Overview of MBSE at GMT

Josema Filgueira
GMTO

Overview

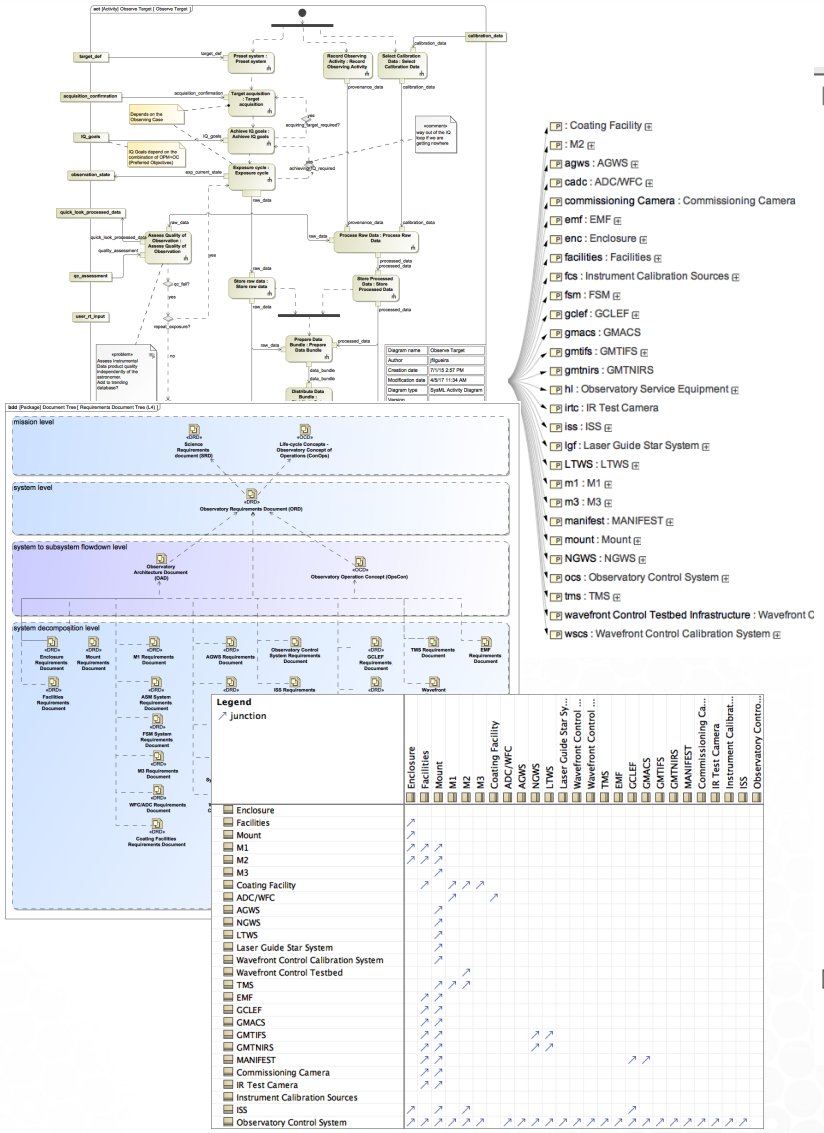
- MBSE effort goals
- Overview of system modeling at GMT
- Modeling challenges
- Conclusions

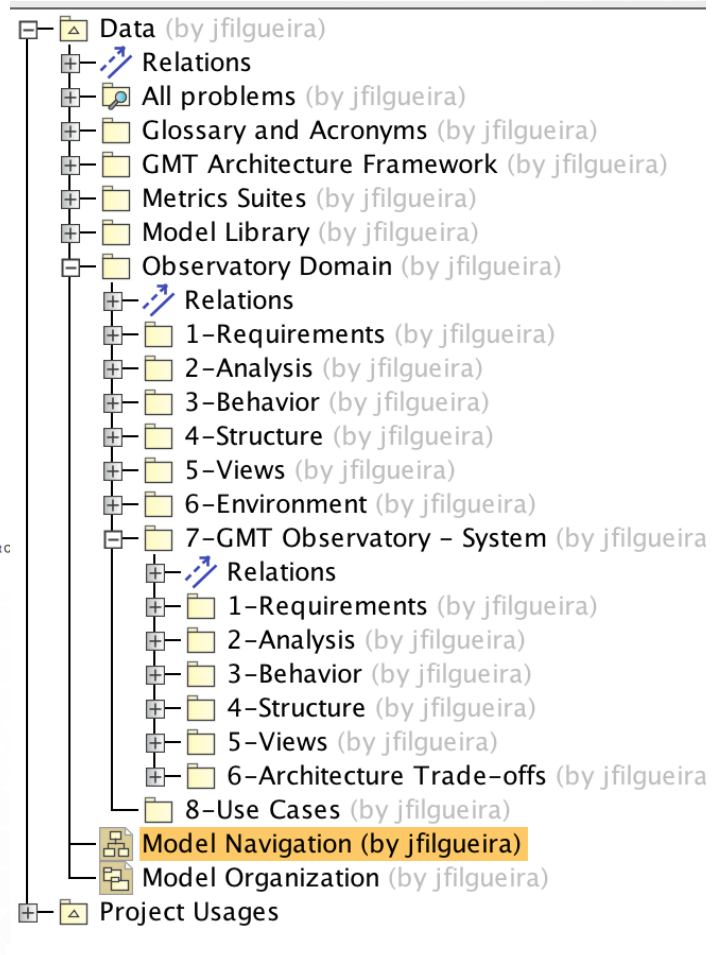
MBSE goals

- Provide consistency in the flow down of requirements
- Ensure traceability between analysis and requirements
- Provide support for system decomposition
- Develop observatory top-level life-cycle concepts model

Overview of system modeling

- Product Tree
- Document Tree
- NxN
- Doc generation
- Behaviors
- …

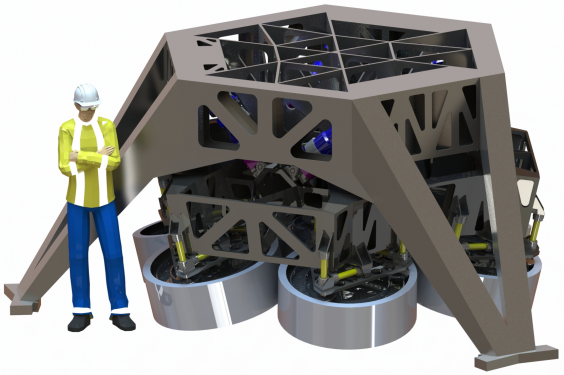




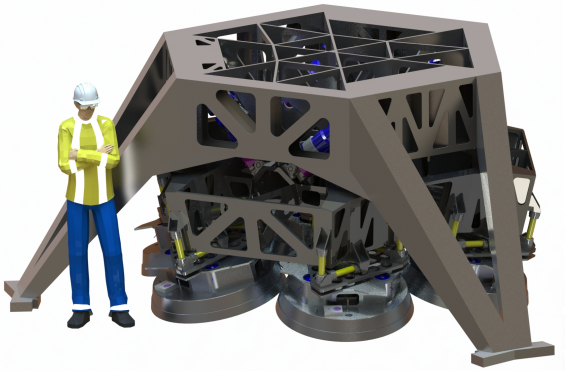
Modeling challenges

- Large ground based observatories have complex characteristics:
  - Complex mission expressed often as a science book or set of white papers
  - Complex environment (e.g. seismic, wind,…)
  - Long life time ~50 years
  - Project already in motion
  - Required multiple arrangements of optics and instruments that are deployed incrementaly to deliver the mission

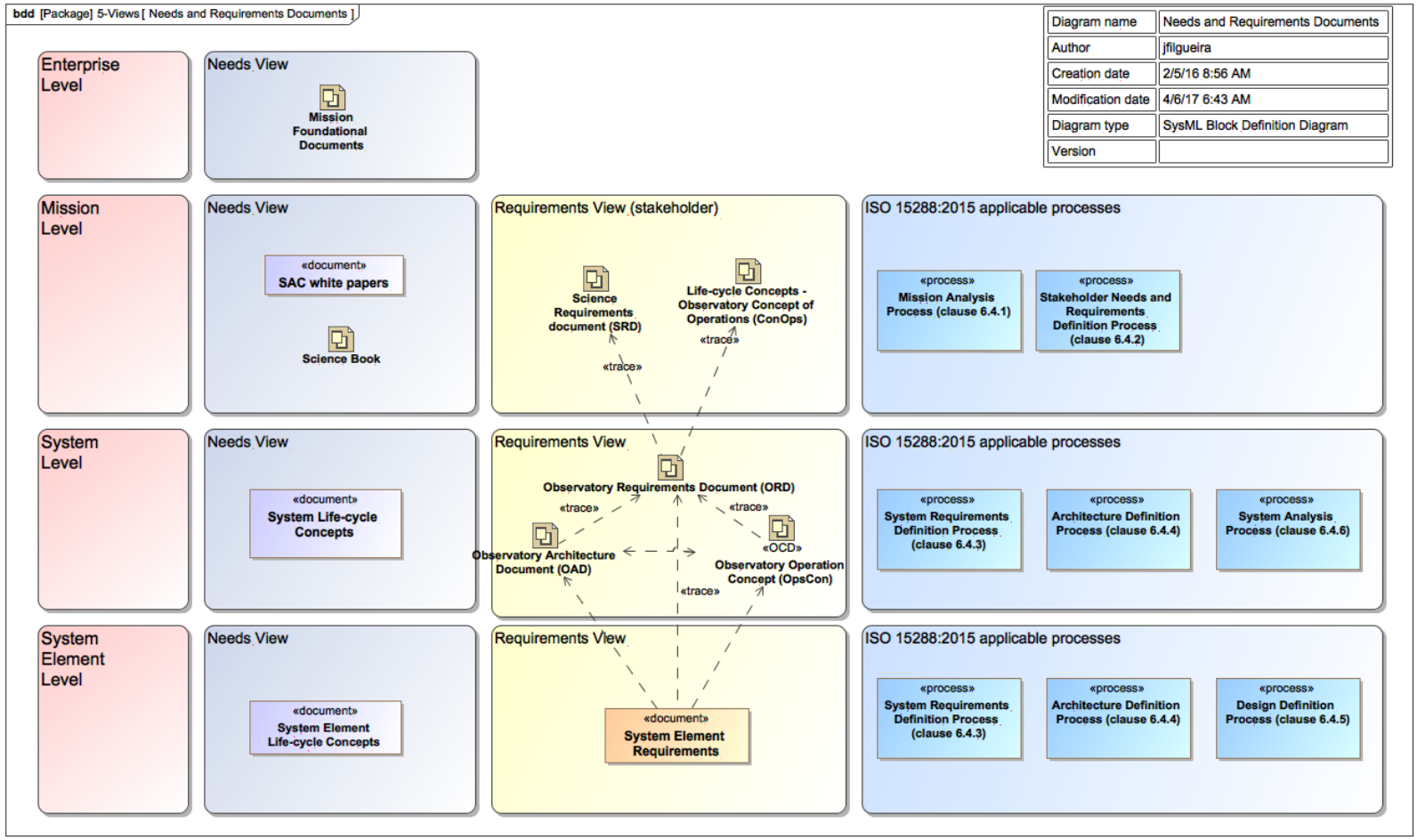
Adaptive Secondary Mirror (ASM) used in standard operation



Fast-Steering Secondary Mirror (FSM) (used in commissioning)



Modeling challenges playground



- How MBSE can help to address those challenges?

MBSE approach

- Build a vocabulary

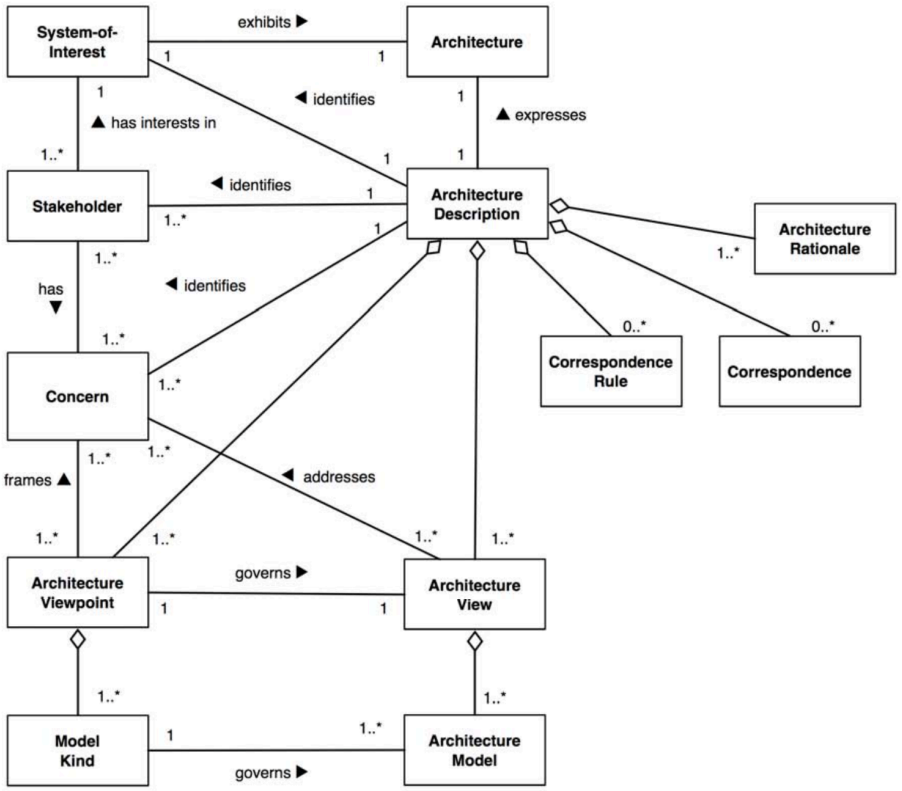
INTERNATIONAL STANDARD

ISO/IEC/ IEEE 42010

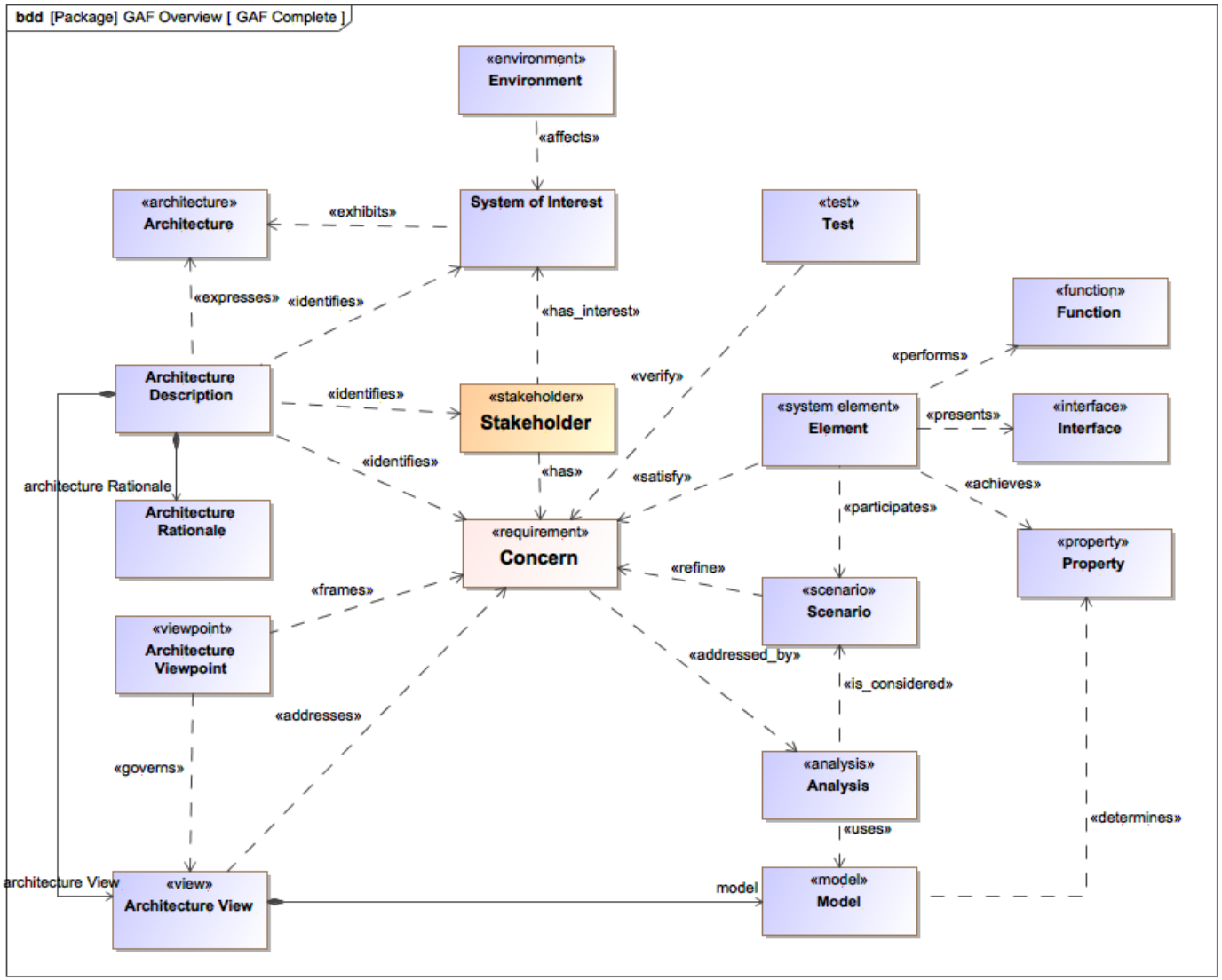
First edition
2011-12-01

Systems and software engineering — Architecture description

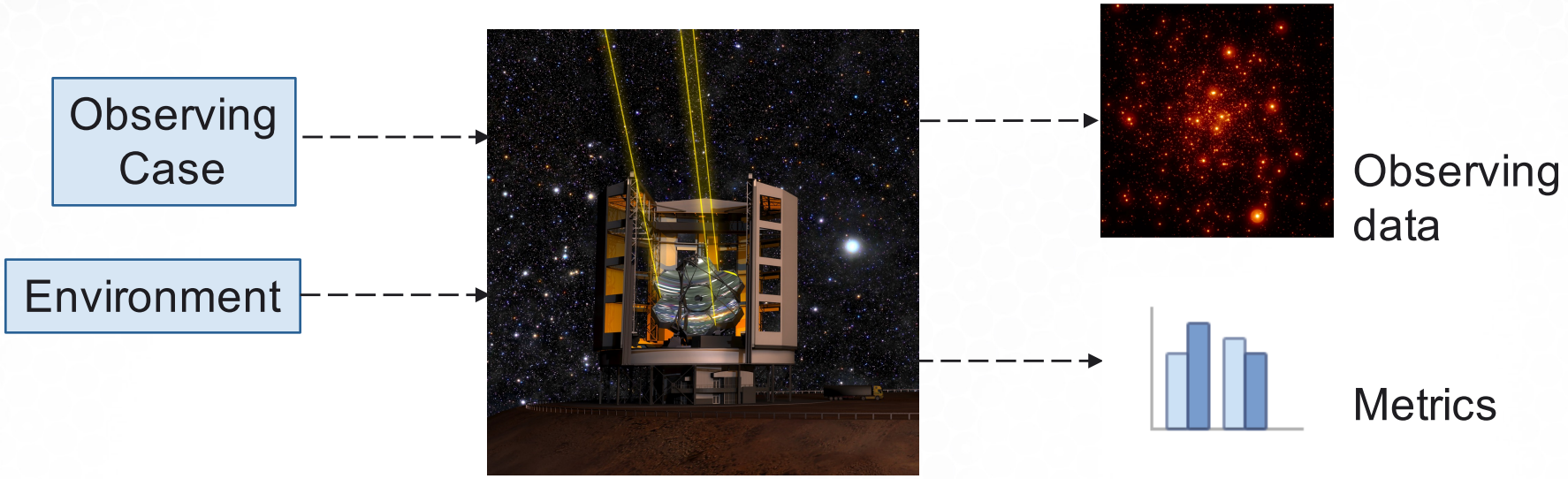
Ingénierie des systèmes et des logiciels — Description de l'architecture



Define an Architecture Framework

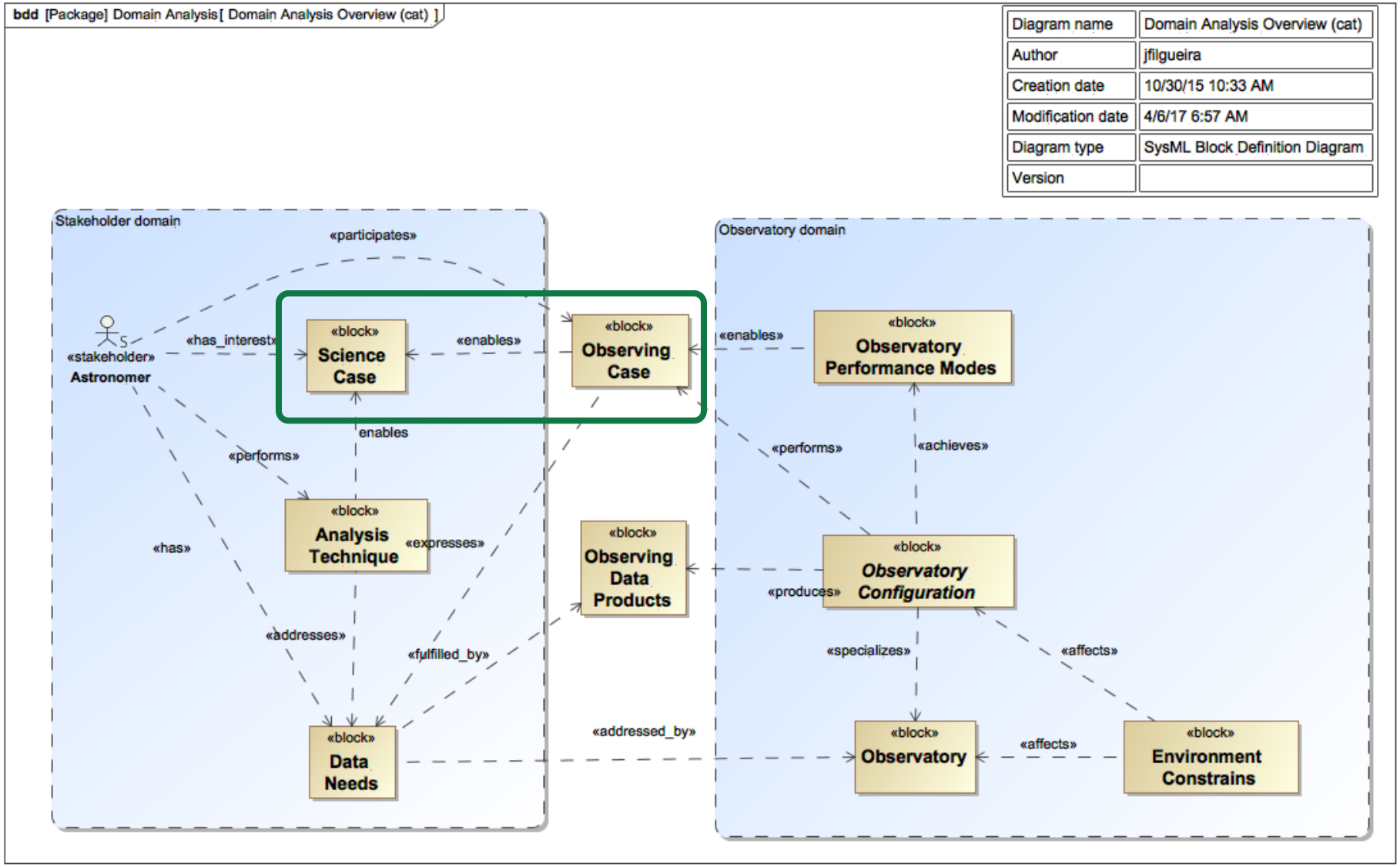


Observatory as a function

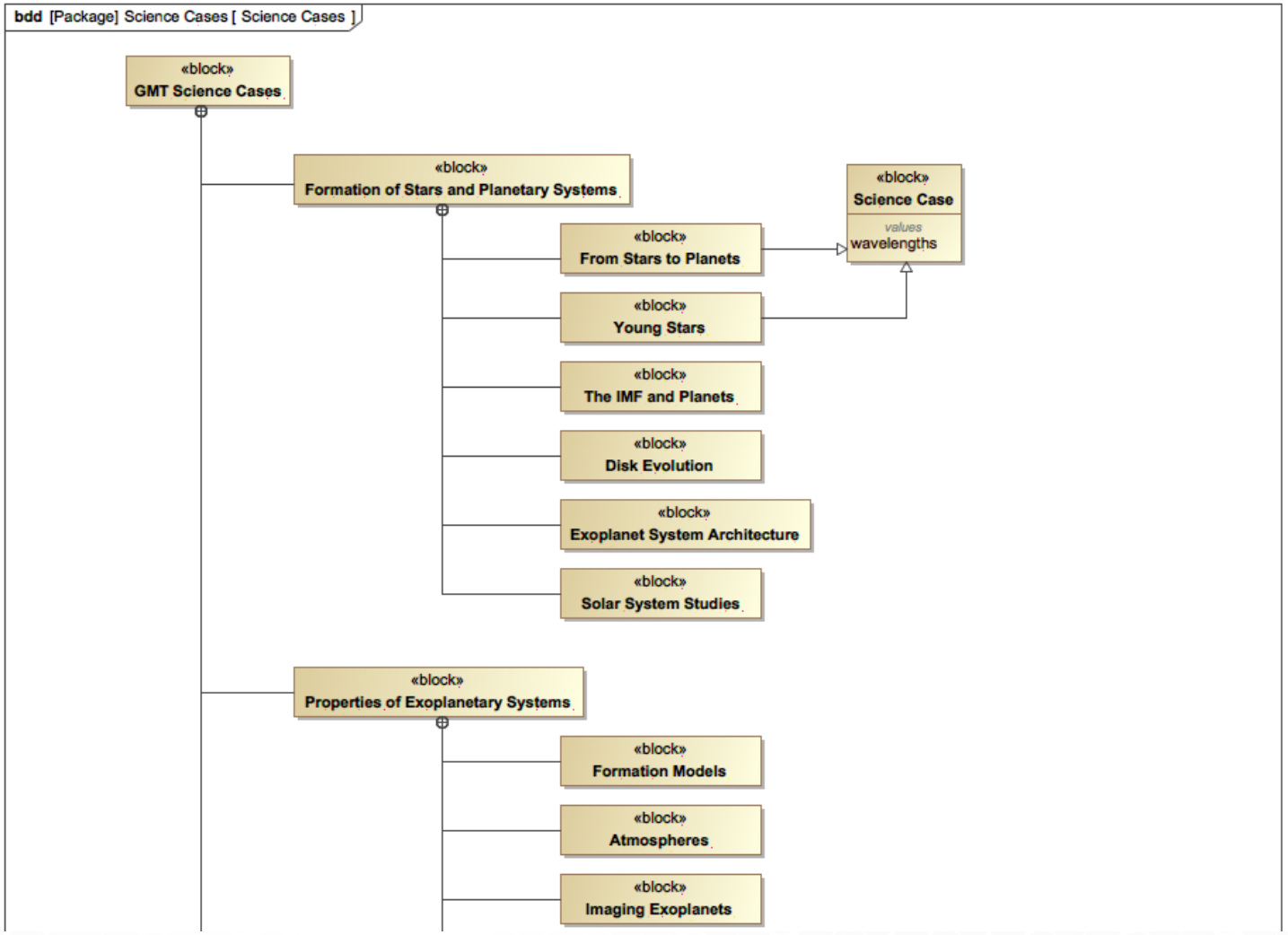


- Performance function : $f_P(obs\_case, env) = obs\_data$
- Efficiency function : $f_E(obs\_case, env) = obs\_efficiency\_metrics$
- Safety function : $f_S(obs\_case, env) = obs\_safety\_metrics$

Top level concepts

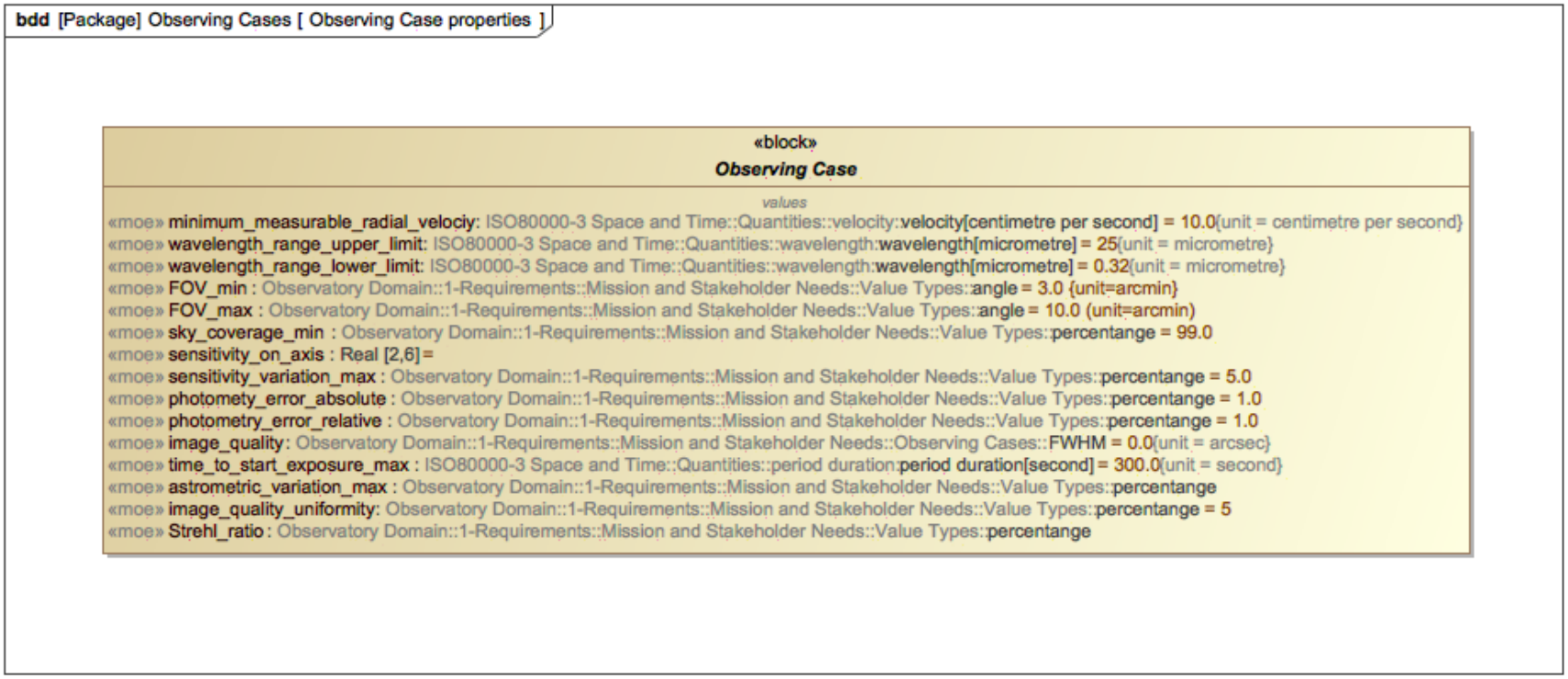


Science Cases

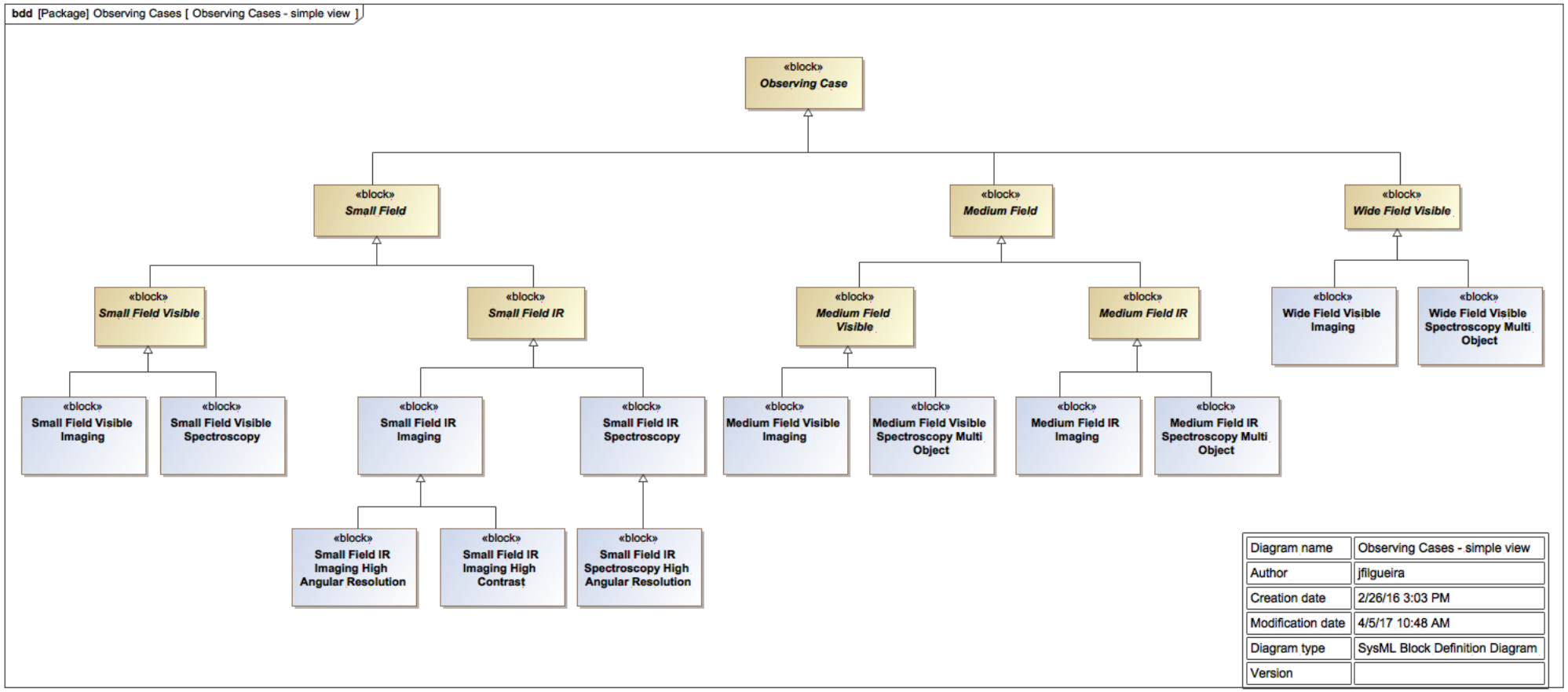


Observing Cases

- Set of properties relevant to the astronomer that need to occur simultaneously



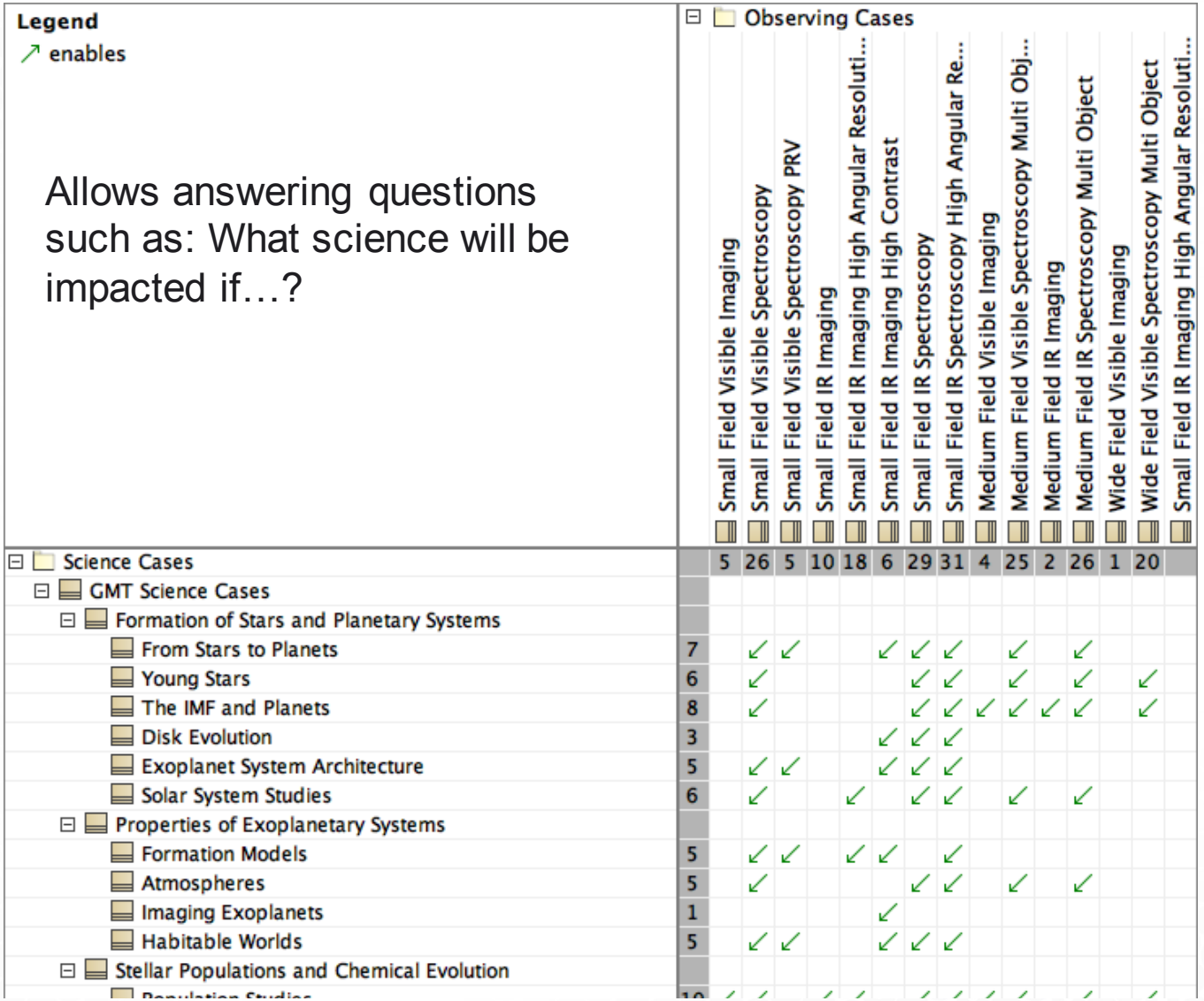
Observing Cases



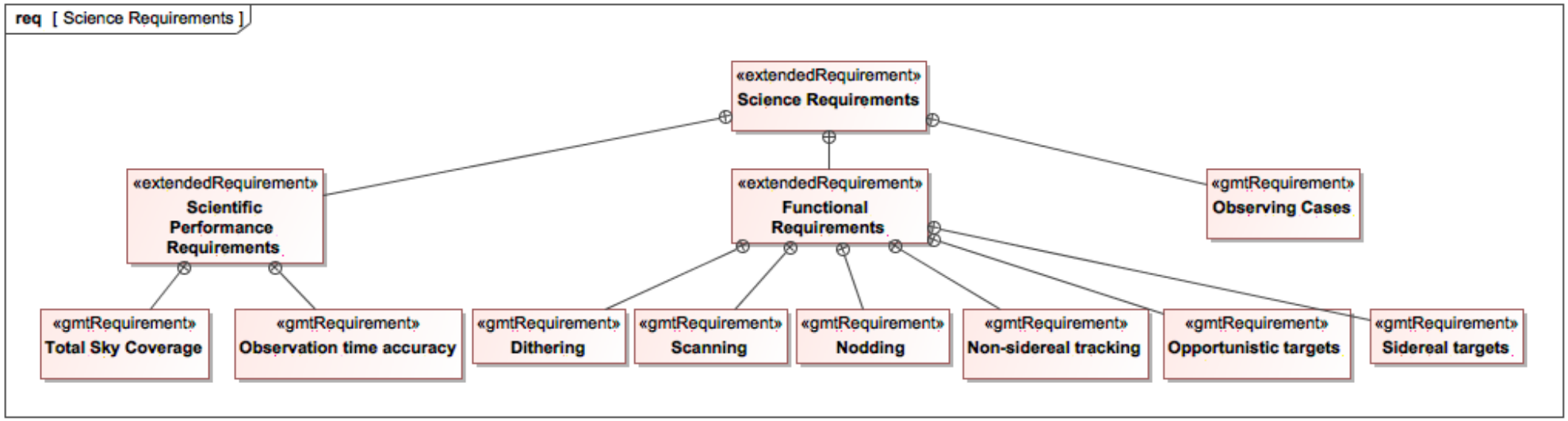
Observing Cases

#	Name	Attribute
1	Medium Field	FOV_min : angle [arcmin] = 10.0 (unit=arcmin) FOV_max : angle [arcmin] = 10.0 (unit=arcmin) time_to_start_exposure_max : time[second] = 3600.0 sky_coverage_min : percentange = 99.0 astrometric_variation_max : percentange = 0.003
2	Medium Field IR	wavelength_range_upper_limit : wavelength[micrometre] = 25 wavelength_range_lower_limit : wavelength[micrometre] = 0.8 sensitivity_on_axis : Real [2,6] = sensitivity_variation_max : percentange = 5.0 photomety_error_absolute : percentange = 3.0 photometry_error_relative : percentange = 2.0 image_quality : FWHM = 0.2
3	Medium Field IR Imaging	
4	Medium Field IR Spectroscopy Multi Object	
5	Medium Field Visible	wavelength_range_upper_limit : wavelength[micrometre] = 1.3 wavelength_range_lower_limit : wavelength[micrometre] = 0.32 sensitivity_on_axis : Real [2,6] = sensitivity_variation_max : percentange = 5.0 photomety_error_absolute : percentange = 2.0 photometry_error_relative : percentange = 1.0 image_quality : FWHM = 0.3
6	Medium Field Visible Imaging	
7	Medium Field Visible Spectroscopy Multi Object	
8	Observing Case	minimum_measurable_radial_velociy : velocity[centimetre per secon wavelength_range_upper_limit : wavelength[micrometre] = 25 wavelength_range_lower_limit : wavelength[micrometre] = 0.32 FOV_min : angle = 3.0 {unit=arcmin} FOV_max : angle = 10.0 (unit=arcmin) sky_coverage_min : percentange = 99.0 sensitivity_on_axis : Real [2,6] = sensitivity_variation_max : percentange = 5.0 photomety_error_absolute : percentange = 1.0

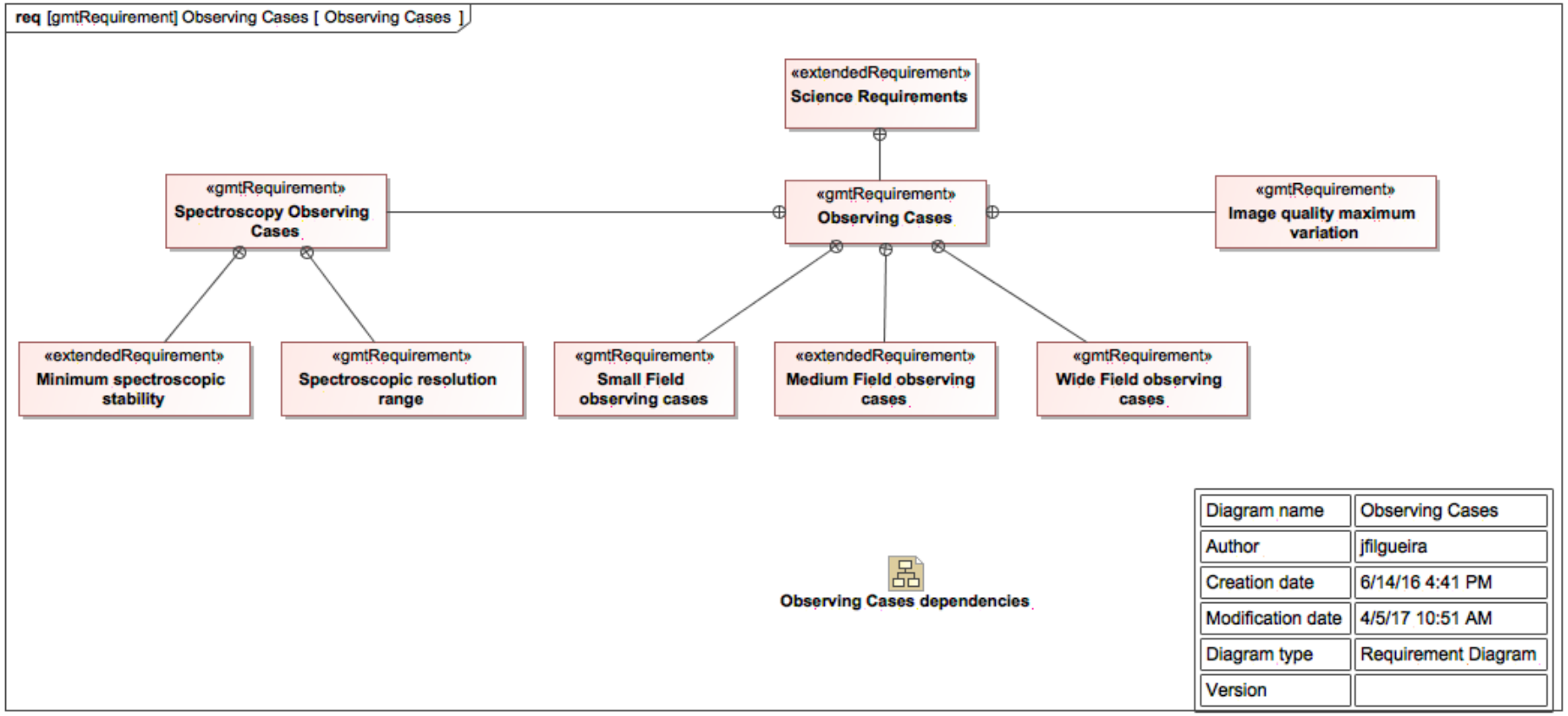
Observing Cases vs Science Cases



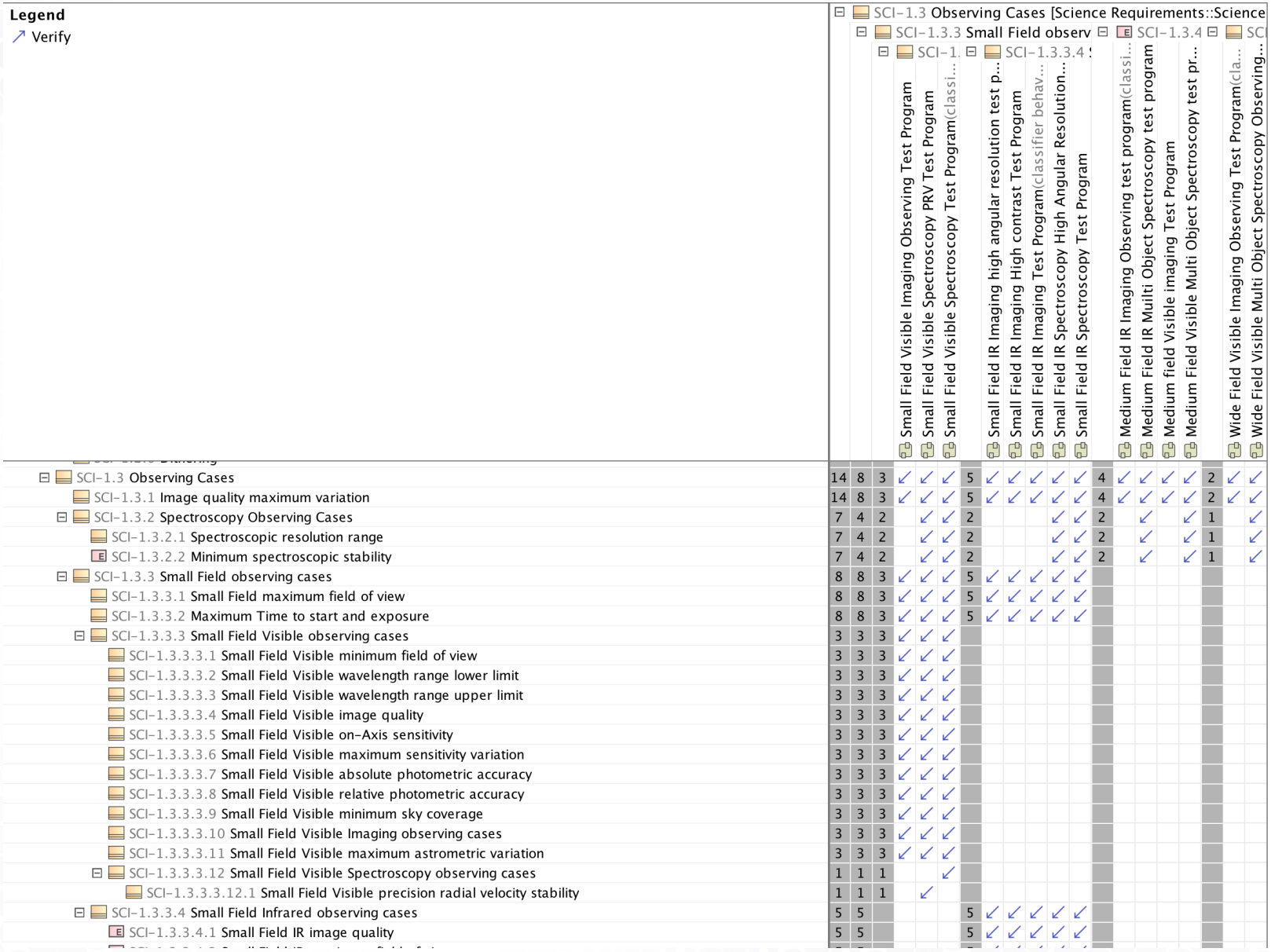
Science Requirements



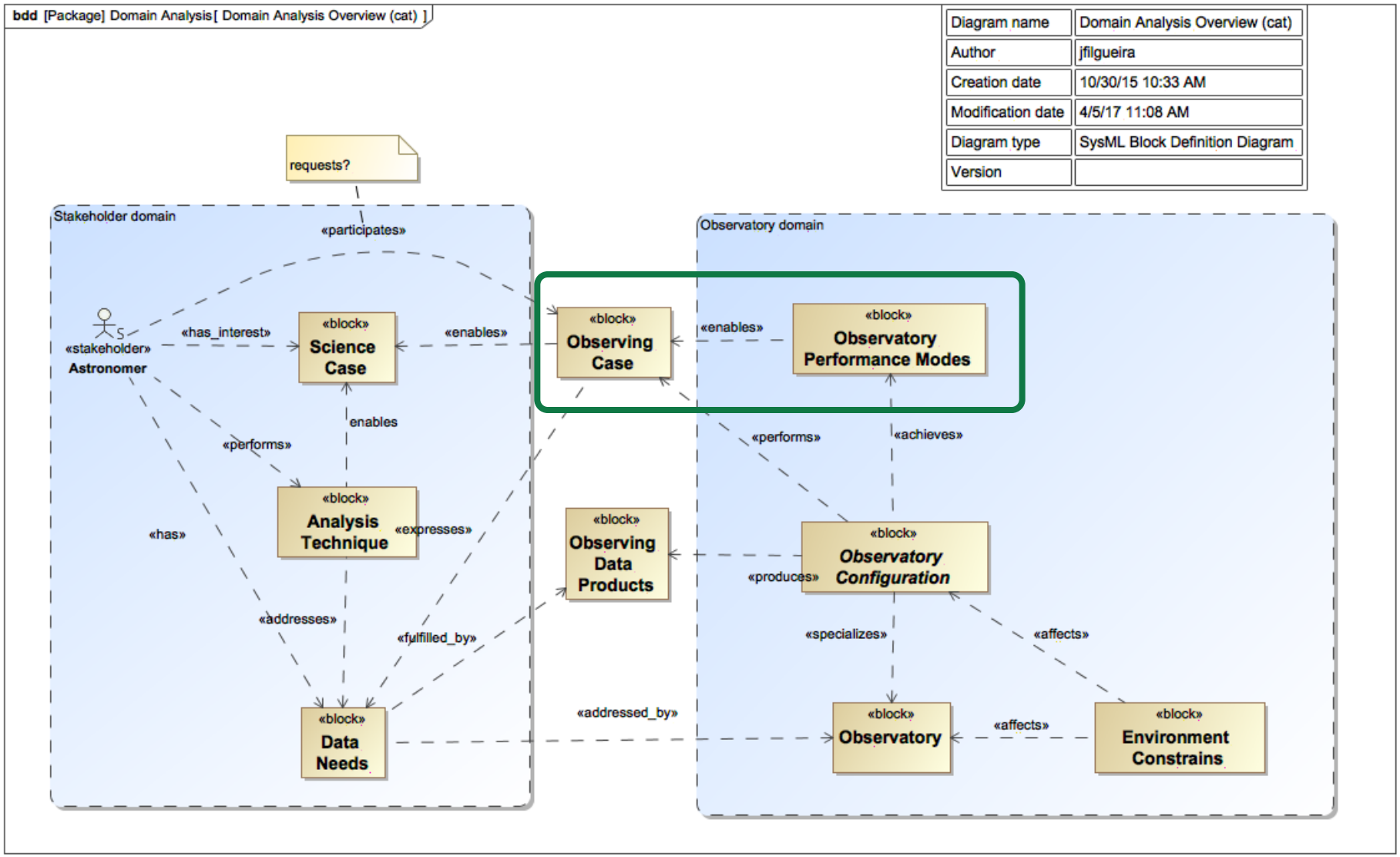
Science Requirements



Observing Cases Test

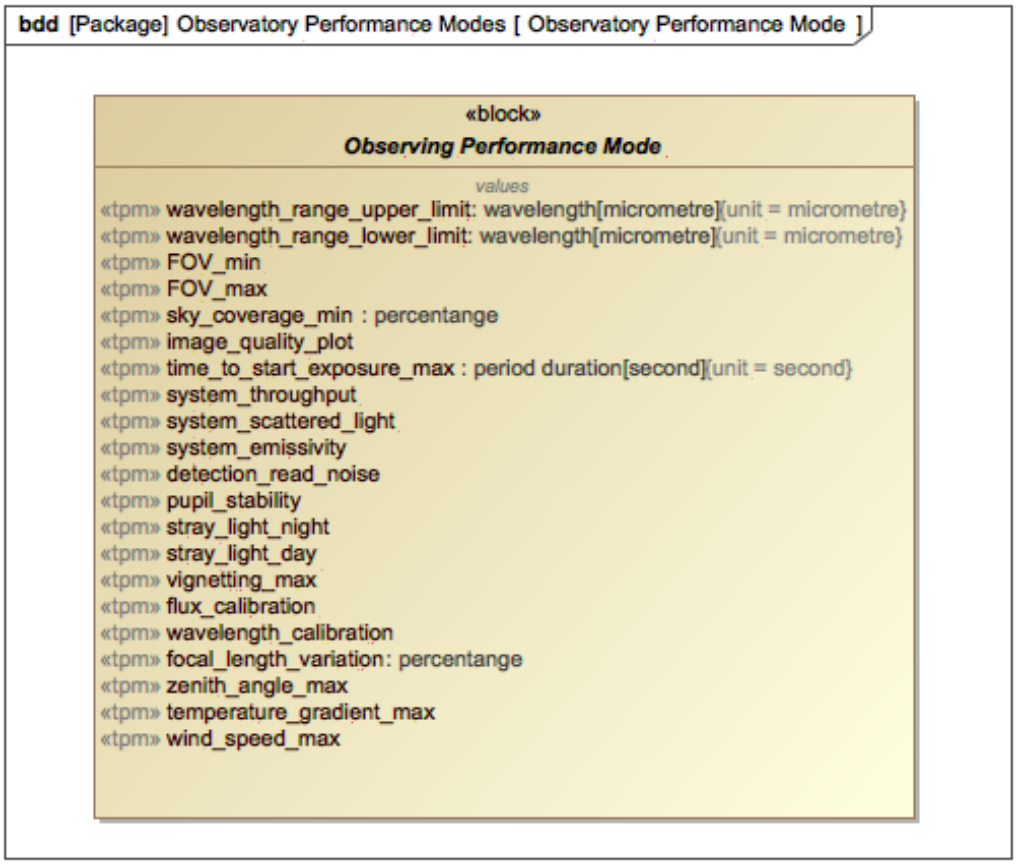


Observatory Performance Modes

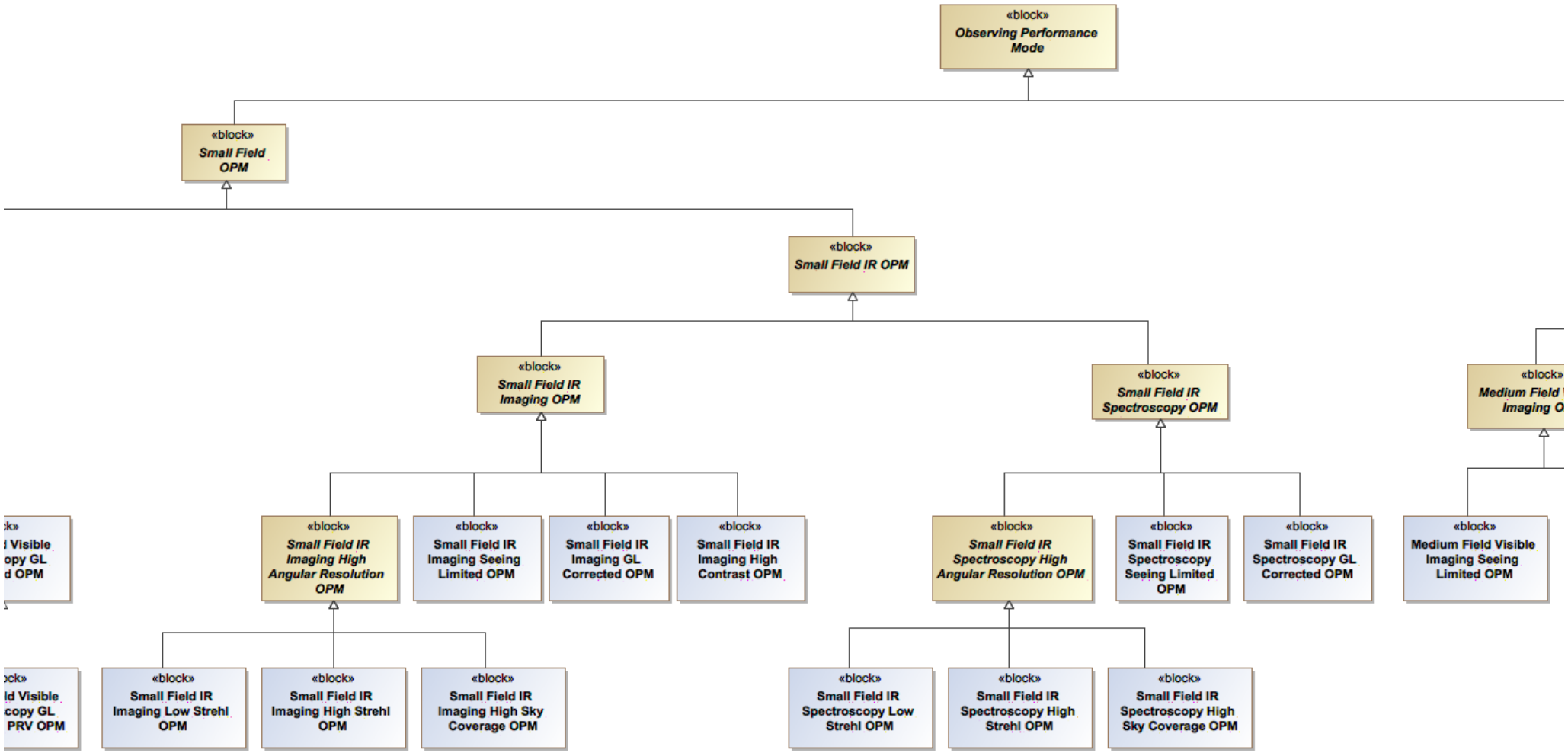


Observing Performance Modes

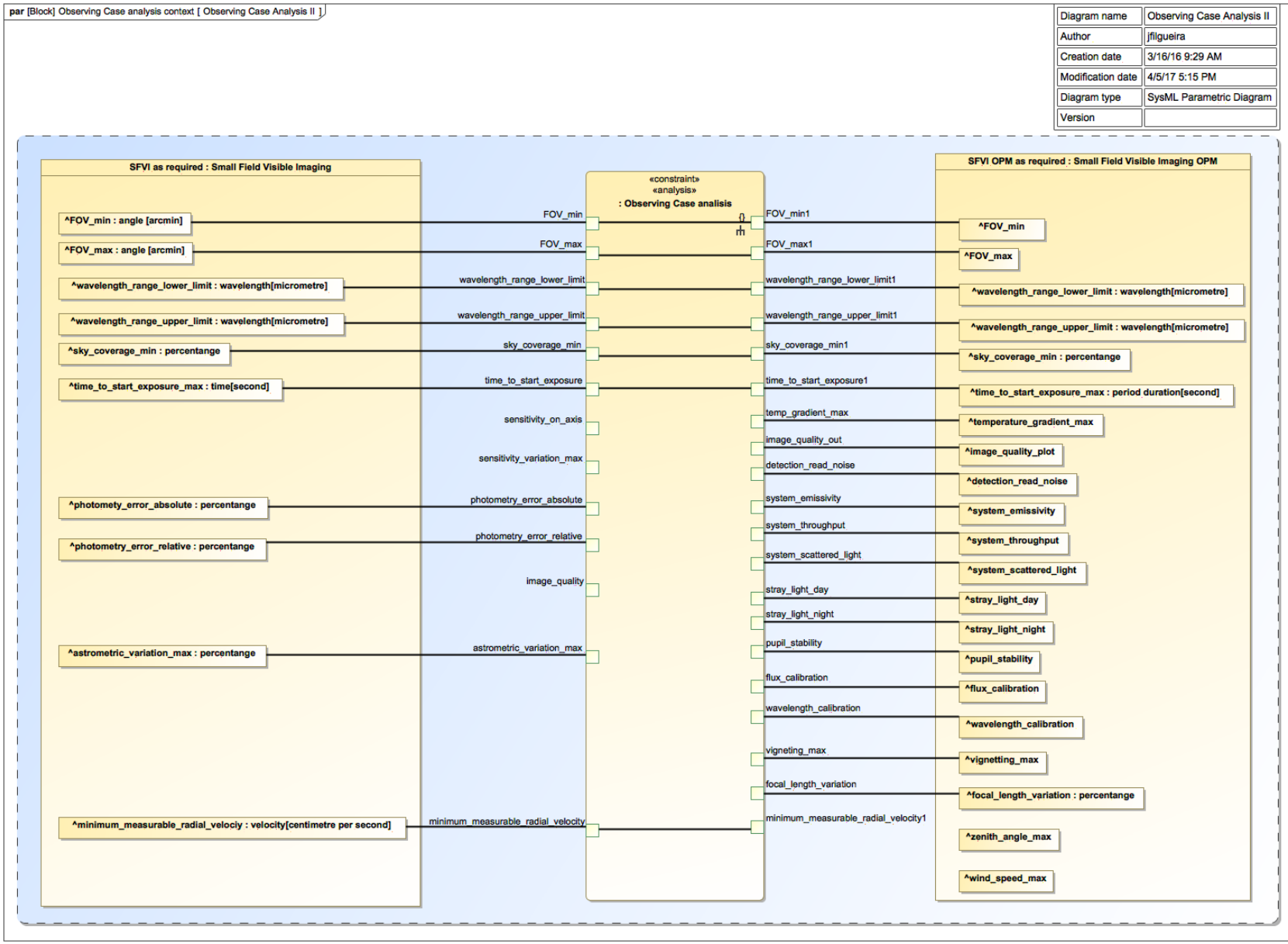
- Set of system properties that need to occur simultaneously



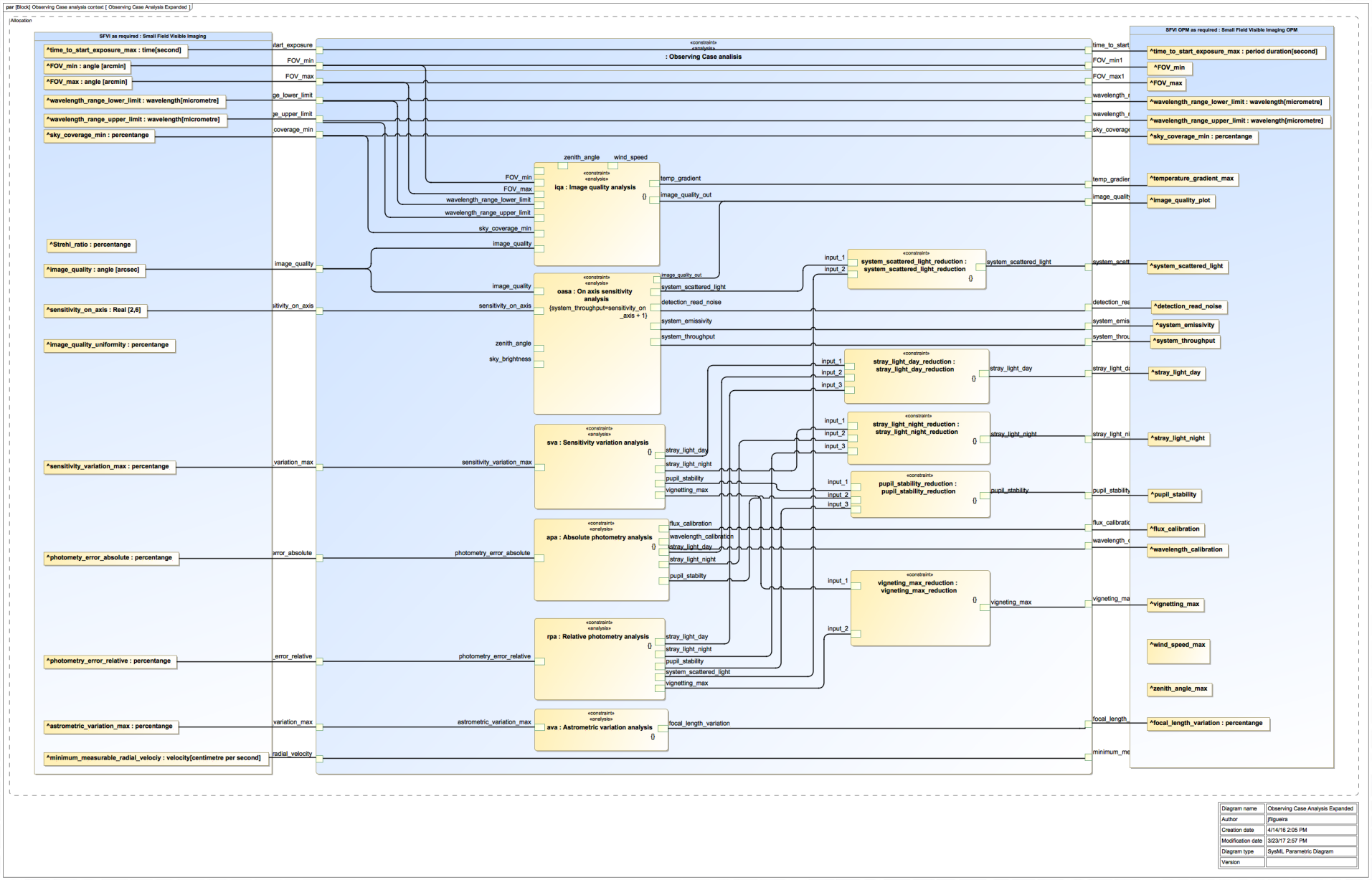
Observing Performance Modes



Observing Case Analysis



Analysis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Allocation
SFVI as required : Small Field Visible Imaging
^time_to_start_exposure_max : time[second]
^FOV_min : angle [arcmin]
^FOV_max : angle [arcmin]
^wavelength_range_lower_limit : wavelength[micrometre]
^wavelength_range_upper_limit : wavelength[micrometre]
^sky_coverage_min : percentage
^Strehl_ratio : percentange
^image_quality : angle [arcsec]
^sensitivity_on_axis : Real [2,6]
^image_quality_uniformity : percentange
^sensitivity_variation_max : percentange
^photometry_error_absolute : percentange
^photometry_error_relative : percentange
^astrometric_variation_max : percentange
^minimum_measurable_radial_velociy : velocity[centimetre per second]
«constraint» «analysis»
: Observing Case analisis
zenith_angle
wind_speed
«constraint» «analysis»
iqa : Image quality analysis
{}
«constraint» «analysis»
oasa : On axis sensitivity analysis
{system_throughput=sensitivity_on_axis + 1}
«constraint» «analysis»
sva : Sensitivity variation analysis
{}
«constraint» «analysis»
apa : Absolute photometry analysis
{}
«constraint» «analysis»
rpa : Relative photometry analysis
{}
«constraint» «analysis»
ava : Astrometric variation analysis
{}
«constraint»
system_scattered_light_reduction : system_scattered_light_reduction
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stray_light_day_reduction : stray_light_day_reduction
{}
«constraint»
stray_light_night_reduction : stray_light_night_reduction
{}
«constraint»
pupil_stability_reduction : pupil_stability_reduction
{}
«constraint»
vigneting_max_reduction : vigneting_max_reduction
{}
SFVI OPM as required : Small Field Visible Imaging OPM
^time_to_start_exposure_max : period duration[second]
^FOV_min
^FOV_max
^wavelength_range_lower_limit : wavelength[micrometre]
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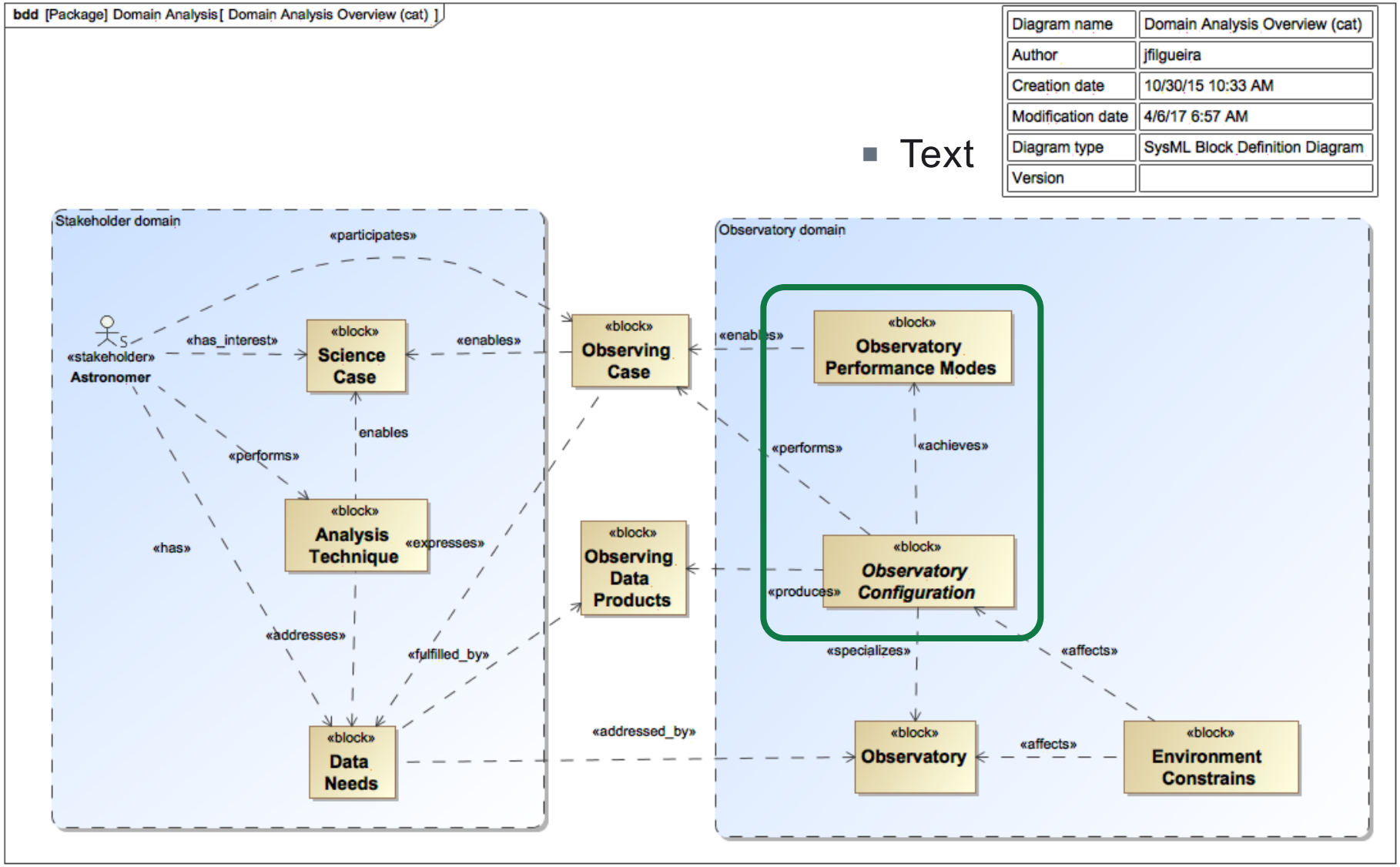
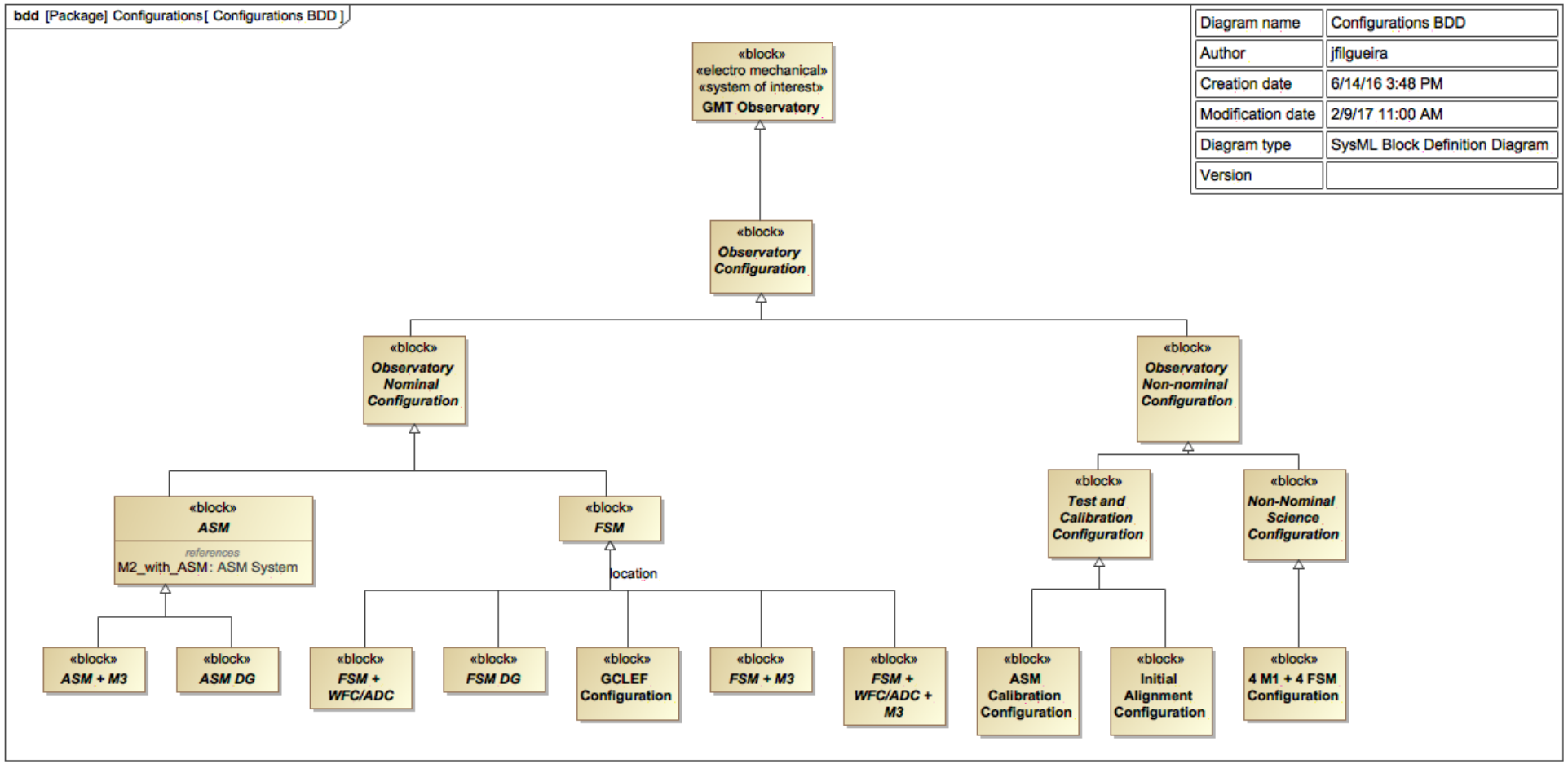
^image_quality_plot
^system_scattered_light
^detection_read_noise
^system_emissivity
^system_throughput
^stray_light_day
^stray_light_night
^pupil_stability
^flux_calibration
^wavelength_calibration
^vignetting_max
^wind_speed_max
^zenith_angle_max
^focal_length_variation : percentange
Diagram name | Observing Case Analysis Expanded
Author | jfigueira
Creation date | 4/14/16 2:05 PM
Modification date | 3/23/17 2:57 PM
Diagram type | SysML Parametric Diagram
Version

Observatory Configurations

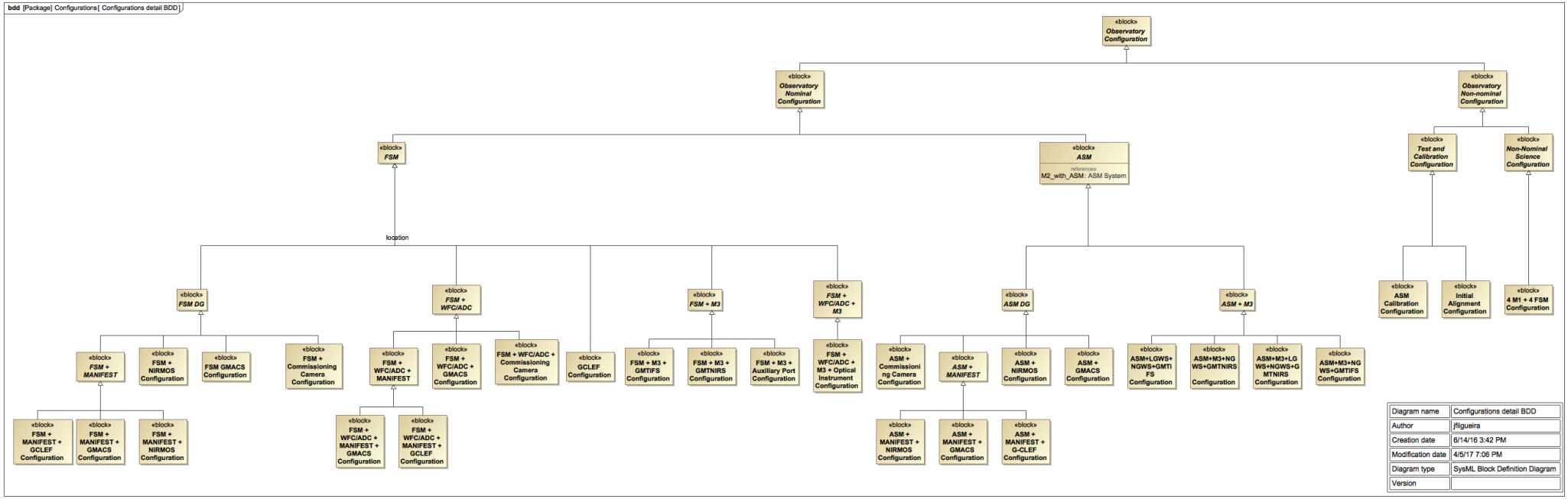
- Text



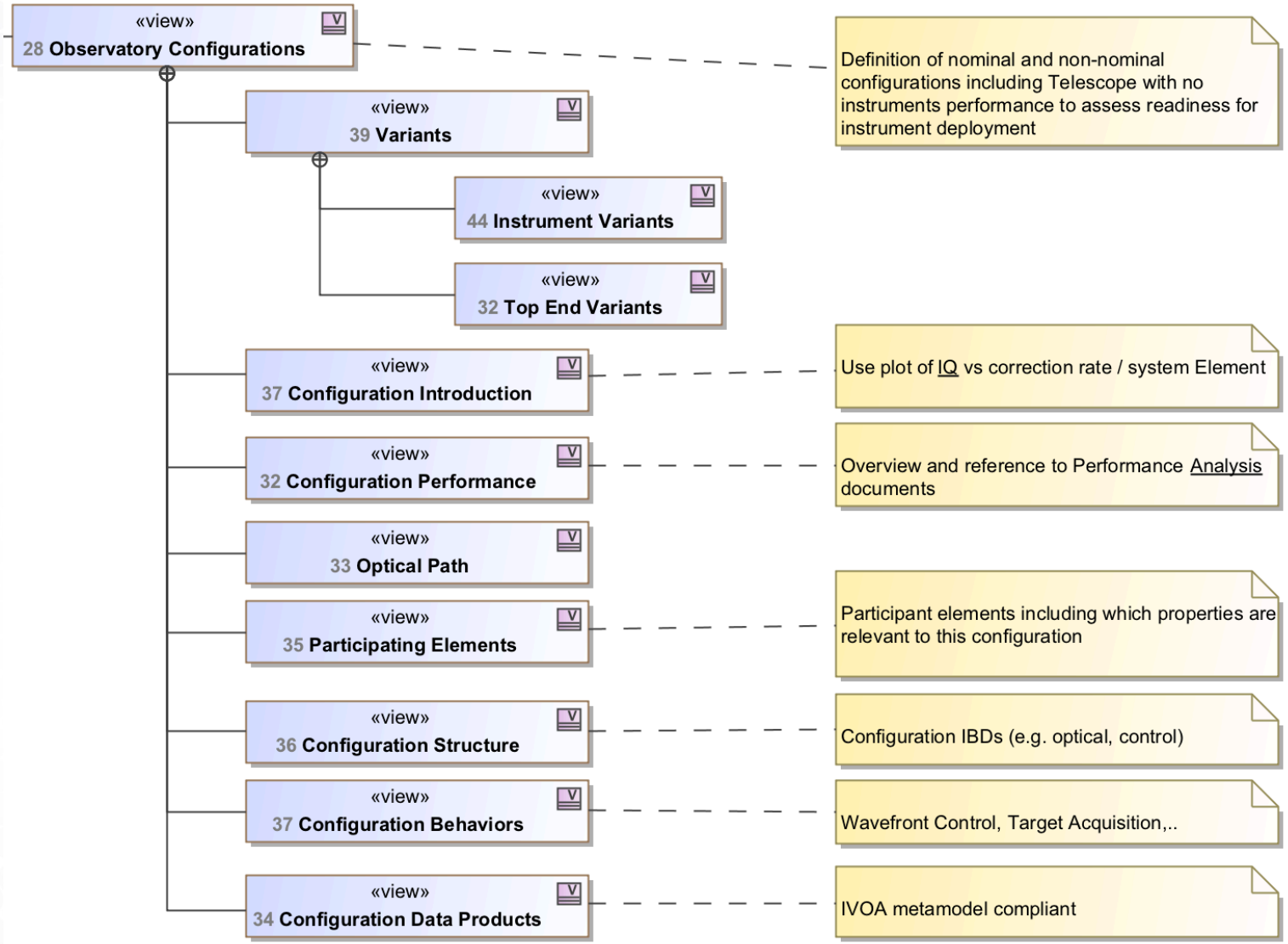
Observatory Configurations



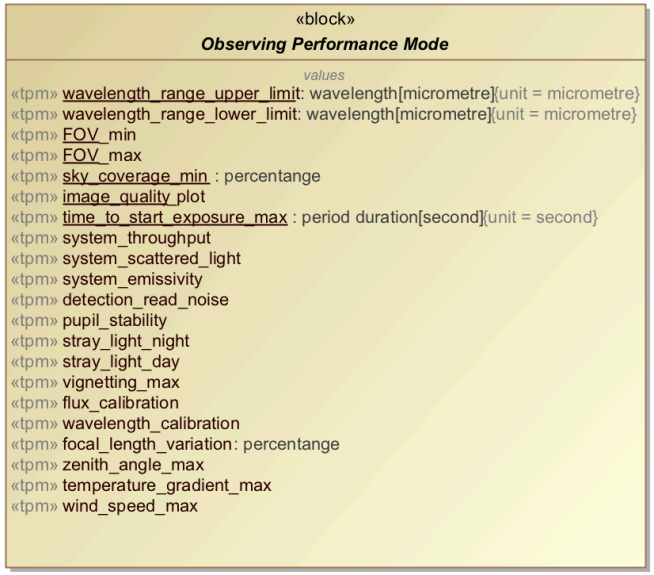
Observatory Configurations

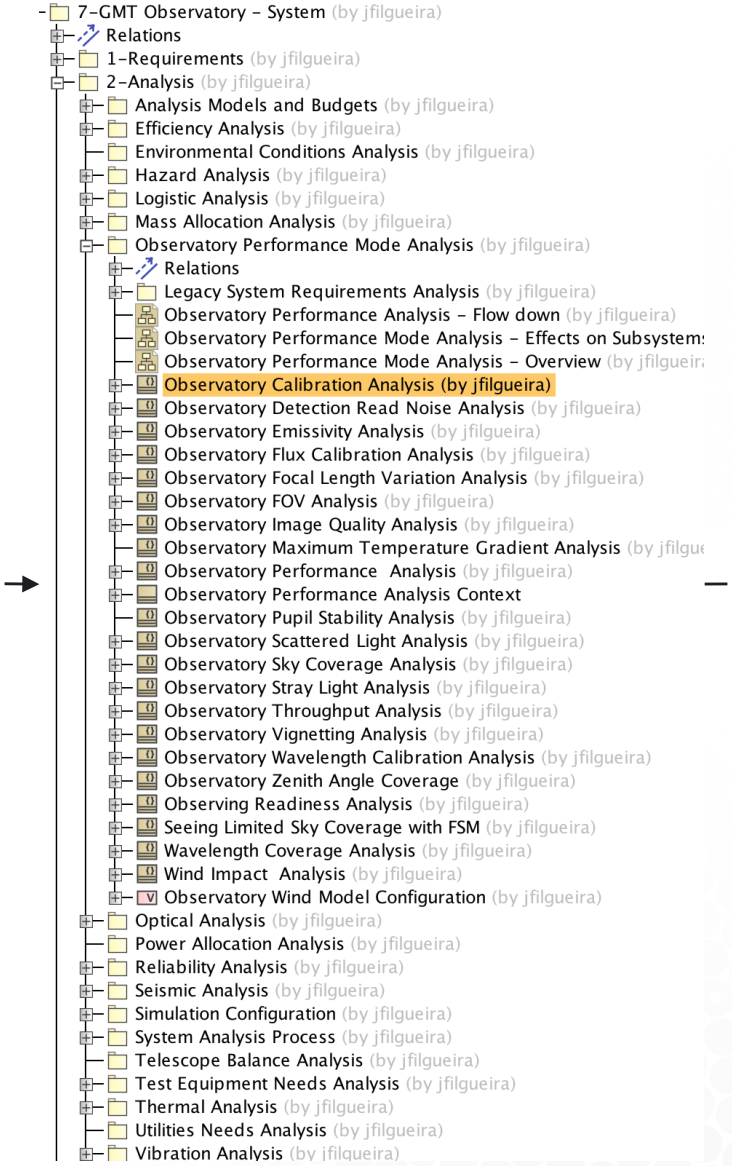


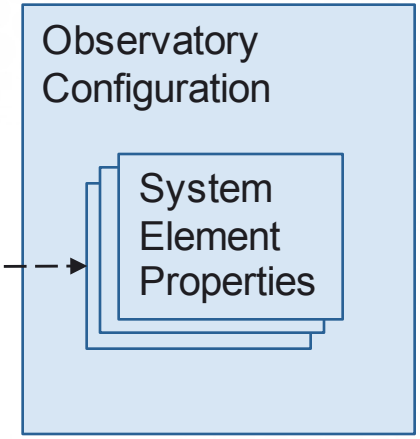
Observatory Configuration Definition



Observing Performance Mode Analysis







MBSE goals

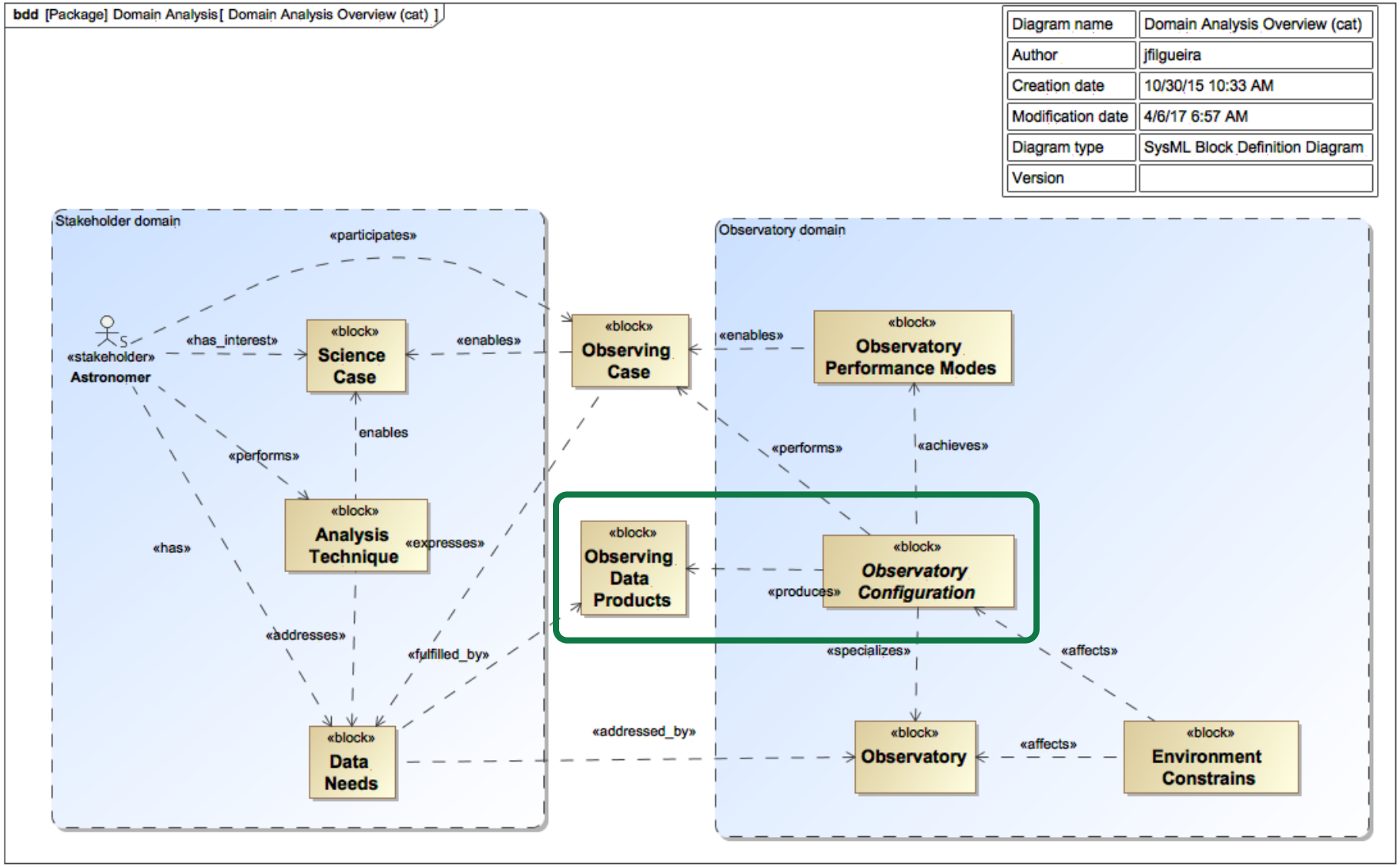

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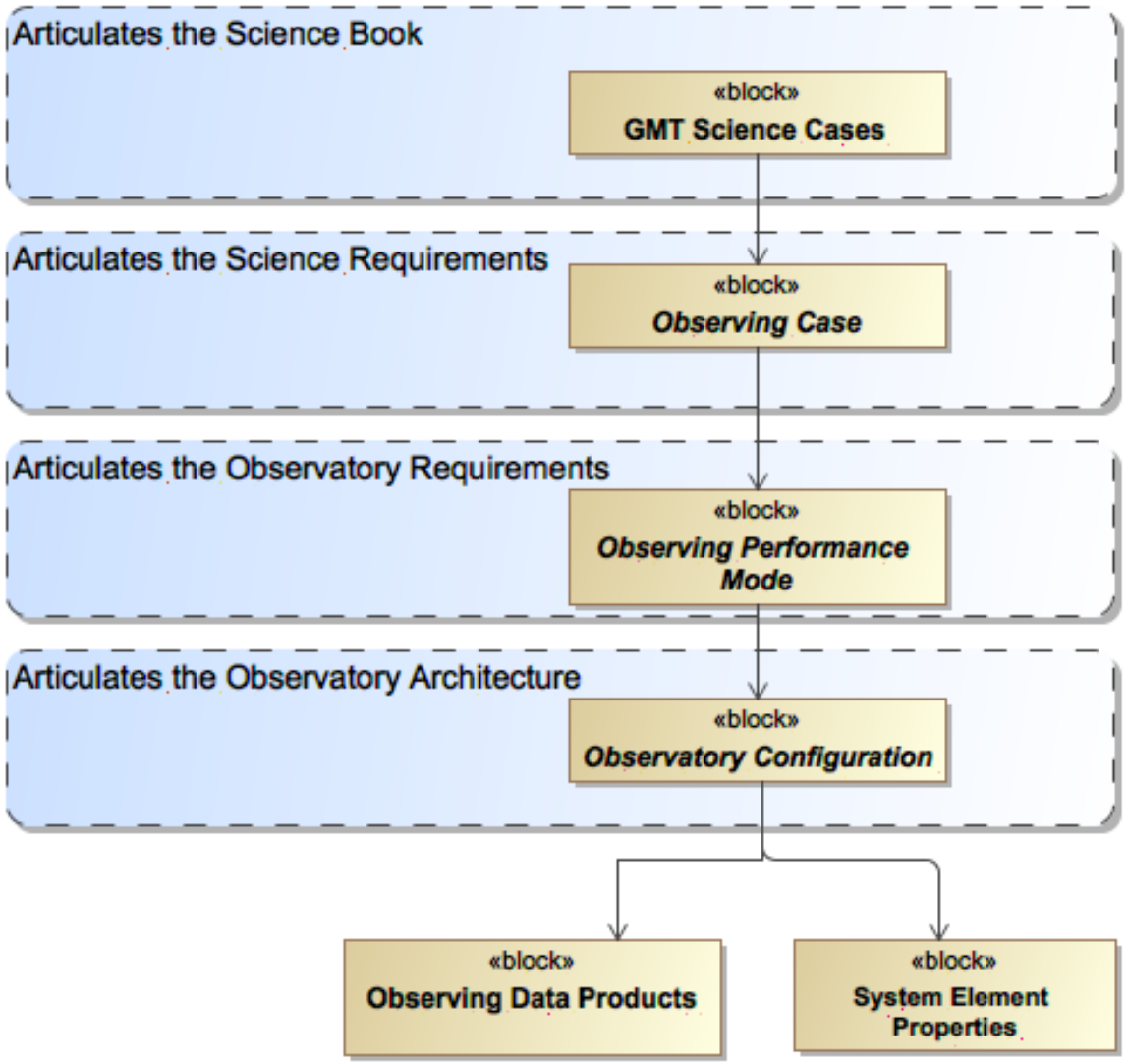
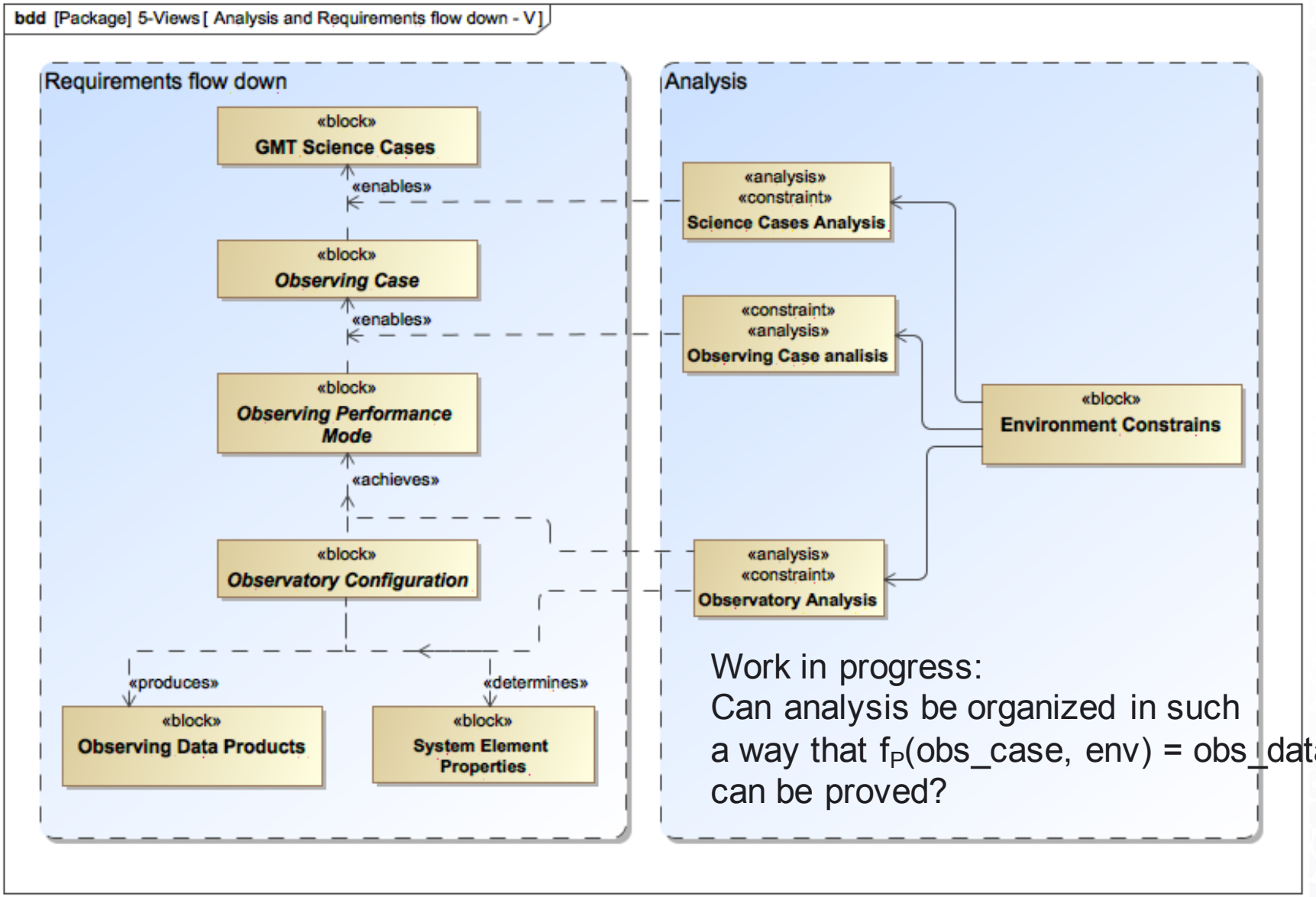
Diagram name | Domain Analysis Overview (cat)
Author | jfilgueira
Creation date | 10/30/15 10:33 AM
Modification date | 4/6/17 6:57 AM
Diagram type | SysML Block Definition Diagram
Version |
Stakeholder domain
Observatory domain
«participates»
«stakeholder»
Astronomer
«has_interest»
«block»
Science Case
«enables»
«block»
Observing Case
«enables»
«block»
Observatory Performance Modes
enables
«performs»
«performs»
«achieves»
«has»
«block»
Analysis Technique
«expresses»
«block»
Observing Data Products
«block»
Observatory Configuration
«produces»
«addresses»
«fulfilled_by»
«specializes»
«affects»
«addressed_by»
«block»
Data Needs
«block»
Observatory
«affects»
«block»
Environment Constrains

Requirements flow down

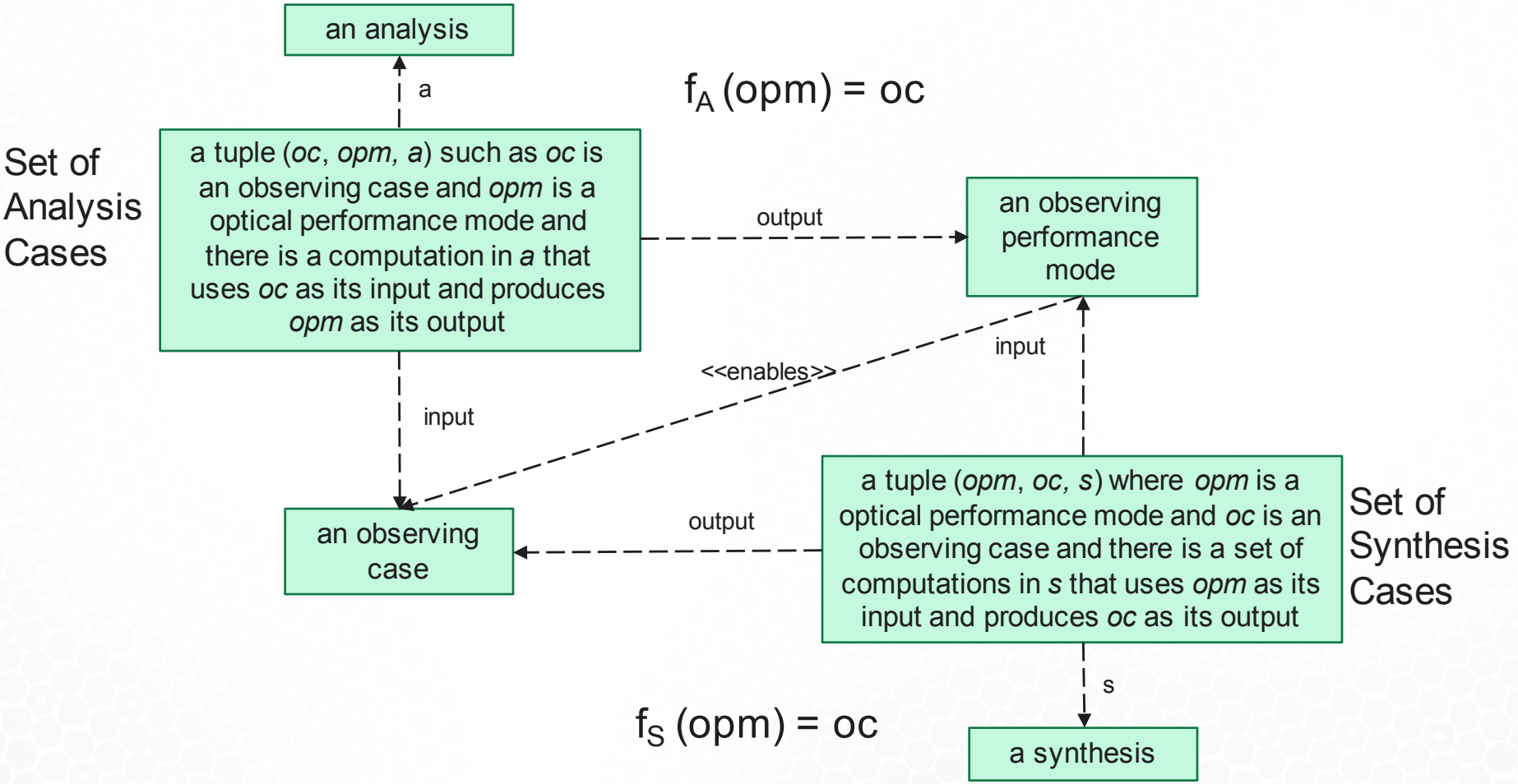


Requirements flow down and analysis

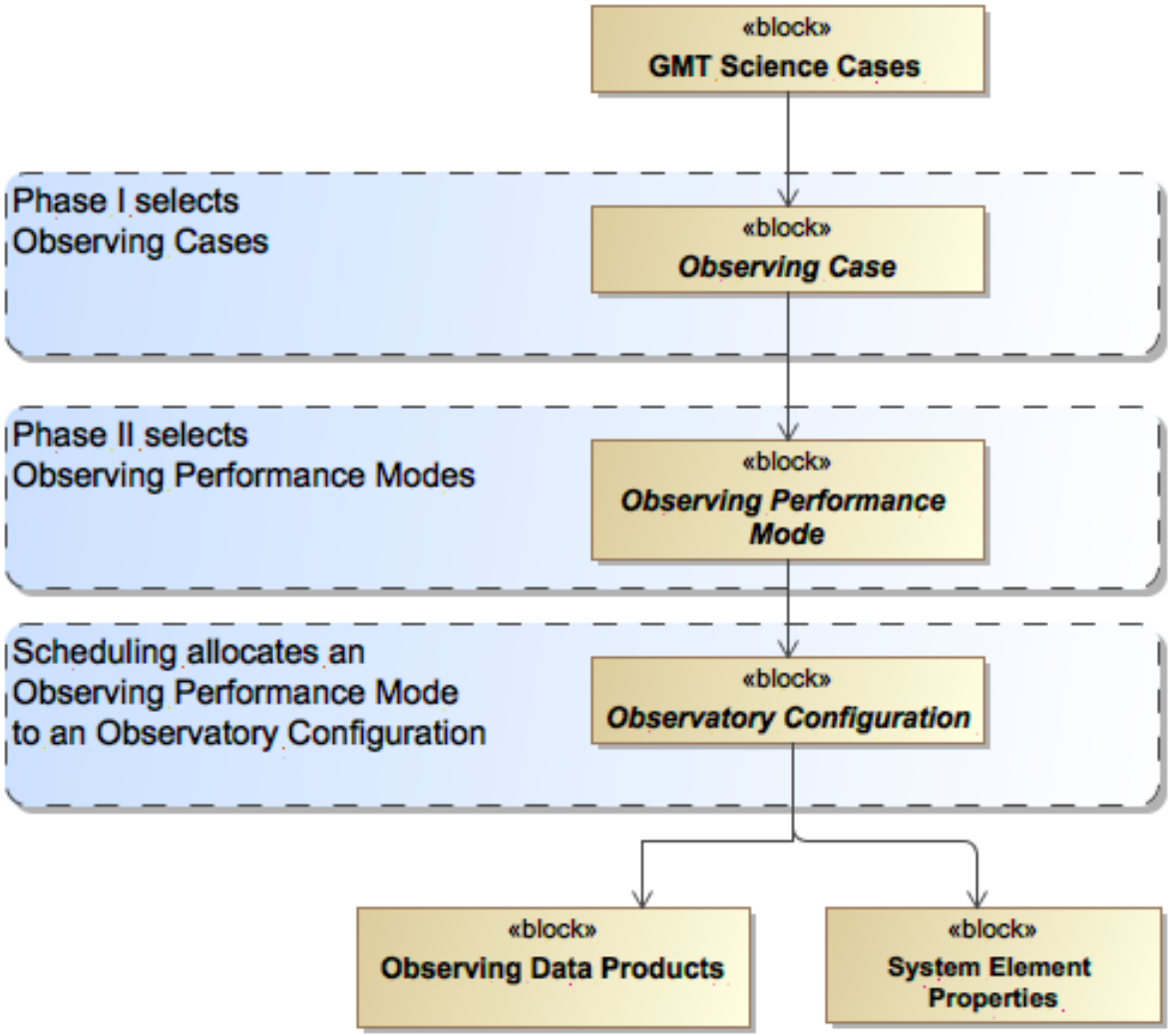


Formal considerations

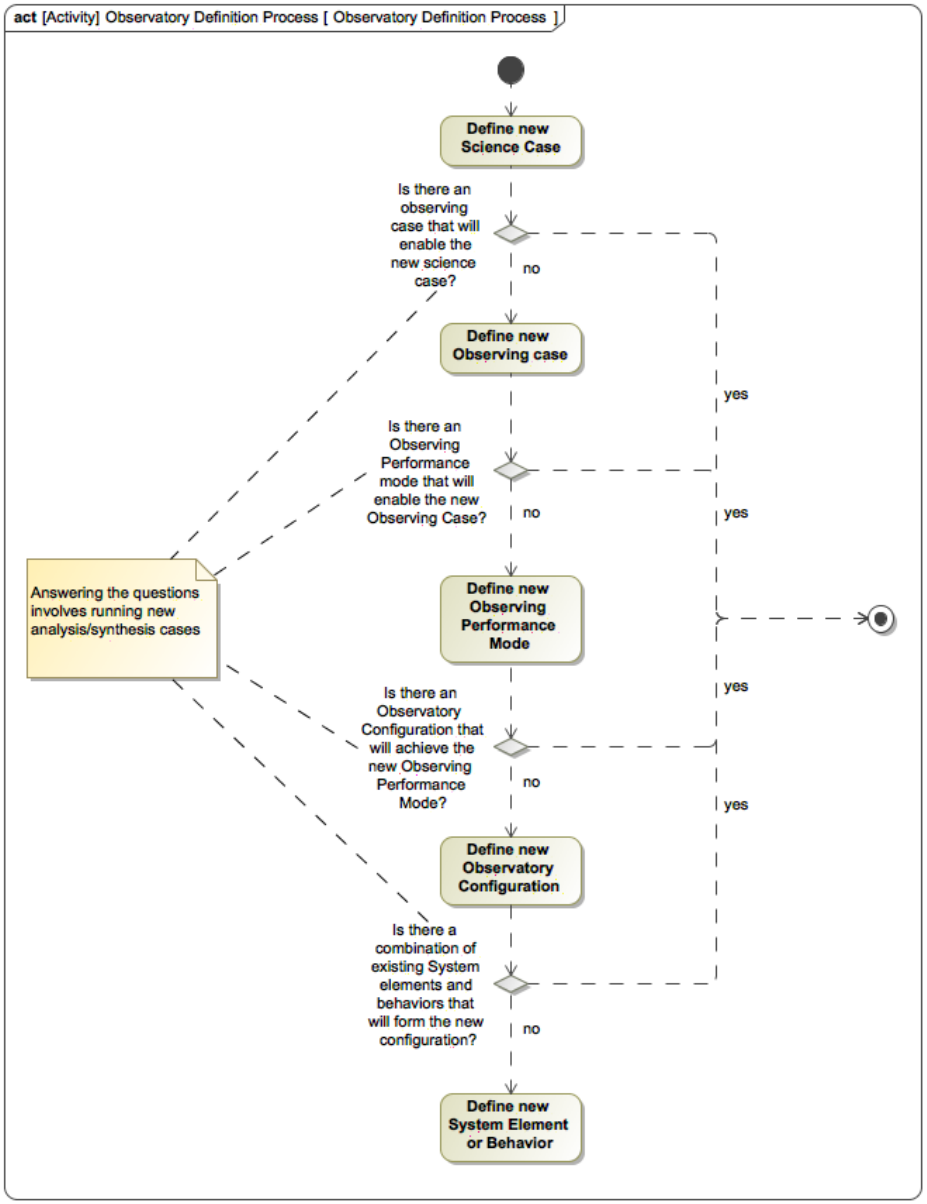
- What are the semantics of the <<enables>> relationship?
- We use some normalization rules to make it more “categorical”



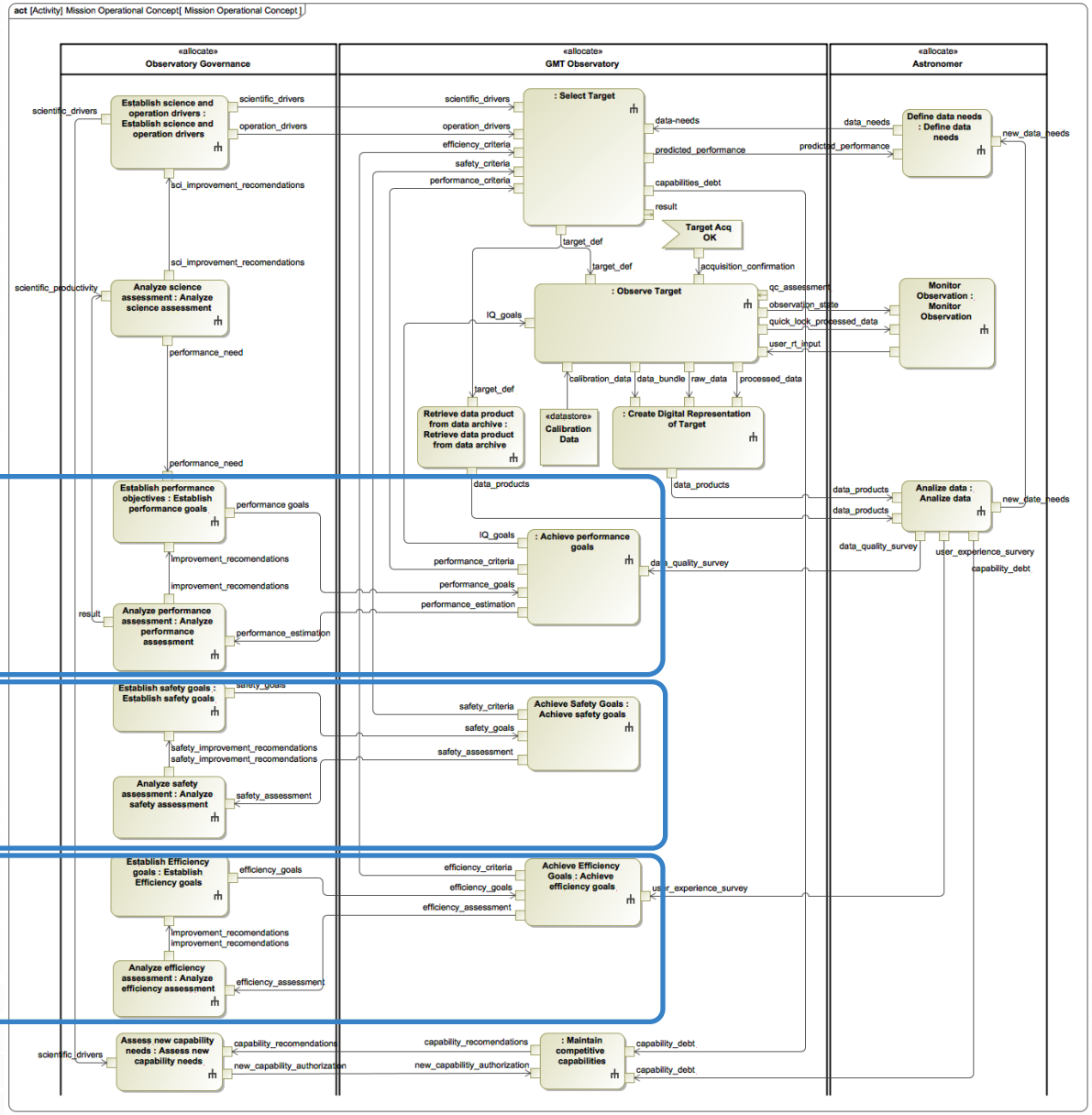
Observing process



Observatory definition process



Operation concept



MBSE conclusions

- MBSE helps finding emerging concepts that are useful for:
  - Decomposing the system
  - Flown down of requirements
  - Articulating life-cycle concepts
  - Organizing the analysis effort
- Provides a formal framework to consider correctness and truth
- Helps to find holes in the specifications