

FLYING VIBRATIONS FOR DRIVING SUCCESS

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Hamburg University of Applied Sciences (HAW Hamburg)





- Hamburg's **second-largest** higher education institution
- Germany's **third-largest** public university of applied sciences
- Member of the UAS7 alliance
- Founded in 1970

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HAW HAMBURG IN NUMBERS

17,125
students

2,745
international students

As of February 2021



HAW HAMBURG IN NUMBERS

418

professors

467

research associates and assistants

555

technical and administrative
staff members

As of March 2019



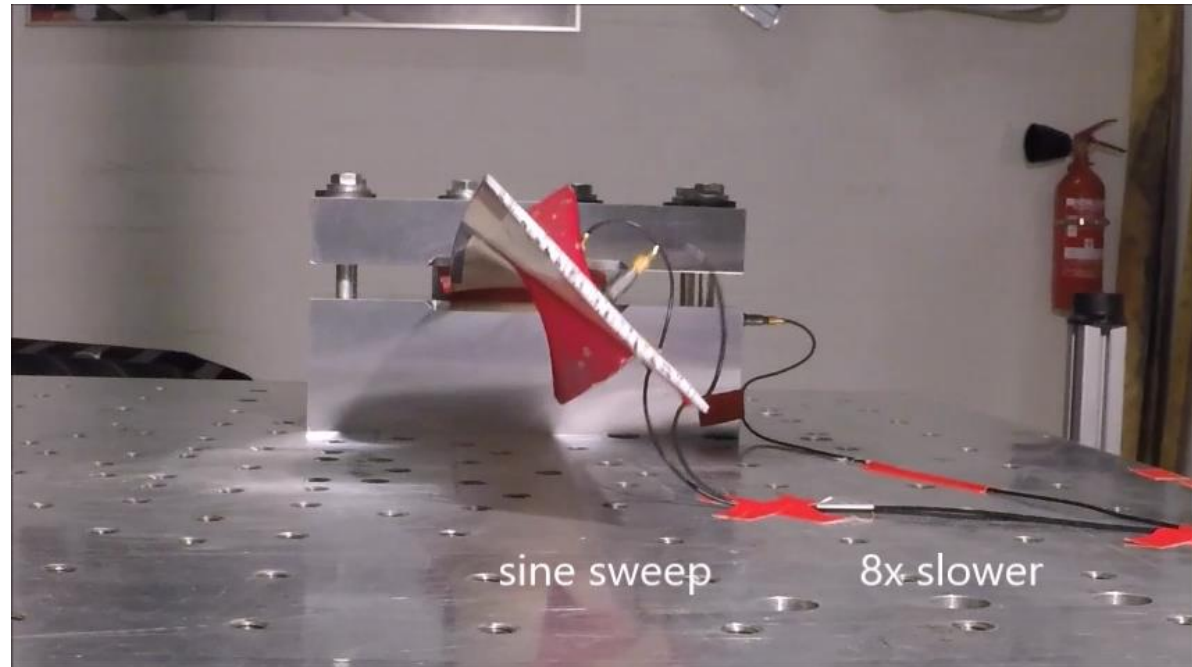
ROADMAP “TOWARDS REALISTIC BEV BATTERY TESTING”



AGENDA

Inspiring technical ideas from a different perspective

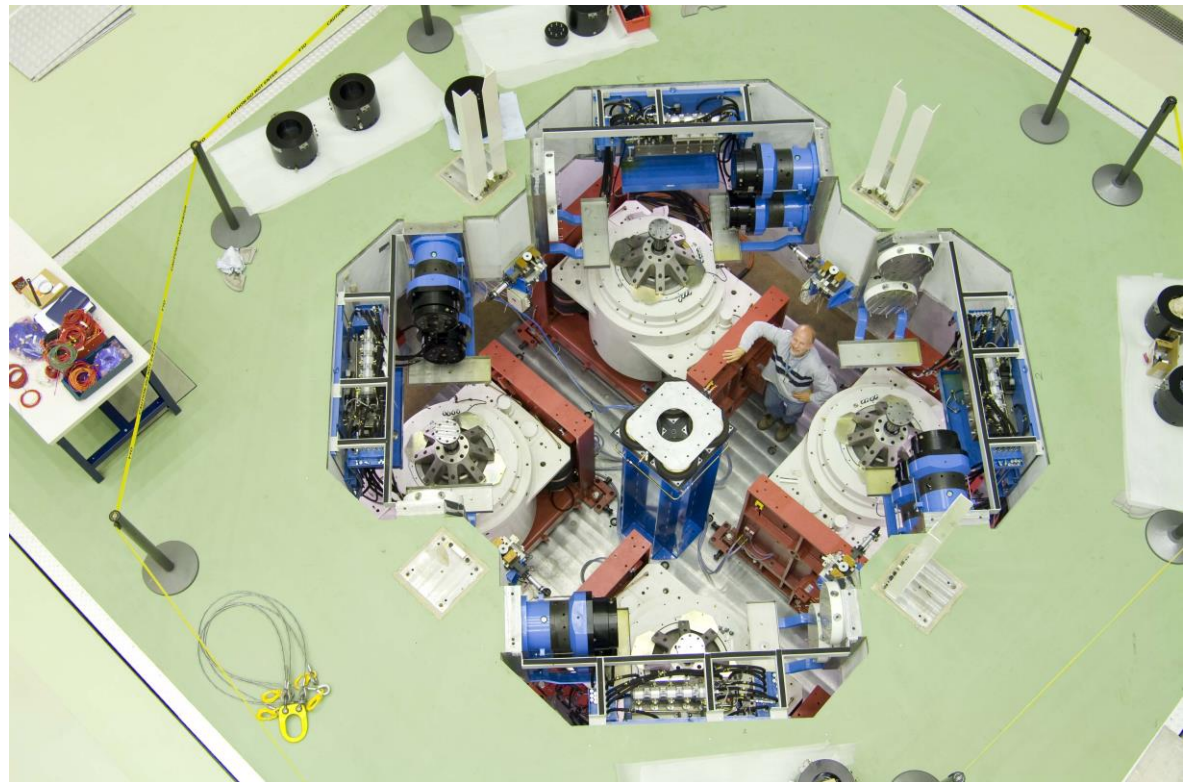
- vibration test rigs of other industries
- acoustical vibration
- multi-axis testing
- coupling and decoupling in Dynamic Substructuring



VIBRATION TEST RIGS

ESA ESTEC Vibration

- Testing of space components
- vibration testing often very short but rather tough
- 4 x 160 kN ED, 10to static



ESA, https://www.esa.int/ESA_Multimedia/Images/2009/09/Internal_view_of_Quad_multishaker
https://www.esa.int/Enabling_Support/Space_Engineering_Technology/Test_centre/Electrodynamic_shakers

VIBRATION TEST RIGS

ESA ESTEC Vibration

- Testing of space components
- vibration testing often very short but tough
- 6 DOF, 8 hydraulic shakers, max 5g, table $m_0 = 18\text{to}, 23\text{to}$ static, head expander only 5.5m x 5.5 m, seismic foundation 1.400 to



ESA, https://www.esa.int/ESA_Multimedia/Videos/2014/10/Hydra_shaker

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ESA, https://www.esa.int/ESA_Multimedia/Videos/2014/10/Hydra_shaker

A GOOD ADVICE – BE HONEST WITH YOUR MU

Air Stairs Vibration Testing

A simple question: What is your measurement uncertainty?



By Aleksandr Markin - Untitled (Global Jet Luxemburgo) Airbus A318-112CJ (Elite) LX-GJC, CC BY-SA 2.0, <https://commons.wikimedia.org/w/index.php?curid=29350809>

VIBRATION TEST RIGS

Space Shock Testing

- stage separation, here VEGA Launch requirement
- shock wave trough structure
- impressive SRS requirement...
- damping 5%

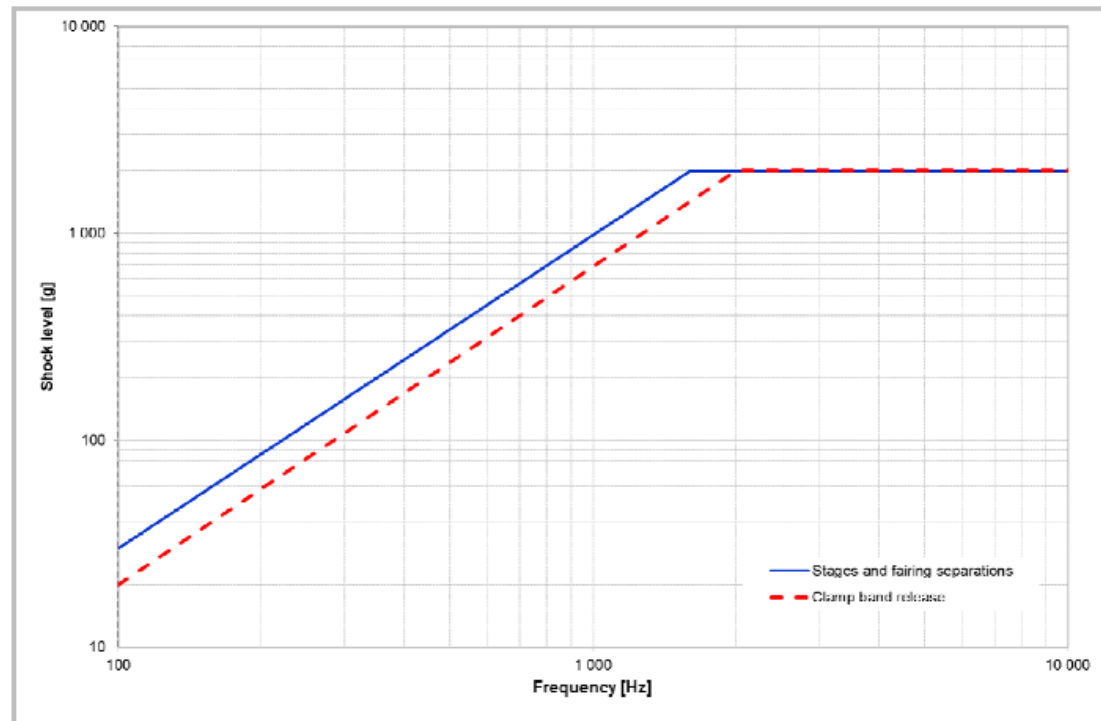
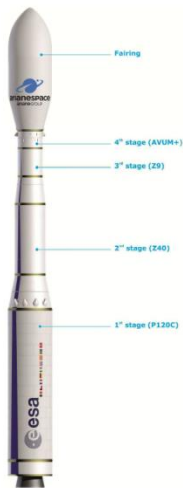


Figure 3.2.7.a – Envelope shock response spectra (SRS) for stages/fairing separations and clamp-band release at the spacecraft base (Q=10)

Quelle: Vega C user manual Issue-0 Revision-0 20180705

Flight event	Frequency (Hz)	
	100 – 1 600	1 600 – 10 000
	SRS, Shock Response Spectra (Q = 10) (g)	
Fairing & stages separations	30 – 2 000	2 000

Table 3.2.7.a – Shock response spectrum for stages and fairing separations

VIBRATION TEST RIGS

Acoustic Vibration at ZAL

- 440 loud speakers for acoustic wave front replications, i.e. 120dB re 20 μ Pa
- free placement over A320 fuselage section
- traveling waves on surface i.e. from Turboprob or open rotor



<https://zal.aero/innovation-rt/research-infrastructure/>

VIBRATION TEST RIGS

Acoustic Vibration at HAW Hamburg HCAT

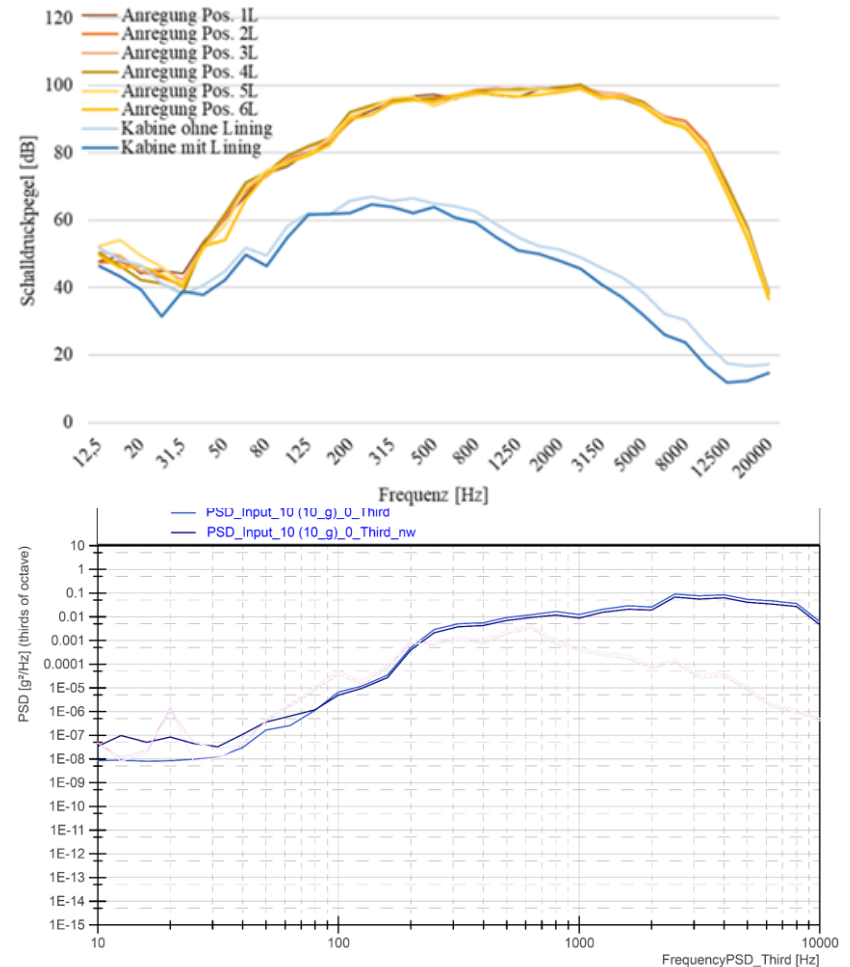
- A320 fuselage section in temperature chamber
- acoustic excitation
- comfort noise and vibration



ACOUSTICAL VIBRATION

Acoustical Excitation

- research project for VIP cabin
- in aviation all acoustic vibrations from outside to inside pass through structure

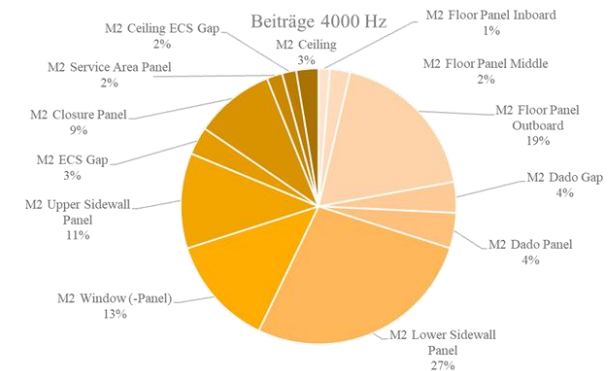
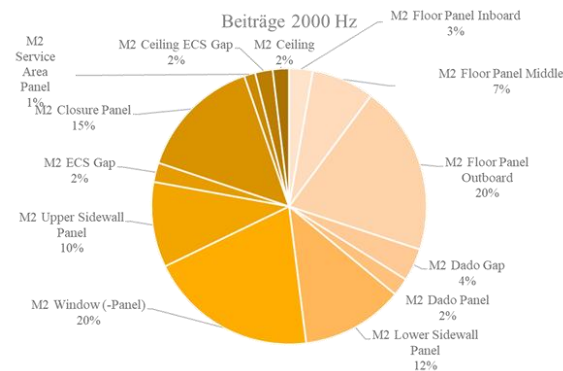
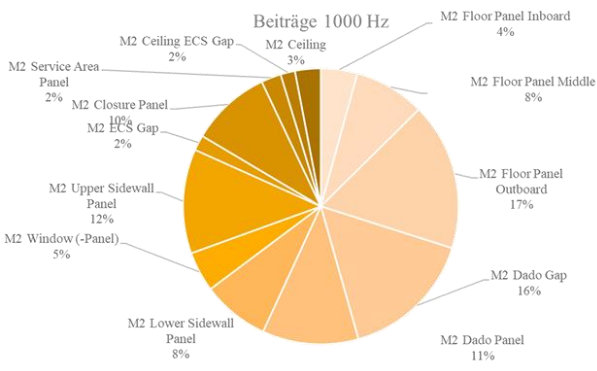


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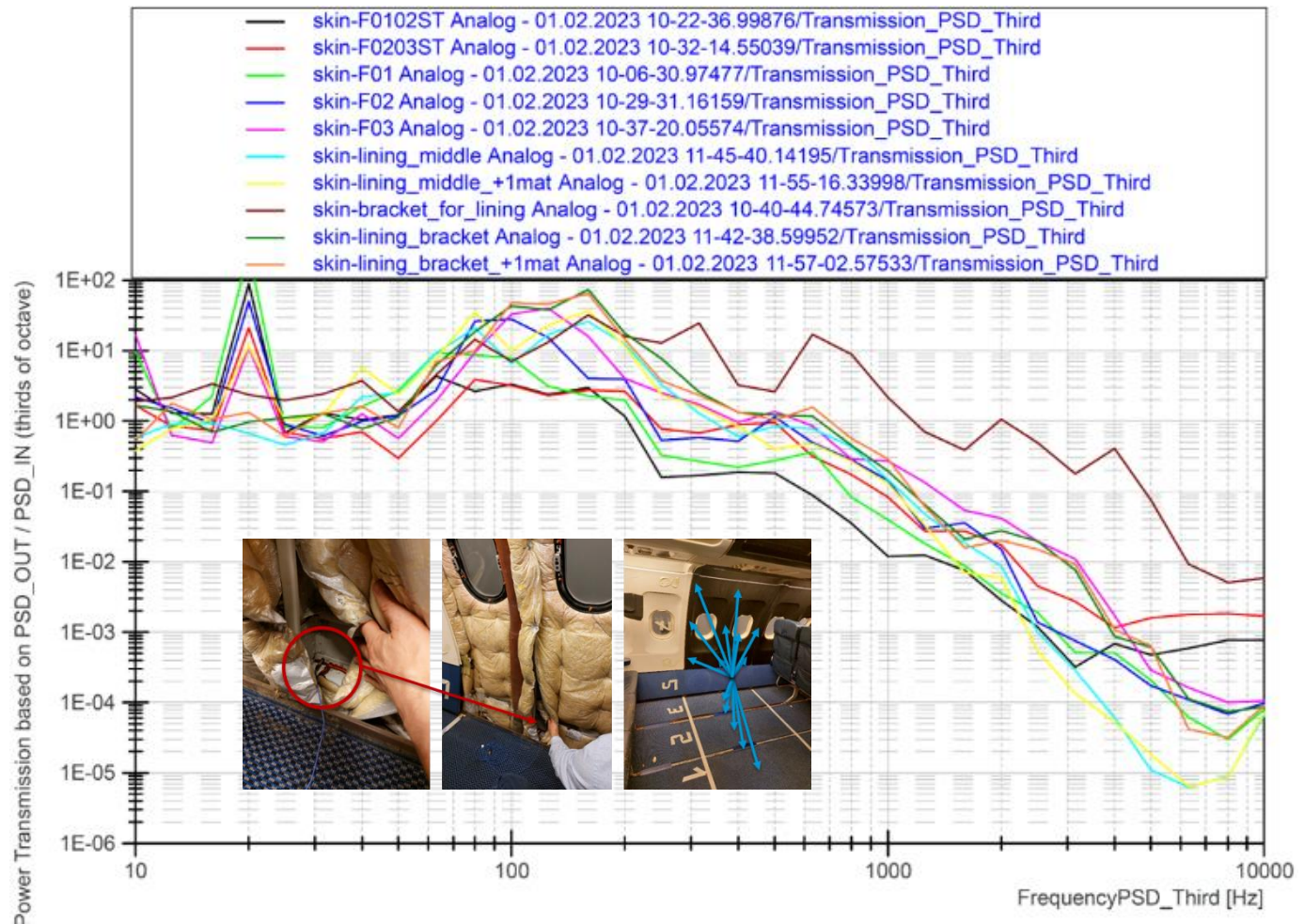
1. Floor Panel Inboard
2. Floor Panel Middle
3. Floor Panel Outboard
4. Dado Gap
5. Dado Panel
6. Lower Sidewall Panel
7. Window (-Panel)
8. Upper Sidewall Panel
9. Air Conditioning/ECS Gap
10. Closure Panel
11. Service Area Panel
12. Ceiling ECS Gap
13. Ceiling



ACOUSTICAL VIBRATION

Acoustical Excitation

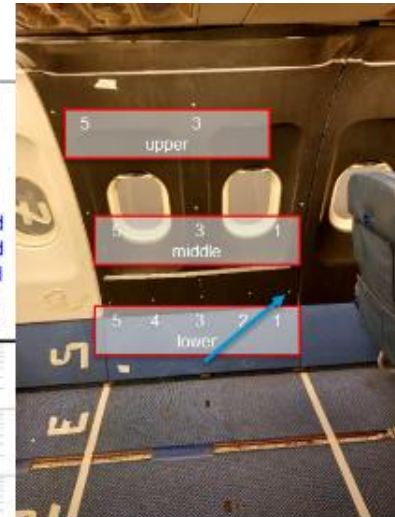
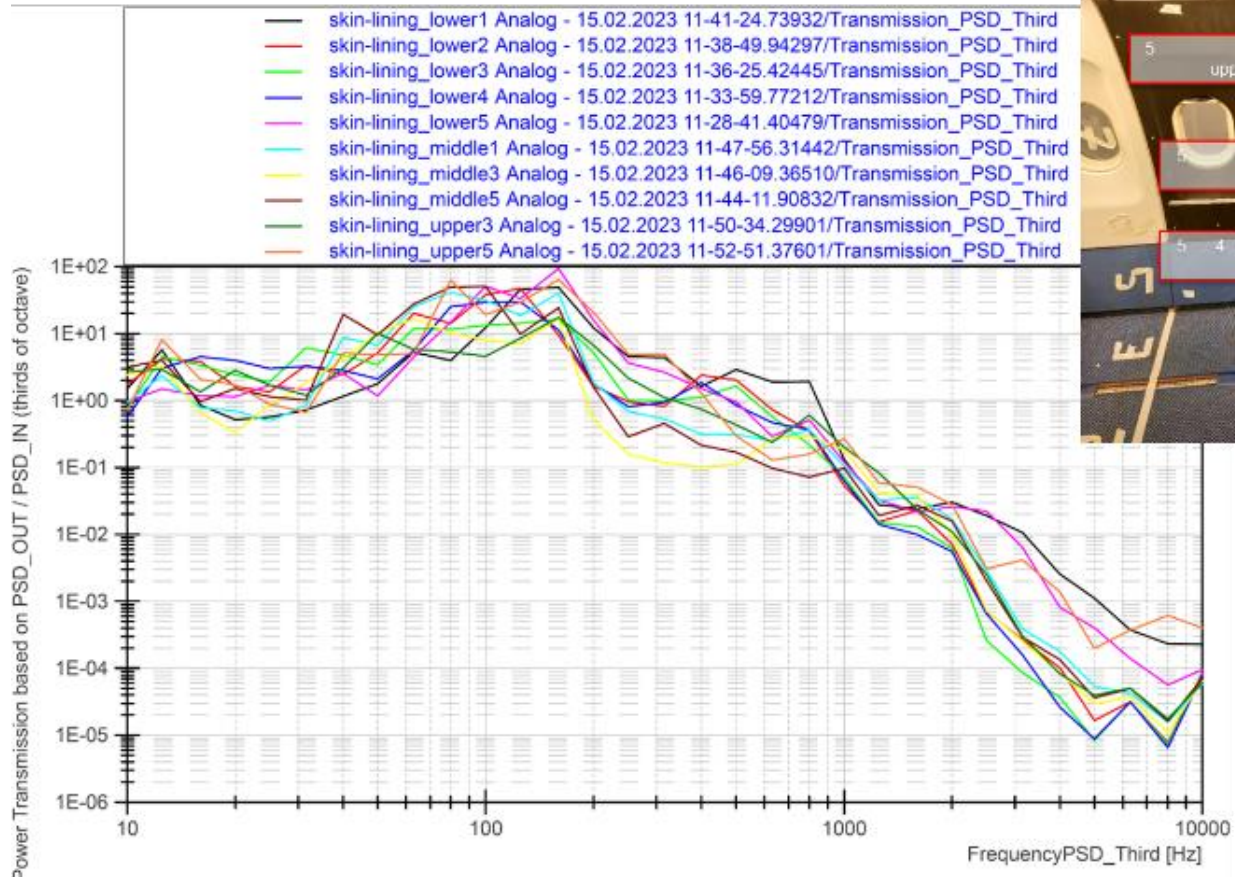
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ACOUSTICAL VIBRATION

Acoustical Excitation

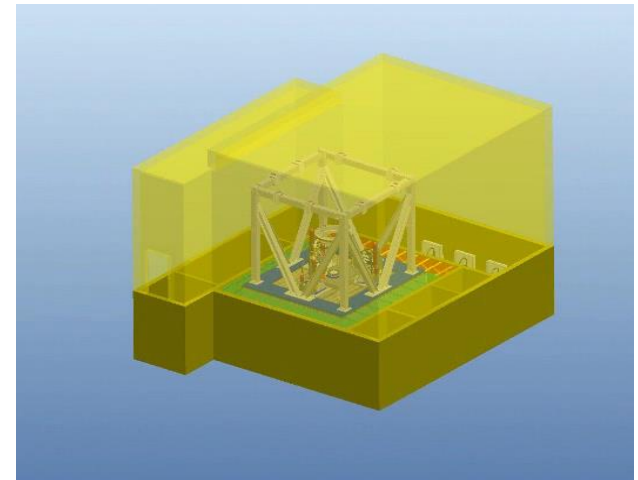
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MULTI-AXIS TESTING

TUHH Hexapod

- 6 axis test rig
- permanent 500kN, 40kNm, +/-300mm
- low frequency excitation
- more realistic excitation of multi-axis mode shapes



<http://www.tuhh.de/pkt>

MULTI-AXIS TESTING

TUHH Hexapod

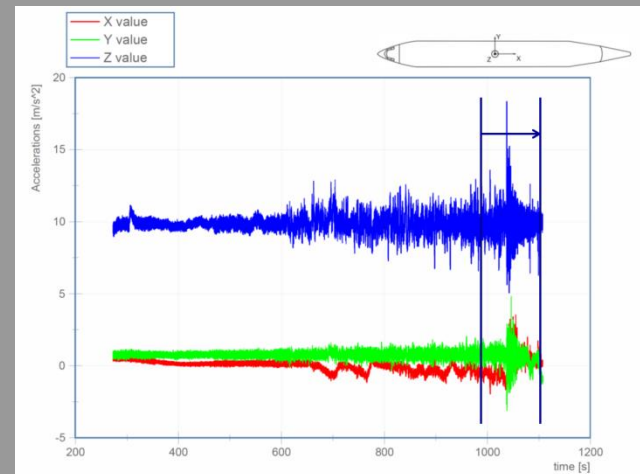


A320 NEO Stretcher Partition CAS

vibration excitation here only relevant for comfort

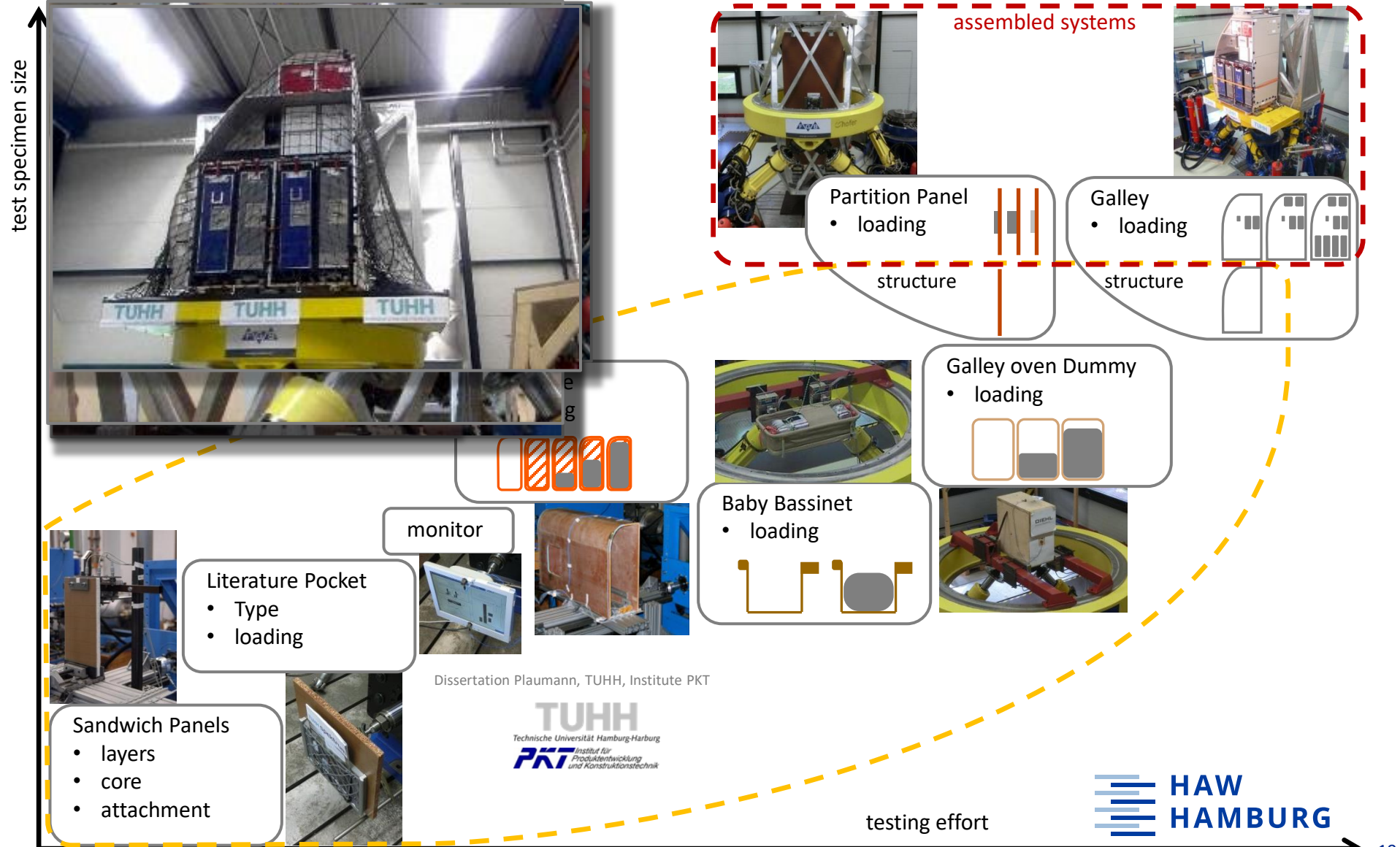
3 dimensions in space (multiaxial)

actual landing Hamburg RW33 A319



DYNAMIC SUBSTRUCTURING

TUHH Testing concepts from my PhD



DYNAMIC SUBSTRUCTURING

Galley vibration sideways



loading removed from oven dummy



partial loading of oven dummy

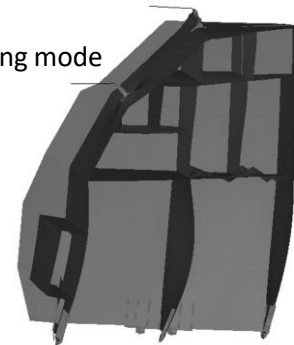


empty oven dummy



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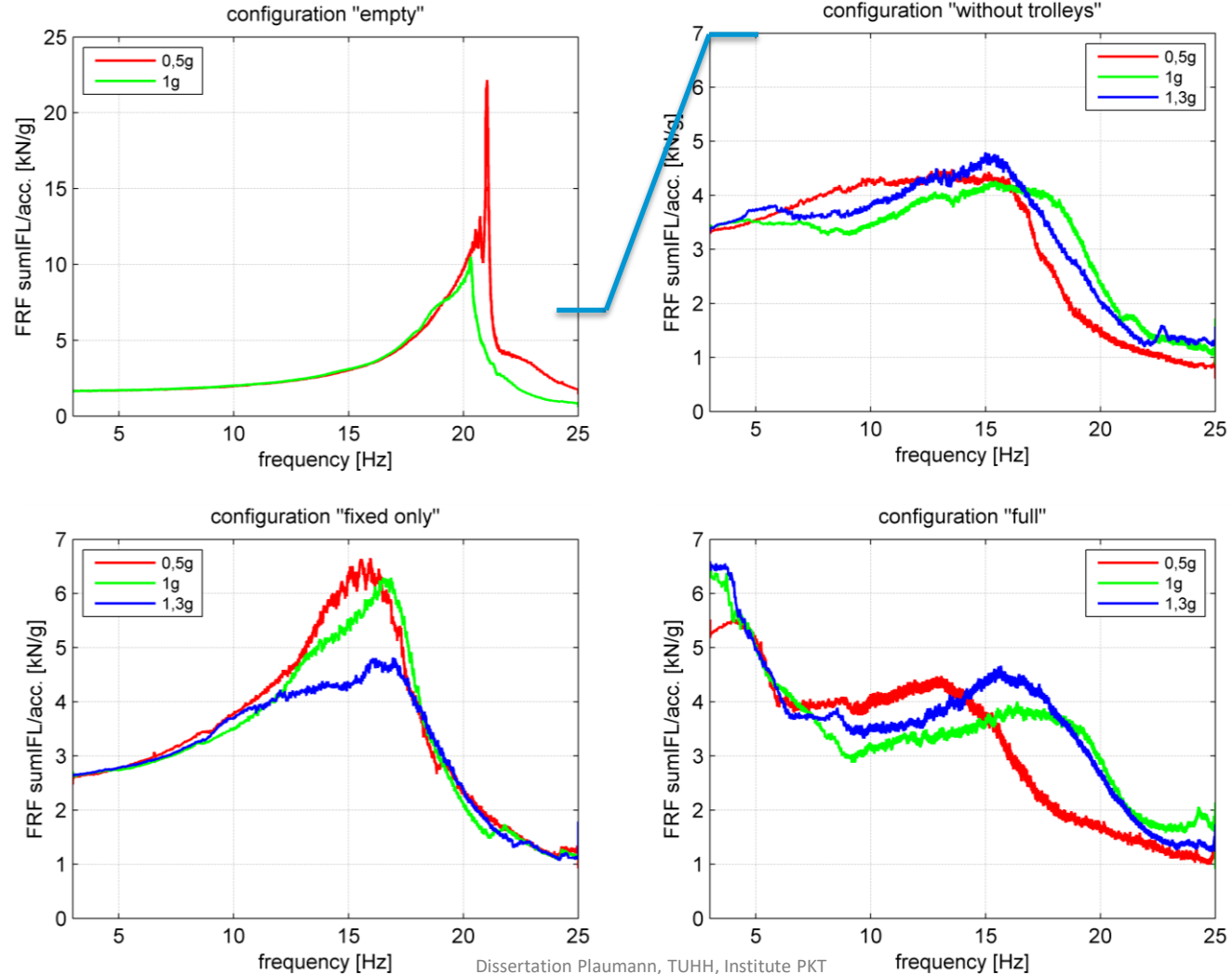
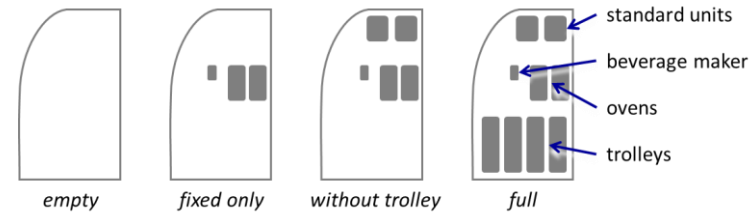
relevant bending mode exaggerated



DYNAMIC SUBSTRUCTURING

Galley vibration sideways

- ACC excitation in Y
- sum of forces in Y
- FRF
- rattle effect of trolleys with decoupling for lower deflection at higher frequencies
- highest loads at attachment points for empty galley

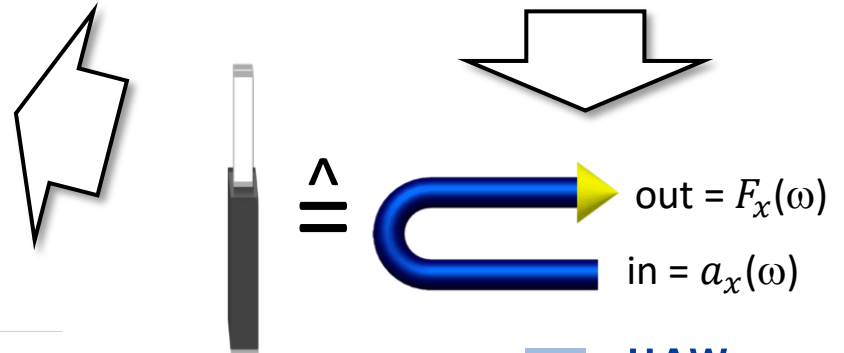
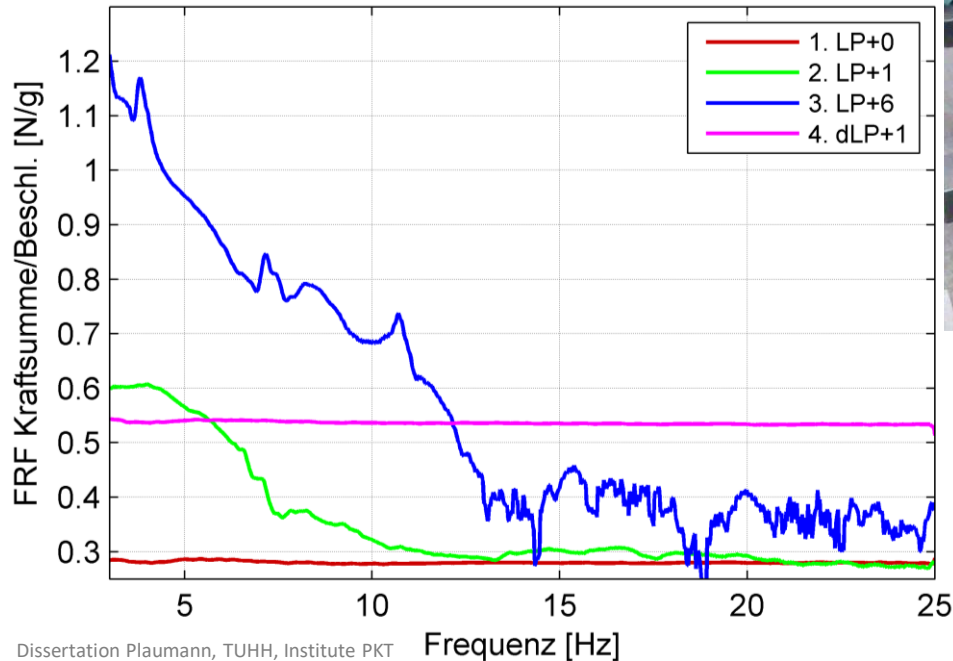
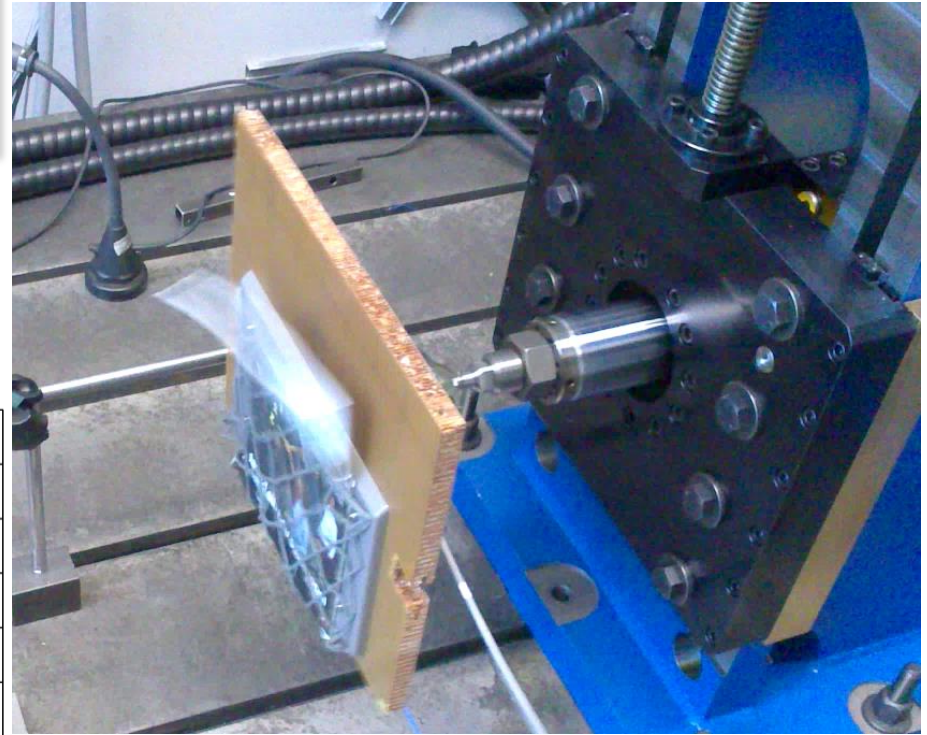
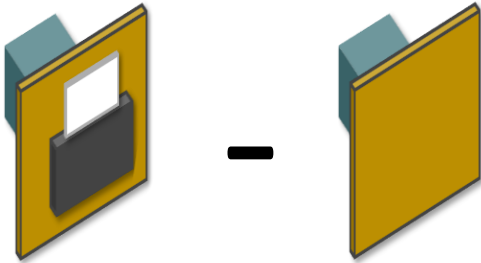
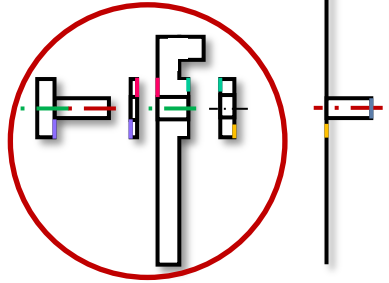


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DYNAMIC SUBSTRUCTURING

Decoupling

- system boundaries
- decoupling needed

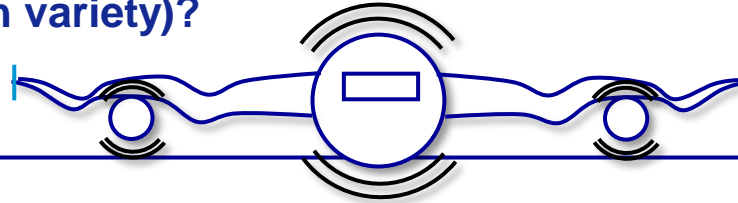


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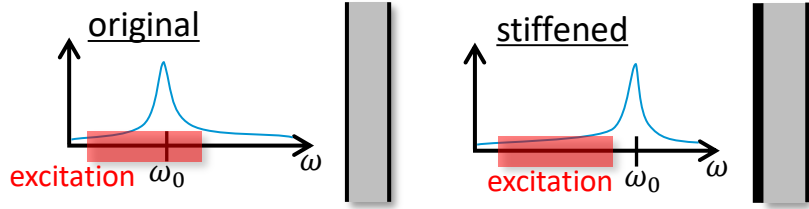
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 Department Automotive and Aeronautical Engineering
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DYNAMIC SUBSTRUCTURING

a vibrational problem, what to do (with variety)?



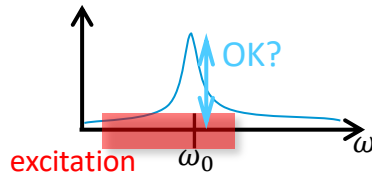
approach 1: stiffening



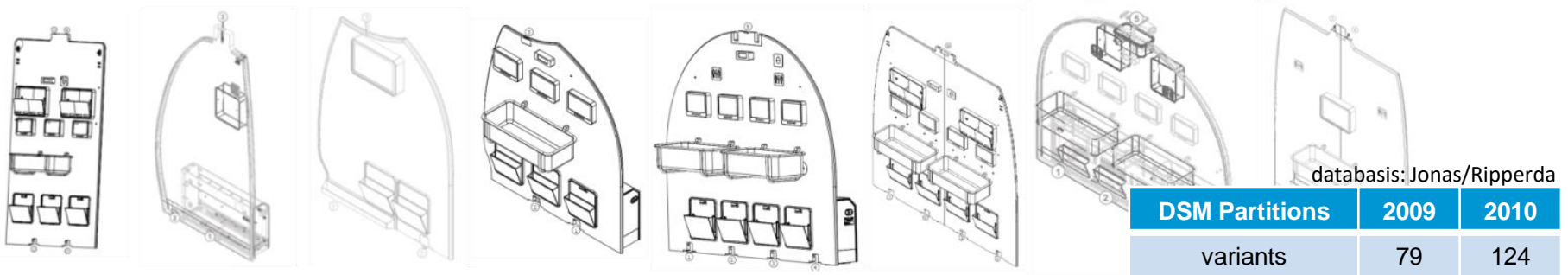
$$\omega_0 = \sqrt{\frac{k}{m}}$$

mass increase and acoustic problems

approach 2: detailed mechanical analysis



lightweight dimensioning



databasis: Jonas/Ripperda

DSM Partitions	2009	2010
variants	79	124
units/variant	4,6	3,7

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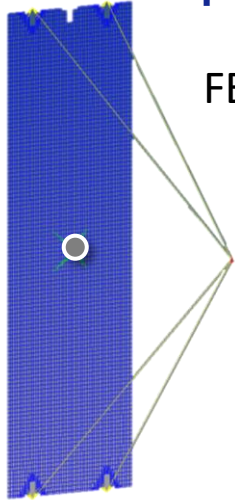
images: Diehl Service Modules

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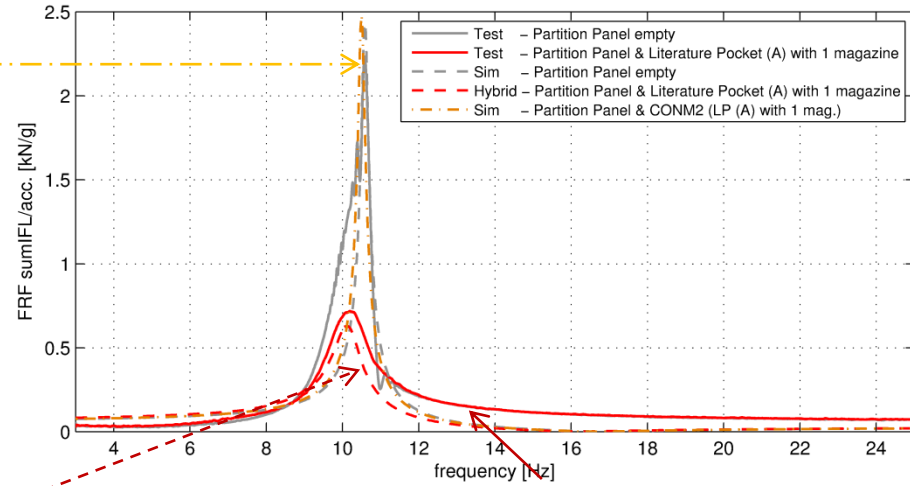
DYNAMIC SUBSTRUCTURING

Partition example



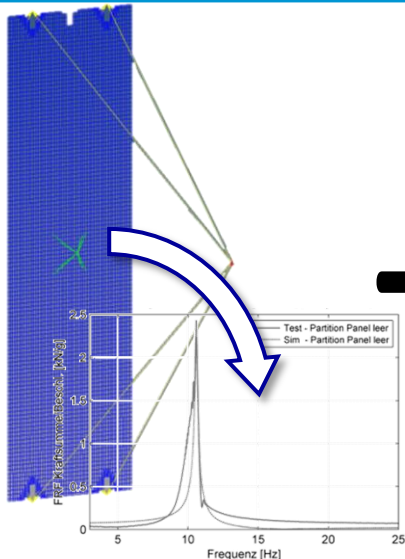
FEM with CONM2 masses

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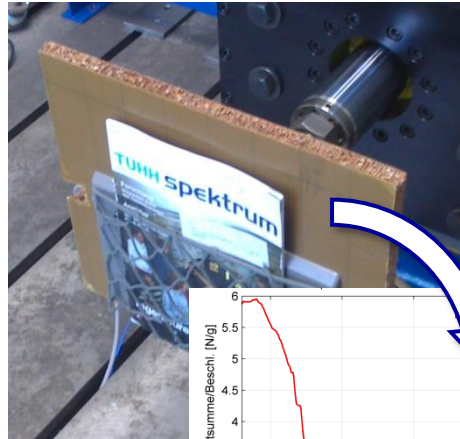


NEW: dynamic substructures in hybrid model

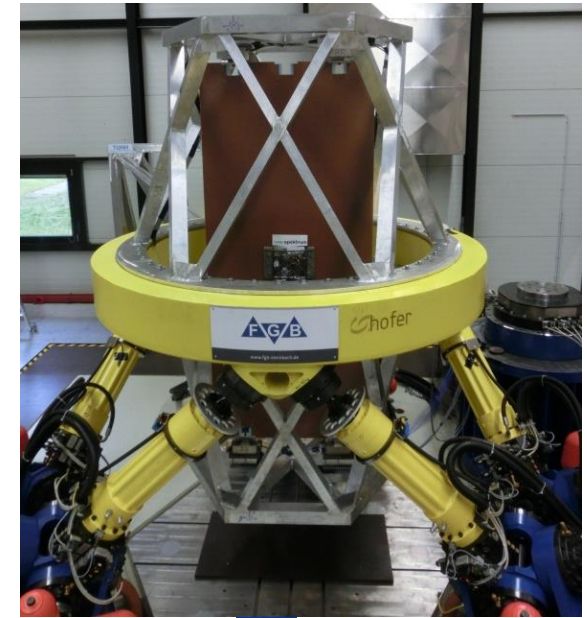
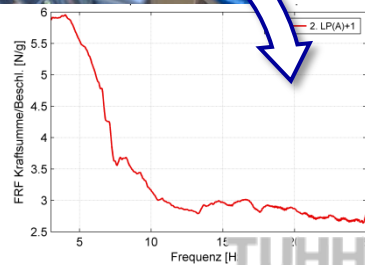
verification



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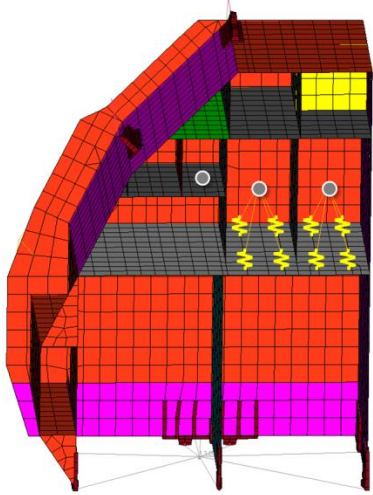


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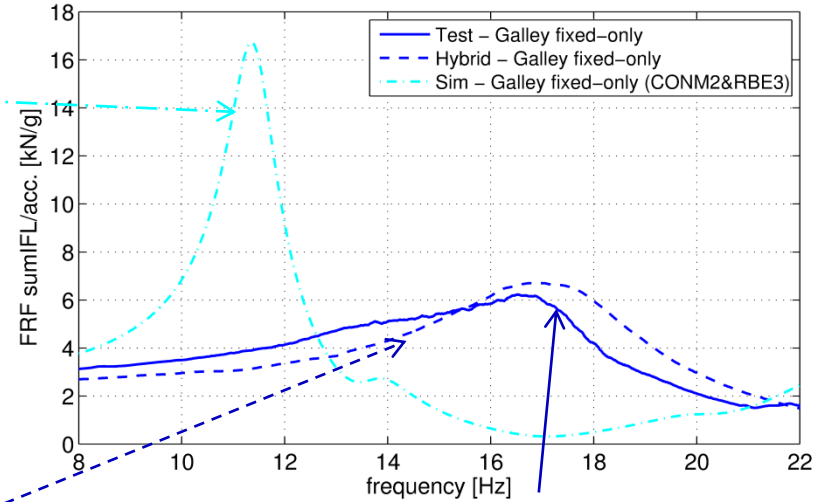


DYNAMIC SUBSTRUCTURING

Galley example

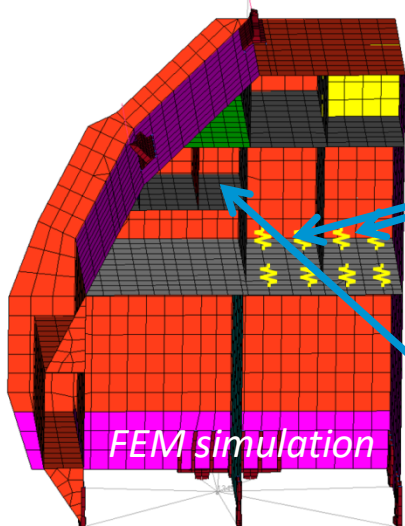


FEM with CONM2 masses

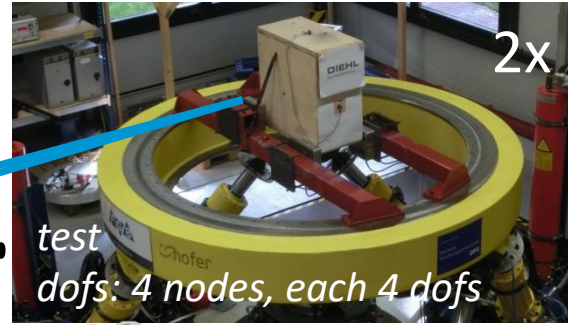


verification

NEW: dynamic substructures in hybrid model



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idealization dofs: 1 nodes, 3 dofs



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Thank you for your kind attention!

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aufgrund eines Beschlusses
des Deutschen Bundestages

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