*Detailed Course Plan, 2019*

# Model-Based Systems Engineering

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**Lena Buffoni, Robert Braun, Erik Herzog, Lennart Ochel**

## Introduction

This is an introductory course in systems engineering with emphasis on model-based systems development, design, and analysis using tools. The course include general methods which are useful within a range of system engineering domains, e.g., computer science, software engineering, machine design, electrical engineering, vehicular systems, aerospace applications, transport systems, project management, sustainability life cycle design and analysis, maintenance.

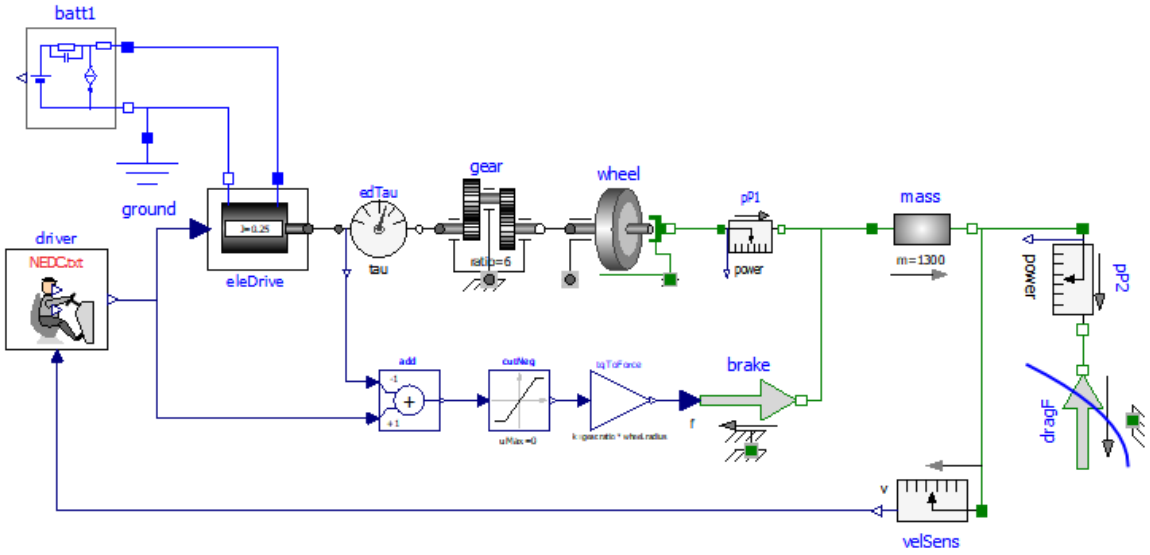
After the course, students should be able to:

- Describe how products and services from different technical areas can be integrated into a system.
- Describe basic concepts in Systems Engineering.
- Specify and analyze system requirements.
- Design and model a system architecture.
- Use modeling languages such as Modelica and UML to describe a small system.
- Model, analyze, simulate, and optimize a system.
- Plan implementation of a system.
- Validate a system.
- Perform environmental and lifecycle design and management of a system.

## Case Study with an Electric Vehicle

The course contains a case study with the design of a plug-in charging electric vehicle. This includes system analysis, design, modeling and simulation, requirement formalization and verification, choice of components, optimization goal, etc.

The plug-in electric vehicle model has the following very simplified schematic connection diagram:




A model library in Modelica with model components relevant for electric cars will be made available. Tool support for modeling, simulation, requirement formalization, requirement verification, optimization, etc. will be available using OpenModelica.¨

## Course Literature

- Peter Fritzson. Principles of Object-Oriented Modeling and Simulation with Modelica 3.3. Wiley-IEEE Press, 2014. Selected parts
- Donella Meadows. Thinking in Systems. Chelsea Green Publishing, 2008 and 2018.
- Peter Fritzson. The DrModelica Interactive Electronic Notebook. Available in OMNotebook in the OpenModelica installer and on the web: http://omwebbook.openmodelica.org/DrModelica
- Functional Mockup Interface (FMI) Overview. Slide presentation.
- Papers on optimization
- Papers on systems engineering

## Short Overview of Course Parts and Lecturers

Week 1

- 1 day, Modelica introduction, Lectures and exercises, Peter Fritzson
- 1 day, Modelica introduction, Lectures and exercises, Lena Buffoni
- 1/2 day, Modelica introduction, Own study, continued exercises; Lena Buffoni
- 1/2 day, Requirements and Dynamic Model-Based Verification, lecture, exercises, Lena Buffoni
- 1 day, Electric Vehicle Modeling, Lectures and exercises, Lars Eriksson (Peter Fritzson)
- 1 day, Systems Engineering, basic concepts and industry perspective, Lectures Erik Herzog

Week 2

- 1/2 day, Functional Mockup Interface (FMI), Lecture and exercises (Lennart Ochel)
- 1/2 day, Own study, 2h exercise support (Lennart Ochel)
- 1 day, Thinking in Systems, sustainable systems modeling. Lectures and Exercises, Ola Leifler (Peter Fritzson)
- 1 day, Model-based system optimization and design exploration, Lectures and exercises, Robert Braun (Peter Fritzson)

- 1 day, Own study day, + 2h exercise support electric vehicle, Lars Eriksson (Peter Fritzson)
- 1 day, UML (Unified Modeling Language) and System Anatomy, Lectures and exercises, Kristian Sandahl.

Total: 10 days

In April: Written and oral exam

# Detailed Overview of Lectures and Schedule

### Day 1, March 18 9.15-17.00

Lecturers: Peter Fritzson

### Lecture Introduction to Modeling and Simulation with Modelica and OpenModelica

Short **presentations by participants** about their interests, 3 min each. Email 1 slide each beforehand.

Introduction to Modelica and OpenModelica

Demo+short exercise: Graphic modeling with OMEdit

OpenModelica OMNotebook usage

Introduction to textual modeling

Demo+Exercise: OMNotebook and DrModelica

### Lecture Modelica Classes, Inheritance and Equations

Lecture+Exercises: classes and inheritance (Lena)

Exercise01-classes-simple-textual.onb

Lecturing on Modelica equations.

Exercise03-classes-textual-circuit.onb

### Lecture – Modelica Connectors, Packages and Libraries

Lecturing+Exercises: Component connectors and connections, graphical modeling (Lena)

Exercise02-graphical-modeling.onb

Lecturing on Modelica packages and libraries

### Lecture – 3D Graphics with 3D animantion

Lecture and exercise on 3D graphics

### Day 2, March 19, 08.15-16.30

Lecturers: Lena Buffoni

### Lecture – Graphical Modeling with Control Feedback

Lecturing and exercise on adding a feedback loop with controller to the DCMotor.

### Lecture – Modelica Algorithms and functions

Lecturing and Exercise04-equations-algorithms-functions.onb

### Lecture – Modelica Hybrid Systems Including Clocked and State Machines

Lecturing and Exercise05-hybrid-discreteevent.onb

Small exercise on clocked synchronous and/or state machine constructs.

### Lecture – Modelica External Function Interface

Lecturing and Exercise on using Modelica's external function interface

### Day 3, March 20, 08.15-17.00

Lecturers: Lena Buffoni,

Half day, Modelica introduction, Own study, continued exercises; Lena Buffoni

Half day, 13.15-17.00, afternoon

### Lecture – Formalization of Requirements and Dynamic Model-Based Verification

Lecture and hands-on exercise using OpenModelica on requirement modeling and dynamic verification.

### Day 4, March 21, 08.15-16.00

Lecturers: Lars Eriksson

### Lectures – Electric Vehicle Modeling

Introduction to electric vehicles and their modeling and simulation. Introduction to the electric vehicle case study.

Exercises on the electric vehicle model

Very short introduction to the model-based optimization case for this application and the OpenModelica optimization tool facilities.

### Day 5, March 22, 08.15-16.00

Lecturers: Erik Herzog

### Lecture – Systems Engineering, Basic Concepts I

Basic concepts. Industry perspective.

### Lecture – Systems Engineering, Basic Concepts II

Continued. Basic concepts.

### Day 6, Functional Mockup Interface, March 25, 08.15-17.00

Lecturers: Lennart Ochel
½ day, Functional Mockup Interface (FMI), Lecture and exercises 8.15-12.00
1/2 day, Own study, 2h exercise support (Lennart Ochel)

### Day 7, March 26, 08.15-17.00 Lectures – Thinking in Systems and Sustainability

Lecturers: Ola Leifler, (Peter Fritzson)

Lecturing on systems thinking, complexity, life cycle

Exercises on modeling such aspects of a system

### Day 8, March 27, 8.15-17.00

Lecturers: Robert Braun

### Lecture – Model-Based System Optimization, Part I

Introduction to methods and tools to optimize a system based on a model, and design exploration.
Exercises

### Lecture – Model-Based System Optimization, Part II

Part II of methods and tools to optimize a system based on a model, and design exploration.
Exercises

### Day 9, Own Study Day, March 28, 08.15-17.00

Lecturers: Lars Eriksson

Lars is available 13.00-15.00 to answer questions and give advice on the electrical vehicle application case study. The lecture room is reserved for own and group work 8.15-17.00.

### Day 10, March 29, 08.15-15.00

Lecturer: Kristian Sandahl

### Lecture – UML

Catch-up lecture for those that are unfamiliar with UML

Use-cases, classes, sequence diagrams, and state charts. Standard UML
Exercises with Papyrus UML Tool

### Lecture – System Anatomy

Introduction and practical exercise in creating a system anatomy as a way to create a common internal view of a system.

**Examination day**: April, 2019. (if this does not work for you, contact the course leaders)