



ACQUISITION INNOVATION
RESEARCH CENTER

Data Interoperability Foundations for being AI-Ready

Mark Blackburn, Megan Clifford, Thomas Hagedorn, Thomas McDermott, Valerie Sitterle, Philomena Zimmerman



Systems Engineering Research Center
Stevens Institute of Technology

Data and Performance

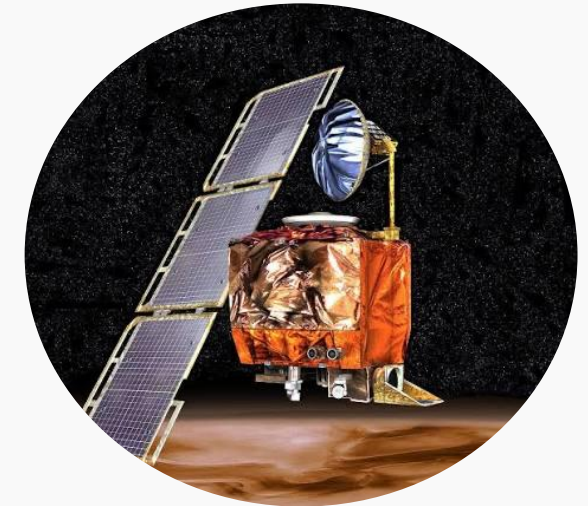


Reengineering the Bedrock: Data Readiness as the Foundation for AI Interoperability and Analytic Superiority



Reengineering the Bedrock: Data Readiness as the Foundation for AI Interoperability and Analytic Superiority

Mars Climate Orbiter (1999)



Data and Performance

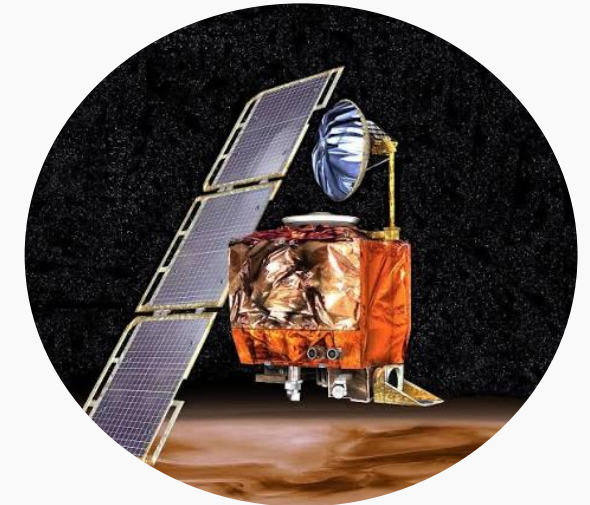


Reengineering the Bedrock: Data Readiness as the Foundation for AI Interoperability and Analytic Superiority



Mars Climate Orbiter (1999)

Every course correction nearly 4.5x weaker than calculated



Data and Performance

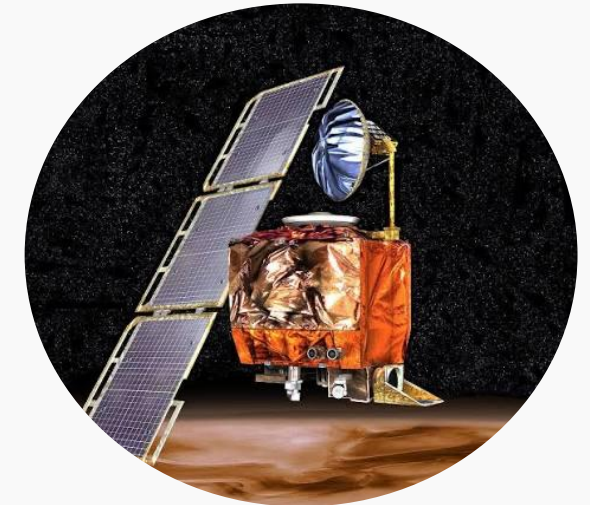


Reengineering the Bedrock: Data Readiness as the Foundation for AI Interoperability and Analytic Superiority



Mars Climate Orbiter (1999)

Every course correction nearly 4.5x weaker than calculated



\$881 M
25% of
workforce

25 Feb 2021: Zestimate – a mature, well-validated model –
No internal representation for depreciation.
Went from advisory (look see) to transactional (binding).
Model's technical uncertainty flag not used in workflow.

***Model capability didn't fail in either example
– the data's meaning or the workflow around it did.***

AI-Ready Data

AI-Ready Data

“Data that is not just machine-readable, but machine-understandable; data that is enriched with contextual metadata and organized in interpretable standard formats for utilization by AI systems.”

[AI and Open Government Data Assets Working Group (January 16, 2025). Generative Artificial Intelligence and Open Data: Guidelines and Best Practices. Department of Commerce, Washington, DC.]

Data plumbing + ecosystem readiness.

AI is treated as a procurement box. It needs to be understood as a maturity state.

“Having the model alone doesn’t change your workflows or how you operate. You need people who can combine the technology with what’s actually happening in the business and implement those changes.”

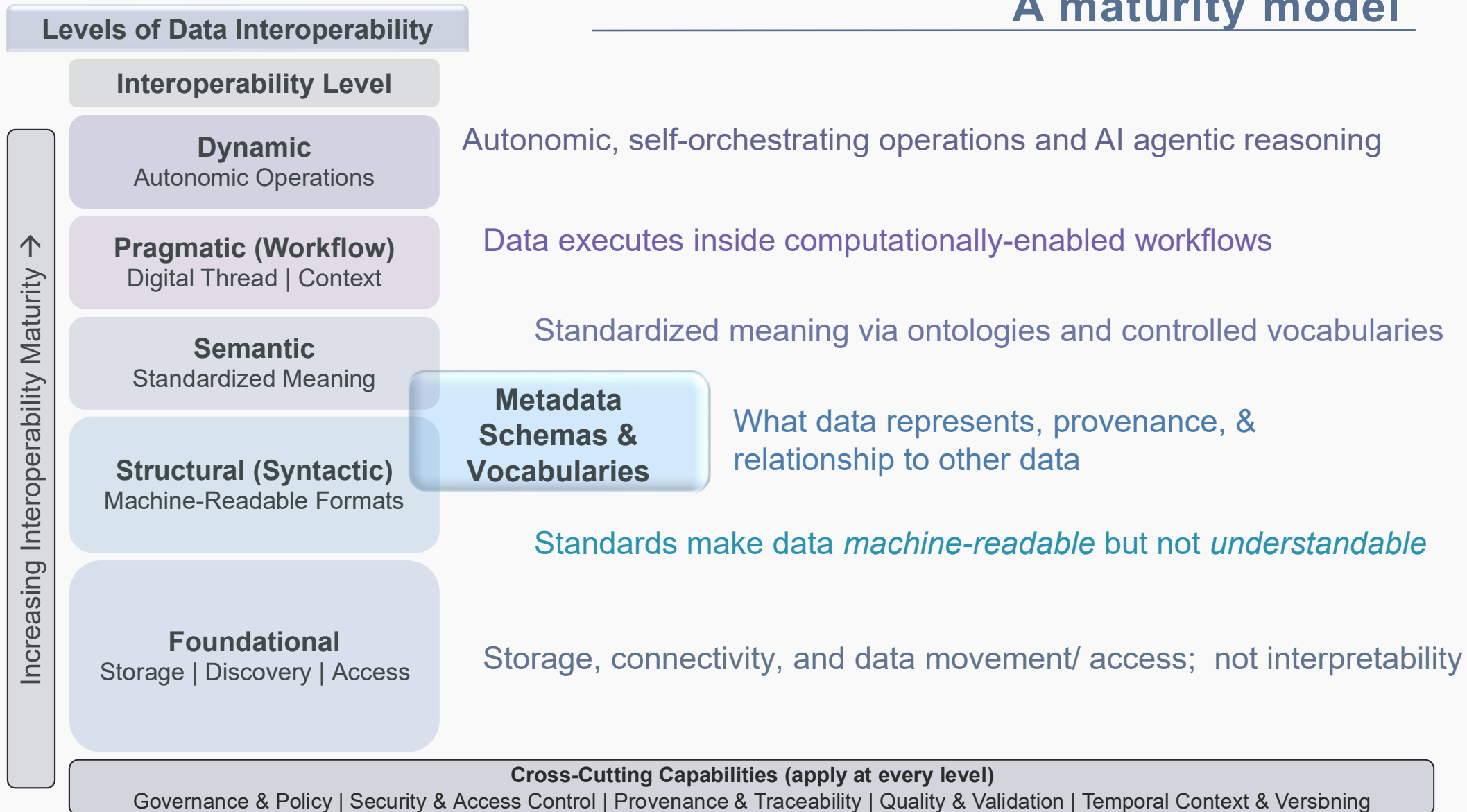
~ Marc Nachmann, Goldman-Sachs [CNBC Interview, 05/04/2026]

Levels of Data Interoperability: A maturity model

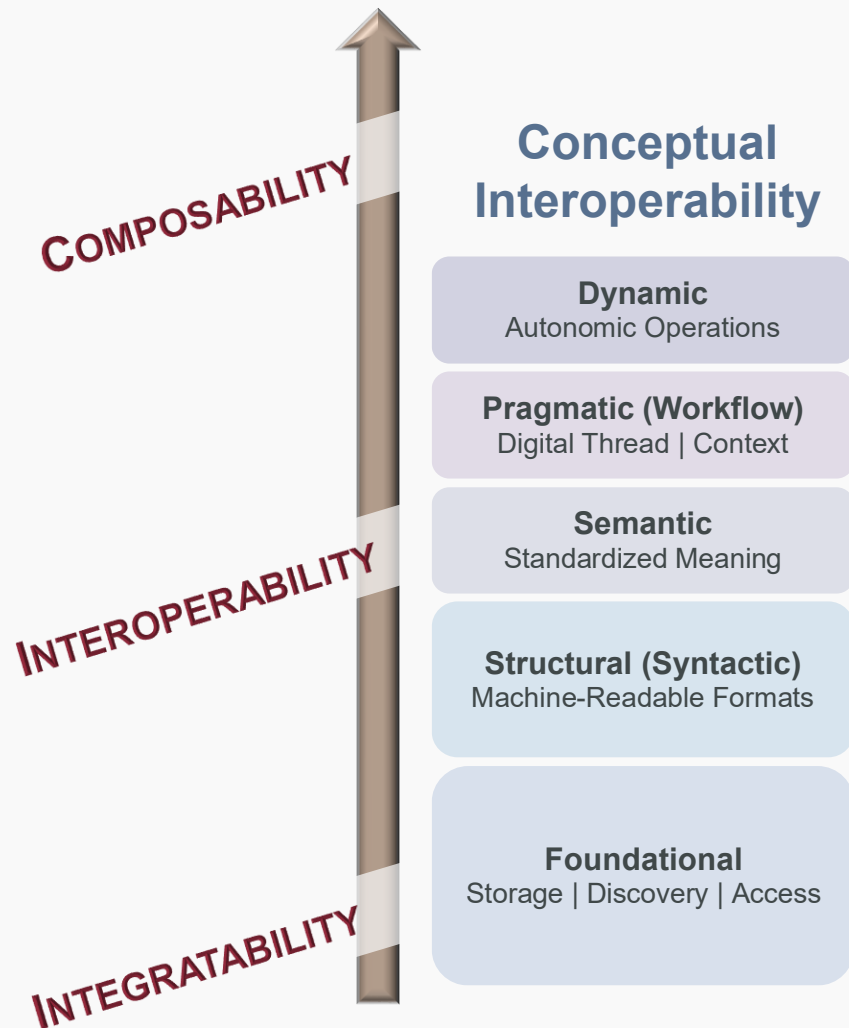
SERC's
adaptation of
Wang & Tolk's
M&S
interoperability
model
to
**data-centric
maturity***

**Evolutionary*

VAULTIS
—
establishing the
basis for data
exchange and use

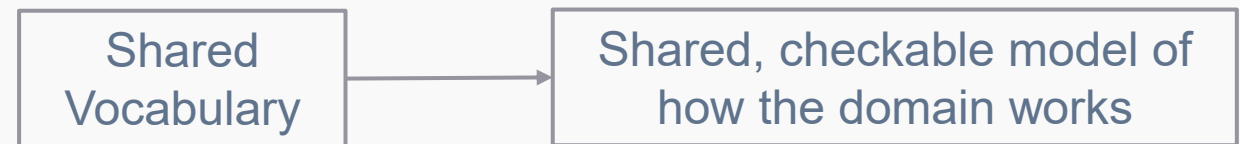


What happened to conceptual interoperability?



Pure semantics formalize vocabulary.

Computational ontologies formalize logical relationships and constraints in a form a reasoner can check for consistency and use to infer new facts.



An ontology is conceptual interoperability expressed computationally

BUT –

Formal ontologies are the mechanism by which conceptual interoperability becomes achievable and inspectable, not the mechanism by which it is guaranteed!

Ontology alignment is important!

Levels of Data Interoperability x AI Tech Stack Layers

Increasing Interoperability Maturity →

Interoperability Level	AI Tech Stack Layer	Key Standards & Tools
Dynamic Autonomic Operations	AI Reasoning & Generation Agentic AI Autonomic Processes Condition-Based Algorithms	LLM/ SLM AI Agents Prompt Engineering Autonomous Decision Orchestration Reinforcement/ Feedback Loops
Pragmatic (Workflow) Digital Thread Context	Knowledge Representation Linked Data & Knowledge Graphs Context Propagation & State Mgt	RDF, JSON-LD Property Graphs & Triplestores Workflow Orchestration Engines Impact Analysis & Change Mgt Tools
Semantic Standardized Meaning	Semantic Standards Ontologies & Taxonomies Meaning, Context, & Relationships	OWL, RDFS SKOS Controlled Vocabularies Semantic Classification & Tagging Cross-Domain Ontology Alignment
Structural (Syntactic) Machine-Readable Formats	Metadata & Data Models Data About Data Structure Definitions	Dublin Core, DCAT XML/JSON Schema Metadata Catalogs
	Data Serialization Syntactic Standards	JSON, XML, CSV, Parquet Protocol Buffers Open API Specs
Foundational Storage Discovery Access	Transport & API How Data Moves Between Systems Networking & Exchange	REST, GraphQL HTTP/HTTPS Message Queues Authentication (CAC, OAuth) API Gateways Data Discovery Catalogs & Registries
	Network & Infrastructure Physical & Network Connectivity Storage (Where Data Lives)	TCP/IP Cloud Storage Edge Computing Zero Trust Network Architecture
Cross-Cutting Capabilities (apply at every level) Governance & Policy Security & Access Control Provenance & Traceability Quality & Validation Temporal Context & Versioning		

What does this mean for us?

Interoperability Level

Dynamic
Autonomic Operations

Pragmatic (Workflow)
Digital Thread | Context

Semantic
Standardized Meaning

Structural (Syntactic)
Machine-Readable Formats

Foundational
Storage | Discovery | Access

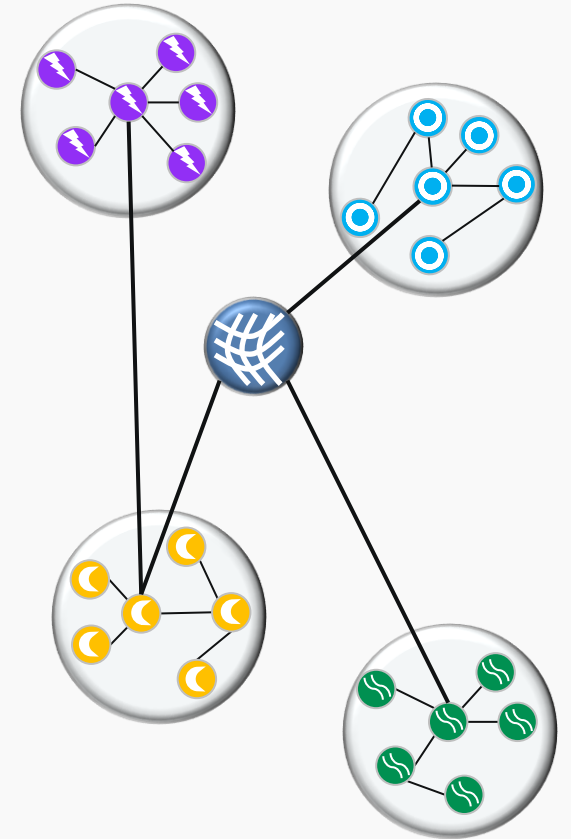
Levels are structurally cumulative, but do not require completeness to start the next; not predictive of the next.

Third-party environments or integration platforms do not guarantee enterprise interoperability.

The advisory-to-autonomous jump is a discontinuity. Required maturity jumps sharply at this boundary.

Organizations can build technical sophistication for uncertainty flags and still have zero workflow or governance sophistication for acting on it.

Frontier model capability advancing faster than most organization's data/ecosystem maturity. The latter will drive AI value.





ACQUISITION INNOVATION
RESEARCH CENTER

Thank you!

Email the presenter

✉ vsitterl@stevens.edu

Stay connected with SERC/AIRC Online

