Multibody Dynamics Simulations with Abaqus from SIMULIA

8.5.2008

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Abaqus Deutschland GmbH

SIMULIA

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SIMULIA

One Company, First Class Brands

DASSAULT SYSTEMES

3D MCAD	Virtual Product	Virtual Testing	Virtual Production	PLM Collaboration	User Experience
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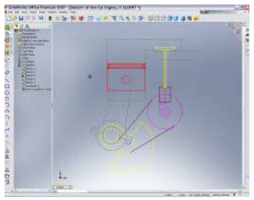		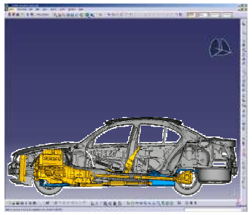	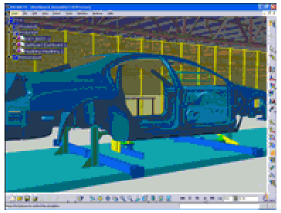		
Productive, easy to use 3D Design	Product Excellence	Engineering Quality	Production Performance	Collaborative Intelligence	Life Experience

DS Brands: delivering customer benefits through the whole value chain

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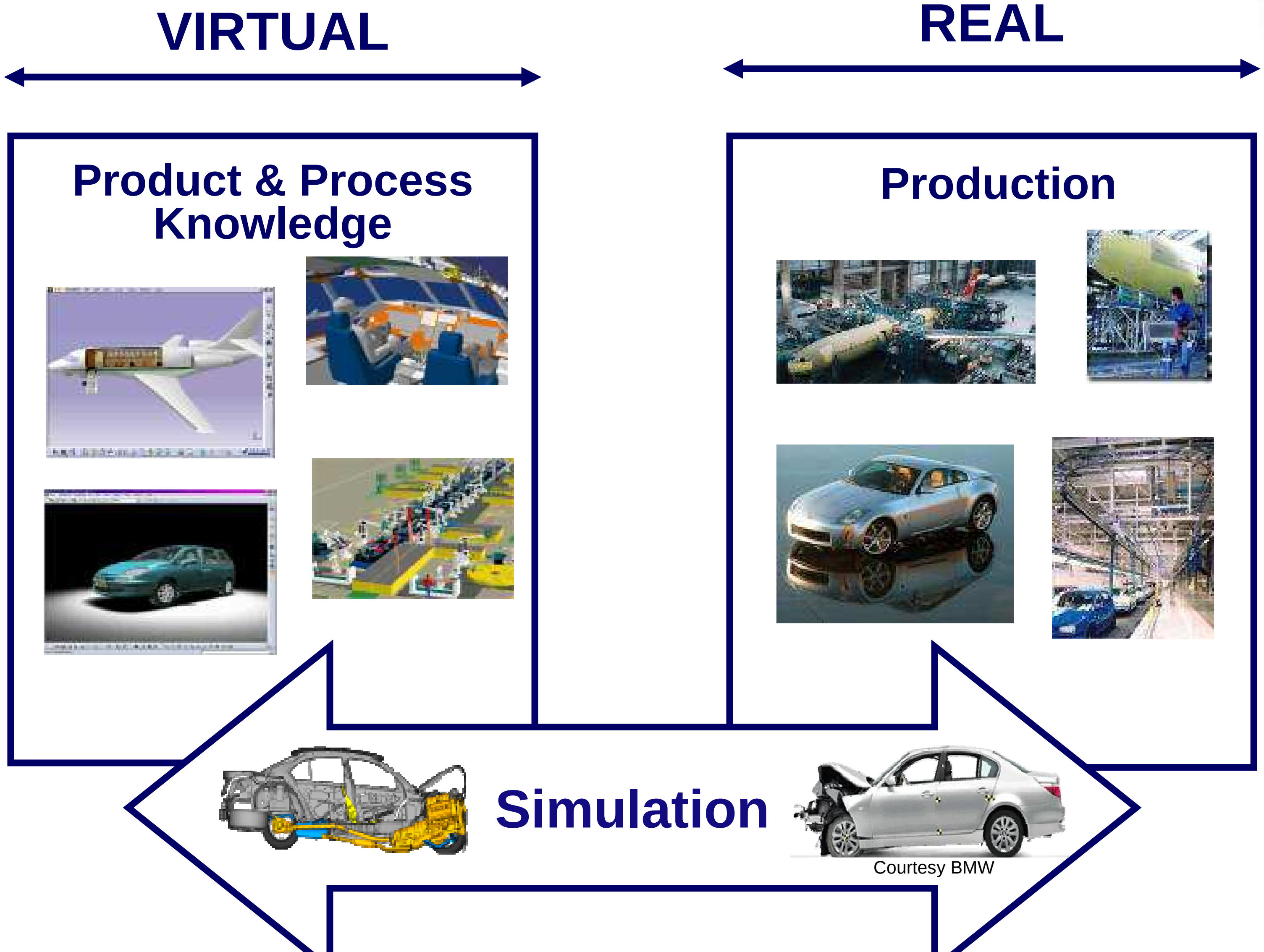
Realistic Simulation

"Define, Monitor and Control the Physical World"

SIMULIA



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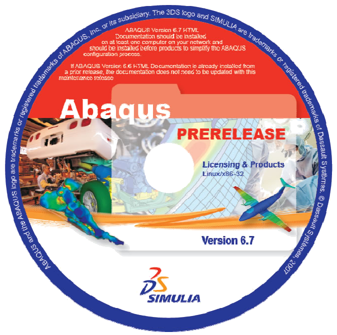
SIMULIA – our identity

- **What is SIMULIA?**
  - SIMULIA is the Dassault Systèmes brand that delivers a scalable portfolio of Realistic Simulation solutions including:
    - Abaqus products for Unified Finite Element Analysis
    - Multiphysics solutions - New!
    - Simulation Lifecycle Management solutions - New!
  - SIMULIA is not a company, product, or technology itself but a brand which is responsible for multiple products and technologies in the simulation domain.
  - Abaqus lives on as the name of our Unified FEA products



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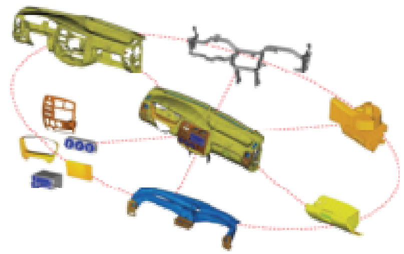
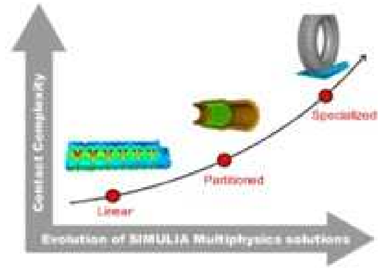
Product Strategy

- **Unified FEA solutions for all users**
  - Scalable Unified FEA products and services with Abaqus quality



- **Multiphysics for the most challenging customer applications**
  - Open Multiphysics platform and complete solutions for key problems



- **Full Simulation Lifecycle Management**
  - Collaborative environment to manage simulation processes, data and IP

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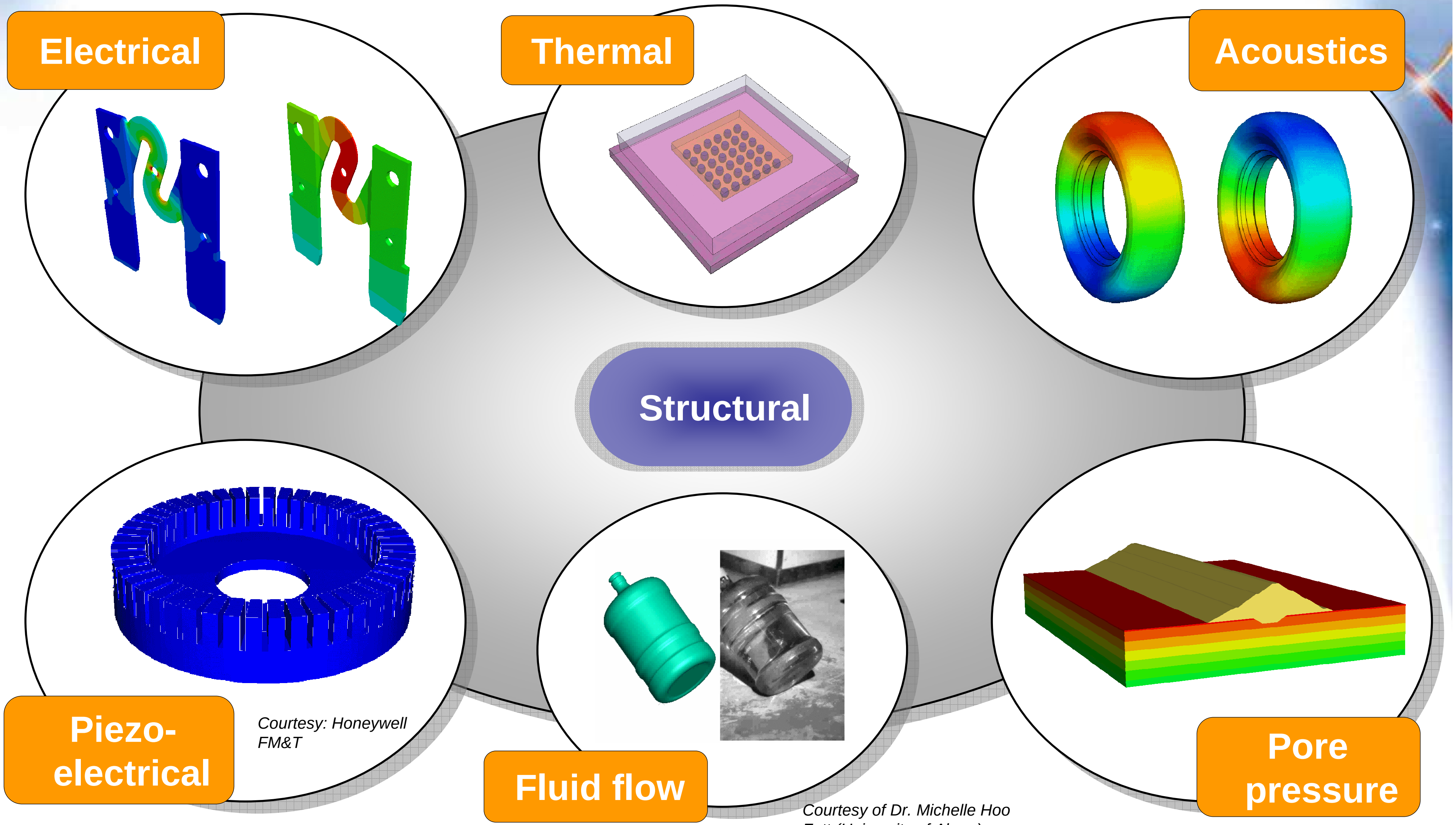
Multiphysics in Abaqus Unified FEA

- **Abaqus enables coupling of multiple fields**



Courtesy of Dr. Michelle Hoo Fatt (University of Akron)

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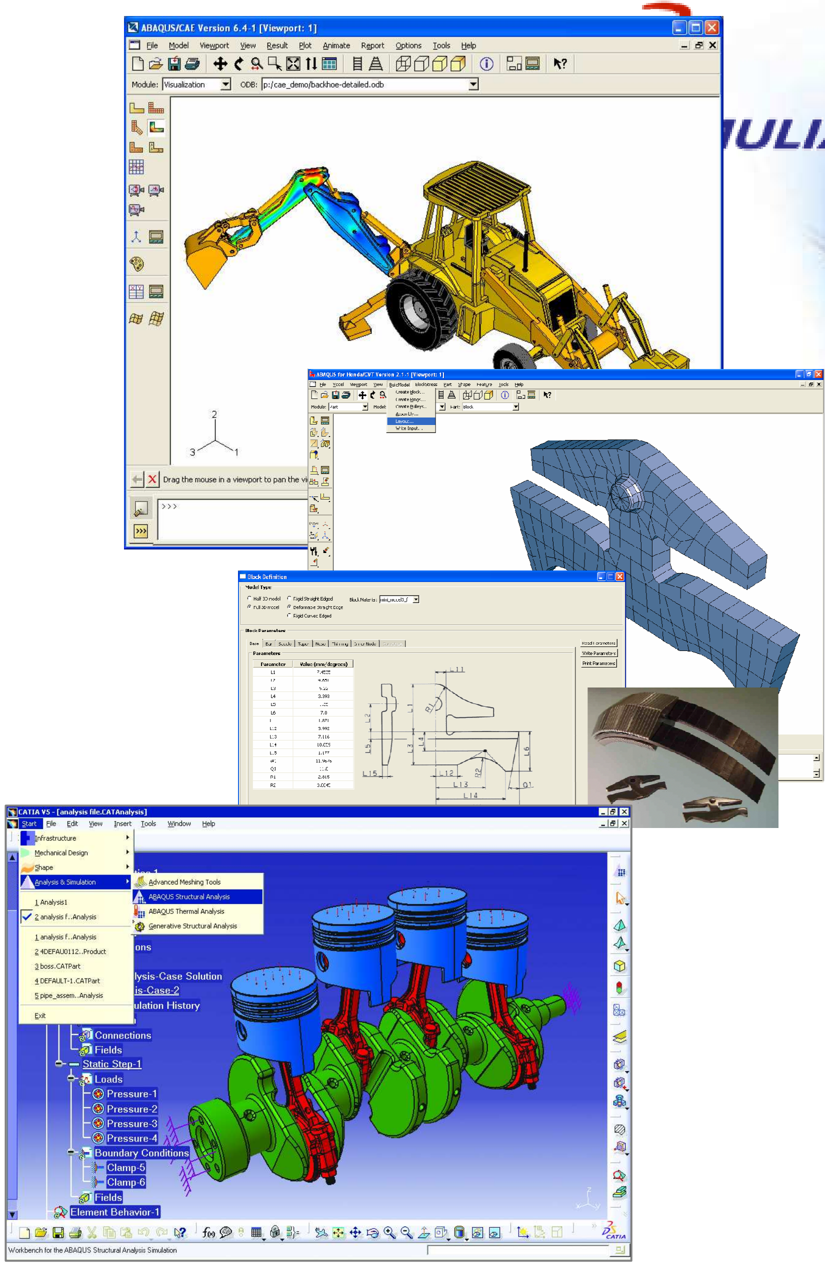
Abaqus FEA Products

- **Interactive Products (modeling and visualization)**
  - Abaqus/CAE
    - Process Automation Toolkit
  - Abaqus for CATIA V5

- **Analysis Products (finite element solution)**
  - Abaqus/Standard
  - Abaqus/Explicit



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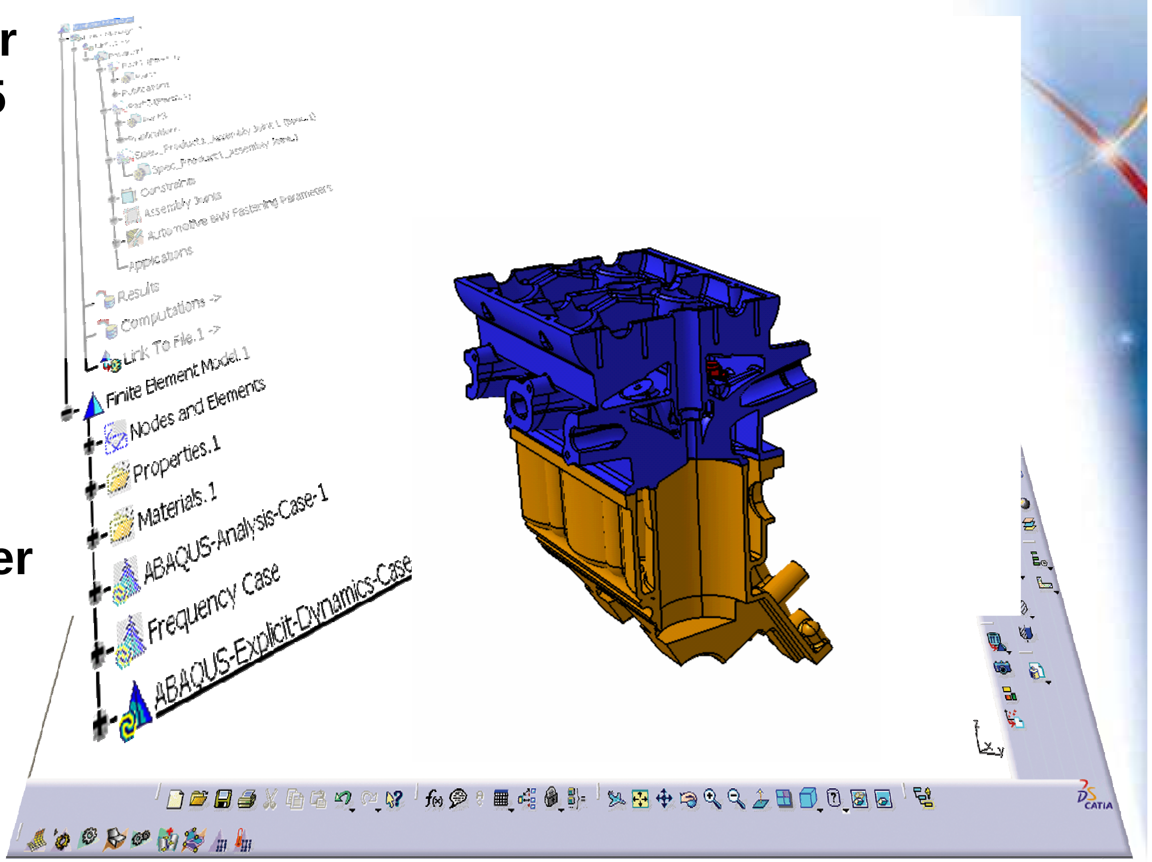
What is Abaqus for CATIA V5?

- **End-to-end Abaqus modeler fully integrated in CATIA V5**
  - Preprocessing
  - Job submission and monitoring
  - Postprocessing



- **Take advantage of the power of Abaqus and CATIA V5**
  - CATIA V5:

    Intuitive modeling of complex assemblies
  - Abaqus:

    Powerful analysis tools for linear and nonlinear FEA

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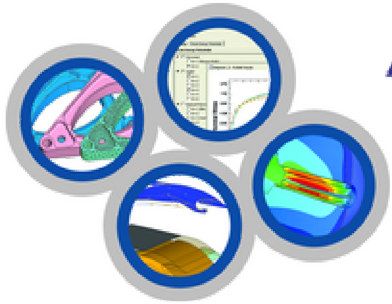
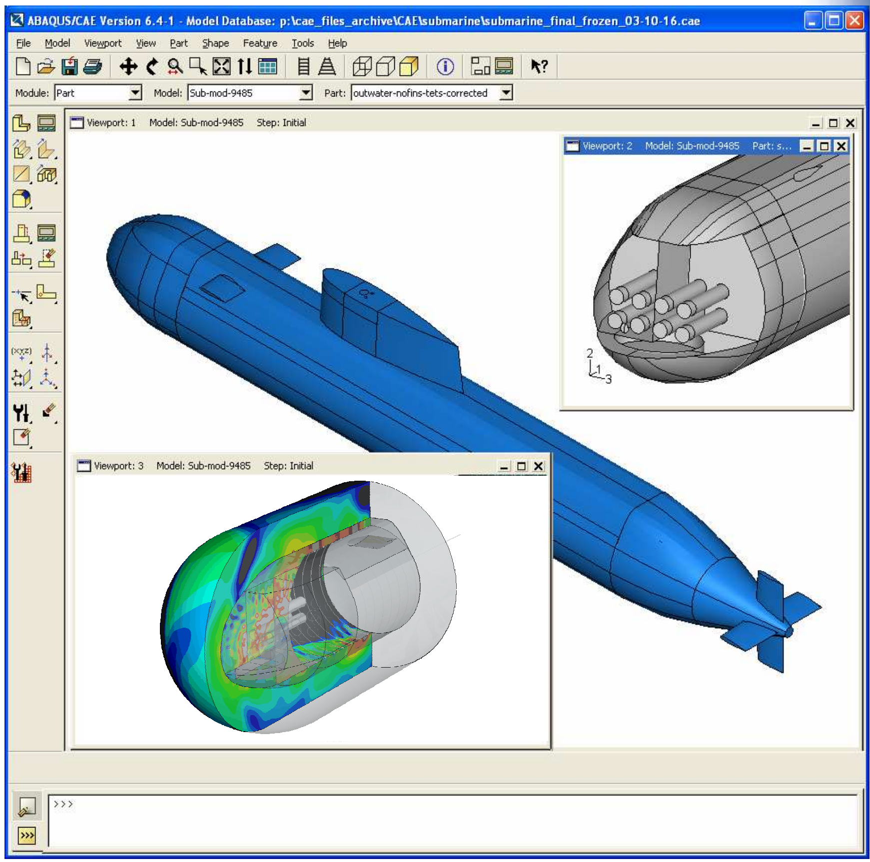
Abaqus/CAE



- **Interactive, parametric, finite element modeler and results viewer**
- **Hybrid (geometry & mesh based) FEA environment for maximum flexibility**
- **The most complete and fastest graphical user interface for the dedicated Abaqus user**
- **Direct interface to CATIA V4, Parasolid, IDEAS**
- **Associative import from Pro/ENGINEER, CATIA V5 and SolidWorks**



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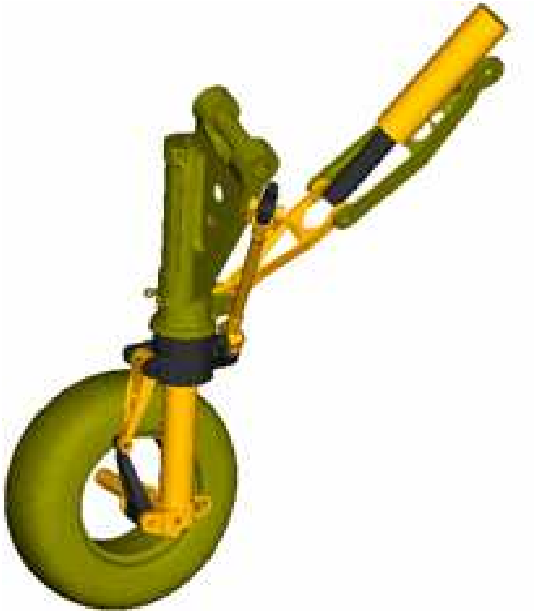
Abaqus/Standard

- Comprehensive linear & nonlinear implicit general purpose finite element analysis of structural, thermal, acoustic & mechanism simulations
- Integration with Abaqus/Explicit provides maximum flexibility for multi-physics simulation ("Unified FEA")
- Sophisticated contact, failure, material modeling & other advanced nonlinear capabilities
- High-performance direct and iterative solvers with support for shared and distributed memory configurations
- Powerful interfaces for user customization



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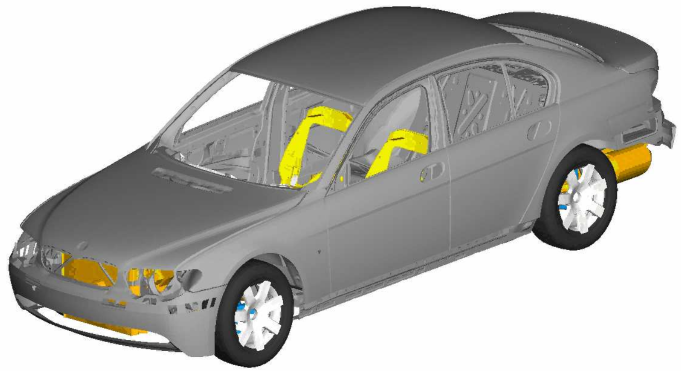
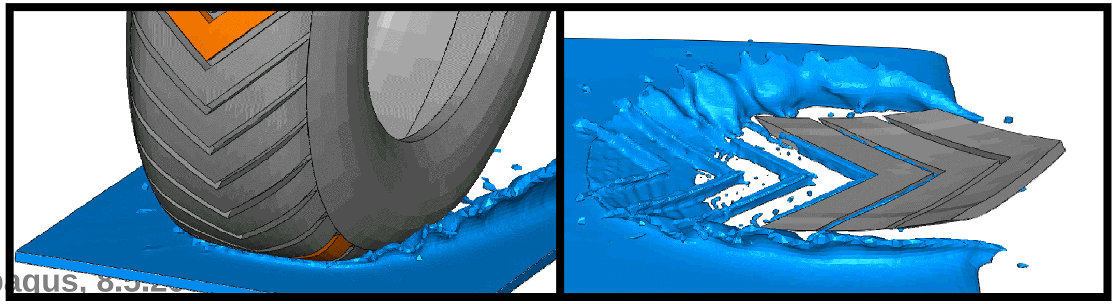
Abaqus/Explicit

- **Comprehensive explicit finite element analysis of structural, thermal, acoustic & mechanism simulations**
- **Integration with Abaqus/Standard provides maximum flexibility for multi-physics simulation ("Unified FEA")**
- **High-performance solver with support for shared and distributed memory configurations**
- **Powerful interfaces for user customization**



Courtesy BMW



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Finite element based multibody dynamics

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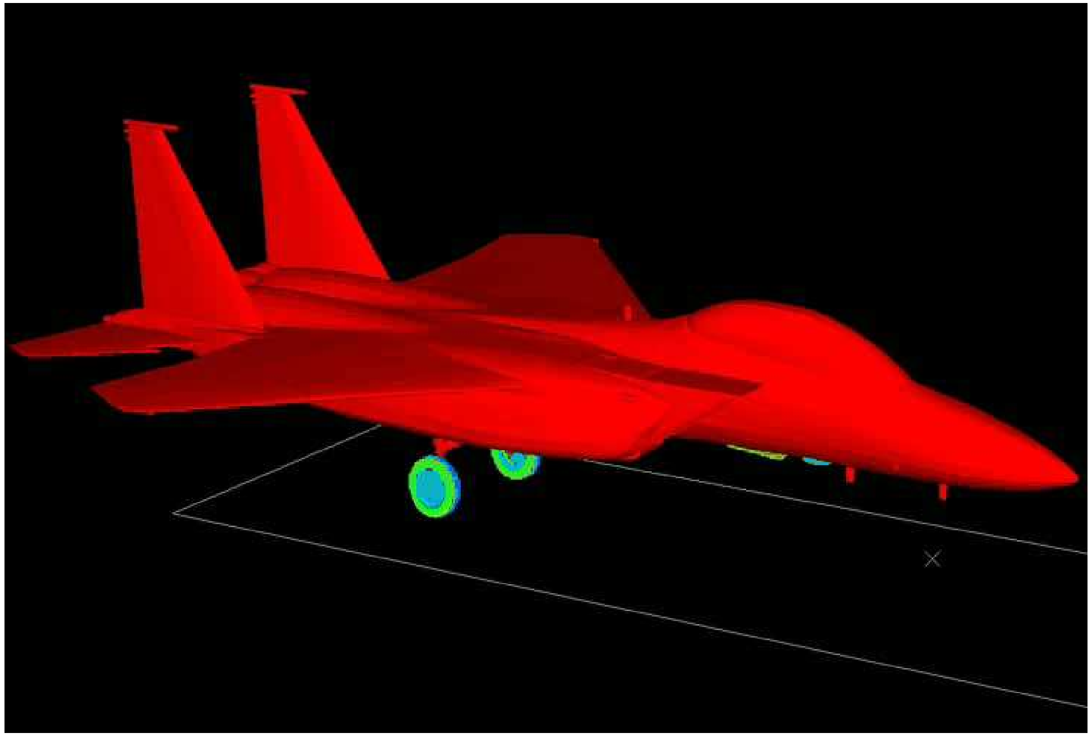
Mechanism analysis

- Mechanism analysis in Abaqus covers the broad class of analyses that include moving parts



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Connectors in Mechanism Analysis

- **Connectors are a fundamental ingredient in mechanism analyses**
  - Enforce kinematic constraints
  - Allow joint flexibility
  - Model sophisticated interactions: joint stops (contact), locking mechanisms, driven motion, internal force/moment controls, friction, etc.

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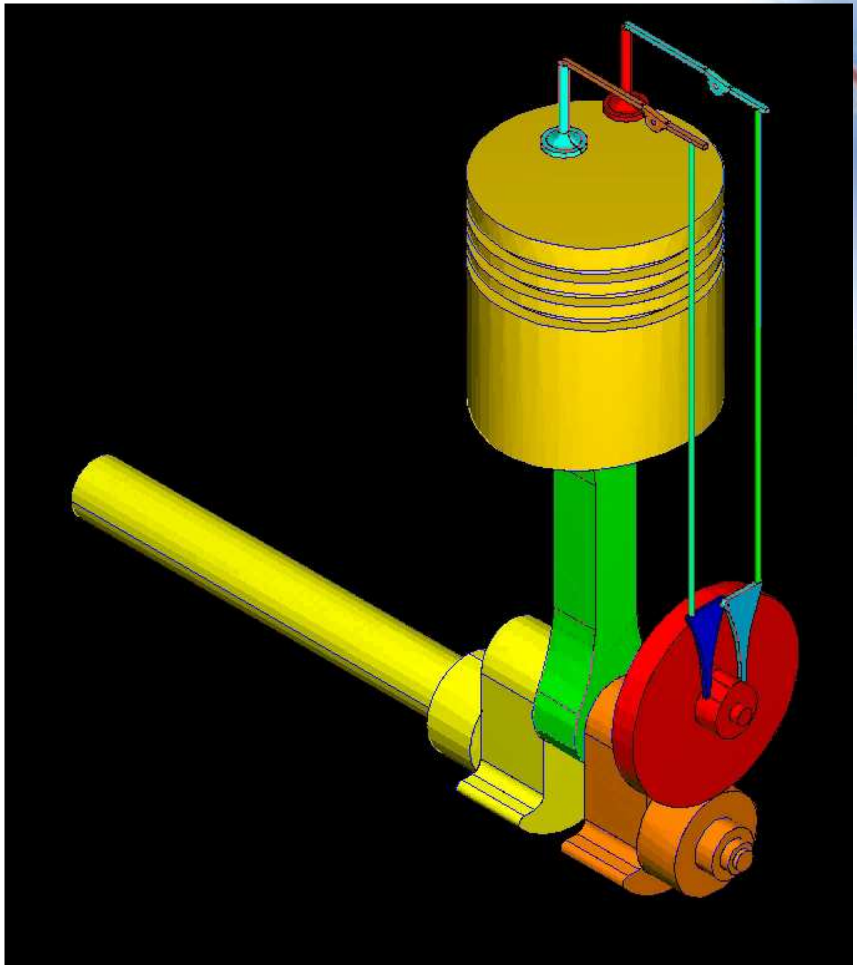
Mechanism Overview

- **Mechanism analysis comes in three categories:**

1 Rigid components connected by joints:

  - Kinematic analysis focusing on constraint forces
  - Multi-body dynamic analysis focusing on inertia forces



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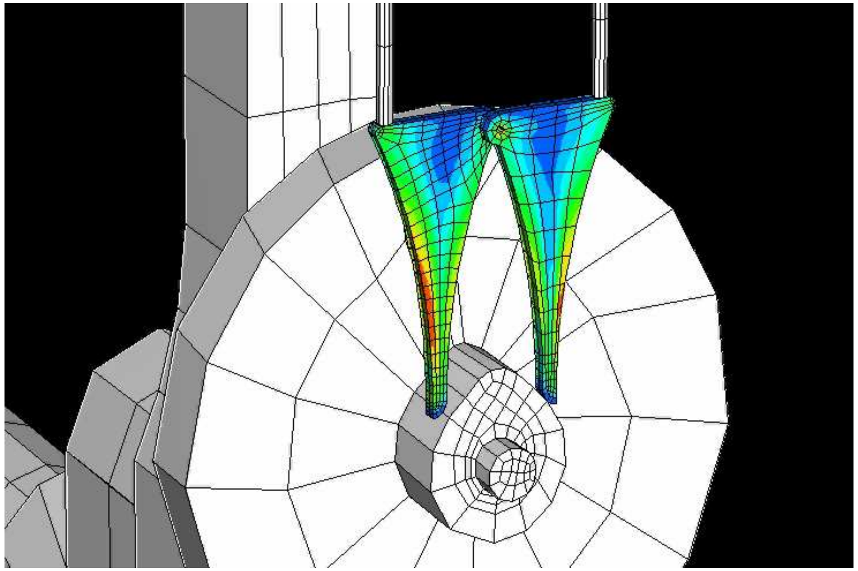
Mechanism Overview

2 Large (nonlinear) deformation of bodies connected by joints:

- Component-level stress analysis



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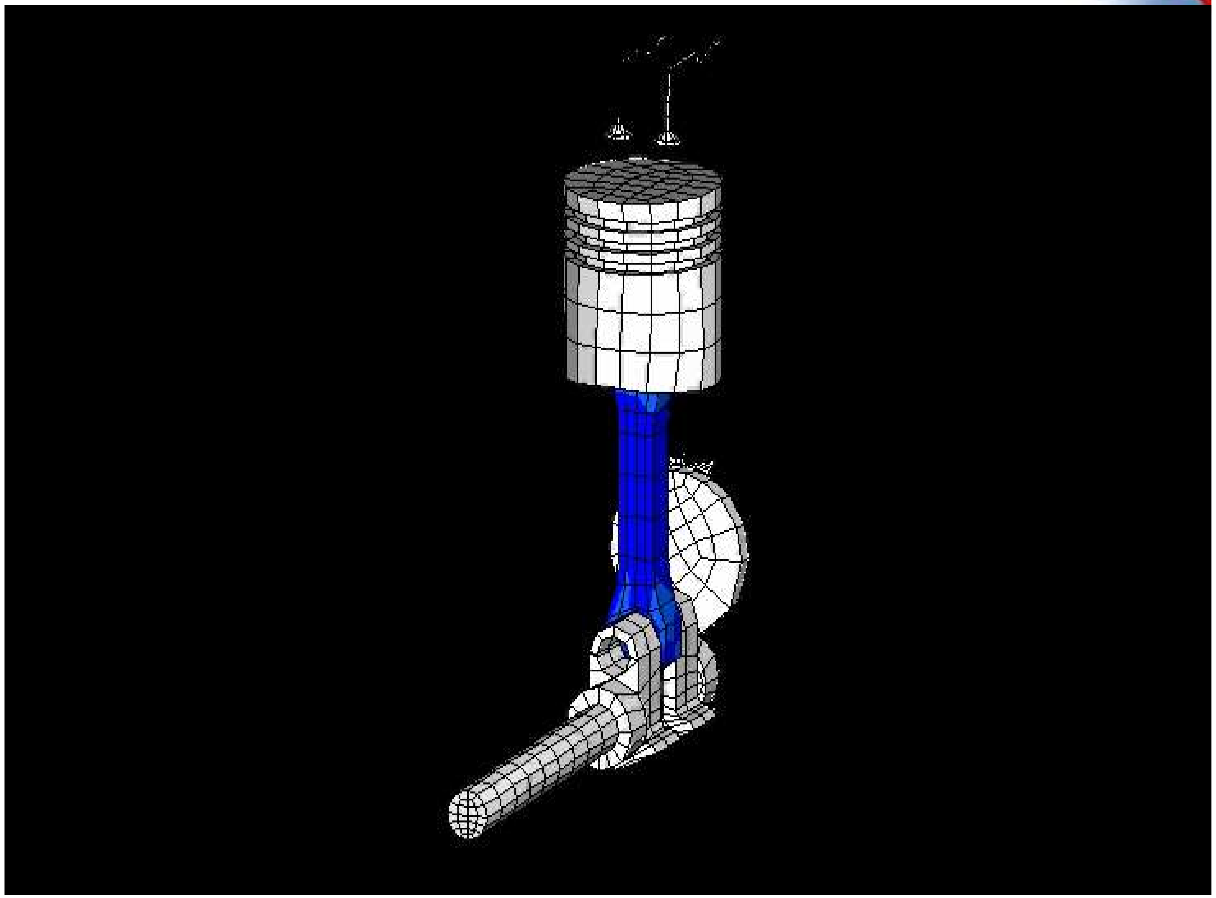
Mechanism Overview

3

Small deformation bodies in geometrically nonlinear analysis connected by joints:

- Linear elastic flexibility in kinematic or multi-body dynamic analysis combined with rigid components or large deformation components



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Connectors

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Connectors

- **Connectors model discrete, physical connections between bodies**
- **Features include:**
  - Kinematic constraints
  - Oriented spring, dashpot, and frictional behavior
  - Joint stops
  - Constraint forces and moment output
  - Joint failure
  - No degree of freedom elimination (connectors can be used between rigid bodies)
  - Relative motion actuation
  - Internal load actuation

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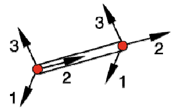
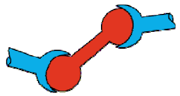
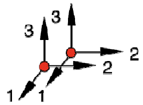
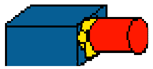
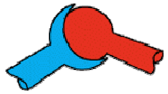
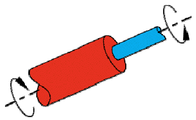
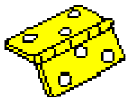
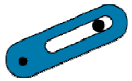
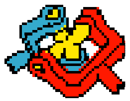
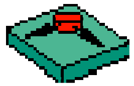
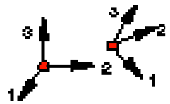
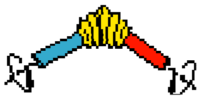
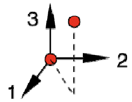
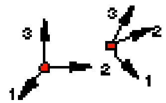
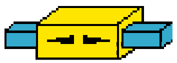
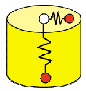
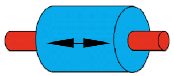
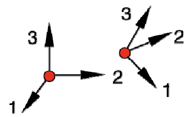
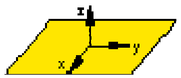
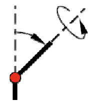
Connection Library

Assembled		Basic translational		Basic rotational	
BEAM		LINK		ALIGN	
WELD		JOIN		REVOLUTE	
HINGE		SLOT		UNIVERSAL	
UJOINT		SLIDE-PLANE		CARDAN	
CVJOINT		CARTESIAN		EULER	
TRANSLATOR		RADIAL-THRUST		CONSTANT VELOCITY	
CYLINDRICAL		AXIAL		ROTATION	
PLANAR				FLEXION-TORSION	

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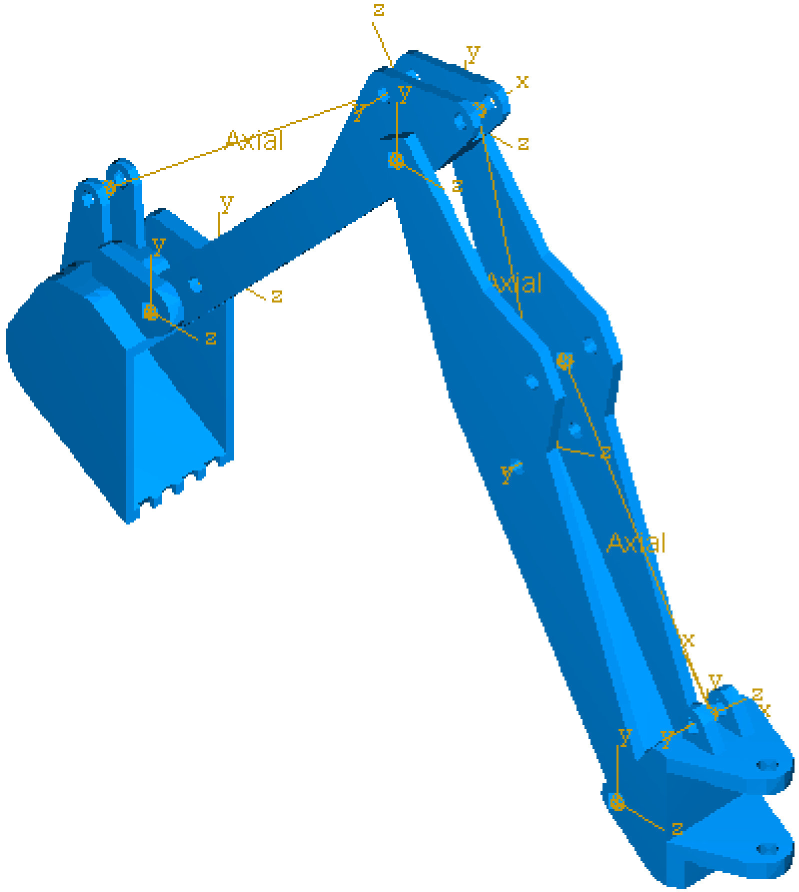
Connector Support in Abaqus/CAE and Abaqus/Viewer

- **Full support of analysis functionality**
  - Definition of all connection types, behavior options, actuations, and output variables supported in Abaqus/CAE
    - Display of the connector orientation systems, important for debugging connection definitions
  - Full display and animation of results in Abaqus/Viewer



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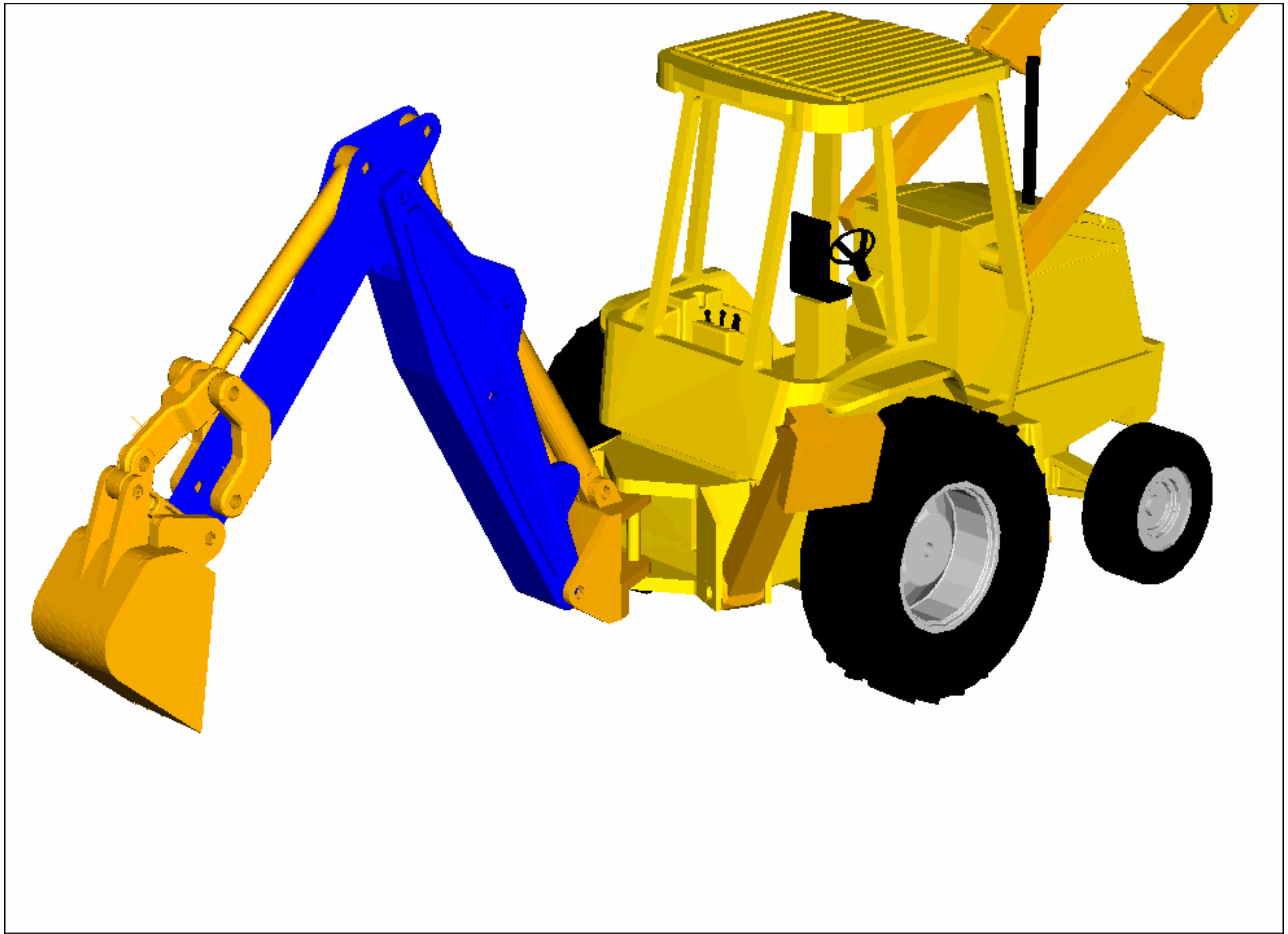
Connector Support in Abaqus/CAE and Abaqus/Viewer



backhoe-3.avi

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Logical-Physical co-simulation

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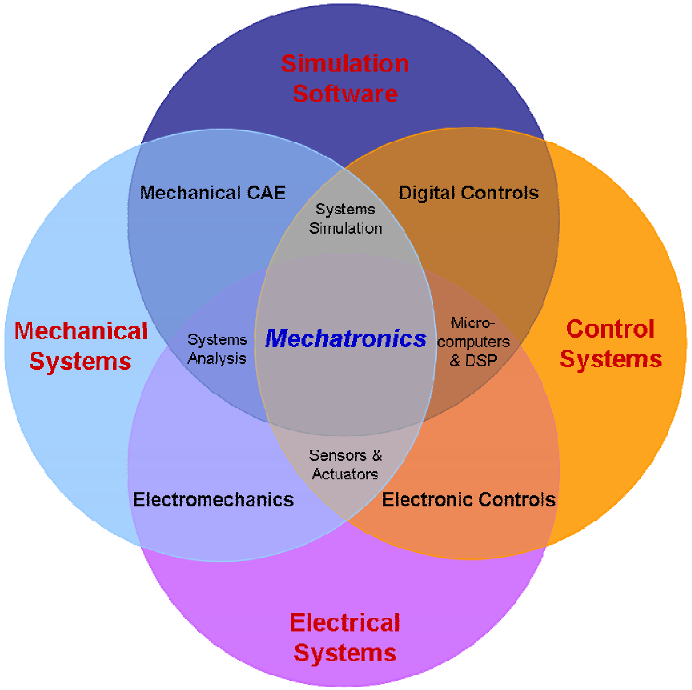
Mechatronics



In many cases:

- ***Sensors:*** **collect data regarding the state of the mechanical system**
- ***Control modules:*** **using the sensor information compute the necessary actuation to advance the mechanical system in the desired state**
- ***Actuators:*** **apply the (mechanical) loading (e.g., electric motors, hydraulic pistons) computed by the control modules.**

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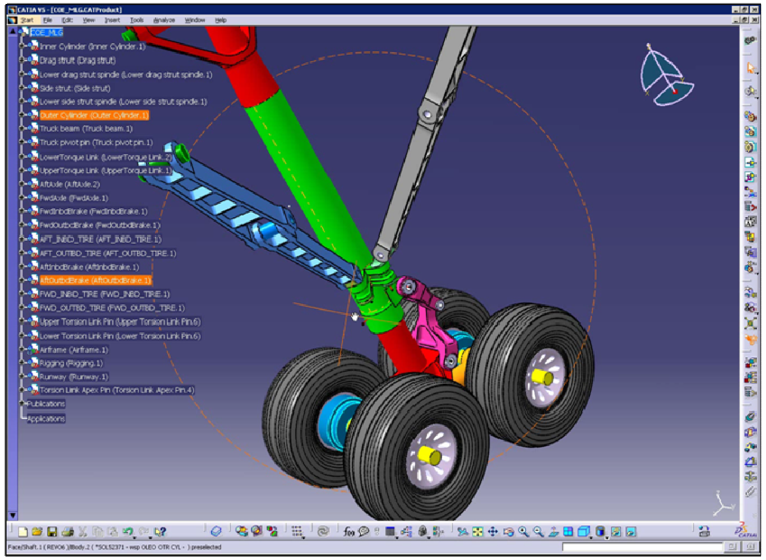
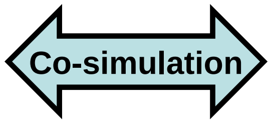
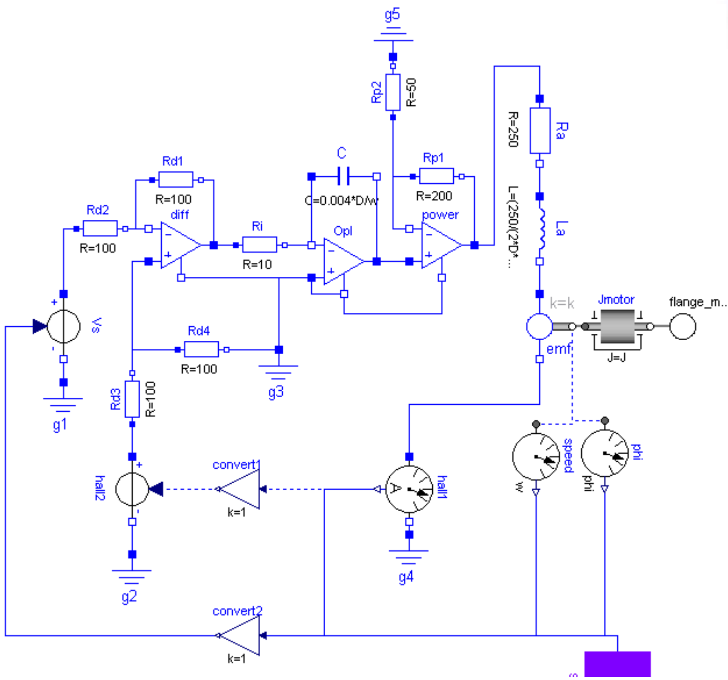
Logical-Physical co-simulation

- **Goal: provide a comprehensive, easy to use capability of modeling system level behavior**
- **How: co-simulation between Abaqus and Dymola, both DS owned products.**
  - Abaqus: models the physics in the system such as mechanical, thermal, acoustics, etc. Provides sensors and actuators.
  - Dymola: models electronics, hydraulics







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Substructures

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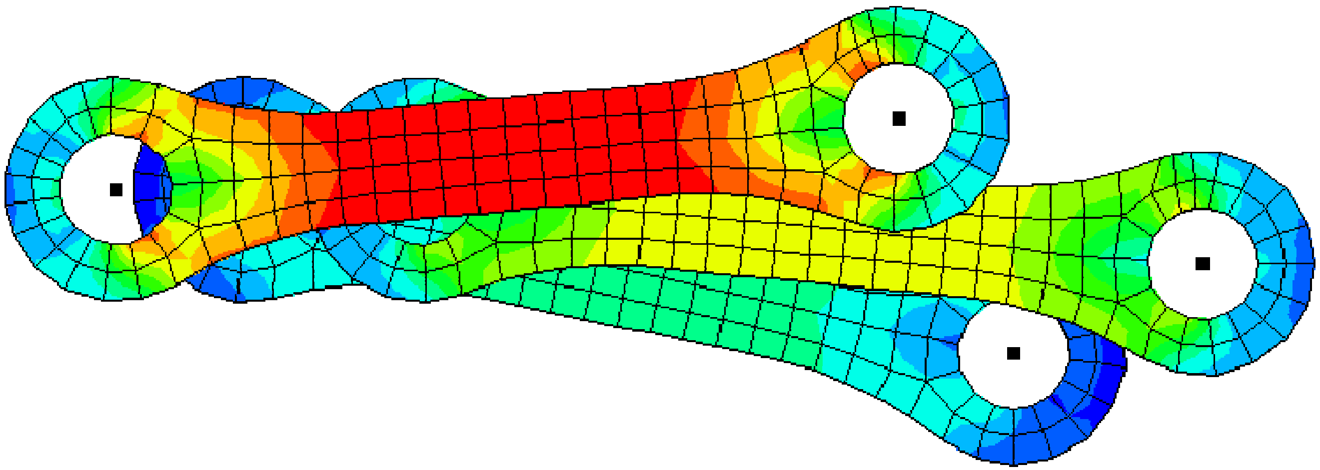
Rotating Substructures

- **Geometrically nonlinear analysis:**
  - Substructures are valid for large rotations and large translations
  - Stress recovery occurs in the current configuration
- **Strains are assumed small**



Tie rod stress during crank rotation

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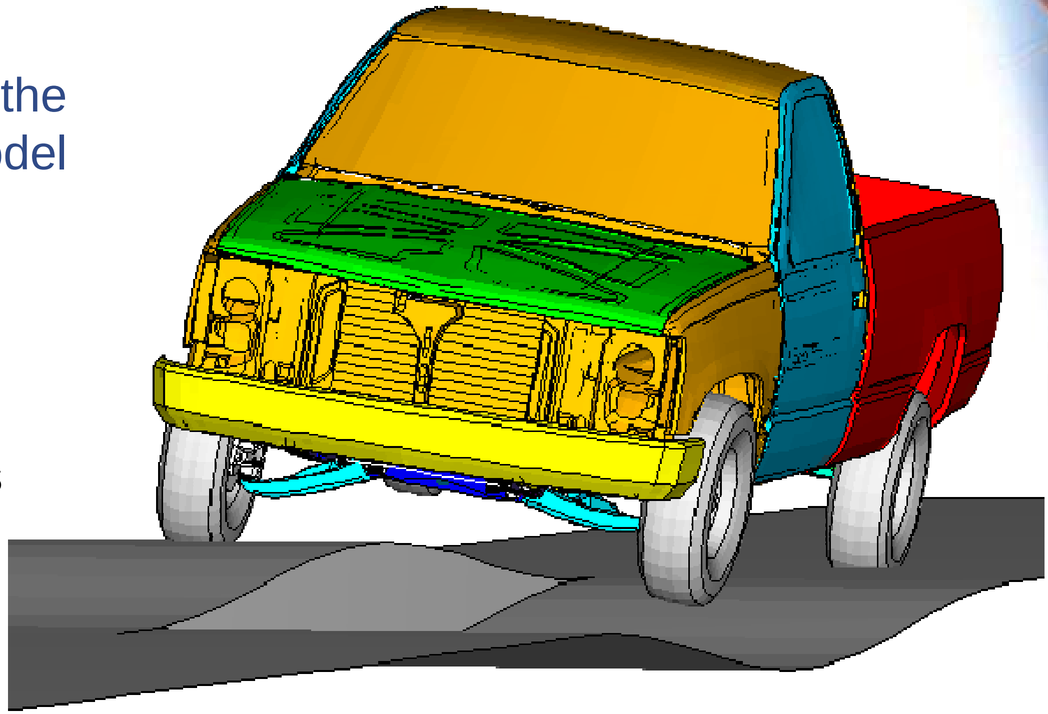
Substructure Model of a Pickup Truck

- **1994 Chevrolet C1500**
  - Example problem:
    - 55,000 elements in the fully-deformable model
    - 20 substructures
    - 2 rigid bodies
    - 81 connectors
  - Analysis speed up by as much as **120** times



The FEM model is obtained from the Public Finite Element Model Archive of the National Crash Analysis Center at George Washington University

(**`http://www.ncac.gwu.edu/archives/model/index.html`**)

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1994 Chevrolet C1500

- **In-phase bump**

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Summary

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Summary

- Finite Element based multibody dynamics
- Implicit and explicit time integration
- Allows for all kinds of nonlinearities
- Coupling with Controls for extended application

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Thank you for your attention

8.5.2008

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