

MBSE Challenge Team SE^2
SysML for Telescope System Modeling

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SysML for Telescope System Modeling - Requirements Modeling -

by the
INCOSE MBSE Challenge Team SE^2

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Speaker



Rudolf is principal consultant and responsible for aerospace and defense at HOOD Group Germany's leading requirements management consulting company.

He takes care for all requirements modeling activities at HOOD Group.

Rudolf has over 15 years of experience in modeling in many large projects, trained SysML and UML methods and published many articles and conference presentations.

He is OCSMP certified system modeling professional.

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Agenda

- **What is the SE² Challenge project about?**
- Requirements Engineering and Modeling - Motivation
- Examples for Specification by Modeling
- Summary

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About SE²

- Collaboration between European Southern Observatory (ESO) and German Chapter of INCOSE (GfSE)
- Access to high-tech project: Active Phasing Experiment (APE).
- The team members are:
 - Robert Karban (ESO)
 - Tim Weilkiens (oose GmbH)
 - Dr. Rudolf Hauber (HOOD Group)
 - Rainer Diekmann
 - Michele Zamparelli (ESO)
 - Andreas Hein (TU Munich)
- Former members:
 - Andreas Peukert (TU Munich)



Working Group Awards 2010
Achieving the Systems Engineering Vision
presented to
MBSE Initiative Challenge Teams
(Telescope Modeling and Space Systems)
Leads: Robert Karban and Chris Delp

For exceptional work and dedication in establishing and managing the Challenge Teams for "Space Systems Modeling" and "Telescope Systems Modeling" in support of the INCOSE mission. These teams have shown tremendous dedication and collaborated within and outside INCOSE to advance the state-of-the-practice of Model-Based Systems Engineering (MBSE).

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ESO

Non-profit Intergovernmental European Organisation for Astronomical Research in the Southern Hemisphere
<http://www.eso.org>

Headquarters in Munich, Germany, 3 Observatories in Chile

Mission statement

Build and operate world class ground based astronomical facilities

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ESO's sites

- Paranal (2600 m)
- La Silla (2400 m)
- Chajnantor (5000 m)

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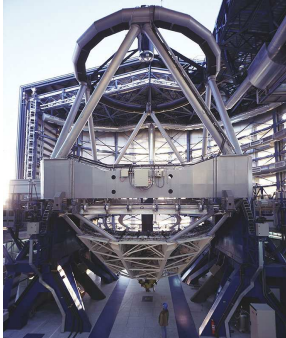
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ESO major projects

Very Large Telescope (VLT)
Started 1988, in operation since 1999



Atacama Large Millimeter Array (ALMA)
Europe-US-Japan
Started 1998, installation starting now



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E-ELT



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- 10000 tons of steel and glass
- 42m segmented primary mirror
- 20000 actuators, 1000 mirrors
- 50000 I/O points, 700Gflops/s, 17Gbyte/s
- Many distributed control loops
- Use MBSE/SysML to model the control system since 2008

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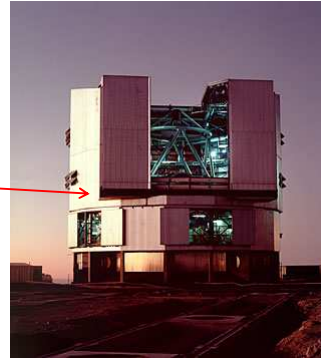
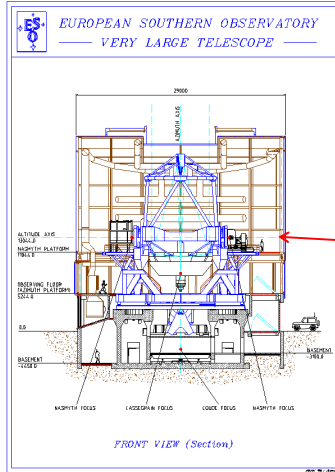
What is the challenge project about?

- System case study (since 2007)
 - APE technology demonstrator for future Extremely Large Telescope (ELT)
 - High-Tech interdisciplinary opto-mechatrical system in operation at Paranal observatory
- Goals
 - Create modeling guidelines and conventions for all system aspects, hierarchy levels, and views
 - Create fully fledged SysML model
 - Documented at <http://mbse.gfse.de>

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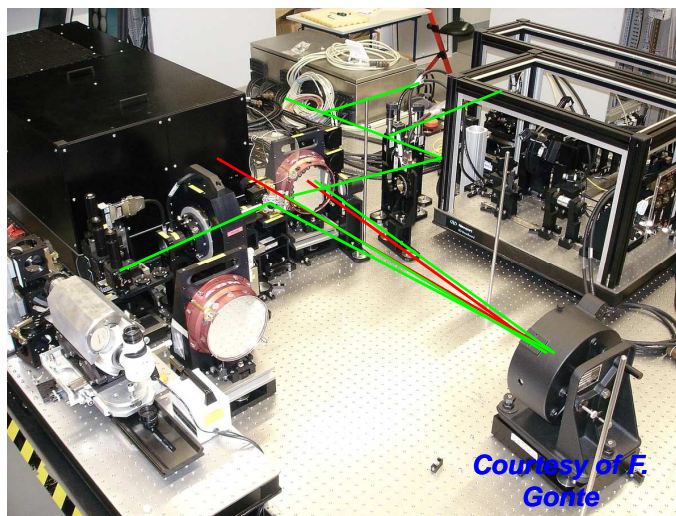
APE was installed at telescope in Atacama desert, Chile.

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Installation on the platform of the telescope



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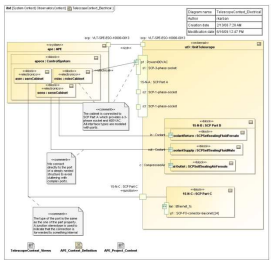
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What have we achieved?

- APE model (re-engineering)
- Guidelines and best practices: MBSE Cookbook
 - Model structure and overview
 - Objectives and Requirements
 - Context, System Structure
 - Behavior and Data
 - Verification
 - Model library and SE Profile
- Plug-in for modeling tool
- Input for tool vendor and SysML RTF



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The difference between **Design** and **System Requirements**:

The diagram illustrates the relationship between different levels of system modeling. It is divided into two horizontal sections: **Customer Language** (top) and **Technical Language** (bottom). In the Customer Language section, there is a large box for **Customer Requirements Specification** and a smaller box for **System Requirements**. In the Technical Language section, there is a box for **System Design** (containing a sub-box labeled **CustReqSpec**) and a box for **Subsystem Requirements**. Below these are boxes for **Subsystem Design** and **Implementation**. Arrows indicate the flow of information: from Implementation up to Subsystem Design, from Subsystem Design up to Subsystem Requirements, from Subsystem Requirements up to System Design, and from System Design up to System Requirements. A dashed line separates the Customer Language and Technical Language sections.

Customer Language

Technical Language

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Requirements Definition - Process

Scope
 Structure
 Input Requirements
 Released Requirements
 Traced to Source

Elicit
 Review
 Specify
 Check Quality

Model

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Modeling supports all Requirements Definition

Model / derive
 Input Requirement Specification
 Feedback
 derive
 satisfy
 Output Requirement Specification
 translate
 VHDL
 Prototypes
 UML/SysML Model

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Why Modeling requirements?

- 100s of textual requirements and their dependencies are hard to understand
- Abstract representation can un-cover hidden inconsistencies/problems
- Formulating precise, context-free, and understandable textual requirements is hard
- Modeling is well-tried to specify specific aspects (formal language, intuitive notation)
- Different aspects can be consistently related in the model

Do you expect 100s requirements or a building plan?

Operational View
 Functional View
 Behaviour View
 Physical View
 Distribution View
 Logical View
 Safety/Security View
 Data View

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System Specification, Test Specification

- What has To Be Specified?
 - Organizational context
 - System functions
 - System quality
 - System interfaces
 - System data
 - System behavior
 - System communication
 - HW elements
- Impact on
 - Test Concept
 - Test Cases

```

    graph TD
        TR[Transition to usage] --> SRA[System Requirements Analysis]
        SI[System integration] --> SD[System Design]
        SI --> SWHWA[SW / HW Analysis & Design]
        SWHWA --> SWHR[System Requirements Analysis]
        SWHWA --> SWI[SW / HW integration]
        SWI --> SWIHW[SW implementation / HW production]
    
```

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1. Clear defined terms - Ontology

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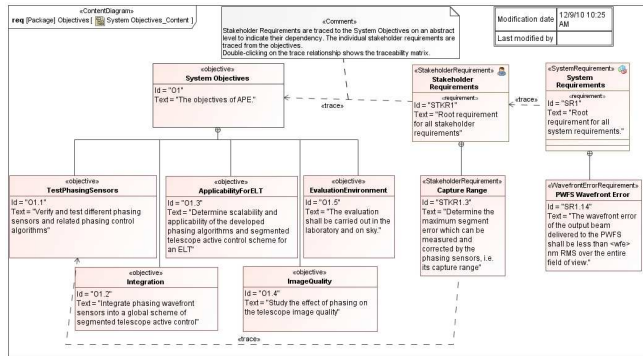
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Project Goals

- Which organizational benefit shall be achieved?
- What are the objectives for the project?
- Which capabilities shall be available?
- Which business use cases exists?
- <<objective>> Requirements

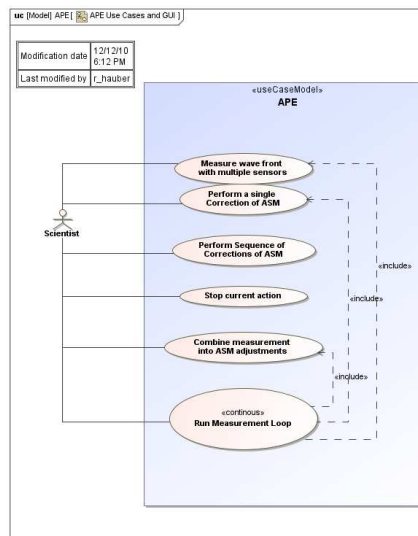


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System Use Case Identification

- Who interacts with the system?
 - Identify actors
- What he wants from the system?
 - identify system use cases based on business processes
- System use cases very good suited for
 - specifying how actors benefit from using the system
 - deriving system test cases



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System Use Case Specification

- What is the workflow of a use case?
- Activities are perfectly suited for specification of use cases!

The diagram shows a SysML Use Case Diagram for 'Run Measurement Loop'. The use case is represented by a circle containing the text 'Run Measurement Loop'. It is connected to several activity nodes (rectangles) that detail the workflow: 'Select which sensor measurement is used to correct which degree of freedom (tilt, focus, figure)', 'Select sensors which are measuring', 'Select number of iterations the ASM is flat before it is decided to be flat', 'Configure all individual parameters of the selected sensors', 'Select sequence of exposures to be started simultaneously', 'Start infinite measurement loop (CYCLAD)', 'Stop Measurement Loop (STPWAIT)', 'Configure Set of Master Sensors', 'Configure Set of Measured sensors', 'Configure report of flat figures', 'Acquire Color Set / Acquire and Acquire Color set', 'Analyze Color Set', 'Correct ASM', and 'Acquire a PSF image'. A note indicates 'Stop only after completion of a cycle'. To the right is a screenshot of the 'APE Phasing Loop Control' software interface, showing various control parameters like 'Current Cycle', 'Master Sensors', and 'Active Sensors'.

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System Use Case Relations

- What are the system states and modes?
- State machines are perfectly suited for specification!

The diagram is a SysML State Machine Diagram for 'InternalMetrology_Content'. It shows a state machine with a start state leading to 'Calibrating'. From 'Calibrating', the state transitions to 'IM operational'. Inside the 'IM operational' state, there is an 'idle' state that transitions to 'measuring segments position' after a 225msec timer. From 'measuring segments position', the state transitions back to 'idle'. From the 'IM operational' state, a 'PowerOff' event leads to a final state. A metadata box shows 'Modification date 1/11/11 6:03 PM' and 'Last modified by'.

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System Verification

- How shall the use cases be verified?
- E.g. show how the system test concepts is affected
- SysML test cases for test case overview / identification

The diagram illustrates the verification of use cases. It shows a 'MAPS Test System Use Cases' package containing a 'MAPS Test System' use case with a 'Perform IMISO measurement' activity. This activity is linked to 'Test Cases' (A and B) and 'Owned Diagrams' (A and B). These test cases are then linked to 'System Requirements' (e.g., 'Turbulence generator') and 'Requirements' (e.g., 'MAPS Spectrum Mean', 'MAPS Spectrum Variance'). Comments explain that test cases can refine multiple requirements and that requirements are not detailed procedures but only requirements for them.

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System Use Case Verification

The diagram shows a state machine on the left and an event tree on the right. An arrow labeled 'Test cases' points from the state machine to the event tree. The event tree is a hierarchical structure of nodes, with some nodes labeled 'A' and 'ω'.

- All test cases can be generated from activities/state machines
- Event chain tree containing all test cases

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System Use Cases: Non-Functional Aspects

- Quality
- Performance
- Security
- Usability
- Tagged values and parametrics

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System Interface Identification

- Identification of services using black-box sequence diagrams for use case scenarios
- Identification of interfaces
- Context diagram with interfaces

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System Interface Specification

- Specify interfaces from different aspects
 - Mechanical
 - Electrical
 - Optical
- Internal Block Definition diagrams can be used to specify ICD

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System Interface Specification

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System Interface and Service Verification

- Black-box sequence diagrams can be directly used for system verification

actual flow

Specified

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Performance Specification

- Performance criteria can be specified, e.g.
 - by time constraints in sequence diagrams
 - Time event in state charts

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System Data Specification

- Which data must be provided, handled and processed by use cases / services?
- Block Definition Diagram

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Physical properties

- Which physical properties are required?
- Tagged values can be used for non-functional requirements: weight, size, etc.

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Constraints

- Which physical constraints must be ensured?
- Parametric diagrams

<<system>>
APE

values
mass: kg = 5000

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Model based Specification – Best Practices

- Define purpose of model
 - Only specification vs development
 - Partial vs complete
- Consider who shall read the model
 - Use appropriate model elements
- Define the deliverable of specification: Document vs model
 - Test the acceptance of deliverable early
- Use model as communication platform with stakeholders
 - Integrate all stakeholders
- Simplicity is key!
 - Use easy to understand elements
 - Use text-based requirement if there is no simple modelling construct
- Training
 - Train stakeholders in understanding the model
 - 10 minutes usually enough for every diagram type

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Live Demo of the Model

- Please fasten seatbelts - setting up the system...
- Check online at <http://mbse.gfse.de/>

The image shows a SysML model for a telescope system. On the left, a 'Usage in Diagrams' menu is open, showing a list of components like 'OptoMechanica@Bench', 'Optical', 'Control', 'Mechanical', and 'Electrical'. Red arrows originate from this menu and point to corresponding elements in a larger, more detailed SysML diagram on the right. This larger diagram shows a complex hierarchy of components and their interdependencies, including sub-diagrams like 'LaboratoryControl_Electrical', 'LaboratoryControl_Mechanical', and 'LaboratoryControl_Optical'. A metadata window for 'LaboratoryControl_Views' is also visible, showing details like 'Diagram name', 'Author', 'Creation date', and 'Modification date'.

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