



3DEXPERIENCE®

Acoustic Analysis with Simpack and wave6

North American Multibody Simulation
User Meeting

Brad Heers, Phil Shorter

Why SIMULIA for noise and vibration simulation?

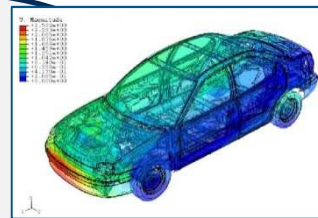
Simpack

multibody dynamics
accurate modeling of high frequency
content of powertrain sources



Abaqus

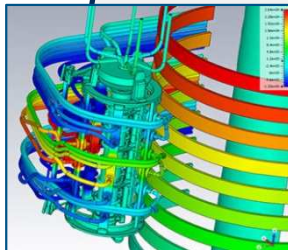
Explicit and Implicit Finite Elements
Best-in-class solvers and materials



SOURCES

CST

electromagnetics
accurate modeling of emag sources
in electric machines/vehicles

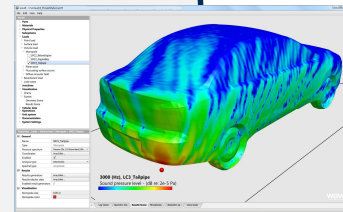


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PATHS

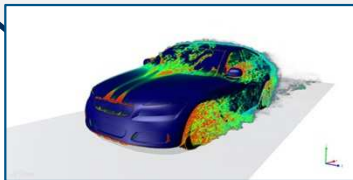
wave6

vibro-acoustics and flow noise
full spectrum analysis methods



xflow

unsteady CFD
accurate and fast modeling of
aerodynamic sources in flow noise

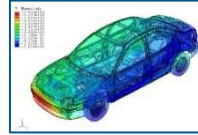


SIMULIA has best in class tools for modeling both the sources and the transmission of noise and vibration

Vibration (“Noise”) at the Vehicle Level

- ▶ “1D” System Approach

- ▶ “FE Approach”



- ▶ “Multi-Body Approach”



Critical Assumptions in (Noise and) Vibration

- ▶ “In-situ” conditions
- ▶ Sources (internal, external, etc.)
- ▶ Joints, bushings, etc
- ▶ Damping
- ▶ Accurately capturing system stiffness and mass
 - ▷ “Substructures”, “FE-bodies”, “flex bodies”, etc.
- ▶ Scalability to large systems and frequency ranges

Traditional 1D Approach

- ▶ “In-situ” conditions
- ▶ Sources (internal, external, etc.)
- ▶ Joints, bushings, etc
- ▶ Damping
- ▶ Accurately capturing system stiffness and mass
 - ▷ “Substructures”, “FE-bodies”, “flex bodies”, etc.
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Traditional FE approach

- ▶ “In-situ” conditions
- ▶ Sources (internal, external, etc.)
- ▶ Joints, bushings, etc 
- ▶ Damping 
- ▶ Accurately capturing system stiffness and mass 
 - ▷ “Substructures”, “FE-bodies”, “flex bodies”, etc.
- ▶ Scalability to large systems and frequency ranges 

Traditional Multi-Body Approach

- ▶ “In-situ” conditions 
- ▶ Sources (internal, external, etc.) 
- ▶ Joints, bushings, etc 
- ▶ Damping
- ▶ Accurately capturing system stiffness and mass
 - ▷ “Substructures”, “FE-bodies”, “flex bodies”, etc.
- ▶ Scalability to large systems and frequency ranges

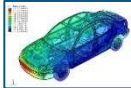
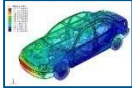
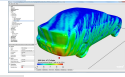
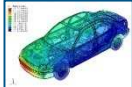
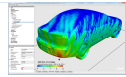
Simpack's Advantages over “Traditional” MBD...

- ▶ Less numerical damping
 - ▷ “Better damping”
 - ▷ More accurate source paths through joints, etc.

- ▶ Powerful linearization and frequency response capabilities
 - ▷ Allows “in-situ” with frequency-based responses
 - ▶ Considerable investment in this approach over last two development cycles

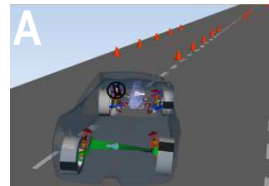
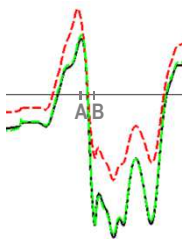
- ▶ Large degree-of-freedom flexible bodies and integration into FE codes
 - ▷ Including Abaqus

Simpack Approach (with integrated technologies)

- ▶ “In-situ” conditions   
- ▶ Sources (internal, external, etc.)  
- ▶ Joints, bushings, etc  
- ▶ Damping    
- ▶ Accurately capturing system stiffness and mass   
 - ▷ “Substructures”, “FE-bodies”, “flex bodies”, etc.
- ▶ Scalability to large systems and frequency ranges    

Flexbody: a variety of options (Abaqus-Simpack)

Simpack linear reduced



Abaqus/Std

Simpack nonlin. reduced

Small deformation

- Increased efficiency for NVH and acoustics
- Substructuring for fluid structure coupling in Simpact
- Flex. body preparation on 3DX platform

Large deformation – reduced

- Research project has been finished
- Project work to study accuracy/efficiency
- Discover synergies with surrogate modeling and machine learning to increase robustness
- Release date: TBD

Large deformation – detailed

- Co-simulation Simpact & Abaqus/XPL
 - speed-up by factor 3
- Co-simulation Simpact & Abaqus/STD
- Generic Interface to couple any flex. body physics with Simpact through a flex. body user routine

Logical

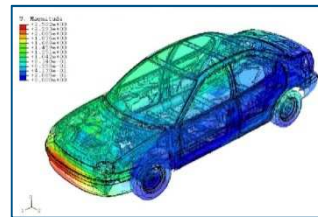
Multi-scale

3D Physical

Combining SIMULIA Products & Technologies

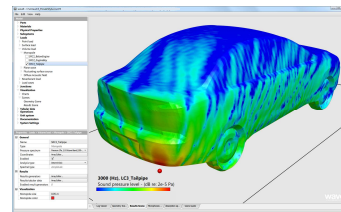
Simpack

multibody dynamics
accurate modeling of high frequency
content of powertrain sources



Abaqus

Explicit and Implicit Finite Elements
Best-in-class solvers and materials

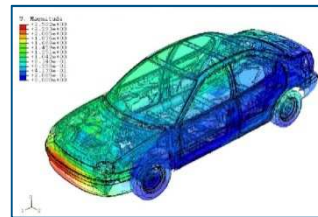


wave6

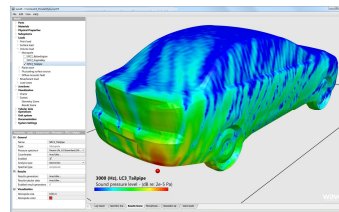
vibro-acoustics and flow noise
full spectrum analysis methods

Combining SIMULIA Products & Technologies

Simpack
multibody dynamics
accurate modeling of high frequency
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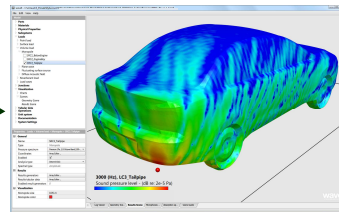
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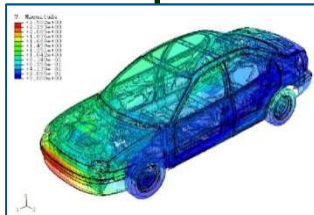
Simpack
multibody dynamics
Powertrain Sources
Chassis sources and paths



wave6
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Abaqus

Substructures used to generate
flexible bodies
Recovery matrices directly within
Simpack





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Acoustic Analysis with Simpack and wave6

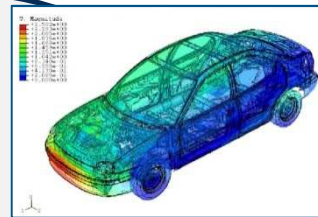
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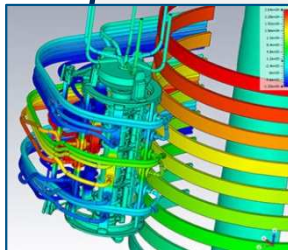


Abaqus

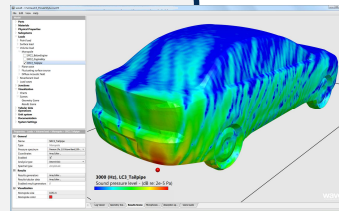
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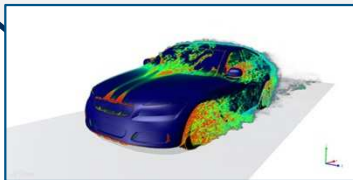


wave6

vibro-acoustics and flow noise
full spectrum analysis methods

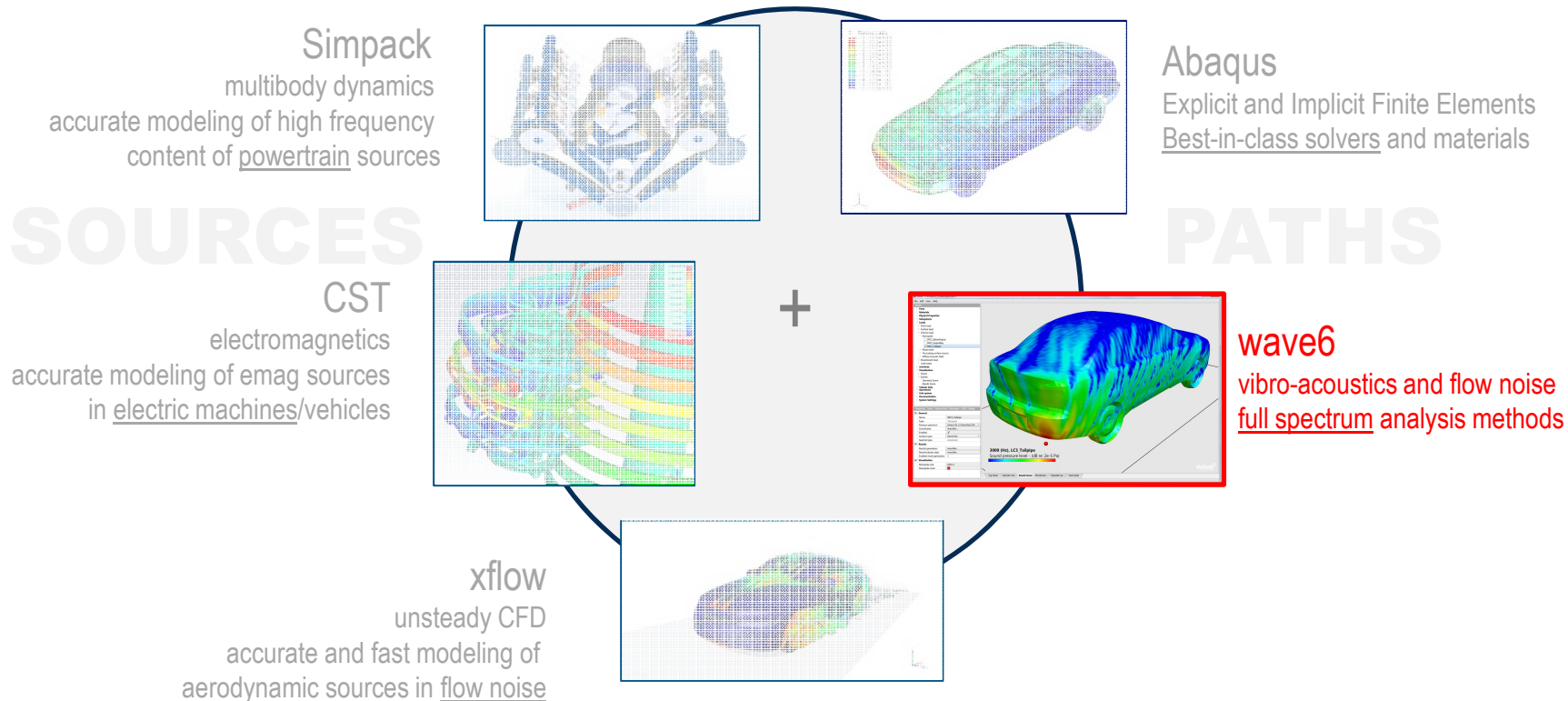
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unsteady CFD
accurate and fast modeling of
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SIMULIA has best in class tools for
modeling both the sources and the
transmission of noise and vibration

What is wave6?



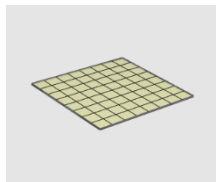


we have released a new standalone product called “wave6” for accurate simulation of noise and vibration (including flow induced noise and vibration) across a broad frequency range

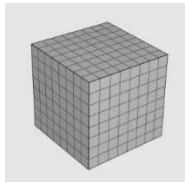
wave6 accurately models wave propagation in structures, fluids, foams and fibers ... across the audible frequency range (120 dB = 1e6)

wave6 : vibro-acoustic analysis methods

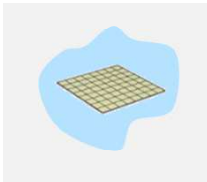
Low frequency (deterministic)



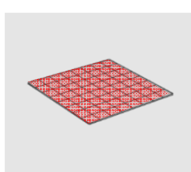
Finite Element
(FE) structure



Finite Element
(FE) acoustics

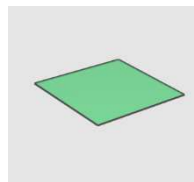


Boundary Element
(BEM) and APML
infinite acoustic
fluids

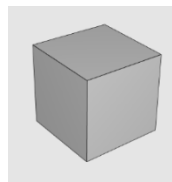


Poroelastic (Foam)
Finite Elements
(PEM)

Mid frequency (mixed)



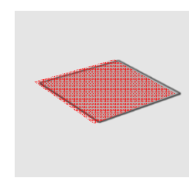
Statistical Energy
Analysis (SEA)
structure



Statistical Energy
Analysis (SEA)
cavities



Statistical Energy
Analysis (SEA)
infinite acoustic
fluids



Poroelastic (Foam)
noise control
treatments

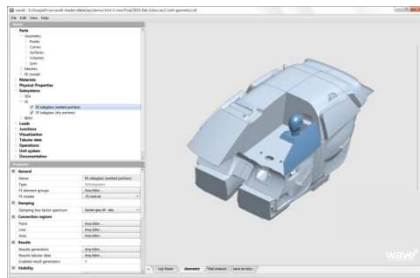
High frequency (statistical)

wave6 contains all of the main vibro-acoustic methods in a single environment with a single license feature
(a “power session” license is also available for solving on unlimited hardware)

Methods can be combined together in the same model for more accurate predictions

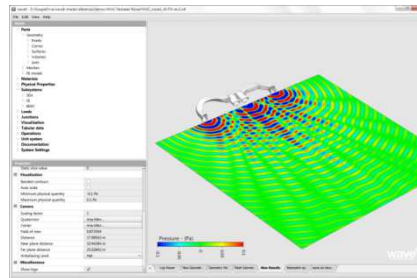
Example applications

Aero-vibro-acoustics (FE+BEM+SEA+CFD)



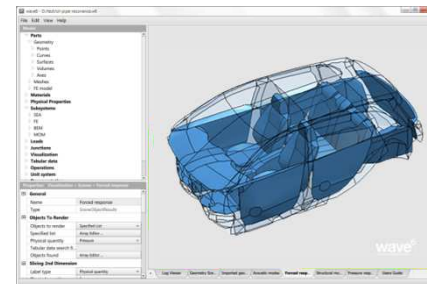
Side mirror interior “wind noise”

Vibro-Acoustics (FE + BEM)



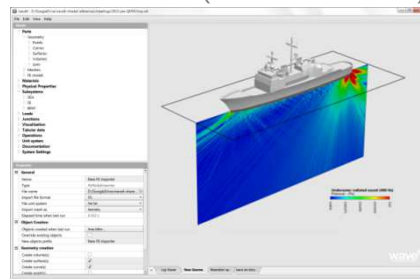
HVAC and muffler “shell noise”

Vibro-Acoustics (SEA)



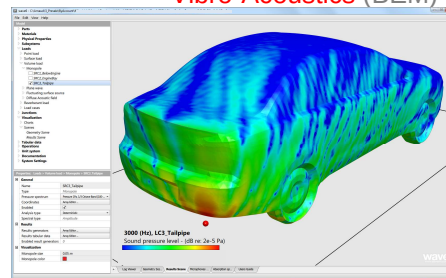
Sound package design

Aero-Acoustics (FE + BEM + CFD)



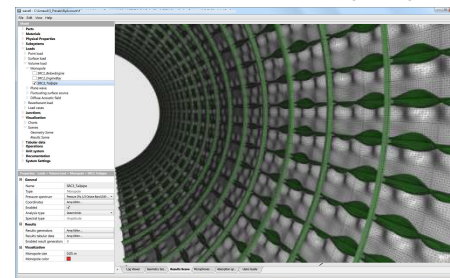
Hydro-acoustics (“installation effects”)

Vibro-Acoustics (BEM)



Exterior diffraction (“pass-by noise”)

Vibro-Acoustics (SEA)



Aircraft/launch vehicle interior noise

Aerodynamic side mirror interior “windnoise” : Daimler

Experiment

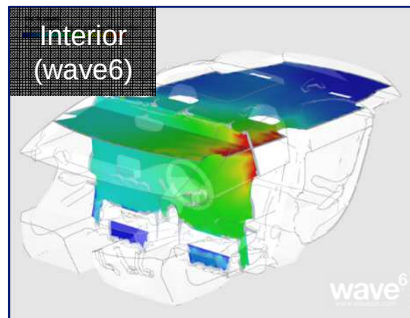
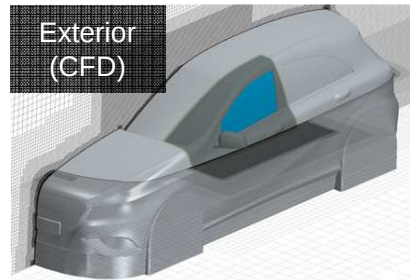


Figure 1: Mercedes-Benz A-class with blocked underbody flow and interior microphone array

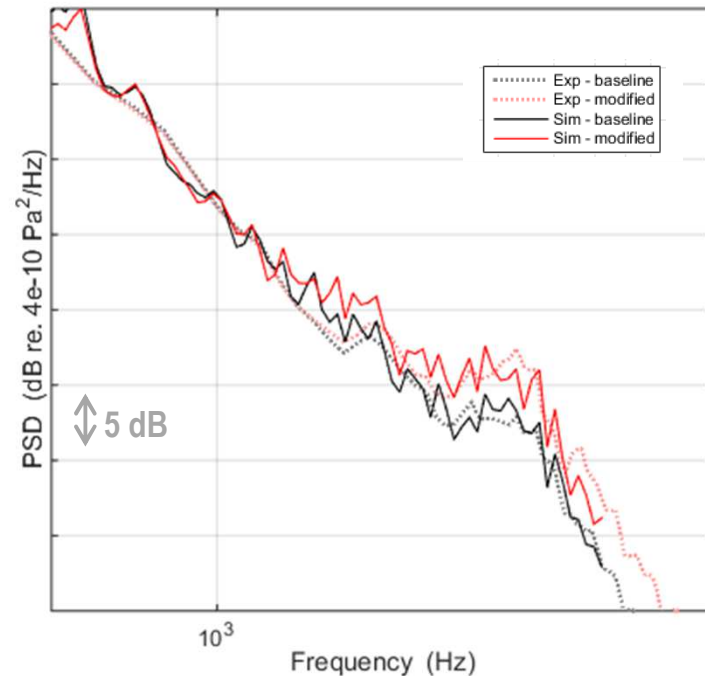


Figure 2: Side mirror modification (4 mm forward facing diffusor step)

Simulation



Drivers ear SPL (prediction vs. test)



A. Schell et al, “Flow Induced Interior Noise Prediction of a Passenger Car” Proc. SAE N&V 2017

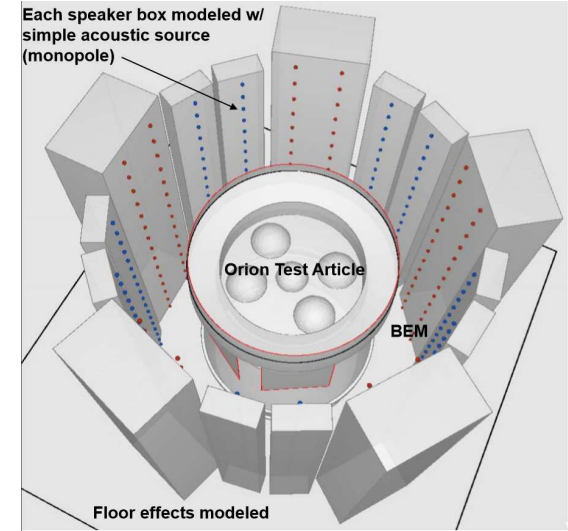
Large fully coupled FE/BEM models: NASA and Lockheed Martin



Image credit: NASA



Image credit: NASA



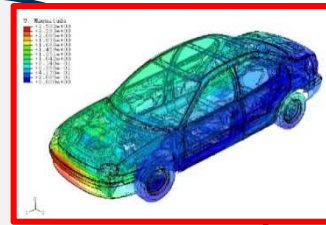
wave6 FE/BEM model

I. Dandaroy "Analytical Tool for Numerically Simulating a Direct Field Acoustic Test" Proc. SCLV 2017

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accurate modeling of high frequency
content of powertrain sources



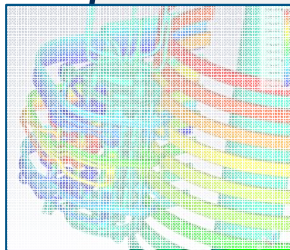
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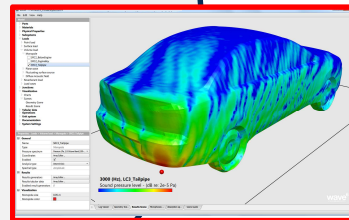
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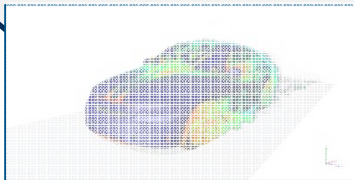


wave6

vibro-acoustics and flow noise
full spectrum analysis methods

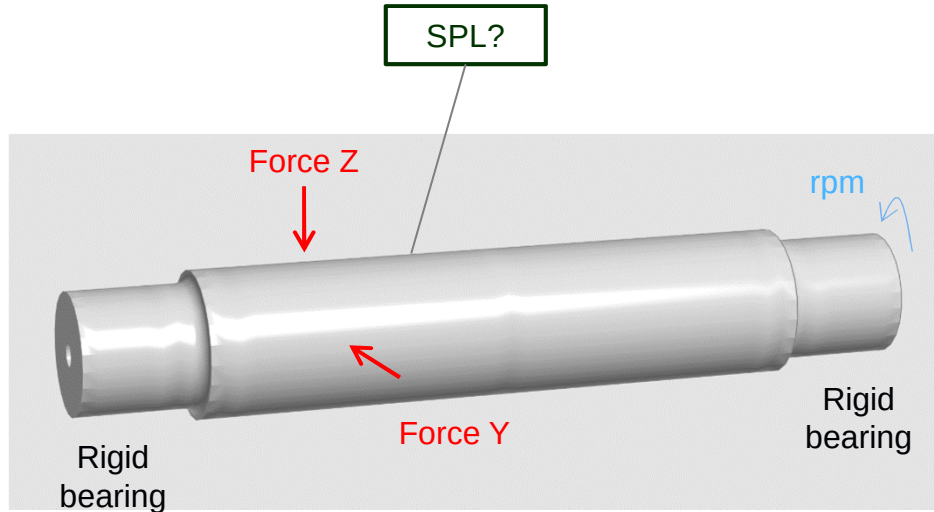
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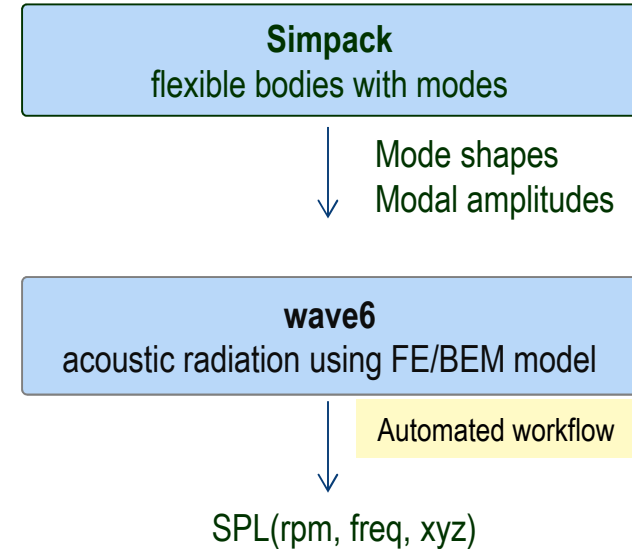


Simple example to demonstrate the
combined use of simpack and wave6

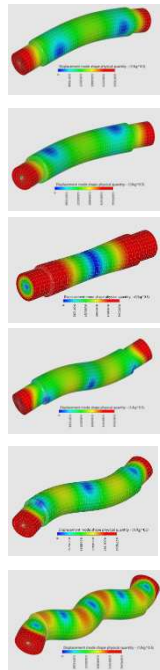
Example : noise from a rotating shaft



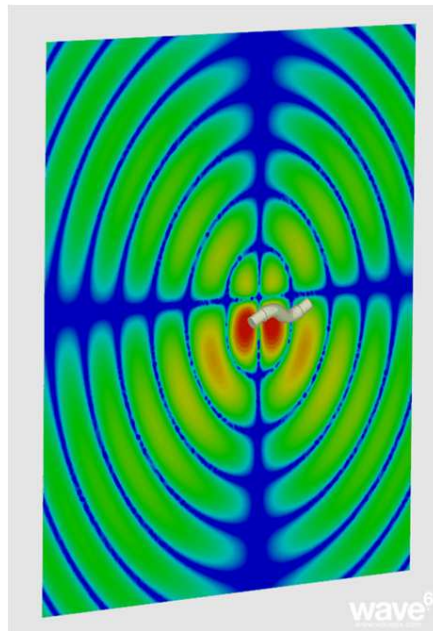
Analysis process



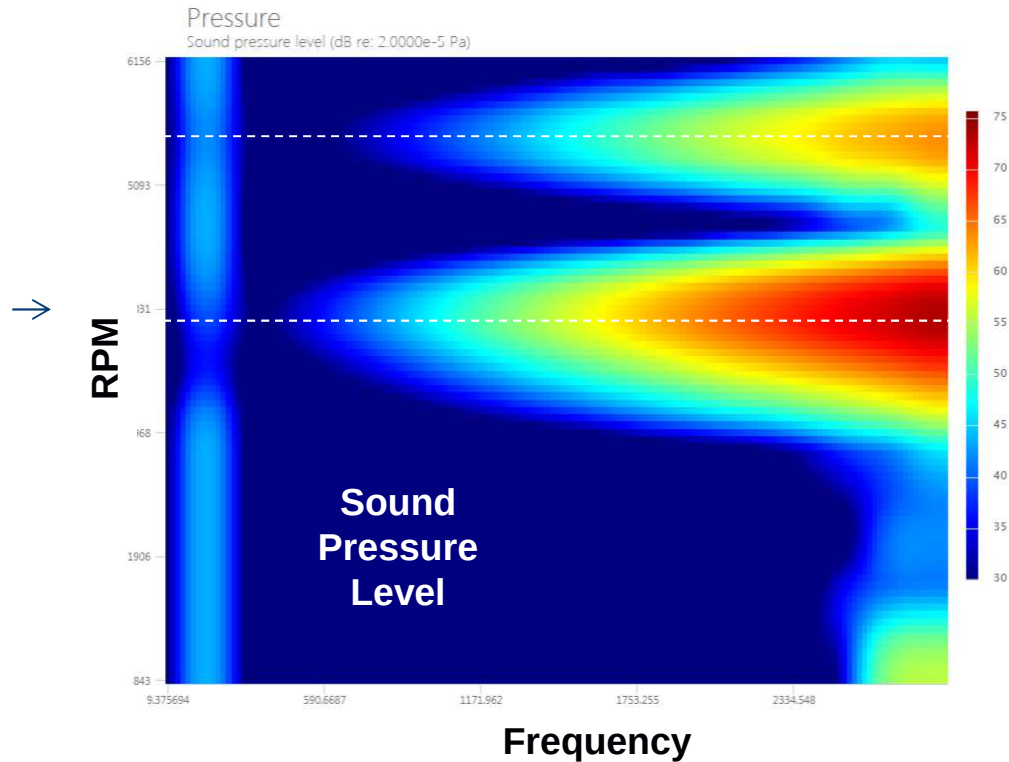
Modal contributions to SPL (and SPL vs rpm/freq)



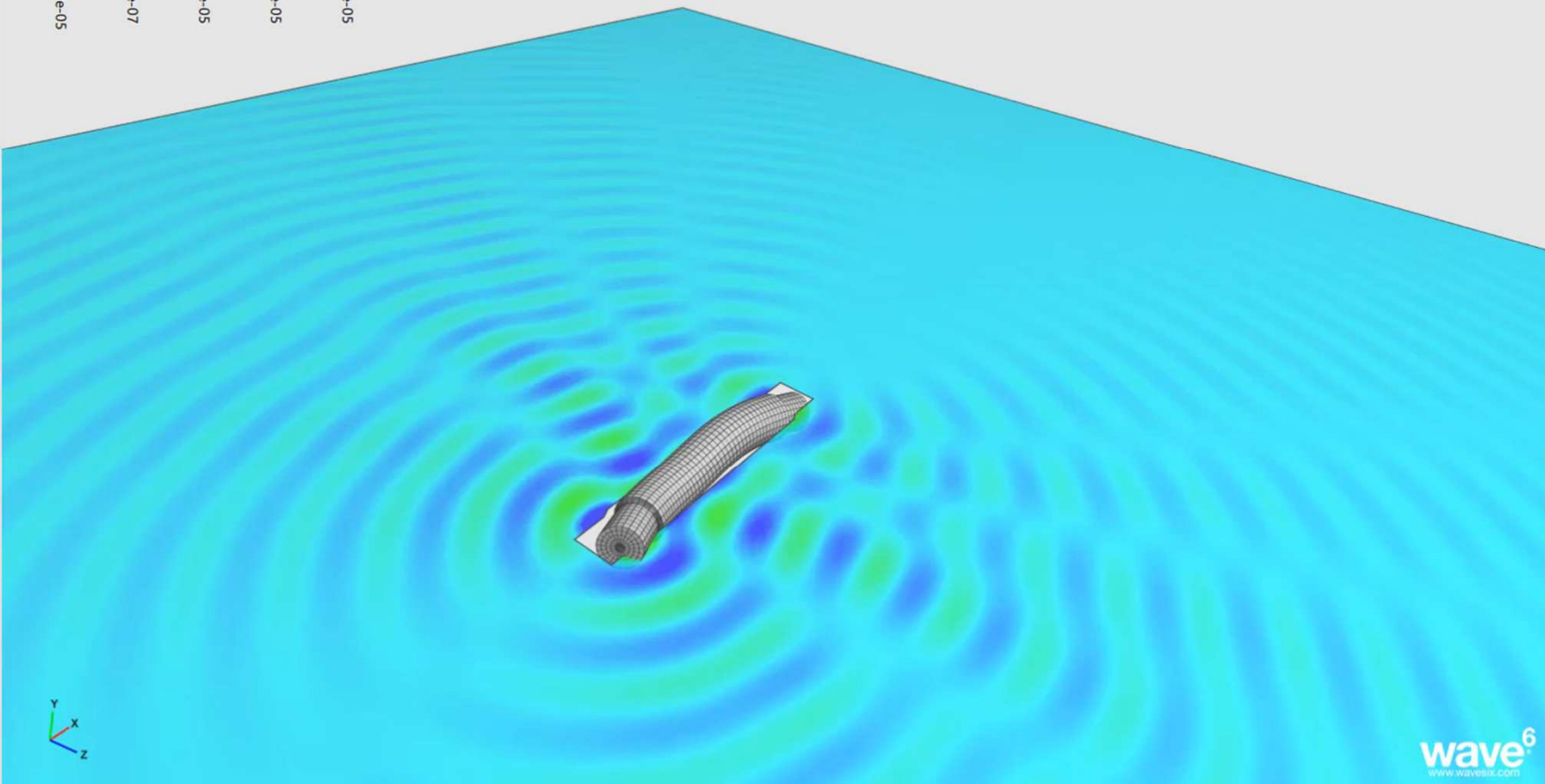
Modes



Mode 4 : SPL@2kHz



Pressure - (Pa)
Forced response (10 kHz)



Radiated
acoustic
field at
10kHz

Summary

- SIMULIA can help you model both the sources and transmission of N&V
- wave6 = next generation software for “full spectrum” vibro-acoustics
- includes automated “templated/pipelined” workflows
- Makes it easy to predict radiated sound from a SIMPACK model
- (you don’t have to be an acoustics expert to predict/diagnose SPL)
- Simple shaft example created to demonstrate the process
- Combines SIMPACK + ABAQUS + wave6
- Contact us for more information

