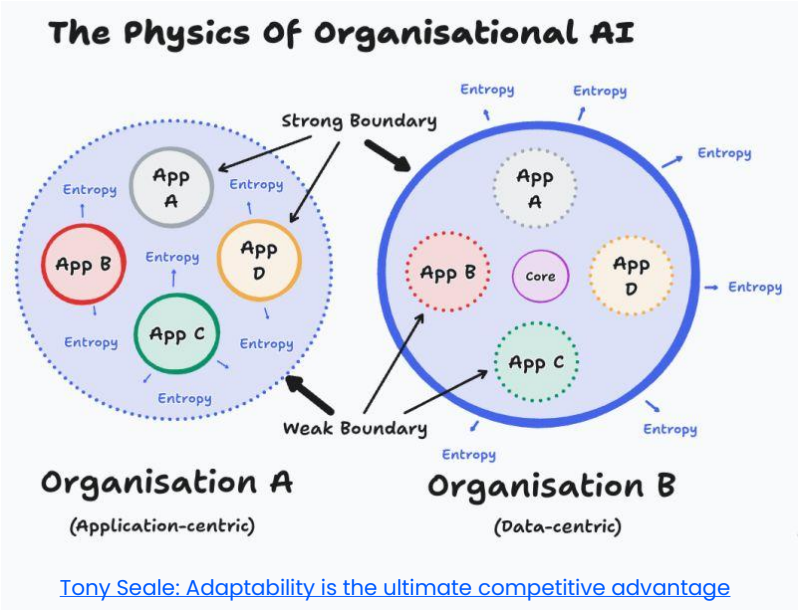
"The real source of competitive advantage in the coming years won't be a slightly better algorithm. It will be having a better model of the world." – Tony Seale

Automated data management through data lifecycle and semantic interoperability create foundation for dynamic, intelligent systems that manage themselves.

Systems thinking approach – embrace complexity

Emergence is central concept here, as I4.0 has been developed for ecosystems. Embrace initial complexity of semantic information implementation, as it ***unleashes exponential potential*** of data while scaling over enterprise and ecosystems (and with agents, of course)

Ecosystems currently empower humans, same must happen to machines (machine-readable meaning for digital twins and AI)!



Tony Seale: Adaptability is the ultimate competitive advantage

Accelerating Business Impact through AI-First Transformation

AI revolution is a data architecture and governance revolution - “By 2030, semantic layers will be treated as critical infrastructure, with data platforms and cybersecurity - Gartner”

Agentic AI success is hindered by operating model deficiencies rather than technology, with 80% of firms stuck in pilots due to missing infrastructure.

The 20% succeeding focused first on unglamorous, foundational elements like governance, data readiness, and decision architecture.

True scaling requires building this infrastructure and redefining operating models, not just deploying faster.

Target: Launching sustainable industrial growth and securing competitiveness in the ongoing turbulence of the business environment

AI-first –transformation: Real productivity gains demands systemic approach with business and operational model redesign

Operational Model Evolution: Traditional discrete-oriented, human-supervised operations must evolve to continuous, AI-driven optimization with real-time governance and safety controls.

Foundation: Data architecture, streaming data, and semantic interoperability

Transformation: Iterative, value-driven change process (managed risk and learning with strangler fig pattern) to introduce enabling capabilities (Industrial standards like ISA-95 with OPC UA and technologies like Industrial DataOps with data products and catalogs for easy data reuse, computational governance within hybrid edge-cloud approach etc.)

Industrial transformation

Enhance new and existing processes to support an intelligent production system that senses current state, learns, decides and evolves continuously. Industry 4.0 Is fundamentally a Data Architecture Challenge.

Transformation capabilities

Modern industrial data architectures for distributed execution within central/meshed governance

Brownfield modernization strategies for digital retrofitting with greenfield-interoperable interfaces (abstracting protocol/asset diversity from actionable data plane) – Industrial DataOps

ET/IT/OT Convergence and Interoperability with Industrial DataOps, Unified Namespace and Digital Thread

Edge-Cloud Continuum with Hybrid Data Fabric/Mesh and data product and data contract –centric approach

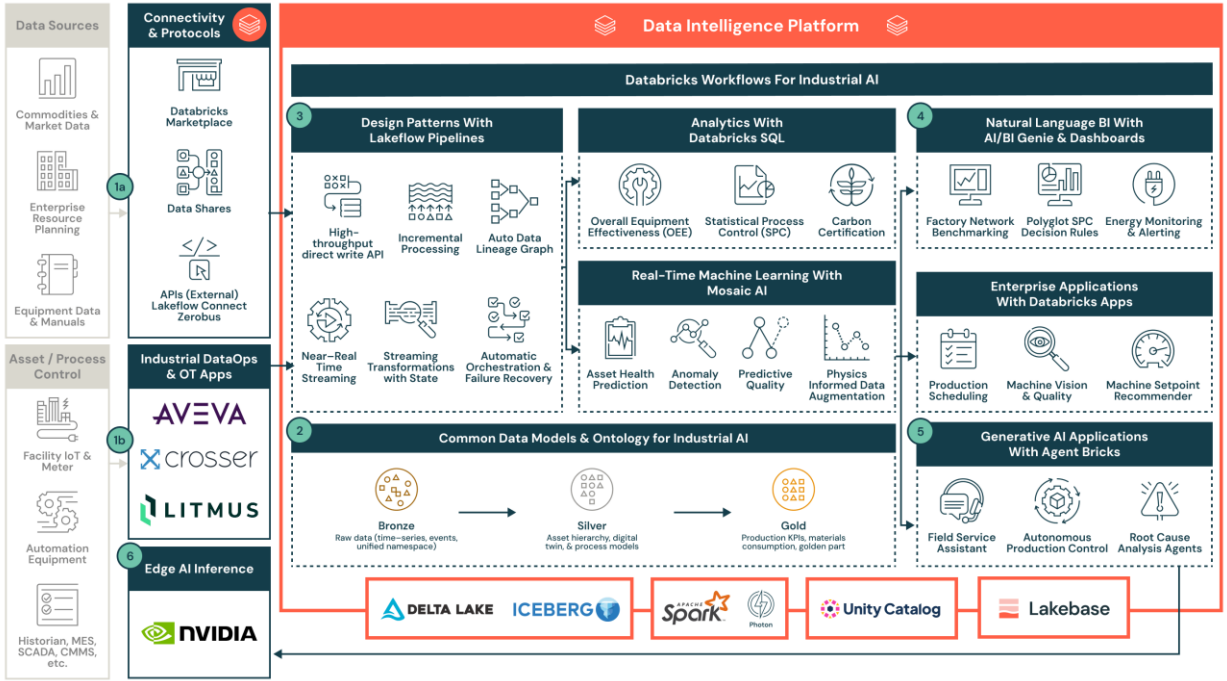
I4.0 standards - OPC UA, AAS, DPP, Data Spaces - and how all connects to coherent, sovereign data architecture (Manufacturing-X, Factory-X)

Develop an actionable plan for decision-centric transformation
- enable AI-age growth with reusable data asset capabilities:

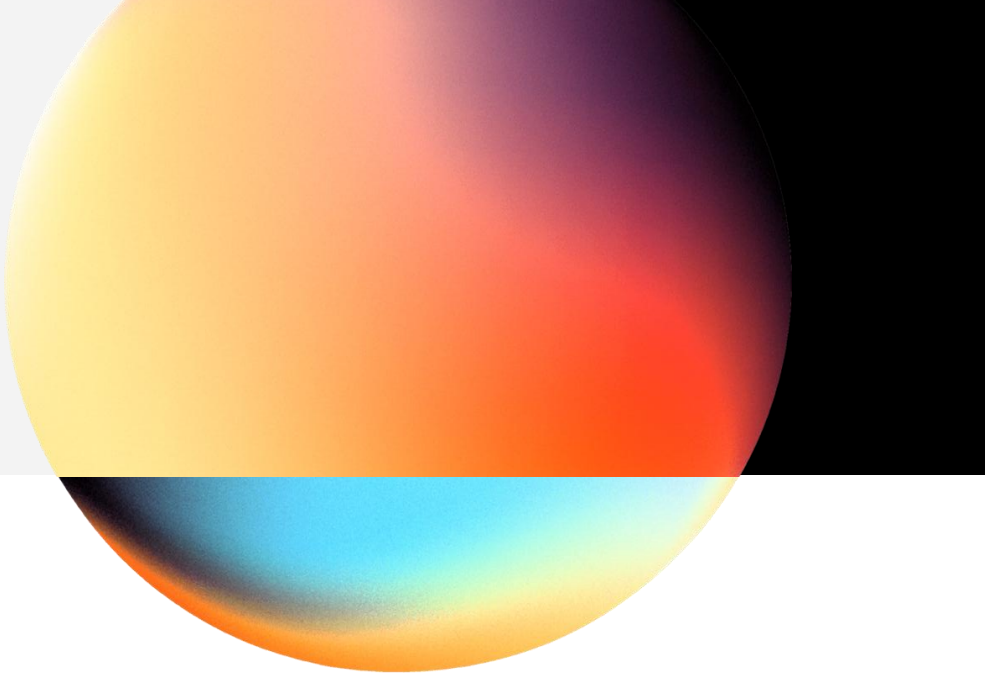
1. Enterprise vision and strategy – state of will; compelling business vision what EA and data architecture needs to support?
2. Current pain points and digitalization maturity assessment to identify gaps between current state and vision
3. Build plan for decision-centric approach to enable agile, resilient data foundations for scaling and productivity benefits
4. Incremental approach to use case –driven modernization implementation for “eating the elephant” piece by piece
5. Transformation program impacts – what and how to communicate, build needed skills and empower teams

>> Result: actionable, prioritized deployment plan for missing capabilities to be implemented (only what is needed) within next business prioritized use case.

Industrial AI blueprint example (Databricks) - Brightly Works core capabilities



[Is Databricks the North Star for Industrial AI? – ARC Advisory]



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