MODEL-BASED SOFTWARE DEVELOPMENT LIFECYCLE

TEC-ED & TEC-SW Final Presentation Days - December 9th 2015

Joan Clua, Patricia López Martínez, Dominique Torette, Jorge Garrido

PROJECT OVERVIEW

Model-Based Methodology Review

- Define a methodology covering the entire SW lifecycle
- Work on ECSS to accommodate model-based projects (deliverables, phases, reviews…)

TASTE Extension

- Explore areas where lifecycle is not deeply covered by the toolset (requirements, timing analysis) and select suitable tools (**jUCMNav**, **RDALTE**, **Rapitime**)
- Integrate these tools in the toolset

Proof of Concept in a Mission

- Define specific mission (Flight Formation based).
- Implement the mission using the toolset integrated in the project according to methodology.
- Exercise point of view of SW developers, system engineers and reviewers to validate the methodology and the tools in a relevant domain.

CONSORTIUM

Project Coordination

- Indra

Model-Based Methodology Review

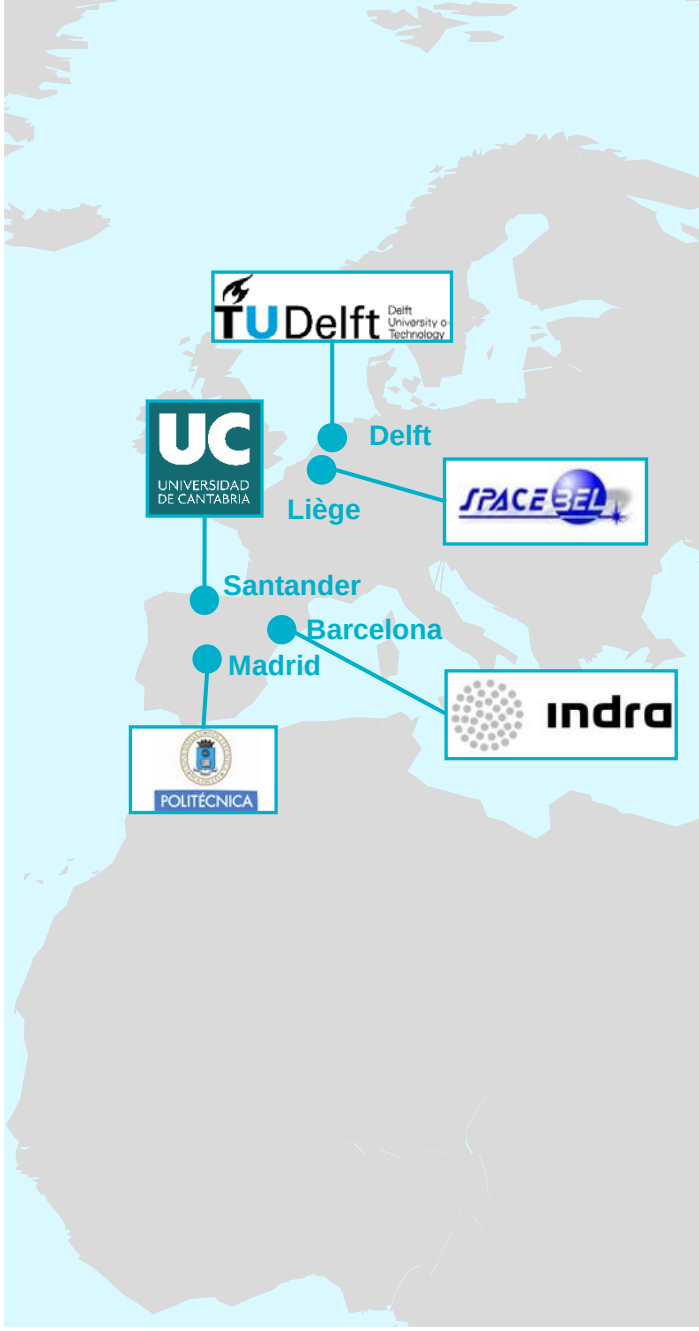
- Universidad de Cantabria (UC)
- Universidad Politécnica de Madrid (UPM)
- Spacebel

TASTE Extension

- Indra
- UC
- UPM

Proof of Concept in a Mission

- TU Delf (Mission Definition)
- Spacebel (Mission Implementation)



TOC

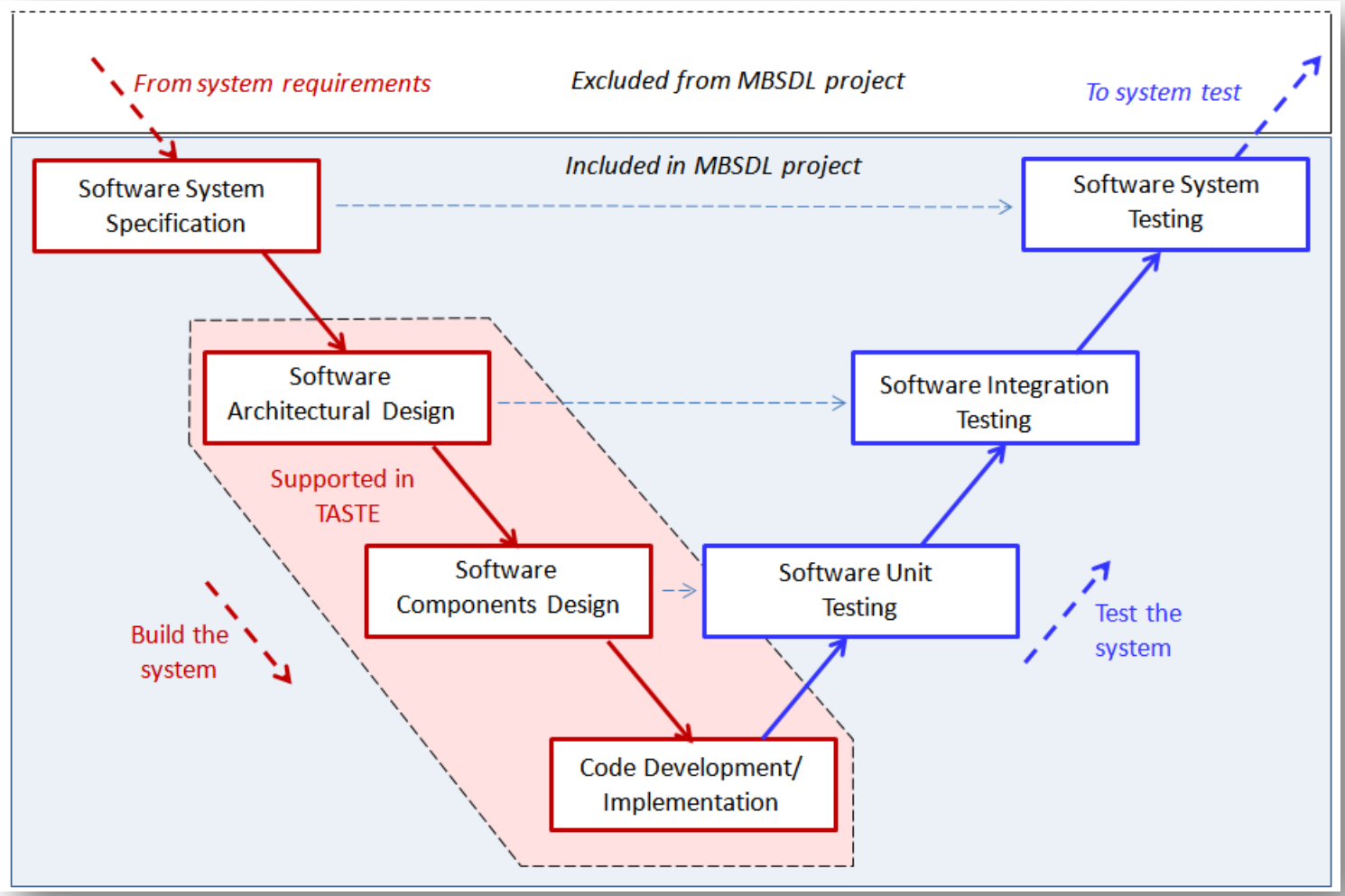
01 Model Based Methodology (P. López, UC)

02 Timing Analysis in TASTE (J. Garrido, UPM)

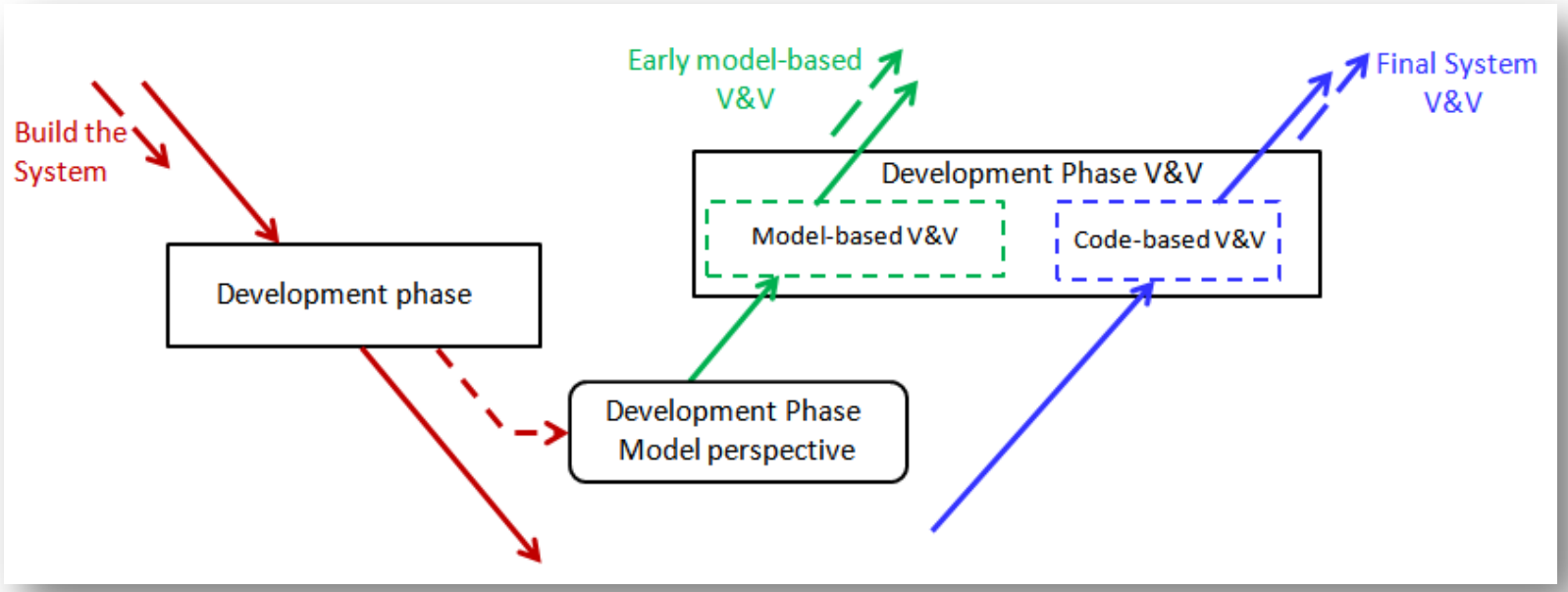
03 Mission Proof of concept (D. Torette, Spacebel)

04 Conclusions

MBSDL – STARTING POINT

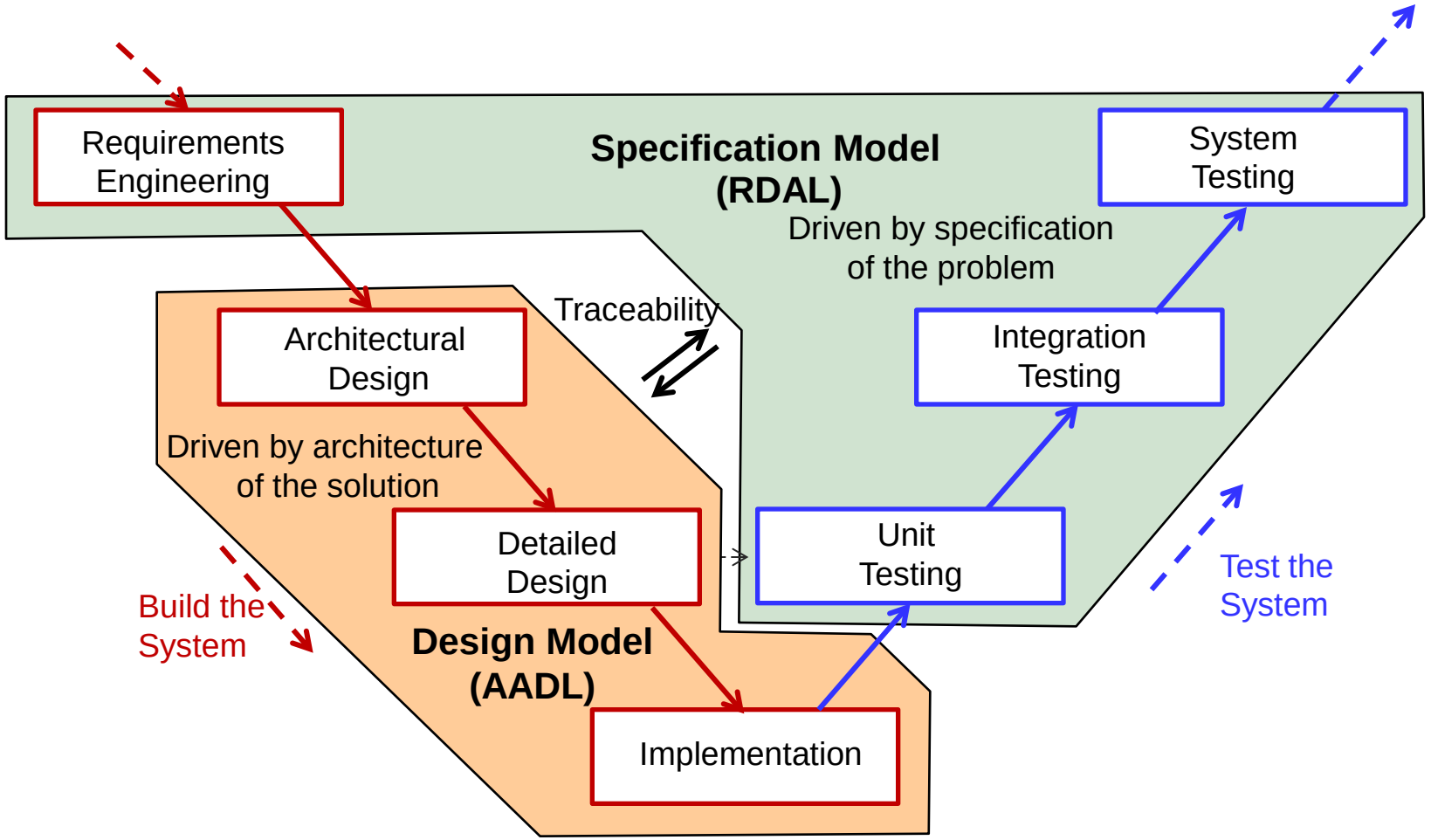


MBSDL – EARLY MODEL-BASED ANALYSIS



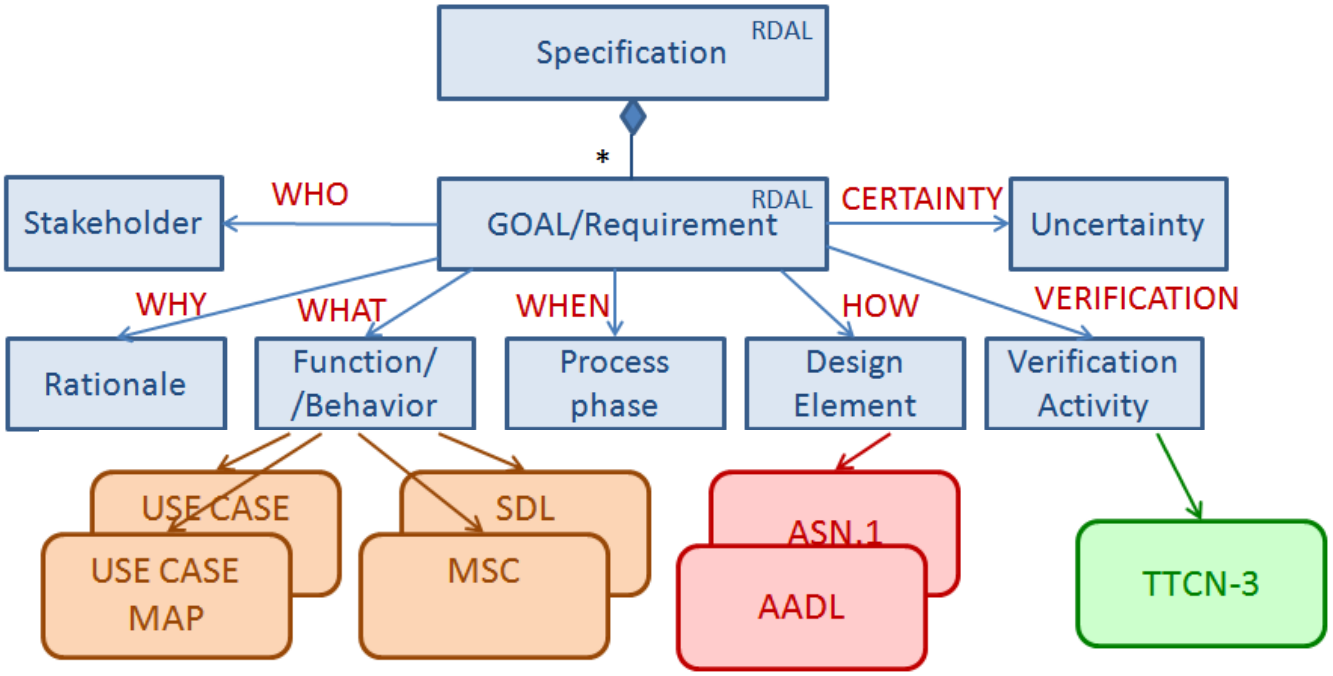
MBSDL DEFINITION

An architecture-centric and specification-centric lifecycle

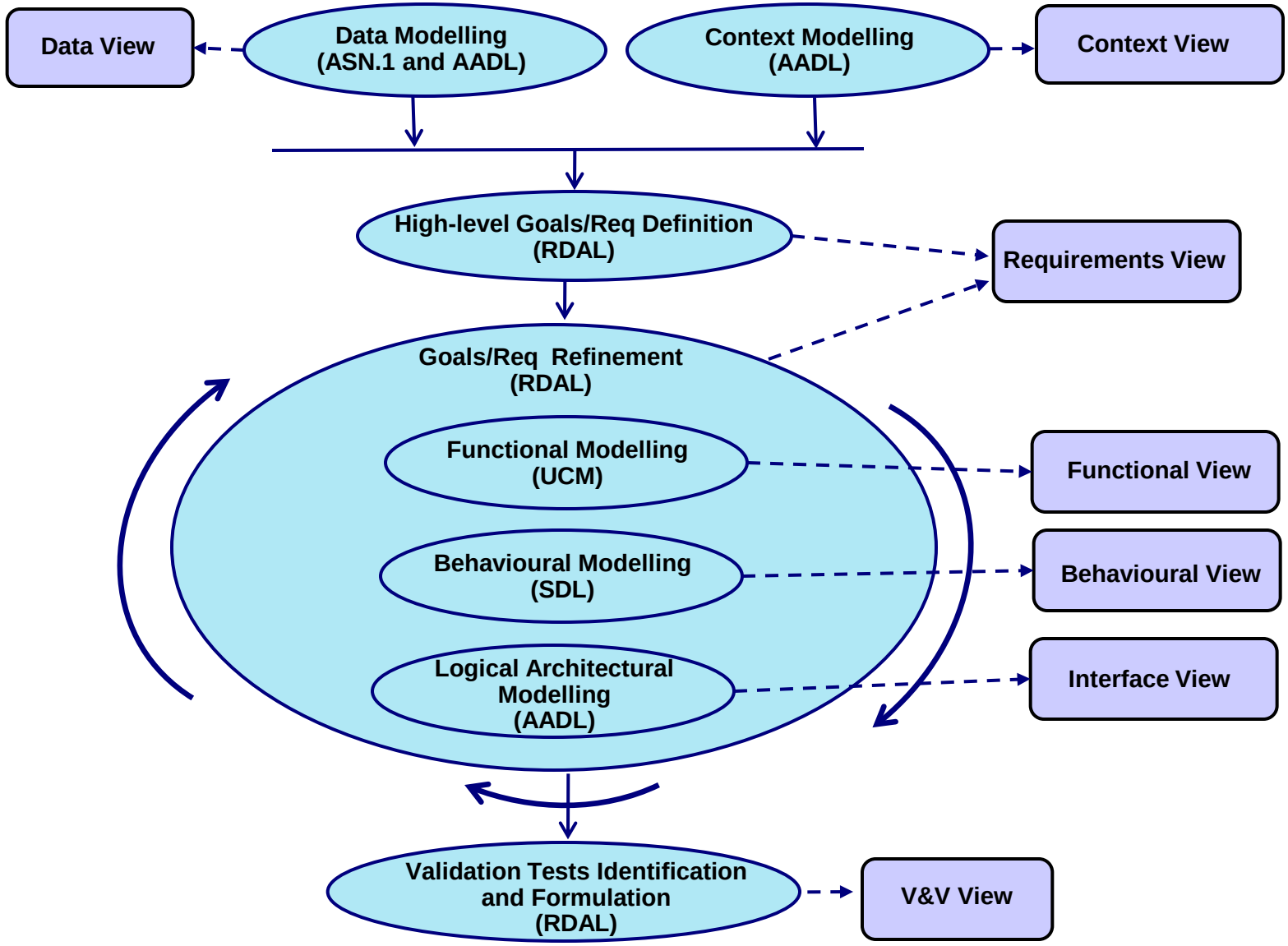


RDAL LANGUAGE

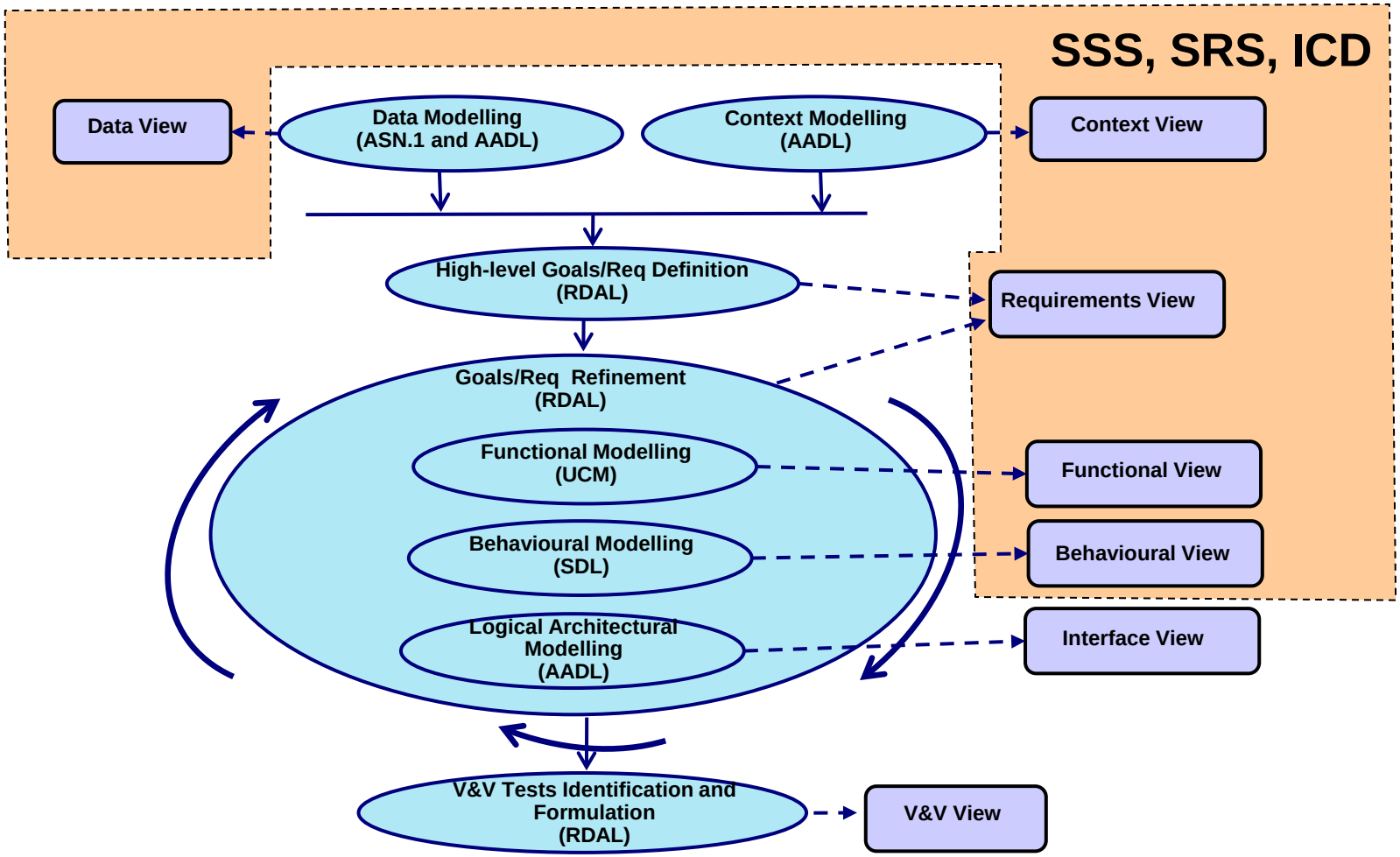
- RDAL: Requirements Definition and Analysis Annex
  - AADL Annex but independent from it
  - In process of standarization
  - Traceability to design elements, functional models, reactive models, V&V Actitivites, etc.



SOFTWARE REQUIREMENTS SPECIFICATION IN MBSDL



SOFTWARE REQUIREMENTS SPECIFICATION IN MBSDL



TOOL SELECTION

MBSDL Phase	Tools
Requirements Specification	**RDALTE** (RDAL Tool) **jUCM** (Use Case Maps Tool) + OpenGeode (SDL Tool) AADL + ASN.1
Software Architectural Design	AADL + ASN.1 OpenGeode (SDL) MAST/Cheedar (Schedulability Analysis)
Software Components Design	AADL + ASN.1 OpenGeode + Simulink/SCADE/RTDS MAST/Cheedar
Implementation	TASTE Code Generators
Software Testing	**Rapita** AADL + MAST/Cheedar MSC Test Tracer (TASTE)

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WORK OVERVIEW

- Objective: provide a working integration of Rapitime
  - Structural analysis
  - Execution time analysis

- UPM and Rapitime Systems collaboration
  - Rapita Systems:
    - Provision of tools
    - Initial integration version
  - UPM:
    - Providing previous integration as starting point
    - Support on TASTE internals
    - Versions iteration with Rapita
    - Validation of final integration

RAPITIME OVERVIEW

On-target timing analysis tool

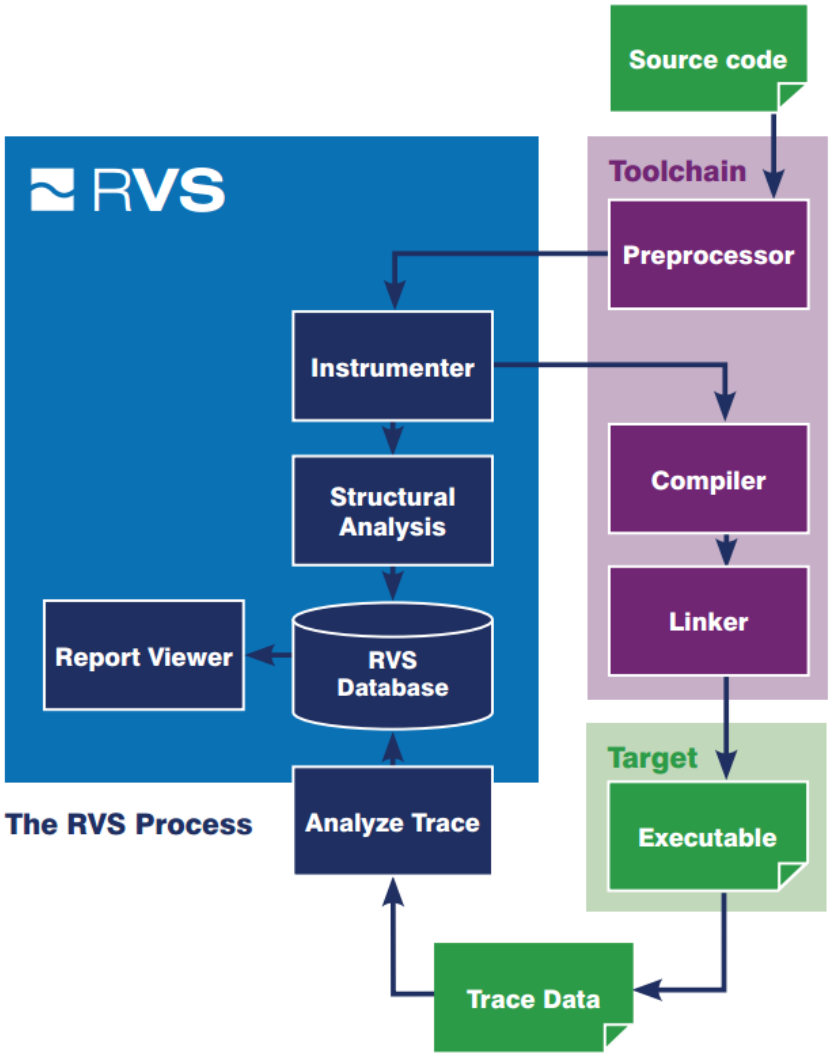
Based on:

- Structural analysis of the code (compiler and user aided)
- Automated instrumentation points
- Execution traces

Provides:

- Automated timing analysis framework
- Execution paths analysis
- Timing behavior of the system (including WCET estimation)
- Graphical and textual results
- Other analysis offered in Rapita Verification Suite (RVS)

Rapitime process



INTEGRATION OVERVIEW

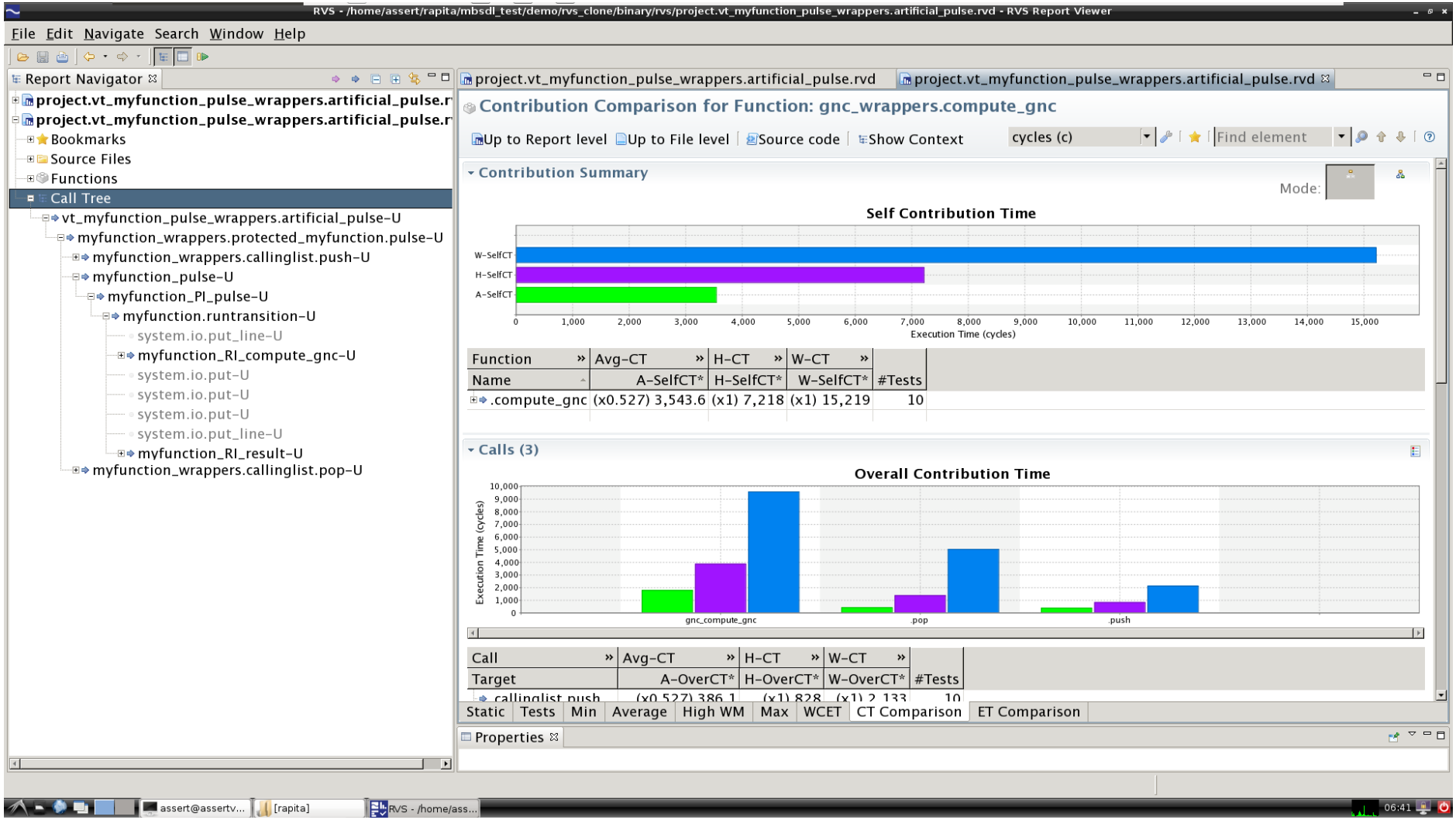
- **Integration based on previous version by UPM**
- **Aimed to follow TASTE methodology:**
  - Command-line based process
  - Python and bash scripts
  - Text-files results
  - Automated system analysis based on AADL and Ocarina generated files
  - Integration within assert-builder-ocarina.py with new parameter –instrument
- **Two-steps integration:**
  - First build generates system as usual
  - Second build generates instrumented system at an auxiliary directory

INTEGRATION RESULTS

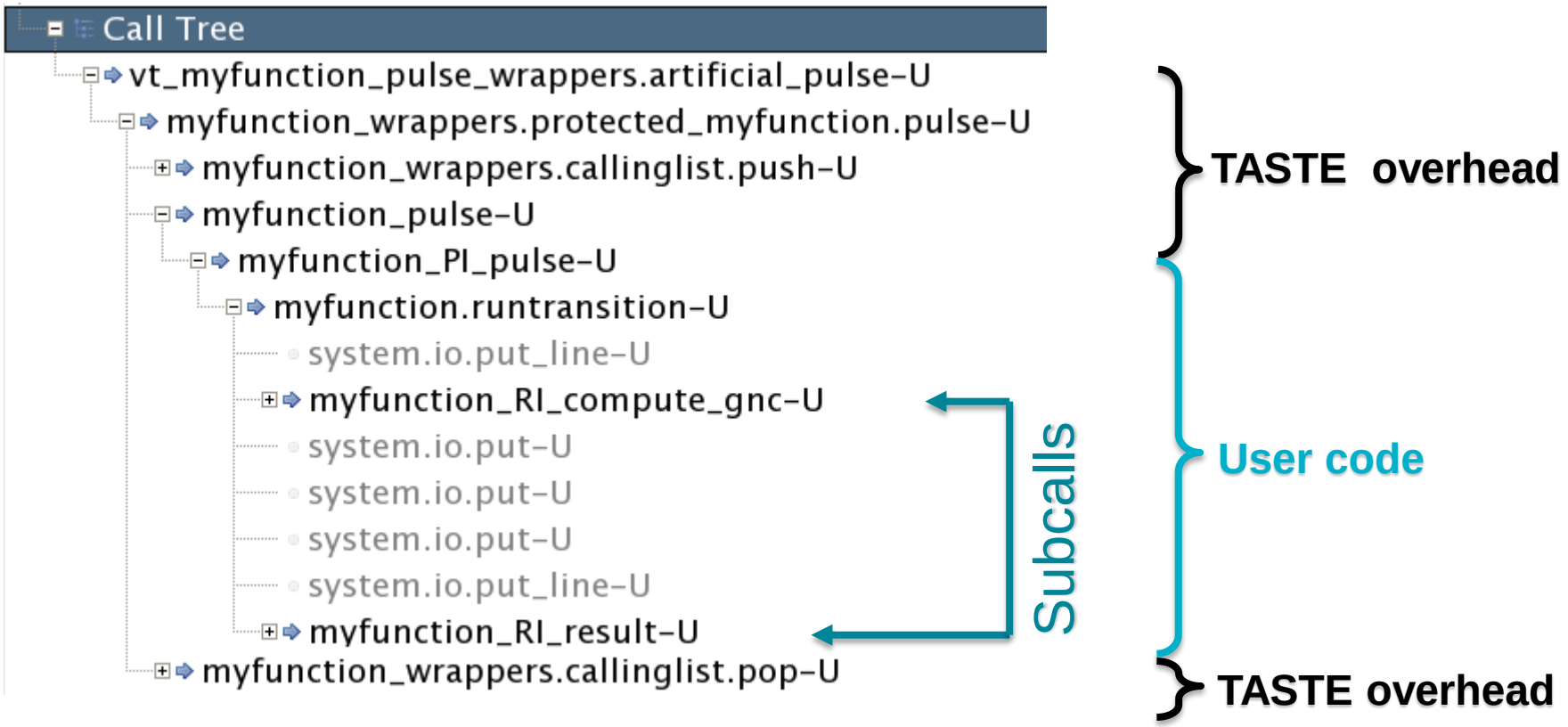
- Automated timing analysis for TASTE projects
- Textual and graphical results
  - Stored in a SQL database
  - Textual output customizable

```
== project.vt_ground_result_wrappers.artificial_result.rvd
vt_ground_result_wrappers.artificial_result: 4077 cycles

== project.vt_myfunction_pulse_wrappers.artificial_pulse.rvd
vt_myfunction_pulse_wrappers.artificial_pulse: 73745 cycles

== project.vt_myfunction_start_processing_wrappers.artificial_start_processing
vt_myfunction_start_processing_wrappers.artificial_start_processing: 2328 cycles
```

INTEGRATION RESULTS



INTEGRATION RESULTS



INTEGRATION RESULTS

project.vt_myfunction_pulse_wrappers.artificial_pulse.rvd

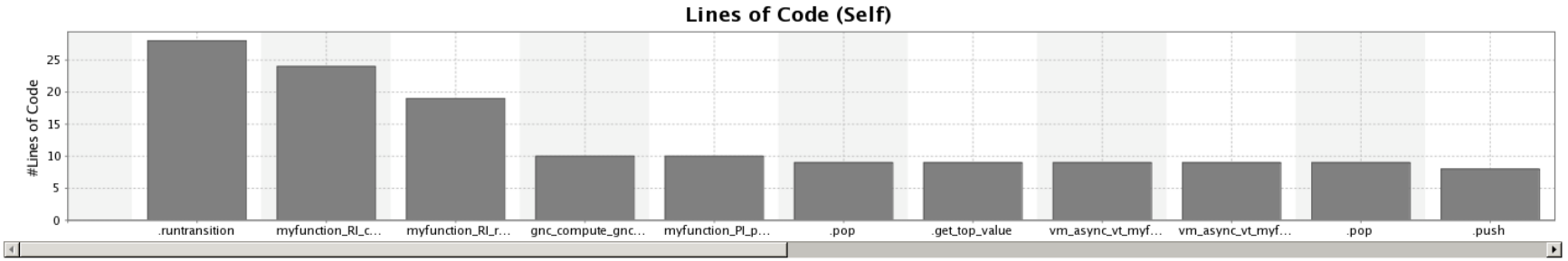
Static Analysis for Report: project.vt_myfunction_pulse_wrappers.artificial_pulse.rvd

Show: Folders Files Functions — Find element

Static Summary

- 38 functions
- 183 Ipoints
- 209 Blocks
- 197 lines of code

Code Size



Functions

Function »	Code Size				Blocks »					Instr. »
Name	#LOC-Self	#LOC-Self%	#LOC-Over	#LOC-Over%	#Blocks	#Loops	#Conditionals	#Calls	#Callers	Y/N
PrintASN1MyReal	6	3.0%	6	3.0%	6	0	0	4	2	Yes
asn1SccMyReal_Initialize	5	2.5%	5	2.5%	2	0	0	0	1	Yes
getTimeInMilliseconds	5	2.5%	5	2.5%	3	0	0	1	2	Yes
gnc_PI_compute_gnc	3	1.5%	3	1.5%	1	0	0	0	1	Yes
gnc_compute_gnc	10	5.0%	18	9.1%	15	0	1	6	1	Yes
.callinglist.pop	9	4.5%	9	4.5%	13	1	4	1	1	Yes
.callinglist.push	8	4.0%	8	4.0%	11	1	3	1	1	Yes

Overview | Static | Tests | Min | Average | High WM | Max | WCET | CT Comparison | ET Comparison

INTEGRATION RESULTS

project.vt_myfunction_pulse_wrappers.artificial_pulse.rvd

Block Tests for Context: vm_myfunction_compute_gnc-U

Up to Report level | Up to Function level | Source code | Find element

Context Summary

Context	Tested Blocks	Tested Calls	
Name	T-Block*	T-Call*	#Tests
vm_myfunction_compute_gnc-U	5 / 5	2 / 2	14

Calls (2)

Call		
Target	T-Call	#Tests
.get_top_value	T	14
.compute_gnc	T	14

Blocks (5)

Call Tree

The hierarchy of calls to this element

Call	Tested Blocks	
Name	T-Block*	#Tests
.artificial_pulse-U	3 / 3	22
.protected_myfunction.pulse-U	7 / 7	22
myfunction_pulse-U	4 / 4	22
myfunction_PI_pulse-U	6 / 7	22
myfunction.runtransition-U	12 / 20	22
myfunction_RI_compute_gnc-U	15 / 28	14
vm_myfunction_compute_gnc-U	5 / 5	14
myfunction.runtransition-U	12 / 20	22
myfunction_RI_compute_gnc-U	15 / 28	14
vm_myfunction_compute_gnc-U	5 / 5	14

Static | Tests | Min | Average | High WM | Max | WCET | CT Comparison | ET Comparison

INTEGRATION RESULTS

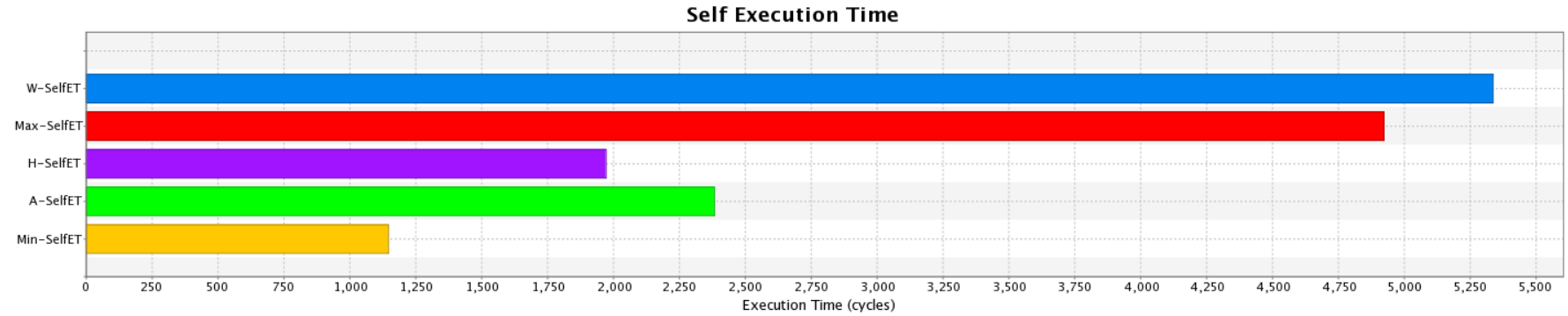
project.vt_myfunction_pulse_wrappers.artificial_pulse.rvd

Execution Time Comparison for Context: vm_myfunction_compute_gnc-U

Up to Report level | Up to Function level | Source code | cycles (c) | Find element

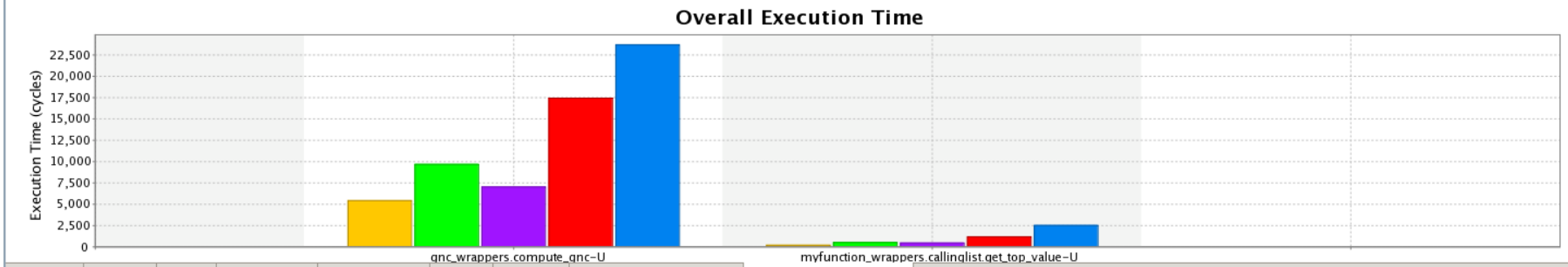
Summary

Charts:



Function	Min-ET		Avg-ET		H-ET		Max-ET		W-ET		
Name	Min-Freq	Min-SelfET	A-Freq	A-SelfET	H-Freq	H-SelfET	Max-Freq	Max-SelfET	W-Freq	W-SelfET	#Tests
vm_myfunction_compute_gnc-U	0	1,146	0.637	2,383	1	1,972	1	4,923	1	5,337	14

Calls (2)



Static | Tests | Min | Average | High WM | Max | WCET | CT Comparison | ET Comparison

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04 Conclusions

USE CASE

- Software Requirement Specification for a Formation Flying Mission
  - GNC FF Algorithms
  - FF Operational modes
  - Distribution of the responsibilities across the formation
  - Routing of PUS TM/TC
  - Ground and Inter Satellites Link communication interfaces
- Top inputs : High Level Specifications from TUDelft
  - Introduction to AOCS/GNC functionalities of FF Satellites
  - Mission Requirement Document
  - System Requirement Document
  - Operational Requirement Document
- Additional inputs : In-house ongoing PROBA-3 FF project feedbacks

OUTPUTS

- Models
  - Specification and Documentation Generation
    - Use Case Maps : URN/UCM
    - RDAL : RDAL
  - Design and Code Generation
    - TASTE (Interface, Deployment) : AADL
    - TASTE (Data model) : ASN.1
    - TASTE/OpenGeode (Behavior, modes) : SDL
  - Traceability links
- ECSS-like documentation (Fully generated from models - template based)
  - SSS
  - SRS

USER REQUIREMENTS NOTATION (URN)

- User Requirements Notation (URN) is intended for
  - Elicitation and specification of requirements.
    - Discover and specify requirements for a proposed system
  - Analysis and validation of requirements.
    - Analyze such requirements for correctness and completeness
      - Execution of Scenarios and branches coverage
    - Simple formal language for Behaviors and Scenario expected results definition
  - Impact analysis of Implementation Trade-Off.
    - Explore impacts of alternative responsibilities assignments.
  - Graphical Representation
    - Visually communicate design choices

USE CASE MAPS (UCM)

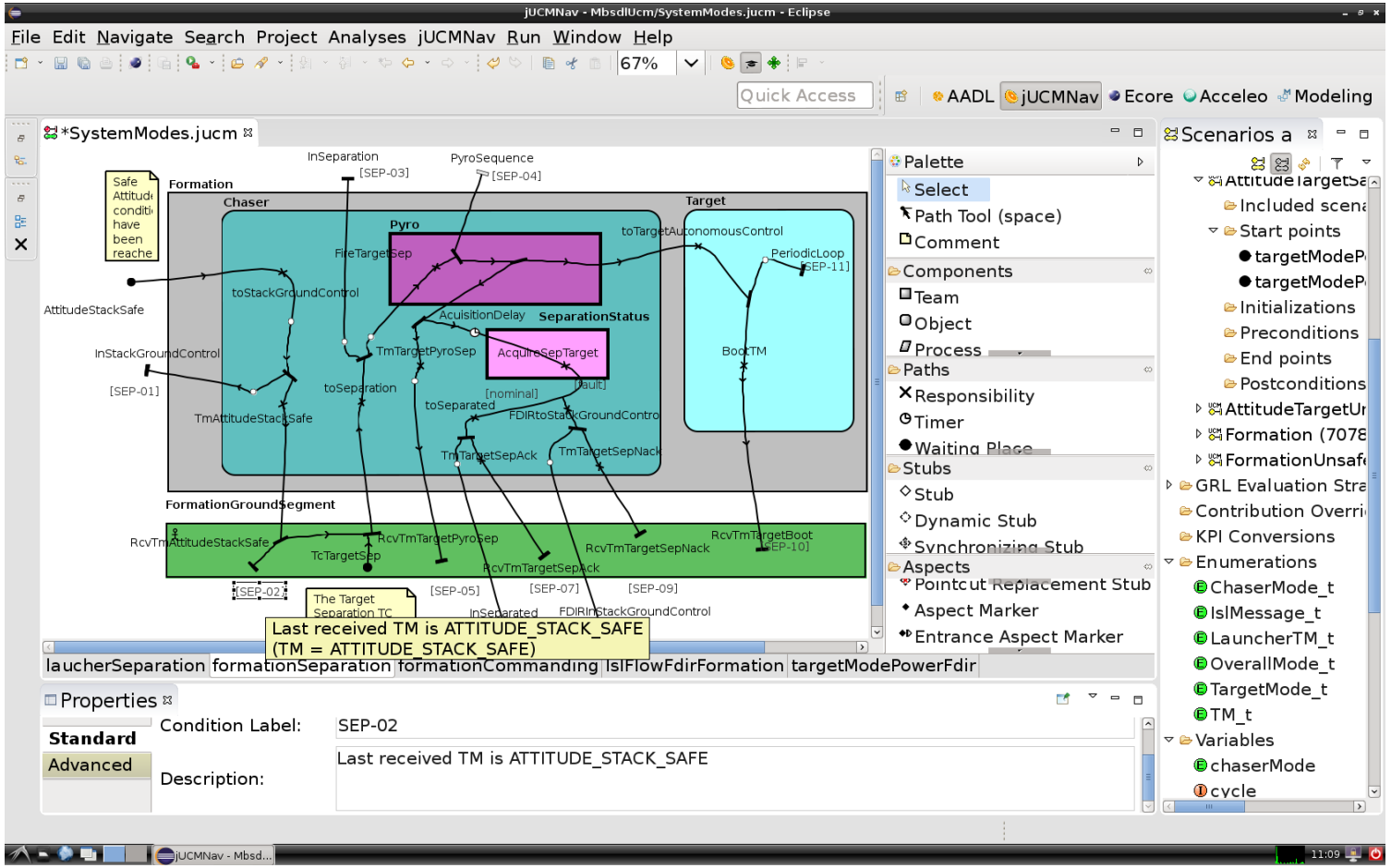
- Use Case Maps (UCM)
  - graphically describes the functional requirements of a software system,
  - precisely describe processes (alt. view to Message Sequence Chart),
  - represents control flows and distributes *responsibilities* to actors, by *superimposition of scenario paths on a structure of components*.
- Use Case Map fairly addresses
  - operational requirements,
  - functional requirements,
  - architectural *trade-offs*.
- At later stages, UCM may be further refined into:
  - MSCs or UML sequence diagrams,
  - SDL state machines or UML state chart diagrams.

No new concepts, but same concepts introduced earlier in the development cycle.

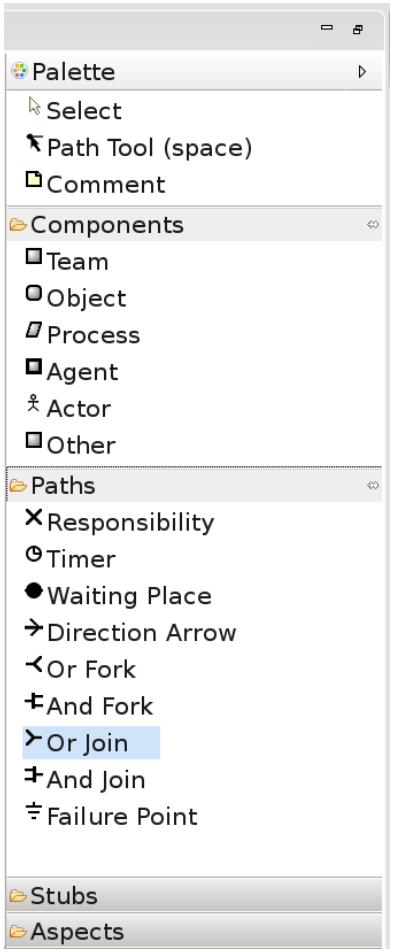
JUCMNAV

- UCM Tool
- Free Eclipse-based plug-in/editor
  - Now in version 6.0, August 2014
  - Since May 2006
- Dedicated Perspective, Graphical editor with palette
- Eclipse Navigator, Outline view and Preferences
- EMF metamodel
  - Allows model to model and model to text transformations
- Export to graphical representations (.jpg, .dot, .png)
- Export to Message Sequence Charts (.jucmscenarios)
  - Included Message Sequence Charts viewer
- Allows the early definition, execution and verification of Scenarios
- Allows graphical animation of Scenarios
- Cross platform (Linux, Windows 7, Mac OS X)

JUCMNAV: PERSPECTIVE



JUCMNAV: PALETTE



- *Structure of components*
  - Team, Object, Process, Agent, Actor.
- *Scenario paths*
  - Start Point : Scenarios initial conditions
  - **End Point** : Scenarios completion conditions
    - **This is the place to allocate/verify requirements**
    - **Textual description**, but also **formal expression to be verified** on scenario completion. Boolean expression based on variables updated by Responsibilities.
  - Or Fork : Execution path Or Fork (logical conditions)
  - And Fork : Execution path And Fork (logical conditions)
  - Or Join : Execution path Or Join
  - And Join : Execution path And Join
  - Responsibility: Pseudo-code fragment
  - Stubs : Hierarchical decomposition, refer another UCM

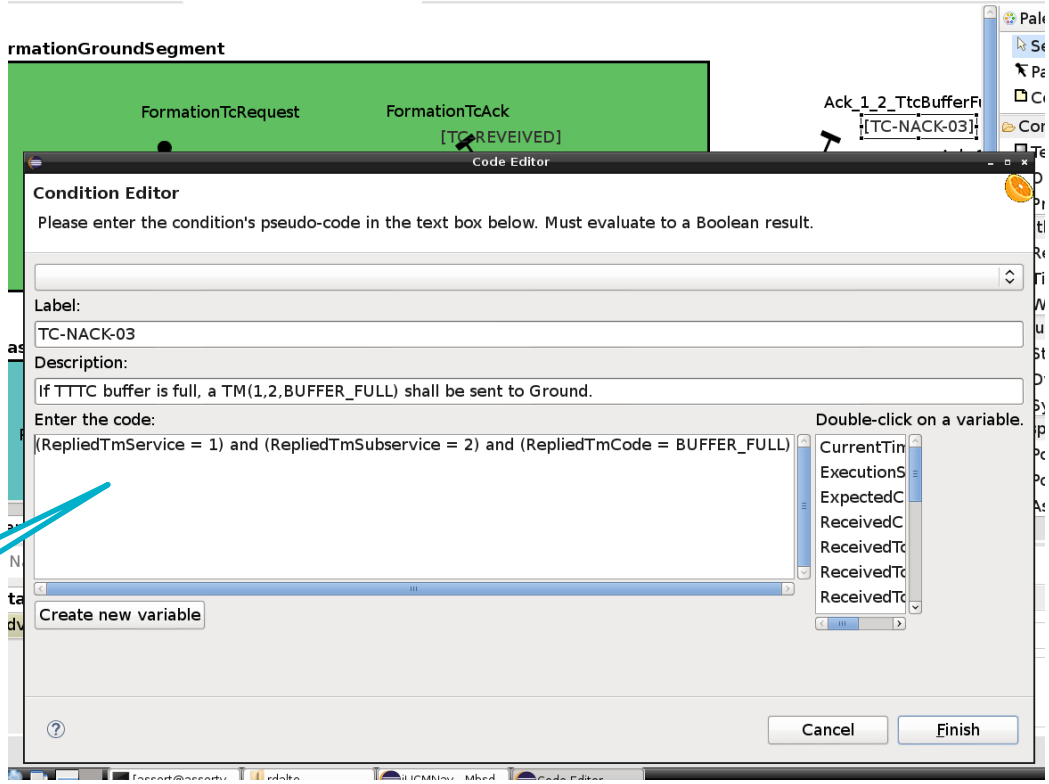
JUCMNAV: CODE/CONDITION EDITOR

Editor for

- Responsibility code
- Requirement condition

Variables list

Variables creation



Syntax Verification

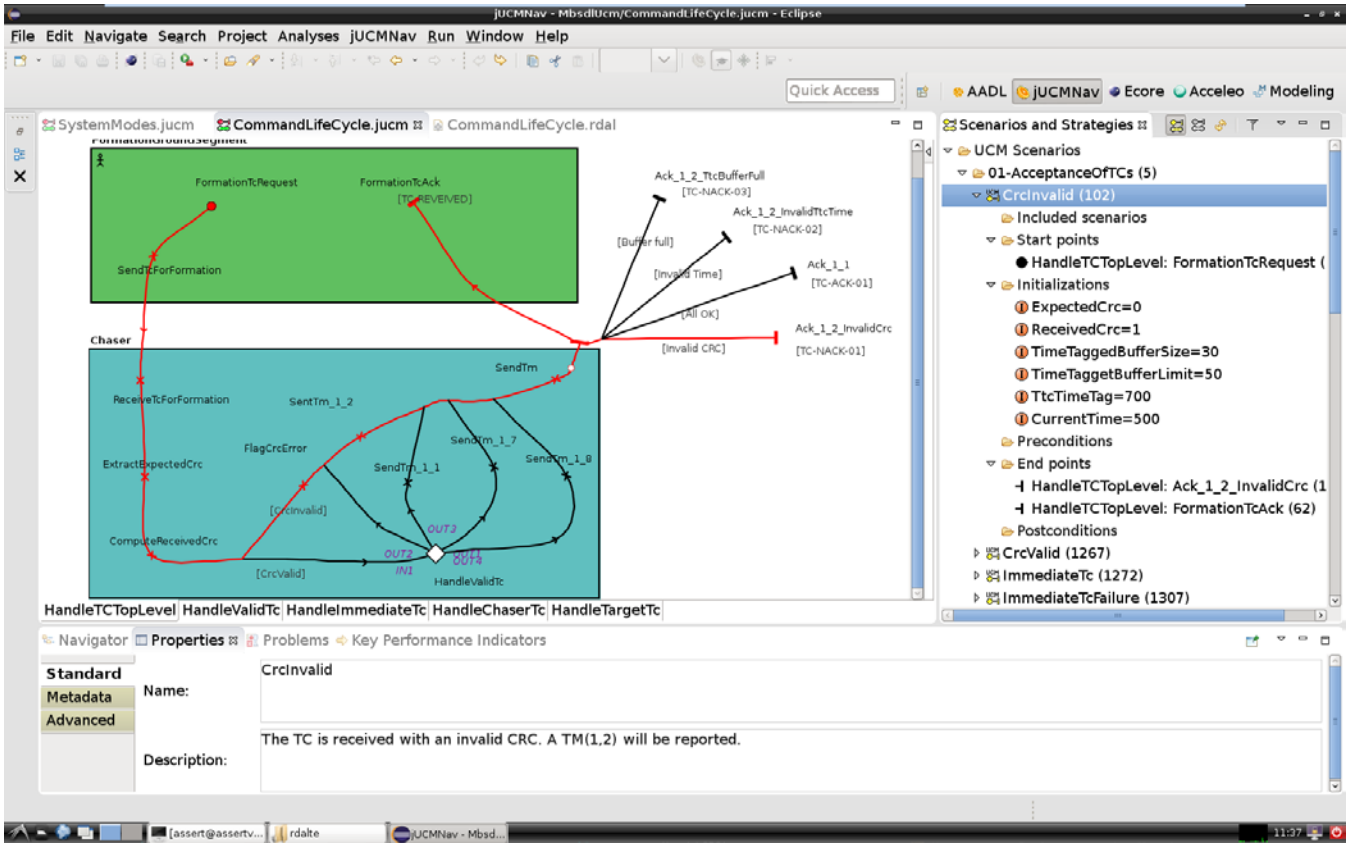
JUCMNAV: SCENARIO EXECUTION

Scenario:

- **Start points**
- **Initializations**
- **End points**
- **Inclusions**

Scenario Group:

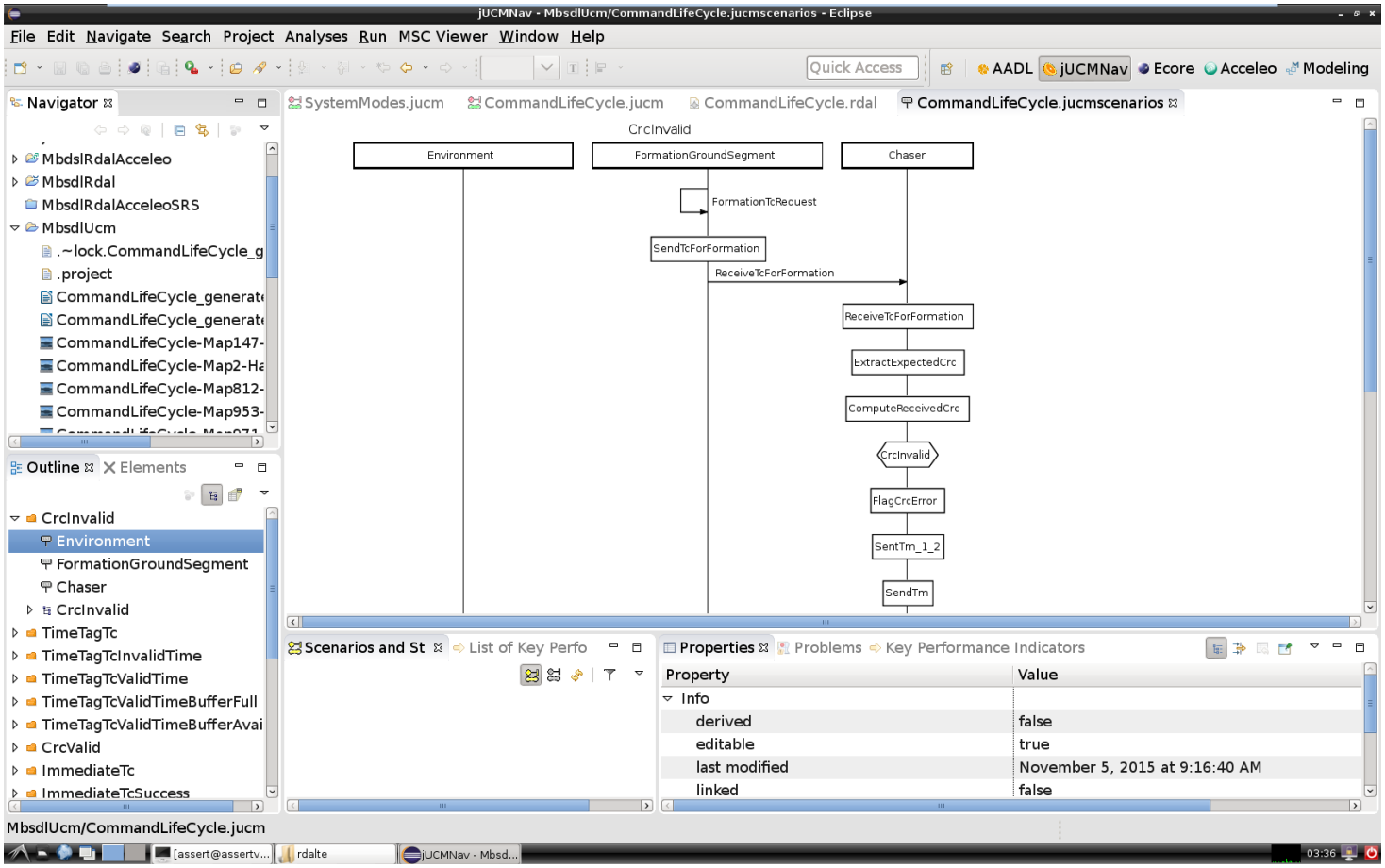
- **Run all**
- **Coverage**



Unsatisfied Conditions reported as errors in problems panel

JUCMNAV: MESSAGE SEQUENCE CHART EXPORT

Once Executed scenarios can be exported and viewed as MSC



GENDOC: MODEL BASED SSS GENERATION

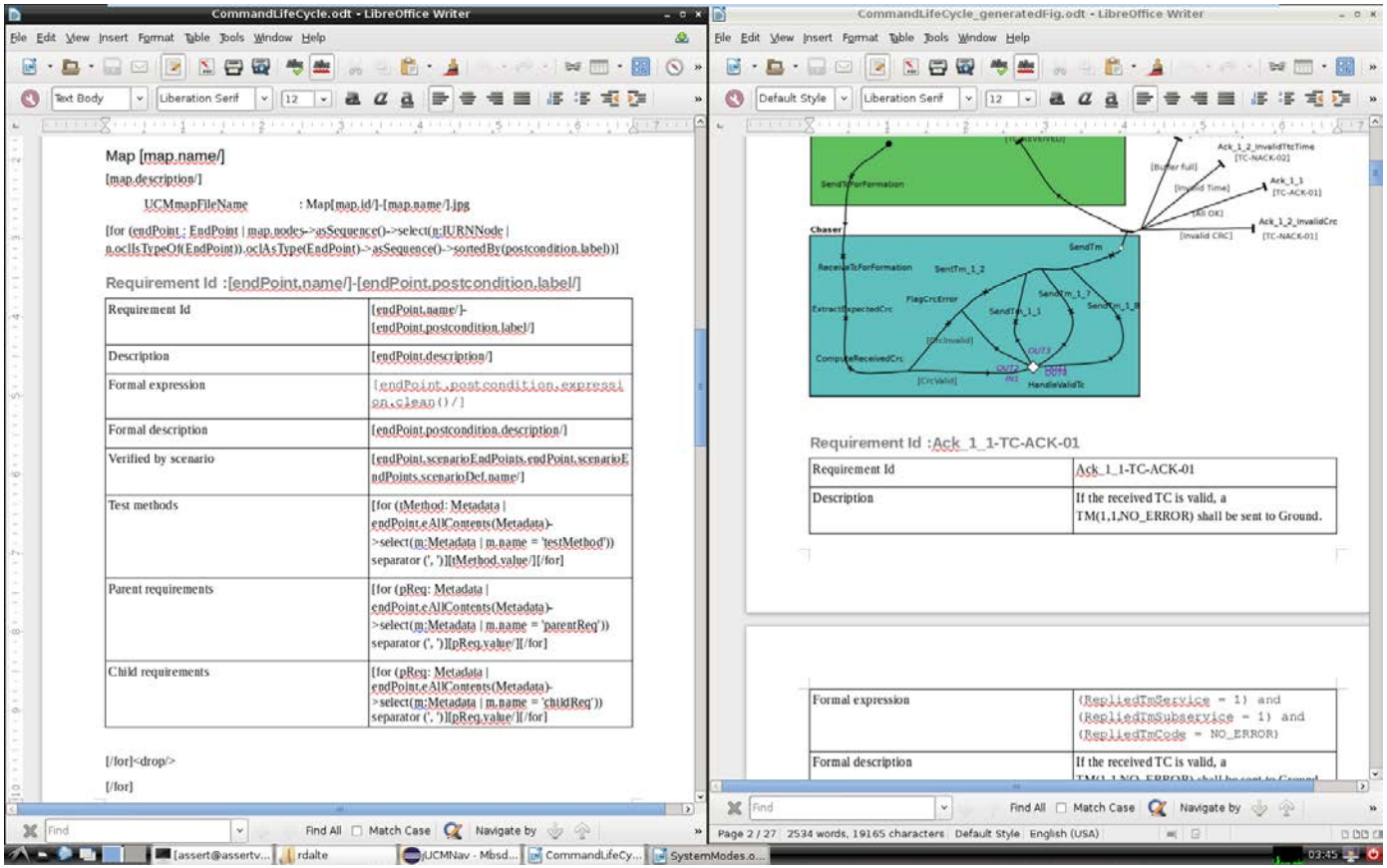
Template based Model2Txt transformation

EMF Gendoc

Embedded Acceleo in .odt or .docx templates

Support for tables and figures

Test coverage and requirements traceability's



RDAL METAMODEL: SYSTEM OVERVIEW

Identification of the System and its Environment.

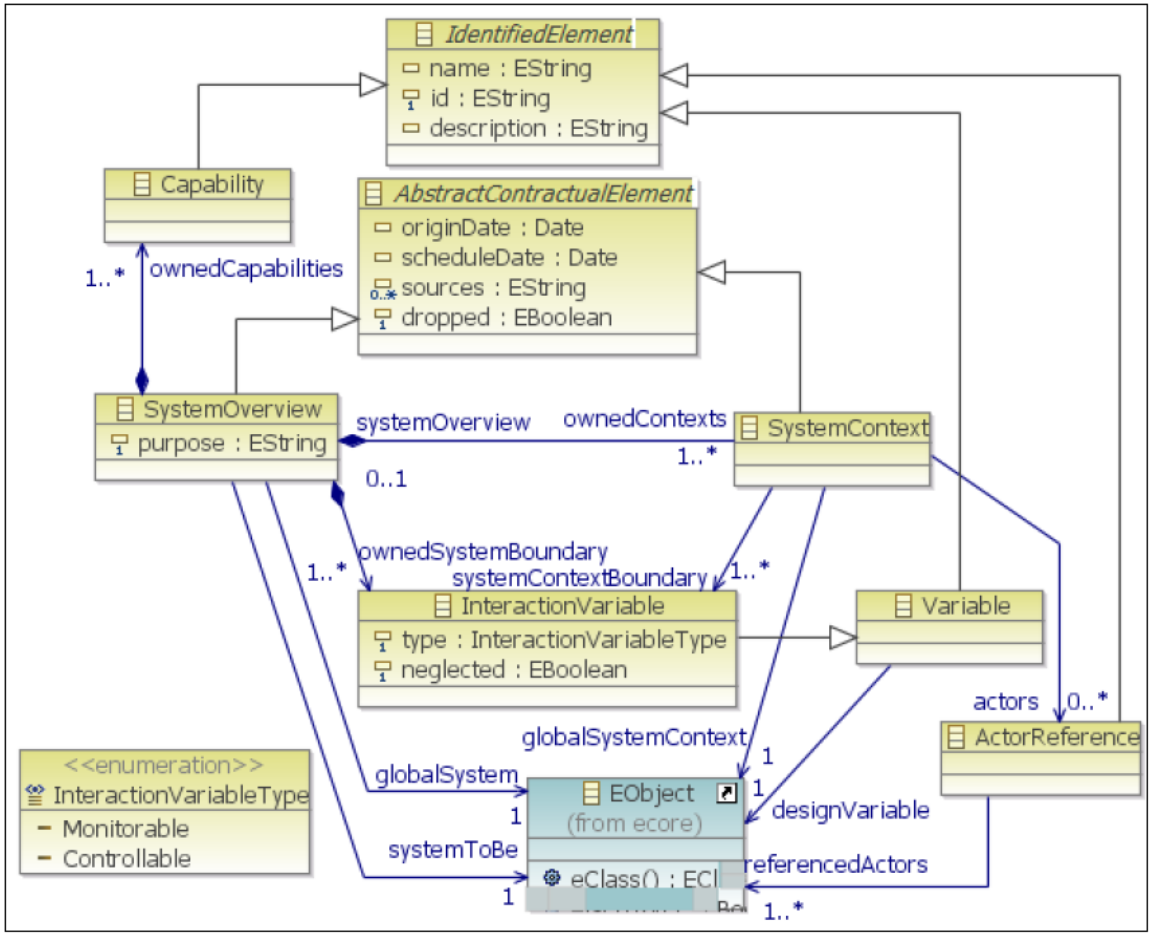
Identification of Data Interface.

Concept of

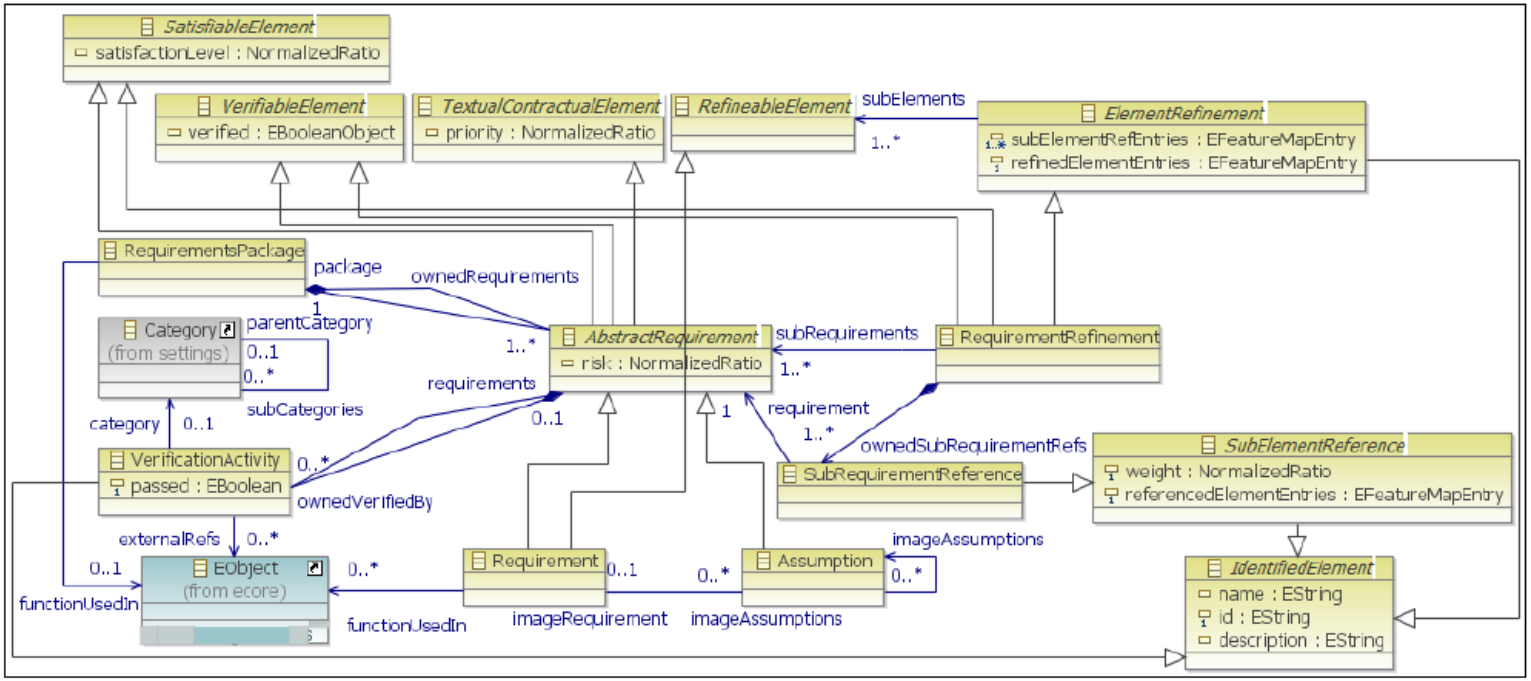
- **Monitored Variables**
- **Controlled Variables**

but only at top level.

Similar to Simulink Block inputs/outputs.



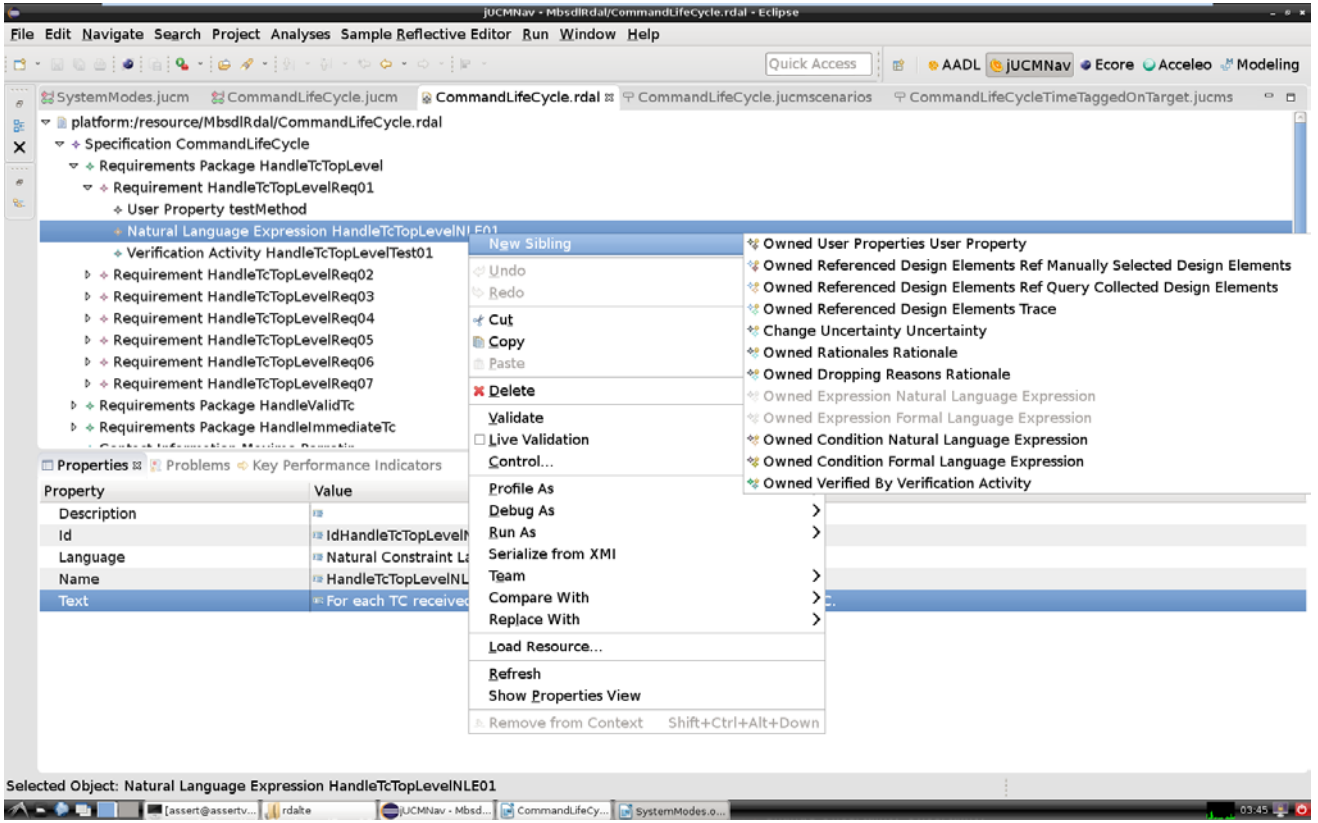
RDAL METAMODEL: REQUIREMENT



Organized in Packages
Complex structure, oversized for mid-size project
Reference to external models (traceability) through EObject
Natural language
Formal languages: BLESS, Lute, OCL but no provers support

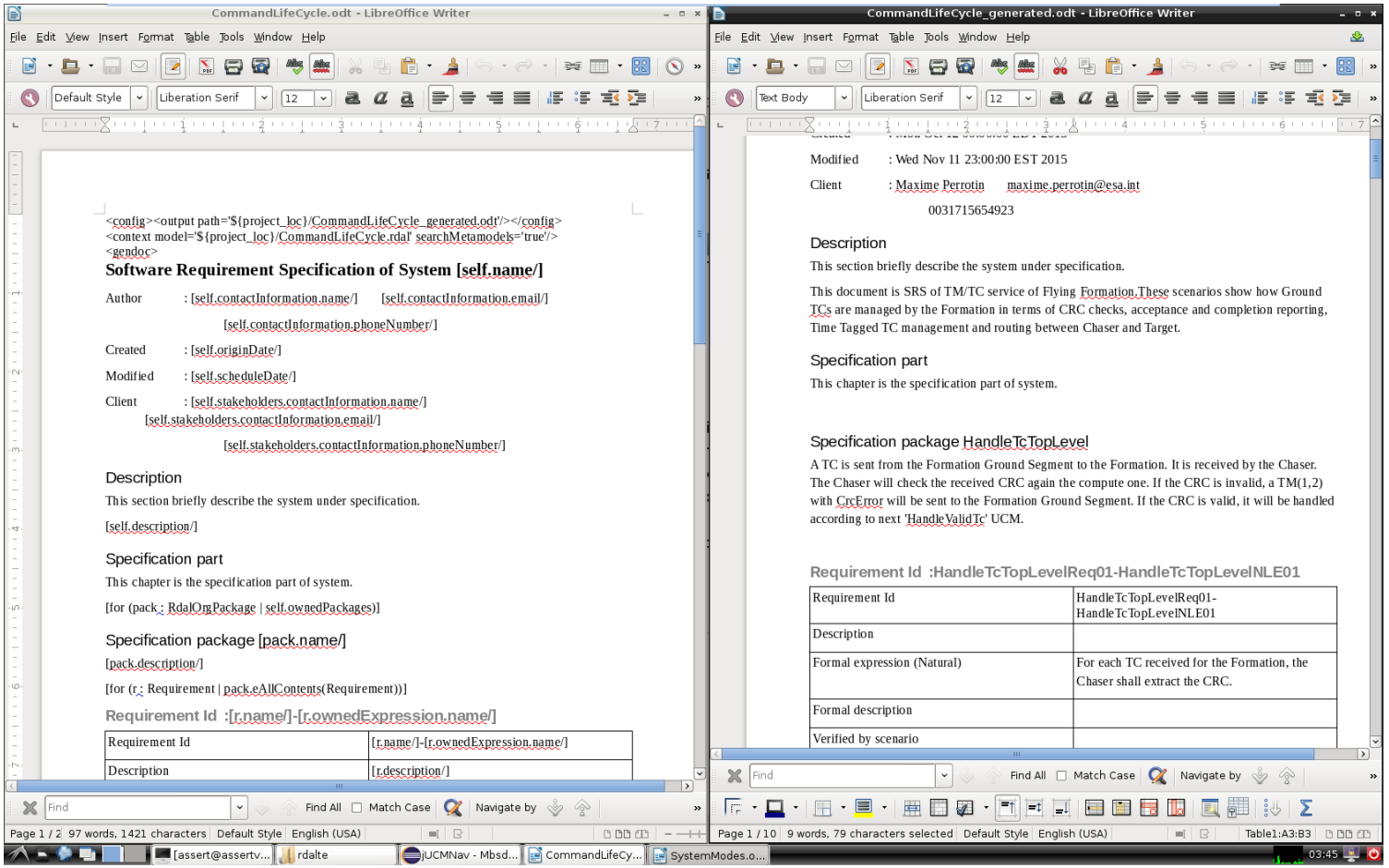
RDAL TOOLING: RDALTE

- EMF meta-model
- EMF Sample Reflective Model Editor
- Live validation



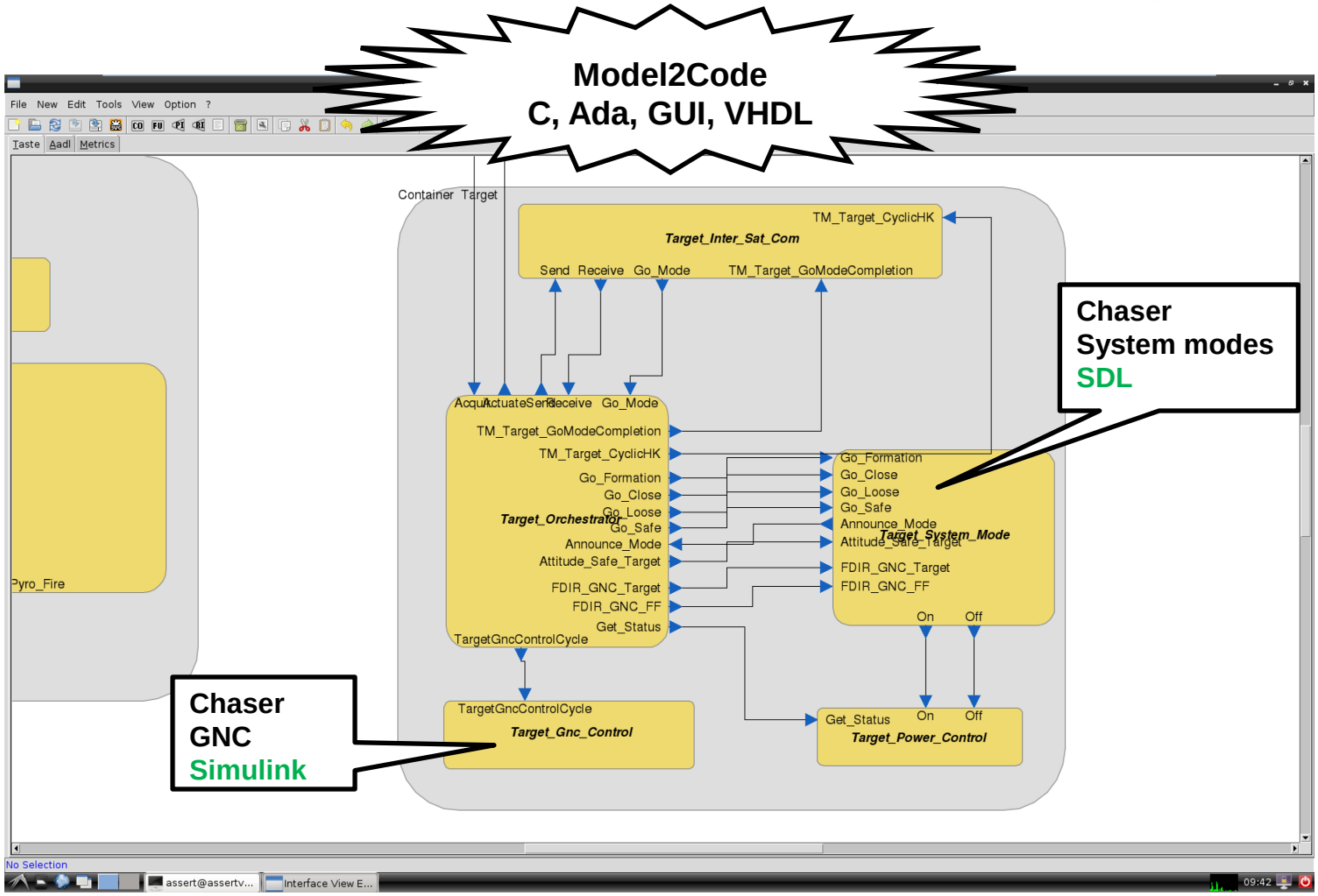
- RDAL Graphical Representation V2 not yet implemented by RDALTE
- **Export to textual representation implemented in the project (UC)**

GENDOC: MODEL BASED SRS GENERATION

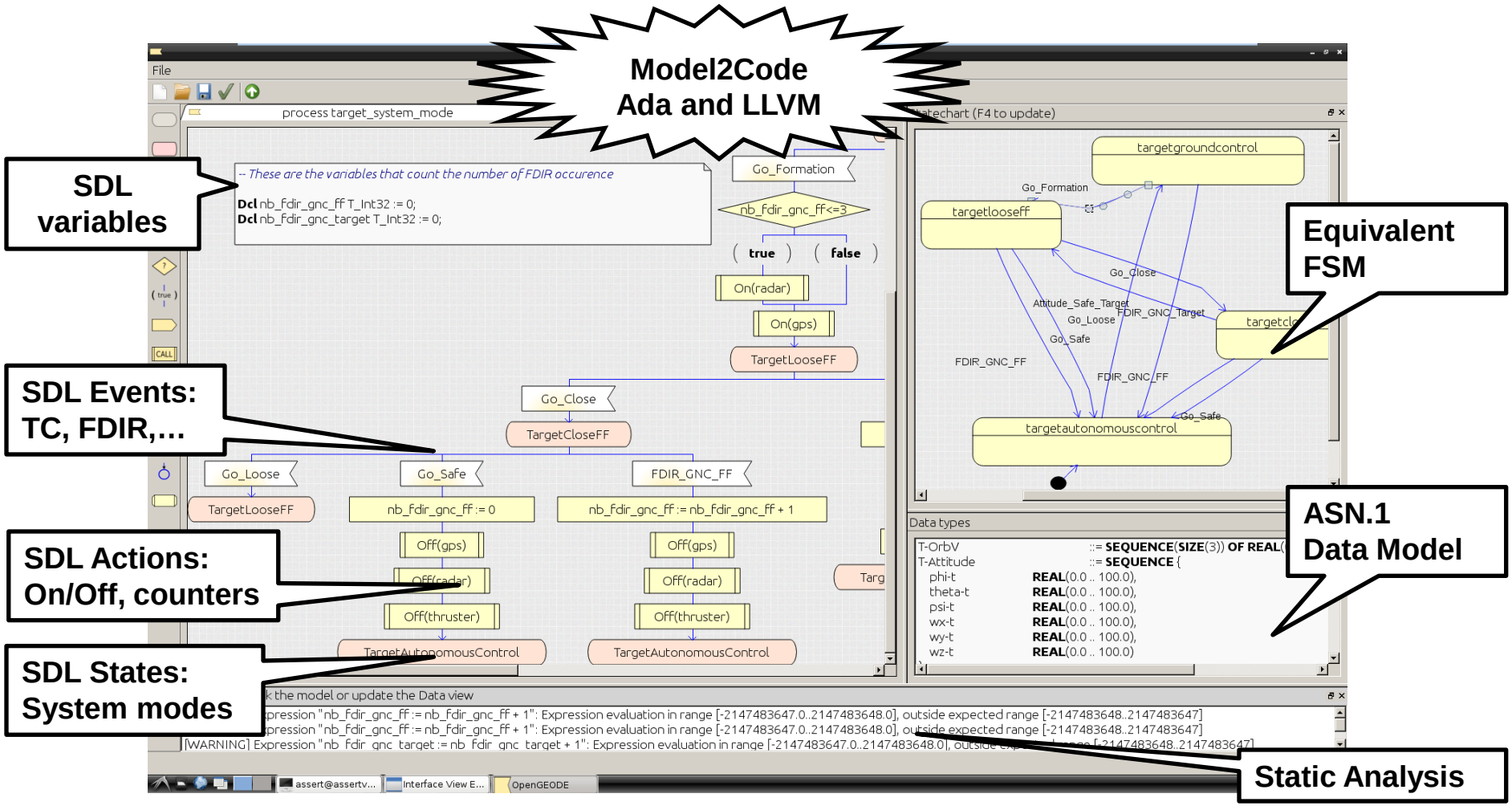


Same M2T tooling as for jUCMnav
No graphical representation

TASTE: AADL AND ASN.1 OPEN-SOURCE EDITOR



OPENGEODE: SDL OPEN-SOURCE EDITOR



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04 Conclusions

CONCLUSIONS

- Software Requirements Specification has been integrated into a Model Based Software Development Lifecycle
- Use Case Maps and rdal language tools have been integrated in TASTE
- The methodology and the tools have been evaluated on a realistic mission
- Rapitime has been integrated in TASTE

- **Software Requirements can be adequately modelled using rdal and UCM, providing a bridge with system architects**
- **TASTE is an excellent platform to add new functionality**

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MODEL-BASED SOFTWARE DEVELOPMENT LIFECYCLE

esa

TEC-ED & TEC-SW Final Presentation Days
December 9th 2015

THANK YOU VERY MUCH FOR YOUR ATTENTION