



Architecture Description and ISO/IEC/IEEE 42010

Lecture 14, v01

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BSEE

MSSE

INCOSE ESEP

Architecture Description and ISO/IEC/IEEE 42010



- An Architecture Description (AD) is an artifact that expresses and documents an Architecture
 - Architects and other system stakeholders use Architecture Descriptions to understand, analyze and compare Architectures, and often as “blueprints” for planning and construction of a system based on the architecture
 - The Architecture Description artifact is the primary subject of ISO/IEC/IEEE 42010
- An AD could be a document, a repository or a collection of artifacts used to define and document an architecture
- ISO/IEC/IEE 42010, Systems and Software Engineering – Architecture Description is an international standard that addresses the architectural elements that are to be identified and described in an AD
 - The current version of this standard is the 2011 edition
 - This standard lays down the precepts (rules) by which an AD should be created

Applying Architectural Precepts (Rules)



- Architecture as design
 - An architectural description is used as the vehicle for expressing high-level system characteristics that define and organize its major elements and their interrelationships
 - The architectural description is often developed through an evolutionary process from the initial expression of a system concept as a high-level abstraction to one of a more detailed and tangible expression that is widely accepted as being an expression of design
 - Architecture as design is useful for individual product development

Applying Architectural Precepts (Rules)



- Architecture as style

- A subset of the information used in a full architecture description is used to capture a style to facilitate certain common attributes among systems, ranging from system compatibility, interoperability, interchangeability (of components), to replaceability (of the system)
- An architectural style is a set of patterns or rules for creating one or more architectures in a consistent fashion
 - There are many ways to capture and communicate a style
 - A reference model can be used to embody a style
 - Style is a partial characterization of a system; it does not represent the complete architecture for a system, but is a template for specifying the architecture of a specific system
- Architecture as style is also useful for harmonizing a common expression of architectures that facilitates better understanding of architecture descriptions constructed by assorted individuals or entities
- The use of an Architecture Framework (AF), a Modeling Methodology, and a Modeling Language to specify additional precepts to be observed during development of an architecture description also promotes consistency of style among disparate architectural development projects

Architecture-Related Terms

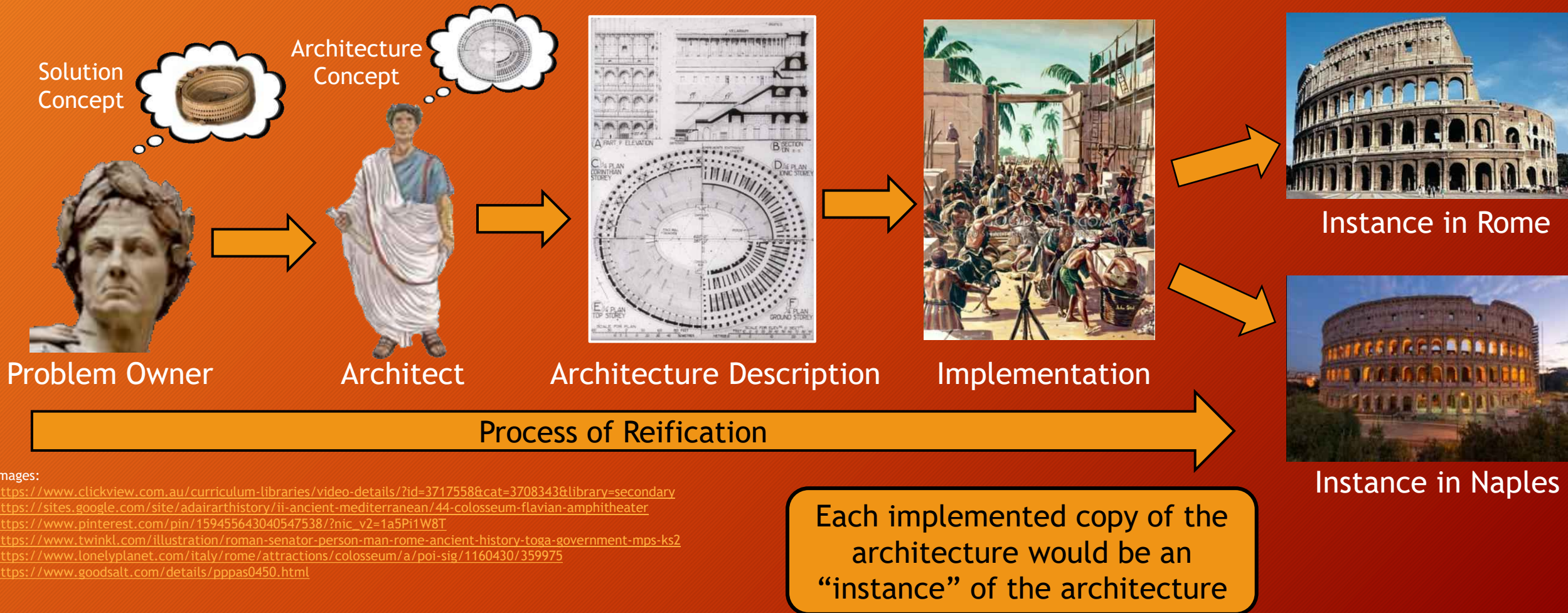


These terms/concepts are often confused, this slide will address the differences briefly, and then further slides will go into more detail

- Architecture
 - The fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution
- Architecture Description
 - An Architecture Description is a work product used to express the Architecture of some Sol
 - The Standard specifies requirements on ADs
 - An AD describes one possible Architecture for a Sol
 - An AD may take the form of a document, a set of models, a model repository, or some other form
 - The AD format is not defined by the Standard
- Implementation of an Architecture
 - When the parts of a system are built, in accordance with the architectural design, the production of the parts is said to be the implementation of the architecture
- Integration of the System
 - When the system is built up from its parts, the assembled system is said to be the integration of all the parts
- Instance of an Architecture
 - When one copy of the system is produced on an assembly line, that copy is said to be an instance of the architecture
 - If multiple copies of the system are produced, all in exact conformance to the architecture, all such copies are said to be instances of the architecture

Architecture-Related Terms (Example 1)

Suppose two colosseums were built in Italy ...



Images:

<https://www.clickview.com.au/curriculum-libraries/video-details/?id=3717558&cat=3708343&library=secondary>
<https://sites.google.com/site/adairarthistory/ii-ancient-mediterranean/44-colosseum-flavian-amphitheater>
https://www.pinterest.com/pin/159455643040547538/?nic_v2=1a5Pi1W8T
<https://www.twinkl.com/illustration/roman-senator-person-man-rome-ancient-history-toga-government-mps-ks2>
<https://www.lonelyplanet.com/italy/rome/attractions/colosseum/a/poi-sig/1160430/359975>
<https://www.goodsalt.com/details/pppas0450.html>

Architecture-Related Terms (Example 2)

Many instances of the same architecture ...



Conceptualization

Design Team

Implementation

Multiple Instances based on exact same architecture

Process of Reification

Images:
<https://www.latimes.com/business/la-fi-boeing-737-max-park-in-desert-20190524-story.html>
<https://www.businessinsider.com/finance-jobs-highest-salaries-2018-4>
<https://3dwarehouse.sketchup.com/model/db96e3af2b07248b84d3db4b0fade3b2/Commercial-airliner>
https://www.barewalls.com/art-print-poster/engineers-in-a-meeting-studying_bwc2772814.html
<https://www.youtube.com/watch?v=hpJWpYWKx6A>

Philosophies of the Term Architecture



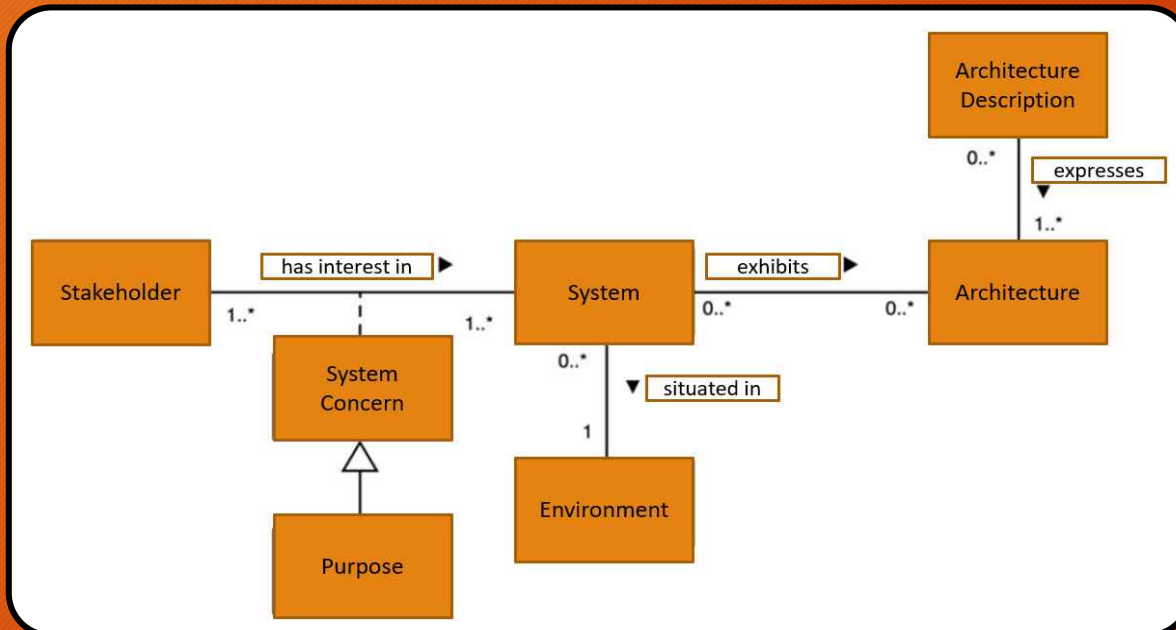
- There exists two different philosophies regarding the term architecture:
 - Architecture as Conception
 - An architecture is a concept of a system in one's mind
 - Architecture as Perception
 - An architecture is a perception of the properties of a system as viewed by an observer
 - Under either philosophy, an architecture is abstract — it is not an artifact
 - The “Architecture Description” includes all the artifacts used to express and document an architecture (ISO/IEC/IEEE 42010)
- Systems have architectures
 - The architecture of thing X is what is fundamental to X
 - Whether X is an enterprise, system, system of systems, or some other entity
 - A system can have an architecture even if that architecture is not written down
 - The architecture can exist in the mind of an architect before being committed to artifacts (documentation of some kind)
 - An architecture is what is fundamental to a system — not necessarily everything about a system, but the essentials
 - It is practically impossible to conceptualize/document EVERYTHING about a system

ISO/IEC/IEEE 42010 Systems and Software Engineering – Architecture Description

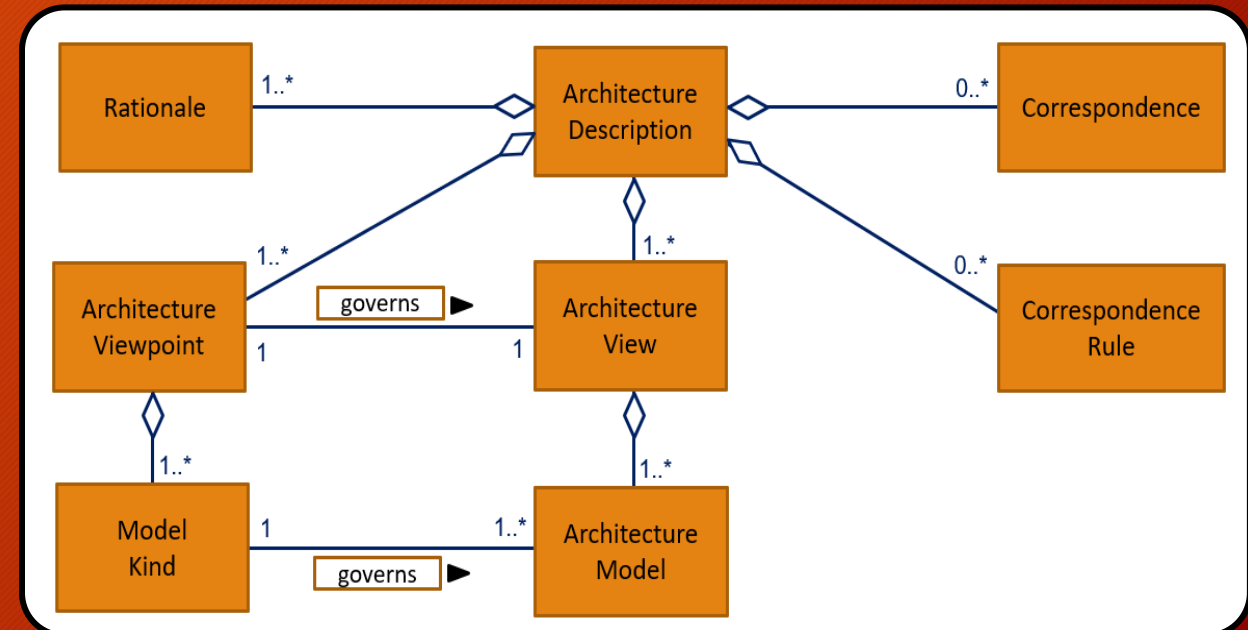
Two Sections to ISO/IEC/IEEE 42010

- ISO/IEC/IEEE 42010 covers the topic of the Architecture Description in two sections:
 - Architecture Description Context
 - Architecture Description
- These sections are presented in the form of analysis of the related metamodels
 - A metamodel is a “model of a model”
 - A meta-model typically defines the languages and processes from which to form a model.
 - If a system model is a representation of the system, then the meta-model is the representation of the model of the system
 - The two metamodel diagrams below are two representations (models) of a model of a system

Architecture Description Context



Architecture Description

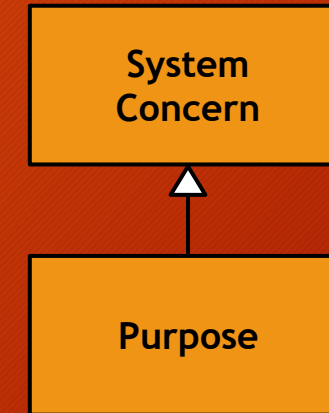


How to Read these two Metamodel Diagrams



The above says:

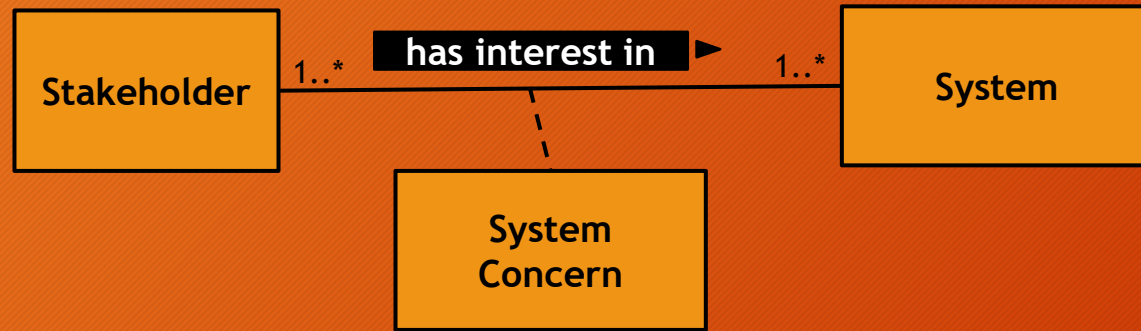
- An **Architecture Description** “expresses” one or more **Architectures**
 - This means that an Architecture Description is meaningless if there is no architecture upon which it is based (can’t be 0..*)
- Conversely: An **Architecture** “is expressed by” zero or more **Architecture Descriptions**
 - This means you can have an Architecture that is not expressed by any Architecture Description (although that is not recommended practice)



The above says:

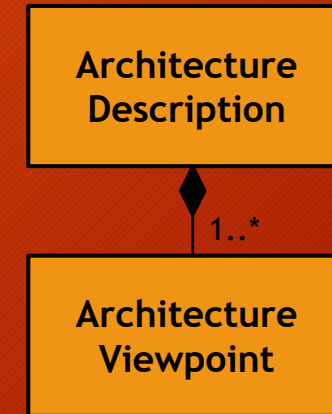
- The **Purpose** of the system “is a kind of” **System Concern**

How to Read these two Metamodel Diagrams (continued)



The above says:

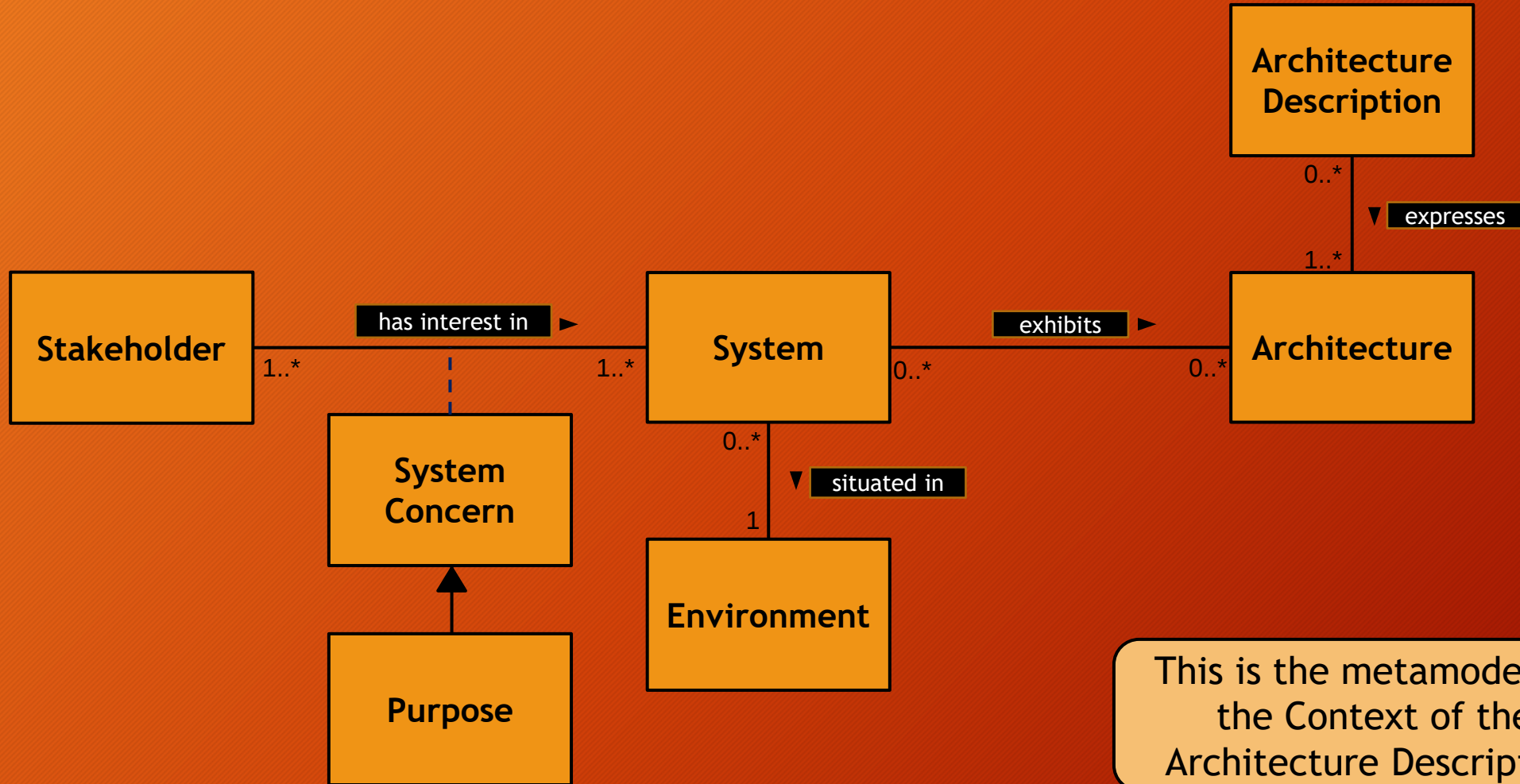
- The relationship (association) between the **Stakeholder** and the **System** “is characterized as” a **System Concern** (it is a property of the association)



The above says:

- An **Architecture Viewpoint** “is part of” an **Architecture Description**

Metamodel for the Context of Architecture Description

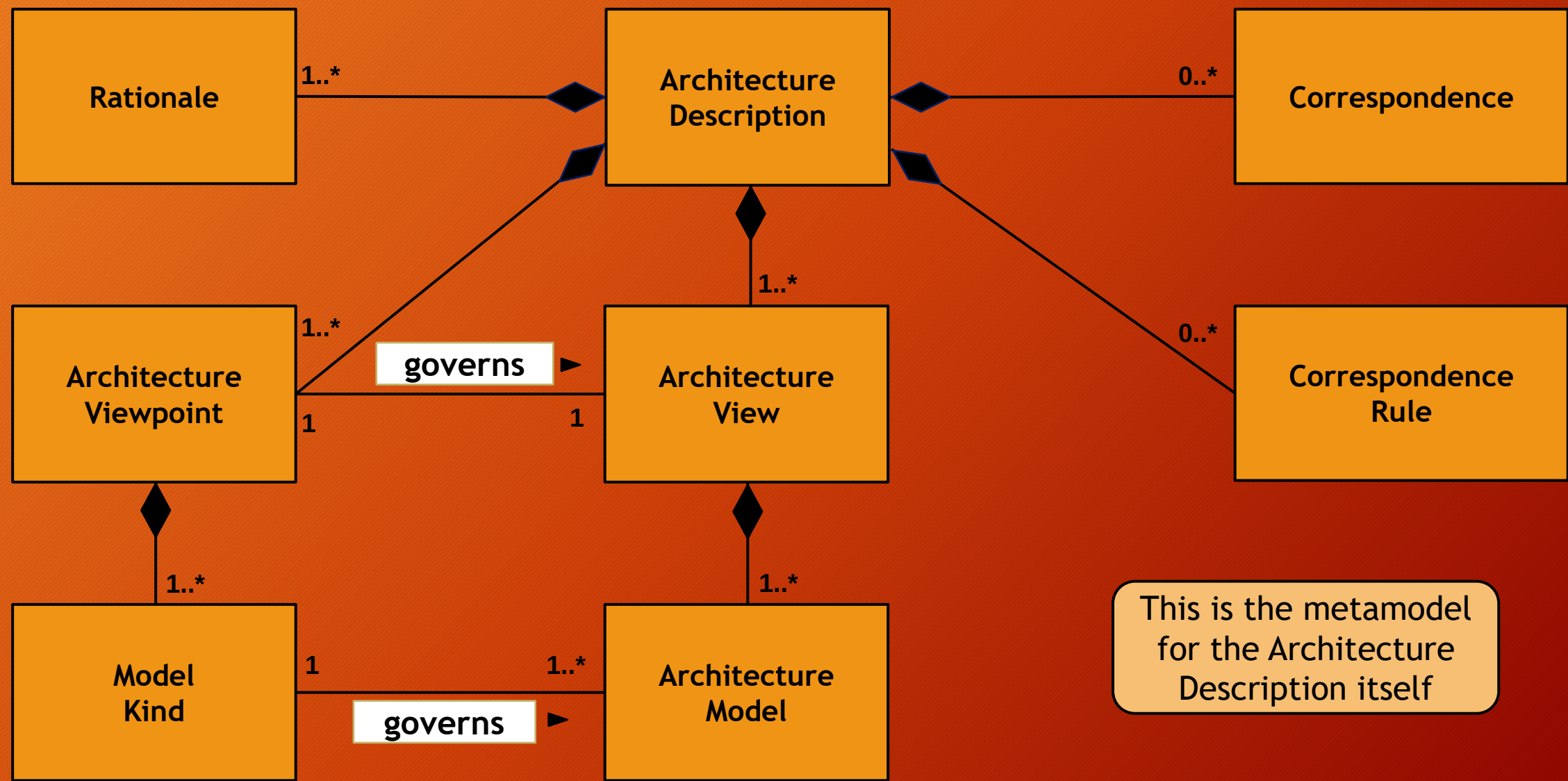


Terms Related to the Context of Architecture Description



- **System**
 - Systems exist
 - Nothing in the Standard depends upon a particular definition of system
 - Users of the Standard are free to employ whatever system theory they choose
- **Environment**
 - A System is situated in its environment
 - That environment could include other Systems
- **Stakeholder**
 - Stakeholders are individuals, groups or organizations holding Concerns for the System of Interest (Sol)
 - Examples of stakeholders: client, owner, user, consumer, supplier, designer, maintainer, auditor, CEO, certification authority, architect
- **Concern**
 - A Concern is any interest in the system
 - The term derives from the phrase “separation of concerns” as originally coined by Edsger Dijkstra
 - Examples of concerns: (system) purpose, functionality, structure, behavior, cost, supportability, safety, interoperability
 - Once the stakeholders and their concerns have been identified, they must be framed (captured) by one or more viewpoints
- **Purpose**
 - A system’s Purpose is one very common Concern
- **Architecture Description**
 - An Architecture Description is a work product used to express the Architecture of some Sol
 - The Standard specifies requirements on Ads
 - An AD describes one possible Architecture for a Sol
 - An AD may take the form of a document, a set of models, a model repository, or some other form
 - The AD format is not defined by the Standard
- **Architecture**
 - An architecture is the fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution

Architecture Description Metamodel



This is the metamodel
for the Architecture
Description itself

Terms Related to the Architecture Description Itself



- Architecture Rationale
 - Records the explanation, justification or reasoning about Architecture Decisions that have been made and architectural alternatives not chosen
- Correspondence
 - Expresses a relation between elements of the AD
 - Correspondences are used to express architecture relations of interest within an AD or between Ads
 - Correspondences can be governed by Correspondence Rules
 - Correspondences can be used to capture and enforce architecture relations such as composition, refinement, consistency, traceability, dependency, constraint and obligation
- Correspondence Rule
 - Correspondence Rules enforce relations within an AD or between Ads
- Viewpoint
- View
- Model Kind
- Model

These terms will be described in detail in the following slides

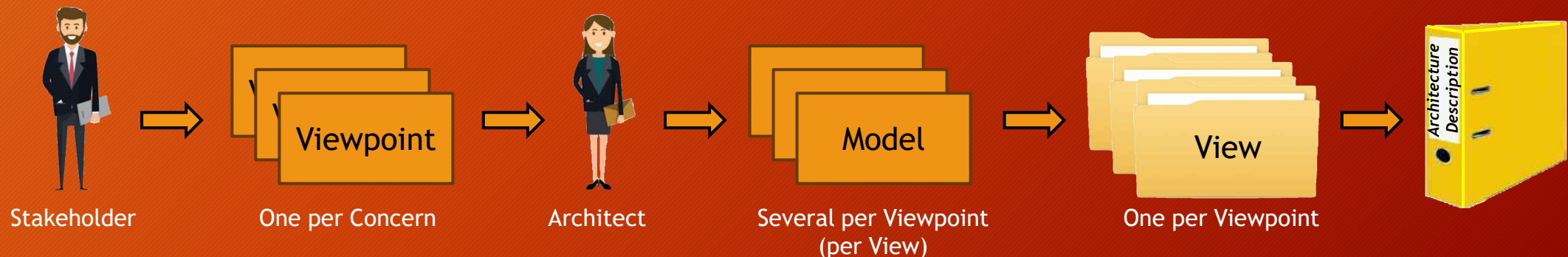
- **Architecture Viewpoint**

- A set of conventions for constructing, interpreting, using and analyzing one type of Architecture View
- Includes Model Kinds, viewpoint languages and notations, modeling methods and analytic techniques to frame a specific set of Concerns
- Examples of viewpoints: operational, systems, technical, logical, deployment, process, information
- Included in the AD
- Expresses the rules for well-formedness, completeness and analyzability of each architecture view
- A viewpoint may be separately specified from an AD, an Architecture Framework (AF) or an Architecture Description Language (ADL)
 - The Standard does not put requirements on these, but establishes a minimal basis for comparison in terms of the stakeholders, concerns and viewpoints
 - In practice, AFs and ADLs may have much more information, practices and processes associated with their use
 - An ADL (such as SysML) will typically have automated tool support

- Once viewpoints have been selected, there must be a view, with its models, adhering to the conventions of each viewpoint
- A View in an AD expresses the Architecture of the Sol from the perspective of one or more Stakeholders to address specific Concerns, using the conventions established by its viewpoint
 - An Architecture View consists of one or more Architecture Models
- A View is established as a section of the AD (and as a part of the system model)
 - Within the system model, each View is similar to a SysML package that will contain all the models (modeling artifacts) associated with the View (and with its associated Viewpoint)
- Consistency among the various views is a potential problem whenever multiple models and views are used
 - Sometimes, consistency rules or procedures are defined as a part of Viewpoint specifications
 - In other cases, organizations will have practices they use to check and enforce consistency

Viewpoint Versus View

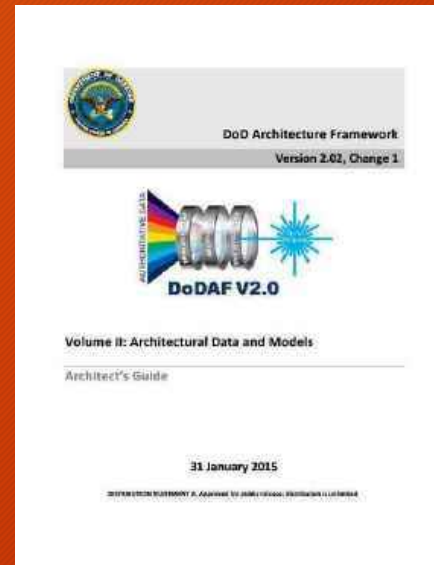
- An architecture viewpoint is a way of looking at a system
 - An architecture viewpoint documents the conventions for constructing, interpreting and analyzing a particular kind of view
 - Viewpoint conventions include languages, notations, model types, modeling methods, analysis techniques, design rules and any associated methods
- An architecture view is what you see when looking at a system from a chosen viewpoint
 - An architecture view is a collection of models representing the architecture of the whole system relative to a set of architectural concerns
 - Architects use multiple views for two reasons:
 - Different notations have different strengths for expressing various aspects of a system
 - Separation of concerns is a useful technique for managing complexity
- A view is part of a particular architecture description for a system of interest
 - For example, a structural view of a system might include a model showing components and their interfaces and models of their dependencies and inheritance relationships
 - A performance view might consist of models for resource utilization, timing schedules and cause-effect diagrams
 - The key idea of a view is that it addresses a specific set of concerns about a system using well-defined notations and models
- There is one and only one View established in the system model to address each and every stakeholder Viewpoint
 - All architectural artifacts that address a particular stakeholder Viewpoint will be placed within the system model View for the associated Viewpoint



Typical Types of Systems Architecture Viewpoints

- Static (structure)
- Dynamic, Timing
- Behavioral, Operational
- Data, Material, Energy (items and flows)
- Development, Maintenance
- Network
- Conceptual (mission)
- Logical (configuration)
- Physical (performance)

Architecture Frameworks (AFs) typically define the Viewpoints to be used in a system modeling activity

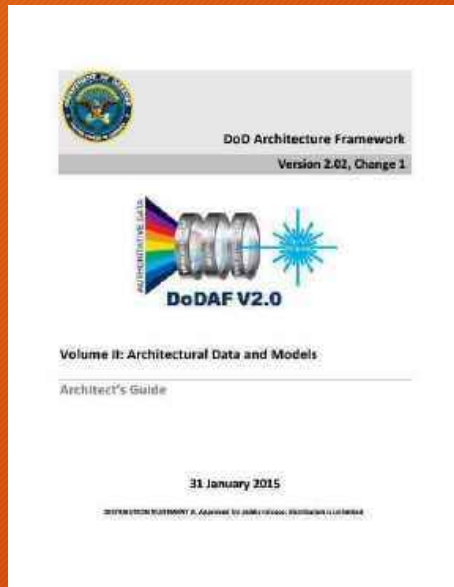


DoDAF Viewpoints
All Viewpoint
Capability Viewpoint
Data and Information Viewpoint
Operational Viewpoint
Project Viewpoint
Service Viewpoint
Standards Viewpoint
System Viewpoint

The DoD Architecture Framework (DoDAF) lists the 8 Viewpoints that address the concerns of a DoD Stakeholder

Model Kinds

- A View is comprised of Architecture Models
- Each Model is constructed in accordance with the conventions established by its Model Kind, typically defined as part of its governing Viewpoint
- Models provide a means for sharing details between Views and for the use of multiple notations within a View



Capability Viewpoint Model Kinds
CV-1 Capability Effects
CV-2 Capability Hierarchies
CV-3 Capability Schedules
CV-4 Capability Dependencies
CV-5 Capability Deployments
CV-6 Capability Activities
CV-7 Capabilities & Services

Architecture Frameworks (AFs) typically define the specifications for the Model Kinds that conform to the identified Viewpoints

Models

- A View is comprised of Architecture Models
- Each Model is constructed in accordance with the conventions established by its Model Kind, typically defined as part of its governing Viewpoint
- Models provide a means for sharing details between Views and for the use of multiple notations within a View

Capability Viewpoint Model Kinds

CV-1 Capability Effects
CV-2 Capability Hierarchies
CV-3 Capability Schedules
CV-4 Capability Dependencies
CV-5 Capability Deployments
CV-6 Capability Activities
CV-7 Capabilities & Services

Model Format Examples

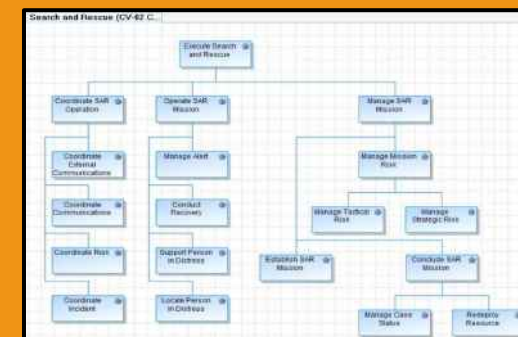
UML/SysML Diagram
Other Diagram Kind (N²)
Table
Matrix
Text
Spreadsheet
Graph or Plot
Image

Model Examples

Graphic



Diagram



Matrix

Criteria	Select Row Scope: CV-2	Select Column Scope: CV-5
Assistance	Coordinate SAR Operations	Operate SAR Mission
Land SAR	Coordinate SAR Communications	Coordinate SAR Risk
Maritime SAR	Coordinate SAR Incident	Coordinate SAR Support
Recovery	Coordinate SAR Logistics	Coordinate SAR Intelligence
SAR	Coordinate SAR Planning	Coordinate SAR Execution
Search	Coordinate SAR Evaluation	Coordinate SAR Reporting
UML SAR Capability	Coordinate SAR Analysis	Coordinate SAR Synthesis

Table

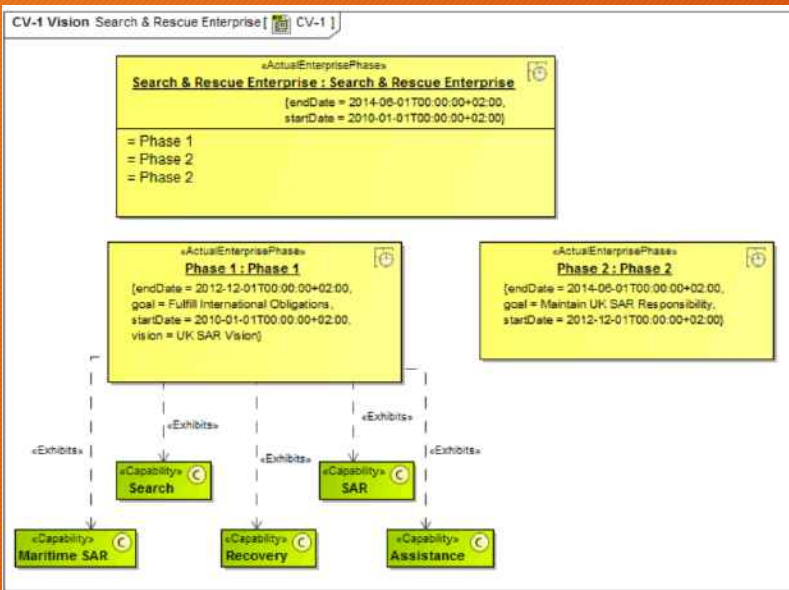
Capability	Definition	Activities	Rules	Services
Connect	The set of computing and communications infrastructure capabilities enabling any user or service to reach any other user or service and use any other service.	Coordinate SAR Operations	CR 01	S1.1.6.1 Storage On Demand Services
Infrastructure Provisioning	The ability to provision and allocate shared computing and data storage infrastructure resources in a computing platform.	Operate SAR Mission	CR 05	S1.1.6.2 Computing On Demand Services
Unified Communications and Collaboration	The ability to seamlessly integrate communications voice, video, and data applications services so they are delivered ubiquitously across a secure and highly available single protocol network infrastructure.	Manage SAR Mission	CR 06	S1.1.6.3 Software as a Service

Models created by the architect can take on any of multiple formats

The DoDAF “recommends” the format that each Model Kind might take

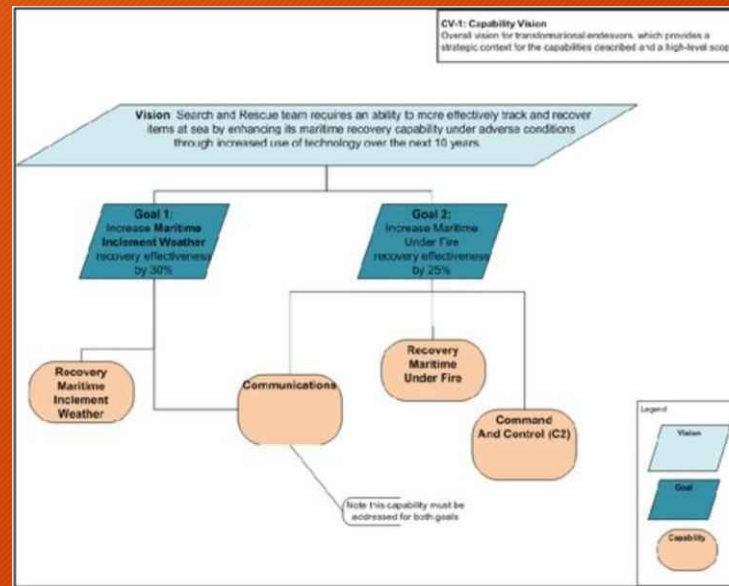
DoDAF CV-1 Capability Effects

- The CV-1 is intended to illustrate the most important of the capabilities that the SOI is going to deliver or demonstrate
- This can be presented simply as a list, or graphic itemizing these capabilities in some kind of relative order



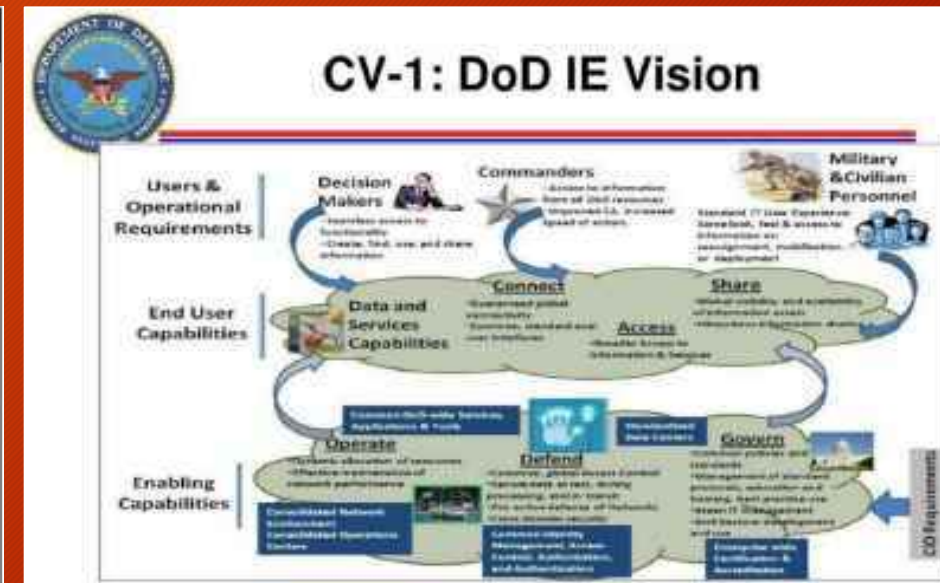
<https://docs.nomagic.com/display/UAFP190/CV-1+Vision>

Shows (partially) when the capabilities will become available



<https://slideplayer.com/slide/13707254/>

Shows capabilities relative to Vision and Goals

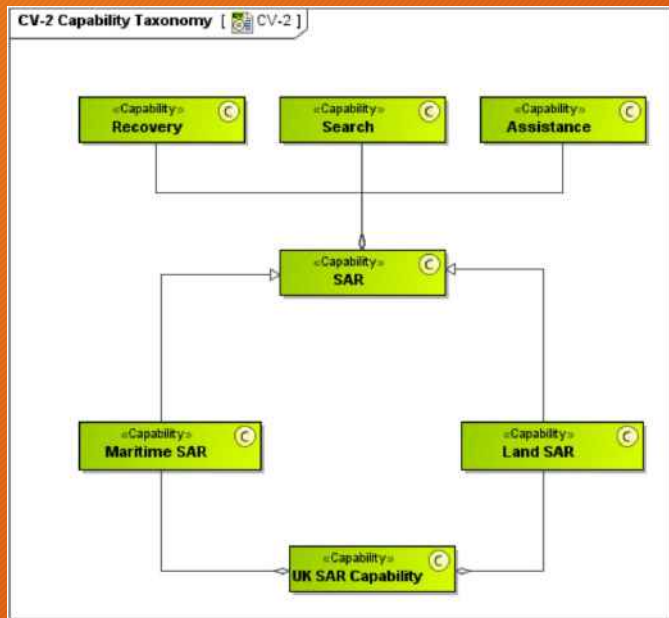


https://dodcio.defense.gov/Portals/0/Documents/DODAF/1050-1110_DoD%20IEA%20v2%200_Mazyck_01-05-2012_V1.pptx

Shows End-User capabilities relative to Requirements and Enabling Capabilities

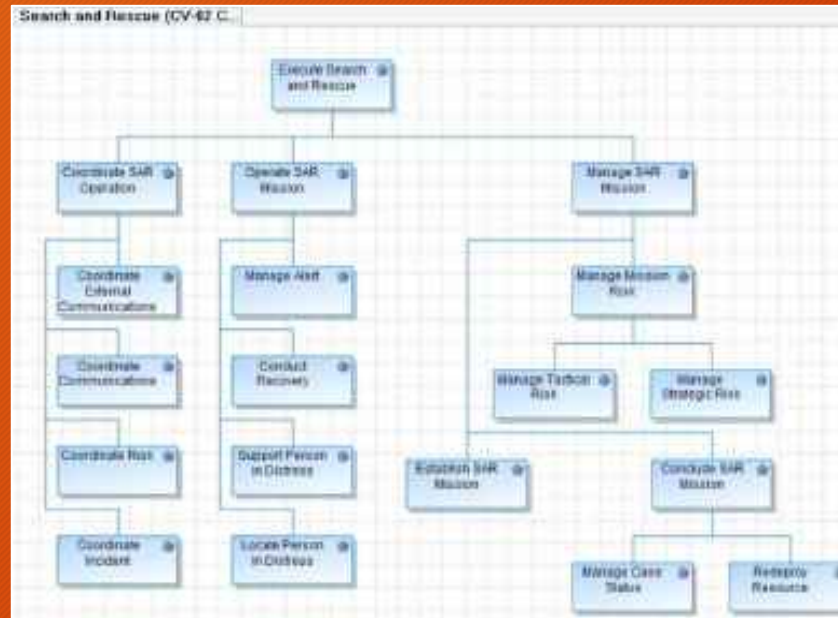
DoDAF CV-2 Capabilities Hierarchy

- The CV-2 is intended to illustrate the hierarchy (decomposition) of the system capabilities
- It is understood that the lower tier capabilities in the hierarchy are in some way related (as in parent-child relationship) to the upper tier capabilities



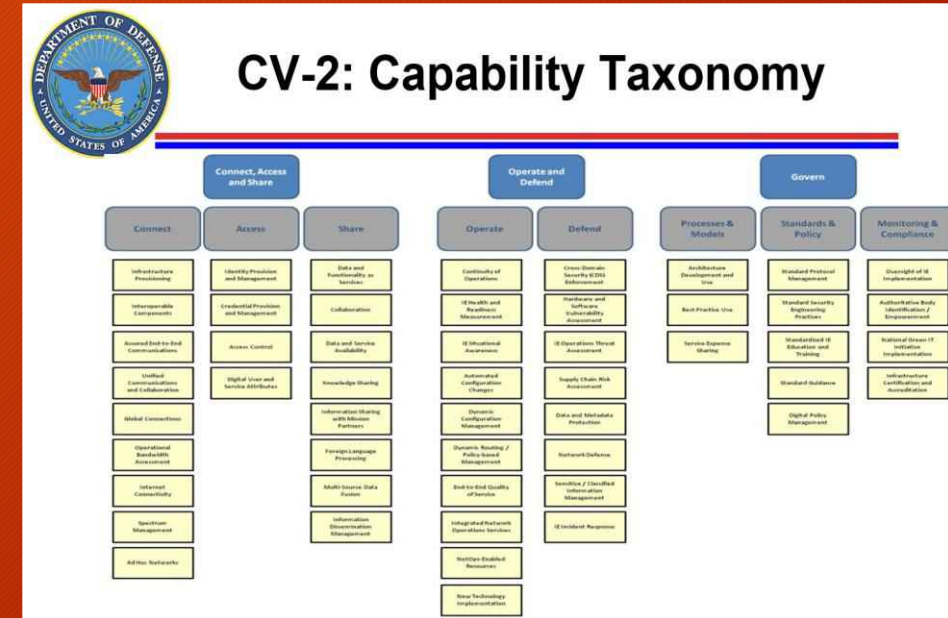
<https://docs.nomagic.com/display/UPDMP182/CV-2+Capability+Taxonomy>

Shows combination of decomposition of capabilities as well as specialization of capabilities



<https://www.pinterest.com/pin/490610953132849062/>

Shows a pure hierarchy of capabilities to four tiers (levels)

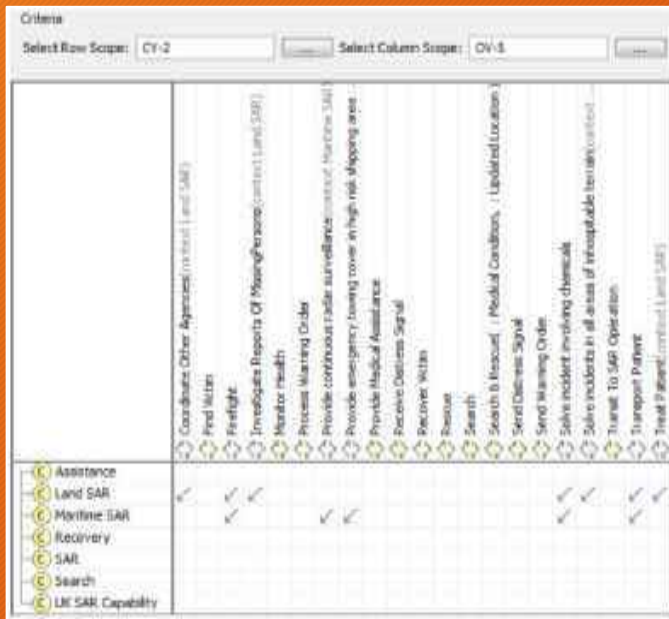


https://dodcio.defense.gov/Portals/0/Documents/DODAF/1050-1110_DoD%20IEA%20v2%200_Mazyck_01-05-2012_V1.pptx

Shows a pure hierarchy of capabilities to three tiers (levels)

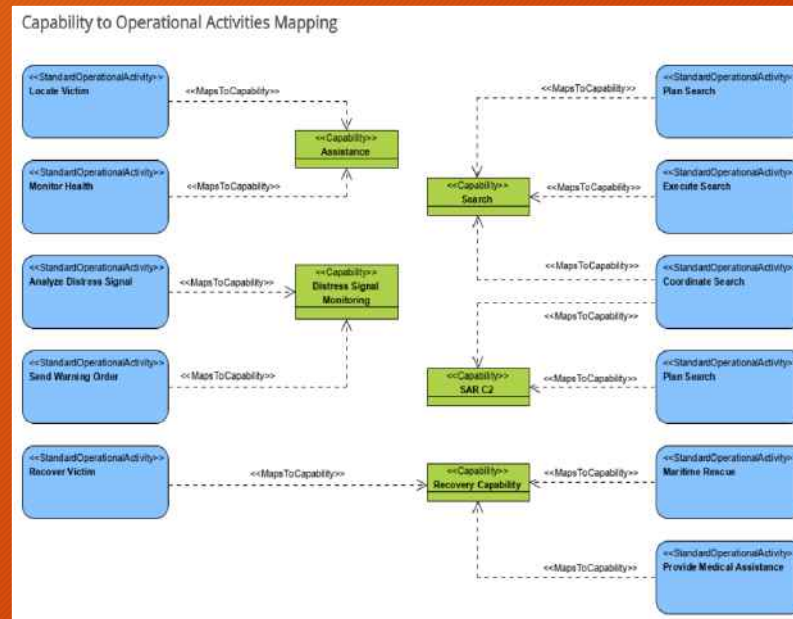
DoDAF CV-6 Capabilities Activities

- The CV-6 is intended to illustrate the mapping of activities that perform function to the observable capabilities delivered by the system
- Mapping is often illustrated by a matrix



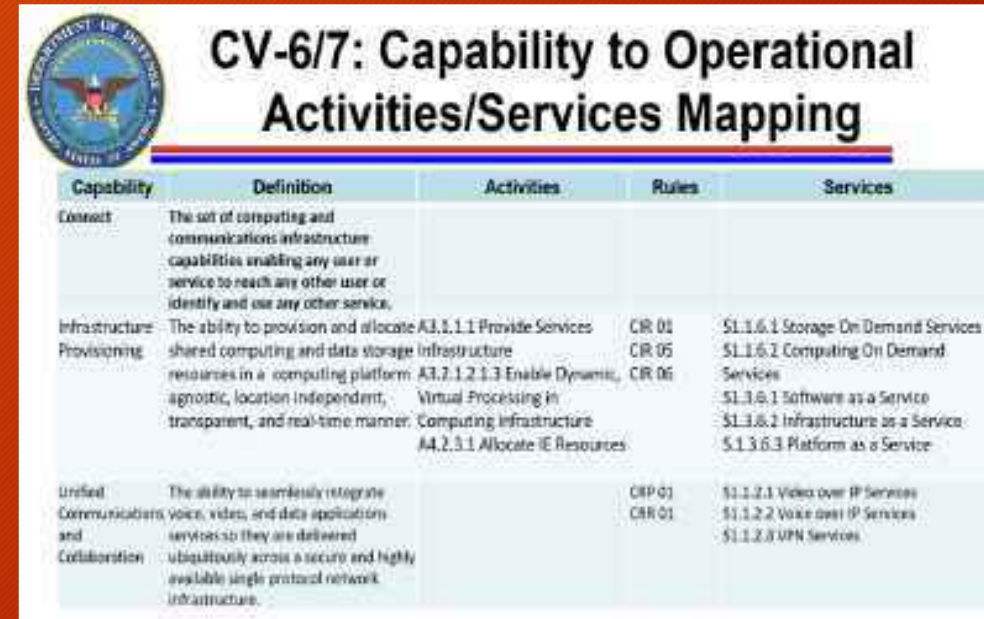
<https://docs.nomagic.com/display/UAF190/CV-6+Capability+to+Operational+Activities+Mapping>

Shows mapping (matrix) of activities (columns) that are mapped to capabilities (rows) - that result in delivering capabilities



<https://circle.visual-paradigm.com/docs/dodaf-tool/capability-viewpoint/cv-6-capability-to-operational-activities-mapping/>

Shows activities mapped to capabilities using customized dependency relationship



https://dodcio.defense.gov/Portals/0/Documents/DODAF/1050-1110_DoD%20IEA%20v2%200_Mazyck_01-05-2012_V1.pptx

Shows a simple text matrix mapping activities to capabilities

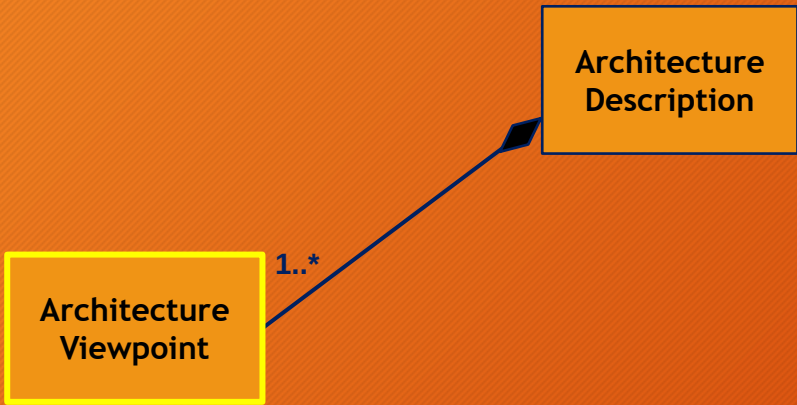
Analogy of Architecture Description Terms to Common Everyday Concepts

Analogies with Common Everyday Concepts



- In order to relate these architecture description concepts to common concepts, two analogies will be made with everyday activities:
 - Photography
 - Construction
- Photography
 - In this activity, the concept of a Viewpoint should be easy to grasp
- Construction
 - In this activity, the concept of drawings and diagrams as architectural artifacts should be easy to grasp
- Following these analogies, a more relevant systems example will be presented based on the Department of Defense (DoD) Architecture Framework (AF), or the “DoDAF”

System Architectural Viewpoint Analogies



The Architecture Description should contain a listing of the Viewpoints included in the architecture

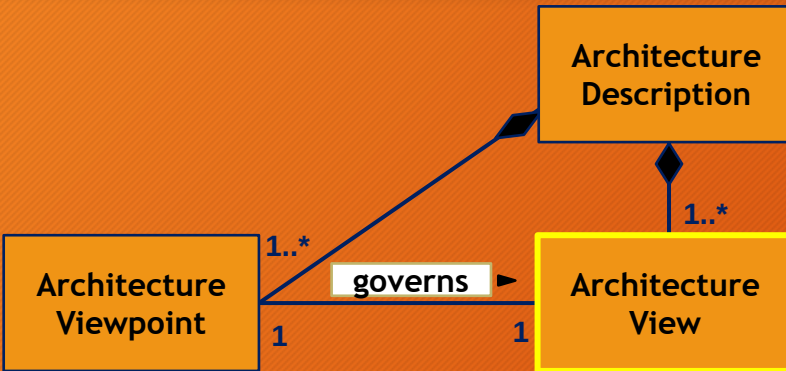
Photography Analogy	Construction Analogy
Viewpoint refers to the location, relative to the subject, from which a photograph is taken	Viewpoint refers to a particular aspect or discipline of construction techniques



Two Viewpoints: 1) North Rim, 2) South Rim

Construction “Viewpoints”
Architectural
Structural
HVAC
Electrical
Plumbing

System Architectural Views (Photography Analogy)



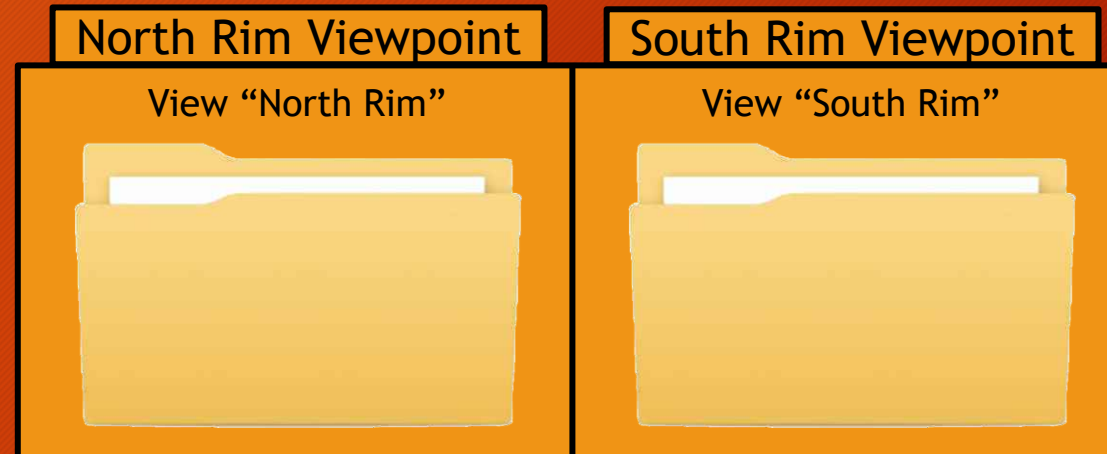
The Architecture Description should contain only one View for each Viewpoint of the architecture

Each Viewpoint specifies (governs) that the photographer should add a single View that to the portfolio that will contain artifacts related to that Viewpoint

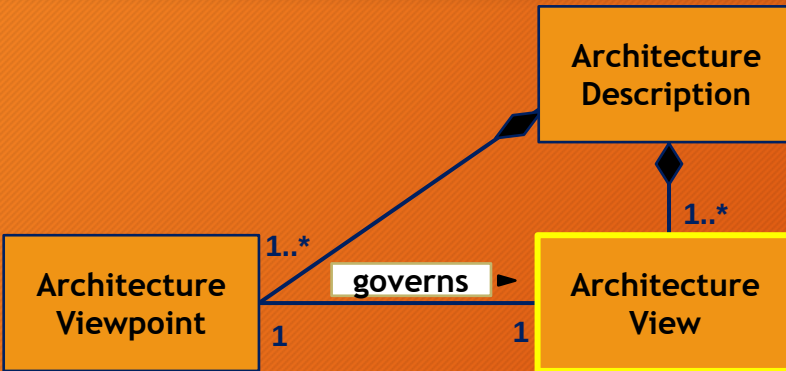


The “Views” are NOT the actual photographic artifacts that will go into the photographer’s portfolio

They are just the sections of the portfolio where the photographic artifacts will go



System Architectural Views (Construction Analogy)



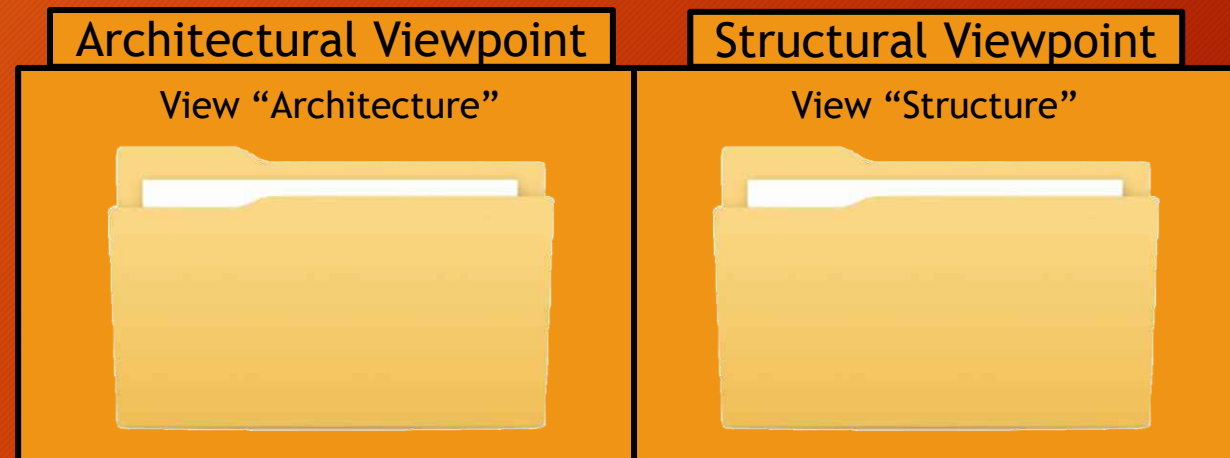
Each Viewpoint specifies (governs) that the builder should add a single View that to the portfolio that will contain artifacts related to that Viewpoint

The Architecture Description should contain only one View for each Viewpoint of the architecture



The “Views” are NOT the actual building drawings that will go into the builder’s portfolio

They are just the sections of the portfolio where the building drawings will go



System Architectural Model Kinds (Photography Analogy)

Architecture
Description

The Architecture Description should contain a listing of the Model Kinds that make up (compose) the Viewpoint

Model Kinds specify (govern) for the Models that will go into the Architecture Description

Architecture
Viewpoint

1..*

Model
Kind

1..*

Each Viewpoint is composed of a set of Model Kinds

Each Viewpoint can be composed of the same or different Model Kinds as other Viewpoints

Viewpoint “North Rim”



The “Model Kinds” are NOT the actual artifacts that go into the photographer’s portfolio, they are a description of the “kinds” of photographic artifacts that will eventually go into the photographer’s portfolio

Model Kind “Photograph”



<https://www.apogeephoto.com/>

Model Kind “Color Histogram”



<https://phlearn.com/magazine/histograms-better-photos/>

Model Kind “Saturation Sweep”



<https://www.anandtech.com/show/10243/>

System Architectural Model Kinds (Construction Analogy)

Architecture
Description

View “Elevation Plan”

The Architecture Description should contain a listing of the Model Kinds that make up (compose) the Viewpoint

Model Kinds specify (govern) for the Models that will go into the Architecture Description

Architecture
Viewpoint

1..*

Model
Kind

1..*

Each Viewpoint is composed of a set of Model Kinds

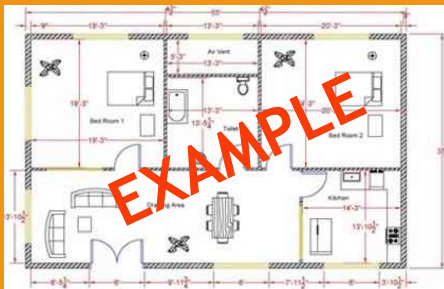
Each Viewpoint can be composed of the same or different Model Kinds as other Viewpoints

Viewpoint “Architectural”



The “Model Kinds” are NOT the actual artifacts that go into the builder’s portfolio, they are a description of the “kinds” of building drawings that will eventually go into the builder’s portfolio

Model Kind “Floor Plan”



<https://civilmdc.com/learn/2020/07/15/>

Model Kind “Elevation Plan”



<http://www.dwgnet.com/2017/06/>

Model Kind “Landscape Plan”



<https://www.polikofflandscapes.com/>

System Architectural Models (Photography Analogy)

The Architecture Description should contain a set of Models for each View in the Architectural Description

The Models are placed in the appropriate section of the portfolio for the View that they cover

Photographer's Portfolio



View "North Rim"

Model "Saturation Sweep of Grand Canyon"

Model "Color Histogram of Grand Canyon"

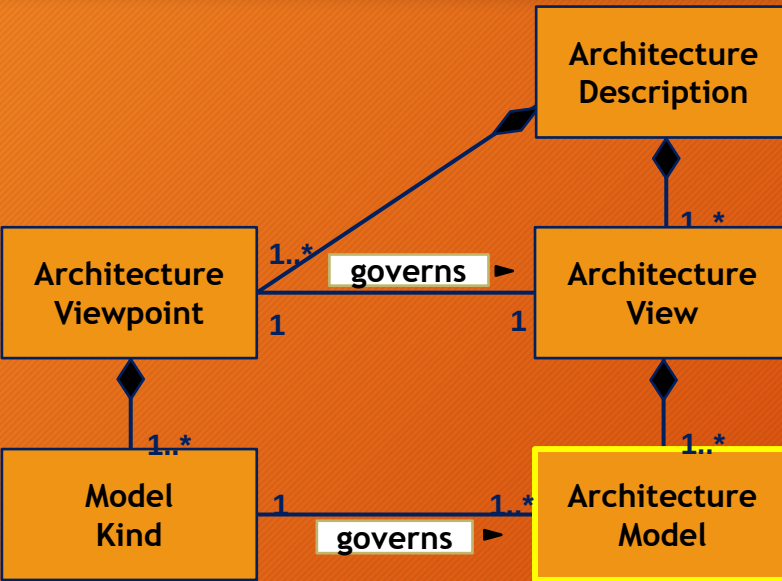
Model "Photograph of Grand Canyon"



<https://ramblerken.blogspot.com/2019/08/>

The "Models" ARE the actual photographic artifacts that go into the photographer's portfolio

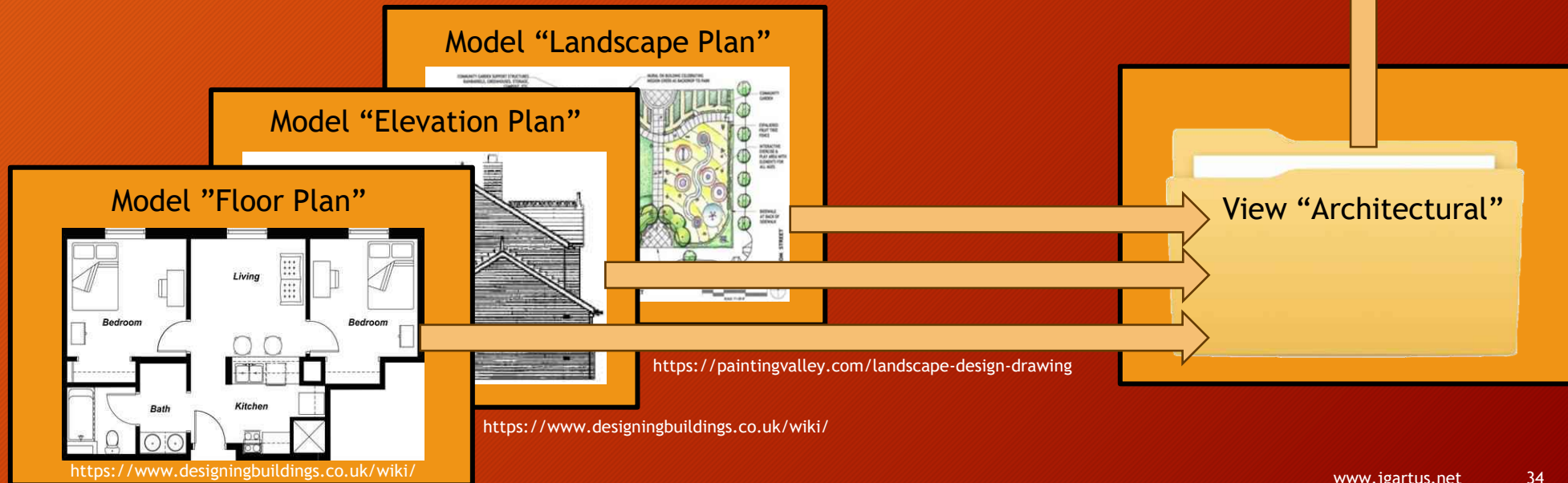
System Architectural Models (Construction Analogy)



The Architecture Description should contain a set of Models for each View in the Architectural Description

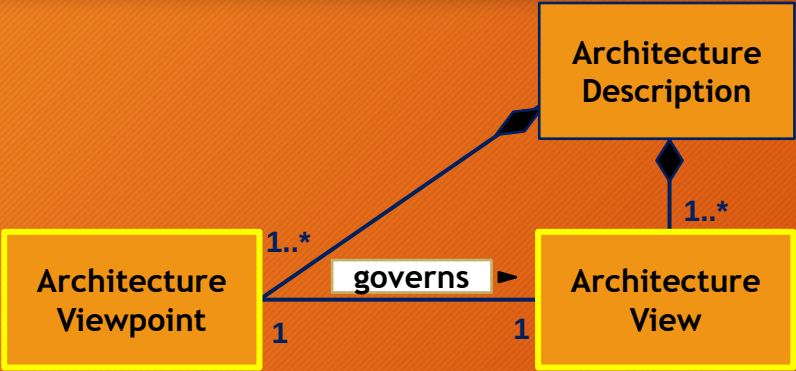
The Models are placed in the appropriate section of the portfolio for the View that they cover

The “Models” ARE the actual building drawing artifacts that go into the builder’s portfolio

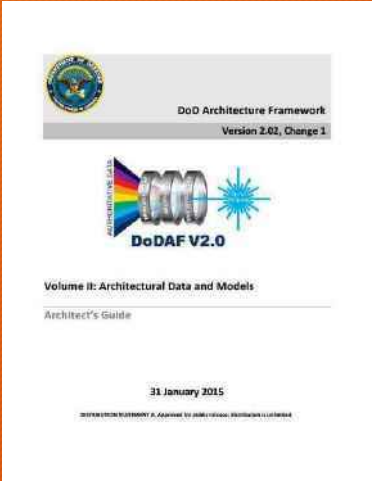


Architecture Description Terms - DoDAF Example

System Architecture Viewpoints and Views (DoDAF Example)



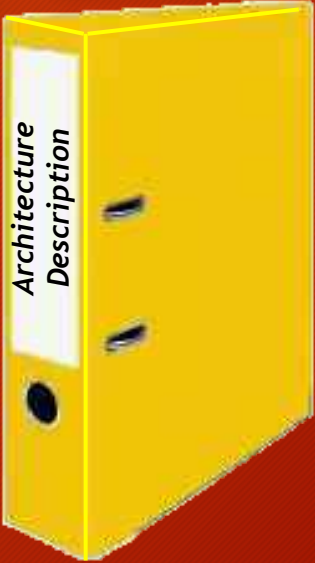
The Architecture Framework identifies the Viewpoints (and therefore, the Views) that the architect should include in the system model and in the AD



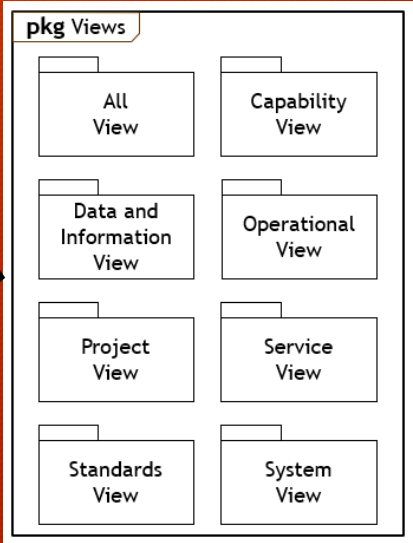
The DoD Architecture Framework (DoDAF) lists the 8 Viewpoints that address the concerns of a DoD Stakeholder

DoDAF Example
All Viewpoint
Capability Viewpoint
Data and Information Viewpoint
Operational Viewpoint
Project Viewpoint
Service Viewpoint
Standards Viewpoint
System Viewpoint

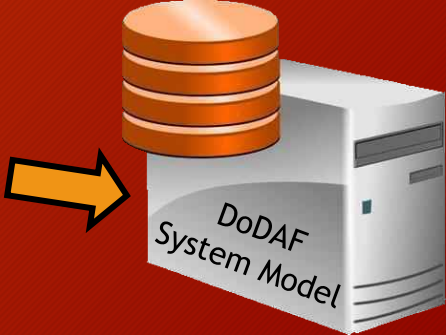
Viewpoints Identified



Model Artifacts

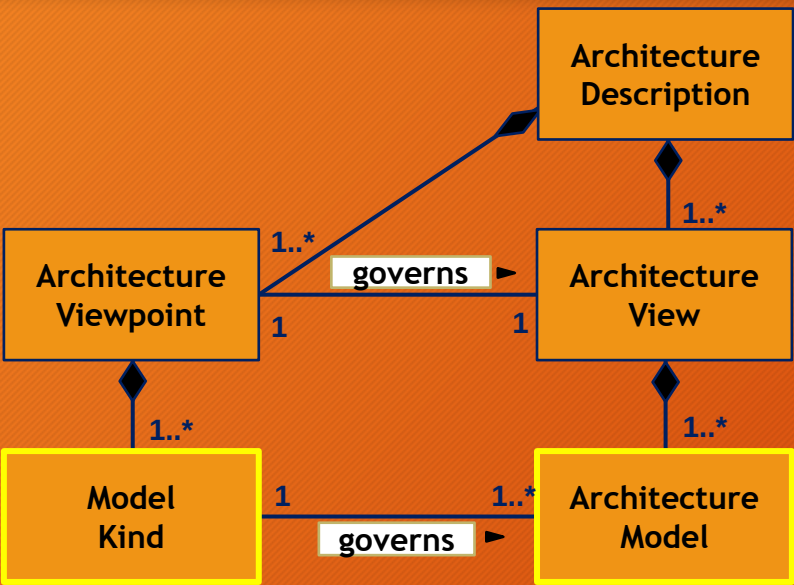


View Packages hold Models



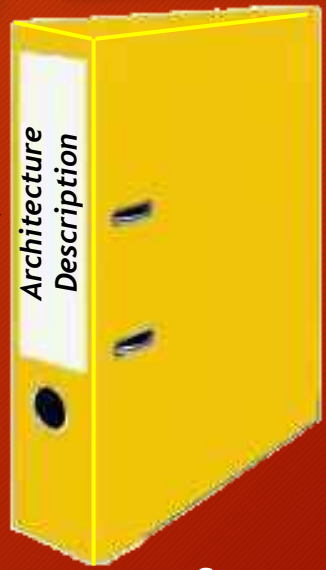
Model-Based Systems Engineering

System Architecture Model Kinds and Models (DoDAF Example)



Capability Viewpoint Model Kinds
CV-1 Capability Effects
CV-2 Capability Hierarchies
CV-3 Capability Schedules
CV-4 Capability Dependencies
CV-5 Capability Deployments
CV-6 Capability Activities
CV-7 Capabilities & Services

Model Kinds Identified

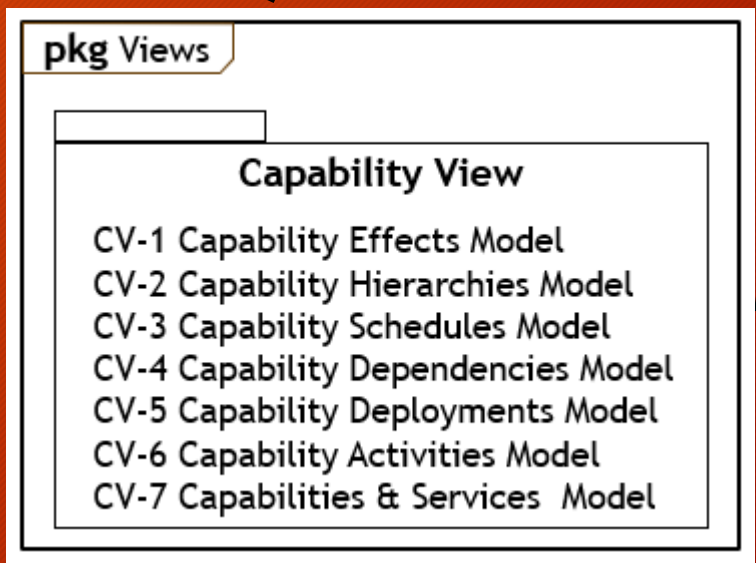


Model Format Examples
UML/SysML Diagram
Other Diagram Kind (N ²)
Table
Matrix
Text
Spreadsheet
Graph or Plot
Image

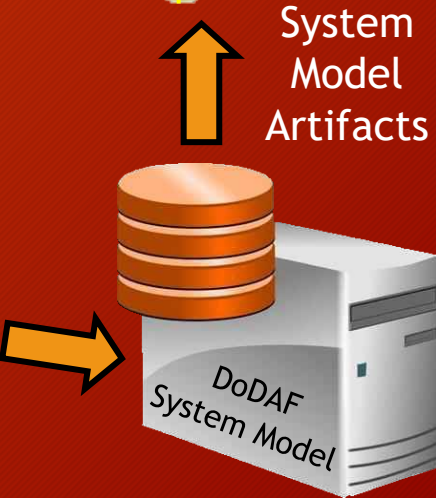
The DoDAF “recommends” the format that each Model Kind might take



The DoDAF identifies the Model Kinds for each Viewpoint



View Packages hold Models



Model-Based Systems Engineering

References



- The ISO/IEC/IEEE 42010 Website (and related pages); Retrieved from <http://www.iso-architecture.org/42010/index.html>
- Ellis, W., Hilliard, R., Poon, P., Rayford, D., Saunders, T., Sherlund, B. (1996) Toward a Recommended Practice for Architectural Description; Retrieved from <http://www.iso-architecture.org/42010/toward.pdf>
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- Emery, D., Hilliard, R. (2009) Every Architecture Description Needs a Framework: Expressing Architecture Frameworks Using ISO/IEC 42010
- Sami, M. (2020) Architecture Model, Meta-Model, and Meta-Meta Model; Retrieved from <https://melsatar.blog/2020/01/12/architecture-model-meta-model-and-meta-meta-model/>