Towards an Ontology of Digital Engineering Terminology to Support Digital Information Exchange

INCOSE IS
7/4/2024

PRESENTER Dr. **Joe Gregory** *Postdoctoral Research Associate*
Department of Systems & Industrial Engineering

Co-chair: Clarence (Moe) Moreland

Contents

- **DEIX Overview**
- DEIX Taxonomy WG Goals
- Core Digital Engineering Concepts
- Current Status and Examples
- Conclusions

INCOSE
Digital Engineering Information Exchange

(DEIX)

Chair: Terri Chan: terri.chan@incose.net

Deputy Chair: Celia Tseng: Celia.Tseng@3ds.com

Co-Chair (OSD Liaison): Frank Salvatore: Frank.J.Salvatore@SAIC.com

Co-Chair (NDIA Liaison): Chris Schreiber: Chris.Schreiber@LMCO.com

Tech Leads (Taxonomy): Joe Gregory joegregory@arizona.edu

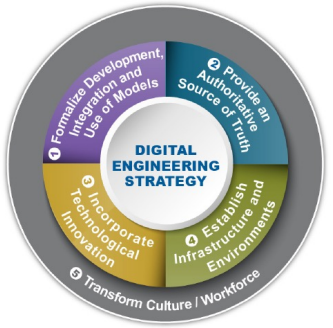
Moe Moreland moe.moreland@mtsi-va.com

What is the DEIX WG?

- Formed as INCOSE Working Group in 2018
- Collaboration between:
  - International Council of Systems Engineers (INCOSE)
  - National Defense Industrial Association (NDIA)
  - Office of the Under Secretary of Defense for Research and Engineering (DoD OUSD(R&E))

- The DEIXWG:

  "supports the strategic objective of accelerating digital engineering transformation by characterizing the content and relationships involved in the exchange of digital artifacts between stakeholders of various disciplines throughout the engineering lifecycle"



Use the authoritative source of truth to produce digital artifacts, support reviews, and inform decisions

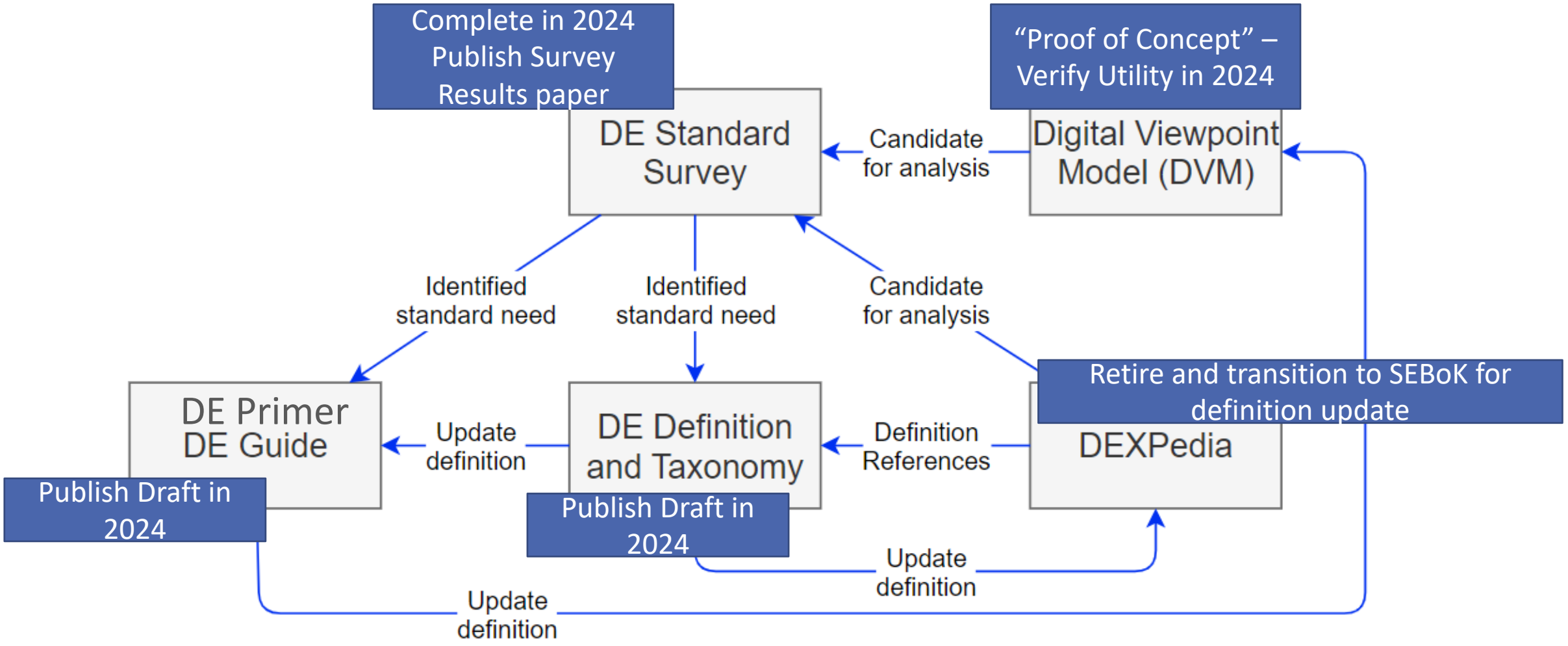
As the technical baseline matures, preserving the knowledge across programs and lifecycle phases is essential. Technical reviews can be conducted from the authoritative source of truth on a continuous basis. Stakeholders will generate digital artifacts, representing multiple views and various perspectives from the authoritative source of truth. Digital artifacts provide visibility of appropriate information across functional domains, disciplines, and organizations.

--- DoD Digital Engineering Strategy, 2018

Why DEIXWG Is Important

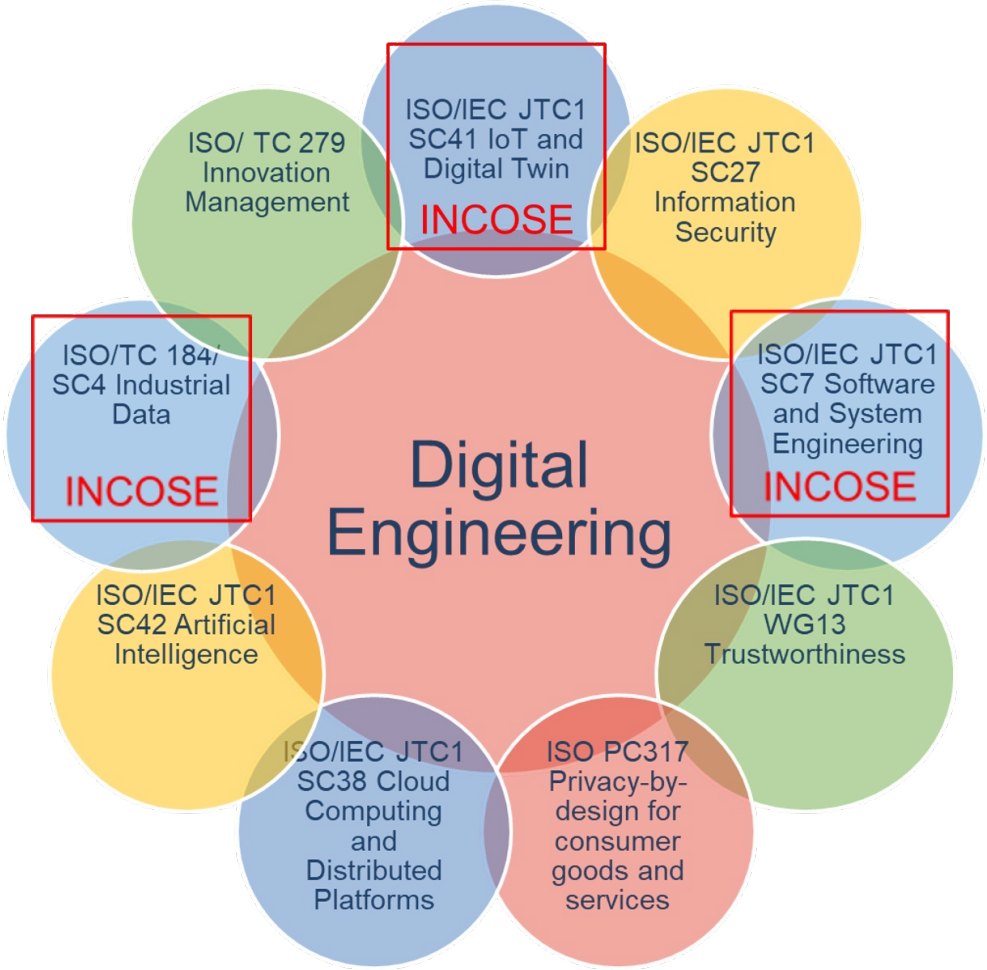
- Digital Engineering is the future of any industry that produces complex systems and is one of the tenets of the INCOSE Vision for 2035
  - Aerospace and Defense
  - Technology/E-Commerce
  - Financial and Banking Institutions
  - Healthcare
- Opportunity to lead in the transformation to DE
  - Work with other experts participating in AIAA, INCOSE, IEEE, ISO, PDES
  - Joint Session coming soon to coordinate efforts

DEIX Product 2024 Status and Relationship

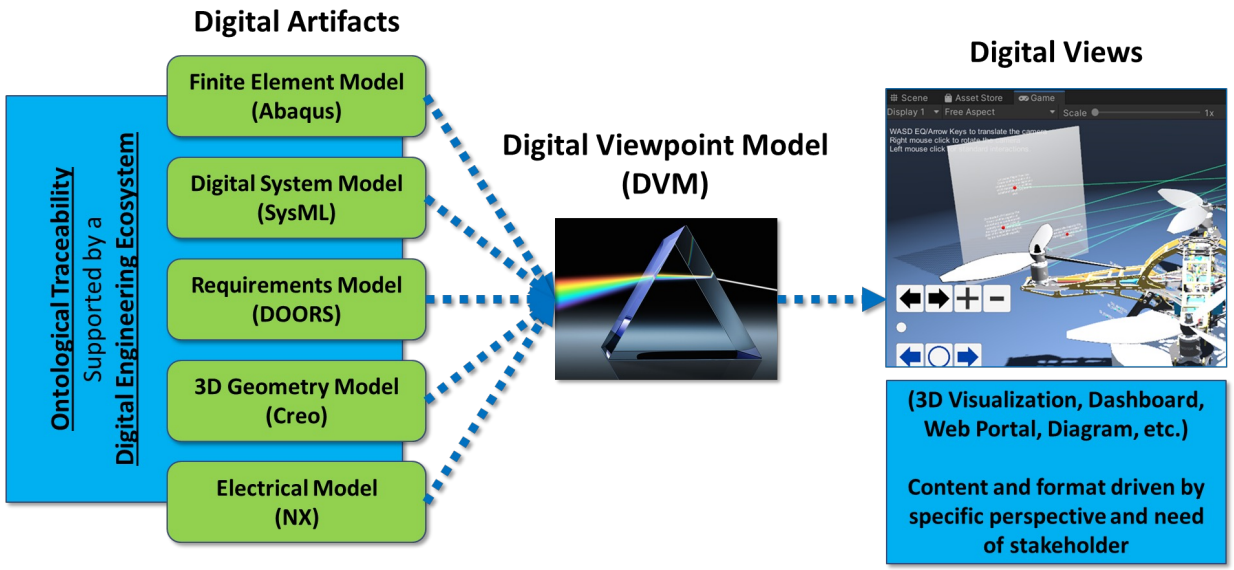


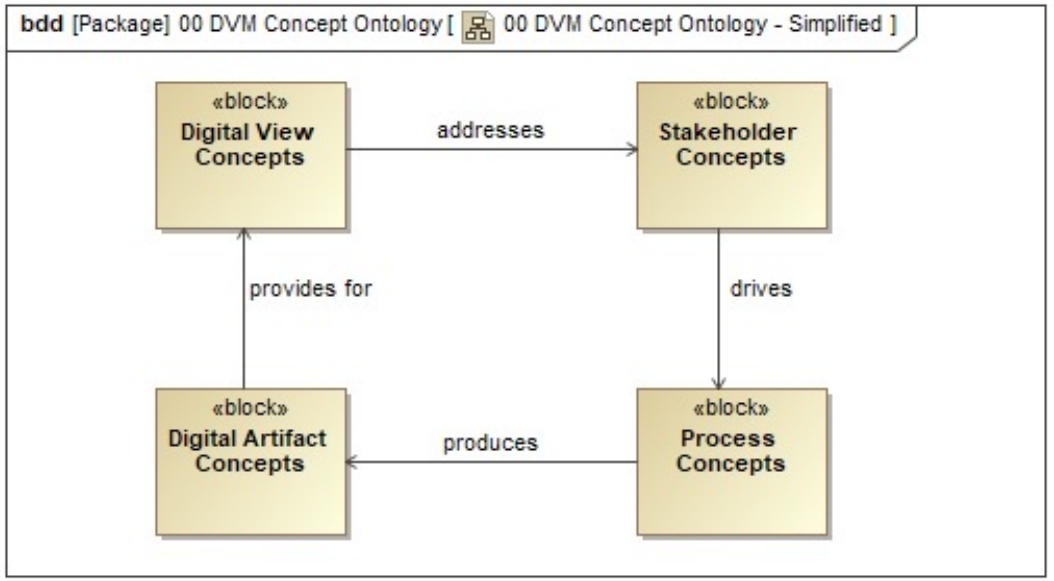
DE Standard Survey

- Scope: Collaboration with ISO/IEC JTC1 SC7 AHG 6 to provide analysis of the requirements of the market for DE standard development
  - Alignment of standardization needs identified in INCOSE SE Vision 2035
    - Presented in 2023 INCOSE IS
  - Alignment of ongoing standard development activities and identify standard gaps
  - Collect SE community input via DE survey
- Outcome: Analysis report completed in Dec 2023, 2 standards proposal accepted for draft development



Digital Viewpoint Model (Lead: Ken Zhang)





While the DVM is modeled using SysML, the concepts are agnostic of any particular language, tool, or infrastructure

- The Digital Viewpoint Model (DVM) is an **implementation-agnostic (platform independent), reference framework** developed from DEIXWG
- The DVM provides a high-level framework for describing sources of digital information in a digital engineering ecosystem (DEE)
- The DVM also conceptualizes how that information can be transferred, translated, transformed, and related for the purpose of exchanging digital information between stakeholders… who might not have the same DEE infrastructure or standards

DE Guide

Key areas of focus

- Tailors ISO/IEC/IEEE 15288 process to the unique challenges presented by digital engineering
- Clearly describes digital considerations across all system lifecycle stages
- Follows format of ISO/IEC/IEEE 21840

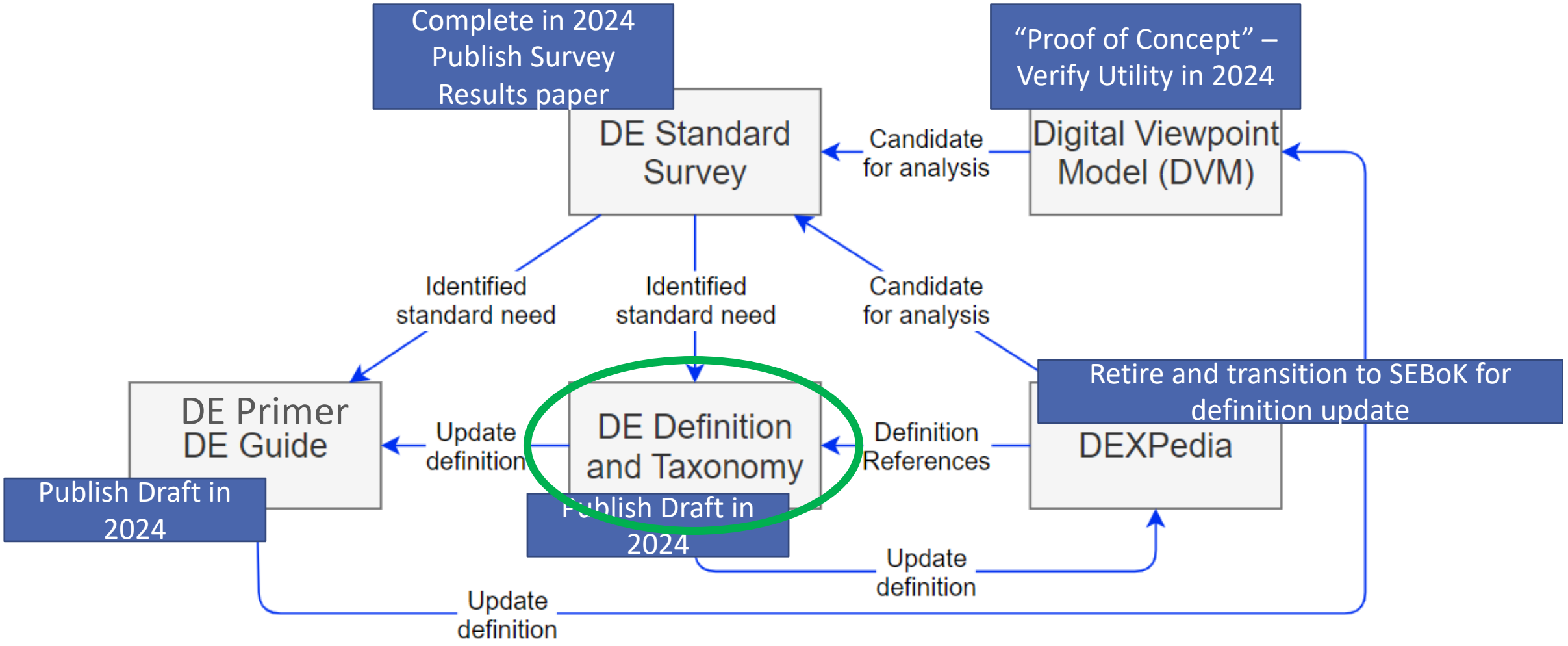
Objectives in terms of ISO alignment and industry impact

- Sets a foundation for cross-industry collaboration
- Provides general guidance for each ISO/IEC/IEEE 15288 process and process outcome in the context of DE
- Follows similar standards alignment to ISO/IEC/IEEE 21840

How the DE Guide aims to address current challenges and gaps in digital engineering

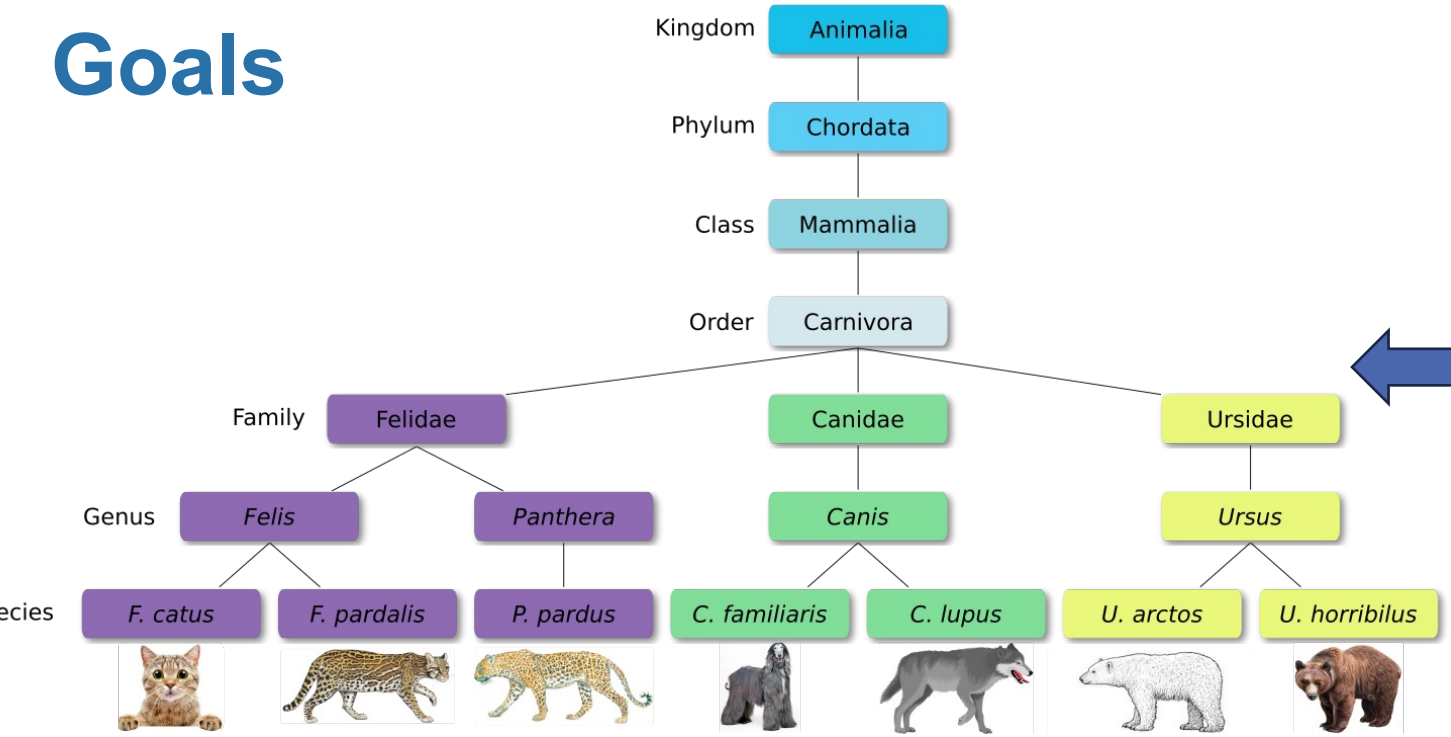
- Bridge gap between traditional systems engineering and digital engineering practices
- Provides adaptable guidelines that evolve with digital engineering practices

DEIX Product 2024 Status and Relationship



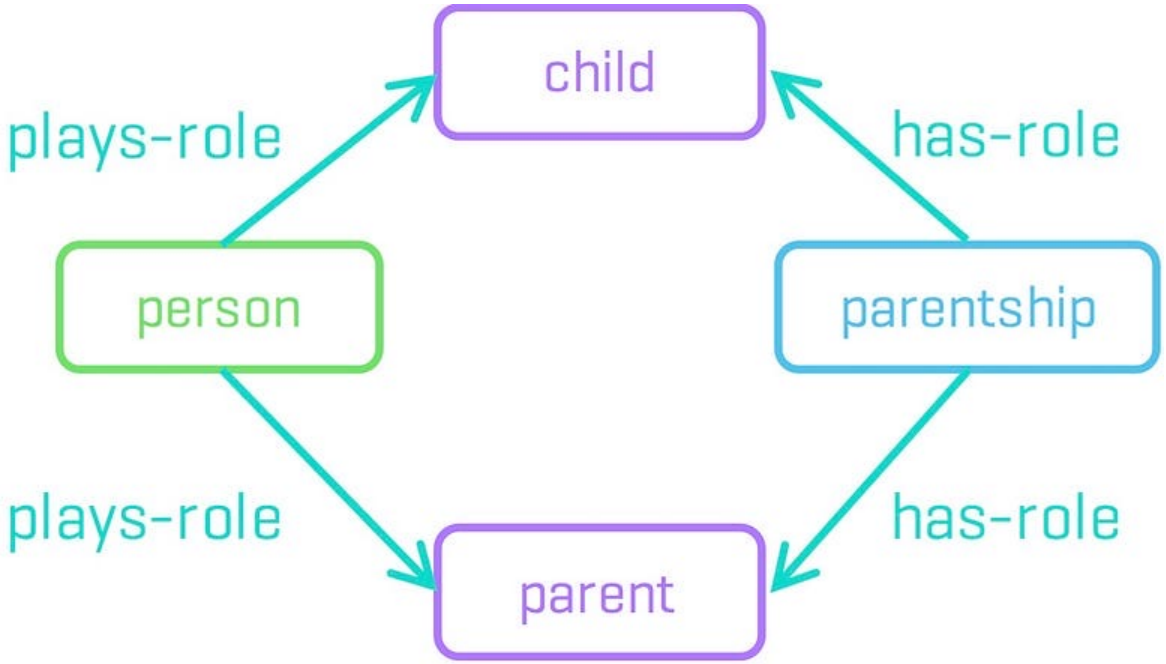
- DEIX Overview
- **DEIX Taxonomy WG Goals**
- Core Digital Engineering Concepts
- Current Status and Examples
- Conclusions

Goals



Taxonomy

Ontology



https://training.galaxyproject.org/trainingmaterial/topics/microbiome/faqs/taxon.html
https://www.kdnuggets.com/2017/05/ontology-simplest-definition.html

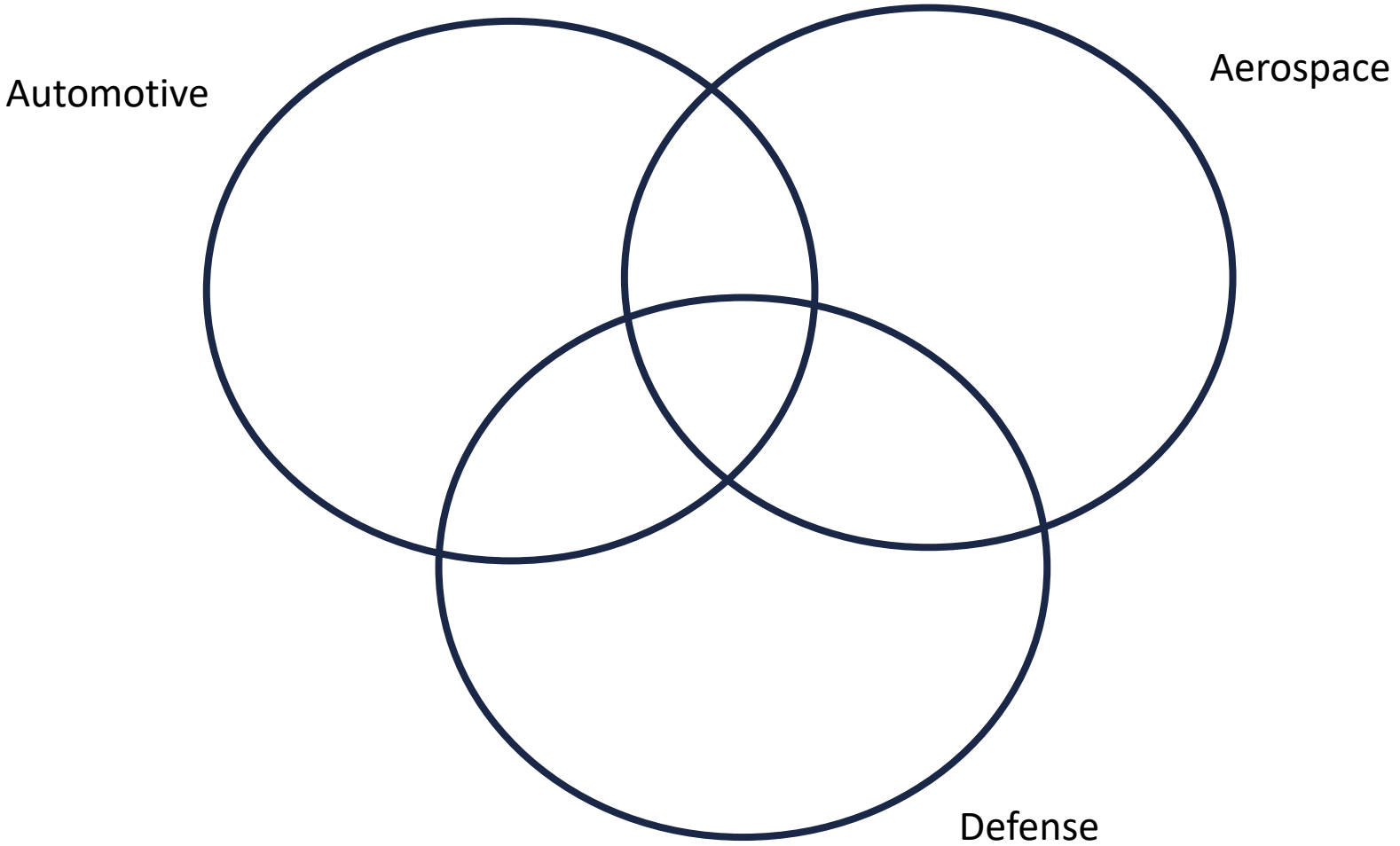
Goals

"Support the DEIX WG (the **Digital Viewpoint Model** and the **DE Primer**) by providing clear, concise, consistent definitions of DE concepts"

- **Concept-based**
  - i.e., focus on definition of the *concept* rather than specific *terminology*
  - This allows us to define synonyms / mappings between domains
- **Focus on definitions to support relevant domains**
  - Reached by consensus, and aligning with standards from relevant domains
  - Concepts are defined by their relationships
- **Machine-readable**
  - Web Ontology Language (OWL) or similar
  - Protégé or similar
- **Align with similar work in other areas**
  - Industrial Ontology Foundry (IOF) SE Working Group
  - OntoCommons

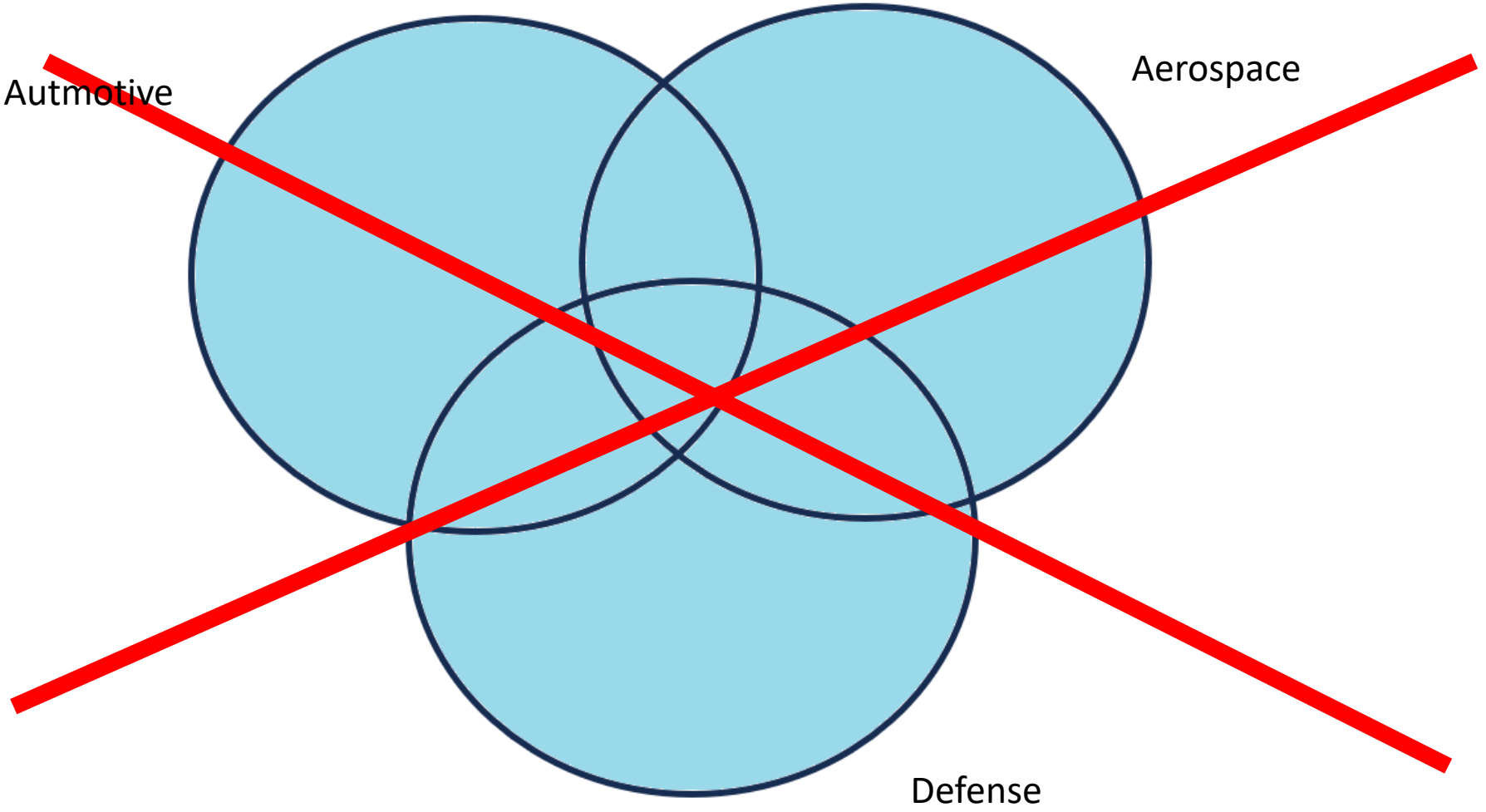
Goals

Domains and Standards of Interest (example):



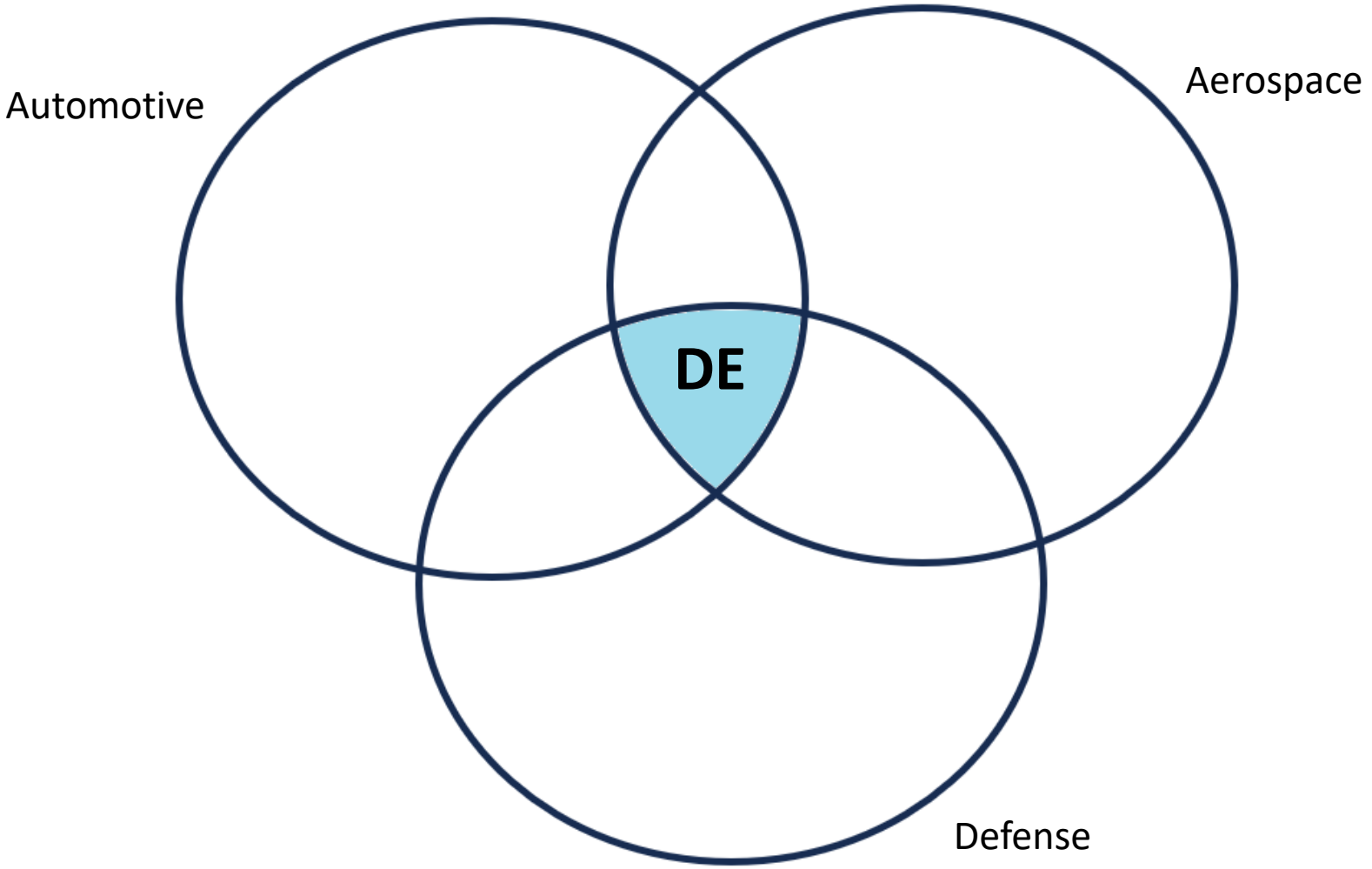
Goals

Domains and Standards of Interest (example):



Goals

Domains and Standards of Interest (example):



Standards (and other Sources)

• ISO 15288	SE Processes
• ISO 15289	SE Information Items
• (ISO 21838)	TLO
• ISO 21841	SoS
• ISO 24641	MBSSE (models)
• ISO 24765	SE Vocab
• ISO 37000	Governance
• ISO 42010	Architecture
• ISO 42020	Architecture
• AIAA Digital Thread Position	Digital Thread
• DAU Glossary	DE
• DEBoK	DE
• DoD DE Strategy	DE
• MoSSEC	M&S Metadata

- Others not listed

Goals

We have also defined three use cases that define our objectives re: **reasoning** capabilities

Goals

We have also defined three use cases that define our objectives re: **reasoning** capabilities

- **1. Classification Reasoning**
  - What concept is this instance typed by?
    - e.g., is this *thing* a **Digital Artifact** or a **Digital System Model**?
    - Dependent on that *thing's* relations and attributes

Goals

We have also defined three use cases that define our objectives re: **reasoning** capabilities

- **1. Classification Reasoning**
  - What concept is this instance typed by?
    - e.g., is this *thing* a **Digital Artifact** or a **Digital System Model**?
    - Dependent on that *thing's* relations and attributes

- **2. Reusability Criteria**
  - Is this artifact suitable for reusability, given the context I wish to reuse it in?
    - Considers *Reusable Asset Criteria* (RAS), from OMG Model-Based Acquisition WG
    - Criteria generally includes metadata as well as content.

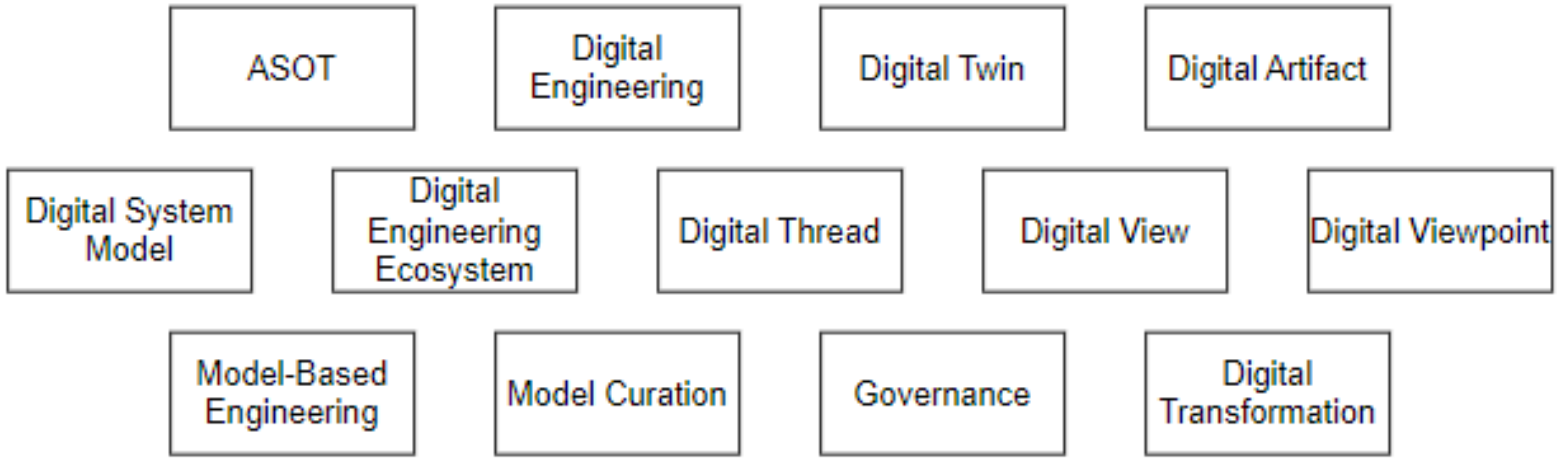
Goals

We have also defined three use cases that define our objectives re: **reasoning** capabilities

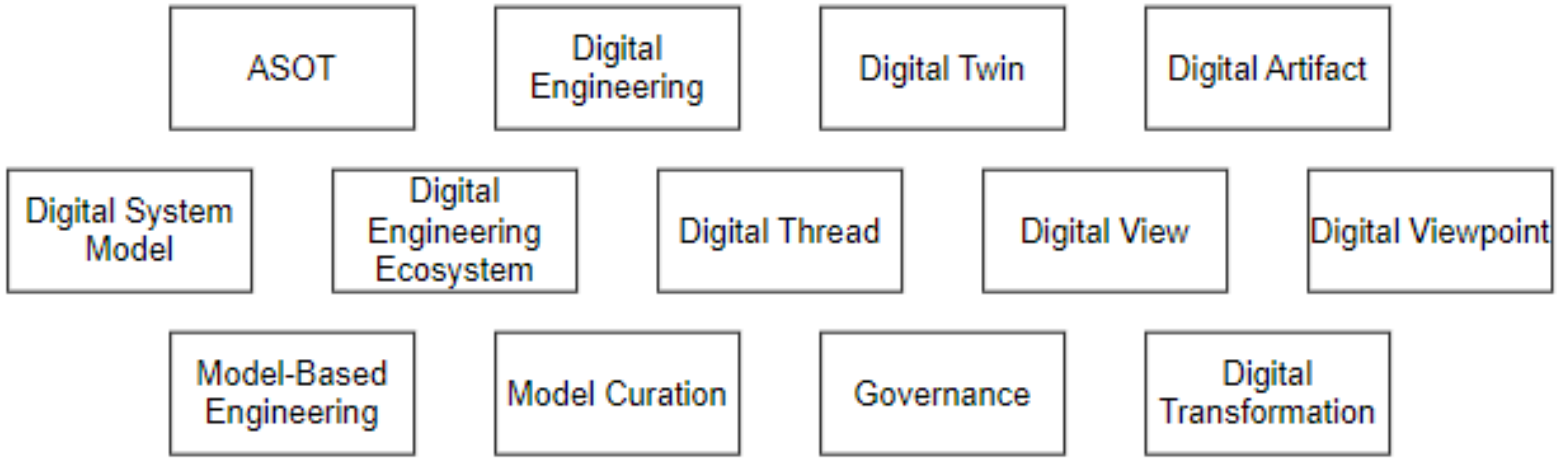
- **1. Classification Reasoning**
  - What concept is this instance typed by?
    - e.g., is this *thing* a **Digital Artifact** or a **Digital System Model**?
    - Dependent on that *thing's* relations and attributes
- **2. Reusability Criteria**
  - Is this artifact suitable for reusability, given the context I wish to reuse it in?
    - Considers *Reusable Asset Criteria* (RAS), from OMG Model-Based Acquisition WG
    - Criteria generally includes metadata as well as content.
- **3. Asset Utility**
  - Does this asset address a particular need?
    - Analogous to traceability from system component, through function and requirement, to need
    - Reverse the question: impact analysis for particular business / use cases. How many artifacts?

- DEIX Overview
- DEIX Taxonomy WG Goals
- **Core Digital Engineering Concepts**
- Current Status and Examples
- Conclusions

DE Core Concepts

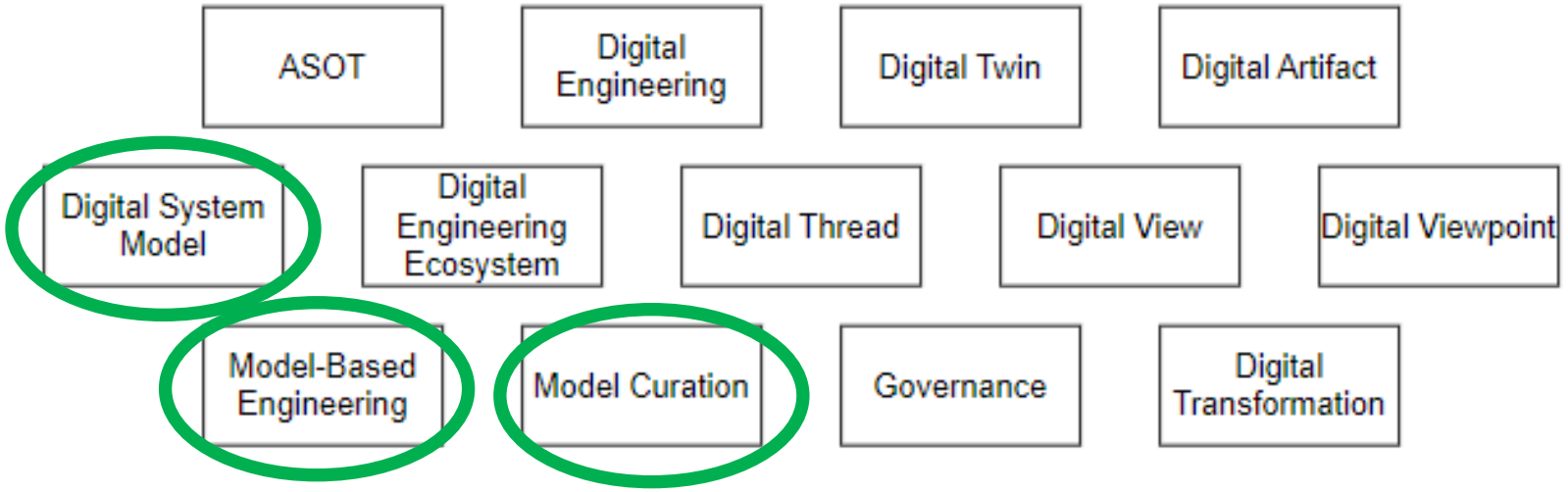


DE Core Concepts

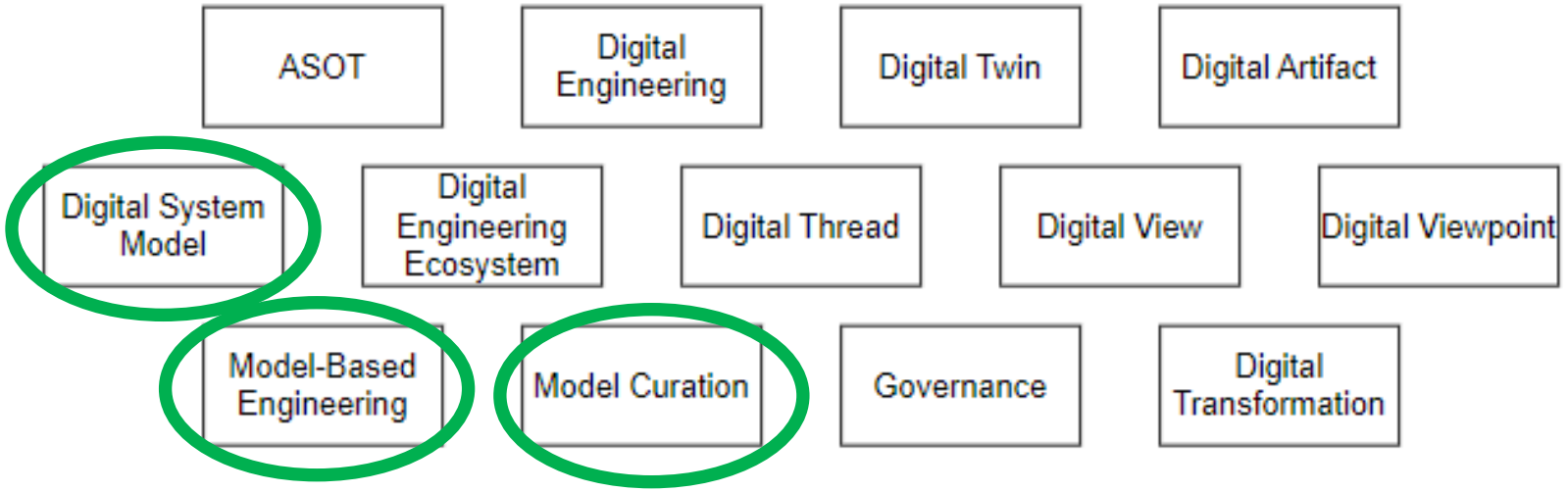


Concepts are defined by their relationships

DE Core Concepts

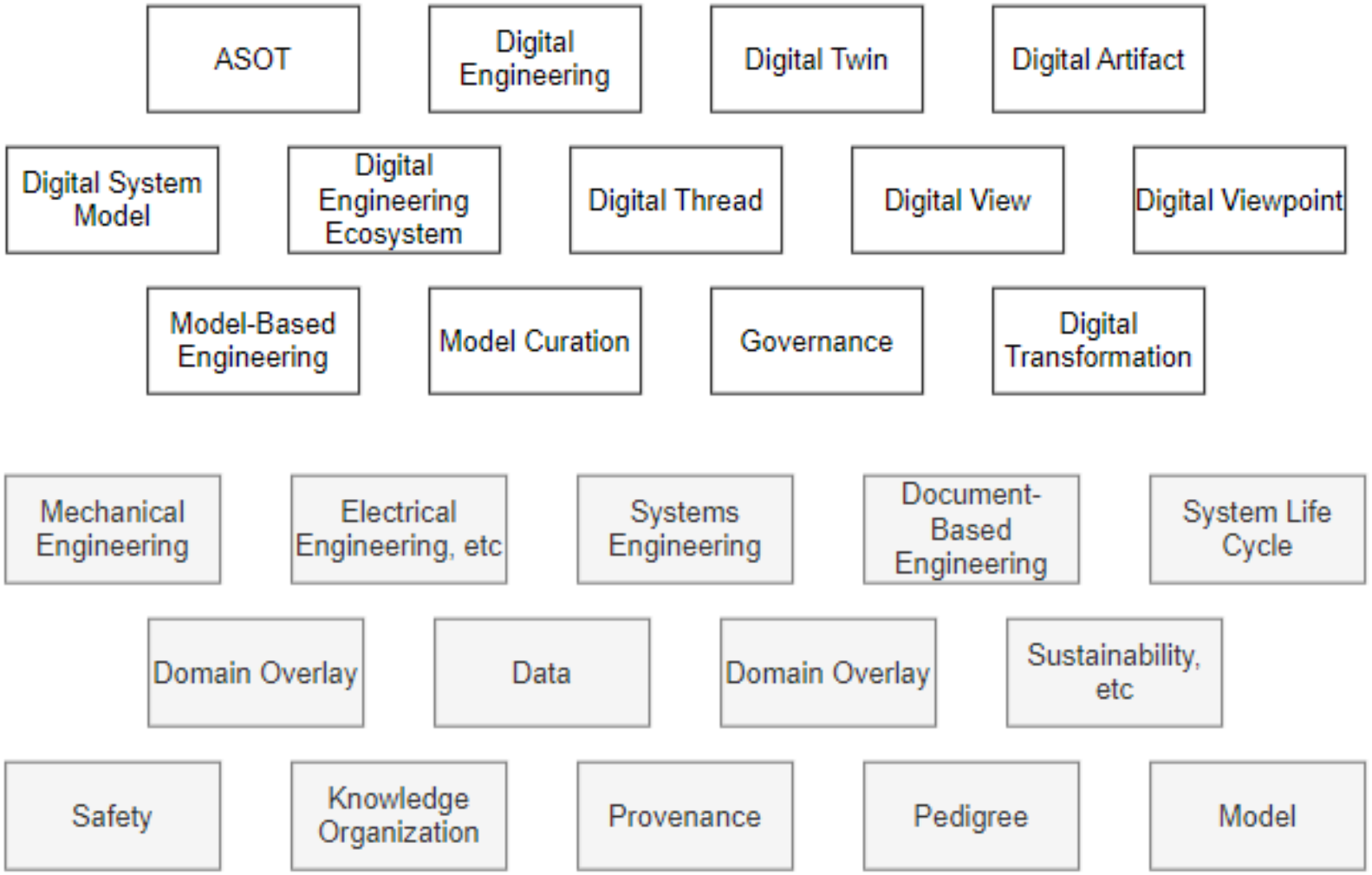


DE Core Concepts



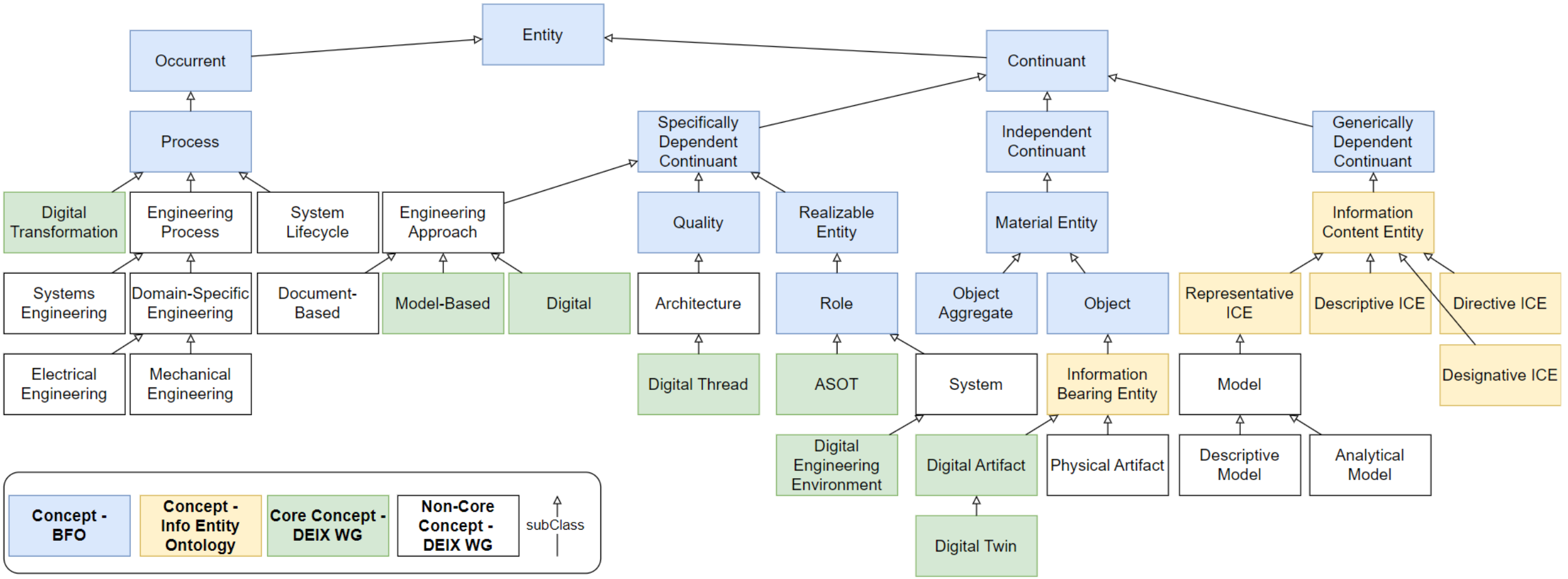
Model

DE Core Concepts

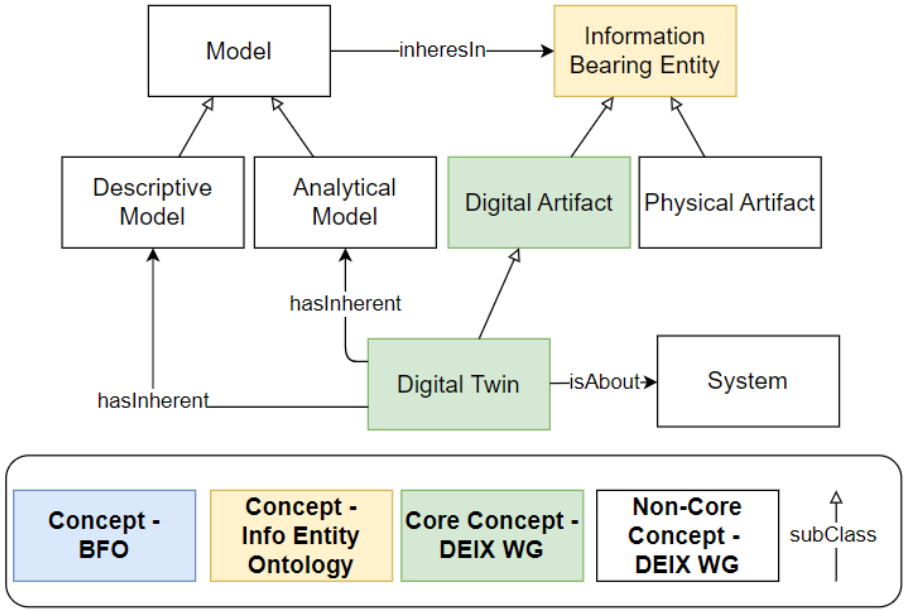


- DEIX Overview
- DEIX Taxonomy WG Goals
- Core Digital Engineering Concepts
- **Current Status and Examples**
- Conclusions

DE Prelim. Taxonomy (based on BFO)



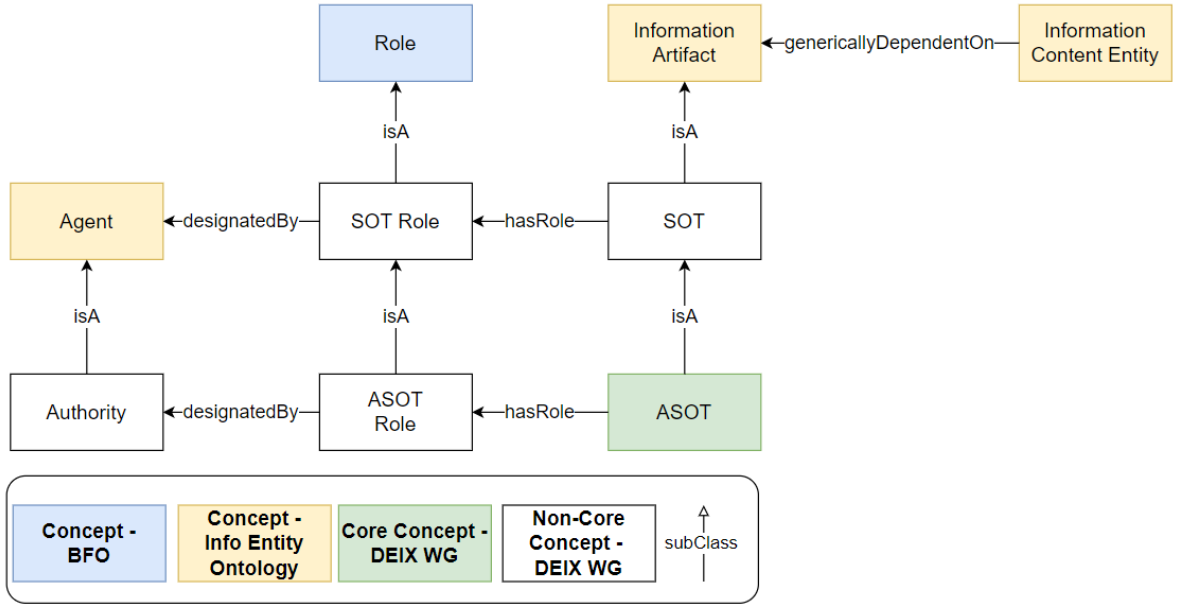
DE Partial Ontology – Digital Twin



A Digital Twin *x* is a 'Digital Artifact' that is about some 'System' and has some inherent 'Descriptive Model' and has some inherent 'Analytical Model'

DigitalTwin(x) <-> DigitalArtifact(x) ∧ ∃s (System(s) ∧ isAbout (x,s))
∧ ∃d (DescriptiveModel(d) ∧ hasInherent (x,d))
∧ ∃a (AnalyticalModel(a) ∧ hasInherent (x,a))

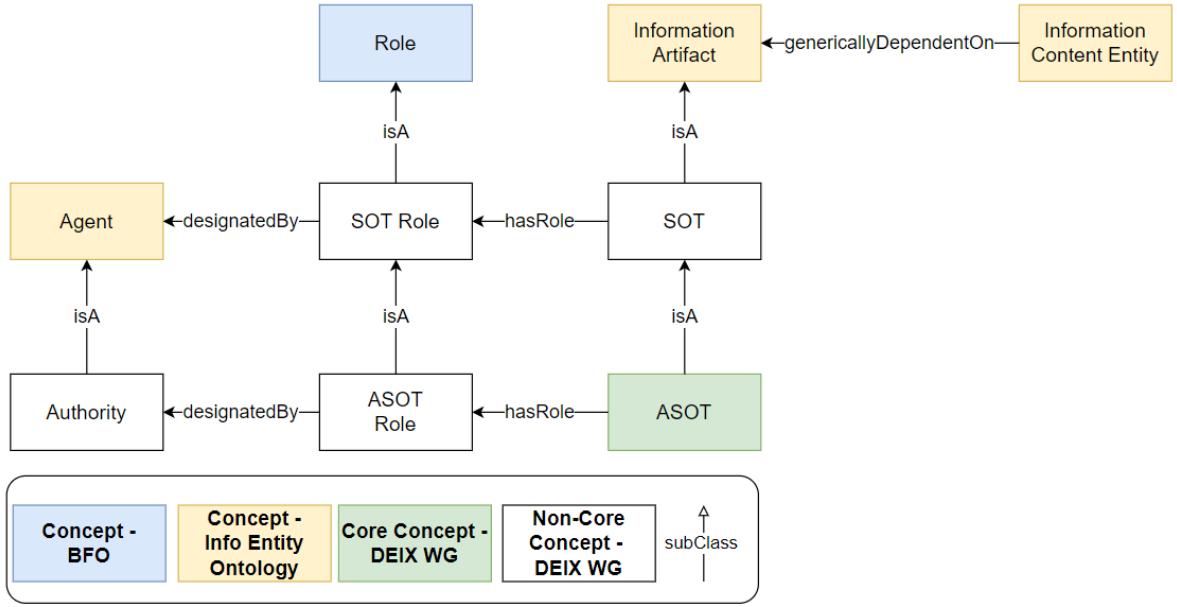
DE Partial Ontology – ASOT



A Source of Truth (SOT) *x* is an 'Information Artifact' that has a role of 'SOT Role' where the 'SOT Role' has been designated by some 'Agent'

SOT(x) <-> InformationArtifact(x) ∧ ∃r (SOTRole(r) ∧ hasRole (x,r))
∧ ∃a (Agent(a) ∧ designatedBy (r,a))

DE Partial Ontology – ASOT

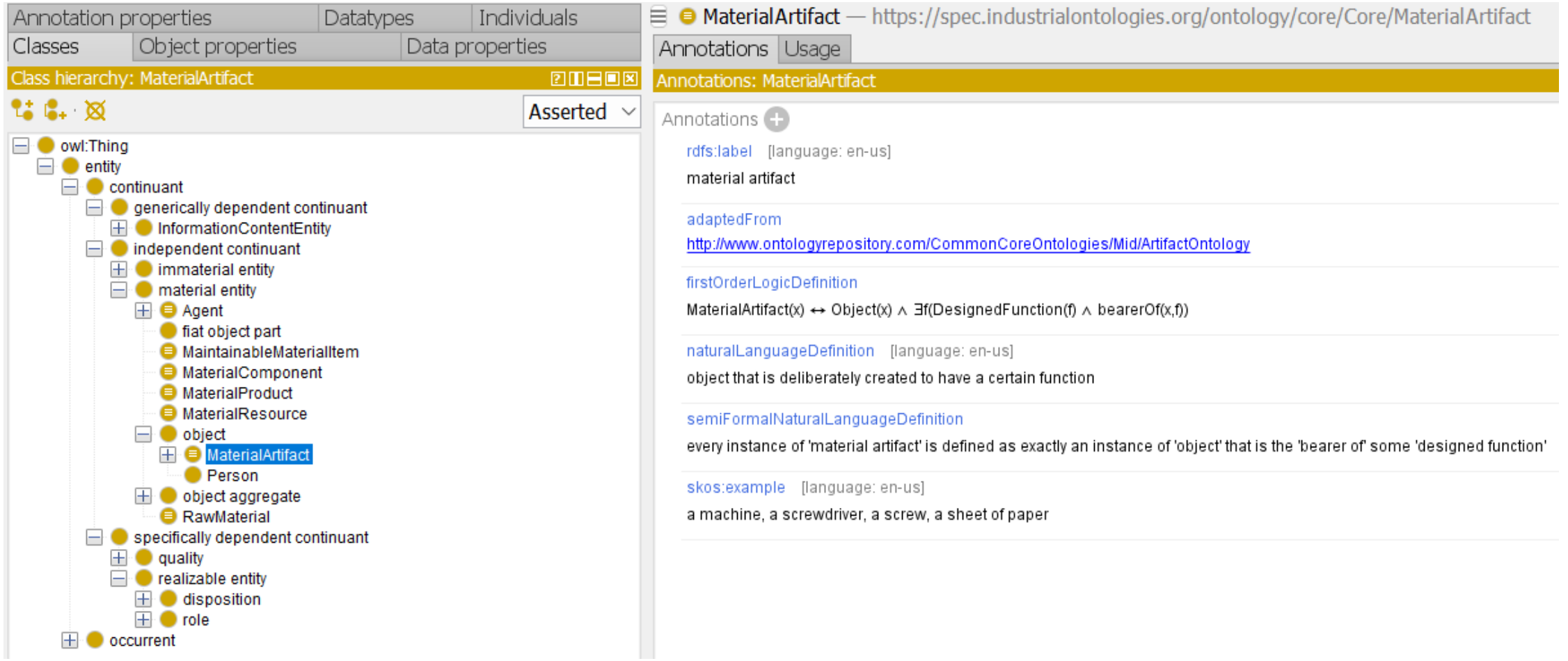


An Authoritative Source of Truth (ASOT) *x* is a 'Source of Truth' that has a role of 'ASOT Role' where the 'ASOT Role' has been designated by some 'Authority'

ASOT(x) <-> SOT(x) ∧ ∃r (ASOTRole(r) ∧ hasRole (x,r))
∧ ∃b (Authority(b) ∧ designatedBy (r,b))

DEIX Ontology – Protégé

- We are in the process of building in Protégé, on top of BFO/CCO



- DEIX Overview
- DEIX Taxonomy WG Goals
- Core Digital Engineering Concepts
- Current Status and Examples
- **Conclusions**

Conclusions

- We are developing a DE Ontology to support DEIX WG.
- Pulling together definitions from multiple domains.

Next Steps

- Continue definition of DE Core Concepts.
- Combine effort with AIAA (DE Integration Committee).
- Represent in Protégé and Cameo Concept Modeler.
- Demonstrate Use Cases as they become available (DE Primer).
- Goal to publish complete first draft for review by end of 2024

Thanks

- We have a core group of regular contributors – thanks to them all!

- If you are interested in contributing, reach out!
  - 1 hr / week.
  - Tend to focus on one concept for 2-3 weeks.
  - joegregory@arizona.edu

Positioning of DE Terminology

Thanks to Hyman Duan

- **1st dimension: matter and energy**
  - Natural science
  - Traditional disciplines of engineering
- **2nd dimension: relationships: Quantitative and Qualitative**
  - Mathematics, Systems science
  - Software engineering, Systems engineering
  - Specialty engineering: -ilities
- **3rd dimension: Approach, information, digitalization**
  - Information theory
  - (traditional document-based engineering / paper-based knowledge)
  - Digital engineering: including Model-based X Engineering
  - (AI-based digital engineering)