32nd Annual INCOSE international symposium
hybrid event
Detroit, MI, USA
June 25 - 30, 2022

# An MBSE Architectural Framework for Inter-Satellite Communication in a Multiorbit Disaggregated System

www.incose.org/symp2022

# The Research Team…

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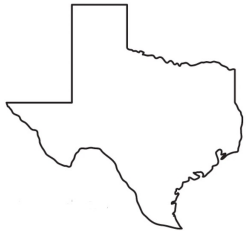

Austin, TX


**Matthew Hause**

Principal Engineer

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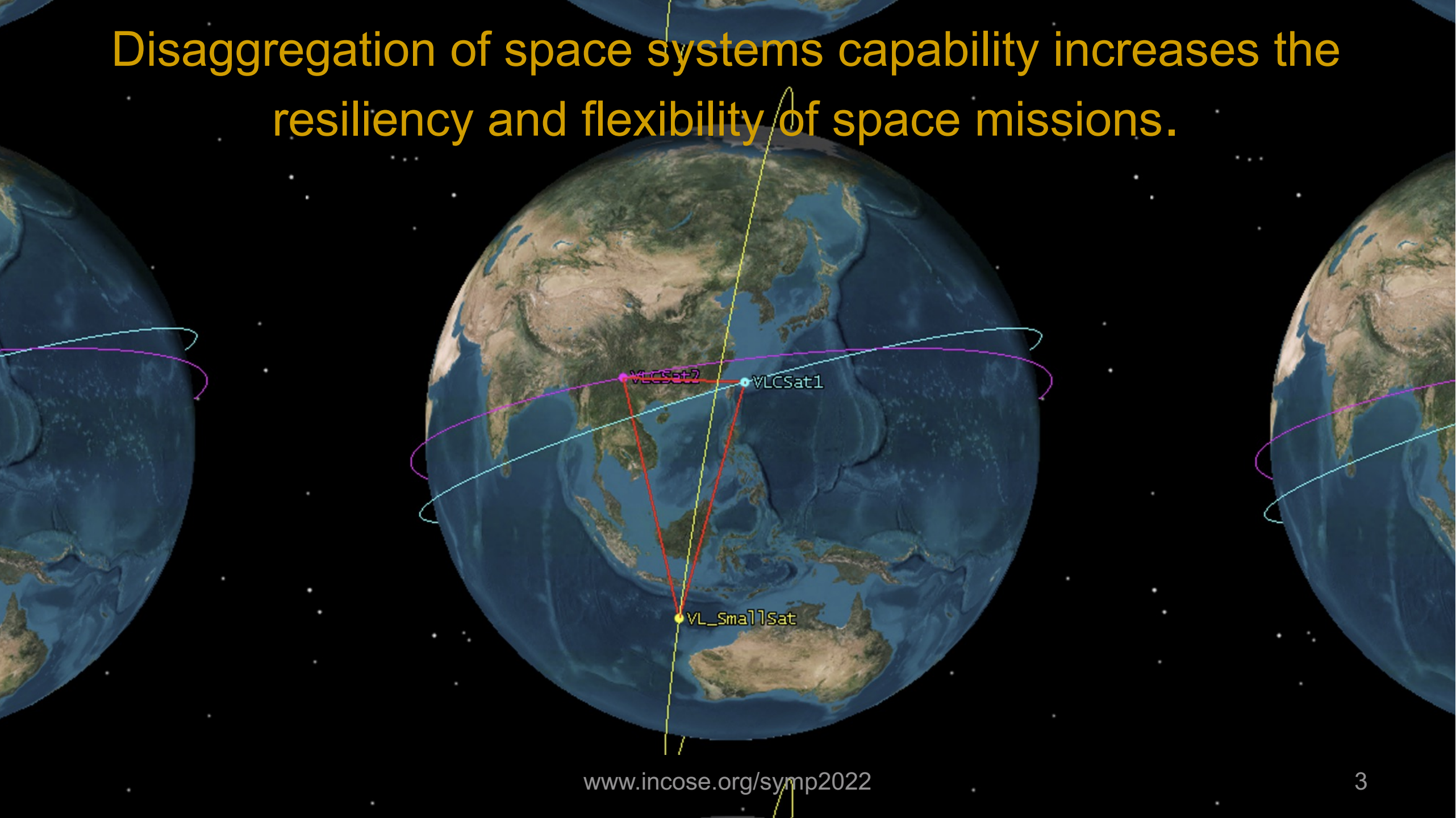
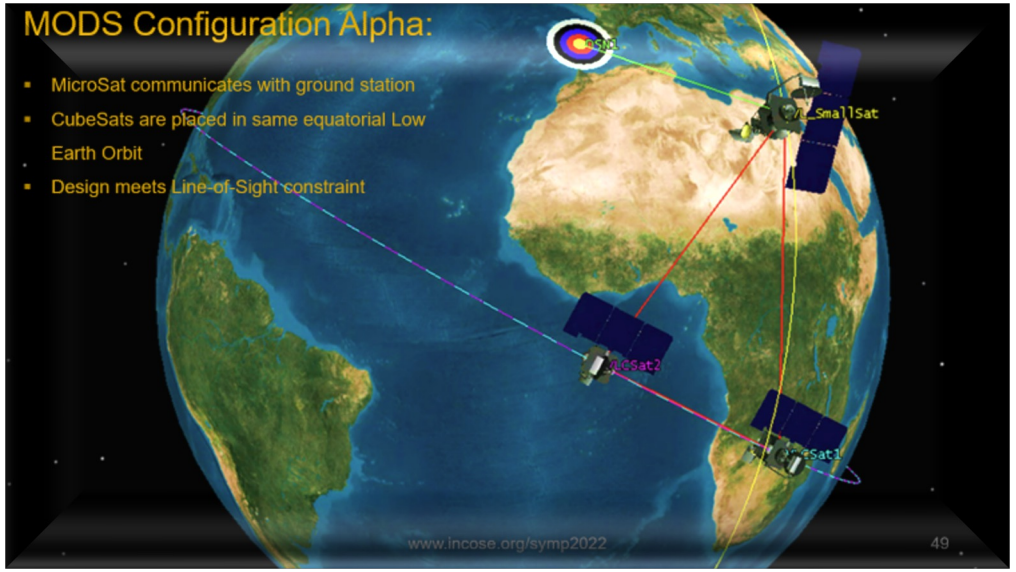
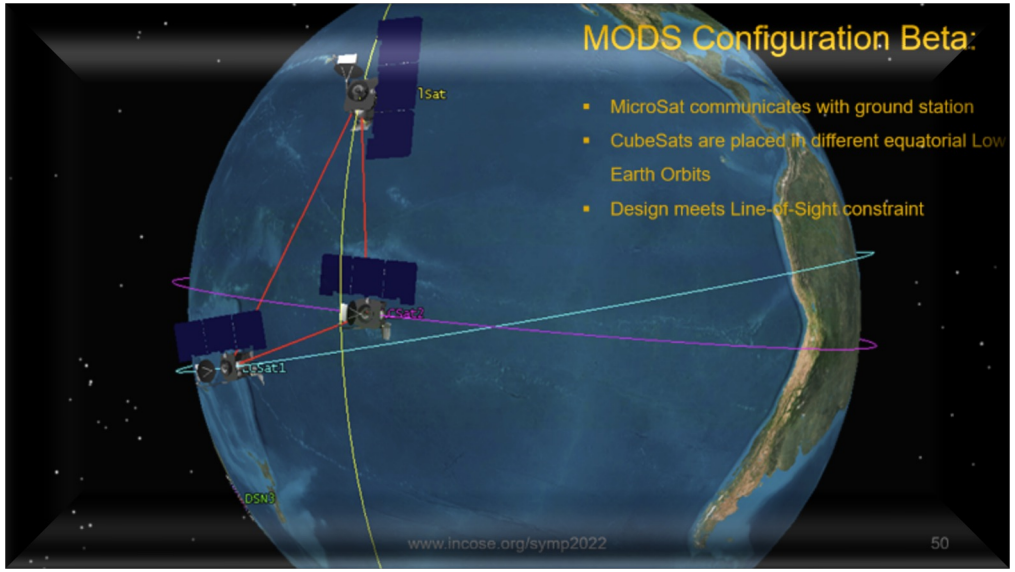
# Disaggregation of space systems capability increases the resiliency and flexibility of space missions.



# A multi-orbit disaggregated system enables flexible architectural configurations for space missions.

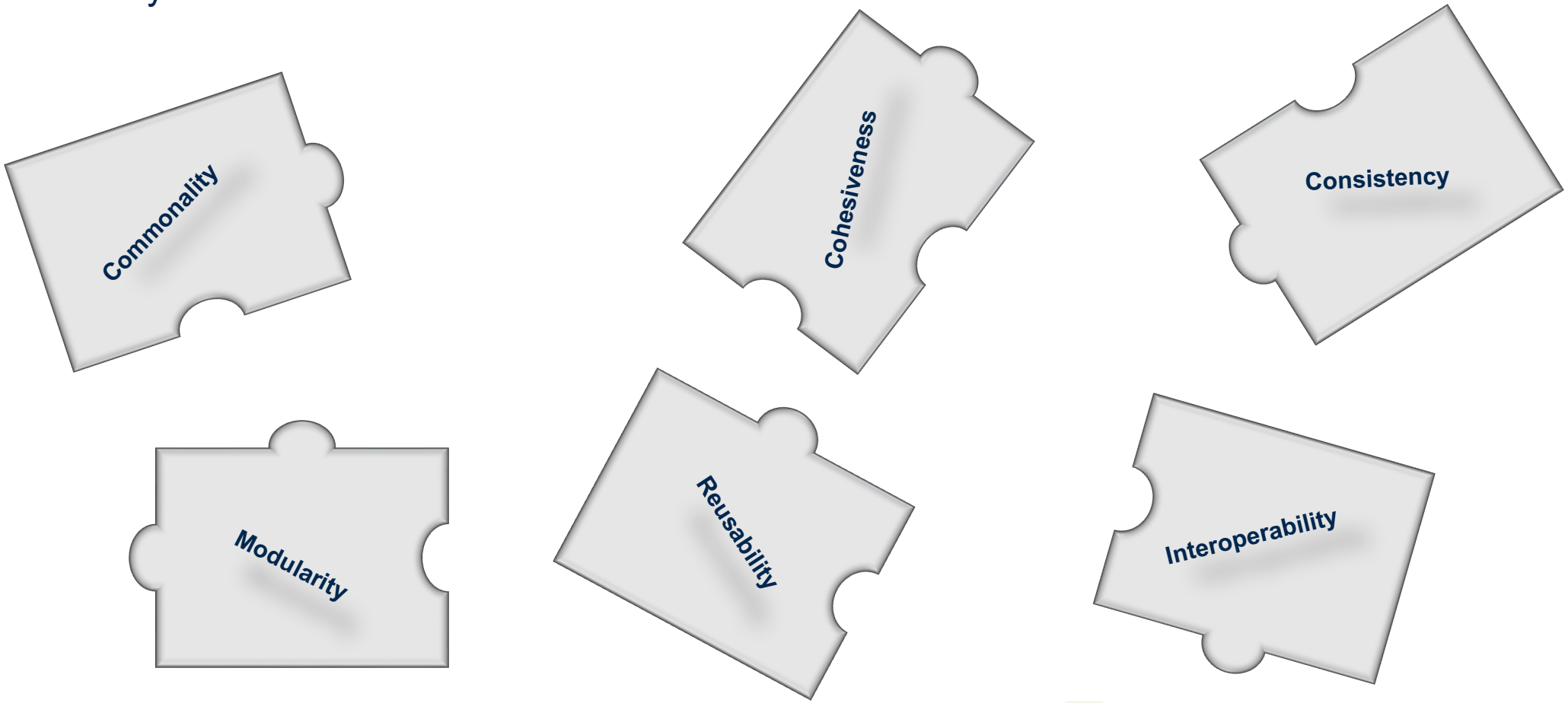
- High-speed inter-satellite communication **(ISC)** links enable flexible architectural options.
- ISC-enabled low cost SmallSats make good candidates for such missions.
- Two mission configurations are proposed.



# Can a common set of architectural decisions drive the development of every aspect of the MODS?

- How do we guide and constrain ISC architecture solutions in a manner consistent with other subsystem architecture solutions?



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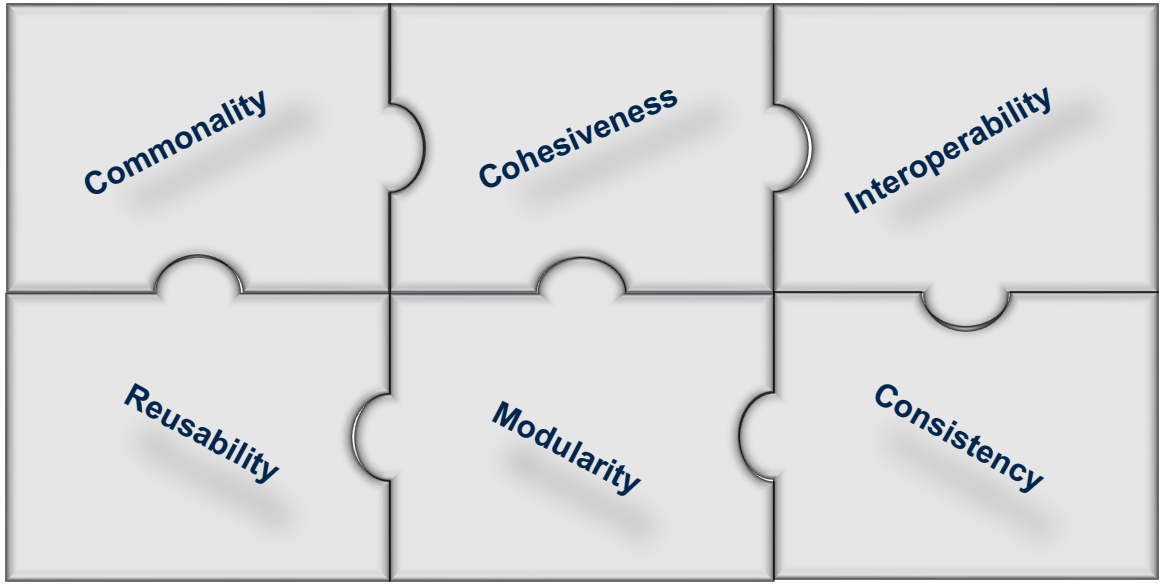
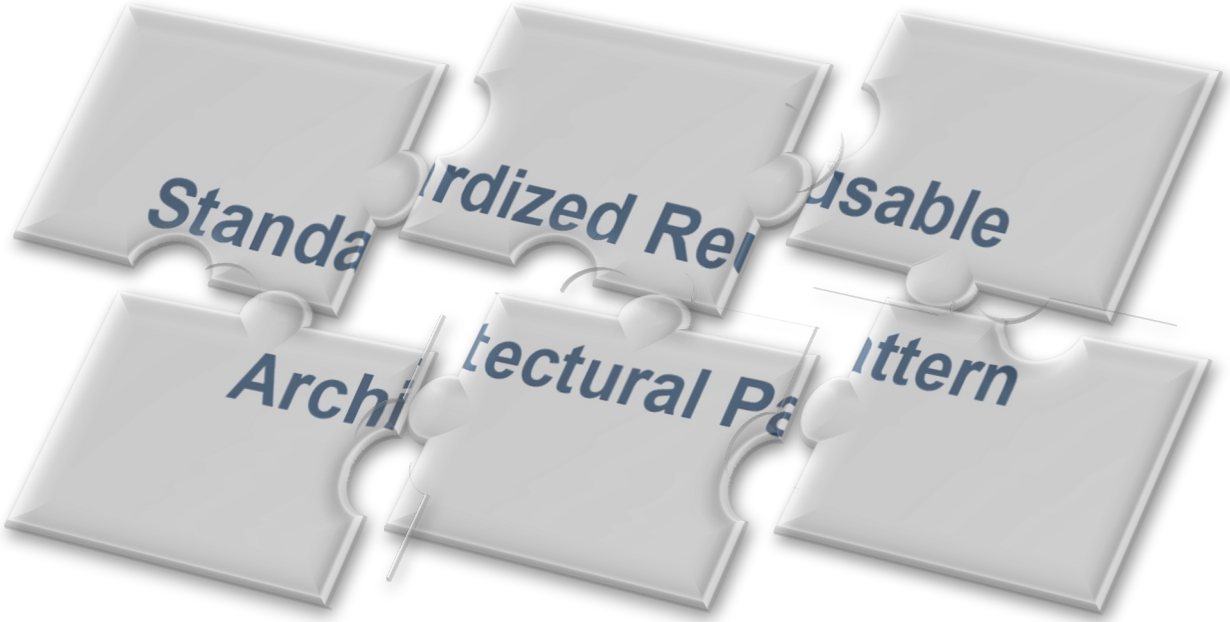
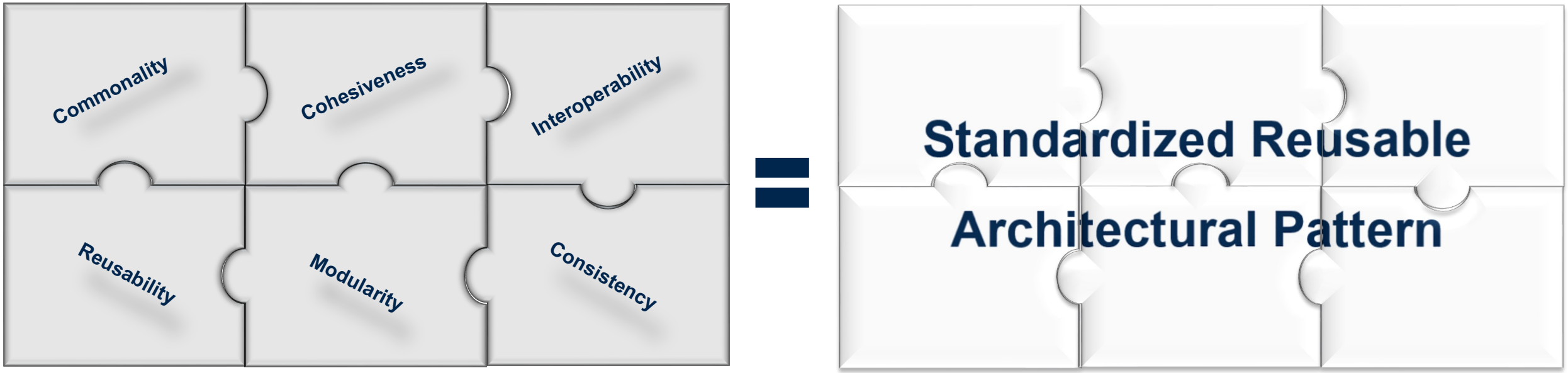


# Can a common set of architectural decisions drive the development of every aspect of the MODS?

- We architect for success using a standardized reusable pattern



# Our goal is a viable and resilient multi-orbit disaggregated system for space missions

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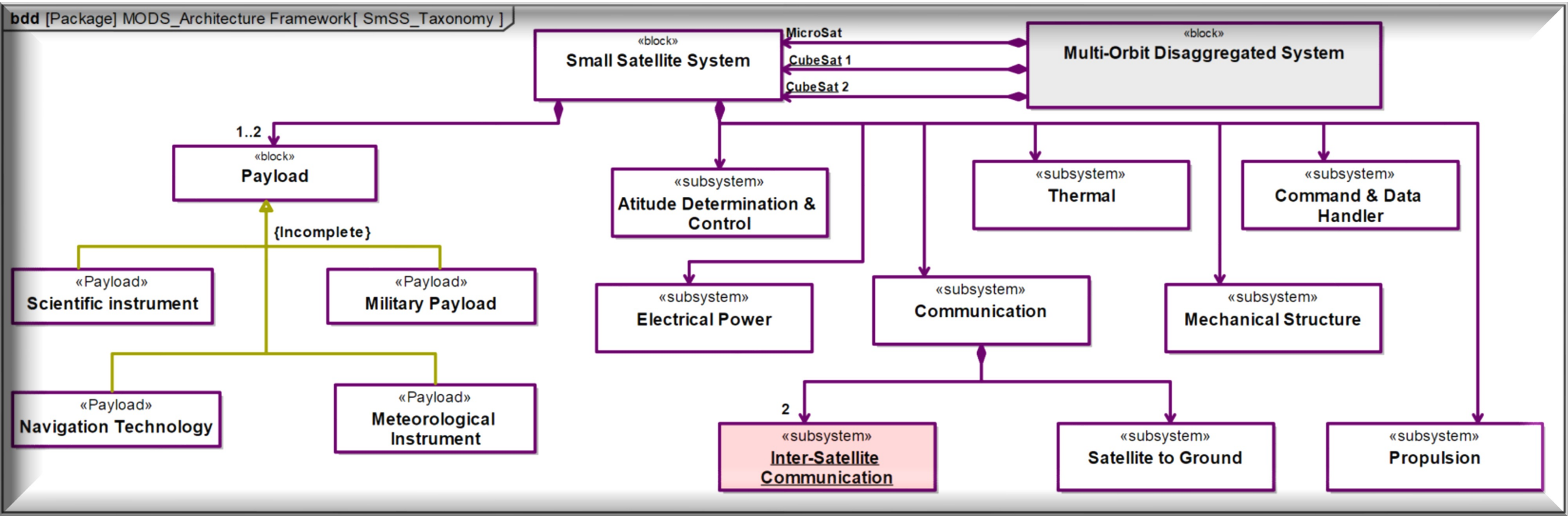
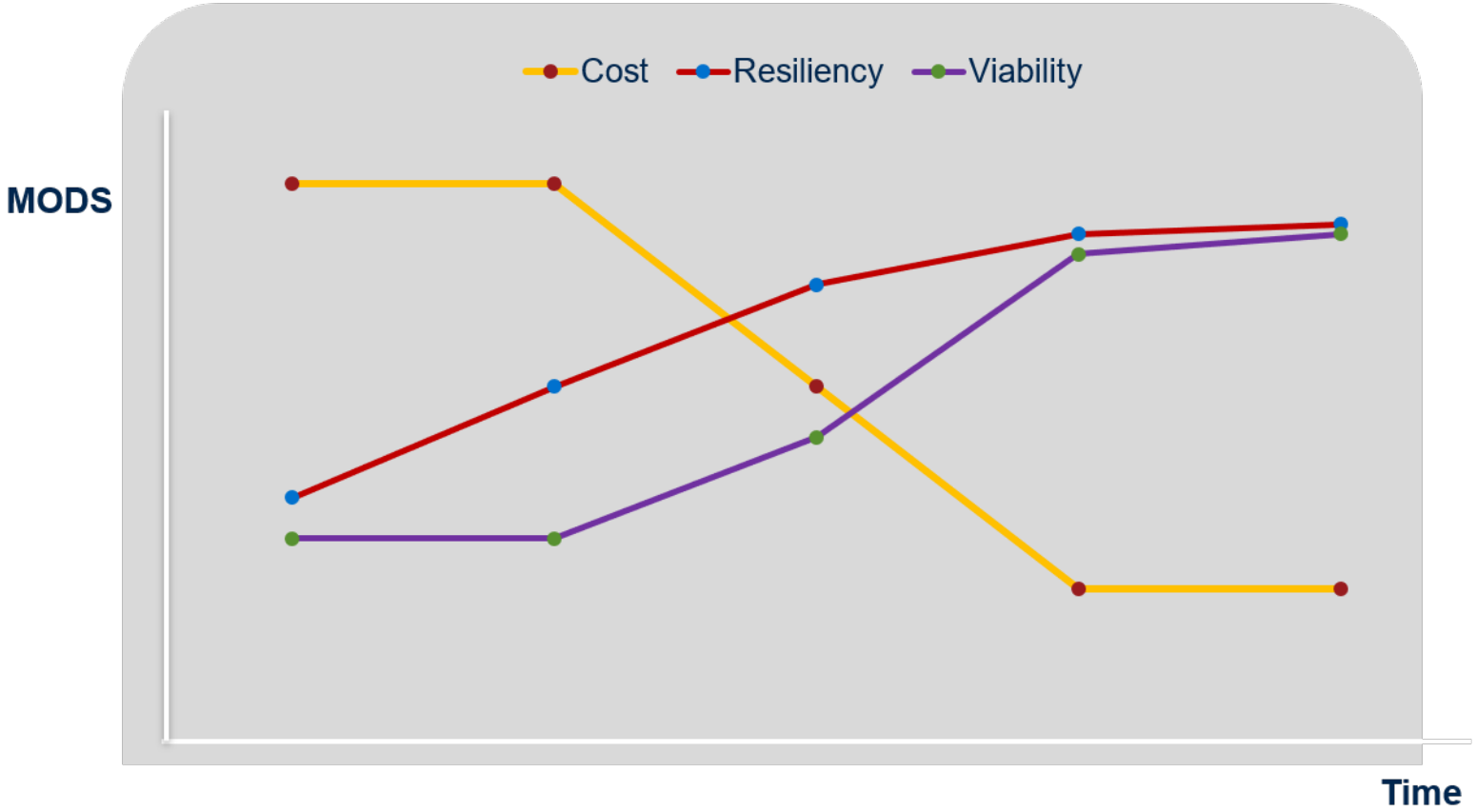
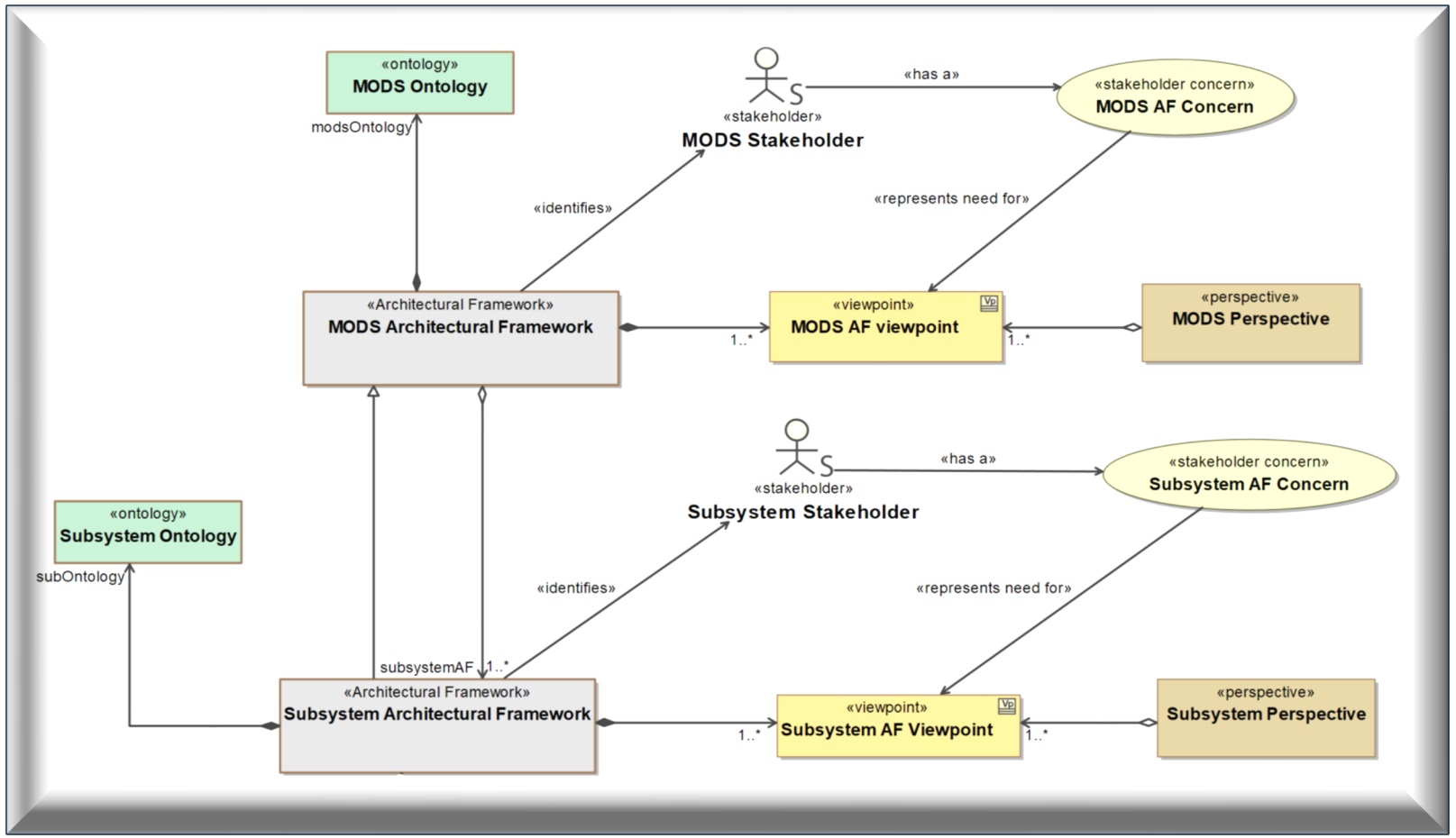
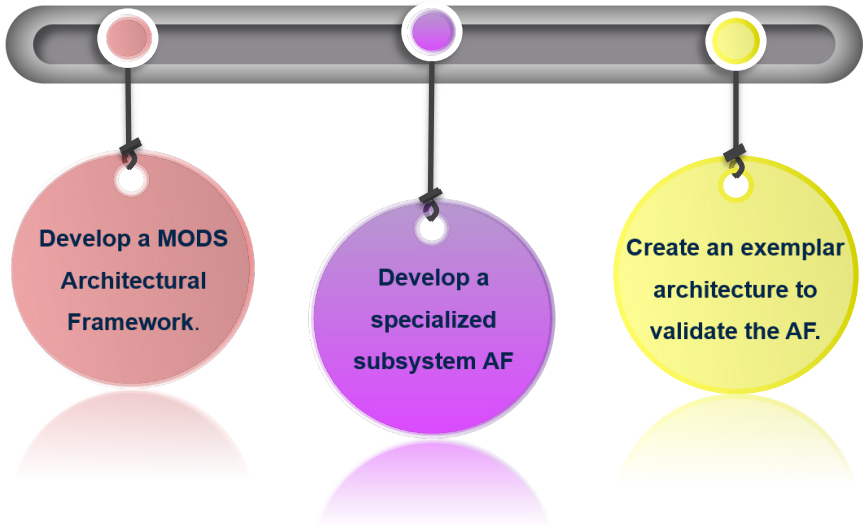


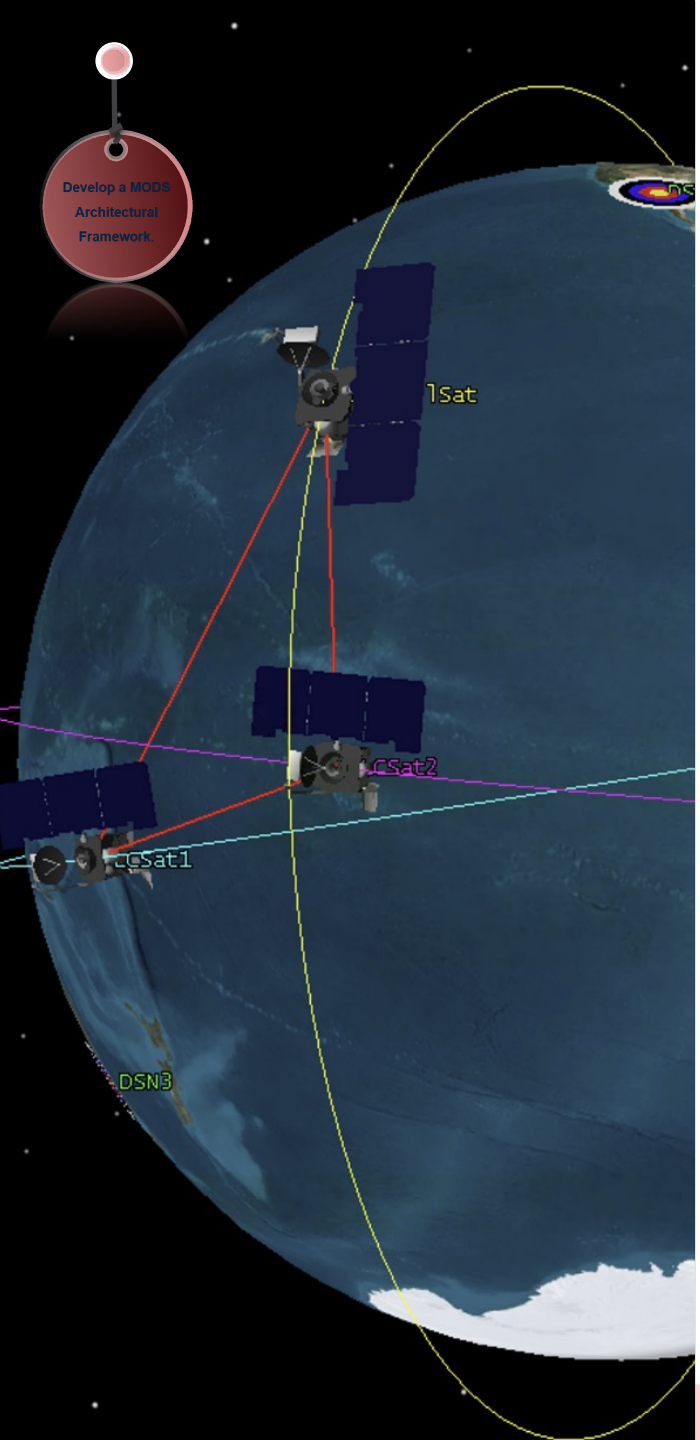
# Our goal is a viable and resilient multi-orbit disaggregated system for space missions



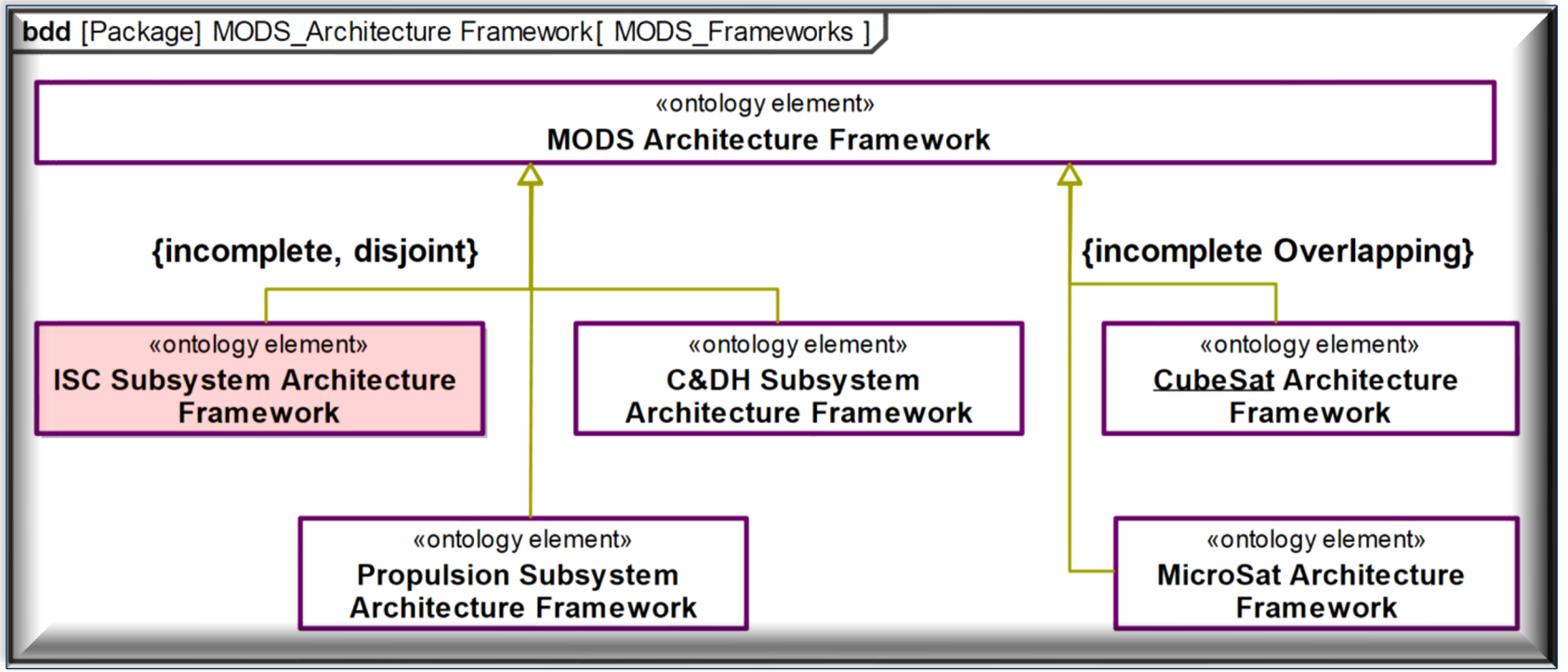
# An architectural framework **(AF)** pattern approach provides the structure and guidance to capture vital architectural decisions.



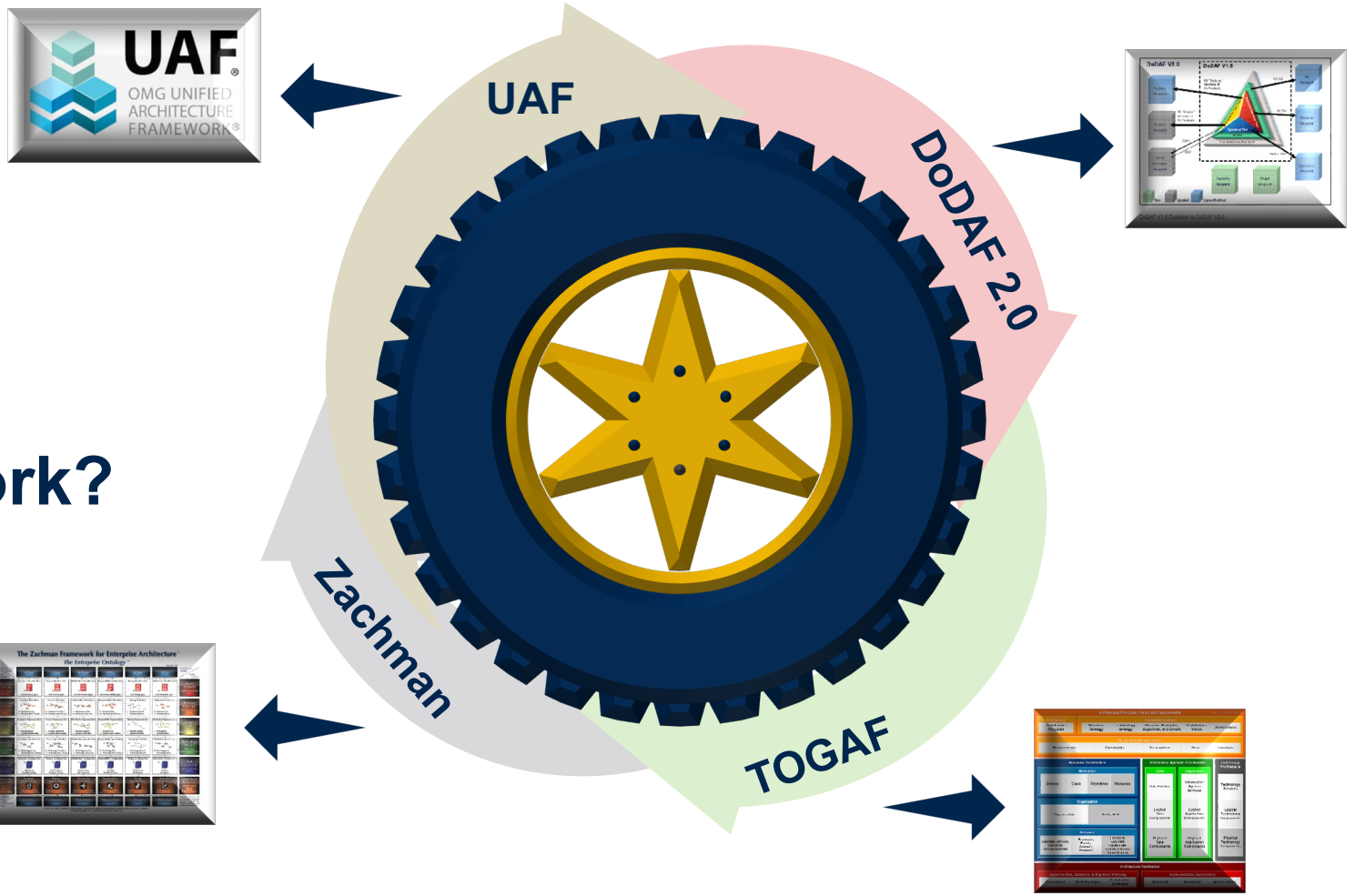



# Develop a MODS-AF that prescribes a pattern for all subsystem AFs.



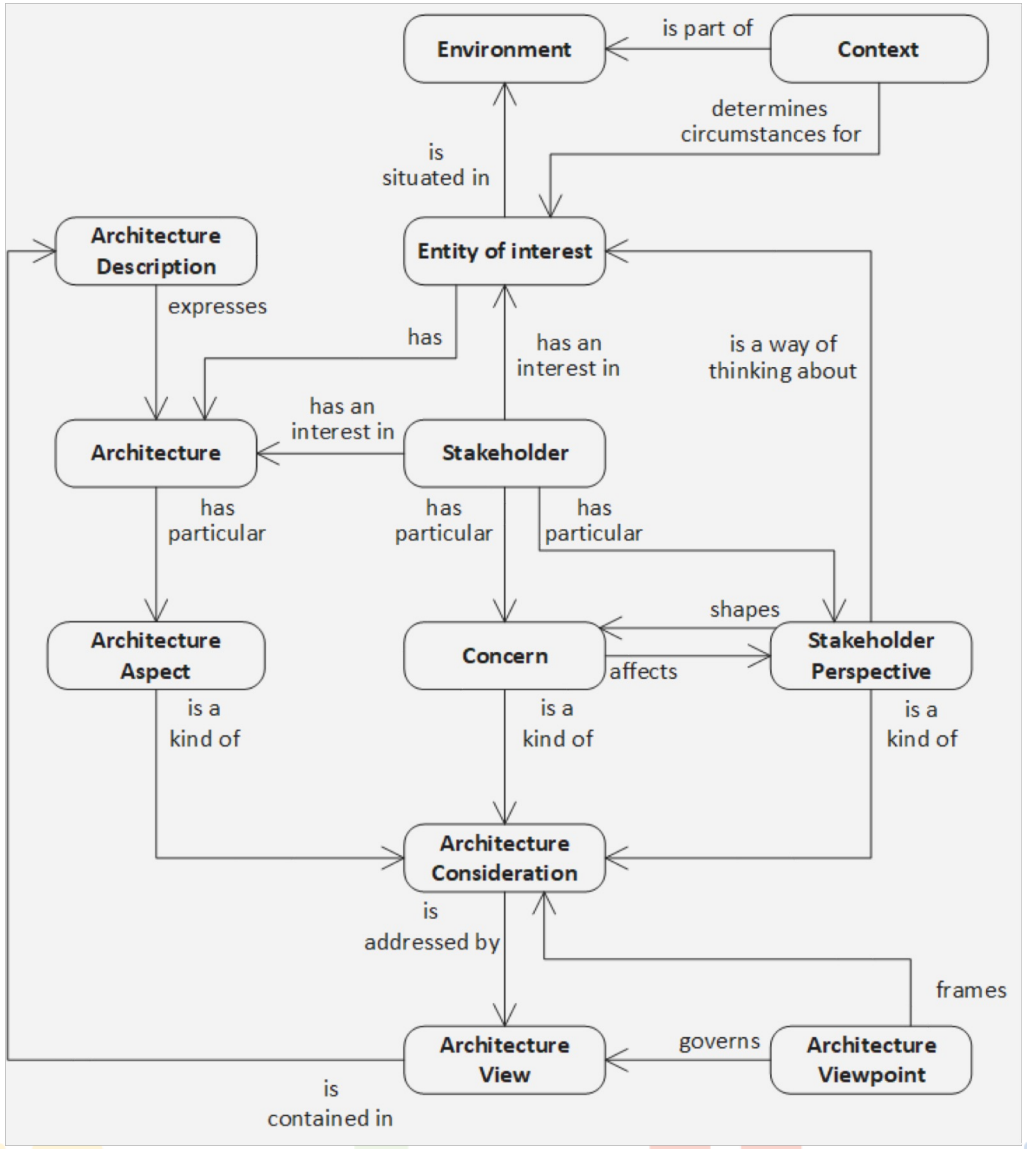
# Are we reinventing the wheel?

- **Why model another architectural framework?**



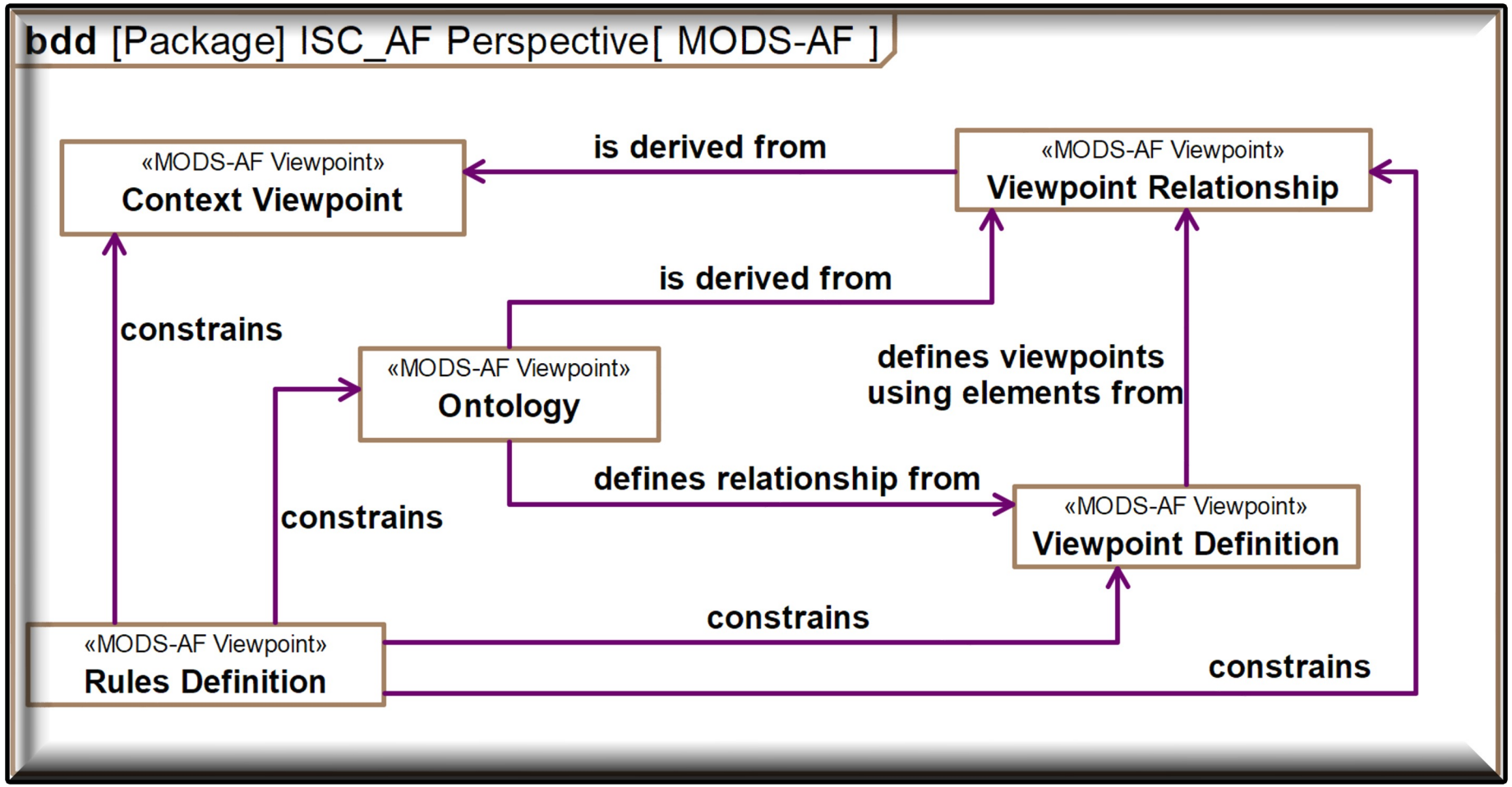
# ISO 42010 is the basis for all graphical modeling languages

- ISO/IEC/IEEE 42010:2011 addresses the creation, analysis and sustainment of architectures of systems through the use of architecture descriptions.
- The viewpoint is an information item that establishes the conventions for creating, interpreting, presenting and analyzing the view to address the considerations framed by that viewpoint.
- A view is governed by its viewpoint



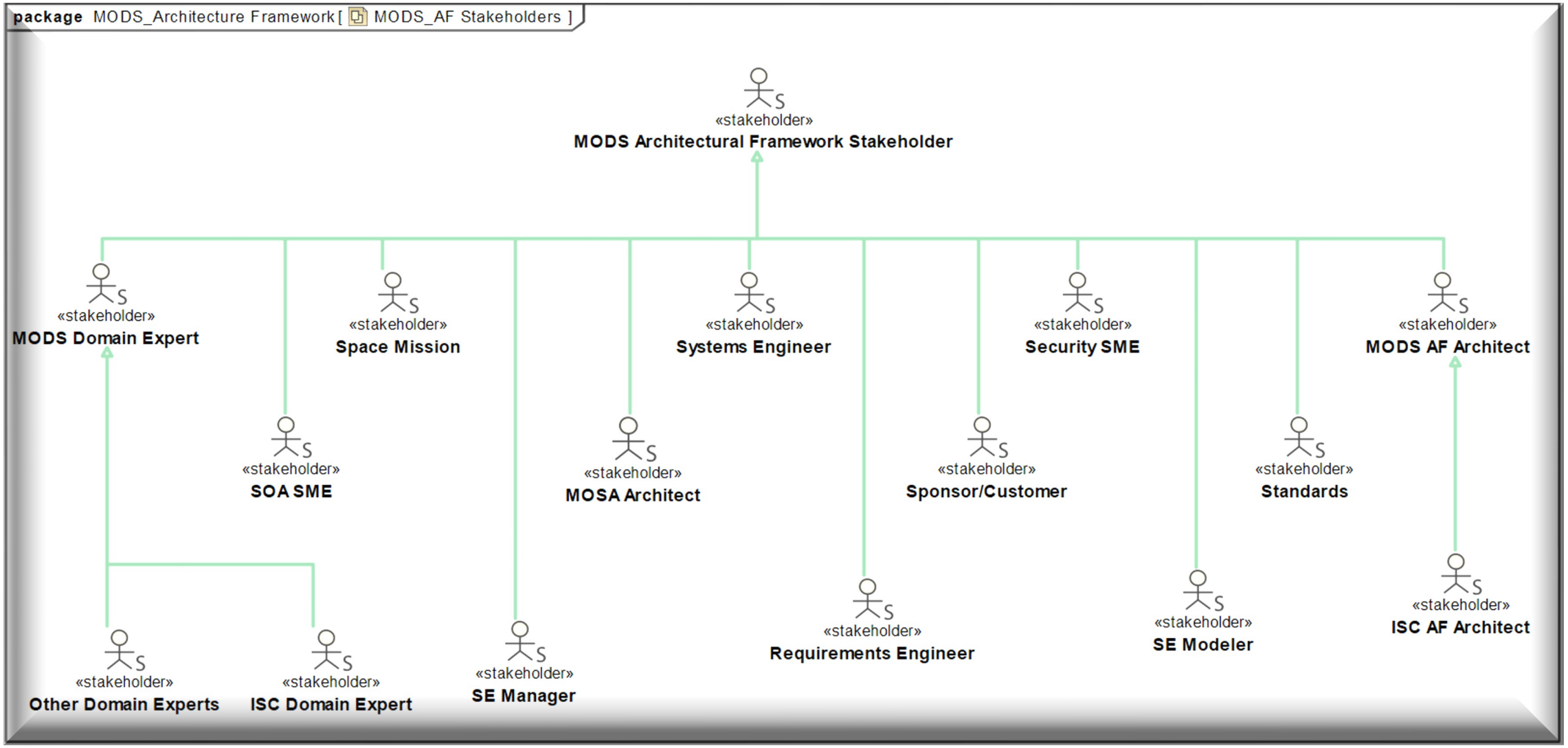
# All views of the MODS-AF and subsystem AFs will conform to one of these five viewpoints.

- Each AF viewpoint describes the structure needed to define views of the AF

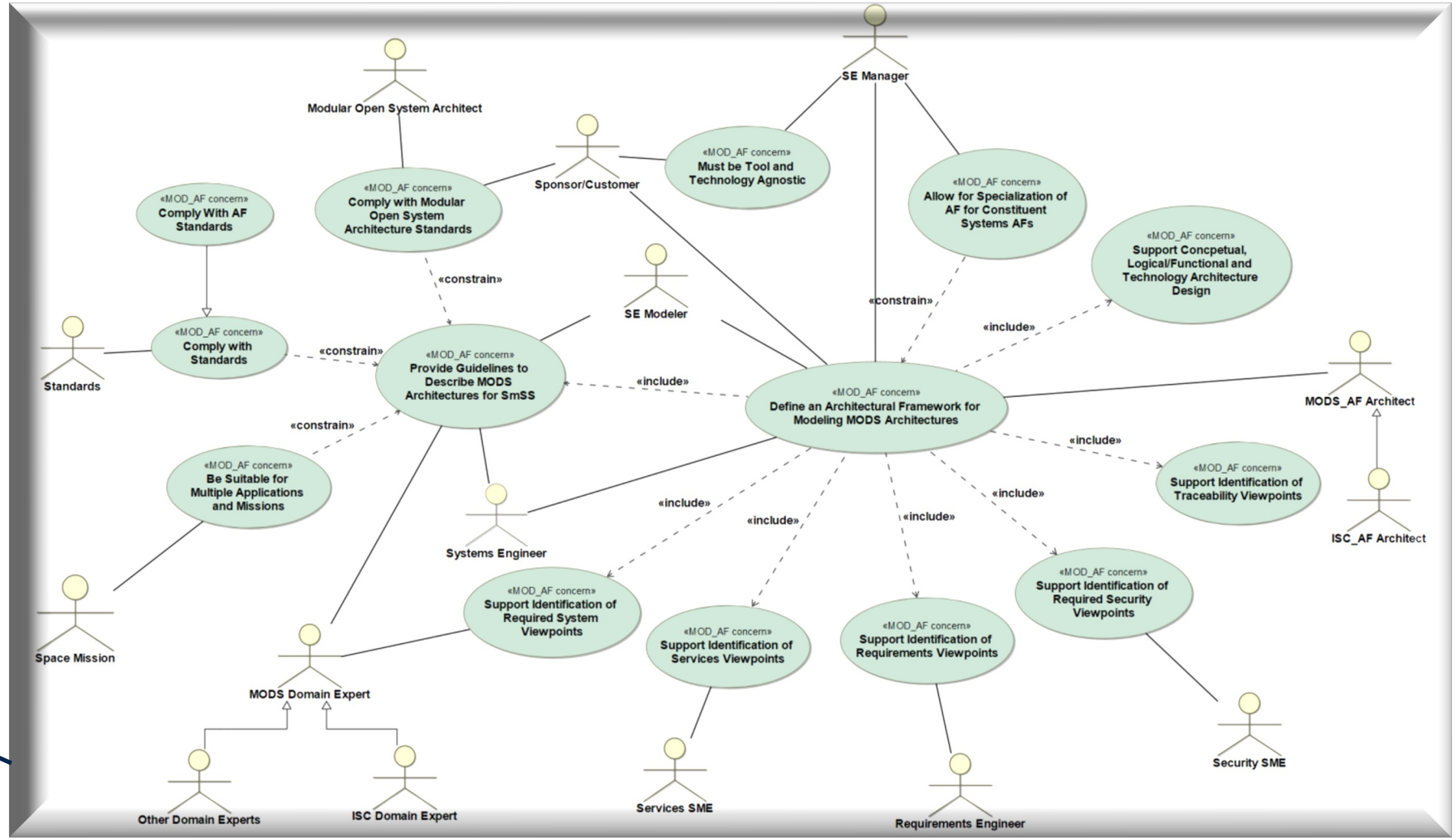



Holt, J. and Perry, S. (2014) SysML for systems engineering, 2nd Edition: A model-based approach, vol. 10, chapter 11. IET

# Identifying stakeholders of the MODS-AF is a crucial step towards ensuring the right AF is built, and built right!.



# Stakeholder concerns represent the needs the AF must address and form the basis for its existence.

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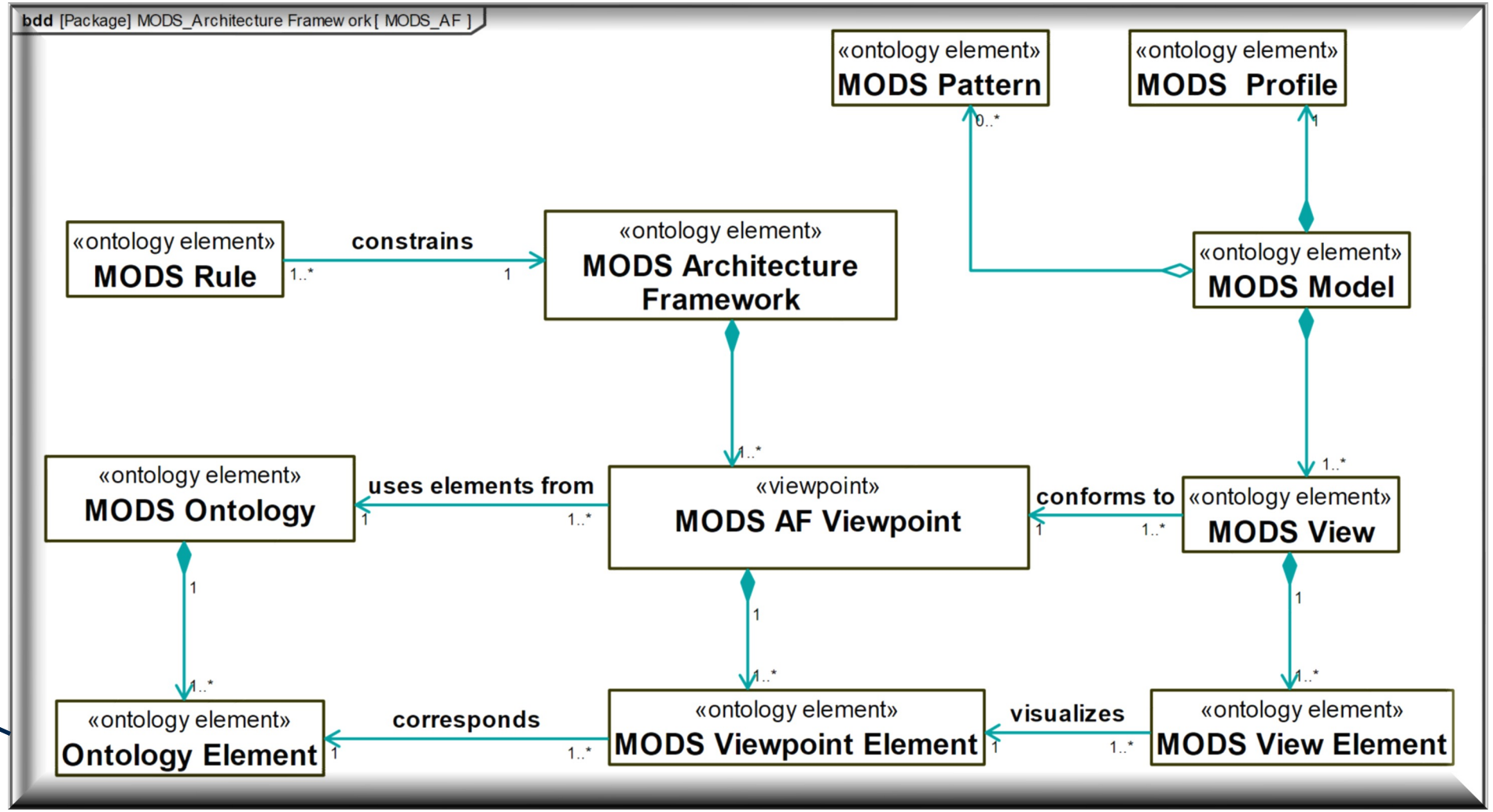
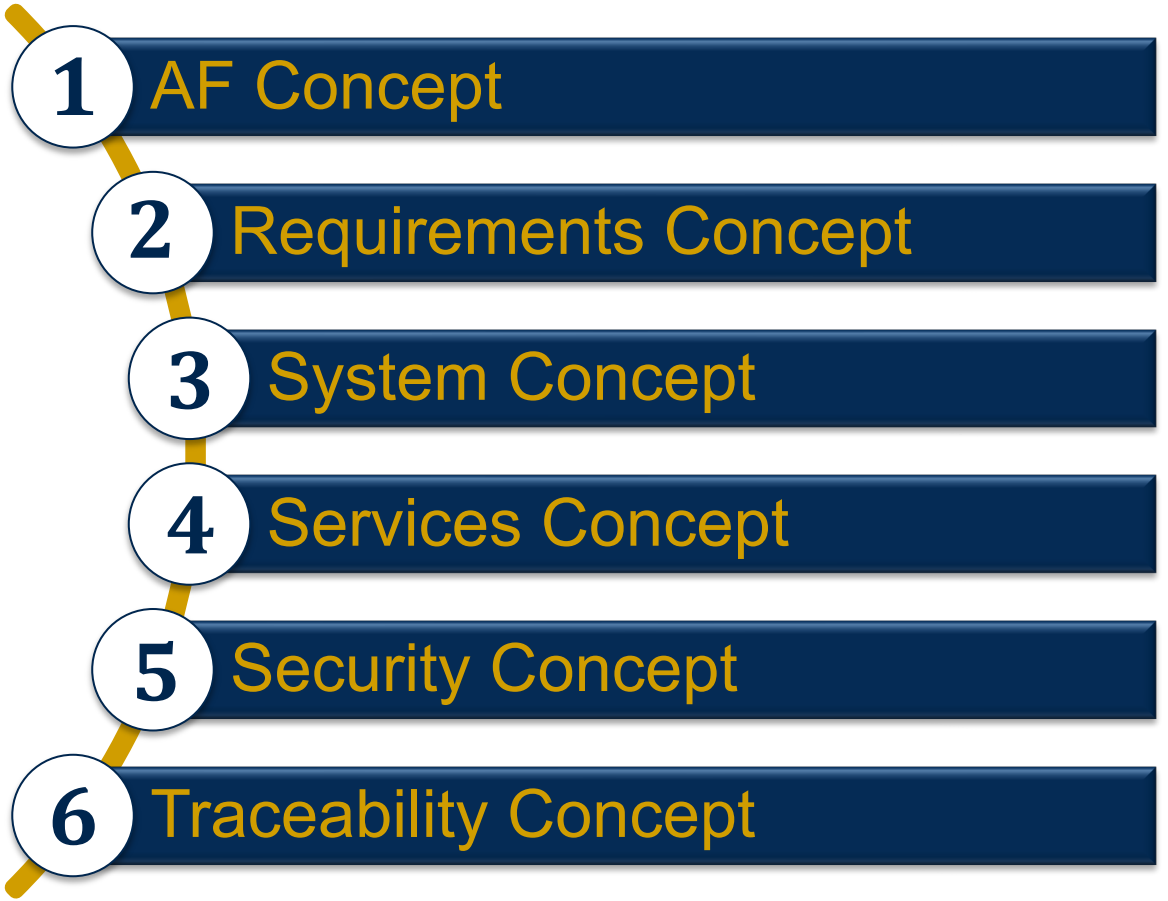
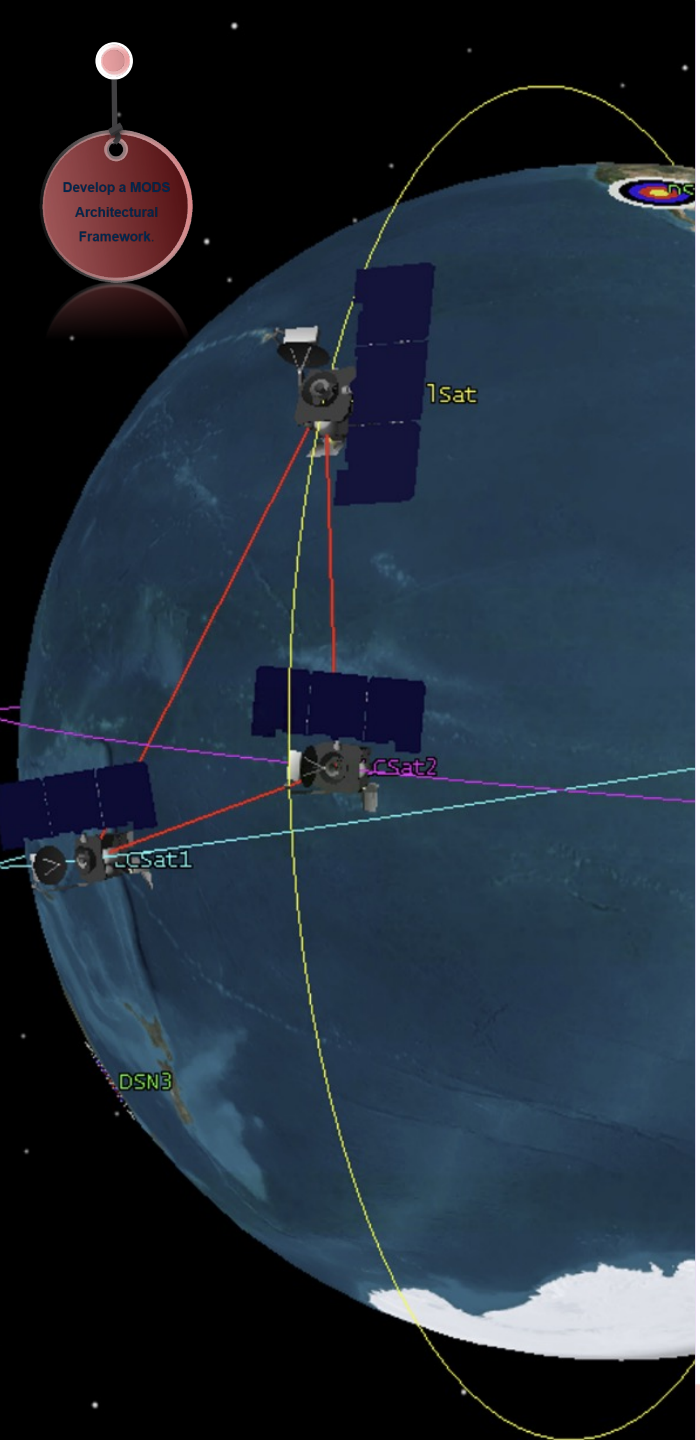
# A conceptual ontology is developed to standardize relevant concepts.



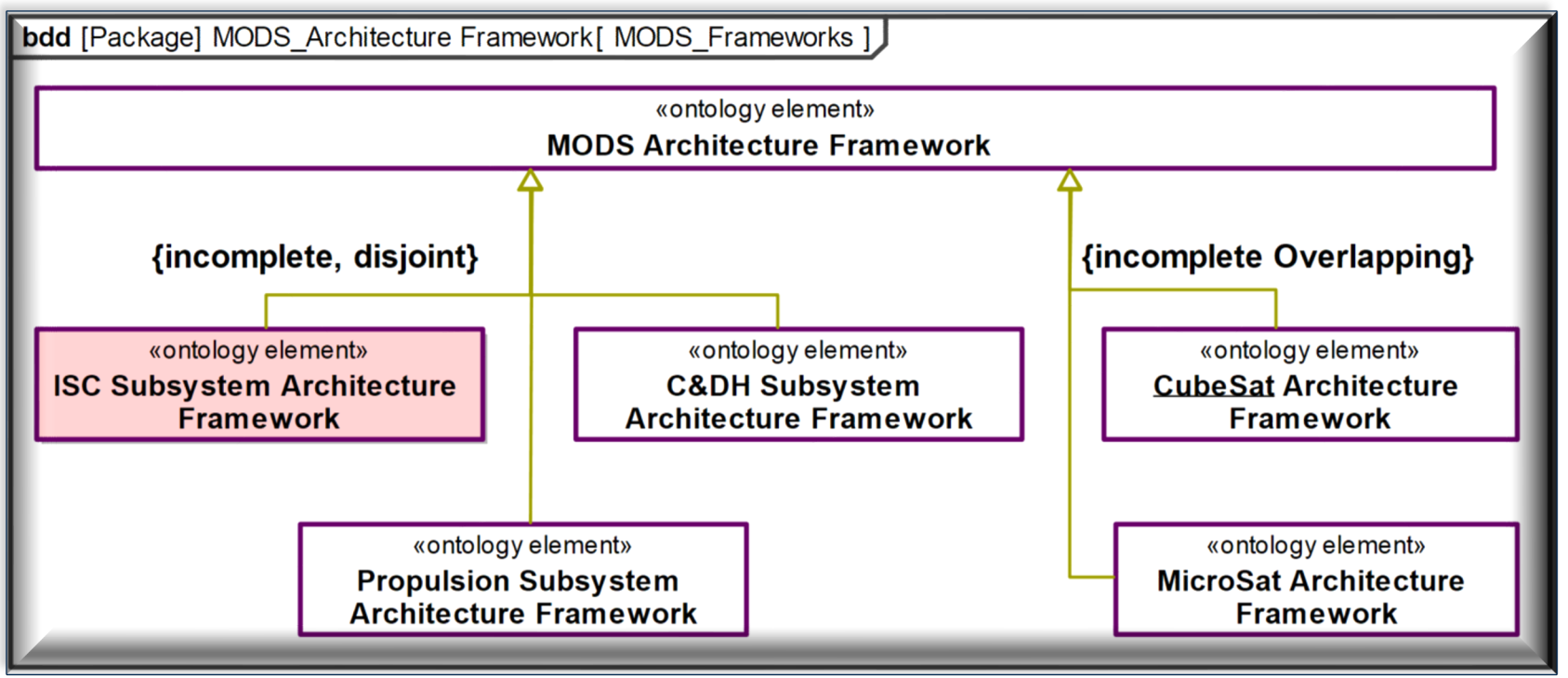
# Six categories are used to classify concepts and enforce consistency across all AFs.

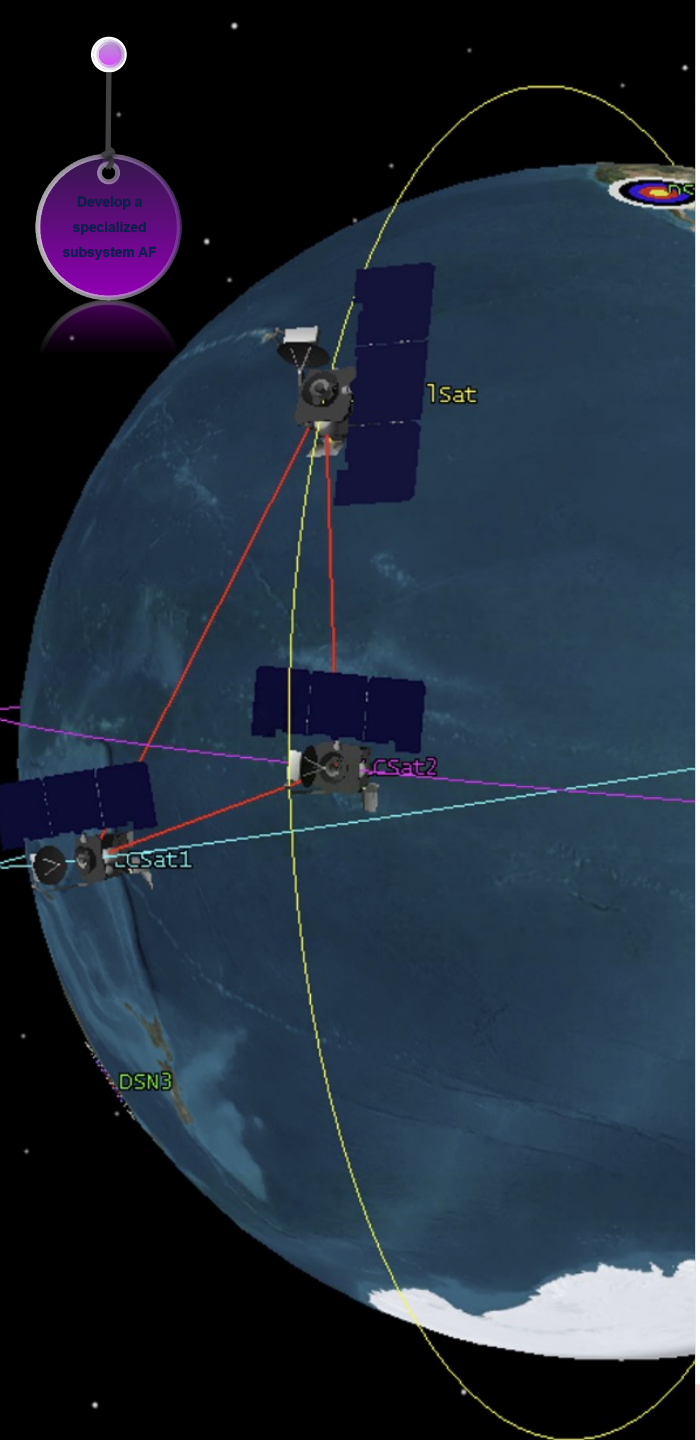
**MODS Concepts Categories**



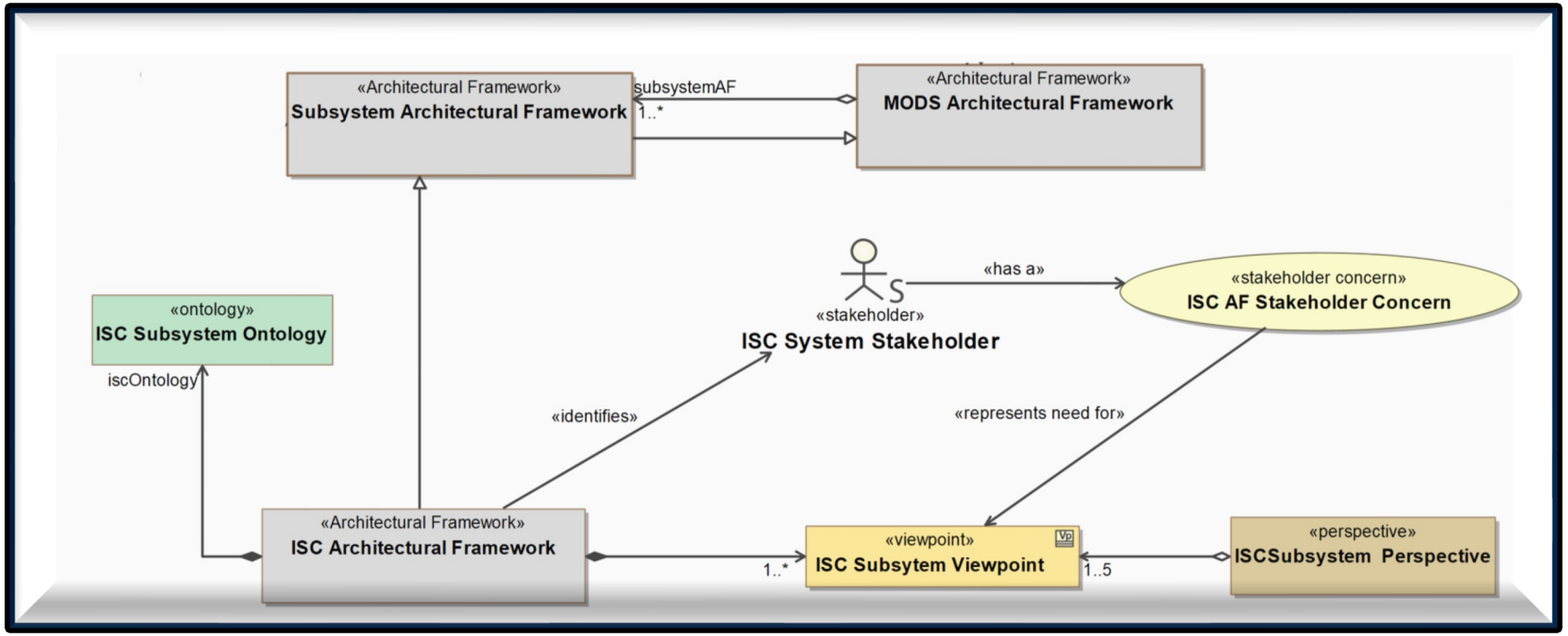



# The MODS-AF prescribes a pattern for all subsystem AFs.

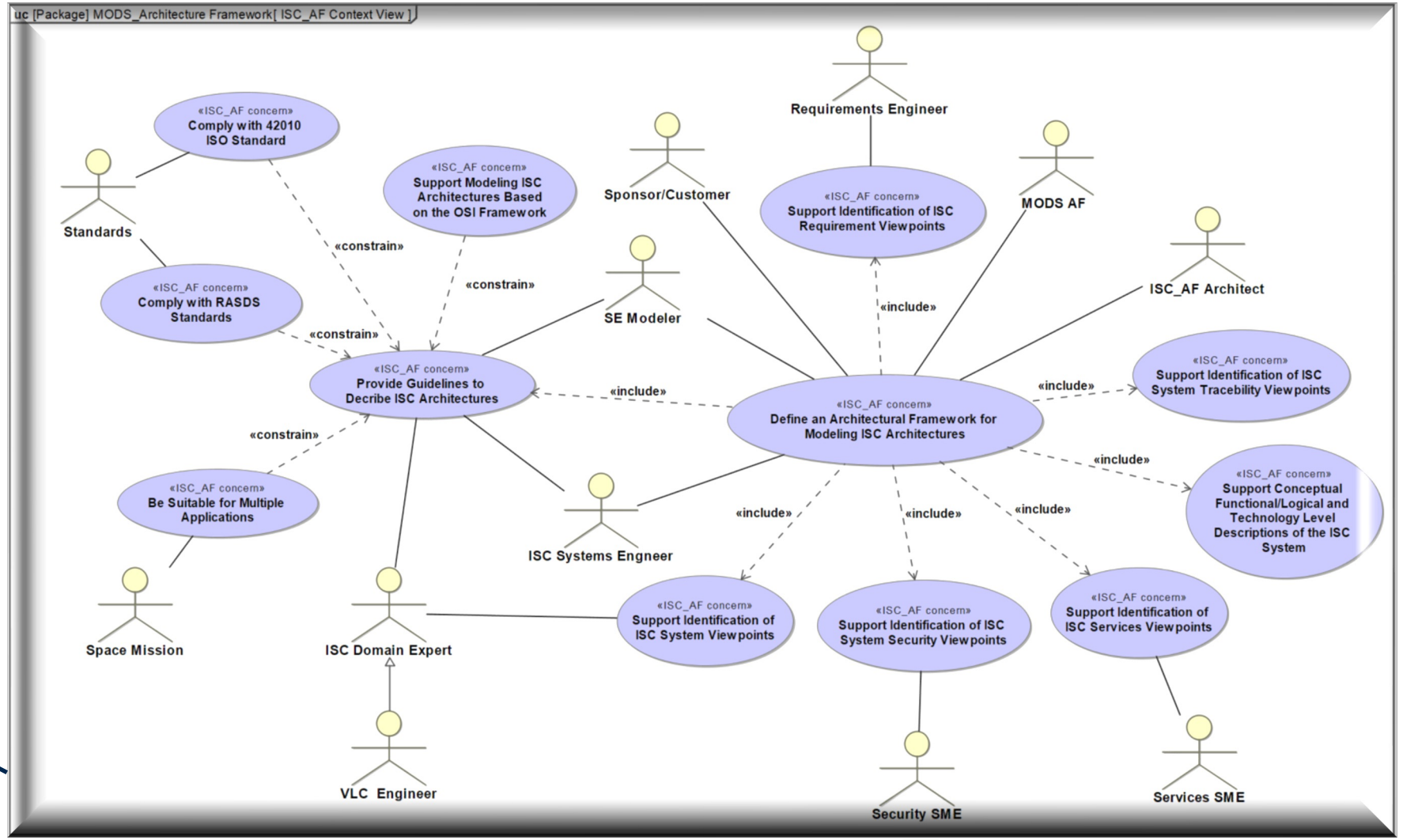





# Develop an AF for the ISC system to address the primary capability of the MODS



# The ISC-AF specializes the MODS-AF and specific ISC-AF stakeholder concerns are captured.

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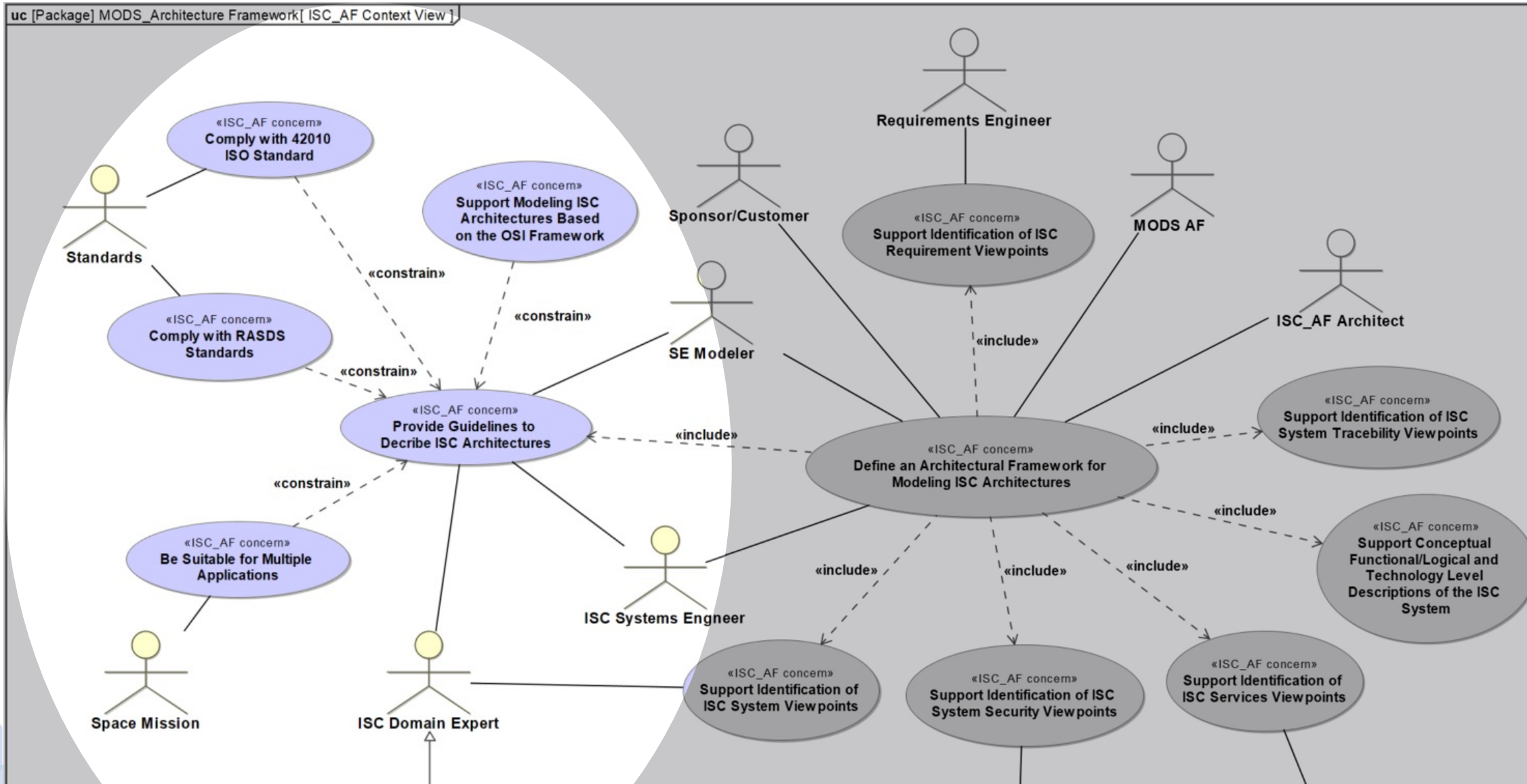

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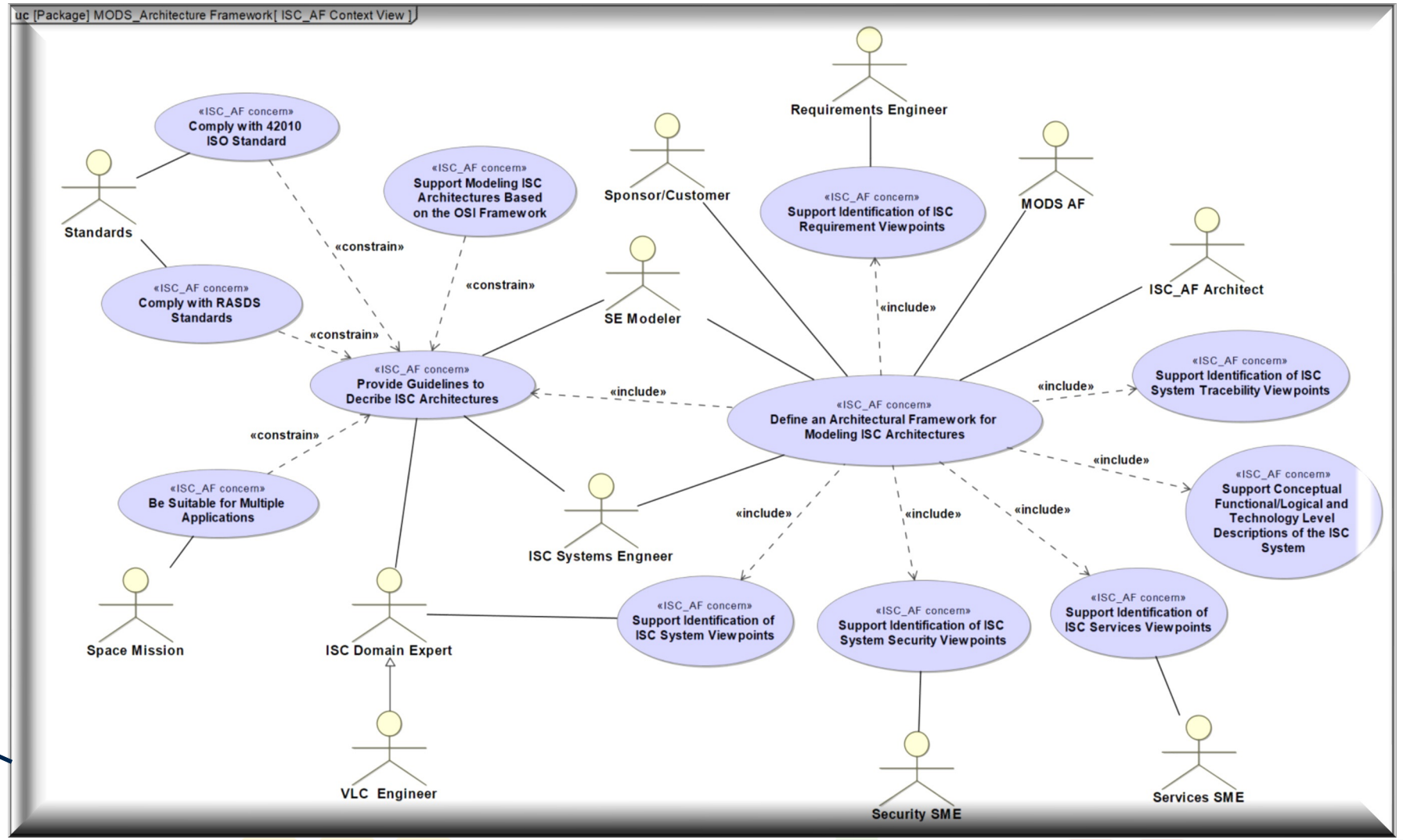


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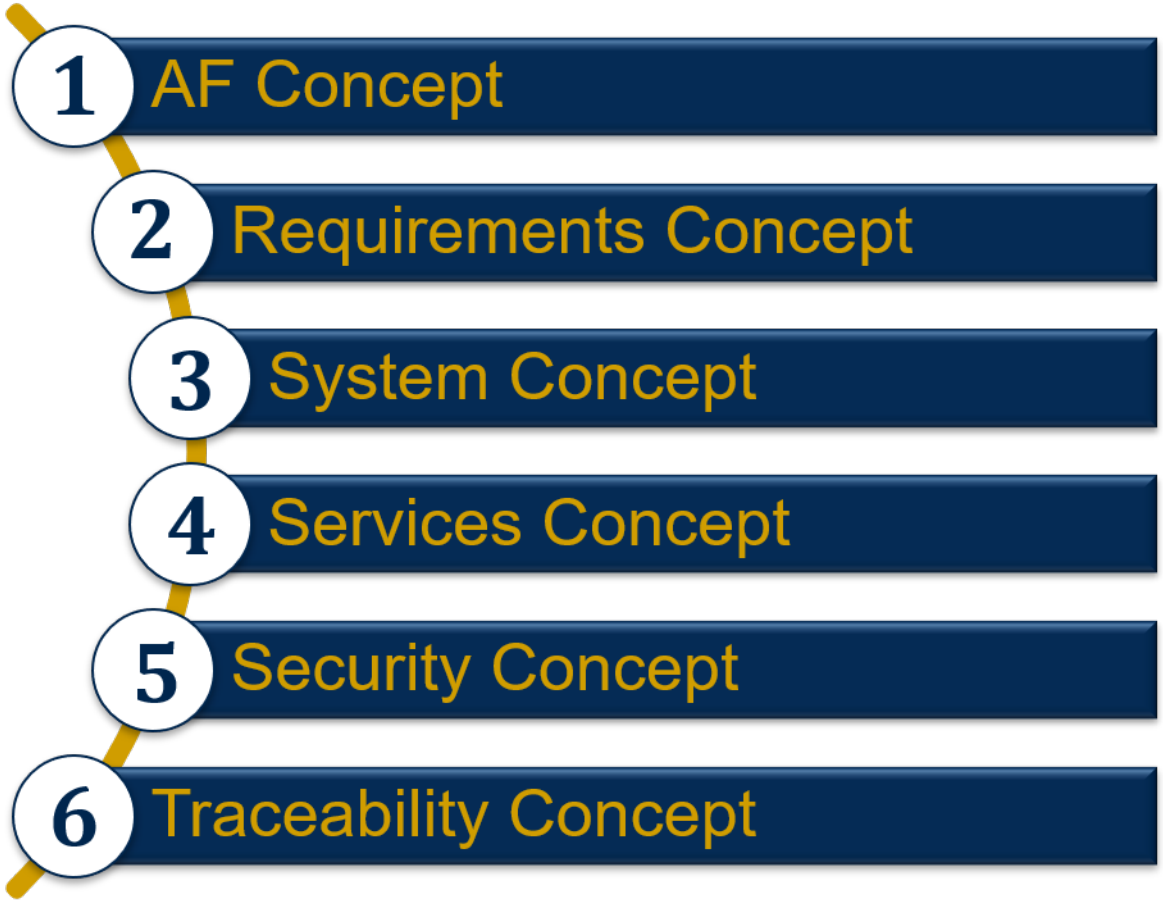
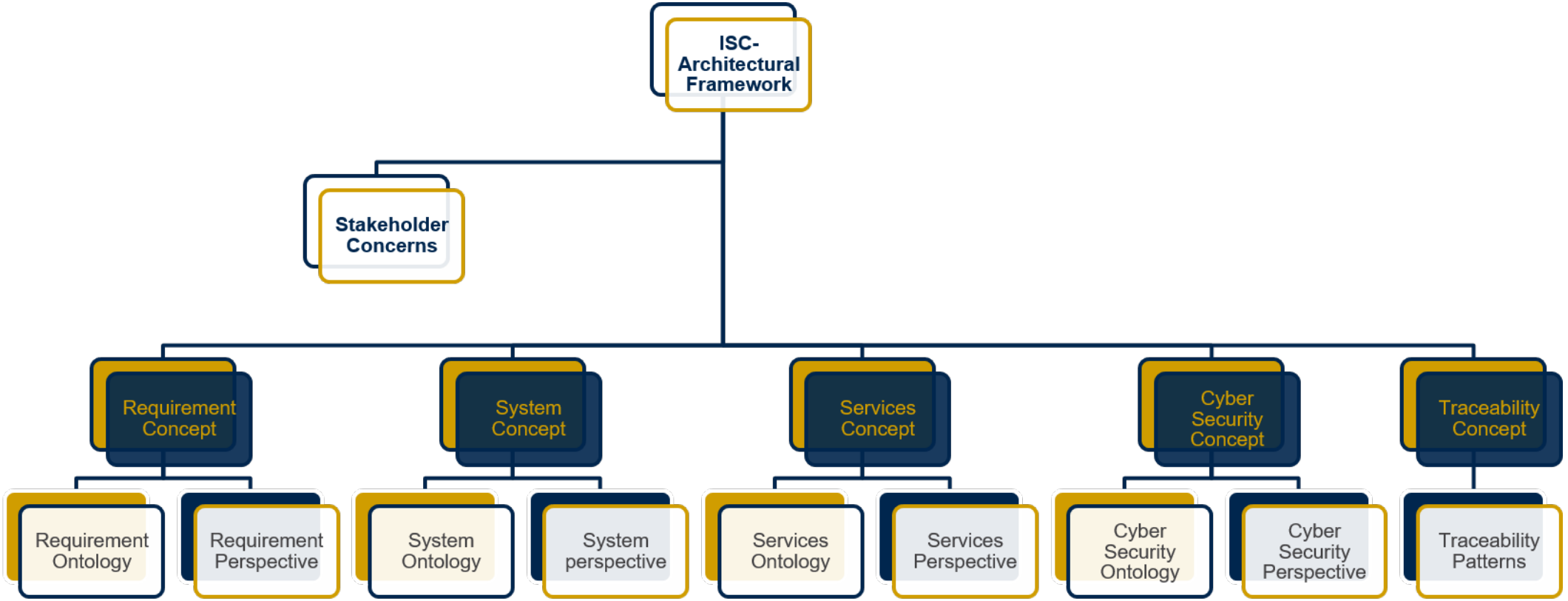
# Five of these six categories are used to classify concepts and enforce consistency in the ISC-AF.

**MODS Concept Categories**



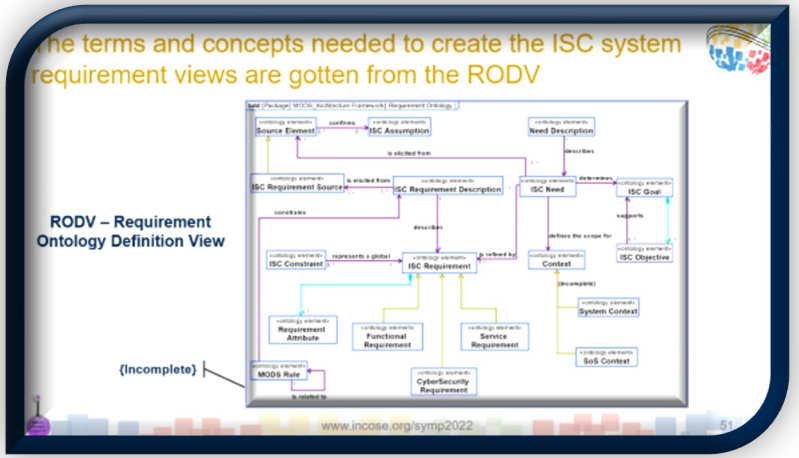
# The ISC-AF ontology and perspective are grouped into five concept areas.

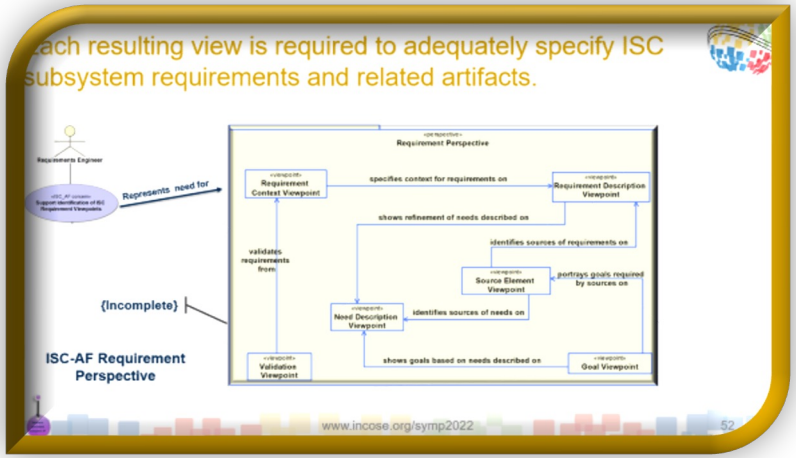


# ISC-AF Requirement Concept

# The requirement concept frames the viewpoints and concepts relevant to specifying ISC requirements.

**ISC-AF Requirement Ontology**



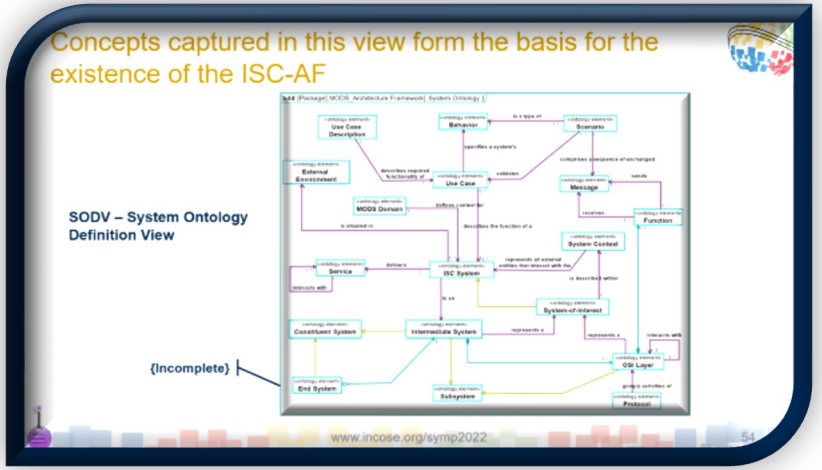



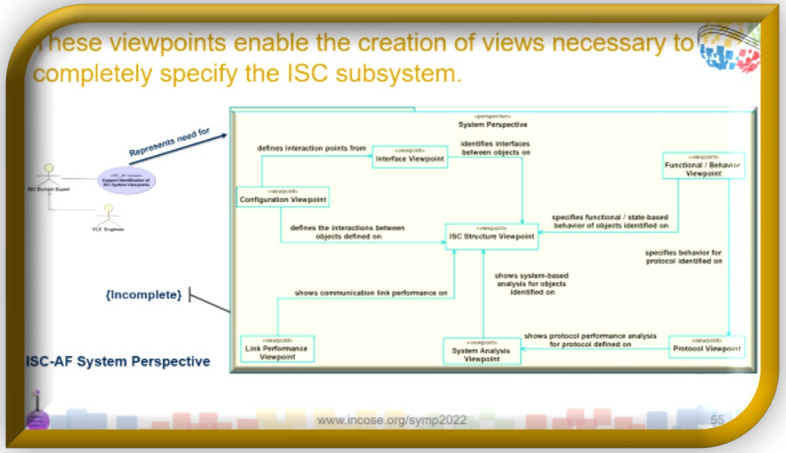

**ISC-AF Requirement Perspective**

# ISC-AF System Concept

# The system concept frames the viewpoints and concepts relevant to specifying the ISC system.

**ISC-AF System Ontology**



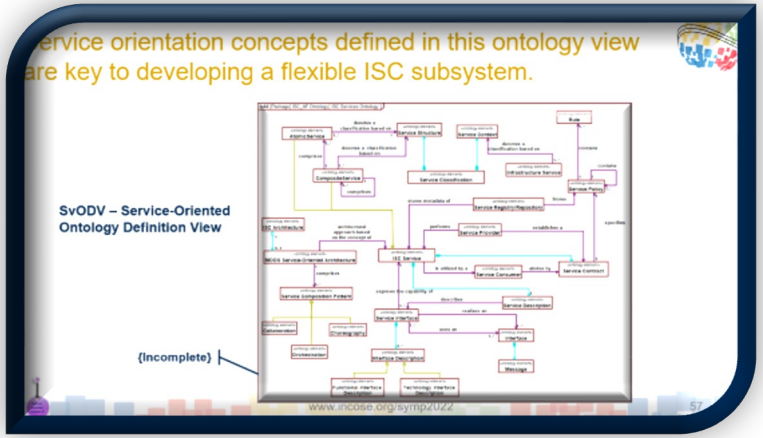



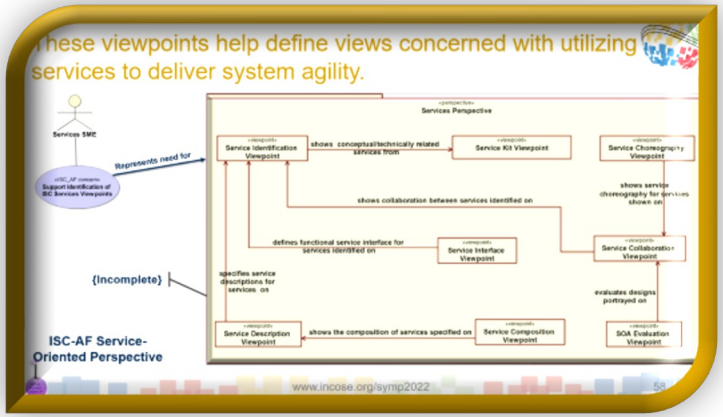

**ISC-AF System Perspective**

# ISC-AF Service-Orientation Concept

# The service-oriented concept frames the viewpoints and concepts relevant to specifying services for the ISC system.

**ISC-AF Service Orientation Ontology**



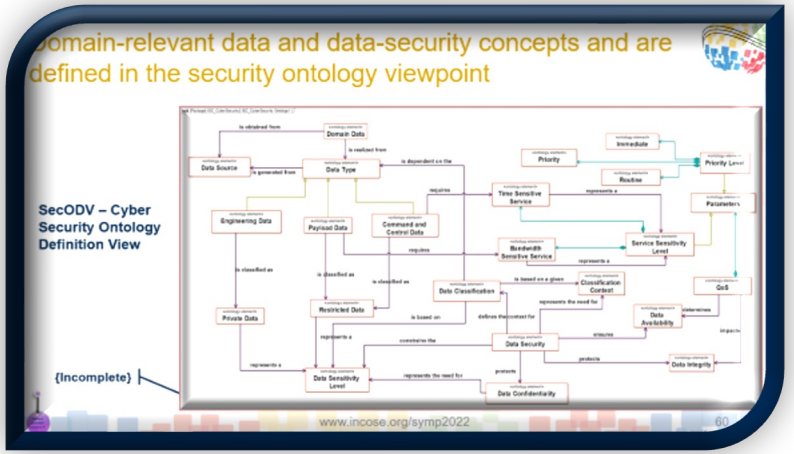



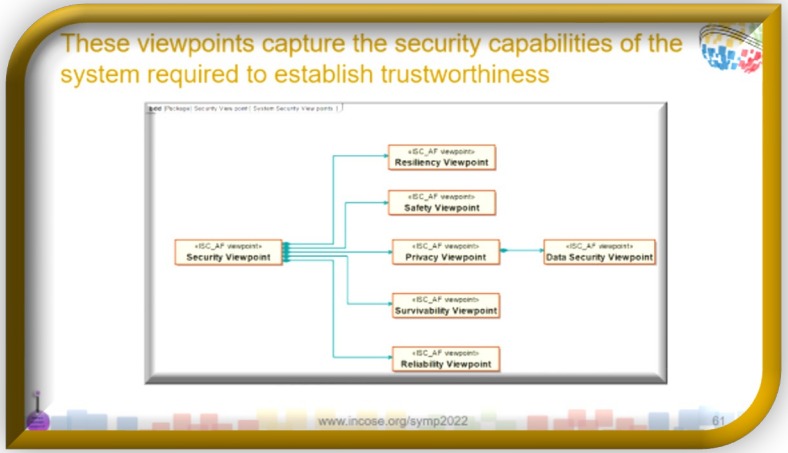

**ISC-AF Service Orientation Perspective**

# ISC-AF Information Security Concept

# The information security concept frames the concepts and viewpoints relevant to safeguarding information.

**ISC-AF System Ontology**



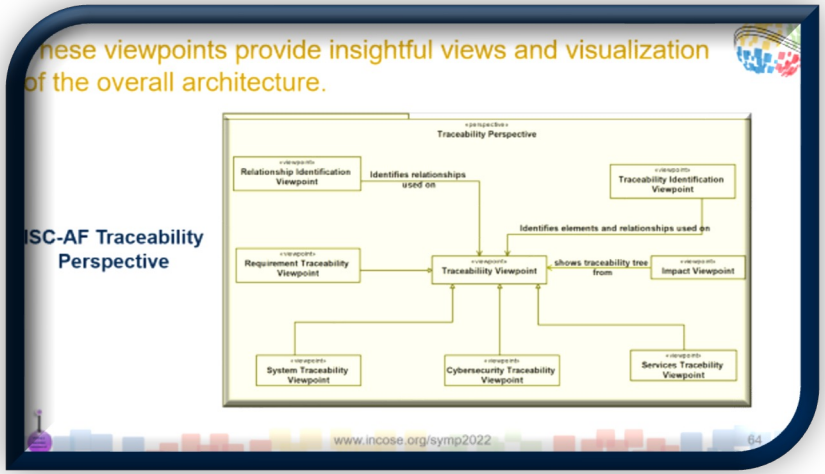



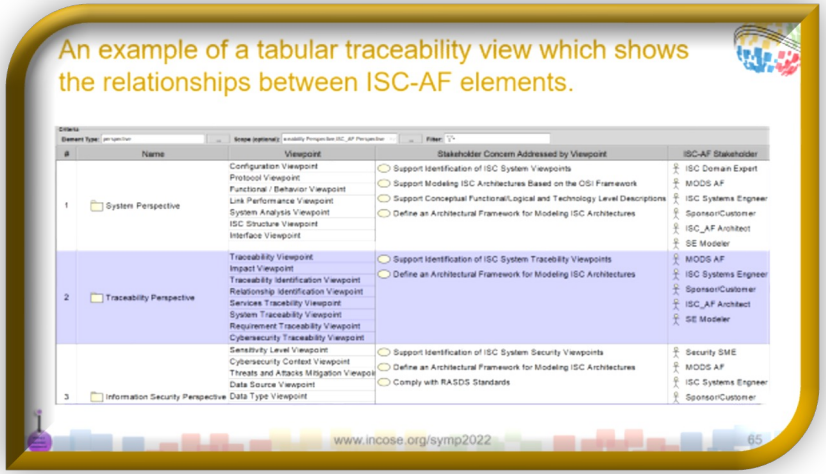

**ISC-AF System Perspective**

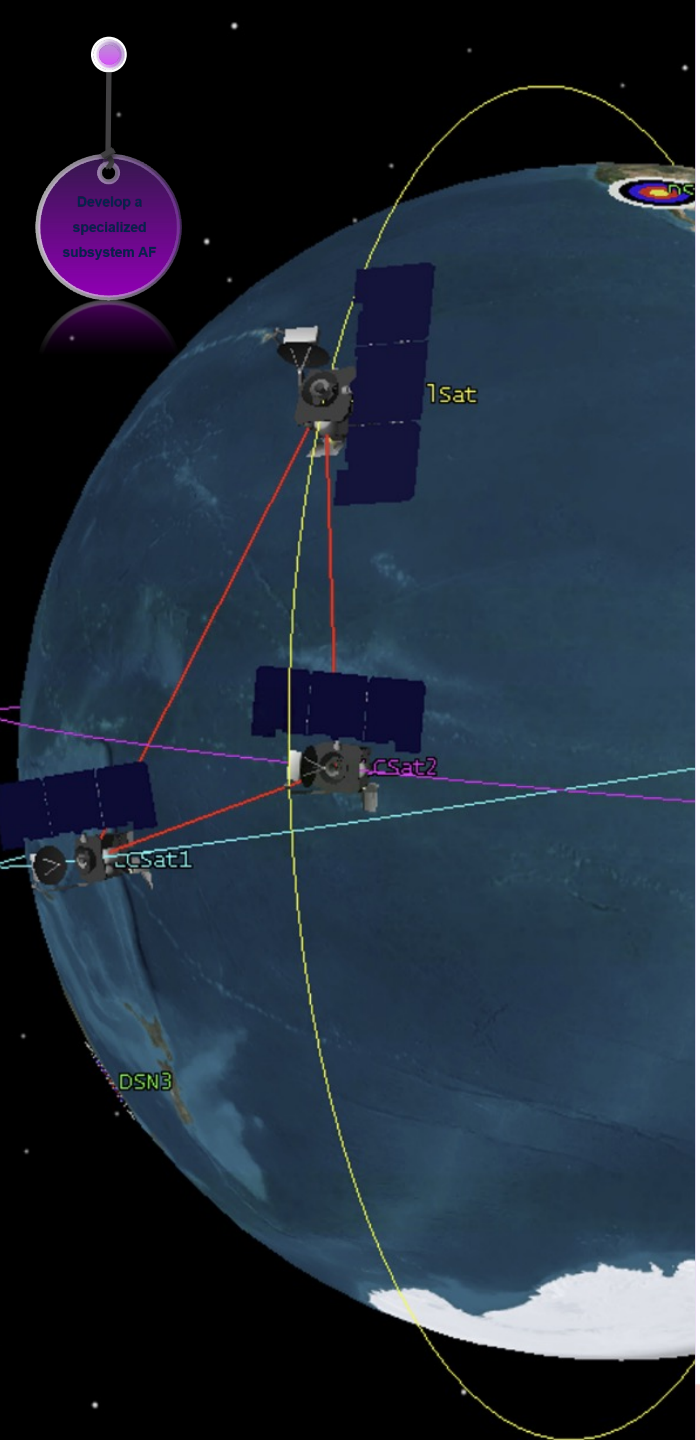
# ISC-AF Traceability Concept

# Traceability views are fundamental to a model-based approach to systems engineering.

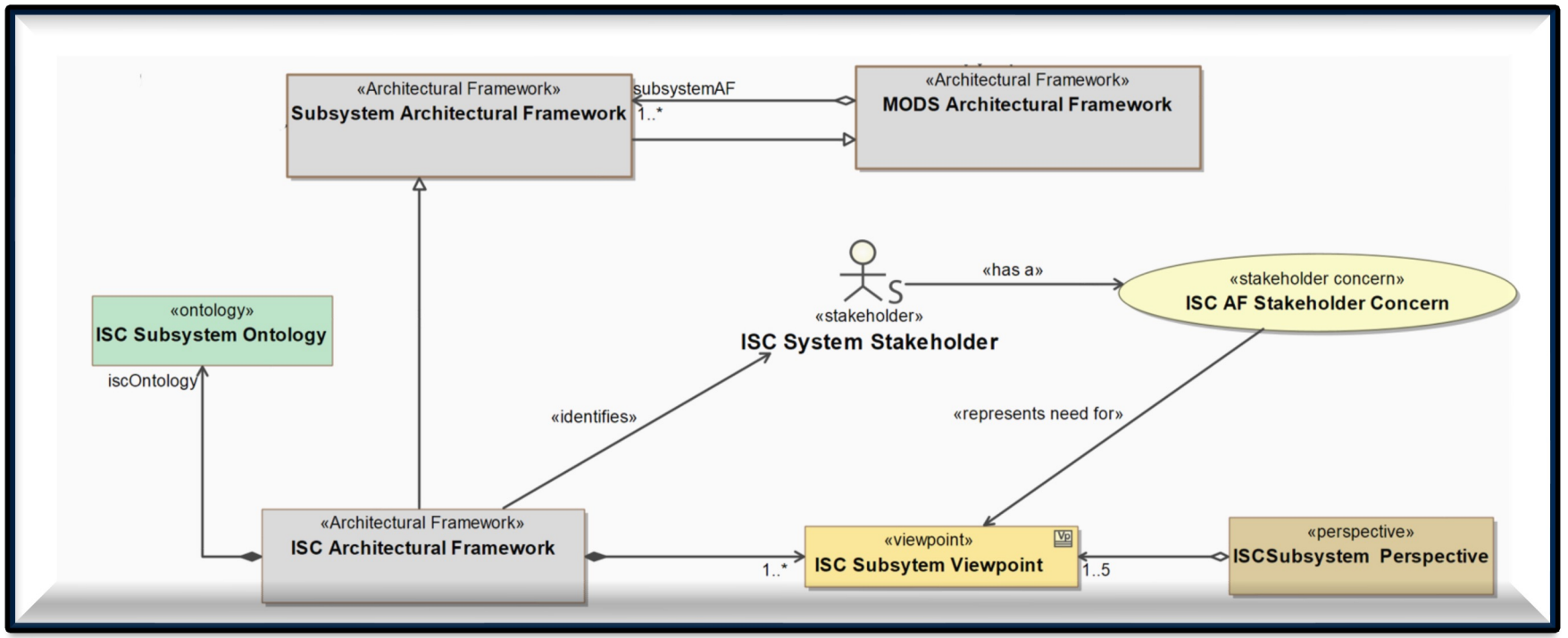
**ISC-AF Traceability Viewpoint and View**

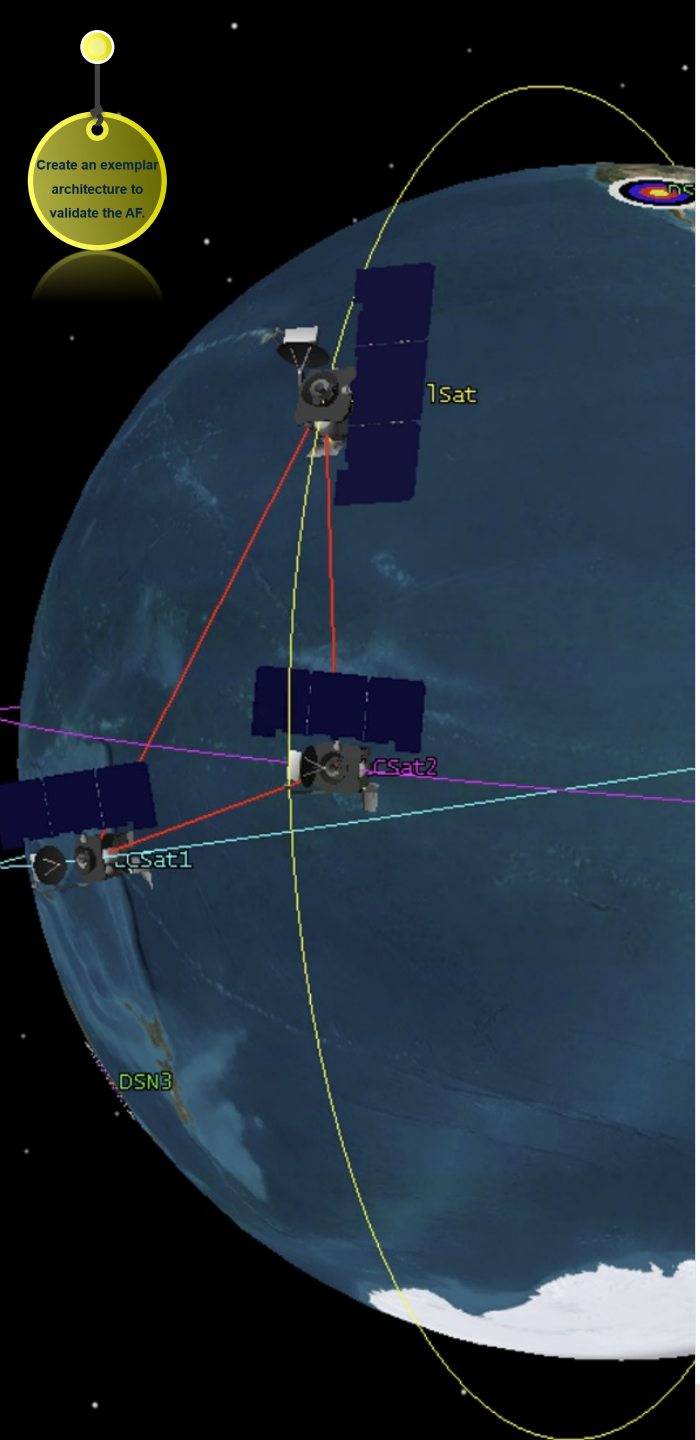


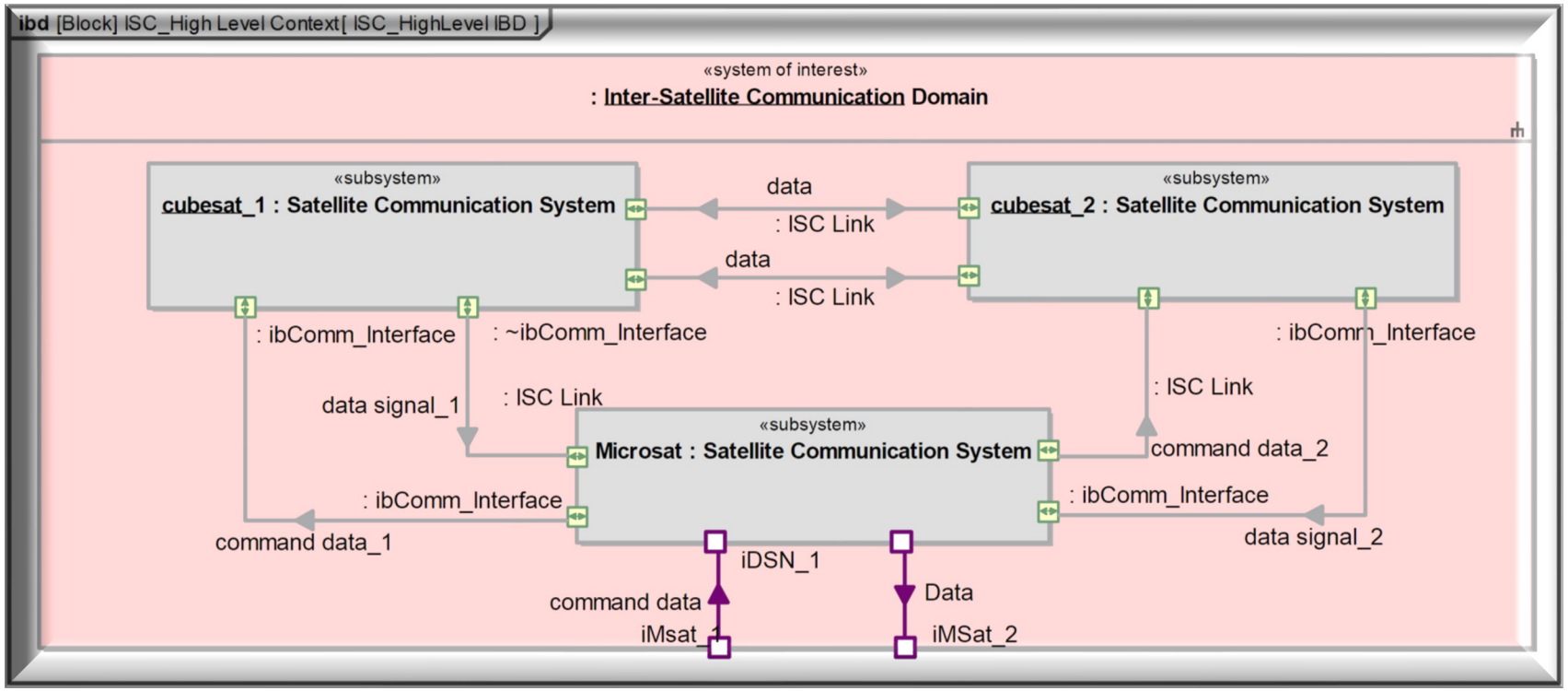



# The ISC-AF prescribes how to architect the ISC system.

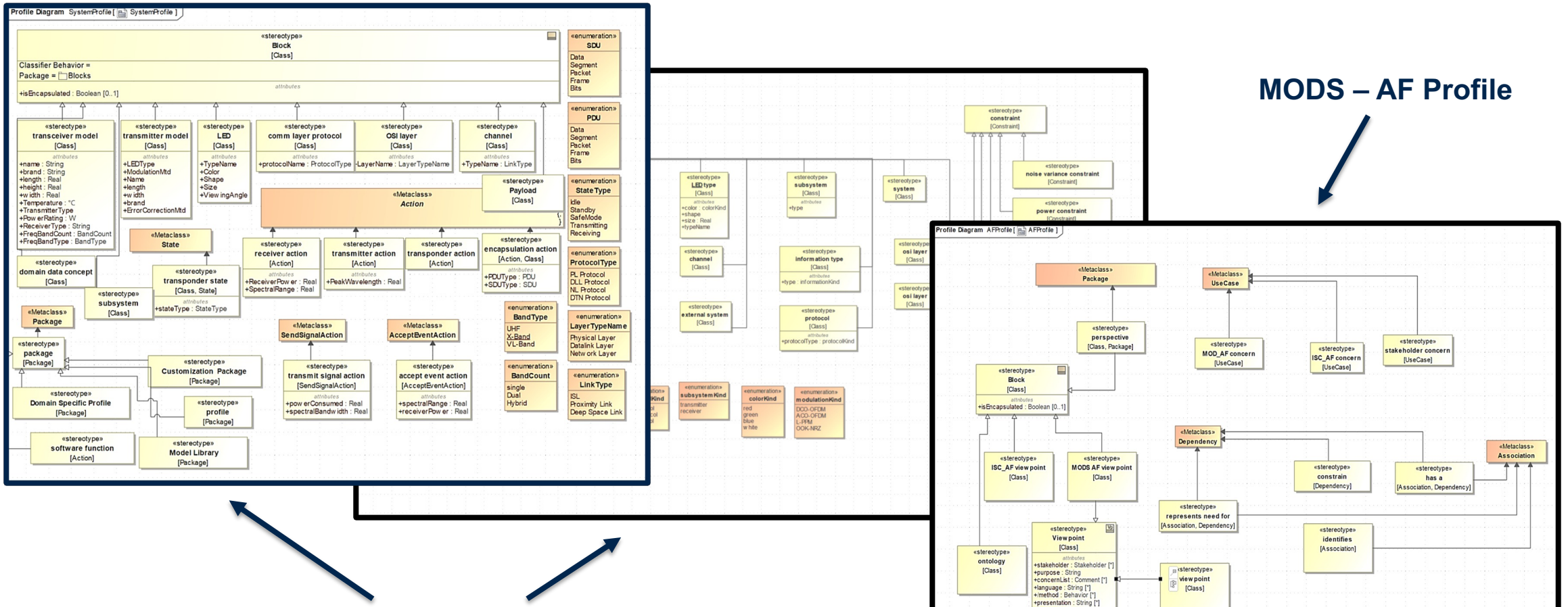




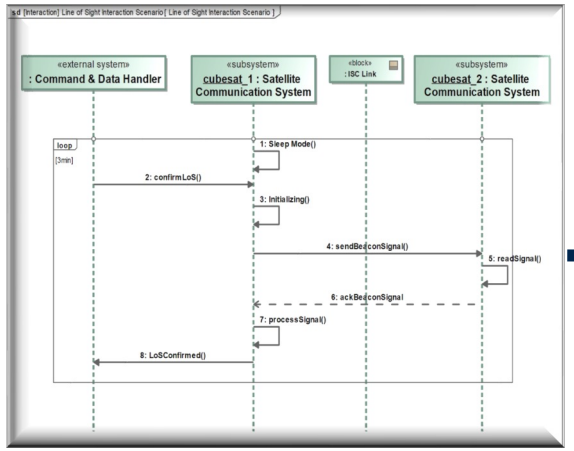

# Create an exemplar architecture description model to validate the ISC-AF.

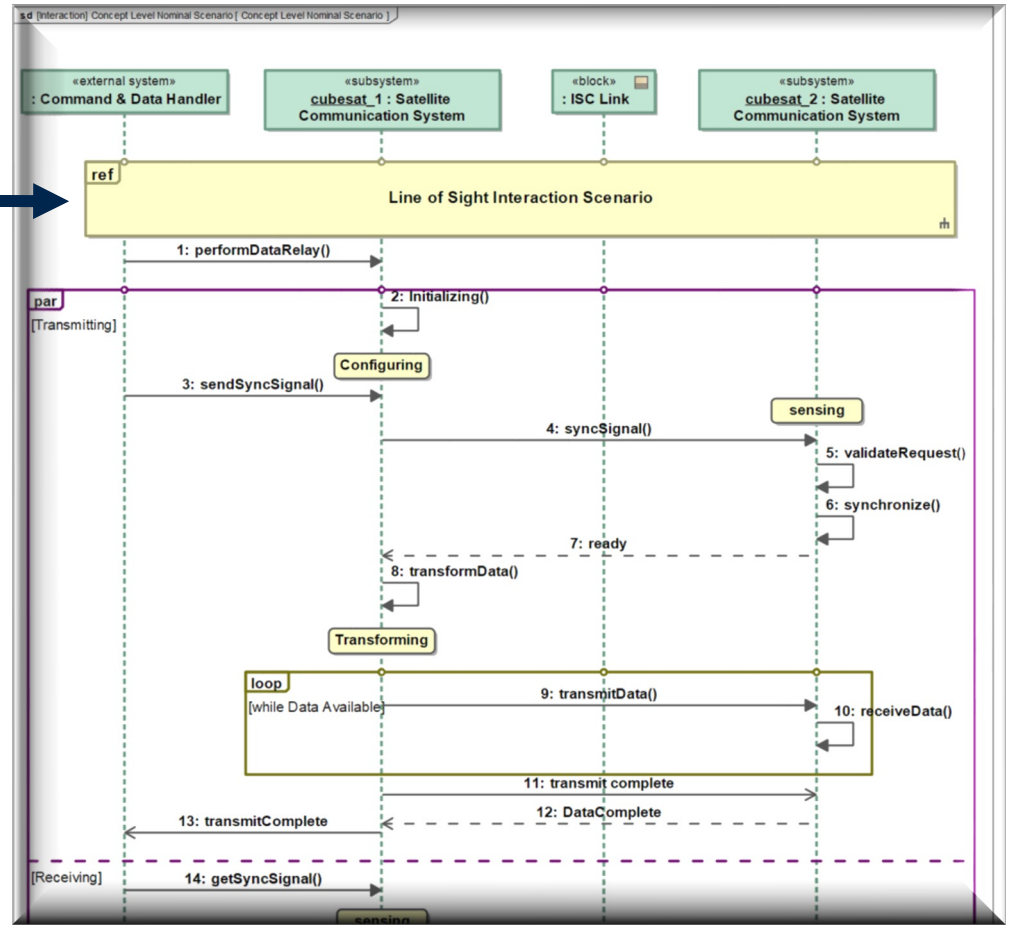


# A lightweight domain specific language profile is created to provide better semantics for capturing relevant concepts



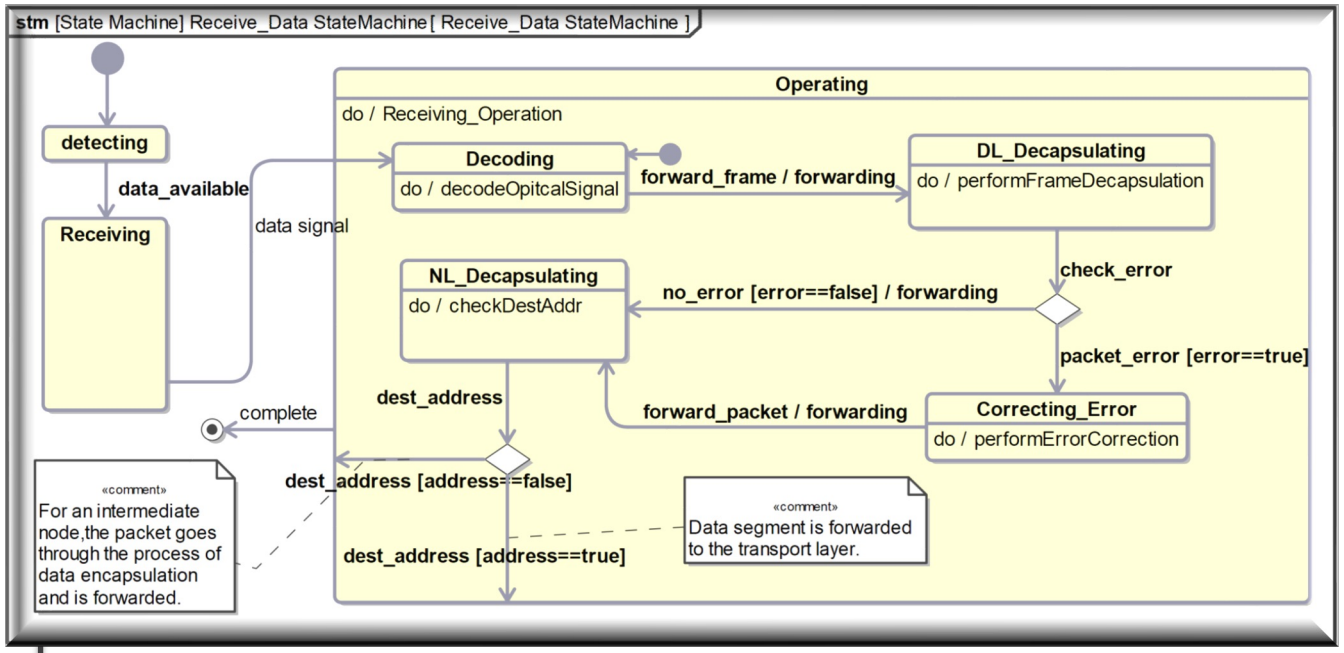
# ISC system views created to conform to ISC system behavior viewpoints.



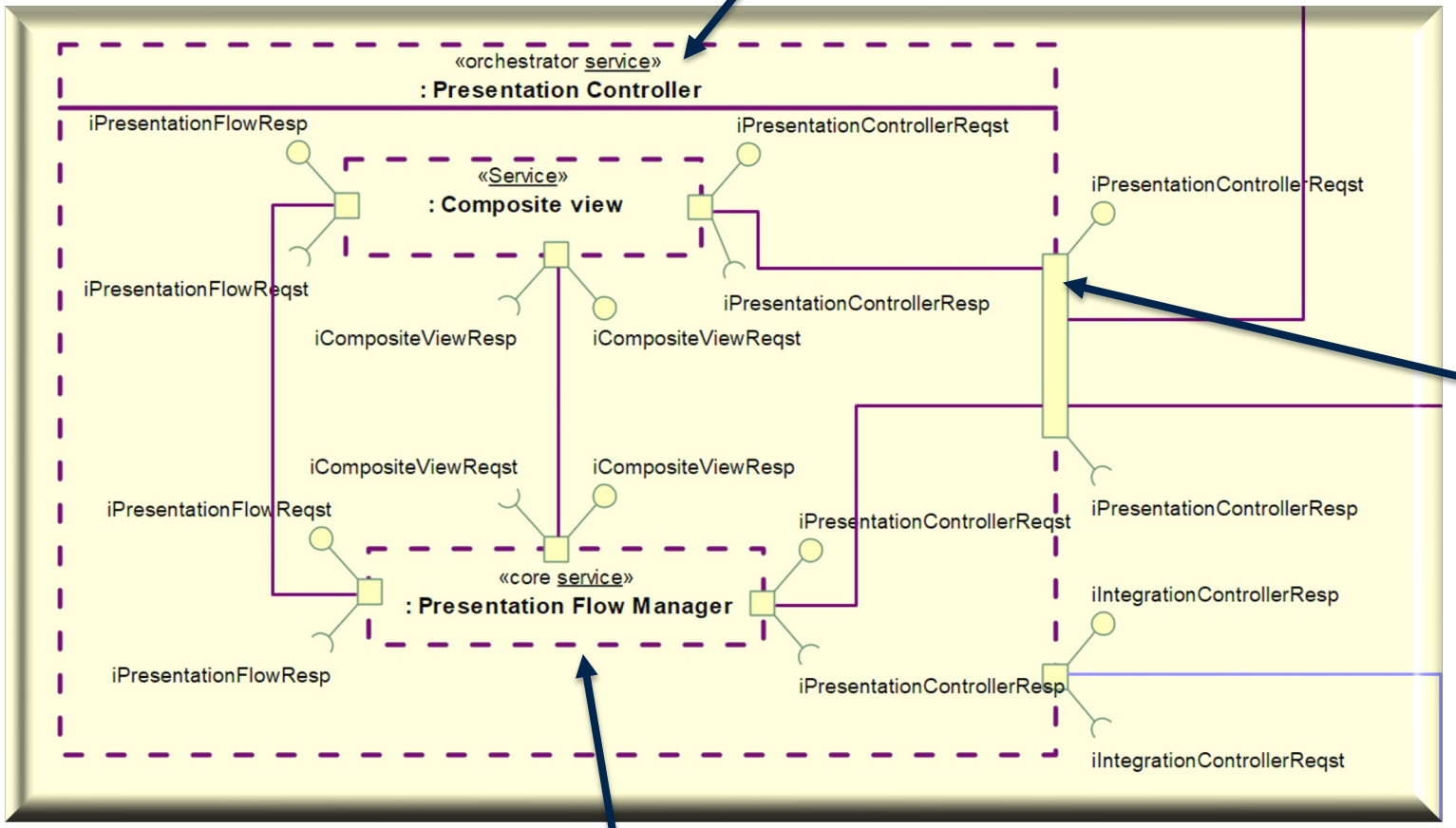

## ISC System Scenario View

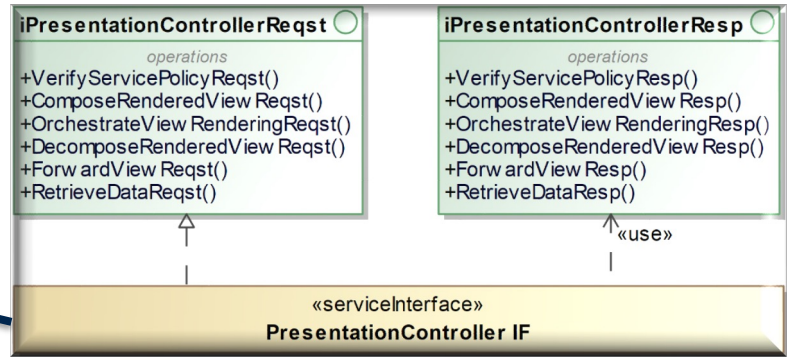
## "Receive Data" State Machine



# ISC services views created to conform to ISC service-oriented viewpoints.

## Presentation Controller Orchestrator Service View

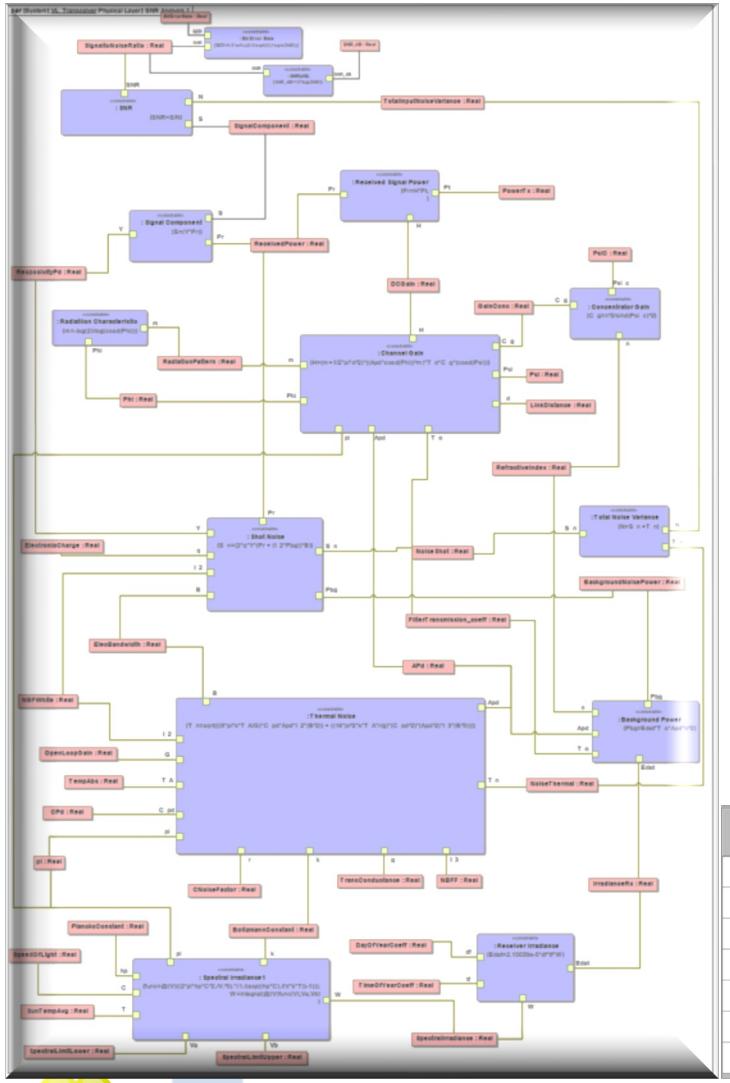


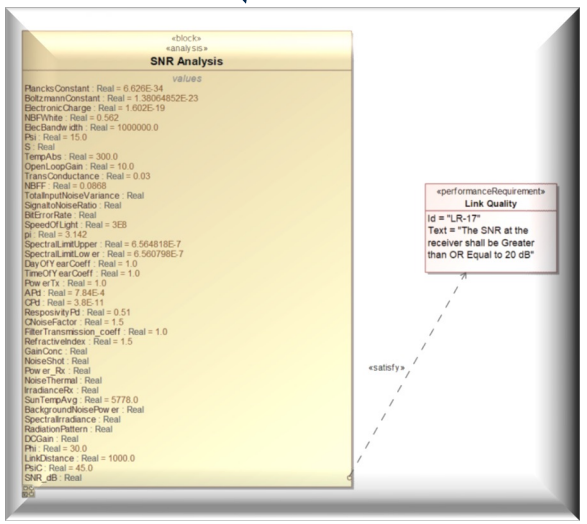

## Service Interface View

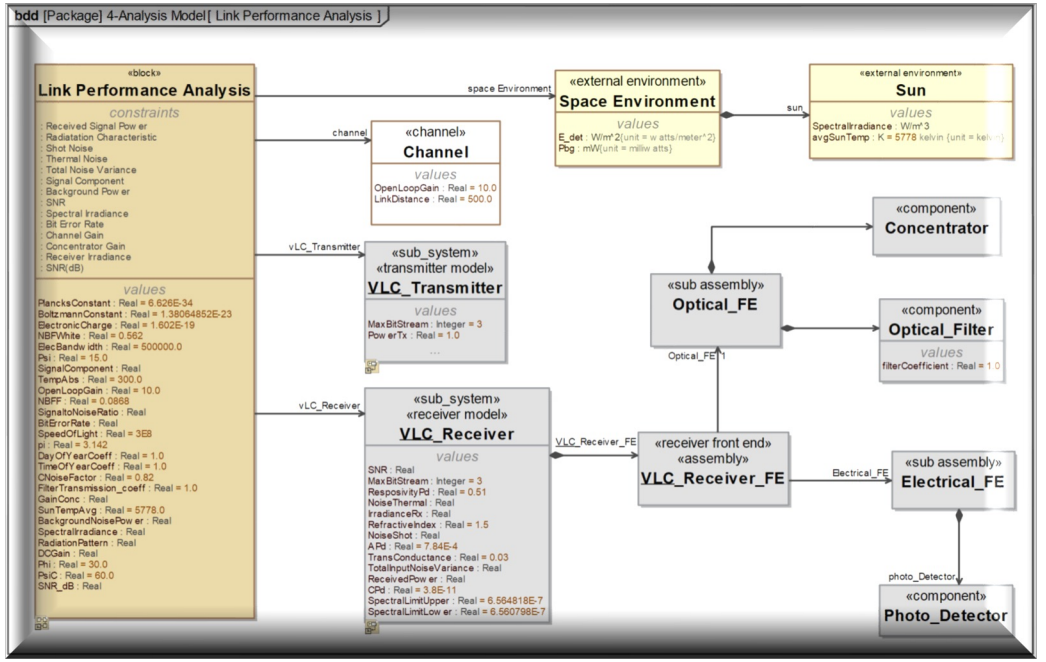
## Core Service

# ISC system views created to conform to ISC analysis and link performance viewpoint.



## SNR Analysis View



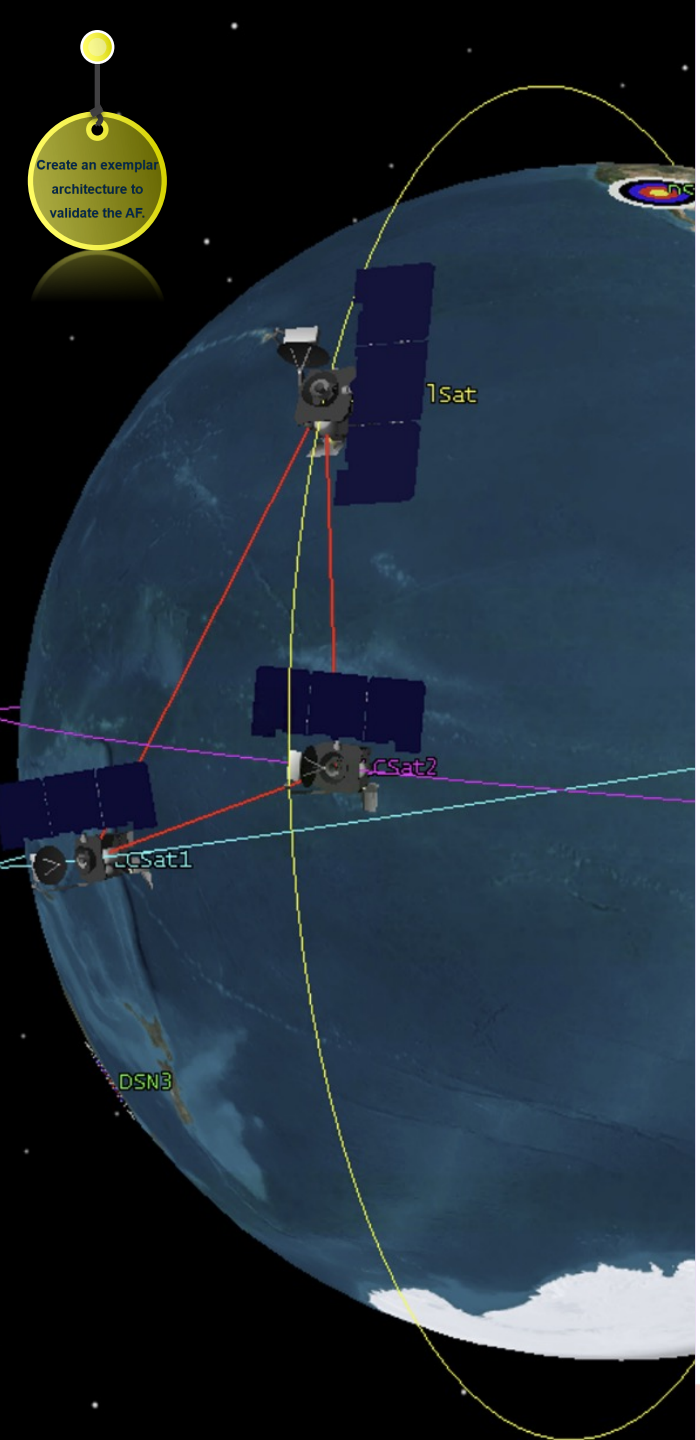



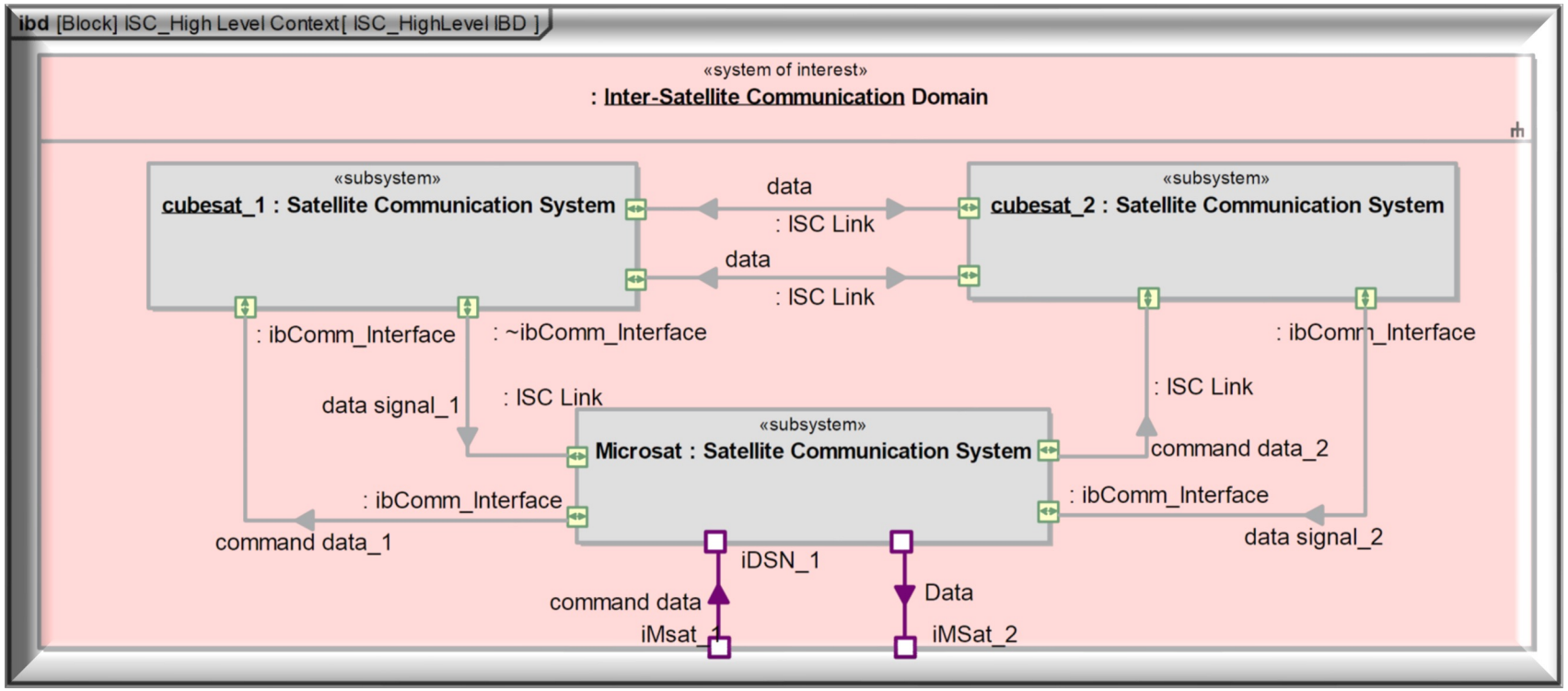

## Link Performance Analysis Context View

| # | Name | PsiC : Real | ElecBandwidth : Real | LinkDistance : Real | PowerTx : Real | ReceivedPower : Real | SNR_dB : Real | BitErrorRate : Real |
|---|---|---|---|---|---|---|---|---|
| 1 | vl_transceiver | 35 | 500000 | 500 | 2 | 2.8072E-9 | 53.7929 | 8.9773E-14 |
| 2 | vl_transceiver1 | 35 | 1000000 | 1000 | 2 | 1.1229E-8 | 60.7242 | 1.0805E-25 |
| 3 | vl_transceiver2 | 35 | 500000 | 500 | 1 | 1.4036E-9 | 46.8614 | 9.618E-8 |
| 4 | vl_transceiver3 | 45 | 500000 | 500 | 1 | 9.2352E-10 | 42.6756 | 1.2034E-5 |
| 5 | vl_transceiver5 | 45 | 1000000 | 1000 | 1 | 3.6941E-9 | 49.6069 | 1.1668E-9 |
| 6 | vl_transceiver6 | 60 | 1000000 | 500 | 2 | 1.2314E-9 | 38.6209 | 0.0003 |
| 7 | vl_transceiver7 | 60 | 500000 | 500 | 1 | 6.1568E-10 | 38.6209 | 0.0003 |

Create an exemplar architecture to validate the AF.

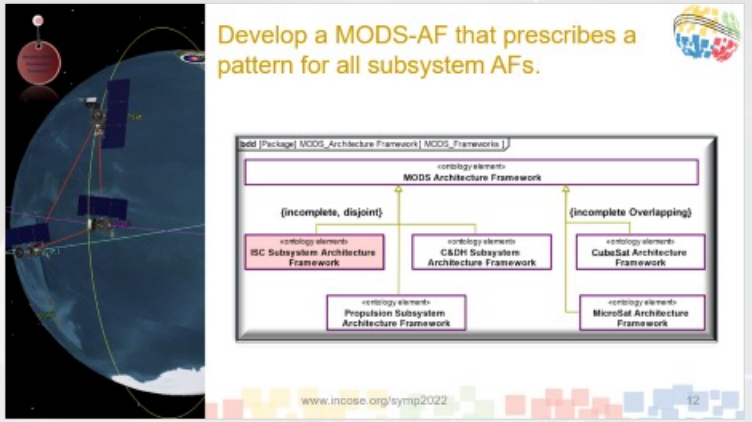
# An exemplar architecture description model validates the ISC-AF.

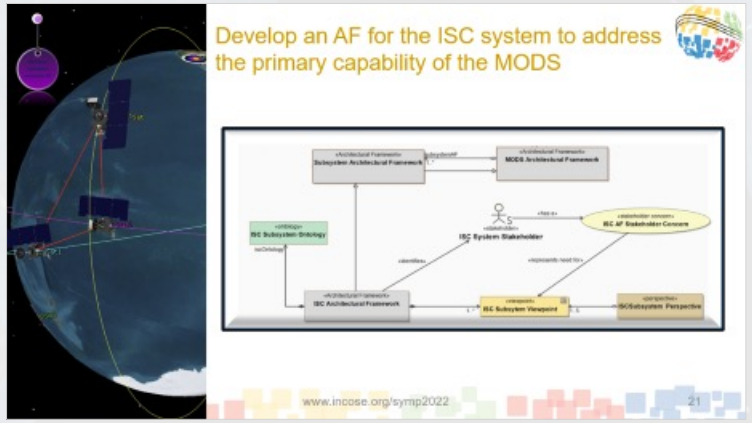


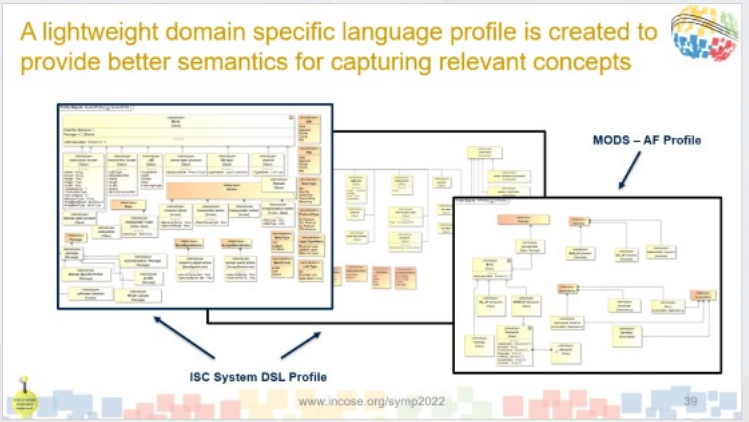



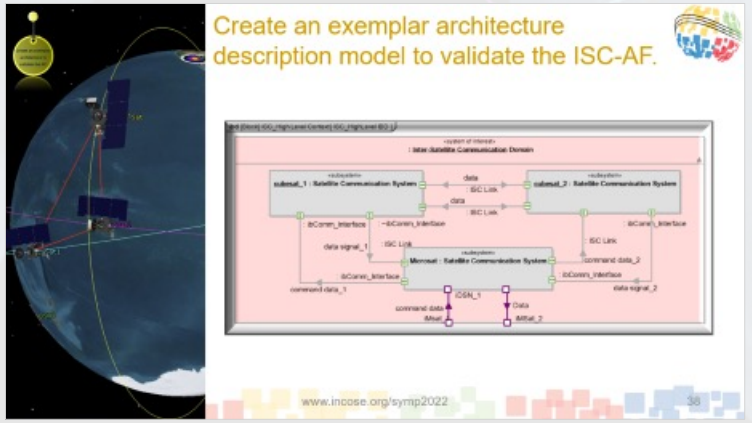
# Summary

# In summary, the MODS architectural framework provides the structure needed to codify key architectural decisions.



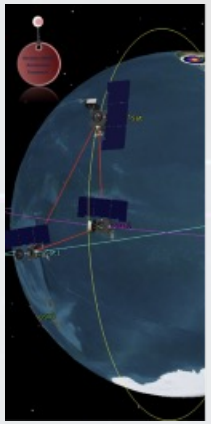



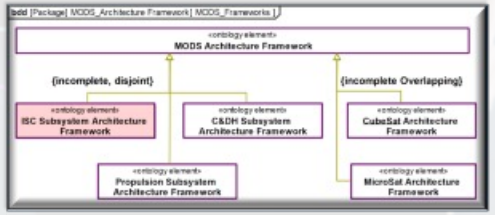



# Questions

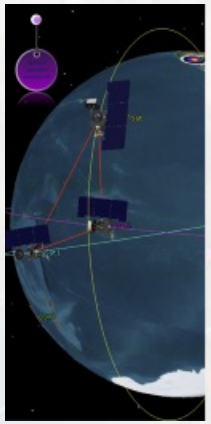
# An MBSE Architectural Framework for Inter-Satellite Communication in a Multiorbit Disaggregated System



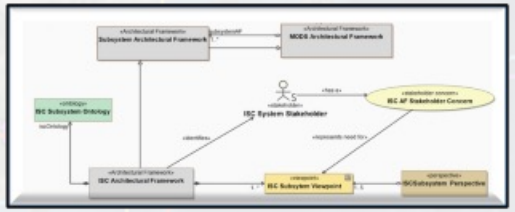
Develop a MODS-AF that prescribes a pattern for all subsystem AFs.



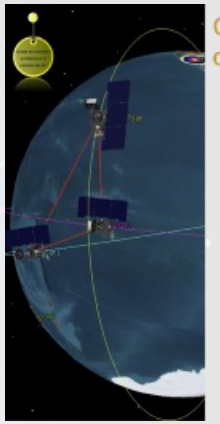


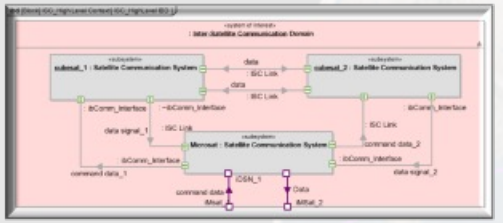
Develop an AF for the ISC system to address the primary capability of the MODS







Create an exemplar architecture description model to validate the ISC-AF.





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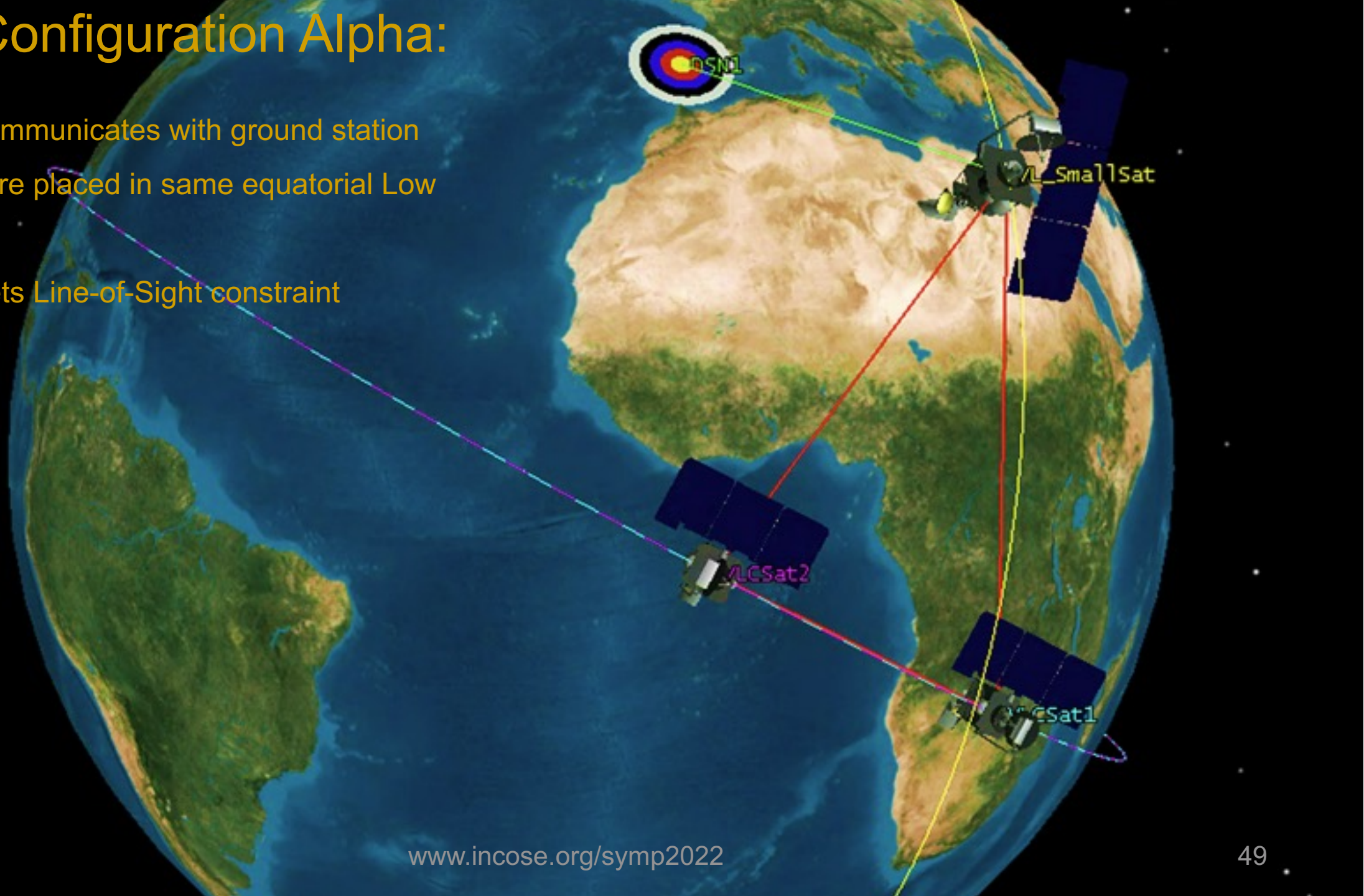
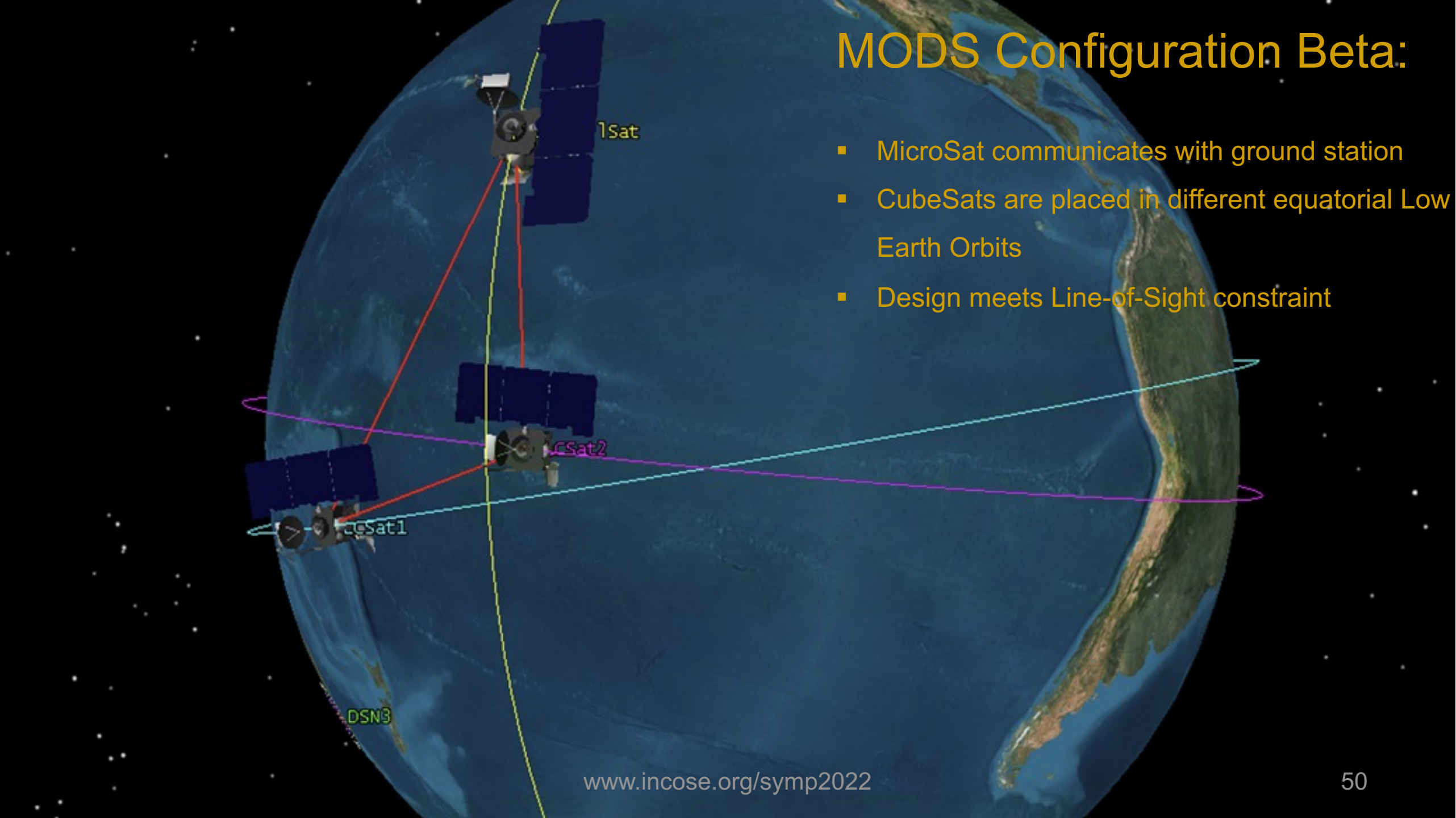
9. Holt, J. and Perry, S. (2014) SysML for systems engineering, 2nd Edition: A model-based approach, vol. 10, chapter 11. IET

# MODS Configuration Alpha:

- MicroSat communicates with ground station
- CubeSats are placed in same equatorial Low Earth Orbit
- Design meets Line-of-Sight constraint



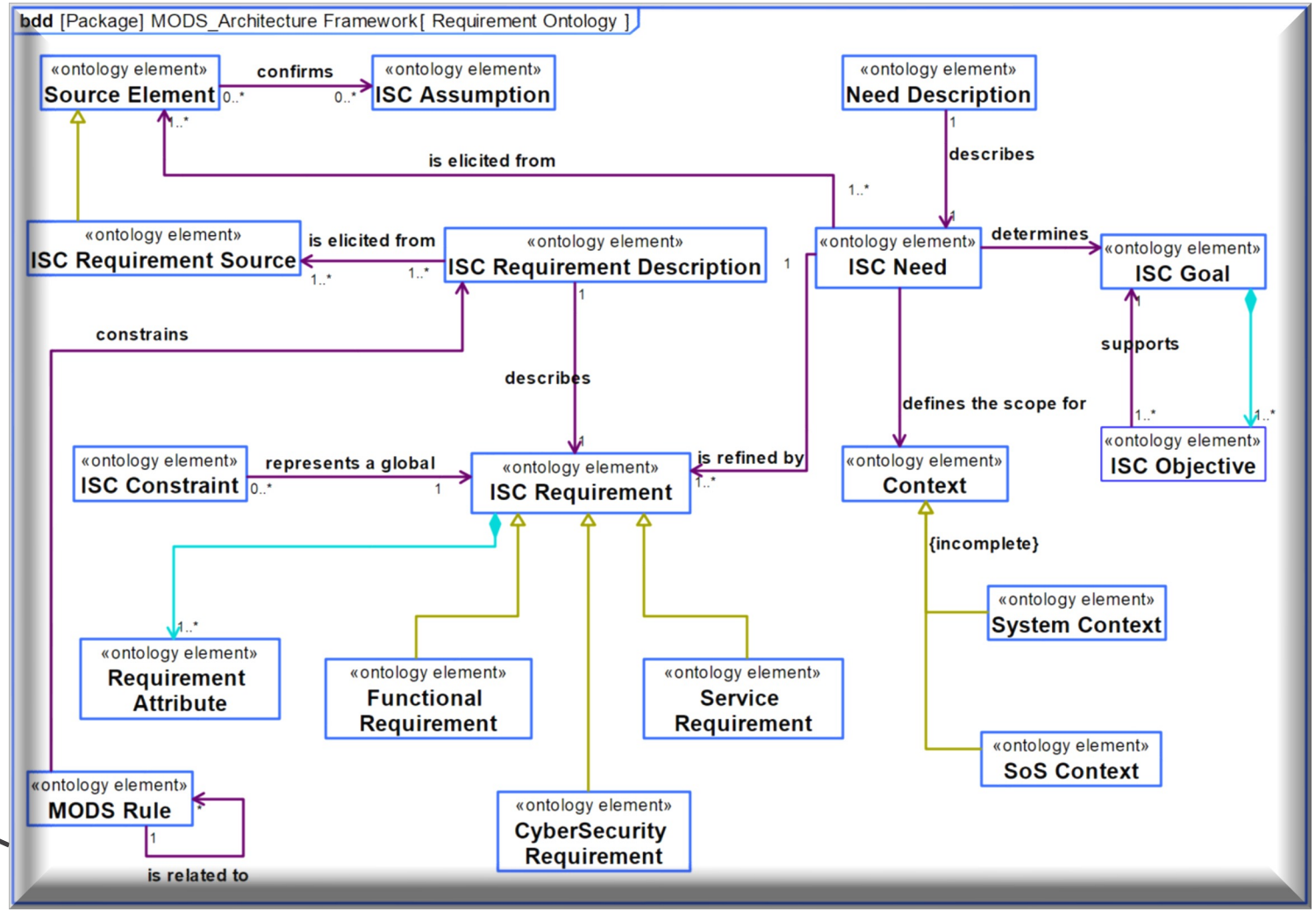
# MODS Configuration Beta:




- MicroSat communicates with ground station
- CubeSats are placed in different equatorial Low Earth Orbits
- Design meets Line-of-Sight constraint

# The terms and concepts needed to create the ISC system requirement views are gotten from the RODV

**RODV – Requirement Ontology Definition View**

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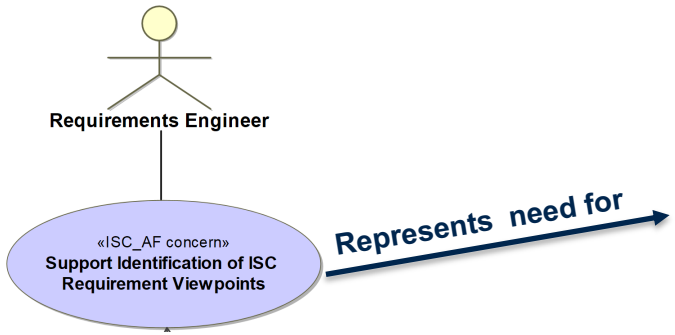
# Each resulting view is required to adequately specify ISC subsystem requirements and related artifacts.

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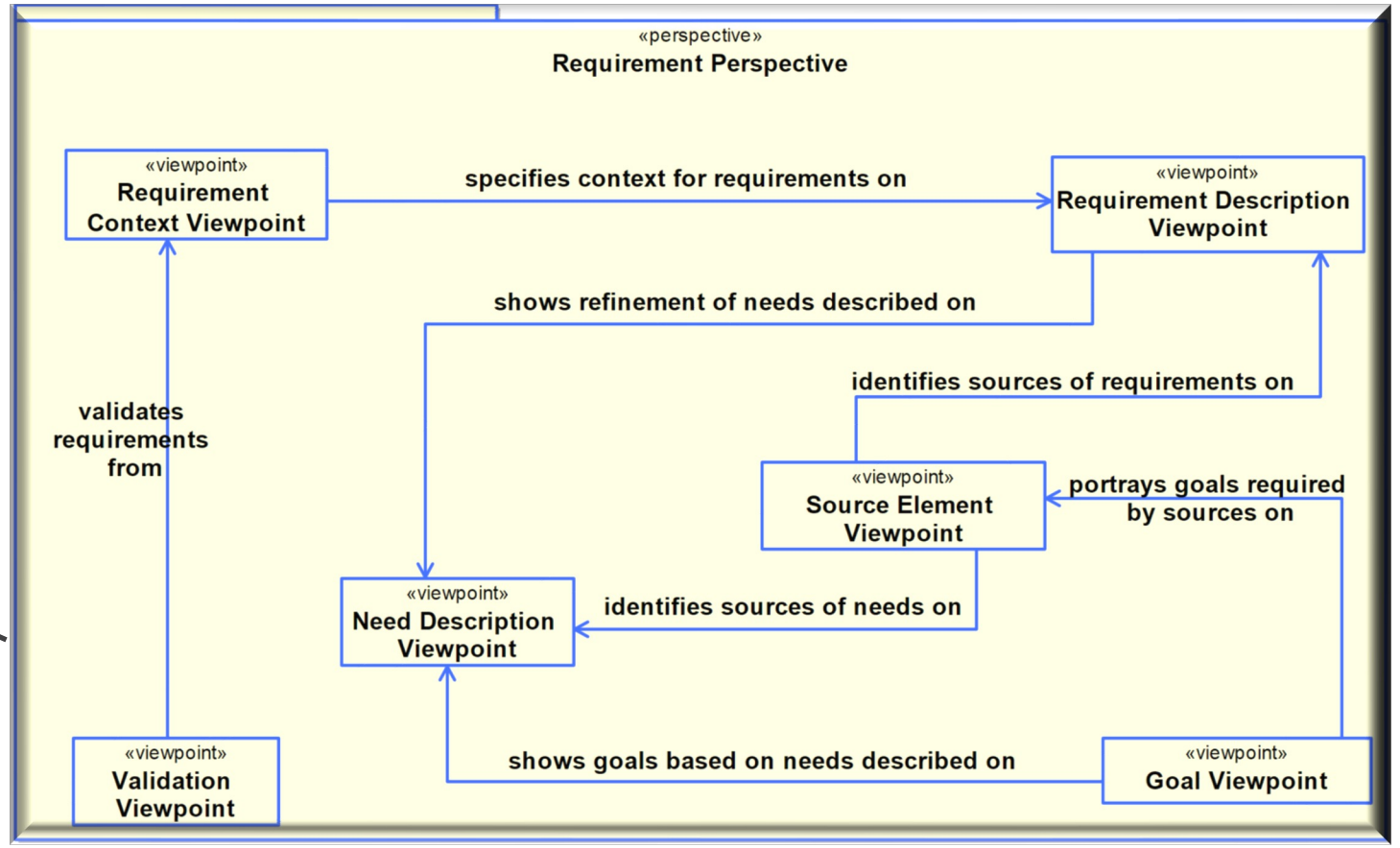
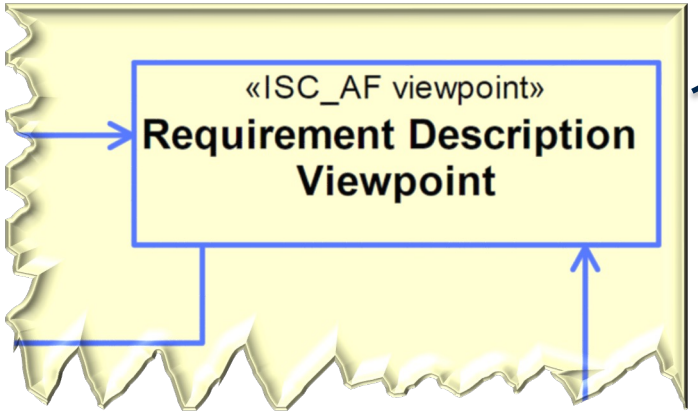
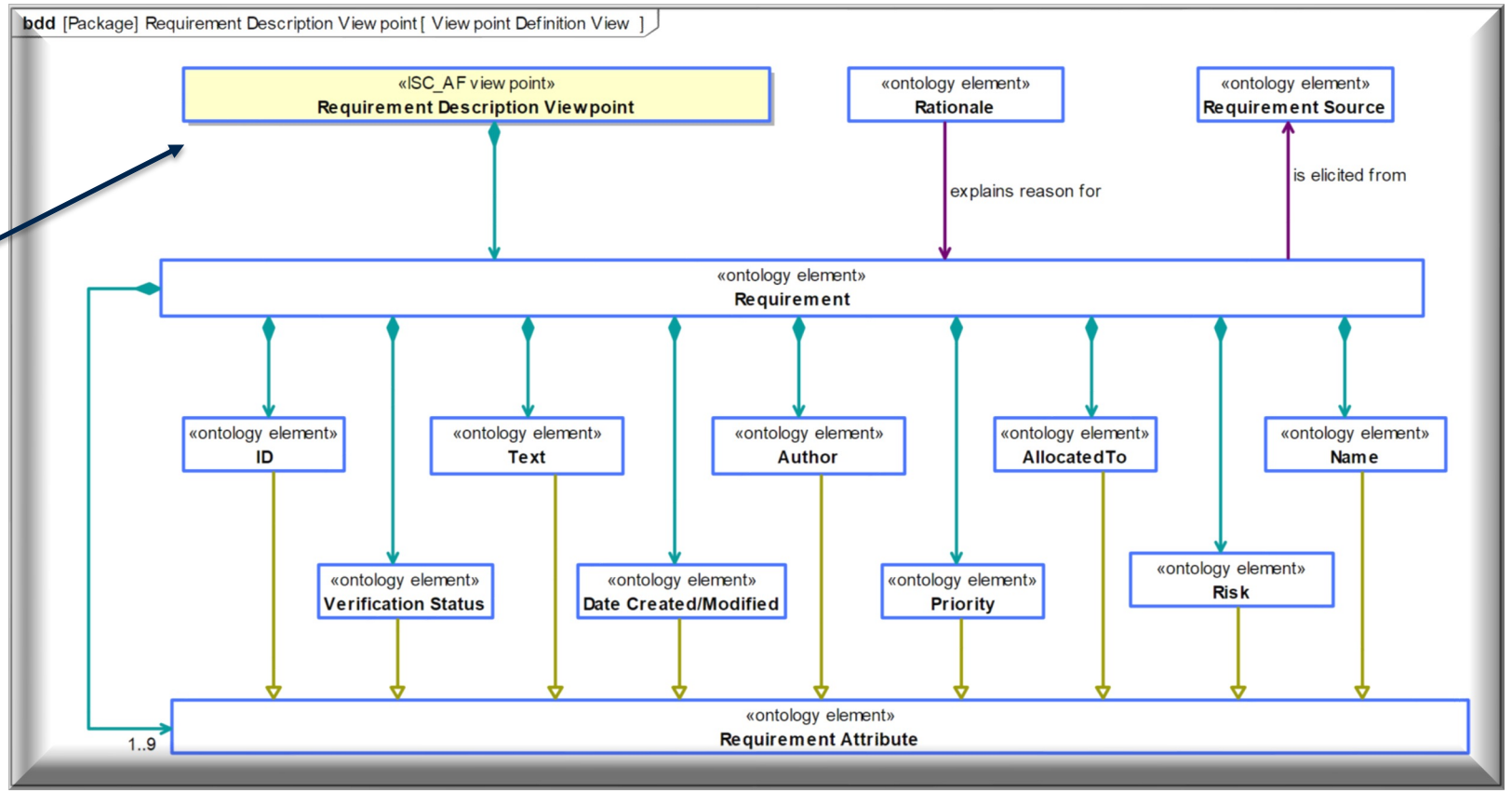
**ISC-AF Requirement Perspective**



# Ontology elements used to specify the Requirement Description View are shown in this Viewpoint Definition View

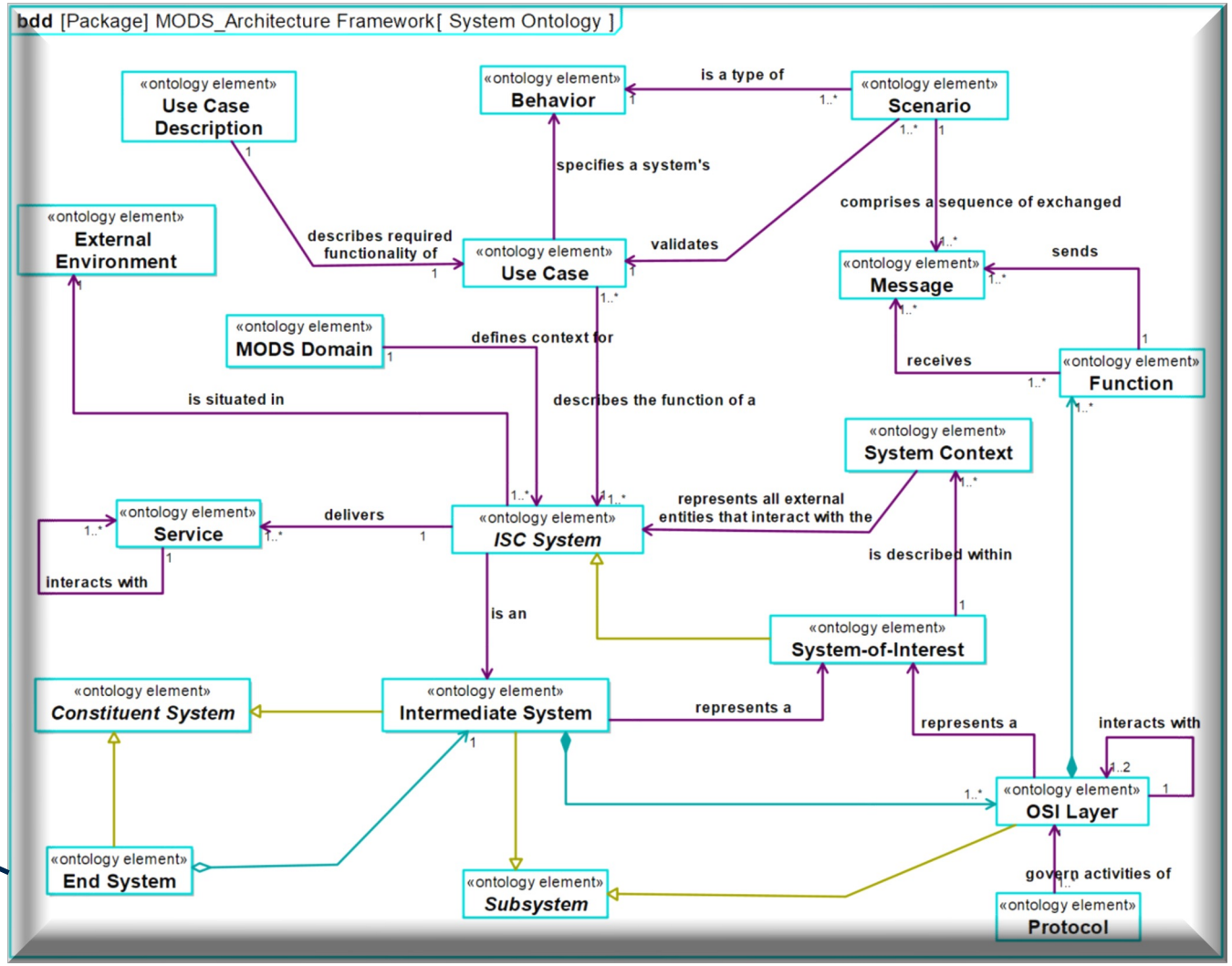
- **Requirement Description Viewpoint:** - This viewpoint defines structured descriptions of requirements. Each requirement description has associated attributes and is assessed individually.



# Concepts captured in this view form the basis for the existence of the ISC-AF

**SODV – System Ontology Definition View**

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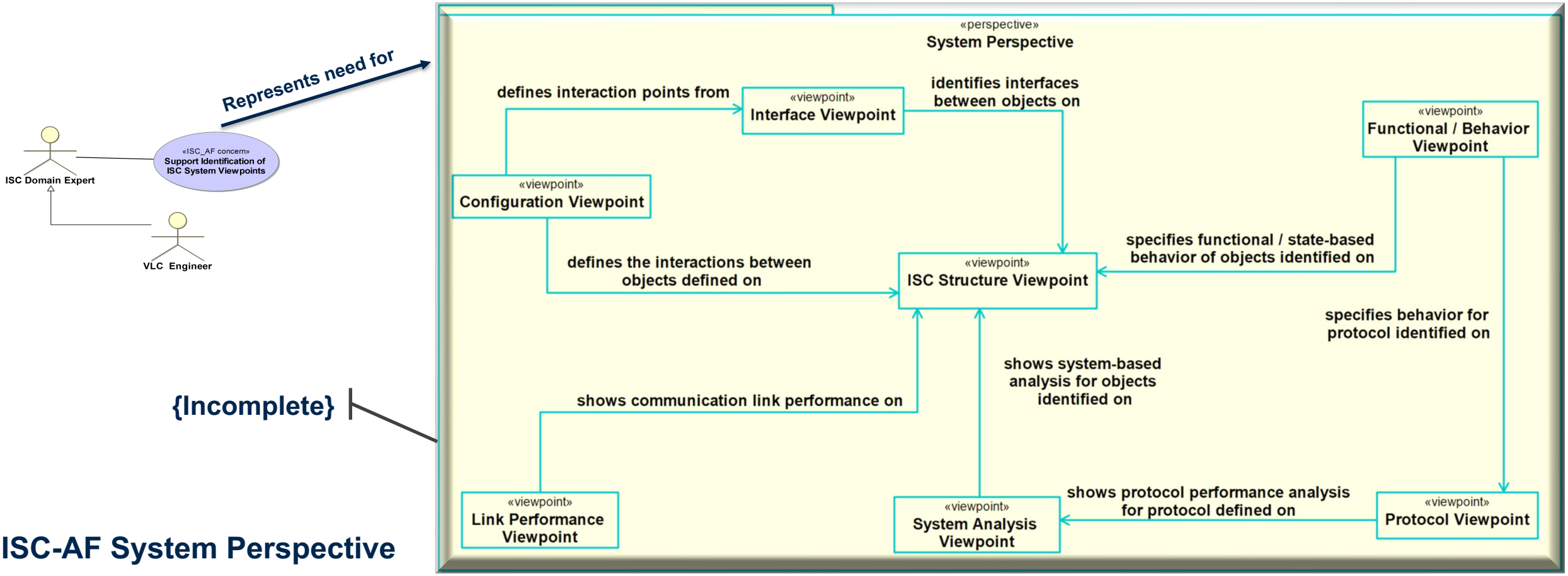
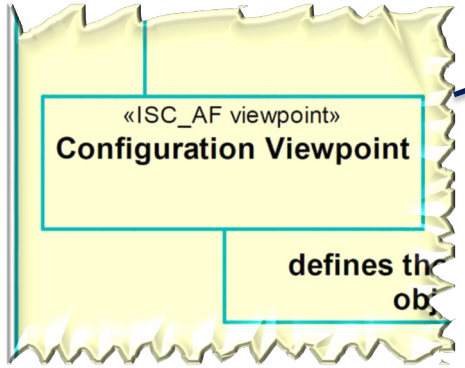
# These viewpoints enable the creation of views necessary to completely specify the ISC subsystem.

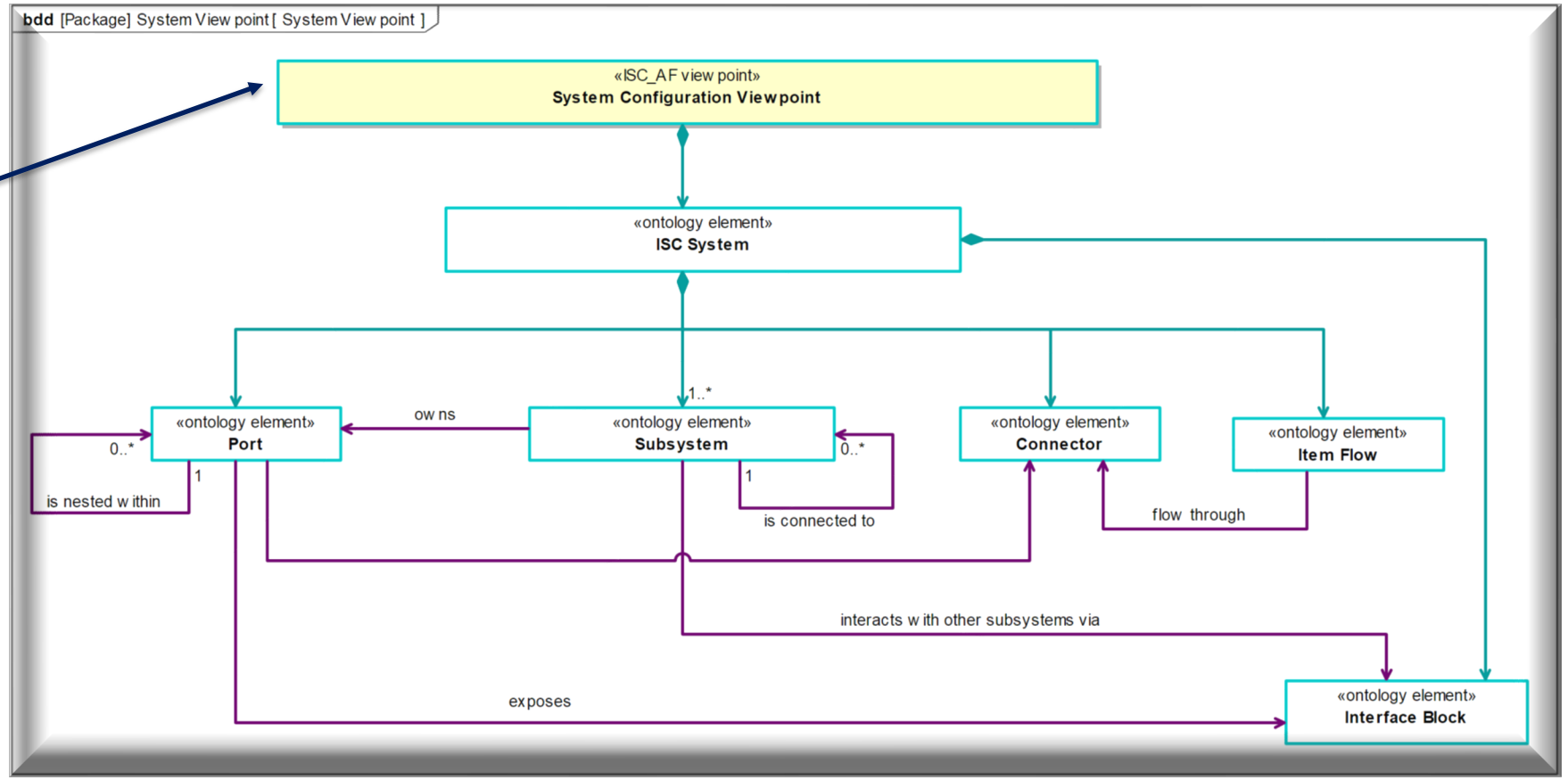



**ISC-AF System Perspective**

# Ontology elements used to specify the Configuration View are shown in this Viewpoint Definition View

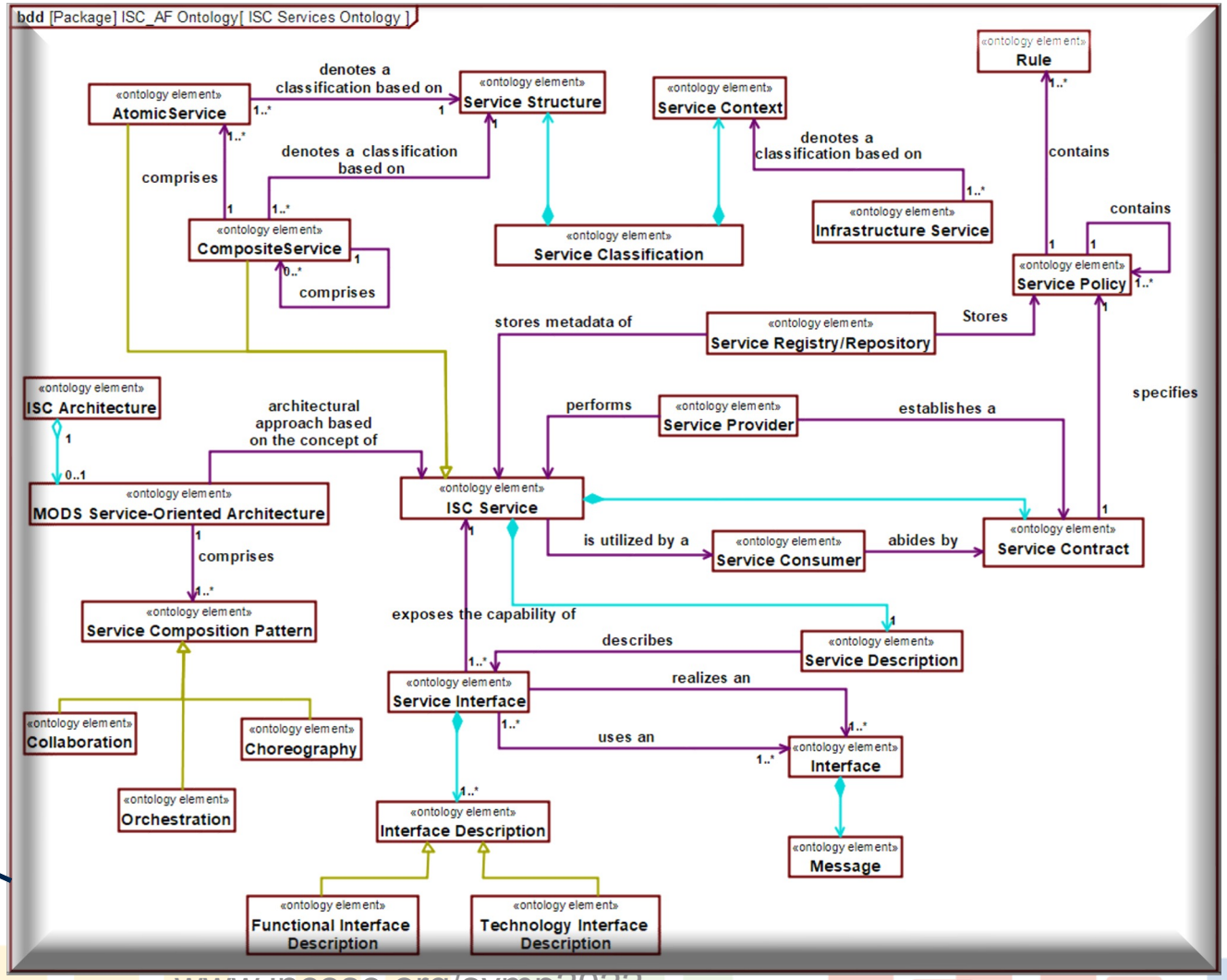
- **Configuration Viewpoint:** - This viewpoint defines how the ISC system and subsystems are configured based on their structure and the interfaces between System Elements.



# Service orientation concepts defined in this ontology view are key to developing a flexible ISC subsystem.

**SvODV – Service-Oriented Ontology Definition View**

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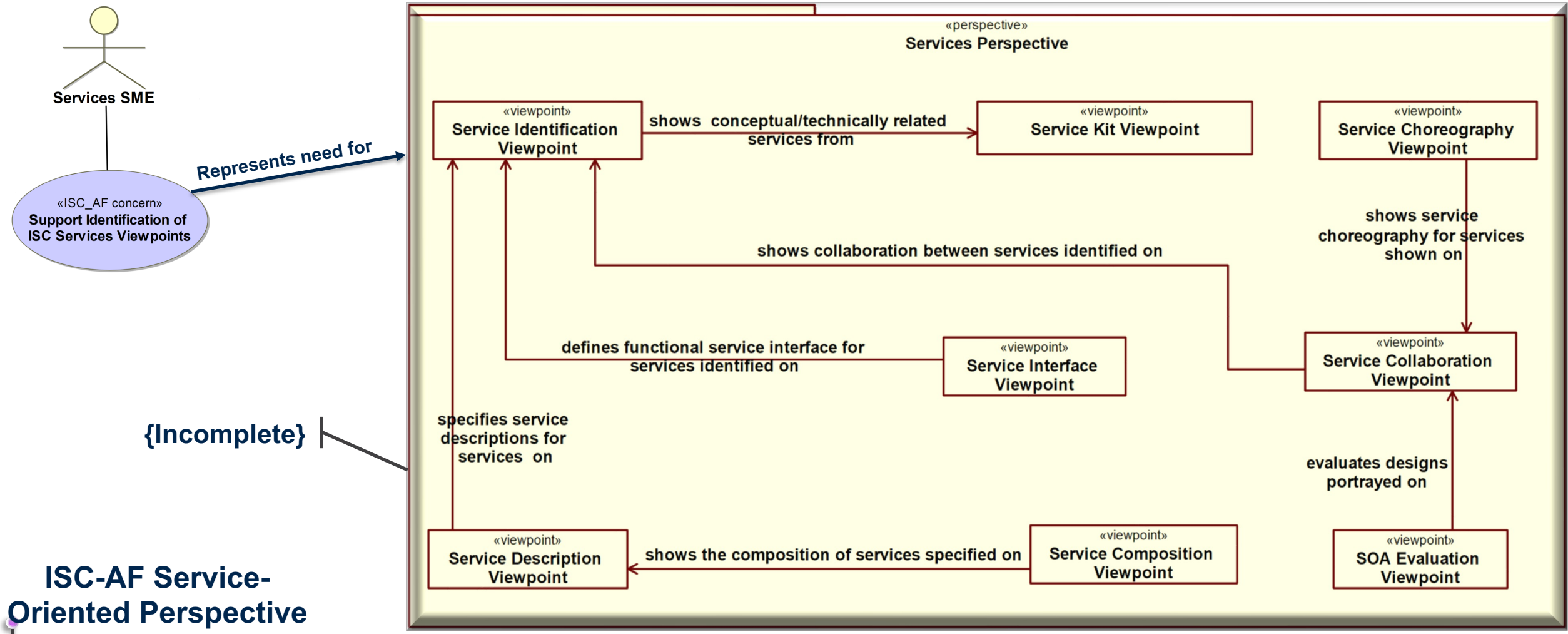
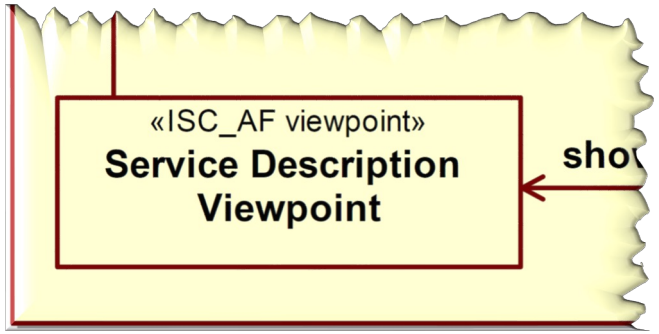
# These viewpoints help define views concerned with utilizing services to deliver system agility.

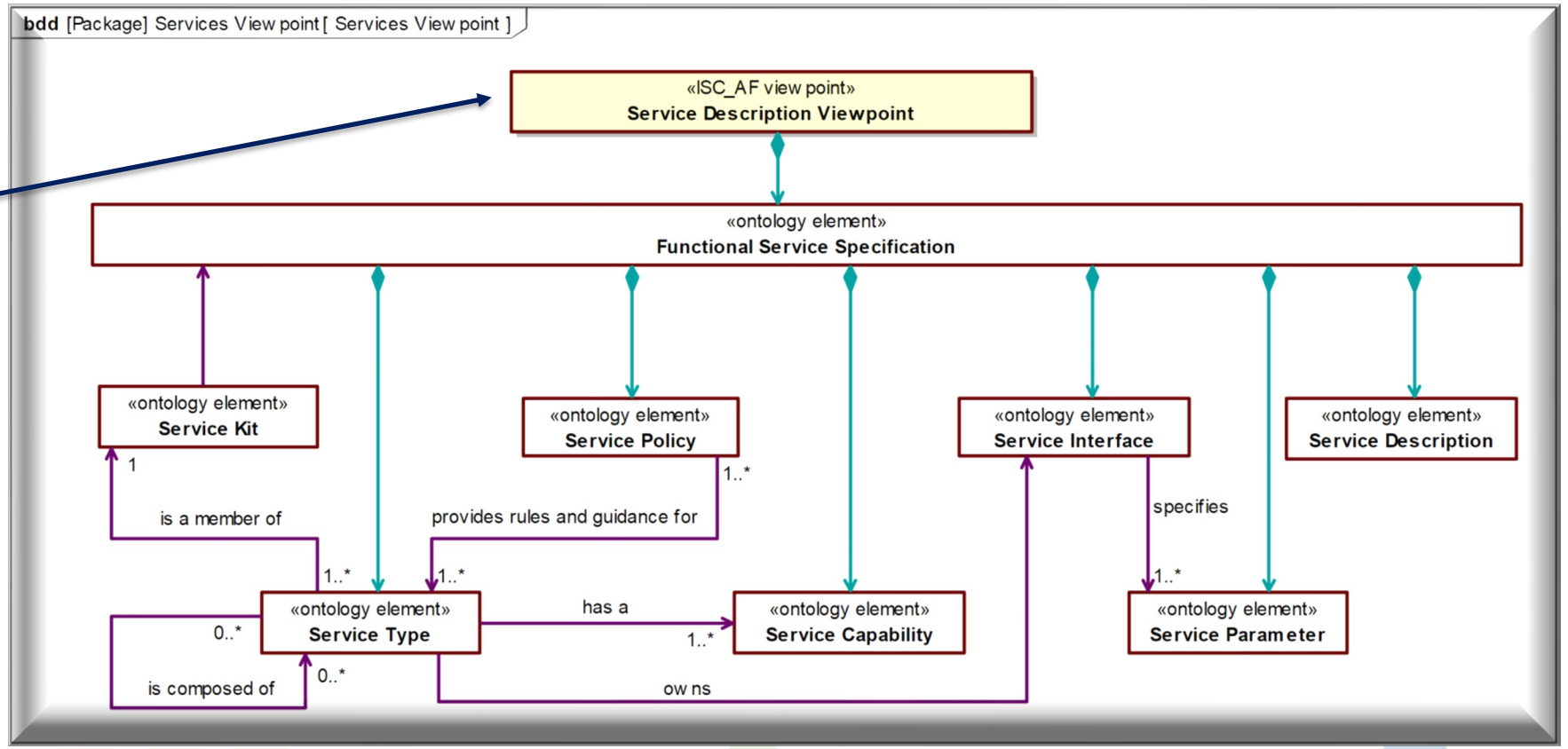



**ISC-AF Service-Oriented Perspective**

# Ontology elements used to specify the Service Description View are shown in this Viewpoint Definition View

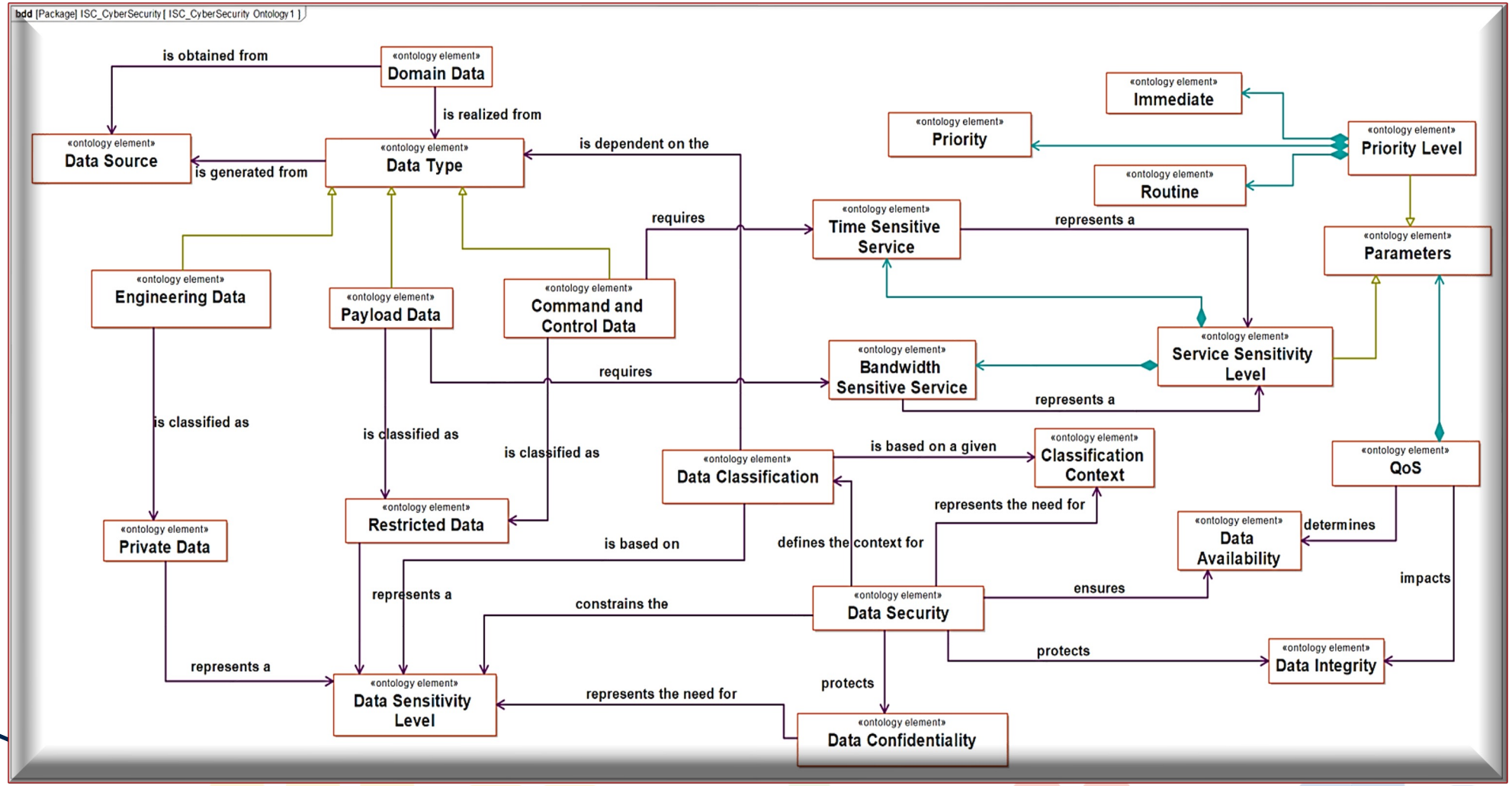
- **Service Description Viewpoint:** - This viewpoint specifies the functional Service Interface for each identified Service which includes a description of the service capability.



# Domain-relevant data and data-security concepts and are defined in the security ontology viewpoint

**SecODV – Cyber Security Ontology Definition View**

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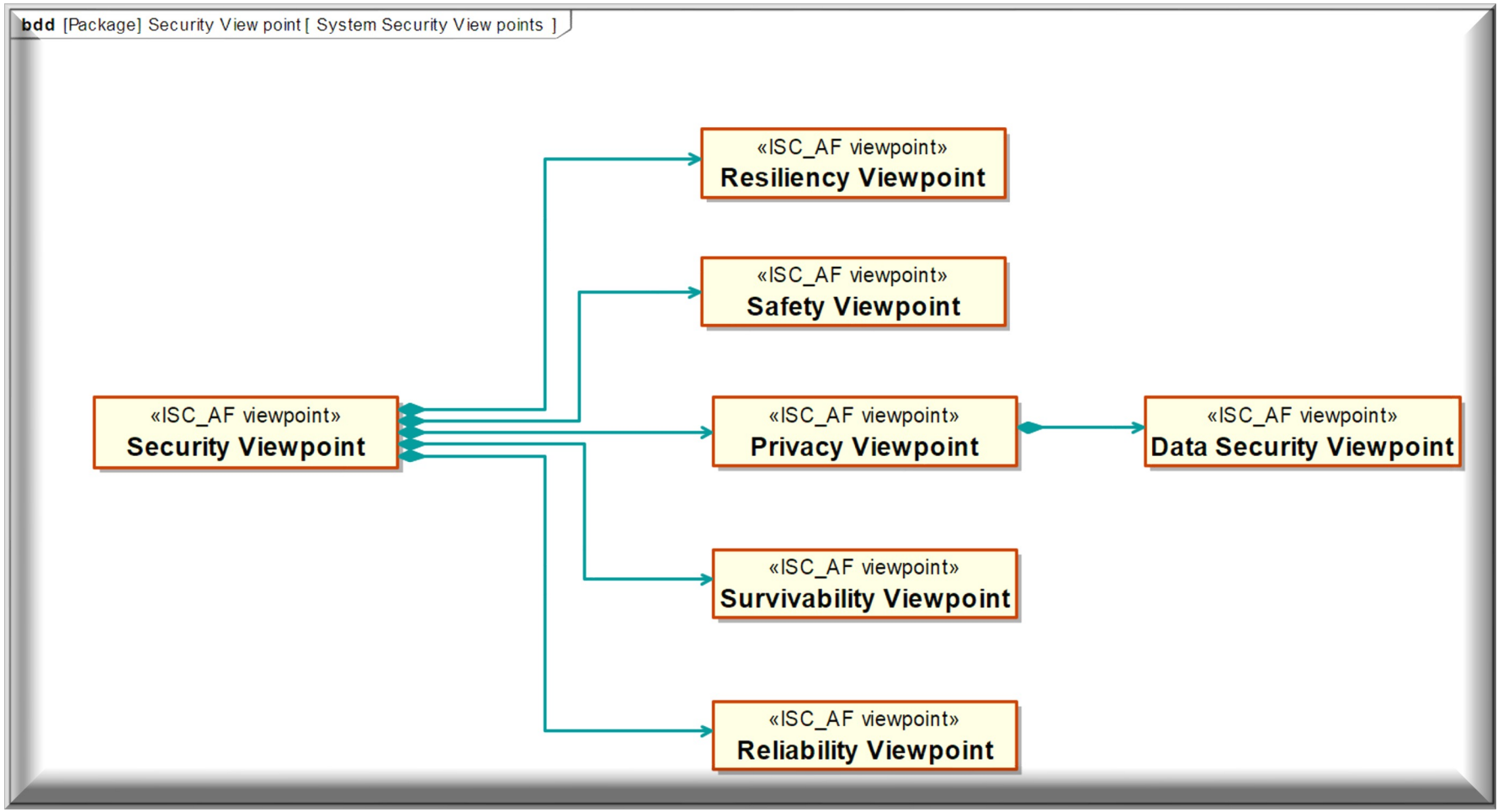
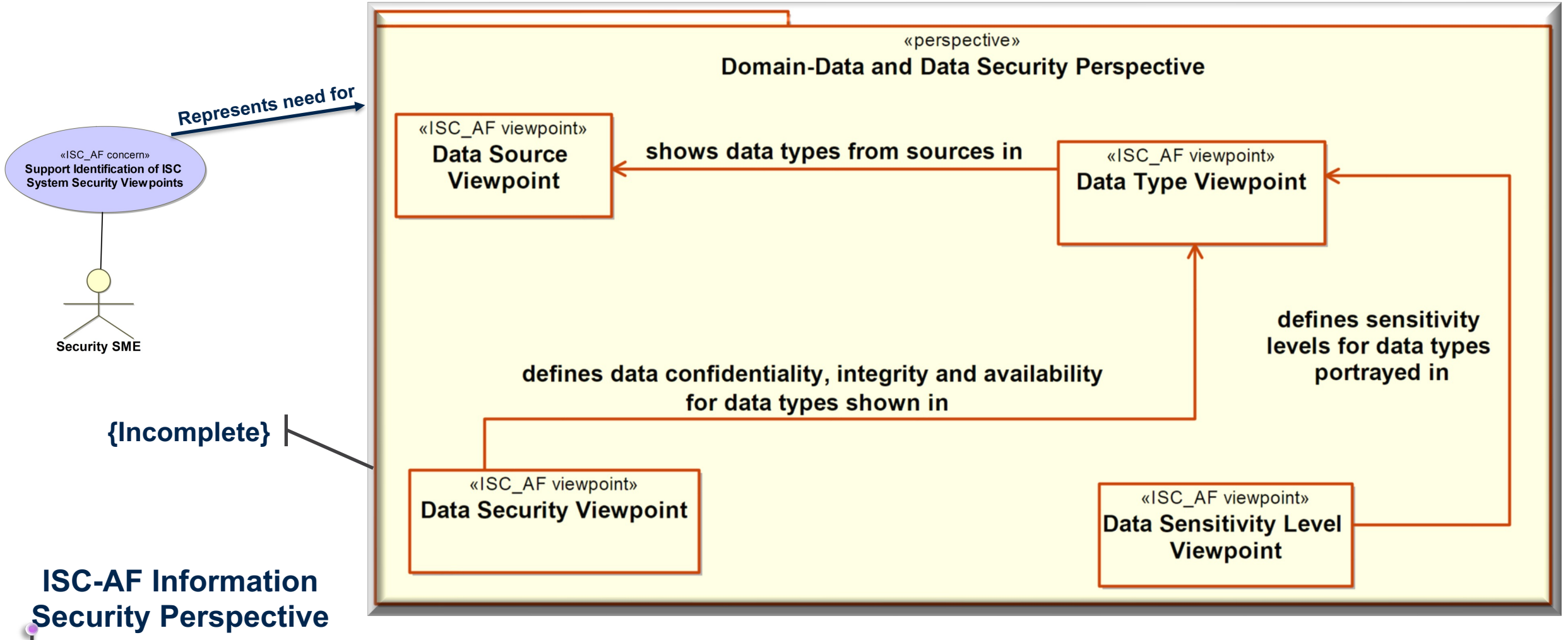
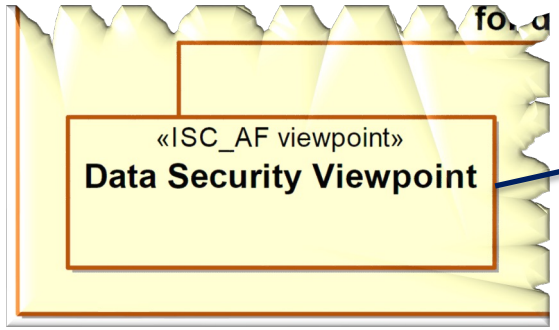
# These viewpoints capture the security capabilities of the system required to establish trustworthiness

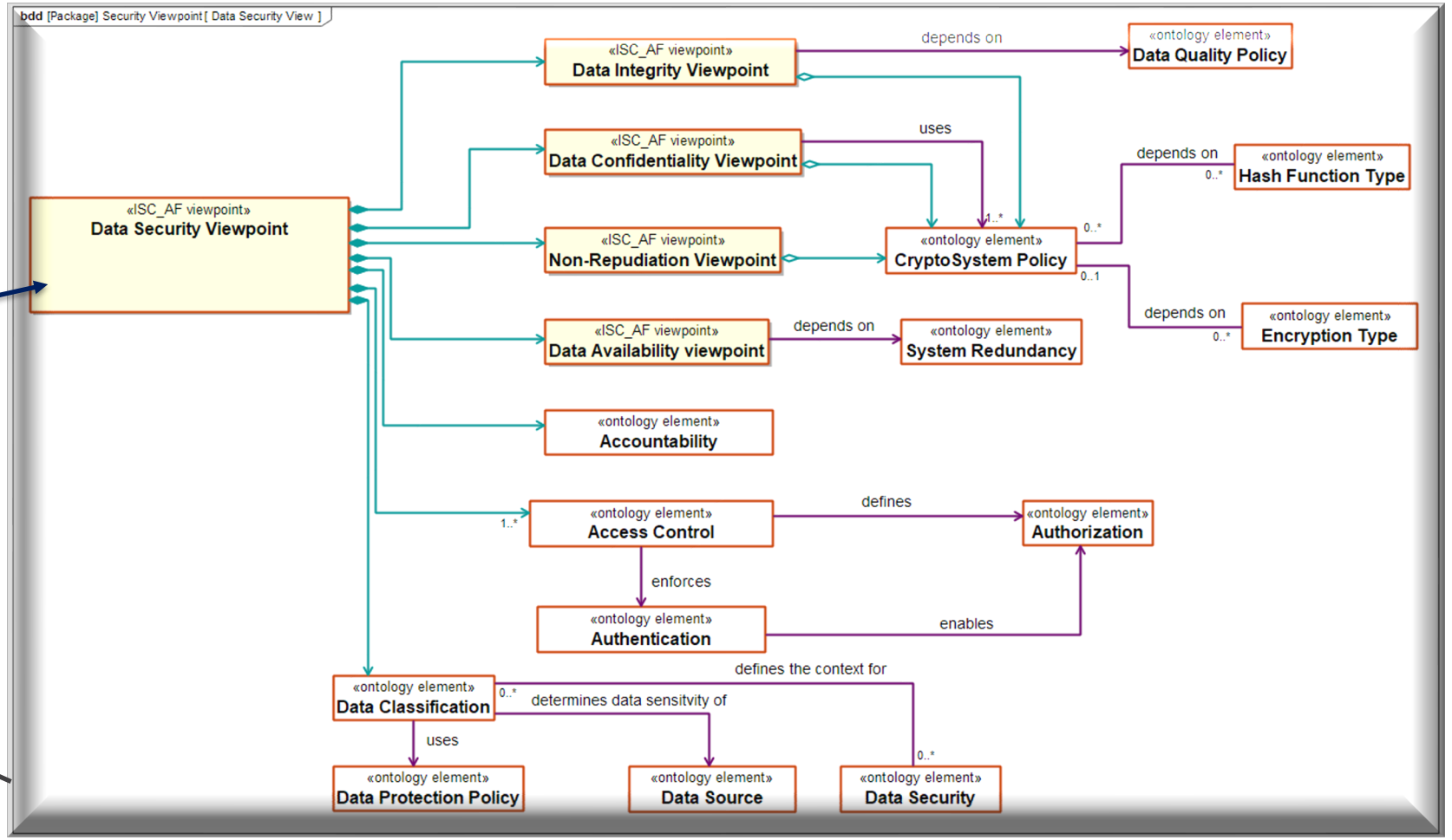


# These viewpoints enable the capture of data and data-security views of the system.



# Shown are derived viewpoints and some ontology elements required to create data security views.

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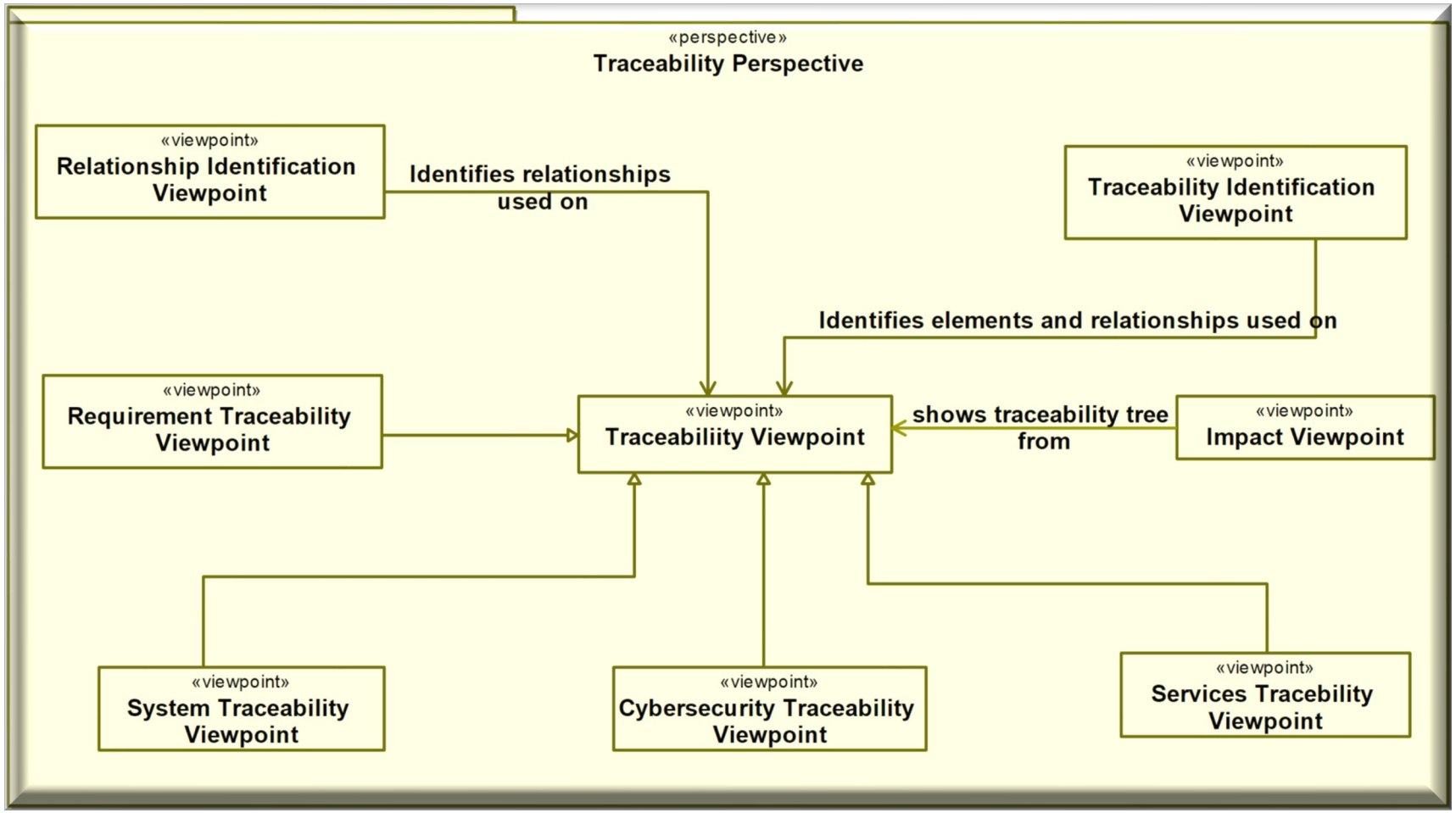
# These viewpoints provide insightful views and visualization of the overall architecture.

## ISC-AF Traceability Perspective



# An example of a tabular traceability view which shows the relationships between ISC-AF elements.

Criteria

Element Type: perspective ... Scope (optional): aceability Perspective,ISC_AF Perspective {}xy ... Filter:

| # | Name | Viewpoint | Stakeholder Concern Addressed by Viewpoint | ISC-AF Stakeholder |
|---|---|---|---|---|
| 1 | System Perspective | Configuration Viewpoint<br>Protocol Viewpoint<br>Functional / Behavior Viewpoint<br>Link Performance Viewpoint<br>System Analysis Viewpoint<br>ISC Structure Viewpoint<br>Interface Viewpoint | Support Identification of ISC System Viewpoints<br>Support Modeling ISC Architectures Based on the OSI Framework<br>Support Conceptual Functional/Logical and Technology Level Descriptions<br>Define an Architectural Framework for Modeling ISC Architectures | ISC Domain Expert<br>MODS AF<br>ISC Systems Engneer<br>Sponsor/Customer<br>ISC_AF Architect<br>SE Modeler |
| 2 | Traceability Perspective | Traceabiliity Viewpoint<br>Impact Viewpoint<br>Traceability Identification Viewpoint<br>Relationship Identification Viewpoint<br>Services Tracebility Viewpoint<br>System Traceability Viewpoint<br>Requirement Traceability Viewpoint<br>Cybersecurity Traceability Viewpoint | Support Identification of ISC System Tracebility Viewpoints<br>Define an Architectural Framework for Modeling ISC Architectures | MODS AF<br>ISC Systems Engneer<br>Sponsor/Customer<br>ISC_AF Architect<br>SE Modeler |
| 3 | Information Security Perspective | Sensitivity Level Viewpoint<br>Cybersecurity Context Viewpoint<br>Threats and Attacks Mitigation Viewpoi<br>Data Source Viewpoint<br>Data Type Viewpoint | Support Identification of ISC System Security Viewpoints<br>Define an Architectural Framework for Modeling ISC Architectures<br>Comply with RASDS Standards | Security SME<br>MODS AF<br>ISC Systems Engneer<br>Sponsor/Customer |