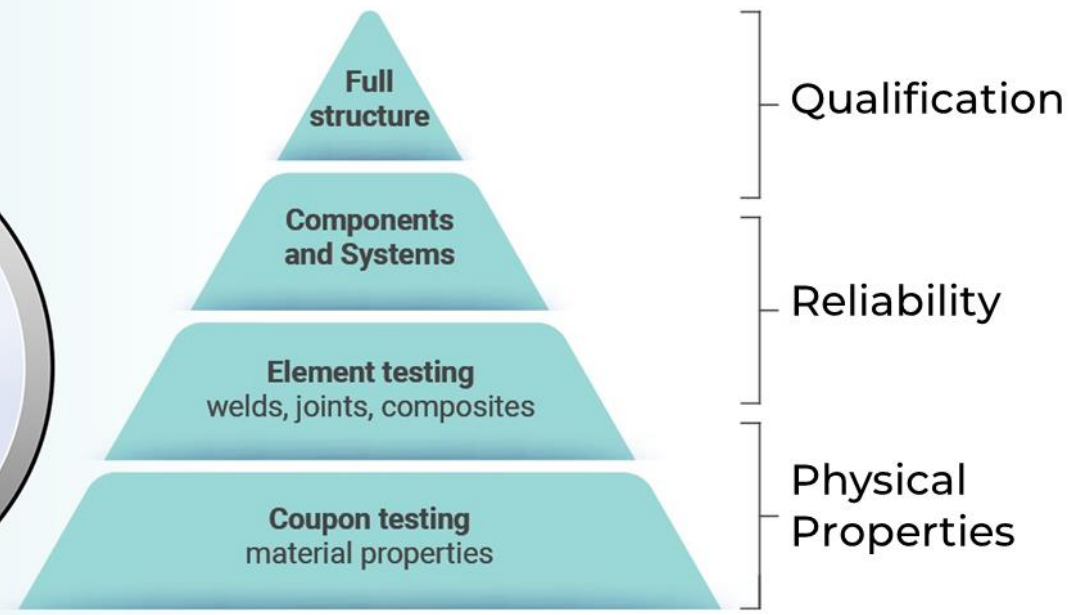
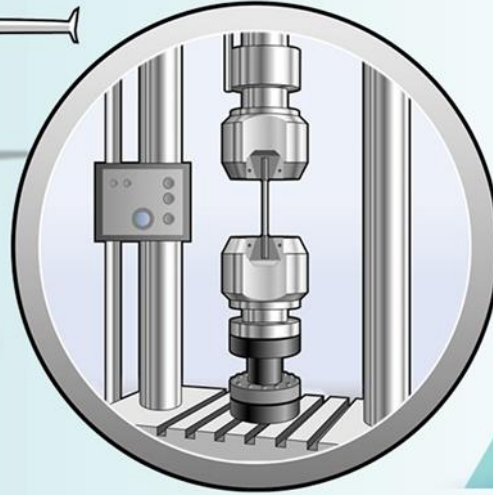
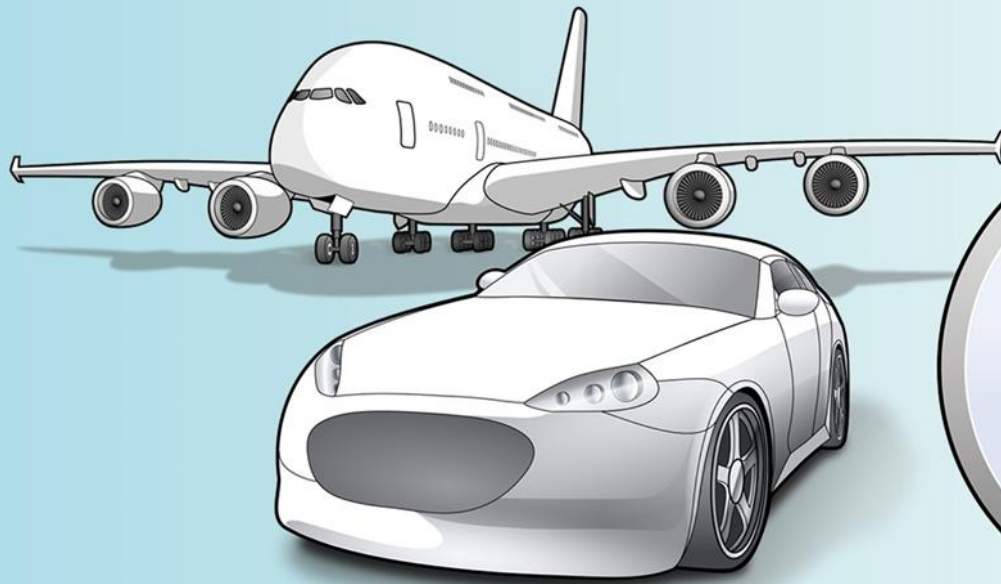
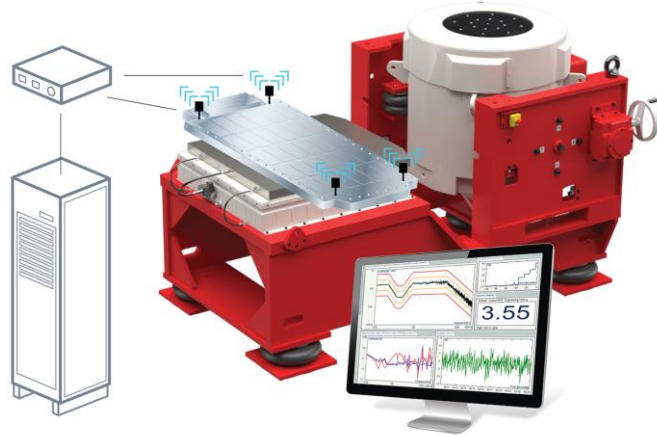




2023 HBK Technology Days

7 November 2023



- An introduction to vibration shaker testing: a prelude to EV battery testing,

Tim Gardiner,
Product Manager - Vibration Test Systems, HBK

An introduction to vibration shaker testing: a prelude to EV battery testing

Abstract

- Vibration testing aims to reduce the risk of product failing in the field by simulating the vibration conditions that products are exposed to during their lifetime. Test specifications define the applied vibration levels. It is a crucial process in various industries, including aerospace, automotive, and telecommunications, where the failure of mechanical and electronic systems can have severe consequences.
- This presentation will describe shaker systems and introduce vibration testing and the theory behind it. A wide range of shaker solutions are required to meet many different industry challenges and applications within this fast evolving test arena. A summary of topics include:
 - Electrodynamic shakers – the what and the how
 - Brief range overview
 - Applications overview
 - Combined vibration testing of EV batteries

About the presenter, Tim Gardiner, Product Manager - Vibration Test Systems, HBK

- Tim Gardiner joined Hottinger Brüel & Kjær in 2021. Tim has nearly 20 years of experience in product management and commercial leadership both in the UK and Europe with a background in test and measurement. Tim has responsibility for all VTS products that serve in the aerospace, automotive and defence industries, He has a business degree from the Solent University in the UK.

Shaker Testing Basics: A Prelude to Battery Testing

Tim Gardiner
Head of Product
Management - VTS



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Agenda

1. Shaker Testing – The “Why”
2. What is a Shaker System?
3. “The How”
4. Typical vibration profiles
5. An introduction to EV Battery Testing

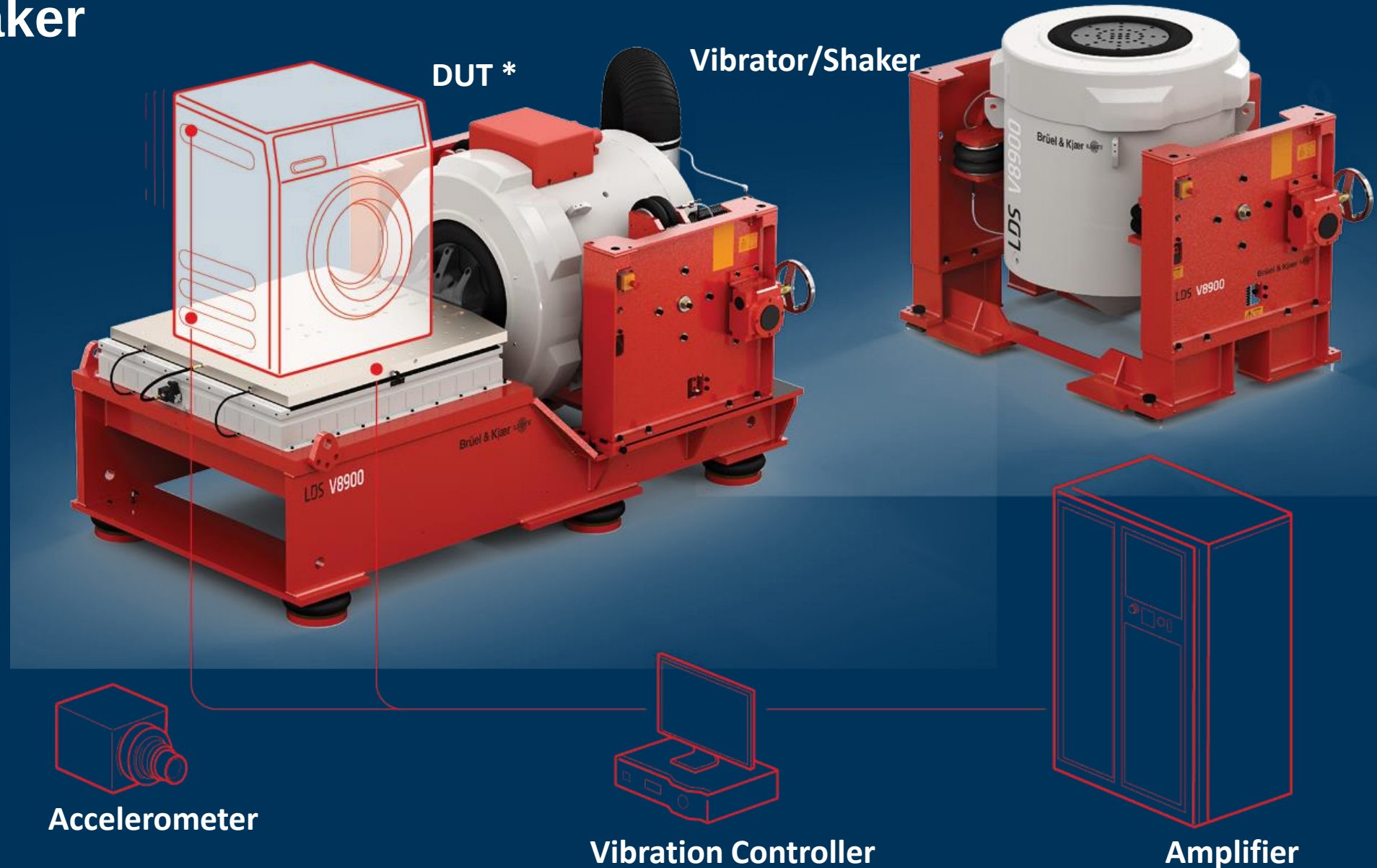
Shaker Testing – the Why

- ▲ Vibrations are all around.....
- ▲ Determine if a product can withstand the rigour of its environment
 - To ensure the final design will not fall apart during transportation
 - Environmental Stress Screening to ID production defects
 - As a form of Accelerated Stress Testing
- ▲ Typical applications
 - Satellite testing
 - Military hardware
 - Avionics instrumentation
 - Consumer electronics
 - Automotive components
 - Telecoms equipment

What is a shaker system?

Traditional Ecosystem

1. Vibrator to simulate the vibration profile required for the DUT
2. Amplifier or field supply to provide DC field and armature drive to the vibrator
3. Vibration Controller and computer to provide an input signal to the amplifier
4. Accelerometers are affixed to the DUT and the moving masses of the shaker
5. Accelerometers provide the feedback loop to the vibration controller to ensure the control profile



A Brief History

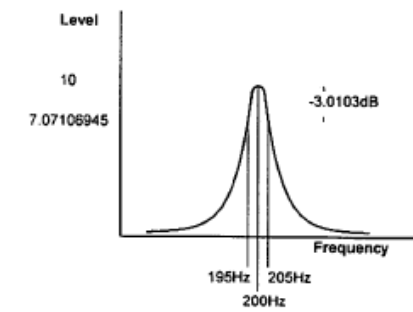
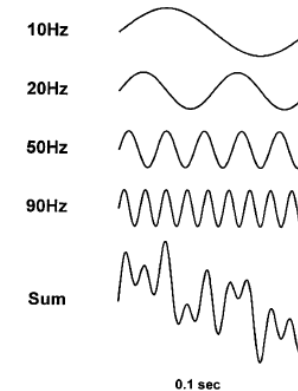
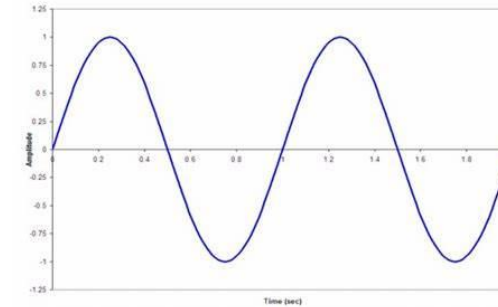
- ▲ NASA - Saturn V Apollo Shake Test
- ▲ Ensure the rocket would survive instability and not break apart
- ▲ Now things are a little more controlled



Source: Youtube (<https://youtu.be/s0UYNoTPdNs>)

Electrodynamic Shakers – The How

- ▲ Sine Profiles
 - Single frequency or swept over a range of frequencies.
- ▲ Random Profiles
 - Gaussian distribution of different level of vibration.
- ▲ Shock Profiles
 - Single or multiple Pulses with a given duration at specific frequencies.
- ▲ Mixed Mode Profiles
 - SOR, ROR, SRS etc.



Electrodynamic Shakers – The How

▲ Swept Sine Test

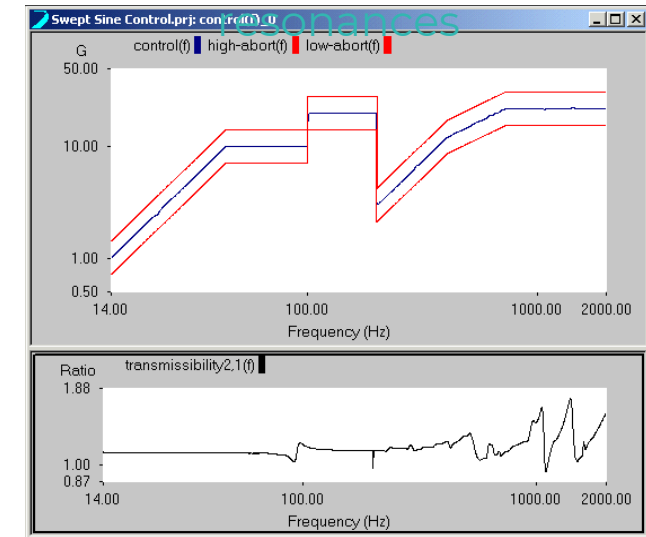
- The units used for sinusoidal vibration testing are:
 - Frequency Hz or radian/s
 - Displacement mm or inches peak-peak or peak
 - Velocity m/s or in/s peak
 - Acceleration m/s² or gn peak

$$\frac{1}{\log 2} = 3.321280$$

$$\frac{1000}{15} = 66.666666$$

$$(\log 3.321280) \times (\log 66.666666) = \underline{6.058893}$$

The classical Vibration Test
Locating structural

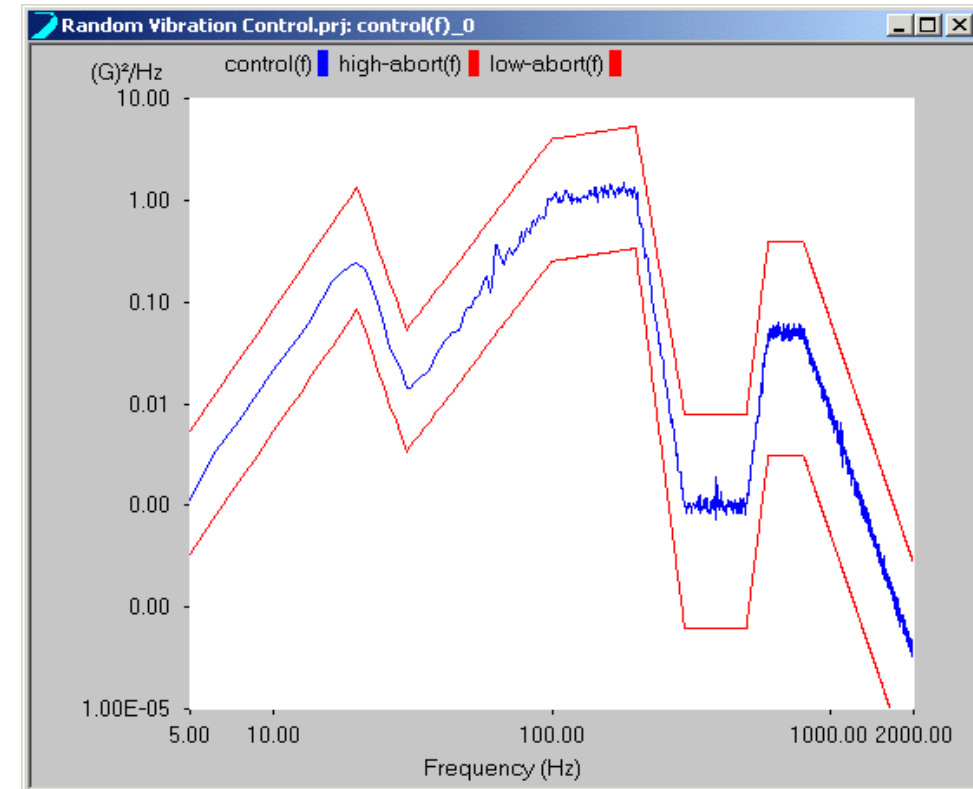


6.058893 mins @ 1
Octave/min

Electrodynamic Shakers – The How

- ▲ Random Test 
- Varying level test
- Unpredictable levels
- Has no fixed frequencies

A classical broadband test

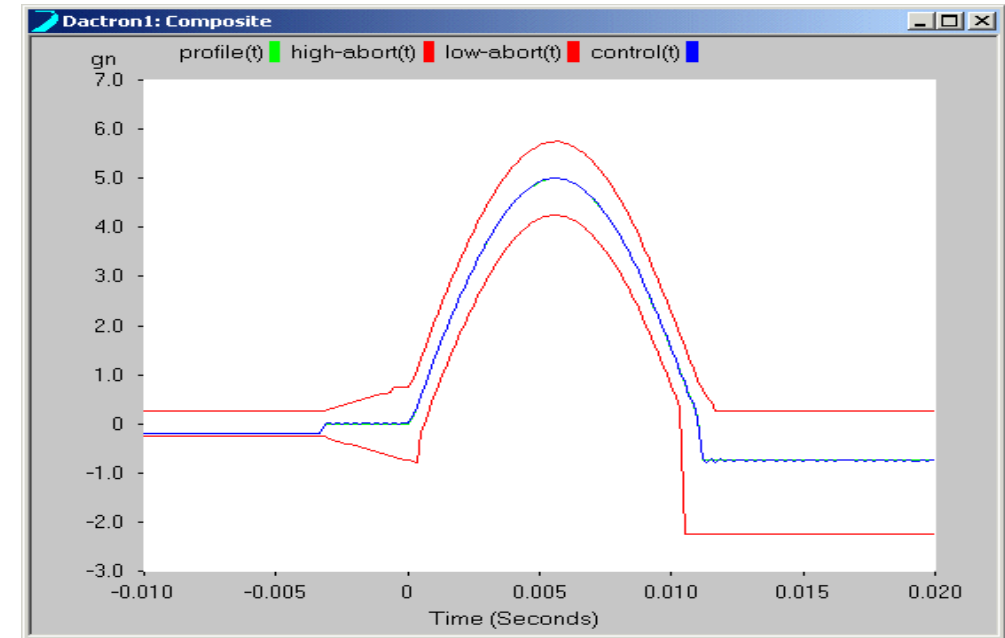


Electrodynamic Shakers – The How

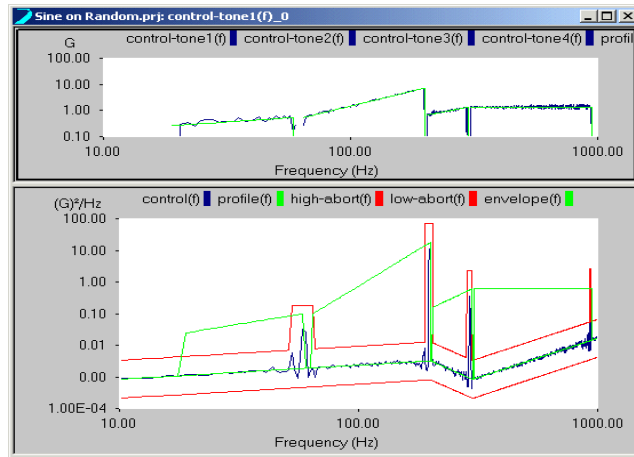
▲ Shock Test

- Transient pulse – sudden and severe impacts
- Duration = period of time to go from zero to maximum to zero acceleration,
- Usually defined in milliseconds.

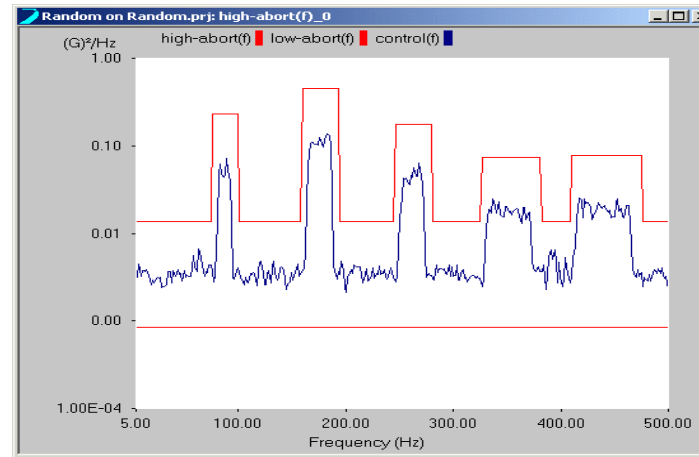
A classical drop test



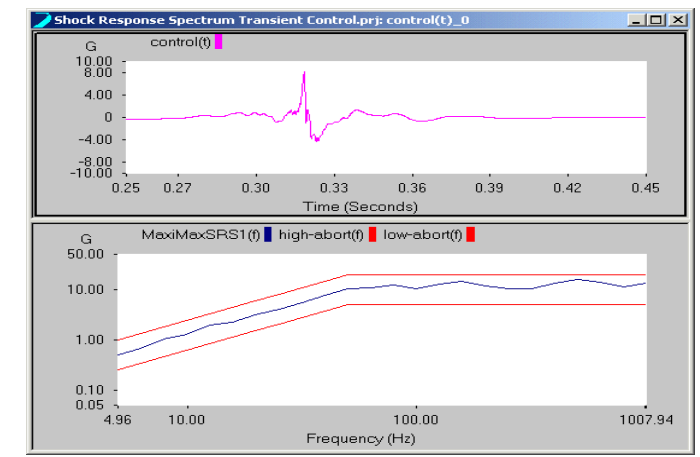
Electrodynamic Shakers – The How



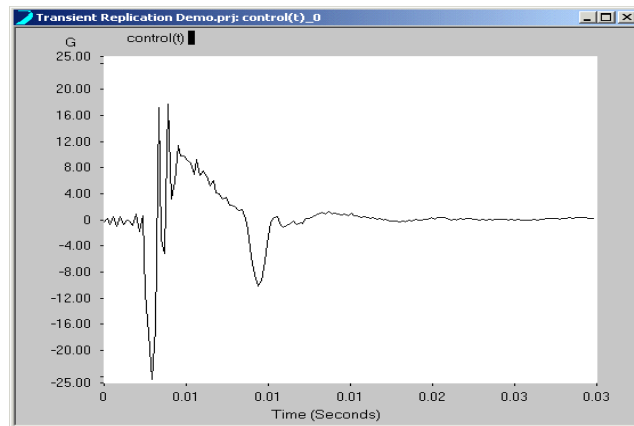
Sine on Random (SoR)



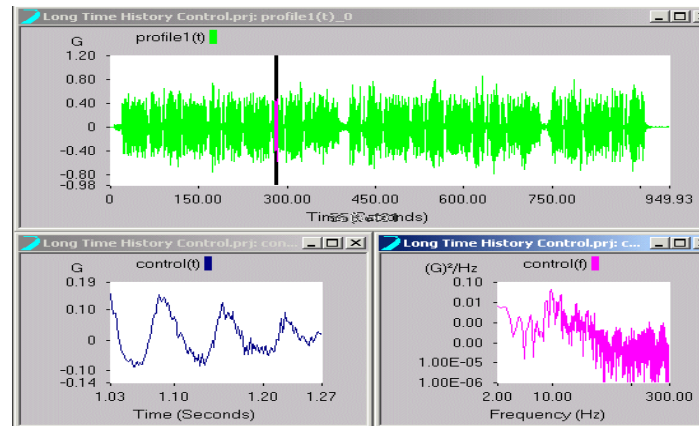
Random on Random (RoR)



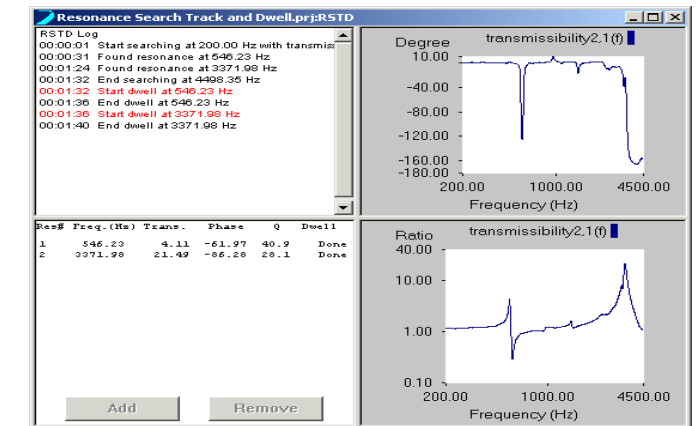
Shock Response Spectrum (SRS)



Transient Replication



Replication of Long Time Histories

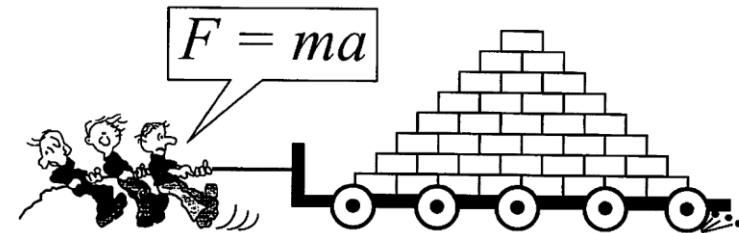


Resonance Dwell



Electrodynamic Shakers – The How

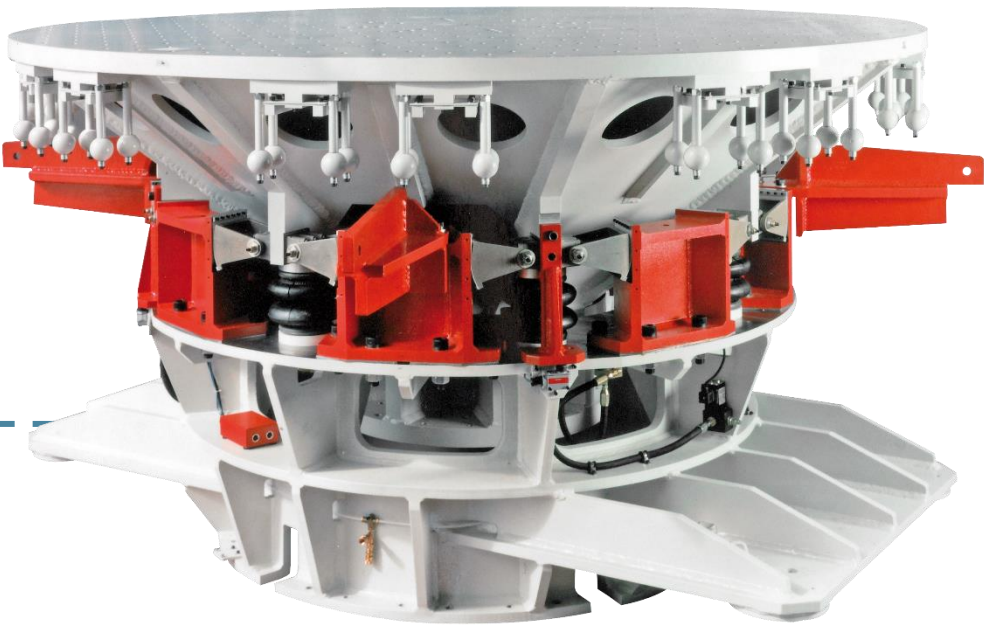
- ▲ Most fundamental rule is Newtons 2nd law of motion ($F=MA$):
 - Force (F) required to move an object is the Mass (M) multiplied by the Acceleration (A)
- ▲ However, there are other factors that need to be considered:
 - Displacement (physical distance to move)
 - Velocity (speed at which to move)
 - Frequency Range



Test Accessories

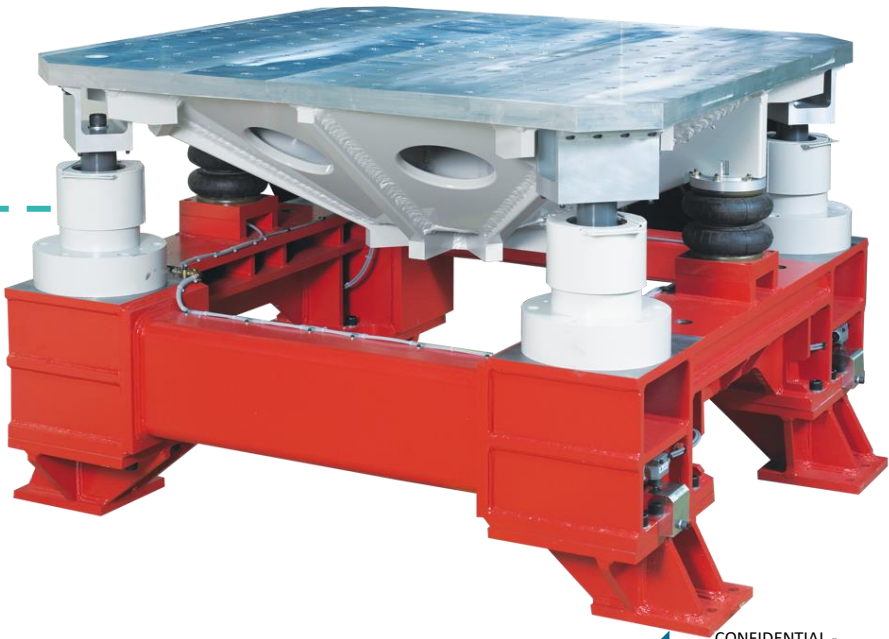


Slip
Tables



Head
Expanders

Load
Bearing
Platforms



Custom
Fixturing

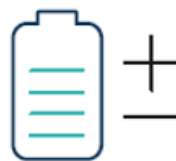
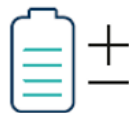
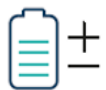


Vibration Testing of EV Batteries



- ▲ The battery's performance and reliability are critical to ensure the quality of the whole electric vehicle
- ▲ Electric car battery testing and certification ensure that batteries comply with global safety requirements and performing reliably.
- ▲ Over the course of their service life, batteries will deteriorate – perhaps to total failure
- ▲ It is essential to carry out EV battery testing to verify ***durability, safety*** and ***reliability***.

Vibration Test Systems for Small, Medium and Large Batteries



Shaker Model	V8750	V8800	V8900	V9940
Battery type	Cell	Cell/Smaller Modules	Module	Packs
Max. Sine Force	35.6 kN	59 kN	80 kN	300 kN
Max. Shock Force	140 kN	175 kN	254.1 kN	800 kN
Profile	ECE R100, AK LH 5.21, UN38.3, ISO 12405   50 g/6 ms shock 50 g/11 ms shock 25 g/15 ms shock 30 g/6 ms shock 30 g/11 ms shock 100 g/6 ms shock 100 g/11 ms shock 150 g/6 ms shock  LV124/VW80000, UL 1973, EN 61373			

- ▲ ECE R100 and ISO12405, have been developed to standardize the testing procedures of batteries and their subsystems
- ▲ UN38.3 Transport Safety - Lithium or Lithium-Ion batteries are able to be shipped by air, ground, sea or rail.
- ▲ Battery packs are always rectangular
- ▲ Always have a low centre of mass
- ▲ Typical sizes from 1.2 m length to 3 m
 - 2.4 m x 1.8 m battery is typical (family sedan, inc. fixture)
 - Typical DUT mass 700 kg, fixture 250 kg

Environmental Testing and Safety in testing EV Batteries



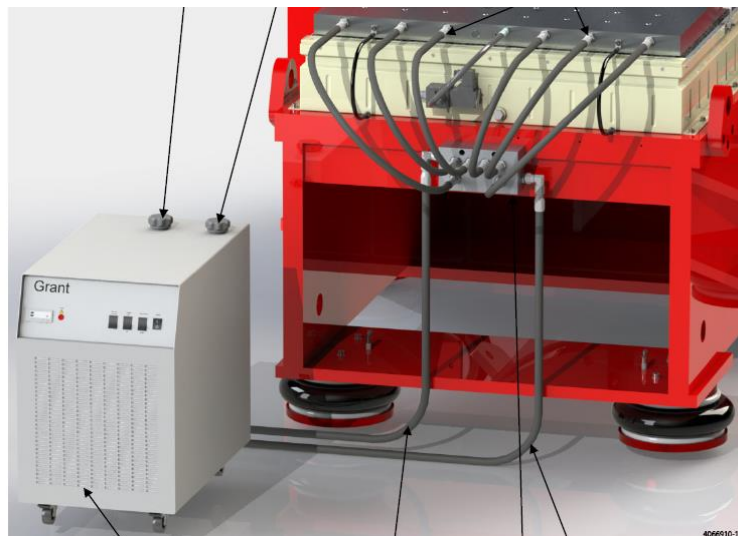
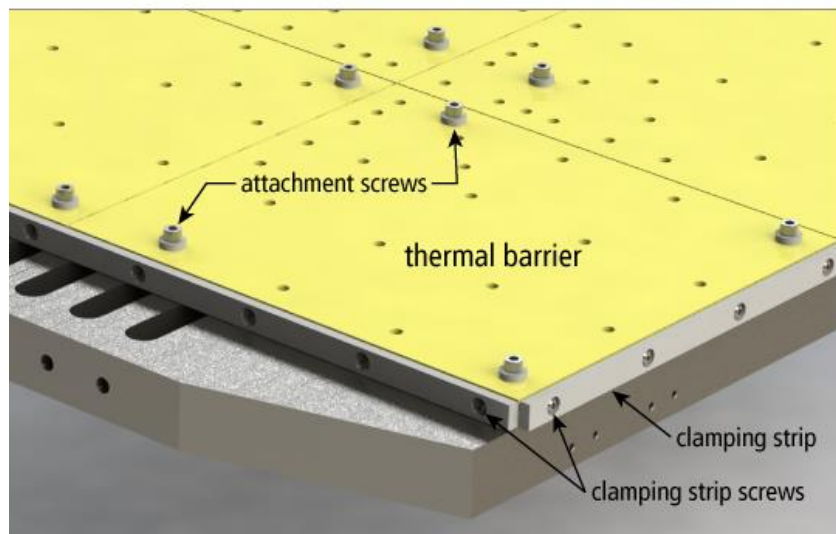
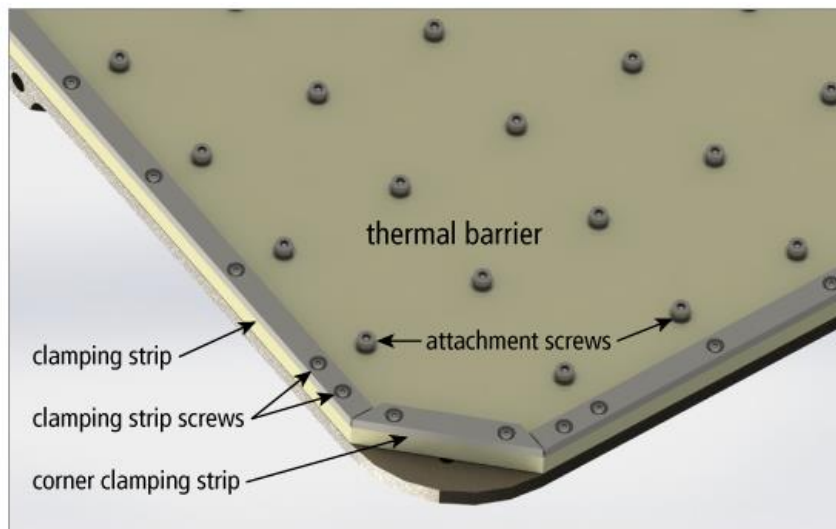
▲ **Practical considerations:**

- Civil works
- Testing “pit”
- Fundament/seismic base
- Lifting equipment
- Chamber integration – horizontal & vertical
- Environmental testing with Variable temp/humidity typically -40C to +
- In the ecosystem there will be Battery Abuse, and Performance facilities

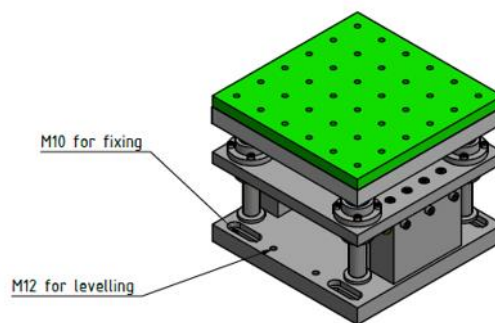
▲ **Thermal management options** for:

- Water spray/mist
- Humidity/temp.
- Flooding – safety

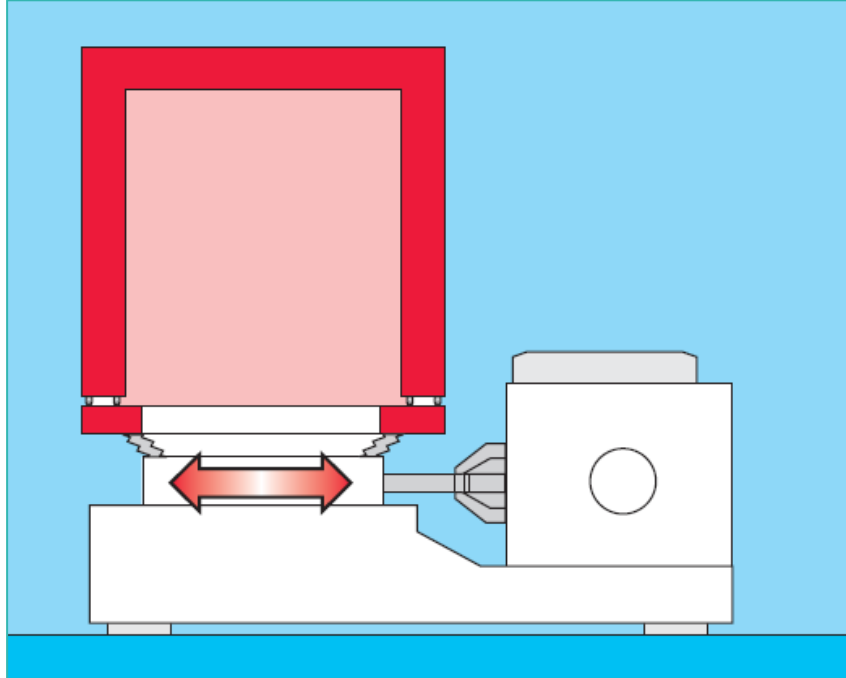
Thermal Management Options



- Thermal barriers (on slip plate, head expander and pedestals)
- Low thermal conductivity with very high compressive strength
- Effective for battery testing application
- Resistant to: electrolytes, water-glycol coolant, gear box oils & gases (H_2 , CH_4 , CO , CO_2 , C_2H_4 , C_2H_6 , etc.)
- Hot and cold units used for tempering the slip plate and oil

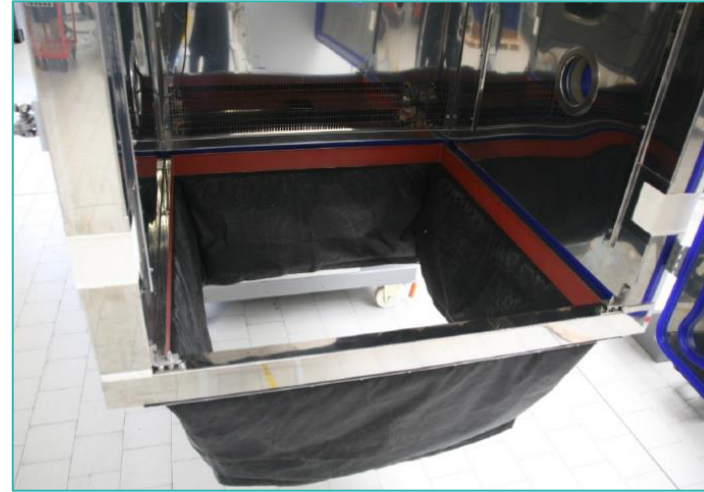


Traditional Horizontal Connection to Slip Plates



Typical connection

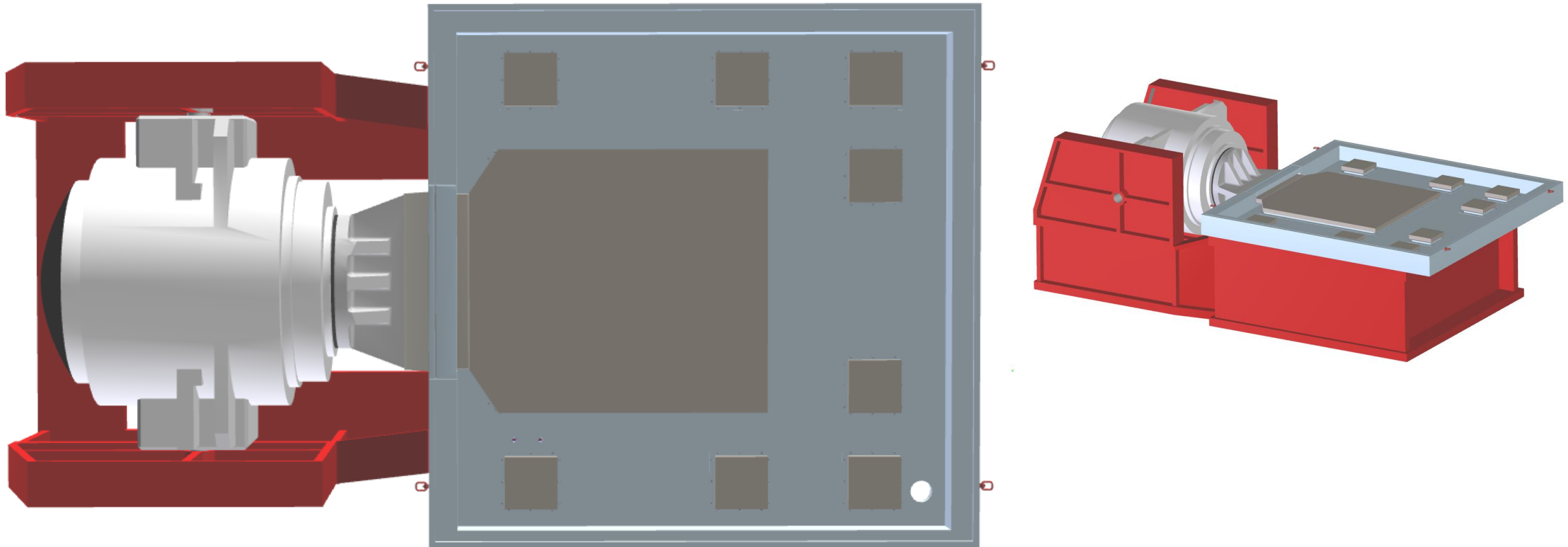
- Height difference between slip plate and chamber floor
- Outside of the chamber
- Standard sealing with clamping strips and membrane



Special Horizontal Connection to Sliptable for V9940

With extra cutout for driver bar

→ No height difference between the slip plate and chamber floor



Extension Bar + Chamber floor with Trapeze Cutout

Electrodynamic Shakers – re cap

- ▲ What do you want to test?
- ▲ What vibration do you want to simulate?
- ▲ What data do you wish to capture?
- ▲ What information do you want to acquire?
- ▲ What budget do you have?



▲ Tim.gardiner@hbkworlId.com

www.hbkworld.com

**INTRODUCING THE NEXT GENERATION OF SHAKER TESTING:
LDS V8800 + XPA-K SHAKER SYSTEM**

www.bksv.com

LDS VIDEO

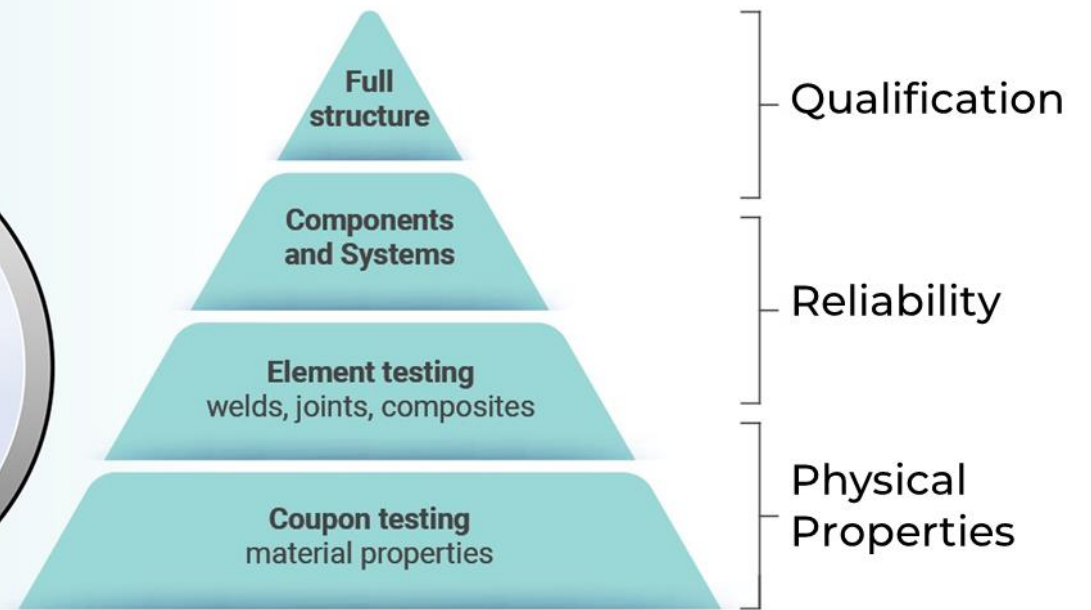
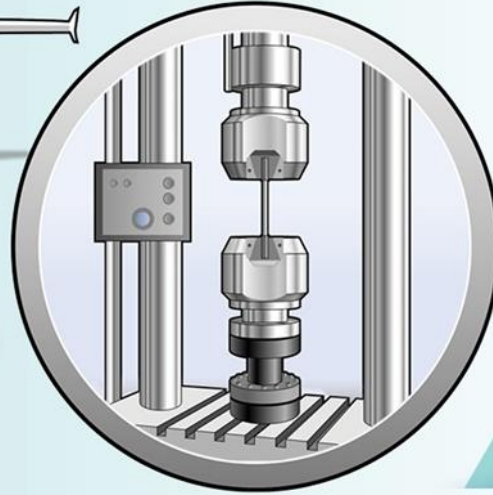
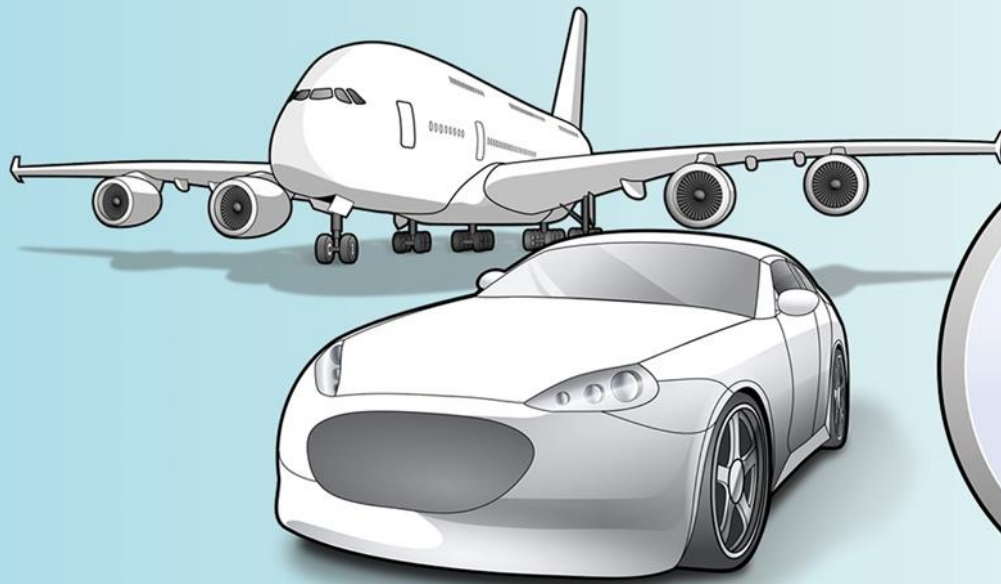
Thank You

Questions?



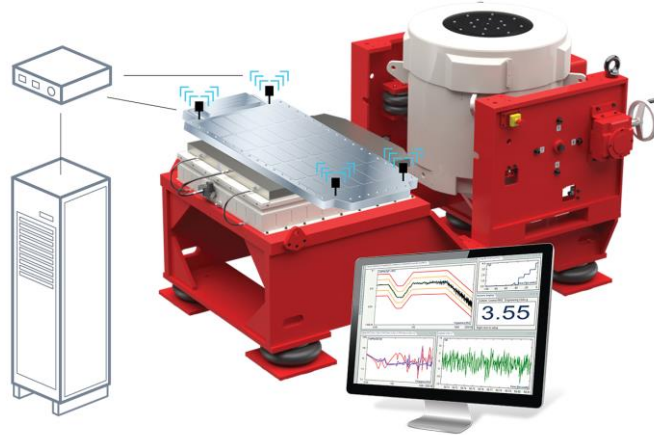
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