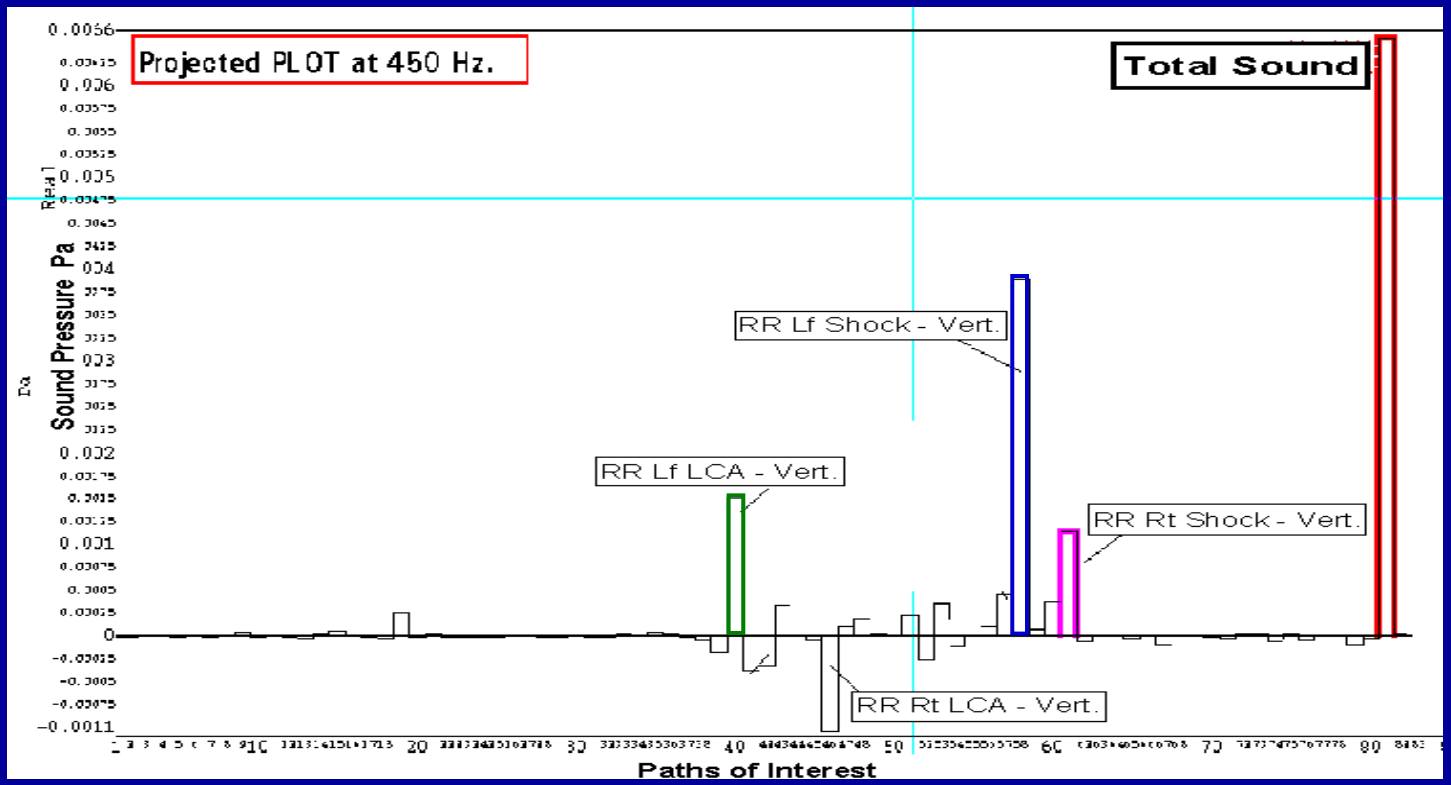
Axle Whine Example

- **Before embarking on identifying the root cause for under-target performance at dominant noise paths, it is a good practice to perform a reasonableness check on the response.**
- **Steps for Reasonableness Determination:**
  - **Judging the response based on System Knowledge**
    - **Total response content is dominated by rear excitation. This is reasonable since vehicle has IFS and solid axle rear suspension which is harder to isolate for noise**
  - **Forced Mode Animation**
    - **Operating deformed shape motion is rear axle pitching about ring gear axis. This was expected since input excitation is MTE imposed as enforced angular rotation between ring and pinion gear**
  - **Disconnect Studies**
    - **Disconnecting rear suspension noise paths (shock in particular) had the most significant effect on Driver's SPL response**

Axle Whine Example

- **Transfer Path Analysis**



- **Dominant Paths**
  - **Rear left shock vertical**
  - **Rear LCA vertical : Left is positive whereas right is negative contributor**
  - **Rear Right shock vertical**

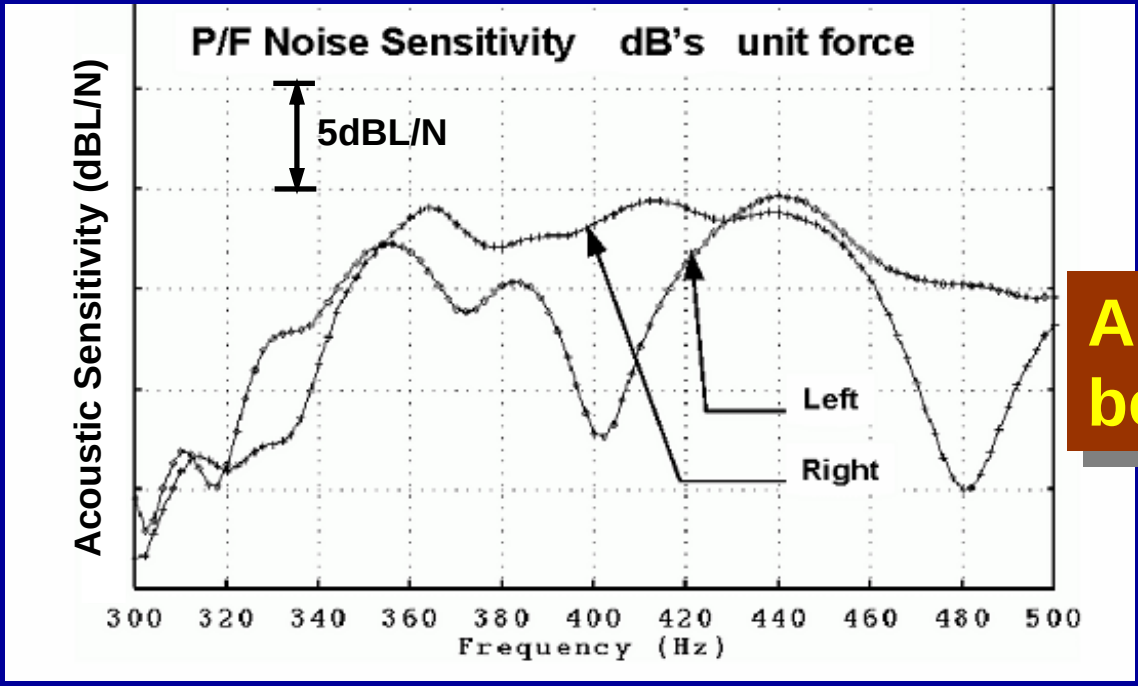
- **The conclusion matches with reasonableness checks**

[Figure Courtesy of DaimlerChrysler Corporation]

Axle Whine Example

- Is it high forces or high acoustic sensitivity at shock to body attachment ?

$$P_t = \Sigma_{paths} [P_i] = \Sigma_{paths} [F_i * (P/F)_i]$$



Acoustic sensitivity was better than generic target

- The issue is with high forces into the body through shock attachment due to stiff shock bushings
- Stiff shock bushings gave low body-to-bushing stiffness ratio

[Figure Courtesy of DaimlerChrysler Corporation]

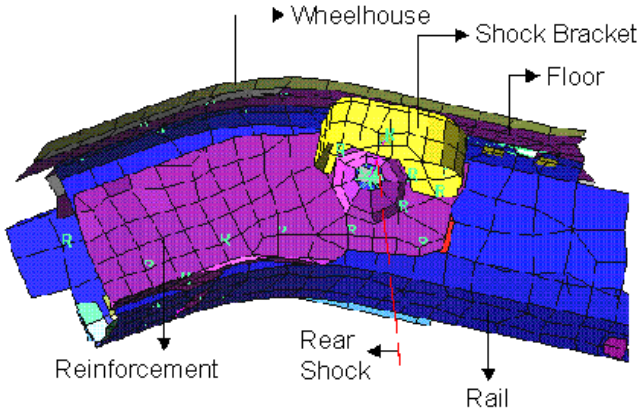
Axle Whine Example

Solution

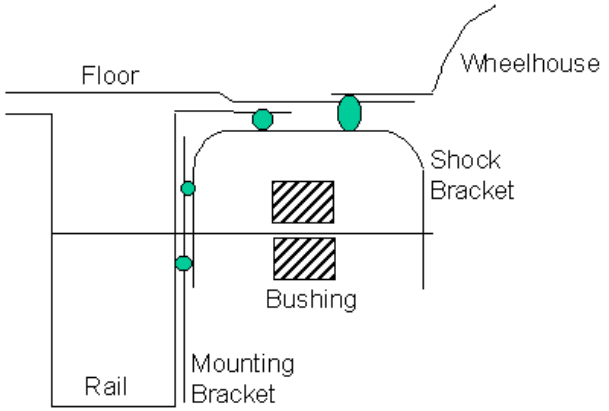
- Soften shock vertical bushings by 65%

- To balance this against Ride and Handling requirement of stiff bushing, local attachment stiffness between shock and body was improved through a new bracket design

- This addition of bracket improved right shock mobility 3 times whereas left shock mobility by 1.5 times thereby improving isolation effectiveness of shock bushing



Configuration of Shock Bracket

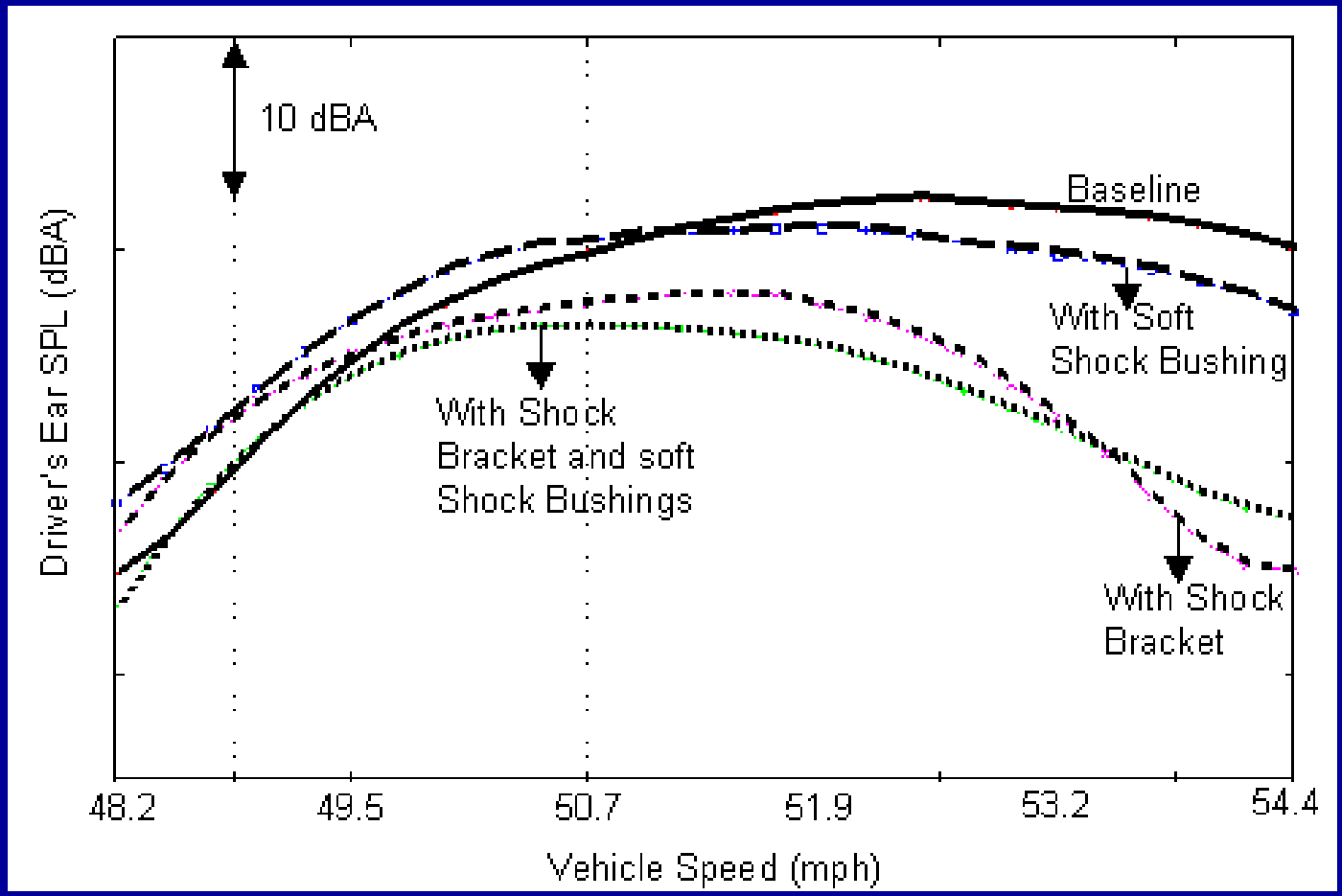


Rear View Section of Shock Bracket

[Figure Courtesy of DaimlerChrysler Corporation]

Axle Whine Example

Response Improvement due to proposed solution



[Figure Courtesy of DaimlerChrysler Corporation]

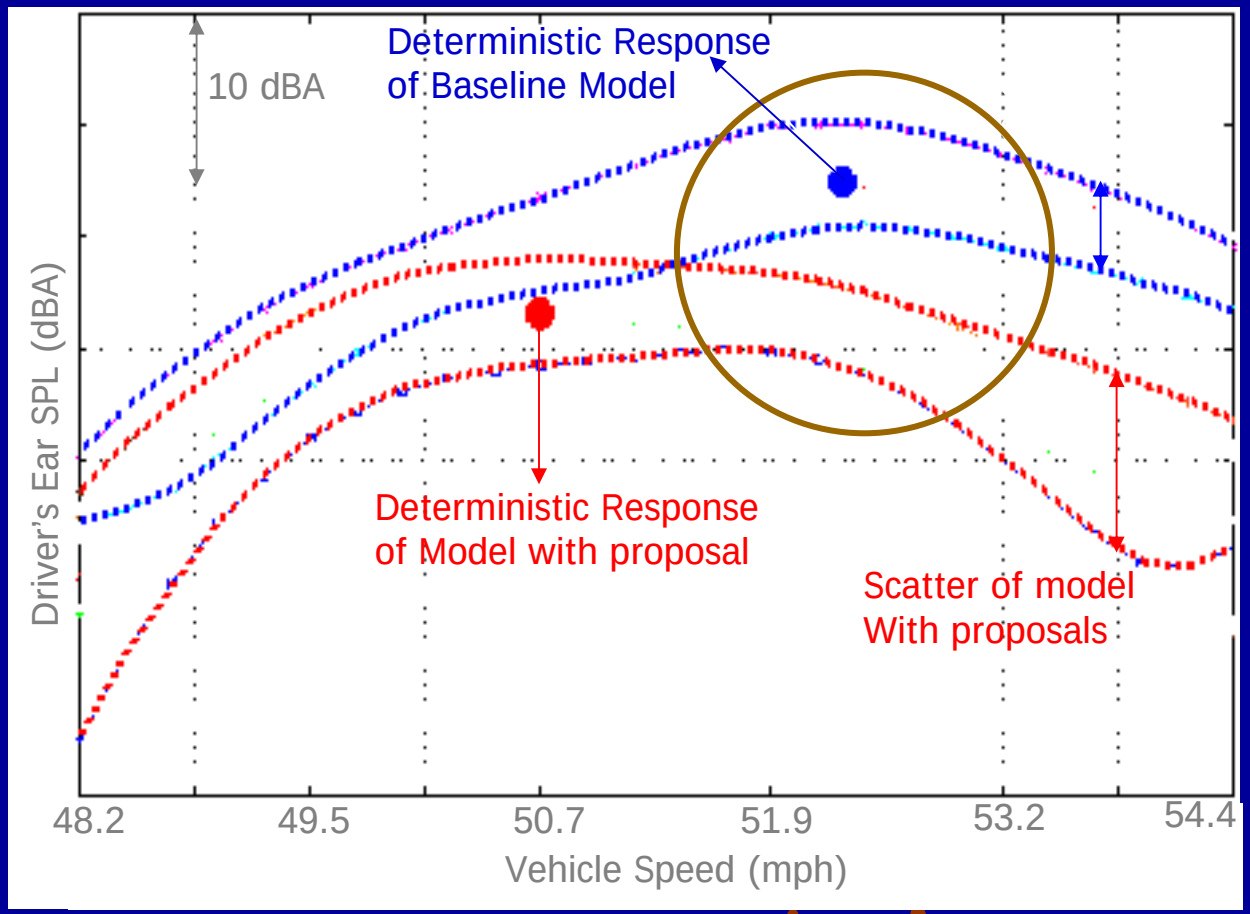
Axle Whine Example

How Robust is the proposed solution ?

- **Parameter variations such as weld deletion in "new bracket" and gage changes were considered to study robustness of solution**

- **Response scatter of model with proposal does not overlap baseline model response scatter indicating a robust solution**

- **The problem peak has now shifted to a new vehicle speed of 50.7 mph which requires a new contribution analysis**



[Figure Courtesy of DaimlerChrysler Corporation]

Final Remarks on Mid Frequency Analysis

- Effective isolation at dominant noise paths is critical
- Reduced mobilities at body & source and softened bushing are key for effective isolation
- Other means of dealing high levels of source input (Tuned dampers, damping treatments, isolator placement at nodal locations) are also effective
- It is important to balance NVH requirements against other functionalities (Ride and Handling, Impact)
- It is important to understand the robustness of design recommendations

NVH Workshop Topic Outline

- Introduction
- Fundamentals in NVH
- Automotive NVH Load Conditions
- Low Frequency Basics
- *Live Noise Attenuation Demo*
- Mid Frequency Basics
- **Utilization of Simulation Models**
- Closing Remarks

Utilizing NVH Simulation Models

Considerations

- Some Agreement: Math Models can be used as Trend Predictors.
  (but not for absolute levels, yet.)

- Q. How do I know my model is good?
- ANS. We require correlation work to know the simulation compares to test values to some degree.

- Q. How do I make design decisions before hardware is available?
- ANS. Correlation must be performed on existing hardware to establish modeling methods and correlation criteria to be applied to the future design.

  (The Reference Baseline Ref. 3)

  A model of the new design is built with the same Methodology as the Reference Baseline to predict the change in performance as the design process progresses but before prototypes are available.

Utilizing NVH Simulation Models

Considerations

- Q. How do I compare my model to test measurement and how close does it have to be to assure it can be used as a trend predictor?
- ANS. If model predictions were within the band of variability of the test measurement, for a statistically significant number of samples, this would increase confidence in the predictive capability.

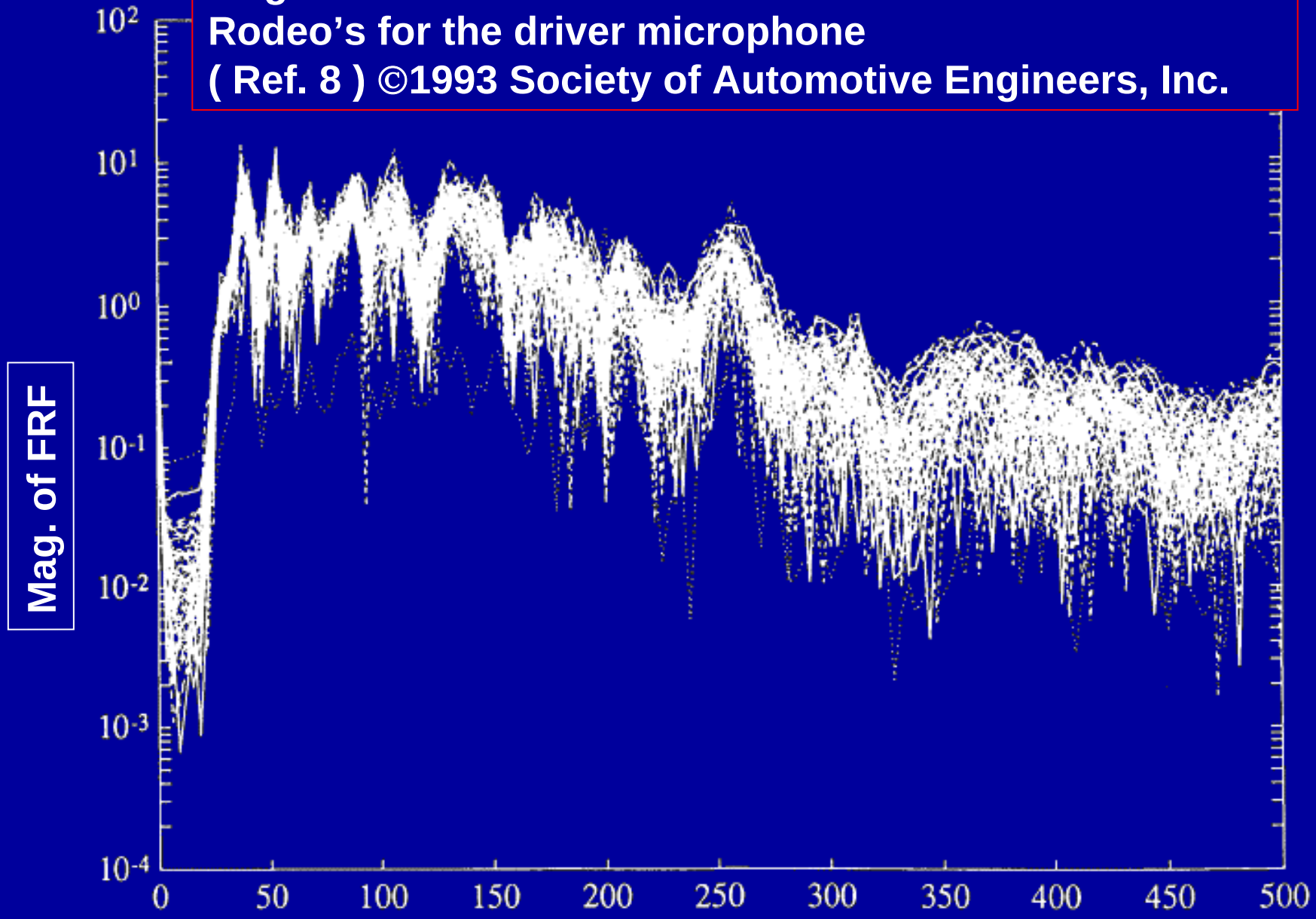
- Q. How wide is the band of variability?
- ANS. Let's EXPLORE it !!!!

Discussion of Product Variability

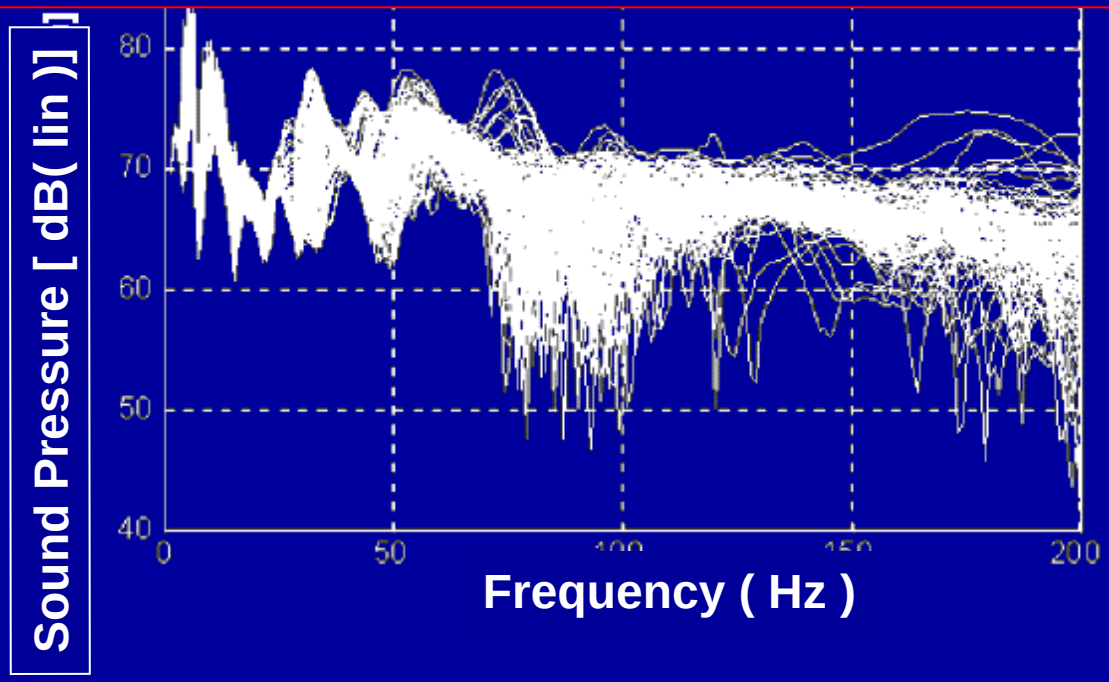
Topics

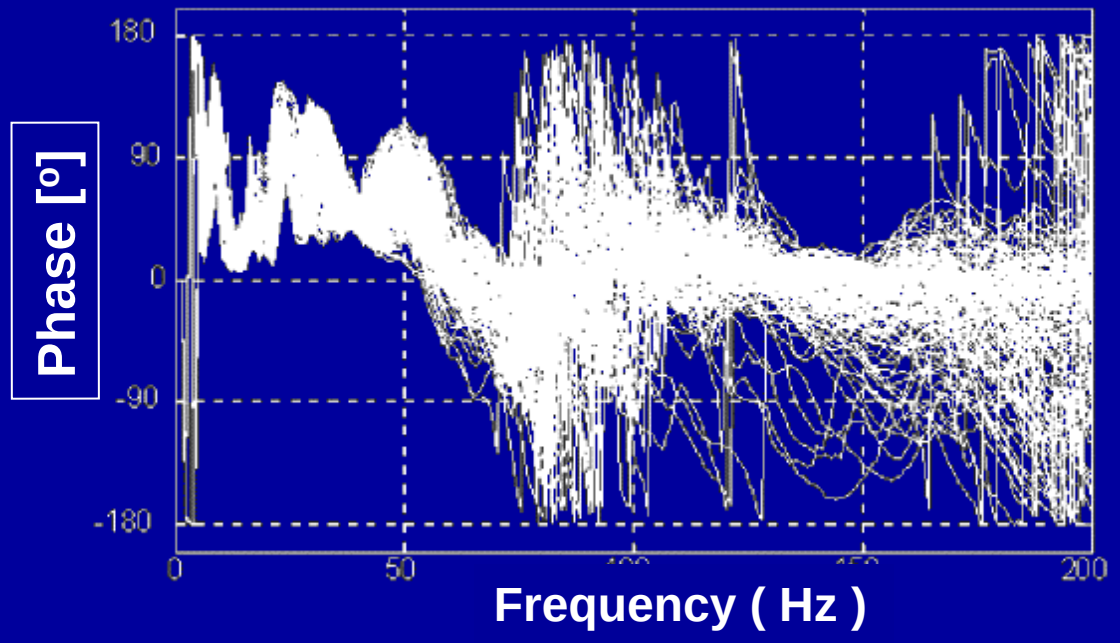
- Kompella and Bernhard Observations
- Freyman NVH Scatter Results
- Model Confidence Criteria
- Conclusions

Magnitude of 99 Structure – borne FRF's for the Rodeo's for the driver microphone
(Ref. 8) ©1993 Society of Automotive Engineers, Inc.



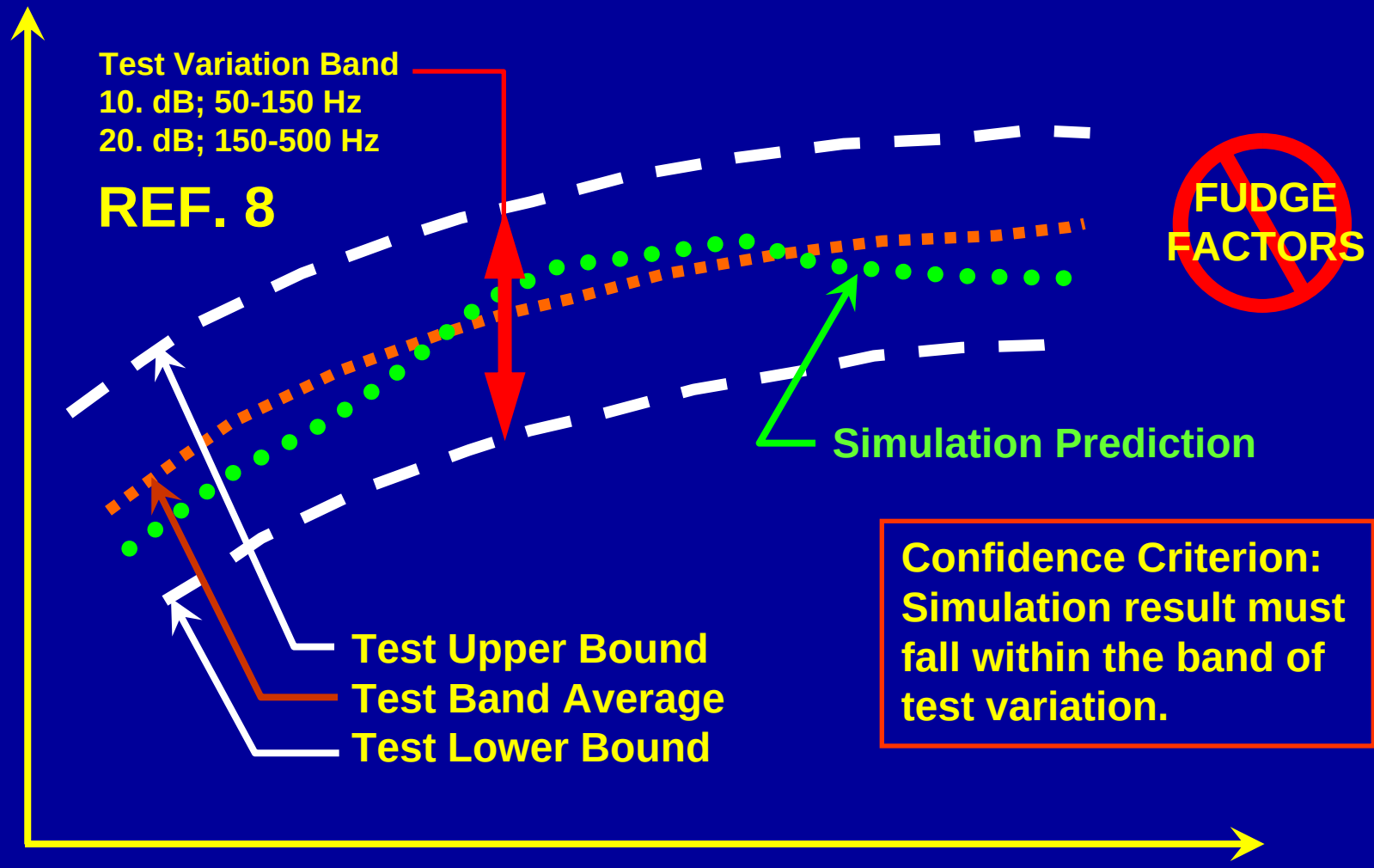
Acoustic scatter numerically determined in the vibro – acoustic behavior of a vehicle due to possible tolerances in the component area and in the production process





Reference Baseline Confidence Criterion

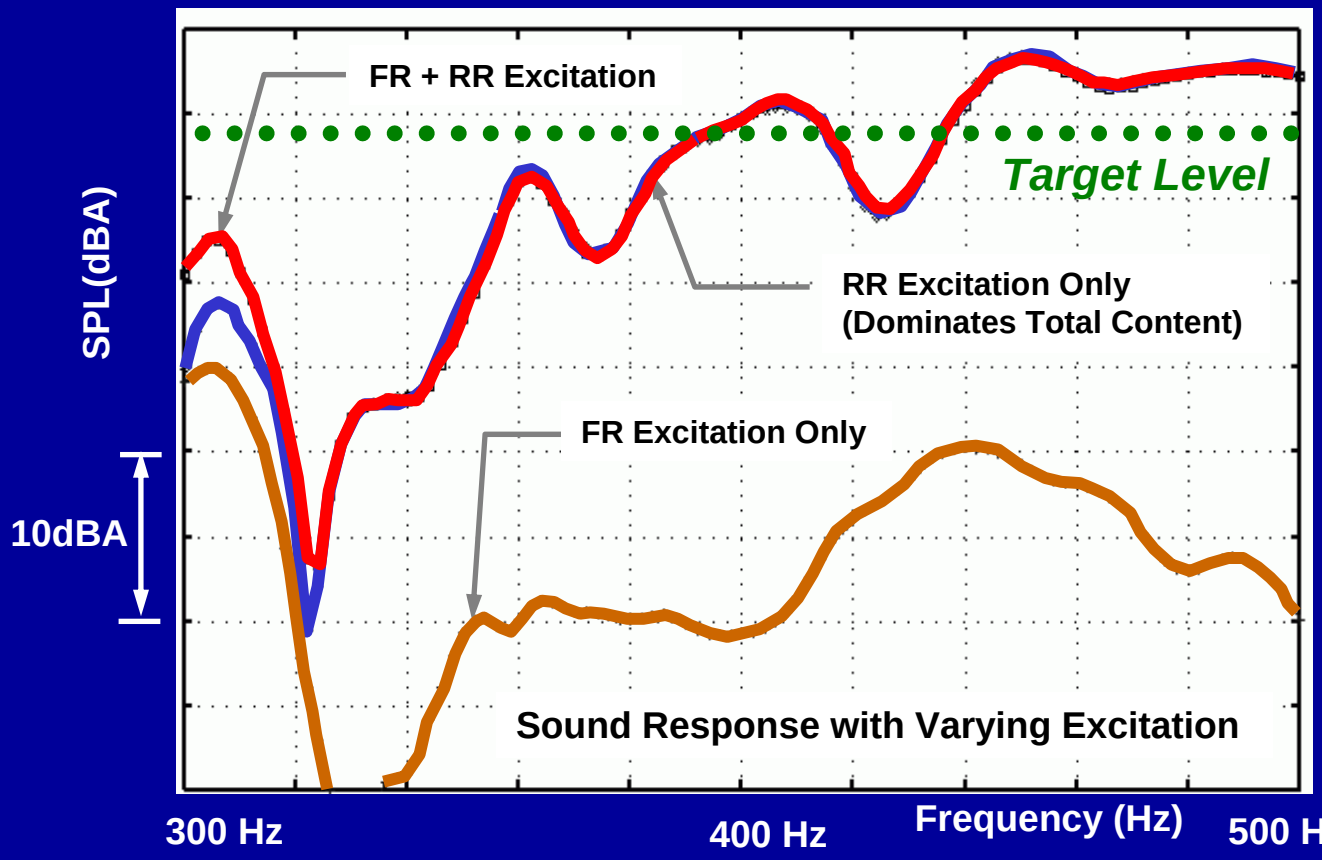
For *Operating* Response Simulations



Confidence Criterion:
Simulation result must fall within the band of test variation.

Axle Whine Example

- **Design work was focused in the beginning towards achieving generic targets for all noise paths**
- **As the design was firmed out, full vehicle analysis revealed under target performance for Driver's ear SPL response which was dominated by rear excitation**



[Figure Courtesy of DaimlerChrysler Corporation]

Conclusions:

Significant Product Variation exists even in best-in-class vehicles.

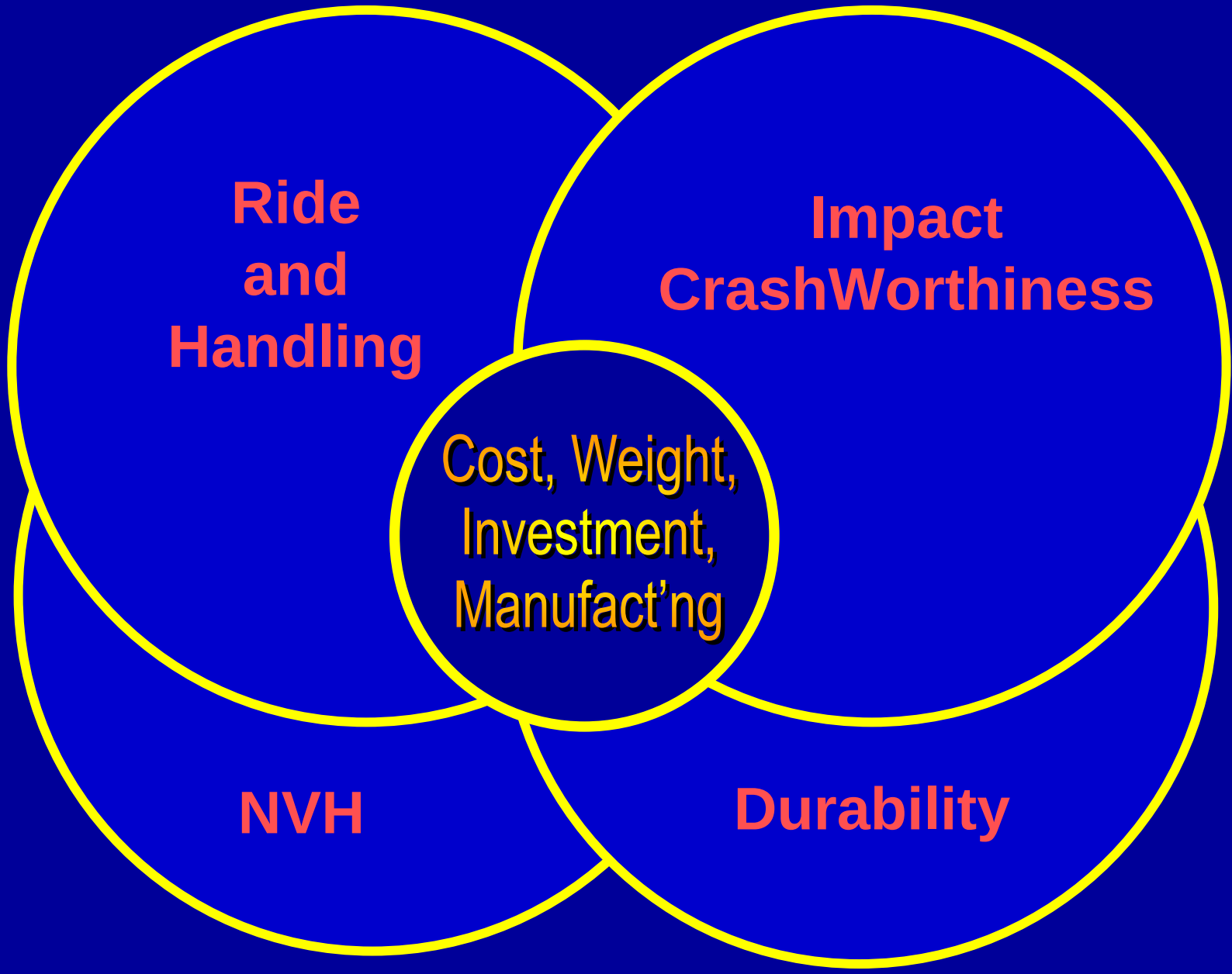
Correlation should be considered as being within the band of variability whether test or simulation.

The Confidence Criteria, for operating responses, is a relatively challenging condition to meet when considering the following:

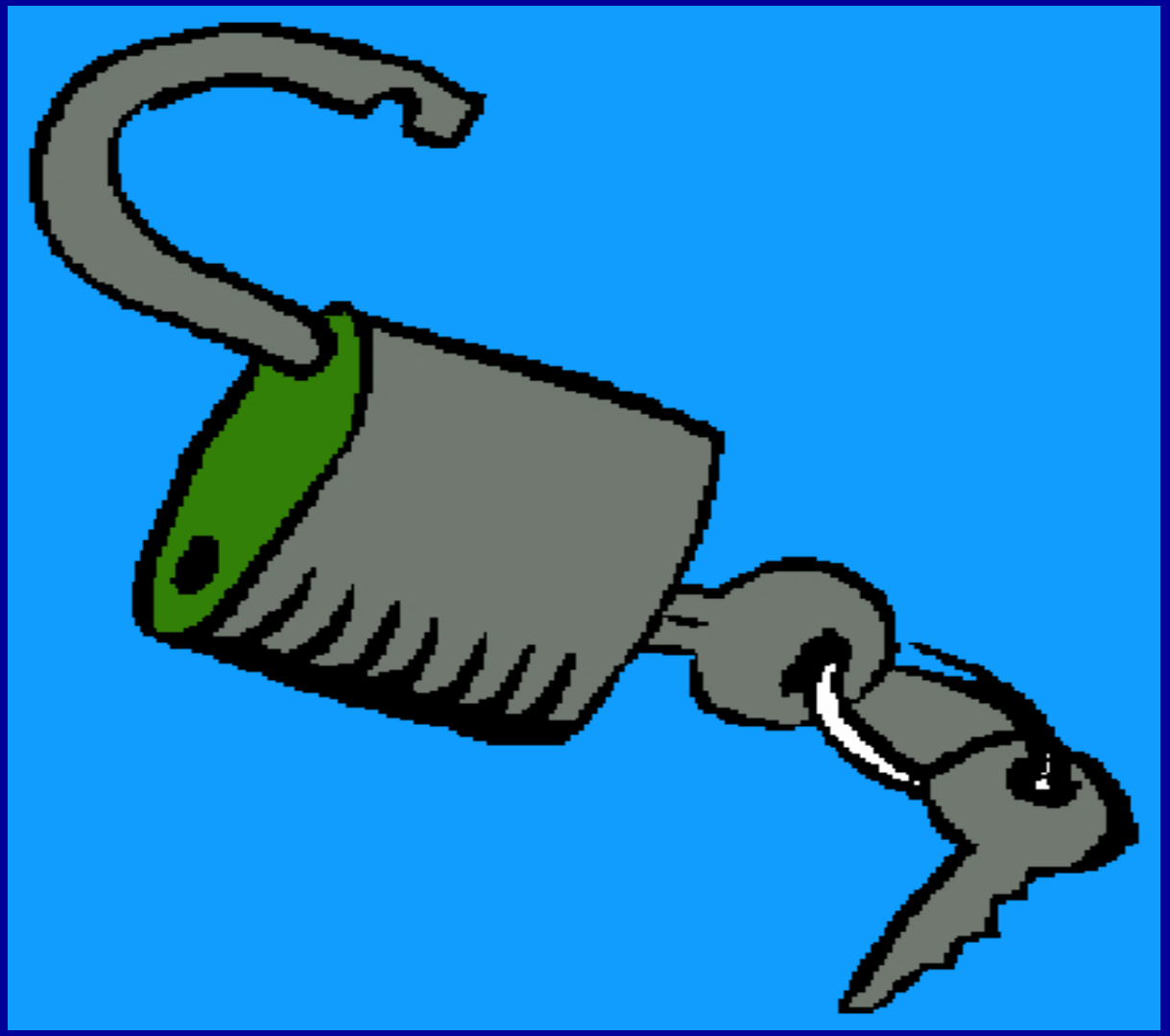
- ✓ **It uses the same bandwidth as Kompella (Ref. 8), determined from simple FRF's, while the criteria is for operating responses which are subject to additional variation in the operating loads.**
- ✓ **It assumes that one test will generate the mean response level in the band subject to the condition that a "qualified" median performer will be tested. This requires a test engineer extremely experienced with the vehicle line in order to "qualify" the vehicle.**

Best hope for reduced product development times is a coordinated effort of Virtual Vehicle Simulation and Reference Baseline and Physical Prototype Testing to grasp the complexities of NVH responses and the robustness of their sensitivity to variation.

Competing Vehicle Design Disciplines



The Fundamental Secret of Structure Borne NVH Performance



Revealed here today !

The Fundamental Secret of Structure Borne NVH Performance

To Minimize Structure Borne NVH, connect between Source and Receiver Sub-Systems at Locations where the Motion is at a Minimum.

Meets Conditions of the Attenuations Strategies

- *Minimize the Source Load*
- *Manage Mode Placement*
- *Provide Isolation*
- *Mount at Nodal Points*
- *Provide Dynamic Absorber*
- *Reduce Source - Receiver Mobility*

The Fundamental Secret of Structure Borne NVH Performance

To Minimize Structure Borne NVH, connect between Source and Receiver Sub-Systems at Locations where the Motion is at a Minimum.

1st Corollary

First Best Principle for NVH Improvement is Minimization / Understanding of the Source Excitation.

2nd Corollary

Effectively Isolate the remaining source from the receivers at Key paths

The Fundamental Secret of Structure Borne NVH Performance

To Minimize Structure Borne NVH, connect between Source and Receiver Sub-Systems at Locations where the Motion is at a Minimum.

That's All Folks !

Thank You for Attending the

2007 Structure Borne NVH Workshop

Your Presenters today were:

Alan Duncan, Material Sciences Corp.

Greg Goetchius, Material Sciences Corp.

Sachin Gogate, DaimlerChrysler Corp.

Visit: www.AutoAnalytics.com/papers.html (or www.sae.org) to download the 2007 Structure Borne NVH Workshop

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