PHOENIX INTEGRATION

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

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Systems Design & Development Process

Detect Design Issues Early

Avoid High Cost of Late-stage Design Changes

Functional Mockup Release Candidate System Validation System Integration Subsystem Test Unit Test

Functional Specification System-level Synthesis Detailed Design Detailed Analysis Implementation Software/Hardware/Procurement

Concept

System Requirements

Compliance Test Plan

Architectural Models

Analytical Models

Product

Release Candidate

System Validation

System Integration

Subsystem Test

Unit Test

Systems Design & Development Process Functional Verification

• System-level virtual prototype
• Multi-domain sub-system integration

Identify design issues very early
Systems Design & Development Process

Functional Verification

Compliance Test Plan

ModelCenter

DOORS, Rhapsody, MagicDraw...

Maple, MapleSim, Simulink...

CAD, FEA, CFD, Spice, Saber...

System Requirements

Functional Specification

System-level Synthesis

Subsystem Design

Detailed Design

Detailed Analysis

Performance

ID = P001
This vehicle performance must be sporty and provide an affordable driving range for inter-city mobility.

DrivingRange

Performance::Velocity

ID = P002
The driving range must be longer than 300km in the normal drive mode.

lowerBound:RhpReal=300
units:RhpString=km

Performance::Acceleration

ID = P003
The max velocity must be larger than 130km/h

lowerBound:RhpReal=130
units:RhpString=km/h

SystemLimitation::BatteryTemperature

ID = S001
For safety and regulations, the vehicle must conform to the conditions defined here

SystemLimitation::VehicleWeight

ID = S003
The total weight must not exceed 1900kg

upperBound:RhpReal=1900
units:RhpString=kg

weight:Kilogram=1800
<<Attribute>>

range:Meter
<<Attribute>>
satisfy

Systems Design & Development Process

Functional Verification

CAD, FEA, CFD, Spice, Saber...

Maple, MapleSim, Simulink...

DOORS, Rhapsody, MagicDraw...
Functional Verification against formal requirements models

- Control (SW)
- Electrical
- Mechanical
How to scale MBSE beyond “Expert use”? 

MBSE Experts

Design Stakeholders
Engineering, UX, Software, Business process etc

Engineering Analysts

System Architecture (SysML)
Structure
Behavior
Requirements
Parametric Constraints

Architecture

Detailed Architecture

Impact Analysis

Compliance Tests

Trade studies, etc

MagicDraw, Rhapsody...

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
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)
Andy Ko

Design Verification with ModelCenter
Connect systems architecture models with engineering analyses to calculate system performance, check requirements, and perform design trade-offs.

Capabilities:
- Execute SysML parametric diagrams to evaluate designs
- Perform requirements compliance analysis using modeling and simulation
- Perform design trade-off studies
- Update SysML models with analysis results
- Import engineering analyses into a SysML model
Example Scenario

Maple MBSE

Maple & MapleSim

MBSE Pak

Systems Model
Analytical Model
Multi-domain System-level Dynamics

**Li-Ion Battery Model**
Graphite - Lithium Cobalt Oxide electrodes
**Captures:**
- Thermal effects on the battery chemistry
- Temperature dependent internal resistance
- Degradation effects
- Power electronics/Inverter efficiency

**DC Motor Model**
**Model described by**
- A torque - speed curve
- A Motor efficiency map
- Rated power and angular speed

### Vehicle Dynamics model
**Captures:**
- Longitudinal motion dynamics
- Tire dynamics (Pacejka tire model)
- Fixed reduction gear from the motor
- Effects of aerodynamic drag forces
- Effects of tire sizing (radius and inertia)
- Effects of variable road grade

**Driver model**
PID Controller
Tuned to follow predefined speed profile

**Cooling system model**
Active and passive heat extraction from battery
Temperature control using on-off thermostat
Requirements Compliance Testing

MapleMBSE

Phoenix ModelCenter with MBSE Pak

No Magic Teamwork Cloud

Cameo Systems Modeler

Maple

MapleSim

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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**
Thank You

Questions?
FREE Maple Plug-in for 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