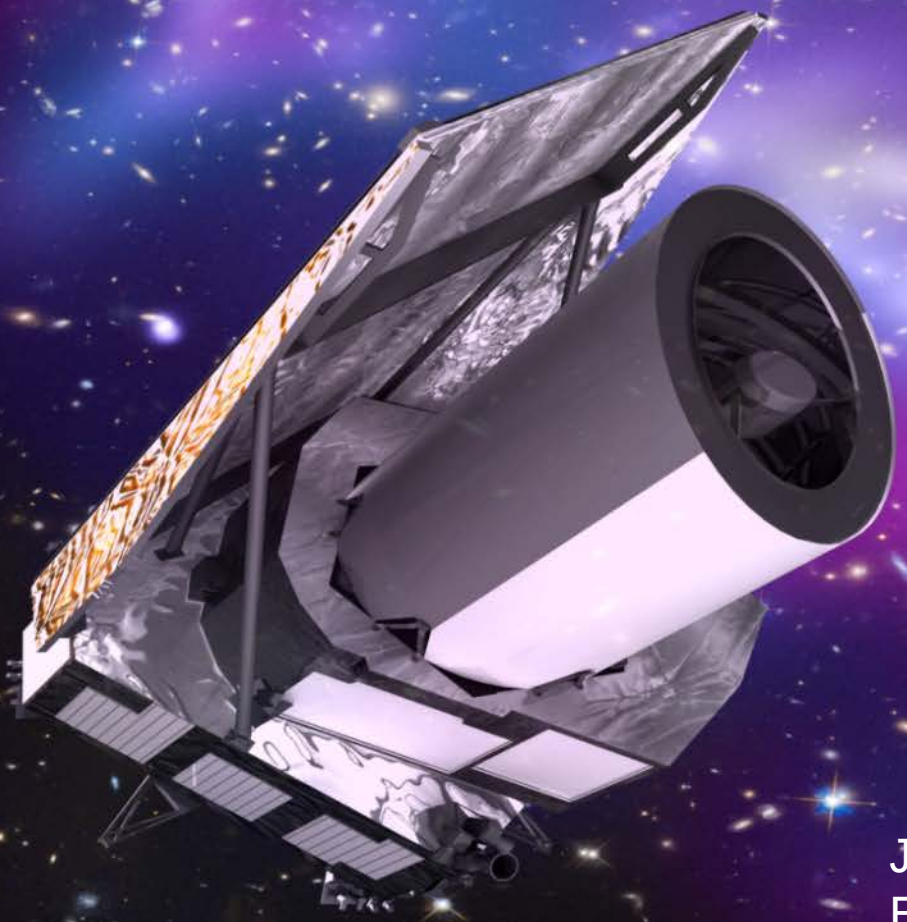
Euclid Requirements Engineering supported by SysML

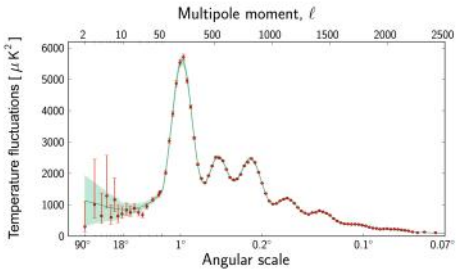


Jose Lorenzo Alvarez
ESTEC
ADCSS - 28/10/2014

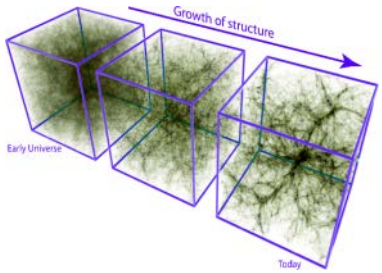
Euclid Mission Overview

Dark Matter

Dark Energy



Ade et al 2013

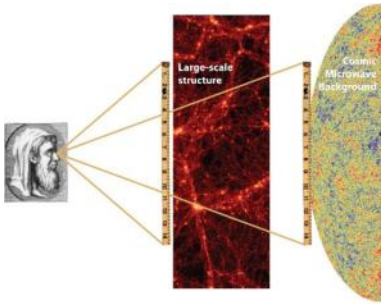


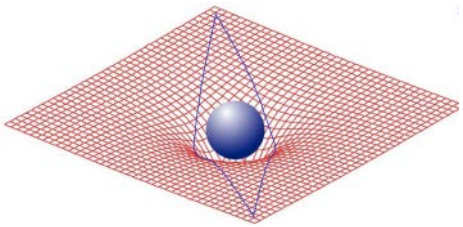
WHAT?
Cosmology beyond the Planck mission:

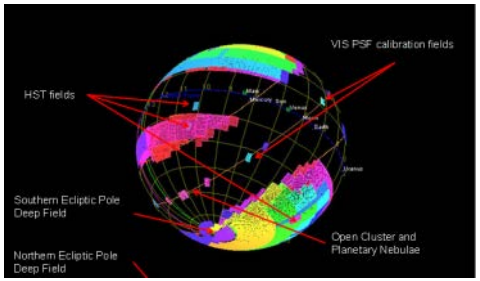
- Dark Matter distribution
- Dark Energy nature

HOW?

- Probed through:
  - BAO
  - Weak Gravitational Lensing







The Mission:

- Large Sky Survey:
  - 15,000 deg2
  - Visible imaging
  - Near-Infrared Photometry
  - Near-Infrared Spectroscopy

Euclid: a global endeavour

ThalesAlenia Space
A Thales / Finmeccanica Company

AIRBUS DEFENCE & SPACE

esa

arianespace service & solutions

SENER

Selex ES
A Finmeccanica Company

Euclid MBSE Approach

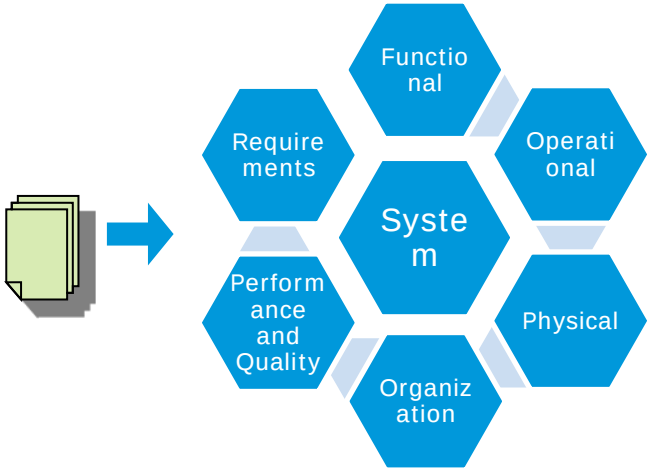
- **Model Based System Engineering (MBSE) approach for Euclid**

– Complex system and requirement interaction

– Several actors in the system: ESA, Industry, NASA, large/distributed Euclid Consortium

– Need to manage information exchange and control efficiently <u>and</u> coherently

– Decided to implement a Model Based System Engineering (MBSE) collaborative approach with Euclid Consortium

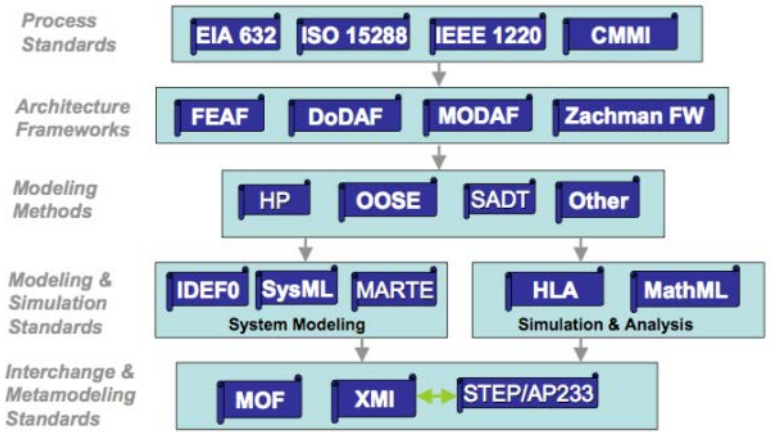


– Two main elements (to date):

  – Euclid Mission System SysML Model

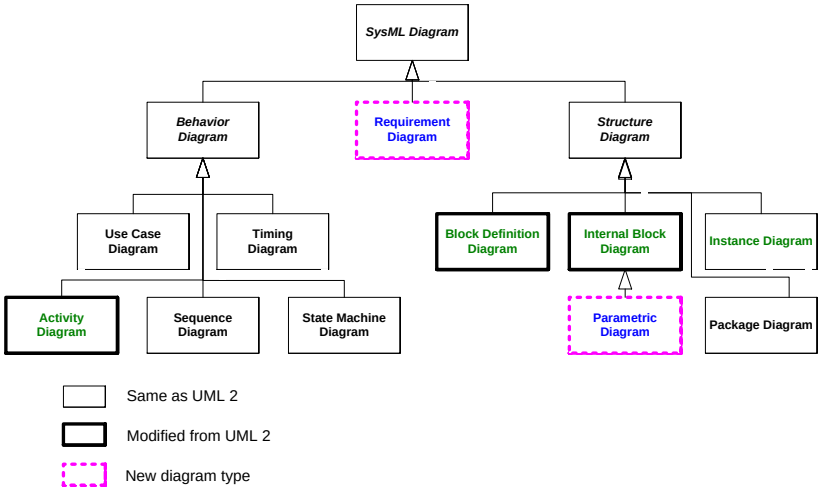
  – Euclid Mission Parameter Database (in development)

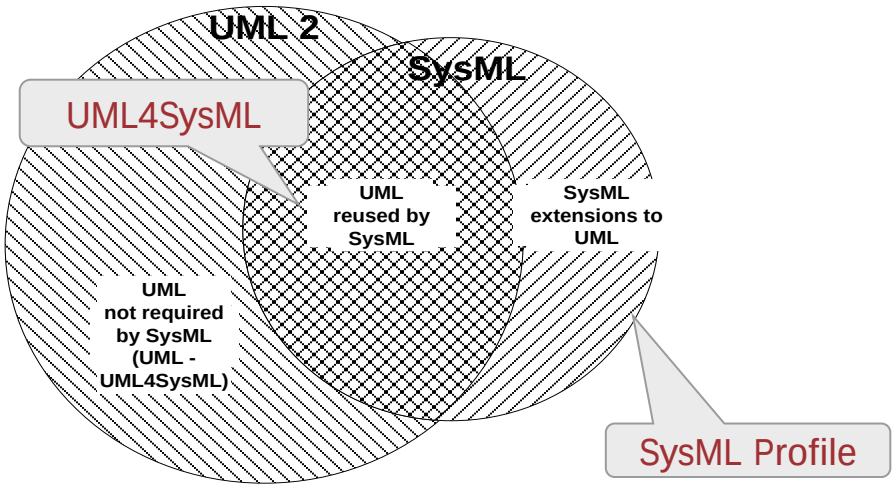
Euclid MBSE Approach



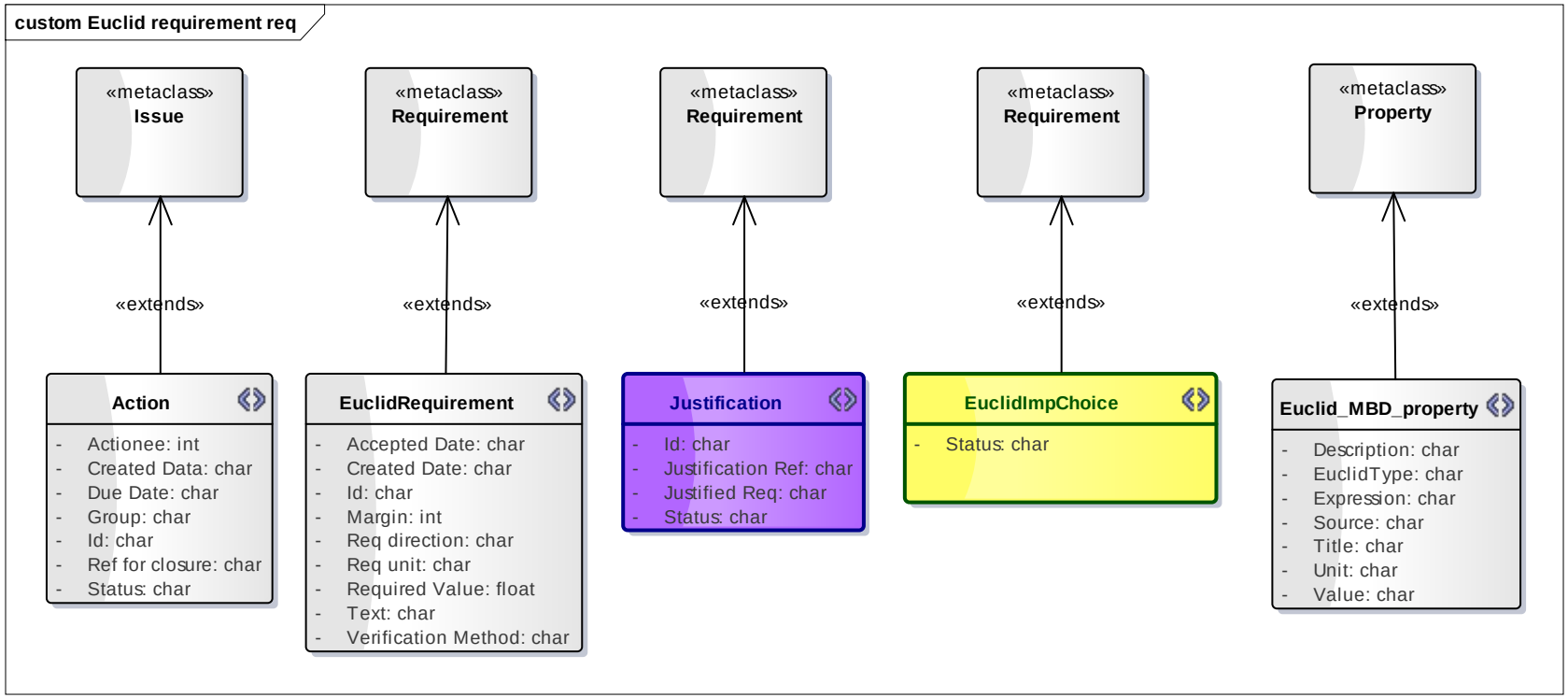
- MBSE framework: selected System Modelling Language (*SysML)*

- Full OMG Systems Modeling Language (OMG SysML) Specification released and available at http://www.omgsysml.org/

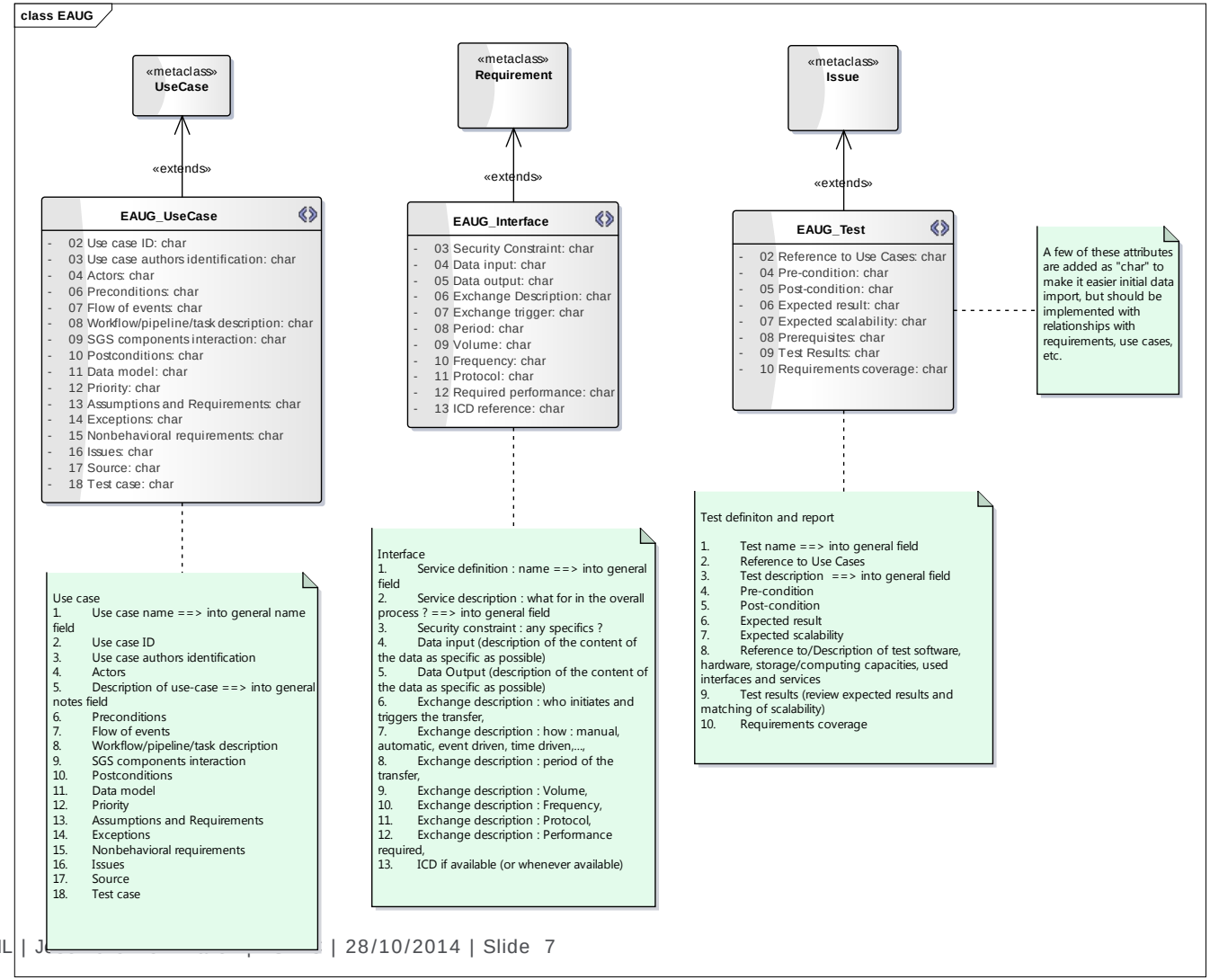




Euclid specific SysML extension



Euclid specific SysML extension



Euclid MBSE Approach

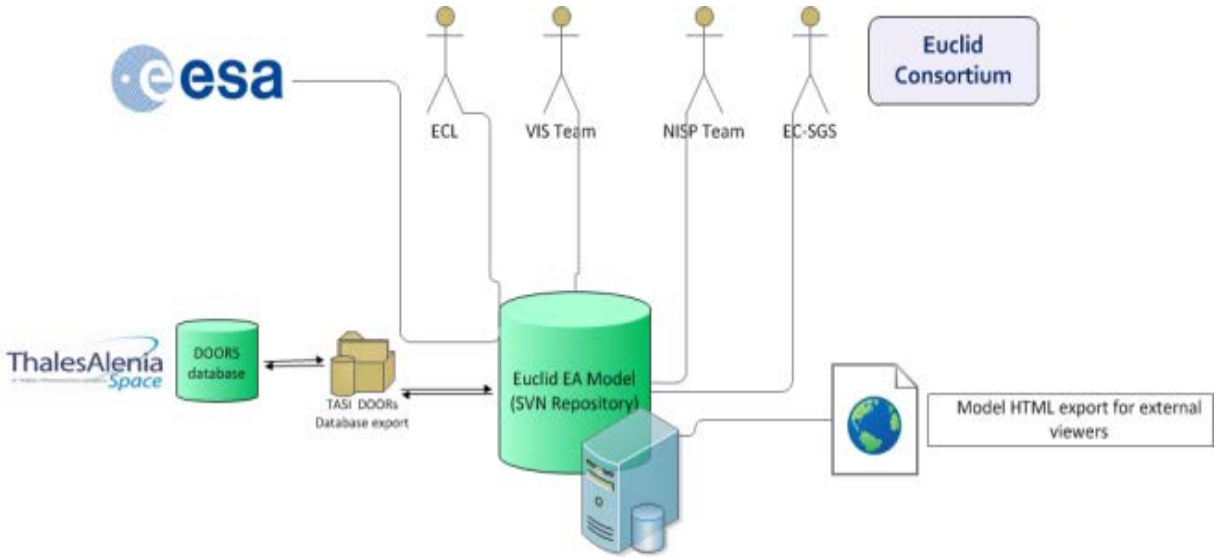
Mission System Engineering Model:

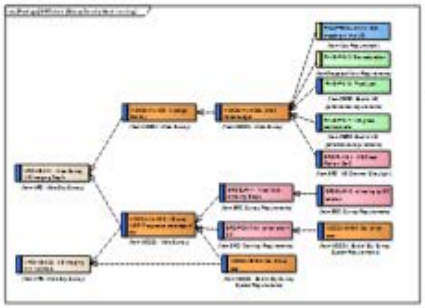
- Tool: *Enterprise Architect* by Sparx Systems

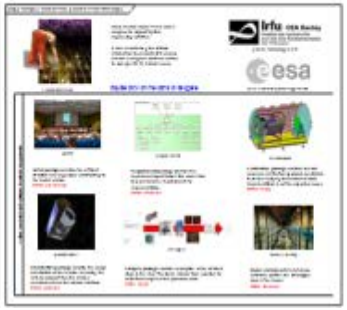
Controls:

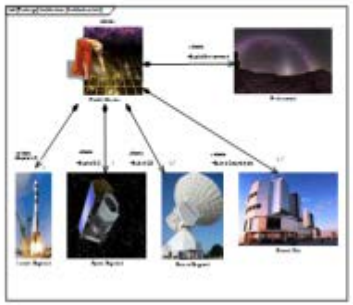
- Requirements baseline, traceability, flow-down and maintenance
- In the future: System architecture and interactions, Verification

The Mission level model is developed and maintain by ESA and the European Consortium Mission system teams.









Euclid SysML Model

pkg Euclid Mission start page

Euclid Mission

Euclid Mission Model: This model is designed to support System Engineering activities.

It aims a containing the suitable information to ensure that the Euclid Mission is designed, built and verified to comply with its mission needs.

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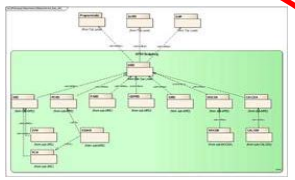
esa
Jose.Lorenzo.Alvarez@esa.int

double click on the icons to navigate.

«allocateActivityPartition» Model Components

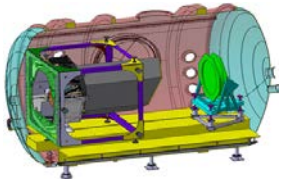
Actor

Actor package describe the different structure and key people contributing to the Euclid Mission.
Status: preliminary



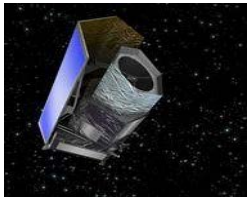
Requirement

Requirement package contains the requirement specification flow down from top level Science Requirements to implementation.
Status: Advanced



Verification

Verification package contains the test cases and verification approach description that allow verifying that current mission implementation meet the expected needs.
Status: empty

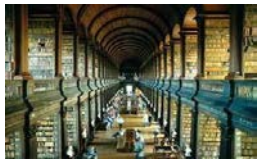


Architecture

Architecture package describe the design architecture of the mission, including the Mission product tree, the Mission environment and the Mission interface.
Status: advanced

Lifecycle

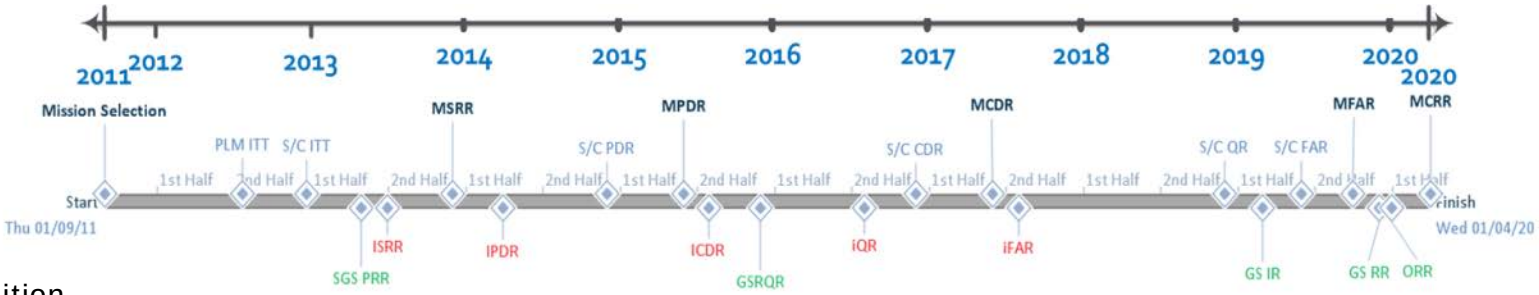
Lifecycle package contains description of the different steps in the life of the Euclid Mission from selection to scientifical analysis of the processed data.
Status: empty



Model Library

Model Library contains reference definition, profiles and stereotypes used in the model.
Status: advanced

Euclid Requirement Engineering



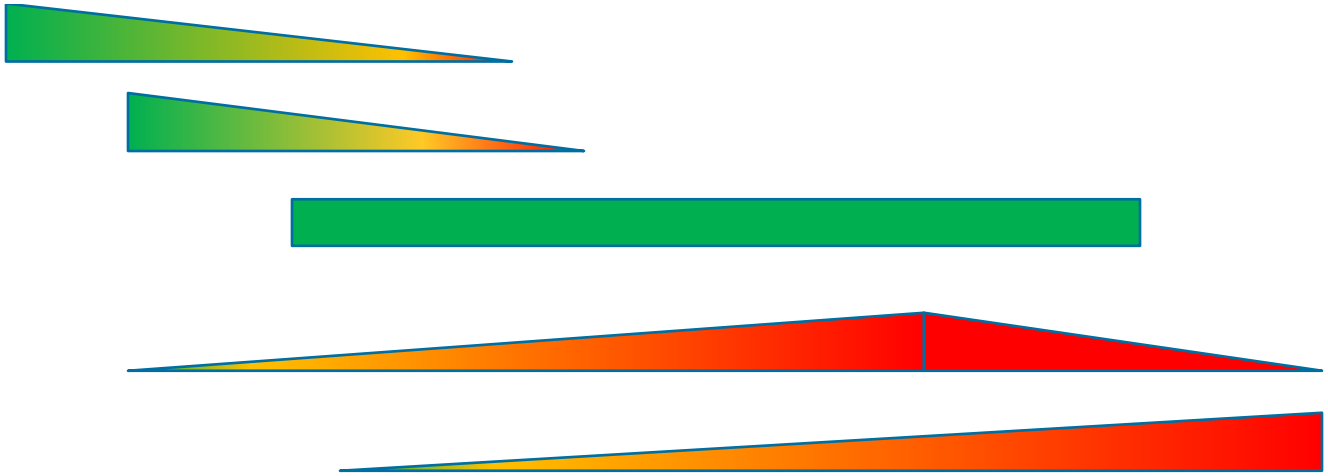
Requirements definition and traceability

Interface Consolidation

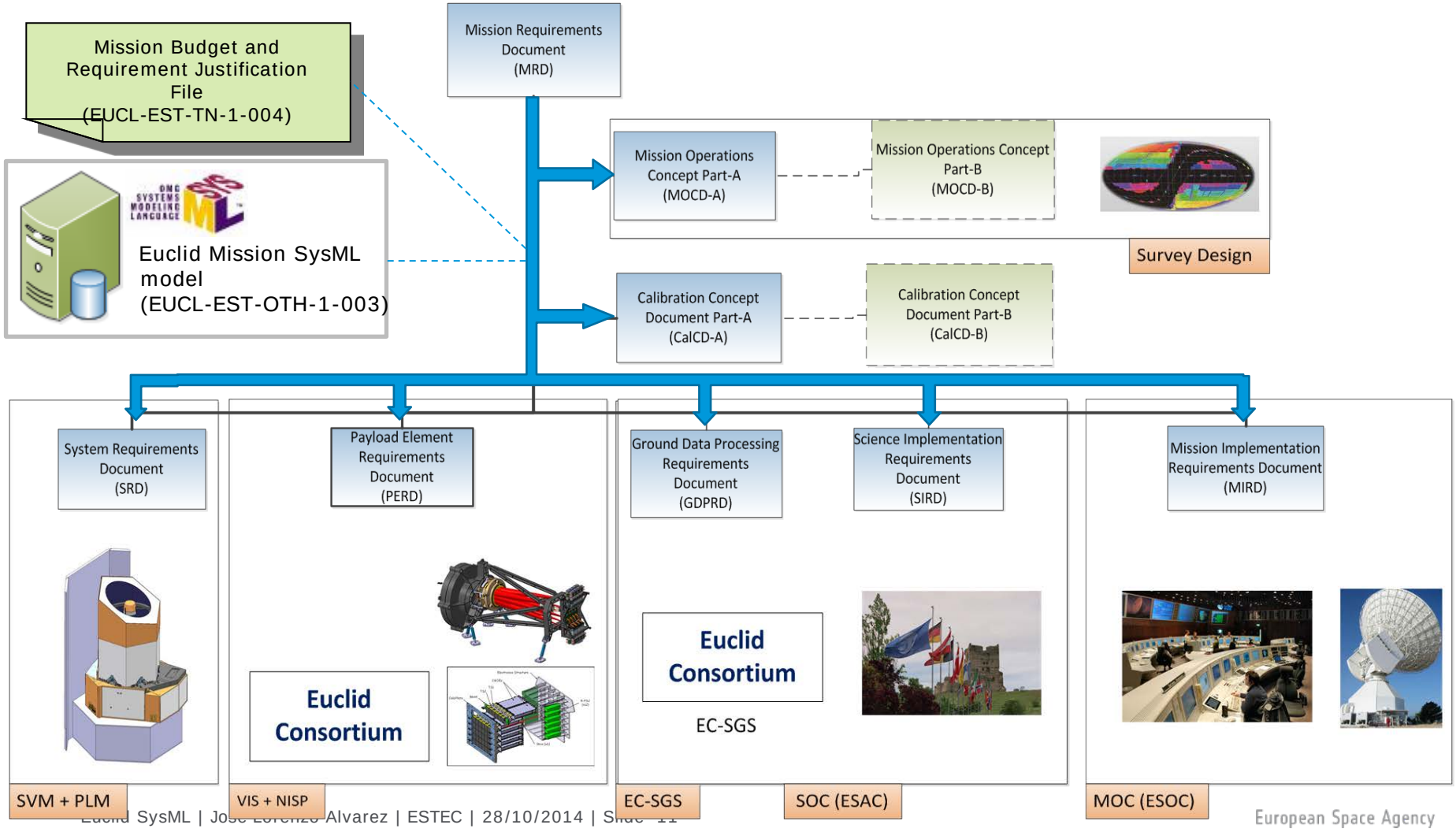
Req. Maintenance & Change Control

Technical Control & tracking

Mission Verification and validation



Euclid Requirement Engineering



Euclid Requirement Engineering

MRD top-level functional requirements

Functions

- Perform Wide Survey: 15,000 deg2
- Perform Deep Survey: 40 deg2
- Visible imaging
- Near-Infrared Slitless Spectroscopy
- Near-Infrared Photometry
- Provide mission data products in a Euclid Legacy Archive (ELA)

Architecture

Space Segment
- Single Telescope
- VIS Instrument provided by EC
- NISP Instrument provided by EC

Ground segment
- MOC at ESOC
- SOC at ESAC
- EC-SGS
- GSN with X & K-band capability

Launch Segment
- Soyuz Launcher

Mission

- Science Lifetime 6 years
- L2 orbit

Agency Constraints

- ECSS Standards
- Decommissioning
- Passivation

Euclid Requirement Engineering

MRD Main Galaxy Clustering Science requirements

Galaxy sample selection

Survey size	15,000 deg^2
	85% survey efficiency
Average Number of galaxies 3500 gal/deg^2 Galaxy redshift distribution	Flux limit Hα-line: $3x10^{-16}$ erg cm^{-2} s^{-1} @ 1600nm
	Flux limit other wavelenghts: $3.6x10^{-16}$ erg cm^{-2} s^{-1}
	Completeness > 45%
Median redshit 0.7<Z<2.05	NISP-P spectral range 1100-2000nm

Spectroscopic red-shift determination

Redshift (z) precision, uncertainty and systematic offset (see SciRD)	Wavelength error
	NISP-S Imaging of the NISP-P field with sensitivity m_{AB} = 24 (5σ)
	Spectral resolution > 250
Redshift catastrophic error fraction f_{cat} < 0.2% And f_{cat} knowledge better than 1%	Z measurement purity > 80%
	Subsample with purity > 99%
	External data under EC responsibility

Euclid Requirement Engineering

MRD Main Weak-Lensing Science requirements

Galaxy Shape Measurement

Galaxy sample selection

Survey size	15,000 deg^2
	85% survey efficiency
Average Galaxy density 30 deg^2	Sensitivity: mAB = 24.5 (10σ)
Median redshit Z>0.8	VIS spectral range 550-900mn

Measurement Bias Control

VIS PSF Shape	FWHM < 0.18”
	$\varepsilon_i < 0.15$
	$\left(\frac{R_{PSF}}{R_{ref}}\right)^2 < 4$
VIS PSF knowledge	$\frac{\sigma(R_{PSF})^2}{\langle R^2 \rangle} < 10^{-3}$
	$\sigma(\varepsilon_i) < 2\text{x}10^{-4}$
Distortion	Residual < 0.003%
CTI effects	$\sigma(\varepsilon_{NC})$ < 1.1x10-4
Shear Model bias	Additive $\sigma[c]$ < 5x10-4
	Multiplicative $\sigma[\mu] < 2\text{x}10^{-3}$

Photometric red-shift determination

Photo-z precision and uncertainty

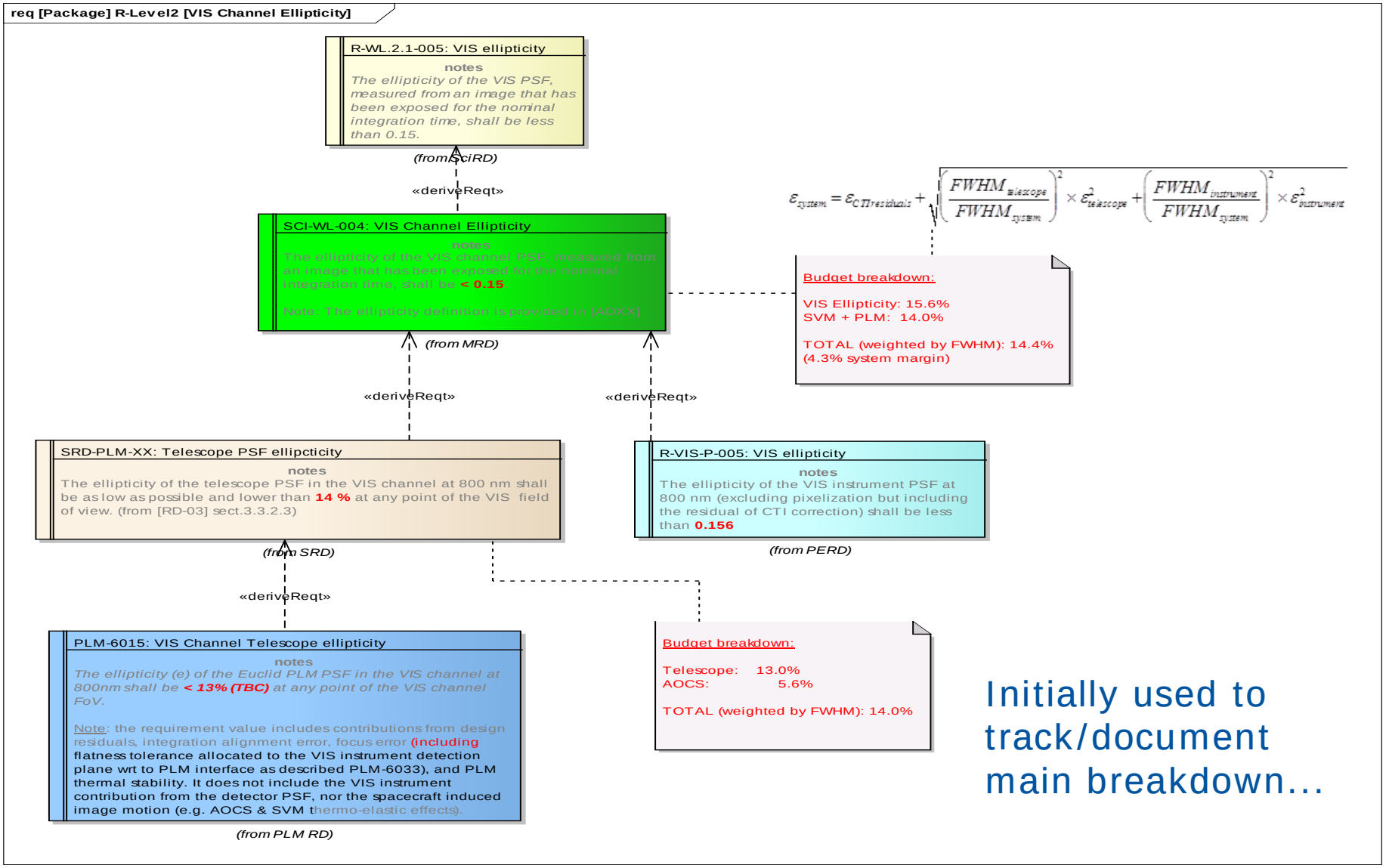
σ(z)/(1+z) < 0.05

σ(<z>)/(1+z) <0.002

f_{cat} < 10%

Image quality	Encircled Energy
	Pixel scale: 0.3”/pix
Sensitivity	m_{AB} = 24 (5σ) in all bands
Calibration	Relative Photometric error post-calibration <1.5%
Number of photo-z bins	NISP-P wavelength range
	3 Euclid NIR bands
	External g,r,i,z data under EC responsibility

Euclid Requirement Engineering



Initially used to track/document main breakdown…

Euclid Requirement Engineering

MRD Main Weak-Lensing Science requirements

Progressive growth to full req. complexity

Galaxy Shape Measurement

Galaxy sample selection

- Survey size
  - 15,000 deg^2
  - 85% survey efficiency
- Average Galaxy density 30 deg^2
  - Sensitivity: mAB = 24.5 (10σ)
- Median redshit Z>0.8
  - VIS spectral range 550-900mn

Measurement Bias Control

- VIS PSF Shape
  - FWHM < 0.18”
  - $\varepsilon_i < 0.15$
  - $\left(\frac{R_{PSF}}{R_{ref}}\right)^2 < 4$
- VIS PSF knowledge
  - $\frac{\sigma(R_{PSF})^2}{\langle R^2 \rangle} < 10^{-3}$
  - $\sigma(\varepsilon_i) < 2\text{x}10^{-4}$
- Distortion
  - Residual < 0.003%
- CTI effects
  - $\sigma(\varepsilon_{NC})$ < 1.1x10-4
- Shear Model bias
  - Additive $\sigma[c]$ < 5x10-4
  - Multiplicative $\sigma[\mu] < 2\text{x}10^{-3}$

R-WL.2.1-0

(from SciRD: R Weak

Photometric red-shift determination

- Photo-z precision and uncertainty
  - σ(z)/(1+z) < 0.05
  - σ(<z>)/(1+z) <0.002
  - f_{cat} < 10%
- Image quality
  - Encircled Energy
  - Pixel scale: 0.3”/pix
- Sensitivity
  - m_{AB} = 24 (5σ) in all bands
- Calibration
  - Relative Photometric error post-calibration <1.5%
- Number of photo-z bins
  - NISP-P wavelength range
  - 3 Euclid NIR bands
  - External g,r,i,z data under EC responsibility

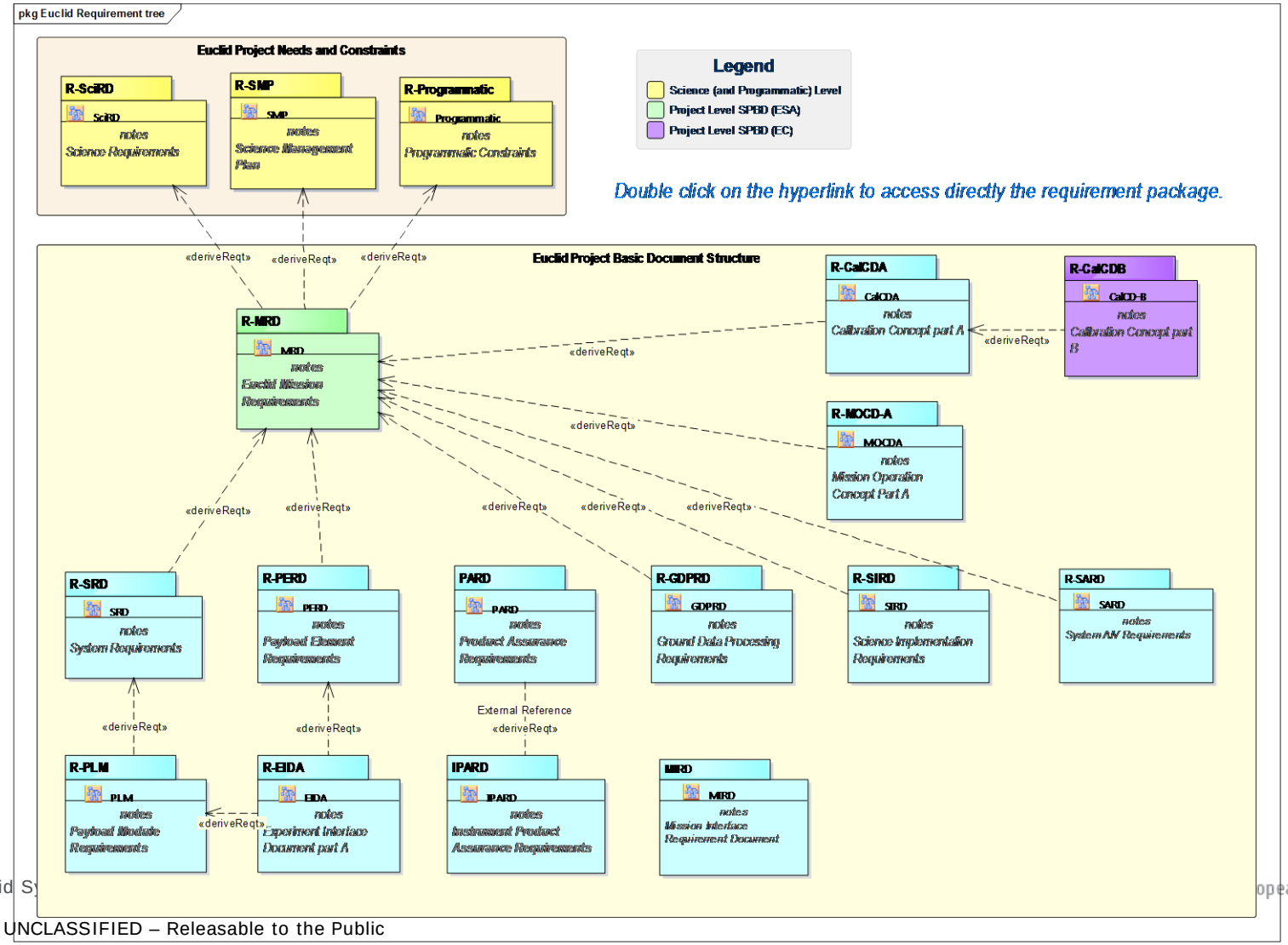
R-VIS-P-005: VIS instrument ellipticity <0.156

(from PERD: Euclid VIS performance requirements)

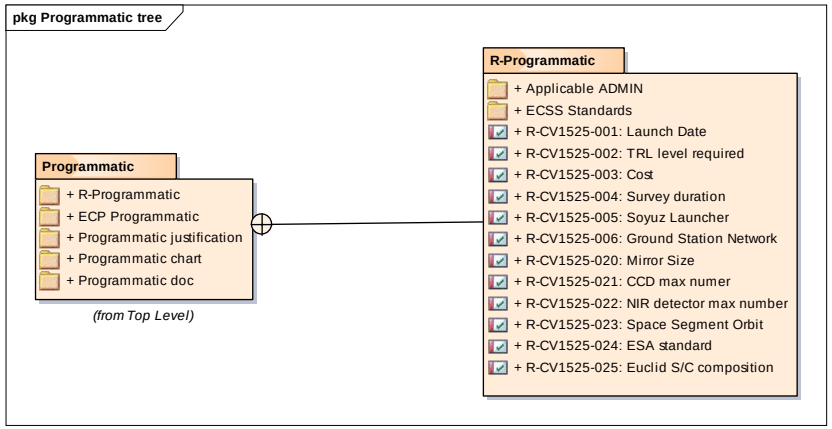
Legend

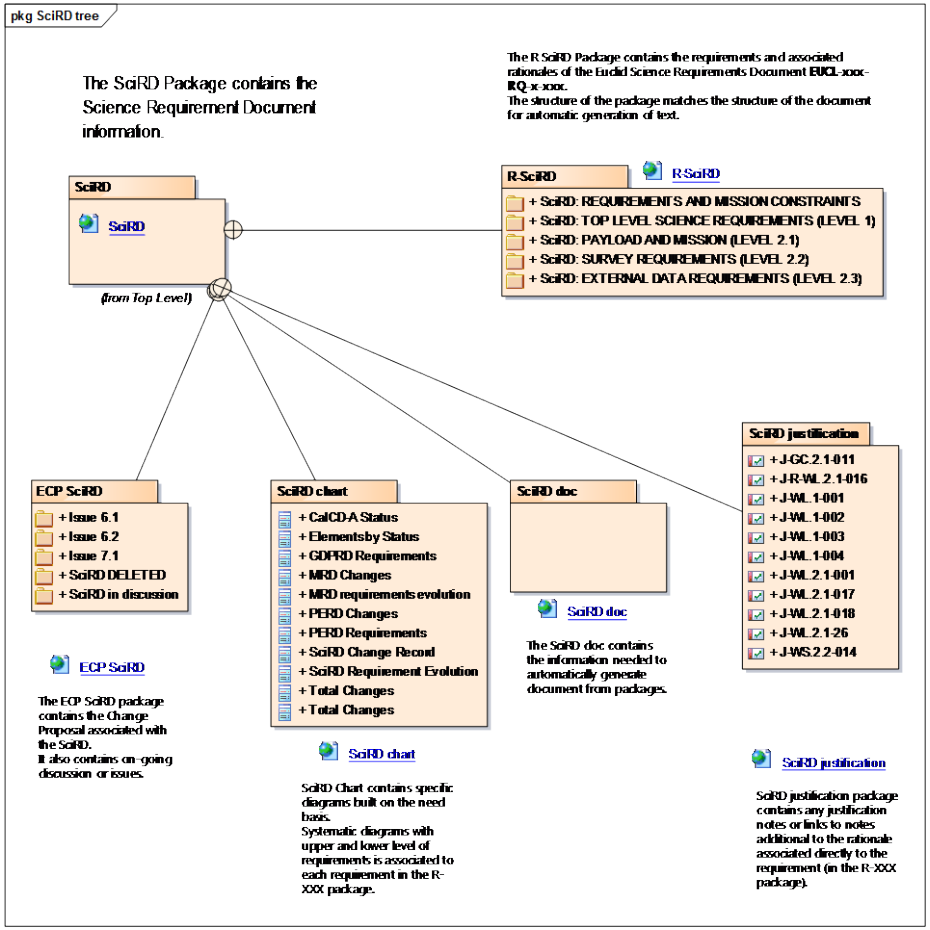
- SciRD Requirement
- PERD Requirement
- MRD Requirement
- MOCD Requirement
- MIRD Requirement
- SRD Requirement
- GDPRD Requirement
- CalCD-A requirement
- EID-A Requirement
- SIRD requirement
- Justification

Euclid Model Organization



Euclid Model Organization

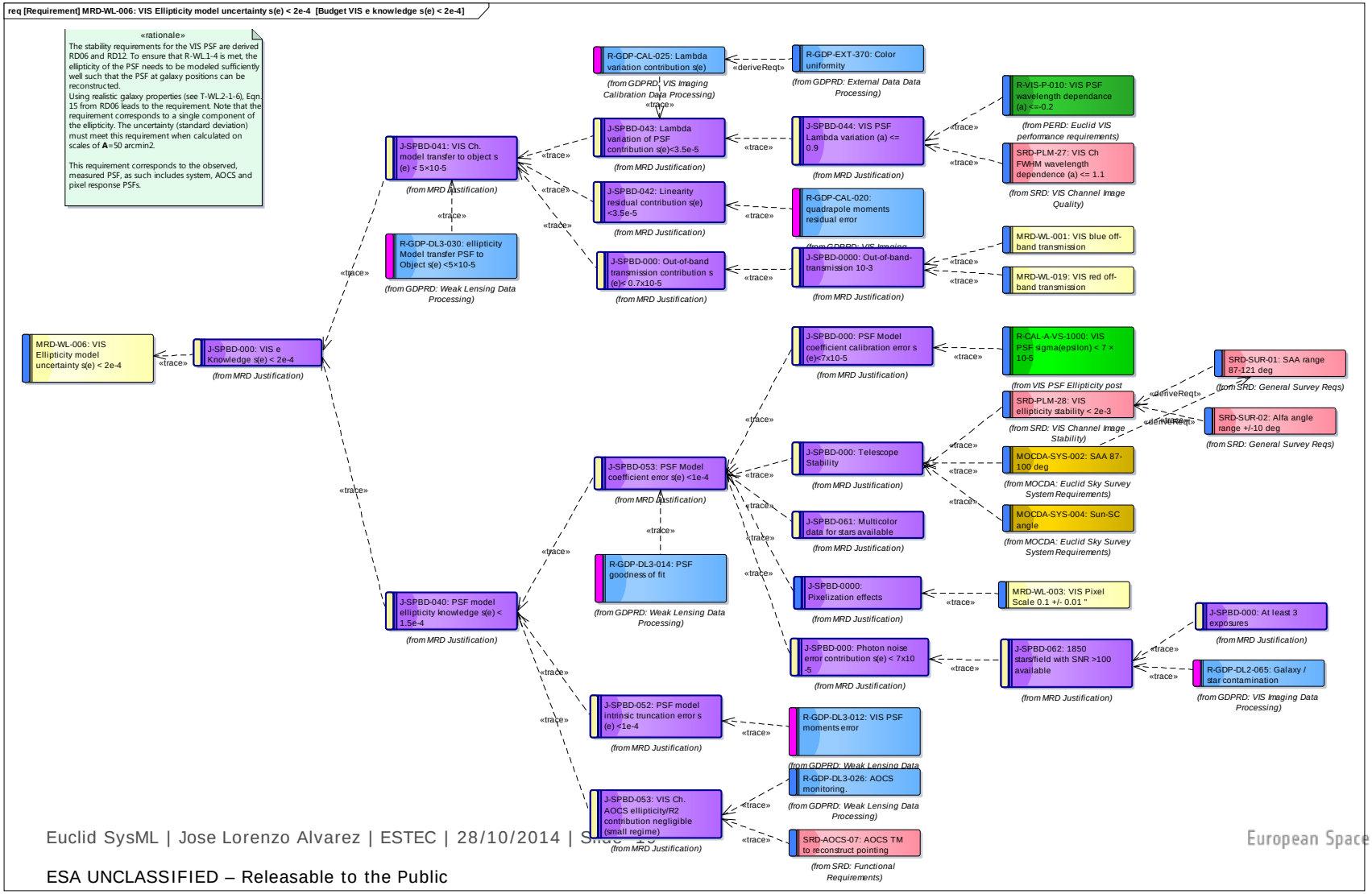




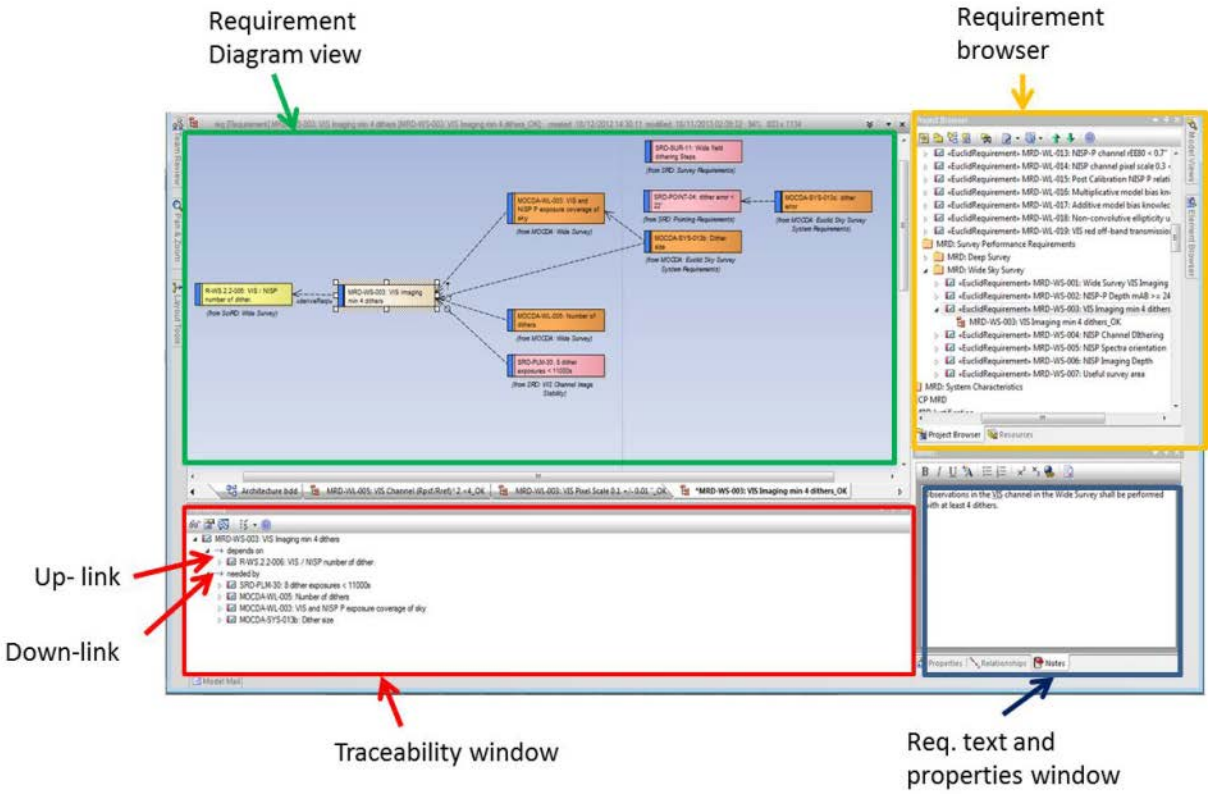
All top level requirements implemented and traceable in the EA SysML model:

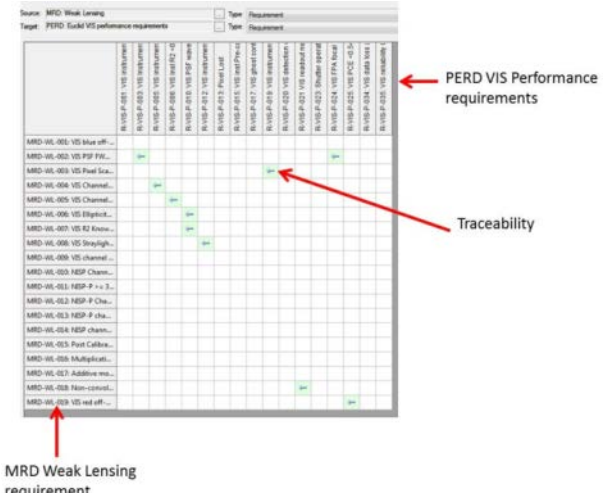
- NISP instrument and SGS requirements created and maintained in EA model
- Industry requirements liked from DOORs database.
- Changes generated and managed in model.

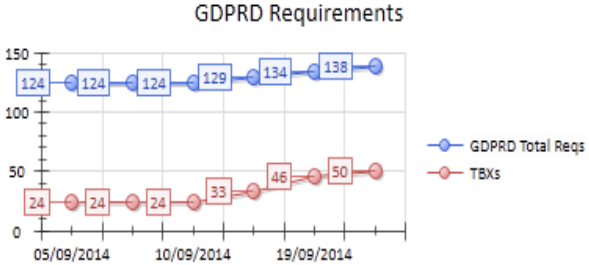
Benefits: Full justification logic track

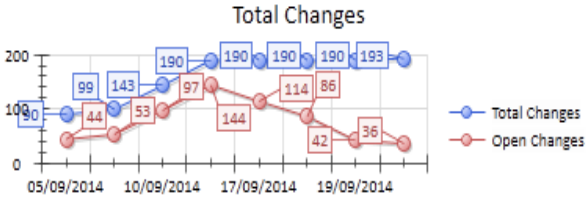


Benefits: Requirement Traceability and control





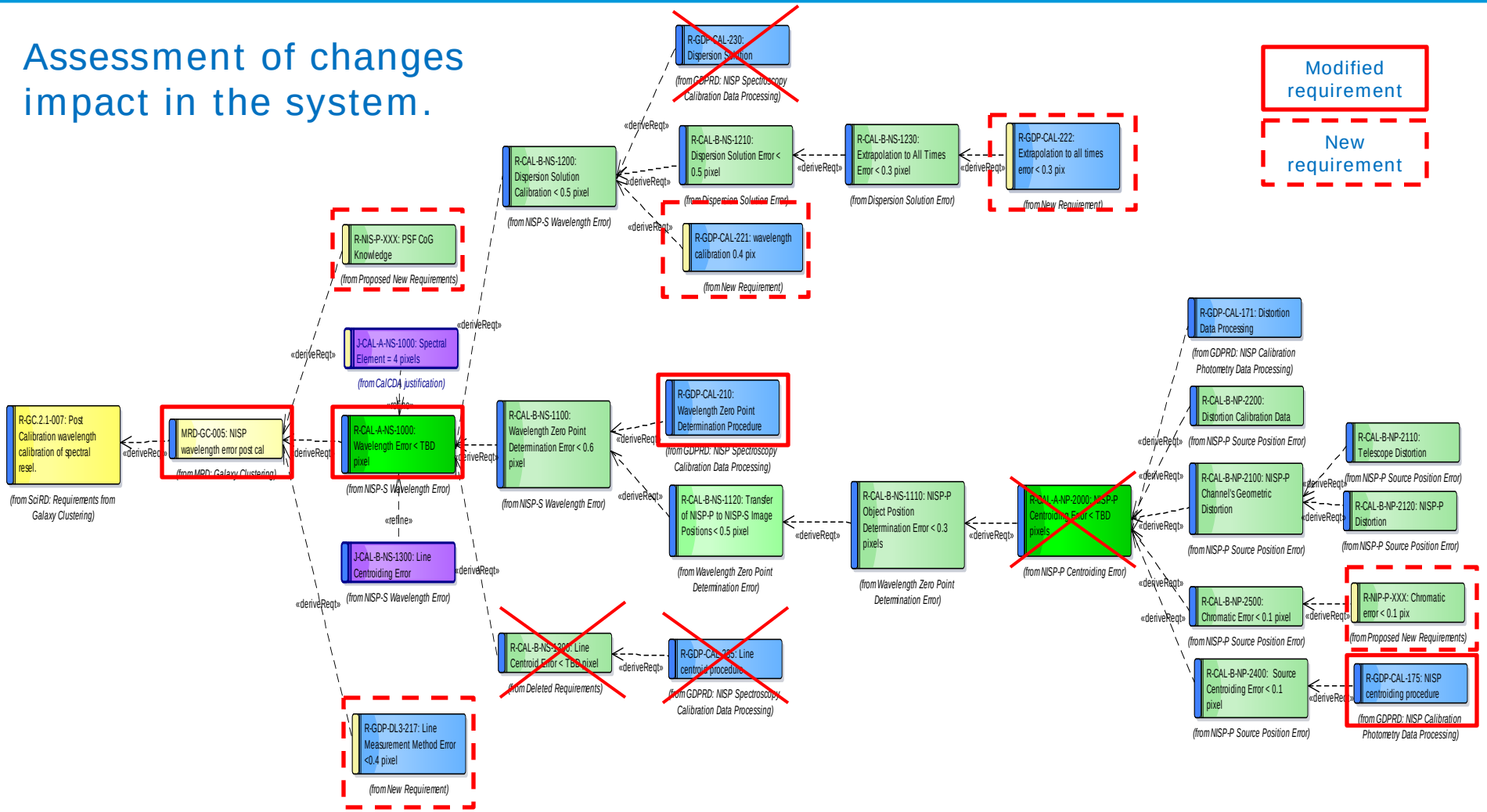




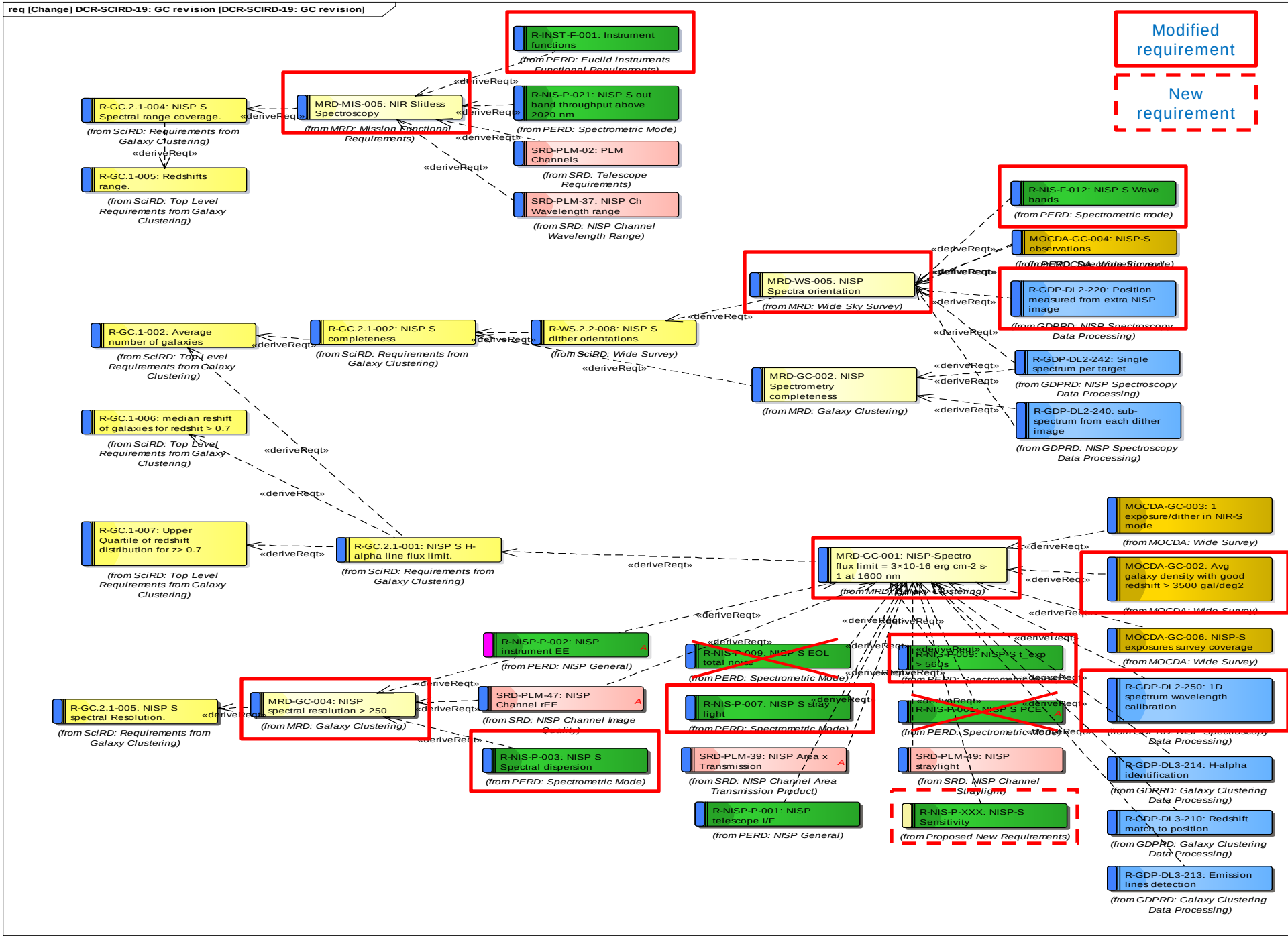
- Model IS the Mission System Engineering control tool.
- Traceability matrixes generated from model.
- Requirement related KPIs to track the system health and progress.

Benefits: adequate requirement change impact assessment

Assessment of changes impact in the system.



req [Change] DCR-SCIRD-19: GC revision [DCR-SCIRD-19: GC revision]



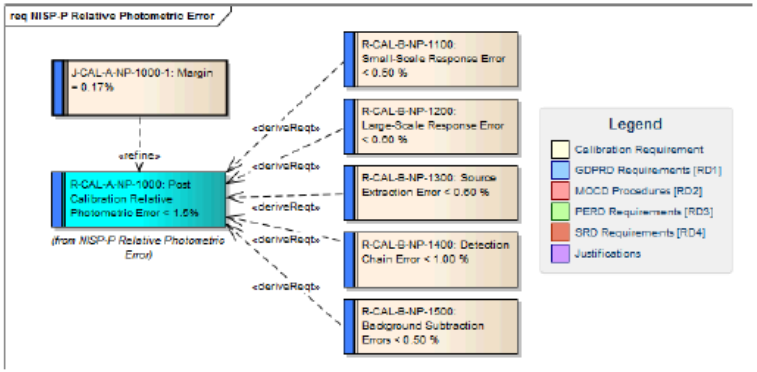
Requirement Document Generation

- Requirement document generation and maintenance from model
  - Still some documentation generated “manually”: ESA/Industry paradigm shift to MBSE not mature enough
  - SGS, NISP, Calibration Control Document Part-B, Requirement Justification File fully generated from Model
  - Model includes configuration control through baselines => Consistency ensured across documents.

Euclid consortium	**Calibration Concept Document: Part B**	Ref: EUC-MPIA-RD-1-001 Version: 3.0 Date: 01 / 09 / 2014 Page: 22 / 175

6.1 NISP-P Relative Photometric Error

This sub-section details the requirement flow for the NISP-P's Relative Photometric Error. We assume that all the contributing errors are uncorrelated and can be added in quadrature. As the small- and large-scale instrument response allocations are significant, they are separated from the other detector effects.



Name	Requirement	Parent ID
R-CAL-B-NP-1100: Small-Scale Response Error < 0.50 %	After calibration, small scale (< 100 pixels) NISP-P channel response non-uniformities shall contribute < 0.50 % to the NISP-P relative photometric error.	R-CAL-B-NP-1100 R-CAL-B-NP-1100 R-CAL-B-NP-1100 R-CAL-B-NP-1100 R-CAL-A-NP-1000
R-CAL-B-NP-1200: Large-Scale Response Error < 0.60 %	After calibration, large scale (>= 100 pixels) NISP-P channel response non-uniformities shall contribute < 0.60 % to the NISP-P relative photometric error.	R-CAL-B-NP-1200 R-CAL-B-NP-1200 R-CAL-B-NP-1200 R-CAL-B-NP-1200

Beyond requirement management

pkg Euclid Mission start page

Euclid Mission

Euclid Mission Model: This model is designed to support System Engineering activities.

It aims a containing the suitable information to ensure that the Euclid Mission is designed, built and verified to comply with its mission needs.

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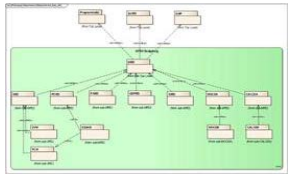
esa
Jose.Lorenzo.Alvarez@esa.int

double click on the icons to navigate.

«allocateActivityPartition» Model Components

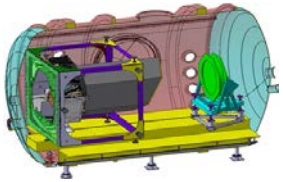
Actor

Actor package describe the different structure and key people contributing to the Euclid Mission.
Status: preliminary



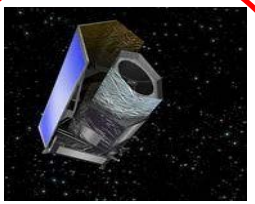
Requirement

Requirement package contains the requirement specification flow down from top level Science Requirements to implementation.
Status: Advanced



Verification

Verification package contains the test cases and verification approach description that allow verifying that current mission implementation meet the expected needs.
Status: empty

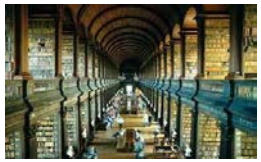


Architecture

Architecture package describe the design architecture of the mission, including the Mission product tree, the Mission environment and the Mission interface.
Status: advanced

Lifecycle

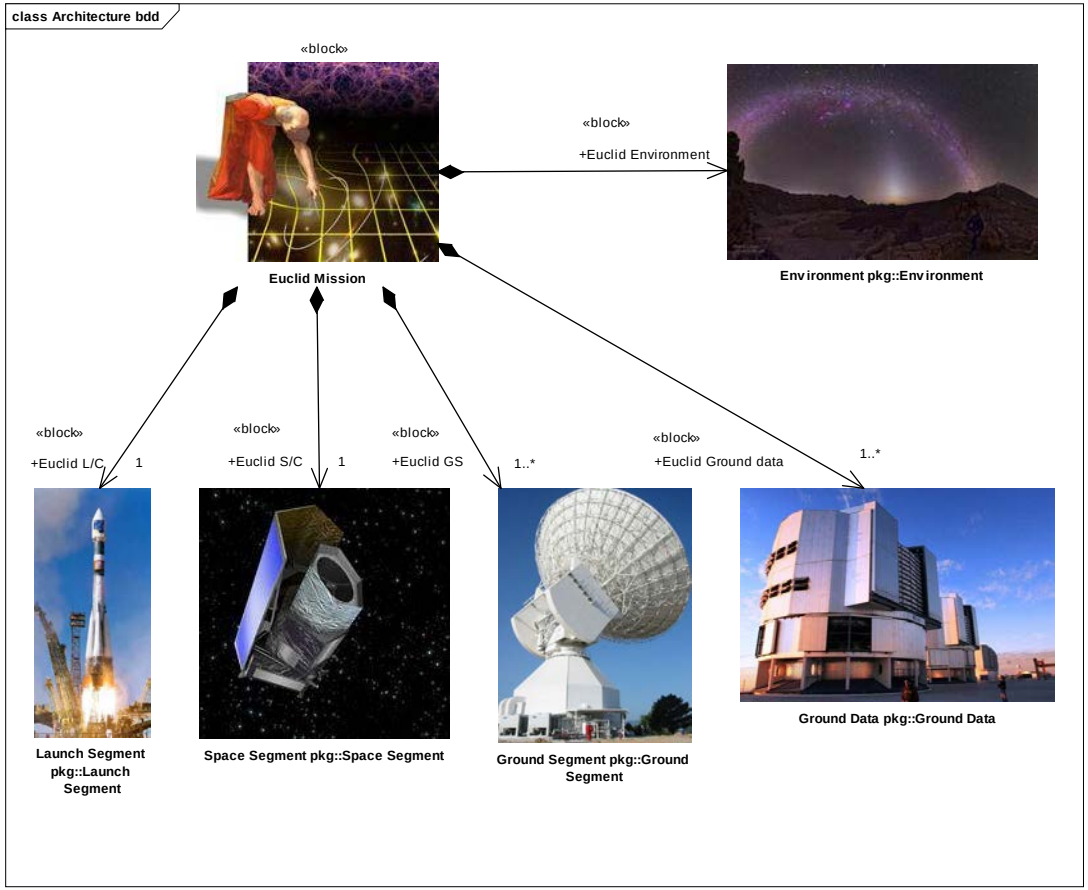
Lifecycle package contains description of the different steps in the life of the Euclid Mission from selection to scientifical analysis of the processed data.
Status: empty



Model Library

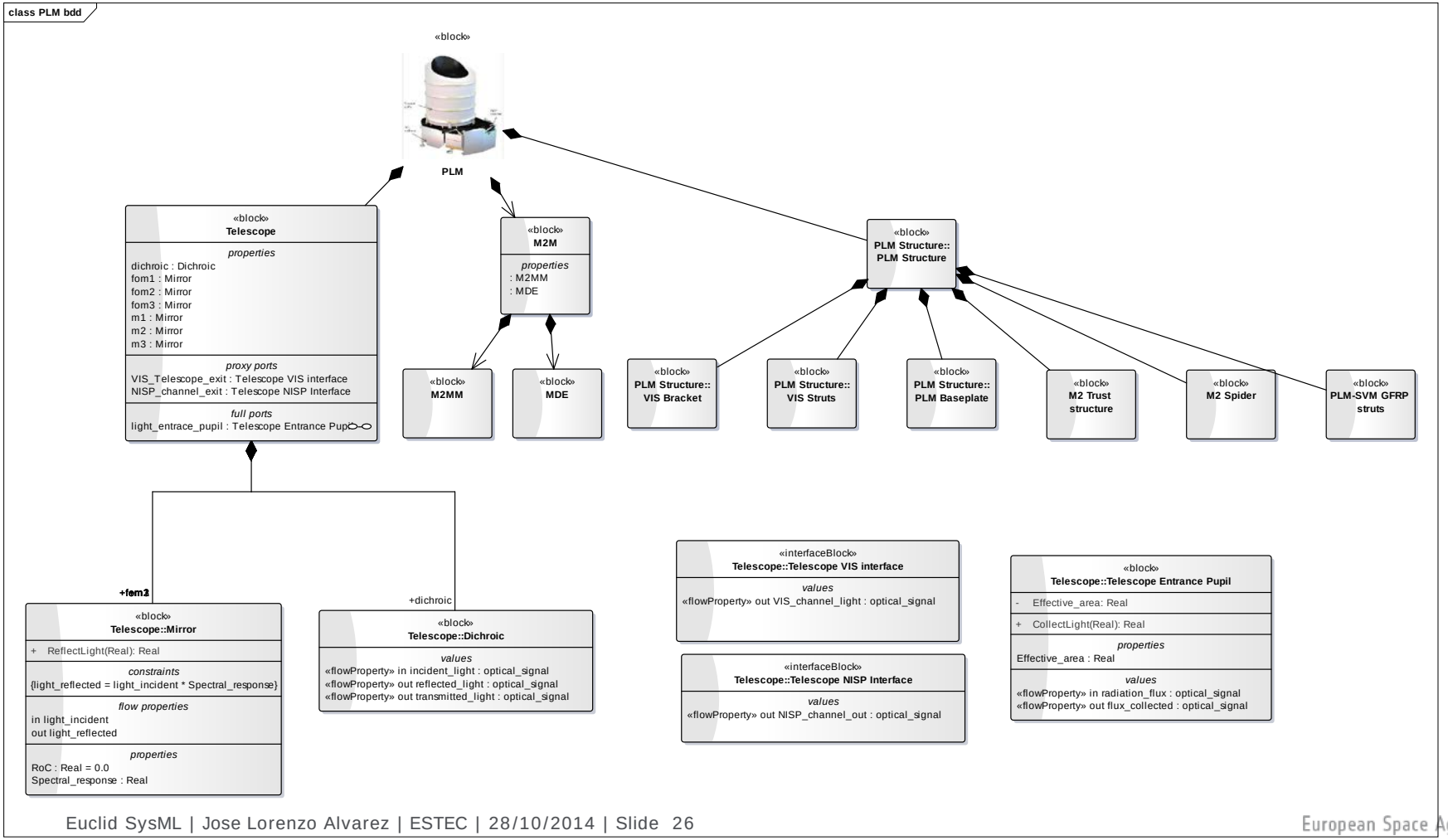
Model Library contains reference definition, profiles and stereotypes used in the model.
Status: advanced

Architecture modelling

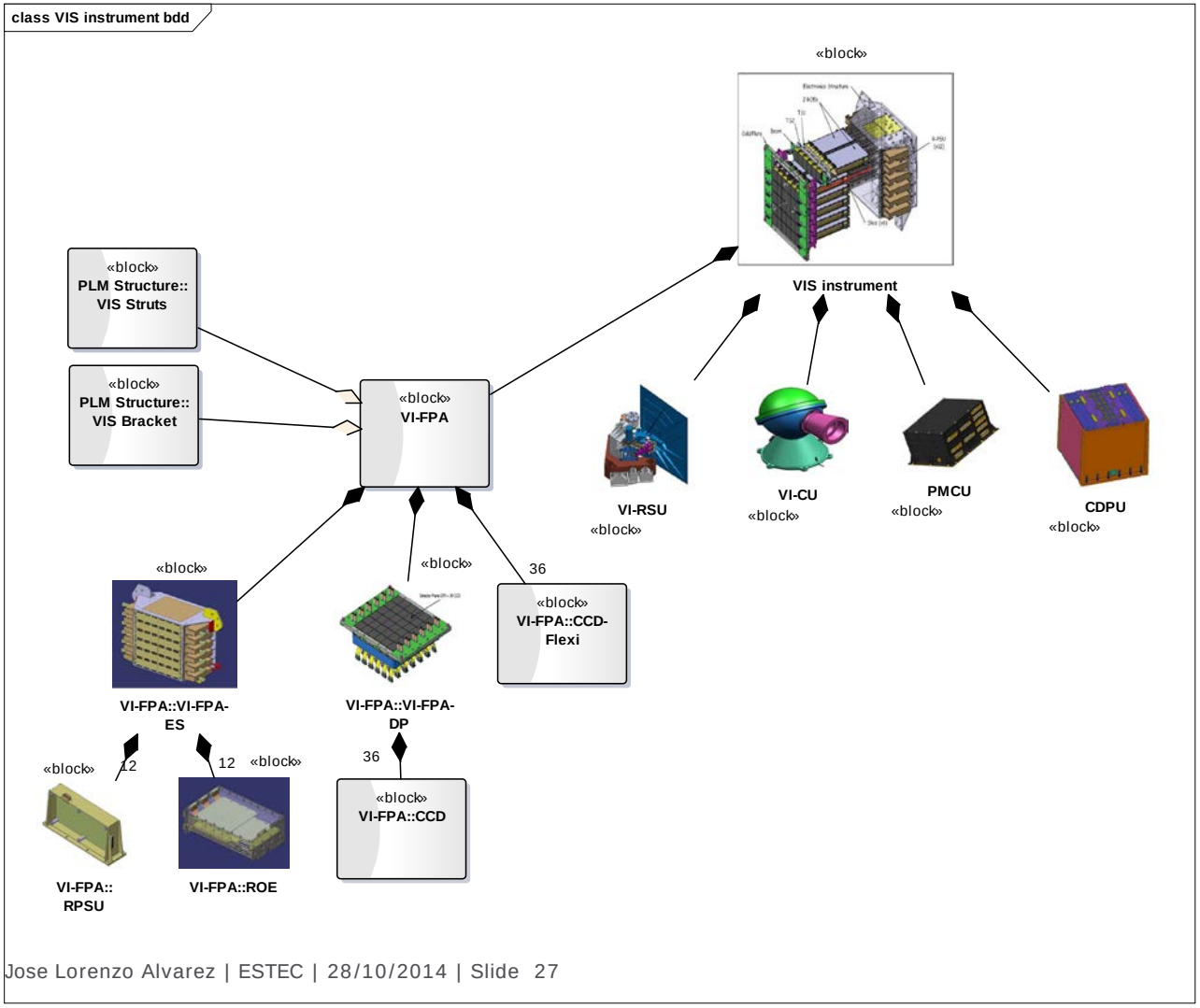


- Euclid system architecture modelling progressing as the system gets more defined:
  - PLM, Instruments top level model already in place
  - SGS intensive use of SysML to define their structure and interfaces.
  - Interaction between elements being built (IBD, parametric diagrams).

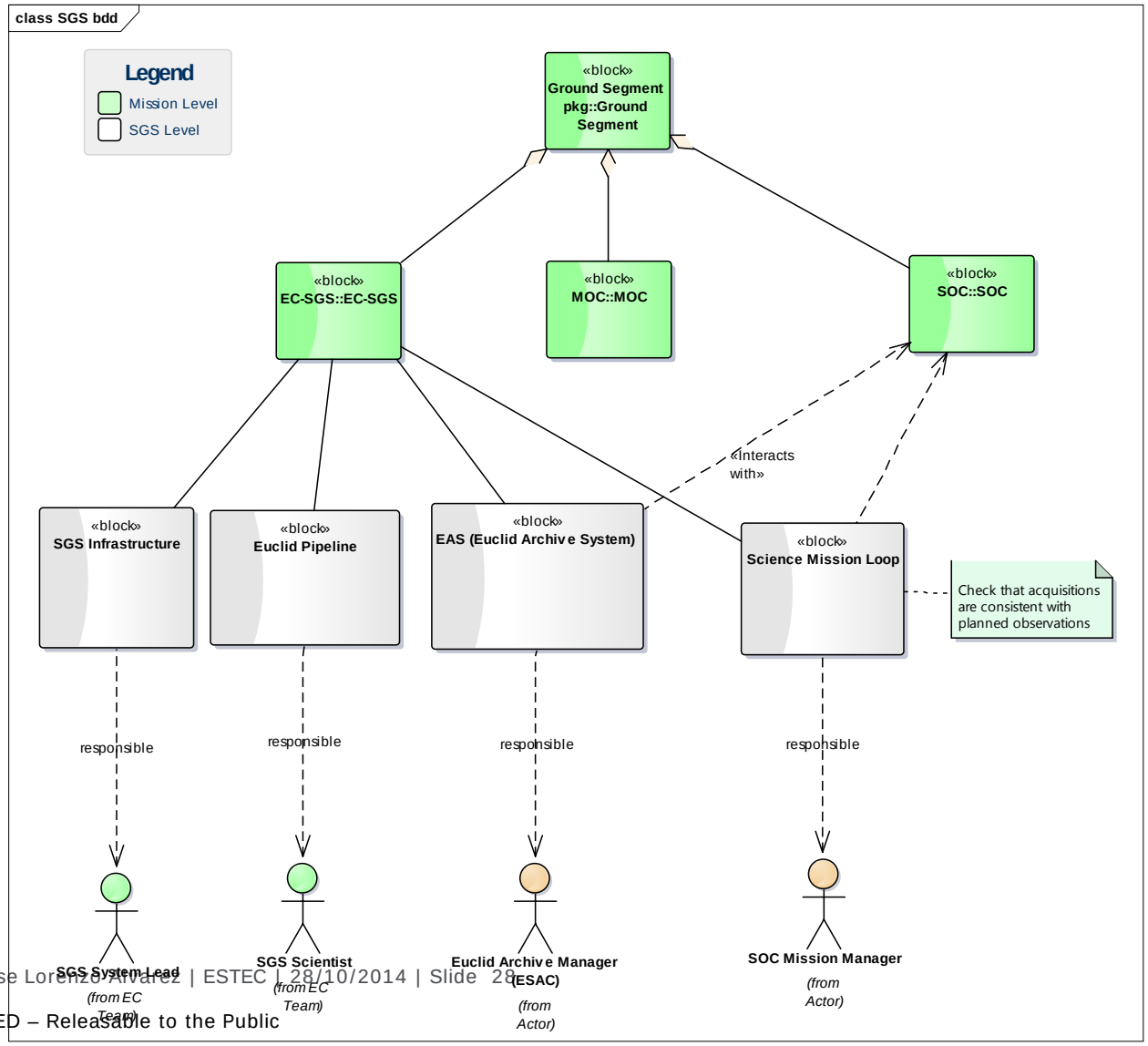
Architecture modelling



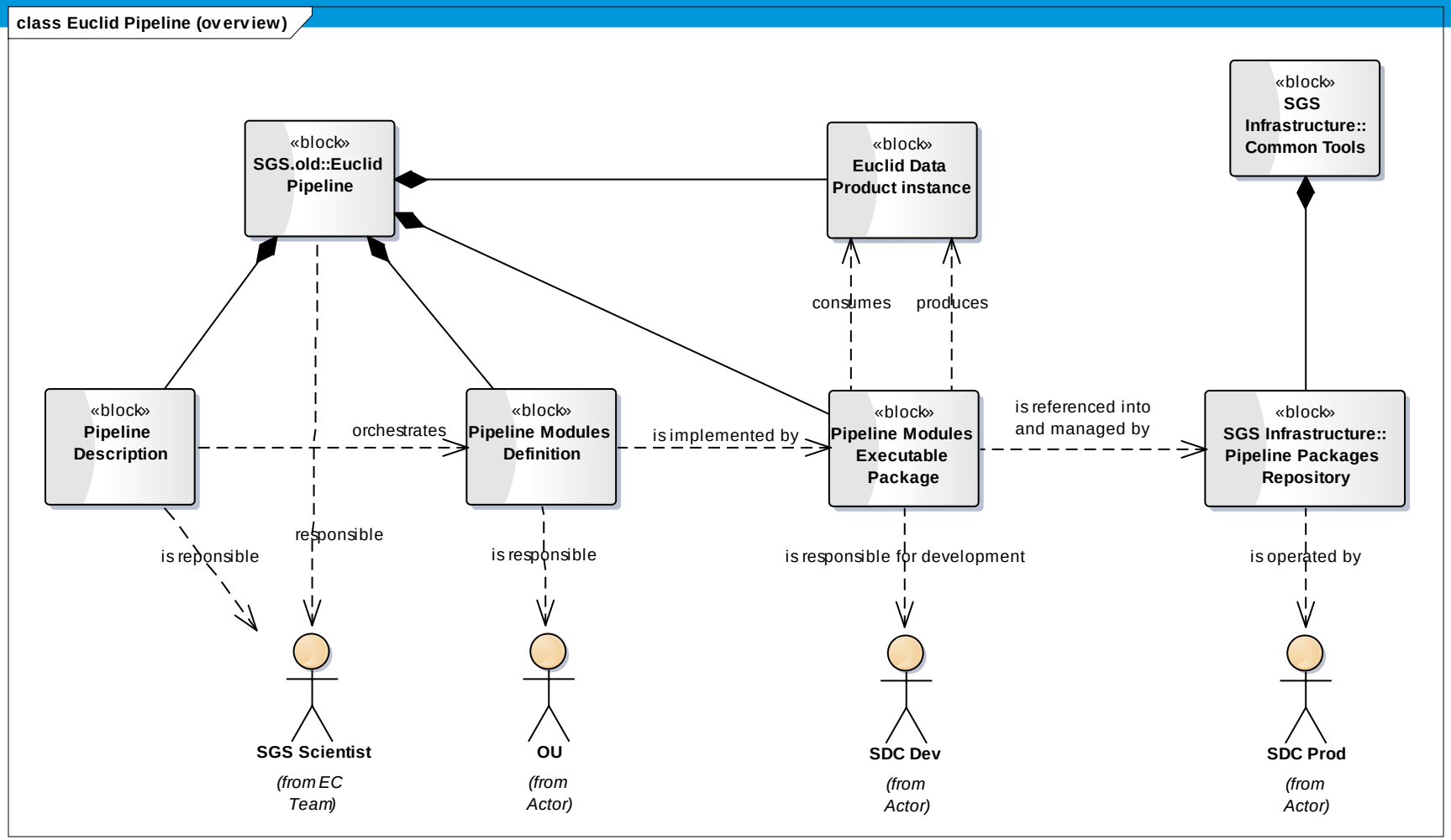
Architecture modelling



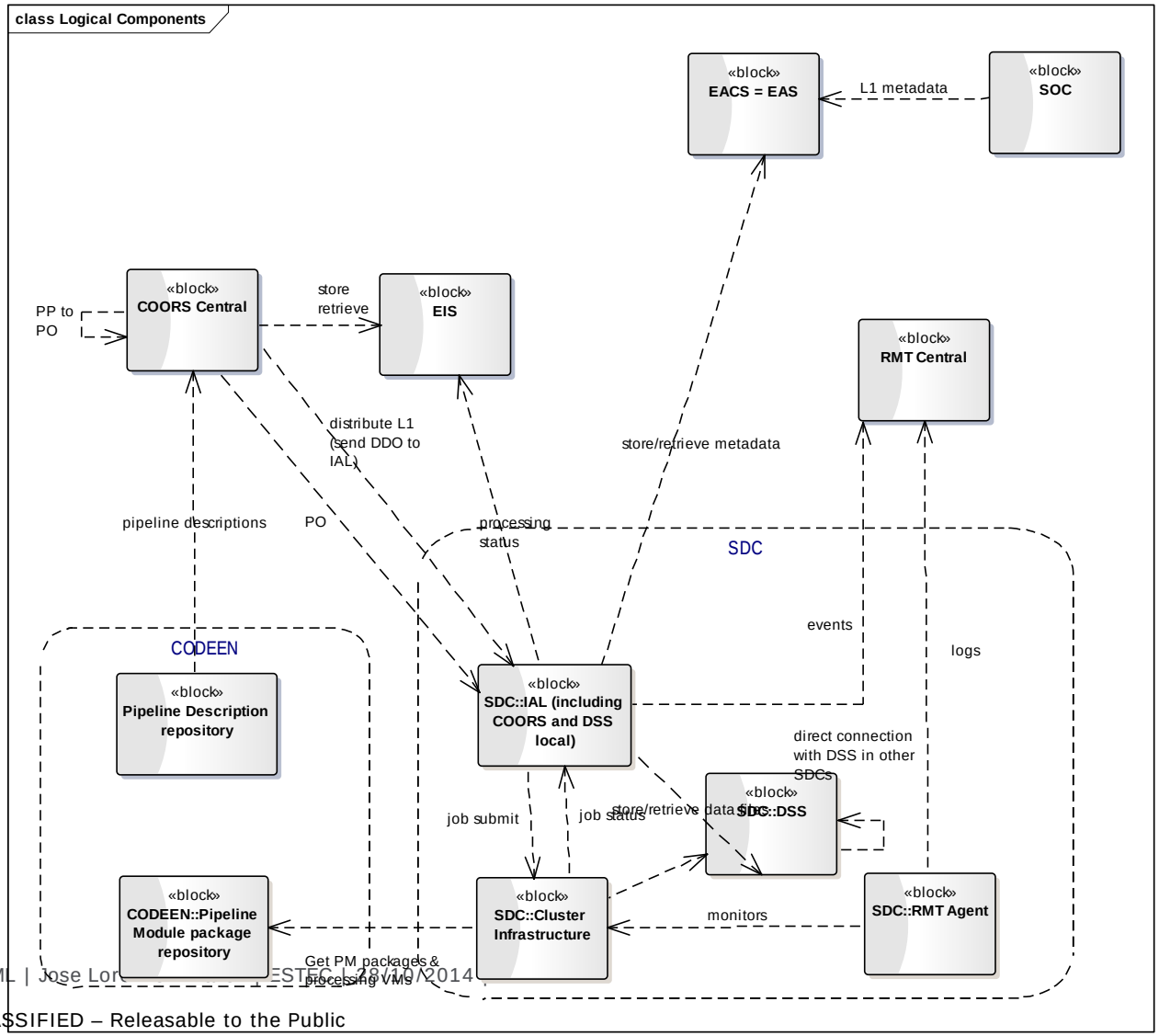
SGS Architecture Modelling



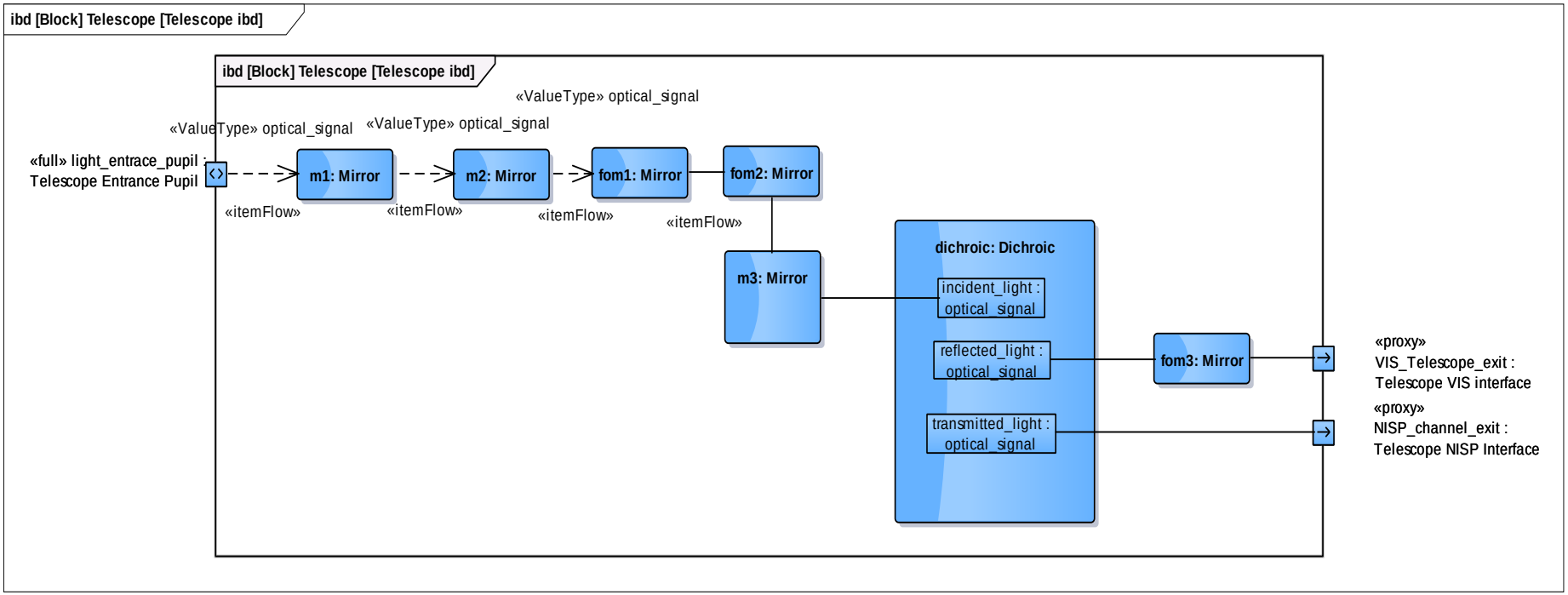
SGS Architecture Modelling



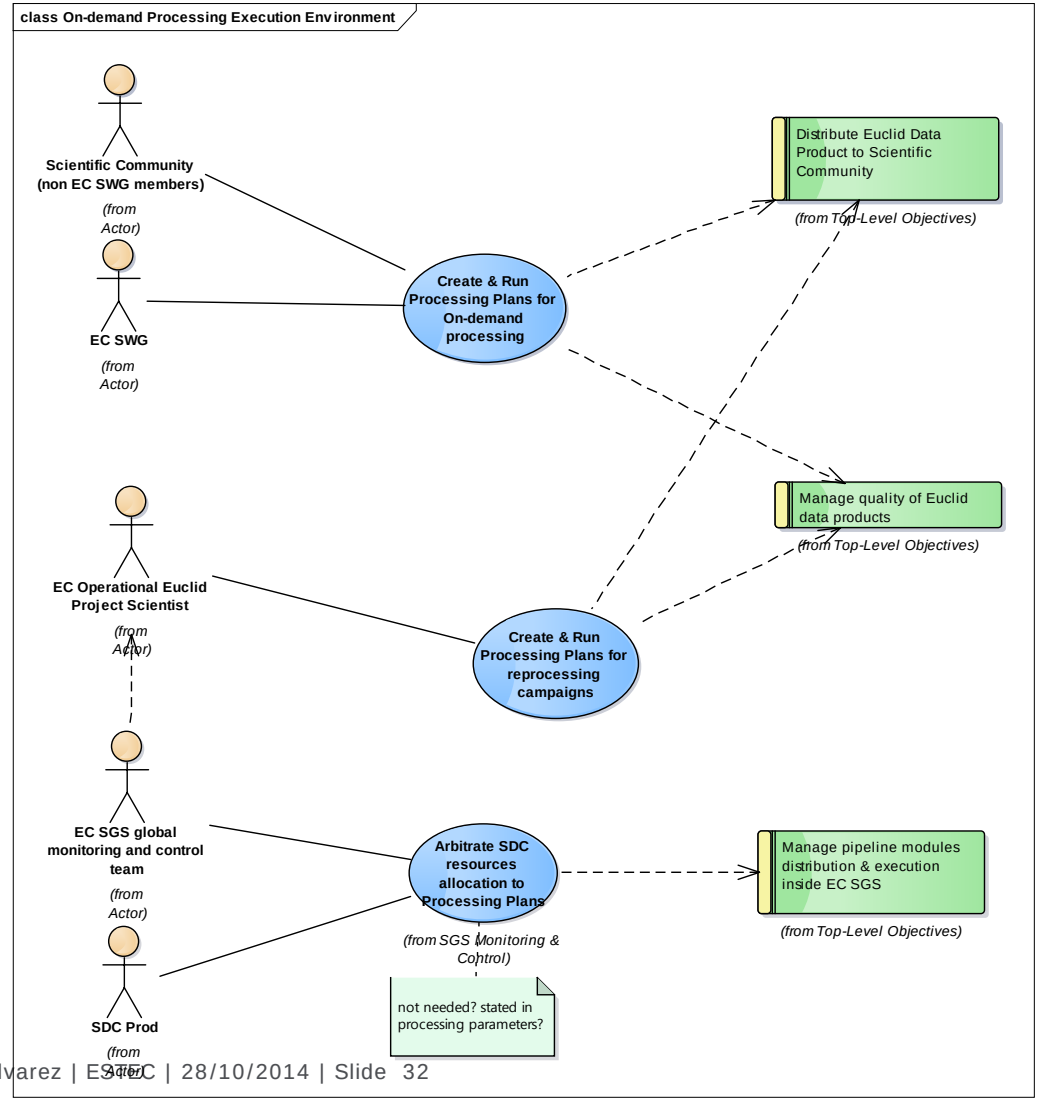
SGS Architecture Modelling



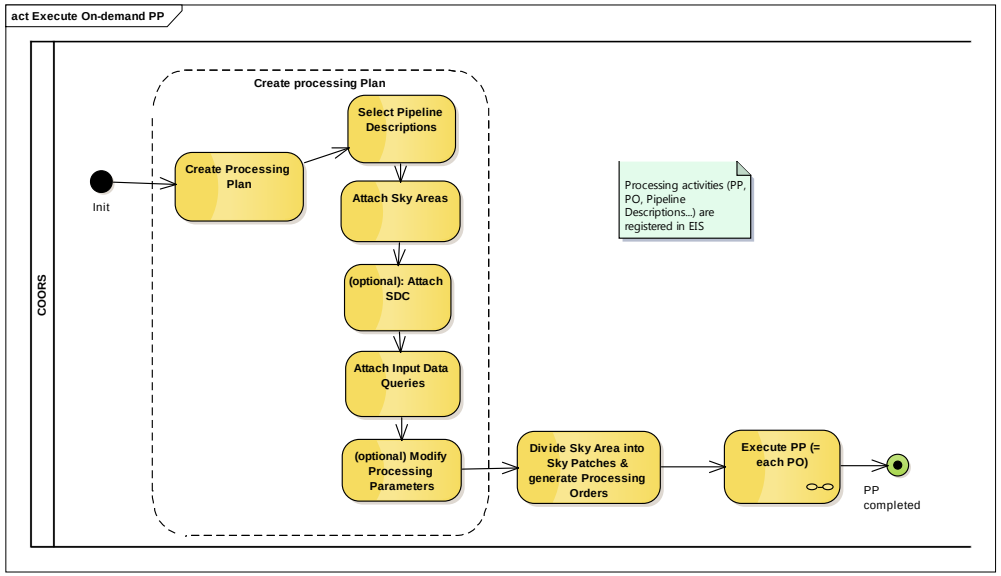
System Internal data flow modelling

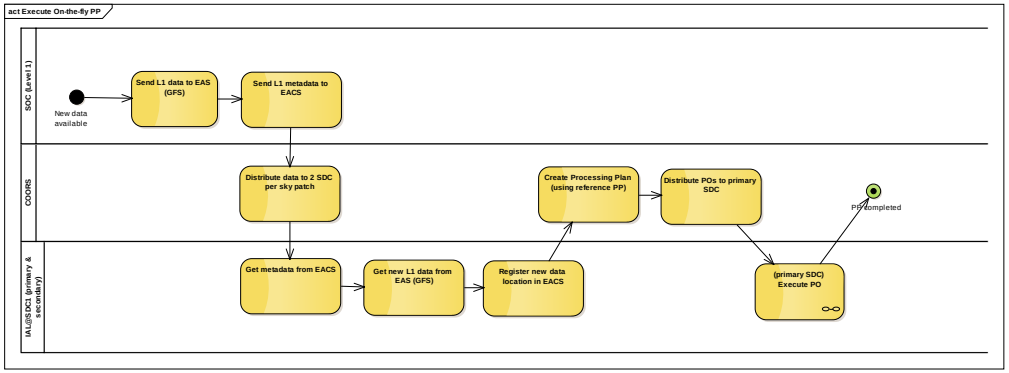


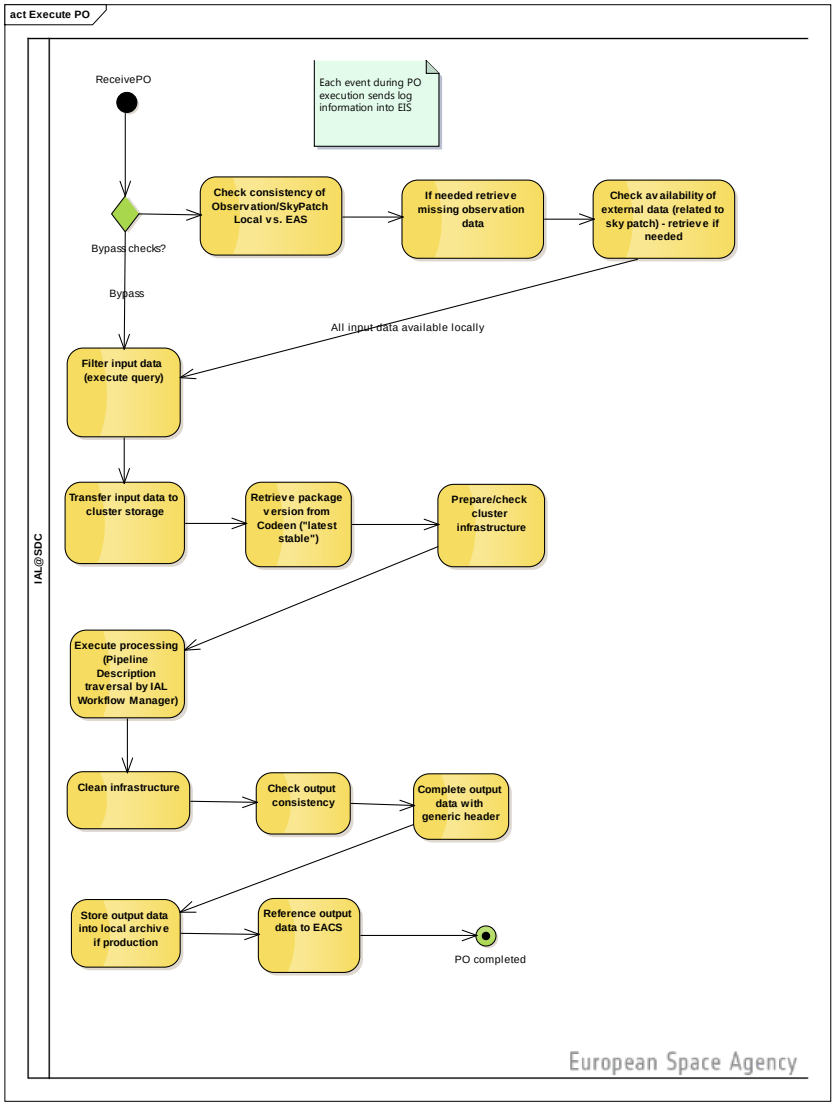
Use-case definition for SGS



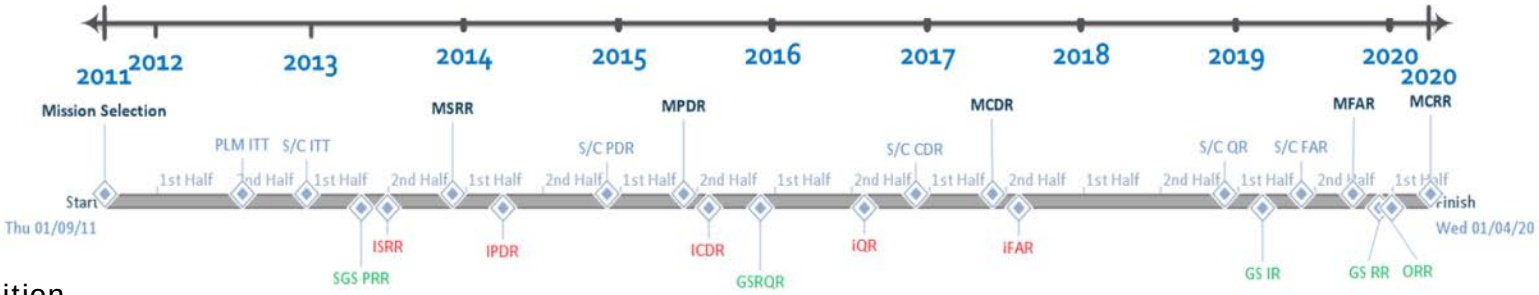
Activity diagrams for pipeline process







Focus for coming year(s)



Requirements definition and traceability

Interface Consolidation

Req. Maintenance & Change Control

Technical Control & tracking

Mission Verification and validation

Focus for the coming year

pkg Euclid Mission start page

Euclid Mission

Euclid Mission Model: This model is designed to support System Engineering activities.

It aims a containing the suitable information to ensure that the Euclid Mission is designed, built and verified to comply with its mission needs.

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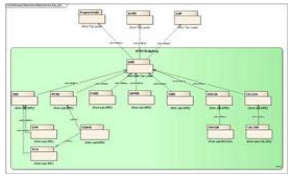
double click on the icons to navigate.

«allocateActivityPartition» Model Components

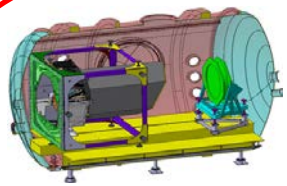
Actor

Actor package describe the different structure and key people contributing to the Euclid Mission.
Status: preliminary



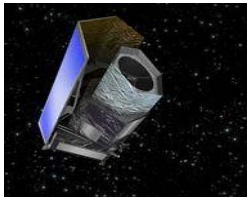
Requirement

Requirement package contains the requirement specification flow down from top level Science Requirements to implementation.
Status: Advanced



Verification

Verification package contains the test cases and verification approach description that allow verifying that current mission implementation meet the expected needs.
Status: empty



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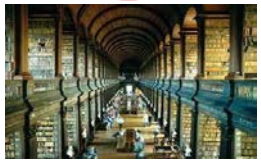

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THANKS!