



Durability Assessment Comparison Using Frequency Domain (PSD) and Modal Time Histories Approach



ALBERTO SIGNORINI
SOUTH EUROPE – VIRTUAL ENGINEERING
Vehicle Body & Closures Exteriors Structural Validation Manager

Nicola Moliterno
Gennaro Daniele Trinchillo
SOUTH EUROPE – VIRTUAL ENGINEERING
Vehicle Body Structural Validation Specialist

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1. INTRODUCTION

2. PSD to TIME HISTORIES to PSD

3. MODAL SUPERPOSITION VS DIRECT FRF

4. SHEET METAL RESULTS COMPARISON

5. SPOT WELDS RESULTS COMPARISON

6. TIMING ANALYSIS

7. CONCLUSIONS

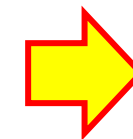
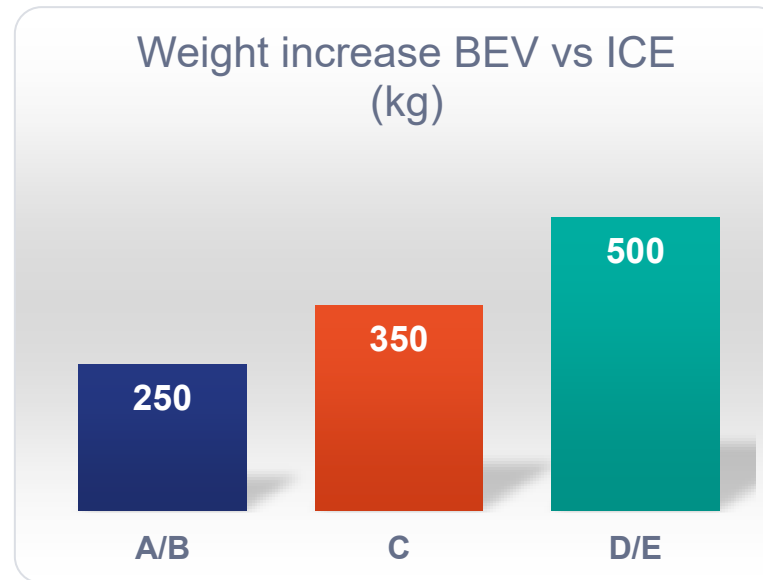
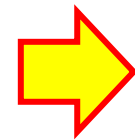


Steady growth in BEV share in Europe and globally

- Increasingly stringent CO₂ regulations
- Rapid expansion of manufacturers' BEV portfolio
- Reduction of battery costs and increased range
- Development of charging infrastructure
- Increased environmental awareness among customers

Why BEVs Weigh More:

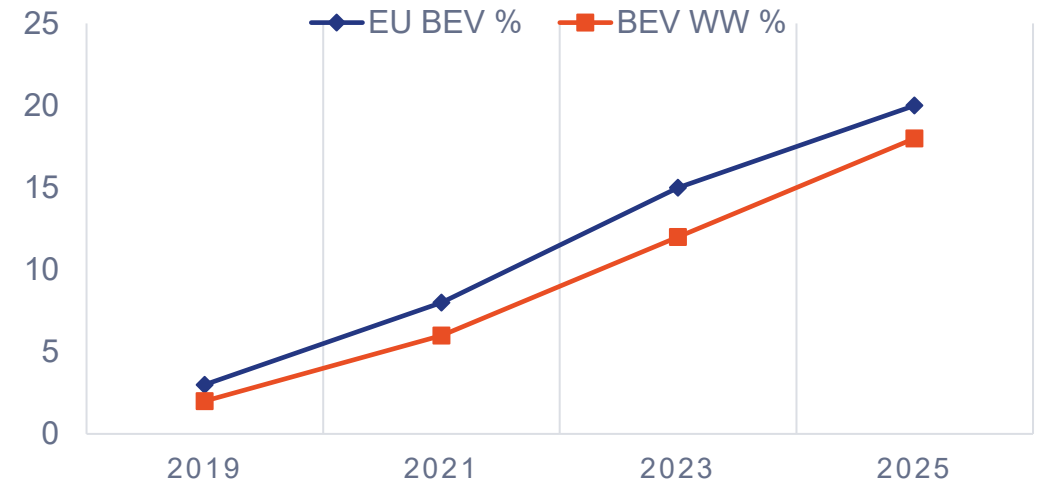
- High-capacity Batteries
- Dedicated Vehicle Architecture
(Crash, Durability, Undebody contacts)



Implications:

- Energy Efficiency
- Structure and Component Sizing

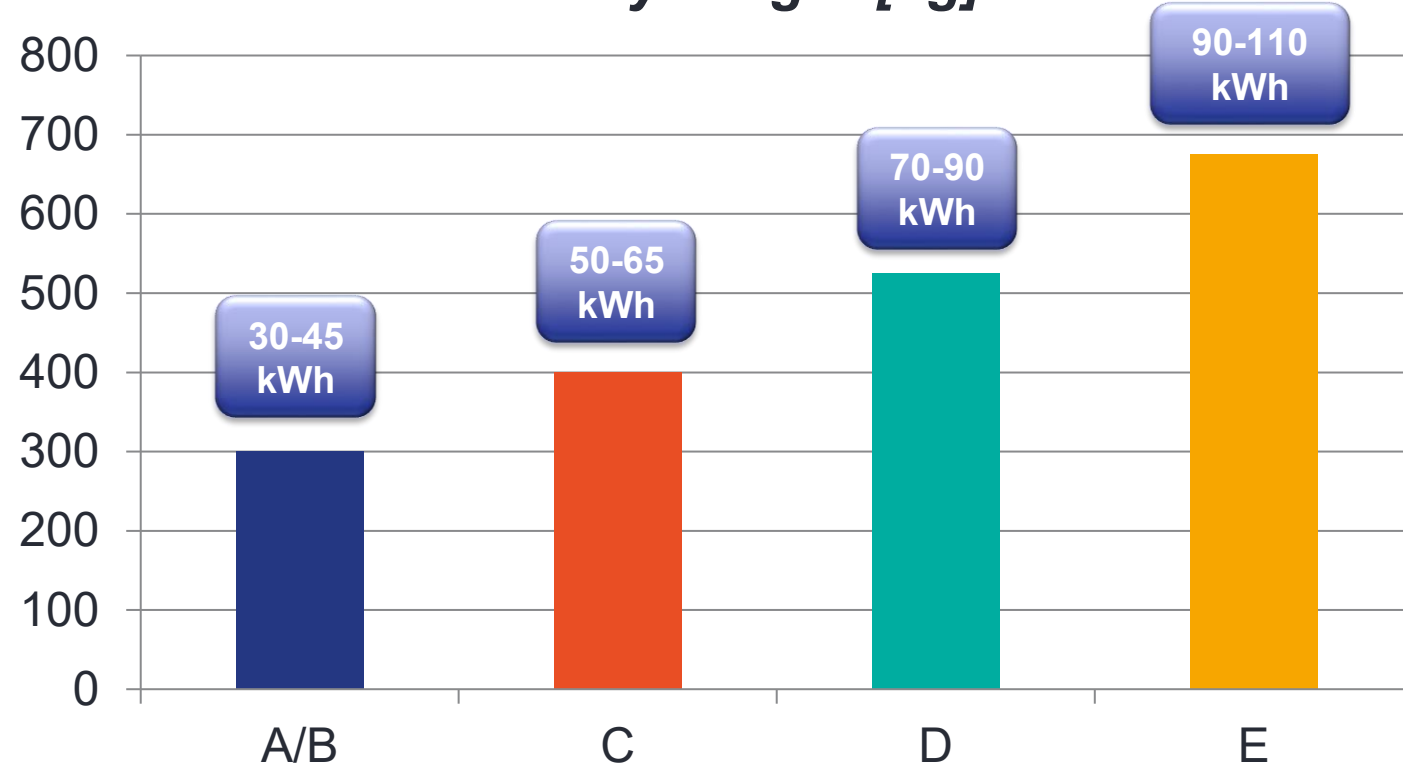
BEV Market Presence



Electronic device



Battery weight [kg]





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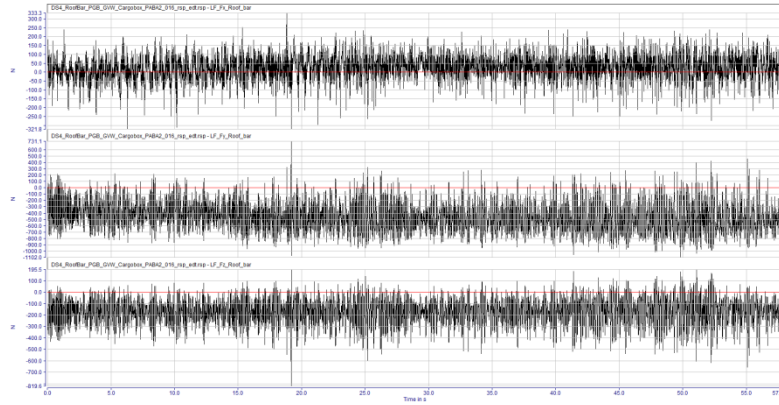
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Time Histories Consolidated approach for Body / Chassis / components durability validation



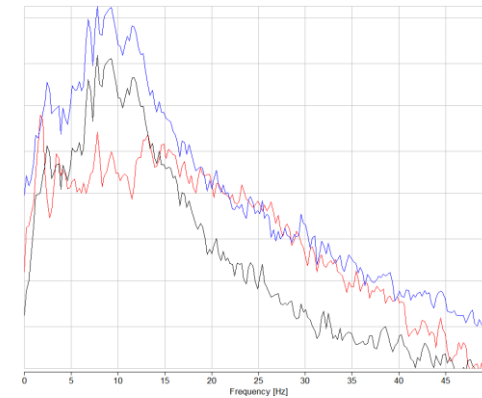
PRO

- Load time histories can analyze transient events and limit conditions, which are essential for non-stationary problems.
- They account for the superposition of effects.
- Deterministic, they represents the real usage of the vehicle

CONS

- High computational cost
- Dependence on signal quality

PSD (Generally used for electronic devices)



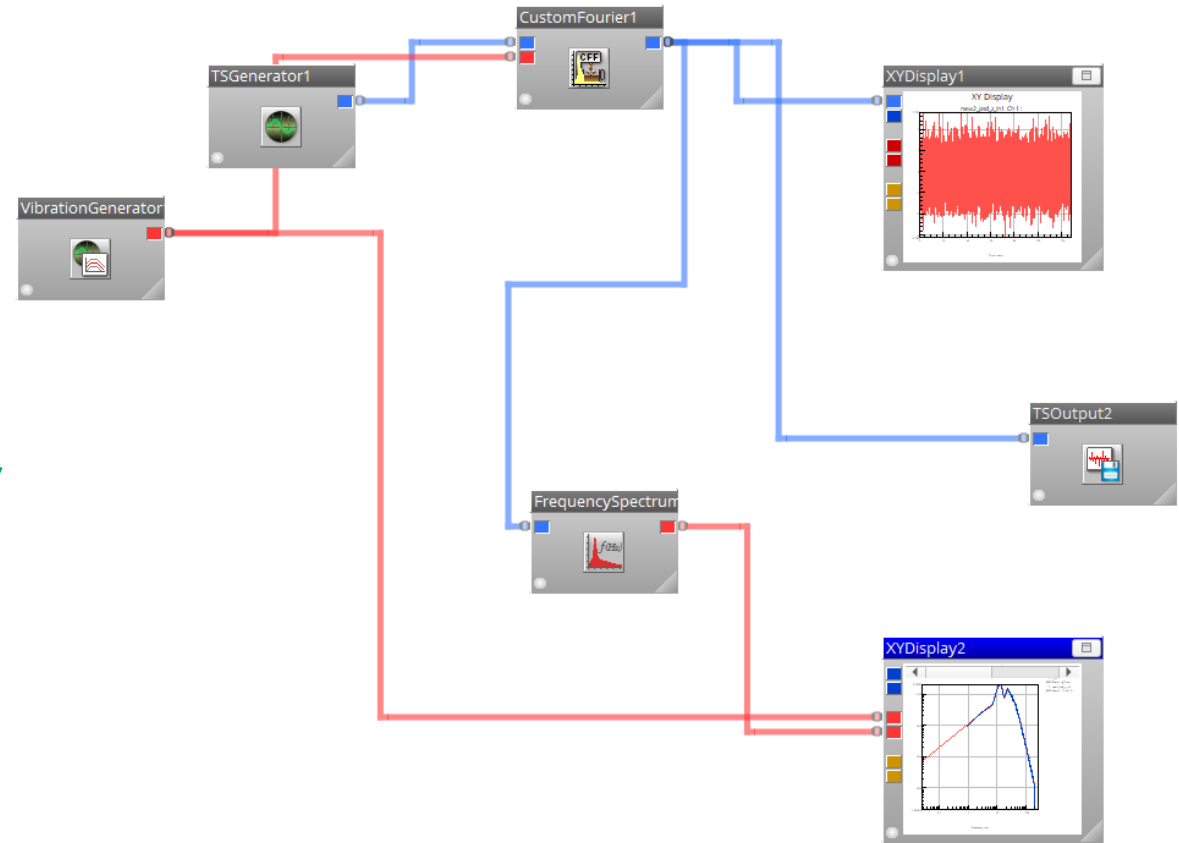
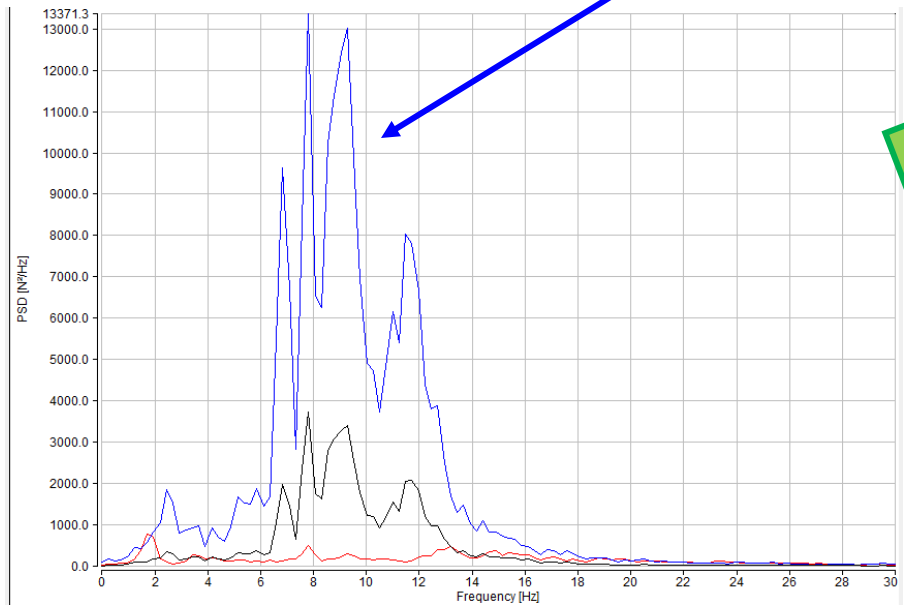
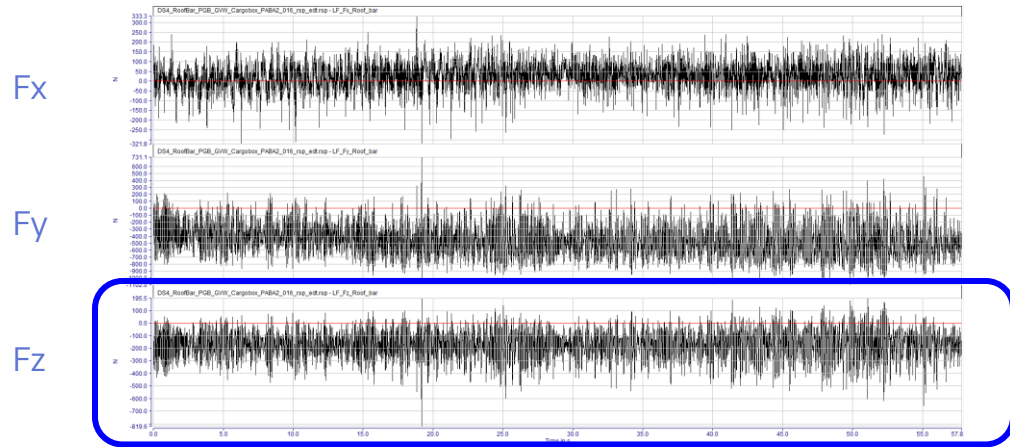
PRO

- The PSD method reduces computation time
- It provides statistically robust results

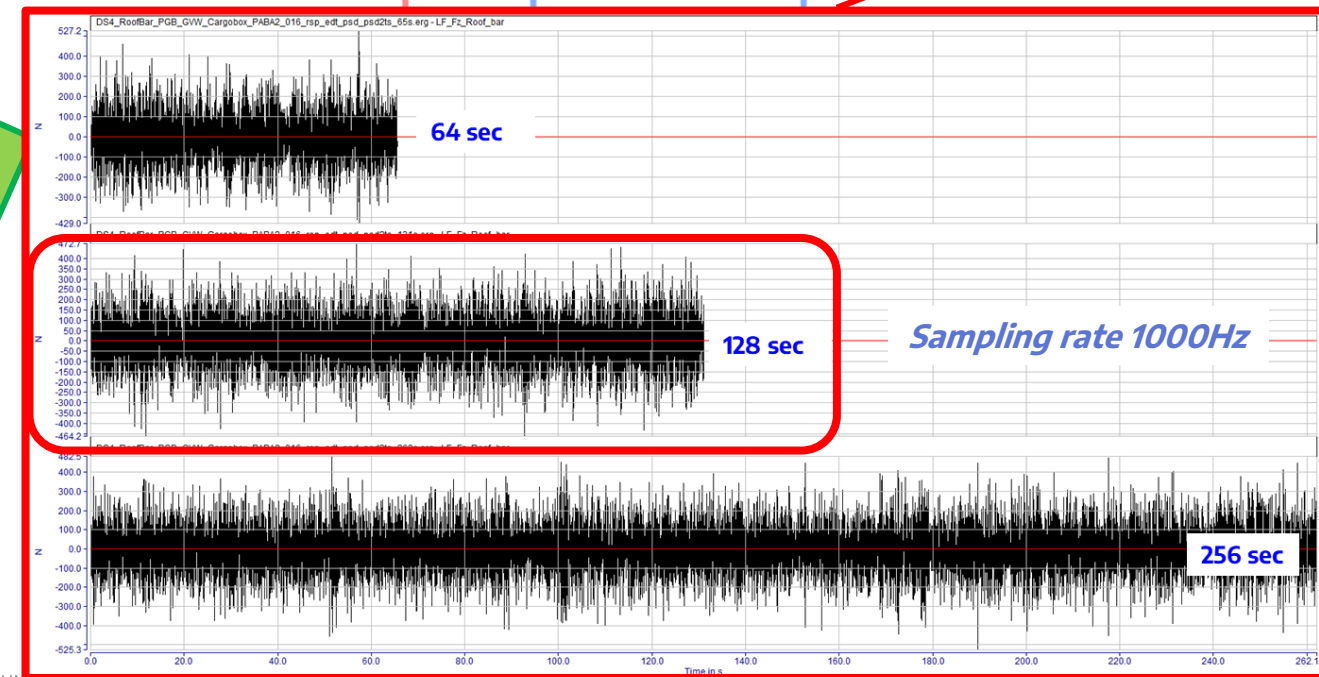
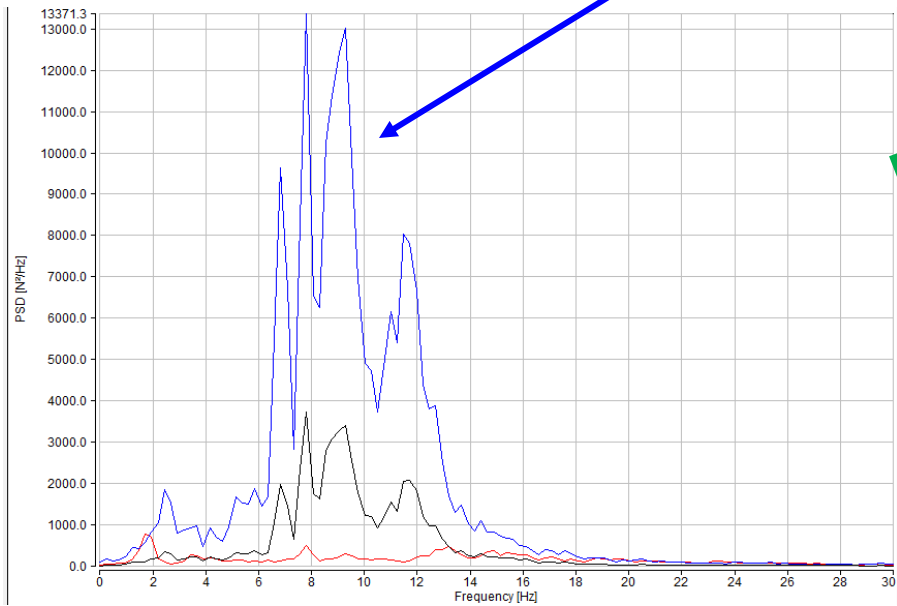
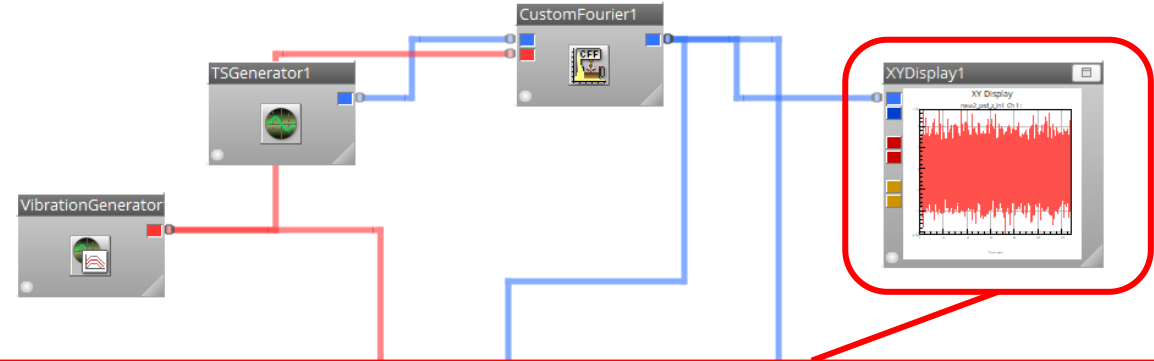
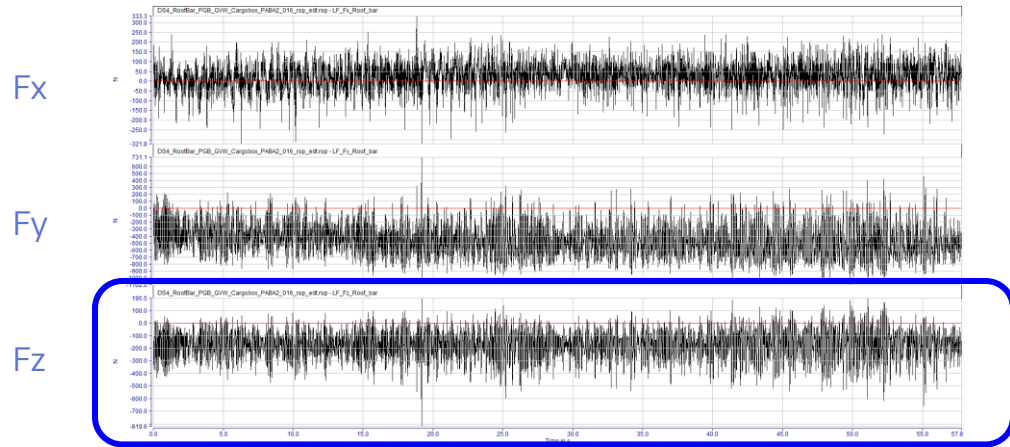
CONS

- Loss of time-domain information
- Requires stationary phenomena
- Does not account for the superposition of inputs and directions
- Loss of mean stress and phase influence

nCode Flow from PSD to Time Histories



nCode Flow from PSD to Time Histories



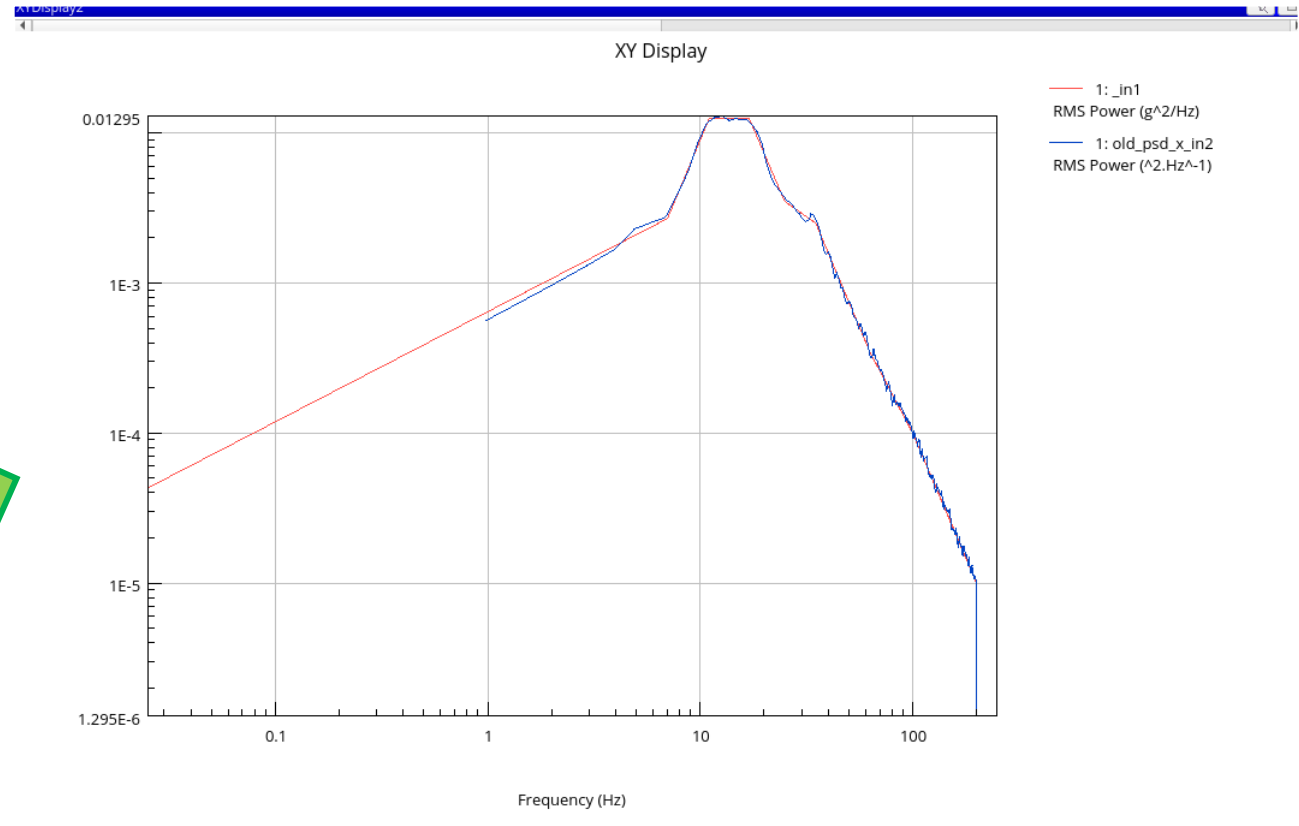
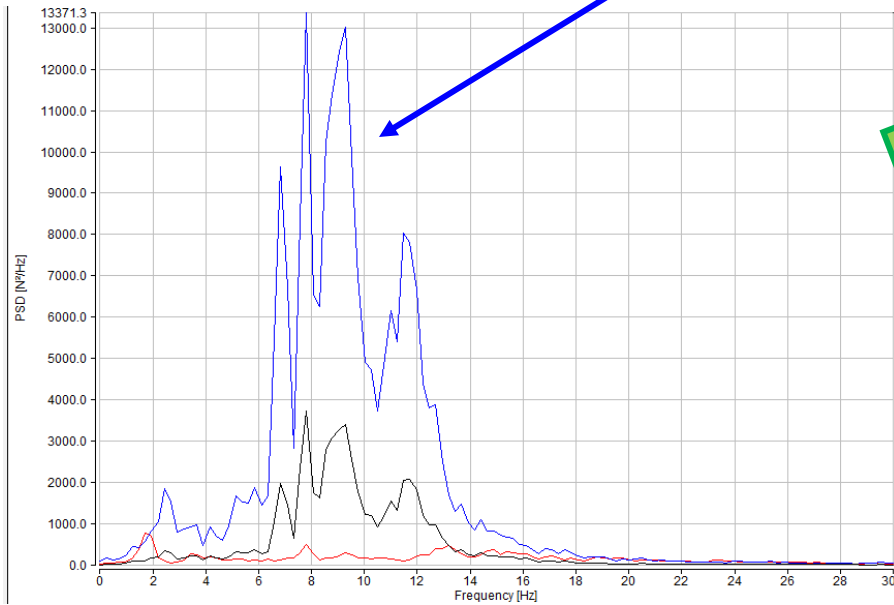
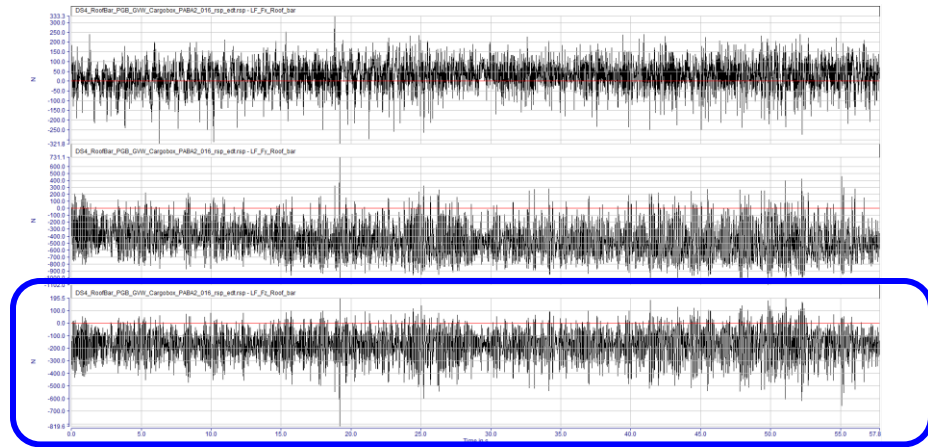
nCode Flow from PSD to Time Histories

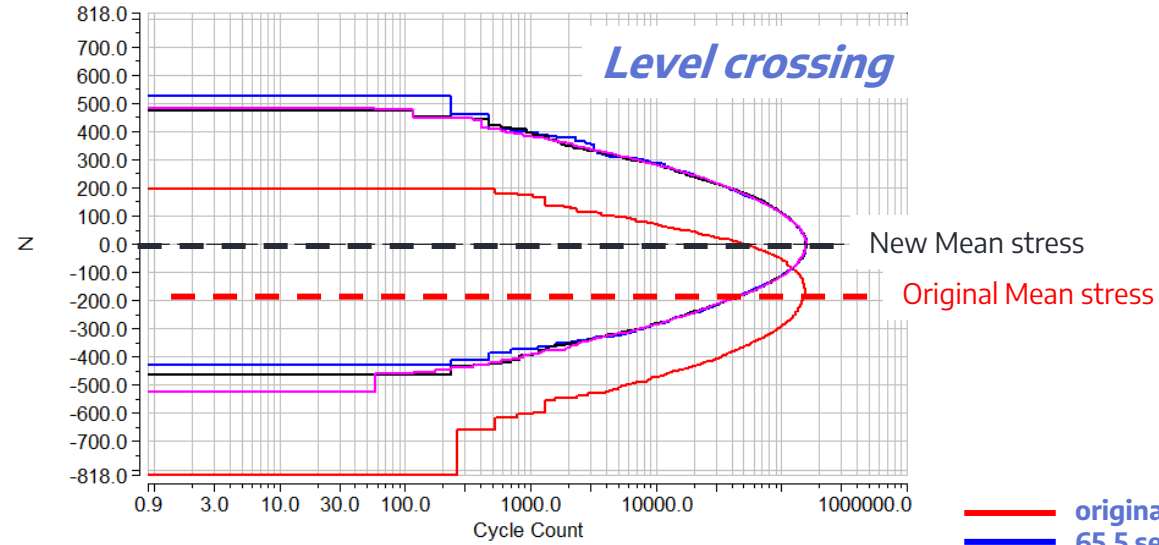


Fx

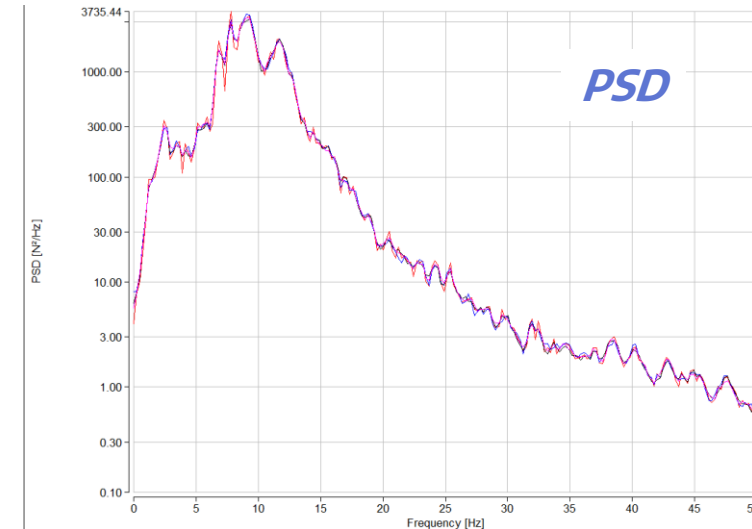
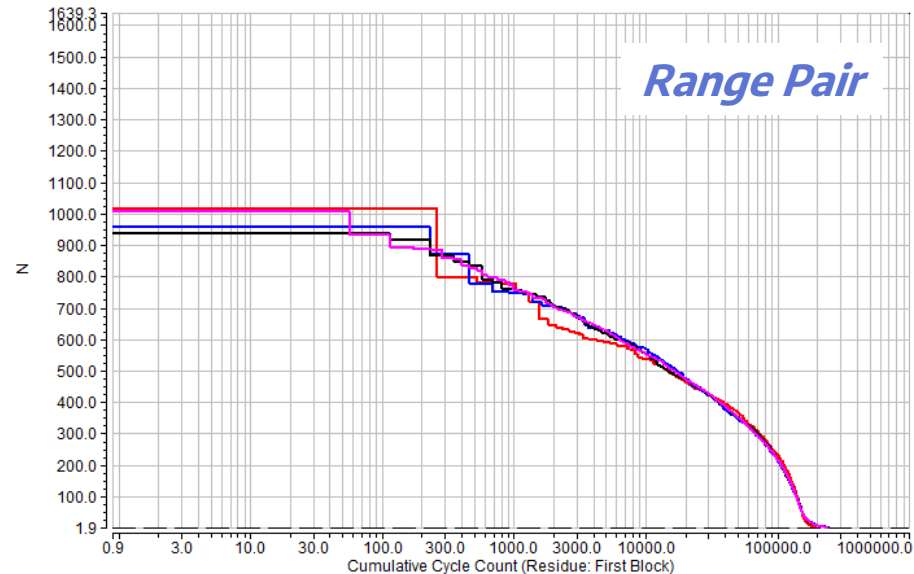
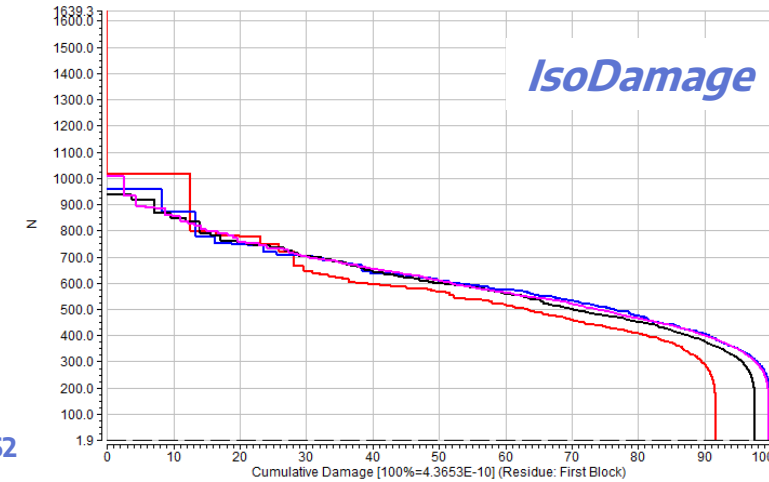
Fy

Fz





- original 58sec x 262
- 65.5 sec x 231
- 131 sec x 116
- 262 sec x 58





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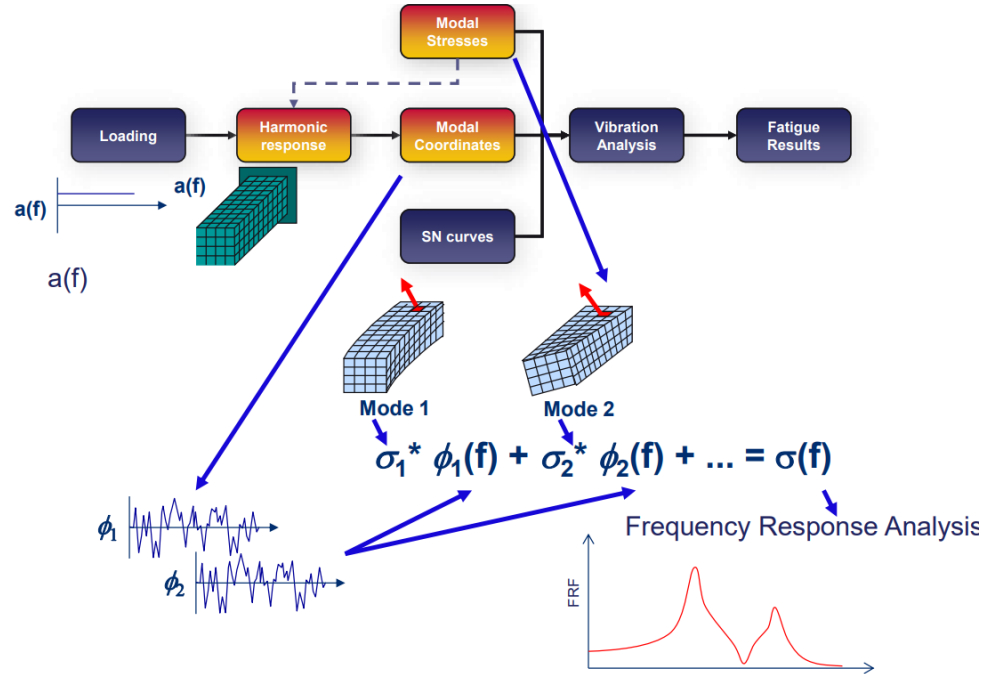
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Modal superposition with modal coordinates



Standard Approach for body durability:

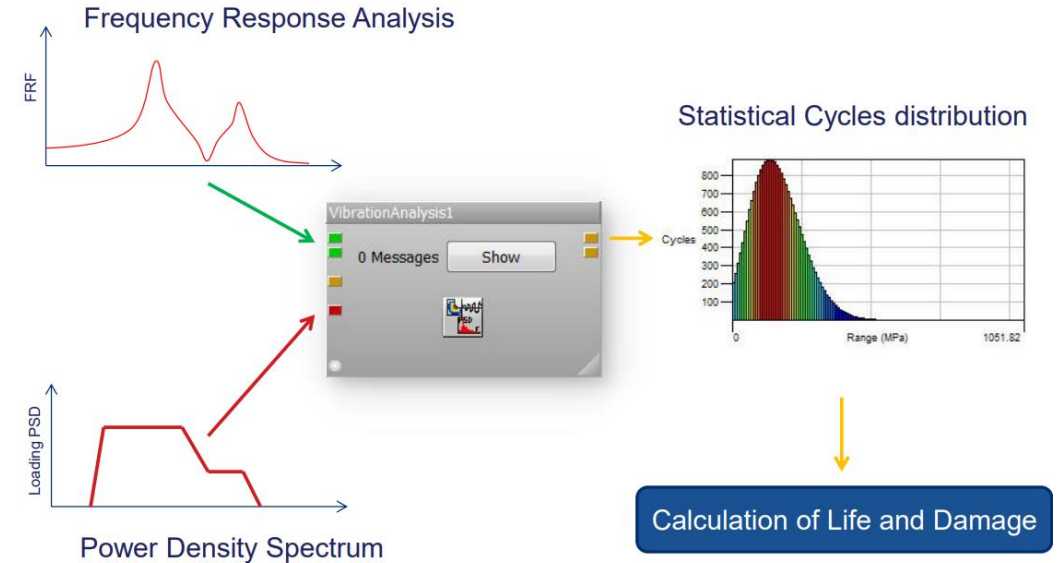
Modal stress built by modal analysis and modal coordinates from harmonic analysis

➔ stress is reconstructed by modal superposition

Useable for plane / solid component and for spotwelds

Time histories approach is based on the same theory

Modal superposition with direct FRF results



Alternative method:

Directly from stress results at each frequency FRF + Modal excitation from PSD

Not appropriate for Plane and solid components due to the big structural results files > 3 TeraB (Abaqus)

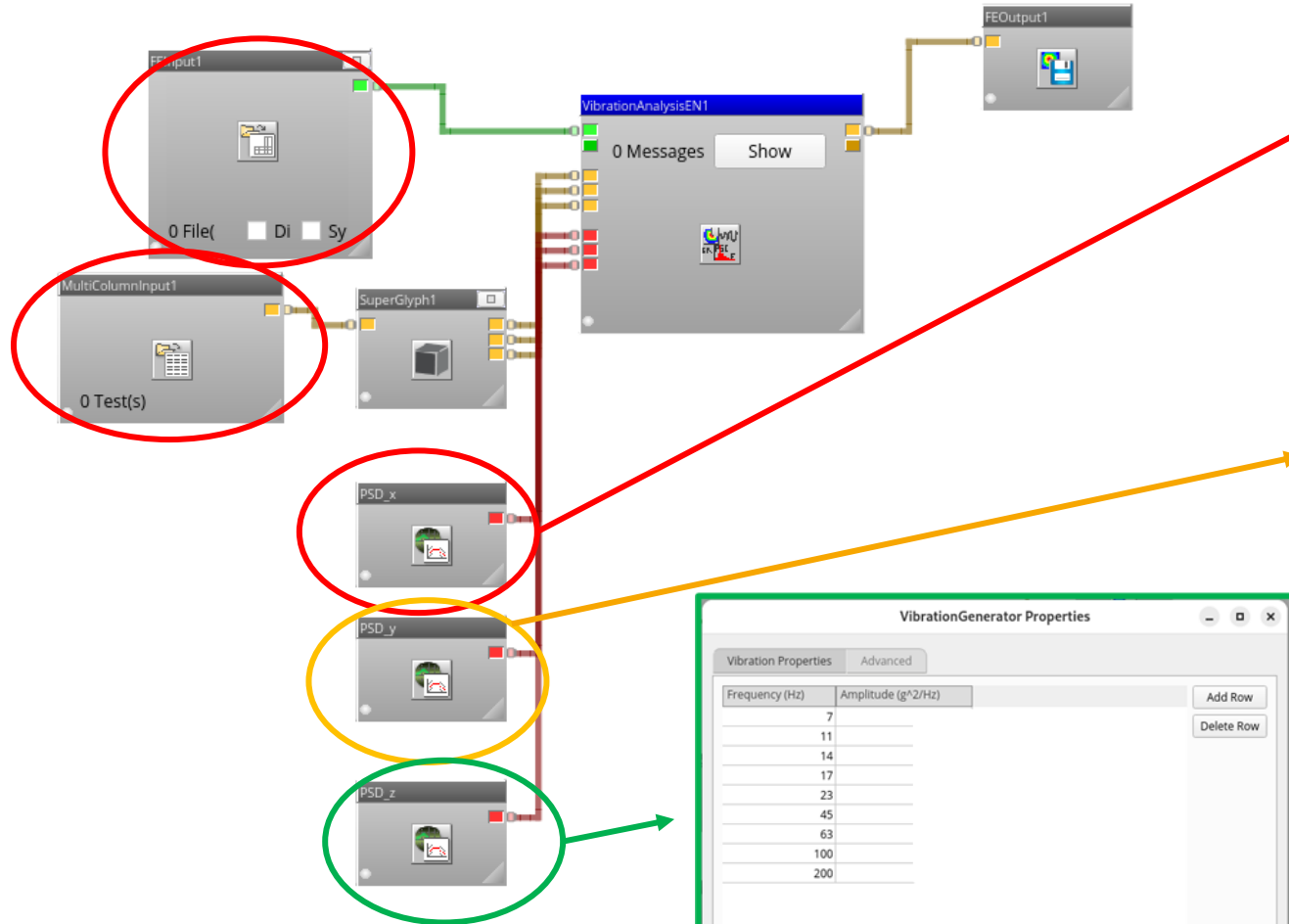
Method is the only available for Spotwelds with PSD approach

Ncode work flow for PSD durability

Modal superposition with modal coordinates *Reference for plane sheets / solid durability*

Available Data

- ASCII Files
- FE Models
 - Run_PSD_Battery_on_SCC_SHEET.odb - /data/Stru
- Modal Coordinate Files
- Multi-column
 - Run_PSD_Battery_on_SCC_SHEET_out.s3m - /data
- nCode S3 fatigue results



VibrationGenerator Properties

Vibration Properties | Advanced

Frequency (Hz)	Amplitude (g ² /Hz)
7	
11	
17	
25	
35	
63	
100	
200	

Buttons: Add Row, Delete Row, Apply, OK, Cancel, Help

VibrationGenerator Properties

Vibration Properties | Advanced

Frequency (Hz)	Amplitude (g ² /Hz)
7	
10	
18	
30	
45	
100	
200	

Buttons: Add Row, Delete Row, Apply, OK, Cancel, Help

VibrationGenerator Properties

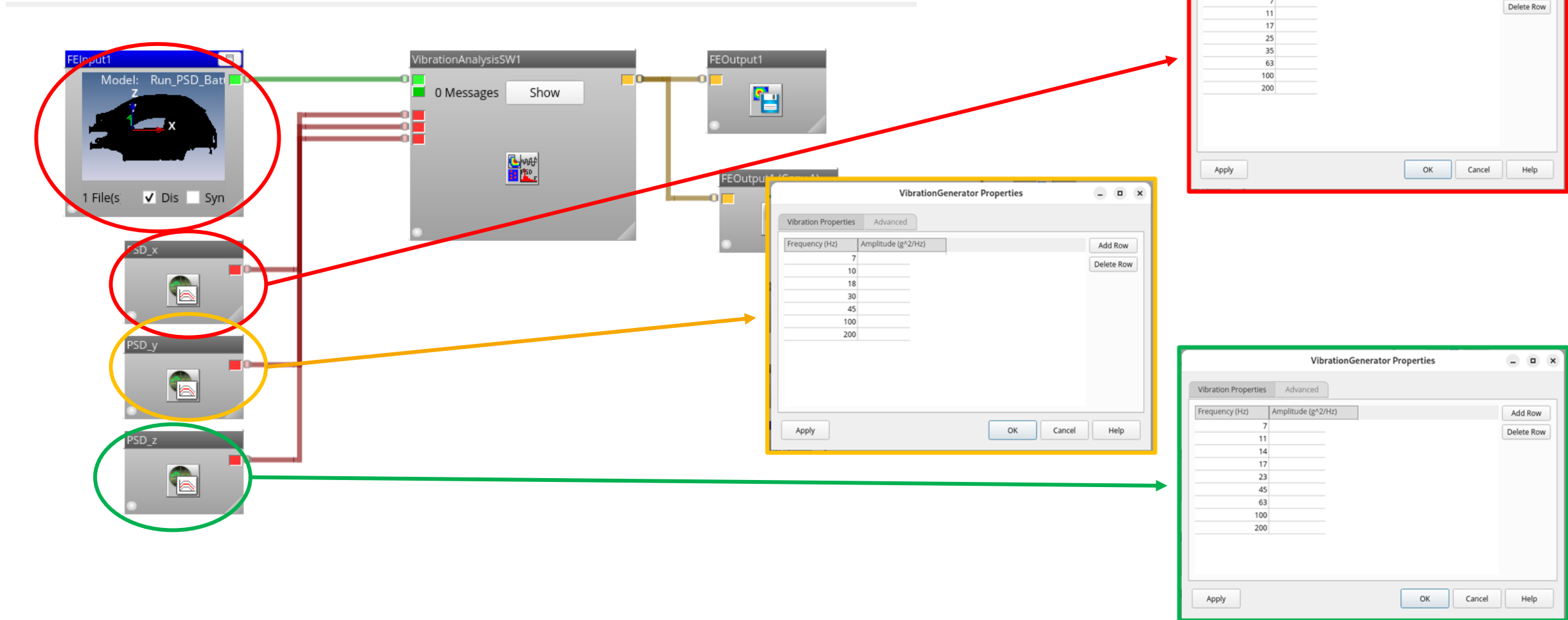
Vibration Properties | Advanced

Frequency (Hz)	Amplitude (g ² /Hz)
7	
11	
14	
17	
23	
45	
63	
100	
200	

Buttons: Add Row, Delete Row, Apply, OK, Cancel, Help

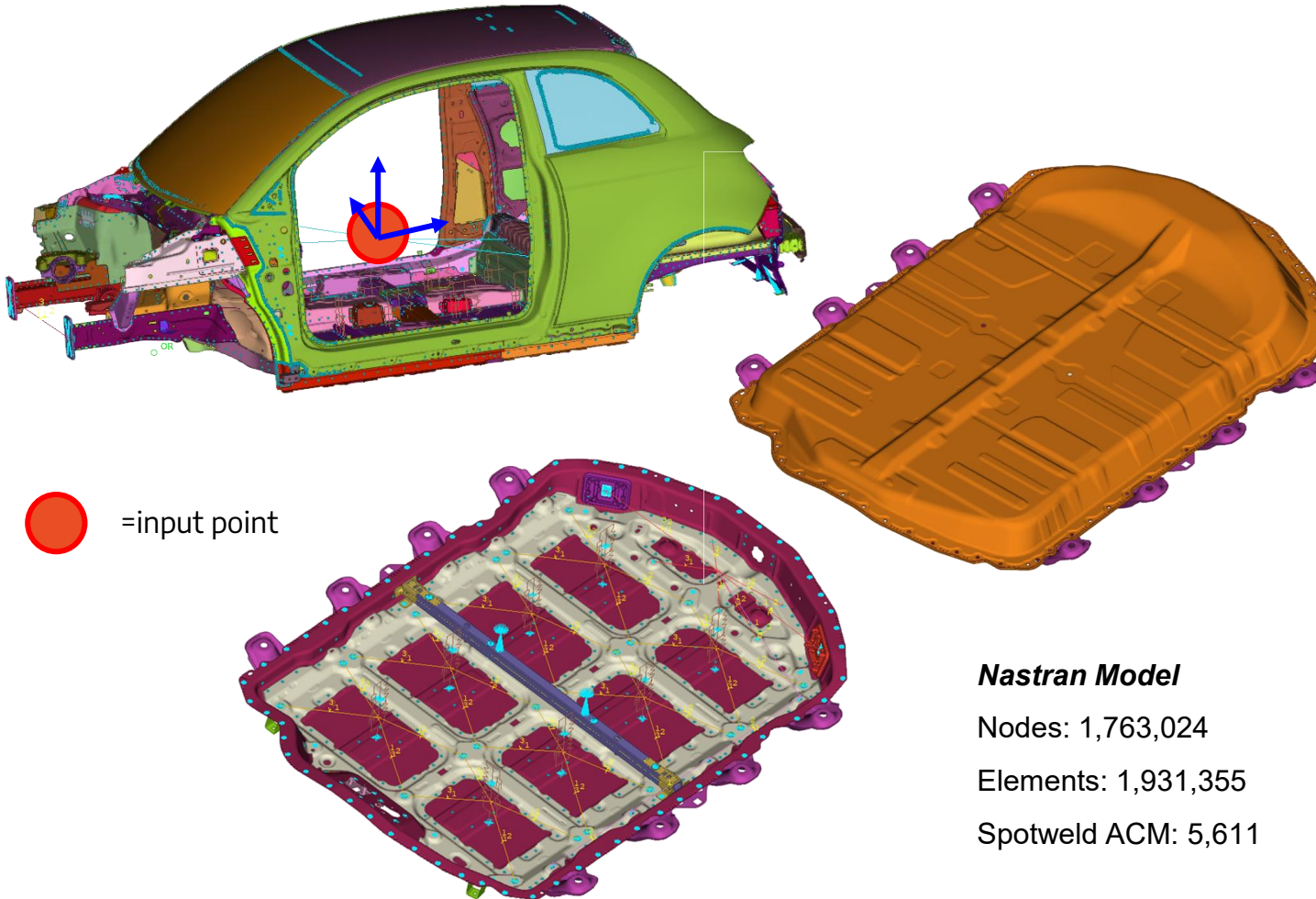
Ncode work flow for PSD durability

Modal superposition with direct FRF results *Unique approach for Spot Welds*



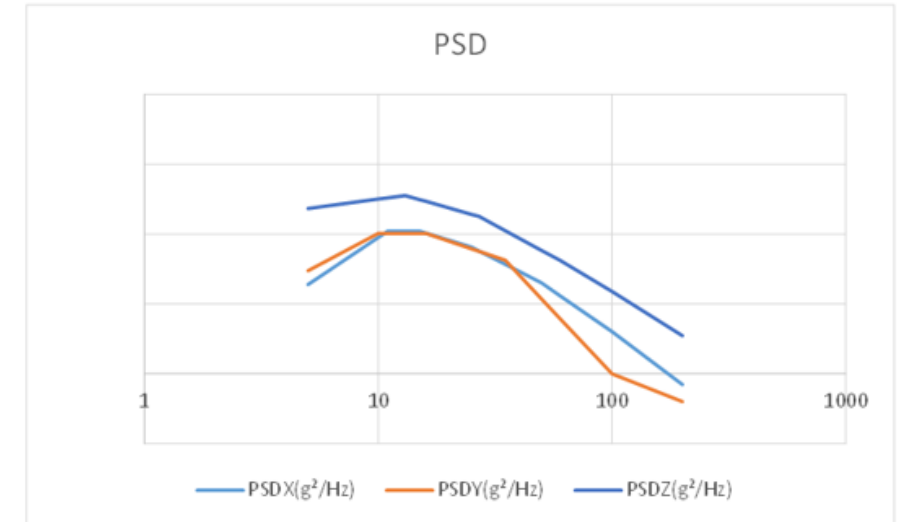


FE Model : Body and Battery simplified to have the best correlation between Nastran and Abaqus analysis



=input point

Input PSD with X,Y,Z direction



Frequency considered up to 200 Hz

About 170 modes

Nastran Model

Nodes: 1,763,024

Elements: 1,931,355

Spotweld ACM: 5,611

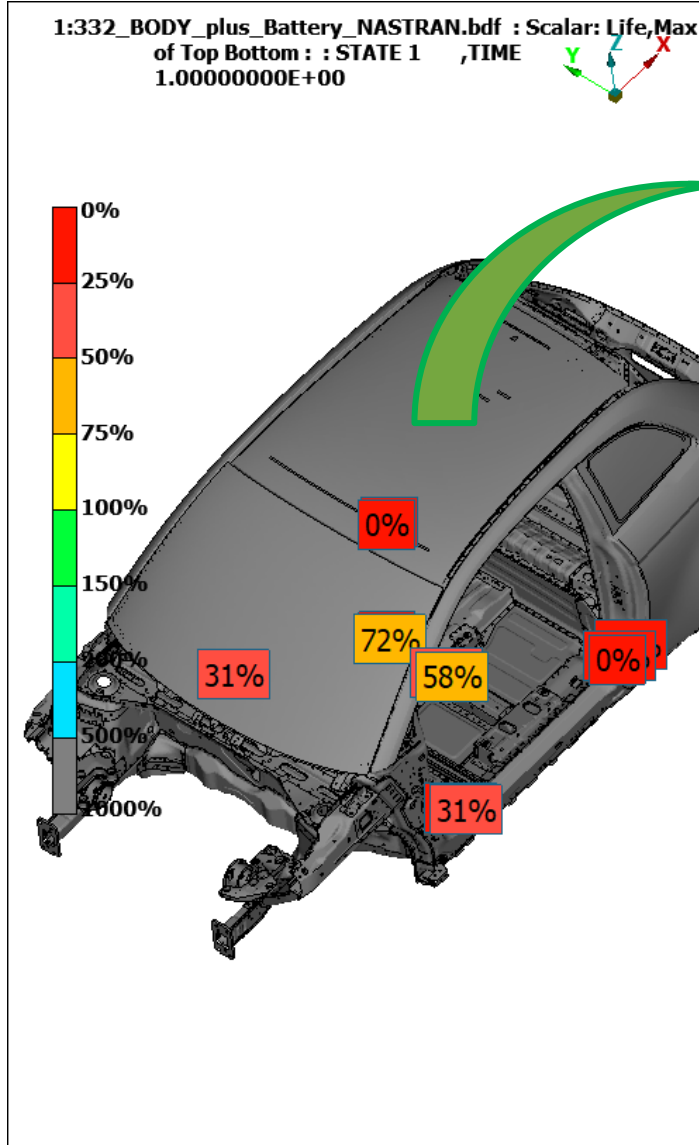
Abaqus Model

Nodes: 1,763,022

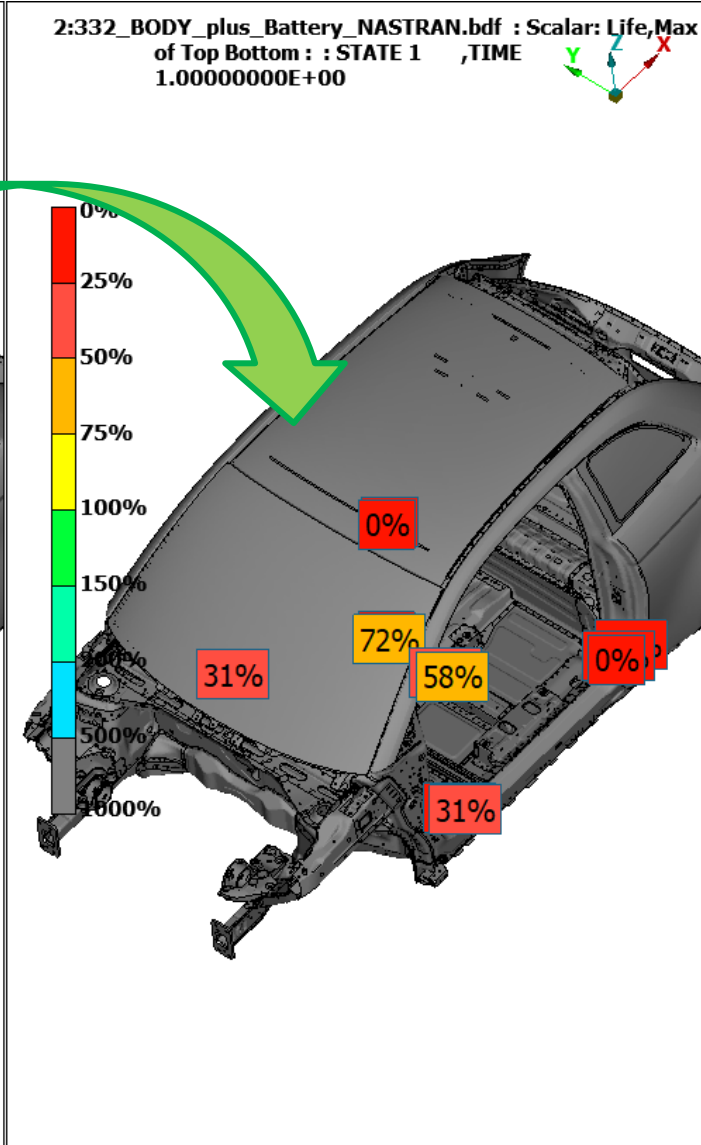
Elements: 1,931,351

Spotweld ACM: 5,611

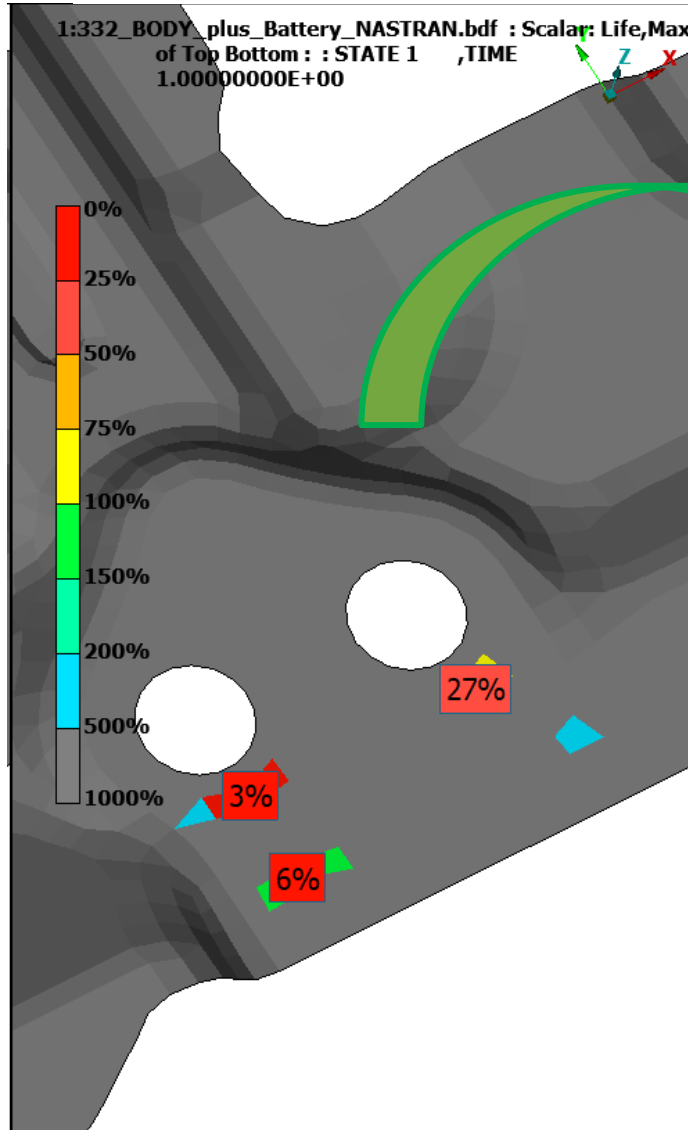
NASTRAN – PSD Modal coordinates



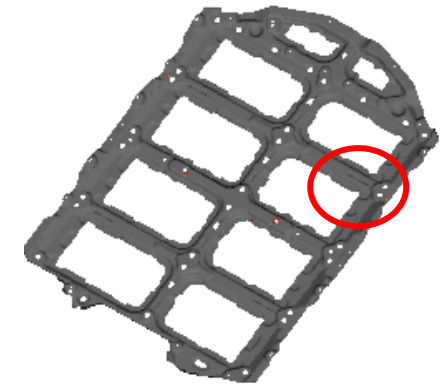
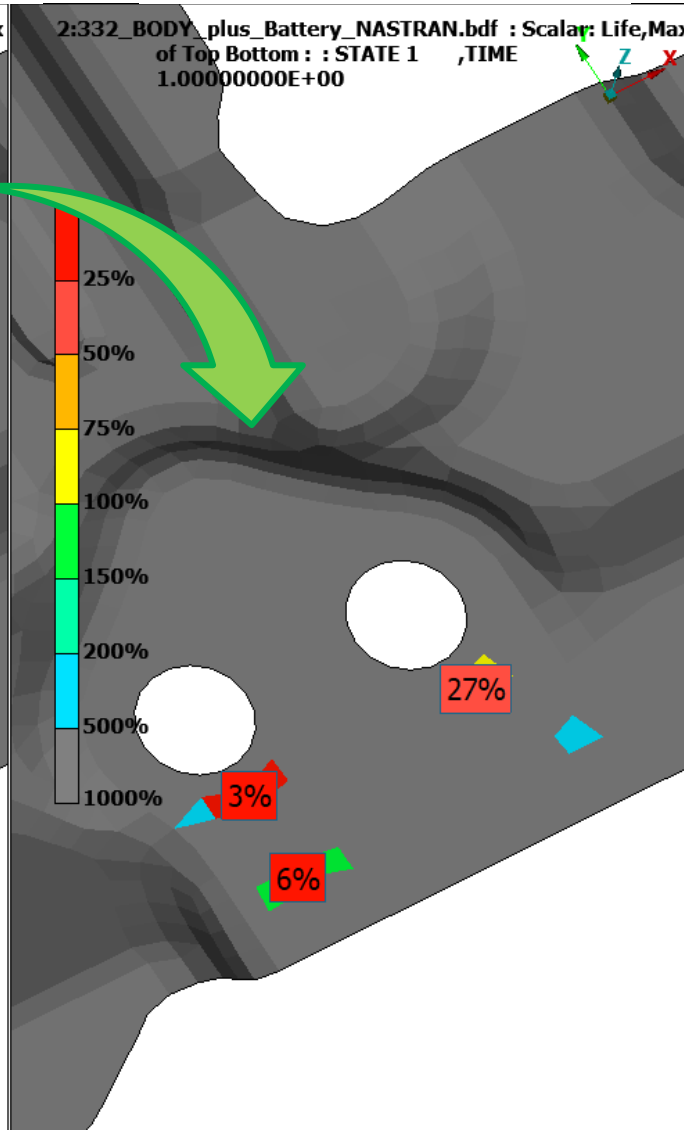
NASTRAN – PSD Direct FRF



NASTRAN – PSD Modal coordinates



NASTRAN – PSD Direct FRF



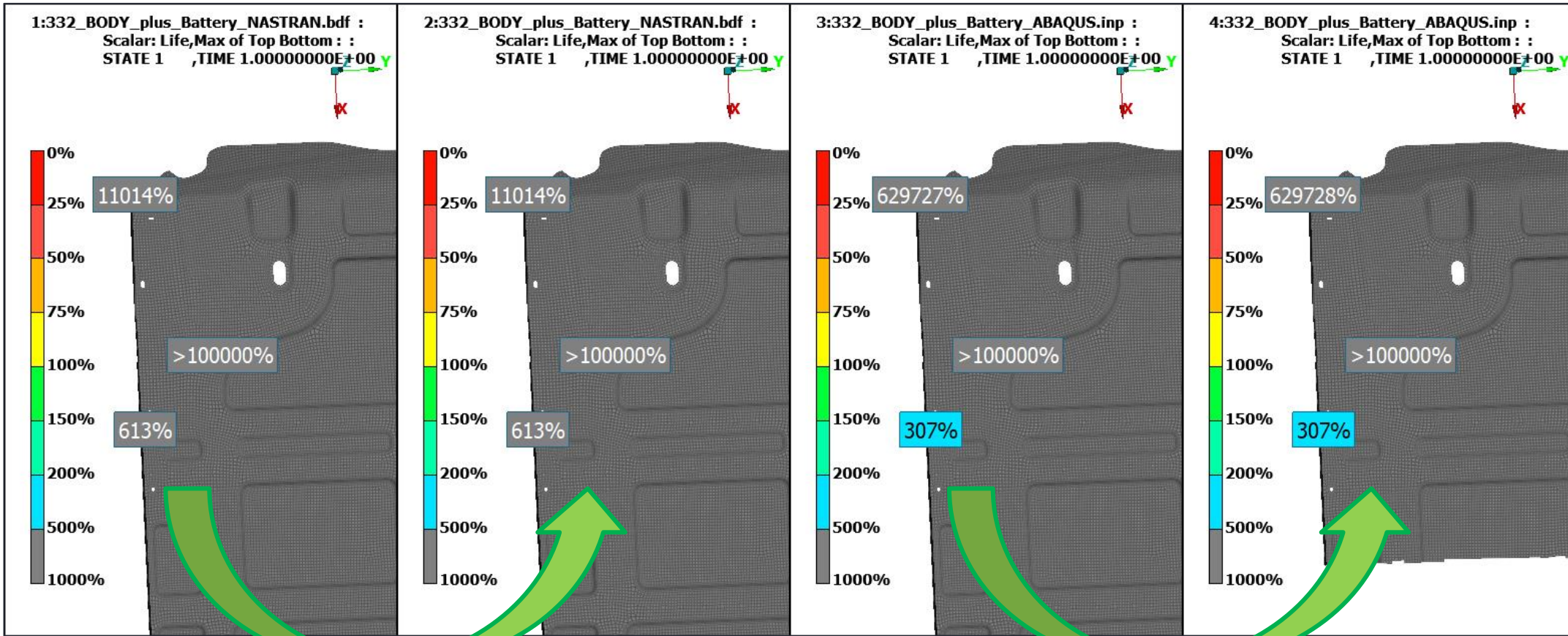


**NASTRAN
PSD Modal coordinates**

**NASTRAN
PSD Direct FRF**

**ABAQUS
PSD Modal coordinates**

**ABAQUS
PSD Direct FRF**





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Modal frequencies comparison

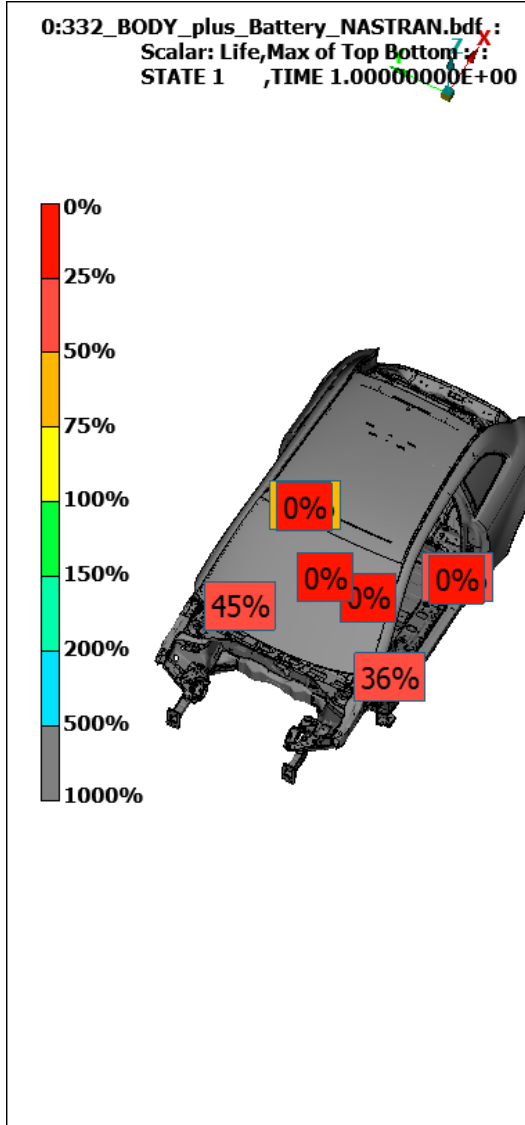
Freq 1-200Hz	TimeHistory Nastran	PSD Nastran	Time History Abaqus	PSD Abaqus
# modes	171	171	164	164

First 10 modes frequency comparison

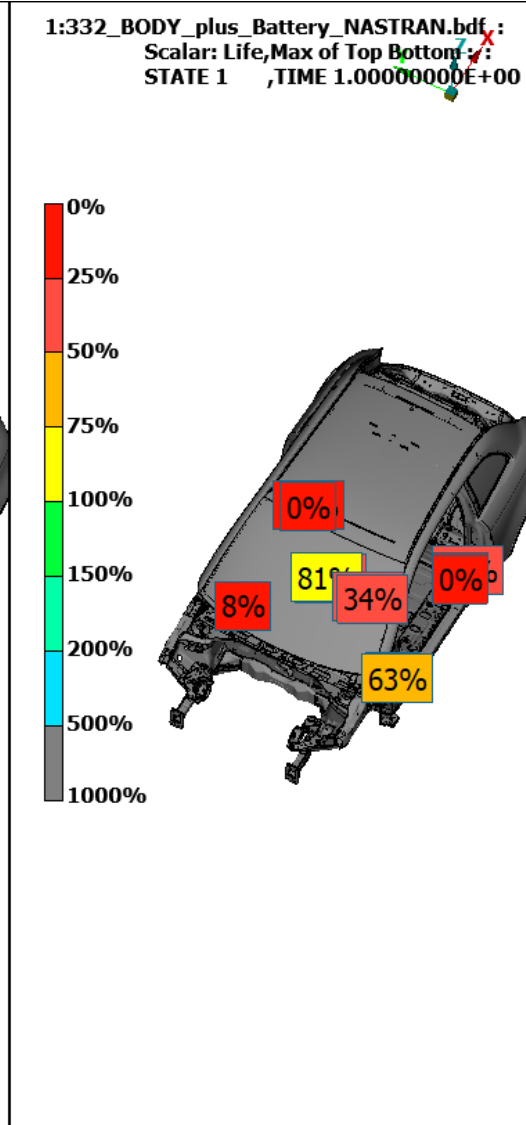
# mode	Nastran TimeHistory [Hz]	Nastran PSD [Hz]	Abaqus TimeHistory [Hz]	Abaqus PSD [Hz]	Comparison Nastran/Abaqus [Hz]
1	23.1487	23.1487	24.1880	24.1880	1.0393
2	29.0867	29.0867	29.7790	29.7790	0.6923
3	30.8833	30.8833	31.7380	31.7380	0.8547
4	37.8711	37.8711	39.2490	39.2490	1.3779
5	43.5534	43.5534	46.9630	46.9630	3.4096
6	48.8412	48.8412	50.9470	50.9470	2.1058
7	52.6690	52.6690	53.4990	53.4990	0.8300
8	53.8999	53.8999	56.6060	56.6060	2.7061
9	61.4989	61.4989	62.2970	62.2970	0.7981
10	62.0047	62.0047	63.5130	63.5130	1.5083



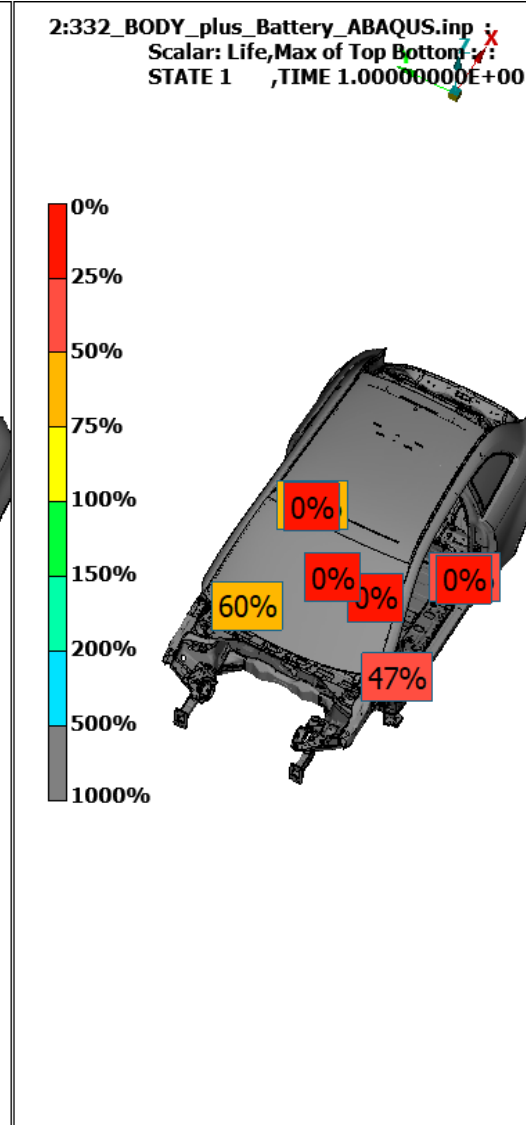
NASTRAN - TimeHistory



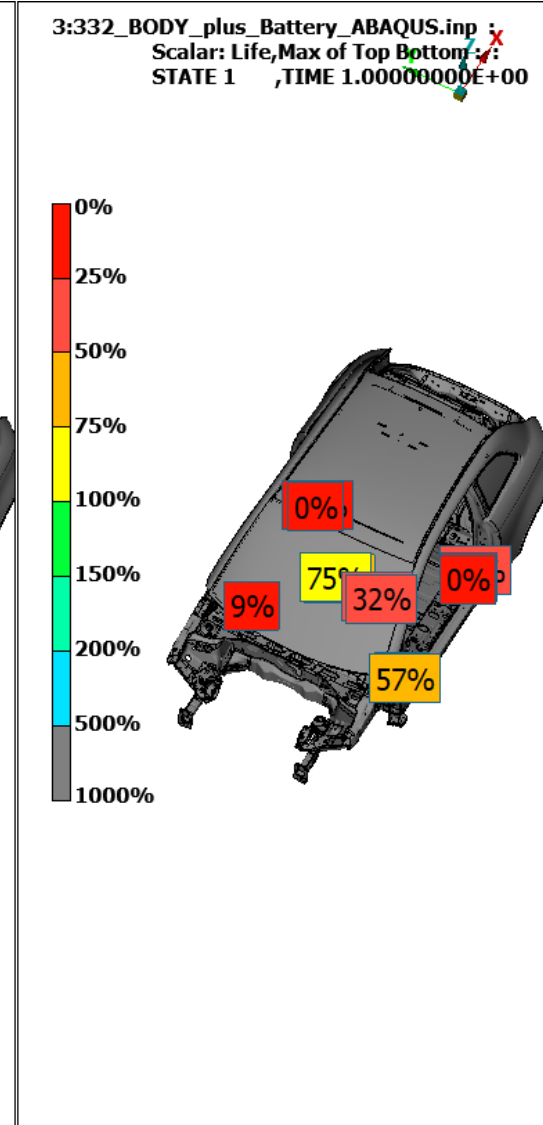
NASTRAN - PSD



ABAQUS - TimeHistory



ABAQUS - PSD



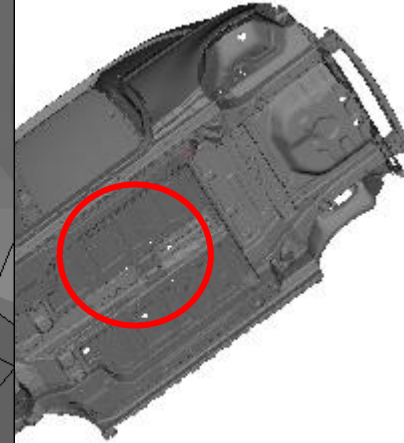
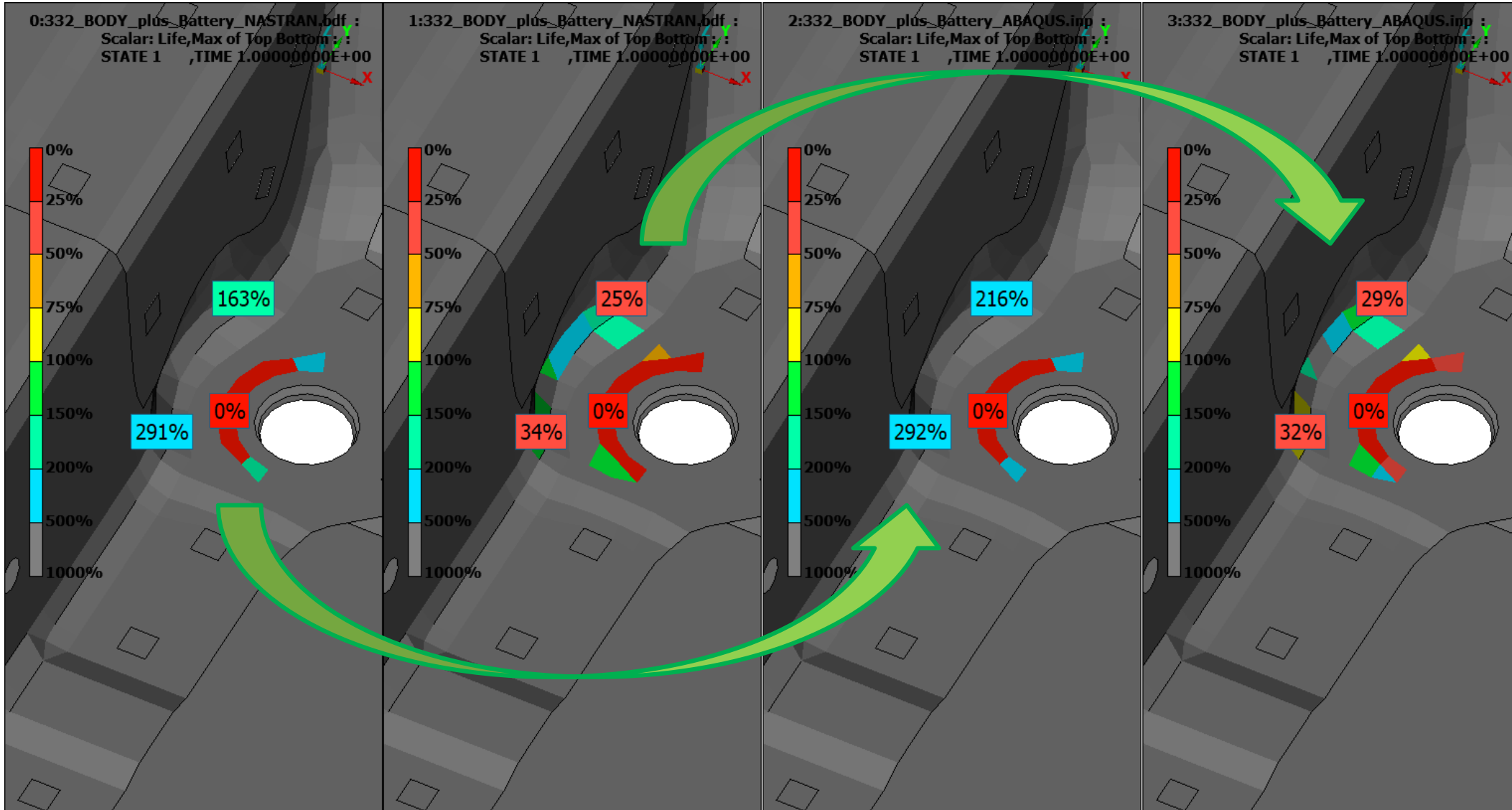


NASTRAN - TimeHistory

NASTRAN - PSD

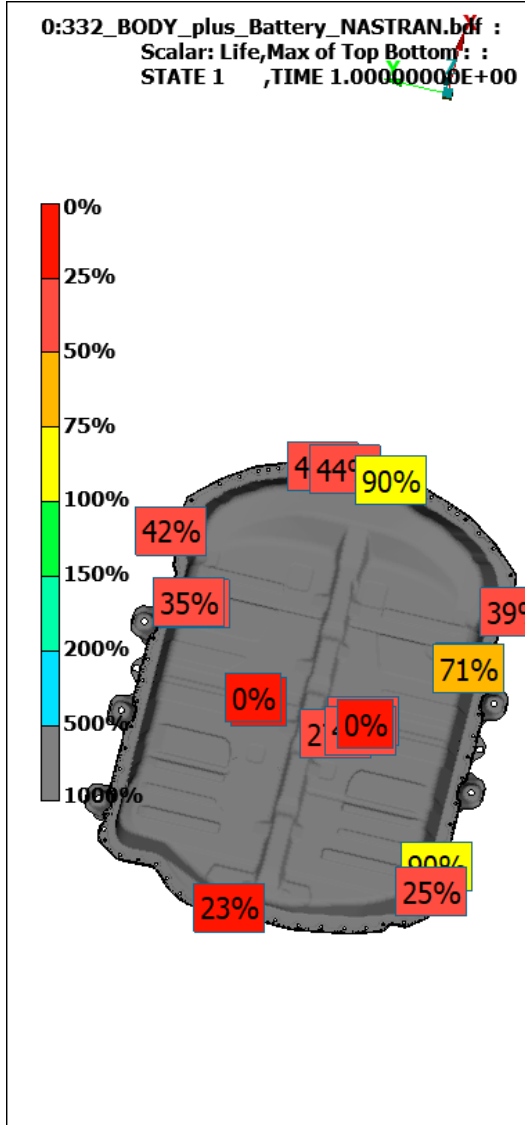
ABAQUS - TimeHistory

ABAQUS - PSD

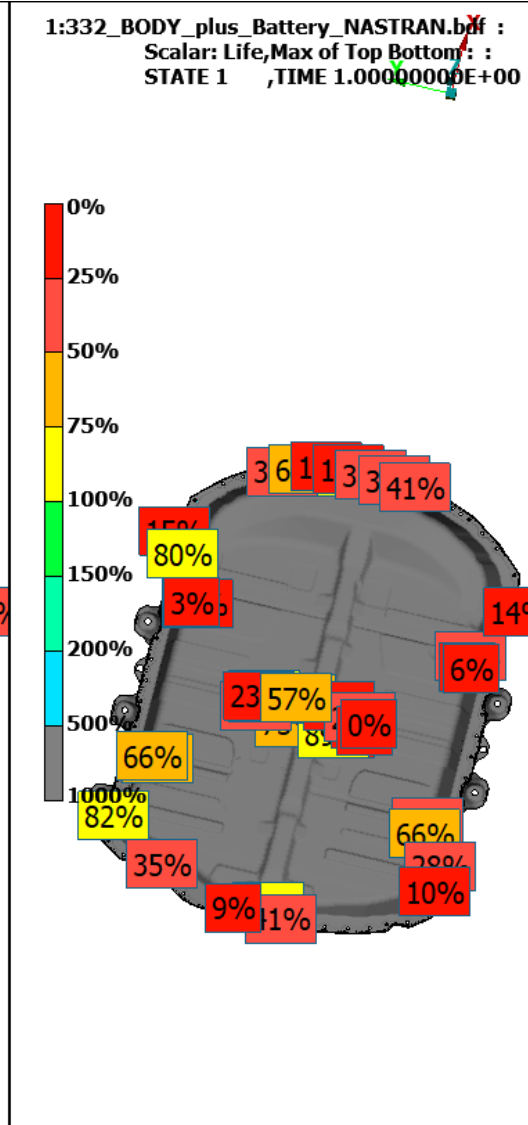




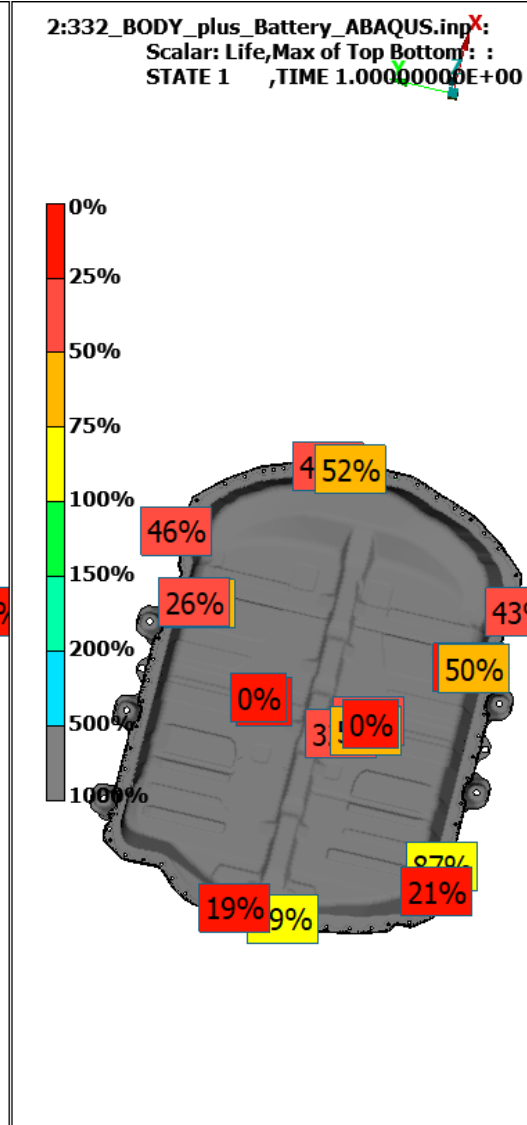
NASTRAN - TimeHistory



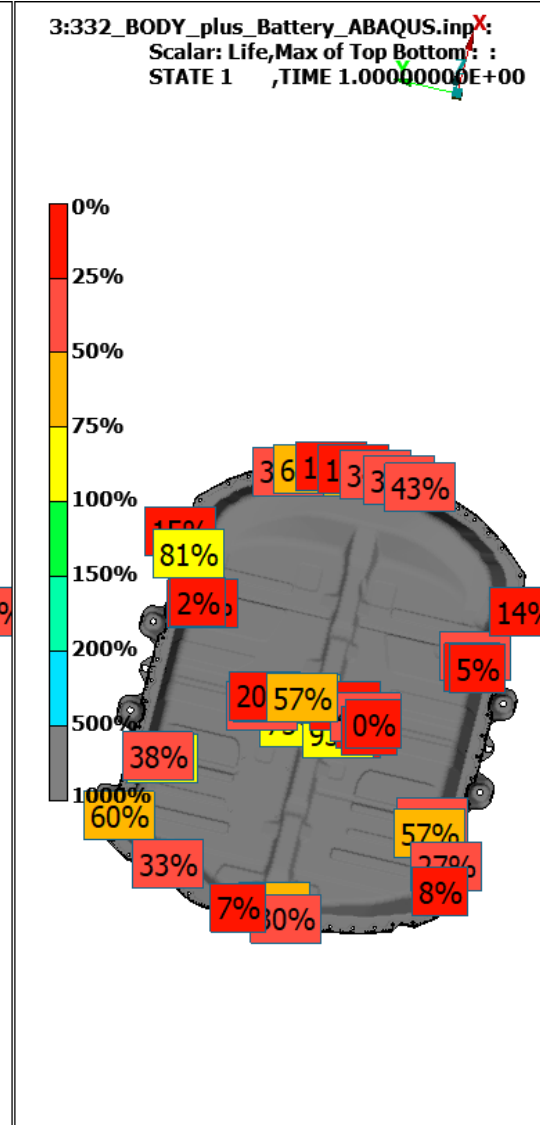
NASTRAN - PSD



ABAQUS - TimeHistory



ABAQUS - PSD



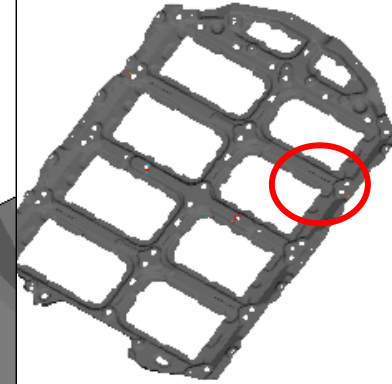
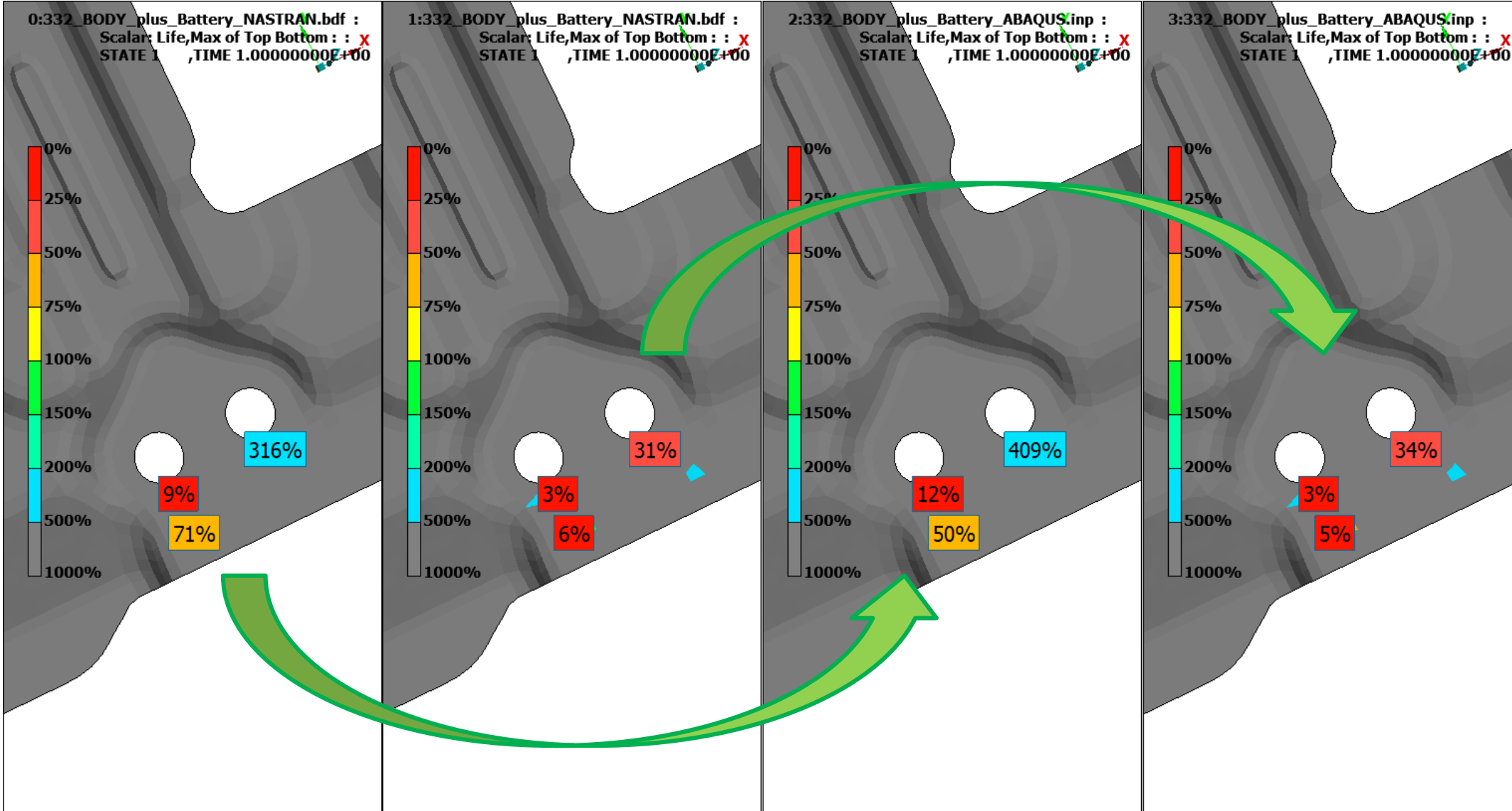


NASTRAN - TimeHistory

NASTRAN - PSD

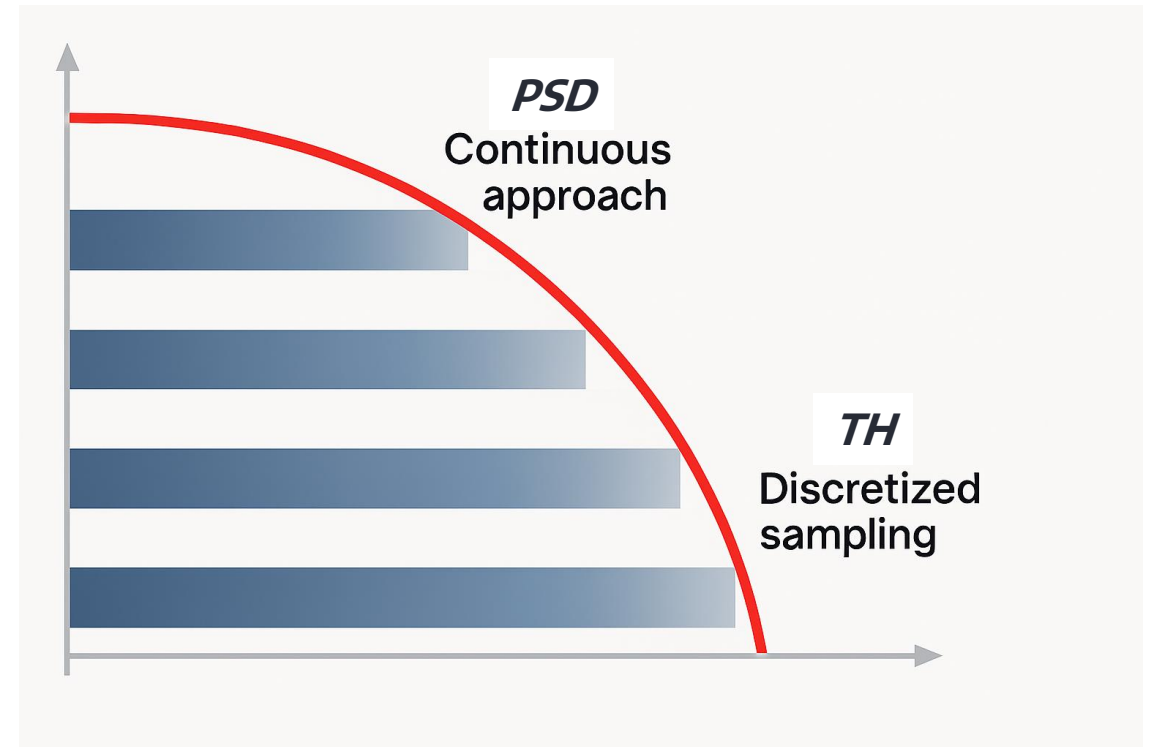
ABAQUS - TimeHistory

ABAQUS - PSD



- ✓ Nastran and Abaqus have comparable durability results
- ✓ PSD approach is more conservative in respect to time histories approach.

The capability of PSD approach to better explore the complete frequencies contents in respect to time histories approach that represents a finite discretization of the frequencies should explain the phenomenon





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Spotweld Results - Battery

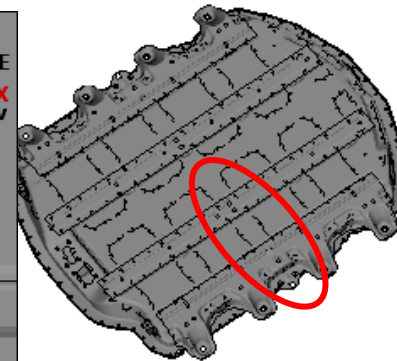
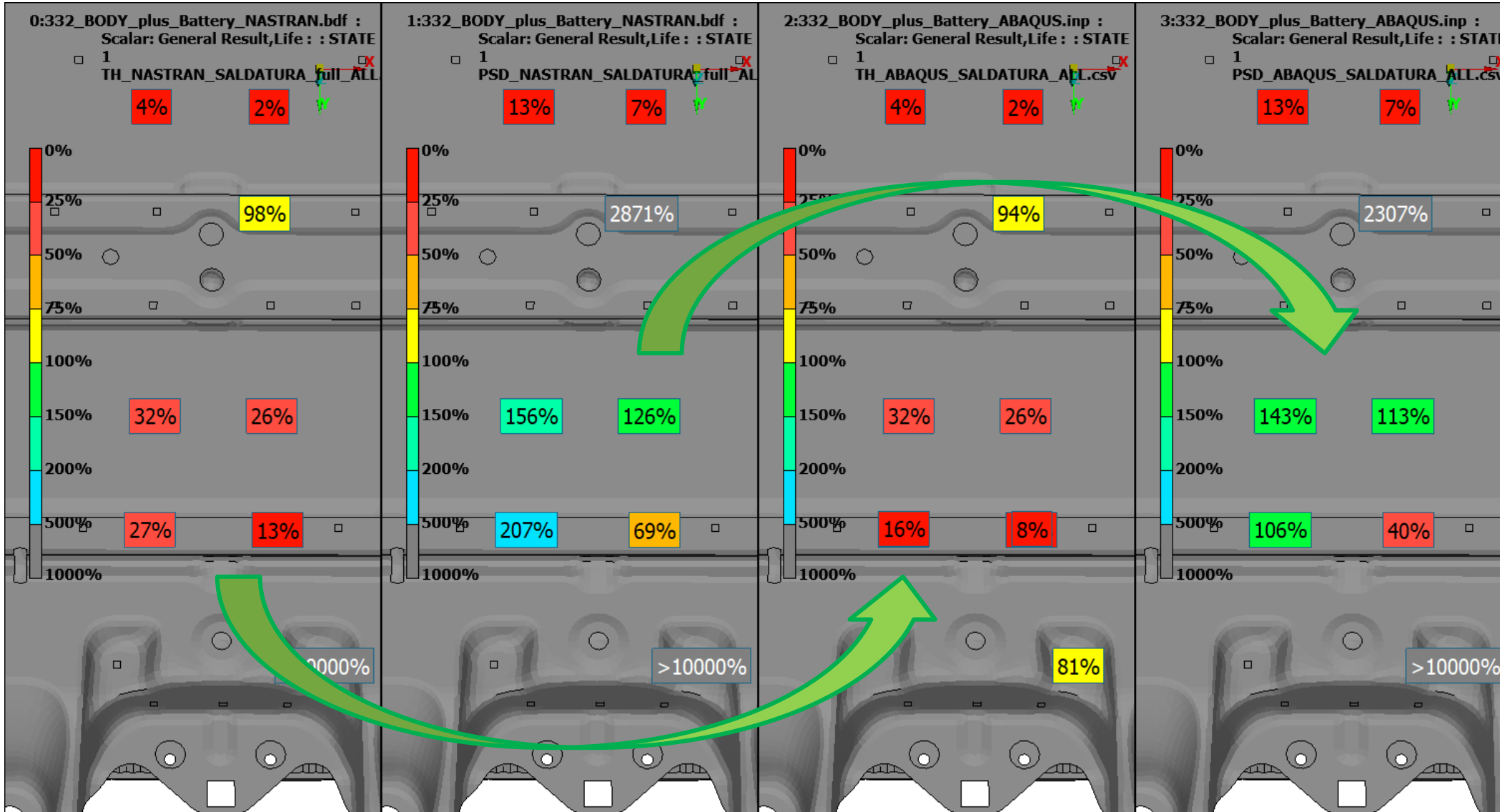


NASTRAN - TimeHistory

NASTRAN - PSD

ABAQUS - TimeHistory

ABAQUS - PSD

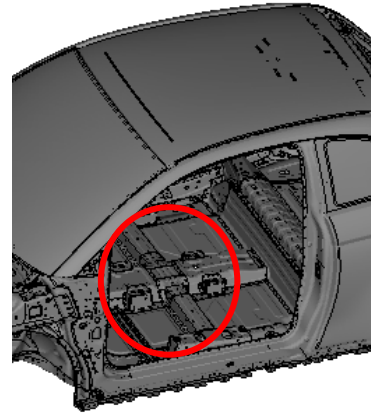
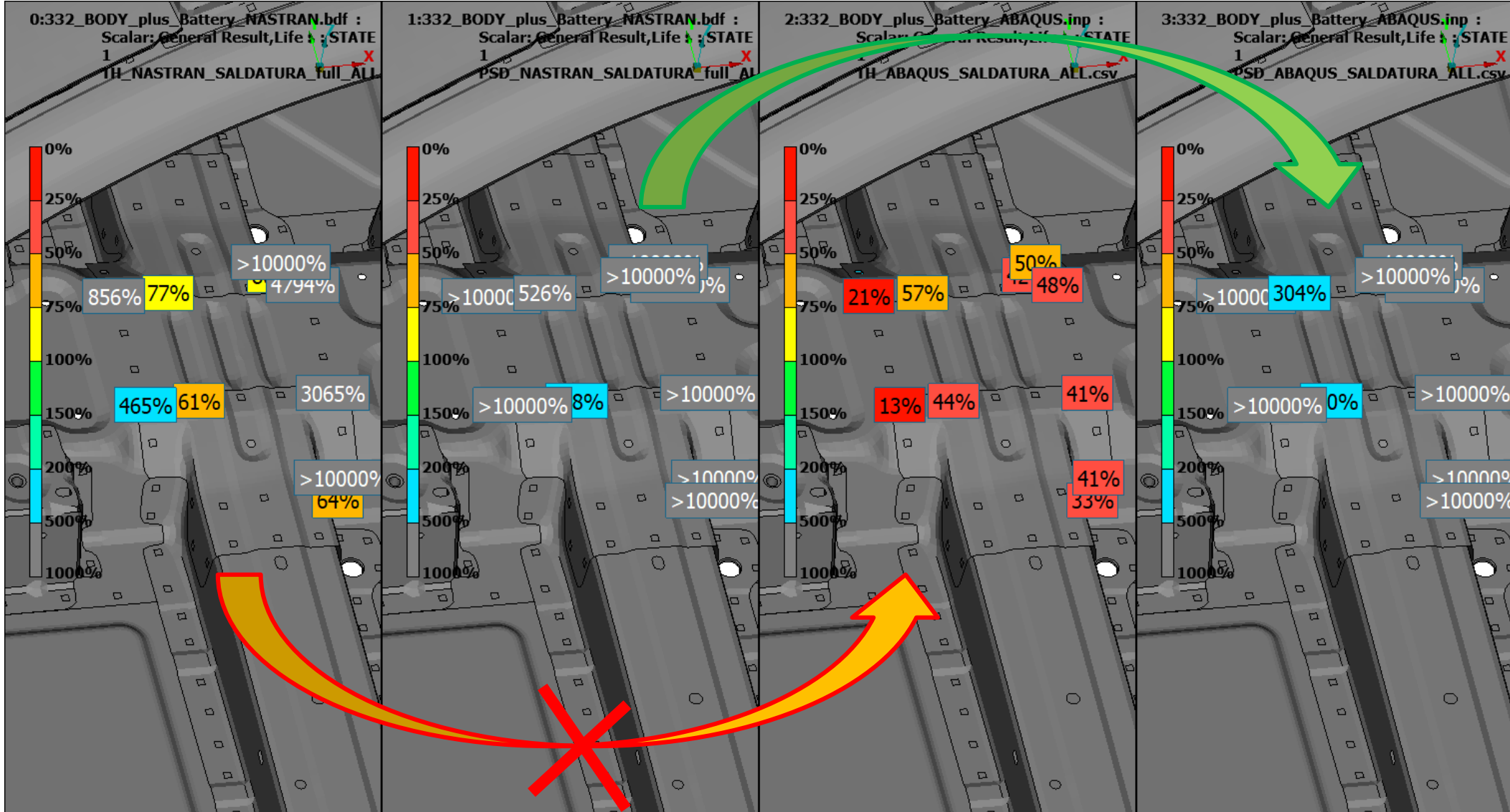


NASTRAN - TimeHistory

NASTRAN - PSD

ABAQUS - TimeHistory

ABAQUS - PSD



Spotweld Results – Body



STELLANTIS



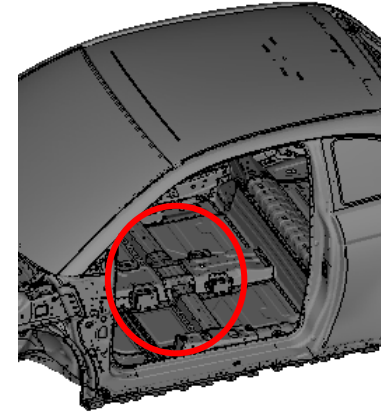
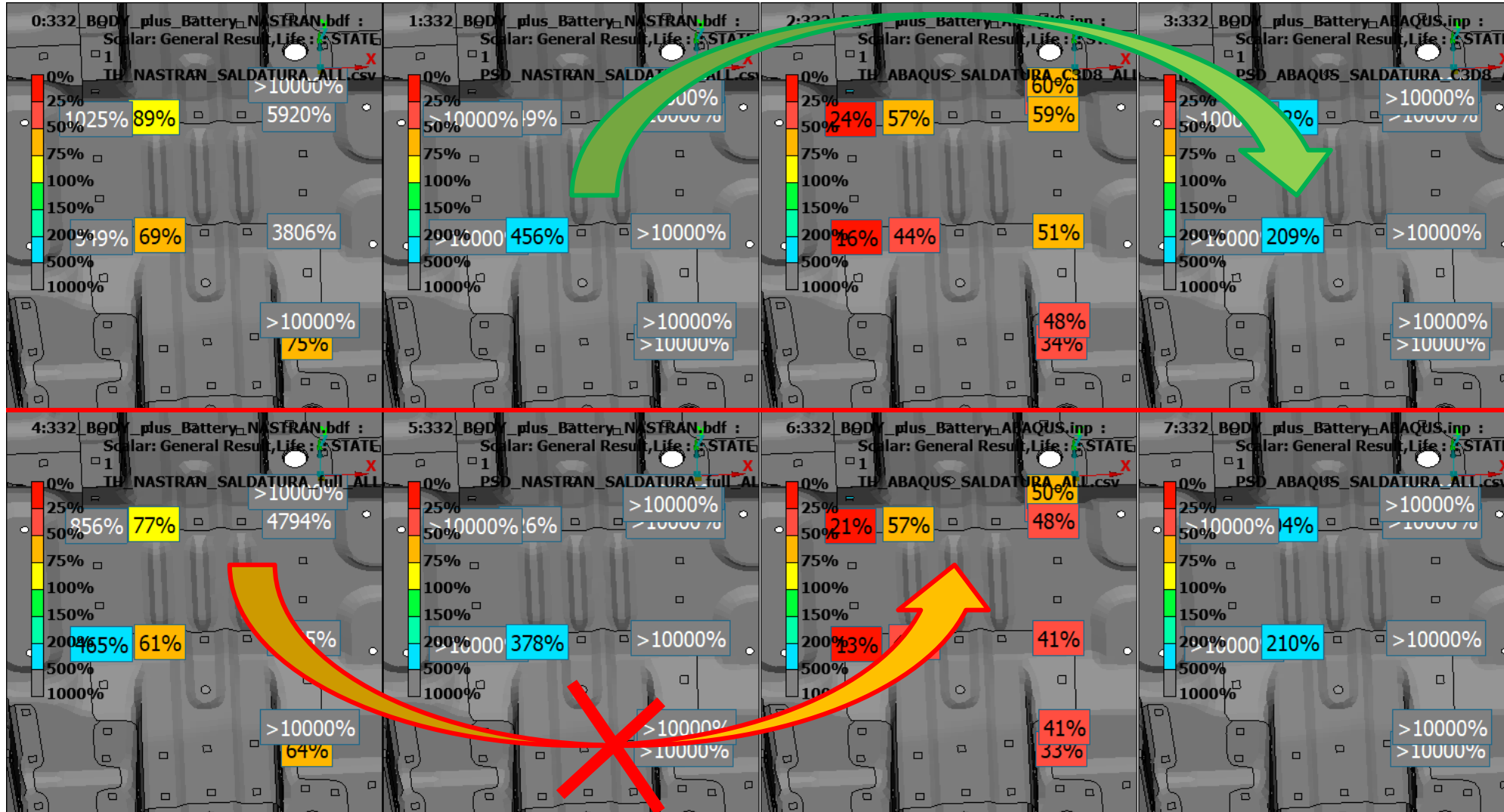
Influence of Full / Reduced Hexa elements for ACM2 spotwelds

NASTRAN - TimeHistory

NASTRAN - PSD

ABAQUS - TimeHistory

ABAQUS - PSD



NASTRAN - Reduced
ABAQUS - C3D8



NASTRAN - Full
ABAQUS - C3D8I

Spotwelds analysis

- ❑ On battery side the results are comparable between Nastran and Abaqus
- ❑ TH approach is more conservative in respect to PSD approach
- ❑ Abaqus TH is the most conservative on body side
- ❑ The influence of Hexa reduced vs Full for ACM model is investigated, the Full/C3D8I elements lead to a slightly more conservative results
- ❑ No relevant difference was highlighted on metal sheet due to Full/Reduced Hexa elements

→ The modeling of spotwelds should be refined because the results are driven by the area of the models



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		NASTRAN	ABAQUS
Structural analysis PSD	Metal sheets	≈ 3 hours	≈ 6 hours
	Spotwelds	≈ 3 hours	≈ 24 hours
Structural analysis Time Histories	Metal sheets	≈ 3 hours	≈ 22 hours
	Spotwelds	≈ 3 hours	
nCode PSD	Metal sheets	≈ 30 minutes	≈ 3 hours
	Spotwelds	≈ 2 minutes	≈ 9 hours
nCode Time Histories	Metal sheets	≈ 3 hours	≈ 3 hours
	Spotwelds	≈ 3 minutes	≈ 6 minutes



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Challenge

Due to the increasing relevance of the batteries in the current vehicles it becomes more and more important to understand how are correlated the PSD validation generally used for electronic devices and the standard durability approach for vehicle validation
Different approaches and different workflows are to be compared

Solution

HBK software (Glyphworks & nCode Durability) well supported all the approach and the intermediate steps to meet the final comparisons

Results

- ✓ nCode Desing life and Glyphworks support in a clear and effective way all the durability work flow both with time histories and with PSD.
- ✓ Both the time histories and the PSD manipulation and the translation from one approach to the other is easy thanks to the glyphs user interface
- ✓ The results based on a high complexity model and with a high number of modes (about 170 modes) show high level of reliability using all the approach available
- ✓ The spot weld modeling is to investigate more in deep to have more comparable results



THANK YOU

CONTACT

Alberto Signorini
ENLARGED EUROPE - DURABILITY, STRENGTH & MISUSE
Body, Closures, Exteriors Structural Validation Manager
Email: alberto.signorini@stellantis.com
Phone: +39 335 82 68 492