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Realistic Simulation – Virtually Test Product Performance As Part of Design

Learn How Aerospace & Defense Companies Use Simulation

Kyle Indermuehle
Aerospace Lead, SIMULIA

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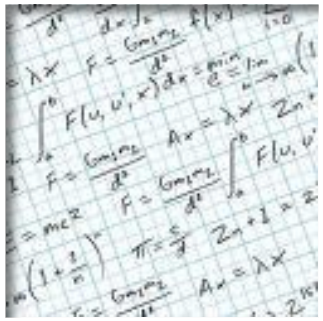
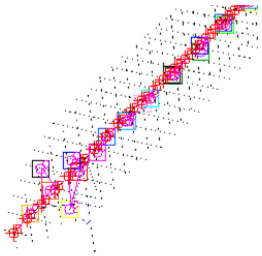
SIMULIA in the A&D Industry

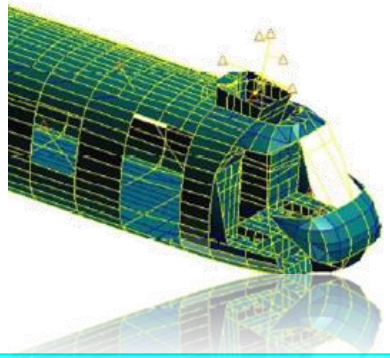
- Industry trends
- How companies are taking advantage of Abaqus today
- Customer examples

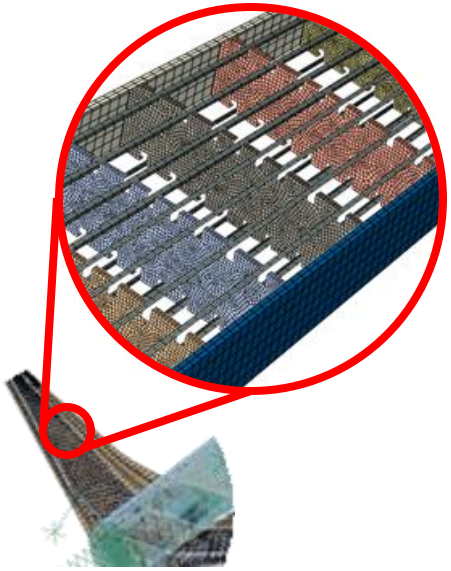
Evolution of Simulation in the A&D Industry

Models









1970 1980 1990 2000 2010

Simple FEA

Realistic FEA

Tools

NASA Structural Analysis

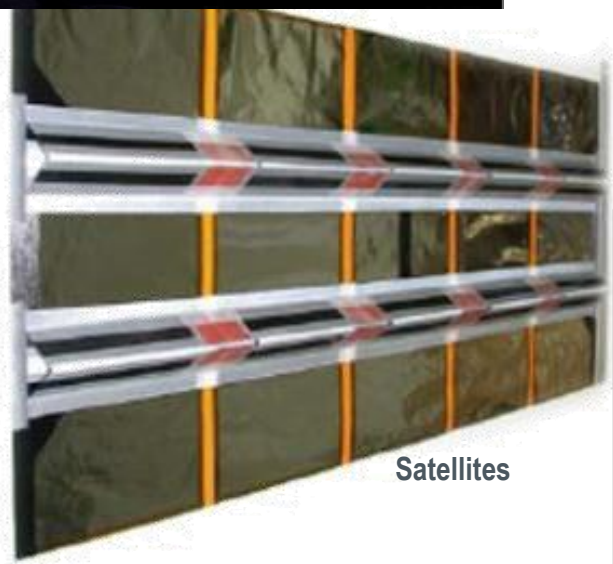
3

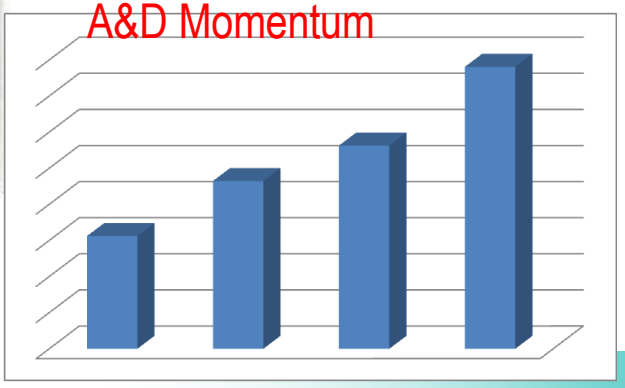
Firms Today Are Selecting SIMULIA to Obtain Better Designs

Rotorcraft

Airframe

Ship / Naval


Satellites



Selection of SIMULIA Not Just for Software, But in a Partner for Innovative Developments

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- VCCT-for-Abaqus technology was developed by Boeing Commercial Aircraft Group as part of the Composite Affordability Initiative (CAI)
  - SIMULIA selected by Boeing to commercialize
- We are an active participant in industry groups
  - FAA Center of Excellence
  - ASTM/D30 Composites workshop
  - ASC
- We host a Fracture Customer Review Team (CRT) for feedback and guidance

BOEING

Air Force Research Laboratory | AFRL
Science and Technology for Tomorrow's Air and Space Force

Success Story

COMMERCIALIZATION OF COMPOSITE STRUCTURE DESIGN TECHNOLOGY

Officials from the AFRL Materials and Manufacturing Directorate's Manufacturing Technology (ManTech) Division and the AFRL Air Vehicles (VA) Directorate announced that key structural analysis software developed under the Composites Affordability Initiative (CAI) team banner will be commercialized by ABAQUS, Inc. This will ensure long-term government/industry investment in advanced structural analysis tools.

Fracture Customer Review Team

BOEING · ExxonMobil · ALSTOM · RHOMBUS CONSULTANTS GROUP · intel · Cooper TIRES · NASA · Snecma Moteurs groupe snecma · NAL INSTITUTE OF AEROSPACE

SIMULIA

Who's Using Abaqus?

- Customers that have presented at past SIMULIA users conferences
  - Boeing
  - Airbus
  - Lockheed Martin
  - EADS
  - NASA
  - Dutch Space B.V.
  - MTU Aero Engines
  - Rolls-Royce
  - SNECMA
  - Swales Aerospace
  - Northrop Grumman
  - ATK Thiokol
  - Sandia National Labs

How are A&D Customers Using Abaqus? Advanced Composites Simulation

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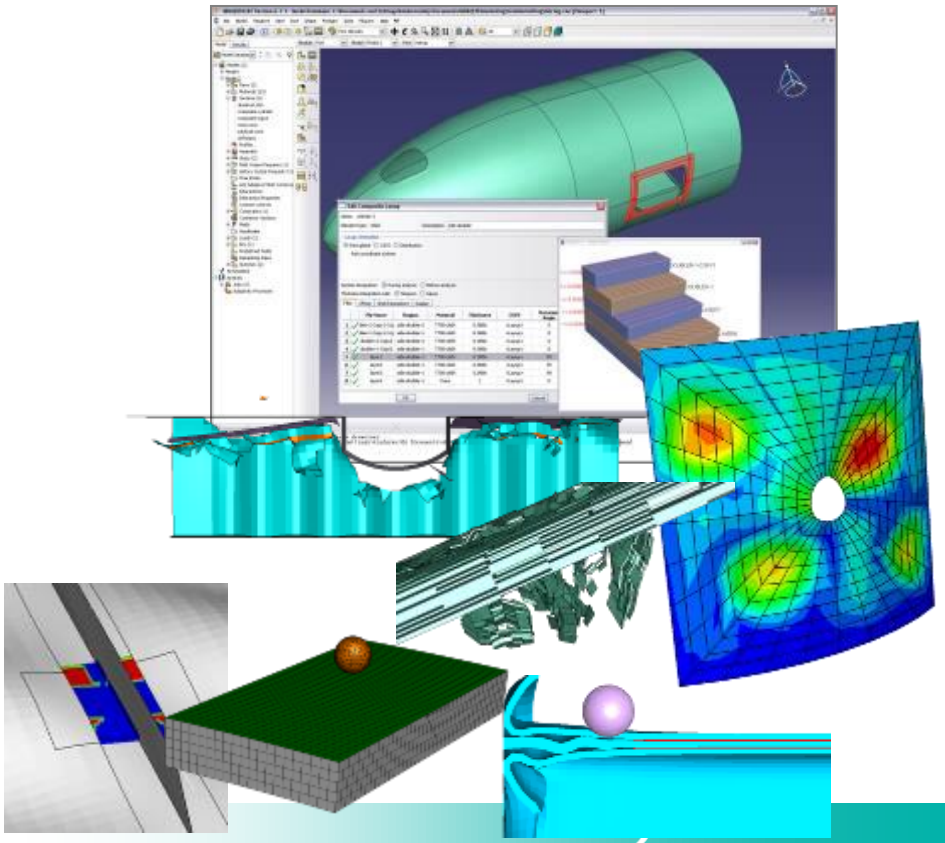
- EASY composites modeling / meshing
- Linear static analysis evaluating ply-by-ply stresses
- Fracture / crack growth in composites
- Delamination due to thermal loads
- Calculation of failure theories
  - Tsai-Wu, Tsai-Hill, Max Strain, Max Stress
- VCCT analysis
- Interlaminar shear predictions
- Manufacturing simulation
- Calculation of flat patterns
- High speed / ballistic impact
- Draping analysis
- Buckling and post-buckled performance
- Macro-modeling capabilities
- Micro-modeling capabilities
- Crashworthiness of composites
- Thru-thickness stress / strain plots
- BVID (Barely Visible Impact Damage)
- Visualization of ply stack-ups
- Interface with EXCEL for layup definitions
- User defined damage modeling
- Designer-centric composite modeling



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How are A&D Customers Using Abaqus?
Advanced Composites Simulation

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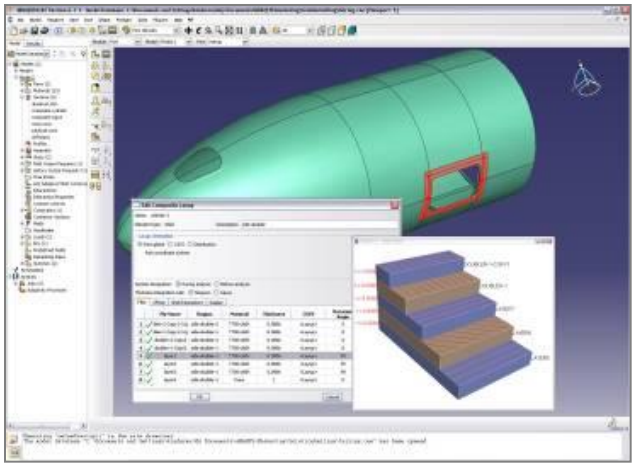
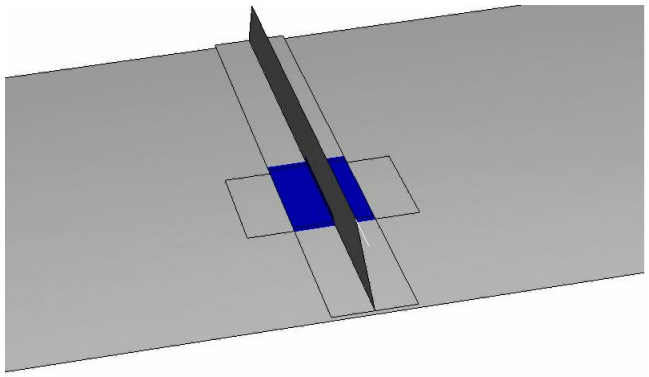
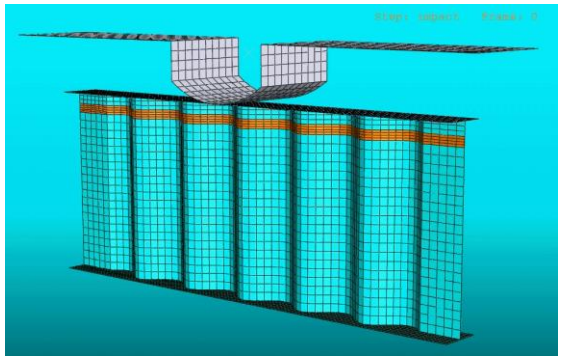


Composites Pre / Post in Abaqus/CAE

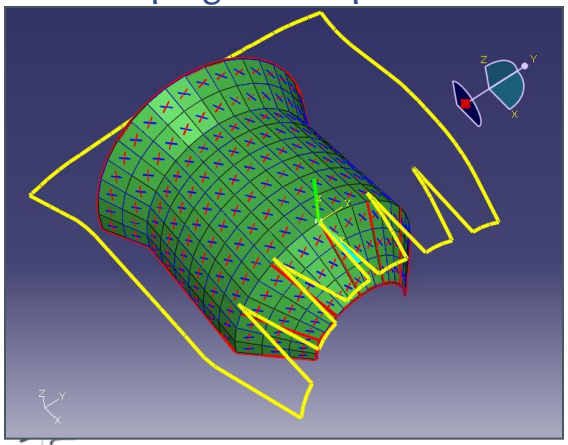
Crack propagation using VCCT



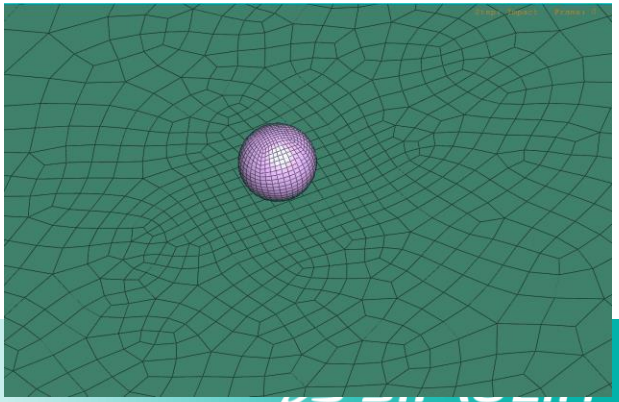
Composites Crush



Draping in Abaqus/CAE

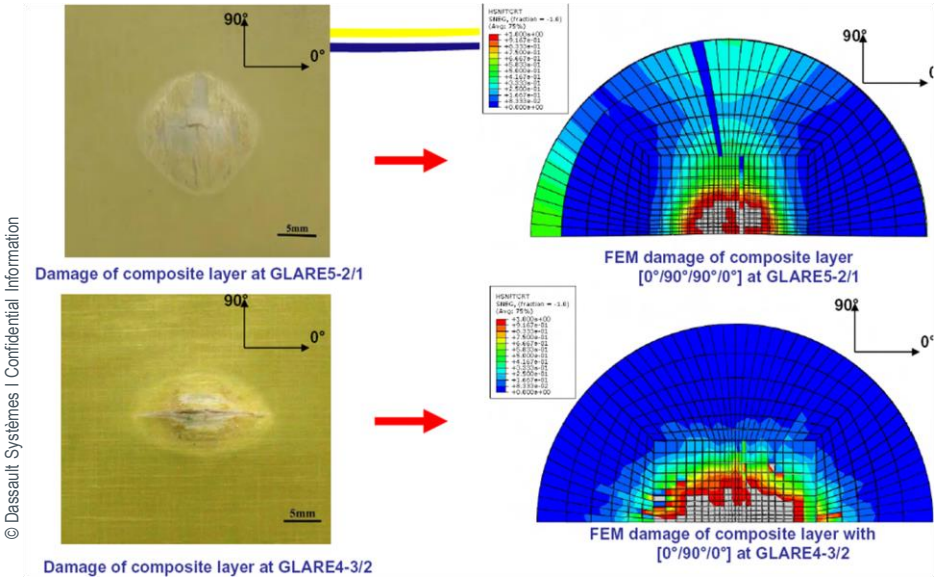


Ballistic Impact



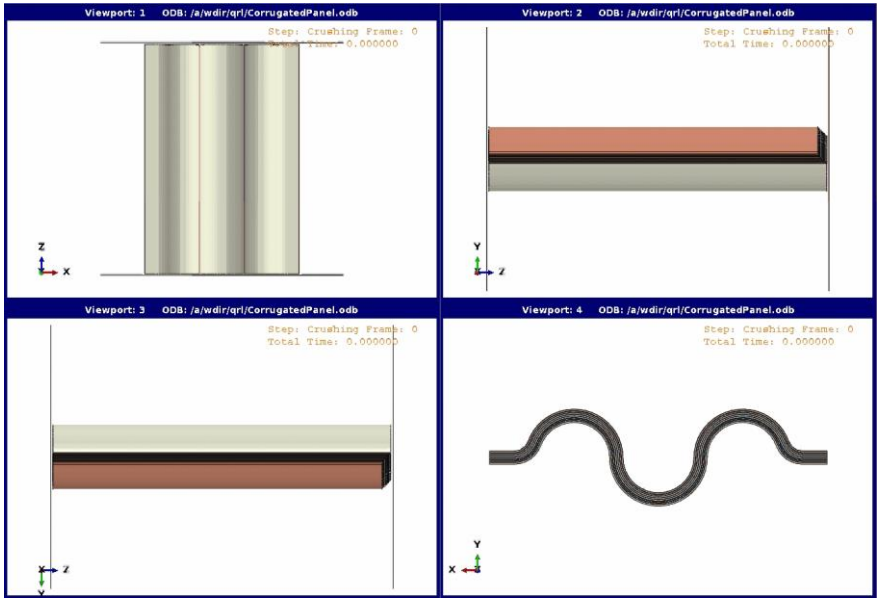
Composites Fracture & Failure

VCCT, Damage modeling, Hashin, Puck, Cohesive for Delamination



BVID using Hashin's criteria

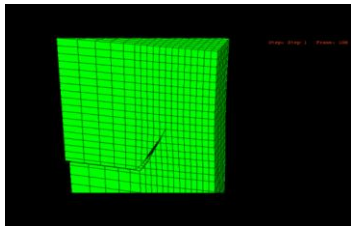
Composites crush using continuum shells, Puck's criteria, cohesive surface for delamination,and general contact

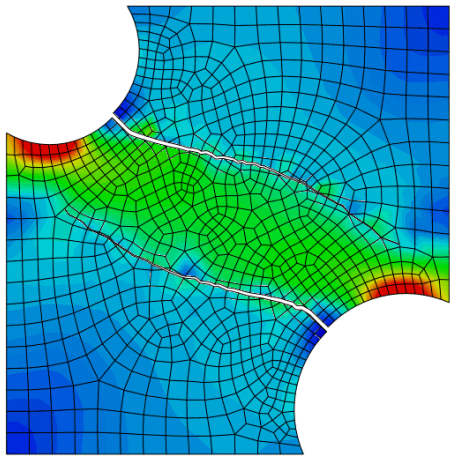


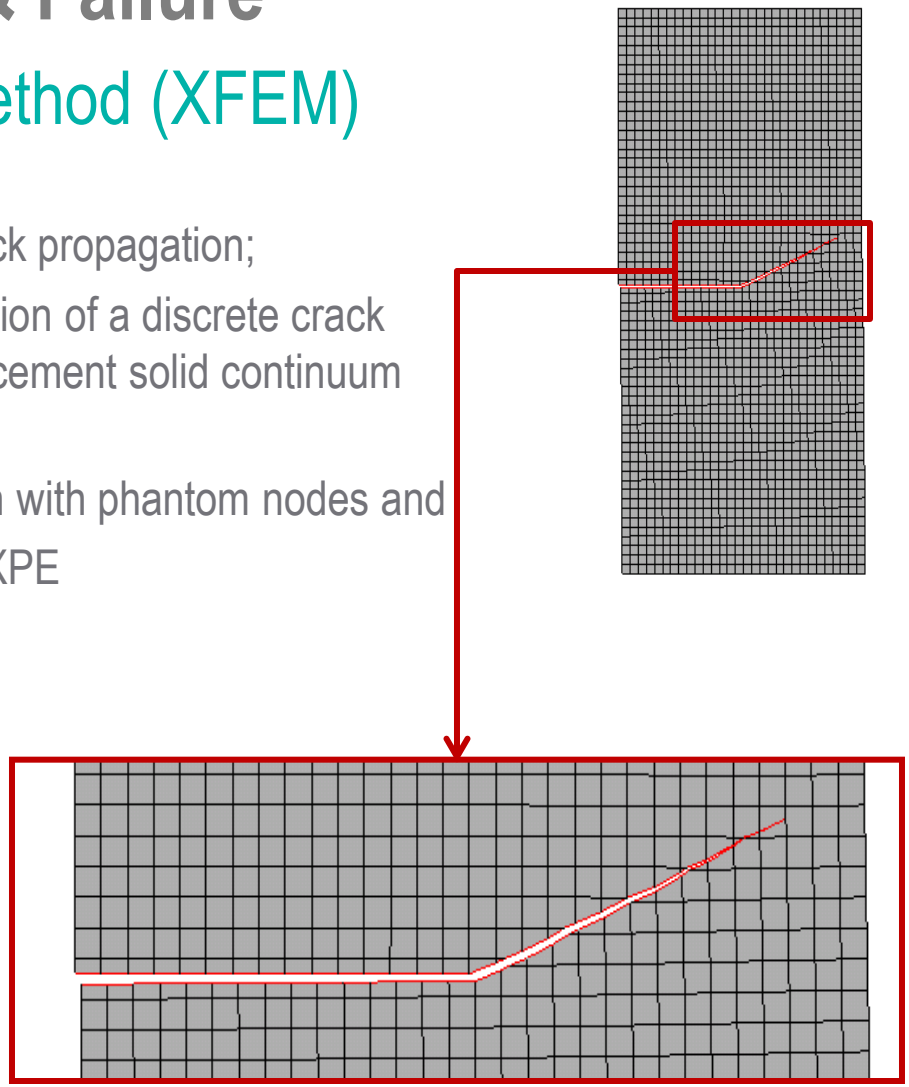
Composites Fracture & Failure

eXtended Finite Element Method (XFEM)

- XFEM was first introduced in 6.9 for modeling crack propagation;
- Support simulation of crack initiation and propagation of a discrete crack along an arbitrary path with 1st order stress/displacement solid continuum elements in a static procedure;
- Use the cohesive segments method in conjunction with phantom nodes and
- The damage initiation is based on MAXPS or MAXPE







How are A&D Customers Using Abaqus?
Kinematic / Mechanism Simulation w/ Control Systems

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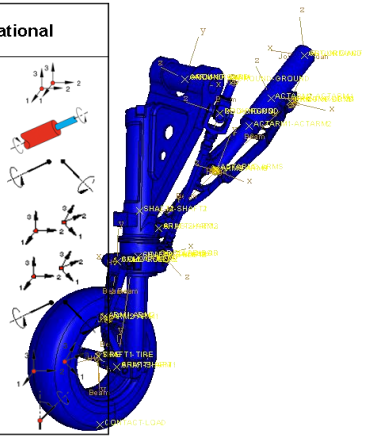
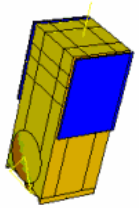
Assembled	Basic translational	Basic rotational
BEAM	LINK	ALIGN
WELD	JOIN	REVOLUTE
HINGE	SLOT	UNIVERSAL
UJOINT	SLIDE-PLANE	CARDAN
CVJOINT	CARTESIAN	EULER
TRANSLATOR	RADIAL-THRUST	CONSTANT VELOCITY
CYLINDRICAL	AXIAL	ROTATION
PLANAR		FLEXION-TORSION

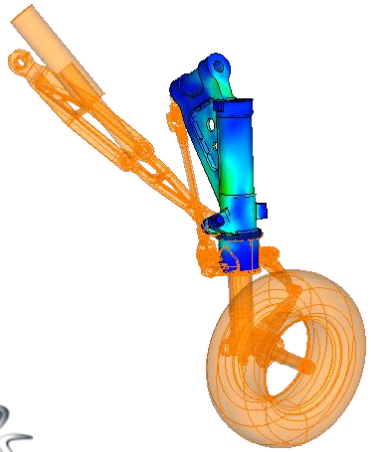


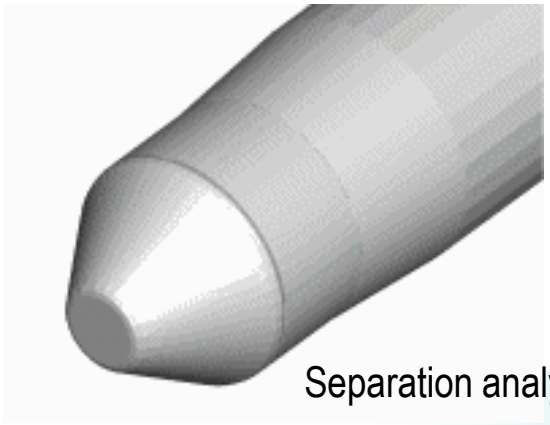
Full library of connector types

Rigid body kinematics

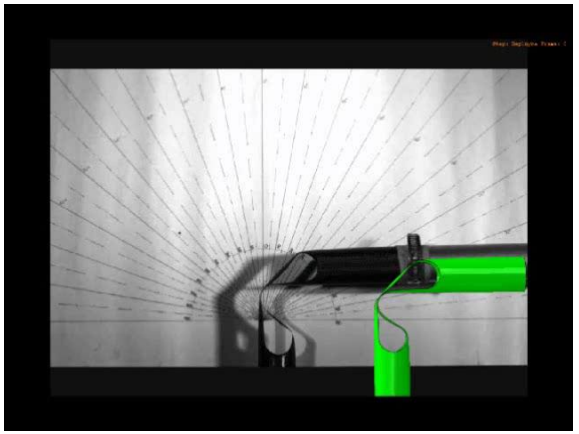


Coupled Mechanisms and Stress Analysis





Separation analysis



Composite Hinges

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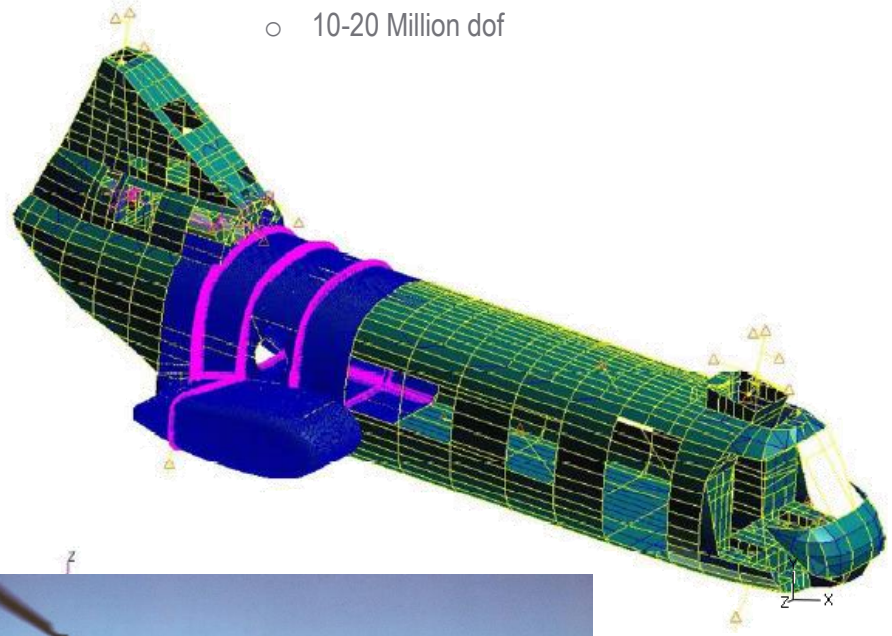
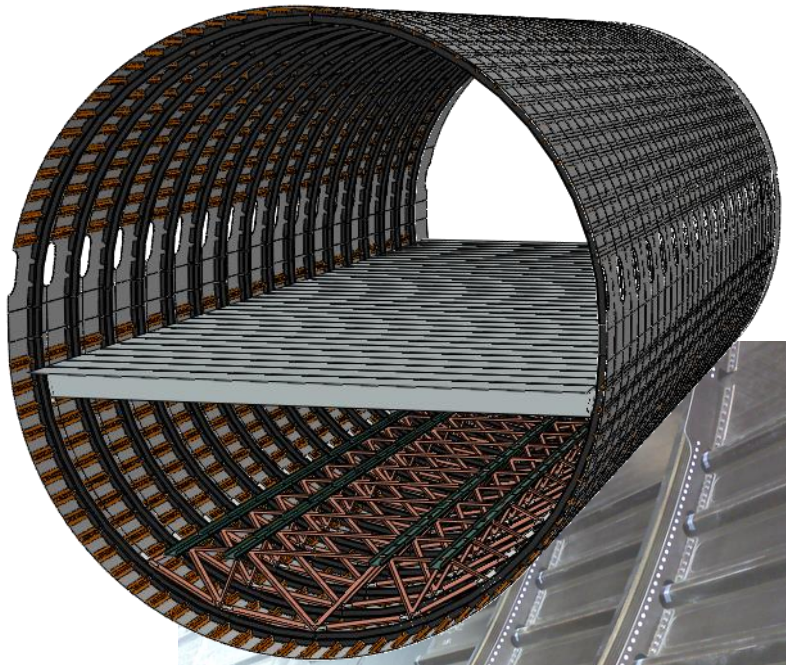
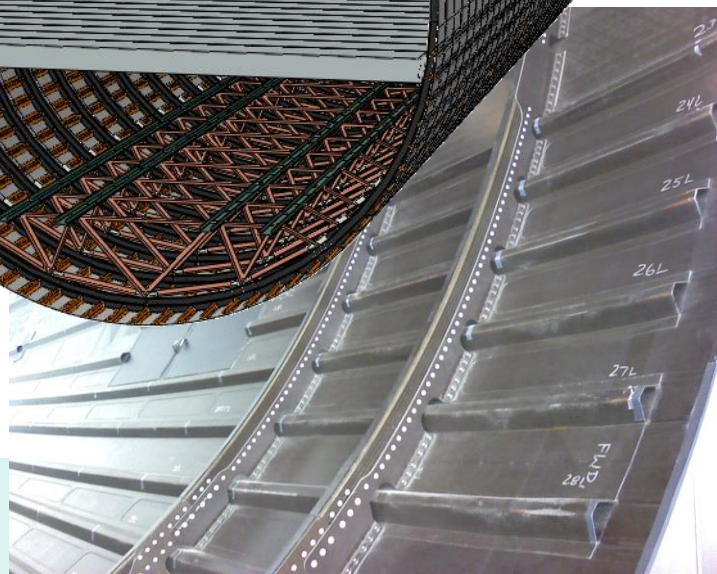
How are A&D Customers Using Abaqus? Large Scale Nonlinear Analysis

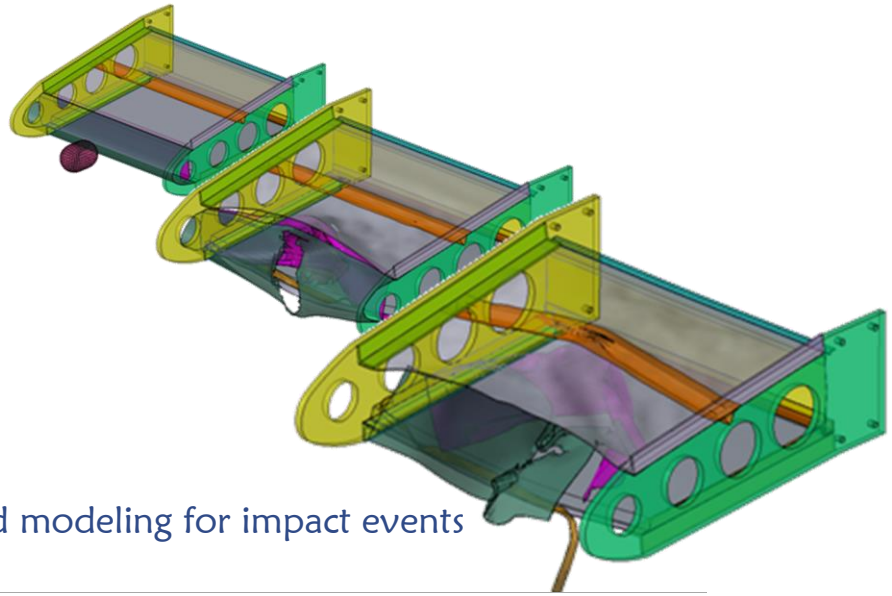
- Full vehicle nonlinear analysis using Abaqus
  - Boeing CH-47 Chinook Helicopter
- Large scale nonlinear analysis
  - Detailed full vehicle models for fuselage and wings
    - 10-20 Million dof





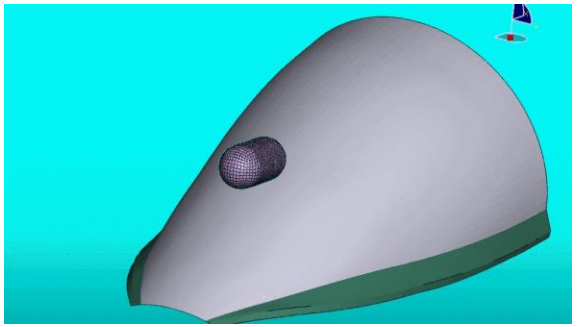


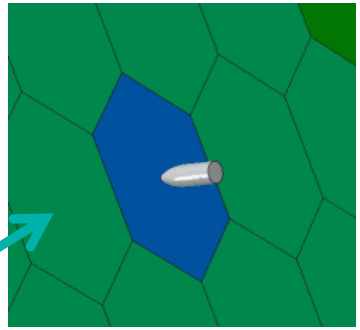
How are A&D Customers Using Abaqus? Severe Events



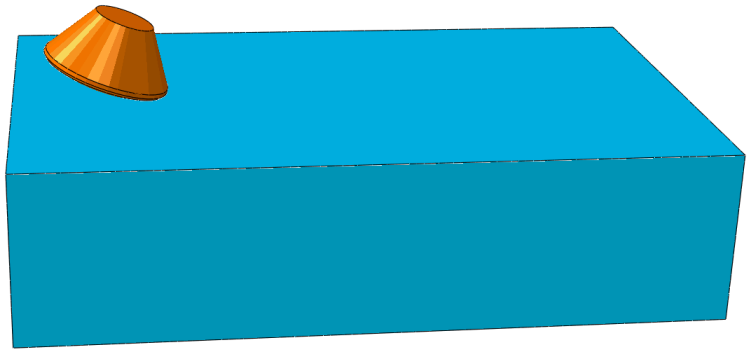
Bird modeling for impact events

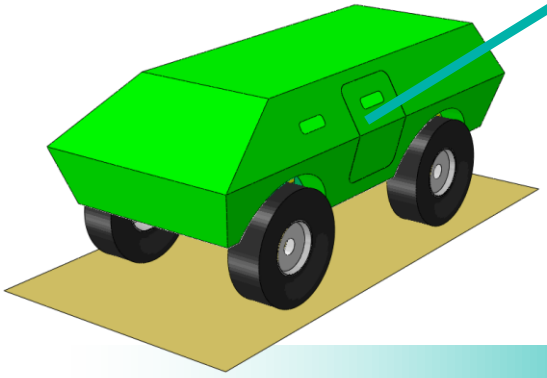
Bird strike on cockpit canopy





Ballistic impact





Reentry Vehicle splash-down

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Interoperability Between Abaqus & Nastran

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Nastran Interoperability was Developed in Response to Customer Needs

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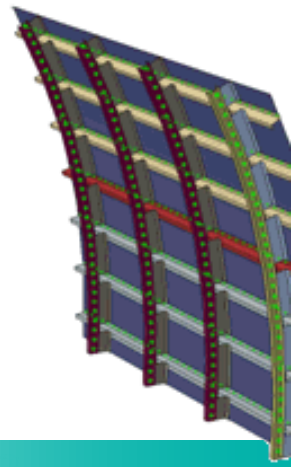
1. Customers want access to the power of the Abaqus solver, but want to continue to use their current pre/post processor
   - Response: *fromNastran* and *toOutput2* translators
2. Customers want to convert legacy Nastran models into Abaqus for more sophisticated simulations
   - Response: Direct import of Nastran models into Abaqus/CAE; where contact, cohesive surfaces, and nonlinear damage models can be applied to the model
3. Customer want to add/include matrix representation models to their Abaqus model
   - Response: Ability to import DMIG models
4. Customers want to use Abaqus/CAE to pre- and post-process their models, but use Nastran as the solver
   - Response: Abaqus/CAE can directly export a Nastran input deck
   - Response: Nastran .op2 files can be converted into an Abaqus .odb result file
5. Customers want to extend their composites models
   - Abaqus/CAE understands Nastran PCOMPG ply definitions and retains the lay-up definitions and ordering on import. Composite models can then be easily extruded into 3D continuum shell models and include composites damage and cohesive surface definitions for delamination analysis.



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Customer Examples

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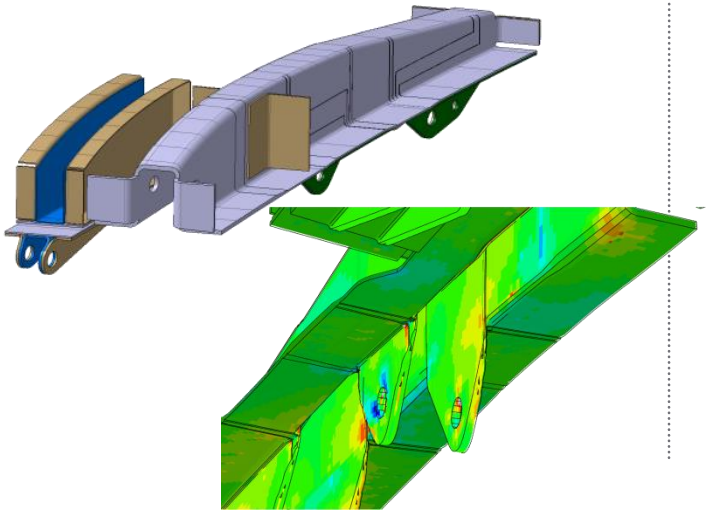
EADS



Customer Profile

EADS (European Aeronautical Defense and Space) is a global leader in aerospace, defense and related services.

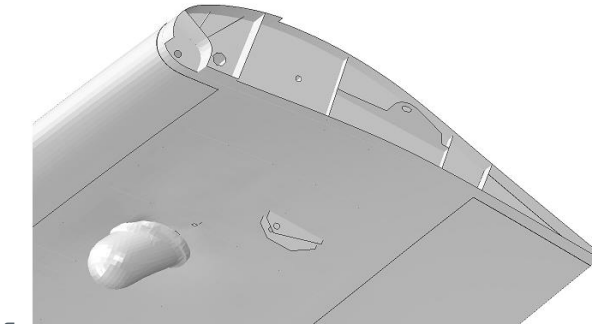
Application

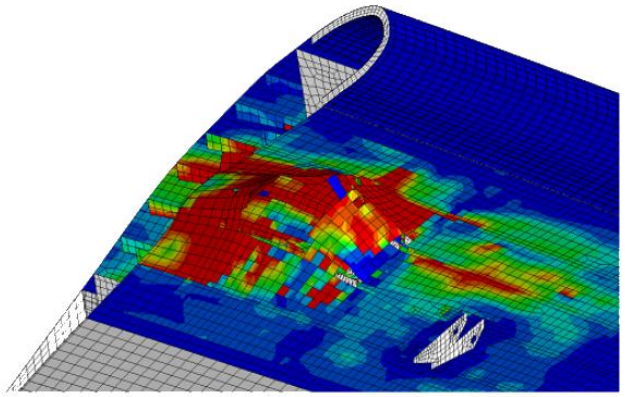
Analysis of an advanced composite load introduction rib (LIR), an important wing flap support structure in the Airbus A340 aircraft.

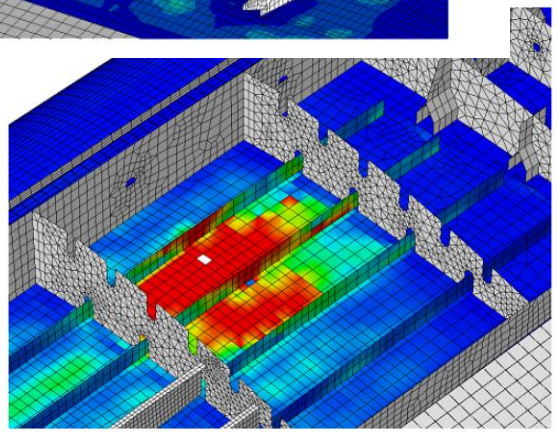
Benefits

FEA assists EADS in continuous innovation for the design of future sustainable “greener, cleaner” aircraft—with lighter weight, greater fuel efficiency, and fewer emissions.

Bird Strike







Customer Profile

Department of Aeronautical Engineering, University of Zagreb uses Abaqus to evaluate bird strike on commercial aircraft.

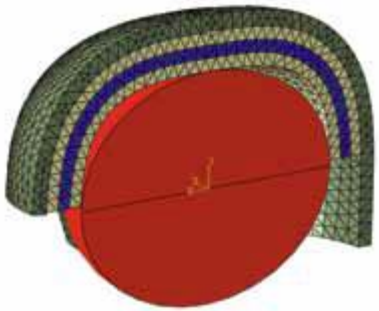
Application

Advanced material models, composites damage, and CEL (Coupled Eulerian Lagrangian) modeling for the bird.

Benefits

To accurate simulate this impact event, you need accurate composite damage models and an accurate bird model.

Making Helmets Safer -- MIT

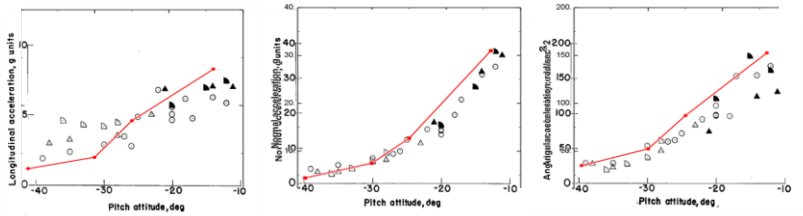


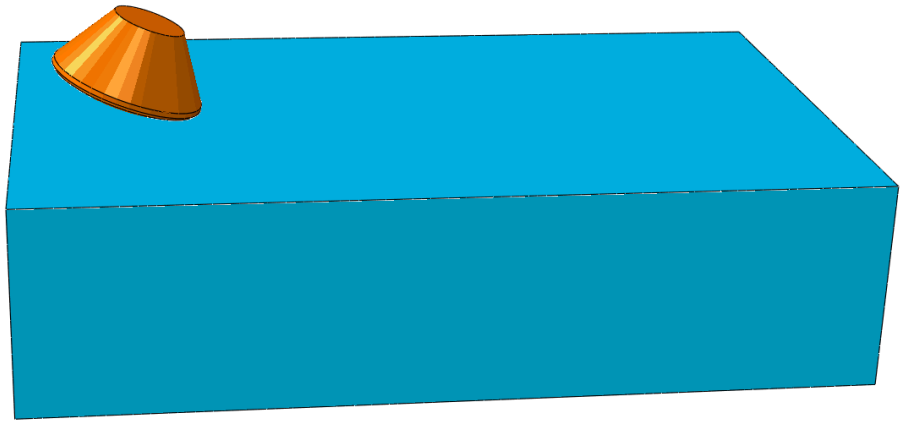
The helmet and head models are Used to benchmarking helmet-liner filler materials.

- MIT Man-Vehicle Laboratory uses Abaqus to explore and improve helmet design to prevent traumatic brain injury caused by blast events
- "Simulating a blast event provides important, realistic data without the risk of involving test subjects", **Andrew Vechart,** *Researcher, MIT, Man-Vehicle Laboratory*

Customer Reference – Apollo Command Module

- Splash down simulation



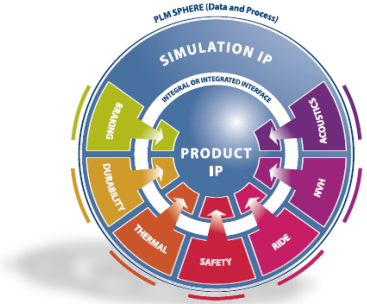


* "Dynamic Model Investigation of Water Pressures and Accelerations Encountered During Landings of the Apollo Spacecraft", Sandy M. Stubbs, Langley Research Center, NASA TN D-3980, 1967

SIMULIA – Your Competitive Advantage

- Unified FEA
  - One product for many types of analyses: Linear, Non-linear, Explicit, Kinematic, CFD, Thermal

- Leader in Advanced Simulation
  - Advanced composites
    - Fracture and failure, XFEM
  - MBD (Multi-body Dynamics)
  - Severe events
  - High performance computing



- Focus on customer satisfaction
  - High-quality products, services, and support

SIMULIA in the A&D Industry

- Industry trends
- Customer examples
- How companies are taking advantage of Abaqus today

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SIMULIA for Aerospace & Defense

www.3ds.com/simulia/aerospace

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