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A model-based analytic viewpoint to promote consistency in systems engineering practice

Analytic Viewpoint for Information Normalization (AVIaN)

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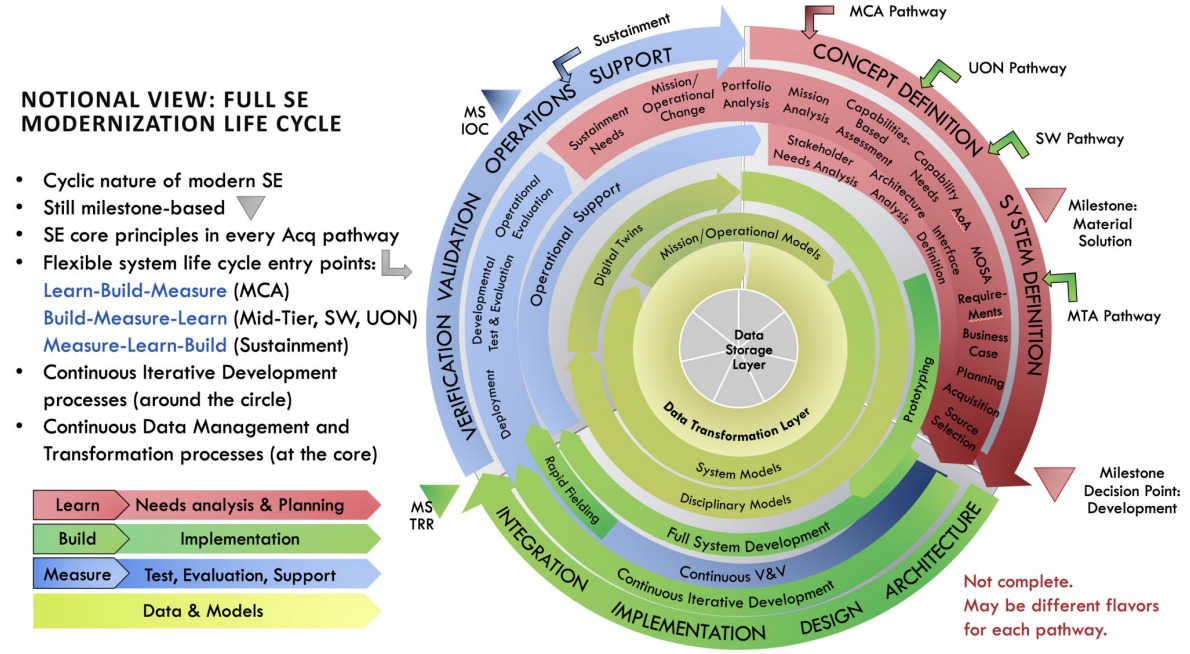
Systems Engineering Modernization



Models and data central to systems engineering modernization

Requires a way to capture how certain data or information representing key aspects of a system relates to other data or information in the semantic and structural forms necessary for effective synthesis or co-use with other data or information

(Systems Engineering Research Center, 2022)

Ontological Principles – The Goal

- Ontologies: Semantic data models that describe general types of things in a domain of interest, properties used to describe them, and their relationships
- Ontology challenges:
  - Multiple ontology formalisms in existence and development takes time (e.g., BFO and BORO)
  - Different ontologies express commitments differently, which impact compatibility and extensibility
  - Interoperability challenges with UML-based system modeling languages used in system descriptions

Value of ontologies lies in what they allow us to communicate – unambiguously and consistently across diverse stakeholders

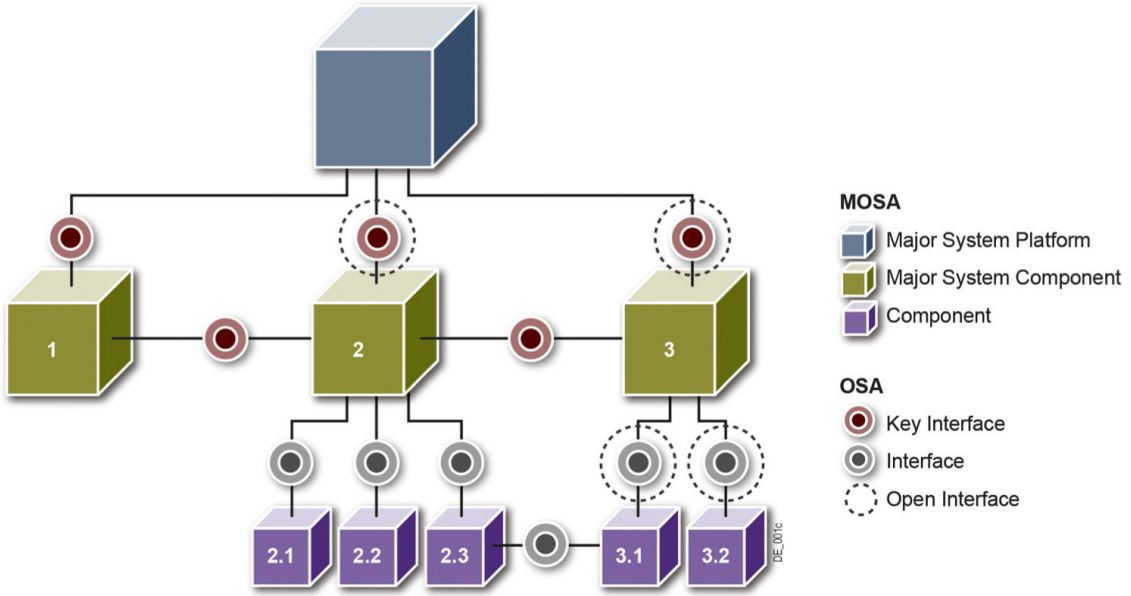
GOAL:

Develop an approach, grounded in SE and MBSE practice, to harmonize and normalize a set of different sources that define elements, concepts, and relationships differently.

- **Promote commonality and consistent application across development, integration, and modernization of systems and technologies**
- **Empower our ability to synthesize, compute on, and reason about engineering data and decisions**

Example Problem Space: MOSA

U.S.C Title 10 §4401 MOSA Requirement



Modularity

– "Degree to which systems, major constitutive subsystems and components within a system, and major subsystems and components across subsystems can function as modules ..."
(Text - H.R.6395 - 116th Congress (2019-2020): William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021 | Congress.Gov | Library of Congress, n.d.)

Interface Standardization

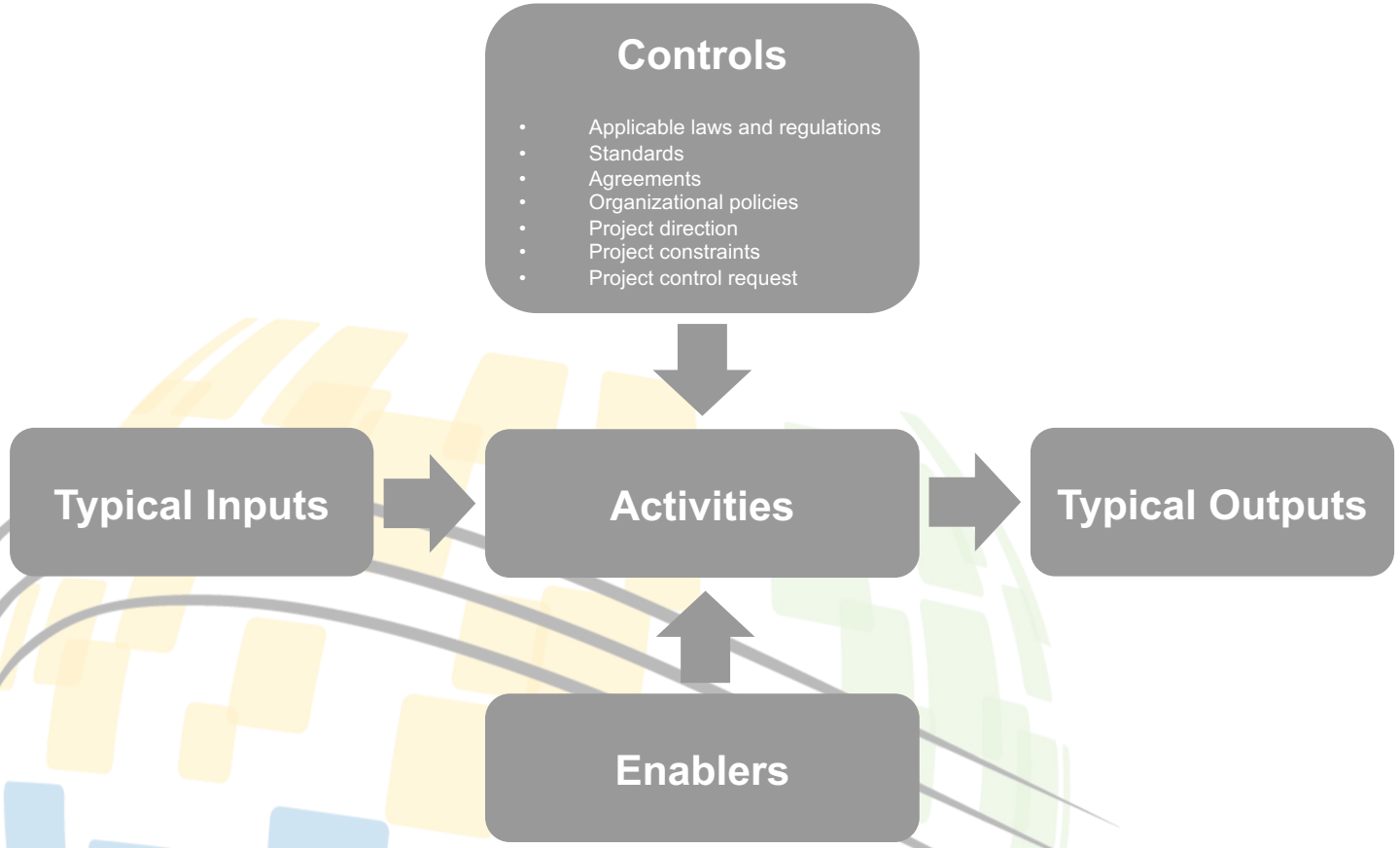
– Logical and physical interface aspects are based on and comply with widely-supported, **consensus-based standards**

Both lead to increased integration of components and interoperability between systems among other benefits

Problem across MOSA standards:
No semantic harmonization. No level of abstraction consistency.

(Zimmerman et al., 2019)

Bigger than MOSA: Controls guide and constrain execution of system lifecycle processes

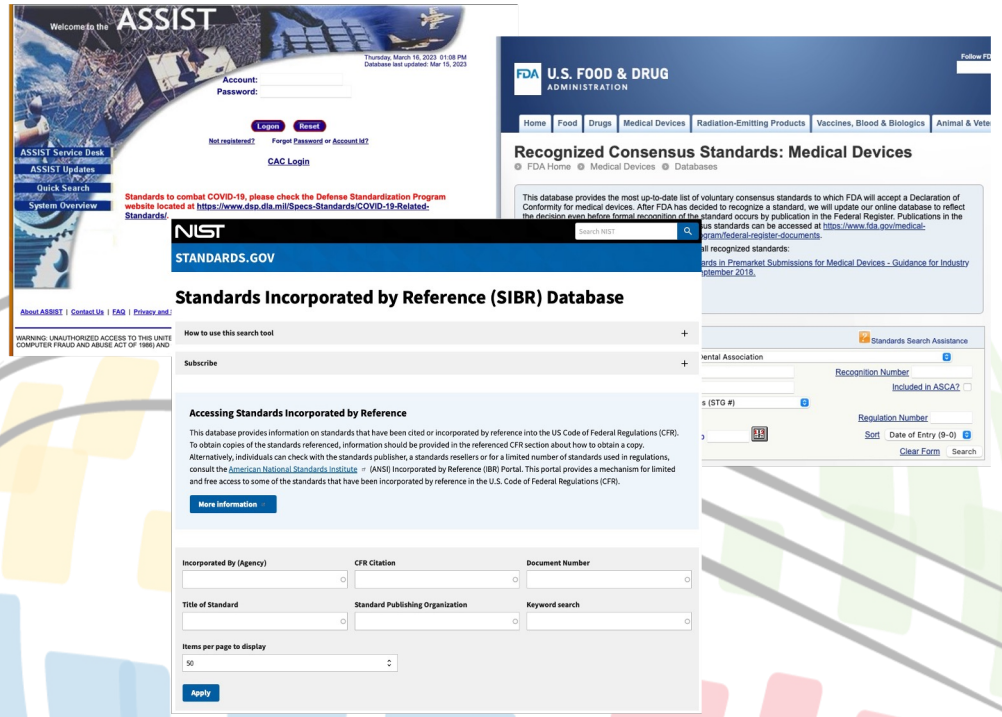


- Controls, e.g. standards, govern, in varying degrees and kinds, all system lifecycle process activities
- Numerous standards addressing multiple domain concerns, e.g. MOSA, safety, cyber security, etc., levied on a system
- Most standards are text based
  - i.e. no semantic data model

(Walden et al., 2023)

There is no easy button…

- Several databases available to identify standards applicable to a system
  - But they id individual standards and do not create harmonization across standards



Numerous consensus-based standards available, but…

- require deep technical knowledge of the standard
- overlap and compete and/or conflict with each other
- present options that when chosen may not work with other implementations of the same standard using different options
- address multiple domain concerns, e.g. interoperability, safety, and cyber security

Each standard…

- talks about things uniquely within the scope of the standard
- defines adherence of an implementation to the standard differently, e.g. compliance vs. conformance

Can't apply a standard to a system *in universum*

(*Recognized Consensus Standards*, n.d.; *Standards Incorporated by Reference (SIBR) Database | Standards Incorporated by Reference (SIBR)*, n.d.; *Welcome to the ASSIST (Database for Military Specifications and Military Standards)*, n.d.)

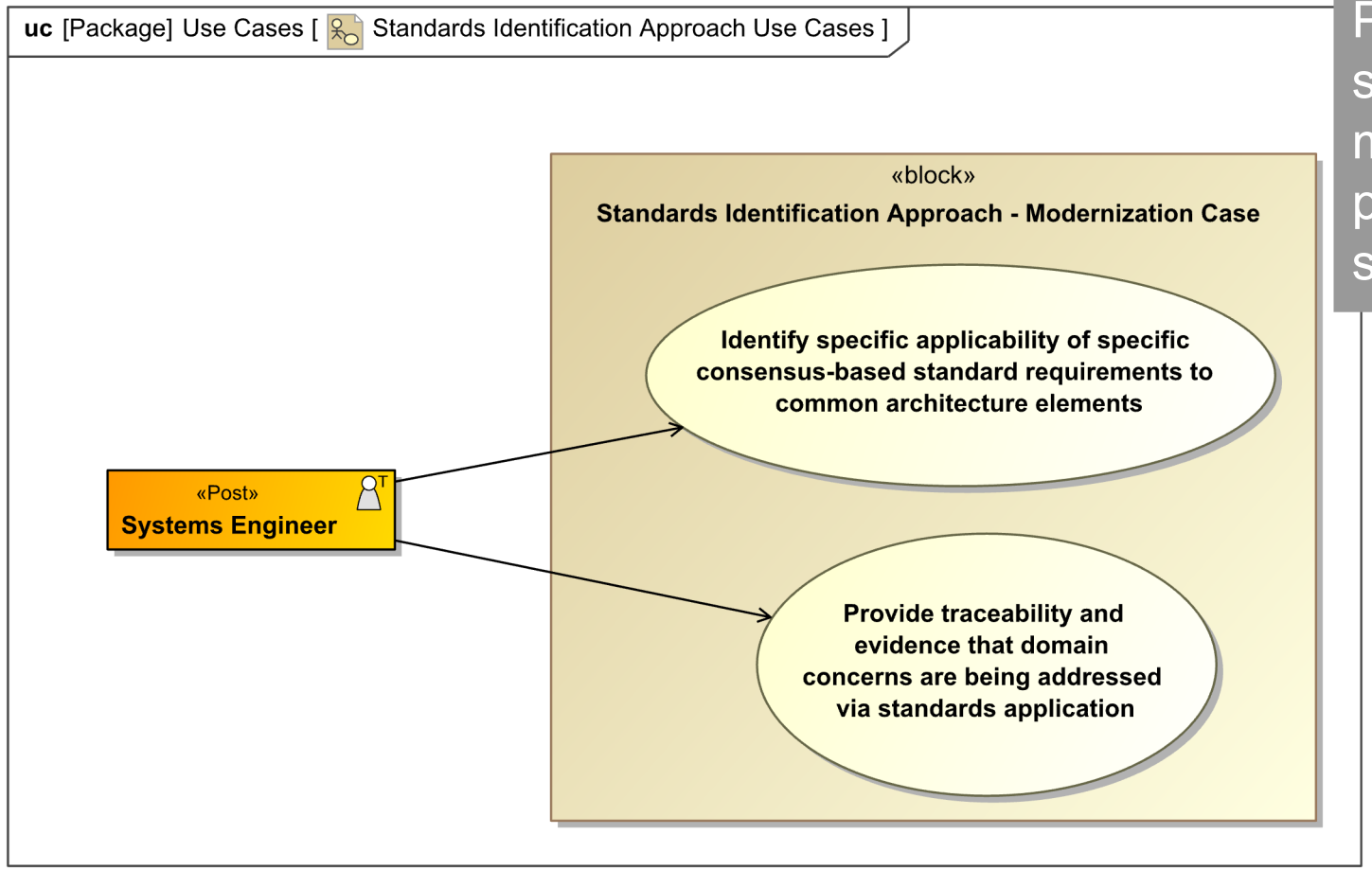
Help please!

- As a systems engineer…
  - Which standards and which parts of the standard are applicable to my system?
  - I don't have time to become intimately familiar with all the standards
  - How do I choose the standards that don't conflict?
  - How do I choose an option that will work with other implementations of the same standard?
  - How do I normalize all the concepts and terms into a coherent, consistent understanding?
  - How do I do this in a model-based way?

- As an organization…
  - How do we govern the development of systems and enforce consistent application of standards across our family of systems or product line?

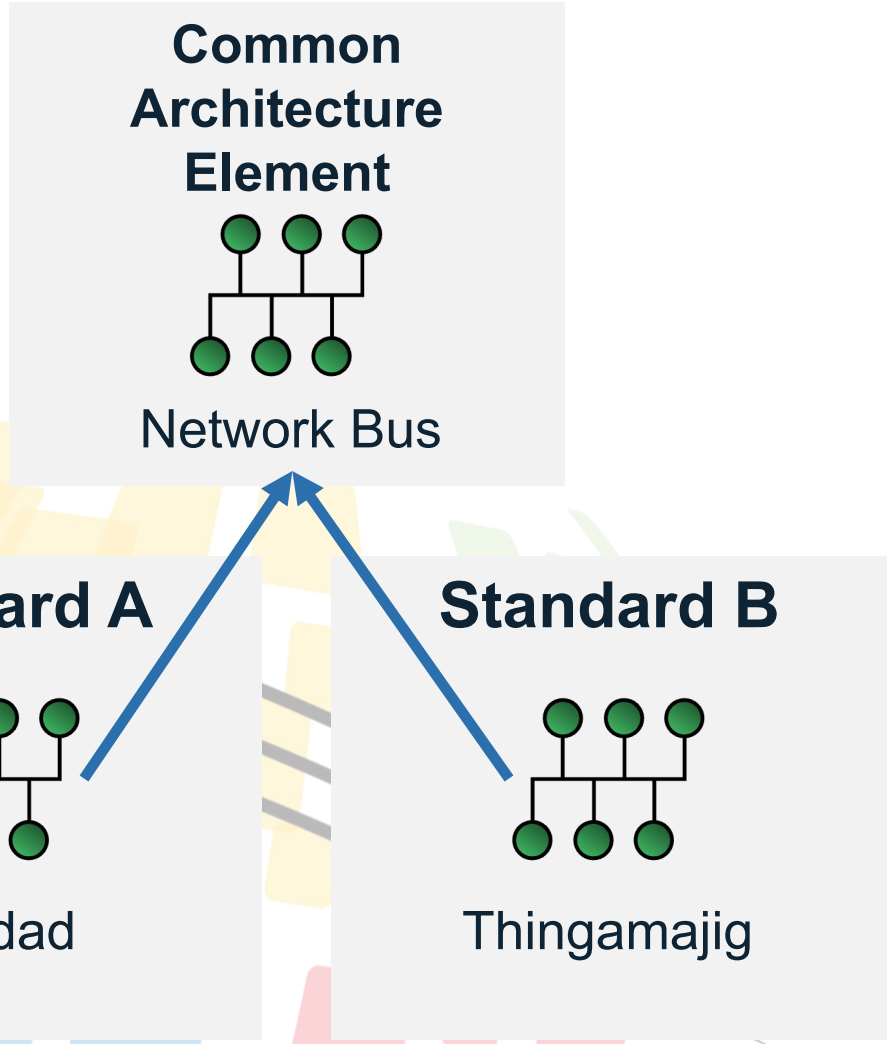
Organizations and SEs need a starting point that is flexible for their specific program technical and business needs in a model-based framework

Standards Identification Approach



Problem scoped to system modernization programs vice new start

Information Normalization



- Basic standard requirement/clause structure
  - The <*subject clause*> shall <*action verb clause*> <*object clause*> <*optional qualifying clause*>, when <*condition clause*>. *(Ryan & Wheatcraft, 2023)*
- Many standards bound clauses to standard-specific conceptual entities, i.e. subjects
  - Makes it difficult to know the applicability of a standard clause
- Need a means to:
  - Normalize the conceptual entities under a common architecture element
  - Align a referencing architecture to the common architecture elements within a specific domain

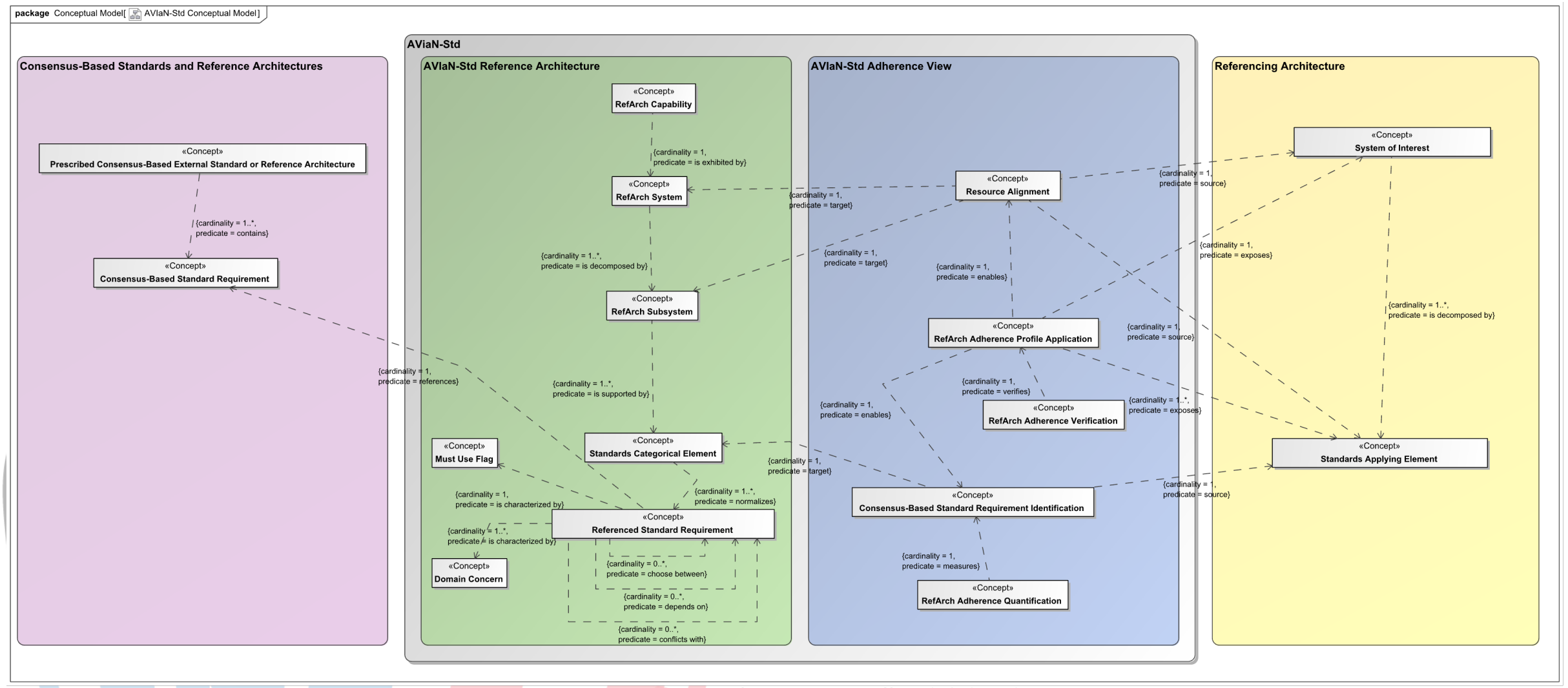
Architecture Assessment

- How do you assess if a referencing architecture, e.g. system architecture, addresses domain concerns via standards identification and application?
  - Reduce manual inspection as much as possible
- Need a means to quickly and efficiently:
  - Expose architecture elements
  - Perform mappings
  - Conduct the assessment
  - View the results

Analytic Viewpoint for Information Normalization

- Model-based architectural viewpoint that frames stakeholder concerns related to the analysis and assessment of an architecture against engineering domain concerns
- AVIaN establishes:
  - An information normalization framework
  - Architecture assessment metrics based on normalized governance
  - Methods for analysis and assessment of an architecture against the assessment metrics
  - Model kinds and views used to support analyses with respect to system development and modernization needs relevant to the standards and guidance captured

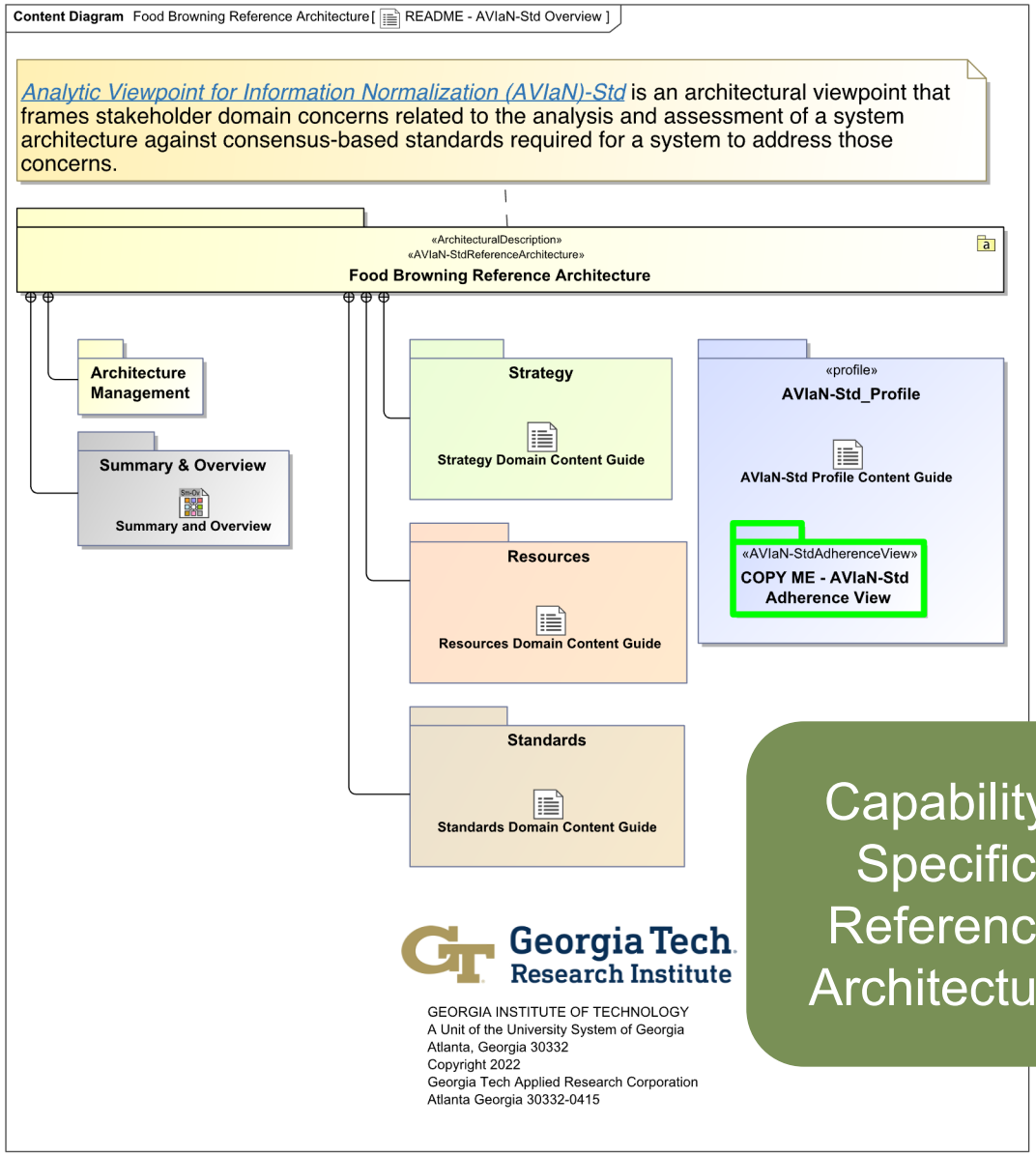
AVIaN Standards Identification Ontological Framework



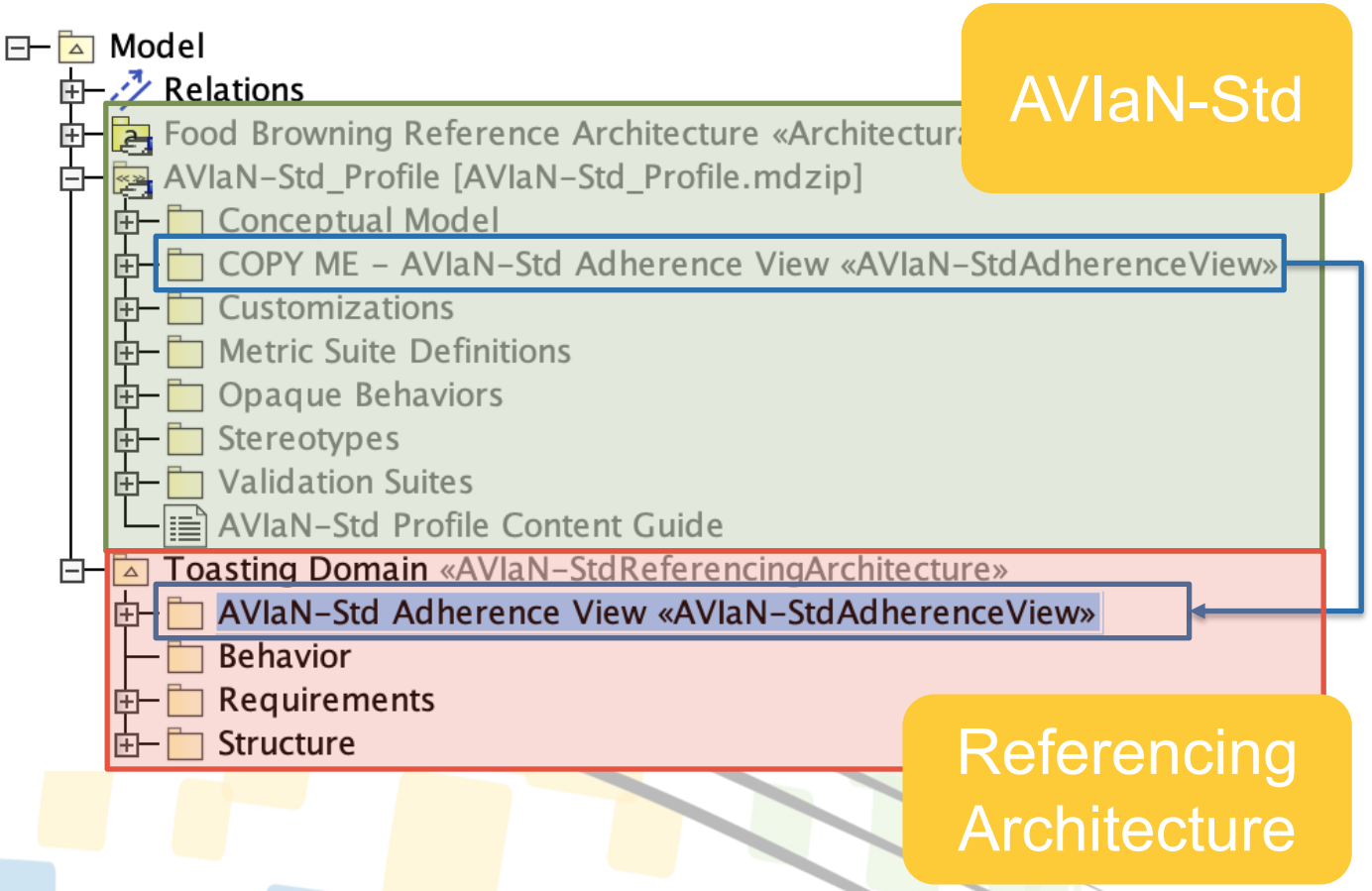
AVIaN-Std

Ontological framework implemented as UAF fit-for-purpose reference architecture and profile designed to:

- Identify, categorize, and normalize standards into common architecture elements within a capability domain
- Present options, dependencies, and conflicts among standards
- Support flexibility, innovation, and ability to meet unique program needs while constraining overall space to appropriate levels of commonality
- Promote information discovery
- Provide mechanism for traceability and evidence of adherence for referencing architectures
- Tailor to specific capability



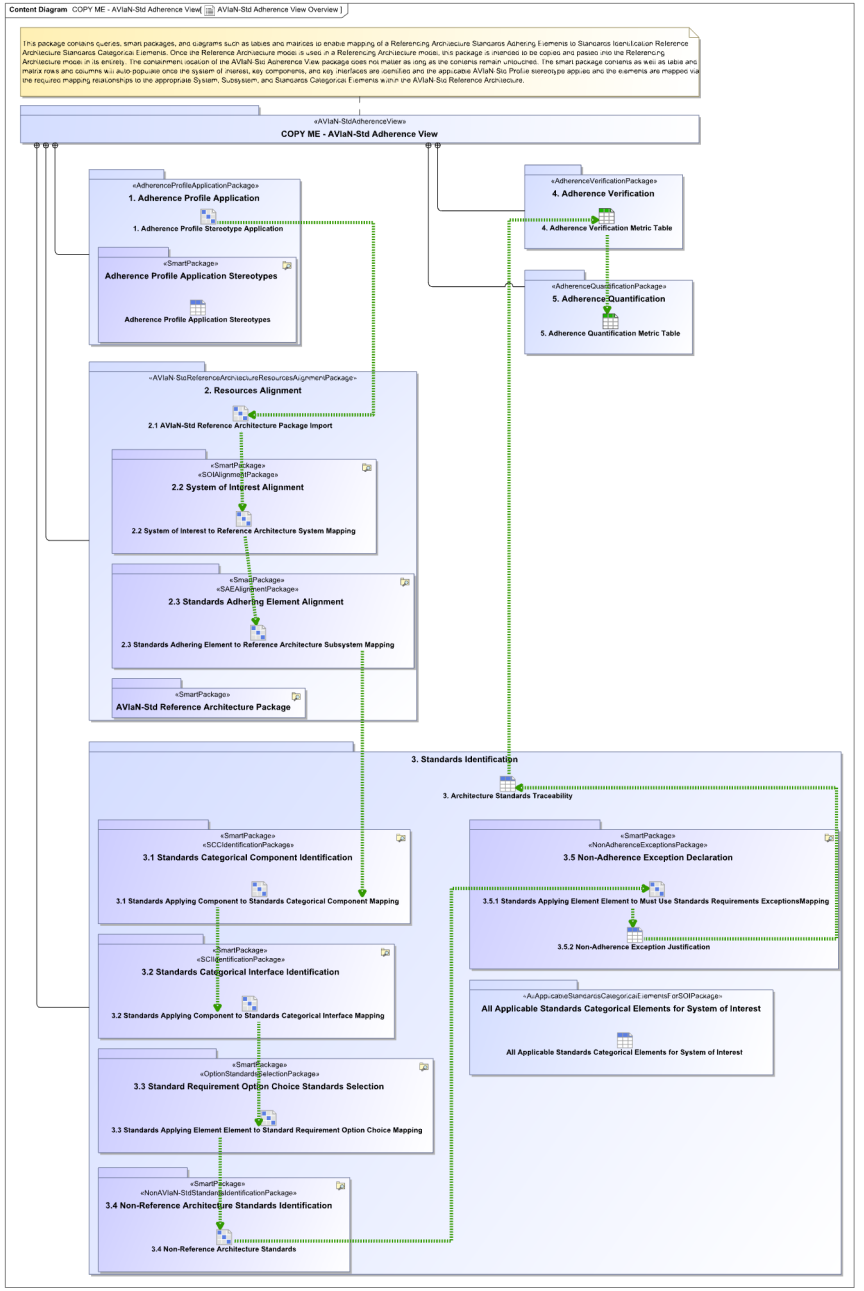
Using AVIaN-Std



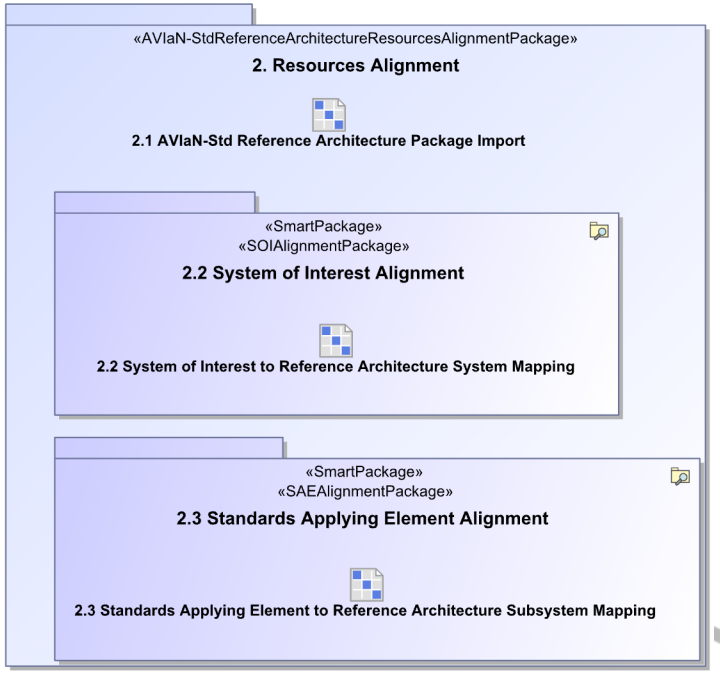
- Capability-specific AVIaN Reference Architecture used as read-only project in referencing architecture
- AVIaN-Std Adherence View package copied into referencing architecture

AVIaN-Std Adherence View

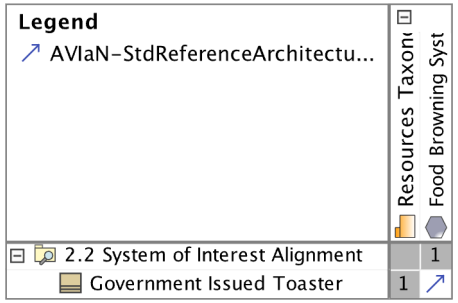
- User-guided workflow implemented in 5 packages with smart packages, preconfigured matrices, and tables:
  1. Adherence Profile Application
     - Expose relevant architecture elements
  2. Resource Alignment
     - Assert capability and functional alignment
  3. Standards Identification
     - Identify relevant and applicable standards
     - Choose among options
     - Declare exceptions to required standards
     - View standards traceability
  4. Adherence Verification
     - Analyze verification of tracing to the Reference Architecture
  5. Adherence Quantification
     - Quantify adherence to Reference Architecture

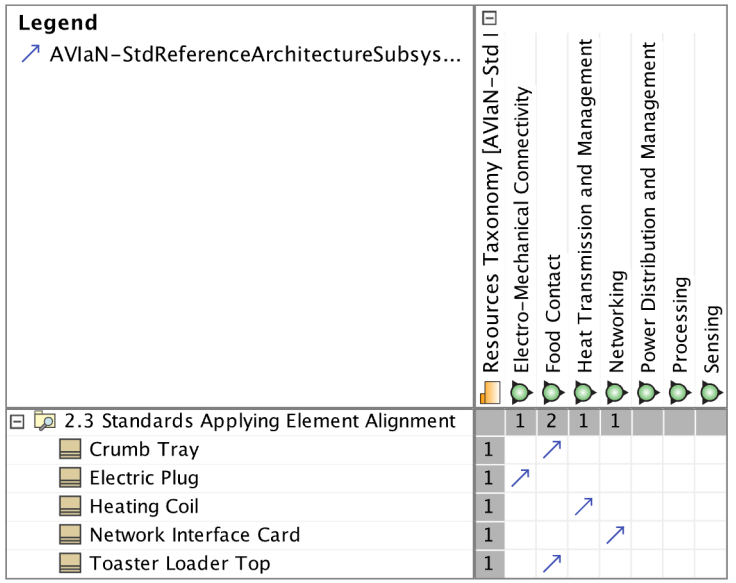


Functionally align Referencing Architecture to Reference Architecture

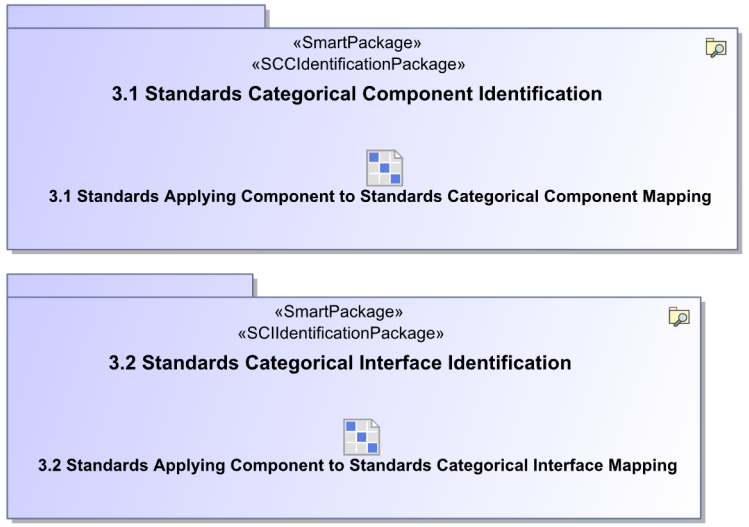


- Many kinds of systems may be defined in the Reference Architecture if the capability domain is broad
  - Align referencing architecture system with the appropriate, reference architecture system
- Every standards applying element must align with Reference Architecture subsystem
  - Filters standards applicable to element to those

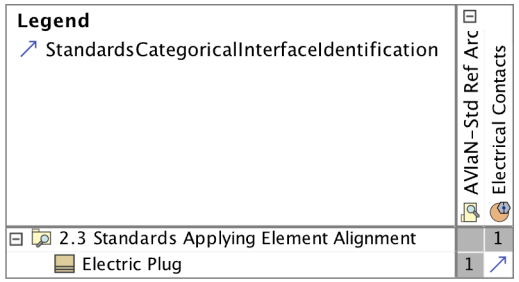


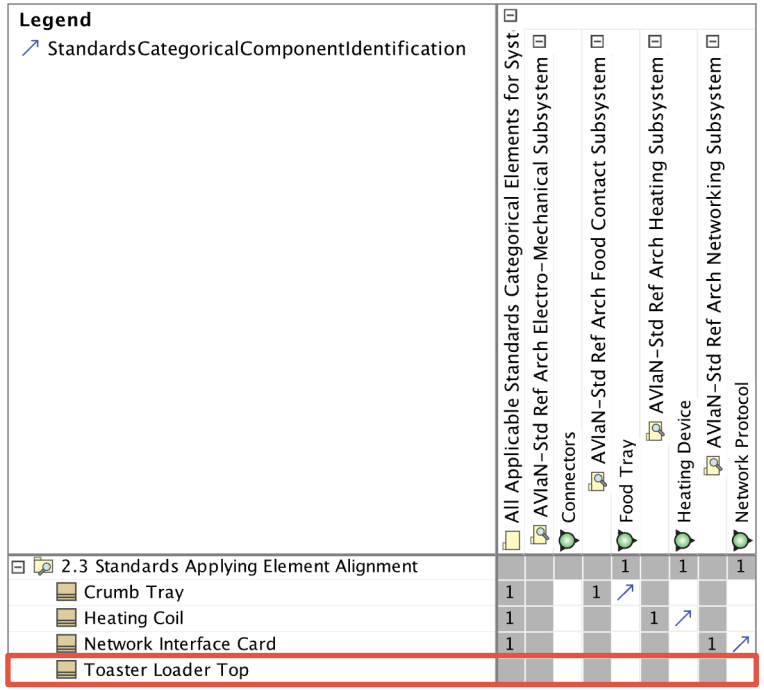


Identify applicable standards



- Map standards applying elements in Referencing Architecture to Standards Categorical Elements that are logically and physically similar
- Constraints prevent mapping to Categorical Elements not in aligned subsystem
- Not all standards applying elements will map
  - Can't know everything



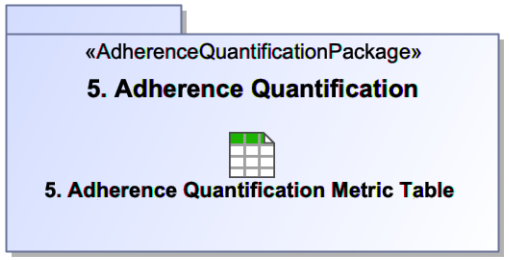


View Standards Traceability Summary

#	Name	Identified Standards Categorical Elements	Identified Standard Requirements	Chosen Optional Standard Requirements	Choice Resultant Standard Requirements	Must Use Standard Requirements	Excluded Must Use Standard Requirements	Referencing Architecture Specific Standard Requirements	All Applied Standards
1	Crumb Tray	Food Tray	Food Equipment Sanitation Regulation Reqt 2 Food Equipment Sanitation Regulation Reqt 1 Food Equipment Sanitation Regulation Reqt 3	Food Equipment Sanitation Regulation Reqt 2-2	Food Equipment Sanitation Regulation Reqt 4	Food Equipment Sanitation Regulation Reqt 1 Food Equipment Sanitation Regulation Reqt 3 Food Equipment Sanitation Regulation Reqt 2-2 Food Equipment Sanitation Regulation Reqt 4	Food Equipment Sanitation Regulation Reqt 1		Food Equipment Sanitation Regulation Reqt 1 Food Equipment Sanitation Regulation Reqt 3 Food Equipment Sanitation Regulation Reqt 2-2 Food Equipment Sanitation Regulation Reqt 4
2	Electric Plug	Electrical Contacts	Electrical Interface Standard Reqt 2			Electrical Interface Standard Reqt 2			Electrical Interface Standard Reqt 2
3	Heating Coil	Heating Device	Food Service Equipment Safety Guidance Reqt 1 Food Service Equipment Safety Guidance Reqt 2 Food Service Equipment Safety Guidance Reqt 4			Food Service Equipment Safety Guidance Reqt 1 Food Service Equipment Safety Guidance Reqt 4			Food Service Equipment Safety Guidance Reqt 1 Food Service Equipment Safety Guidance Reqt 4
4	Network Interface Card	Network Protocol	Networking Standard Reqt 1 Networking Standard Reqt 2 Networking Standard Reqt 4			Networking Standard Reqt 1 Networking Standard Reqt 2 Networking Standard Reqt 4	Networking Standard Reqt 4	1 Proprietary Messaging Standard	1 Proprietary Messaging Standard Networking Standard Reqt 1 Networking Standard Reqt 2 Networking Standard Reqt 4
5	Toaster Loader To								

Easily derived requirements can be levied on vendors

Run analysis to quantify degree of adherence to Reference Architecture



«MetricSuite»
AVIaN-Std Reference Architecture Adherence Quanitification
{target = 5. Adherence Quantification}

attributes

«MetricDefinition» -Total Number Of Reference Architecture Must Use Standard Requirements : Integer
«MetricDefinition» -Total Number Excluded Must Use Reference Architecture Standard Requirements : Integer
«MetricDefinition» -Percent Adhering Referencing Architecture Standards Adhering Elements : Real
«MetricDefinition» -Total Number Of Must Use Safety Standard Requirements : Integer
«MetricDefinition» -Total Number Excluded Must Use Safety Standard Requirements : Integer
«MetricDefinition» -Percent Safety Concern Addressed Via Applied Standards : Real
«MetricDefinition» -Total Number Of Must Use Interoperability Standard Requirements : Integer
«MetricDefinition» -Total Number Excluded Must Use Interoperability Standard Requirements : Integer
«MetricDefinition» -Percent Interoperability Concern Addressed Via Applied Standards : Real
«MetricDefinition» -Total Number Of Must Use Cyber Security Standard Requirements : Integer
«MetricDefinition» -Total Number Excluded Must Use Cyber Security Standard Requirements : Integer
«MetricDefinition» -Percent Cyber Security Concern Addressed Via Applied Standards : Real

- Adherence stratified by domain concern

#	Date	Scope	Total Number Of Reference Architecture Must Use Standard Requirements	Total Number Excluded Must Use Reference Architecture Standard Requirements	Percent Adhering Referencing Architecture Standards Adhering Elements	Total Number Of Must Use Safety Standard Requirements	Total Number Excluded Must Use Safety Standard Requirements	Percent Safety Concern Addressed Via Applied Standards	Total Number Of Must Use Interoperability Standard Requirements	Total Number Excluded Must Use Interoperability Standard Requirements	Percent Interoperability Concern Addressed Via Applied Standards	Total Number Of Must Use Cyber Security Standard Requirements	Total Number Excluded Must Use Cyber Security Standard Requirements	Percent Cyber Security Concern Addressed Via Applied Standards
1	2024.04.24 13.00	Toasting Domain	10	2	80	6	1	83.3333	3	0	100	2	1	50

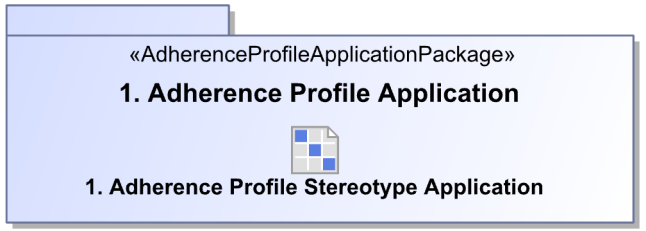
$$Adherence = \left(1 - \frac{Number\ Excluded\ Must\ Use\ Requirements}{Total\ Number\ Must\ Use\ Requirements}\right) x\ 100$$

Summary

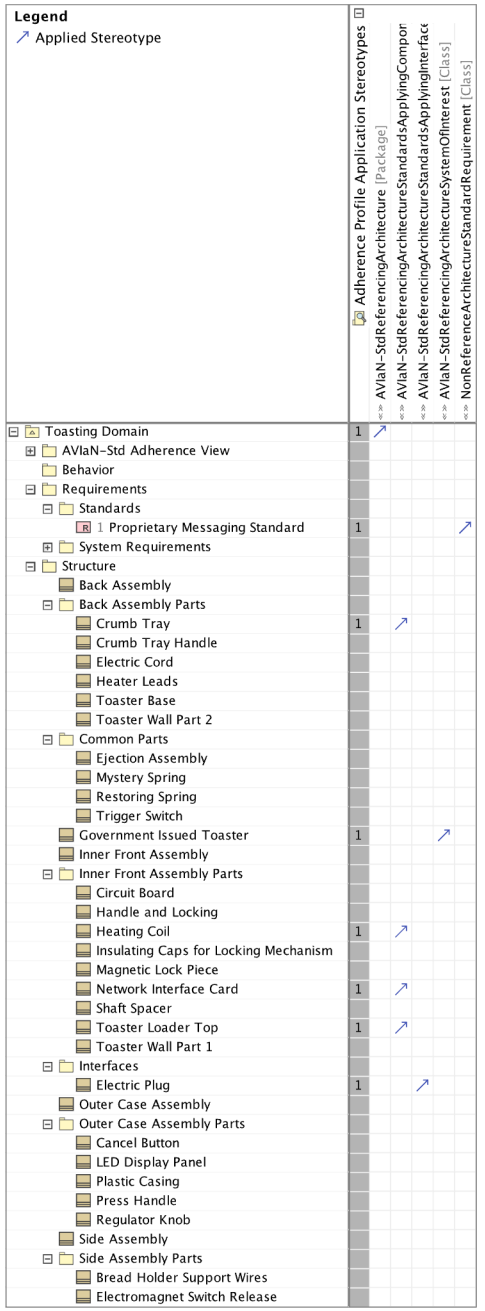
- AVIaN-Std is a model-based analytic viewpoint based on an ontological framework
- AVIaN-Std aids systems engineers and organizations to consistently identify and apply consensus-based standards to their system and provide traceable and justifiable evidence for addressing domain concerns by:
  - Defining how to capture information about standards relevant in a domain context
  - Defining how to normalize and unify the applicable concepts extracted from the relevant standards
  - Defining how to identify and apply standards consistently across a family of systems or product line
  - Giving program offices the flexibility they need to choose the right standards based on their specific business and technical needs
  - Enabling traceability and evidence for addressing domain concerns via standards application
  - Being reusable
- AVIaN-Std can be tailored and applied to any capability domain

Additional Slides

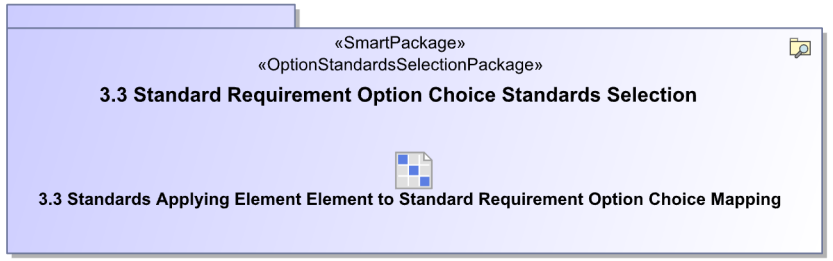
Apply AVIaN-Std Profile



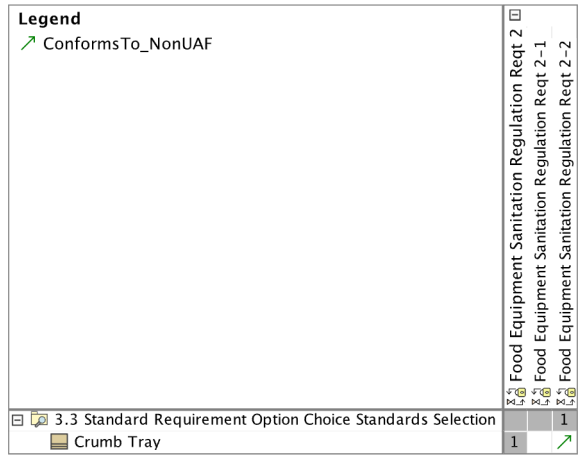
- Matrix preconfigured to facilitate applying information exposing stereotypes to relevant parts of the Referencing Architecture
- Not all architecture elements need to apply a standard
  - Only stereotype those that are needed

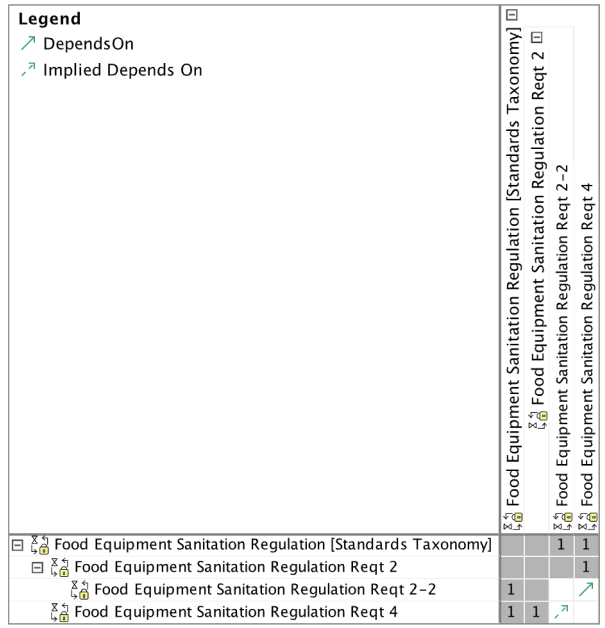


Select standard requirement option choice



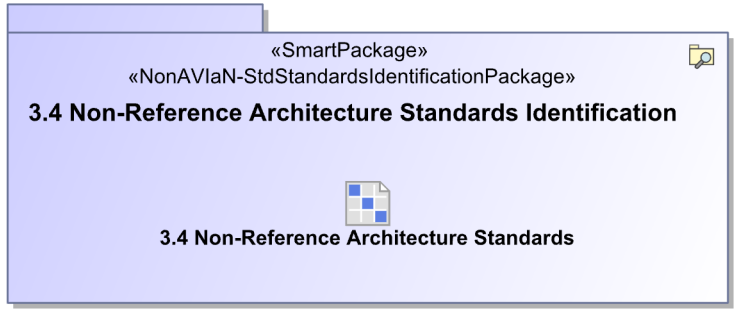
- Many standard requirements present options
  - Choose the one that makes the most business and technical sense
- Selections may result in additional, indirect standard requirements due to dependencies

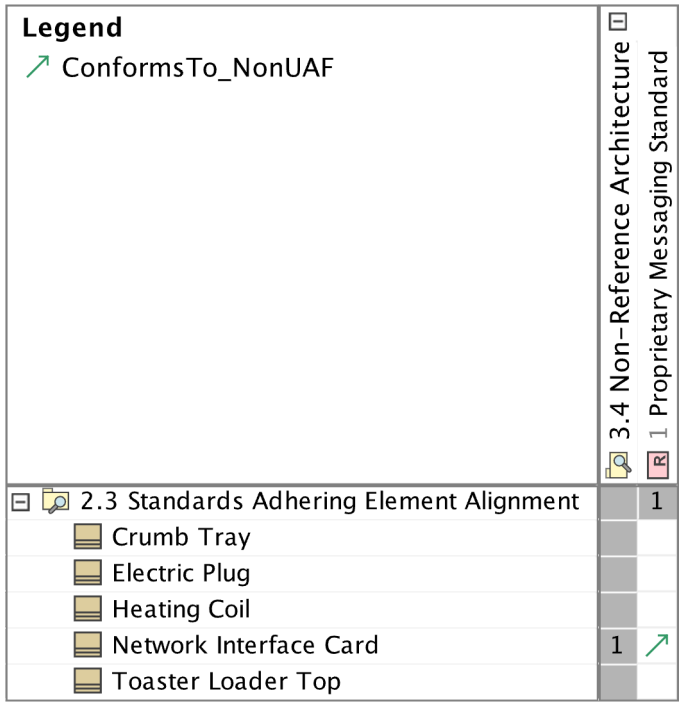




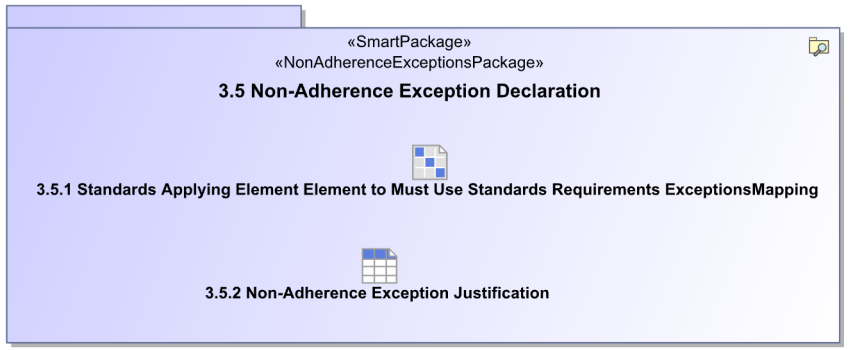
Map to standards not identified in Reference Architecture

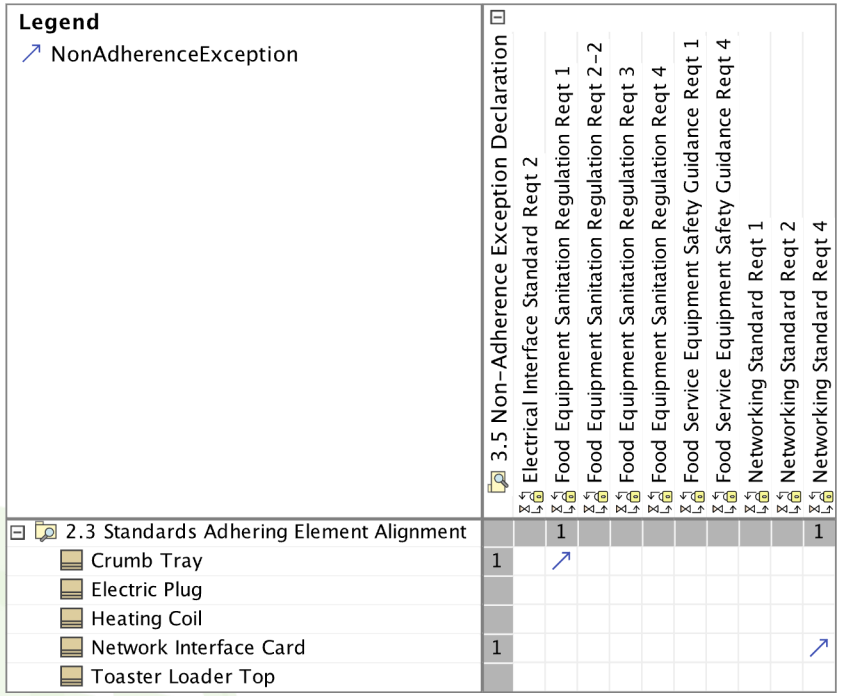
- Every standards applying element must apply a standard
  - Either identified in Reference Architecture
  - Or specific to the Referencing Architecture





Declare exceptions to must use requirements and provide justification





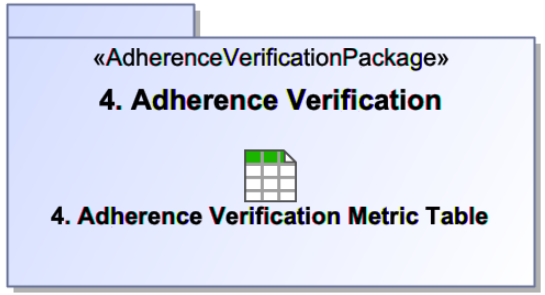
- It may not make technical or business sense to map to standard requirements flagged as must use
- Must declare exception and provide justification

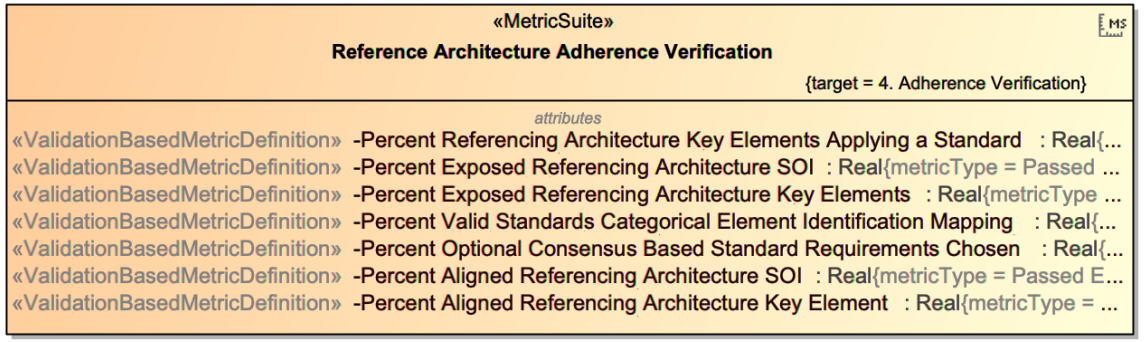
#	Standards Adhering Element	Non Adhering Must Use Reference Architecture Standard Requirement	Justification	Authority	Date
1	Crumb Tray	Food Equipment Sanitation Regulation Reqt 1	Application of this standard could result in significant cost and schedule increase.	Gina Burdell	4/23/24, 1:17 PM
2	Network Interface Card	Networking Standard Reqt 4	Do not agree that this standard aids in addressing cyber security.	Gina Burdell	4/23/24, 1:17 PM

Auto-Generated Requirements

#	Id	△ Name	Text	Refined By
1	STDREQ-1	STDREQ-1 Network Interface Card - Proprietary Messaging Standard Requirement	The Network Interface Card shall adhere to Proprietary Messaging Standard.	Network Interface Card
2	STDREQ-2	STDREQ-2 Network Interface Card - Networking Standard Reqt 2 Requirement	The Network Interface Card shall adhere to Networking Standard Reqt 2.	Network Interface Card
3	STDREQ-3	STDREQ-3 Network Interface Card - Networking Standard Reqt 1 Requirement	The Network Interface Card shall adhere to Networking Standard Reqt 1.	Network Interface Card
4	STDREQ-4	STDREQ-4 Network Interface Card - Networking Standard Reqt 4 Requirement	The Network Interface Card shall adhere to Networking Standard Reqt 4.	Network Interface Card
5	STDREQ-5	STDREQ-5 Electric Plug - Electrical Interface Standard Reqt 2 Requirement	The Electric Plug shall adhere to Electrical Interface Standard Reqt 2.	Electric Plug
6	STDREQ-6	STDREQ-6 Crumb Tray - Food Equipment Sanitation Regulation Reqt 2-2 Requirement	The Crumb Tray shall adhere to Food Equipment Sanitation Regulation Reqt 2-2.	Crumb Tray
7	STDREQ-7	STDREQ-7 Crumb Tray - Food Equipment Sanitation Regulation Reqt 3 Requirement	The Crumb Tray shall adhere to Food Equipment Sanitation Regulation Reqt 3.	Crumb Tray
8	STDREQ-8	STDREQ-8 Crumb Tray - Food Equipment Sanitation Regulation Reqt 4 Requirement	The Crumb Tray shall adhere to Food Equipment Sanitation Regulation Reqt 4.	Crumb Tray
9	STDREQ-9	STDREQ-9 Crumb Tray - Food Equipment Sanitation Regulation Reqt 1 Requirement	The Crumb Tray shall adhere to Food Equipment Sanitation Regulation Reqt 1.	Crumb Tray
10	STDREQ-10	STDREQ-10 Heating Coil - Food Service Equipment Safety Guidance Reqt 1 Requirement	The Heating Coil shall adhere to Food Service Equipment Safety Guidance Reqt 1.	Heating Coil
11	STDREQ-11	STDREQ-11 Heating Coil - Food Service Equipment Safety Guidance Reqt 4 Requirement	The Heating Coil shall adhere to Food Service Equipment Safety Guidance Reqt 4.	Heating Coil

Run analysis to determine if mappings have been done correctly





#	Date	Scope	Percent Aligned Referencing Architecture SOI	Percent Aligned Referencing Architecture Standards Applying Element	Percent Exposed Referencing Architecture SOI	Percent Exposed Referencing Architecture Standards Applying Elements	Percent Valid Standards Categorical Element Identification Mapping	Percent Optional Consensus Based Standard Requirements Chosen	Percent Referencing Architecture Standards Applying Elements Applying a Standard
1	2024.04.23 13.31	Toasting Domain	100	80	100	100	100	100	80

- Validation based metrics defined to to quantify degree of well-formedness to the ontology underpinning the framework

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