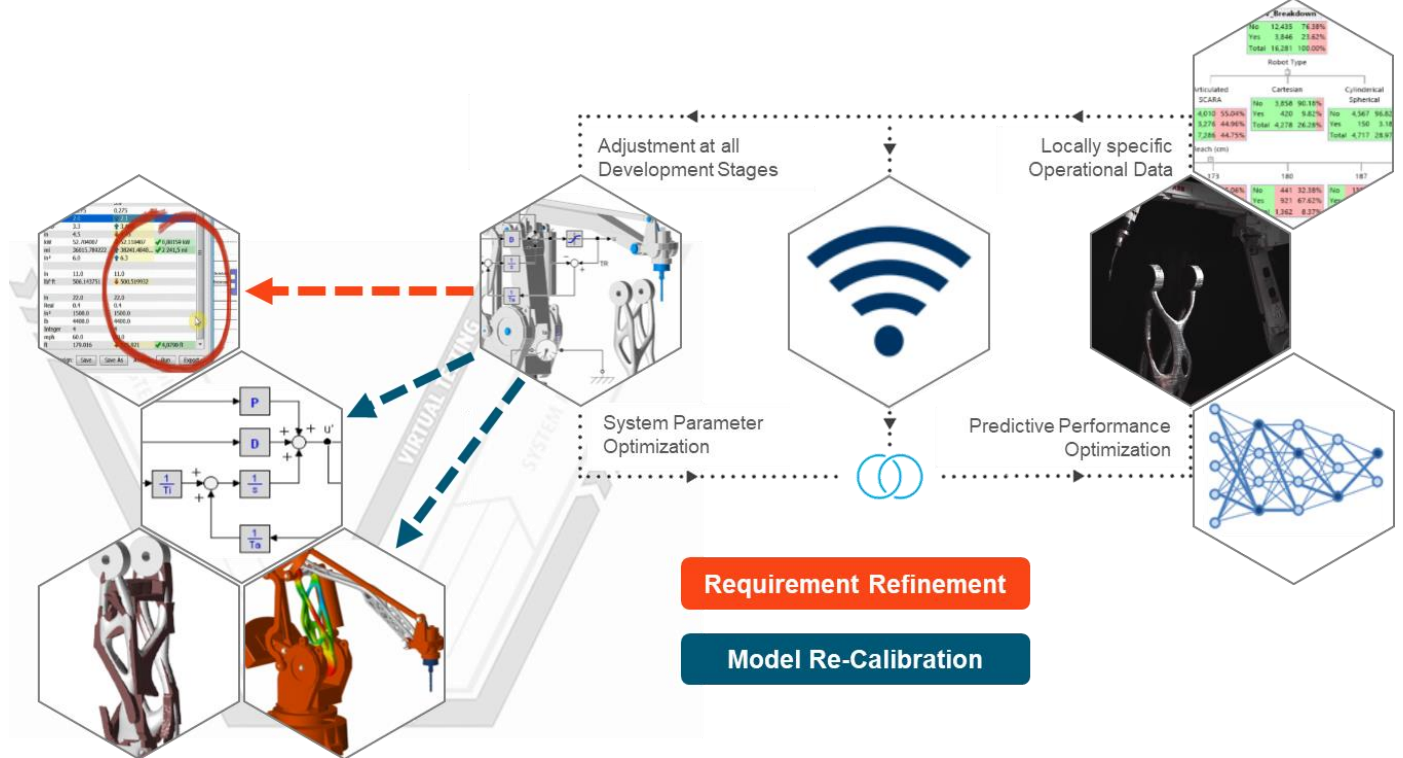


- Requirements Management
- Functional Concept
- Detailed Design



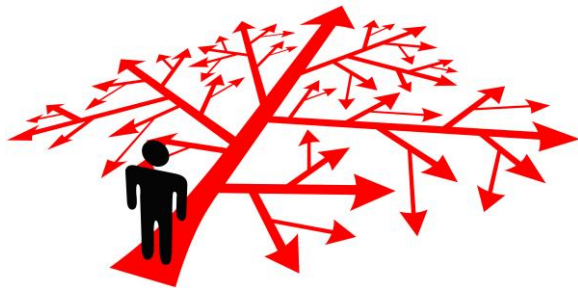
Breakdown			
Robot Type			
No	12,428	78.90%	
Yes	3,046	21.62%	
Total	16,281	100.00%	
Cylindrical Spherical			
Articulated SCARA		Yes	3,958 90.18%
		No	4,010 55.04%
		Yes	420 9.82%
		No	4,567 98.82%
Total		4,278	26.28%
		Yes	150 3.34%
		No	4,127 28.94%
Reach (mm)			
179		Yes	441 32.88%
		No	321 67.82%
180		Yes	1,062 8.27%
		No	187

MODEL-BASED DEVELOPMENT WITH ALTAIR COMPOSE® AND ALTAIR ACTIVATE®



Common Challenges of Mechatronic Product Development

Manage Risks
due to Product Complexity
(Smart, Connected, Electro-Mech)



Accelerate
Time-to-Market



Reduce
Development Costs



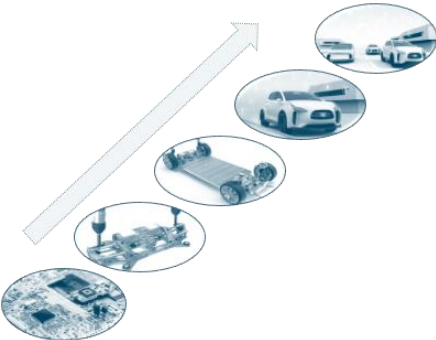
Altair's Top 3 Solutions addressing those Mechatronics Challenges

Manage Risks
due to Product Complexity
(Smart, Connected, Electro-Mech)

Handling Complexity

Optimizing mechatronic product performance holistically as system-of-systems

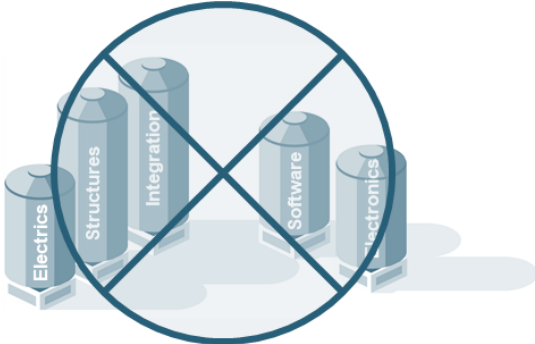
(using physics-based Digital Twins)



Accelerate
Time-to-Market

Facilitating Teamwork

Breaking down silos between mechatronic disciplines
(Mechanical, Electrical, Controls, etc.)

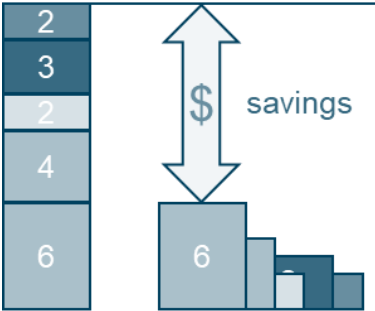


Reduce
Development Costs

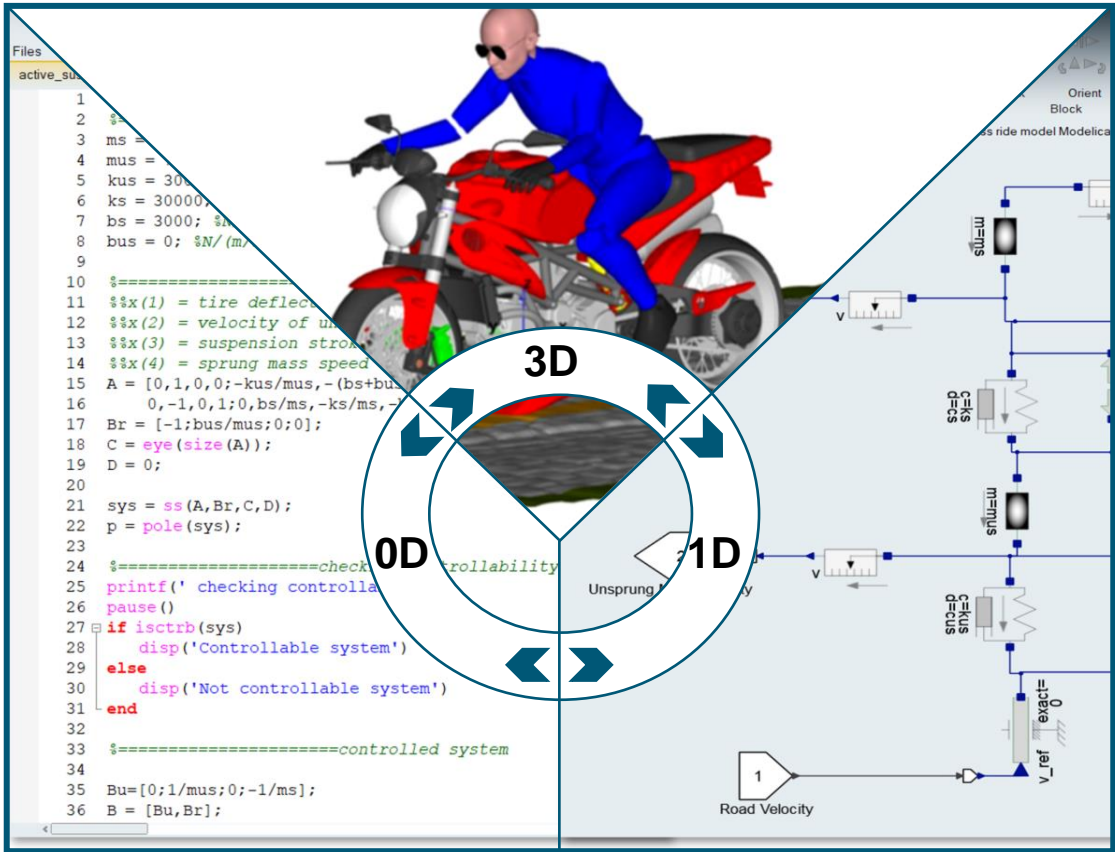
Managing Costs

Streamline Product Development teamwork & tool set, affordably

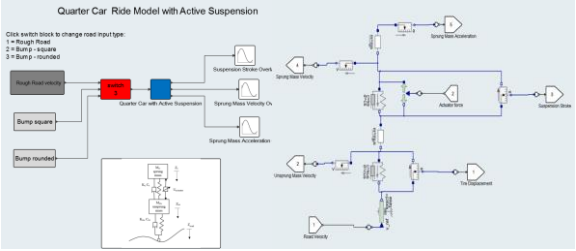
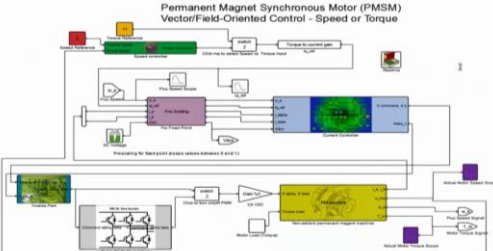
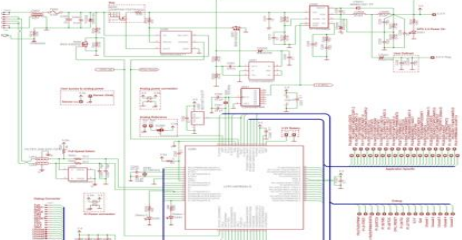
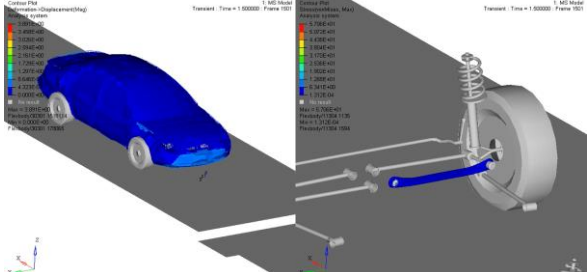
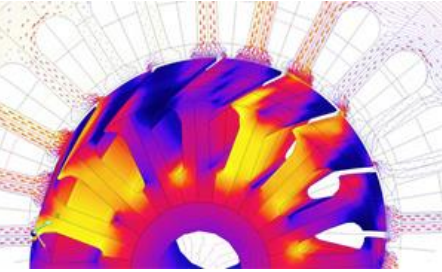
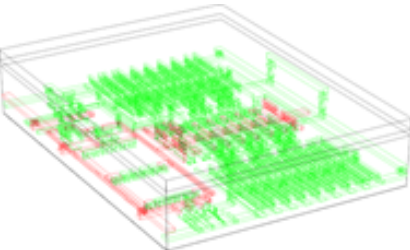
Cost of Alternative mechatronics toolset (likely from different vendors) Cost of Altair mechatronics toolset



Flexible, Purpose-Driven Modeling



Models: From 0D to 3D

	Suspension	E-Motor	Electronics
0D	$\begin{bmatrix} \dot{x} \\ y \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \cdot \begin{bmatrix} x \\ u \end{bmatrix}$	$\frac{\Theta(s)}{E_{in}(s)} = \frac{\alpha}{JRs^2 + (B_r R + \alpha^2)s}$	$\begin{aligned} \dot{x} &= f(x,u,t) \\ y &= g(x,u,t) \end{aligned}$
1D	 <p>Quarter Car Ride Model with Active Suspension</p> <p>Click switch block to change road input type: 1 = Rough Road 2 = Bump - square 3 = Bump - rounded</p> <p>Inputs: Road Road Velocity, Bump square, Bump rounded</p> <p>Control: Suspension Striker Control, Spring Mass Velocity CV, Spring Mass Acceleration</p> <p>Outputs: Suspension Striker Velocity, Suspension Striker Acceleration, Spring Mass Velocity, Spring Mass Acceleration, Road Velocity</p>	 <p>Permanent Magnet Synchronous Motor (PMSM) Vector/Field-Oriented Control - Speed or Torque</p> <p>Inputs: Reference Speed, Reference Torque</p> <p>Control: PMSM Controller, PMSM Motor</p> <p>Outputs: Motor Speed, Motor Torque, Motor Currents</p>	 <p>Detailed circuit board simulation showing various components like resistors, capacitors, and integrated circuits.</p>
3D	 <p>3D finite element analysis of a car chassis showing stress distribution. The car is blue, and the suspension components are grey.</p> <p>Simulation Parameters: Material: Steel Element Type: Solid Mesh Size: 10mm Results: Displacement (mm), Stress (MPa)</p>	 <p>3D finite element analysis of a motor stator showing magnetic flux density distribution. The stator is colored with a gradient from blue (low flux) to red (high flux).</p>	 <p>3D finite element analysis of a PCB layout showing electromagnetic field distribution. The PCB is colored with a gradient from green (low field) to red (high field).</p>

MATH AND SCRIPTING WITH ALTAIR COMPOSE[®]

A Digital Bridge from Present to Future: Altair Compose®

Present

- Costly
- Proprietary
- Less flexible
- MATLAB, SAS, Excel etc.



Future

- Affordable
- Open source
- Fast evolving, nimble
- Python, R, Modelica, etc.



Present and Future Challenges



Converge and connect
Simulation, Data Science and
Engineering



Reuse Math-based
procedures invested over
the years



Foster new Technology
horizons leveraging open-
source languages

- More throughput/insight, faster with your CAE simulations

- Commercial, well-supported tool compatible to MATLAB
 - Reduce dependence on MathWorks with minimal disruption
 - Reduce #1 largest spend (\$) on engineering software

- Freedom & flexibility with scripting tools: synchronize MATLAB®, Python and user communities

*Which
ones are
yours?*

Different Tools for Similar Tasks

MATLAB

Python



MS Excel



CAE Tools

Altair Compose[®] - All-in-one Math Tool

MATLAB

Python



MS Excel

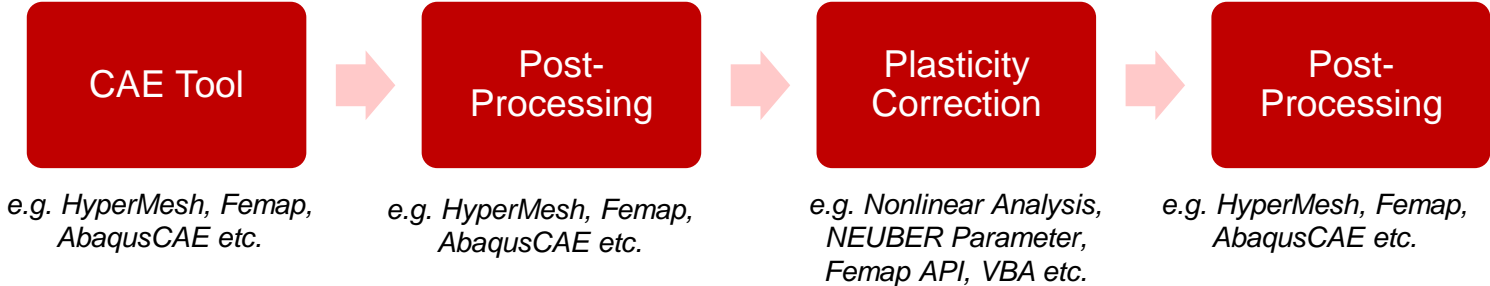


CAE Tools

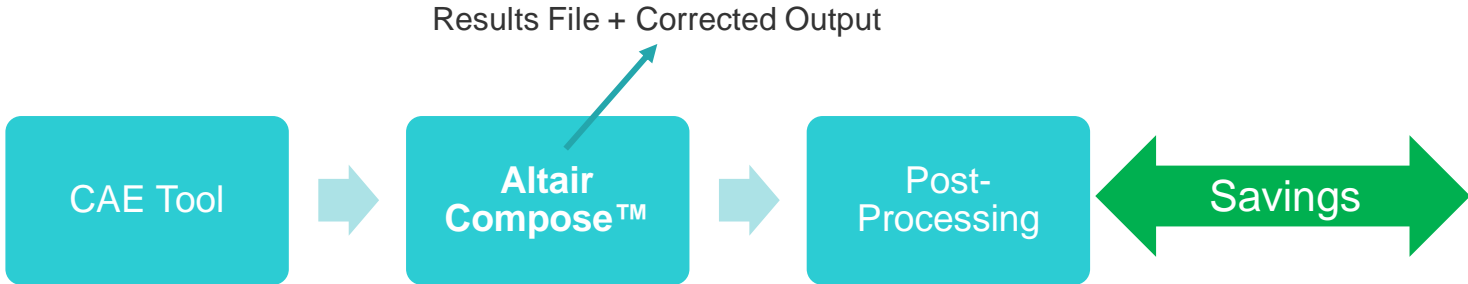


DEMO: Altair Compose™ for Advanced Post Processing

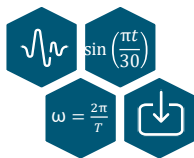
Current Process:



Enhanced Process:

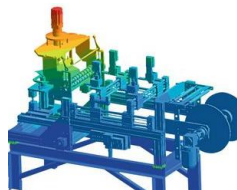


Our Solutions for Your Present Challenges: CAE Workflows



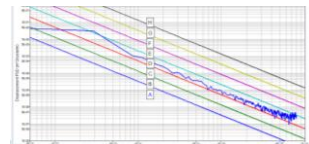
No Additional Toolboxes Required

Extensive Math and Engineering libraries available in a single, multi-functional tool



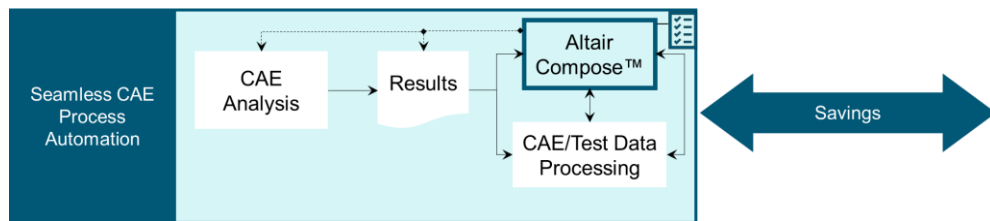
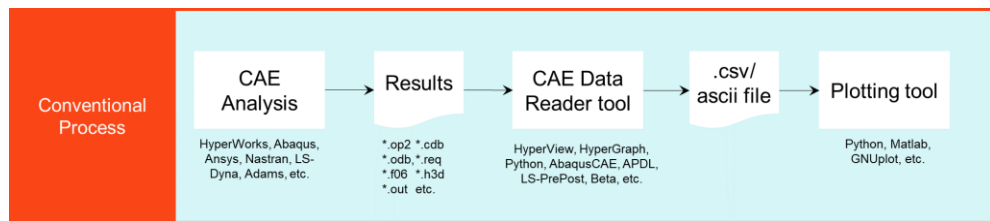
Solver-Neutral CAE Readers

Extremely simple and fast importation and manipulation of input and output data for CAE tools



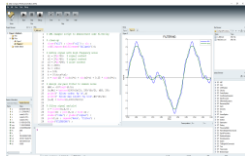
Efficient Numerical Computing

Hundreds of powerful Math functions applied for Data Science



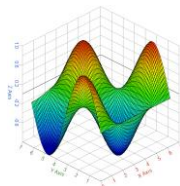
Customer	Benefit
Sarcos	-81% time savings for human & exoskeleton evaluation
Mabe	Complete process automation from lab data preparation to simulation post processing
Altran	Shorter time-to-market due to >90% Simulation time reduction

Our Solutions for Your Present Challenges: Compose[®] Adoption



Compatibility with MATLAB[®]

High-level matrix-based language (OML) with syntax compatible with MATLAB[®]



Reuse of Legacy Data

OML leverages the reuse of past investments in other matrix-based languages



NUMBER OF TOOLS CONVERTED

14



LINES OF CODE CONVERTED

160.000+



AVERAGE CARRY-OVER PERCENTAGE

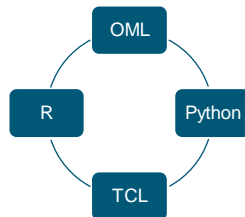
95%

Domain	Customer Use Case	Effort
Signal Processing	<ul style="list-style-type: none"> CAE & test data processing: NVH, fatigue & durability Squeak & Rattle process automation 	< 3 days
Statistics	<ul style="list-style-type: none"> RMS & Rainflow cycles for accelerometers Seat pull testing 	< 3 days
Electromagnetics	<ul style="list-style-type: none"> Wireless data transmission – Bianchi generation & link budget analysis 	< 1 day
Plant & Control Design	<ul style="list-style-type: none"> First-principles modeling and analysis of multi-axle vehicle & stability controller 	< 1 day

Our Solutions for Your Future Challenges: Diversity

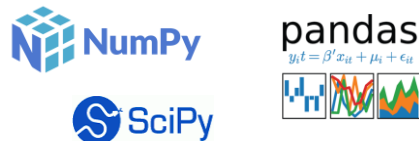


Open and Multi-language IDE
Support for OML (*Open-Matrix Language*),
Python, R and TCL



Interoperation of Different Languages
Supported languages are able to communicate and
be part of the same workflow

- **Expand** OML functionalities with ready-to-use Python libraries, seamlessly
- **Increase usage** with custom, user-friendly GUIs around your proven Python scripts
- **Combine** different scripting languages without long-term migration and validation of existing *.m files to Python
- **Benefit** from strong technical support



matplotlib



References

TOYOTA AUTO BODY: SIGNAL ANALYSIS

TATA DAEWOO: TRUCK RIDE COMFORT
Truck Ride Comfort Analysis

FORD: BORE DISTORTION

FCA: HYDRO MOUNT OPTIMIZATION - COMPOSE WITH HYPERSTUDY
Objective: Improve the vehicle isolation characteristics dictated by the engine mount design.

Compose for HyperWorks Integration
CEVT
Compose as Standard Tool for CAE Engineers → apps

Compose as Standard Tool for Streamlining CAE Workflows

Motor Thermal Resistance and Heat Capacitance

$$R_2 = \frac{-1}{4\pi k_v L s (r_1^2 - r_2^2)} \left[r_1^2 + r_2^2 - \frac{4r_1^2 r_2^2 \ln\left(\frac{r_1}{r_2}\right)}{r_1^2 - r_2^2} \right]$$

mabe
Compose Used via Altair Business Model

Enedym
Compose as alternative to MATLAB for wider applications

FE-Union
FEA results from Optistruct
Math calculations (for frequency response, PSD, damage calculation)
Visualization in HyperView

Structural Optimization of Railway and Machinery Components
DIEHL Aviation

Integrated Solutions for Aircraft Cabins

Challenge

- Ensure structural safety of aircraft cabins made of composite elements

Solution

- Efficient post-processing routine with user-defined interface to calculate allowable based on an open scripting environment for multi-language development, programming and debugging in C++ and Python.
- Altair Compose™ Script-based data processing incl. reserve factor calculation and automated generation of H3D result files
- Altair HyperView™ Visualization of generated H3D files

Value

- Reduced reporting time by 14% and compressed results
- Increased robustness for streaming post-processing workflow
- Flexibly post-process versatile CAE result file formats

ALTAIR

Value Proposition – What to keep



- ☑ **Streamline workflows** and automate processes for Math & Visualization of **CAE simulations and test results**

- ☑ Democratization of a Math-based tool based on Altair Units
 - ☑ **Reuse legacy scripts** from MATLAB with minimal adjustment
 - ☑ **Immediate, significant cost savings** from the beginning while stepwise, use-case driven adoption

- ☑ Open Environment for **multi-language development**, scripting, programming and debugging

MULTIDISCIPLINARY SYSTEM SIMULATION WITH ALTAIR ACTIVATE®

Altair Activate[®] – System Integration PLATFORM

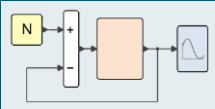
MODELING LANGUAGES

Scripts

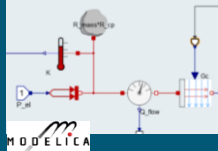


0D

Signal blocks



Physical components



1D

Electric/ Electronics



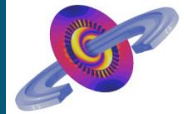
CO-SIMULATION

Multibody Dynamics



NATIVE (3D)

Electro-magnetics

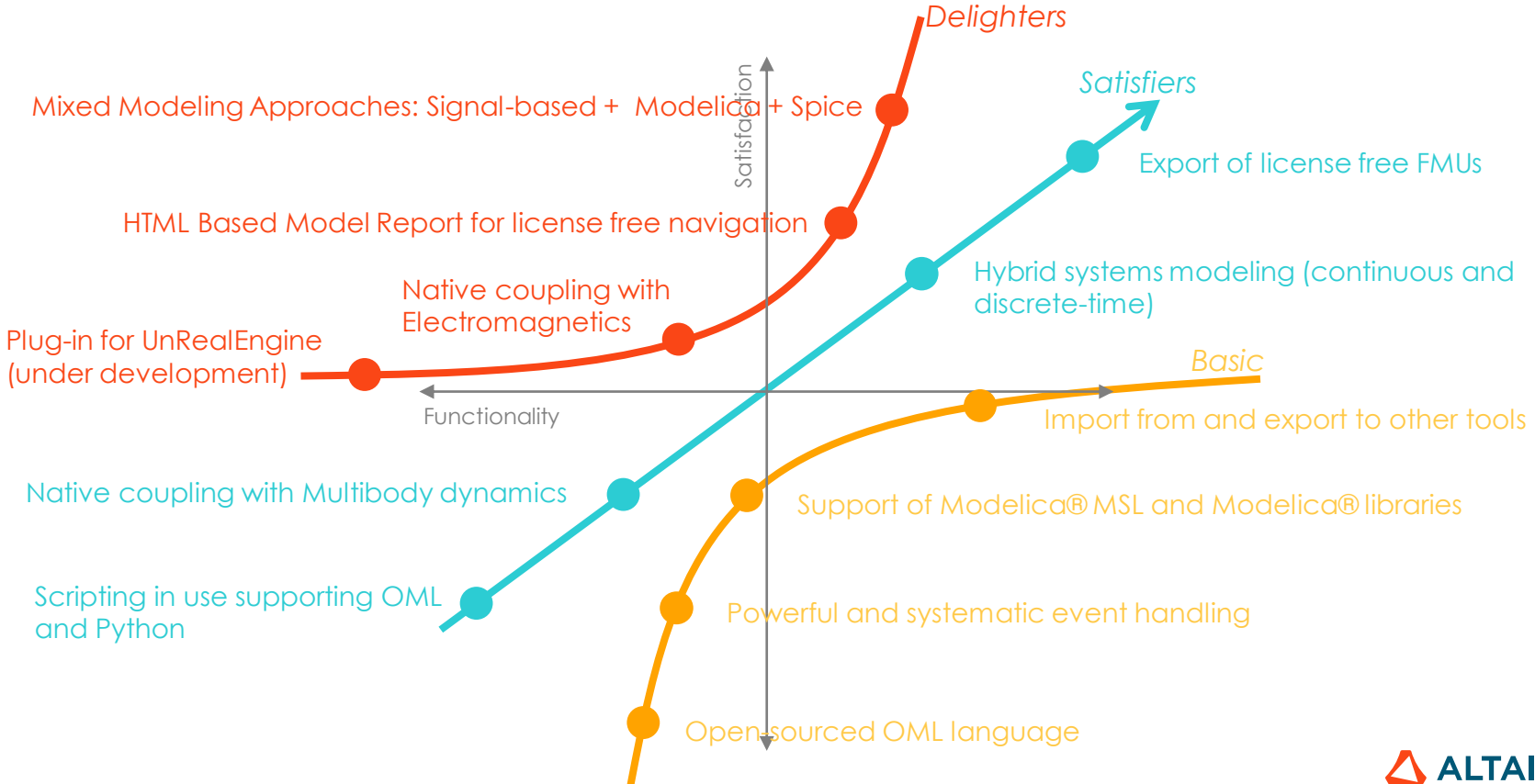


Standards



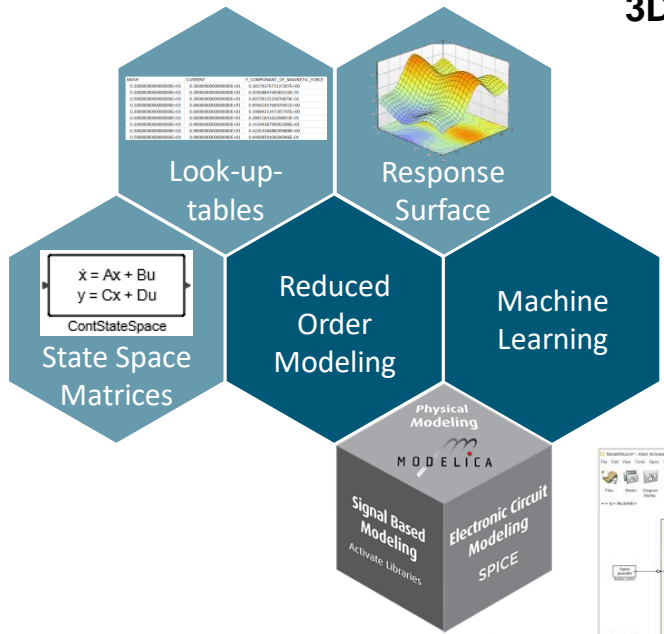
3rd PARTIES

Altair Activate® – Unique Features



AI for Reduced Order Model Generation and System Identification

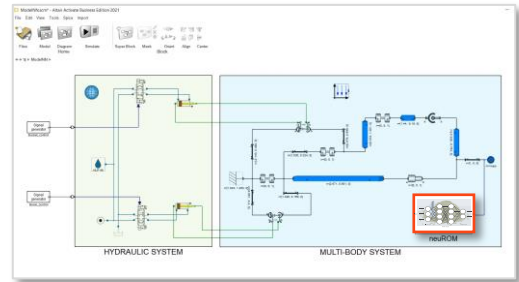
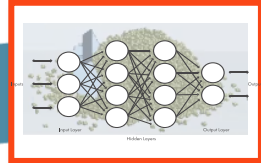
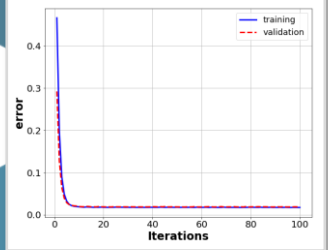
3D Analysis / Measurement



Training Data

$$\begin{bmatrix} u(t_i) \\ y(t_i) \end{bmatrix}$$

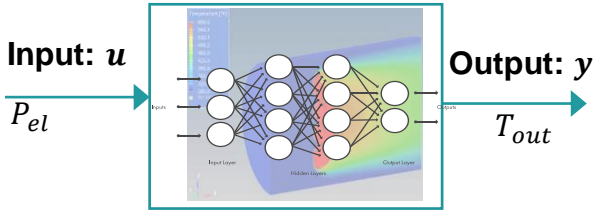
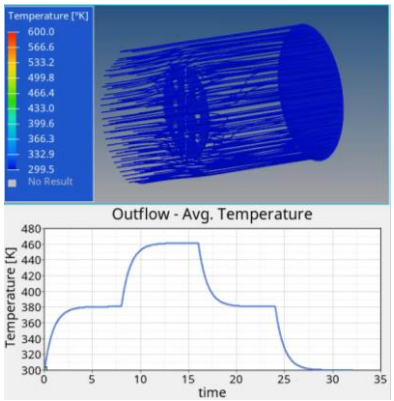
Machine Learning



System Simulation

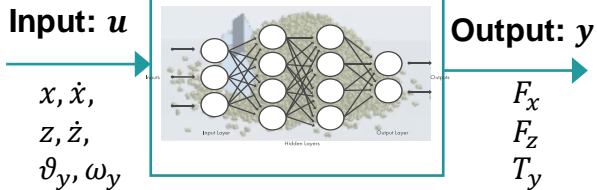
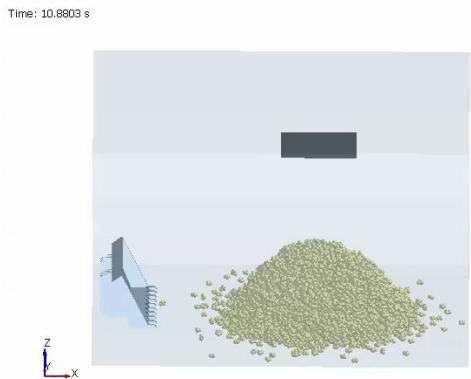
romAI™: Application Examples

CFD



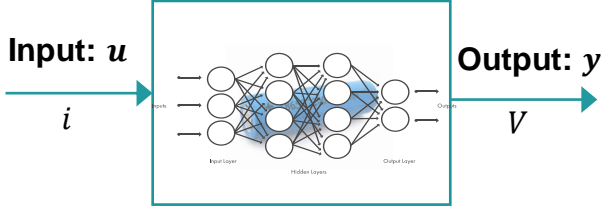
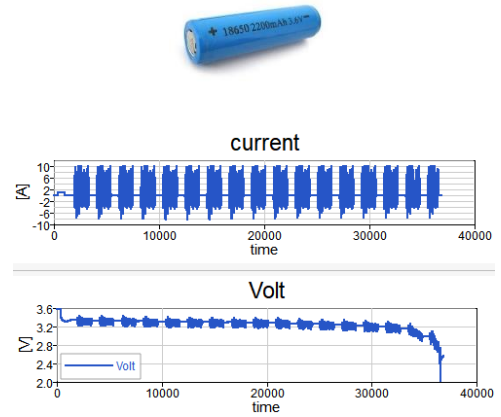
Speed-up factor: 3 000

DEM



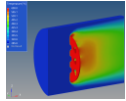
Speed-up factor: 60

Battery Test Data

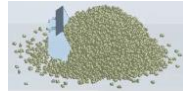
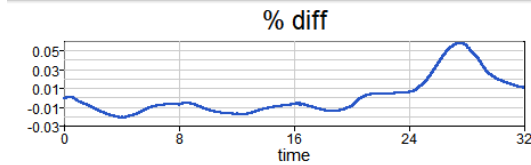
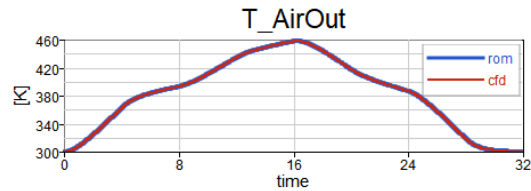
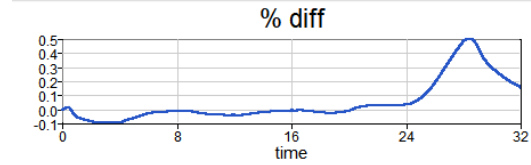
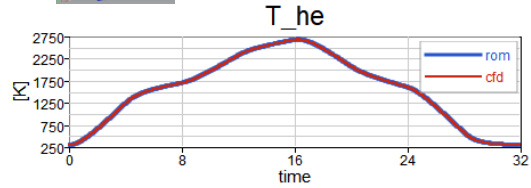


Speed-up factor: n.a.

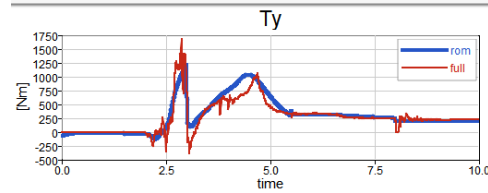
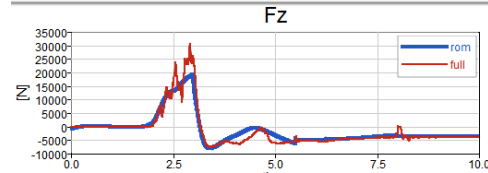
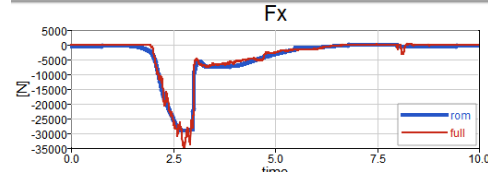
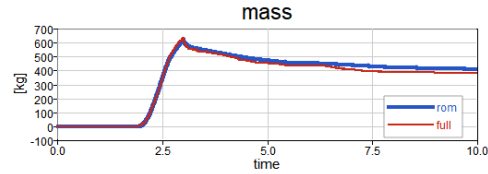
romAI™: Application Examples - Validation



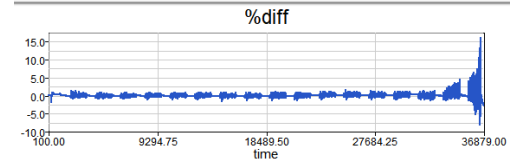
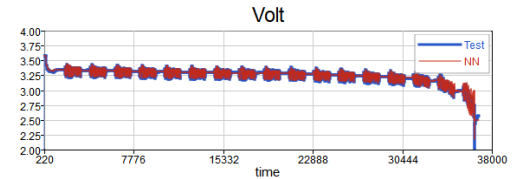
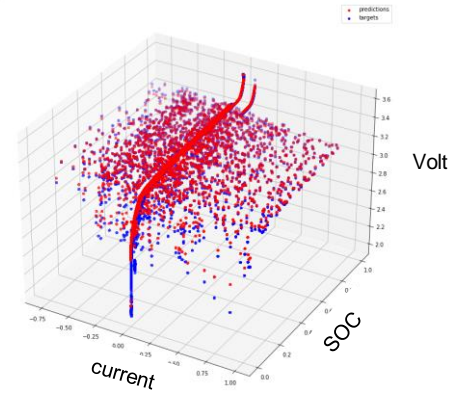
CFD



DEM



Battery Test Data



romAI™ generation using Altair Compose®

The screenshot displays the romAI Manager v2.0 software interface, which is used for configuring and training a neural network model. The interface is divided into several sections:

- TrainData File:** A text input field with a "Browse" button.
- Data Labels:** A large empty text area for defining data labels.
- Inputs:** A text input field with a checked "X" button.
- Outputs:** A text input field with a checked "X" button.
- States:** A text input field with a checked "X" button.
- Physical constraints:** An unchecked checkbox.
- romAI Model Folder:** A text input field with a "Browse" button.
- romAI Name:** A text input field.
- Net Architecture:**
 - Model Type:** Radio buttons for "linear" (unchecked) and "non linear" (checked).
 - (Hidden) Activation Fun.:** A dropdown menu set to "tanh".
 - Hidden Layers:** A numeric input field set to "2" with increment and decrement buttons.
 - Neurons x (Hidden) Layer:** A text input field set to "(50,50)".
- Training Params:**
 - Output Normalization:** A checked checkbox.
 - Early Stopping:** An unchecked checkbox.
 - Epochs:** A numeric input field set to "10".
 - Test Split Ratio:** A numeric input field set to "0.2".
 - Regularization Coeff.:** A text input field set to "1e-6".
 - CrossVal. Split Ratio:** A text input field set to "0.25".
- Buttons:** "RESET" and "TRAIN" buttons at the bottom.

On the right side of the interface, there is a "Python Window" which is currently empty. Below the Python Window, there is a photograph of a physical experimental setup. The setup consists of a white rectangular box with a red component on the left, a black component on the right, and a central black spherical object mounted on a red base. Wires connect these components to a power source.

USE CASES

Mechatronic System: Human-Cobot-interaction

Description



GOAL:

- Cobot contact forces do not exceed a certain threshold in case of an impact

REQUIREMENT:

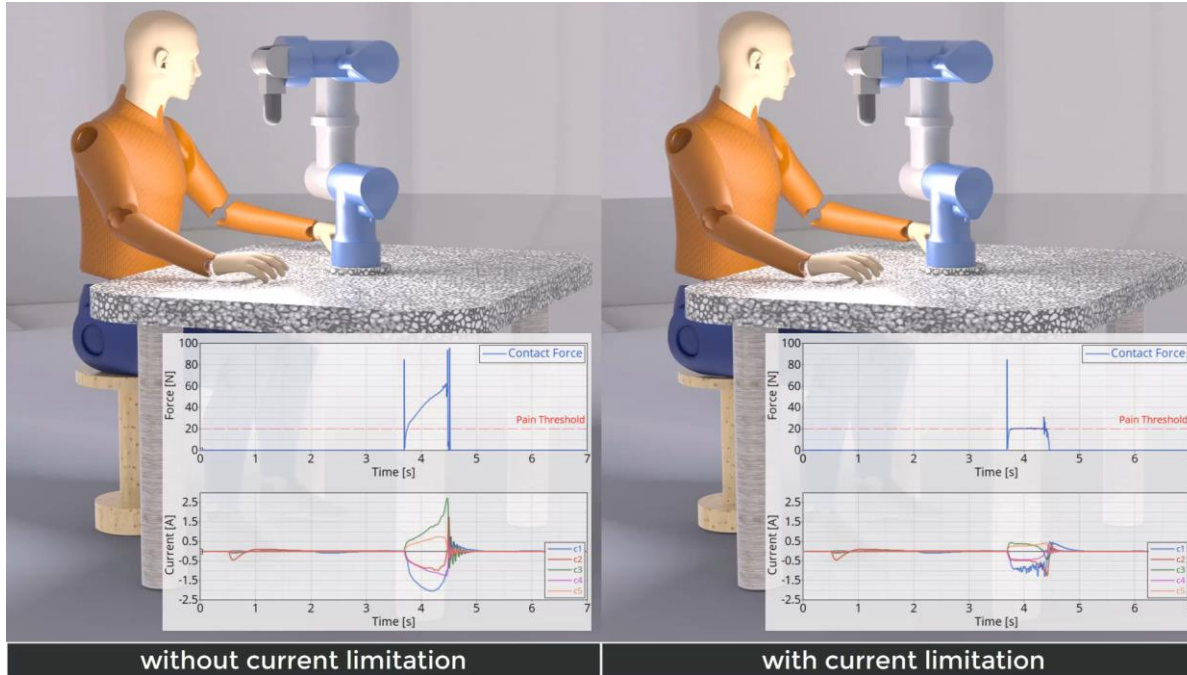
- Accurate model of the contact between the dummy and the cobot

SOLUTION:

- 3D modeling of the plant

Mechatronic System: Human-Cobot-Interaction

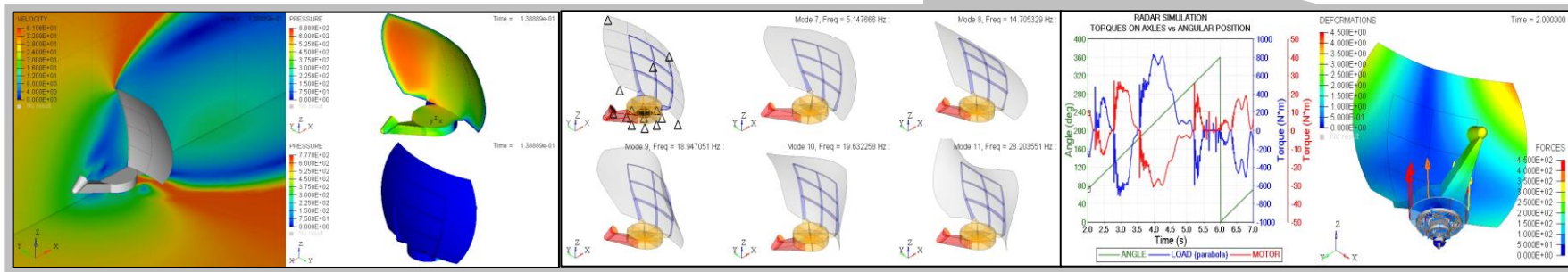
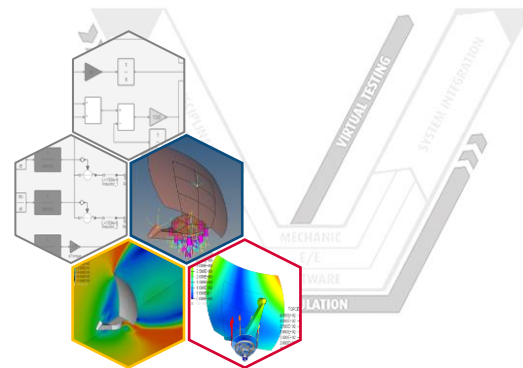
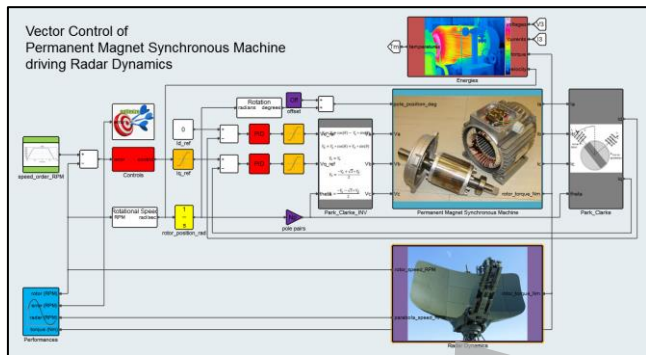
Results



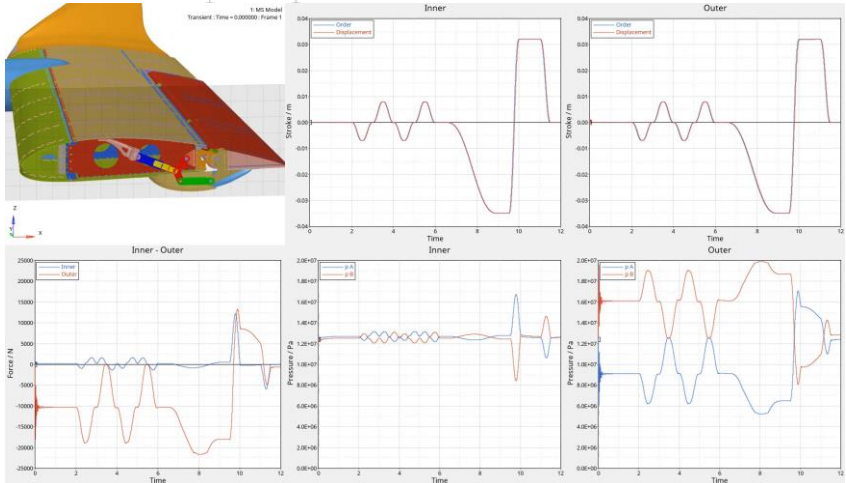
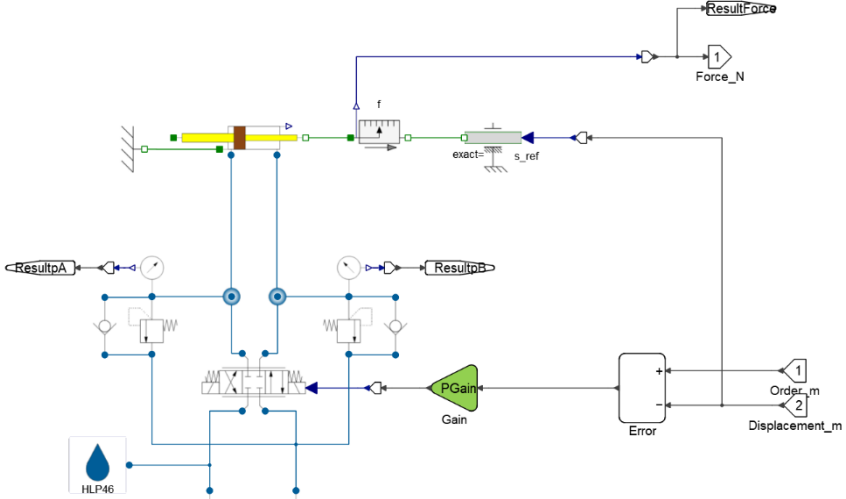
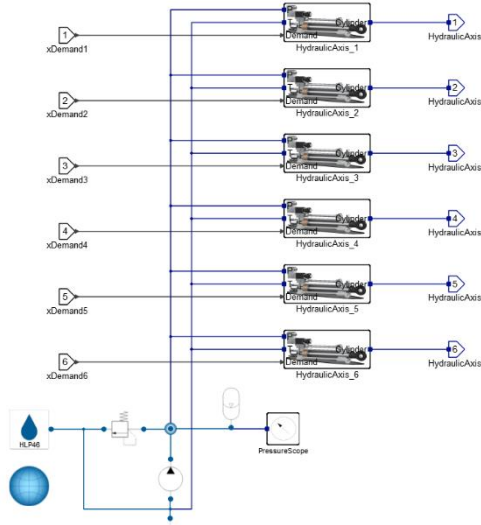
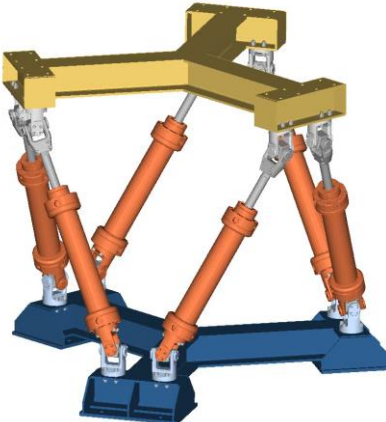
- ✓ Cobot contact forces do not exceed a certain threshold in case of an impact
- ✓ Accurate model of the contact between the dummy and the cobot
- ✓ 3D modeling of the plant

Radar Antenna: (Aero)Dynamics + Vibration

- Level 1:
 - Modelica® + Look-up tables (CFD results)
- Level 2:
 - Modelica® + state matrices (MBS)
- Level 3:
 - MBS co-simulation + aerodynamic loads (CFD)



Hydraulically actuated mechanisms



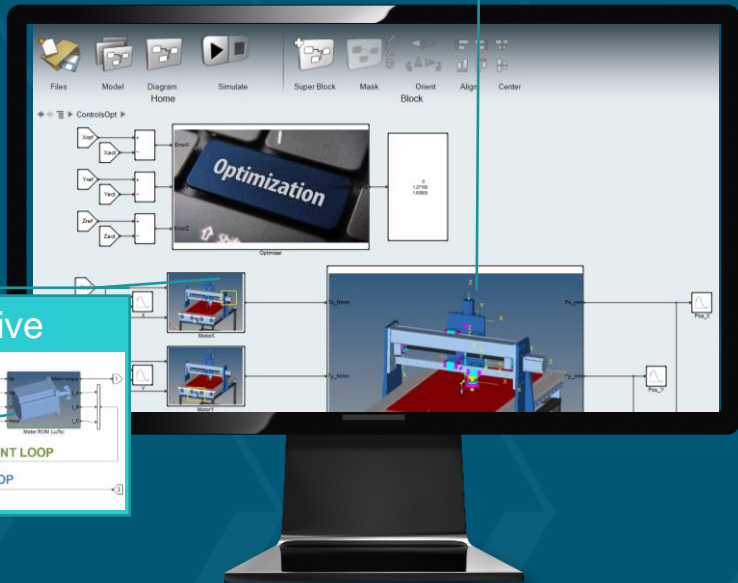
Optimization of a CNC Milling Machine

Multi Body Dynamics Model

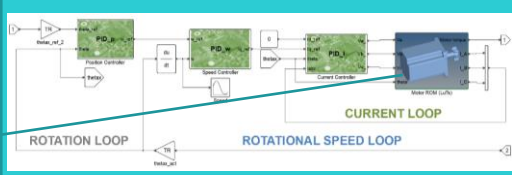
Improving speed & precision

Optimizing the dynamic interaction of multiple system components combining

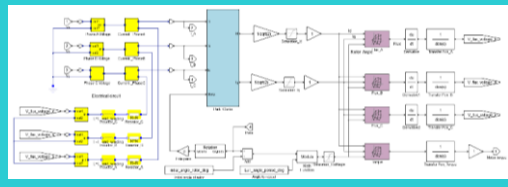
- 3D Finite Elements Analysis
- Multi-Body Dynamics and
- System simulation



Cascade Controller Drive

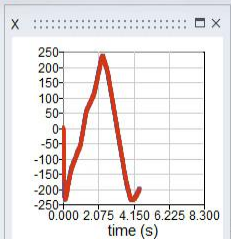


Efficient Motor Model

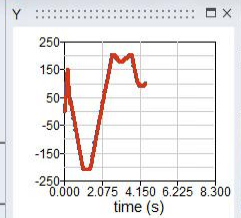


Cost Function vs Runs

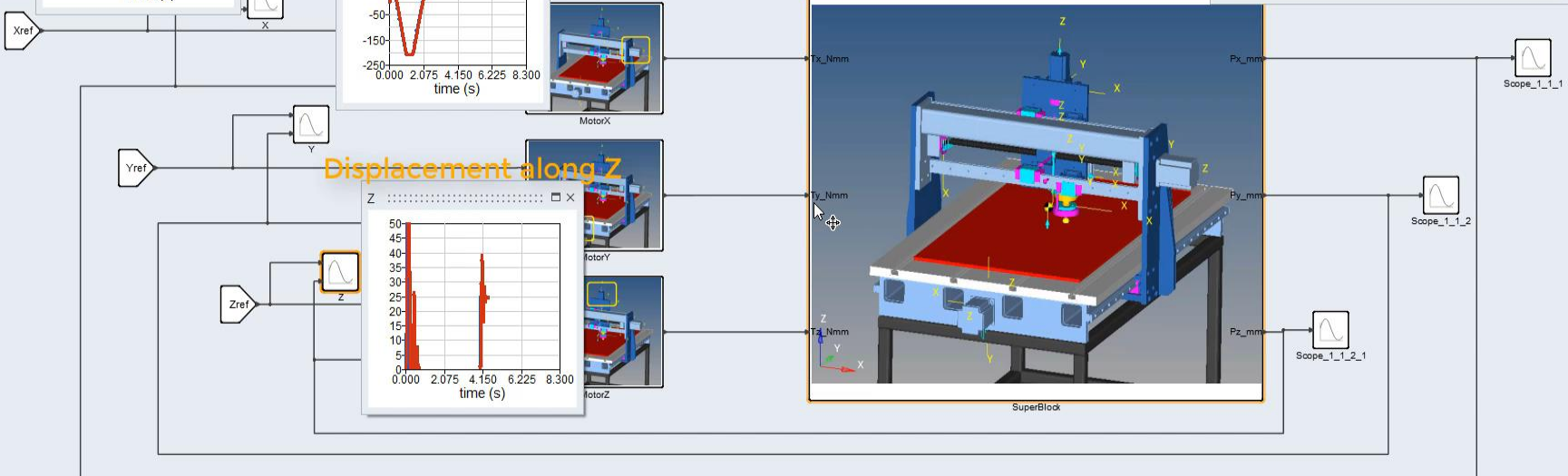
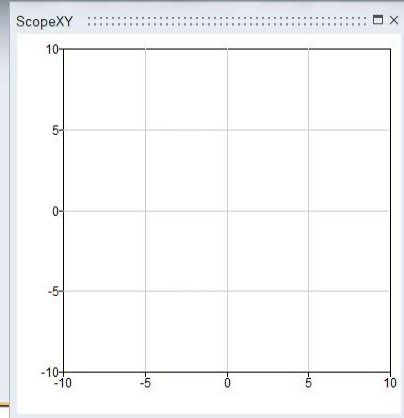
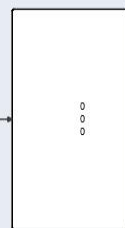
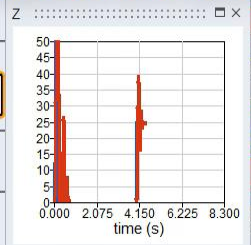
Displacement along X

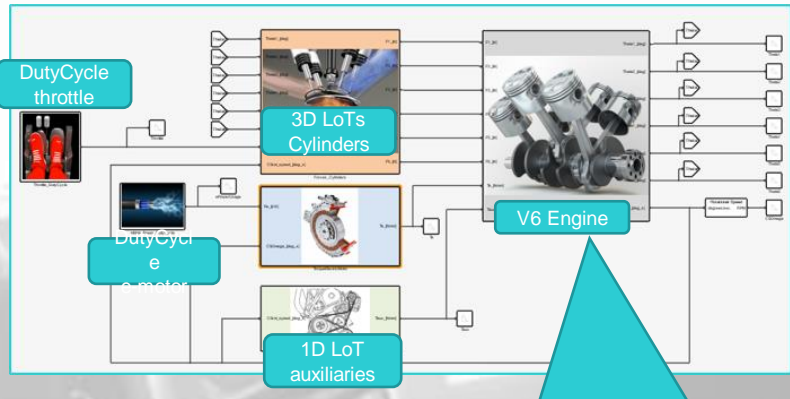


Displacement along Y



Displacement along Z





V6 HYBRID power unit

Challenge

Target conflict between strict budget reductions, more accurate simulation models and democratization of analysis methods

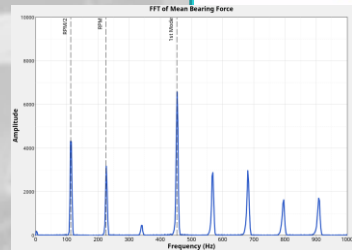
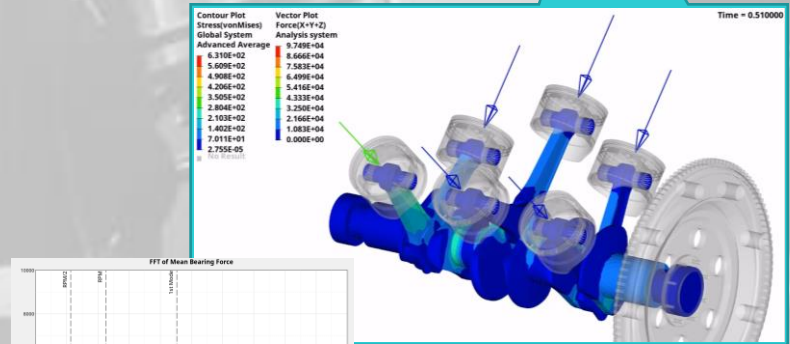
Solution

Simulation environment based on Altair tools with an Excel interface:

- Modular, parametric system model (**Activate[®]**)
- Structural 3D analysis of crankshaft and cylinders (**MotionSolve[™]**)
- Automated model set-up, simulation, and post processing realizing an Excel interface (**Compose[®]**)

Value

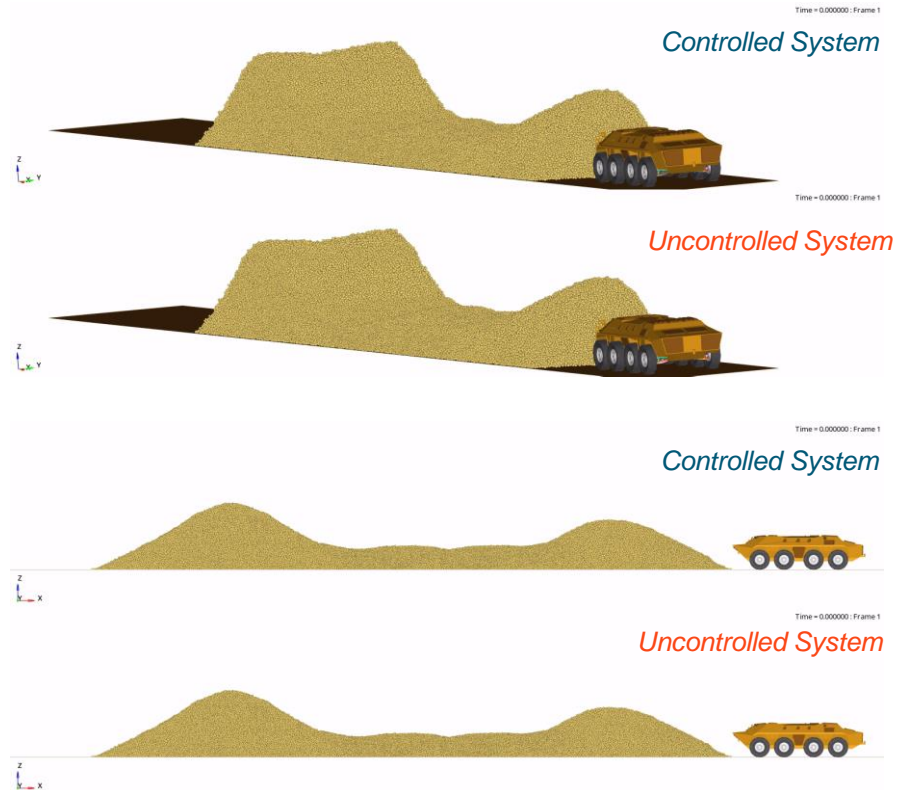
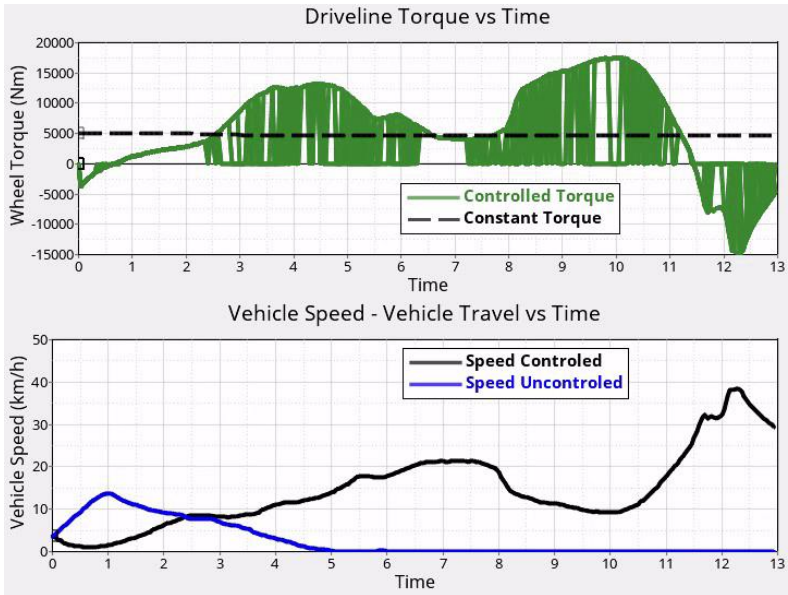
- Reduce software spend
- Simplify simulation environment
- Enhance simulation capabilities
- Spread simulation know-how across the company



1D-3D Interaction for Traction-Control

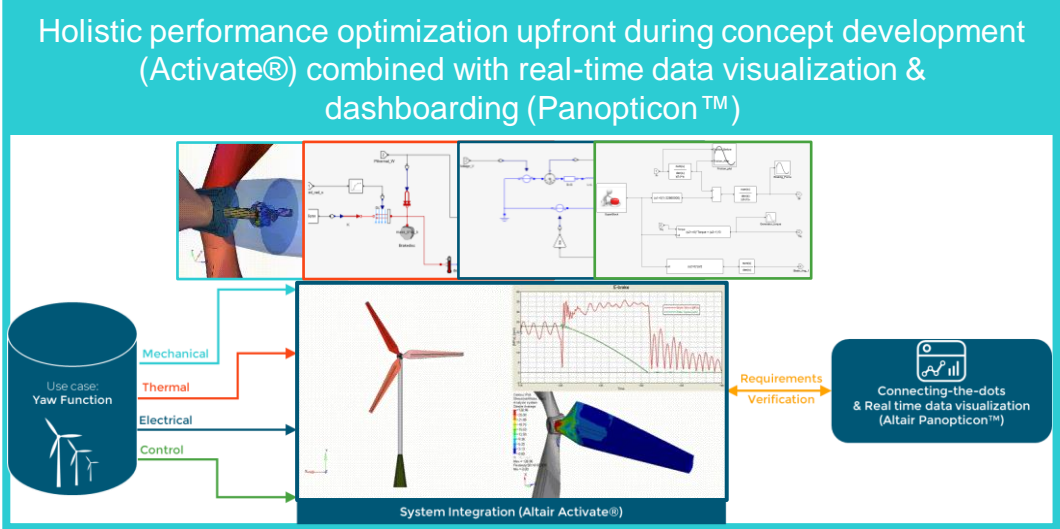
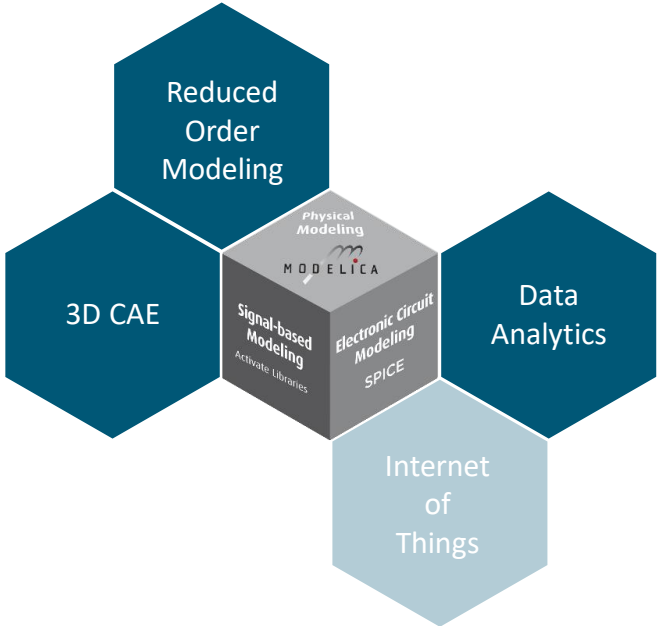
Driveline Control Comparison

Driveline control vs Constant Torque (Uncontrolled Driveline)



Altair System Integration for Wind Turbines

Helps Break Siloed Mechatronic Product Development

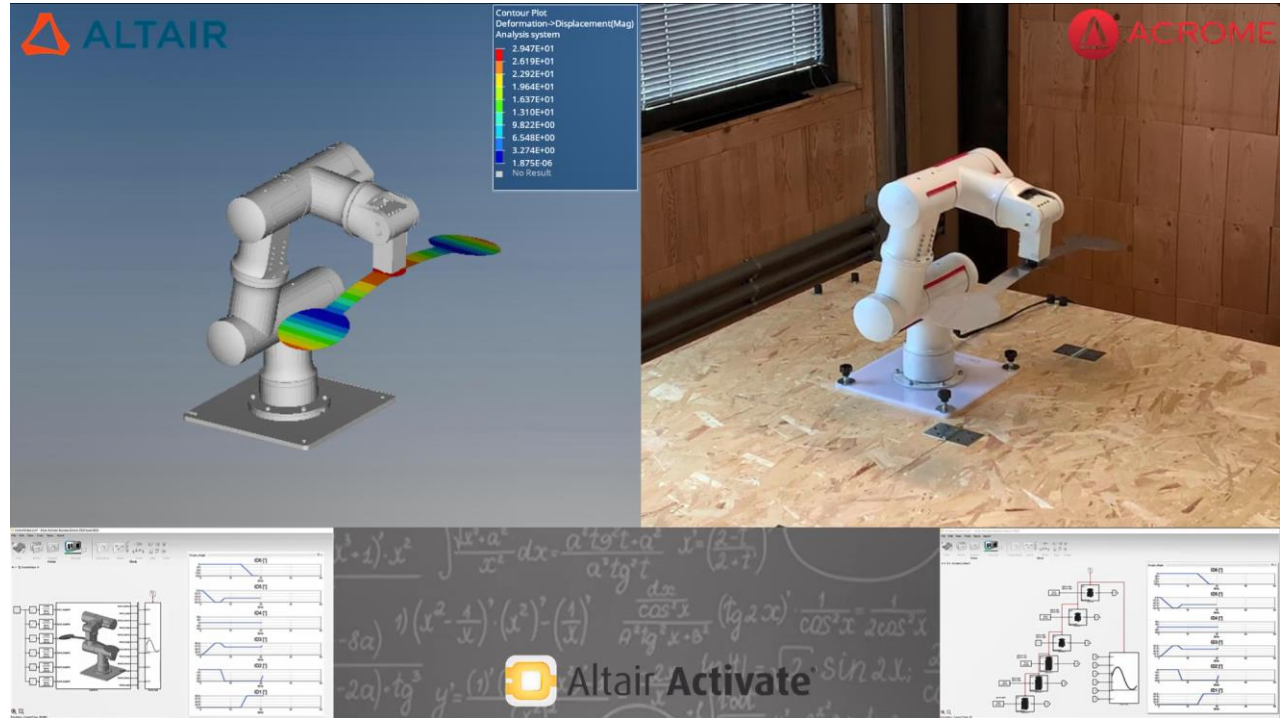
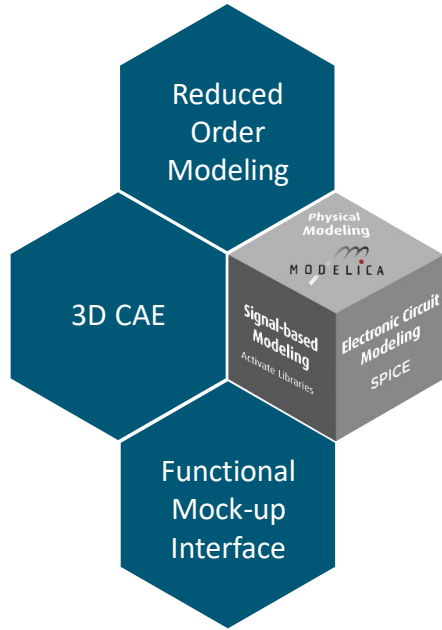


AFTER

Benefits:

- 1. Better teamwork
- 2. Streamlined Mechatronic product development;
- 3. Estimated efficiency gain of 6 months
- 4. Estimated warranty savings of 10%

Digital Twin for Mechatronics: Acrobot



REFERENCES

Industrial References

Ankers: Improving vehicle brake performance

Challenge
Reduce vehicle stopping distance through performing brakes

Solution
Brake subsystem in **Activate** co-simulated with full-vehicle dynamics **MotionSolve**

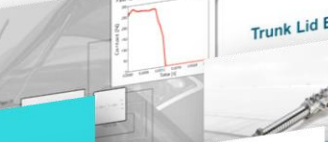
- Value**
- Complete high-fidelity system simulation
 - Thermal effects on brake pad included
 - Better performance insight, earlier



Axle, transmission and steering systems for diesel and electric forklift trucks



Model-based development of LED head lamps



Trunk Lid Electro-Mechanical Latch



Mechatronic Actuation Systems for Aircraft Wings

Challenge
Develop electro-mechanical aircraft wing actuation systems that perform reliably

Solution
Engineering team and streamline development of mechatronics system simulation platform using Altair **Activate**, **MotionSolve™**, **OptiStruct™** and **FEAUX™**

mabe Continually Improving Washing Machine Performance

Challenge
Improve machine performance by simulating subsystem interactions

Solution
Activate for system-level simulation detailed 1D motor control model, w **MotionSolve** for 3D multi-body sim

- Value (to-date)**
- Energy factor improved 24%
 - PD cycle time reduced 25%
 - Market leadership in Latin America

Developing Miniature Circuit Breakers (MCBs) with a Multi-Disciplinary Approach

Challenge
Adapt an existing standard design for an use in a new geography, under differe (i.e., voltages) – with an ultra-short time-to-market

Solution
Rapidly and accurately assess product performance multi-disciplinary aspects by combining in **Activate™** (1D) with Altair **MotionSolve™** (3D)

Value
Bad news early was actually helpful → S technical risk early and was able to focus to meet the requirements. Maintained high and company reputation for product reliability

"Connecting models between Altair products is simple. This coupling fills an important gap. It simulate the system in a way that we couldn't before."
— Remy Orban, Mechatronics

Smart Industrial Coffee Machines

Challenge
Maintain technology leadership for an amazing coffee machine (i.e. deliver the end-product in a consistent, reliable way while being aesthetically pleasing)

Solution
Optimize the functional performance on system level lifecycle in use of Altair's platform to build physics-based multi-disciplinary physical modeling simulation and **Altair Activate™** physical modeling simulation and thermodynamic process (not real time Human-environment interaction)

- Value**
- Increased performance and energy efficiency
 - Rapid design exploration
 - Reduced costs for physical tests lead to shorter time-to-market
 - Foundation for convergence of simulation and design



MX3D: Applying 3D Printing and Digital Manufacturing



FORM FOLLOWS FUNCTION
THYSSENKRUPP AG - REINVOER
THE ELEVATOR CONCEPT

Dr. Thomas Kuczera, thyssenkrupp Elevator
Christian Kehrer, Altair Engineering GmbH



Slicing, automatization and packaging solutions for food industry

Challenge
Assure customer's requirements for increased throughput and reduced vibrations of highly dynamic operating slicers and packaging machines

Solution
Continuous simulation along the product life cycle to support interdisciplinary teamwork in a purpose-driven way using Altair **Activate**

- Multi-physics system simulation incl. mechanics, actuation and control
- Structural analysis of the multi-body system and topology optimization with Altair **MotionSolve™** and Altair **OptiStruct™**

- Value**
- Improved structural dynamics: + 20% strength and stiffness
 - Lead-time reduction through virtual validation
 - Encouraged interdisciplinary teamwork



E-Learning Material

Signals Processing

Compose Signal Processing

Altair Compose is an environment for doing calculations, manipulating and visualizing data (including from CAE simulations or test results), programming, and debugging scripts useful for repeated computations and process automation. Compose allows users to perform a wide variety of math operations including linear algebra and matrix manipulations, statistics, differential equations, signal processing, control systems, polynomial fitting and optimization.

Using Compose for Signal Processing allows useful information to be extracted from sensors that cannot be measured, can improve transmission, storage efficiency, and quality of signal. It will help you have a more clear understanding of phenomena in many applications.

Select a place to get started.

- Interface Overview
- Signal Processing

NVH in Compose

Compose NVH

Altair Compose is an environment for doing calculations, manipulating and visualizing data (including from CAE simulations or test results), programming, and debugging scripts useful for repeated computations and process automation. Compose allows users to perform a wide variety of math operations including linear algebra and matrix manipulations, statistics, differential equations, signal processing, control systems, polynomial fitting and optimization.

Using Compose for NVH helps to easily understand the results of numerical acoustic analysis, reduce time to compare multiple configurations and quickly identify frequencies and respective parameters that must be attenuated in order to reduce noise and vibration.

Select a place to get started.

- Interface Overview
- NVH Modules

System Simulation & Controls

Systems Simulation and Controls using Activate

Altair Activate® software is an open & flexible tool for rapidly modeling and simulating products as multi-disciplinary systems in the form of 1D models (expressed as signal-based or physical block diagrams), optionally coupled to 3D models. For additional information, download the e-book and scripts that can be run, open the Resources menu in the upper right of this window.

Select a place to get started.

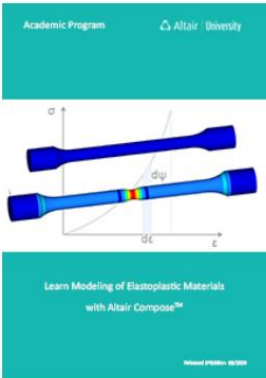
- Interface Overview
- Introduction to Systems
- Linear Systems
- Controls of the BBT
- Hydraulics
- HyperSpice

E-Books

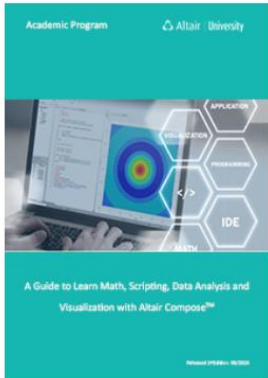
Free eBooks

compose

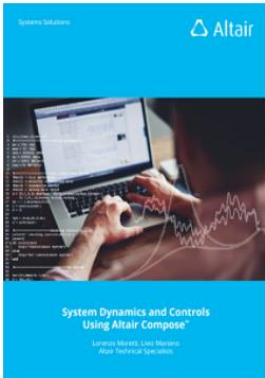
Sort



Learn Modeling of Elastoplastic Materials with Altair Compose



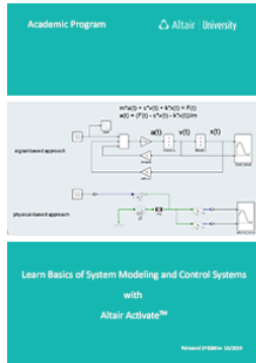
Math, Scripting, Data Analysis & Visualization with Altair Compose



E-book for System Dynamics and Controls Using Altair Compose

activate

Sort



Learn Basics of System Modeling and Control Systems with Altair Activate

Altair as strategic partner for simulation-driven innovation

Handling Complexity



- Manage Risks due to Product Complexity
- Optimizing mechatronic product performance holistically as system-of-systems (using physics-based Digital Twins)

Facilitating Teamwork



- Accelerate Time-to-Market
- Breaking down silos between mechatronic disciplines (Mechanical, Electrical, Controls, etc.)

Managing Costs



- Reduce Development Costs
- Streamline Product Development teamwork & tool set, affordably



Unique Tools for Model-Based Development

<https://www.altair.com/systems-modeling-applications/>



Products download

connect.altair.com | basicportal.altair.com



Altair MBD Forum

https://community.altair.com/community?id=altair_forums#products