A Better Design with Model-Based Systems Engineering
Functional Verification using System-Level Modeling

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Q&A Panel
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Detect Design Issues Early

Avoid High Cost of Late-stage Design Changes

Systems Design & Development Process
Functional Verification

**Concept**
- System Requirements
- Functional Specification
- System-level Synthesis
- Subsystem Design
- Detailed Design
- Detailed Analysis

**Functional Mockup**
- Compliance Test Plan
- Functional Mockup

**Product**
- Release Candidate
- System Validation
- System Integration
- Subsystem Test
- Unit Test

**Implementation**
- Software/
  Hardware/
  Procurement

**MapleSim**
- System-level virtual prototype
- Multi-domain sub-system integration
  Identify design issues very early

Architectural Models

Analytical Models
Functional Verification

- System Requirements
  - DOORS, Rhapsody, MagicDraw...
  - Maple, MapleSim, Simulink...
  - CAD, FEA, CFD, Spice, Saber...

- Functional Specification
- System-level Synthesis
  - ModelCenter
- Subsystem Design
- Detailed Design
- Detailed Analysis
- Compliance Test Plan

- Performance
  - ID = P001
  - This vehicle performance must be sporty and provide an affordable driving range for inter-city mobility.
  - ID = P002
  - The driving range must be longer than 300km in the normal drive mode.
  - lowerBound:RhpReal=300 units:RhpString=km
- Performance::Velocity
  - ID = P003
  - The max velocity must be larger than 130km/h
  - lowerBound:RhpReal=130 units:RhpString=km/h
- Performance::Acceration
  - ID = P004
  - The max vehicle acceleration needs to be larger than 4m/s² but must be lower than 10m/s²
  - lowerBound:RhpReal=4 upperBound:RhpReal=10 units:RhpString=m/s²

- System Limitation
  - ID = S001
  - For safety and regulations, the vehicle must conform to the conditions defined here
  - SystemLimitation::BatteryTemperature
    - ID = S002
    - The battery temperature must be between 250K and 320 K
    - lowerBound:RhpReal=250 upperBound:RhpReal=320 units:RhpString=K
  - SystemLimitation::VehicleWeight
    - ID = S003
    - The total weight must not exceed 1900kg
    - upperBound:RhpReal=1900 units:RhpString=kg

- Compliance Test Plan
  - Functional Mockup

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Multi-domain Systems Design

Control (SW)

Software

Electrical

Domain-Specific Design

Mechanical

eCAD/EDA

MCAD

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Control (SW)

Functional Verification against formal requirements models

Electrical

Mechanical

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How to scale MBSE beyond “Expert use”? 

**MBSE Experts**

**Design Stakeholders**
- Engineering, UX, Software, Business process etc.

**Engineering Analysts**

**Architecture**

**Detailed Architecture**

**Impact Analysis**

**Compliance Tests**

**Trade studies, etc.**

**System Architecture (SysML)**
- Structure
- Behavior
- Requirements
- Parametric Constraints

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**MapleMBSE**

**Maple**

**MapleSim**

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...many stakeholders need to do “modeling”

The aim of Systems Engineering is for many stakeholders to collaborate across many disciplines, so modeling tools for non-experts are vital.

Integrate models with commonly used spreadsheet interface

Project Manager

Req. Analysts

Electronics Engineer

Software Engineer

Dealer

Engineer
MapleMBSE

- Intuitive, spreadsheet-based UI for entering detailed system design definitions
  - Structures
  - Behaviors
  - Requirements
  - Parametric constraints
- Integration with standard MBSE platforms (e.g., Rhapsody, MagicDraw) for rapid impact analysis of design changes, e.g., conflicting requirements
- Optimized views for specific tasks
  - Impact Analysis of Requirements
  - FMEA: Failure Mode & Effects Analysis
  - Trade-off studies
  - Structure analysis (Design Structure Matrix)
Design Verification with ModelCenter
Requirements Compliance Testing

MapleMBSE

Phoenix ModelCenter with MBSEPAk

No Magic Teamwork Cloud

Cameo Systems Modeler

MapleSim

Maple

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Compliance verification demo
Summary

- MBSE: Proven business methodology for managing design complexity, risk and costs
- MapleMBSE provides Excel-based UI for detailed product definition by a wide range of stakeholders, while maintaining integration with SysML architectural model
- MapleSim provide rapid functional mockups for verification of complex multidomain dynamic systems
- ModelCenter brings everything together for rapid requirements-compliance testing, trade-off studies, and impact analysis due to changes in design requirements
- Convergence of tools helps realize the V process
FREE Maple Plug-in for ModelCenter
www.maplesoft.com/products/toolboxes/modelcenter

• Easy implementation of Maple calculation worksheets in ModelCenter.
  – No need to convert to scripts
  – No “ModelCenter version” required

• Automatic detection of inputs and outputs from header information

• Dimensional units support

• Support for execution of MapleSim models
  – Pre-processing of model parameters
  – Model execution
  – Post-processing of results
Thank You

Questions?