



ACCELERATE PRODUCT DEVELOPMENT WITH THE NVH SIMULATOR

We bridge the gap between testing and simulation to
accelerate product development



Design and engineer the sound and vibration of your vehicle to meet brand and customer expectations before building the first prototype.

N V H



VEHICLE DEVELOPMENT CHALLENGES TODAY



TIME TO MARKET



DEVELOP
IN LESS TIME

DEVELOPMENT COSTS



LESS PROTOTYPES AND
TESTING

COMPLEX SYSTEMS INTEGRATION



COLLABORATIVE
DEVELOPMENT PLATFORM
AMONG THE INDUSTRY

CURRENT NVH CHALLENGES



Acoustic signature

- Acoustic Brand
- Acoustic Comfort
- AVAS



Ride comfort

- Study and definition of the contents needed to ensure the vibrational (i.e. feet, seat and handlebar) and acoustic comfort perceived by the rider.



Increased reliance on simulation

- Significant reduction in physical prototype vehicles and parts
- Need to evaluate in advance integration of intake, exhaust, powertrain and transmission
- Listen and drive any design modification



Need to simulate and experience vibration (+ sound)

- Vibration is a long-neglected part of NVH, because it has not been easy in the past to turn vibration simulation results into something people can experience
- The NVH sim addresses this urgent customer need



Electric Vehicles

- Loss of character
- Loss of Brand recognition
- Need to deliver a different ride experience
- AVAS - Legislated low-speed minimum noise generation

WHY IS VEHICLE SOUND AND VIBRATION IMPORTANT?



Rider's ears

- Comfort
 - Annoyance
 - Loudness
- Feeling of Quality
- **Character**
 - Driver satisfaction
 - Communication



Exterior

- **Character**
- Soundscape
- Pedestrian Warning

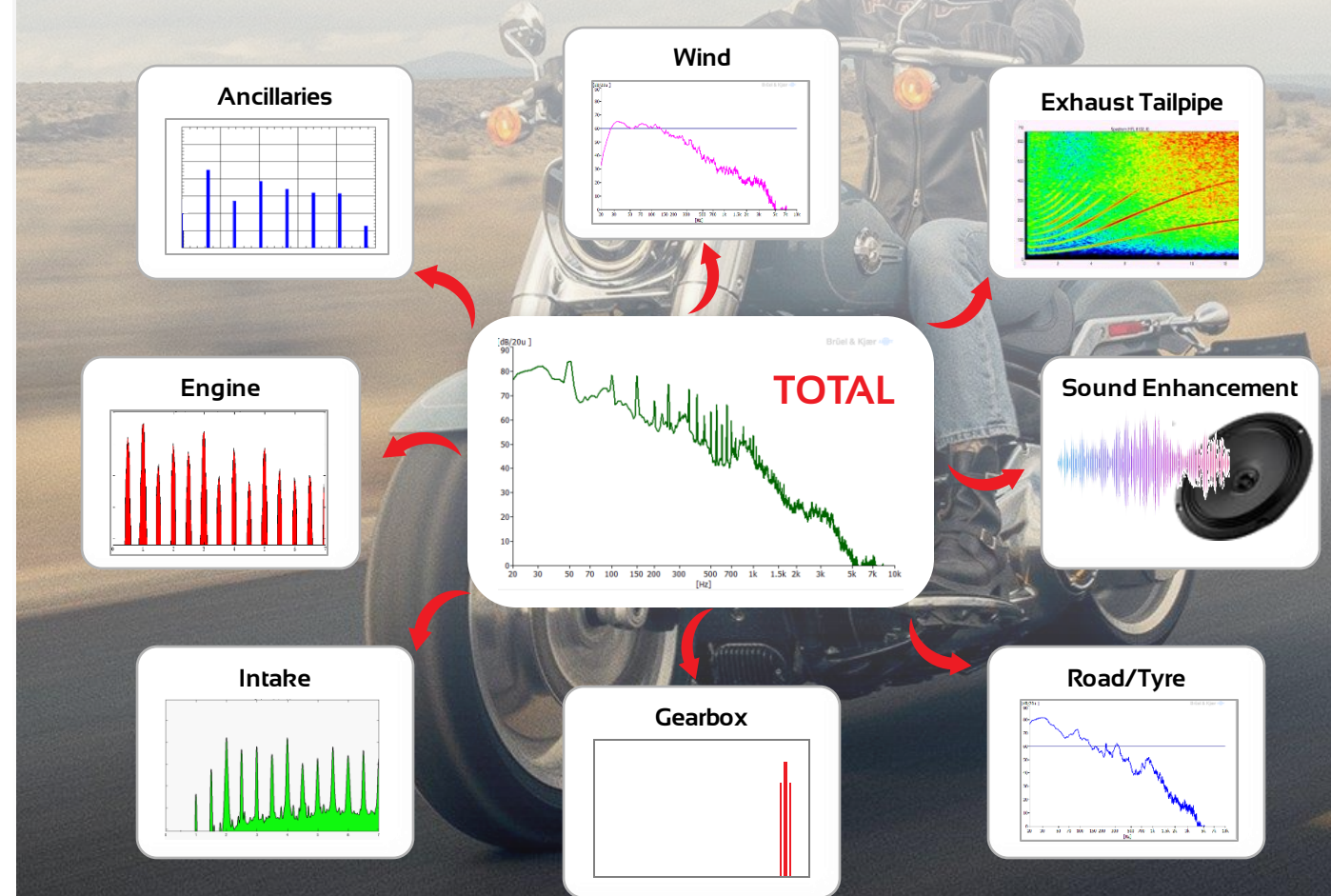


Vehicle NVH affects

- Initial buying decision
- Customer satisfaction/ warranty cost
- Customer loyalty/repeat buyers

Brand
DNA

NVH is one of main attributes controlling and delivering
Vehicle Refinement and Brand DNA



CURRENT CUSTOMERS

66 NVH Simulator systems sold

- 54 systems to 24 separate OEMs
- Each of the 8 biggest OEMs owns at least one NVH Simulator
- 7 to Universities or Research Institutes
- 4 to Tier 1 suppliers
- 1 to engineering services supplier



(plus many others)



WHO WAS THE FIRST NVH SIMULATOR CUSTOMER?

WITH THE AIM OF PRESERVING THE VIBRO-ACOUSTIC HERITAGE OF THE BRAND



VI-NVHSIM FOR MOTORCYCLE MODELING

SOUND & VIBRATION DIGITAL TWIN FOR VEHICLE DEVELOPMENT

MULTI-ATTRIBUTE SIMULATION



VEHICLE NVH MODEL

A detailed vehicle NVH model with main subsystems and components.



VI-WORLDSIM SCENARIO

A detailed and realistic visual model, reproducing the exact test scenario



FREE-DRIVING MODEL

A realistic free driving model to reproduce multi attribute ride comfort conditions

NOISE CONTRIBUTION ANALYSIS USING SPC BASED MODELS

EXTERIOR NOISE MODELING USING TIME-DOMAIN SPC



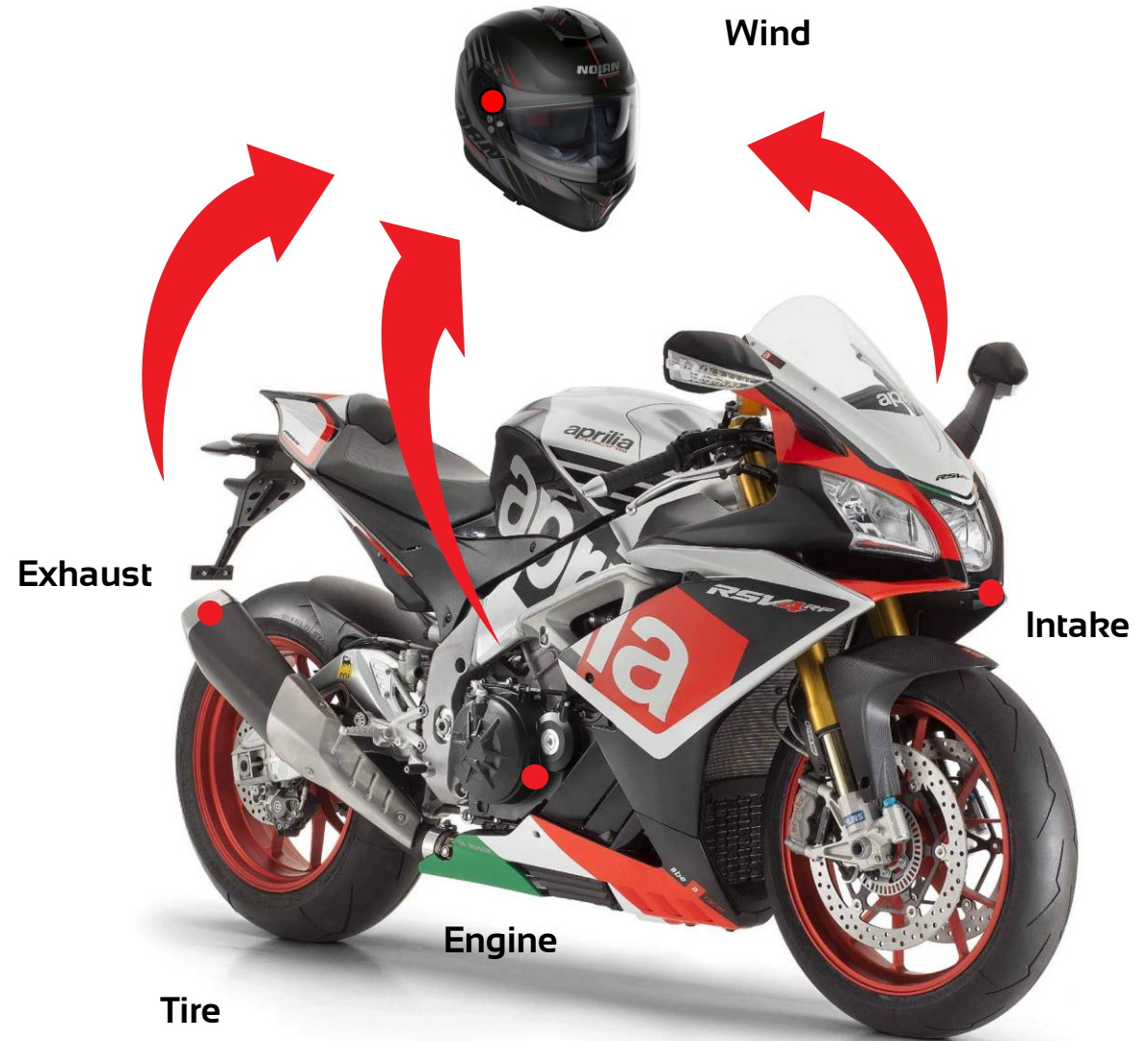
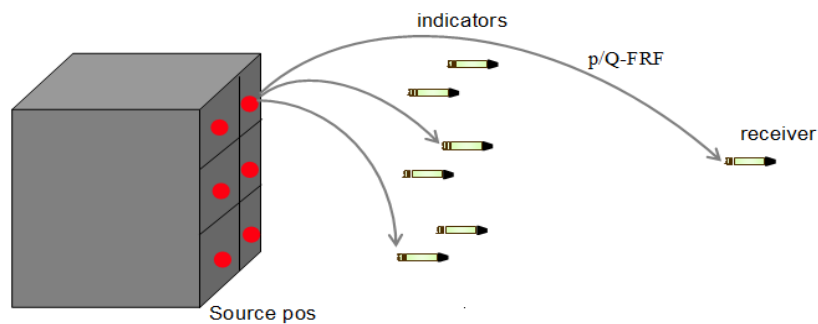
Source: acoustic point sources model



Path: airborne path from source to receiver



Contribution: at rider's ears (binaural)



MOTORCYCLE SPC ACOUSTIC MODEL

SOURCE AND INDICATOR MICROPHONE POSITIONS



Source Substitution

(Airborne) time domain, using matrix Inversion:

- Source strength estimate per path:

$$Q = iFFT\left([H_Q^{Indicator}]^{-1}\right) * p_{indicator}$$

- Partial pressure estimate per path:

$$p = iFFT([H_Q^p] * Q)$$

- Noise Source and volume velocity (Q) transducer:



B&K TYPE 4101-B MINIATURE BINAURAL MICROPHONE

WORN BY THE DRIVER UNDER THE HELMET



DESKTOP NVH SIMULATOR

VI-NVHSim software for Interactive NVH simulation

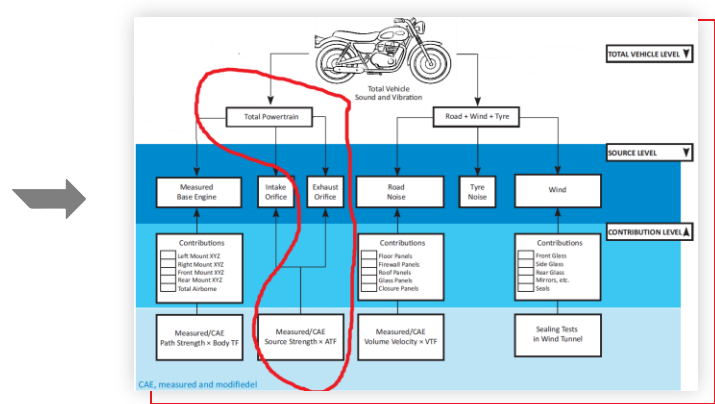
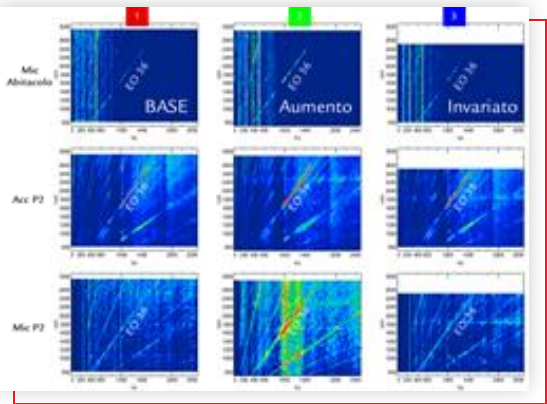
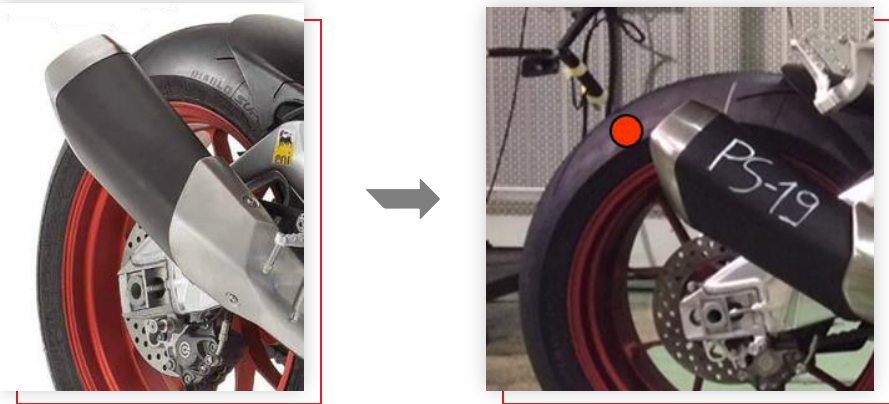
-  Real-time Auralisation of NVH data
-  Adds Context and Interactivity to the Evaluations
-  Experience the sound for any driving condition
-  Switch between vehicles back-to back
-  Create and drive vehicles that don't exist
-  Targets / What If's / New Designs / ...
-  Real-time Visualization & Modification
-  Capture the opinion and driving behavior
-  Make decisions with confidence



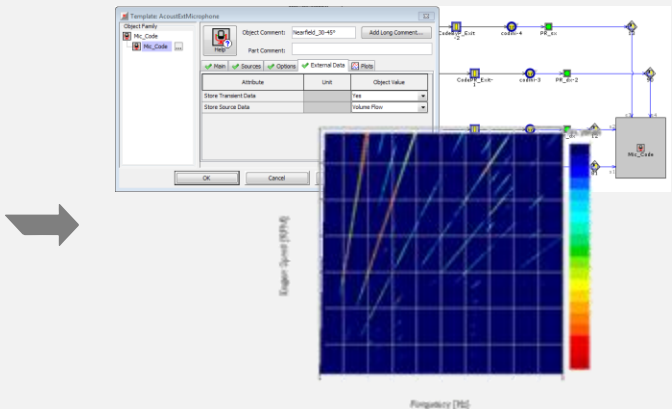
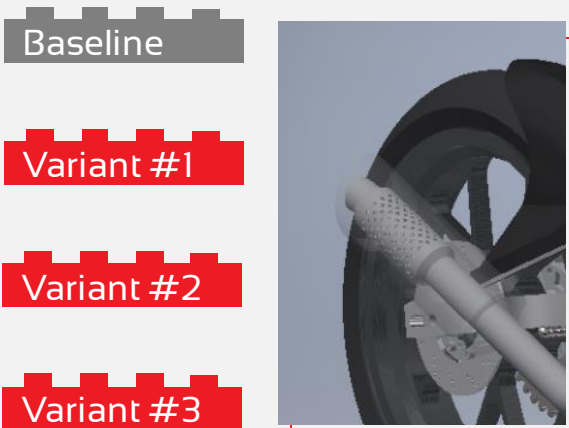
EXHAUST SOUND DESIGN

VI-NVH SIM WORKFLOW – SQ APPLICATION

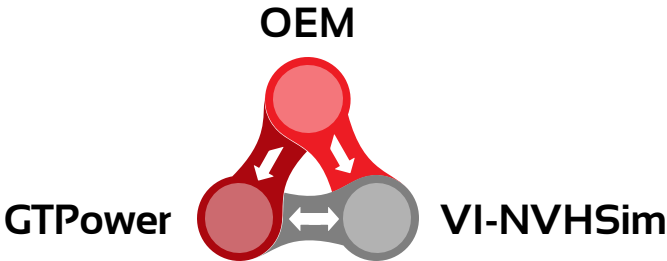
01 Reference SQ NVH Sim model



02 Digital twin/variants: GTPower model integration



03 Virtual Jury assessment (8 new loop or physical prototyping)



ACTIVE SOUND DESIGN APPLICATIONS

VESPA PX SOUND ON A VESPA ELECTRIC FOR GLAUK



Goal: to add a realistic retro 'Vespa PX' sound signature to the electric Vespa



Solution: To build a 'digital twin' of the Vespa PX, a free driving NVH Simulator model that could be installed on the ECU.



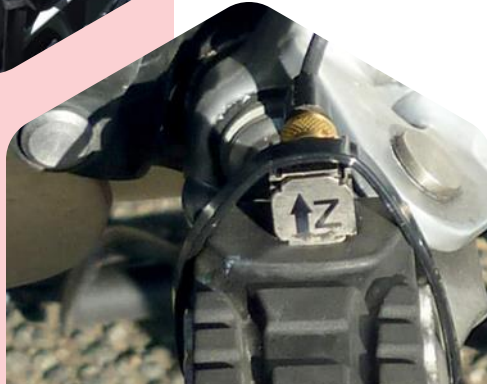
Since traditional loudspeakers cannot be used for obvious reasons, up to 5 panel transducers by Glauk were used to efficiently deliver exterior sound by using using front, mid and rear panels and as radiating surfaces.

The same transducers are used for music playback as well.

The same technology could be applied to electric motorcycles assuming they are using fairings.

SECONDARY RIDE COMFORT - VIBRATIONS

A STUDY BY PROF. JÜRGEN ADAMEK FROM OSNABRÜCK UNIVERSITY FOCUSED ON MOTORBIKE VIBRATIONS



Vibrations were measured over a total of 2500 km, driven on 27 bikes, with 23 different drivers.



Vibration from the engine causes hand numbness – or white-finger syndrome – and other unpleasant physical sensations

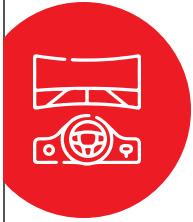


Vibration levels can have a negative impact on health and on a rider's reactions, contributing to accidents.

Despite most bikers do not perceive these vibrations as troubling, bikers are exposed to excessive vibrations and many report effects on their body

<https://www.hs-osnabrueck.de/motorrad-humanschwingungen/>
<https://www.hbkworld.com/en/knowledge/resource-center/articles/vibrating-motorcycle-seat>

STATIC NVH SIMULATOR



Multi-sensory NVH Simulation - Sound, Vibration, Visuals

- Multi-axial, calibrated vibration at all primary driver touch points
- Calibration, synchronized sound and vibration generation



The ultimate NVH experience

- All the same benefits of the desktop simulator, plus vibration and a fully immersive driving experience



Sound, Vibration and Steering

- Multi-DOF Vibration + Sound



COMPACT NVH SIMULATOR

**MULTI-SENSORY NVH SIMULATION -
SOUND, VIBRATION, VISUALS**

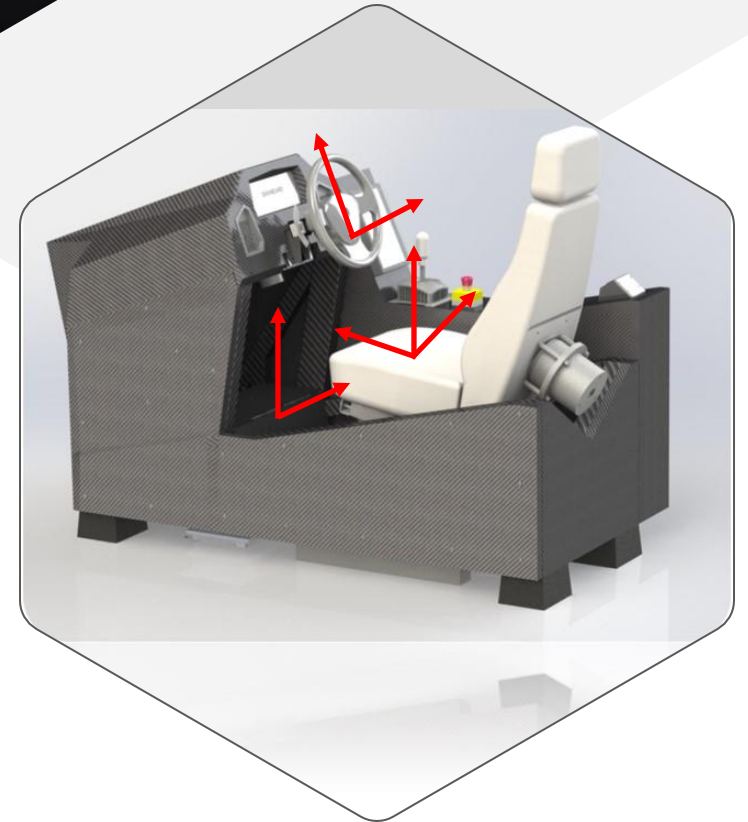


Calibrated Vibration over 7 DOF

- Seat vertical, lateral, fore-aft
- Steering wheel vertical and lateral
- Footwell / heel point vertical and lateral



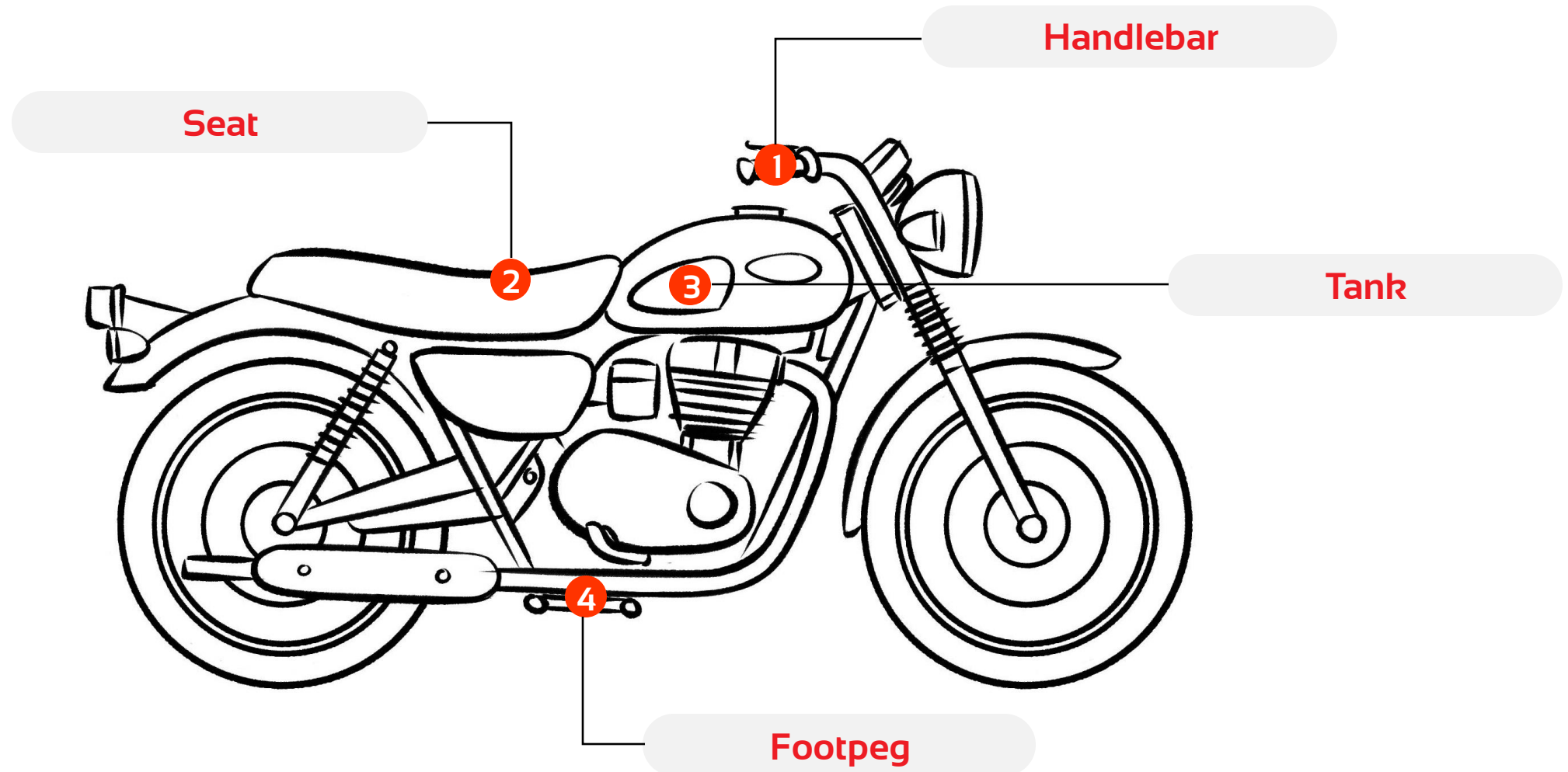
Calibrated, full-spectrum Sound



STATIC NVH SIMULATOR FOR TOURING MOTORCYCLES



LIST OF RIDER'S TOUCHPOINTS WHERE TO DELIVER SECONDARY RIDE COMFORT VIBRATIONS



COMPACT FSS FULL SPECTRUM SIMULATOR

ACCURATE MOTION, VIBRATION AND
SOUND IN A SINGLE SIMULATOR



Overall vehicle motion

- 4 high-precision corner actuators



Controlled vibration

- Seat vertical, lateral, fore-aft
- Steering wheel vertical and lateral



Calibrated, full-spectrum Sound





**WHAT COULD THE
FUTURE BE?**



THANK YOU FOR YOUR ATTENTION

Take the opportunity to step in our SimCenter to experience the COMPACT NVH and the COMPACT FSS Simulators yourself

Visit www.vi-grade.com for more information on the NVH simulators and our other simulators and simulation solutions