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Ingenuity for life

Downsizing Powertrains

NVH Implications and Solutions for Vehicle Integration

Downsizing Powertrains / 传动系轻量化
NVH Implications and Solutions for Vehicle Integration
汽车NVH的影响和解决方案的整合

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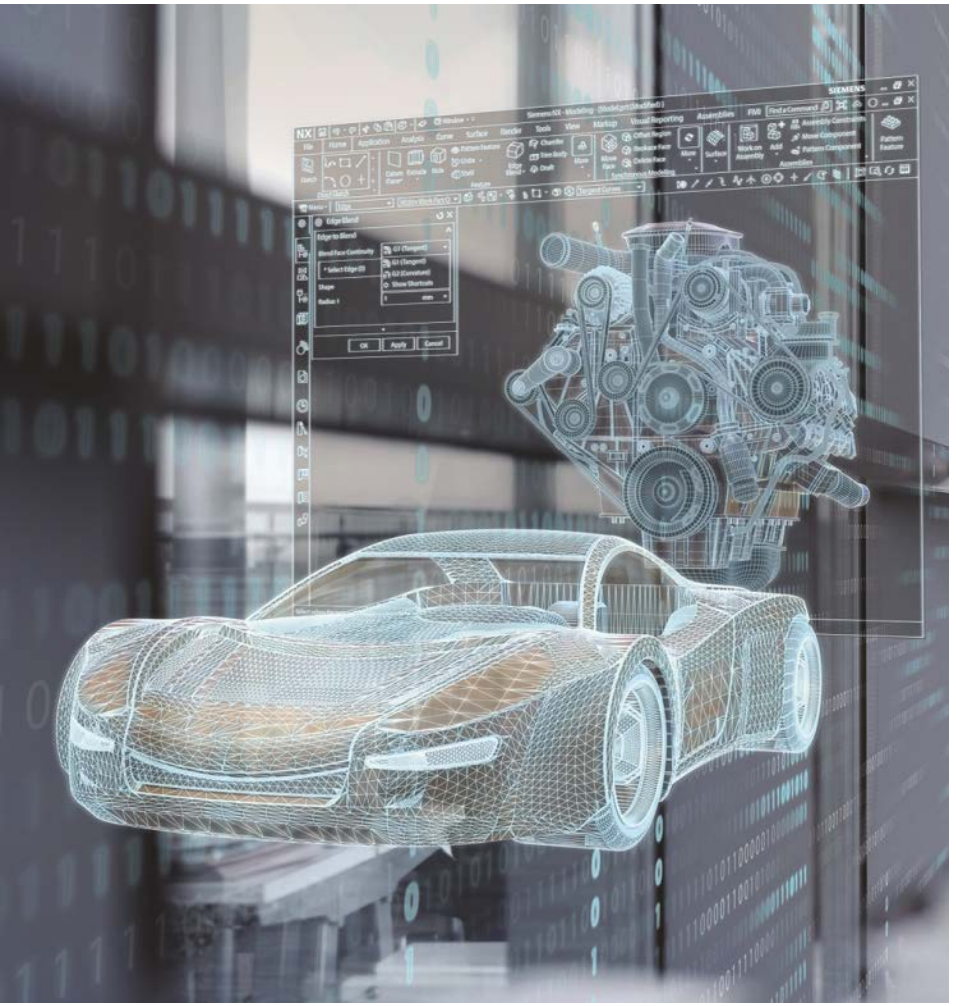


- **Downsizing trends and NVH impact**

  轻量化趋势及NVH影响
- Traditional Approach for NVH studies

  NVH研究的传统方法
- New Integrated approach

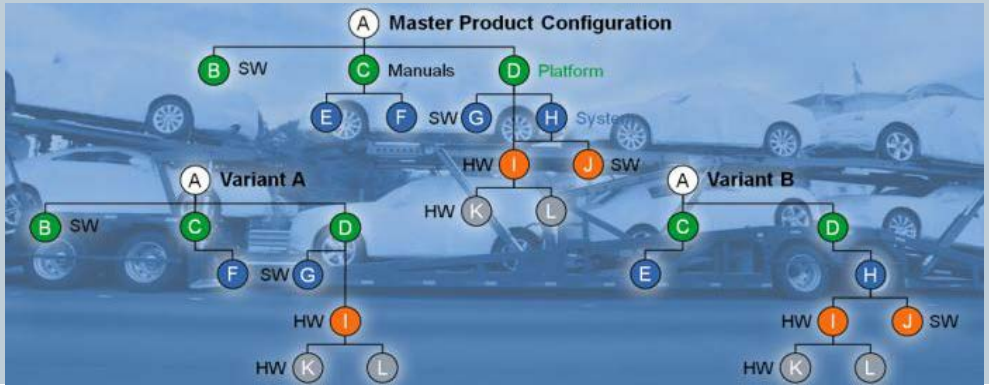
  新的集成方法
- Examples/示例:
  - Low Frequency Booming Noise/低频Booming噪声
  - Clunk

Addressing the challenges/课题、挑战

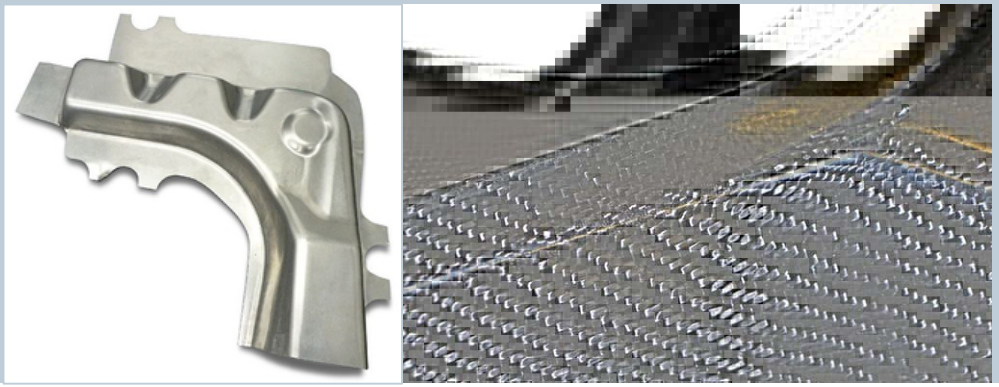
Continued focus on fuel economy & emissions
燃油经济性和排放要求的持续提高

NVH & driving pleasure impacted by fuel economy
NVH&驾驶乐趣受到燃油经济性的约束

Multitude of options to be evaluated
多种配置方案评估



New materials – new engineering challenges
新材料、新技术挑战



Technical impact of the fuel economy race/新技术对燃油经济性的影响

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Introduction of new technologies for transmissions/ 新技术简介

- Stop & start, Hybridization, Robotized Automated Manual Transmissions (AMT), Dual Clutch Transmissions (DCT), Continuous Variable Transmission (CVT), Increase of gear ratios up to 10 in AT, CPVA (Centrifugal Pendulum Vibration Absorber)
  起停技术、混合动力、自动离合器AMT、双离合器DCT、CVT、AT速比级数的增加（AT中可能多达10个）、离心摆式减震器CPVA
- Dampers technologies on pendulum, DMF, Variable stroke pumps, ...
  摆式阻尼器技术、双质量飞轮、变量泵…
- Control strategies to reduce LU opening, CVT clamping pressure, increase energy recovery, …
  控制策略：离合器锁止转速降低，CVT压紧压力，增加能量回收

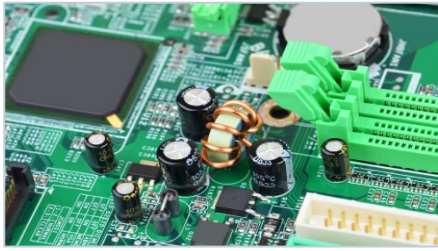
Growing stresses in the driveline/传动系应力的增加

- Weight reduction, reduced size of components/轻量化，部件小型化
- Downsizing/down-speeding engines / 轻量化/低转速发动机

Attributes balancing requirement/多属性平衡要求

Defining the best compromise between fuel economy, performance, drivability and vibration/acoustics is requested to improve brand value

在各属性间定义最佳的平衡指标：燃油经济性，最佳的性能，驾驶性能和振动/声学品质，进而提升品牌价值



Reducing CO_2 at the price of NVH and driving comfort?
通过牺牲NVH和驾驶舒适性来降低排放？

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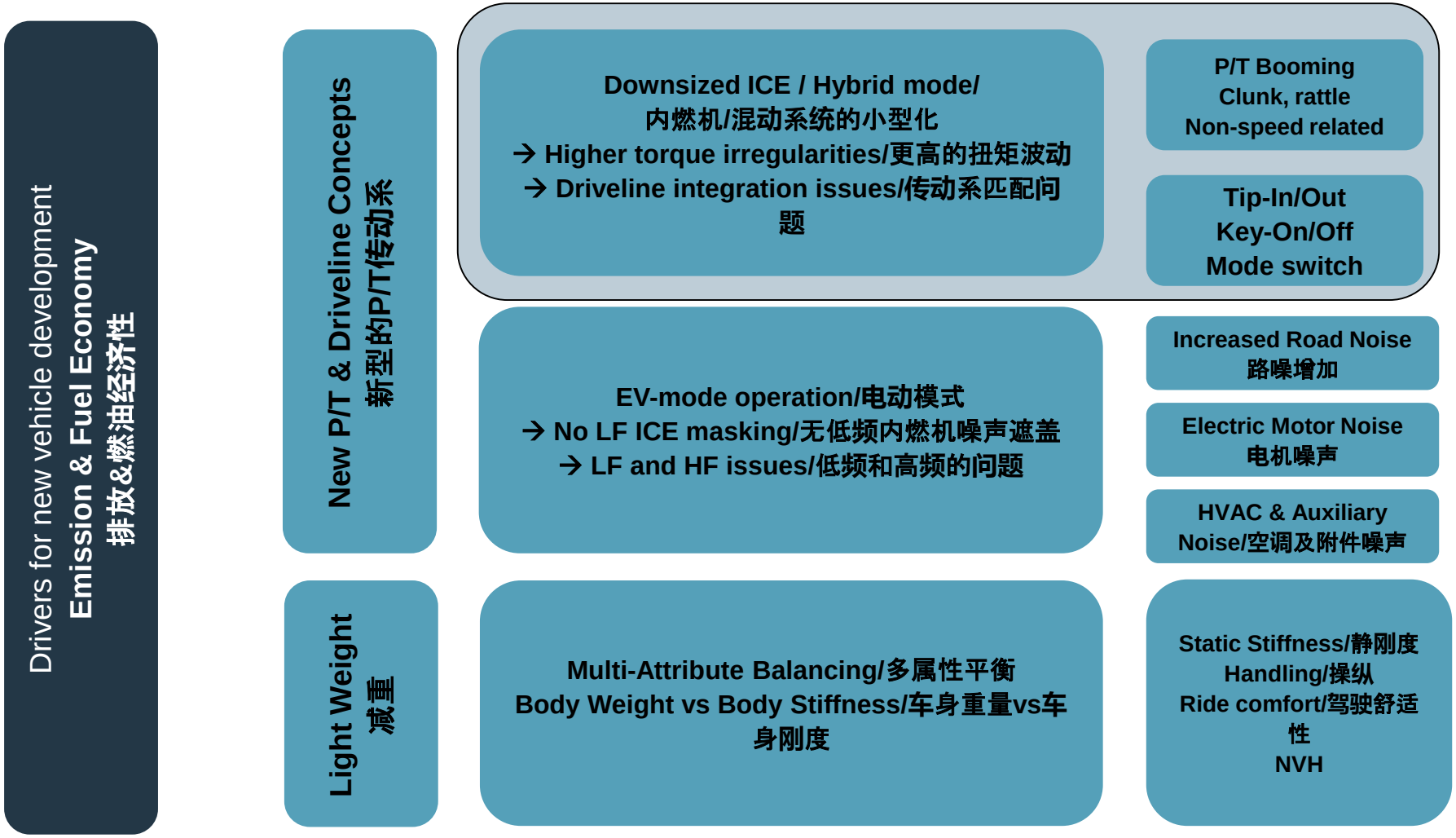

Analysis requirements for vehicle integration performance
整车集成性能分析的要求

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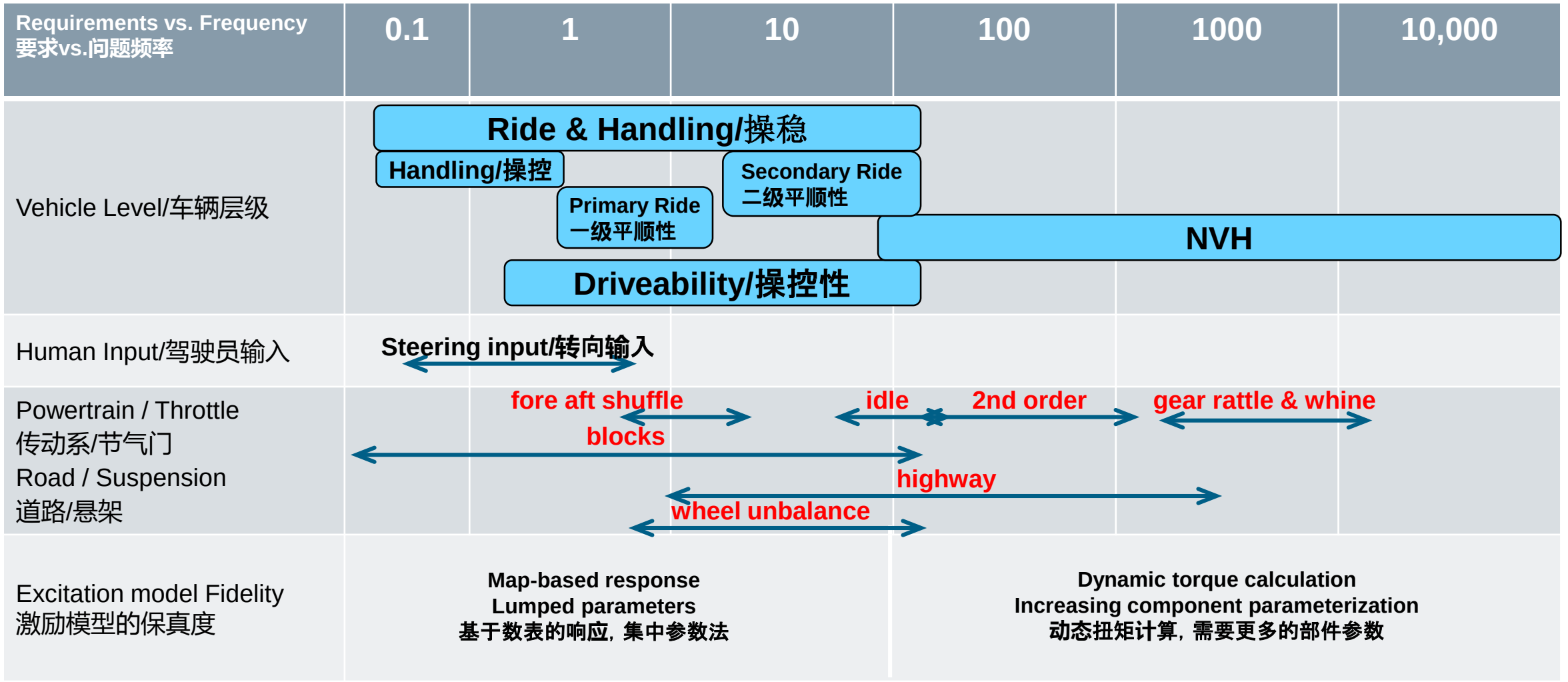
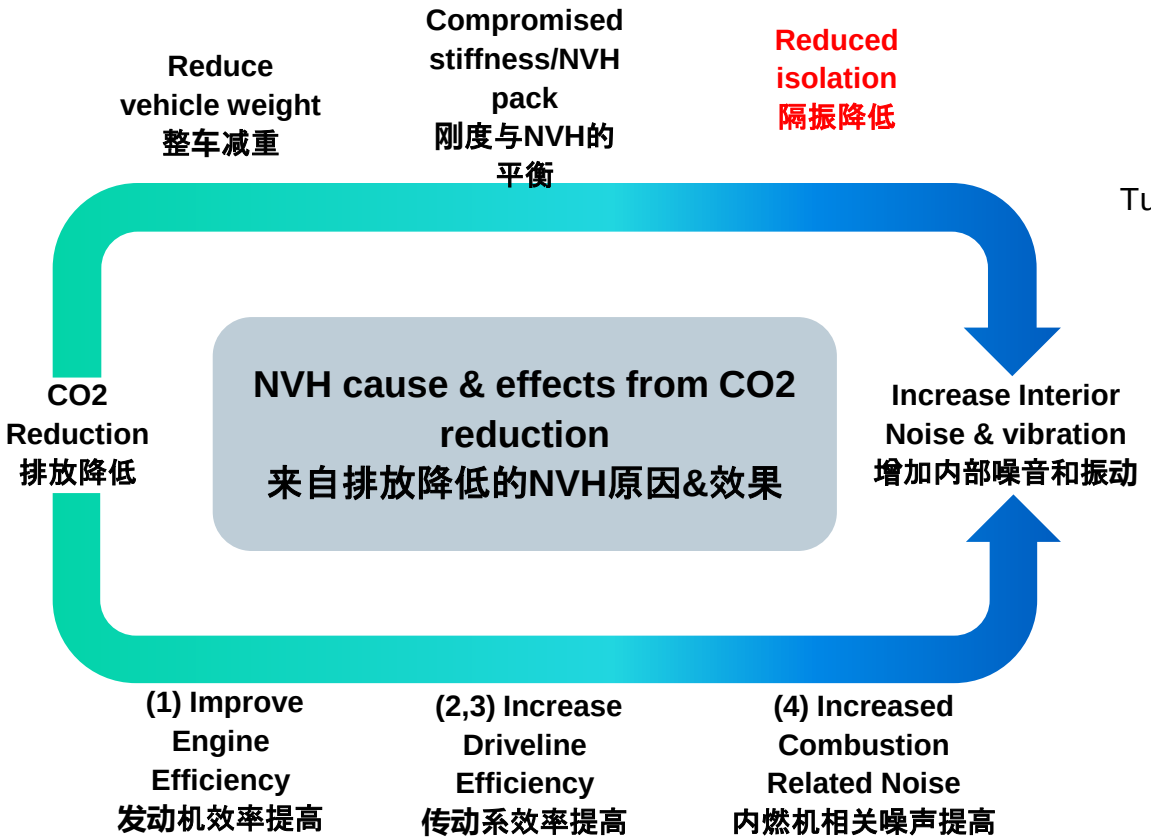
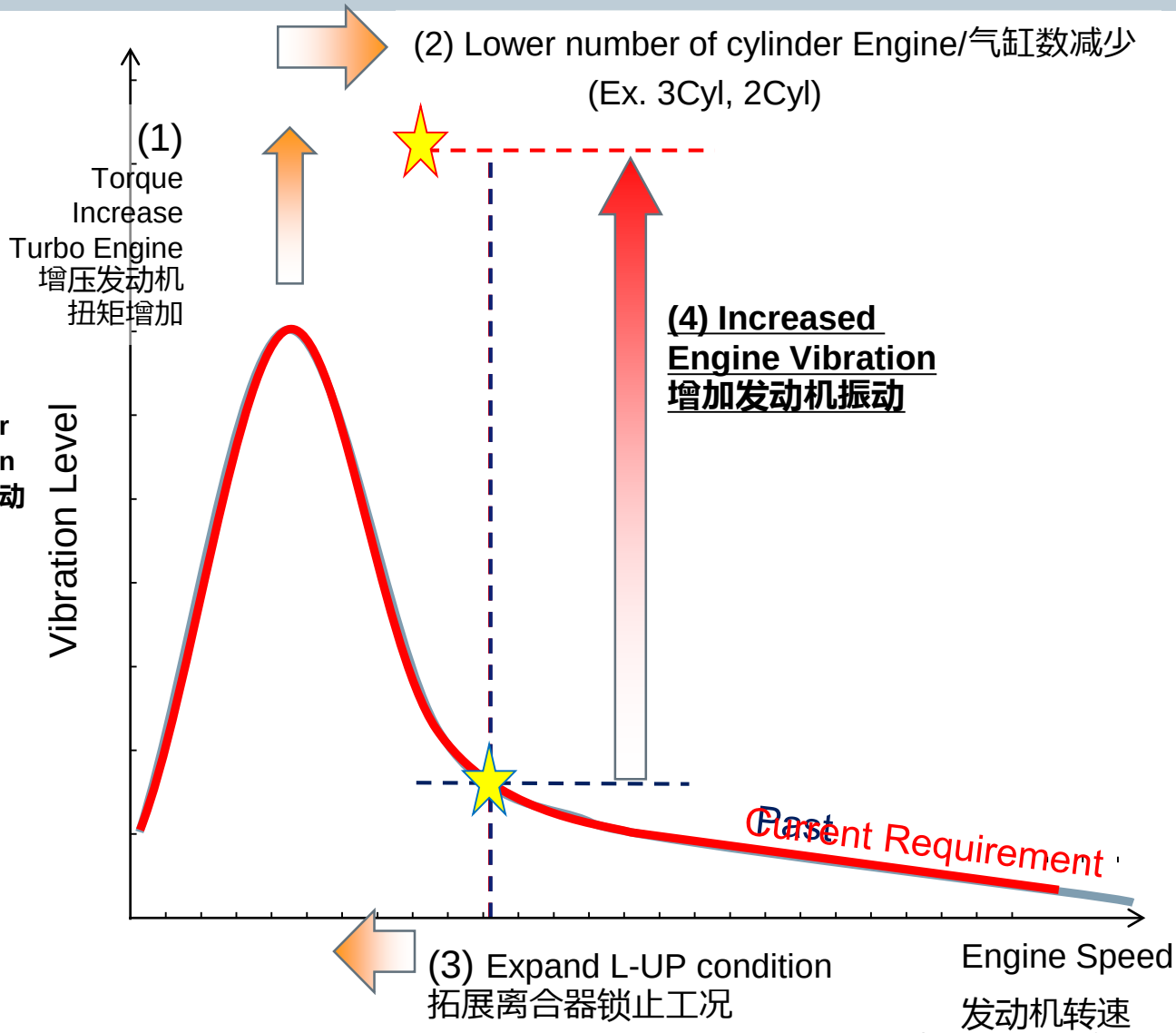


CO_2 reduction effect on NVH/降低排放对NVH的影响





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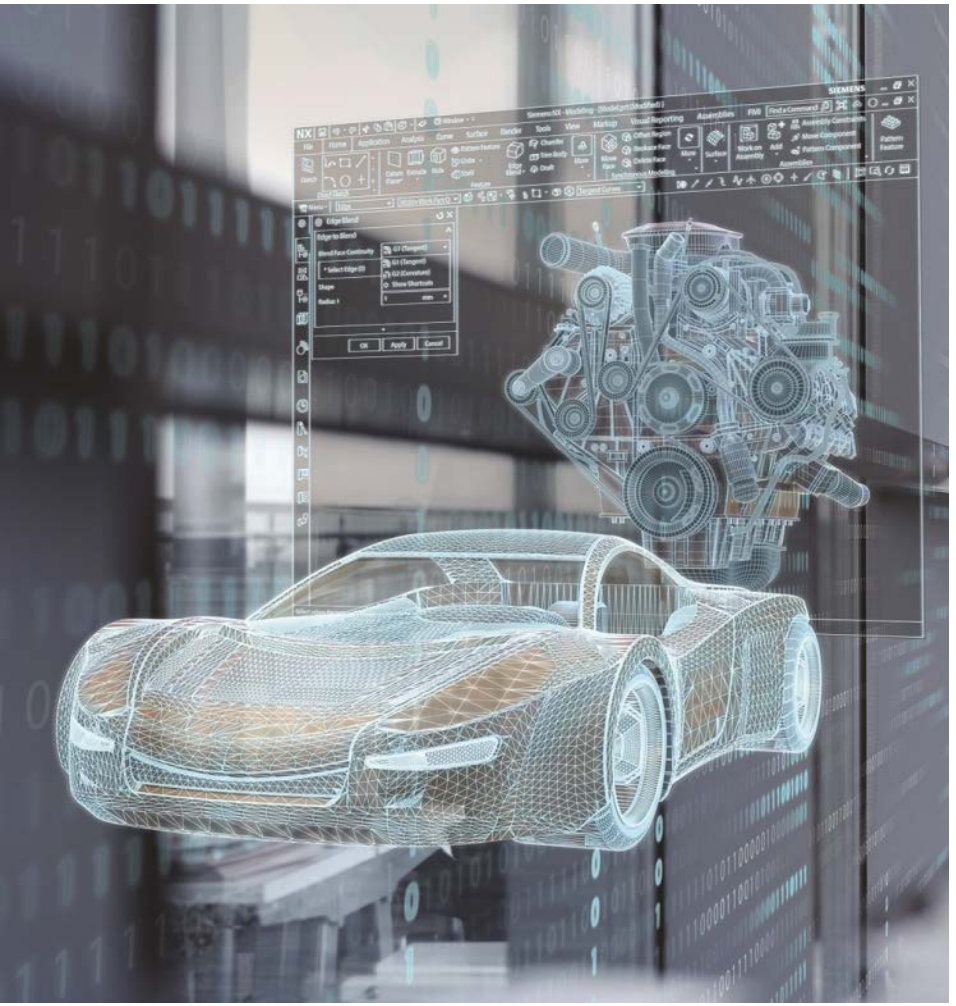

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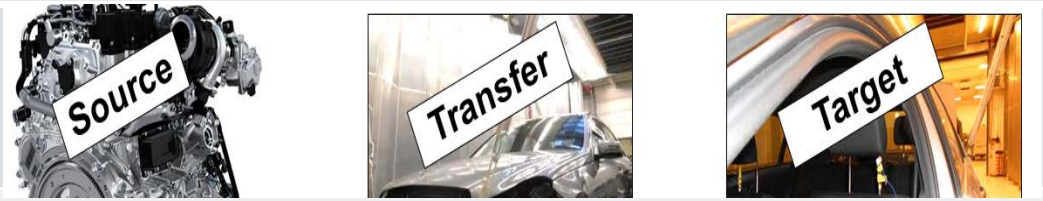
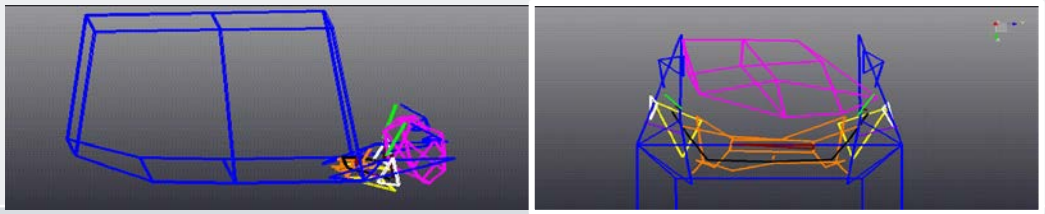
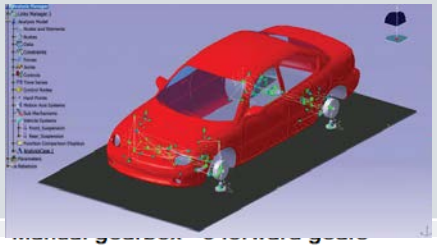
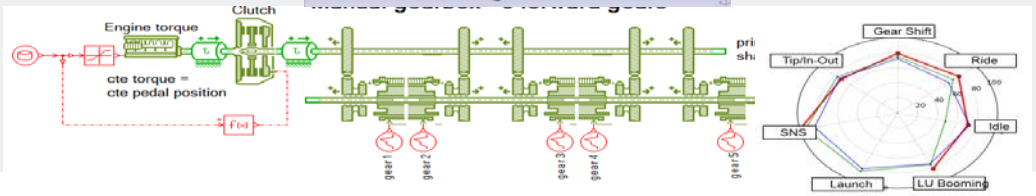
Traditional technologies for NVH studies/NVH研究的传统方法

Method/方法	Insight /细节	Limitation/限制	Picture/图片
Transfer Path Analysis 传递路径分析	Separate root cause of vibration / noise 区分振动噪声的原因	Time consuming, single configuration 耗时，单一路径状态	
Operational Deflection Shapes 工作状态变形	Visualization of forced response, ability to select key components 强迫响应可视化，主元件的识别选择功能	Vehicle level only, no rotational dynamics 仅对整车级，没有旋转动态	
Full 3D 全3维	Detailed optimization possible 详细的可能优化方案	不容易开展旋转动力学研究	
1D Driveline 1维传动系	Detailed rotational dynamics 详细的旋转动力学	Full vehicle dynamics not easy to include 不好涵盖整车动力学模型	

Traditional driveline NVH evaluation approach
Limitation

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Classical approach → Assumptions　传统方法→假设

- Modification prediction → Limitation in low frequency booming range
  更改预测→低频booming范围有所限制

Clutch stiffness especially with DMF

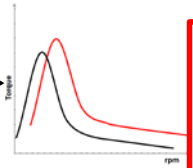
离合器刚度（尤其与双质量飞轮结合）

Influence of the preload/预紧力影响

Change shaft stiffness/轴刚度改变

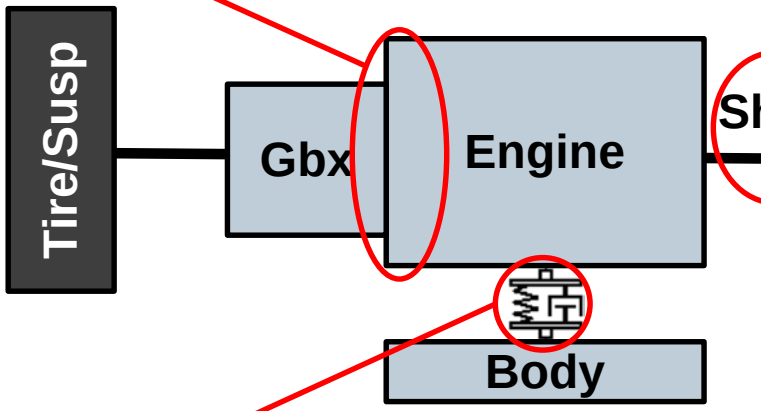
Modify rotational mode

旋转模态更改

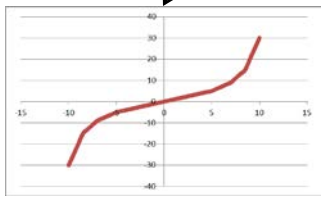


Modified input

输入更改



Non-linear mount stiffness/非线性悬置刚度

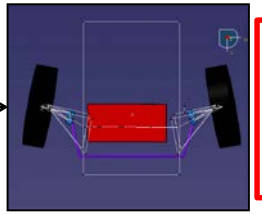


Influence of the preload/预紧力影响

Change suspension stiffness/悬挂刚度改变

Modify suspension mode

悬挂模态更改



Coupling with rotational mode

与旋转模态耦合

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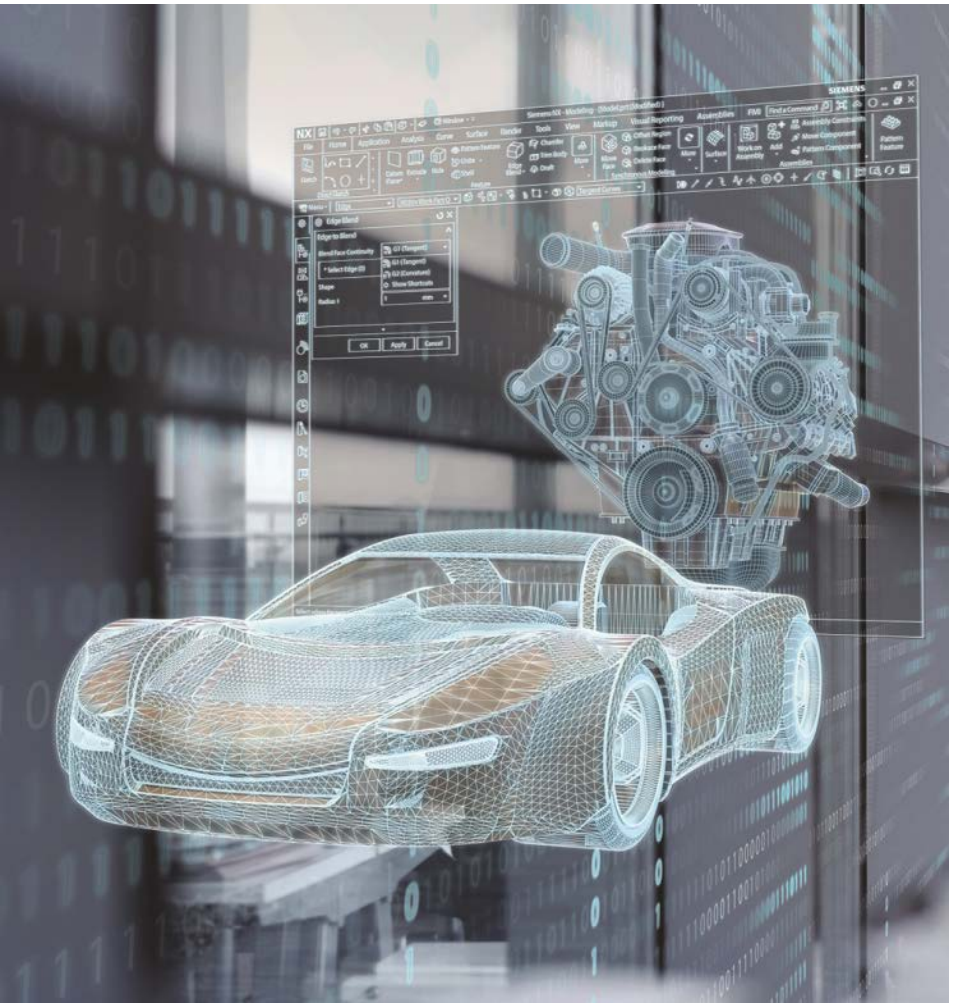

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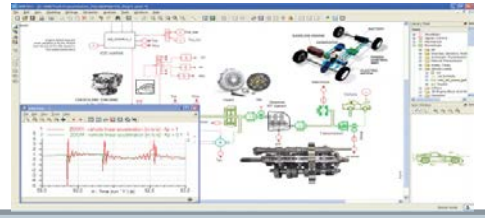
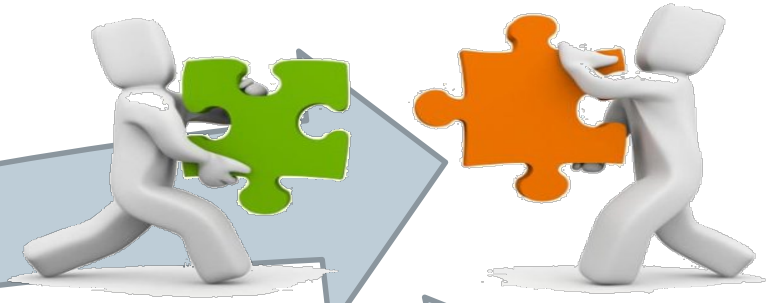
New integrated approach/新的集成方法

From two different worlds…
来自不同角度…



“A model can solve the question.
My model is correct,
your test data is wrong.”

…To polyvalent engineers combining 1D simulation, 3D simulation and testing capabilities
工程师需要结合一维，三维仿真方法与测试能力



“Let’s combine the available technologies to provide the best answer for the customer”

“Test is the answer.
My measurement is correct,
your model is wrong.”

Context / Expectations from customer – Booming
来自客户方的期望/背景---Booming

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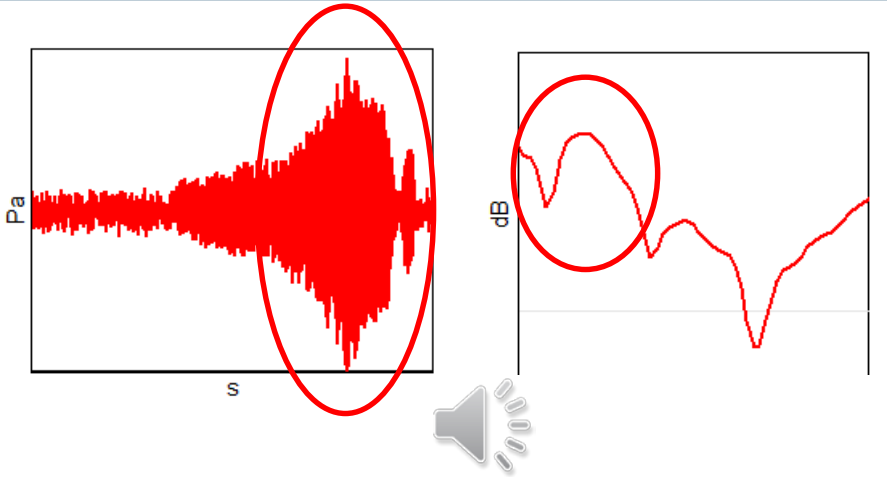
General trend: increasing pressure on fuel economy/趋势：燃油经济性的压力

- Downsized engines/发动机小型化
- Advanced torque lock-up strategies (for the case of automatic transmissions)
  高等离合器锁止策略（针对AT变速器）
- Cylinder deactivation /闭缸技术



Consequences/结果

- Use of the engine at lower RPMs/在低转速下发动机的应用
- Higher torque irregularities due to lower cylinder number/发动机缸数

→ Higher booming noise and vibration/增加booming振动噪声

Questions/问题

- **How are competitors dealing with booming noise?/竞争对手是如何解决booming噪声的**
  - What is the efficiency of the driveline rotational damper?
    传动系统的旋转阻尼器的效果是什么？
  - How are torsional vibration transferred to the cabin?
    扭转针对是如何传递至驾驶舱的？
  - What is the root cause of the high torsional vibration?
    高扭转振动的原因是什么？
  - Is there any coupling of structural modes to rotational dynamics?
    会有结构模态与旋转动力学耦合吗？
  - What is the real added value of a CPVA or a DMF?
    离心摆动减震器与双质量飞轮带来的好处是什么？

LMS Engineering answer – Booming
LMS解决方案-Booming

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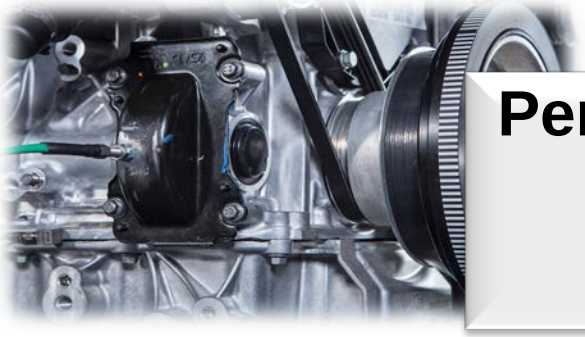
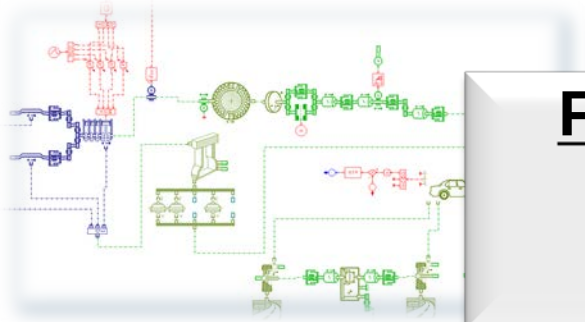


Performance of driveline damper

传动系性能—阻尼器

Full vehicle test diagnosis

整车测试—诊断



Full vehicle model diagnosis

整车建模—诊断

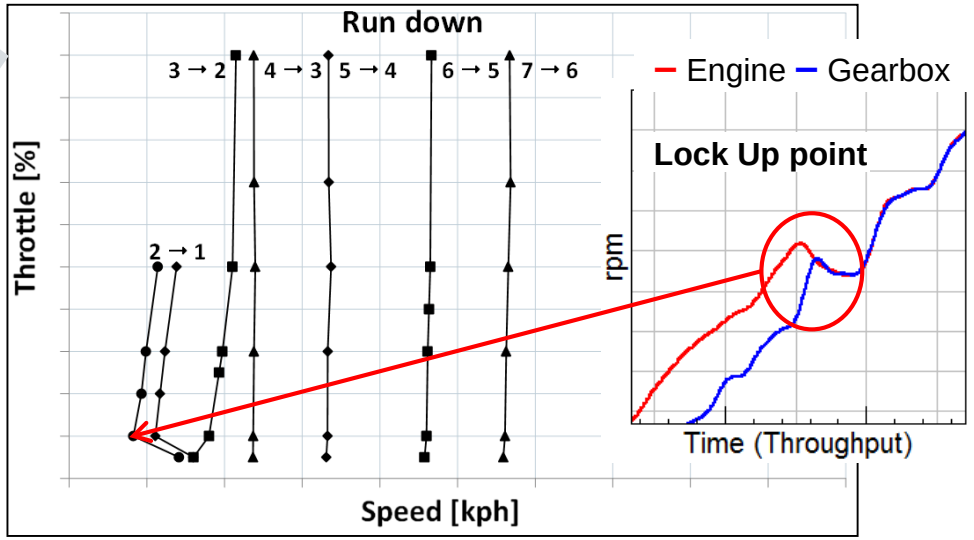
- ✓ **Evaluate the performance of the damper (CPVA, DMF…)**
  评价阻尼器的性能（CPVA，DMF）
- ✓ **Identify the problem and pinpoint the main contributors**
  识别影响问题的主要来源
- ✓ **Objectivize the decision making process for next driveline design**
  传动系设计的具体方案
- ✓ **Provide information about components not available from supplier**
  提供供应商无法提供的部件属性信息

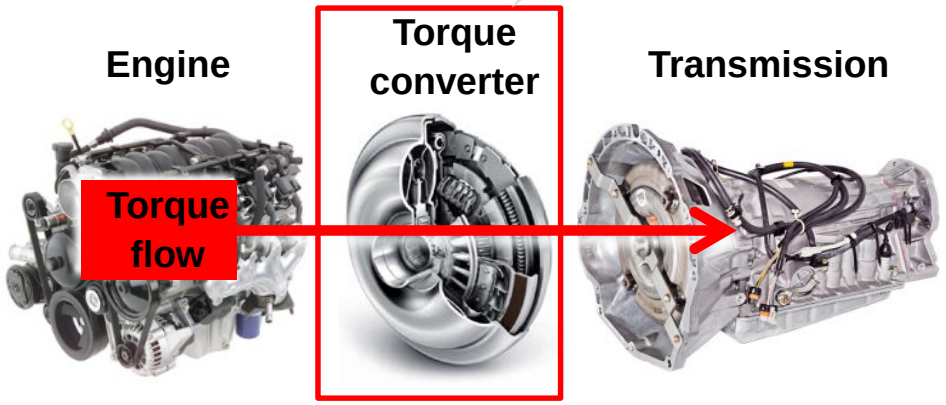
Characterization of lock-up damper / 锁止阻尼器特性
Lock up and damping performance analysis
锁止和阻尼器性能分析

What is the effective range of the lock-up damper?

锁止阻尼器的有效范围？

Lock up map

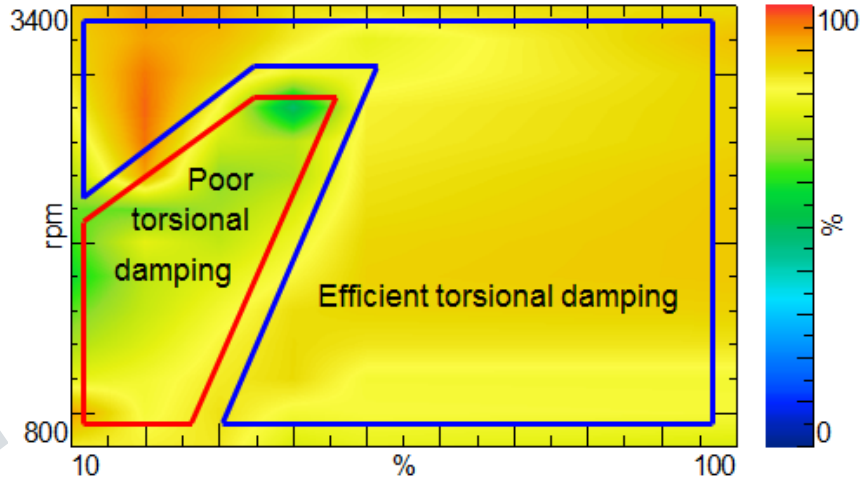




How efficient is the lock-up damper?

锁止阻尼器的效果？

Damping map



Full vehicle diagnosis using test based load／基于测试的整车诊断 identification in time and frequency domain, ODS, EMA 时域和频域中的数据识别，ODS，EMA

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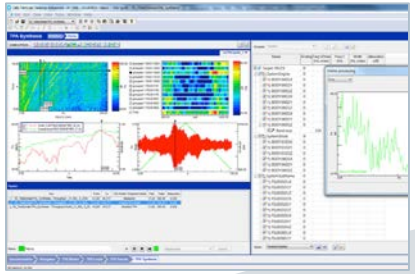
Trimmed body FRF

内饰车身频响

Full vehicle FRF

整车频响

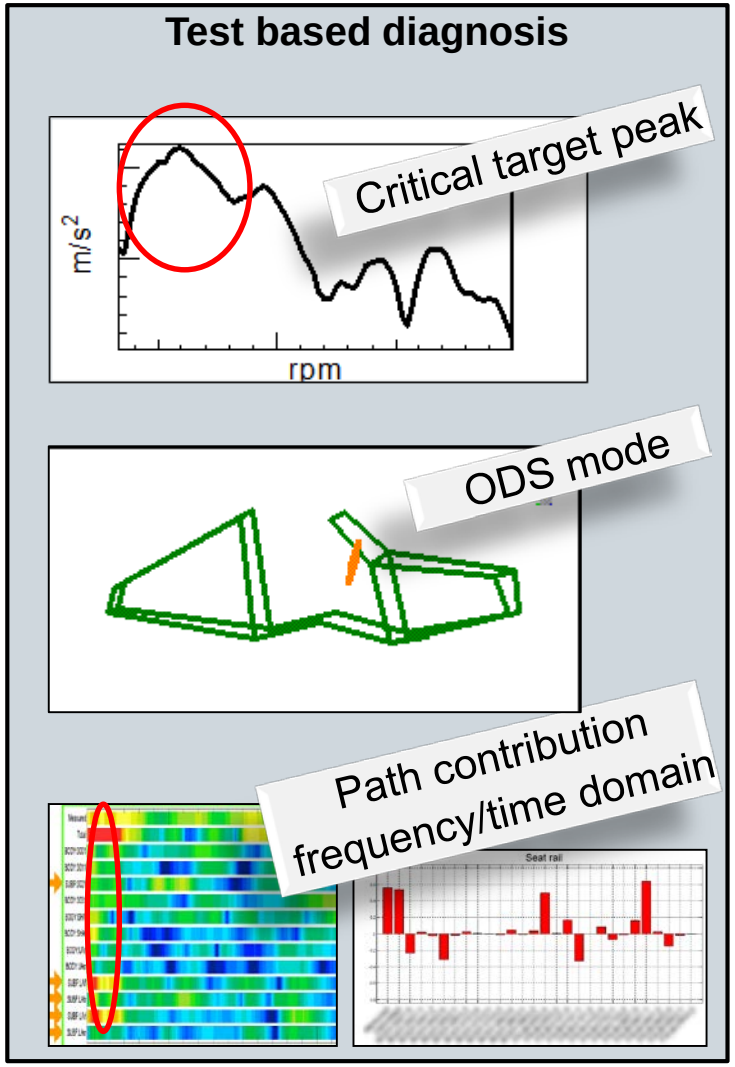


Operational measurements

工作点测试

Transfer path analysis

传递路径分析



Reverse engineering/逆向工程
Obtaining model parameters not available to the customer
获取客户无法提供的参数

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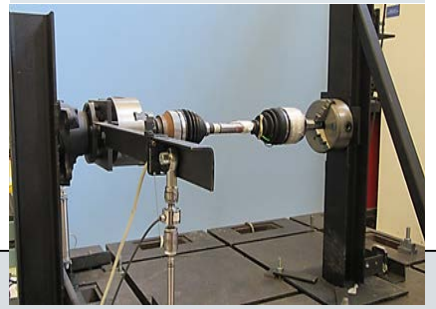
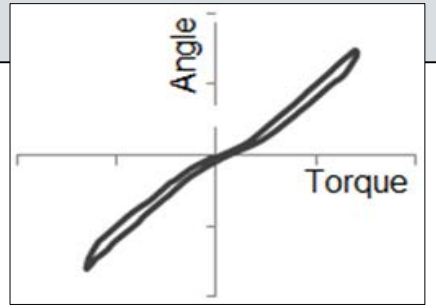
Benchmark vehicle
➔ No parameters
标杆车型
➔ 无参数

Suspension/body characterization
悬挂/车体特性

Driveshaft characterization
驱动轴特性



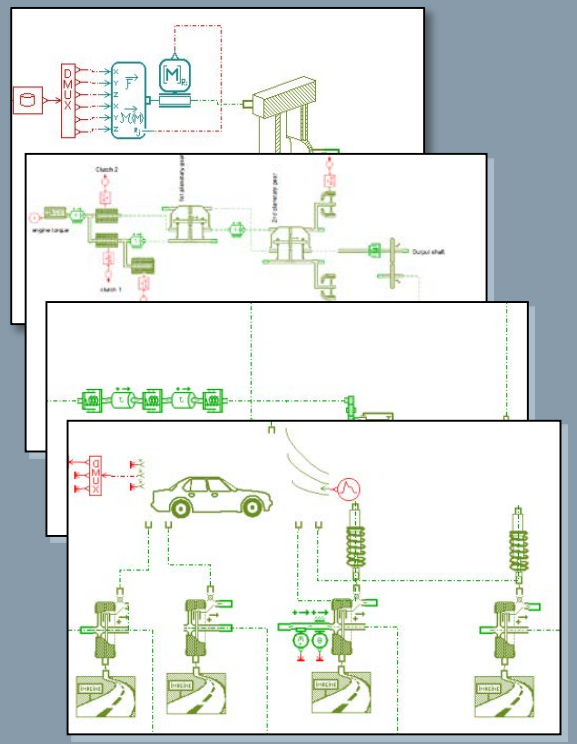
Component testing/部件测试



Torsional damper static and dynamic characterization
扭转阻尼器静态和动态特性

Powertrain mounts stiffness
传动系悬置刚度

Full vehicle model creation
➔Full component visibility
整车模型创建



Calculation of acoustic target response based on combustion pressure excitation
基于燃烧压力激励的声目标响应计算

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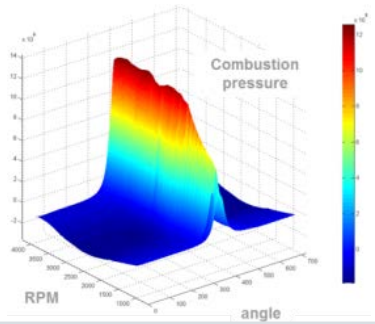
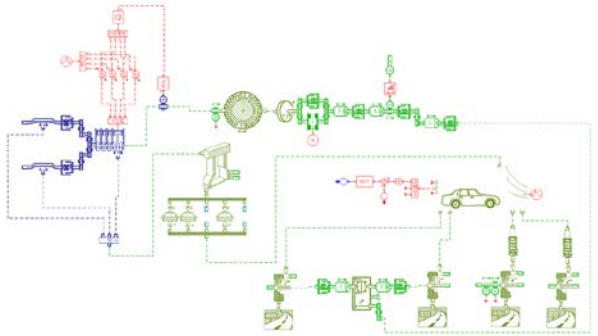
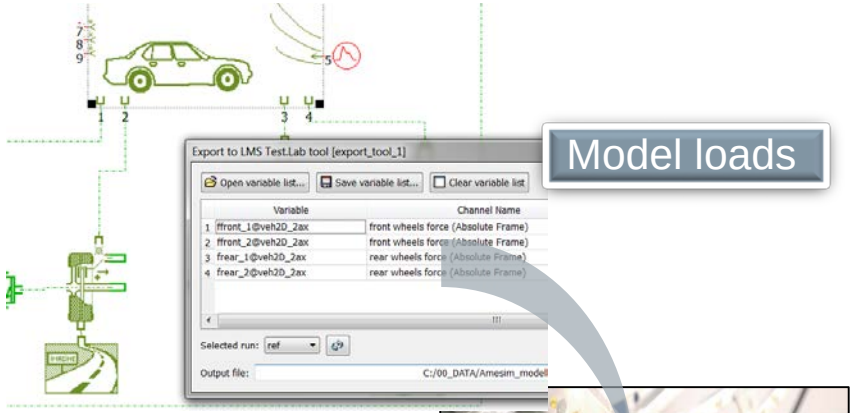






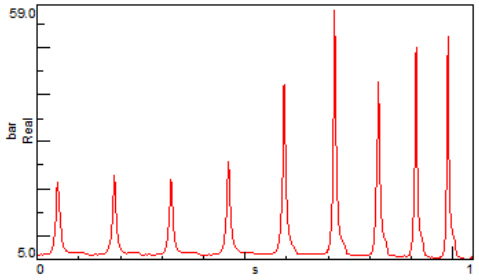
Model loads

Combustion pressure maps as model input
燃烧缸压表作为模型输入

Interface forces calculated from full vehicle model
整车模型计算界面力

Target response calculated based on model loads + measured FRF
基于模型负载和测试频响的目标响应计算

Test FRF



Loads

Target response

Context / Expectations from customer – Multi-attribute balancing
来自客户的背景/期望—多属性平衡

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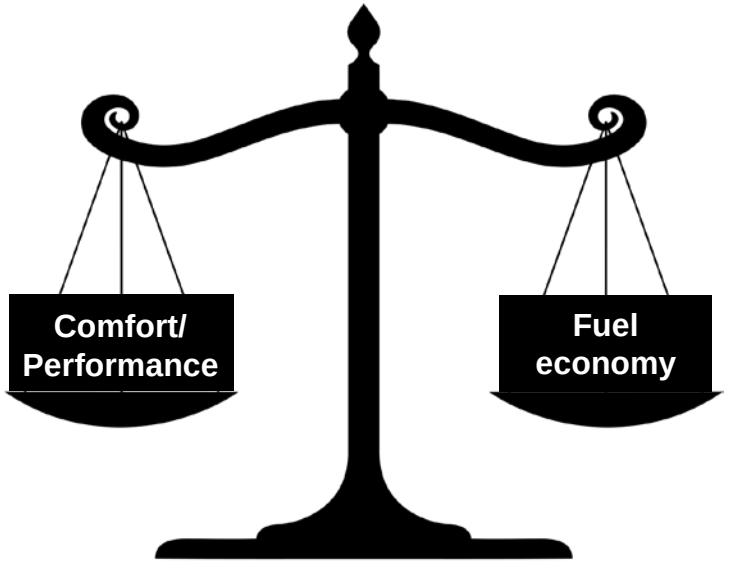
General trend: higher competitor pressure on vehicle market/趋势：更加激烈的竞争

- Different attributes in different departments: design decisions can impact other teams, cross department communication not always easy

  不同部门的任务不同：设计方案可能会影响其他团队的工作，部门间的交叉交流通常是困难的
- Need to save vehicle development cost

  需要降低车辆开发的成本



Consequences/结果

- Front loading multi-attribute study to early development phase

  前期开发阶段，进行多属性的研究
- Balance between fuel economy, performance and vehicle comfort required

  平衡各属性：燃油经济性、性能和舒适性
- Need accurate models that can handle different attributes

  需要不同的模型来针对不同的属性

Question/问题

- **How to balance the comfort/fuel economy request?/如何平衡舒适性/燃油经济性需求？**
  - How to frontload multi-attribute balancing? /如何提前进行多属性平衡？
  - How to properly define a unified modelling environment?/ 如何正确定义统一的建模环境？
  - How to provide objective evidence that performance is not compromised?

    如何提供客观证据证明性能不受影响？
  - Where should we direct our investment strategy for Fuel Economy/NVH?

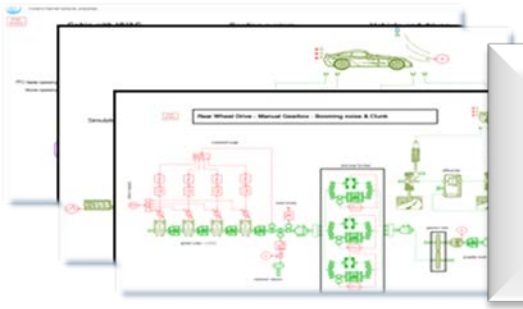
    针对燃油经济性和NVH的投资策略我们应该把重点放在哪里？

LMS Engineering answer – Multi-attribute balancing
LMS解决方案—多属性平衡

SIEMENS

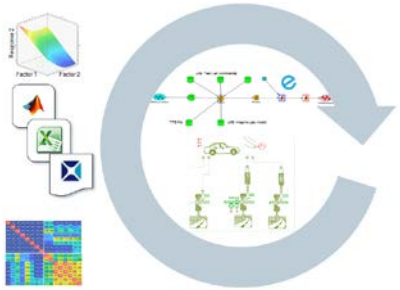
Full vehicle unified testing campaign

整车统一测试环境



Multi level modeling strategy

多层级建模方案



Multi-attribute optimization loop

多属性优化环路

- ✓ **Evaluate the vehicle performance for each attribute**

  针对每个属性对车辆的性能进行评估

- ✓ **Get the right detail level for the attribute to be studied /针对分析的属性获取正确的模型层级**

  Balance the model complexity with the end user need/根据最终用户需求来选取模型的复杂程度

- ✓ **Understand the coupling effect between the attributes**

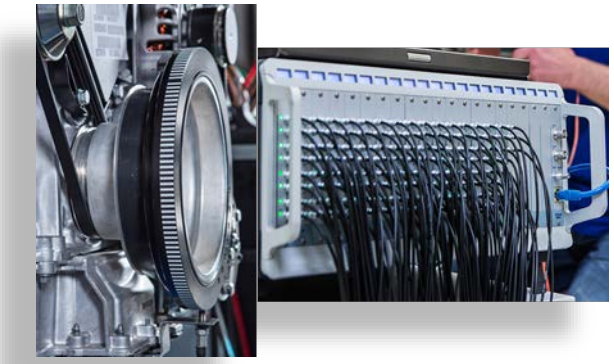
  明确各属性间的耦合

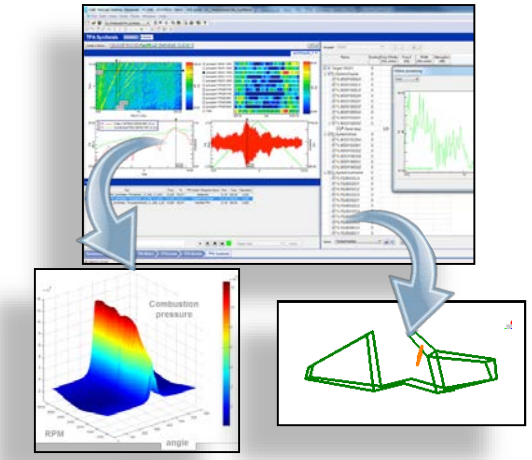
- ✓ **Define the best design strategy for attribute co-optimization**

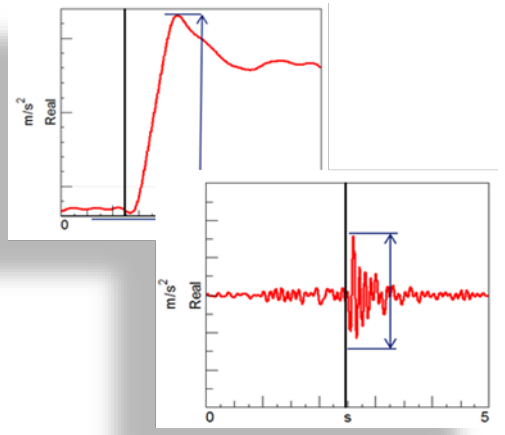
  针对属性耦合优化定义最优的设计方案

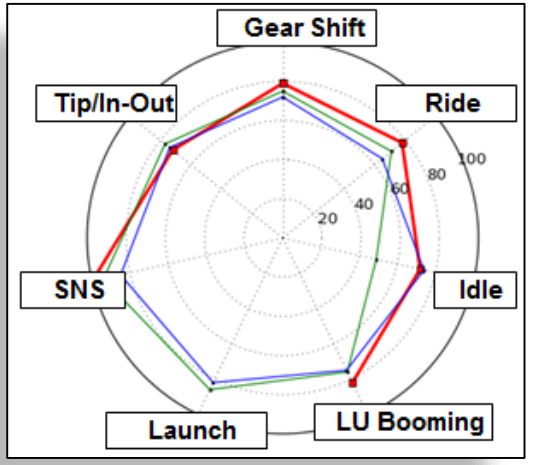
Multi-attribute evaluation (unified testing)
多属性评估测试（同时在统一的边界条件下测试）

SIEMENS









Multi-physic measurement

→ Heavy instrumentation (>200 channels)

多物理量测量

→ 大量的传感器布置

Data processing for model input and validation

→ Vehicle diagnosis

数据后处理用于模型输入和验证

→ 车辆诊断

Metric evaluation for multiple characteristics

→ Sensitivity analysis

针对不同特性的目标评价

→ 敏感性分析

Multi-attribute evaluation

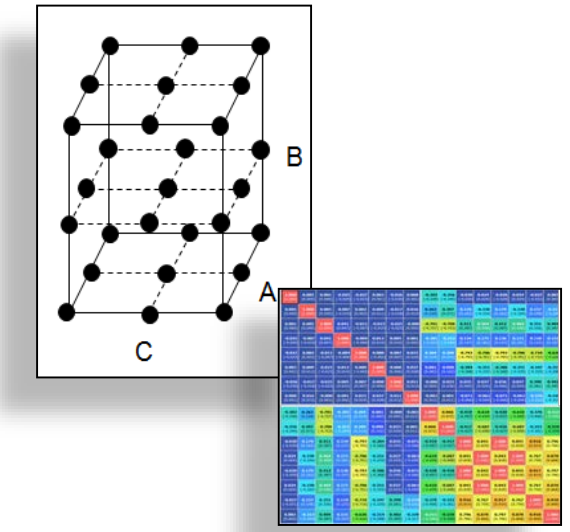
→ cross coupling between the attributes

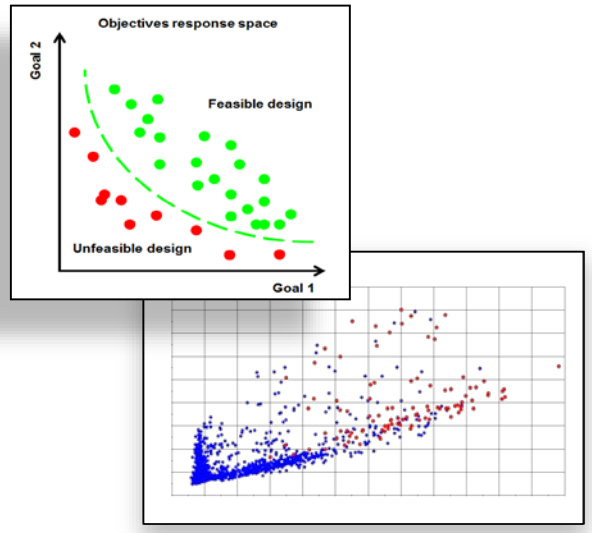
多属性评估

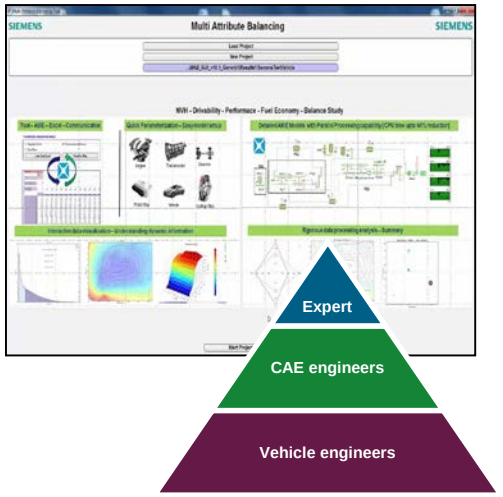
→ 多属性耦合

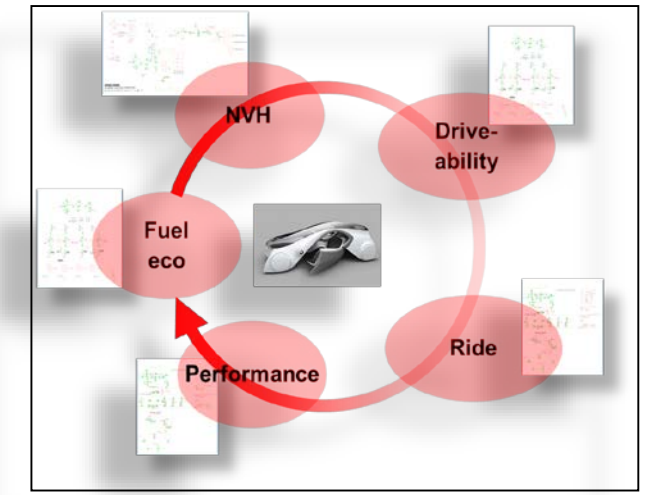
Automatic optimization processes to gain insight in design
通过自动优化过程来获得更好的设计

SIEMENS









Selection of sensitive parameters from Design Of Experiment

选取敏感性分析参数

Multi objective optimization

多目标优化计算

Customization

→ GUI fit for every user level

客户化定制

根据不同用户需求开发GUI

Best visualized solution for multi attribute balancing

对多属平衡的最优方案

Balance between accuracy and complexity
精确度和复杂度间的平衡

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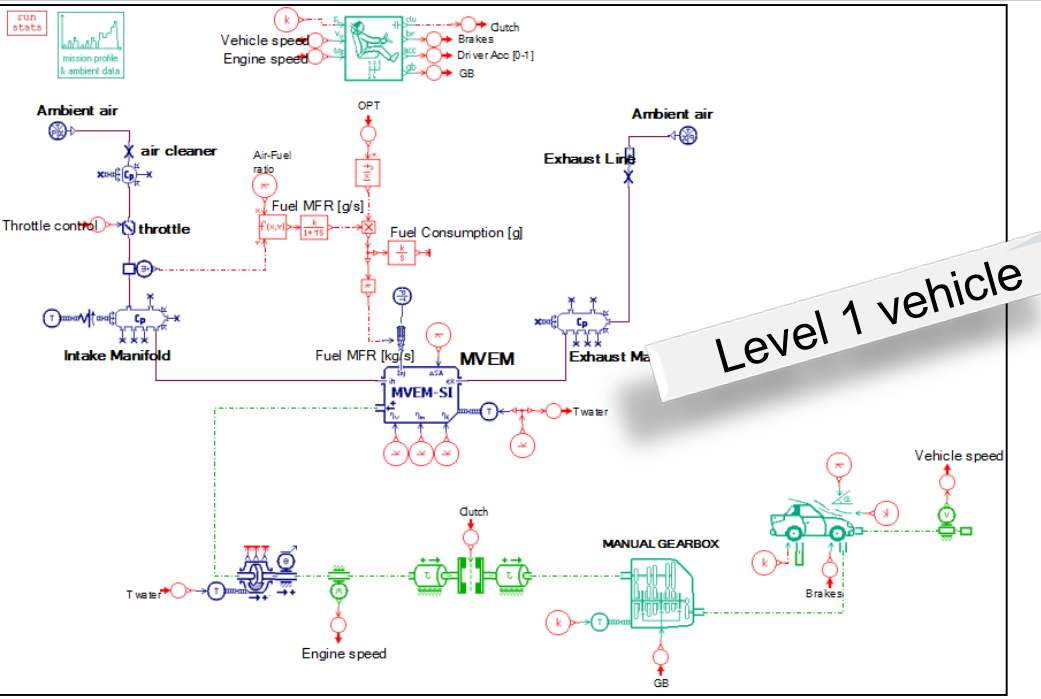
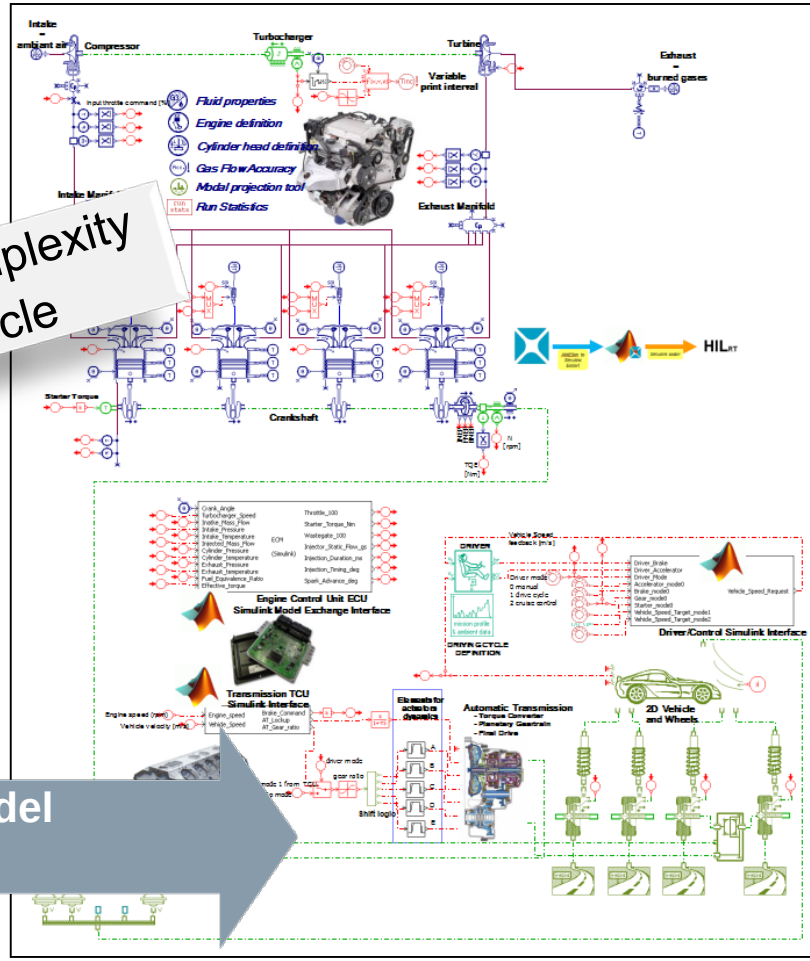


Level 1 vehicle

High complexity vehicle

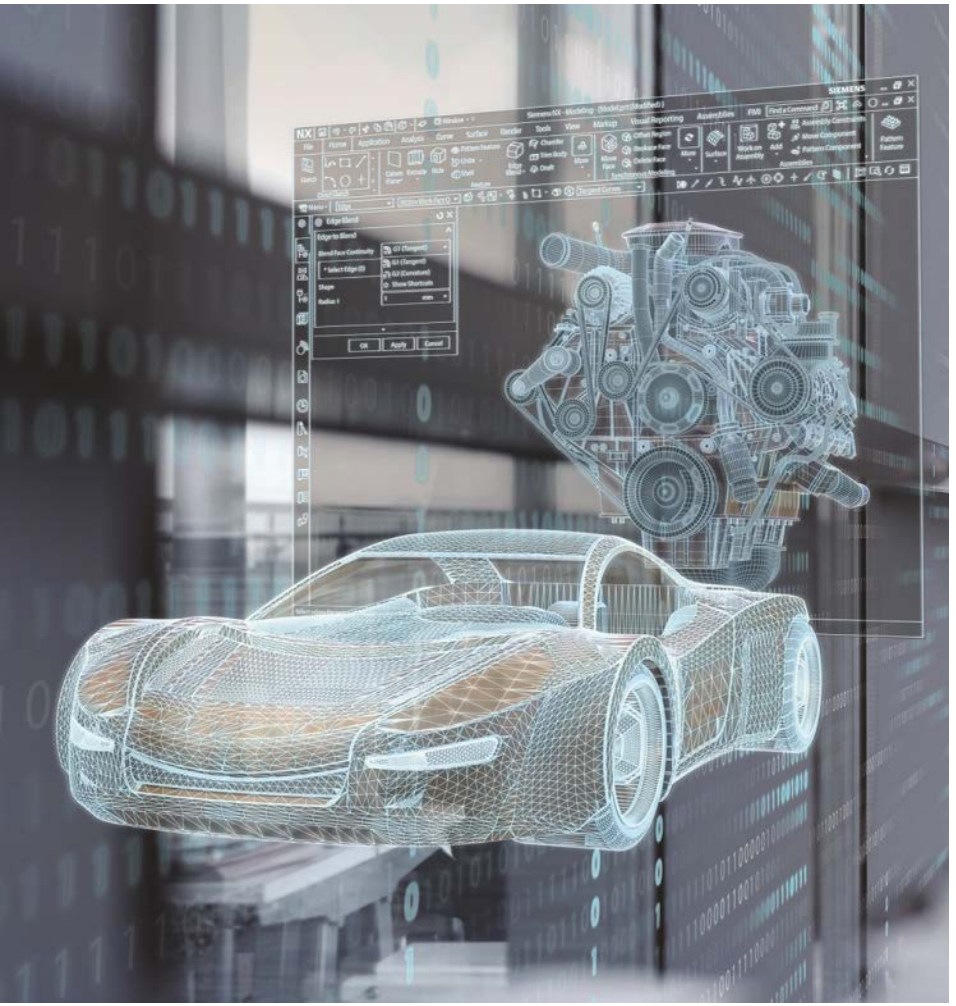


Calculation time
计算时间

Accuracy of the model
模型精度

Downsizing Powertrains / 传动系轻量化
NVH Implications and Solutions for Vehicle Integration
汽车NVH的影响和解决方案的整合

SIEMENS



- Downsizing trends and NVH impact

  轻量化趋势及NVH影响
- Traditional Approach for NVH studies

  NVH研究的传统方法
- New Integrated approach

  新的集成方法
- **Examples/示例:**
  - **Low Frequency Booming Noise/低频Booming噪声**
  - **Clunk**

Aisin AW

Relying on LMS Engineering to strengthen its position as technology partner
依托LMS工程加强其技术合作伙伴的地位

SIEMENS

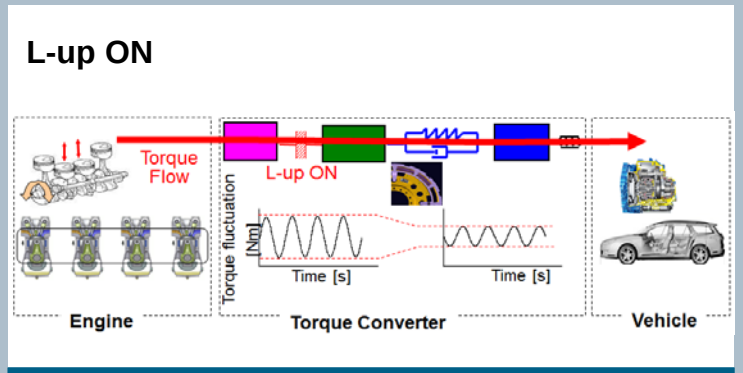
- **Gained 50 percent time reduction when troubleshooting a new NVH issue**

  在解决新的NVH问题时降低了50%的时间
- **Significantly reduced overall development time**

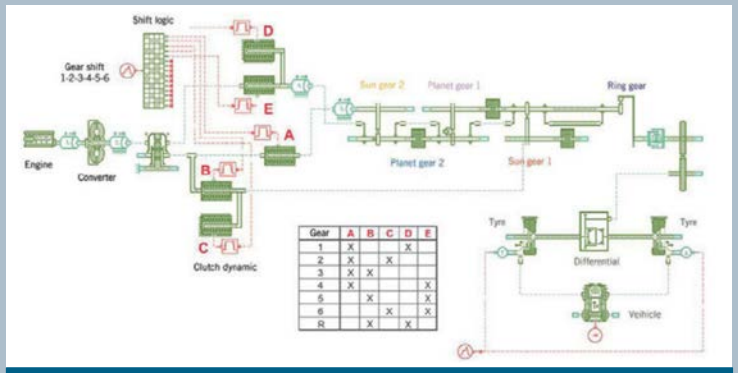
  显著降低了整体的开发时间
- **Recognized as technology partner of automotive OEMs, resulting in competitive advantage**

  作为汽车制造商的技术合作伙伴，形成竞争优势

Reducing booming, judder and gear noise



Energy flow lock-up booming



Full-vehicle simulation

- Deploy a full vehicle model based approach for the prediction and elimination of clutch judder
  通过整车模型的手段，来预测和消除离合器的振动
- Employ full vehicle modeling approach combining test, 3D and 1D simulation methodologies
  采用全车建模方法相结合的：测试，3D和一维模拟方法

“Many NVH techniques we learned from LMS Engineering services are now part of our standard development process, such as transfer path analysis.”
许多从LMS工程服务学到的NVH技术现在已经是我们标准开发中的一个环节，例如传递路径分析

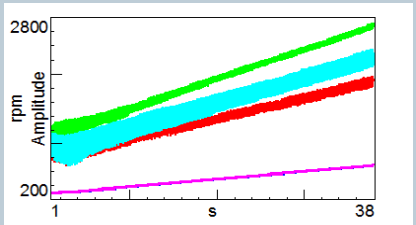
Hiroki Tsuji, Group Manager, Core Component Engineering Department

Aisin AW
Process lock-up booming investigation
离合器锁止booming的研究流程

SIEMENS

1) Testing/测试

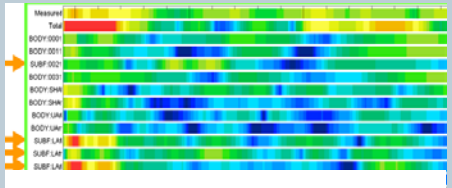
Measurement of input & validation data, data for load identification/测试：参数输入&验证数据，负载



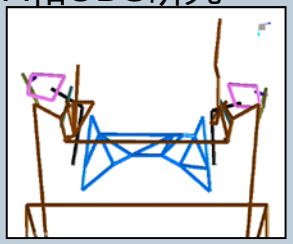
Internal transmission rpm

2) Test based diagnosis/基于测试的诊断

In-depth test investigation including transfer path analysis (TPA) and operational deflection shapes (ODS)/深度的测试研究：包括TPA和ODS研究



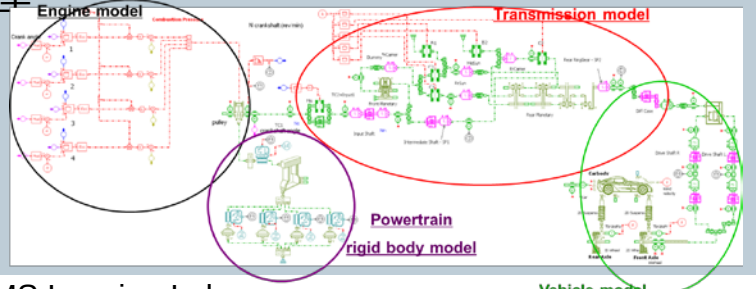
TPA contribution



ODS mode

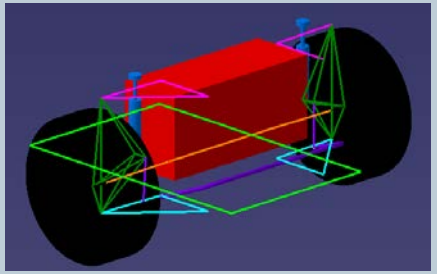
3) 1D Driveline modeling/1D传动系建模

1D model consists of engine model and transmission model/1D模型包括发动机模型和变速器模型



LMS Imagine.Lab

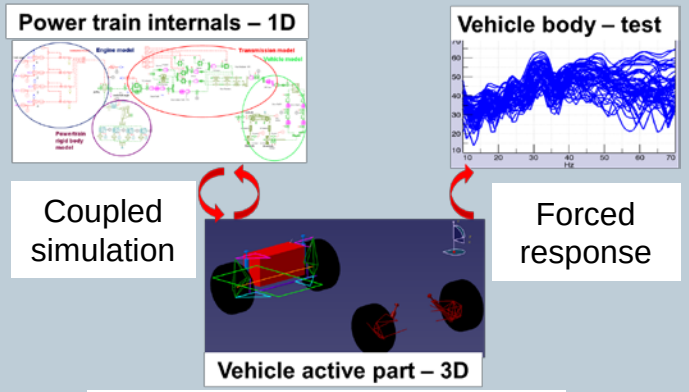
4) 3D Vehicle modeling/3D车辆模型建模

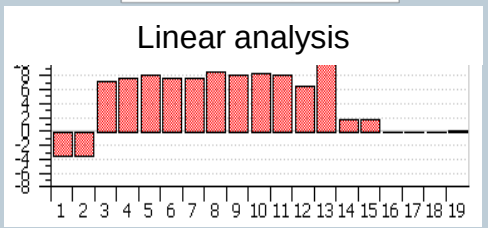


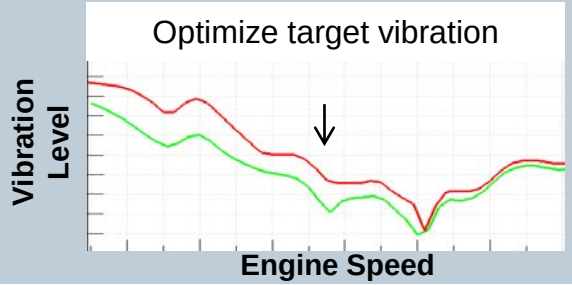
LMS Virtual.Lab

- Powertrain block & mounts/传动系模块&悬置
- Subframe/副车架
- Chassis /底盘
- Front & rear suspension/ 前后悬架
- Driveshafts & tires/传动轴 &轮胎

5) Simulation, correlation and model based diagnosis/仿真、标定和基于模型的诊断







Automobili Lamborghini

Creating a new driveline concept design using LMS Imagine.Lab Amesim
基于LMS Imagine.Lab Amesim创建新型传动系的概念设计

SIEMENS

- **Designed the torsional vibration characteristic of the Aventador LP700-4 driveline**

  针对Aventador LP700-4 传动系的扭转特性进行设计
- **Supported torsional vibro-acoustic driveline optimization**

  支持传动系扭转振动-噪声的优化

Designing the Aventador LP700-4 torsional vibro-acoustic driveline

Powertrain and gearbox noise optimization

Torsional behavior of the driveline

- Model easily complex dynamic systems using prepackaged components
  通过前期封装好的模型可以很容易就复杂系统的动态特性进行研究
- Generate models in function of the phenomena the user intends to investigate
  针对客户关心的问题来开发对应功能的模型

“The true power of LMS Amesim is demonstrated by how easy it is to evaluate different driving conditions, software or hardware changes and even different configurations”.

Ing. Claudio Manzali, R&D