A Knowledge Graph Approach to Transforming to Digital Materiel Management

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Introduction

Vision

- **A digitally-empowered approach that drives model-based enterprise decision-making, leveraging authoritative models and data to ensure seamless stakeholder collaboration across the acquisition lifecycle.**

Challenge

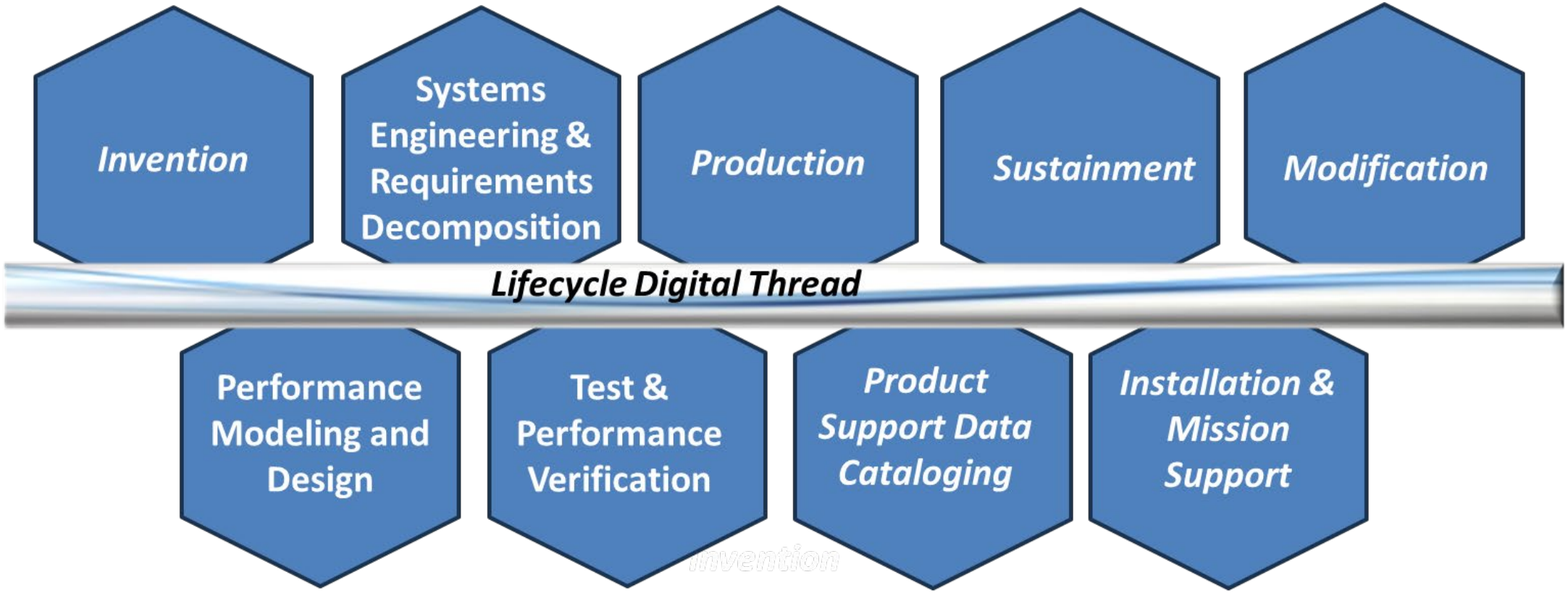
- **Emerging and Legacy systems have a wealth of developmental and operational data, but limited ability to derive knowledge from the data to maximize the transformation to Digital Materiel Management (DMM)**

Objective

- **Introduce a Knowledge-Graph (KG) Based Augmented Knowledge Management (AKM) capability that will enable organizations to unlock stored information to provide a single gateway to Knowledge needed to make scalable, accelerated, informed, authoritative decisions.**

Digital Materiel Management
An Accelerated Future State

"DMM revolutionizes the ability of each functional to accelerate within and across functional domains. *Integrated tools built on models, data, and infrastructure* yield radical transparency throughout government and industry teams. That omniscience results in functional teams that can collaborate like never before to accelerate integrated capability delivery. "



[Digital Materiel Management: An Accelerated Future State (defense.gov)]

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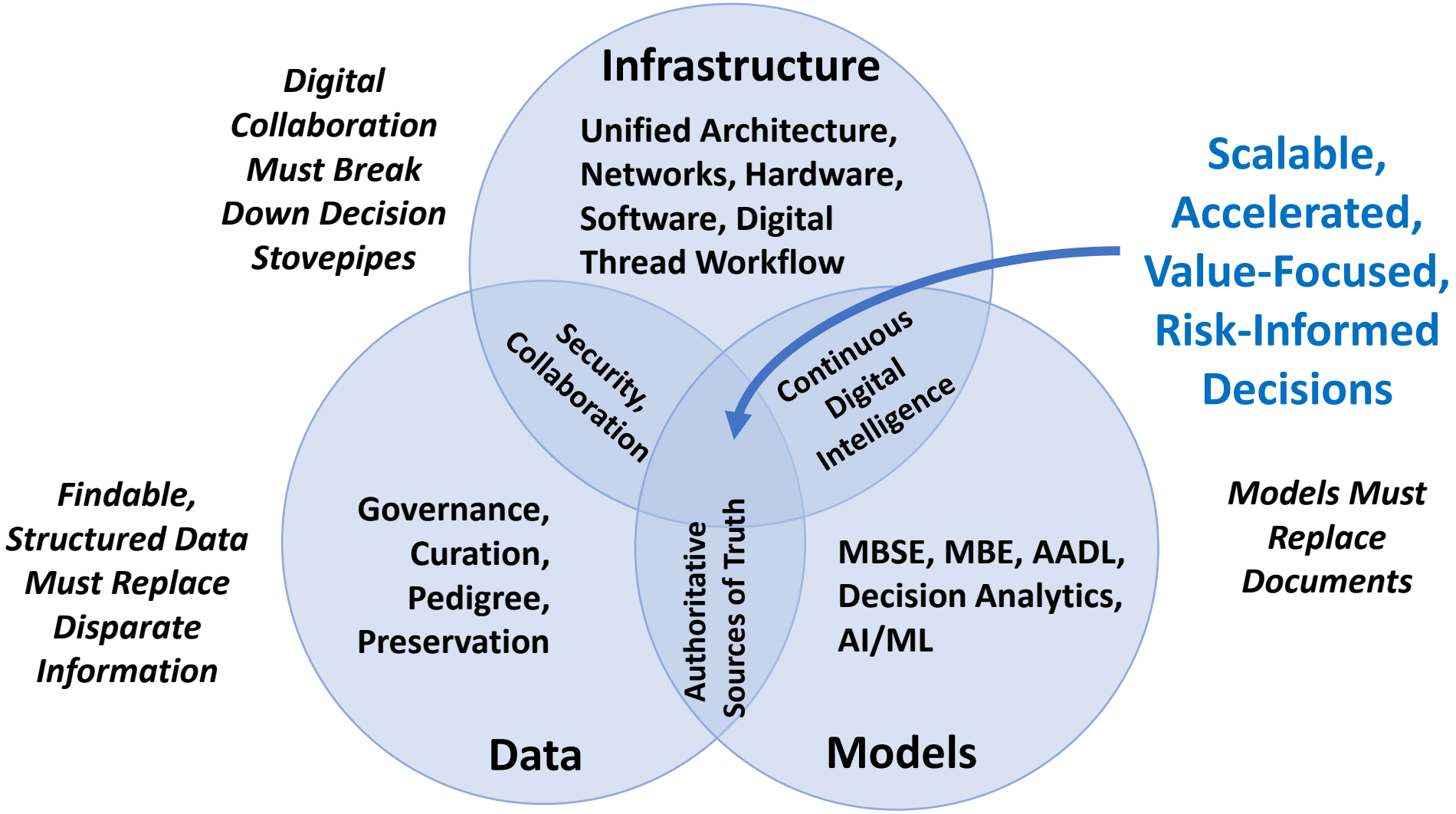
DMM Foundation

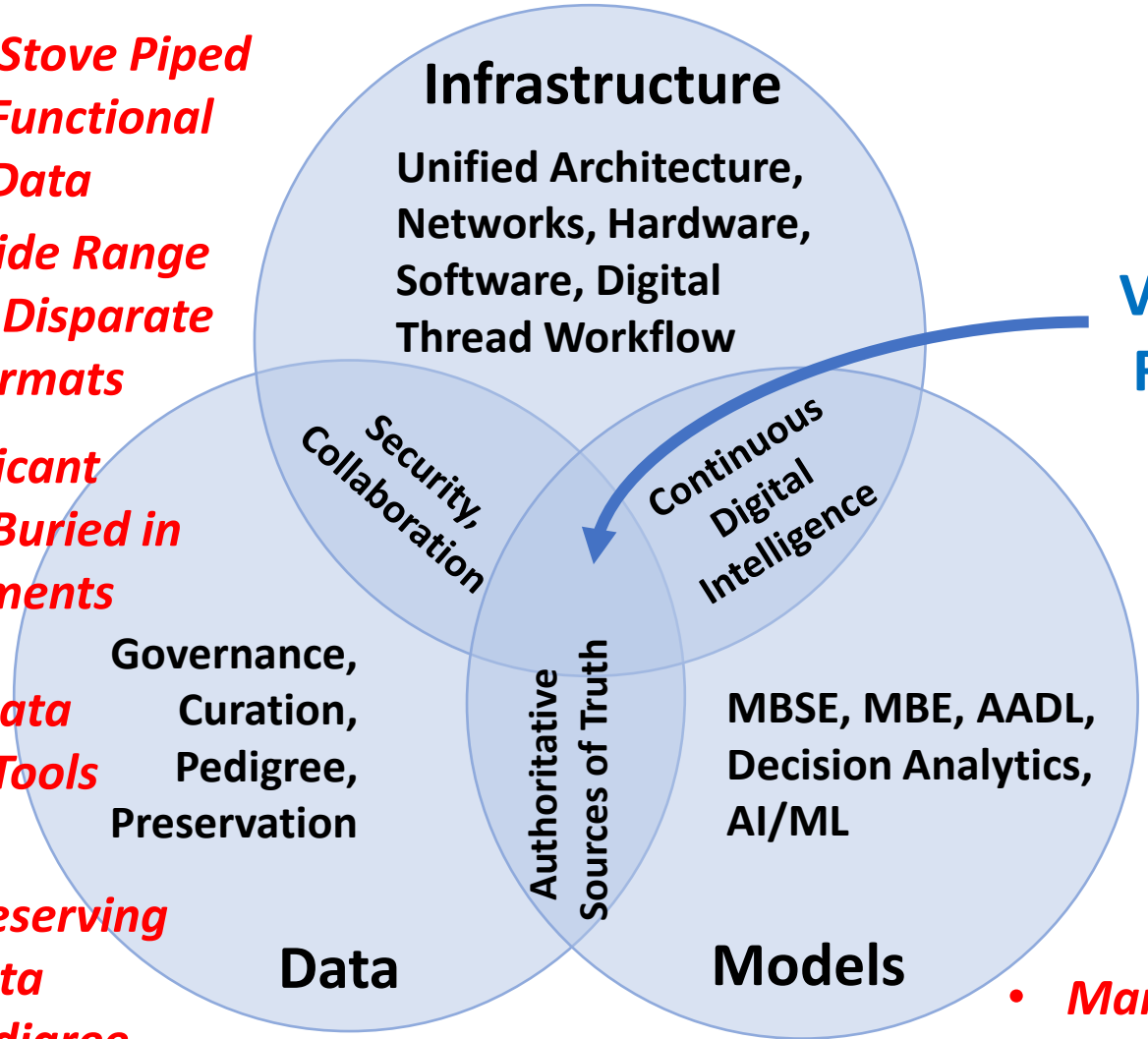
Integrated tools built on models, data, and infrastructure



Challenges

Lacks scalable, timely access to data we need, but don't know where it is, how it works, or how to find it.

- *Stove Piped Functional Data*
- *Wide Range of Disparate Formats*
- *Significant Data Buried in Documents*
- *SQL Data Base Tools*
- *Preserving Data Pedigree, Provenance*



- *"Snapshot VV&A"*

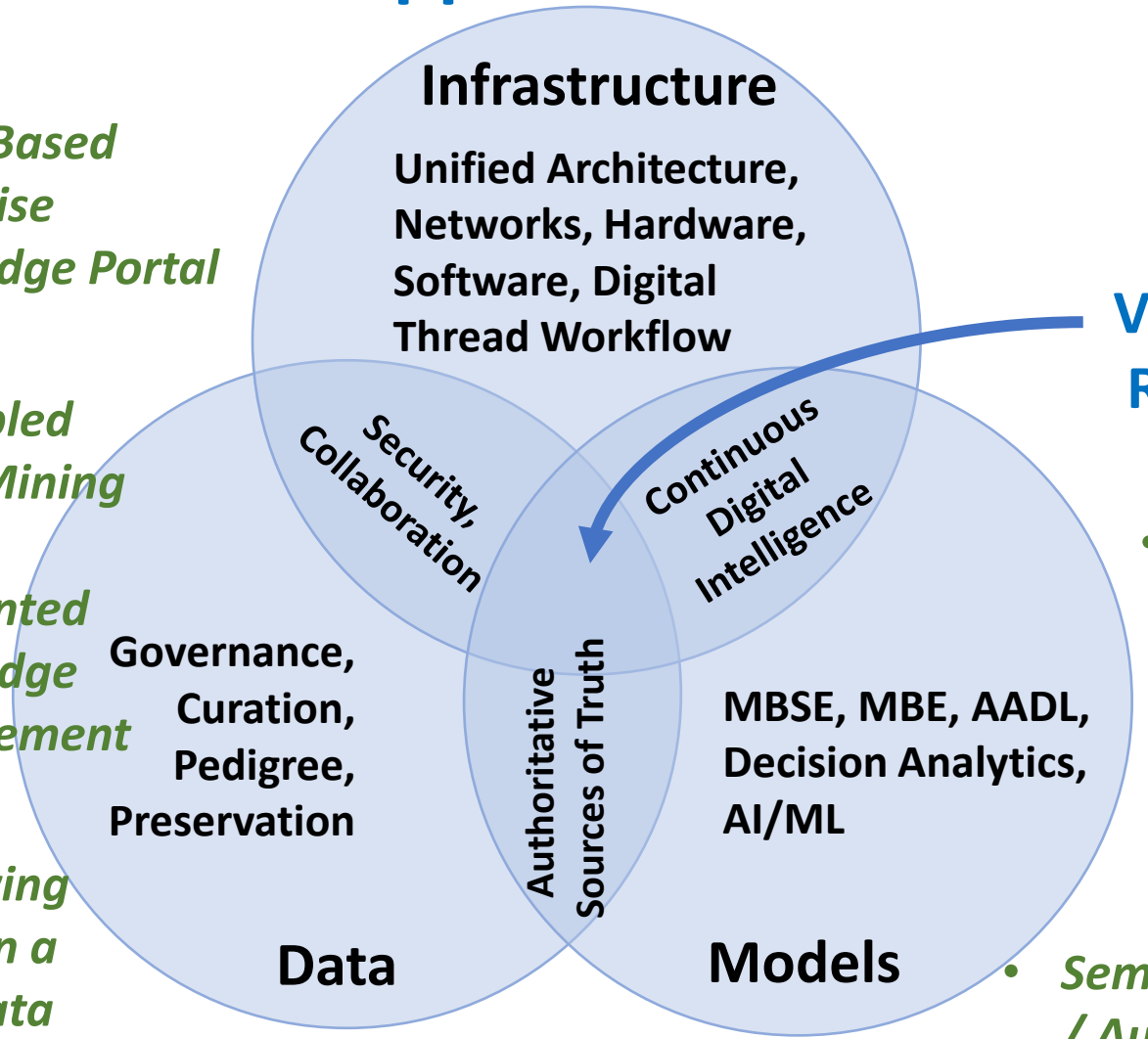
Scalable, Accelerated, Value-Focused, Risk-Informed Decisions

- *Limited Uncertainty Based Risk Analyses*
- *Challenging AI/ML Applications*
- *Manual Model Building*

Opportunities

Single gateway to creating and managing Knowledge needed to digitally support informed authoritative decisions

- *Graph-Based Enterprise Knowledge Portal*
- *AI Enabled Chart Mining*
- *Augmented Knowledge Management*
- *Preserving ASoTs in a FAIR Data Base*

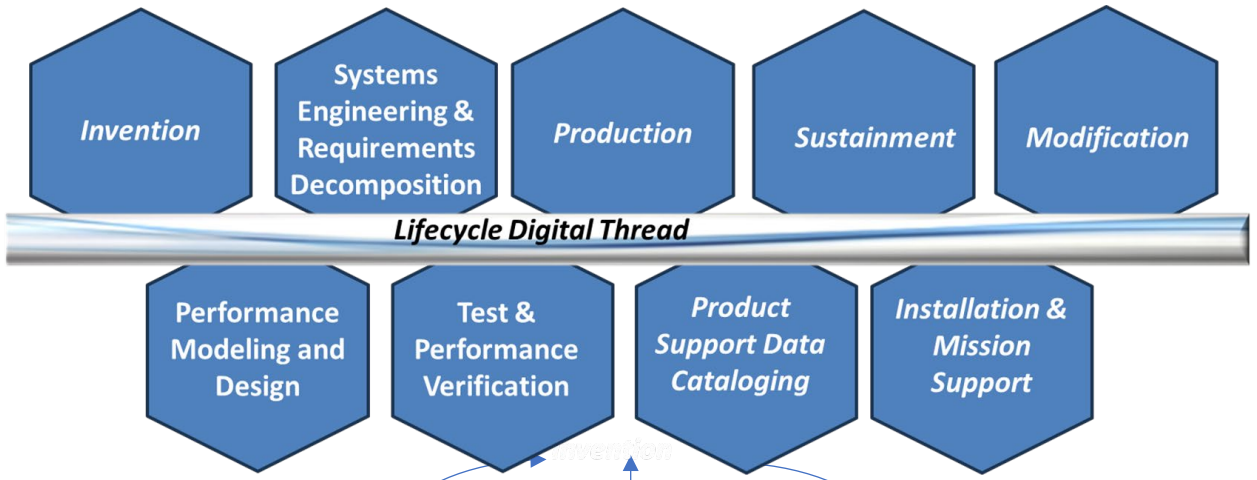


Scalable Accelerated, Value-Focused, Risk-Informed Decisions

- *Quantified Margins and Uncertainties*
- *Automated AI/ML Digital Surrogate Models*
- *Semi-Automated / Automated Model Building*
- *Dynamic Rigorous VV&A*

Digital Thread Elements

- The Digital Thread is a collection of linked authoritative digital information pertaining to a process, product, or system, whose consistency is actively managed throughout the life cycle.
- This enables accessibility, traceability, currency, applicability, and credibility of information, thus facilitating the capture, communication, and use and reuse of knowledge to efficiently inform decisions that realize value.



Engineered System

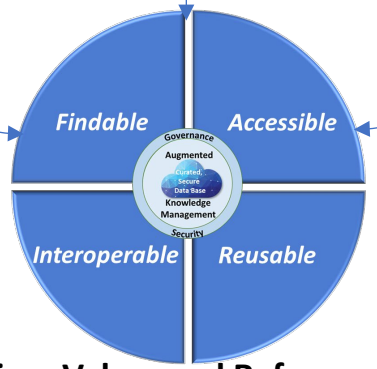
Products and Services at any point in their lifecycle

Life Cycle Domain System

All lifecycle management systems responsible for the Engineered System

Innovation Ecosystem

Environment in which the Life Cycle Domain System Interacts



FAIR Data Base

DT through semantic ontologies, knowledge graphs, and federations enables retrieval of lifecycle data and models

Adapted from "Digital Thread: Definition, Value, and Reference Model" An AIAA, AIA, and NAFEMS Implementation Paper, June 2023

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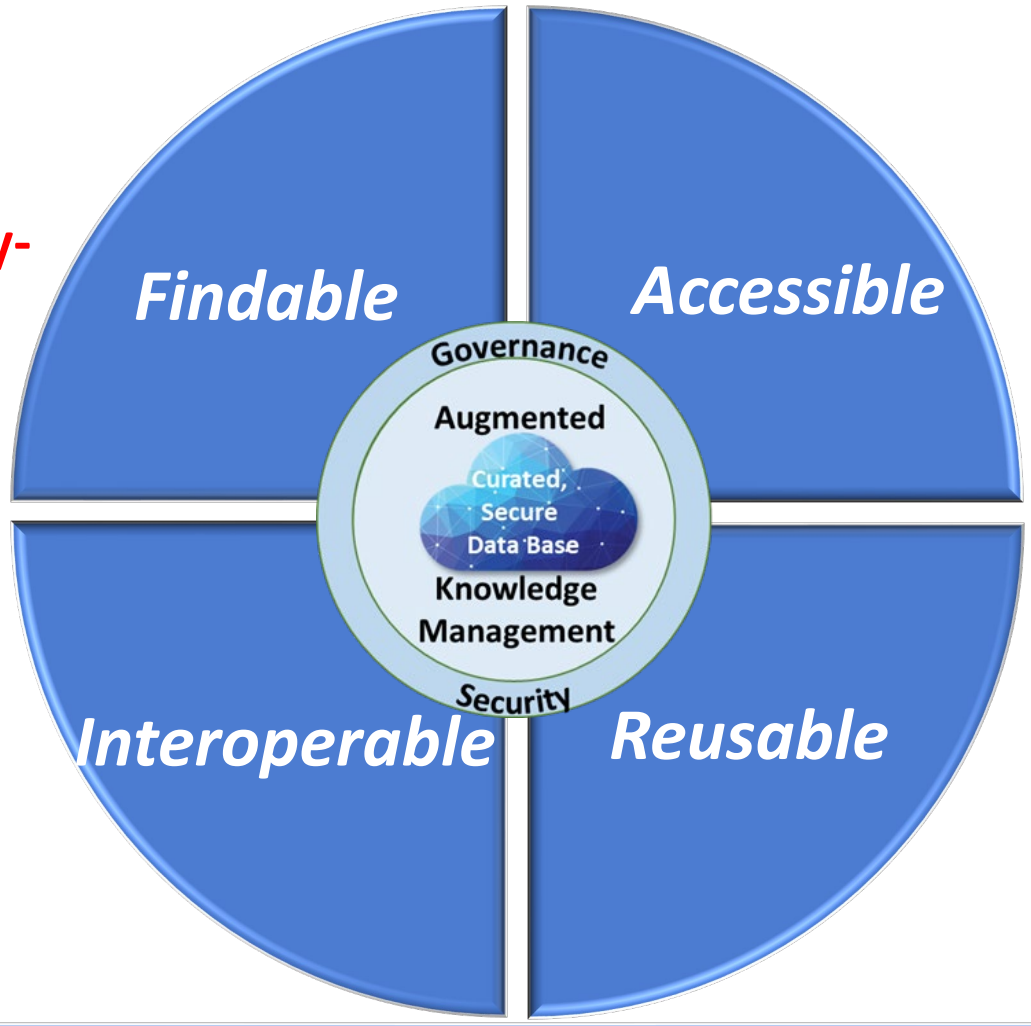
FAIR Data Base

Meta data are assigned a globally unique and persistent identifier to enable an efficient ontology-based search and access

Retrievable by humans and machines using standardized communications protocols with authentication and authorization procedures to facilitate automation

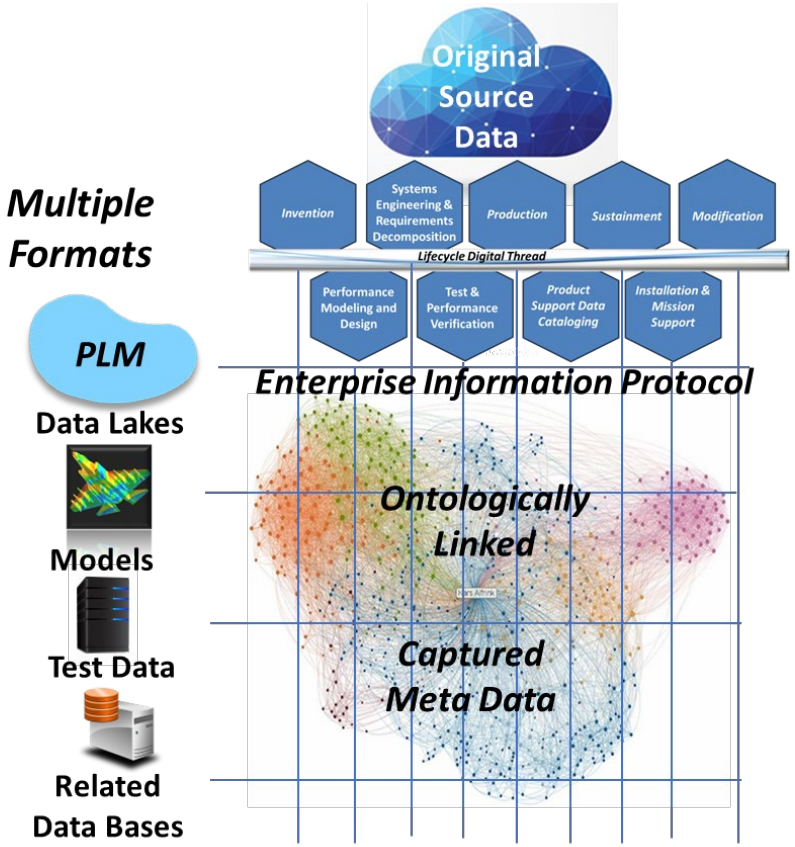


Ability to exchange data with unambiguous, shared meaning and content

Metadata are described with a plurality of accurate and relevant attributes and are associated with detailed provenance to support robust data forensics

The Digital Thread can be viewed as an implementation of FAIR principles in an engineering context

Knowledge Graph Approach



Connects With Source Data Through Existing SQL Architectures

Data integration- can link and harmonize data from diverse sources, fostering data sharing / collaboration.

Enhanced understanding- provides richer understanding of information by representing entities and relationships, enabling humans and machines to better interpret and interact with data.

Improved search and discovery- can deliver more relevant, accurate, comprehensive search results and facilitate discovery of new knowledge /insights.

Inference and reasoning - support various inference and reasoning tasks, enabling discovery of new relationships, identification of inconsistencies, and validation of existing knowledge.

Structured representation - provide a structured way of organizing and representing information, making it more accessible and easier to work with for artificial intelligence and machine learning applications.

Scalability using Graphical Processing Units (GPU) suitable for handling vast datasets and large-scale applications.

RJLee Group Graph-Based Augmented Knowledge Management

Preserving ASoTs in a FAIR Data Base

Original Source Data

FAIR ASoTs

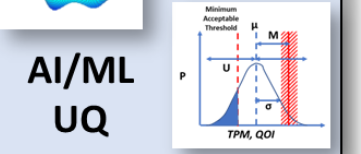
Dynamically Update

Apply

Analytics

Digital Surrogates

AI/ML UQ



Governance

Augmented

Curated, Secure Data Base

Knowledge Management

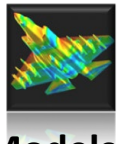
Security

Enterprise Knowledge Portal

Multiple Formats

PLM

Data Lakes



Models

Test Data

Related Data Bases

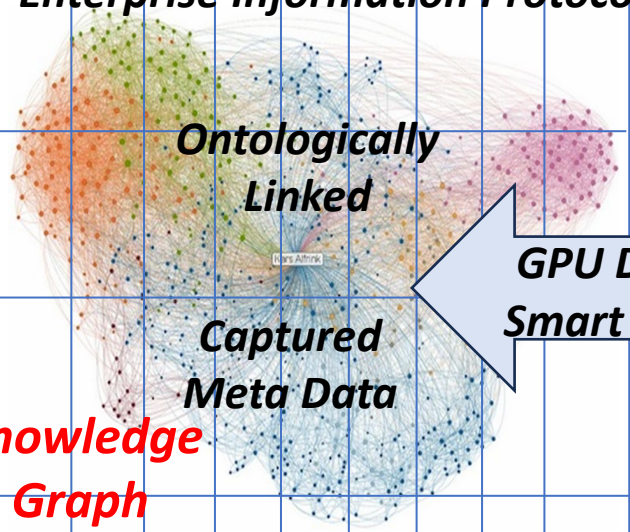
Documents

Invention | Systems Engineering & Requirements Decomposition | Production | Sustainment | Modification

Lifecycle Digital Thread

Performance Modeling and Design | Test & Performance Verification | Product Support Data Cataloging | Installation & Mission Support

Enterprise Information Protocol



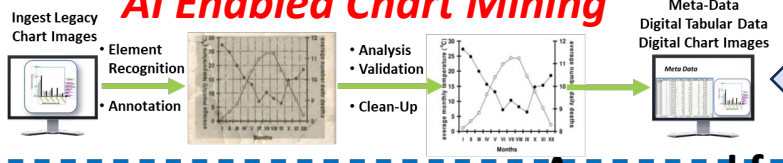
Knowledge Graph

GPU Driven Smart Search

CPU Driven Engage-Transform-Load

Define Ontology	Curate	Preserve	Store / Retrieve
	•Organize	•Authoritative Sources of Truth	•Ontological Search Engine
Ingest Data	•Describe		•FAIR Data Base
	•Clean		
	•Format	•Pedigree	
		•Provenance	

AI Enabled Chart Mining



Conduct Chart Mining

Augmented Knowledge Management

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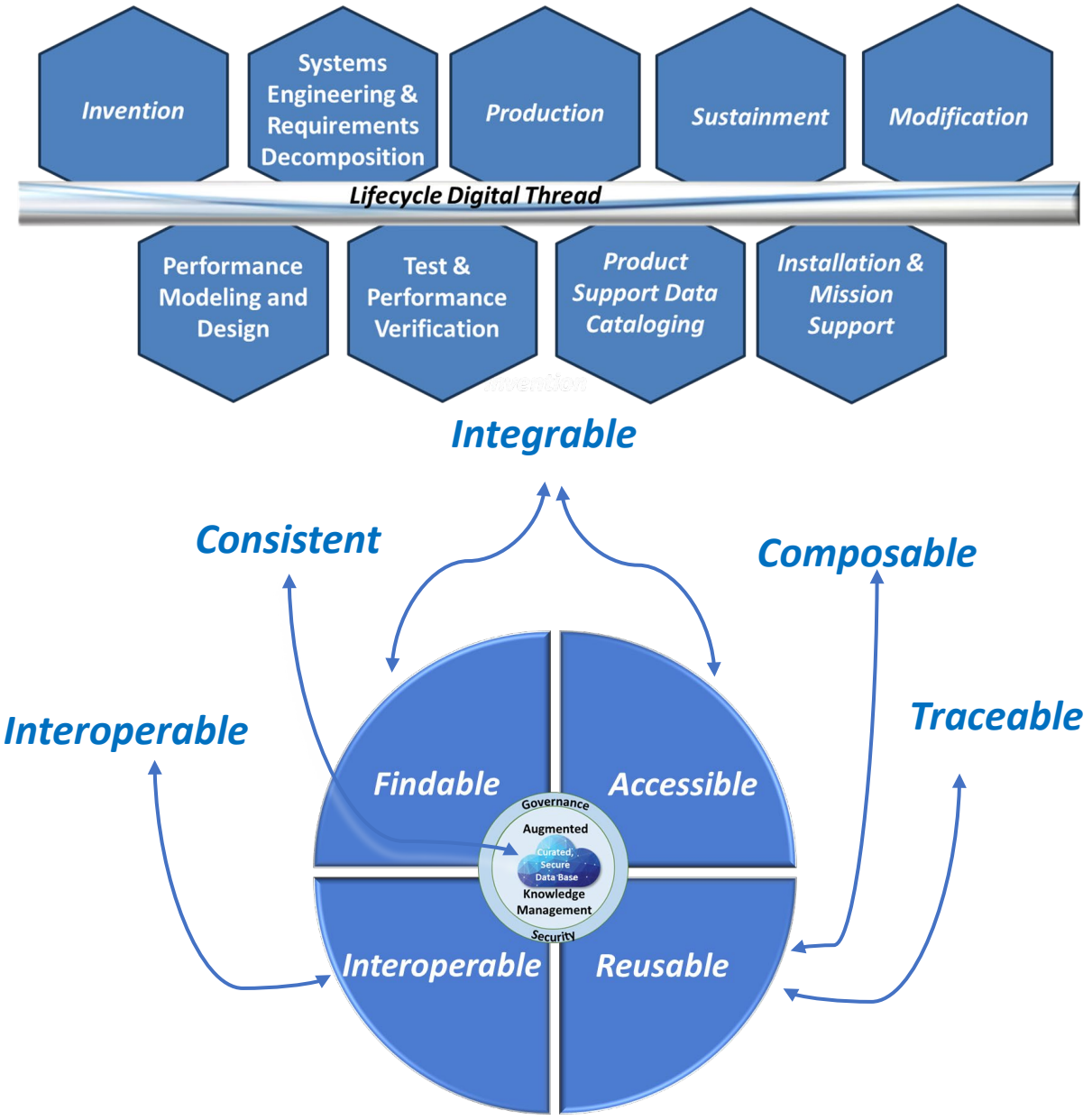
Integration Qualities of the Digital Thread

- **Integrability** – IT connectivity of data and models
- **Interoperability** – collaborative execution of models
- **Composability** – combinatorial assembly and execution of simulations from component models
- **Bidirectional Traceability** – link, trace, reconcile, and communicate configuration managed data and models across the product lifecycle at scale
- **Consistency** – Identifying and preserving the authoritative information and attributing the relationships between *authoritative data and models*



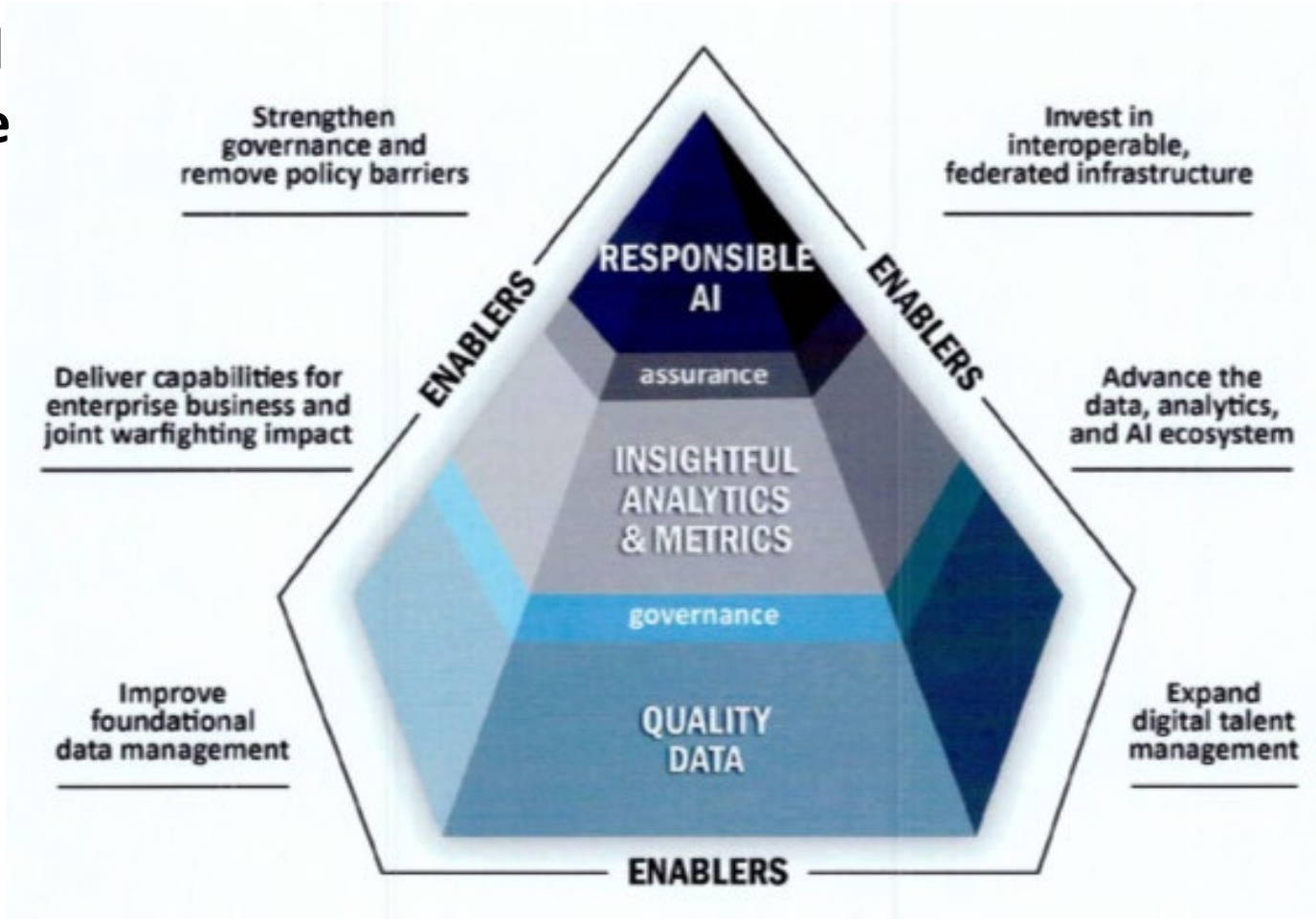
Adapted From"Digital Thread: Definition, Value, and Reference Model" An AIAA, AIA, And NAFEMS Implementation Paper, June 2023

DoD Data, Analytics, and Artificial Intelligence Adoption Strategy Strategic Goals and the AI Hierarchy of Needs

"The AI Hierarchy of Needs is a pyramid with data quality as its foundation since all analytic and AI capabilities require trusted, high -quality data to support decision makers"

"Increased data quality and insightful analytics are achievable through effective enterprise data governance"

"Sound assurance processes for testing, evaluation, validation, and verification are imperative for Responsible AI"



DEPARTMENT OF DEFENSE "Data, Analytics, and Artificial Intelligence Adoption Strategy - *Accelerating Decision Advantage" November 2, 2023*

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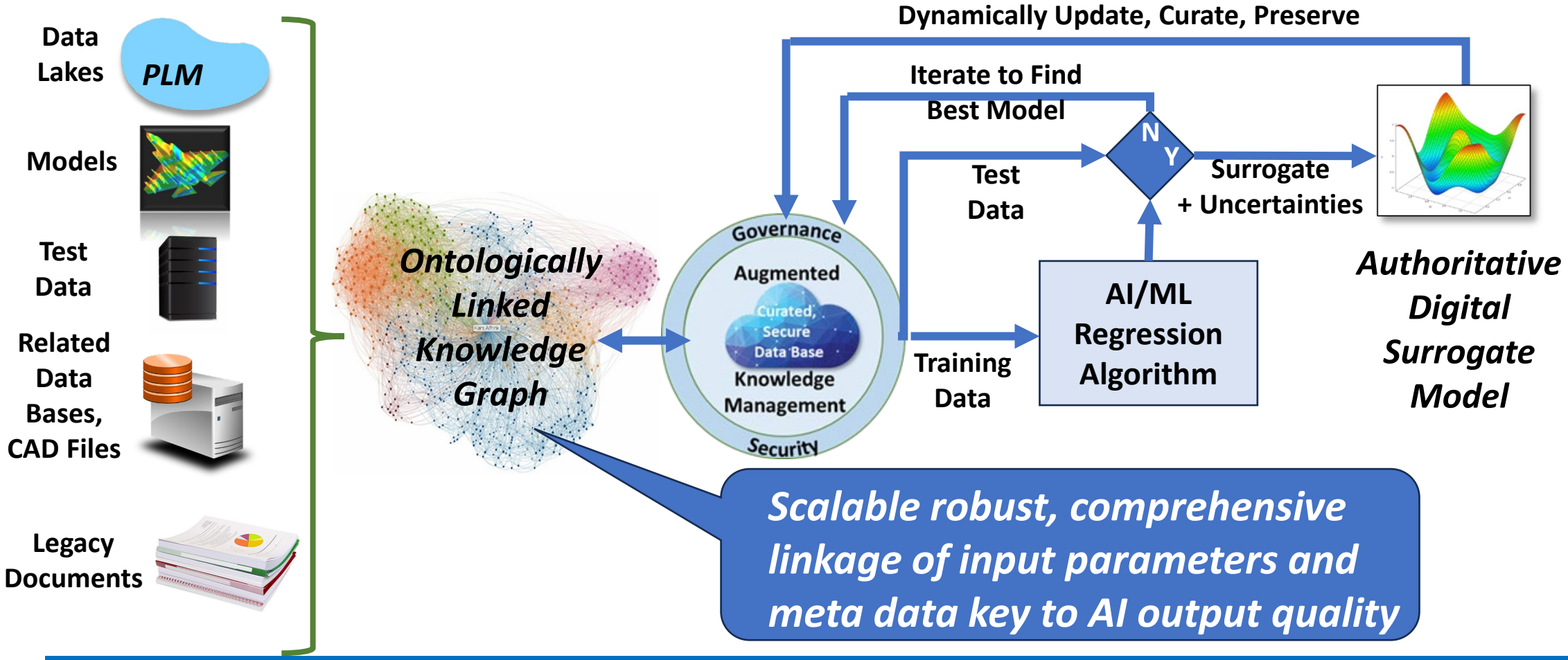
Innovative Application of Artificial Intelligence
From Data Sources to Authoritative Digital Surrogate Models



Direct Path From Existing Data and Documents to an Authoritative Digital Surrogate Model

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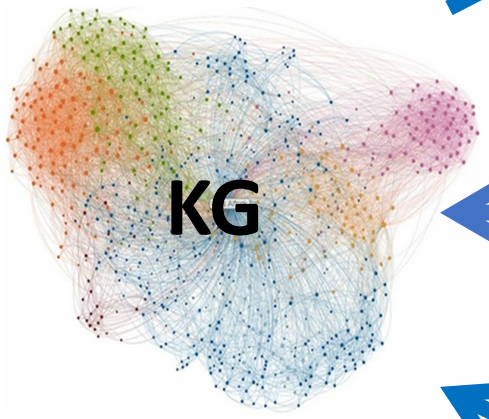
Integrated Knowledge Graph / Large Language Models

Explicitly stores rich factual knowledge, but challenged to generate new facts and represent unseen knowledge

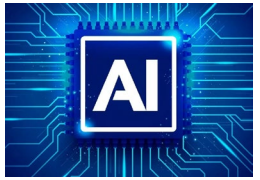
Great at inference , question answering, and text scripting but weak at accessing factual knowledge



Incorporate KG in LLM Training

Bidirectional Reasoning Drive By Both Data and Knowledge

LLM Support to KG Construction and Question Answering



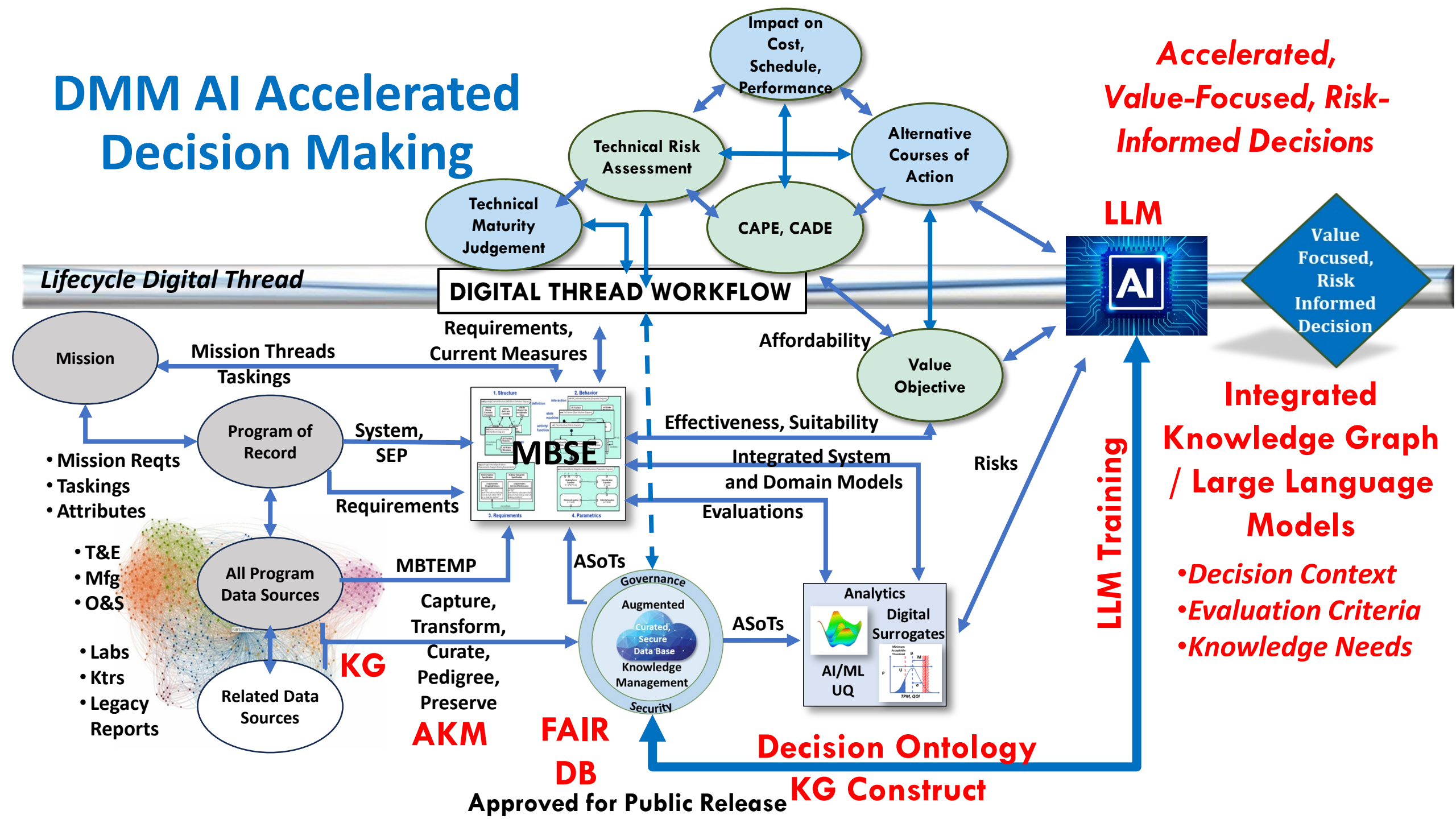
LLM

LLM is 3X better at answering enterprise questions when questions are posed using a KG representation than direct access to a SQL data base*

*** Sequeda, Juan F., et al** [2311.07509] A Benchmark to Understand the Role of Knowledge Graphs on Large Language Model's Accuracy for Question Answering on Enterprise SQL Databases (arxiv.org)

DMM AI Accelerated Decision Making

Accelerated, Value-Focused, Risk-Informed Decisions



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Summary

- A Knowledge-Graph enabled integrated Augmented Knowledge Management / Chart Mining capability is presented
- The key advantages of the approach include
  - Ability to use smart ontological searches to rapidly find and connect knowledge across all original functional data sources to enhance DMM lifecycle collaboration
  - Transforming original data sources, including documents, into Authoritative Sources of Truth that are secured and preserved in a FAIR data base
  - Accelerating the development and validation of authoritative modeling and analytics leveraging AI
  - Enables an integrated KG / LLM approach to enhance authoritative decision making at key decision points to accelerate capability delivery

An Accelerated Future State for Digital Materiel Management