31st Annual INCOSE international symposium

virtual event

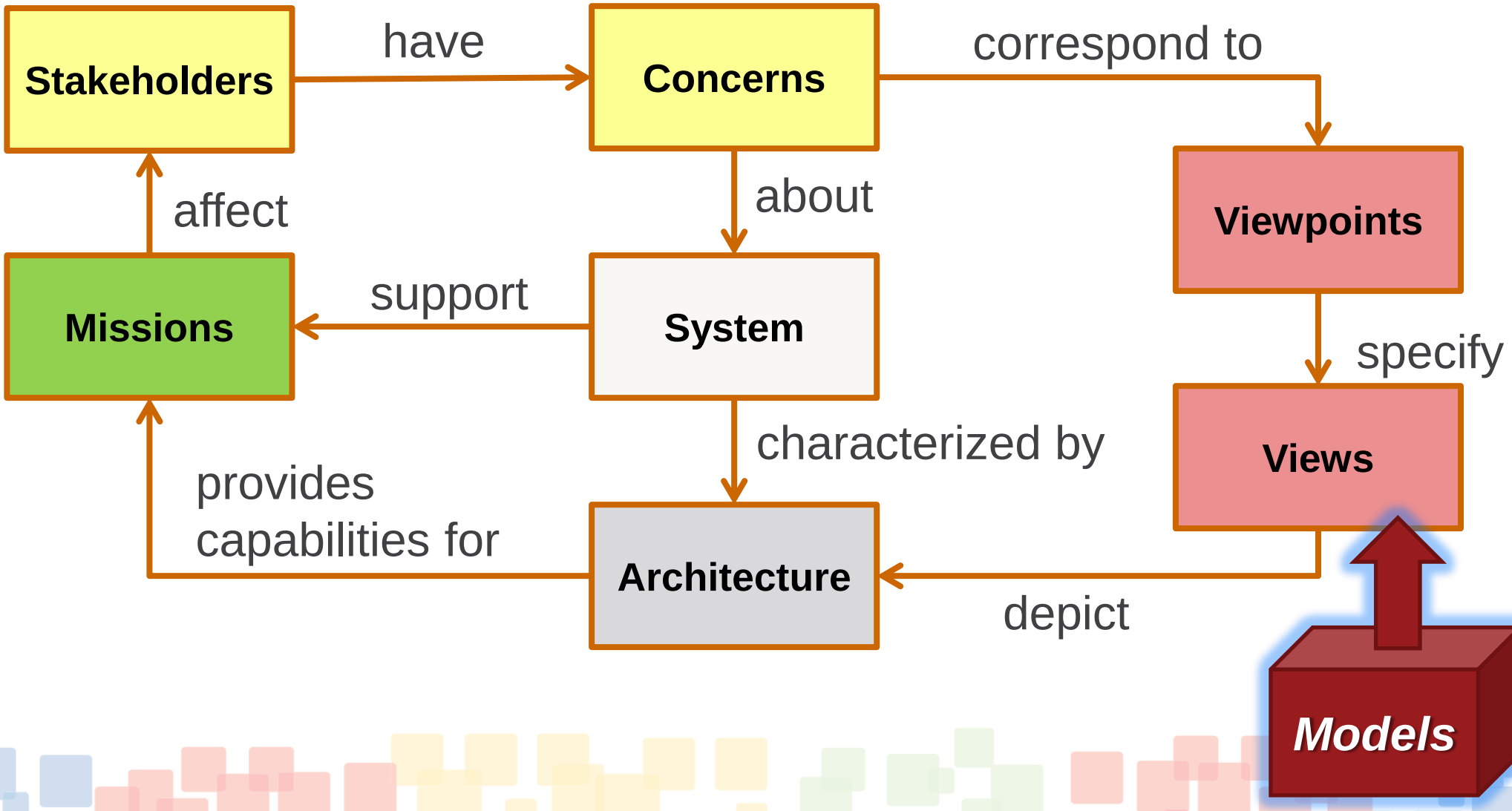
July 17 - 22, 2021

Session 2.4 – Presented by James N Martin, The Aerospace Corporation

Aspect-Oriented Architecting Using Architecture Frameworks

www.incose.org/symp2021

Stakeholders & their Concerns should Drive the Architecture

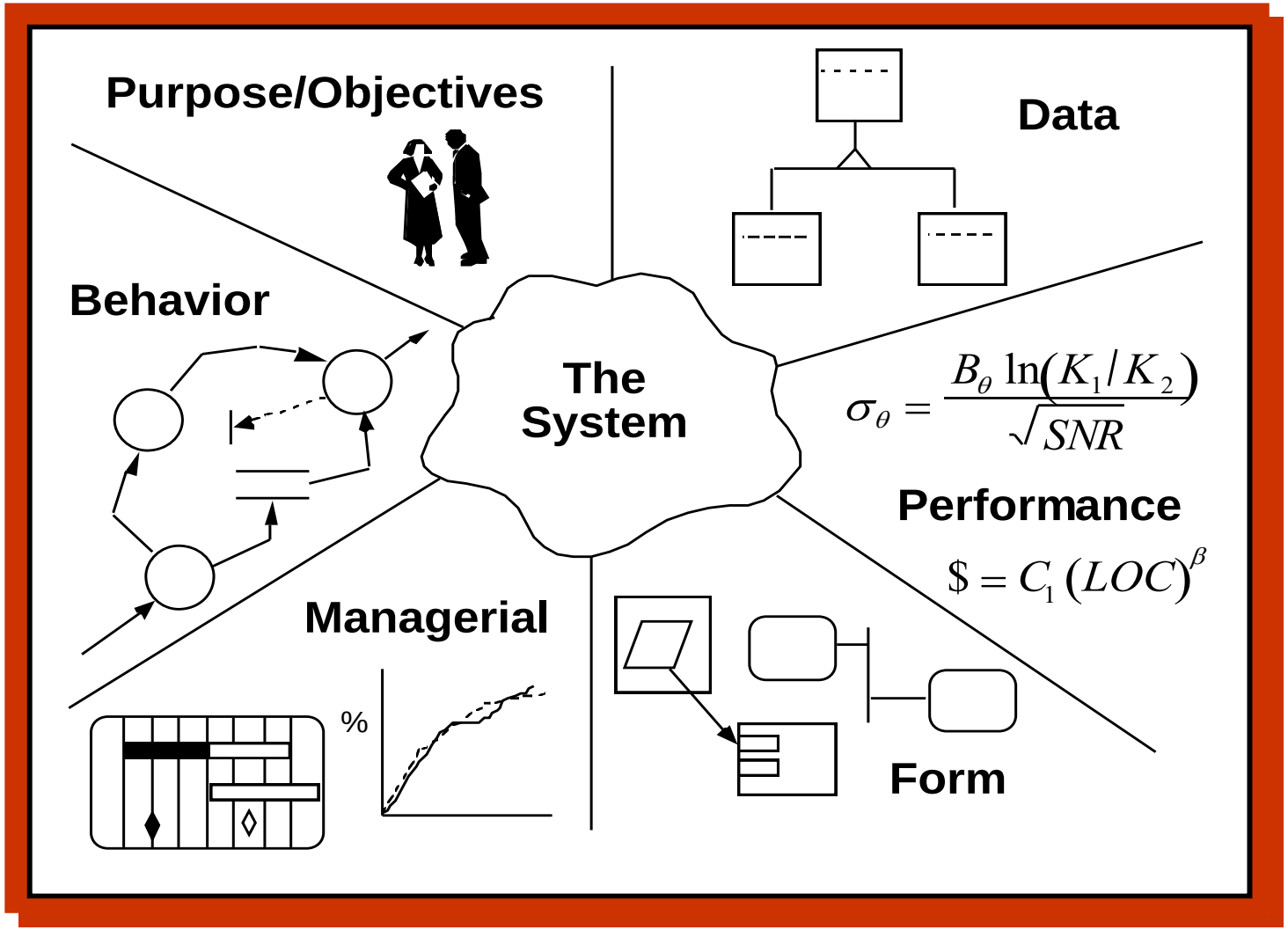


Stakeholders & Concerns

- **Example Stakeholders:** users, operators, maintainers, owners, sponsors, acquirers, developers, builders, integrators, suppliers, industrial base, labor force, third parties (eg, environmental impacts), evaluators, policy makers, certification authorities, auditors, etc.

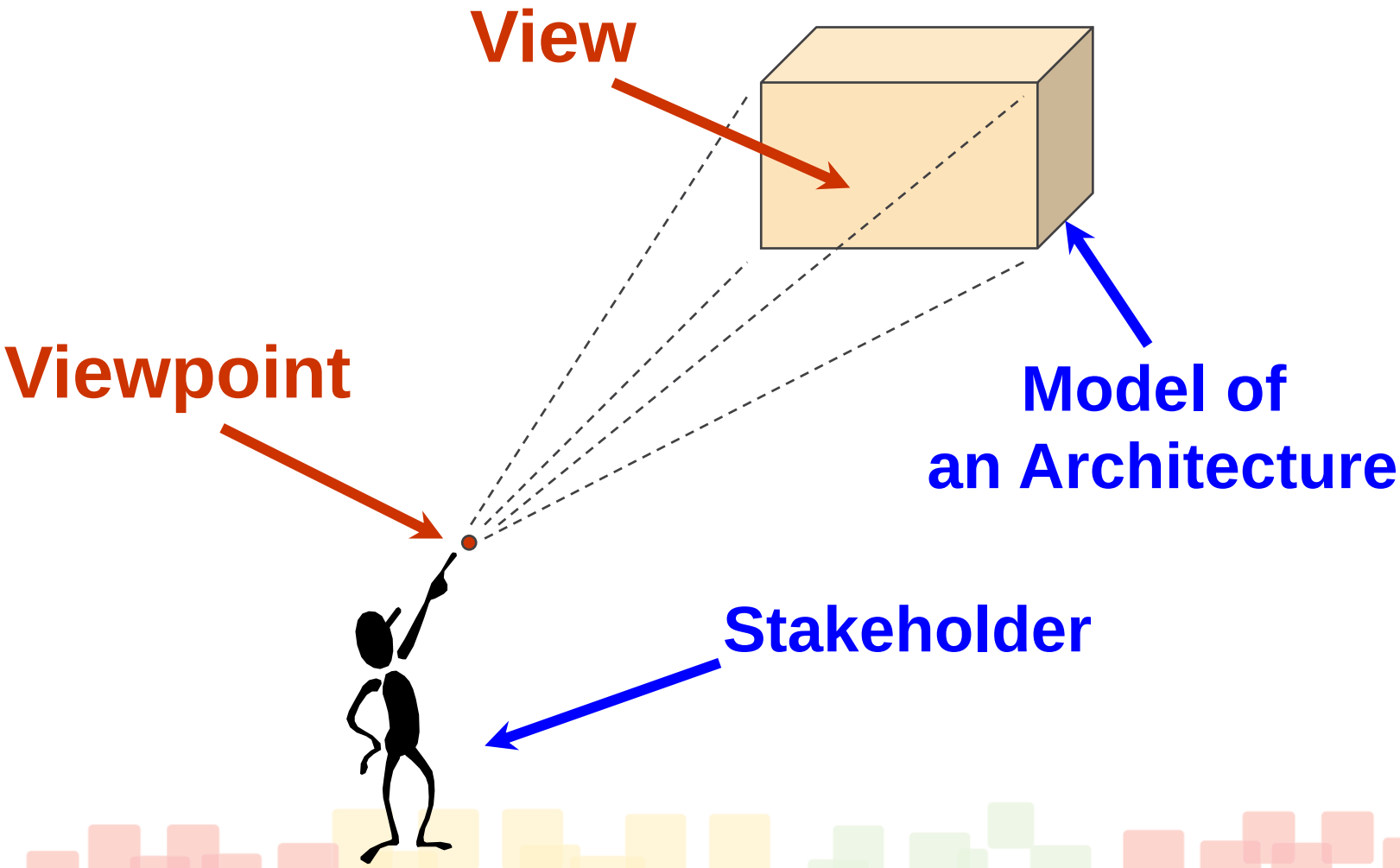
- **Example Concerns:** affordability, agility, alignment with business goals and strategies, assurance, autonomy, availability, behaviour, business impact, capability, complexity, compliance to regulation, concurrency, control, cost, customer experience, data accessibility, deadlock, disposability, evolvability, feasibility, flexibility, functionality, information assurance, interoperability, inter-process communication, known limitations, maintainability, mission impact, misuse, modifiability, modularity, openness, performance, privacy, quality of service, reliability, resilience, resource utilization, schedule, security, shortcomings, state change, structure, subsystem integration, system features, system properties, system purposes, usability, usage, viability, etc.

Categories of Stakeholder Concerns

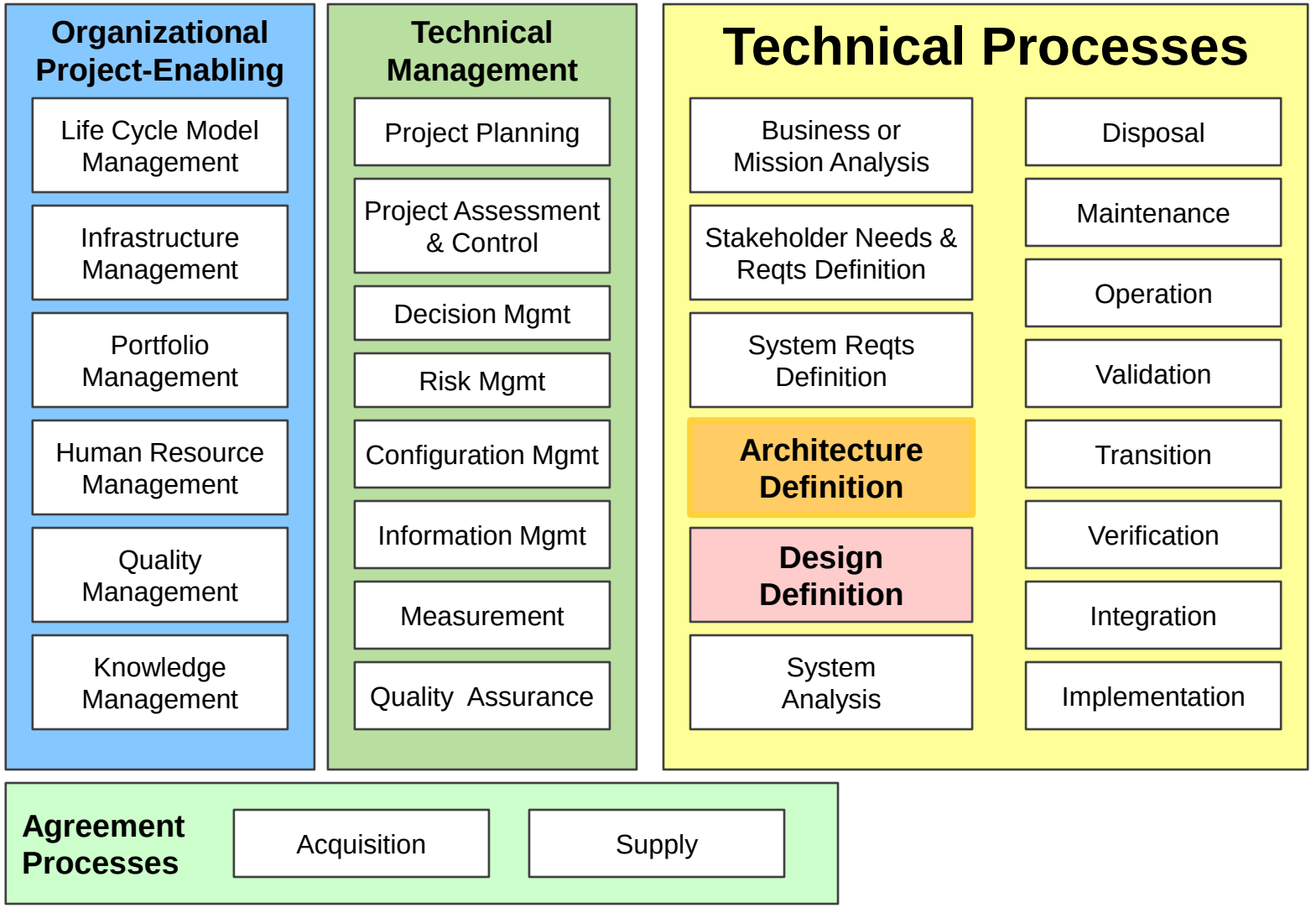


SOURCE: Rechtin and Maier, “The Art of Systems Architecting”

Architectural Models Communicate to Stakeholders through Views

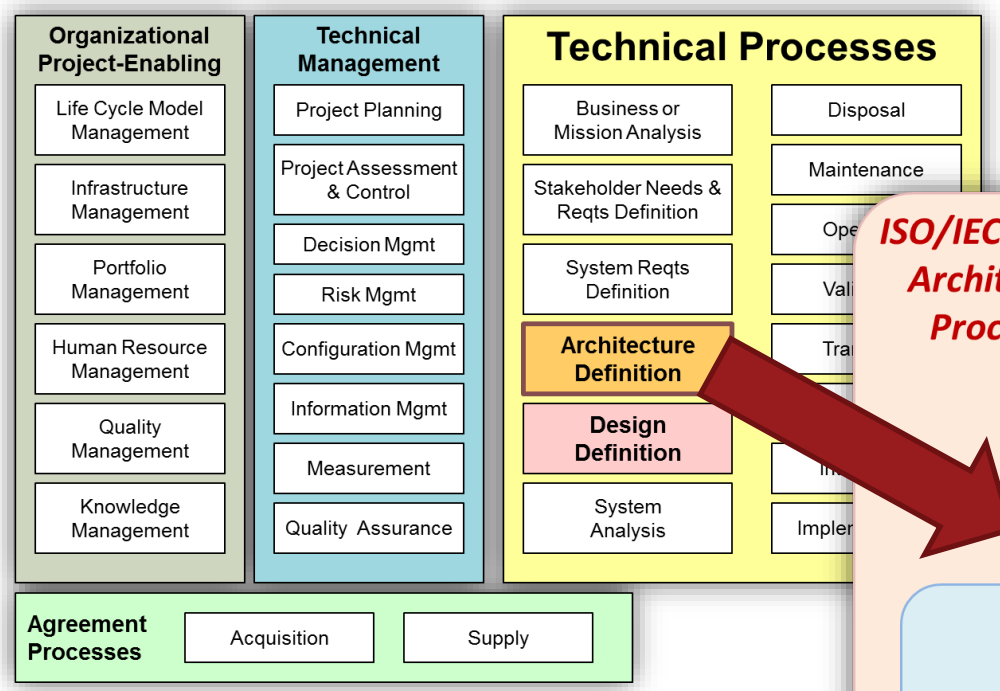


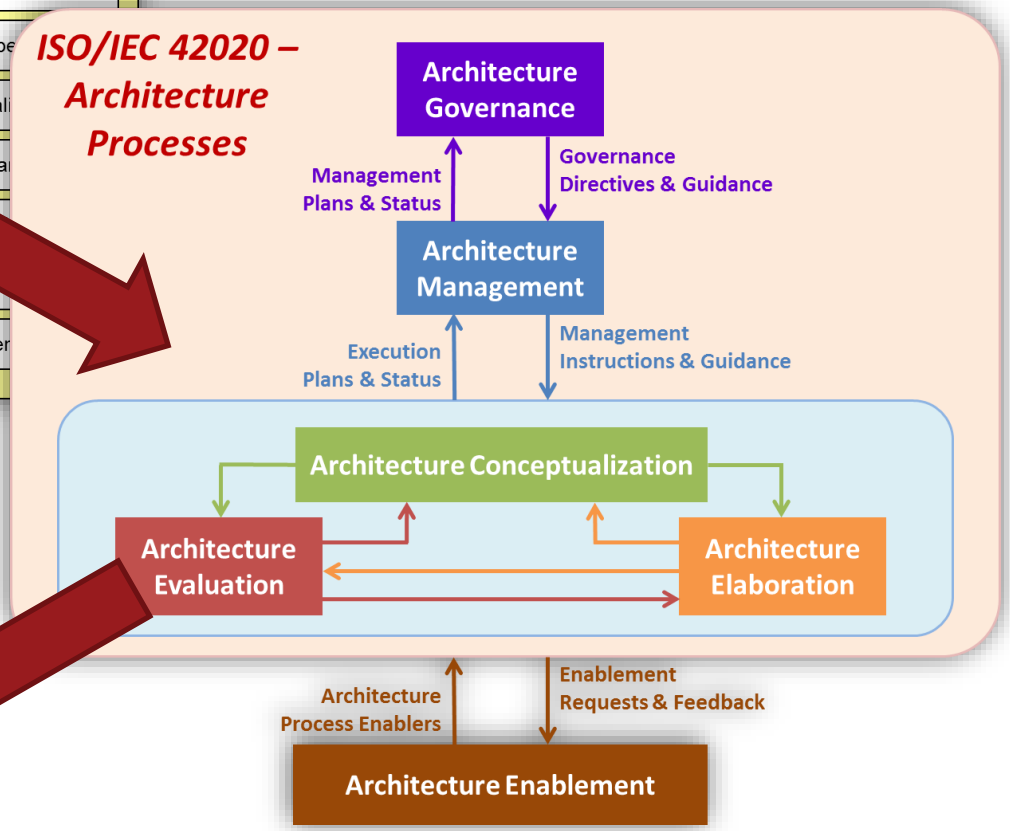
Systems Life Cycle Processes in the ISO 15288 Standard

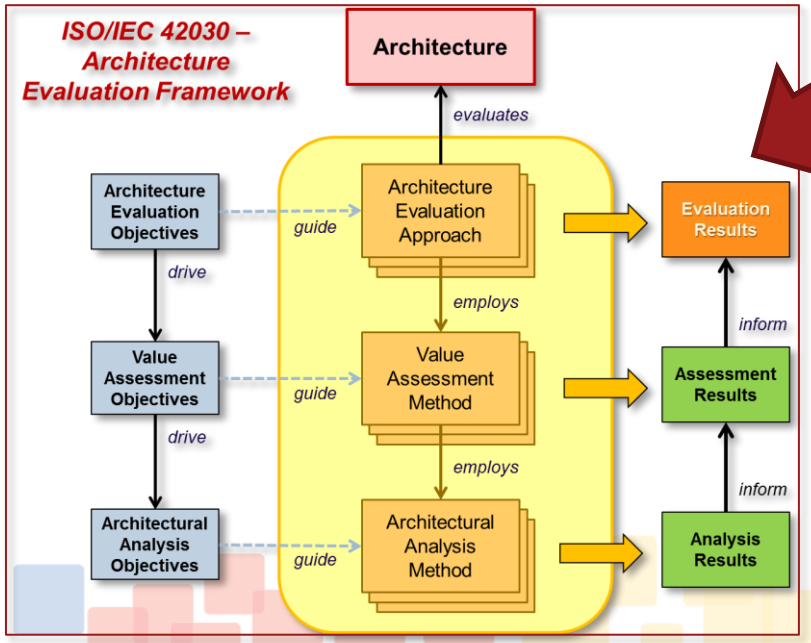


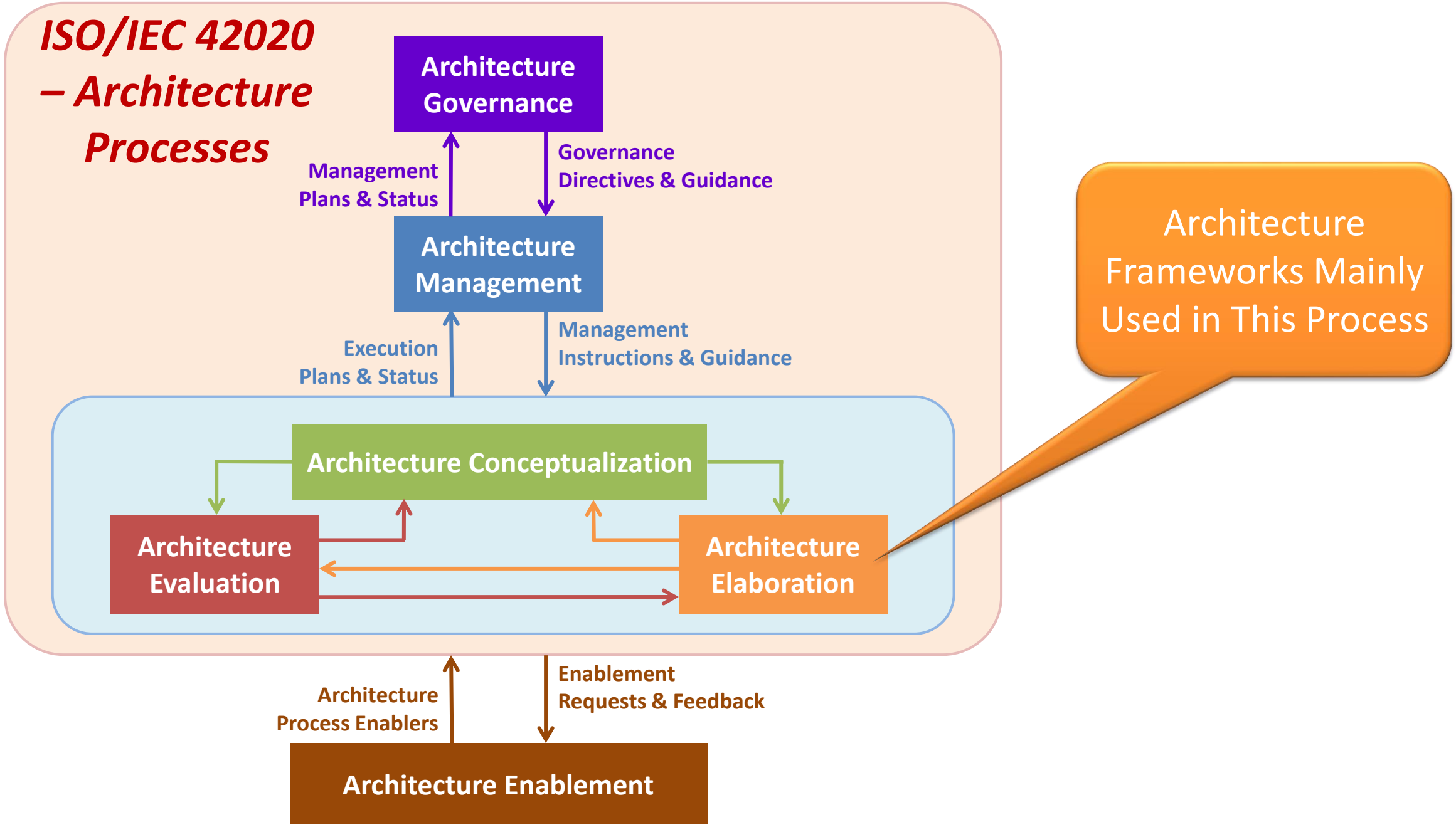
SOURCE: ISO/IEC/IEEE 15288:2015, System Life Cycle Processes

ISO/IEC/IEEE 15288 – Systems Engineering





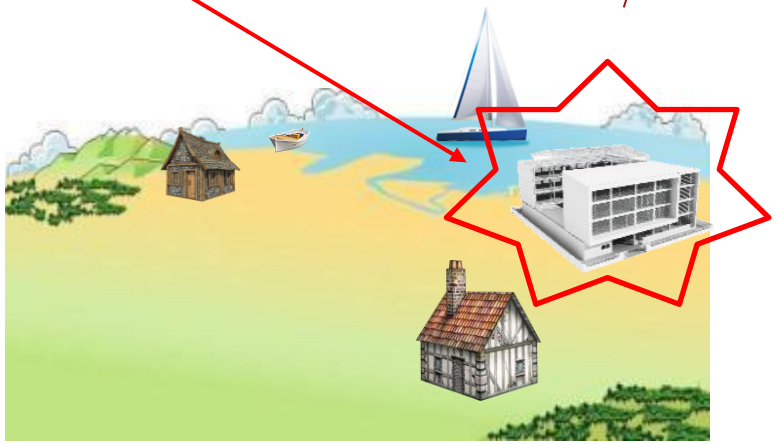



ISO/IEC 42020 – Architecture Processes
Architecture Governance
Management Plans & Status
Governance Directives & Guidance
Architecture Management
Execution Plans & Status
Management Instructions & Guidance
Architecture Conceptualization
Architecture Evaluation
Architecture Elaboration
Architecture Frameworks Mainly Used in This Process
Architecture Process Enablers
Enablement Requests & Feedback
Architecture Enablement

Setting the scene

Stakeholders

Entity of Interest



The architecting work starts
with the current or future reality.

Considering an entity of interest
…and a set of stakeholders.

Architectures and Architecting

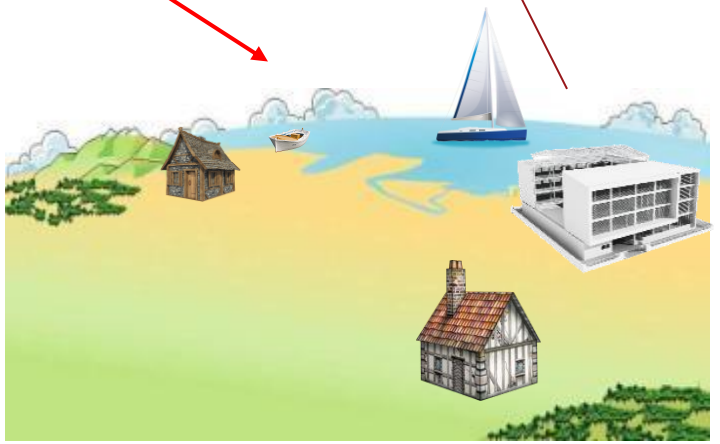
42010 [2nd edition] Architecture
fundamental concepts or properties related to an entity in its environment and governing principles for the realization and evolution of this entity and its related life cycle processes

42010 [2nd edition] Architecting
conceiving, defining, expressing, documenting, communicating, certifying proper implementation of, maintaining and improving an architecture throughout the life cycle of an entity of interest

Stakeholders

Entity of Interest

…has an Architecture



Stakeholders and Concerns

42010 [2nd edition] Stakeholder
role, position, individual, organization or classes thereof, having an interest, right, share, or claim, in an entity of interest

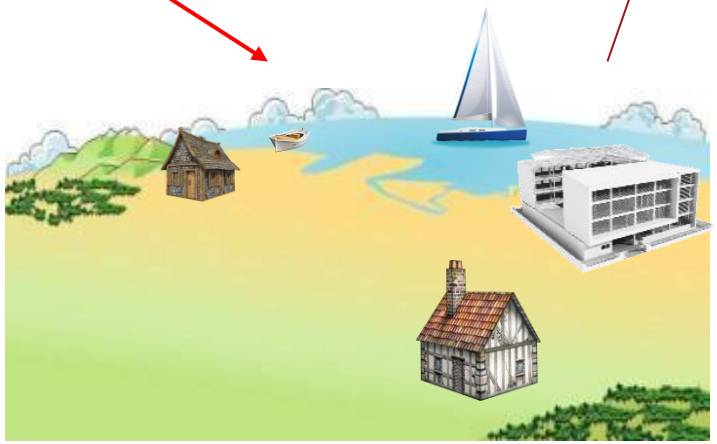
Stakeholders

… have interest in

Entity of Interest

42010 [2nd edition] Concern
matter of relevance or importance to a stakeholder
… regarding an entity of interest to a stakeholder

Examples: How is the system maintained? What system behaviors are safety-critical? Can the entity of interest achieve compliance with national regulations?



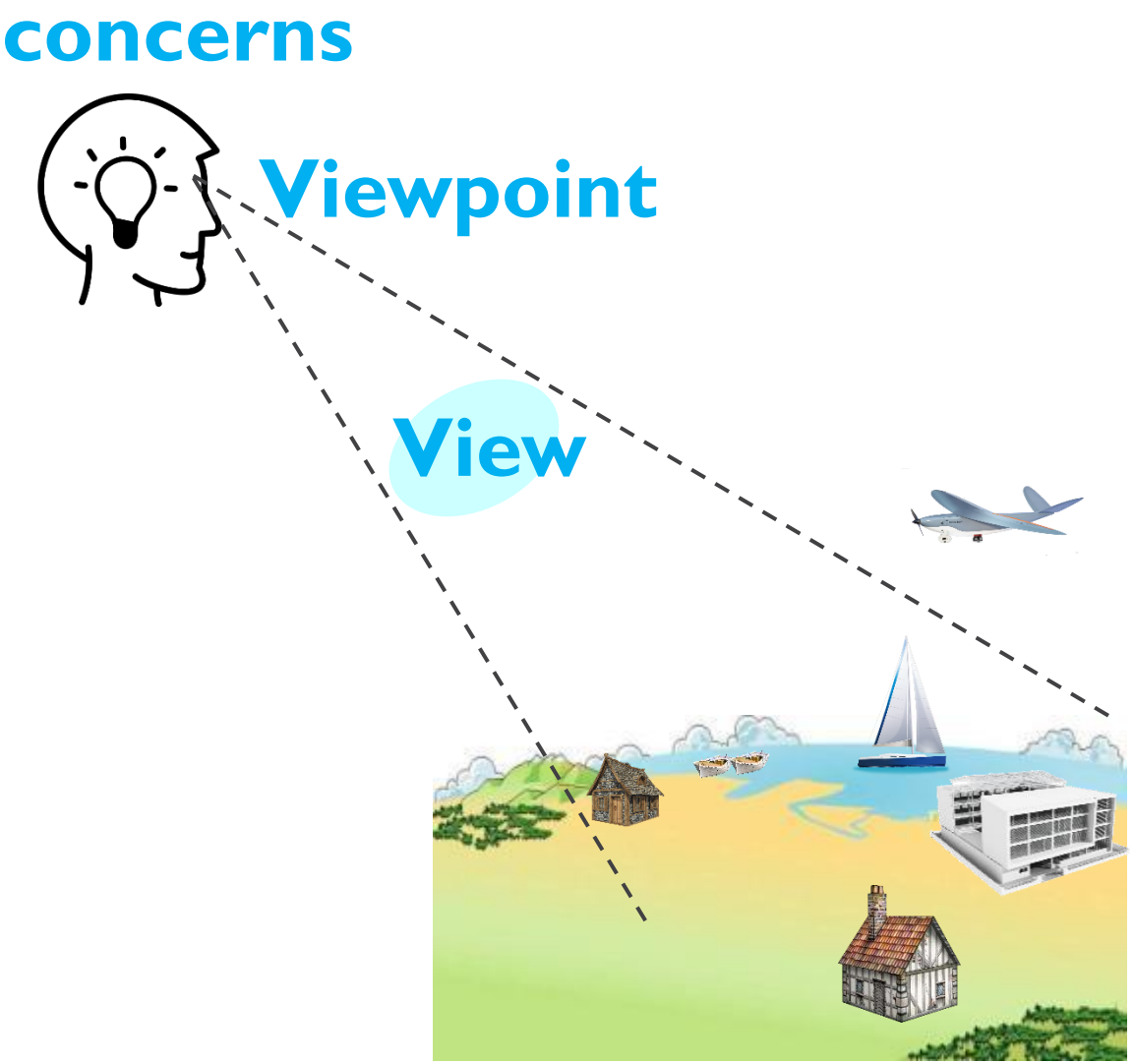
Viewpoints and Views

42010 [2nd edition] Viewpoint
conventions for the creation, interpretation and use of an architecture view to frame one or more concerns

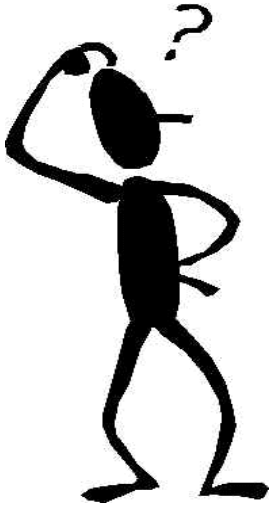
Examples: buyer viewpoint, builder viewpoint, user viewpoint

42010 [2nd edition] View
information part comprising portion of an architecture description
… that expresses the architecture of an entity of interest and that is governed by an architecture viewpoint

Note: *Viewpoint Specification is the set of requirements for the conventions of a viewpoint*

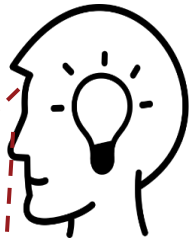


Variety of Stakeholders (and Concerns)

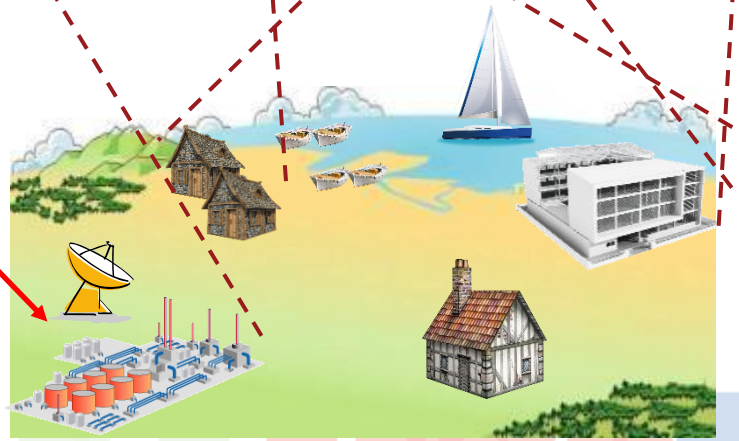


Acquirer **Other** **Provider**

concerns



Not seen here (e.g. another project)



Perspective and Aspect

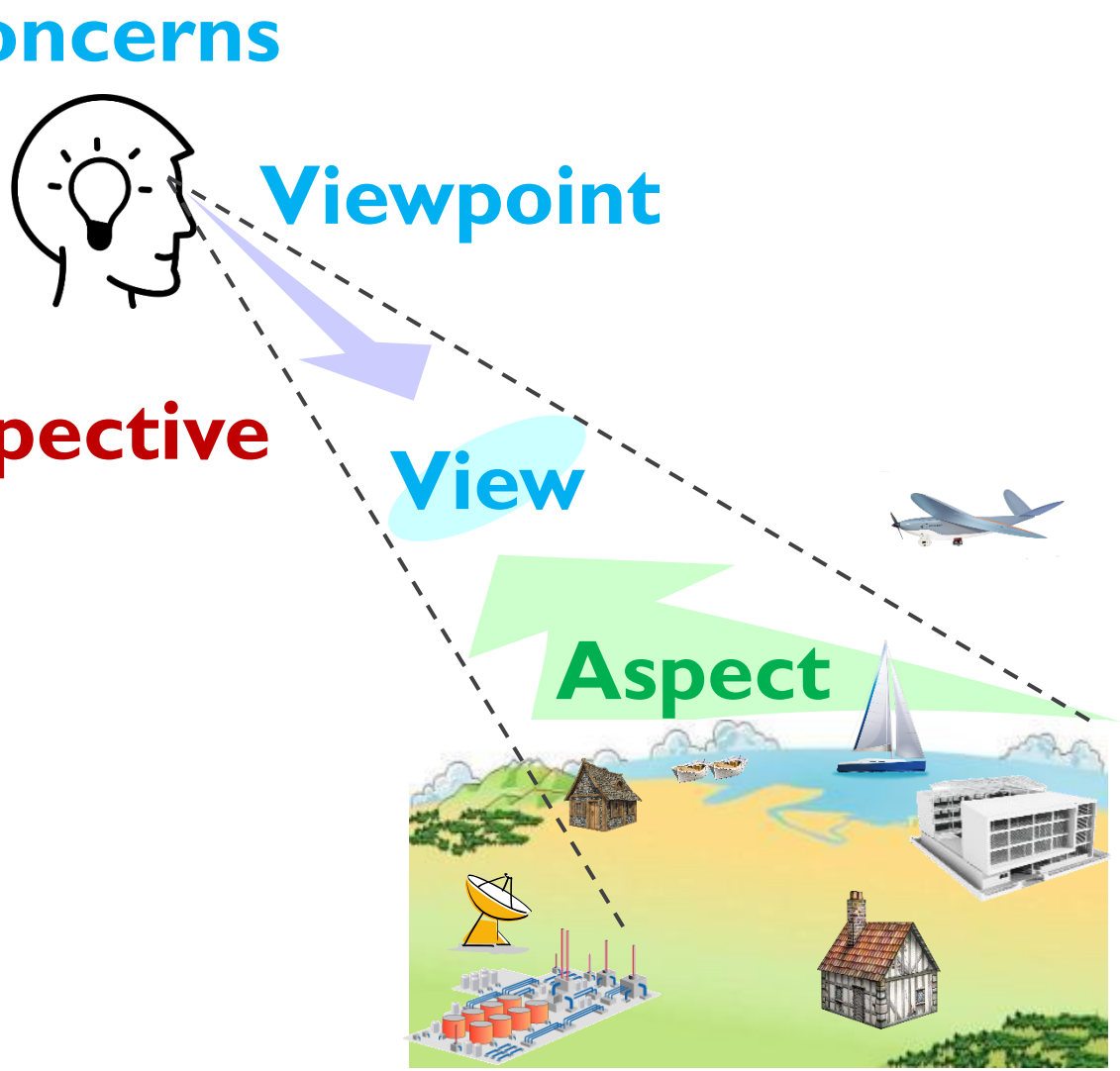
42010 [2nd edition] Stakeholder Perspective
way of thinking about an entity, especially as it relates to concerns

Examples: Viability, cost, risk, usability or operability, legal compliance, ease of maintenance, market acceptability, market share, ease of implementation

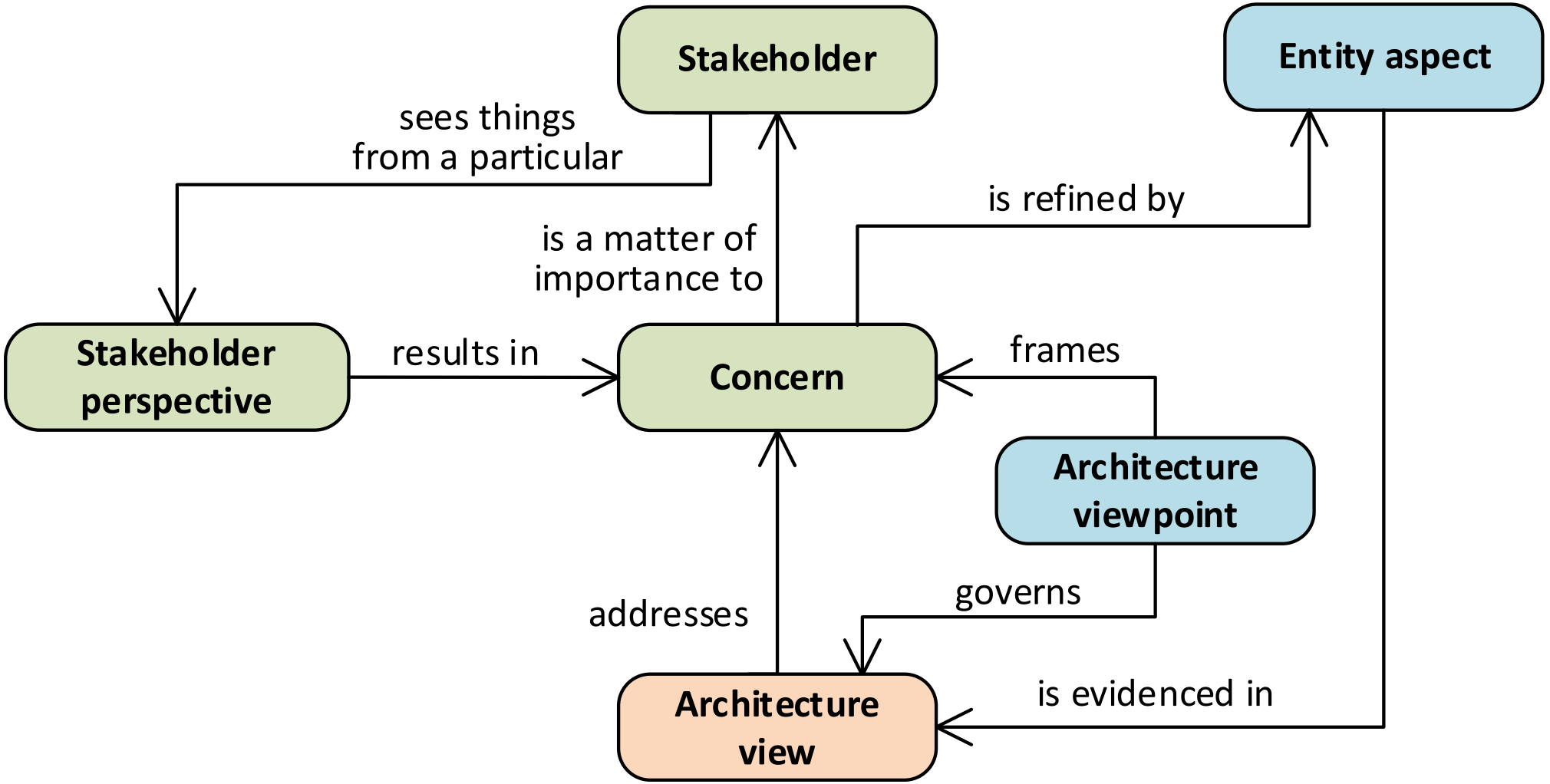
42010 [2nd edition] Architecture Aspect
part of an entity's character or nature
…that deals with particular concerns within an architecture, capturing key characteristics or features of the entity of interest

Examples: Functional & Structural aspects of an Architecture, Informational & Parametric aspects

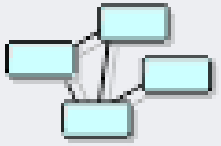
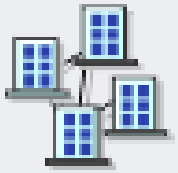
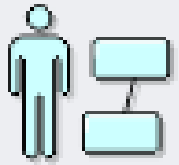
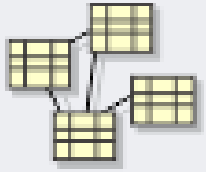
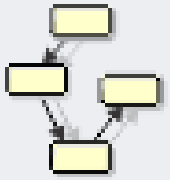
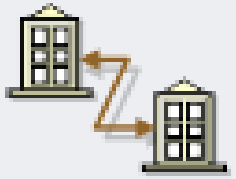
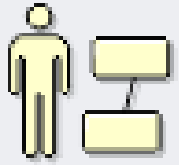
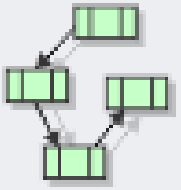
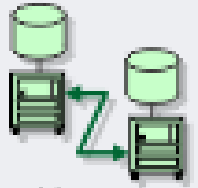
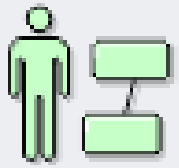
Also, Connectivity, Evolution, Traceability, Taxonomy, Motivation (eg, Requirements, Policy), Location, Timelines



Aspects & Viewpoints in ISO 42010



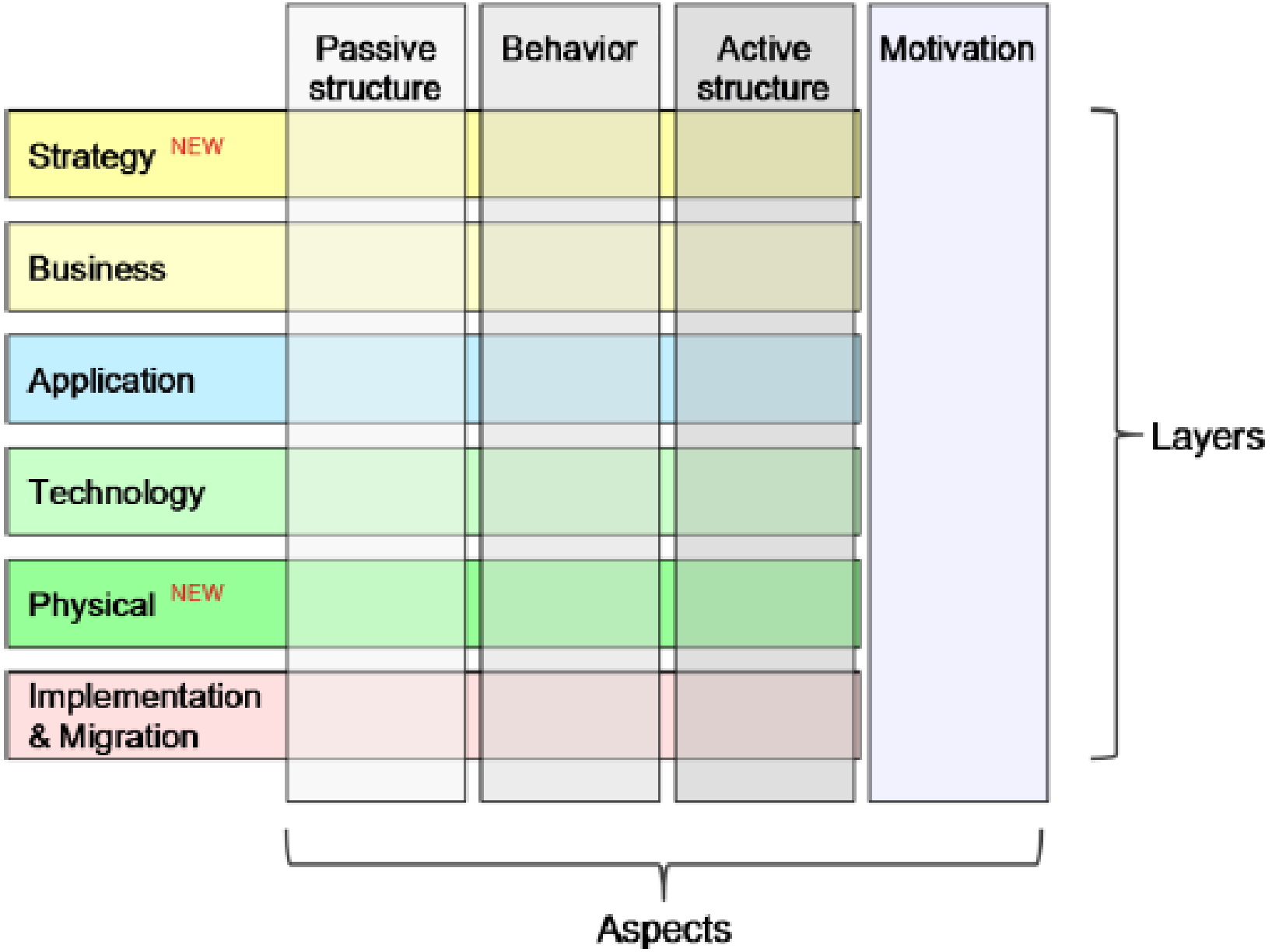
Example Use of Aspects & Perspectives

Perspective	Aspect: Data	Aspect: Activity	Aspect: Location	Aspect: People
Business	Business Entity Model	 Business Process Model	 Business Locations Model	 Business Roles Model
Logical	 Logical Entity Model	 Logical Process Model	 Logical Locations Model	 Logical Roles Model
Technical	Technical Entity Model	 Technical Process Model	 Technical Locations Model	 Technical Roles Model

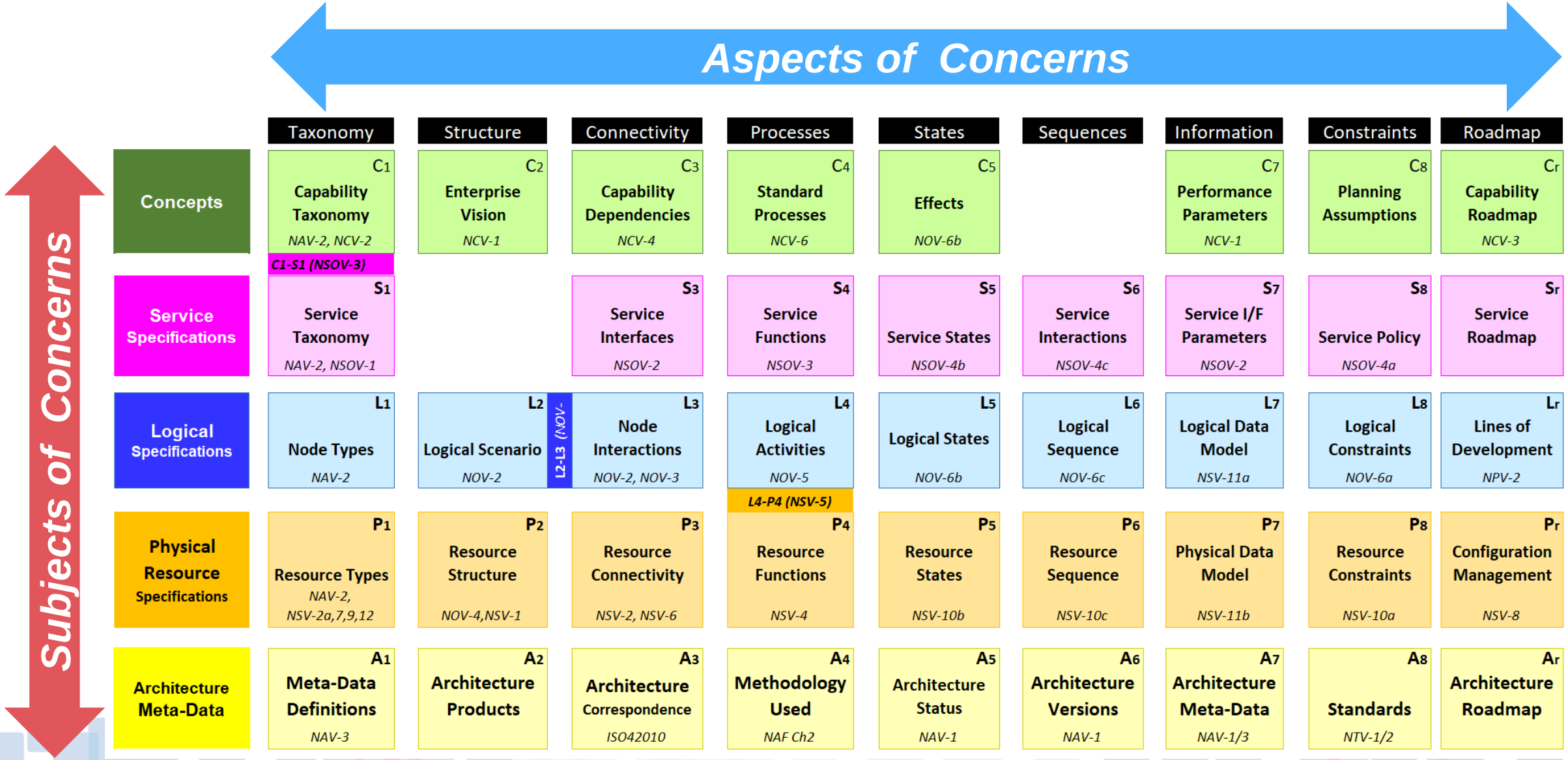
Unified Architecture Method (UAM) Framework

[http://www.unified-am.com/]

ArchiMate Modeling Framework



NATO Architecture Framework



Zachman Framework for Information Systems

Aspects (Interrogatives)

Perspectives

	What (Data)	How (Function)	Where (Locations)	Who (People)	When (Time)	Why (Motivation)
Scope {contextual} Planner	List of things important to the business	List of processes that the business performs	List of locations in which the business operatses	List of organizations important to the business	List of events/ cycles important to the business	List of business goals/strategies
Enterprise Model {conceptual} Business Owner	e.g. Semantic Model	e.g. Business Process Model	e.g. Business Logistics System	e.g. Workflow Model	e.g. Master Schedule	e.g. Business Plan
System Model {logical} Designer	e.g. Logical Data Model	e.g. Application Architecture	e.g. Distributed System Architecture	e.g. Human Interface Architecture	e.g. Process Structure	e.g. Business Rule Model
Technology Model {physical} Implementer	e.g. Physical Data Model	e.g. System Design	e.g. Technology Architecture	e.g. Presentation Architecture	e.g. Control Structure	e.g. Rule Design
Detailed Representation {out-of-context} Subcontractor	e.g. Data Definition	e.g. Program	e.g. Network Architecture	e.g. Security Architecture	e.g. Timing Definition	e.g. Rule Definition
Functioning System	e.g. Data	e.g. Function	e.g. Network	e.g. Organization	e.g. Schedule	e.g. Strategy

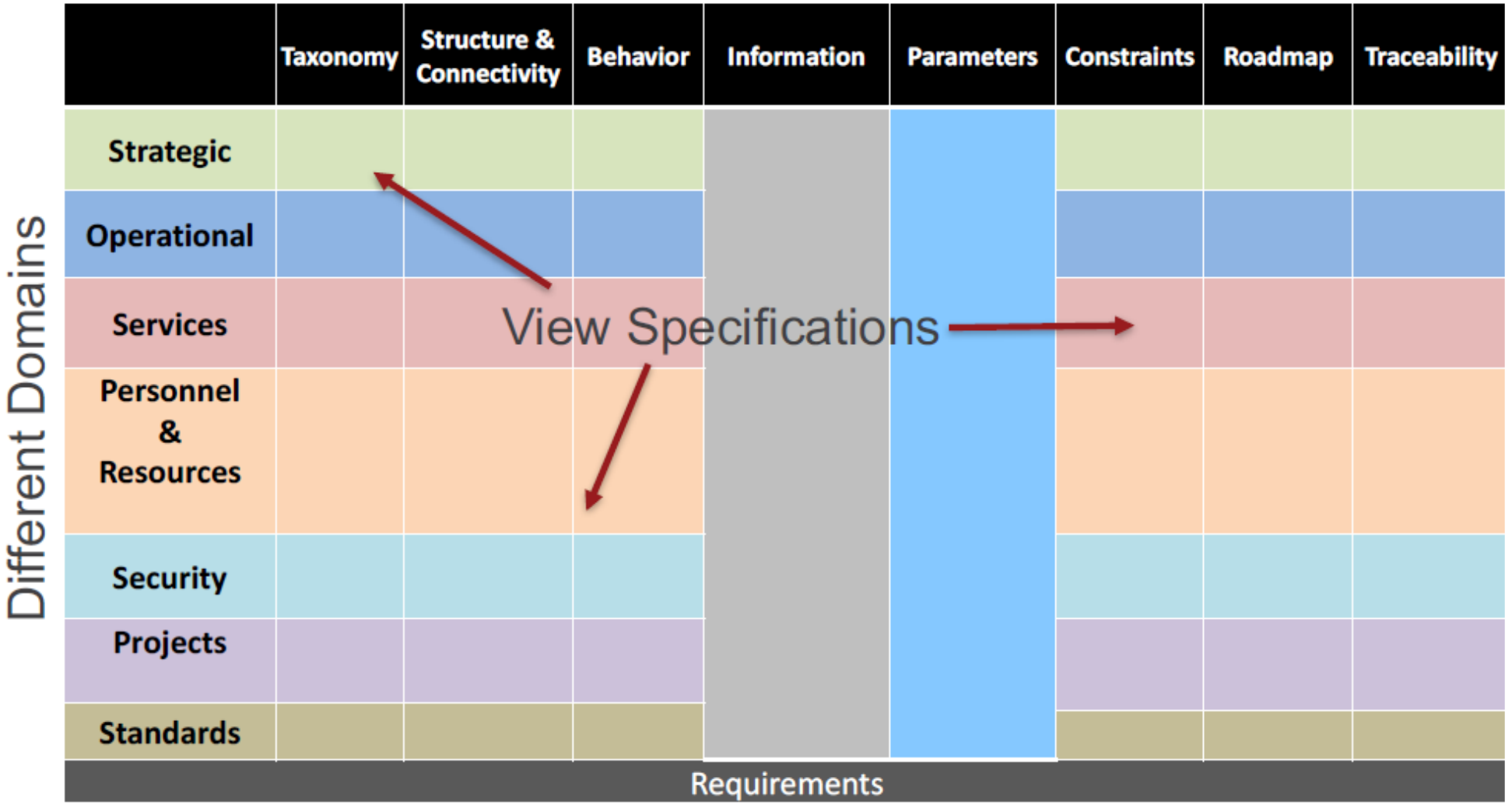
Cross-examination of Frameworks

On the use of Aspects and Perspectives

Source	Domain	Aspects	Perspectives
Enstrom UAM	IT architecture, software	Data, activity, location, people	Business, logical, technical
Zachman 1	Information systems	Why, how, what, who, where, when	Contextual, conceptual, logical, physical, detailed
Zachman 2	Enterprise architecture	Data, function, locations, people, time, motivation	Scope, enterprise, system, technology, detailed representations, functioning systems
TOGAF Archimate	IT systems	Passive structure, behavior, active structure, motivation	Strategy, business, application, technology, physical, implementation & migration
DODAF	Defense systems	Nodes, activities, functions, states, rules, capabilities, measures, information flows, data flows, etc	Capability, operations, services, systems, standards, data, information, projects
NAF v4	System & SOS architectures	Taxonomy, structure, connectivity, processes, states, sequences, information, constraints, roadmap	Concepts, service, logical, physical resource, architecture meta-data
UAF Grid	Enterprises	Taxonomy, structure, connectivity, behaviors (processes, states, interaction scenarios), information, parameters, constraints, roadmap, traceability	Strategy, operations, services, personnel, resources, security, projects, standards, actual resources
Maier	Systems	Purpose/objectives, behavior, performance, data, managerial, form	(not applicable)

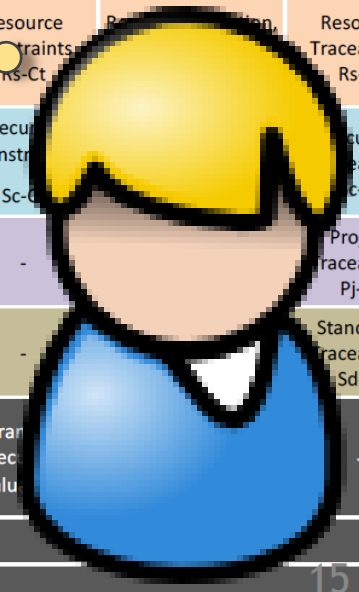
The Unified Architecture Framework (UAF)

Standard means of expression – Aspects

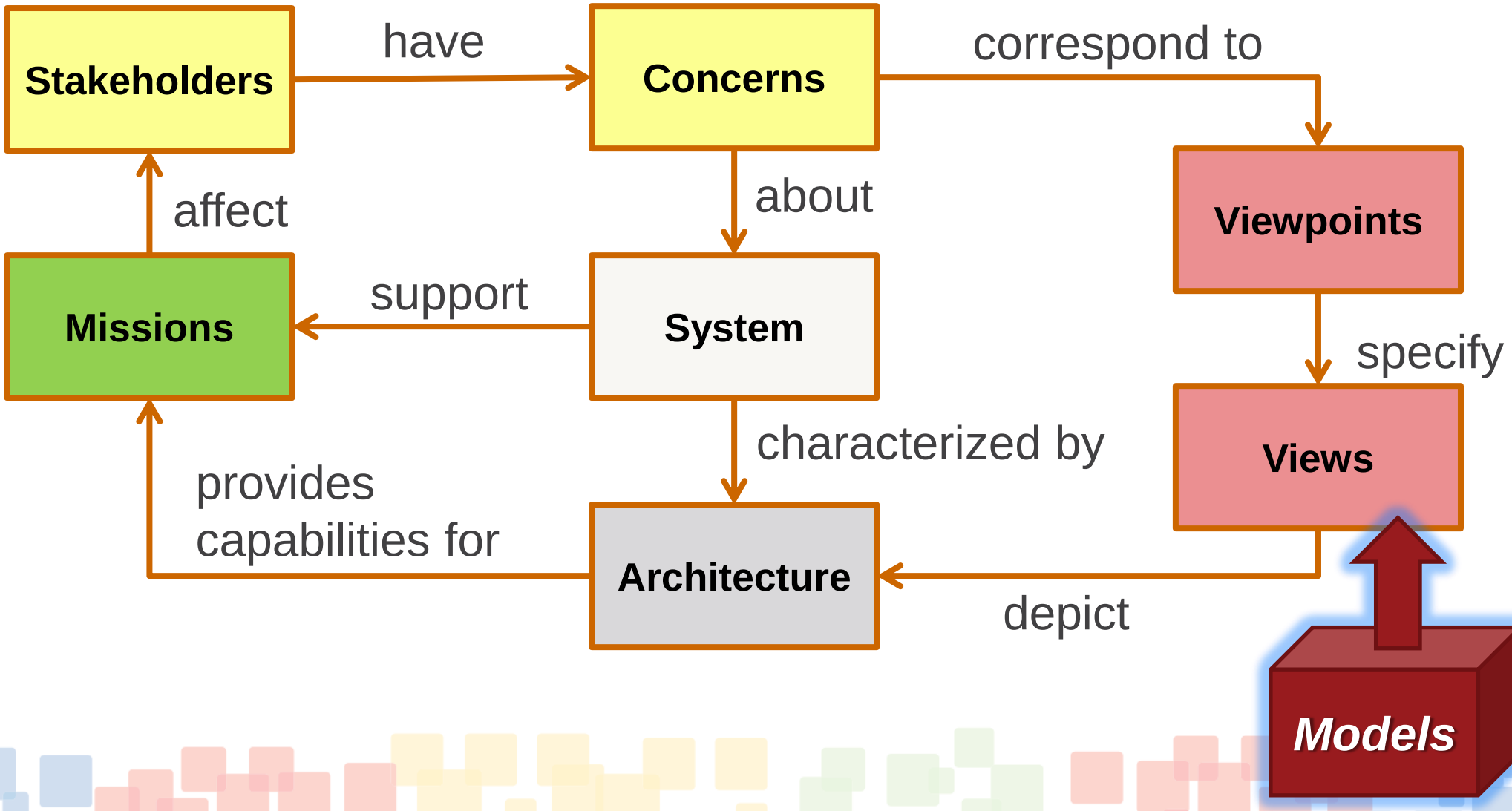


UAF	Taxonomy Tx	Structure Sr	Connectivity Cn	Processes Pr	States St	Interaction Scenarios Is	Information If	Parameters Pm	Constraints Ct	Roadmap Rm	Traceability Tr
Metadata Md	Metadata Taxonomy Md-Tx	Architecture Viewpoints [a] Md-Sr	Metadata Connectivity Md-Cn	Metadata Processes [a] Md-Pr	-	-			Metadata Constraints [a] Md-Ct		Metadata Traceability Md-Tr
Strategic St	Strategic Taxonomy St-Tx	Strategic Structure St-Sr	Strategic Connectivity St-Cn	-	Strategic States St-St	-			Strategic Constraints St-Ct	Strategic Deployment, St-Rm Strategic Phasing St-Rm	Strategic Traceability St-Tr
Operational Op	Operational Taxonomy Op-Tx								Operational Constraints Op-Ct	-	Operational Traceability Op-Tr
Services Sv									Service Constraints Sv-Ct	Service Roadmap Sv-Rm	Service Traceability Sv-Tr
Personnel Pr									Competence, Drivers, Performance Pr-Ct	Personnel Availability, Personnel Evolution, Personnel Forecast Pr-Rm	Personnel Traceability Pr-Tr
Resources Rs	Resource Taxonomy Rs-Tx	Resource Structure Rs-Sr	Resource Connectivity Rs-Cn	Resource Processes Rs-Pr	Rs-St	Resource Interaction Scenarios Rs-Is	Physical Data Model	Measurements Pm-Me	Resource Constraints Rs-Ct		Resource Traceability Rs-Tr
Security Sc	Security Taxonomy Sc-Tx	Security Structure Sc-Sr	Security Connectivity Sc-Cn	Security Processes Sc-Pr	-	-			Sc-Ct		Sc-Tr
Projects Pj	Project Taxonomy Pj-Tx	Project Structure Pj-Sr	Project Connectivity Pj-Cn	-	-	-			-		Project Traceability Pj-Tr
Standards Sd	Standard Taxonomy Sd-Tx	Standards Structure Sd-Sr	-	-	-	-			-		Standards Traceability Sd-Tr
Actuals Resources Ar		Actual Resources Structure, Ar-Sr	Actual Resources Connectivity, Ar-Cn	Simulation [b]					Exec Evalu		-
Dictionary * Dc											
Summary & Overview Sm-Ov											
Requirements Req											

Where do we start?
Which views do we need?
How are these views related?

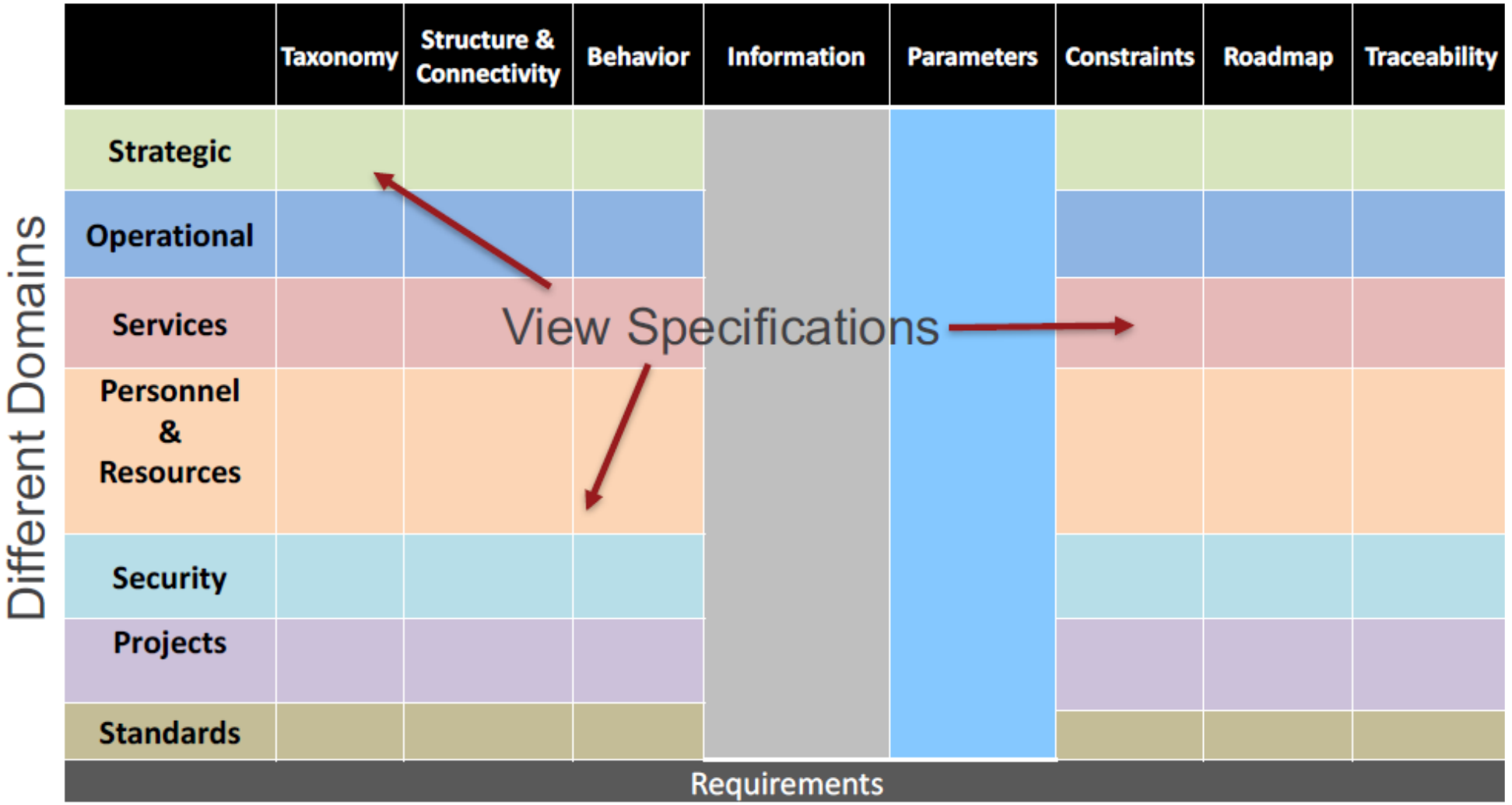


Stakeholders & their Concerns should Drive the Architecture



The Unified Architecture Framework

Standard means of expression – Aspects



Aspect-Oriented Architecting

Stakeholder Perspective

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Examples: Viability, cost, risk, usability or operability, legal compliance, ease of maintenance, market acceptability, market share, ease of implementation

Architecture Aspect

part of an entity's character or nature

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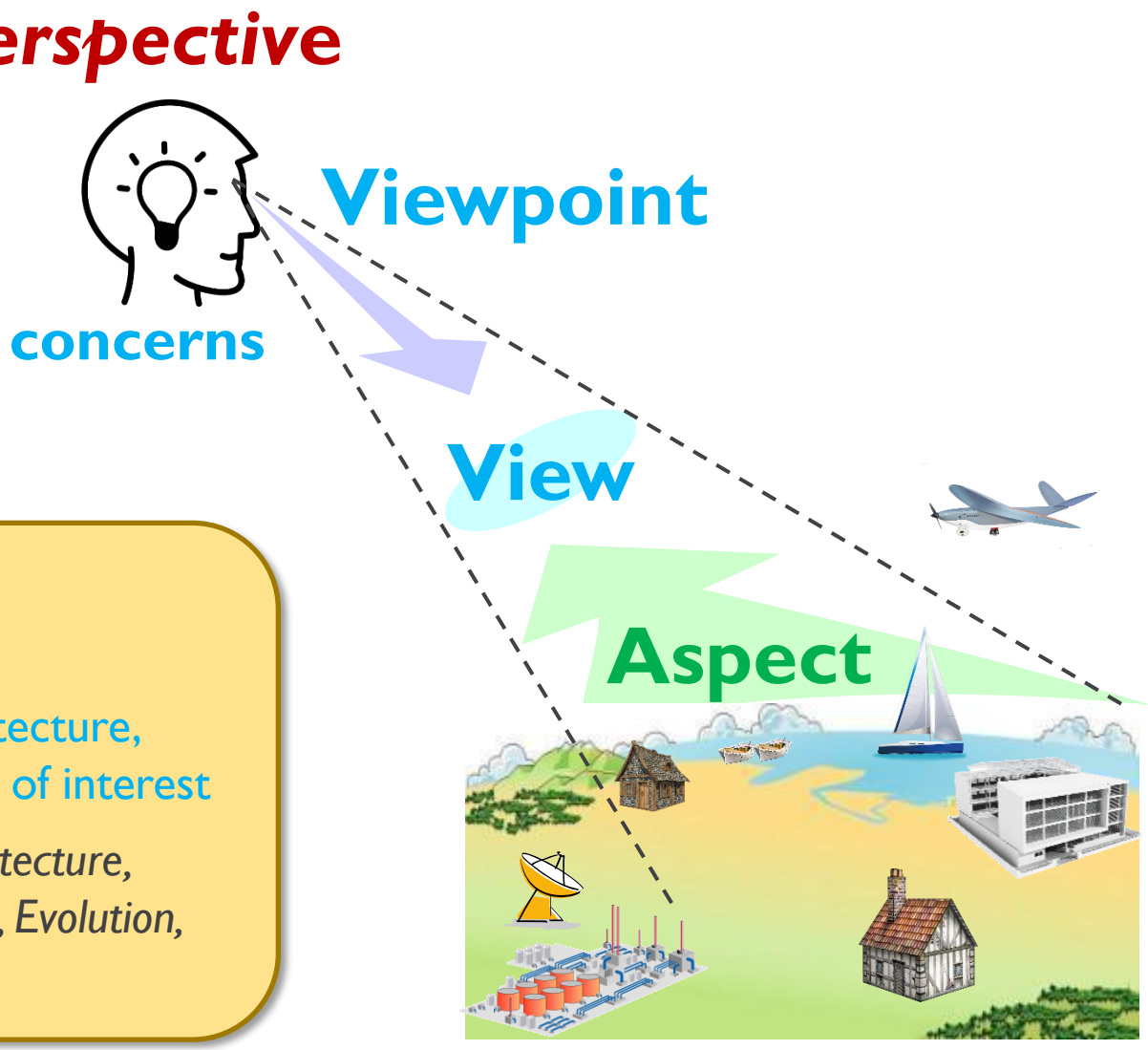
Examples: Functional & Structural aspects of an Architecture, Informational & Parametric aspects. Also, Connectivity, Evolution, Traceability, Taxonomy, Motivation, Location, Timelines



BACKUP

Perspectives & Aspects

As used in commonly used architecture frameworks

- **Purpose:** Incorporate concepts of Perspective and Aspect into the ISO 42010 standard in accordance with the way they are used in several commonly used architecture frameworks and architecting methodologies

- **Goals:**
  1. Standardize these concepts to enable better application of architecting methods
  2. Standardize these concepts and terms to enable more harmony between frameworks
  3. Influence evolution of frameworks, in particular OMG's Unified Architecture Fwk (UAF)

- **Strategy:**
  A. Examine how these concepts are used in the frameworks and in application of these frameworks in the architecting of Enterprises, Systems and Software entities
  B. Analyze common attributes and differences
  C. Converge on unified views of these principles and concepts
  D. Illustrate with examples from real world applications of these concepts

UAF	Taxonomy Tx	Structure Sr	Connectivity Cn	Processes Pr	States St	Interaction Scenarios Is	Information If	Parameters Pm	Constraints Ct	Roadmap Rm	Traceability Tr
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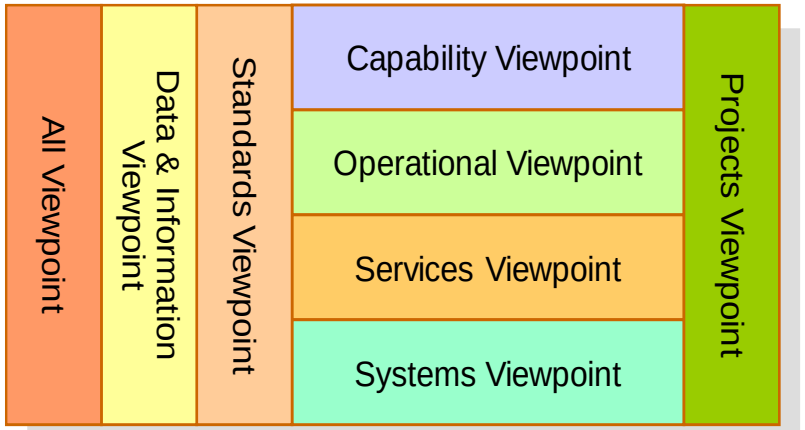
Operational Op	Operational Taxonomy Op-Tx	Operational Structure Op-Sr	Operational Connectivity Op-Cn	Operational Processes Op-Pr	Operational States Op-St	Operational Interaction Scenarios Op-Is			Operational Constraints Op-Ct	-	Operational Traceability Op-Tr
Services Sv	Service Taxonomy Sv-Tx	Service Structure Sv-Sr	Service Connectivity Sv-Cn	Service Processes Sv-Pr	Service States Sv-St	Service Interaction Scenarios Sv-Is	Conceptual Data Model,	Environment Pm-En	Service Constraints Sv-Ct	Service Roadmap Sv-Rm	Service Traceability Sv-Tr
Personnel Pr	Personnel Taxonomy Pr-Tx	Personnel Structure Pr-Sr	Personnel Connectivity Pr-Cn	Personnel Processes Pr-Pr	Personnel States Pr-St	Personnel Interaction Scenarios Pr-Is	Logical Data Model,		Competence, Drivers, Performance Pr-Ct	Personnel Availability, Personnel Evolution, Personnel Forecast Pr-Rm	Personnel Traceability Pr-Tr
Resources Rs	Resource Taxonomy Rs-Tx	Resource Structure Rs-Sr	Resource Connectivity Rs-Cn	Resource Processes Rs-Pr	Resource States Rs-St	Resource Interaction Scenarios Rs-Is	Physical Data Model	Measurements Pm-Me	Resource Constraints Rs-Ct	Resource evolution, Resource forecast Rs-Rm	Resource Traceability Rs-Tr
Security Sc	Security Taxonomy Sc-Tx	Security Structure Sc-Sr	Security Connectivity Sc-Cn	Security Processes Sc-Pr	-	-			Security Constraints Sc-Ct	-	Security Traceability Sc-Tr
Projects Pj	Project Taxonomy Pj-Tx	Project Structure Pj-Sr	Project Connectivity Pj-Cn	-	-	-			-	Project Roadmap Pj-Rm	Project Traceability Pj-Tr
Standards Sd	Standard Taxonomy Sd-Tx	Standards Structure Sd-Sr	-	-	-	-			-	Standards Roadmap Sd-Rm	Standards Traceability Sd-Tr
Actuals Resources Ar		Actual Resources Structure, Ar-Sr	Actual Resources Connectivity, Ar-Cn	Simulation [b]					Parametric Execution/ Evaluation [b]	-	-
Dictionary * Dc											
Summary & Overview Sm-Ov											
Requirements Req											

The DODAF "Grid"



The 52 DODAF Models

VP	ID	Models
All VP	AV-1	Overview and Summary Information
	AV-2	Integrated Dictionary
Capability Viewpoint	CV-1	Vision
	CV-2	Capability Taxonomy
	CV-3	Capability Phasing
	CV-4	Capability Dependencies
	CV-5	Capability to Org Development Mapping
	CV-6	Capability to Opnl Activities Mapping
	CV-7	Capability to Services Mapping
Data & Info VP	DIV-1	Conceptual Data Model
	DIV-2	Logical Data Model
	DIV-3	Physical Data Model
Operational Viewpoint	OV-1	High Level Operational Concept Graphic
	OV-2	Operational Resource Flow Description
	OV-3	Operational Resource Flow Matrix
	OV-4	Organizational Relationships Chart
	OV-5a	Operational Activity Decomposition Tree
	OV-5b	Operational Activity Model
	OV-6a	Operational Rules Model
	OV-6b	State Transition Description
	OV-6c	Event-Trace Description
Project VP	PV-1	Project Portfolio Relationships
	PV-2	Project Timelines
	PV-3	Project to Capability Mapping
Stds VP	StdV-1	Standards Profile
	StdV-2	Standards Forecast

VP	ID	Models
Services Viewpoint	SvcV-1	Services Context Description
	SvcV-2	Services Resource Flow Description
	SvcV-3a	Systems-Services Matrix
	SvcV-3b	Services-Services Matrix
	SvcV-4	Services Functionality Description
	SvcV-5	Opnl Activity to Services Trace Matrix
	SvcV-6	Services Resource Flow Matrix
	SvcV-7	Services Measures Matrix
	SvcV-8	Services Evolution Description
	SvcV-9	Services Technology & Skills Forecast
	SvcV-10a	Services Rules Model
	SvcV-10b	Services State Transition Description
	SvcV-10c	Services Event-Trace Description
Systems Viewpoint	SV-1	Systems Interface Description
	SV-2	Systems Resource Flow Description
	SV-3	Systems-Systems Matrix
	SV-4	Systems Functionality Description
	SV-5a	Opnl Activity to Sys Func Trace Matrix
	SV-5b	Opnl Activity to Systems Trace Matrix
	SV-6	Systems Resource Flow Matrix
	SV-7	Systems Measures Matrix
	SV-8	Systems Evolution Description
	SV-9	Systems Technology & Skills Forecast
	SV-10a	Systems Rules Model
	SV-10b	Systems State Transition Description
	SV-10c	Systems Event-Trace Description

DODAF's "Viewpoints" are like Perspectives.

DODAF Models when "filled in" become the "Views"

Aspects are not clearly delineated, but can be inferred by looking at the "kinds" of Models specified:

taxonomy, structure, sequencing, data, information, activities, functions, states, measures, rules, services, systems

DODAF Views

	Taxonomy Tx	Structure Sr	Connectivity Cn	Processes Pr	States St	Interaction Scenarios Is	Information If	Parameters Pm	Constraints Ct	Roadmap Rm	Traceability Tr
Metadata Md	-	-	-	-						-	-
Strategic St	CV-2	CV-1	CV-4	-	-	-			-	CV-3 CV-5	-
Operational Op	OV-2 OV-1	OV-2	OV-2 OV-3	OV-5a OV-5b	OV-6b	OV-6c	DIV-1		OV-6a	-	CV-6
Services Sv	SvcV-1	SvcV-1 SvcV-2	SvcV-3a SvcV-3b SvcV-6	SvcV-4	SvcV-10b	SvcV-10c	DIV-2	ScV-7	SvcV-10a	SvcV 8 SvcV-9	SvcV-5 CV-7
Personnel Pr	OV-4	OV-4	OV-4 SV-6	SV-4	SV-10b	SV-10c	DIV-3		OV-4 SV-10a SV-7	PV-2 SV-8 SV-9	SV-5a SV-5b
Resources Rs	SV-1 SV-2	SV-1 SV-2	SV-3 SV-6	SV-4	SV-10b	SV-10c		SV-7	SV-10a	SV-8 SV-9	SV-5a SV-5b
Security Sc	-	-	-	-	-	-			-	-	-
Projects Pj	PV-1	PV-1	PV-2	-	-	-			-	PV-2	PV-3
Standards Sd	StdV-1	StdV-1	-	-	-	-			-	StdV-2	StdV-1
Actual Resources Ar		OV-4	OV-4 SV-1 & SV-2	Simulation					Parametric Execution/Evaluation	-	-

Dictionary Dc (AV-2)

Summary & Overview SmOv (AV-1, OV-1)

Requirements -

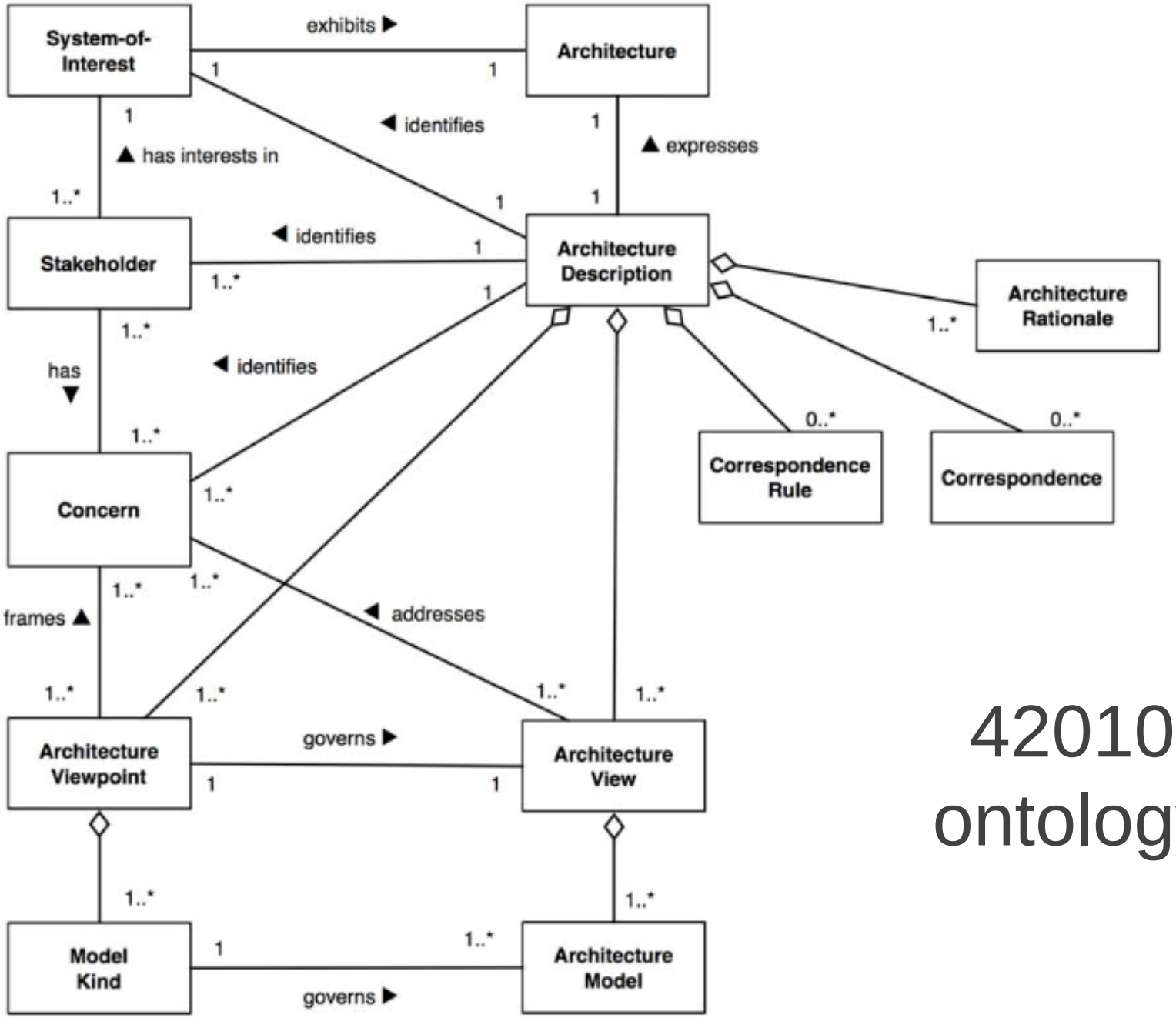
Cross-examination of Frameworks

On the use of Aspects and Perspectives

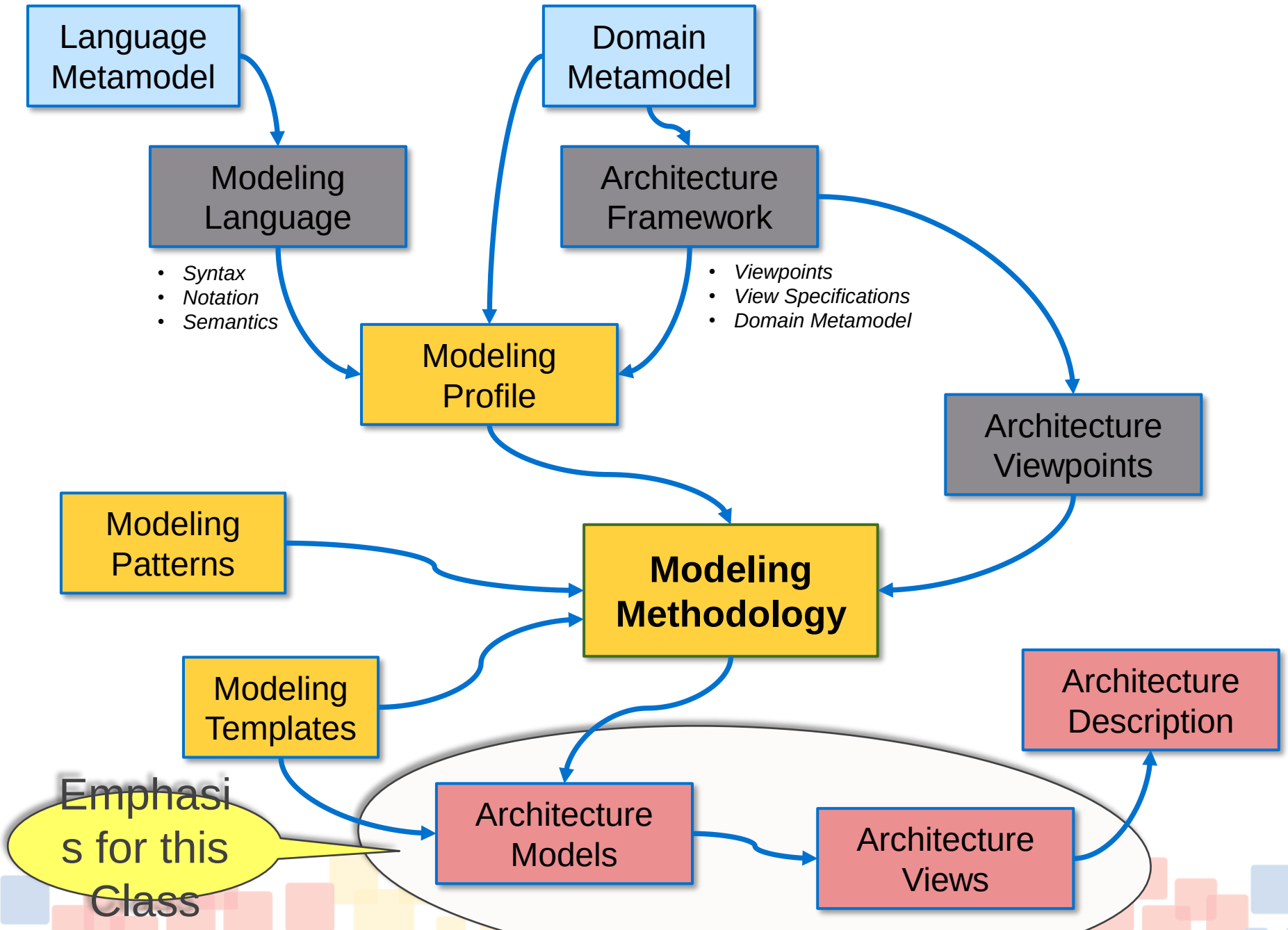
Source	Domain	Aspects	Perspectives
Enstrom UAM	IT architecture, software	Data, activity, location, people	Business, logical, technical
Zachman 1	Information systems	Why, how, what, who, where, when	Contextual, conceptual, logical, physical, detailed
Zachman 2	Enterprise architecture	Data, function, locations, people, time, motivation	Scope, enterprise, system, technology, detailed representations, functioning systems
TOGAF Archimate	IT systems	Passive structure, behavior, active structure, motivation	Strategy, business, application, technology, physical, implementation & migration
DODAF	Defense systems	Nodes, activities, functions, states, rules, capabilities, measures, information flows, data flows, etc	Capability, operations, services, systems, standards, data, information, projects
NAF v4	System & SOS architectures	Taxonomy, structure, connectivity, processes, states, sequences, information, constraints, roadmap	Concepts, service, logical, physical resource, architecture meta-data
UAF Grid	Enterprises	Taxonomy, structure, connectivity, behaviors (processes, states, interaction scenarios), information, parameters, constraints, roadmap, traceability	Strategy, operations, services, personnel, resources, security, projects, standards, actual resources
Maier	Systems	Purpose/objectives, behavior, performance, data, managerial, form	(not applicable)

Zachman Framework

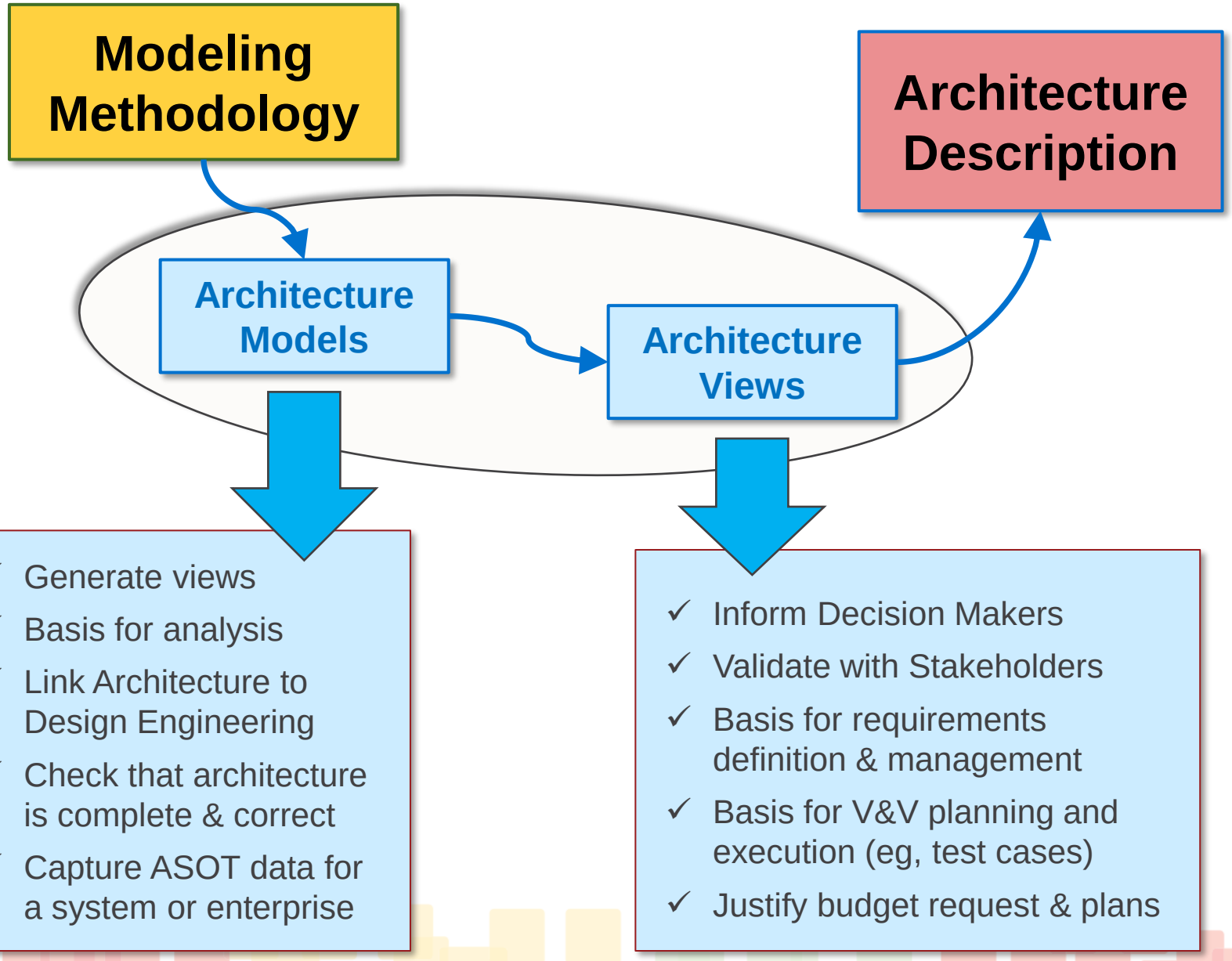
	What (Data)	How (Function)	Where (Locations)	Who (People)	When (Time)	Why (Motivation)
Scope {contextual} Planner	List of things important to the business	List of processes that the business performs	List of locations in which the business operatses	List of organizations important to the business	List of events/ cycles important to the business	List of business goals/strategies
Enterprise Model {conceptual} Business Owner	e.g. Semantic Model	e.g. Business Process Model	e.g. Business Logistics System	e.g. Workflow Model	e.g. Master Schedule	e.g. Business Plan
System Model {logical} Designer	e.g. Logical Data Model	e.g. Application Architecture	e.g. Distributed System Architecture	e.g. Human Interface Architecture	e.g. Process Structure	e.g. Business Rule Model
Technology Model {physical} Implementer	e.g. Physical Data Model	e.g. System Design	e.g. Technology Architecture	e.g. Presentation Architecture	e.g. Control Structure	e.g. Rule Design
Detailed Representation {out-of-context} Subcontractor	e.g. Data Definition	e.g. Program	e.g. Network Architecture	e.g. Security Architecture	e.g. Timing Definition	e.g. Rule Definition
Functioning System	e.g. Data	e.g. Function	e.g. Network	e.g. Organization	e.g. Schedule	e.g. Strategy



42010 ontology


Language Metamodel
Domain Metamodel
Modeling Language
Architecture Framework
• Syntax
• Notation
• Semantics
• Viewpoints
• View Specifications
• Domain Metamodel
Modeling Profile
Architecture Viewpoints
Modeling Patterns
Modeling Methodology
Modeling Templates
Architecture Description
Emphasis for this Class
Architecture Models
Architecture Views

Primary Use Cases for Models & Views



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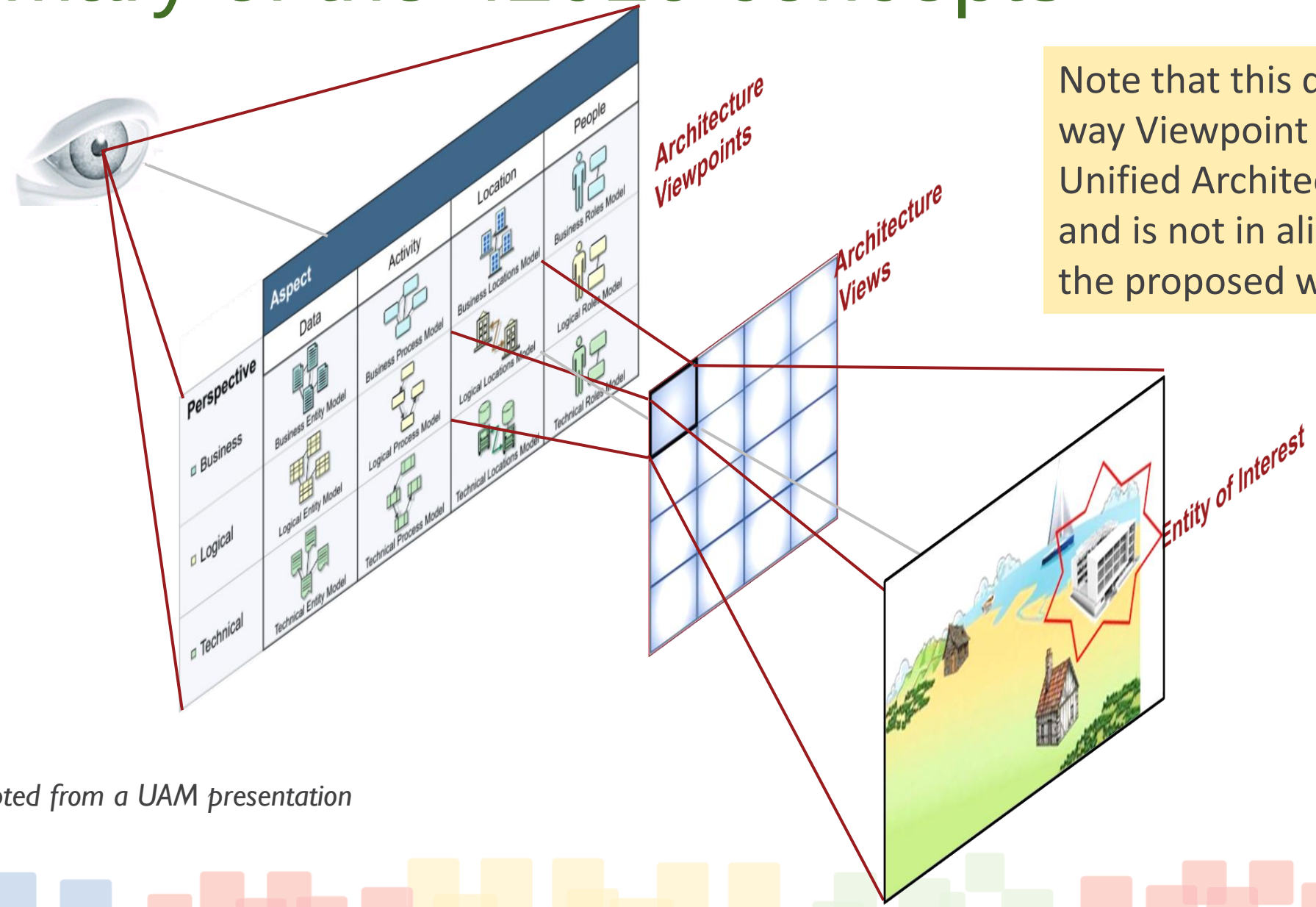
Summary of the 42010 concepts



Note that this depiction is the way Viewpoint is used in the Unified Architecture Method and is not in alignment with the proposed way for UAF

Adapted from a UAM presentation

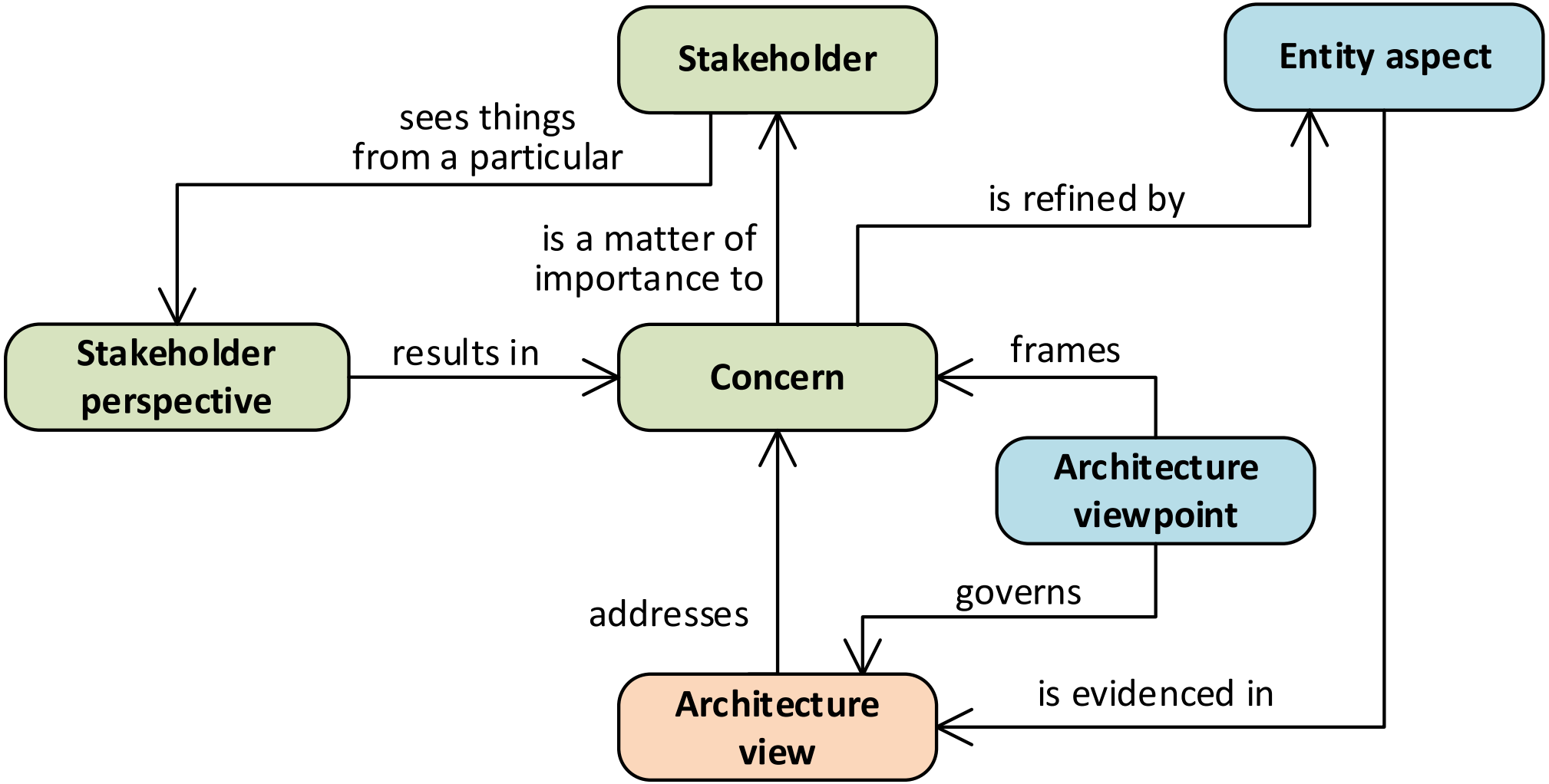
Stakeholder Perspectives

- **5.2.4 Stakeholder perspectives (from 42010)**
- Stakeholders often form distinct groupings, or stakeholder perspectives, based on their common roles, experiences, beliefs or other characteristics. A perspective can reflect domain knowledge, professional experience, training or proximity to the entity of interest in its lifecycle (e.g., design, development, manufacturing, supply, operation and use). Importantly, a stakeholder perspective can also be influenced by personality, character traits, culture, peer pressure, constituency, etc.
- Stakeholder perspectives are ways of thinking about the entity of interest in a context, especially as they relate to concerns. The purpose specified in an AD (6.2) guides the identification of concerns which can affect the perspectives of some stakeholders. Each perspective results in one or more shared concerns.
- Typically, there are several ways of thinking about the architecture of the entity of interest and therefore differing concerns result. There are often multiple stakeholder perspectives for any entity of interest.
    - EXAMPLE 1 Operational and financial stakeholder perspectives of an industrial production system.
    - EXAMPLE 2 Business, management, acquisition and supply stakeholder perspectives of a banking system.
    - EXAMPLE 3 Development, deployment and customization perspectives of a mobile app.
    - EXAMPLE 4 Provider and consumer perspectives of a hospitality service.
    - EXAMPLE 5 Data user and data provider perspectives on a content provider entity.
- Because concerns arise from stakeholder perspectives, architecture viewpoints framing those concerns are often arranged by stakeholder perspectives. Concerns are based on current interests and influences of the stakeholders and are often subjective in nature because they arise from stakeholder perspectives.

More on Definition of Aspect

- **3.3 (from 42010)**
- **aspect**
- part of an entity's character or nature
  - EXAMPLE Functional, structural and informational aspects of an entity.
  - Note 1 to entry: A particular entity aspect can be used for capturing the relevant features of the *entity of interest* (3.12) as a refinement of one or more *concerns* (3.10) under examination with respect to some part of its character, e.g. the structural character, functional character or informational character of the entity.
  - Note 2 to entry: Entity aspects enable the architect to analyse, address and structure *concerns* (3.10). In general, there is a many-to-many relation between aspects and *concerns* (3.10). An aspect can pertain either to an *entity of interest* (3.12), or to an *environment* (3.13) (such as to a situation or scenario).
  - Note 3 to entry: See 5.2.5 for more discussion and examples.

More on Concept of Aspect

- **5.2.5 Entity aspects (from 42010)**
- Entity aspects enable the refinement of concerns within an AD and associated analyses, capturing a select set of characteristics or features of the entity of interest in its environment. Each entity aspect relates to one or more concerns of stakeholders. Usage of known entity aspects based upon prior experience within a field of application enables systematic coverage of the range of established concerns and also the identification of new concerns.
- By examining entity aspects, relevant features or properties of the entity of interest can be discerned or predicted. Analysis of entity aspects can uncover one or more. The definition of the relationships between entity aspects and the concerns are based on the experience of the architects and are assessed by the stakeholders with their understanding and knowledge. While architecting, the architect identifies aspects to show how the architecture views address the concerns.
- EXAMPLES
  1. Spatial, structural, functional, connectivity, taxonomic, information and roadmap aspects in an aircraft AD.
  2. Behavioural, information and structural aspects in a computer AD.
  3. Logical connectivity and physical connectivity aspects in a network AD (corresponding to the so-called logical network and physical network depictions of a configuration of links and nodes in the network).
  4. Safety, security, resilience and sustainability aspects in an Enterprise AD or cyber-physical system AD.

Aspects & Viewpoints