THE AMERICAN MODELICA CONFERENCE 2018

October 9-10
Samberg Conference Center
Cambridge, MA
www.modelica.org

CONFERENCE BOARD MEMBERS

WELCOME

When I first got involved in Modelica, back in 1999, it was in a very nascent state. At that time the language was moving quickly due to the hard work and dedication of many participants in the Modelica Association, with new ideas constantly being designed, discussed and implemented. The Modelica language is now just one of the initiatives of the Modelica Association. Others initiatives include the Modelica Standard Library (MSL), the Functional Mockup Interface (FMI), System Structure and Parameterization (SSP), and the Distributed Co-Simulation Protocol (DCP).

I was recently taking stock of how things have changed in that time. The Modelica language is now supported by at least 9 commercial tools and 2 open source tools. This is personally very gratifying to me because I always hoped that Modelica would one day be available to engineers and students everywhere. And that seems to be very much the case.

Today marks another advance in the slow but steady progress of Modelica. Historically, Modelica Conferences have been organized in Europe, but today I'm pleased to be welcoming everybody to the first formal American Modelica Conference. This milestone of having a true Modelica Conference in North America will hopefully be a watershed moment in the adoption of Modelica and other Modelica Association standards in North America.

With that, I welcome all of you to this significant event in the history of Modelica!

Dr. Michael Tiller
Conference Co-chair

GENERAL INFORMATION

Scan this QR code for updates & info

Venue Address: Samberg Conference Center
Massachusetts Institute of Technology
Chang Building (E52)
50 Memorial Drive
Cambridge, MA 02139

MERL 201 Broadway, Cambridge, MA 02139
Amgen 360 Binney St, Cambridge, MA 02141

Conference Website: https://modelica.org/events/modelica2018Americas
All updated conference information can be found at the website, including conference papers and abstracts.

Emergency Information: To report an emergency, call 9-1-1, call the MIT Police at 100 from a campus phone, or call 617-253-1212 from an off-campus or cell phone.

Internet/Wifi: The MIT-GUEST network should be available for use without a password.

Meals: Coffee breaks and lunches will be provided during the conference.

Dinner Cruise: We have planned an entertaining social program with a cruise around the Boston harbor at end of the conference's first day. This cruise will afford excellent views of local landmarks, including the Seaport District and historic ships in the harbor, and will provide attendees with an opportunity to socialize and unwind in a picturesque setting. Tickets for this event were purchased during conference registration.

Bus transportation: will be provided from the conference center to the cruise ship. The bus will depart from 50 Memorial Drive, Cambridge at 5:30 pm, and will return to the same location at 10:00 pm. If you prefer to use your own transportation, the ship will leave the wharf at 7:00 pm from 174 Seaport Blvd., Boston.

Registration desk: The registration desk is open from Tuesday, 9 October at 7:00am through the duration of the conference.

Travel / Transportation / Parking: Parking in Cambridge and Boston is generally not an enjoyable experience; we recommend using public transportation. The Kendall stop on the Red Line subway (www.mbta.com) provides the most convenient access to the conference location. If you are driving to the conference, we recommend using the public parking available at the Alewife and Braintree stations on the Red Line subway, and taking the subway to the conference. Taxis are generally available, as are Uber and Lyft. Parking is available at the Marriott Parking Garage (50 Broadway, Cambridge) for $47/day.

Tourist information: Boston is a historic city, with many entertaining sightseeing activities and tours (www.bostonusa.com). MIT also has a museum that describes its history up to the present day (mitmuseum.mit.edu).

WORKSHOPS OCTOBER 8

8:30 am - 12:30 pm, provided by Modelon

Introduction to Modeling with Modelica

This workshop will give an introduction to Modelica. We will be presenting the principles of modeling with Modelica and efficient use of model libraries using various multi-domain examples selected to make the workshop attractive for engineers from all branches of engineering.

This workshop will be offered in the morning of October 8, 2018, at Mitsubishi Electric Research Laboratories (201 Broadway, Cambridge). When you arrive at this address, please enter the lobby and take the elevator to the 8th floor. Nearby parking may be available at the One Kendall Square Garage (389 Binney St., Cambridge).

2:00 pm - 5:00 pm, provided by Michael Wetter (LBNL)

Thermo-fluid Modeling with Applications from the Buildings Library

This workshop will give an introduction into modeling of thermo-fluid systems and their control, using Modelon's latest graphical editor. We will be using applications from the Buildings library, but the course will be structured to also appeal to modelers from other application domains that are concerned with thermo-fluid systems.

After an introductory presentation that discusses how to set up thermofluid flow models and how to avoid potential problems, participants will conduct hands-on exercises. As part of the exercises, we will build models of simple heating and air conditioning systems, link them to a thermal load and add feedback control. The models will be built using components from the Buildings library.

This workshop will be offered in the afternoon of October 8, 2018, also at Mitsubishi Electric Research Laboratories (201 Broadway, Cambridge). have attended the morning workshop. Nearby parking may be available at the One Kendall Square Garage (389 Binney St., Cambridge).

▶ continued next page

WORKSHOPS OCTOBER 8

8:30 am - 5:00 pm, provided by Jiří Kofránek, Charles University in Prague

Introduction to Equation Based Modeling and Simulation with Modelica with a Focus on Physiological Modeling

The development of models of human physiology has been facilitated by a new generation of simulation environments using the Modelica language. This tutorial gives an introduction to the Modelica language and an overview of modeling and simulation areas. We will show an acausal approach for modeling physiological systems using Physiolibrary, an open-source library for biomedical modeling, which allows the presentation of complex models composed from different domains in a comprehensible and maintainable form. Attendees should bring their own computers to participate in hands-on sections of the tutorial; instructions on installing the necessary tools will be distributed prior to the workshop.

The first part of the tutorial will introduce acausal and object-oriented modeling using the Modelica language. The second part of the tutorial will consist of sections that will demonstrate the construction of selected models of 1) cardiovascular system dynamics in the hydraulic domain, 2) common biochemical reactions in the chemical domain, 3) body thermal transfer with blood flow using the thermal domain, 4) liquid volume of the penetrating solution in intracellular space, extracellular space, interstitial space, blood plasma, or cerebrospinal fluid using the osmotic domain, and 5) an integrative approach that connects these domains together.

This workshop will be offered over the course of the day on October 8, 2018, at Amgen (360 Binney St., Cambridge) in the Lobby Auditorium. Nearby parking may be available at the One Kendall Square Garage (389 Binney St., Cambridge).

TUESDAY, OCTOBER 9

		ROOM 1	ROOM 2
7:00	9:00	Registration and Mingle	Registration and Mingle
9:00	10:20	Vendor Session	Vendor Session
10:20	10:40	Coffee Break	Coffee Break
10:40	12:10	Vendor Session and News	Vendor Session and News
12:10	13:30	Lunch Break	Lunch Break
13:30	14:15	Keynote 1	Keynote 1
14:15	14:20	Switch Rooms	Switch Rooms
14:20	15:35	Thermofluids 1	Aerospace
15:35	16:00	Coffee Break	Coffee Break
16:00	17:15	Thermofluids 2	Energy Systems
17:15	18:00	Transit to Conference Dinner	
18:00	21:00	Conference Dinner	

WEDNESDAY, OCTOBER 10

		ROOM 1	ROOM 2
7:00	8:00	Mingle	Mingle
8:00	9:40	Tools & FMI	Mechanical Systems
9:40	10:10	Coffee Break	Coffee Break
10:10	12:10	Users: Applications	Users: Tools
12:10	13:30	Lunch Break	Lunch Break
13:30	14:15	Keynote 2	Keynote 2
14:15	14:20	Switch Rooms	Switch Rooms
14:20	15:35	Tools 2	Libraries
15:35	16:00	Coffee Break	Coffee Break
16.00	17:00	Podium Discussion and Wrap-Up	

TUESDAY, OCTOBER 9

Session 1 / Room 1 THERMOFLUIDS 1

Investigation of Fuel Reduction Potential of a Capacity Controlled HVAC System for Buses Using Virtual Test Drives
Christian Kaiser, Sebastian Meise, Wilhelm Tegethoff, Jürgen Köhler

Control Description Language
Michael Wetter, Milica Grahovac, Jianjun Hu

Molten Salt–Fueled Nuclear Reactor Model for Licensing and Safeguards Investigations
Scott Greenwood

Session 1 / Room 2 AEROSPACE

Development and Implementation of a Flexible Model Architecture for Hybrid-Electric Aircraft
John Batteh, Jesse Gohl, Michael Sielemann, Peter Sundstrom, Ivar Torstensson, Natesa MacRae, Patrick Zdunich

A Modelica Library for Spacecraft Thermal Analysis
Tobias Posielek

Exergy Analysis of Thermofluid Energy Conversion Systems in Model-Based Design Environment
Daniel Bender

Session 2 / Room 1 THERMOFLUIDS 2

On Closure Relations for Dynamic Vapor Compression Cycle Models
Christopher Laughman and Hongtao Qiao

Fast Calculation of Refrigerant Properties in Vapor Compression Cycles Using the Spline-Based Table Look-Up Method (SBTL)
Lixiang Li, Jesse Gohl, John Batteh, Christopher Greiner, Kai Wang

Modelica-Based Dynamic Modeling of a Solar Powered Ground Source Heat Pump System
Defeng Qian, Zheng O'Neill

Session 2 / Room 2 ENERGY SYSTEMS

Coalesced Gas Turbine and Power System Modeling and Simulation using Modelica
Miguel Aguilera, Luigi Vanfretti, Francisco Gómez, Tetiana Bogodorova

Analysing the Stability of an Islanded Hydro-Electric Power System
Dietmar Winkler

Modeling of PMU-Based Islanded Operation Controls for Power Distribution Networks using Modelica and OpenIPSL
Biswarup Mukherjee, Luigi Vanfretti

WEDNESDAY, OCTOBER 10

Session 3 / Room 1 TOOLS & FMI

ModestPy: An Open-Source Python Tool for Parameter Estimation in Functional Mock-up Units
Krzysztof Arendt, Muhyiddine Jradi, Michael Wetter, Christian Veje

A Safe Regression Test Selection Technique for Modelica
Niklas Fors, Jon Sten, Markus Olsson, Filip Stenström

Functional Mockup Interface: An Empirical Survey Identifies Research Challenges and Current Barriers
Gerald Schweiger, Cláudio Gomes, Georg Engel, Irene Hafner, Thierry Nouidui, Josef-Peter Schöggl

A Method to Import FMU to Hardware Description Language
Min Zhang

Session 3 / Room 2 MECHANICAL SYSTEMS

Developing a Framework for Modeling Underwater Vehicles in Modelica
Shashank Swaminathan, Srikanth Saripalli

Hybridisation and Splitting of a Crank Angle Resolved Internal Combustion Engine Model Using a Mean Value Intake for Real-Time Performance
Xiaoran Han, Alessandro Picarelli, Mike Dempsey, Romain Gillot

Component-Based 3D Modeling Combined with Equation-Based Modeling
Andrea Neumayr, Martin Otter

The Deployable Structures Library
Cory Rupp, Laura Schweizer

Session 4 / Room 1 USERS: APPLICATIONS

Single Pipe Design for Integrated Community Energy Systems
Ryan Rogers

Dynamic Model of a 725 MW Combined Cycle Gas Turbine Power Plant with a CO_2 Post-Combustion Capture Unit
Baligh El Hefni, Eric Joos

Reduced Modelica Model for Building Thermal and Electrical Loads Estimations
Saber Mohamed, Scott Bucking, James Cotton

Modeling and Control of the IRIS IPWR in a High Renewables Grid Using TRANSFORM
Richard Bisson, Jamie Coble

Dirt Late Model Race Car Simulations with Dymola / Modelica
Nate Horn

WEDNESDAY, OCTOBER 10

Session 4 / Room 2 USERS: TOOLS

Using SystemModeler and Modelica to Rapidly Build and Verify Hardware Control Systems
Neil Singer, Kenneth Pasch

API for Accessing OpenModelica Models From Julia
Bernt Lie, Arunkumar Palanisamy, Alachew Mengist, Lena Buffoni, Martin Sjölund, Adeel Asghar, Adrian Pop, Peter Fritzson

Modeling Integrated Community Energy and Harvesting Systems from Databases using OpenModelica
James LeMoine

Virtual Commissioning and Dynamic Systems Modeling of Complex Systems Using Modelica and ControlBuild Co-simulation
Behnam Afsharpoya, Damien Marchand, Franck Corbier

An Industrial Model-Based Development Systems Engineering Strategy
Trevor Bailey, Larry Biegler, John Cassidy, Bryan Eisenhower, Degang Fu, Clas A. Jacobson, Carl Laird, Kevin Otto, Kristian Tuszynski, J. Åkesson

Session 5 / Room 1 TOOLS 2

Modelica Language – A Promising Tool for Publishing and Sharing Biomedical Models
Jiří Kofránek, Filip Ježek, Marek Mateják

The OpenModelica Integrated Modeling, Simulation and Optimization Environment
Peter Fritzson, Adrian Pop

Modelica on the Web
Tamas Kecskes, Patrik Meijer, Janos Sztipanovits, Peter Fritzson, Adrian Pop, Arunkumar Palanisamy

Session 5 / Room 2 LIBRARIES

A Modelica Library for Thin-Layer Drying of Agricultural Products
Augusto Souza, Brian Steward, Carl Bern

Modelica Library for the Systems Engineering of Railway Brakes
Marc Ehret

Drilling Library: A Modelica Library for the Simulation of Well Construction
Reza Dadfar, Stéphane Velut, Per-Ola Larsson, Mathias Strandberg, Håkan Runvik, Johan Windahl, Pål Kittilsen, John-Morten Godhavn, Åsmund Hjulstad

ABSTRACTS

DR. JOHN F. MCKIBBEN

Technology Section Head
Proctor and Gamble

BIO

John McKibben, PhD, is Section Head in Baby Care Modeling & Simulation for Procter & Gamble (P&G), a global consumer products innovator where, since 2014, he has led a team focused on driving adoption of existing M&S tools by product and process development team.

These efforts were instrumental in significant reduction in physical testing budgets. From 2007 to 2014 he led a multi-disciplinary M&S team within P&G's Family Care business unit where, under his leadership, the team became one of the benchmarks within P&G for integrating M&S into business processes.

His work as the founding leader of a multi-faceted M&S team in P&G's Fabric and Home Care Modeling & Simulation business (2001–2007) resulted in a 10x increase in business benefit and 5x increase in staffing. His leadership of P&G's Corporate Modeling & Simulation CFD team (1994–2001) led to team staffing growth based on demonstrated process and product improvements.

Among the M&S tools brought into play under John's leadership are computational fluid dynamics, finite element analysis, process modeling and reliability simulation. John's career leadership accomplishments were recognized in October 2016 by P&G with his induction into the PRISM Society, P&G's highest engineering mastery award.

Dr. McKibben earned the PhD from the Institute of Paper Science and Technology (Georgia Institute of Technology) with an emphasis on modeling aerodynamically driven instabilities at free surfaces. His master's degree, also from the Institute of Paper Science and Technology, involved research on convergence acceleration of sequential modular process simulations.
He earned bachelor's degrees in Chemical Engineering from Oregon State University and in Chemistry from Southern Oregon University.

ABSTRACT

Simulation Led Innovation at Procter & Gamble

The required pace of innovation continues to increase in the consumer packaged goods industry. Increasingly historical approaches of development by physical prototypes lead to slow execution, high costs and incremental innovations.

By leveraging simulations we can deliver better innovations, faster, at lower costs. Succeeding on this journey requires more than just technical mastery. Changing the way that innovation is done also requires changing how decisions are made and how resources are allocated. It is also necessary to think about the entire lifecycle of the digital assets such as simulation platforms in a manner similar to how we manage our physical assets (e.g. pilot plants). Digital assets required continued funding, maintenance and upgrades to remain viable over time.

ABSTRACT

Modelica - History, State, Needs, Trends, and Possibilities

Model-based product design requires an intuitive and effective user interface, a standard language to encode models, high-fidelity model libraries for reuse, standardized format for simulation deployment, automated workflows and large computing power. The presentation will contain a brief history of Modelica evolution and current state including some applications. Some new needs will be discussed such as virtual testing of autonomous vehicles. New technical possibilities will be introduced, such as web apps for intuitive and effective user interaction and easy deployment and access, domain-specific language extensions for advanced modeling capabilities and cloud computing for large-scale simulation deployment.

DR. HILDING ELMQVIST

CEO
Mogram AB

BIO

Dr. Hilding Elmqvist attained his Ph.D. at the Department of Automatic Control, Lund Institute of Technology, Sweden in 1978. His Ph.D. thesis contains the design of a novel object-oriented model language called Dymola and algorithms for symbolic model manipulation. It introduced a new modeling methodology based on connecting submodels according to the corresponding physical coupling instead of using signal flows. Submodels were described declaratively by equations instead of assignment statements.

Elmqvist spent one year in 1978-1979 at the Computer Science Department at Stanford University, California. His research continued in 1979-1984 on languages for implementation of control systems and for visual modeling. Elmqvist was in 1984-1990 the principal designer and project manager at a subsidiary to Alfa-Laval called SattControl in Malmö for developing SattGraph, a user interface system for process control and SattLine, a graphical, object-oriented and distributed control system. In 1990-1992, he worked for Alfa-Laval in Toronto.

In 1992, Elmqvist founded Dynasim AB in Lund, Sweden. Their primary product is Dymola for object-oriented modeling allowing graphical composition of models and 3D visualization of model dynamics.

Elmqvist took the initiative in 1996 to organize an international effort to design the next generation object-oriented language for physical modeling, Modelica. In April 2006, Dynasim AB was acquired by Dassault Systèmes. Elmqvist was the worldwide Chief Technology Officer for CATIA Systems within Dassault Systèmes until December 2015.

In January 2016, Elmqvist founded Mogram AB. Current activities include designing and implementing an experimental modeling language called Modia, based on the Julia language.

Hilding Elmqvist currently works part-time as a Technical Fellow at Modelon.

Investigation of Fuel Reduction Potential of a Capacity Controlled HVAC System for Buses Using Virtual Test Drives

Christian Kaiser[1] Sebastian Meise[2] Wilhelm Tegethoff[1] Jürgen Köhler[2]

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[2]Institut für Thermodynamik, TU-Braunschweig, Germany,
{s.meise, juergen.koehler}@tu-braunschweig.de

The refrigerant cycle in conventional omnibus HVAC systems has a significant influence on fuel consumption and, as a result, on vehicle emissions. The additional emissions resulting from the use of the air conditioning system are called indirect emissions. In addition, there are so-called direct emissions from the air conditioning system caused by unintended leakage of refrigerant. A reduction in indirect emissions can be achieved, for instance, by adjusting the capacity of the refrigerant compressor. A reduction in direct emissions can be achieved by so-called alternative or natural refrigerants.

To investigate approaches to reducing direct and indirect emissions, a total vehicle simulation model of a coach with detailed HVAC systems was developed with full implementation in Modelica, see Figure 1. For this total vehicle simulation of a coach, the paper presents the modeling of a refrigerant cycle based on the natural refrigerant CO2 (R-744). In addition, the paper presents an efficient refrigerant compressor capacity control method based on a combination of speed control by means of a two-speed pulley gearbox and cylinder bank shutdown by suction gas interlock.

Further, based on two climatically different virtual driving test scenarios, the fuel saving potential of the presented compressor capacity control strategy is investigated and the average annual fuel savings are presented.

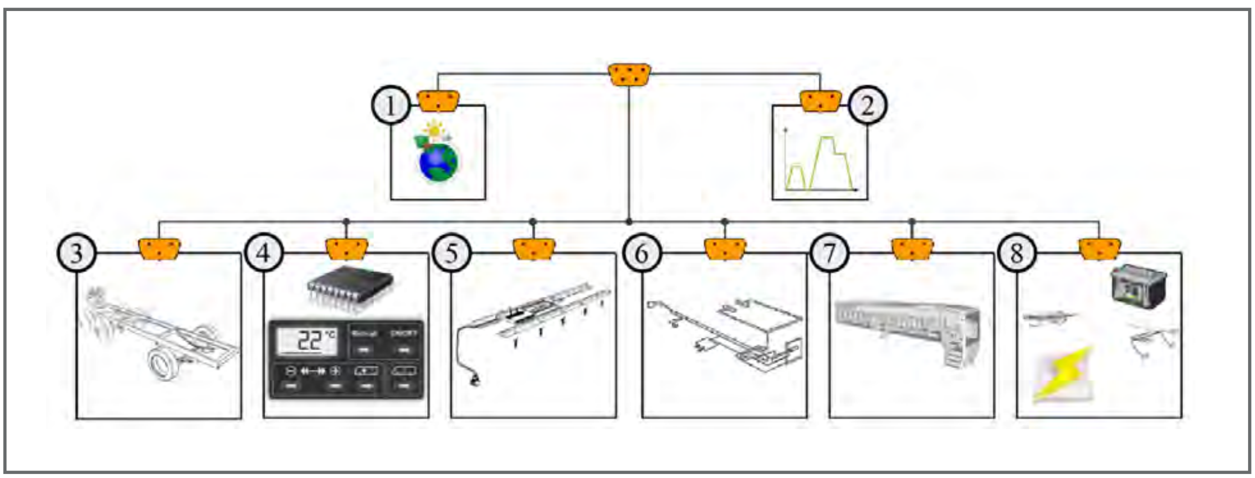

Figure 1. Modelica-based total vehicle simulation model of a coach:
(1) Ambient conditions, (2) Driving conditions, (3) Vehicle longitudinal dynamics,
(4) HVAC controller, (5) Refrigerant cycle, (6) Engine cooling and
interior heating cycle, (7) Vehicle cabin and (8) Electrical system.

Control Description Language

Michael Wetter Milica Grahovac Jianjun Hu

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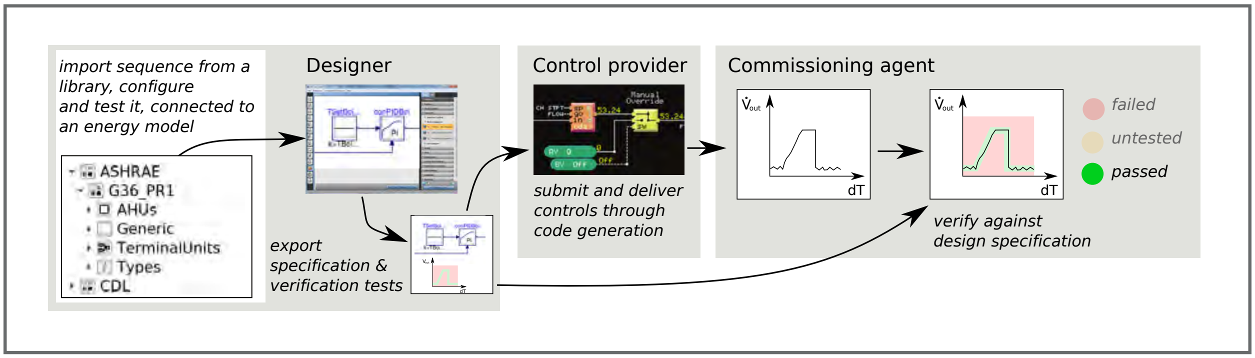

Figure 1. Overview of process for control sequence design, export of a specification, implementation on a control platform and verification against the specification.

Properly designed and implemented building control sequences can significantly reduce energy consumption. However, there is currently no process with supporting tools that allows the assessment of the performance of different control sequences, export the control sequences in a vendor-neutral format for cost estimation and for implementation on a building automation system through machine-to-machine translation, and reuse the sequences for verification during commissioning.This paper describes a Control Description Language (CDL) that we developed to createa model-based design, implementation and verification process as shown in Figure 1.

For CDL, we selected a subset of Modelica that allows a convenient representation of control sequences, simulation of the control sequence coupled to a building energy model, and development of translators from CDL to building automation systems. To aid in the development of such translators, we created a translator from CDL to a JSON intermediate format. In future work, we seek to work with building control providers to develop translators from CDL to commercial building automation systems.

Through a case study, we show that CDL suffices for simulation-based performance assessment of two ASHRAE-published control sequences for a variable air volume flow system of an office building. Moreover, the case study showed that merely due to differences in the control sequences, annual HVAC energy use was reduced by 30%. This difference is larger than the accuracy required when comparing different HVAC systems, thereby questioning the current practice of idealizing control sequences in building energy simulations. The case study also demonstrates the importance of ensuring that the control sequence used during design simulations corresponds to the control sequence that will be implemented in the real building.

Molten Salt–Fueled Nuclear Reactor Model for Licensing and Safeguards Investigations

M. Scott Greenwood

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Fluid-fueled nuclear reactors, particularly molten salt reactors (MSRs), have recently gained significant interest. As with all reactors, modeling and simulation are key factors for advanced reactor design and licensing and will be required for the deployment of MSRs. However, there are significant gaps between simulation capabilities and system behavior for MSRs. This paper presents the system model of an MSR that is based on the Molten Salt Demonstration Reactor. The model includes important physics specific to MSRs, such as fission product and tritium transport and reactivity feedback. The presented model and fission product modeling approach demonstrates the ability of Modelica based models, such as those available in TRANSFORM, to advance the understanding of the dynamics of complex fluid-fueled reactor systems, a critical part of licensing and safeguards analysis, for which few if any tools exist.

Development and Implementation of a Flexible Model Architecture for Hybrid-Electric Aircraft

John Batteh[1] Jesse Gohl[1] Michael Sielemann[2] Peter Sundstrom[3]
Ivar Torstensson[3] Natesa MacRae[4] Patrick Zdunich[4]

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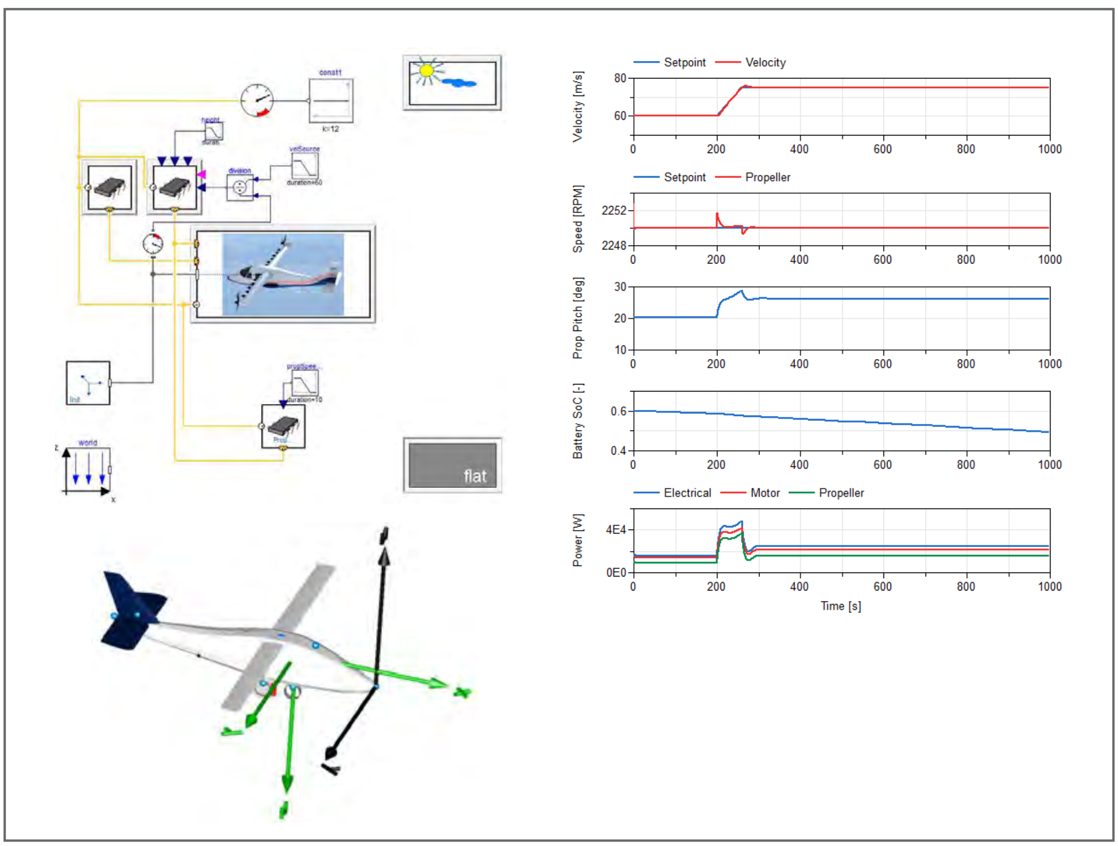
This paper describes the implementation of a flexible, modular, hybrid-electric aircraft modeling architecture for the development of a virtual and physical demonstrator system that will be used in the advancement of sustainable mobility systems by the National Research Council of Canada (NRC).

The initial modeling architecture was established in Modelica based on the NASA X-57 electric flight demonstrator aircraft. A series of models were assembled from a high level aircraft system architecture to mimic the initial developmental path from the baseline conventional aircraft to the X-57 electric aircraft variant. The multi-physics component models describe the aircraft dynamics and performance, integrated with the relevant mechanical, electrical, and thermal dynamics of the electric aircraft power train. The proposed modular architecture allowed the simulation of three different aircraft configurations with different degrees of electrification, demonstrating its effectiveness and versatility in the design and development of hybrid-electric aircraft.



A Modelica Library for Spacecraft Thermal Analysis

Tobias Posielek

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In spacecraft missions it is vital to maintain all spacecraft components within their required temperature limits. High temperatures may lead to battery damage and in the worst case to the failure of the spacecraft mission. Thus, a model incorporating all main heat fluxes acting on the spacecraft is necessary to allow for the design of a thermal control subsystem. The proposed library allows the simulation of the complete spacecraft system including the thermal system as well as the electric and mechanical system providing the dissipated energy and spacecraft orientation dependent on the spacecraft mission. The main environmental heat fluxes, namely the direct solar radiation, albedo radiation, planetary radiation and the radiation to deep space are implemented using the existing Modelica Standard Library.

These fluxes are calculated by introducing the necessary solar angles, the form factor and a shadow function. The necessary solar angles are defined and visualised in order to obtain an intuitive feeling for the determination of the heat fluxes. The form factor is introduced to describe the proportion of the radiation which leaves the sun and strikes spacecraft surface. A shadow function is defined to determine the occultation of the satellite due to the earth. Furthermore, special effort is put into the calculations of the angles describing the orientation of the spacecraft with respect to sun and earth. Issues occurring due to the recalculation of the angles in each time step are pointed out and methods for their determinations are given by using specific methods to define an orthonormal basis.

Details about the Modelica implementation are described and components for the basic thermal dynamic systems are given. In an application example, the heat fluxes of a typical low earth orbit acting on each side of the spacecraft are simulated in order to demonstrate the usefulness and flexibility of the Modelica implementation. The results can be seen in Figure 1.

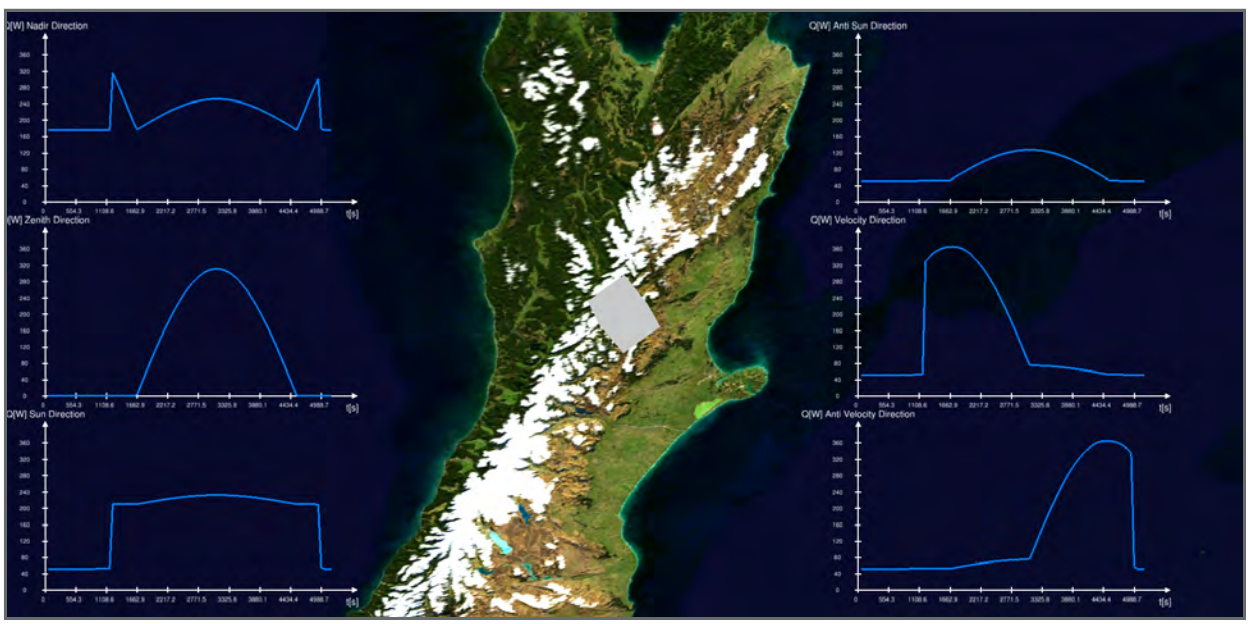

Figure 1. Heat flows acting on the surfaces of a cuboid earth pointing spacecraft

Exergy Analysis of Thermo-Fluid Energy Conversion Systems in Model-Based Design Environment

Daniel Bender

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Daniel.Bender@dlr.de

Exergy-based analysis has been emerging as a powerful tool for the evaluation of energy intensive systems. Exergy is the maximum theoretical useful work obtainable as the system is brought into complete thermodynamic equilibrium with the thermodynamic environment. Besides the thermodynamic efficiency, both the real thermodynamic value of an energy carrier and the real thermodynamic inefficiencies within a system can be identified.

Environmental control systems (ECS) of aircraft as highly interacting systems are an ideal candidate for exergy-based analysis. The design task on architectural level is currently performed using model-based design methods. However, if such systems are evaluated from an exergetic point of view, the analysis is done subsequent of the model-based simulations using rudimentary tools. This work presents a way how exergy-based methods can be integrated into the model-based design environment of Modelica with focus on generic compatibility. An Exergy Library was developed that provides such capabilities and is applied to an example architecture using the Modelica Standard Library and to an aircraft ECS architecture using a new approach for robust modeling of directed thermo-fluid fluids.

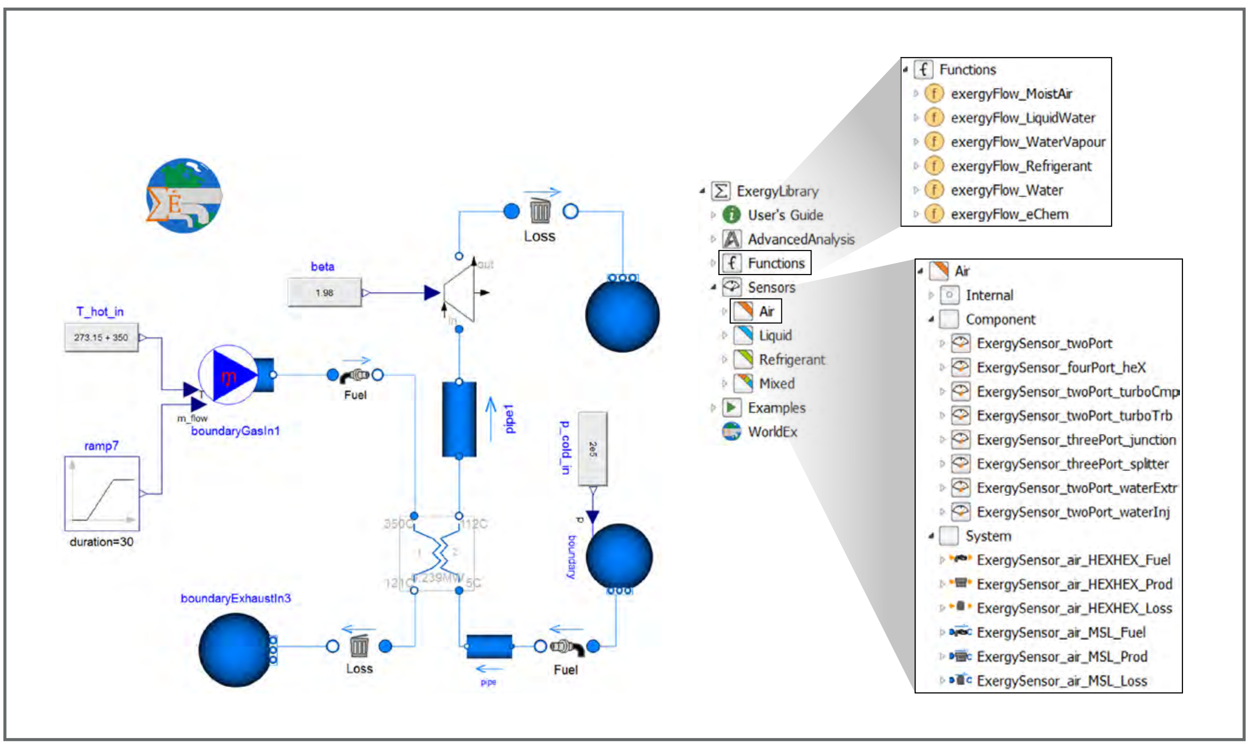

Figure 1. Left side: Modelica diagram of power generation cycle partly modeled with components from MSL having exergy sensors integrated. Right Side: Library structure of exergy library.

On Closure Relations for Dynamic Vapor Compression Cycle Models

Christopher R. Laughman   Hongtao Qiao

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Dynamic model-based design processes provide a promising path to address many challenges of developing large high-performance HVAC systems, as they can describe the temporal interactions between subsystems and allow rapid design iteration. Such a design process is heavily dependent on accurate and computationally efficient models of the dynamical behavior of HVAC systems.

One-dimensional finite volume models are commonly used to describe the heat exchangers in these cycles, as the discretized dynamics can accurately represent spatial and temporal variations. Unfortunately, some approximations of the underlying physical phenomena can introduce non-physical behavior into the models which can reduce the simulation speed and accuracy. As an example, cycle simulations using heat transfer correlations from the literature can exhibit non-physical chattering due to the large changes in the heat transfer coefficients between the two-phase and the single phase regions.

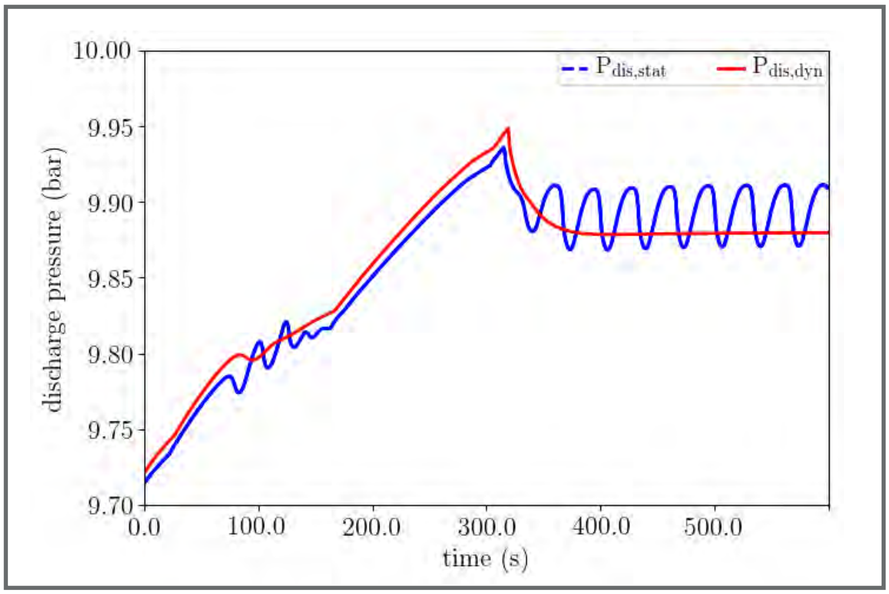

Figure 1. Compressor discharge pressure using simple heat transfer coefficient model with and without low-pass dynamics.

These dynamics can also have a negative impact on linearized models derived from the nonlinear finitevolume models, which are often used in control design. The long computation times and non-physical behavior exhibited by these models are often related to sets of nonlinear algebraic equations that are embedded in the overall structure of the equations representing the system dynamics. Rather than directly solve these equation blocks, we propose adding fast dynamics directly into the heat transfer and frictional pressure loss correlations. These added dynamics improve the simulation speed and better approximate behavior that is experimentally observed without requiring the use of more detailed models. We describe the mathematical structure of these approximations, and compare the performance of these approximate models to the original models. We find that the deviation introduced by these approximations has a minimal effect on simulation accuracy, and can significantly reduce the simulation time.

Fast Calculation of Refrigerant Properties in Vapor Compression Cycles Using Spline-Based Table Look-Up Method (SBTL)

Lixiang Li[1] Jesse Gohl[1] John Batteh[1] Christopher Greiner[2] Kai Wang[2]

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Refrigerant property calculation has a significant impact on the computational performance of vapor compression cycle simulations. This paper summarizes a Modelica implementation of Spline-Based Table Look-Up Method (SBTL) for fast calculation of refrigerant properties. External C functions are used for faster spline evaluation and inversion. Significant improvement in computation speed was observed without sacrificing accuracy. An SBTL property model of R134a is first validated against a highly accurate Helmholtz energy equation of state (EOS) model. Then the new model was tested rigorously from single function calls, to heat exchanger test bench, to system models of the vapor compression cycle in Modelon's Air Conditioning Library. Finally, an SBTL property model of R1234yf was used in a drive cycle simulation and a shutdown-startup test of two complex air conditioning system models developed at the Ford Motor Company. These system models are running more than twice the speed of the ones using Helmholtz energy EOS.

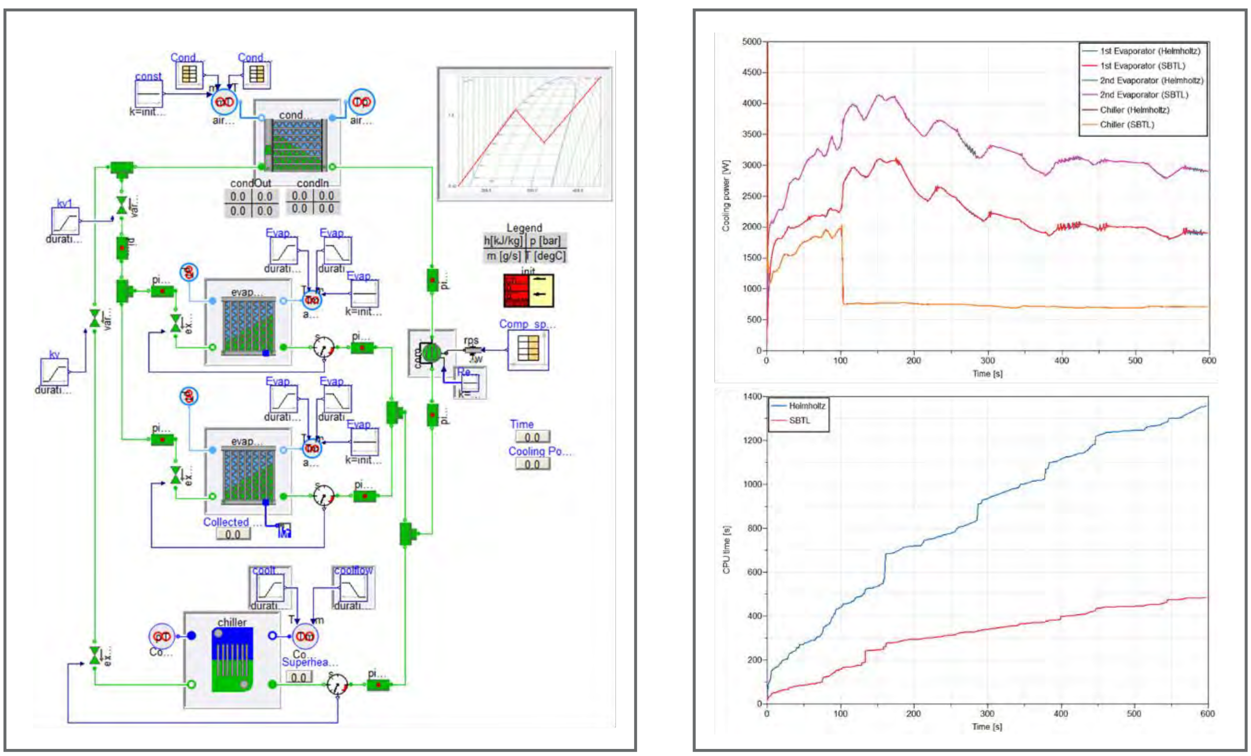

Figure 1. Left: Drive cycle simulation of an air conditioning system with R1234yf.
Right: Comparisons of cooling power and CPU time between SBTL method and Helmholtz energy EOS.

Modelica-Based Dynamic Modeling of a Solar-Powered Ground Source Heat Pump System: A Preliminary Case Study

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According to the annual energy outlook report, the building sector consumed 40% of the energy and 70% of the electricity in the U.S. in 2017 (EIA, 2017). Moreover, majority of the energy was used for space heating, cooling, and water heating in the buildings (DOE, 2010). Besides the system safety and occupants' thermal comfort, improving energy efficiency and reducing energy consumption in buildings is one of the most important priorities during the operation stages of buildings. The Ground Source Heat Pump (GSHP) system has been proved as one of the most energy-efficient solutions for the building heating, ventilation, and air-conditioning (HVAC) system for a wide variety of geology conditions (ASHRAE, 2007). Generally speaking, a high-performance component and system could be less efficient without the appropriated and robust control strategies. Model-based control has been widely used in automobile, aerospace, and industry processes, and starts to emerge in the building industry. The dynamic modeling capability offered by Modelica provides a good framework for such model-based control design.

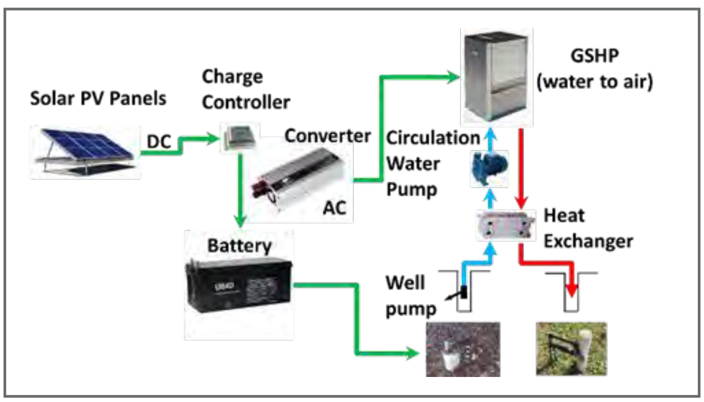

Figure 1. Overall system schematics of the studied solar-powered GSHP system.

This paper presents the preliminary simulation results from a Modelica-based dynamic model of a GSHP unit, together with the comparisons between simulation results and measurements from a test rig (Figure 1). The performance analysis and comparisons were conducted for the cooling mode only since the test rig was only operated in such mode. Only modeling and validations of the heat pump component of the test rig are included in this paper. The performance comparison covers the power consumption of the heat pump unit, unit cooling capacity, and unit Coefficient of Performance (COP). The current Modelica-based model can simulate the performances of the GSHP unit. The output trends for the Modelica simulation match with those from measurements well. This Modelica model will be extended to a full scale of the solar-powered GSHP system that includes solar panels, battery banks, charge controller, and groundwater wells.

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Coalesced Gas Turbine and Power System Modeling and Simulation using Modelica

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This work reports how the multi-domain physical modeling and simulation Modelica language has been employed to create a benchmark power grid and gas turbine model within the ITEA3 OpenCPS project. The modeling approach is not only shown to be useful to test the functionalities of the OpenCPS toolchains, but it also could give rise to potential applications in power system domain studies where the widely-accepted turbine-governor models are not rich enough to represent the multi-domain system dynamics.

Analysing the Stability of an Islanded Hydro-Electric Power System

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Power system simulation is a large arena especially in connection with the large European power system. The challenges of large interconnected electrical power systems call for a sophisticated system modelling solution that can give comparable results. This lead to project "iTesla – Innovative Tools for Electrical System Security within Large Areas" which was funded by the European Commission. One result of that project was the open-source modelling library called "iTesla Power System Library - iPSL" which then later was forked and called "Open Instance Power System Library - OpenIPSL". Those libraries are based on the open-source modelling language Modelica.

This paper presents the results of a Master's thesis where Modelica was used in combination of the "OpenIPSL" library to model a small local distribution grid that is islanded. It describes how to build the power system model using Modelica of a grid that is located in the Westfjord area of Iceland. That area of Iceland is only connected to the national grid by one transmission line. The reliability of the power supply is poor due to harsh weather conditions during winter. Two models of the transmission system of the Westfjords were build. One is a base model with three generating units and one is an extended model with four generating units (see Figure 1). Two different load scenarios were simulated. The result of which could give indicators as to what actions would help to keep the islanded grid stable.

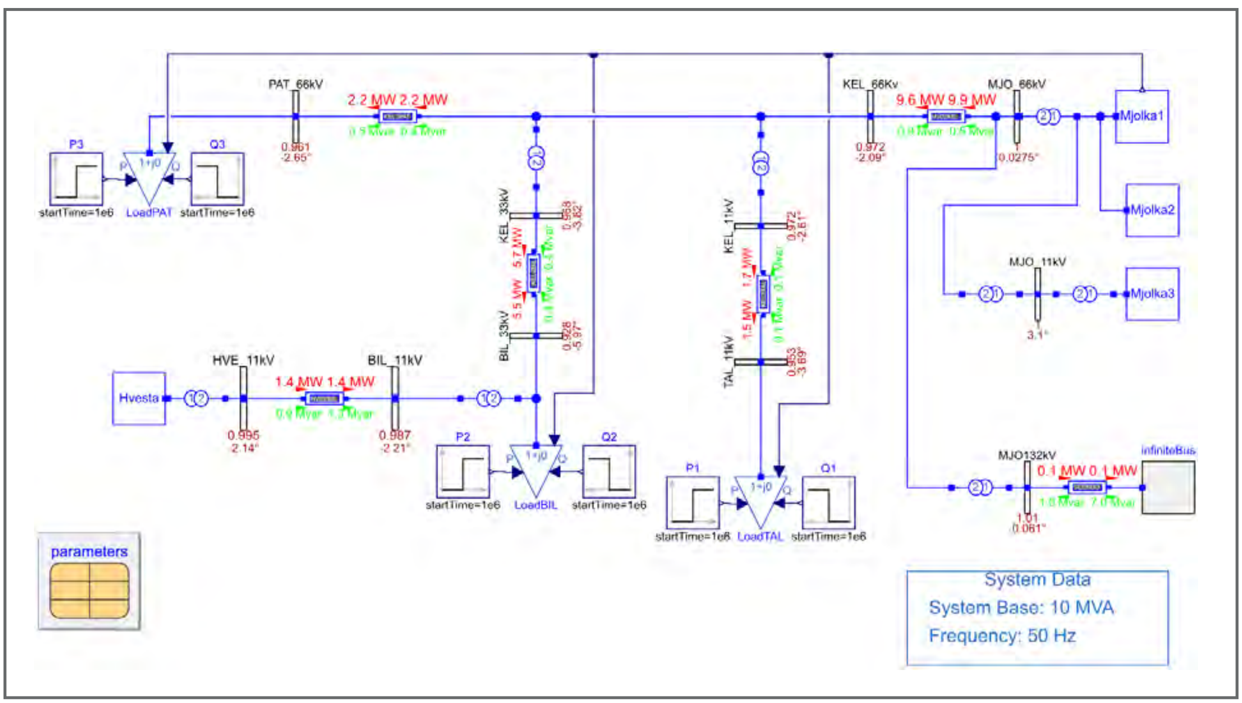

Figure 1. Four-generator model

Modeling of PMU-Based Islanded Operation Controls for Power Distribution Networks using Modelica and OpenIPSL

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This paper describes the modeling of a frequency controller that can be applied when islanding occurs at a power distribution network with a single distributed generator. The controller function requires bus frequency measurements which, for design purposes, need to be derived (computed) during dynamic simulations. Therefore, this paper also proposes a simple new frequency computation technique that can be used during dynamic simulations. The paper also addresses a technique for stochastic modeling of load uncertainties in the time-domain using the Modelica Noise library's features. The performance of the islanded controller is evaluated under load uncertainties, different PMU (phasor measurement unit) reporting rates and communication latencies.

ModestPy: An Open-Source Python Tool for Parameter Estimation in Functional Mock-up Units

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The paper presents an open-source Python tool for parameter estimation in FMI-compliant models, called *ModestPy*. The tool enables estimation of model parameters using userdefined sequences of methods, which are particularly helpful in non-convex problems. A user can start estimation with a chosen global search method and subsequently refine the estimates with a local search method. Several methods are available already, including Genetic Algorithm (in-house code), Generalized Pattern Search (in-house code), as well as the gradient-based methods from the *SciPy* eco-system.

In addition, the tool's architecture allows for easily adding new methods. The advantages of having a single interface to multiple methods and using them in sequences are highlighted on a case study in which the parameters of a Modelica-based gray-box model of a building zone (nonlinear, multi-output) are estimated using 9 different combinations of methods.

The methods are compared in terms of accuracy and computational performance. *ModestPy* is designed with the ease of use and installation in mind. It is compatible with both Python 2.7 and 3 and was tested on Windows and Linux. The package can be installed using the command `pip install modestpy`. The package structure is modular (Fig. 1). A user needs to interact only with one class, `Estimation` from `estimation.py`, and its two methods: `estimate()` and `validate()`. Whenever the Genetic Algorithm is used in the optimization, a plot visualizing the evolution of parameters is generated, helping to evaluate different values of parameters against the model error (Fig. 2).

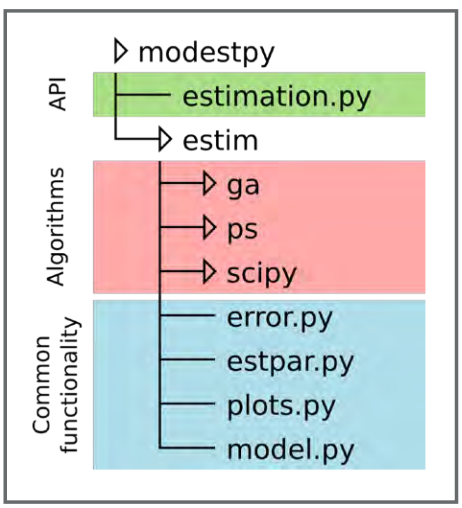

Figure 1. Package Structure

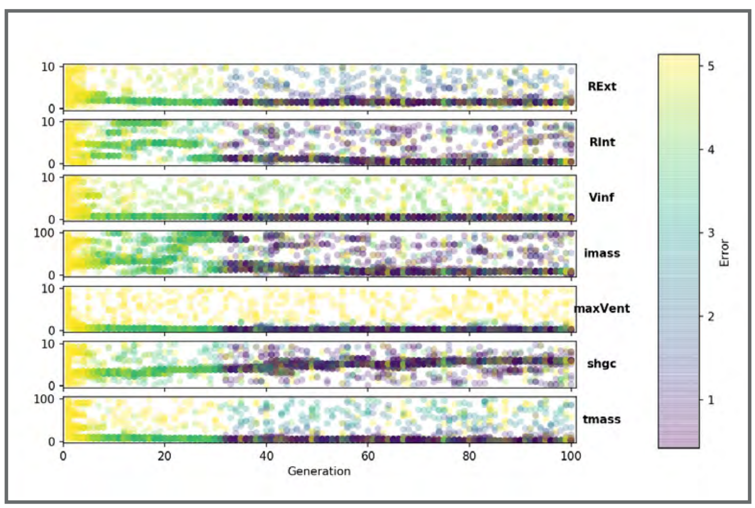

Figure 2. Genetic Algorithm Evolution of Parameters

A Safe Regression Test Selection Technique for Modelica

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Running regression tests for Modelica models usually takes a long time. This paper presents a safe regression test selection technique for Modelica based on static analysis.

The technique tracks dependencies between classes to compute which tests that need to be run given a change. The dependency rules have been verified using mutation testing. The technique has been evaluated on the Modelica Standard Library and another library with promising results.

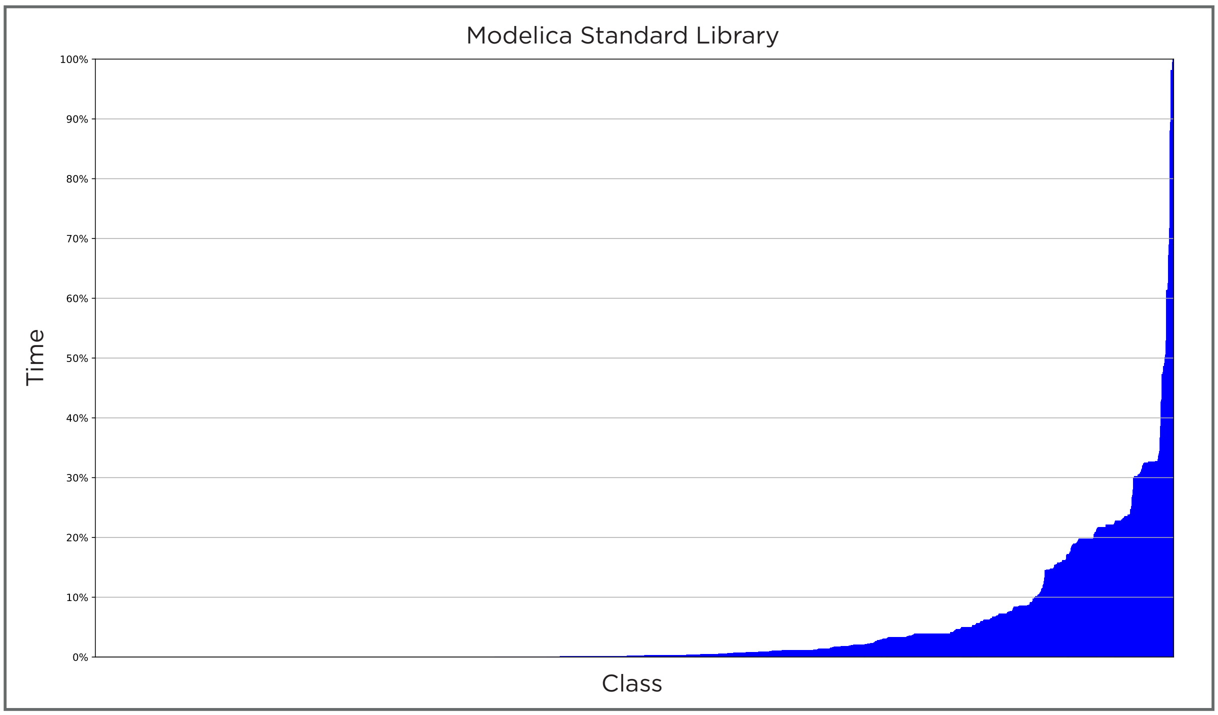

Figure 1. Expected testing times when one class changed in MSL. The figure can be viewed as a bar chart where each x-value represents a class, and the corresponding y-value is the total expected testing time if the class is changed. The classes on the x-axis have been sorted in ascending order.

Functional Mock-up Interface: An Empirical Survey Identifies Research Challenges and Current Barriers

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Co-simulation is a promising approach for the analysis of complex, multi-domain systems, that leverages mature simulation tools of the intervening domains. It has been applied in many different disciplines in academia and industry, with limited sharing of findings. With the increasing adoption of the Functional Mock-up Interface (FMI) standard, researchers have set to work on surveying the scattered knowledge on co-simulation in academia. This paper complements the existing surveys by taking on the social and empirical aspect, corroborating, and prioritizing, previous findings. We collected interviews with international experts from various fields (both academic and industry) regarding applications, barriers and future challenges of FMI. We focus on understanding the perceived research challenges, and the current barriers, based on expert assessment.

For the preparation of questions and collection of answers, we followed the Delphi method, which is regarded as useful for addressing interdisciplinary research problems. The Delphi method is a forecasting technique with which the opinions from a defined group of experts are systematically collected and processed. For the selection of the sample of participants, we used a Knowledge Resource Nomination Worksheet (KRNW) as a framework, consisting of five steps: (1) Preparation of the KRNW; (2); Population of the KRNW; (3) Nomination of additional experts; (4) Ranking of experts; and (5) Invitation of experts.

A total of 28 experts answered questions regarding potential barriers to the adoption of FMI, which are presented in this paper. An excerpt of the results is presented in Table 1.

Score: Entirely agree (7) Mostly agree (6) … Mostly disagree (2) Entirely disagree (1)	Mean	Median	Interpolated Median
Not a Barrier			
It is difficult to post-process simulation results	3.57	2.50	**2.50**
Concerns of industry/academia regarding FMI and IP protection	3.52	3.00	**2.83**
▪ ▪ ▪			
Somewhat of a Barrier			
▪ ▪ ▪			
Barrier			
FMI has limited support for hybrid co-simulation and it is not easily applicable	5.82	5.00	**5.00**
Lack of transparency in features supported by FMI tools	5.12	5.00	**5.05**
▪ ▪ ▪			

Table 1. Excerpt of Results

A Method to Import an FMU to a Hardware Description Language

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In this paper, a new method of importing FMUs (Functional Mock-up Unit) to a multi-domain, mixed-mode simulator is presented. Supporting FMI (Functional Mock-up Interface) 2.0 for Model Exchange by converting an FMU to an HDL (Hardware Description Language) wrapper model not only takes advantage of the existing simulator capabilities, but also avoids a significant amount of work in the core of the simulator. The selected HDL in this paper is MAST which is used in both Saber and SaberHDL simulators. To make the FMU import process easier, a general conversion utility, FMU2MAST, was developed which converts an FMU to a MAST model automatically. Two examples, bouncing ball and motor drive system are presented. With these two examples, three techniques used in this method are discussed: Accurate event detection in a variable time-step integration algorithm; Re-initialization of a state variable in MAST; and solving DAE (Differential Algebraic Equation) of a coupling FMUs system. This new FMU import method has been proved a success with 44 examples exported from five different tools.

To support the FMI 2.0 for Model Exchange in an HDL simulator, it requires a significant work in the core of the simulator. In this paper, a new method to import FMUs for Model Exchange is explored. Instead of supporting the FMU in a simulator core, the method proposed in this paper is to convert an FMU into a MAST wrapper model. This method has the following advantages:

1. Reduce significant work in the core of the simulator, which is time consuming as well as risky.

2. Avoid the duplicated work in another MAST simulator to support FMU import. Once an FMU is successfully converted to a MAST model, the generated MAST model works in Saber simulator, it also can work in another MAST simulator, SaberHDL, without any extra work.

3. The generated MAST wrapper model inherits all the features of the MAST language, and is applicable for all the existing simulator analyses, such as operating analysis, transient analysis, and advanced Monte Carlo analysis.

4. The generated MAST wrapper models can be used along with other models written in MAST or VHDL-AMS. It increases the model availability and helps the study of a more complex and interesting system.

In chapter 2, a detail analysis of the data types and variables in FMU and MAST language is presented. Based on that, the equivalent objects in MAST language is derived. A new interface, saberFMI is introduced in chapter 3. It creates the communication channel between MAST models and FMUs through FMI interfaces. In chapter 4, a general conversion utility, FMU2MAST is introduced. It parses the model description file in the FMU, generates an equivalent MAST wrapper model automatically, which makes the conversion from FMUs to MAST models easier. Two FMU examples are presented in the chapter 5 and 6 to discuss the detail techniques used in the method. Although the bouncing ball example is simple, it is useful to discuss two issues: accurate event detection in variable-time step integration algorithm and re-initialization of a state variable in MAST model. The motor drive system is used to illustrate how a coupling system with multiple FMUs are solved in a DAE solver. The method has been verified in two simulators with 44 FMU examples exported by five different tools.

Developing a Framework for Modeling Underwater Vehicles in Modelica

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When developing Remotely Operated Vehicles (ROVs), models prove extremely useful in determining design parameters and control strategies. Currently, there exist several models of underwater vehicles, but these are focused on specific underwater vehicle designs; the few initiatives geared towards modeling a variety of underwater vehicles were purpose-built programming environments. This paper's goal is to develop a general-purpose modeling framework for underwater ROVs in Modelica.

The framework focuses on rigid-body principles instead of CFD principles, to aid in modeling speed and scalability; it also addresses basic hydrodynamic forces and provides a simple propeller model template. To allow for quicker prototyping and testing of ROV design and control, it provides integration with the Robotic Operating System (ROS).

Named as the Underwater Rigid Body Library (URBL), the modeling framework treats the effect of water on submerged bodies as interactions with a "field" of water to capture the effects of buoyancy and drag. This is implemented within Modelica via replaceable functions and the "inner" "outer" qualifiers, to widen the field model's potential scope. The propeller incorporates both a simple electric motor and mechanical rotor model; the rotor model captures the conversion of momentum transfer from the rotor to the water. The URBL is connected to ROS via a TCP/IP socket interface.

Its usage is demonstrated by applying it to the BlueROV2, a commercially available ROV from Blue Robotics. The BlueROV2 is modeled as a combination of URBL rigid bodies and propellers; it is driven by specifying the input voltage to the propellers. Using a derived controller matrix to determine appropriate input values per desired motion commands, the model was tested with various motion profiles to achieve different composite motions. Constant motor commands were provided from Modelica via parameter input; the simulation results indicated that the model responded appropriately. A separate controller was constructed in ROS; it translated and sent joystick input as motor commands to the model. The results of simulating the model driven by the ROS controller showed that it responded appropriately.

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Hybridisation and Splitting of a Crank Angle Resolved Internal Combustion Engine Model Using a Mean Value Intake for Real-Time Performance

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This paper describes splitting a crank angle resolved three cylinder combustion engine with an air path model and a combustion model. This is to distribute the computational effort on hardware by running models on separate cores to achieve real time capability. Hardware tests show the split models are not able to achieve real time because the thermal dynamics of air path model and combustion model are highly interconnected and computing the models on separate cores will introduce delay and solution can become inaccurate and even infeasible. In order to achieve real time capability while ensuring the results are accurate (2-5% percent max. error), a new method is proposed, in which instead of running with a complete fluid intake and exhaust model, the combustion model runs with a mean value intake model calibrated for many operating points across the speed-load range.

The results show that the combustion model running with mean value intake model is able to produce highly accurate result and real time capability is achievable. By using mean value intake model, calibration effort is significantly reduced compared to purely table-based method as the mean value model captures essential dynamics and is able to predict reliably between transition from one operating point to another. The mean value method takes into account Air Fuel Ratio (AFR) dynamics and thus calibration against AFR becomes unnecessary. Comparing to a non-mean value purely table-based method, the latter requires calibration at densely scattered operating points in order for the transition between each calibration point to be smooth enough.

In calibrating the mean value model, a controller is designed to control the dynamics error to zero. This control-based method shows high efficiency compared to optimization tools as it does not depend on initial values and iteration process of the calibrating parameters. A function is created to automatically create the tables calibrated. The calibrated mean value intake model is run with a combustion model on a Concurrent test/HiL rig and shows real time capability is achieved with good accuracy. The physical engine model is built in Dymola.

Component-Based 3D Modeling of Dynamic Systems

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The objective is to model and simulate larger and more complex 3-dimensional systems as it is possible with a pure equation-based modeling system such as Modelica. The approach shall combine component-based 3D modeling, as used in modern game engines, with equation-based modeling.

The proposed methodology has been evaluated and tested with the open source prototype Modia3D (version 0.2.0-beta.1). It is implemented with the Julia programming language. Modia3D takes advantage of Julias powerful language features such as multiple dispatch and metaprogramming. Modia shall be used for the equation-based modeling. The intention is to utilize the results of this prototyping in the design of the next Modelica language generation. Issues are:

- The data structures of an equation-based modeling system are limited as compared to a programming language such as C++ or Julia. For example, it is virtually impossible to define 3D meshes and collision handling algorithms in Modelica.
- Specialized operations in the 3D world are hard to use, such as to remove redundant constraints of a planar loop automatically, solve kinematic loops analytically, or use an O(n) multibody algorithm. In Modelica, a user has to explicitly model such situations with specialized elements or use a pre-processor that generates Modelica code.
- Since Modelica compilers expand the models for the symbolic engine, the same equation is analyzed many times. Thus, the number of expanded equations grows at least linearly with the number of model instances and therefore the compilation time grows at least linearly with the model size.

In the article it is shown how ingredients from different communities are used: The basic architecture is taken from game engines, in particular to use component-based 3D modeling to achieve a very flexible way to build-up 3D systems, to model collisions and to use various handlers for the different computational tasks. Kinematic and dynamic simulation is performed with multibody algorithms, in particular to simulate systems with kinematic loops, and by utilizing variable-step solvers with zero crossing functions. Constructing consistent initial configurations is performed by using ideas from parameterized CAD systems. The hierarchical modeling and naming of sub-components follows the Modelica/Modia approach. The equation based modeling language Modia shall be used to provide dynamic models from other domains, e.g. as actuators to drive a joint. On the other hand, it is planned that Modia3D models can be utilized as components in a Modia model.

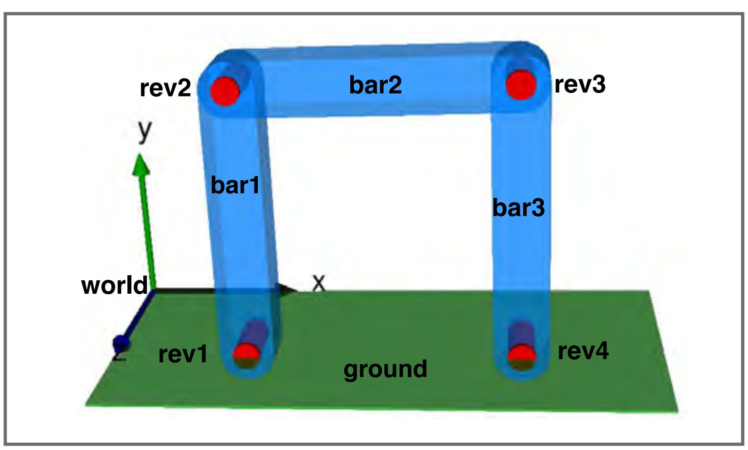

Figure 1. Planar four-bar mechanism

The Deployable Structures Library

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Deployable structures are an enabling technology for many space- and ground-based structures and vehicles. Accurate modeling of multibody kinematics and dynamics in early design phases is critical to ensure deployment reliability and overall structural integrity of these structures and associated mechanisms.

This is particularly true for expensive, highly engineered space-based structures such as solar arrays, antennas, and booms where deployment failure results in mission failure. Not only is deployment the number one risk to these systems, they also must meet stringent mass and stiffness requirements that make structural dynamics responses an important consideration in preliminary design phases.

In this paper, a Modelica library is presented that provides a number of building blocks to enable and ease the development of models of deployable structures. Several examples using the library are presented that would be difficult or impossible to model using other technologies.

Single Pipe Design for Integrated Community Energy Systems

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With an enhanced focus on energy efficiency and resiliency, Integrated Community Energy (ICE) Systems provide an attractive alternative to traditional energy infrastructure. ICE Systems aim to reduce peak period emissions by integrating both thermal and electrical energy generation and coupling them with storage at a local community level. These systems are especially important in colder climates where thermal demands dominate electrical need and natural gas is the dominant method for heating.

Traditionally these systems utilize a four-pipe thermal network to transport heating and cooling liquids throughout the community in parallel to the heating source. The focus of this research is to investigate the use of a single pipe design. This, with appropriate design considerations, would reduce pipe installation costs and can reduce the heat losses associated with district systems. Furthermore, a single loop with buildings connected in series allows for a shared thermal energy economy, where excess heating or cooling can be rejected into the loop to be used downstream by other community members – truly integrating the system.

The system features a single pipe with a thermal generation station and connects to a suite of buildings in series before returning to the original source. Each building interfaces with the thermal network pipe using a heat pump, which raises transfers heat to or from the loop to meet the requirements of the building. Currently work is being done to model this whole system in OpenModelica and test it against different heat pumps, pipe designs, building sizes, building arrangements and community densities. The goal is to characterize the single pipe design and compare it's performance to traditional 4 and 6 pipe designs and determine when it should be implemented in place of traditional systems to create a more sustainable community energy system.

Dynamic Model of a 725 MW Combined Cycle Gas Turbine Power Plant with a CO_2 Post-Combustion Capture Unit

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A detailed dynamic model of a CO2 post-combustion capture unit based on 30wt% monoethanolamine (MEA) solvent was developed, written in the Modelica language. Interphase gas-liquid mass transfers in the absorber and stripper packed columns were treated as well as diffusion limitation in gas and liquid phases. Chemical equilibria in the liquid phase were also taken into account. The model has been validated with the use of many experimental data after a review of different validation sources.

The carbon capture model was afterwards coupled to an EDF dynamic combined cycle model also written in Modelica, using ThermoSysPro library developed by EDF R&D, and validated with actual power plant data. The simulation results provided by this model were verified with data available in the literature from the FP7 CESAR project and results provided by PSE's gCCS model based on its proprietary gPROMS code.

This paper describes in detail the Combined Cycle Gas Turbine model (CCGT) with a CO2 capture unit model, the test-case (parameterization and data), the results for steady state and dynamic simulations of CCGT model with or without post-combustion CO2 capture unit and the comparison between the model and results from the FP7 CAESAR project are presented.

All this study concerning the development and evaluation of the CO2 capture model and the CCGT model with this capture module was performed within the framework of a project funded by the Energy Technologies Institute (ETI) with additional financial support from EDF R&D: the CCS Systems Modelling Tool-Kit.

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Reduced Modelica Model for Building Thermal and Electrical Loads Estimations

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Building energy models are important tools to identify the building thermal and electrical demands which are the main inputs in design and operate building energy operating systems. Existing building models in Modelica are engineering models which take into accounts all the building characteristics and all-weather information. Using all the details increases the computational time and cost of these models. In this work, a reduced building energy model using less weather and building parameters is presented. The methodology generates correlations between the cooling, heating degree hours (Coskun et al, 2014), benchmarks for non-space conditioning loads and the building energy demands.

This model will be a part of a new library in Modelica for the Integrated Community Energy-Harvesting project at McMaster University (ICE-Harvest). ICE-Harvest is an innovative whole-systems thinking approach to integrate thermal and electrical energy production, storage, redistribution, and consumption to significantly reduce greenhouse gas (GHG) emissions, create a more sustainable energy infrastructure and improve the quality of life for people living in high energy intensity communities.

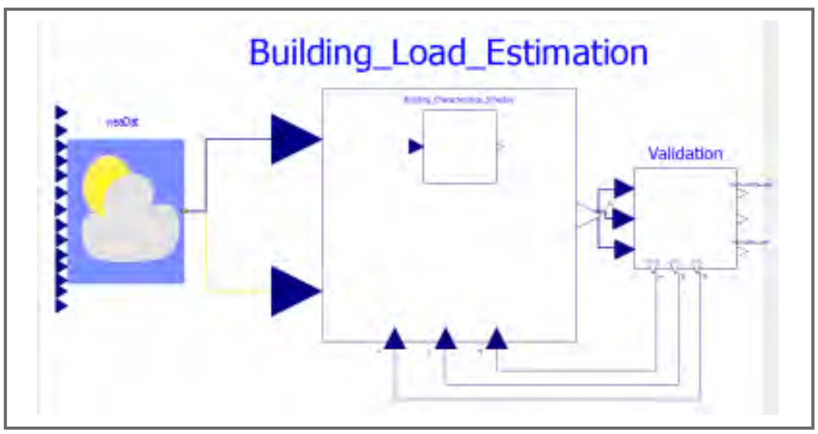

Figure 1. Load Estimation Modelica Model

The reduced load estimation Modelica model modifies the weather ReaderTMY3 from the AixLib (Müller et al, 2016) to calculate the cooling and heating degree hours. Then input these data and some building envelops characteristics such as the operating schedule, the total surface area and the ratio of the window to wall area will be inputted to the building load estimation tool. The output will be hourly thermal and electrical loads.Turning up of these loads can be done by comparison to the actual consumptions data of the existing building or engineering model data for new buildings under construction.

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Modeling and Control of the IRIS IPWR in a High Renewables Grid Using TRANSFORM

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As more variable renewable energy enters the grid, peaking power is increasingly supplied by carbon-emitting natural gas plants. Significant greenhouse gas emissions can be avoided if these gas plants are replaced with carbon-neutral nuclear facilities to provide power to complement renewable generation and meet overall power demand. There is a significant body of work regarding reactor power shaping, especially with control rod movement in mechanical shim control strategies, for both currently operating nuclear power plants and future plant designs, but the literature on load following to meet rapidly varying power demand is less extensive.

This work expands the literature by evaluating plant behavior under a more aggressive regime of load following with greater emphasis on the balance of plant, particularly in the context of a high renewables penetration grid or distributed generation system. We have selected the Westinghouse International Reactor Innovative and Secure (IRIS) Integral Pressurized Water Reactor (IPWR) as our demonstration for modeling, simulation, and control studies in this endeavor. The current plant model, developed with the aid of the TRANSFORM Library in Modelica, has the primary reactor system with a point reactor kinetics model, the steam generator system, and a simple balance of plant.

The TRANSFORM Library is a Modelica based library for modeling thermal hydraulic energy systems and other multi-physics systems (M. S. Greenwood, 2018). The physicality, modularity, and scalability of models in Modelica make the language and its readily available libraries excellent tools for modeling and validation of prospective reactors like IRIS and associated secondary systems for which there is much published literature available. Using and extending the components of the TRANSFORM library, the reactor core model has been augmented to capture additional reactor physics phenomena related to fission products and fuel burn up that affect the nuclear chain reaction.

These phenomena arise over the course of power level maneuvers that add difficulties to plant operation over a period of time of up to several hours and at different stages of the reactor life cycle as the fuel is burned. Preliminary results for load following operation in a previous IRIS Simulink model developed at the University of Tennessee suggest candidate actuators and strategies for control, especially in the balance of plant for fast transients. The control scheme for the load following operation of the IRIS IPWR model would ultimately lead to the development of real operational mechanisms and principles for small modular reactors (SMRs) in a grid with a large renewables share. Such principles include the consideration of figures of merit regarding the effect of maneuvers and actuation on plant economics. In the future FMU xport may be used in control design and optimization in conjunction with MATLAB and Simulink.

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Dirt Late Model Race Car Simulations with Dymola / Modelica

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A multi-body vehicle dynamics model of a Dirt Late Model (DLM) car and application specific set of simulations were created to explore the available suspension adjustments relationship to handling characteristics. The set of simulation tools were built in Dymola, using the VeSyMA suite of libraries from Claytex. The Dymola models were specifically used to assess the effect of setup adjustments on handling and sensitivity to laptime changes. Even with input data of less than desirable accuracy, the simulation results proved both valuable and enlightening.

Using SystemModeler and Modelica to Rapidly Build and Verify Hardware Control Systems

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AC Kinetics (Armonk, NY) is a company that develops new AC induction motor drive software that simultaneously increases motor performance and energy efficiency. We use proprietary optimization technologies to develop our software. SystemModeler and Modelica are an integral part of our workflow and I will be presenting several use cases for SystemModeler and Modelica for hardware development and control.

In Commercial applications AC Kinetics uses both SystemModeler and Modelica to develop its software for controlling AC Induction motors. We will demonstrate how we use Modelica to verify our real time digital controller C code in simulation and then deploy the verified software in hardware. Using this approach, we can quickly prototype and test software that runs our motor drive at powers up to 400 hp. AC Kinetics along with its industrial partner, Koch Industries (Wichita, KS) field tested the software demonstrating energy savings in some applications as high as half of the total energy. We will present our Modelica workflow and show a comparison between our simulation results and hardware field testing.

In addition, we will demonstrate how to use SystemModeler, Modelica and Mathematica to generate the equations of motion of a dynamic system. Next the equations of motion will be used to design a controller and then the controller can be implemented and tested with the Modelica model in SystemModeler. We will demonstrate how this workflow provides significant time savings over conventional approaches to controller design.

API for Accessing OpenModelica Models From Julia

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This paper describes a new API for operating on Modelica models from Julia, through OpenModelica. Modelica is an object oriented, acausal language for describing dynamic models in the form of Differential Algebraic Equations. Modelica and various implementations such as OpenModelica have limited support for model analysis, and it is of interest to integrate Modelica code with scripting languages such as Julia, which facilitate the needed analysis possibilities.

The API is based on a new class ModelicaSystem within package OMJulia of OpenModelica, with methods that operate on instantiated models. Emphasis has been put on specification of a systematic structure for the various methods of the class. A simple case study involving a water tank is used to illustrate the basic ideas, while a chemical reactor model gives a more advanced illustration of possibilities.

Modeling Integrated Community Energy and Harvesting Systems from Databases Using OpenModelica

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This presentation will provide an overview of an implementation of performance characteristics for various equipment types into OpenModelica through interfacing with an SQL database and Python 3.6. This database is to be used dynamically in models to aid in the system level design and matching equipment operating parameters for a novel implementation of Integrated Community Energy and Harvesting Systems – a new approach to embedded generation of heating, cooling and electricity within North American Communities. By using this approach, feasibility studies and preliminary sizing of mechanical equipment from existing components will become greatly simplified in OpenModelica.

The purpose of this tool is to easily replace equipment performances in a system involving absorption chillers, electric chillers, combined heat and power generation, heat pumps and thermal energy distribution to identify key equipment synergies and matching of operating parameters to ease in detailed design. By having a database partnered with the modelling software, system designers will be able to easily call and replace equipment, or search and install equipment with matched temperature and pressure operating parameters for the thermal working fluids.

The database includes equipment specifications, as in machine performance curves and component parameters; and experimental data, such as dynamic requirements for a system, to be used in different Modelica models. This presentation will demonstrate how to input the different data into several different OpenModelica models using Python (v3.6) to bridge the gap between the SQL database and the OpenModelica models. The Python libraries will access both the MySQL Python Connector library to interface with the SQL database collecting the needed information for the current model and OMPython to input that collected data.

The use of an SQL database which can be easily imported into OpenModelica is advantageous as it allows for ease of access to query desired performance characteristics of specific mechanical units which can then be simulated. Python is used as an interface language as it interacts simply with both OpenModelica through OMPython and MySQL with PySQL.

Virtual Commissioning and Dynamic Systems Modeling of Complex Systems Using Modelica and ControlBuild Co-simulation

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Virtual Commissioning is an economical method to validate and verify design of a complex system before its operation. Dynamic systems analysis tools such as Modelica predicts the behavior of a system under different environmental and working conditions. Co-simulation of 1D and 3D models can provide an economical method to simulate very large systems with many details in a small processing timeframe. This paper describes a methodology based on Modelica that simulates very large mechatronics models in realtime with complex PLC based control systems. There are many examples of virtual commissioning of complex systems using Computer Aided Design software (CAD) and Hardware-in-the-Loop (HIL). The proposed methodology is based on the Modelica that simulates dynamic behavior of the system and implements it to the ControlBuild software that directly controls PLCs. This platform can provide digital continuity from CAD design, requirements, functional and logical models in systems architecture to the real PLC system that controls an industrial machine.

The advantages of this system are discussed by (Chioran and Machado, 2011). (Hofmann et al, 2015) explained similar methodology that generates C codes for PLC programing. In this methodology any change in the hardware according to requirements and functionalities is automatically implemented to CAD and Kinematic model that updates Modelica model. The dynamics behavior of the system is predicted and can be examined directly through the connectivity between Modelica and PLC programming software (ControlBuild). Instead of running the physical plant, ControlBuild can run a virtual PLC and provide feedback to the Modelica model. Validated final design and PLC program can be used directly to control the physical plant with no extra operational step. Figure 1 shows a schematic of this methodology.

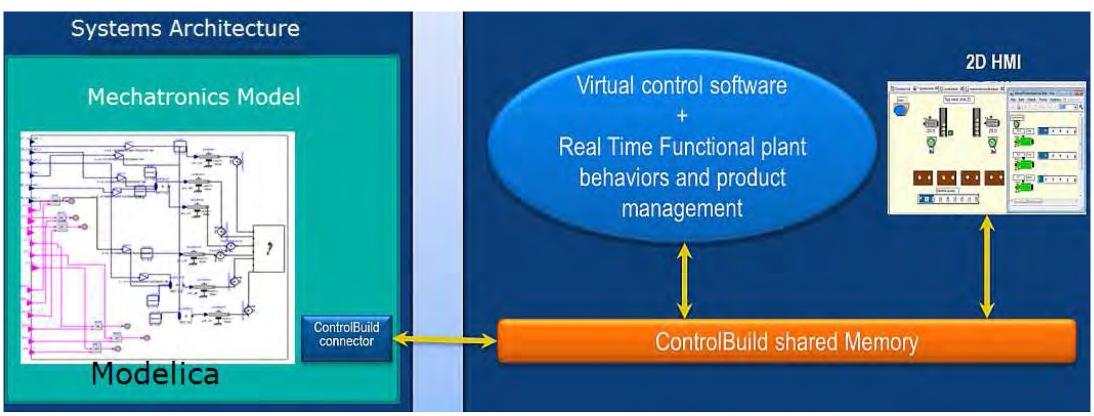

Figure 1. Schematic of Modelica and ControlBuild Co-simulation Method.

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An Industrial Model Based Development Systems Engineering Strategy

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This paper presents model based systems engineering principles that are important for the development of thermo-fluid products and the use of Modelica. Systems engineering is concerned with the organization of product architectures that meet customer requirements and the arrangement of development steps that reduce risk in meeting the requirements as the design is developed and tested. Modelica is a formal language that captures multiphysics and as such is a powerful tool in creating virtual designs and validating requirements and also verifying the product performance against subsystem and full scale system tests. The current state of the Modelica environment can significantly advance model based systems engineering, moreover, there is considerable opportunity for the development of Modelica constructs that include embedding the Modelica physics capture into heterogenous toolchains as well as the extension of modeling elements that can enable robust design and optimization to get rapid and robust system design and verification.

Systems engineering is the integrated product view and overall management of what will be delivered including components, communications and controls along with the coordinated product design including requirements elicitation and analysis, product development methodologies and allocation of requirements to subsystems and the validation, verification and certification. Systems engineering organizes the product development and over the product lifecycle reduces the overall risk of delivering the product that meets requirements. There are four key elements in a model based systems engineering approach: (1) requirements gathering and analysis, (2) architecture selection, (3) use of models throughout the process for analysis of key functionality and (4) the use of a design flow that fundamentally uses models (and reduces test).

The role of Modelica in model based systems engineering is to provide a formal language for capturing the physics of the product. Modelica has features that are very useful for systems engineering work, namely, that the multiphysics nature can capture the entire system behavior which for thermo-fluid systems spans fluid flow, mechanical elements (pumps, etc), thermodynamics (cycles) and controls. In addition the multiscale nature (object orientation) allows for the refinement of models as the design is developed during the development process.

There are opportunities and challenges using Modelica in systems engineering workflows. The opportunities with the current Modelica environment are to use the multiphysics and multiscale to evaluate the required behavior (or services) and chosen architecture to deliver the services (in a platform based design methodology). The Modelica models can be used to both optimize performance — statically and dynamically — and in addition to find "corner points" or to look for system interaction using robust design methodology and tools. These areas — optimization and robust design— require that the models be crafted in different ways.

(*continued next page*)

An Industrial Model Based Development Systems Engineering Strategy (page 2)

Robust design. A key element of product design is the overall robustness of the product. In a model based development workflow it is important to compute product performance margins. Modelica — used to capture the system behavior — can also be used to compute the output variations given variations on inputs and parameters. This kind of computation is important in that commercial HVAC/R systems are certified at design points for capacity and efficiency. The challenge is to extend the Modelica environment to be able to capture probabilistic information on the inputs and parameters — in short to extend the capture of the uncertainty in the model.

Optimization. A key element of product design is to optimize performance. The Modelica models at the system level enable trade studies and optimization of system level performance. The use of Modelica models as input to languages as Pyomo or CasADi enable broad use of the physics capture and to use the models for both static optimization (set points) and dynamics (movement between set points). For optimization the models need to be smooth and to use automatic differentiation methodologies to be fast and robust in gradient based methods. This type of use is also enabled by a common library with both static and dynamic versions of models so that a "flip of a switch" different analyses and trades can be carried out.

Toolchains. Implementation of system engineering calls for development of toolchains that flexibly support creation, transformation and execution of Modelica models. Such toolchains exploit Modelica tools, the integration environments, and scripting and numerical algorithms to implement custom product design workflows. The use of FMU as a standard interface enables the creation of heterogenous toolchains — the use of Modelica to capture physics and the passage of the models to tools like Pyomo for optimization. This coupling of Modelica and FMU enables flexibility and extensibility over time and the coverage of many analyses that extend the value of model based development in product development. In this paper we present examples of how Modelica is leveraged for systems engineering in product design of thermo-fluid products. We highlight how Modelica-based transient and steady state simulation, optimization and robust design is leveraged to implement toolchains to support execution of design workflows.

Modelica Language – A Promising Tool for Publishing and Sharing Biomedical Models

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Current biomedical models are so extensive that their description (and reproducibility) requires more than a set of equations. A scientific paper describing a model should thus be accompanied by a digital enclosure (accessible on the Internet) containing a detailed description of the model structure, including the values of all parameters and most of all containing a complete source code in a common, formal programming language, adequate for the reader to be able to run the model, reproduce the model results and to potentially use the model as a basis for their own work where appropriate. The sharing of the complete source code is becoming common practice and even a requirement in a number of journals publishing scientific papers on computer models, especially the open-access ones. A serious obstacle arises if a model is published in a modeling language requiring a commercial license (such as Matlab/Simulink by MathWorks), because the reader must be a licensee of the particular system to be able to just reproduce the model results.

This is why considerable efforts have been made within the international ***PHYSIOME*** Project to create specific simulation languages appropriate for describing biomedical models and saving them in specific databases – model repositories (Cooling et al., 2016). Specific electronic archives associated with specific languages (e.g. CellML, JSim) and publicly accessible simulation platforms for the creation and archiving of biomedical models have been set up, however each of them has some disadvantage and an agreement on a common language for model sharing is missing. Let us sum up the factors owing to which Modelica is a language suitable for publishing and sharing biomedical models:

- Modelica is a modeling language, not a proprietary product owned by a commercial company (such as, e.g. Mathworks' Matlab and Simulink).
- Publicly accessible noncommercial developmental tools (such as OpenModelica and JModelica) exist for Modelica and are mature and reliable enough, the development is driven by well-funded industries.
- Modelica includes application libraries facilitating biomedical system modeling, such as Physiolibrary and Chemical (www.physiolibrary.org).
- The model structure in the acausal Modelica language is clear, reflecting more the structure of the original modeled than that of the calculation and enabling extensive hierarchic models to be set up.

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The OpenModelica Integrated Modeling, Simulation and Optimization Environment

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Rüdiger Franke[7] Mahder Gebremedhin[1] Bernt Lie[8] Alachew Mengist[1]
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OpenModelica is currently the most complete open-source Modelica- and FMI-based modeling, simulation, optimization, and model-based development environment. It is based on Modelica and uses an extended version of Modelica for its implementation. Moreover, the OpenModelica environment provides a number of facilities such as debugging, optimization, visualization and 3D animation, web-based model editing and simulation, scripting from Modelica, Python, Julia, and Matlab; efficient simulation and co-simulation of FMI-based models, embedded system support, Modelica-UML integration, requirement verification, and generation of parallel code for multi-ore architectures. This overview paper intends to give an up-to-date brief description of the capabilities of the system, and the main vision behind its development.

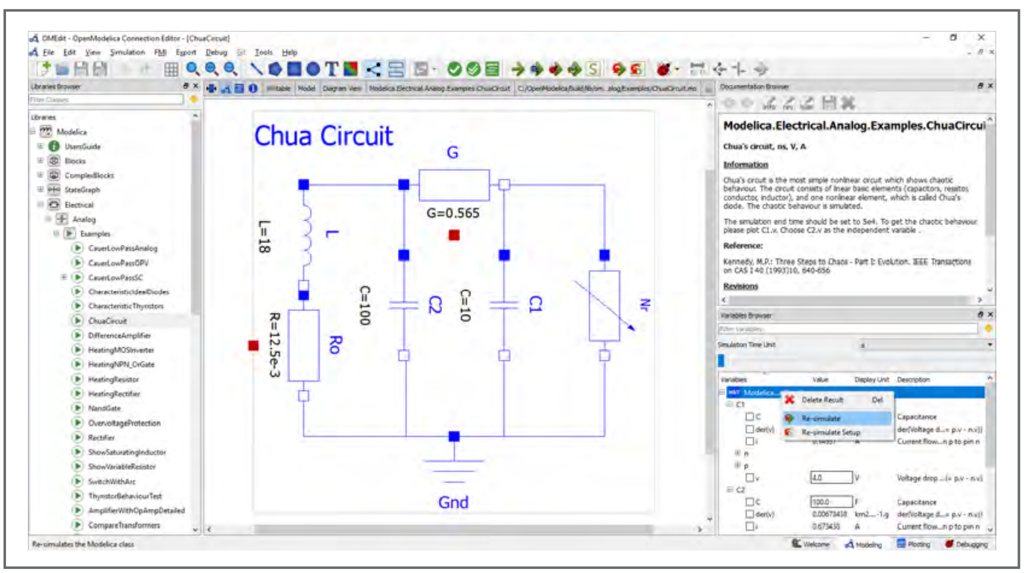

Figure 1. OMEdit on the Modelica.Electrical.Analog. Examples.ChuaCircuit model.
Center: Model connection diagram. Upper right: information window.
Lower right: plot variable browser will a small popup re-simulate menu on top.

Modelica on the Web

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Although Modelica (Fritzson and Engelson (1998)) has been around as a language from the late 1990's and many editor, compiler, and simulation tool supports it; all of them follow the approach of requiring each end-user to install the application (typically together with a set of dependencies) on their local machine making the learning curve steep. These solutions also lack any integrated collaboration feature that could help out bigger teams of users. In response, we present the WebGME Dynamic Systems Studio, the first web-based collaborative graphical and textual modeling environment for Modelica based onWebGME (Maróti et al. (2014)) and OpenModelica or JModelica as compilation and simulation engines.

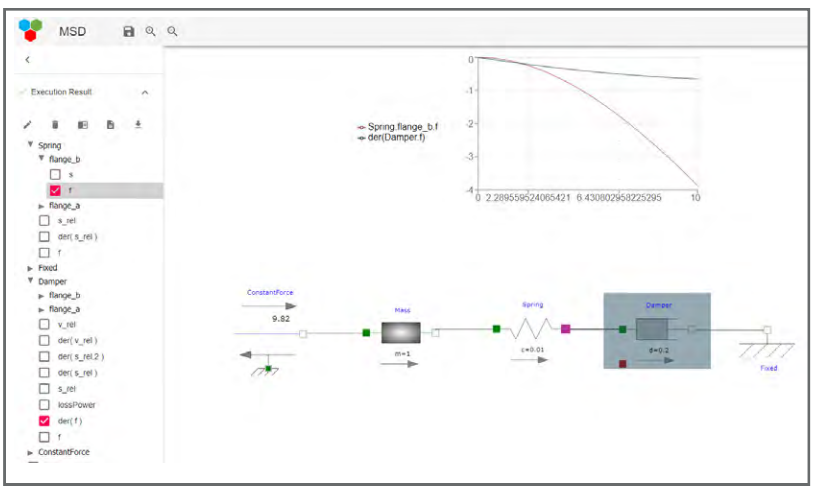

Figure 1. Simulation result visualization in WebGME-DSS

Our proof of concept implementation leverages the features of the meta-programmable WebGME framework to provide a tightly integrated user interface with collaboration and simulation capabilities as shown in Figure 1. Future work will also include integration with OMWebBook (Fritzson (2017), an interactive Modelica textual notebook for the web.

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A Modelica Library for Thin-Layer Drying of Agricultural Products

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Environmental and technical factors profoundly influence the agricultural grains' drying. Thus, it is essential to track the psychrometric properties of the drying air beside other grain characteristics for successful control of the operation. Mathematical modeling of a drying process can be non-trivial when considering all the involved factors and difficult to solve using simple tools. Therefore, based on theoretical differential equations, this study calculates different aspects of grain during its drying process. Modelica and Dymola were used to model blocks of thin-layers of three types of material, as observed in Figure 1. Additionally, Air Connectors were modeled to estimate the psychrometric properties of the air at any point. All these blocks could be used to reproduce a simulation of grain drying and keep track of its moisture content and temperature. It was tested using different air temperatures and the number of grain layers for a close simulation of the drying process.

Preliminary results showed that corn reached moisture ratio of approximately 0.60, 0.35, and 0.07 at drying temperatures of, respectively, 25, 50, and 90 0C for a layer of 25 cm and after 3 hours. For corn, soybean, and barley, the latest dried faster during a simulation of two hours. A simulation with 50 layers resulted in a difference of 2% in moisture content between the first and last layer. It also showed that the humidity ratio of the input air was higher for the last layer compared to the first, reiterating how the air was saturated with water at the end of the column and had its drying capacity reduced. The simulation results were compared with experimental data, which showed a resemblance over time, even though there were differences between them. The model developed has the potential to be used to either to monitor a real grain drying process or to be used as a teaching instrument for grain handling. Additional capabilities could be added to this model, such as weather influence, different kinds of dryers, and more grain types. This work is just one example of how Modelica can be used and expanded to numerous agriculture applications.

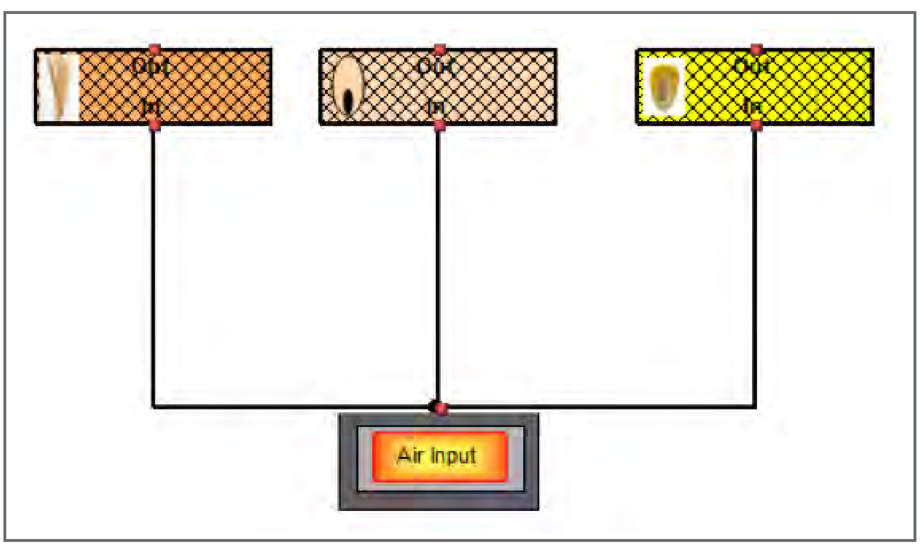

Figure 1. Thin barley, soybean, and corn layers connected to the dryer model.

Modelica Library for the Systems Engineering of Railway Brakes

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This work outlines the role of system simulation for the development process of railway brakes. The principles of systems engineering motivate the use of computer based simulation in order to enhance the understanding of systems and to verify the behavior of systems in early design phases. The goal of this work is to develop the concept of the Modelica library "Virtual Train Brakes" which provides an environment for the application of system simulation throughout the entire development process of railway brakes as shown in Figure 1. The development of the library is an ongoing work. This paper is primarily meant to motivate its usage and to present the modeling concept.

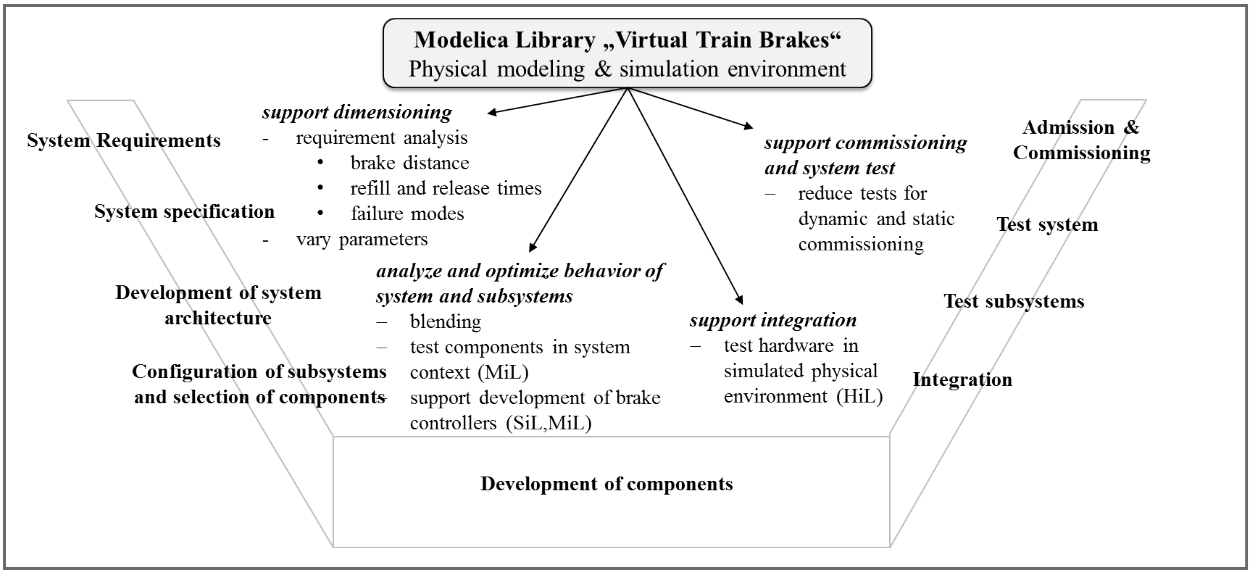

Figure 1. "V-Model" as development process of railway brake systems with use cases for system simulation

Initially, railway brake systems and the role of systems engineering in the scope of their design are introduced. Subsequently, use cases of system simulation during the development process are discussed which are the basis for the structure and implementation of the library with Modelica in Dymola. Varying requirements concerning the accuracy and the computational effort of the models are considered and the generic composition and diverse configuration variants of railway brake systems are respected. After the presentation of the library it is applied to model pneumatically actuated frictional brake systems of a passenger and a freight train. By simulating typical brake application scenarios useful knowledge of the system behavior is generated. This can be used to verify a system against its requirements, such as the brake distance, and to analyze the states of the system yielding the resulting behavior, e.g. the pressurization of brake cylinders. Furthermore, the application of numerical optimization allows to study the system behavior with respect to sensitive parameters, for instance the mean value of the friction coefficient between pad and disc, and to identify model parameters by comparing simulation results to measurements in scope of model validation.

Drilling Library: A Modelica Library for the Simulation of Well Construction

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The simulation of the drilling operation using a flexible tool makes it possible to obtain a realistic behavior of the operation, graphical representation of the results, sensitivity analyses and control design. In the modern, high pressure and high temperature, HPHT, wells, it is crucial to have a profound understanding of the dynamic behavior of the well for accurate well planning, training and operational assistance. In this regard, Modelica is a well-known tool providing a flexible platform to simulate multi domain physics including the thermo-flow and mechanical dynamics[1]. Hence it is well suited for the simulation of the drilling operation and control.

In this paper, a Modelica library for the simulation of well construction (drilling) is presented. The library contains most of the components of a drilling system. The simulation model is able to capture the main dynamics of the well, including the hydraulics, the mud transport, the mechanics of the drill string as well as the drill bit interaction with the bore hole. The library is well suited to simulate the well operation and to support the development of new technologies.

The main purpose of the library is to simulate:

1. Well hydraulics: From the main pump at the surface to the topside interface.

2. Drill string mechanics:
   • Detailed mechanics of the string (torsion and elongation)
   • Rotational friction between string and surrounding fluids
   • Interaction of the drill bit with the surroundings to describe the bore hole growth

3. Mud transport: The transported fluid that is normally a mixture of oil, water and granular particles.)

This library presented is a first step towards a versatile tool for new technology development for well construction. It shows the potential of the Modelica technology in a simple but quite complete drilling system with fluid-mechanical interactions. The chosen imple-mentation strategies show computation times that are suitable for interactive work. In Equinor, Modelica is used for control studies and design within oil and gas production and pro-cessing, and also as a tool to produce FMUs for integration in process simulators. The modularity and extensibility of Modelica is expected to lower the threshold for using dynamic simulation in prototyping systems and control functions for well construction. The proposed library is currently planned to be used by Equinor within research work and in cooperation with academia. The authors welcome also industrial partners to participate in the further development of the library.

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VENDOR ABSTRACTS

AND

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ANSYS Twin Builder Capabilities: Build, Validate and Deploy Complete Systems Simulations and Digital Twins for Predictive Maintenance

ANSYS Twin Builder is a predictive maintenance product that allows you to save on warranty and insurance costs and optimize your product operations. To build your system easily and quickly, ANSYS Twin Builder combines the power of a multidomain systems modeler with extensive 0D application-specific libraries, 3D physics solvers, ROM capabilities and embedded software tools.

To validate your system, ANSYS Twin Builder combines multidomain systems simulation capabilities with rapid HMI prototyping, systems optimization and XIL validation tools, ensuring that your system design will perform as expected. To connect your twin to test or real-time data, ANSYS Twin Builder easily integrates with IIoT platforms and contains runtime deployment options, allowing you to perform predictive maintenance on your physical product.

Claytex develops a range of FMI tools, Modelica libraries and related tools focused on the modelling and simulation of multi-domain systems. As a consultancy we help our customers apply these tools to simulate many different types of vehicle including electric and autonomous vehicles.

The Vehicle Systems Modelling and Analysis (VeSyMA) platform is a suite of compatible Modelica libraries for modelling automotive vehicles and their subsystems. This suite of Modelica libraries was created to provide a modular approach to vehicle modelling, where the user can tailor the complexity of the model to meet their specific needs. The foundation of this capability is the VeSyMA library which provides the architecture of the vehicle, and the base classes for the vehicle subsystems. It builds upon the open-source Vehicle Interfaces Library to promote compatibility with libraries from other vendors. VeSyMA provides application specific extensions for modelling Internal Combustion Engines, Transmissions, Drivelines, Vehicle Dynamics and Cooling.

To support the development of these Modelica libraries, Claytex has developed the RegressionTest Tool. This tool is used to automate the checking and testing of Modelica libraries and is designed to improve their quality and maintain the consistency of results. The tool is designed to work with Dymola and tests are triggered by committing changes to a supported revision control system.

A new addition to our product portfolio is an extension to the FMI Blockset that allows this to run FMU’s in the cloud. The simulation platform provides a REST API to allow co-simulation FMU’s to be run leveraging the power of the cloud. A web browser based front end has also been developed that allows the user to setup parameters and run simulations. The platform lends itself to efficiently running a wide range of analysis types such as Design of Experiments, parameter sweeps and more complex analysis that require multiple simulations to be run such as a laptime simulation. The goal of this approach is to make complex simulation models more easily available to non-experts to run “what-if” and design exploration studies.

Dassault Systèmes: Dymola and 3DEXPERIENCE

Dassault Systèmes will present recent enhancements in Dymola and the 3DEXPERIENCE Platform, for example to manage initialization of nonlinear equation systems, and discuss candidate directions for the future.

An overview will be given of the systems simulation offerings on the cloud surrounding the Modelica technology, from runtime only to full development environment. The overall positioning, a preview of usability and customer use-cases will be discussed.

Dymola, Dynamic Modeling Laboratory, is a complete tool for modeling and simulation of integrated and complex systems for use within automotive, aerospace, robotics, process and other applications. Dymola is also available on the 3DEXPERIENCE Platform in order to leverage the power of Modelica with CATIA applications to rapidly develop, simulate and validate complex mechatronic or fluidic systems, bridging the 3D product definition and multi-physics system simulation for our leading edge customers.

Starting with a brief overview of the graphical-interactive tool for modeling, simulating and analyzing multi-domain systems from 1D to 3D, the presentation provides a quick overview of the application-oriented libraries of SimulationX before it dives into the new software version.

The latest version 3.9 comes amongst others with a new solution for belt conveyor modeling in the mining industry and extended model libraries for developing and virtually testing electric vehicles. Novel features in SimulationX' graphical user interface ease the handling of complex model structures in the diagram view. The newly integrated Modelica Synchronous technology helps to efficiently model and simulate synchronous circuits, as used in most digital controllers, and is the basis for Modelica state charts.

Furthermore, the recent partnership between ESI and Modelon opens new applications through dedicated model libraries in SimulationX.

Modelon offers a broad range of products that empower companies to develop complex products faster and with lower risk through model-based systems design and simulation.

Modelon' s product portfolio is organized into three product families:

- Modelon Library Suite - Our industry leading suite of libraries, built on the Modelica standard, deliver state-of-the-art system models for a wide range of industries including automotive, aerospace, industrial equipment, and energy and process. The Modelon Library Suite is currently compliant to operate in Dymola, OPTIMICA, Twin Builder, SimulationX, IGNITE, and MapleSim.
- Modelon Creator Suite - Our creator suite is a powerful platform solution used for the creation, automation, simulation and optimization of system behaviors and quality assurance throughout the model-based design cycle.
- Modelon Deployment Suite - Our comprehensive suite of deployment products, built on the FMI standard, enables users to rapidly deploy and integrate system models across multiple platforms, varying tools, and organizations.

Coming soon is Modelon' s newest platform product, a Web Architecture for Modeling and Simulation (WAMS) which will offer a holistic approach to modeling and simulation in your browser using the Modelica language. Compilation and simulations are done on a server using the OPTIMICA Compiler Toolkit (OCT) from Modelon. All simulations are based on the FMI standard and can be executed with all products in the Modelon Deployment Suite, or other FMI-compatible tools.

Such an architecture is appropriate for making design space explorations such as sensitivity analysis, DOE, Monte Carlo analysis, optimizations, parameter estimation, etc. efficiently. WAMS supports the complete Modelon Library Suite. It ties Modelon' s offer into a coherent real-world solution for end-to-end system simulation and for building digital twins.

Assessing the impact of driveline design and battery thermal management on the fuel economy and driveability using Ricardo's IGNITE complex system engineering tool

In this presentation, Ricardo's complex system engineering software, IGNITE, is used to demonstrate how to solve one of the key questions relating to electrical vehicle architecture development: how the battery thermal management approach and driveline system configuration can be optimized to improve overall performance of the vehicle including energy consumption, vehicle range, passenger comfort and vehicle driveability.

The complete vehicle model was developed within the IGNITE platform, using Ricardo's proprietary libraries (Powertrain and iMoved for vehicle dynamics) in combination with the Modelon Liquid Cooling library to model thermal system behavior. The vehicle driveline is configured as an e-machine with a 2-stage transmission unit, targeting improved energy efficiency while maintaining the comfort and vehicle performance. The model is used for the system optimization and trade-off analysis between vehicle acceleration and battery cooling performance using the HEEDS optimization tool.

During the presentation, Ricardo will demonstrate the ease and intuitiveness of the IGNITE tool for complex system modelling and its ability to integrate with other commercially available products. New technologies for Modelica 3D visualization and animation of the vehicle driving scenarios integrated within IGNITE will be demonstrated.

How to develop Modelica models in Simcenter Amesim and combine them with causal libraries and FMI-based components?

With its powerful facilities and easy-to-use environment, Simcenter Amesim™ multiphysics system simulation software supports the Modelica® language, which enables users to model and analyze multi-physical, intelligent systems so they can predict their performance, but also to deeply analyze their model, using the time and frequency domain analysis tools, such as plots, animations, linear analysis and design exploration.

In this session, we propose to demonstrate how Modelica models can easily be developed, enhanced in a dedicated integrated development environment, and then combined with Simcenter Amesim libraries as well as with heterogeneous components based especially on Functional Mockup Interface (FMI) standard.

TLK-Thermo GmbH
Engineering Services and Software for Thermal Systems

Modelica and Software Tools from TLK-Thermo

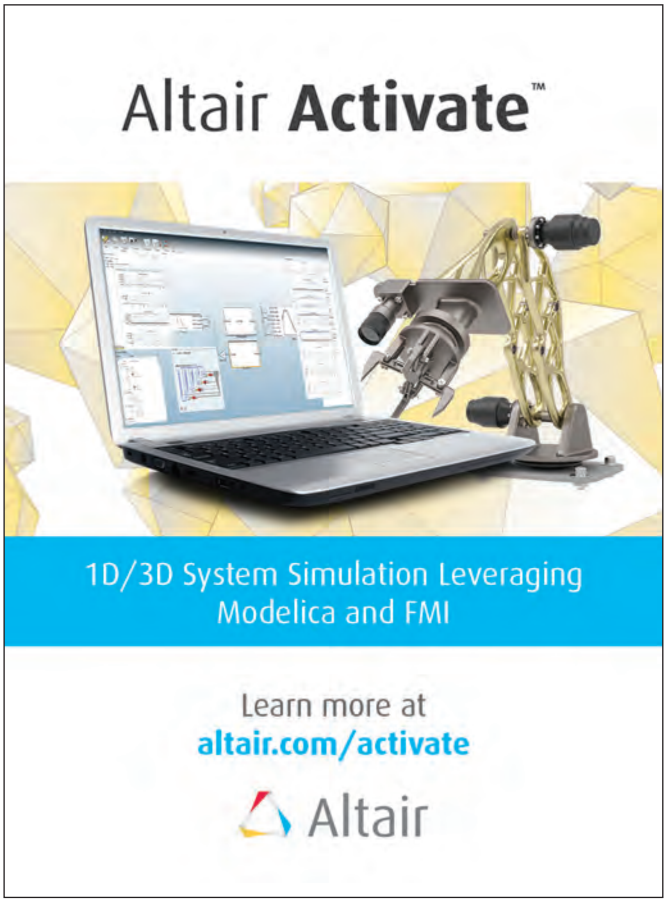
TIL Library is used for both, desktop simulation for the design of thermal systems, and simulation on real-time environments such as DS-1006. Simulation results can be visualized in TLK's visualization tool DaVE, which enables the use of different thermodynamic state charts. The TILMedia Library consists of a program core written in C and several optional modules for which individual licenses can be purchased. This flexible structure allows for the diverse and relatively cost-effective use in various applications or computer languages.

The TIL Library uses the Modelica interface of TILMedia for fluid property calculations. TILMedia provides a comprehensive range of different substances, ranging from the implementation of scientific highly precise multi-parameter fundamental equations to our own numerically efficient and accurate real-time substance property implementations.

MoBA Lab gives the user a wide-ranging portfolio of different tools for the modelbased development process of different types of systems. MoBA enables the import, configuration and combination of single FMU models as well as simulation in different simulators. The user can solve optimization problems, such as parameter optimization, parameter estimation, state estimation or optimal control problems, by using stand-alone modules. It assists you with your model-based product development process and gives you a deeper understanding of your simulation systems.

With the MoBA Lab simulation core (MoBA Simulator), it is possible to simulate models in the form of an FMU as well as many other model formats. Our newest software tool works on a high-quality level. This can be proven by the results of the FMI-CrossChecks in which TLK is participating. The MoBA Simulator provides detailed information about the loaded model, and further enables to analyze the mathematical properties and linearized form. It is available for: Excel, Python, LabVIEW, C++, TRNSYS, Simulink, and TLK's Co-simulation environment TISC.

MoBA Automation is another module from the MoBA Lab portfolio. It is a useful Python-based graphical tool for general purpose automation on desktop-PCs, LAN or for cloud-based applications. A standard library of many predefined tasks is available to get started immediately. Additionally, the user can define own tasks to extend the task library and adapt the software to the users environment. MoBA Automation can be used large scale parameter studies, including tasks to setup the model or system definition, and tasks for post-processing of simulation results.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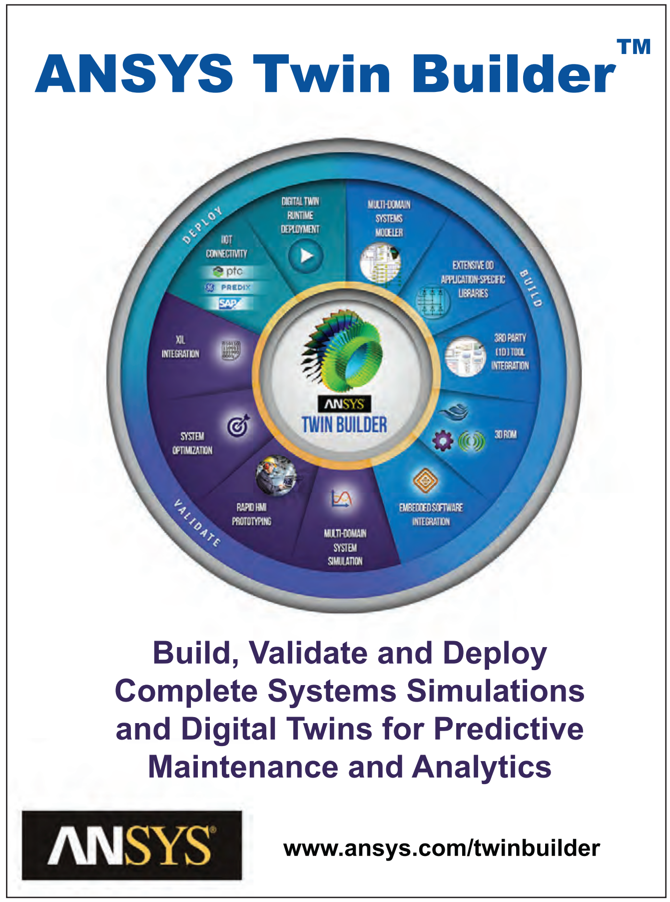
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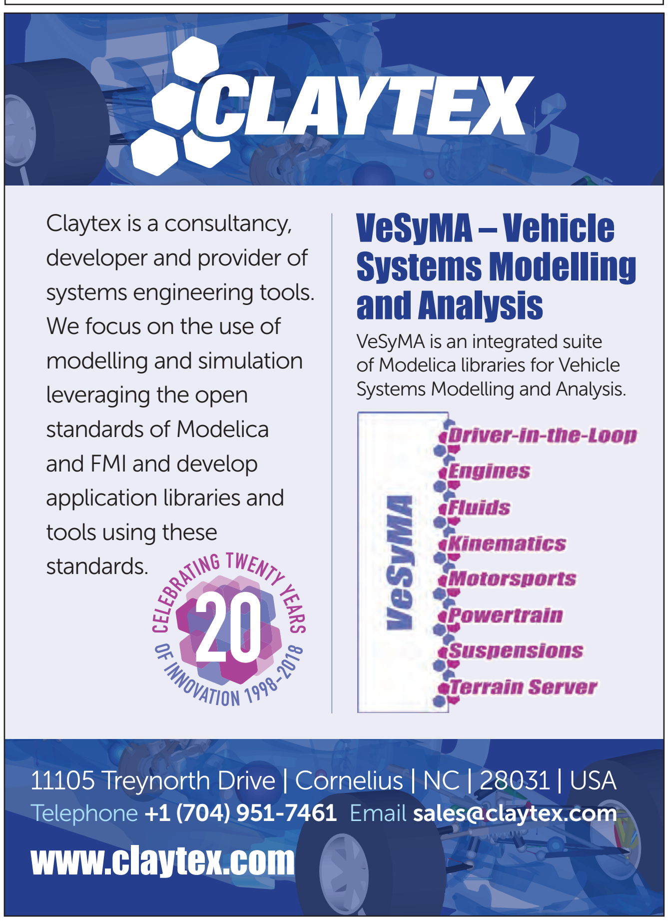
CLAYTEX
Claytex is a consultancy, developer and provider of systems engineering tools. We focus on the use of modelling and simulation leveraging the open standards of Modelica and FMI and develop application libraries and tools using these standards.
CELEBRATING TWENTY YEARS OF INNOVATION 1998-2018
20
VeSyMA – Vehicle Systems Modelling and Analysis
VeSyMA is an integrated suite of Modelica libraries for Vehicle Systems Modelling and Analysis.
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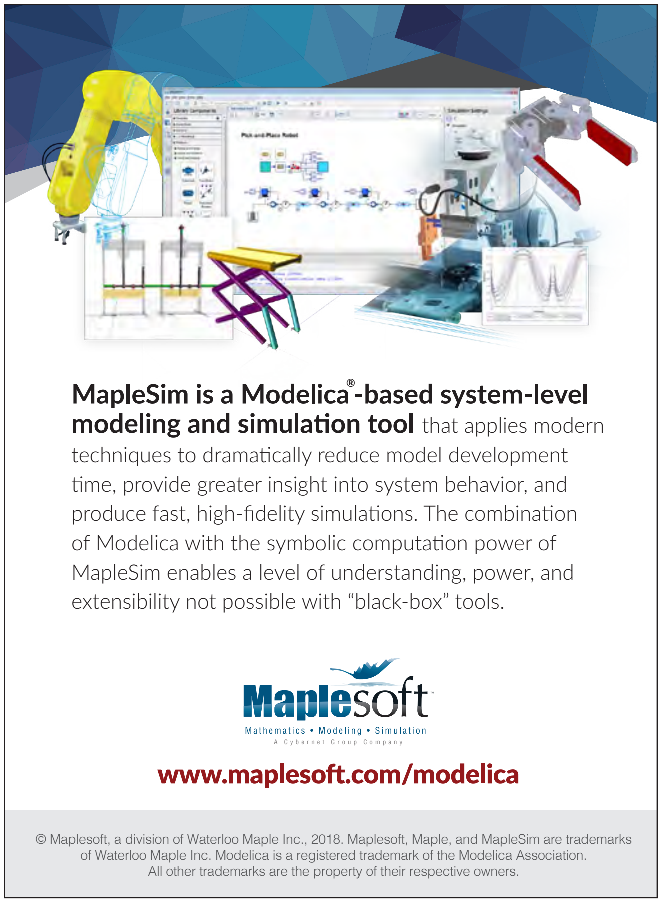
MapleSim is a Modelica®-based system-level modeling and simulation tool that applies modern techniques to dramatically reduce model development time, provide greater insight into system behavior, and produce fast, high-fidelity simulations. The combination of Modelica with the symbolic computation power of MapleSim enables a level of understanding, power, and extensibility not possible with "black-box" tools.
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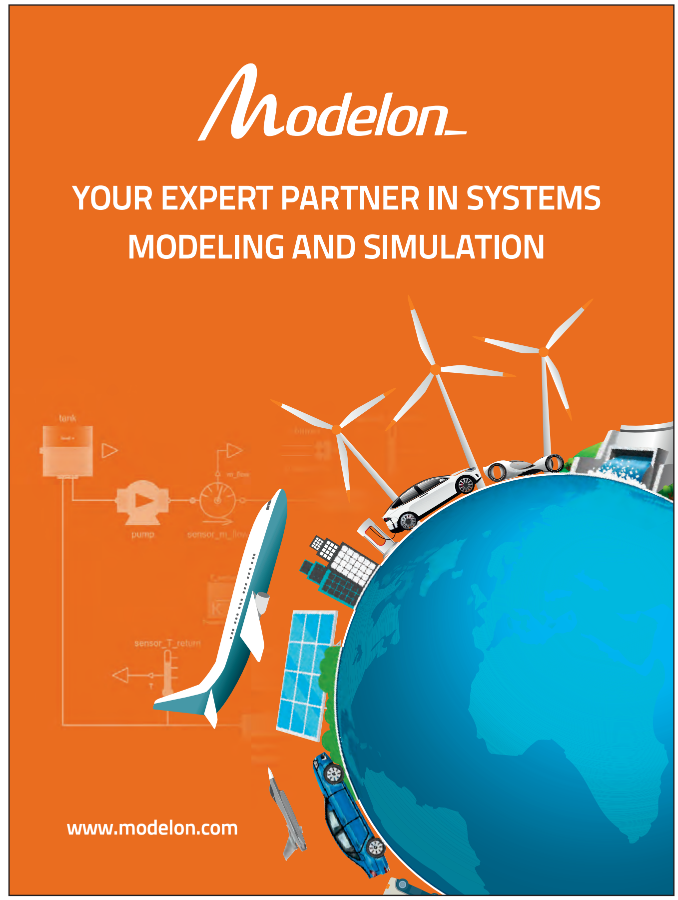
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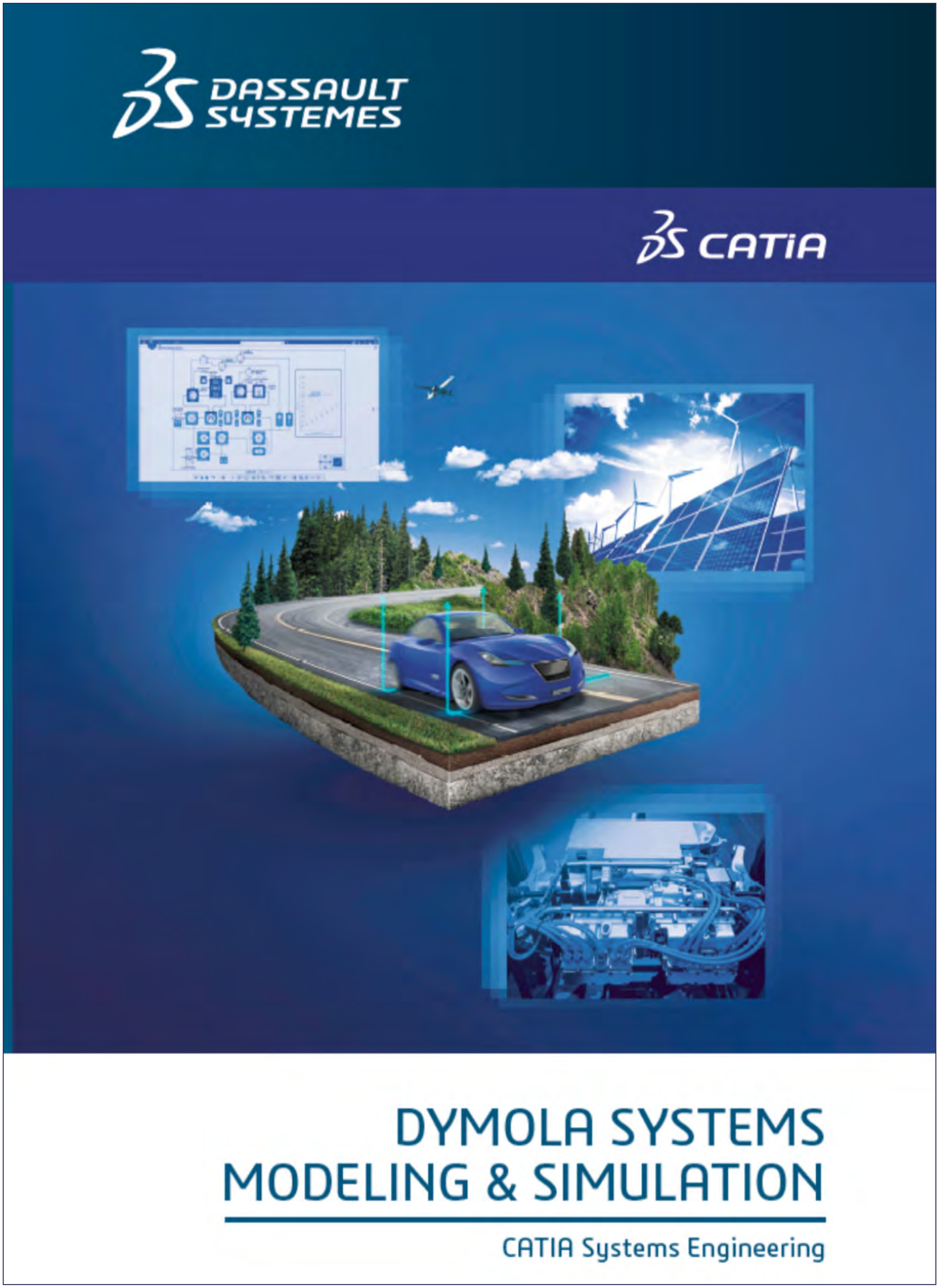
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