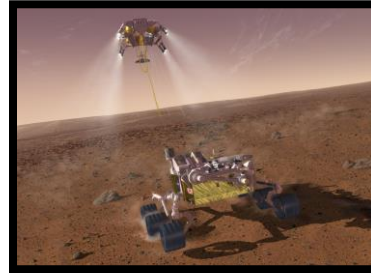




National Aeronautics and  
Space Administration

Jet Propulsion Laboratory  
California Institute of Technology  
Pasadena, California



# Model-Driven Development For PDS4 Software And Services

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# Topics

- Overview of Model-Driven Development
- Benefits to the Information System
- Current Applications
- Conclusion



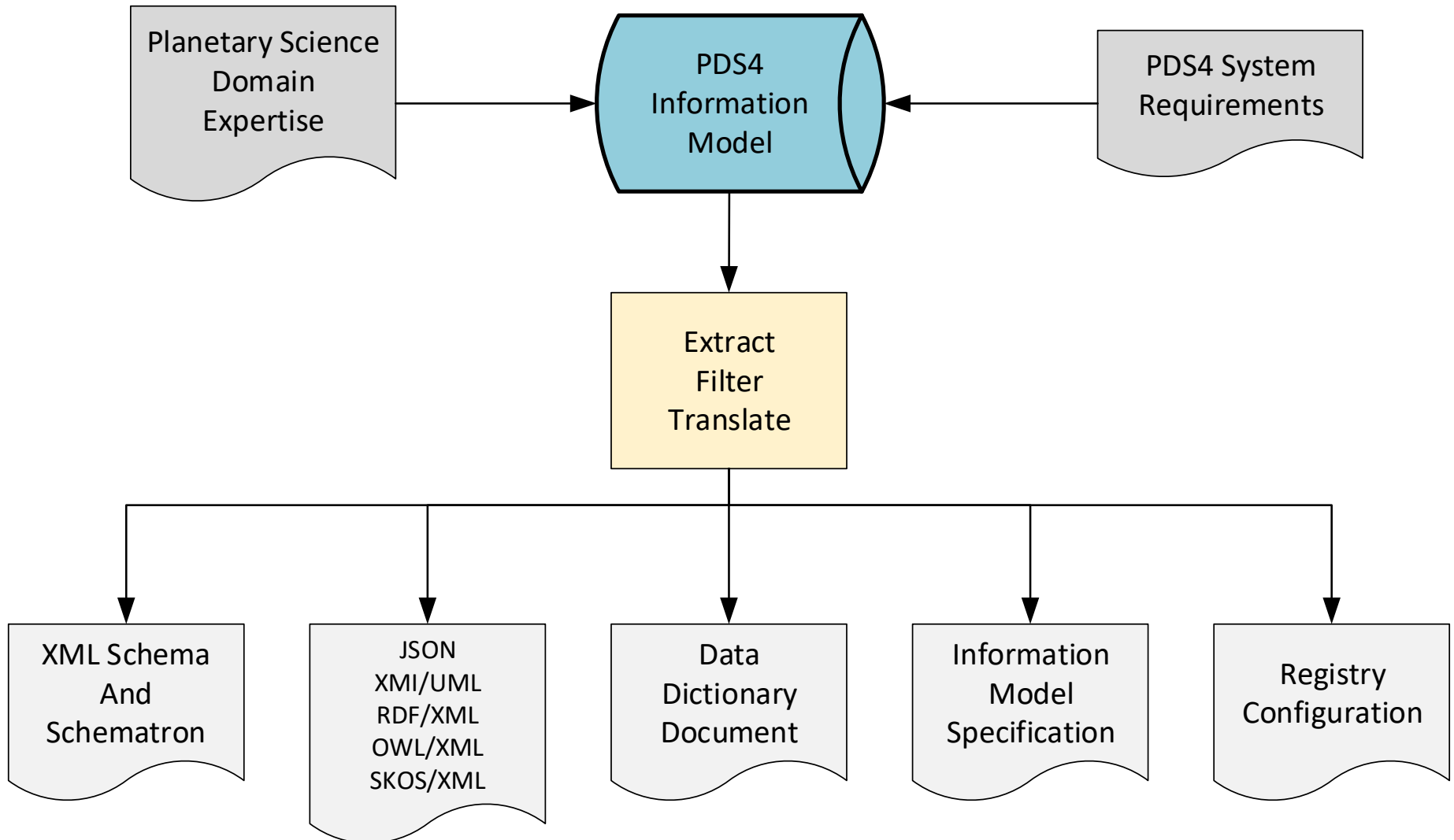
# Information Model

- “An information model is a representation of concepts, relationships, constraints, rules, and operations to specify data semantics for a chosen domain of discourse.”<sup>1</sup>
- It provides a sharable, stable, and organized structure of **information requirements** or knowledge for the domain context.

<sup>1</sup> Lee, Y. T. 1999. Information Modeling: From Design To Implementation. In Proceedings of the Second World Manufacturing Congress, ed. S. Nahavandi and M. Saadat, 315-321. Canada/Switzerland: International Computer Science Conventions.



# Information Model



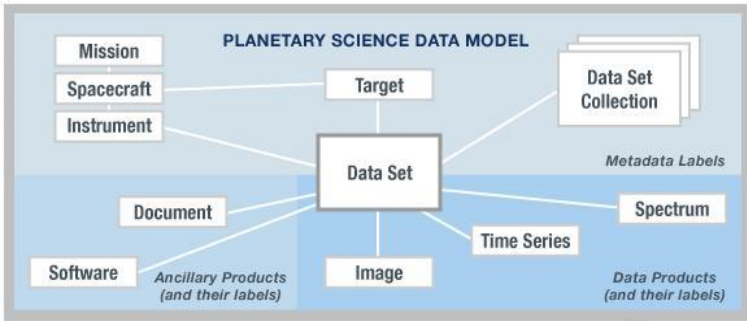
# Background

- Developed using lessons learned from over 25 years of science data archiving
  - Acquired a good understanding of data representations in different planetary disciplines
- Used best practices for information model development and foundational principles adopted from:
  - Open Archival Information System (OAIS) Reference Model - ISO 14721 - Foundational Principles
  - ISO/IEC 11179 - Volume 3 – Metadata Registry Specification - Hierarchy of data dictionaries and governance model
  - CCSDS 312.0-G-1 - Reference Architecture for Space Information (RASIM)
  - Management - W3C XML (Extensible Markup Language) - Rules for encoding documents electronically
- Few systems have developed a rigorous model for describing data management, discovery, and analytics

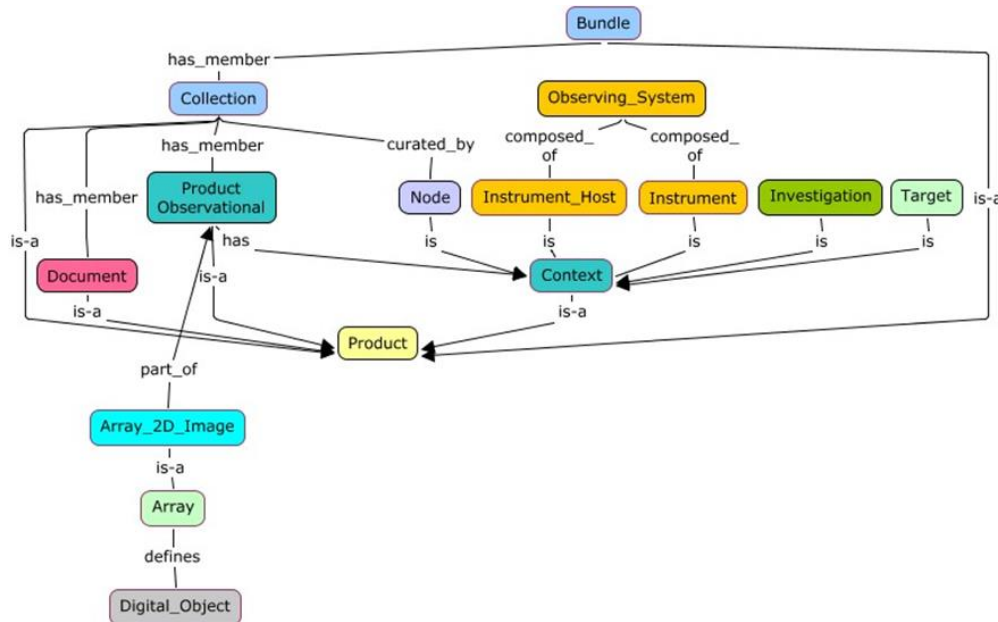


# Views

## Community's View



## Information Modeler's View



## Repository View

### Product

#### Tagged Data Object

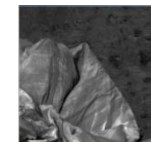
(Information Object)

```

<local_identifier>MPFL_M_IMP_IMAGE</local_identifier>
<offset unit="byte">0</offset>
<axes>2</axes>
<axis_index_order>Last_Index_Fastest</axis_index_order>
<encoding_type>Binary</encoding_type>
<Element_Array>
  <data_type>SignedMSB4</data_type>
  <unit>pixel</unit>
</Element_Array>
<Axis_Array>
  <axis_name>Line</axis_name>
  <elements>248</elements>
  <sequence_number>1</sequence_number>
</Axis_Array>
<Axis_Array>
  <axis_name>Sample</axis_name>
  <elements>256</elements>
  <sequence_number>2</sequence_number>
</Axis_Array>
</Array_2D_Image>

```

Describes



Data Object

# Roles of the IM

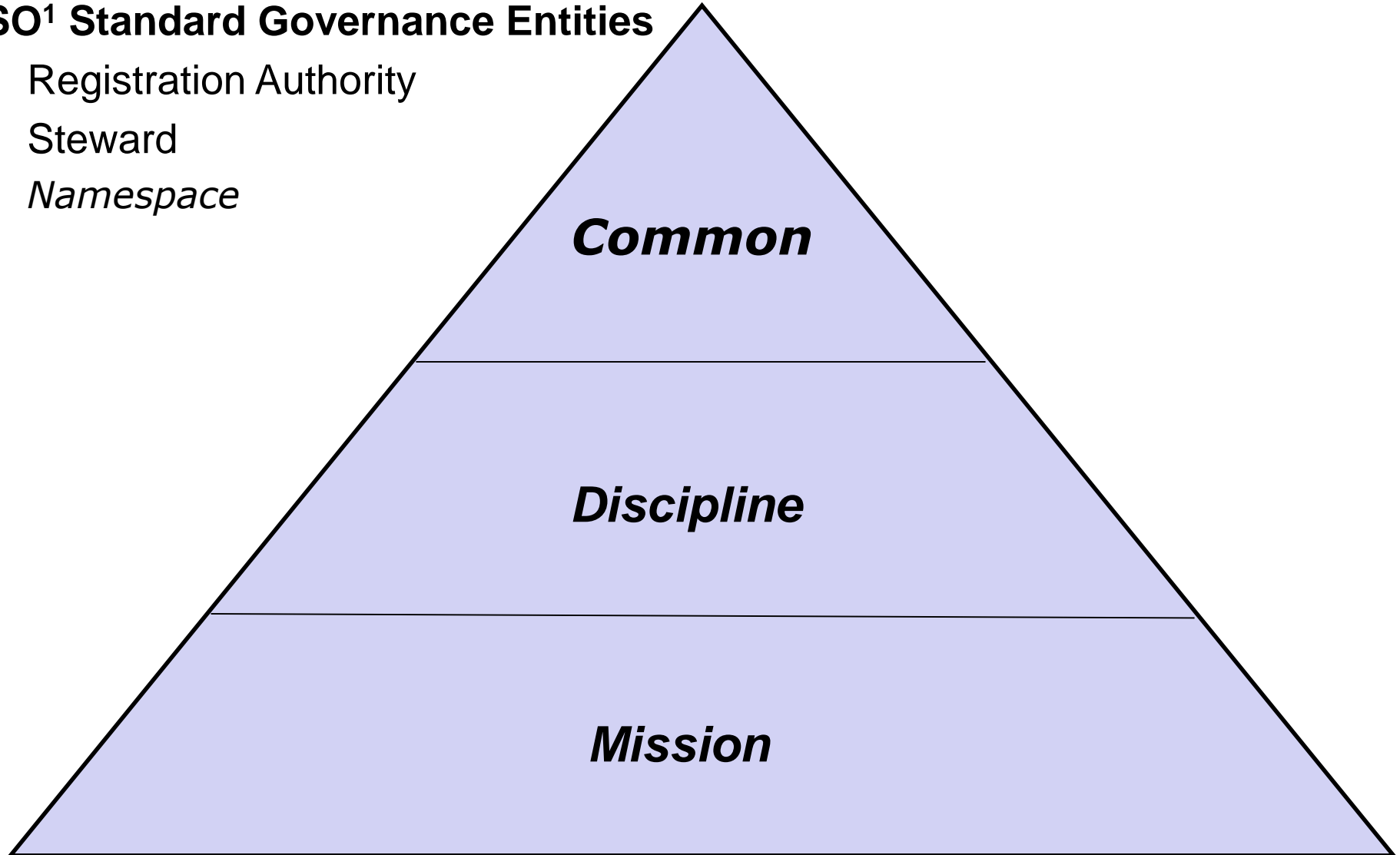
- Captures domain expertise:
  - *science interpretation and use of the data*
  - *context within which the data was captured, processed, and archived*
- Defines:
  - *data structure (format)*
  - *relationships between the data*
- Single authoritative source for the data standards
  - *Promotes a self-describing archive*
- Drives the PDS4 infrastructure by providing:
  - *A sharable, stable, and organized structure of information requirements.*
  - *Formal definitions that are suitable for configuring and generating code.*
- Remains independent of the implementation



# Multi-Level Governance

## ISO<sup>1</sup> Standard Governance Entities

- Registration Authority
- Steward
- *Namespace*



<sup>1</sup>ISO 14721:2003 - Open Archival Information System (OAIS) Reference Model





# - Benefits - Interoperability

- Enables the development of software and services to support interoperability
  - *The Common dictionary provide terminology (syntactic and semantic) that enables interoperability across the entire community*
  - *The Discipline dictionaries enable interoperability within science and engineering disciplines*
    - Cartography and Geometry
    - Rings and Atmospheres
  - *The Mission dictionaries provide a local vocabulary for a mission or project.*



# Minimizes the Impact of Change

- An independent Information Model disentangles the information model from the implementation technology.
  - *Technology changes at a rate different from the domain*
  - *Software and Services can be designed to respond to the information model*
- Multi-level governance limits the impact of change
  - *The Common dictionary is relatively stable*
  - *The Mission and Project dictionaries are localized and more dynamic.*



# Extensions

- Extensions to the model inherit the full capability of the parent model, while retaining the ability to add customized capability.
  - The Common dictionary defines the core entities: products, collections of products, data types, and units of measure
  - The Discipline and Mission reference the common elements as necessary



# A Self Describing Archive

Identification_Area Logical_Identifier Version_Id	
Observation_Area Time_Coordinates Primary_Result_Summary Investigation_Area Observing_System Target_Identification	<i>Discipline_Area</i> <i>Mission Area</i>
Reference_List Internal_Reference External_Reference	
File_Area_Observational File Header Array_2D_Image	



# - Applications - Templates and Product Labels

<Product\_Observational

<Identification\_Area>

<logical\_identifier>urn:nasa:pds:example.dph.sampleproducts:exampleproducts:array2d\_image ...

<version\_id>1.0</version\_id>

<title>MARS PATHFINDER LANDER Experiment</title>

<Array\_2D\_Image>

<local\_identifier>MPFL-M-IMP\_IMG\_GRAYSCALE</local\_identifier>

<offset unit="byte">0</offset>

<axes>2</axes>

<axis\_index\_order>Last Index Fastest</axis\_index\_order>

<Element\_Array>

<data\_type>UnsignedMSB2</data\_type>

<unit>data number</unit>

<scaling\_factor>1</scaling\_factor>

<value\_offset>0</value\_offset>

</Element\_Array>

<Axis\_Array>

<axis\_name>Line</axis\_name>

<elements>248</elements>

<sequence\_number>1</sequence\_number>

</Axis\_Array>

<Axis\_Array>

<axis\_name>Sample</axis\_name>

<elements>256</elements>

<sequence\_number>2</sequence\_number>



# Structure, Semantics, and Rules

```
<xs:complexType name="Array_2D_Image">  
  <xs:annotation>  
    <xs:documentation>The Array 2D Image class is an extension of the  
      Array 2D class and defines a two dimensional  
      image.</xs:documentation>  
  </xs:annotation>  
  <xs:complexContent>  
    <xs:extension base="pds:Array_2D">
```

```
<xs:complexType name="Array">  
  <xs:annotation>  
    <xs:documentation>The Array class defines a homogeneous N-dimensional array of scalars. ...  
  </xs:annotation>  
  <xs:complexContent>  
    <xs:extension base="pds:Byte_Stream">  
      <xs:sequence>  
        <xs:element name="offset" type="pds:offset" minOccurs="1" maxOccurs="1"> </xs:element>  
        <xs:element name="axes" type="pds:axes" minOccurs="1" maxOccurs="1"> </xs:element>  
        <xs:element name="axis_index_order" type="pds:axis_index_order" minOccurs="1" ...  
        <xs:element name="description" type="pds:description" minOccurs="0" maxOccurs="1"> ...  
        <xs:element name="Element_Array" type="pds:Element_Array" minOccurs="1" ...  
        <xs:element name="Axis_Array" type="pds:Axis_Array" minOccurs="1" ...
```

```
<sch:pattern>  
  <sch:rule context="pds:Array/pds:axis_index_order">  
    <sch:assert test=".= ('Last Index Fastest')">  
      The attribute pds:axis_index_order must be equal to the value 'Last Index Fastest'.</sch:assert>
```

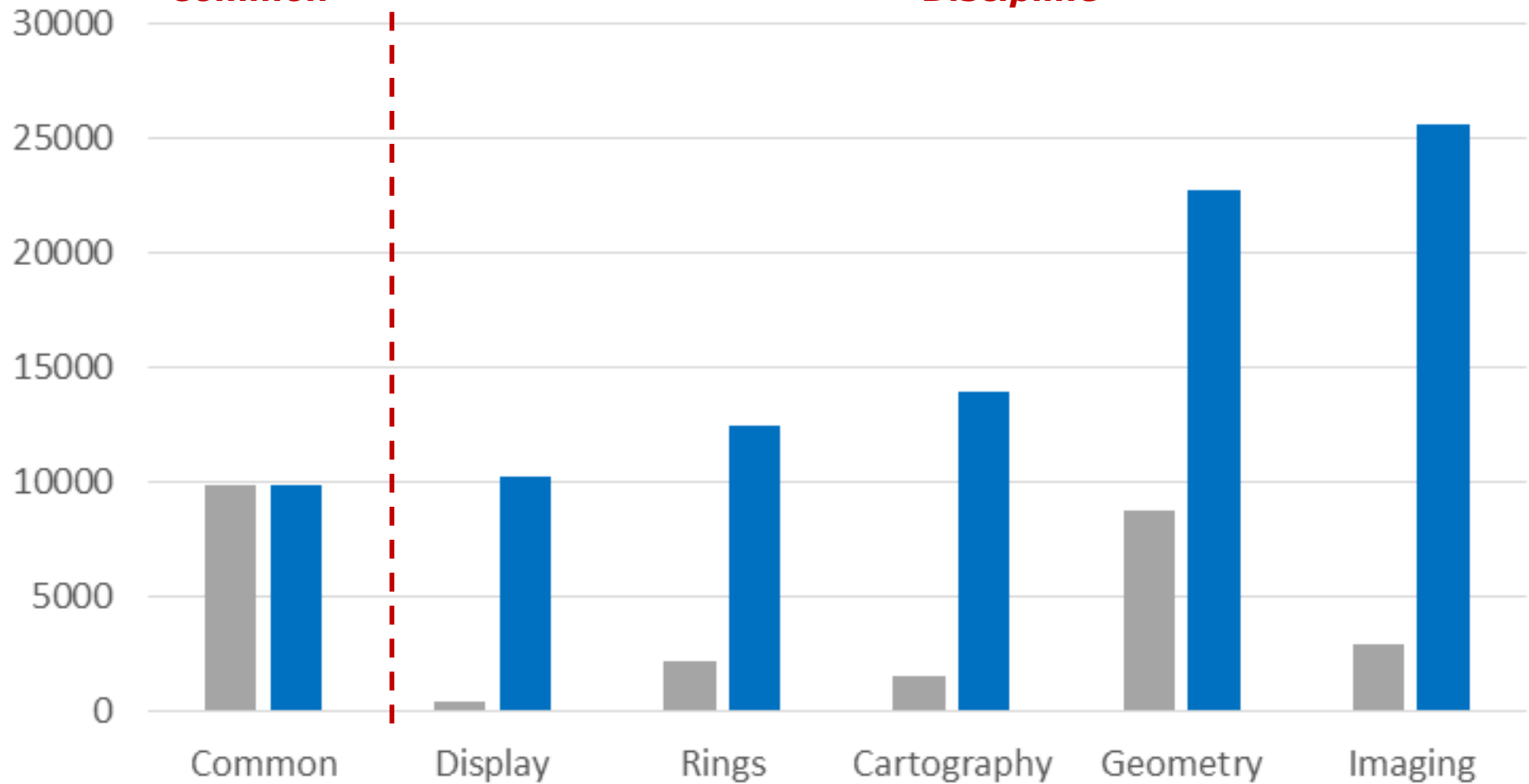


# Validation

## Lines of XML Schema and Schematron

*Common*

*Discipline*





# PLAID

- ✓ Investigation Area
- ✓ Internal Reference
- ✓ Observing System
- ✓ Observing System Component
- ✓ Target Identification
- ✓ File Area Observational
- ✓ File
- ✓ Array 2D
- ✓ Axis Array
- ✓ Element Array
- ✓ Discipline Dictionaries
- ✓ Mission Specifics
- 18. Export**

**Label Template Preview**

```

1 <?xml version="1.0"?>
2 <Product_Observational xmlns="http://pds.nasa.gov"
3   <Identification_Area
4     <logical_idenfier></logical_idenfier>
5     <version_id></version_id>
6     <title></title>
7     <information_model_version></information_model_version>
8     <product_class></product_class>
9   </Identification_Area>
10  <Observation_Area>
11    <Time_Coordinates>
12      <start_date_time></start_date_time>
13      <stop_date_time></stop_date_time>
14    </Time_Coordinates>
15    <Investigation_Area>
16      <name></name>
17      <type></type>
18      <Internal_Reference>
19        <reference_type></reference_type>

```

Filename:  Export

Previous Finish

**Your label template is complete!**

Before exporting your label, please review the preview to ensure your label template is accurate.

After that, please enter a valid\* filename for your label template and then click 'Export'. The file will be available in your Downloads folder.

\*Filename may have characters, digits, underscores, and hyphens. It must start with a character and end with an .xml extension.





# Term Mapping

## Terminological\_Entry

<identifier>pds3:ARM\_ARTICULATION\_STATE.ARTICULATION\_DEVICE\_ANGLE\_NAME

<namespace\_id> pds3

<steward\_id> pds3

<title>ARM\_ARTICULATION\_STATE.ARTICULATION\_DEVICE\_ANGLE\_NAME

<referenced\_identifier>

insight:Instrument\_Parameters insight:index\_value\_angle

<skos\_relation\_name> closeMatch

<instance\_id> npds:Observation\_Area/pds:Discipline\_Area/geom:Geometry

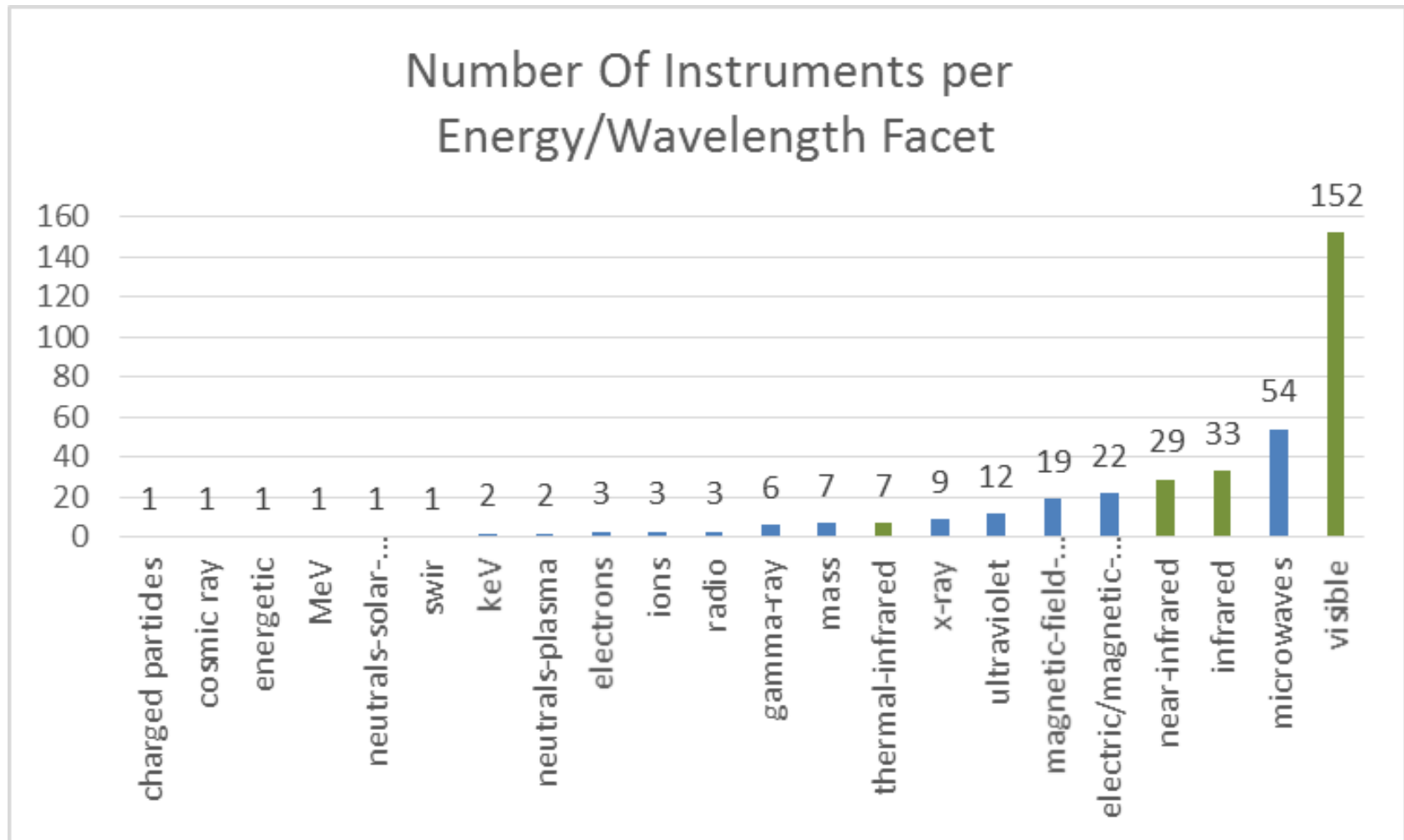
/geom:Geometry\_Lander/geom:Articulation\_Device\_Parameters[1]

/geom:Device\_Angle/geom:Device\_Angle\_Index/geom:index\_value\_angle



# Analytics

Identify data products within the Planetary Data System (PDS) Archive that are scientifically useful for the Exoplanet project.





# Conclusion

- The PDS4 Information Model is the core of the PDS4 Information System.
  - *Provides the Information Requirements for the system.*
  - *Used to help configure common services and software*
  - *Provides the basis for a self-describing archive*
- The semantic and syntactic information in the model is increasingly use to support data analytics
- Being used as a prototype in the development of an implementable architecture for Trusted Digital Repositories.
  - *Open Archival Information System (OAIS) Reference Model – ISO-14721*



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# Thank You

## *Questions and Answers*

PDS homepage: <https://pds.nasa.gov/>

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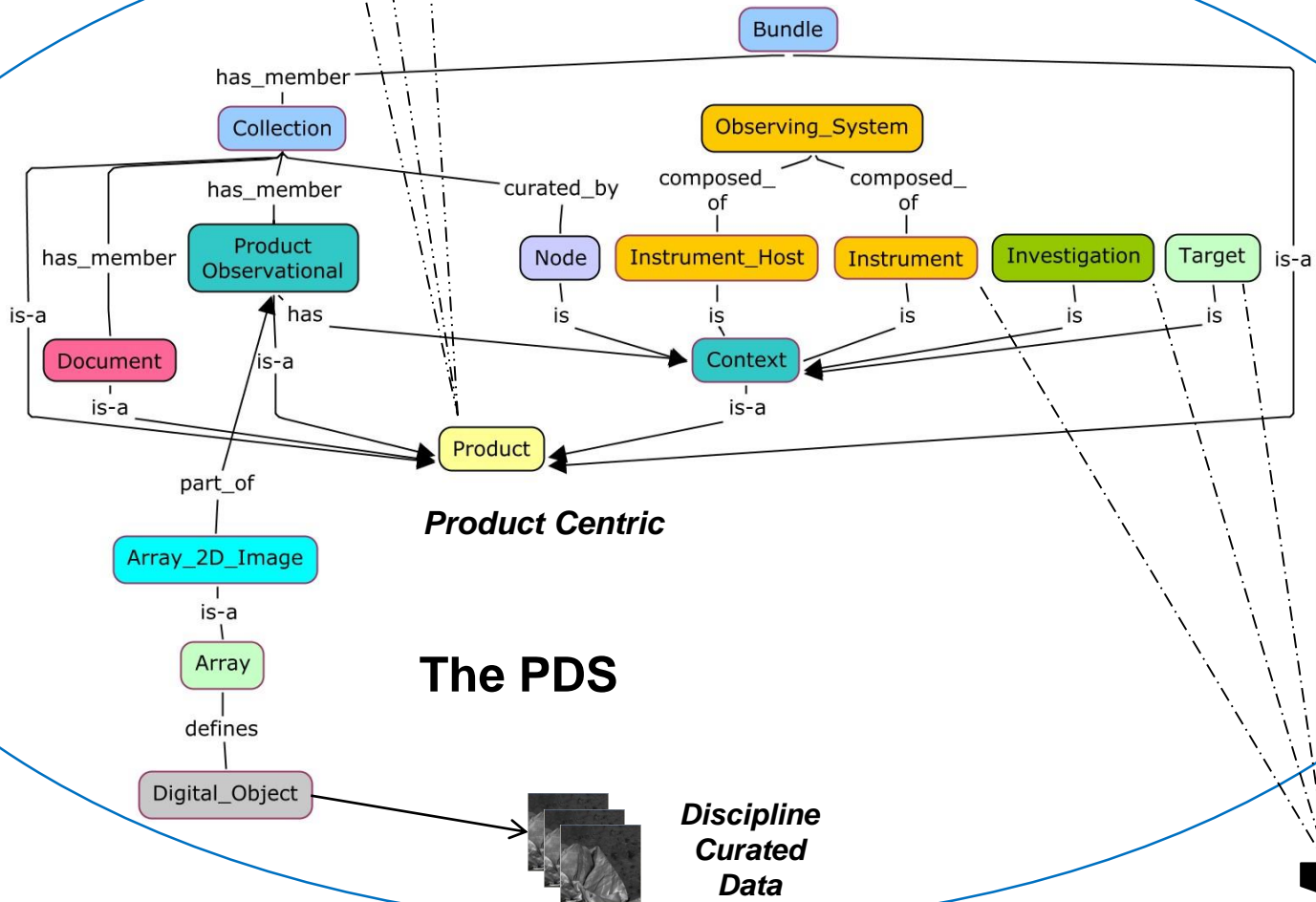
# Backup



# Core Components in Context

Internet Users

Internet Service Endpoints  
*Search, Retrieve, Transport, Transform, ...*



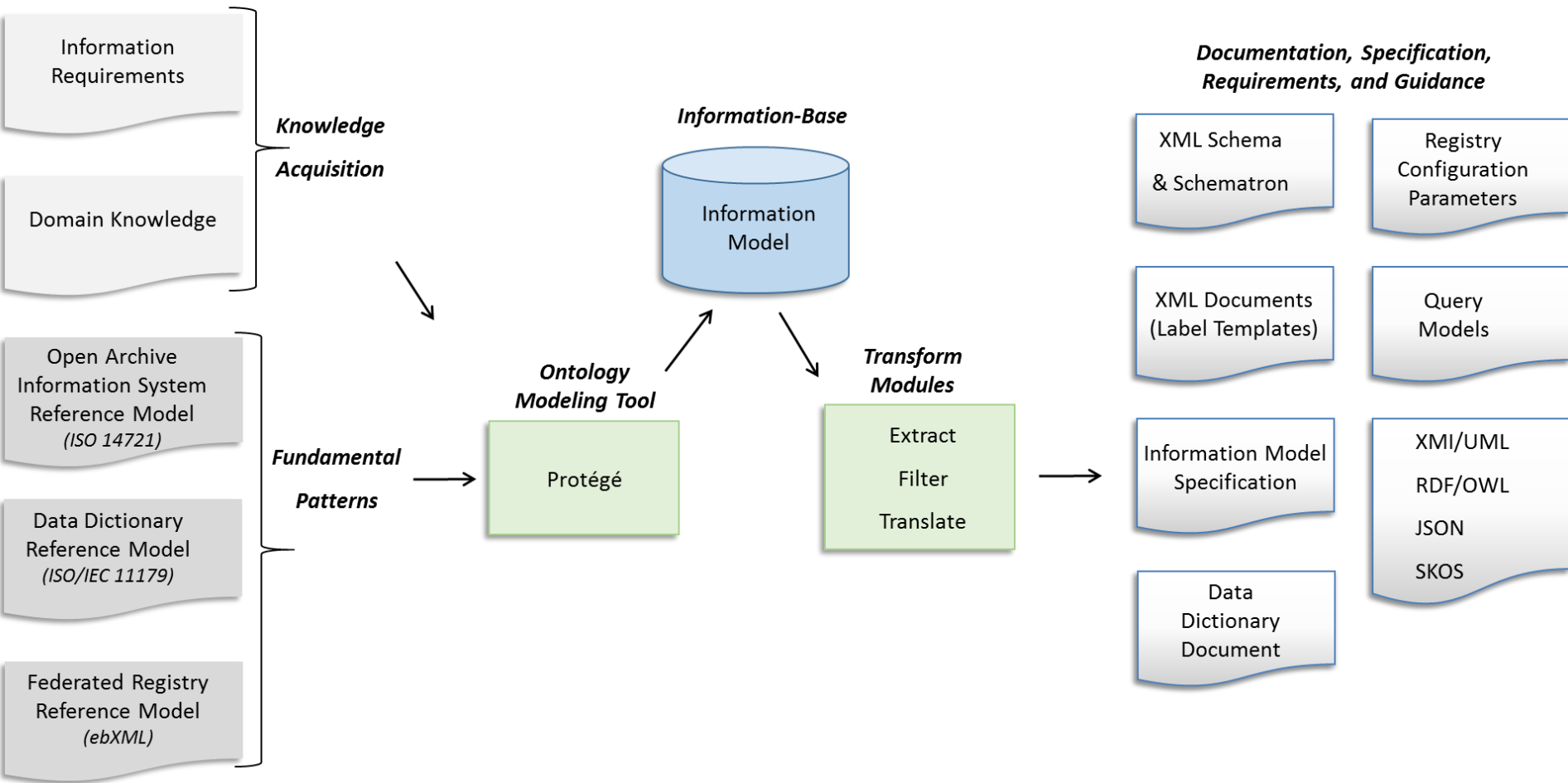


# Dictionaries

Registration Authority	Steward Id	Namespace Id*	XML Schema Namespace	Logical Identifier Prefix	Governance Level	Steward	Oversight
0001_NASA_PDS_1	pds	pds	http://pds.nasa.gov/pds4/pds/v1	urn:nasa:pds:	Common	PDS EN Node*****	CCB
0001_NASA_PDS_1	atm	atm	http://pds.nasa.gov/pds4/atm/v1	urn:nasa:pds:	Discipline	PDS ATM Node	
0001_JAXA_DARTS_1	darts	darts	http://pds.nasa.gov/pds4/darts/v1	urn:jaxa:darts:	Discipline	DARTS (JAXA)	
0001_NASA_PDS_1	en	dph	http://pds.nasa.gov/pds4/dph/v1	urn:nasa:pds:	Discipline	PDS EN Node	
0001_NASA_PDS_1	geo	geo	http://pds.nasa.gov/pds4/geo/v1	urn:nasa:pds:	Discipline	PDS GEO Node	
0001_NASA_PDS_1	geo	geom	http://pds.nasa.gov/pds4/geom/v1	urn:nasa:pds:	Discipline	PDS GEO Node	
0001_NASA_PDS_1	img	cart	http://pds.nasa.gov/pds4/cart/v1	urn:nasa:pds:	Discipline	PDS IMG Node	
0001_NASA_PDS_1	img	disp	http://pds.nasa.gov/pds4/disp/v1	urn:nasa:pds:	Discipline	PDS IMG Node	
0001_NASA_PDS_1	img	img	http://pds.nasa.gov/pds4/img/v1	urn:nasa:pds:	Discipline	PDS IMG Node	
0001_NASA_PDS_1	naif	naif	http://pds.nasa.gov/pds4/naif/v1	urn:nasa:pds:	Discipline	PDS NAIF Node	
0001_NASA_PDS_1	ops	pds	http://pds.nasa.gov/pds4/pds/v1	urn:nasa:pds:	Discipline	PDS EN Node	
0001_NASA_PDS_1	ppi	alt	http://pds.nasa.gov/pds4/alt/v1	urn:nasa:pds:	Discipline	PDS PPI Node	
0001_NASA_PDS_1	ppi	particle	http://pds.nasa.gov/pds4/particle/v1	urn:nasa:pds:	Discipline	PDS PPI Node	
0001_NASA_PDS_1	ppi	ppi	http://pds.nasa.gov/pds4/ppi/v1	urn:nasa:pds:	Discipline	PDS PPI Node	
0001_NASA_PDS_1	ppi	wave	http://pds.nasa.gov/pds4/wave/v1	urn:nasa:pds:	Discipline	PDS PPI Node	
0001_ESA_PSA_1	psa	psa	http://psa.esa.int/psa/v1	urn:psa:esa:	Discipline	ESA PSA	
0001_NASA_PDS_1	rings	rings	http://pds.nasa.gov/pds4/rings/v1	urn:nasa:pds:	Discipline	PDS Rings Node	
0001_NASA_PDS_1	rs	rs	http://pds.nasa.gov/pds4/rs/v1	urn:nasa:pds:	Discipline	PDS RS Node	
0001_ROS_RSSA_1	rssa	rssa	http://pds.nasa.gov/pds4/rssa/v1	urn:ros:rssa:	Discipline	RSSA (IKI)	
0001_NASA_PDS_1	sbn	sbn	http://pds.nasa.gov/pds4/sbn/v1	urn:nasa:pds:	Discipline	PDS SBN	
0001_NASA_PDS_1	sbn	sp	http://pds.nasa.gov/pds4/sp/v1	urn:nasa:pds:	Discipline	PDS SBN	
0001_NASA_PDS_1	atm	ladee	http://pds.nasa.gov/pds4/mission/ladee/v1	urn:nasa:pds:	Mission	PDS ATM Node	
0001_NASA_PDS_1	atm	ladee	http://pds.nasa.gov/pds4/ladee/v1	urn:nasa:pds:	Mission	PDS ATM Node	
0001_NASA_PDS_1	geo	insight	http://pds.nasa.gov/pds4/mission/insight/v1	urn:nasa:pds:	Mission	PDS GEO Node	
0001_NASA_PDS_1	img	mgs	http://pds.nasa.gov/pds4/mission/mgs/v1	urn:nasa:pds:	Mission	PDS IMG Node	
0001_NASA_PDS_1	img	mpf	http://pds.nasa.gov/pds4/mission/mpf/v1	urn:nasa:pds:	Mission	PDS IMG Node	
0001_NASA_PDS_1	sbn	orex	http://pds.nasa.gov/pds4/mission/orex/v1	urn:nasa:pds:	Mission	PDS SBN	
0001_NASA_PDS_1	ppi	mvn	http://pds.nasa.gov/pds4/mission/mvn/v1	urn:nasa:pds:	Mission	PDS PPI Node	
0001_NASA_PDS_1	ppi	mvn	http://pds.nasa.gov/pds4/mvn/v1	urn:nasa:pds:	Mission	PDS PPI Node	
0001_NASA_PDS_1	sbn	bopps	http://pds.nasa.gov/pds4/mission/bopps/v1	urn:nasa:pds:	Mission	PDS SBN	



# The PDS4 Information Model







# UML Class Diagram

