MBSE Systems Architecture Interoperability:

Taming the Model Zoo for the Manufacturing Digital Thread

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Presenters Bio

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Kyle Hall is a Product Data Interoperability Standards Specialist within Airbus Commercial Aircraft, based in Filton (Bristol), UK

Kyle graduated from the University of Bristol, majoring in Physics. Kyle joined Airbus in 2016, supporting the development of rapid and scalable surrogate modelling techniques and the MoSSEC common metadata standard (ISO 10303-243), eventually becoming the MoSSEC project lead in 2022.

Today Kyle is a key member of the Airbus transdisciplinary Engineering Architecture team, maturing and supporting the implementation of many new and innovative methodologies for Airbus' varied portfolio.

Presenters Abstract

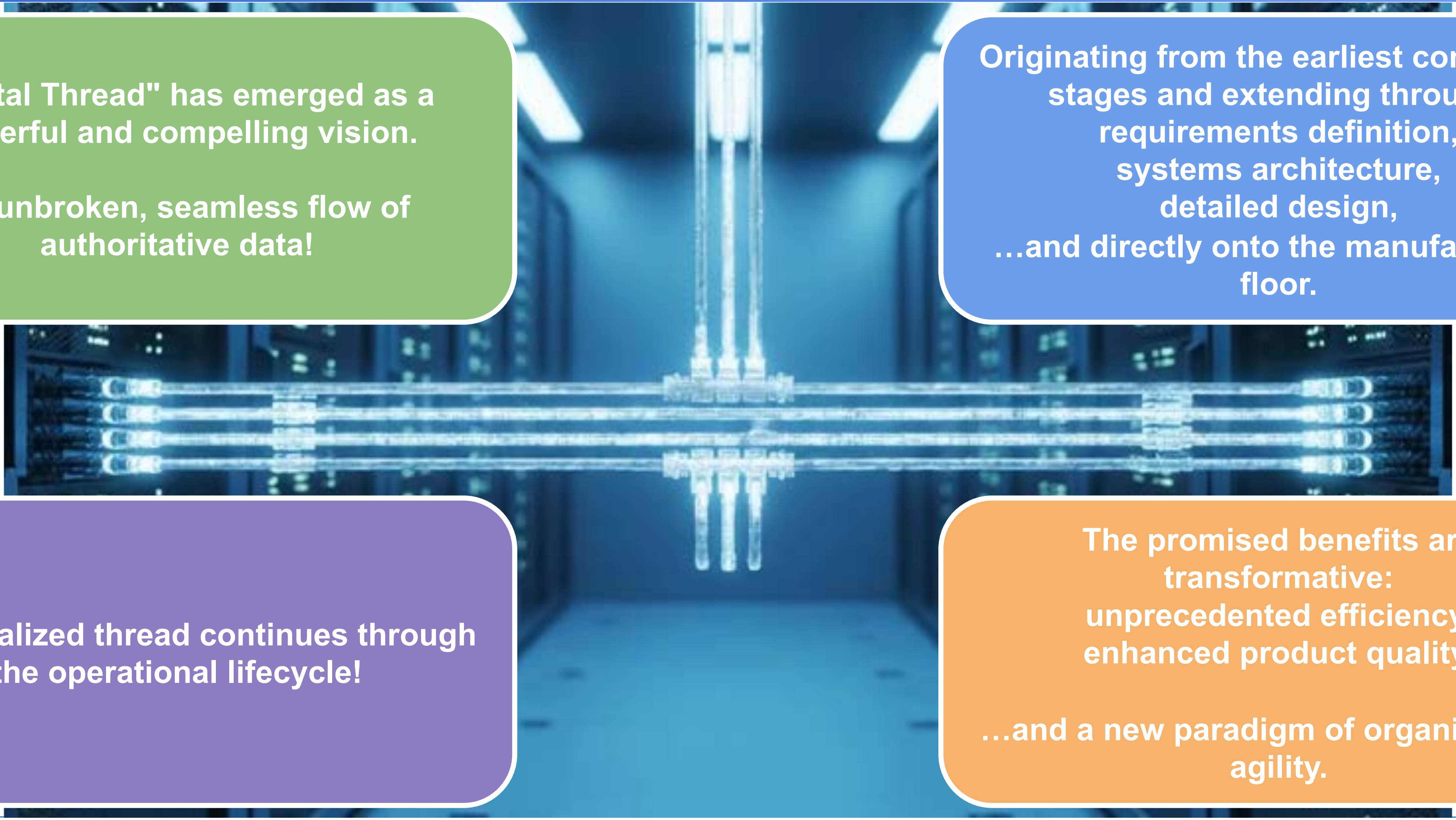
MBSE Functional and Logical architectures. Within PLM circles it's undeniably hot stuff, but **swapping those architectures between tools often feels like pulling teeth**, especially for colleagues in manufacturing where the shiny Digital Thread risks becoming Digital Spaghetti. The big faux-pas? **Thinking Tool B opening Tool A's file means that we understand each other.** Newsflash: that's compatibility, not the interoperability holy grail we need, and it's why collaboration stalls.

Right now, **the landscape for systems architecture frameworks resembles a bit of a free-for-all**. SysML v1 developers planned for ISO 10303-233 to be the foundational metamodel for systems architecture development, but reality check: most folks have adopted, tailored their own, or been forced to use somebody else’s metamodel (MagicGrid, Harmony, Arcadia, UAF, etc.) - and have associated their business processes accordingly to that framework.

So how do we get everyone to understand the same model, or at least parts of it? **True interoperability, the kind that would actually help clarify intent for manufacturing, needs more than file-format compatibility;** it needs standardized semantic interfaces. But forget boiling the ocean; **we need to understand HOW to agree on enough meaning for the job at hand – "selective agreement."**

The pitch? A collaborative, modular common metamodel – flexible building blocks, designed and assembled in an agile way. A stable and coherent foundation for building the robust digital threads manufacturing needs.

Introduction: From Digital Thread…



"Digital Thread" has emerged as a powerful and compelling vision.

An unbroken, seamless flow of authoritative data!

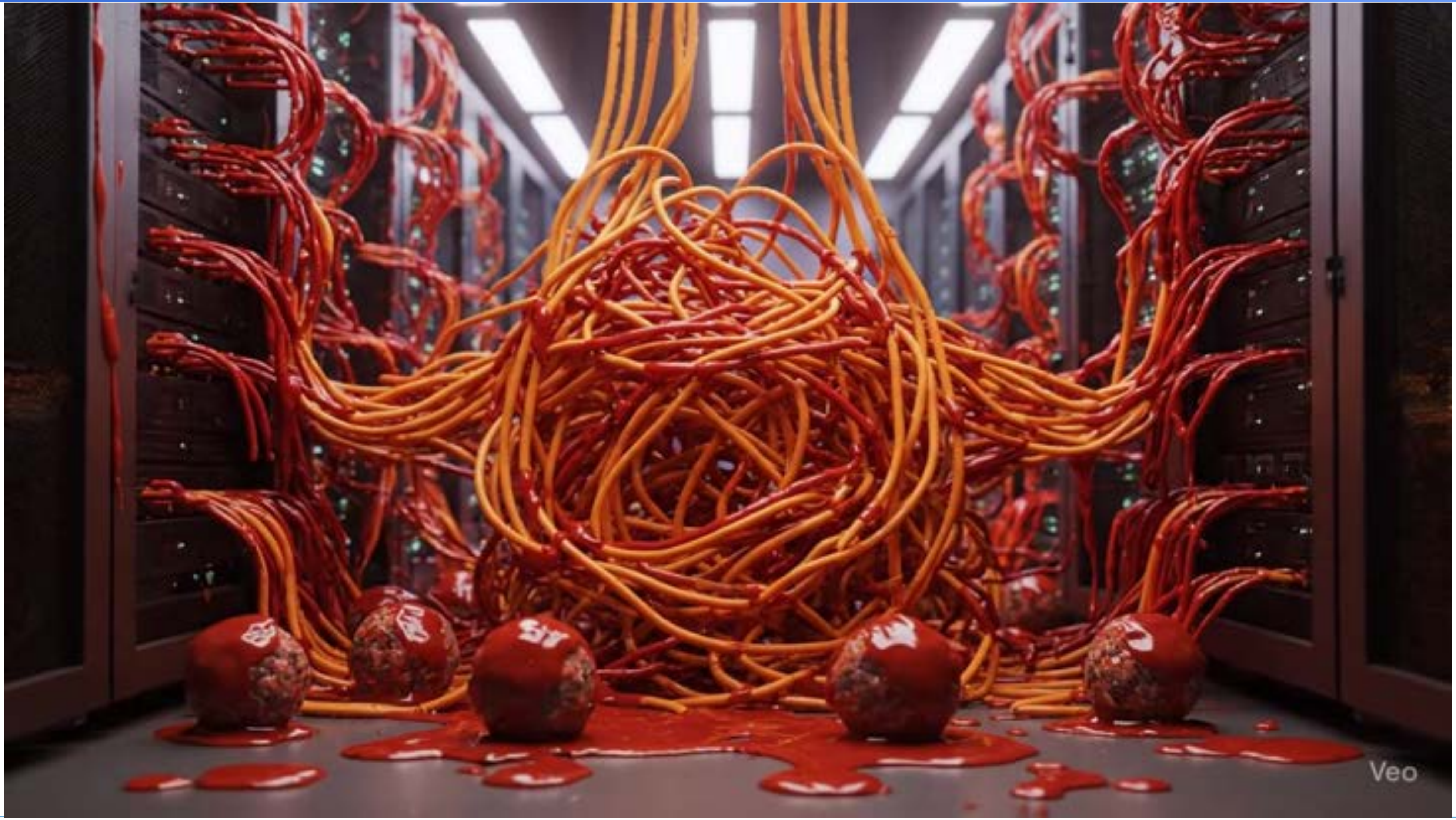
Originating from the earliest conceptual stages and extending through:
requirements definition,
systems architecture,
detailed design,
…and directly onto the manufacturing floor.

This idealized thread continues through the operational lifecycle!

The promised benefits are transformative:
unprecedented efficiency,
enhanced product quality,

…and a new paradigm of organizational agility.

Introduction: From Digital Thread…To…



Introduction: From Digital Thread…To… Digital Spaghetti

For many organizations, this elegant vision remains elusive.

The practical reality is often far removed from the ideal.

Less coherent thread's and more chaotic "Digital Spaghetti"

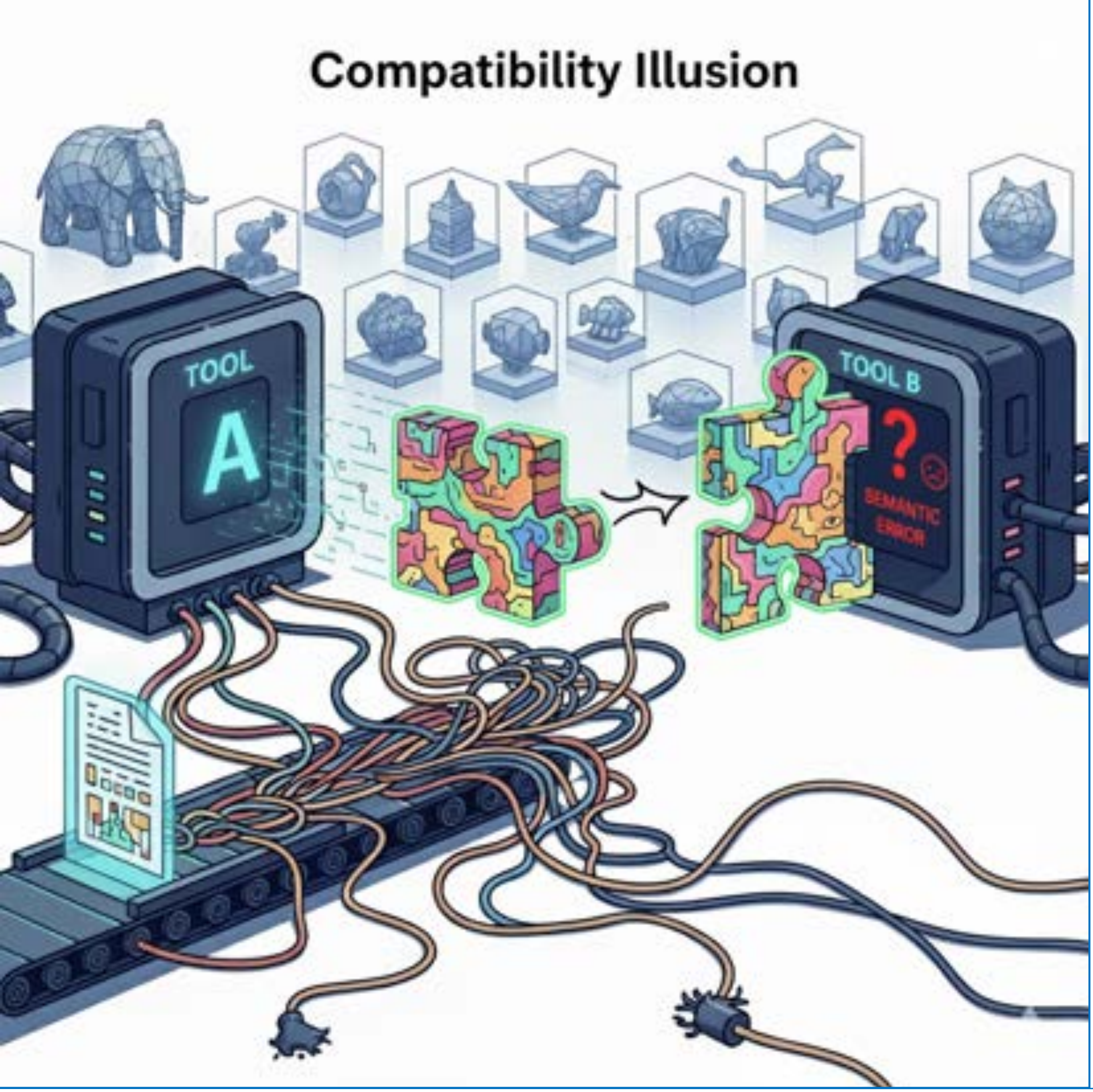
Each strand of spaghetti in this tangled mass represents bespoke, point-to-point data translations; a fragile script, or a manual re-entry of data between the disparate tools

The result is a brittle, inefficient, and opaque data ecosystem,

Laden with technical debt and prone to failure every time a piece of software is updated.

This is not a thread; it is a liability.

Introduction: From Digital Thread…To… Digital Spaghetti - The compatibility illusion



The "big faux-pas":
Because Tool B can open a file generated by Tool A, meaningful communication has occurred.

This is the **"Compatibility Illusion"**

Mistaking the ability to parse syntax for the ability to comprehend semantics.

A fundamental shift in perspective is required!

The challenge is not merely technical, to be solved by yet another file format.

A managed, standards-based strategy for achieving true semantic interoperability is required!

Defining the Interoperability Challenge - Syntactic Interoperability

Syntactic Interoperability is often mistaken for the end goal

Syntactic Interoperability *(noun phrase)* according to Wikipedia:

Syntactic Interoperability is the ability of systems to exchange structured data, ensuring that the grammar and format of the data are correctly parsed.

For example:
An MES (Manufacturing Execution System) could successfully import an XML file with no syntax errors - Syntactic interoperability is achieved!

However this does not guarantee the MES system understands the meaning or intent of the data within the XML file…

You can read the notes, but can’t guarantee you will understand the music!

This is the realm of compatibility, a necessary but profoundly insufficient foundation for a digital thread.

Defining the Interoperability Challenge - Semantic Interoperability

Semantic Interoperability, by contrast, is the "holy grail" of data exchange.

Semantic Interoperability *(noun phrase)* according to Wikipedia:

Semantic Interoperability is the ability for systems to exchange data with unambiguous, shared meaning.

This necessitates a “controlled, shared vocabulary” and rich metadata that links each data element to a common, formally defined ontology.

Considering the previous example:
An MES is now successfully importing an XML file and understanding that a specific set of numerical values represents a specific geometric tolerance, which in turn dictates a particular inspection protocol.

This is the level of understanding required!

A tour of the MBSE Semantic Framework “Model Zoo”

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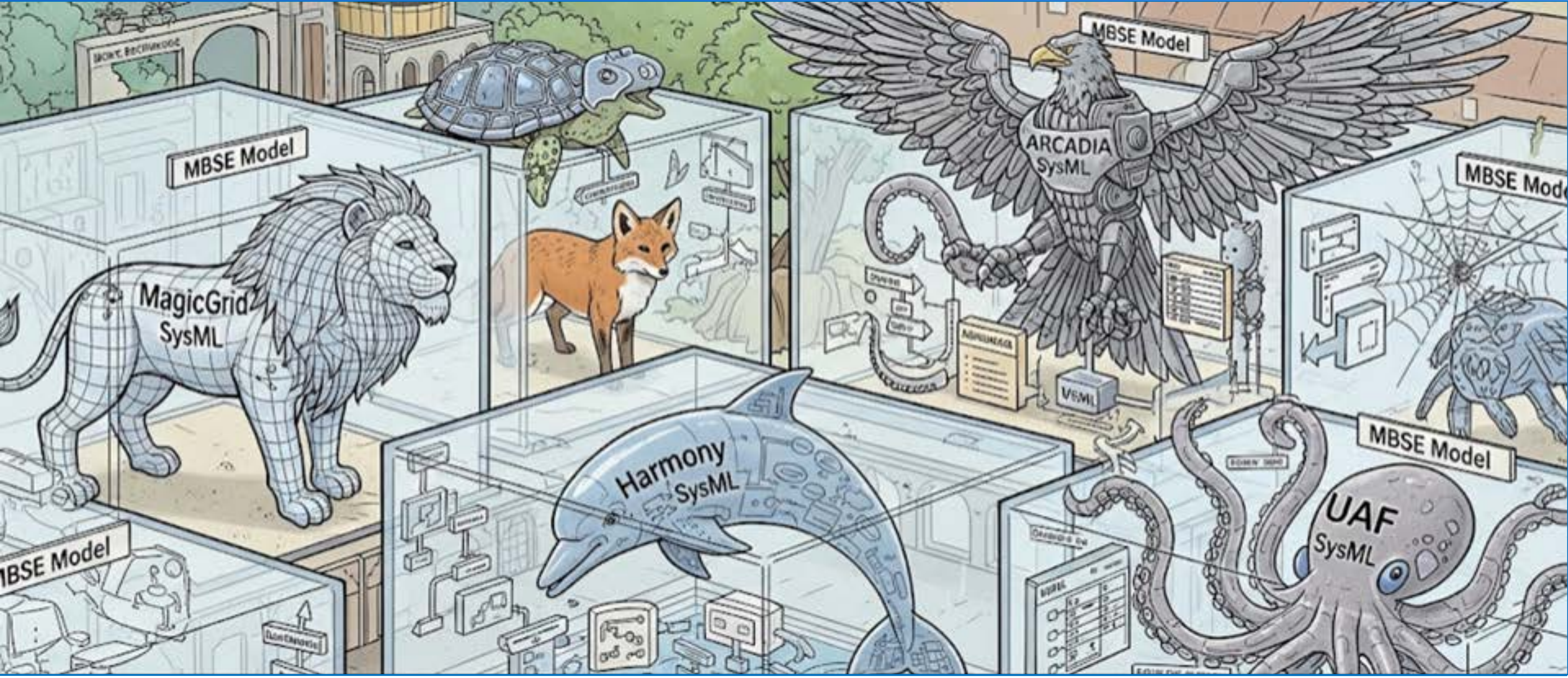

A tour of the MBSE Semantic Framework "Model Zoo"

Framework	Primary Focus	Differentiator?	Underlying Syntax
MagicGrid	Project organization & workflow	Dashboard-like grid (Problem/ Solution/Implementation)	SysML
Harmony	Model-driven development process	Early verification using executable state machine models	SysML
ARCADIA	Systems architecture definition	Viewpoint-driven with tight tool coupling (Capella)	Custom Domain-Specific Language (DSL): A unique language with its own ontology and concepts, implemented in the Capella tool.
UAF	Enterprise architecture & Systems of Systems	Evolved from already standardized military frameworks (DoDAF/MODAF)	Specific UML/SysML profile

A tour of the MBSE Semantic Framework "Model Zoo"

Framework		Differentiator?	Underlying Syntax
		Dashboard-like grid (P... / ...n/ ...tatio...)	SysML
		...veri... ...using ...ble ...ch ...m	SysML
		...dri... ...g ...upling (...ella)	Custom Domain-Specific Language (DSL): A unique language with its own ontology and concepts, implemented in the Capella tool.
		Evolv... ...lready stand... ...ilitary fra... ...rks (DoDAF/MODAF)	Specific UML/SysML profile

How about SysML v2 and a common Ontology library to support ALL frameworks?

The unfulfilled promise of a Systems Engineering Lingua Franca - ISO 10303-233:2012

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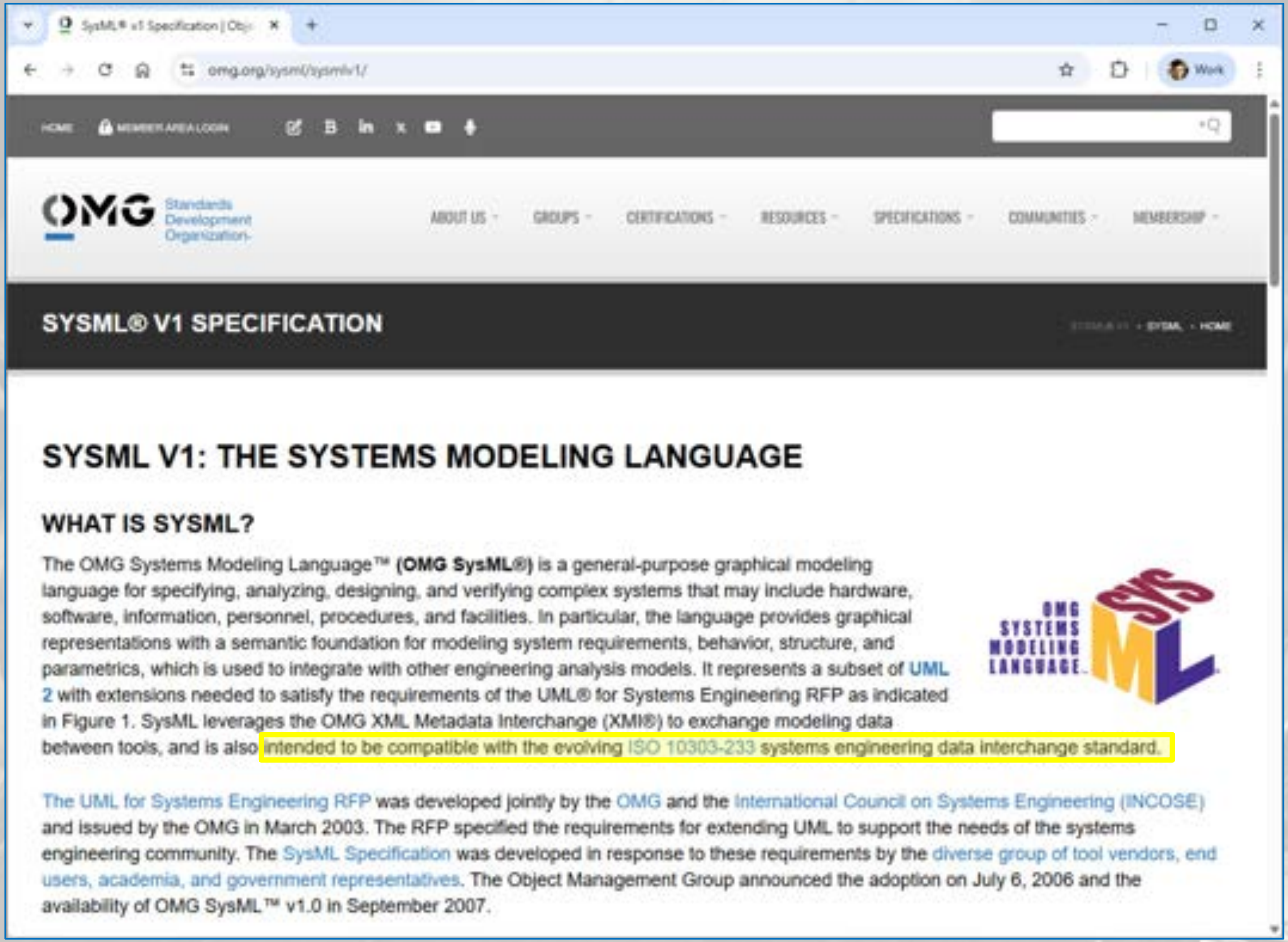

omg.org/sysml/sysmlv1/

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OMG Standards Development Organization

ABOUT US · GROUPS · CERTIFICATIONS · RESOURCES · SPECIFICATIONS · COMMUNITIES · MEMBERSHIP

SYSML® V1 SPECIFICATION

SYSML V1: THE SYSTEMS MODELING LANGUAGE

WHAT IS SYSML?

The OMG Systems Modeling Language™ **(OMG SysML®)** is a general-purpose graphical modeling language for specifying, analyzing, designing, and verifying complex systems that may include hardware, software, information, personnel, procedures, and facilities. In particular, the language provides graphical representations with a semantic foundation for modeling system requirements, behavior, structure, and parametrics, which is used to integrate with other engineering analysis models. It represents a subset of UML 2 with extensions needed to satisfy the requirements of the UML® for Systems Engineering RFP as indicated in Figure 1. SysML leverages the OMG XML Metadata Interchange (XMI®) to exchange modeling data between tools, and is also intended to be compatible with the evolving ISO 10303-233 systems engineering data interchange standard.

OMG SYSTEMS MODELING LANGUAGE SYS ML

The UML for Systems Engineering RFP was developed jointly by the OMG and the International Council on Systems Engineering (INCOSE) and issued by the OMG in March 2003. The RFP specified the requirements for extending UML to support the needs of the systems engineering community. The SysML Specification was developed in response to these requirements by the diverse group of tool vendors, end users, academia, and government representatives. The Object Management Group announced the adoption on July 6, 2006 and the availability of OMG SysML™ v1.0 in September 2007.

A framework for understanding: Stakeholders, Concerns, and Viewpoints: ISO 42010

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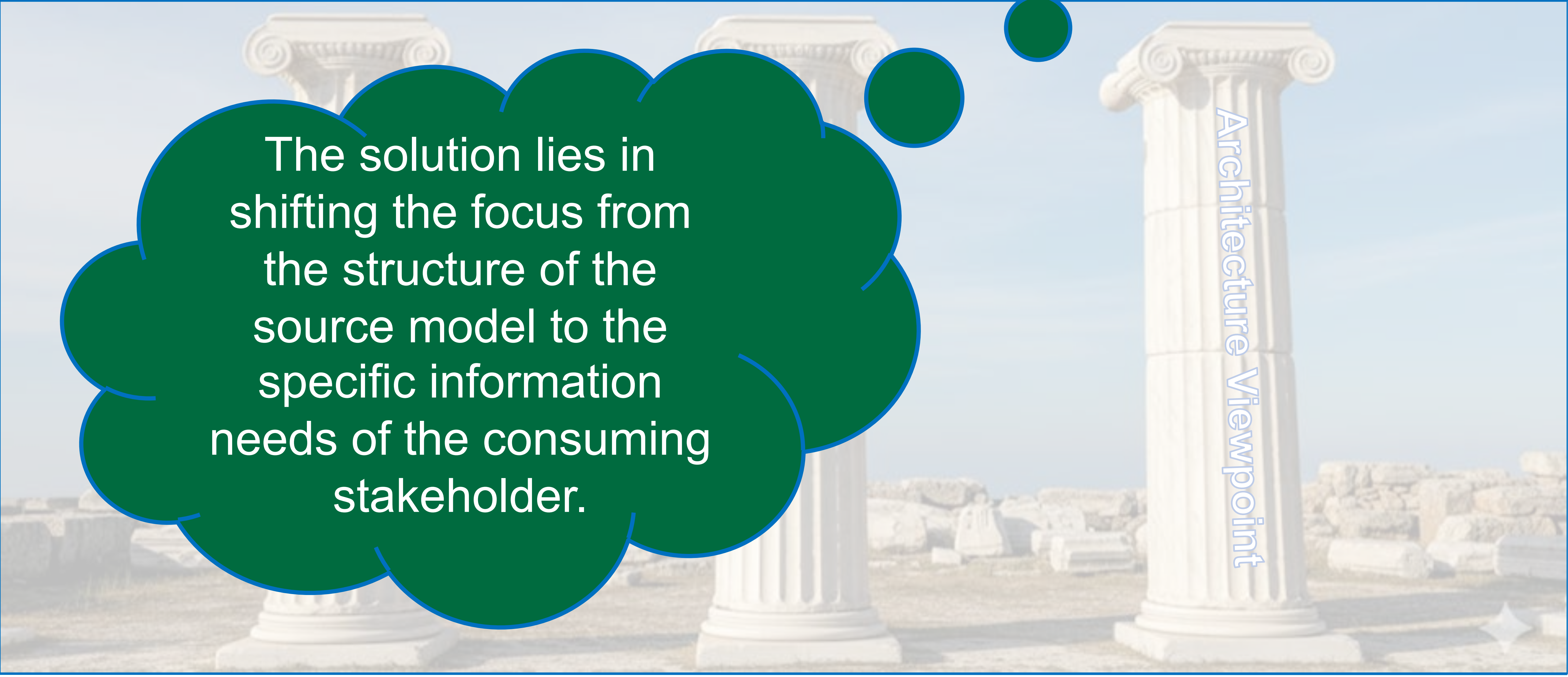


The solution lies in shifting the focus from the structure of the source model to the specific information needs of the consuming stakeholder.

A framework for understanding: Stakeholders, Concerns, and Viewpoints: ISO 42010

The Three Pillars of ISO 42010		
Pillar	**Description**	**Example**
Stakeholder	An "individual or organization... having a right, share, claim, or interest in a system"	Manufacturing Process Planner or Quality Assurance Engineer
Concern	A "matter of interest or importance to a **stakeholder**"	What is the required sequence of assembly for this sub-system? What materials are specified? Are there any special handling requirements?
Architecture Viewpoint	A "specification of the conventions for constructing and using a view"	A "Manufacturing Process Viewpoint" would formally specify that any conforming view must contain the logical product structure, all associated Product and Manufacturing Information (PMI), and material specifications.

A framework for understanding: Stakeholders, Concerns, and Viewpoints: ISO 42010

A **Stakeholder** has a set of **Concerns**.

To address these, an **Architecture Viewpoint** is defined.

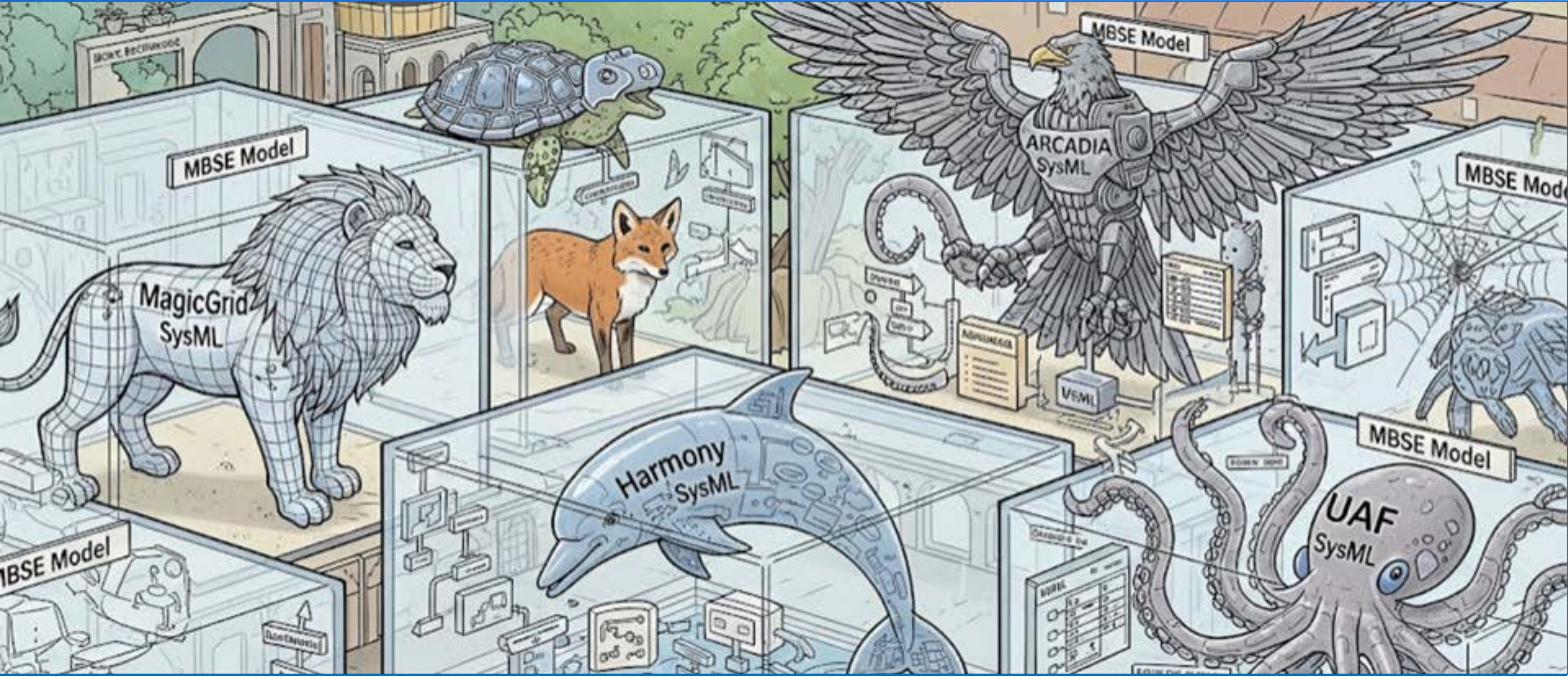
This **Architecture Viewpoint** then governs the creation of one or more **Architecture Views**

Architecture Views contain the specific information extracted from the model to address the **stakeholders concerns.**

i.e. A Standardised Protocol of Selective Agreement

bypassing the complexities of the Model Zoo by focusing solely on the information that actually needs to cross the boundary between disciplines.

But, what else caused the MBSE Semantic Framework “Model Zoo”? Is there more?



But, what else caused the MBSE Semantic Framework “Model Zoo”? Is there more?

Solving the interoperability problem requires more than just a clever technical approach

The models, interfaces, and the resulting digital thread are not merely transient project files; they are high-value, long-lived corporate assets that must be managed with the same rigor as physical plant and equipment.

A Shift in Perspective: From Files to Assets with ISO 55000

A Shift in Perspective: From Files to Assets with ISO 55000 integrated through ISO 15288

This asset management strategy is not an abstract overlay but is directly integrated within the standard System Life Cycle Processes defined in ISO/IEC/IEEE 15288

A Shift in Perspective: From Files to Assets with ISO 55000 integrated through ISO 15288

FILES

ASSETS

Principles of Digital Asset Management and Interoperability must be applied within ISO 15288:	
Process	**Importance**
6.4.4 **System Architecture Definition**	Where the various **stakeholder concerns** are identified and the corresponding **viewpoints** must be defined (i.e. as per ISO 42010)
6.3.5 **Configuration Management**	Essential for managing the baselines of the shared **views** and the modular interfaces, ensuring that all stakeholders are working from an **authoritative source**
6.3.6 **Information Management**	Governs the methods for storing, protecting, and providing access to the model data, treating the information itself as a **managed asset**
6.2.6 **Knowledge Management**	Enabling the reuse of proven solutions, such as **standardized viewpoint definitions** and **modular metamodel components**, across multiple projects and programs

A Shift in Perspective: From Files to Assets with ISO 55000 integrated through ISO 15288

FILES

Principles of Digital Asset Management and Int…	
Process	
6.4.4 System Architecture Definition	…here
6.3.5 Configuration Management	Es…
6.3.6 Information Management	Gov…
6.2.6 Knowledge Management	Enabl… and **modu…** …**initions** …ograms

Consider the approach taken in your organizations towards ISO 15288 application… Does it meet ISO 55000?

Before we put everything together… the models must persist beyond the software…

Enter EN/NAS 9300 LOTAR

LOTAR principles directly support the preservation of the digital thread as a trustworthy asset:

Invariance	The information content of an archived object must not be changed during storage or migration.
Standardized Open Neutral Formats	LOTAR strongly advocates for archiving data in open, standardized, neutral formats like STEP (ISO 10303) rather than proprietary native formats.
Verification and Validation	The process requires storing Validation Properties—such as mass, volume, or center of gravity—along with the model. Upon retrieval, these properties can be recalculated and compared to the stored values to provide mathematical proof that the model's content and semantics have been perfectly preserved

We have almost everything we need for Nirvana

By synthesizing these standards, a holistic strategy emerges:

Achieving an understanding between Systems Architecture considers the Stakeholders, Concerns and Architecture Views on a case by case basis

Organizations must manage their digital models as Assets (ISO 55000), within their established engineering Processes (ISO 15288)

With a concrete plan for long-term Preservation (EN 9300) to ensure these assets deliver value across the entire product lifecycle.

We have almost everything we need for Nirvana

Challenge / Risk	Description	Standards-Based Solution
Semantic Misinterpretation	Manufacturing misinterprets design intent, leading to rework and quality issues.	**ISO 42010 Viewpoints:** Define an unambiguous, agreed-upon "view" of the data that directly addresses manufacturing's concerns.
Data Obsolescence	The native CAD/MBSE tool becomes obsolete, making the model unreadable in 15 years for a mid-life upgrade.	**EN 9300 (LOTAR):** Mandate long-term archiving in a standardized, open, neutral format (e.g., STEP) independent of any single tool vendor
Lack of Trust / Data Corruption	Data is retrieved from the archive, but there's no proof it's identical to the certified original.	**EN 9300 (LOTAR):** Use of Invariance principles and storage of Validation Properties to mathematically verify the integrity of the retrieved asset
Process Chaos	Interoperability efforts are ad-hoc, project-specific, and not repeatable across the enterprise.	**ISO 15288 & ISO 55000:** Embed interoperability and data preservation into formal Information Management and Configuration Management processes as part of a holistic Asset Management System

The Blueprint: A Collaborative, Modular Metamodel - Modular Ontology Engineering

Instead of creating one massive, all-encompassing ontology for systems engineering, use ontology decomposition to extract a minimal, sufficient set of concepts and relationships needed for a specific domain, such as manufacturing. Each module is a self-contained ontology for a specific purpose.

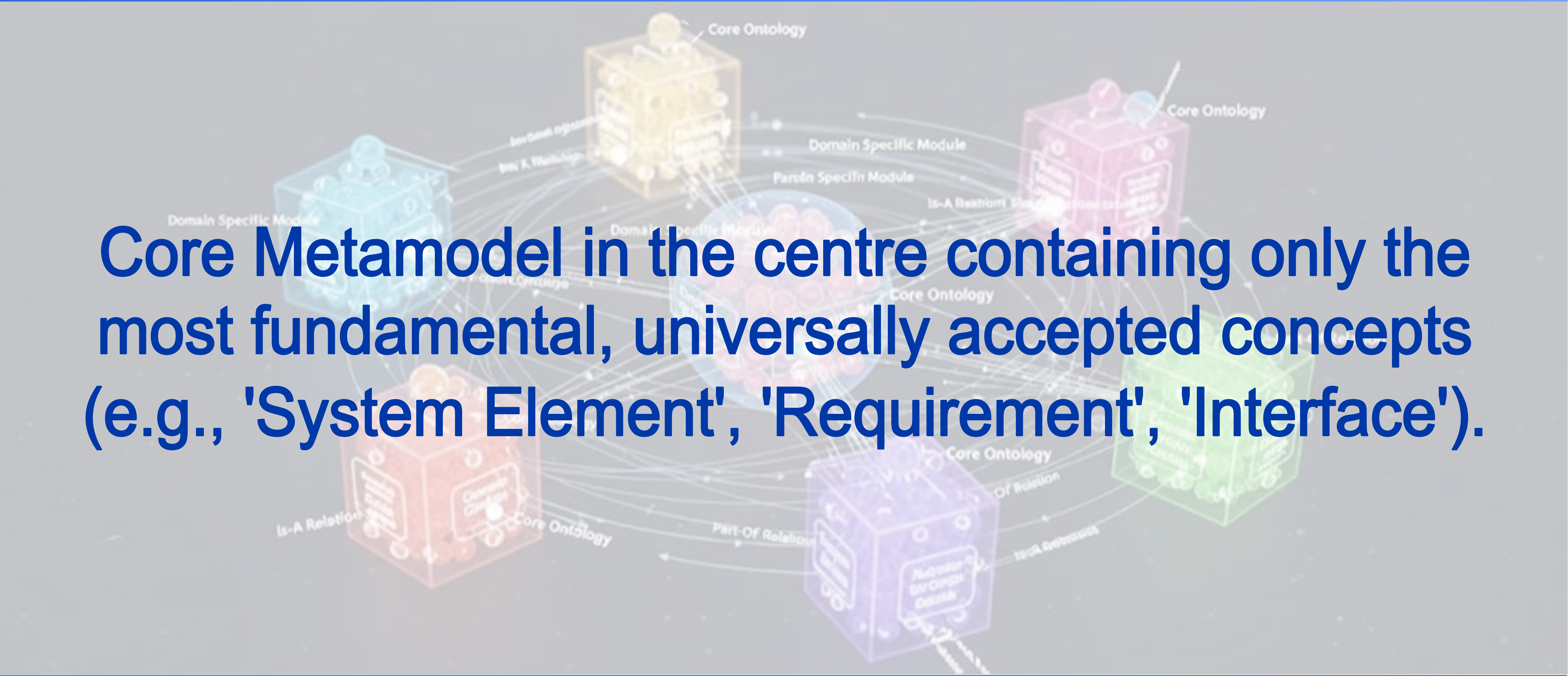
Federated Model Ecosystem

Authoritative Data remains in native tools

Distributed models are linked through standardized modular interfaces (think use of MoSSEC)

This is the technical embodiment of "selective agreement"

The Blueprint: A Collaborative, Modular Metamodel - Visualizing the solution

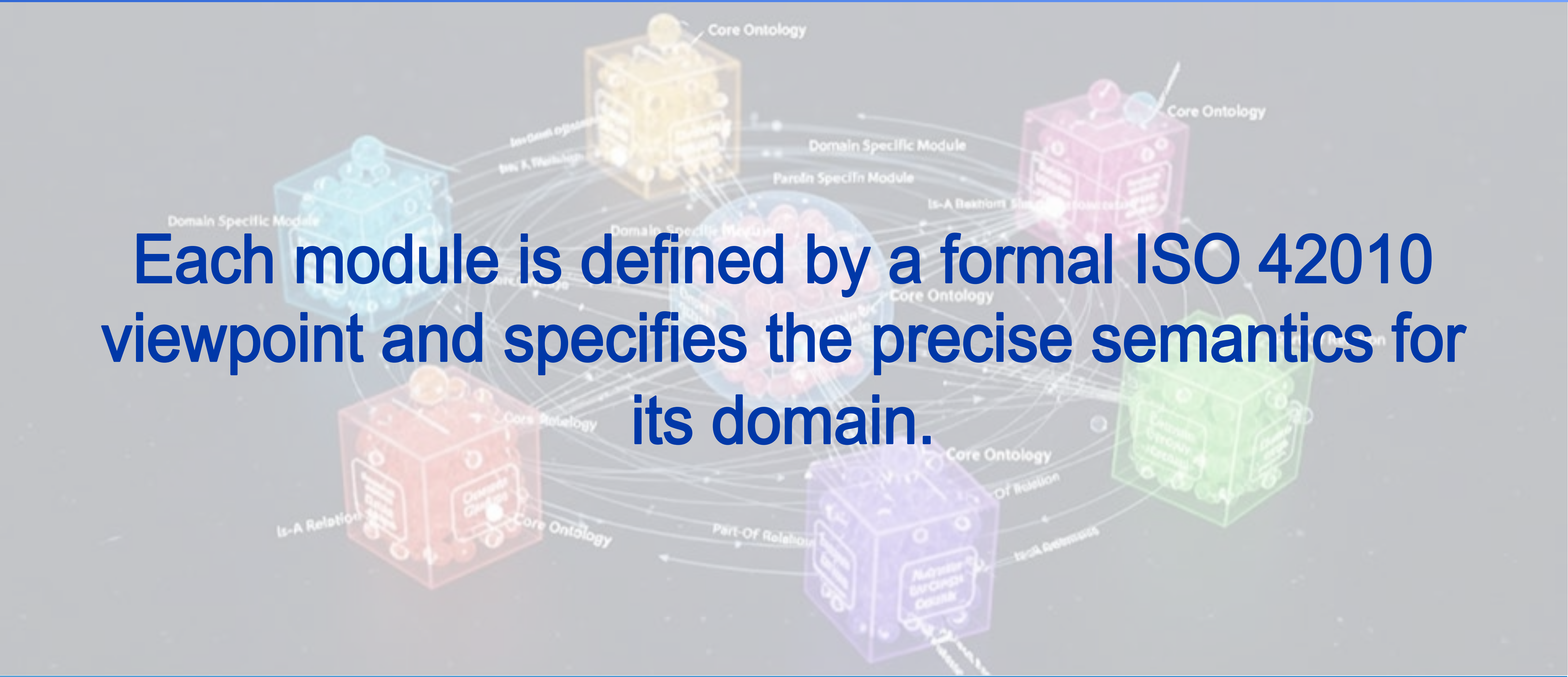


Core Metamodel in the centre containing only the most fundamental, universally accepted concepts (e.g., 'System Element', 'Requirement', 'Interface').

The Blueprint: A Collaborative, Modular Metamodel - Visualizing the solution

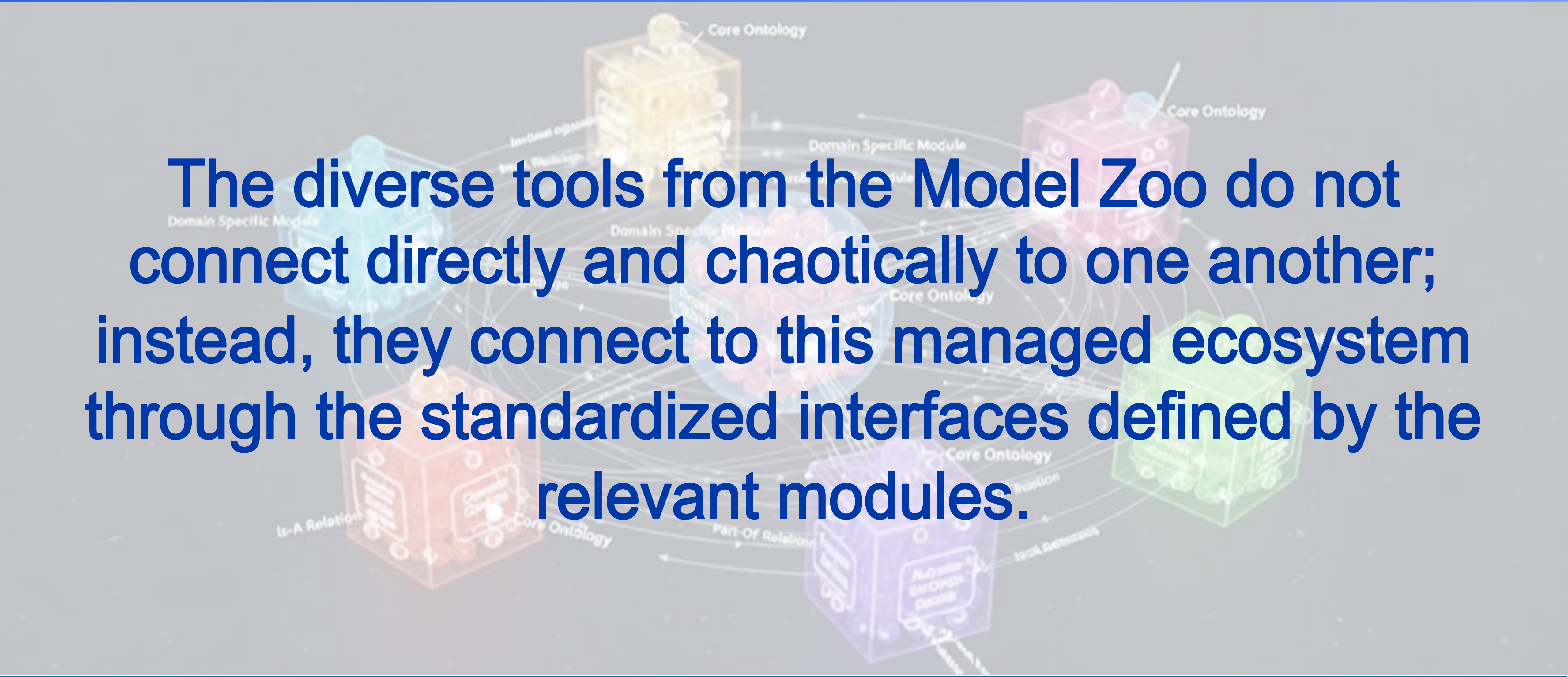
Plugging into this core are multiple, independently managed Domain Modules
(e.g., 'Manufacturing Module',
'Safety Analysis Module',
'Verification & Validation Module').

The Blueprint: A Collaborative, Modular Metamodel - Visualizing the solution



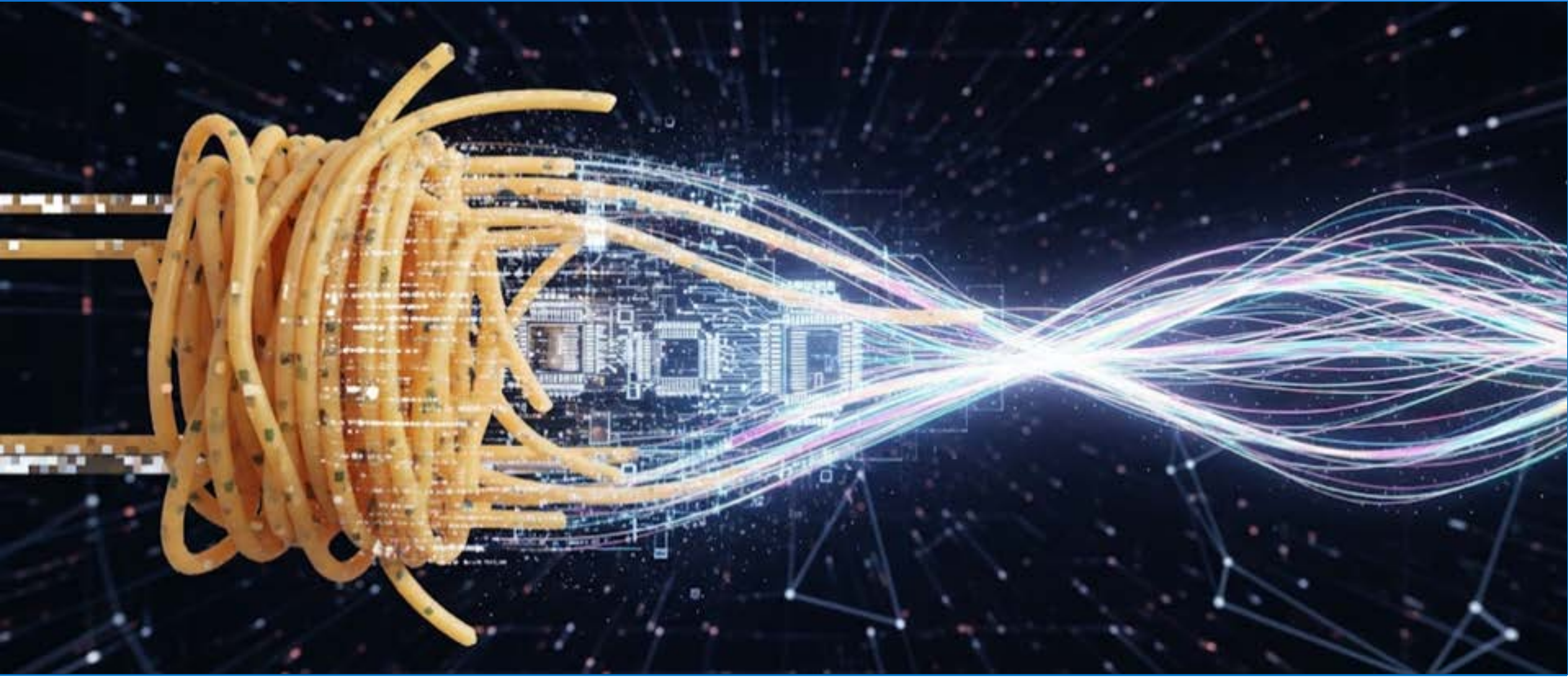
Each module is defined by a formal ISO 42010 viewpoint and specifies the precise semantics for its domain.

The Blueprint: A Collaborative, Modular Metamodel - Visualizing the solution



The diverse tools from the Model Zoo do not connect directly and chaotically to one another; instead, they connect to this managed ecosystem through the standardized interfaces defined by the relevant modules.

Conclusion



Conclusion

Agree Selectively:
As a community we MUST use the rigorous concepts of Stakeholders, Concerns, and Viewpoints from ISO 42010 to define the minimum necessary semantic interfaces for technical domains

Manage as an Asset:
Elevate the digital thread from a collection of files to a critical, long-lived business asset, applying the principles of ISO 55000 for value realization and ISO 15288 for process integration.

Preserve for the Future:
Ensure this asset retains its value and integrity for decades by implementing the robust preservation principles of EN 9300 (LOTAR), using open standards and verifiable data.

Open Source Community:
The INCOSE lead MBSE-IF initiative is opening the possibility to define these modular ontologies to redefine the future of what ISO 10303-233 should have been

The ultimate takeaway is that the solution to taming the Model Zoo is a new strategy, not just a new standard.

Any questions?

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INTEROPERABILITY

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