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Streamlining the Automotive Powertrain Dynamic Analysis Process

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Introduction

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- Background
- Scope
- Improve Speed
  - Condensation
  - Data recovery
  - Results correlation
    - Powertrain vibration
    - Sound Pressure Level
- Established process
- Process Validation/Application
- Summary and Conclusions

Background

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- Use simulation for engine design optimization
- Use multiple software with data flow from one to another
- Reduce calculation speed without loss of accuracy
- Seamless process to evaluate designs
- Establish and standardize simulation process
- Accurate results and quick turn around time to impact the design

SCOPE: Powertrain dynamic analysis

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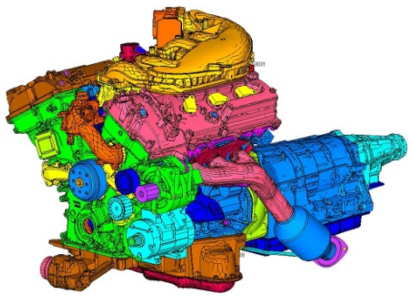
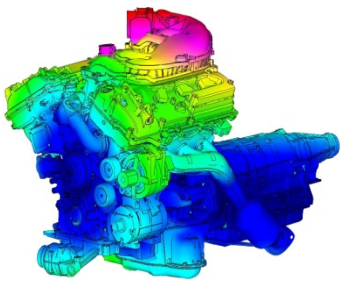


Engine Vibration (AVL-EXCITE)



FE mesh | **Dynamic analysis** | **Surface velocity** | **Radiated noise (SPL)**

- Use multiple software

  MSC Nastran → AVL-EXCITE → MSC Nastran → LMS Virtual Lab (Sysnoise)

- Long computation time to evaluate single design (cannot impact design)
- Need to evaluate at many engine operating conditions

SCOPE: Process

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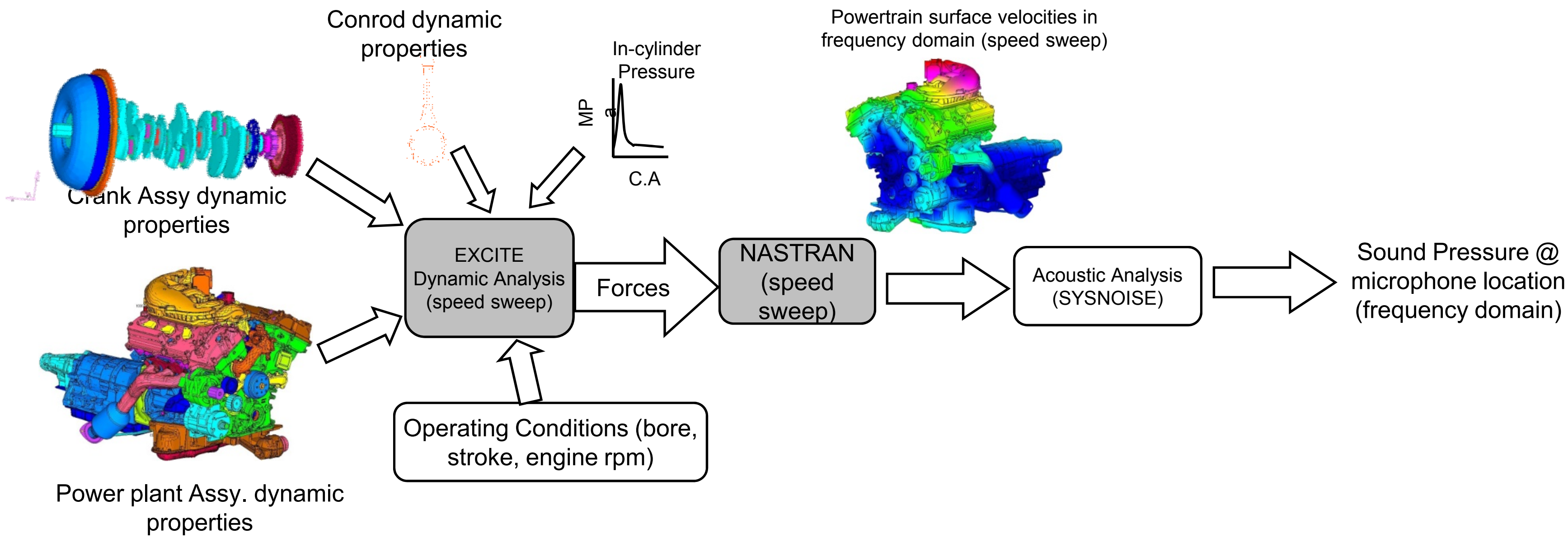

- Need to evaluate at many engine operating conditions
- Need to check parameter sensitivity for results accuracy

SCOPE: Computation time in Nastran

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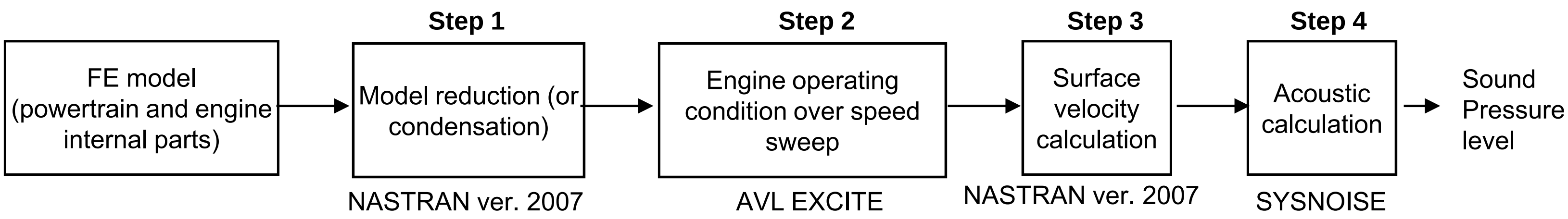

- Step 1: Condensation
  - Powertrain model condensation using CMS method
  - Long computation time (1 day)
    - Big model (2.7 M nodes)
    - Many ASET dofs (~1200)
    - High frequency (upto 3000 Hz)

Target: 2 days / design

- Step 3: Data recovery
  - Long computation time (2 days/rpm)
  - Many engine operating conditions (20-22 rpms)

Improve Speed: Solutions

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- Software
  - ACMS
  - SMP
  - Super Elements
  - Operating system
    - Scratch memory request
    - MIO – IBM OS option
- Hardware
  - CPU computation speeds GHz
    - Example: Power 6 chip speed 4.7 GHz (2007)
  - 15k Disk drive runs a 250 Hz
  - Memory speed and bandwidth
  - Cache memory and bandwidth

Focus

One time or no chance of control

Improve speed: ACMS

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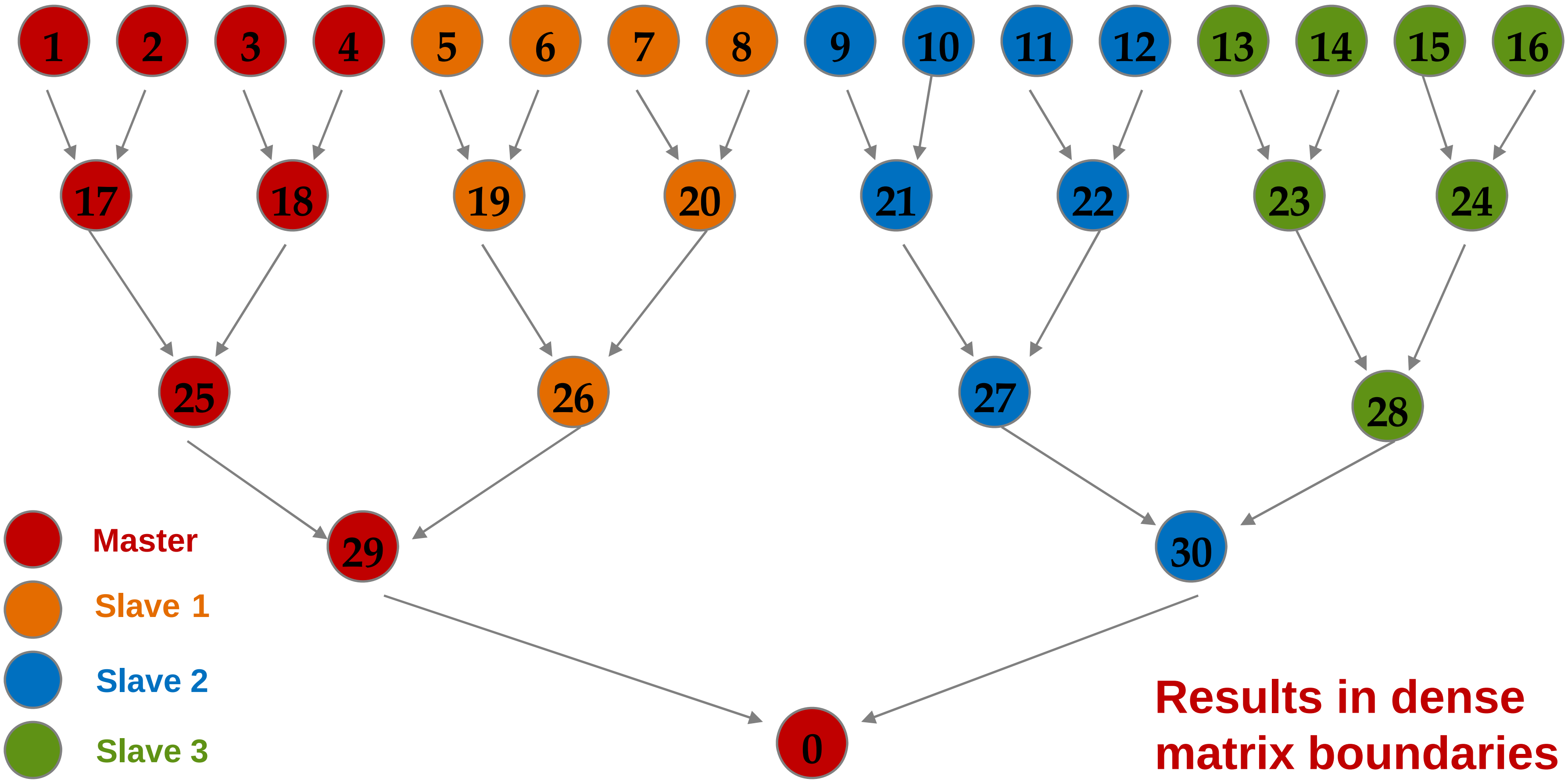
- Automated Component Modal Synthesis - Superelements



Results in dense matrix boundaries

Improve speed: SMP

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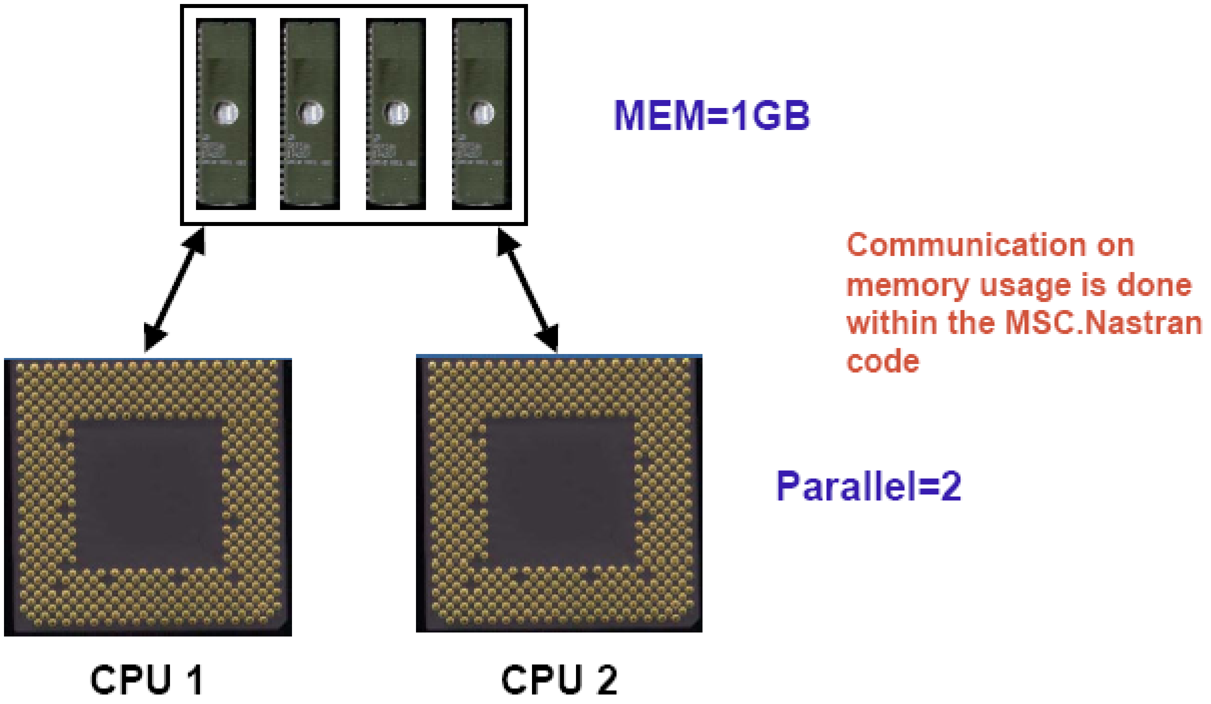
- Shared Memory Parallel
  - CPU share a common block of memory
  - Performance increases with matrix density



Improve speed: External Superelements

- EXTSEOUT
  - Modern version of external superelements
  - Combination of the best features
    - DMAP ALTER external superelements from Space Station project
    - Part superelements to account for duplicate element/grid ID
    - PARAM external super elements for database options
  - Advantages
    - Simple user interface minimizing user interaction
    - ACMS optimized within superelement reduction
    - Minimizes database size storing only information needed for data recovery

Condensation: CMS Reduction theory

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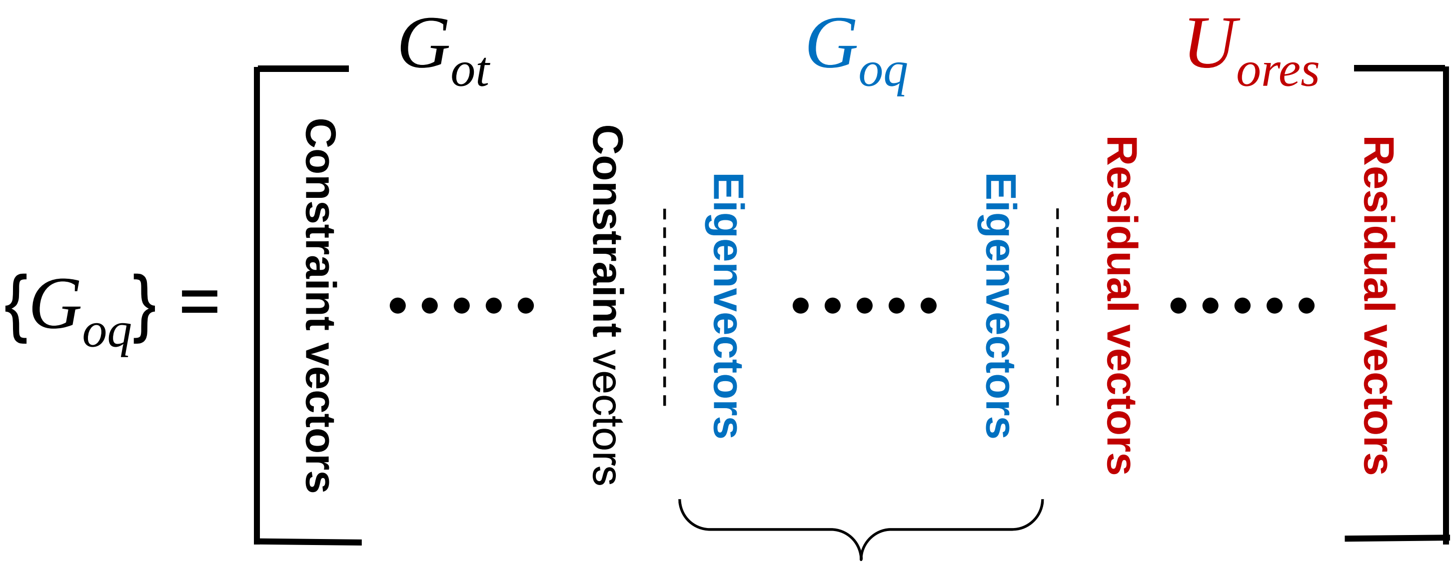
$$[K_{qq}] = \{G_{oq}\}^T [K_{oo}] \{G_{oq}\}$$

$$[M_{qq}] = \{G_{oq}\}^T [M_{oo}] \{G_{oq}\}$$

Where →

$$\{G_{oq}\} = \left(\begin{array}{c|c|c} G_{ot} & G_{oq} & U_{ores} \\ \hline I_{tt} & 0 & 0 \end{array} \right)$$



Using ACMS reduces this time

Condensation: Test Model

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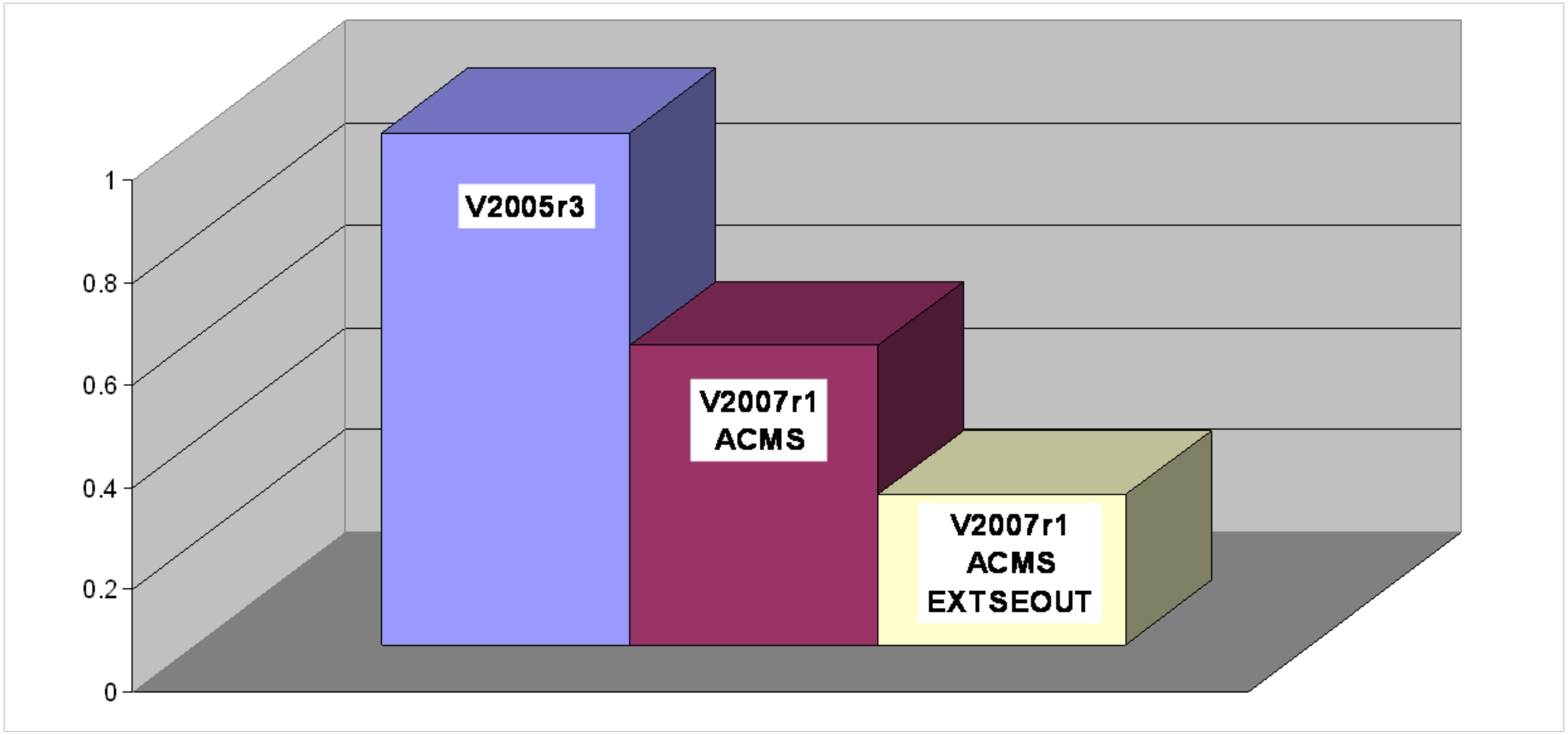
- Normalized wall times



Using a test model to evaluate the performance improvement

Condensation: Production Model

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	Traditional	NEW Method
Version	2005r3b	2007r1
Special Features	None	**-ACMS** **- External Super Element**
Model Size	-10.6M Dofs - 1156 ASET dofs - 607 Modes	-10.6M Dofs - 1306 ASET dofs - 607 Modes
Calculation Time	**24** Hours	**7** Hours

* Using 2 CPUs, 8 Gb of memory and 2 Gb for Mio
** Special Dmaps to output data needed for AVL-EXCITE

Results: Powertrain vibration (AVL-EXCITE)

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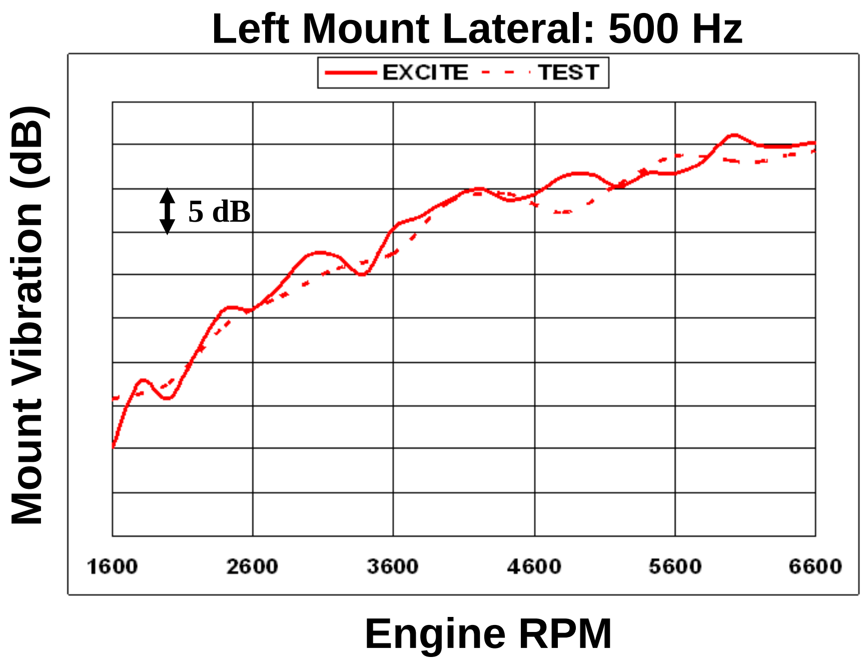

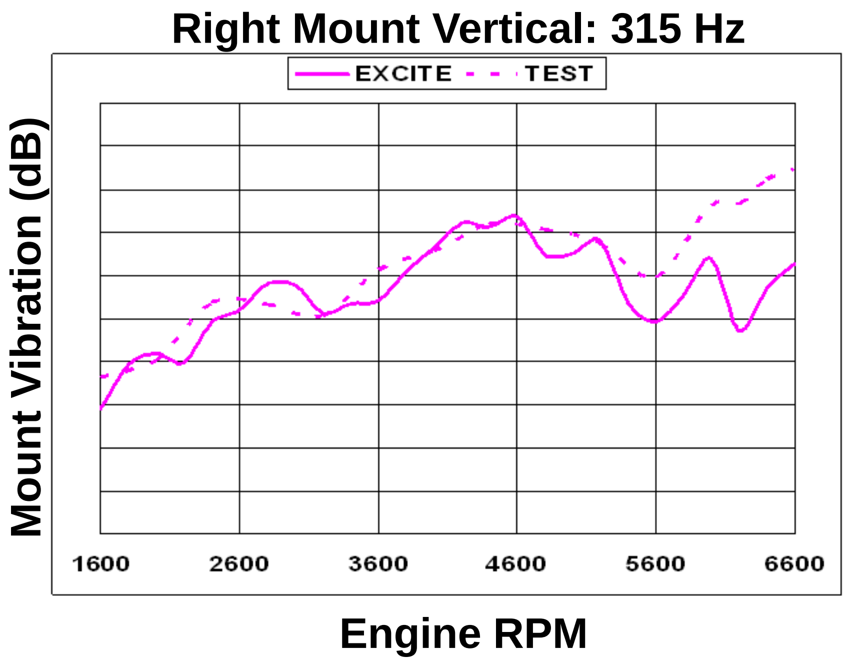

Data Recovery : EXTSEOUT theory

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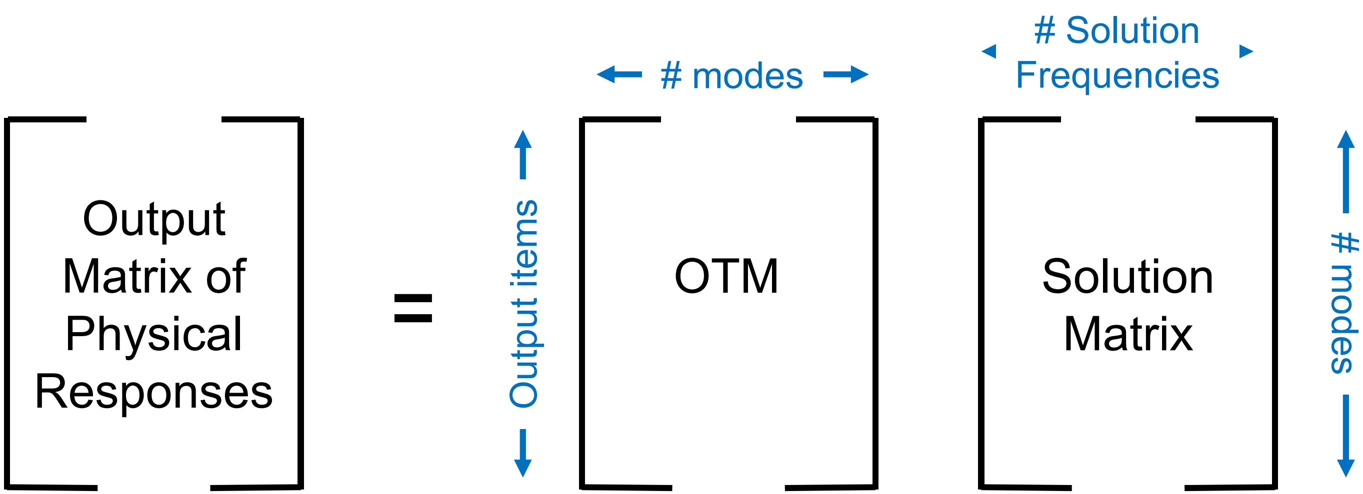
- Output Transformation Matrix
  - Created when the external superelement is processed
  - Unique OTM for grid and element
    - Example: a stress OTM describes the stress in an interior element due to the unit displacement of the boundary GRID points
  - Traditional superelements use a full OTM regardless of need



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Data recovery: Production model

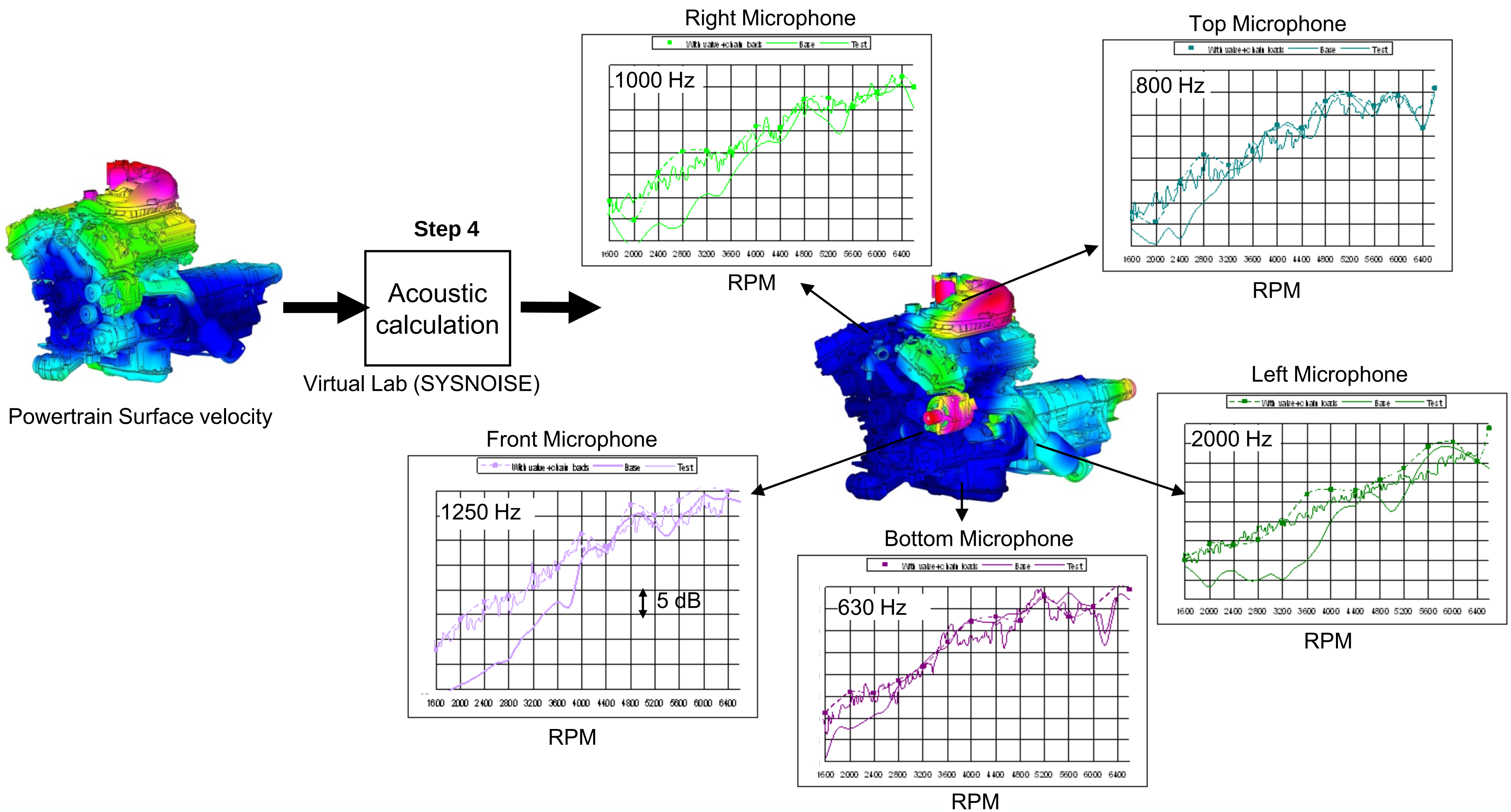
Recover velocities on the powertrain outer surface nodes

	BASE	**NEW Method**
Version	2005r3b	2007r1
Special Features	None	**-ACMS** **- External Super Element**
Model Size	-10.6M Dofs - 1156 ASET dofs - 607 Modes	-10.6M Dofs - 1306 ASET dofs - 607 Modes
Calculation Time	**48** Hours**	**60 mins****

* Using 2 CPUs, 8 Gb of memory and 2 Gb for Mio
** For each RPM, need to repeat this for 20-22 engine RPMs
*** Special Dmap to recover surface velocities (op2 format)

Results: Powertrain radiated noise

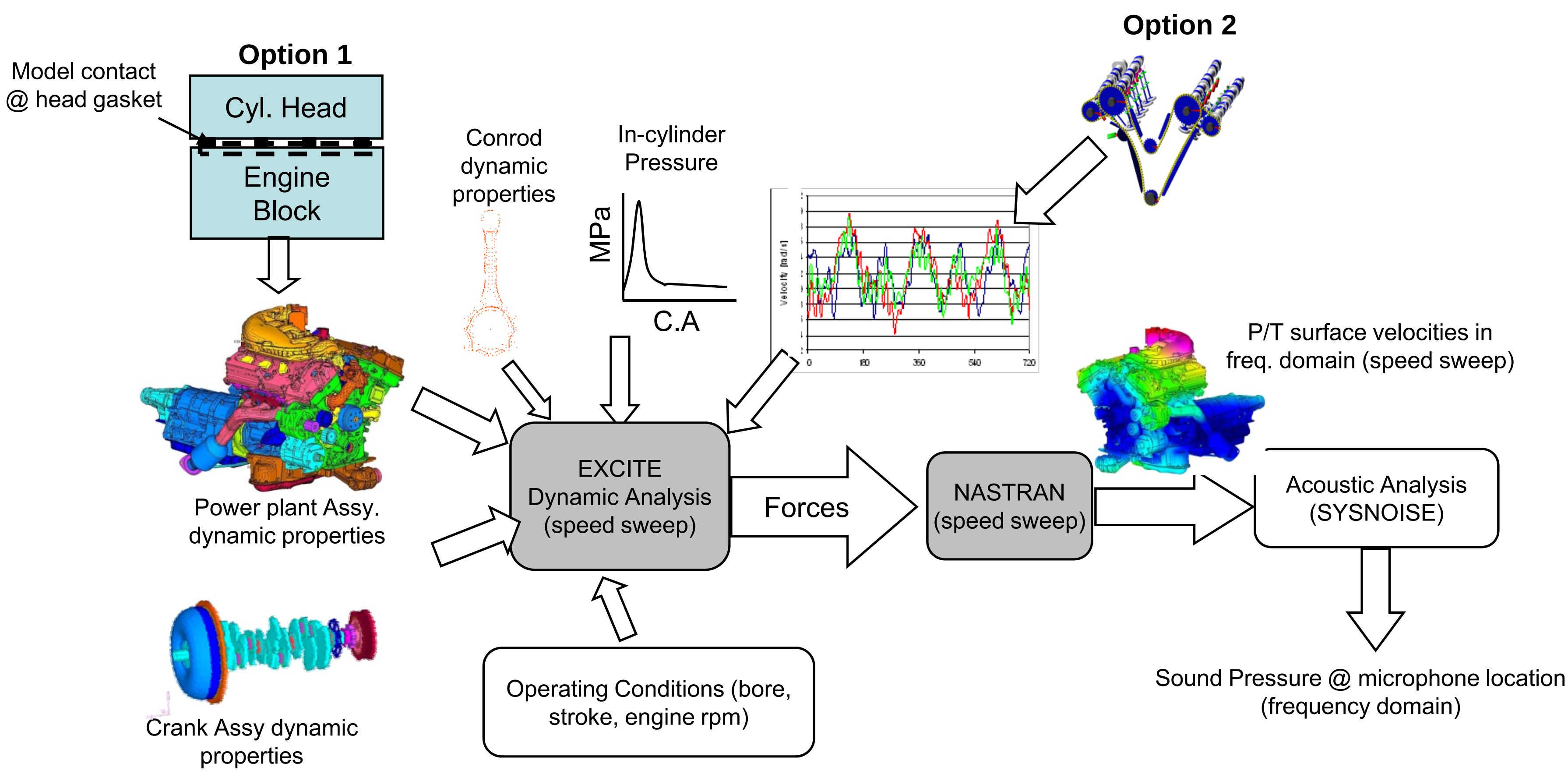
Powertrain Radiated noise Correlation



Established Process

- Use ACMS + EXTSEOUT
  - Condensation: Reduced calculation time from 24 hrs to 7 hrs
  - Data recovery: Reduced calculation time from 2 days/rpm to 60 min/rpm
    - Total calculation time reduce for each design by 1 month
  - Results: Maintain results accuracy
  - Judge results accuracy quickly
  - Establish seamless process with data flow among multiple software
    - Using custom Dmaps from MSC
  - Can use establish process to evaluate design and calculation parameters
    - Quickly improve model correlation
    - Evaluate contribution of different design parameters on results

Process application



Process application: Results

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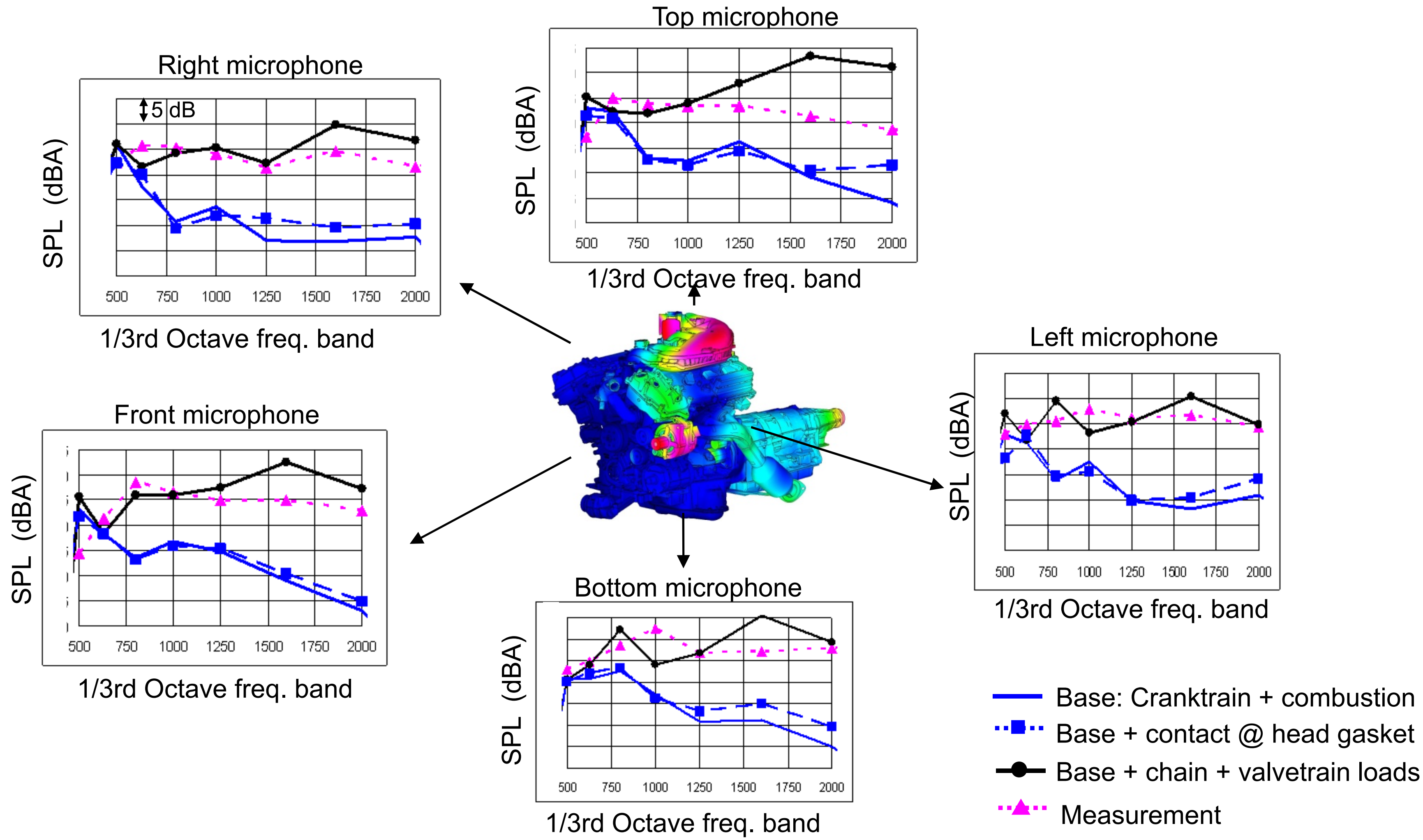
Sound Pressure Level @ 2400 RPM



Conclusions/Future work

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- Established a seamless process to evaluate powertrain design for mount vibration and radiated noise.
- Reduced the calculation time to be able to do single design evaluation from 20-25 days to 2-3 days.
- Using the established process, evaluated effect of parameters on results accuracy (design parameters and calculation parameters)
- Improved sound pressure level results accuracy.
- Apply the process and tools for engine design optimization.
- Evaluate effects of contact and bolt pre-load on vibration and radiated noise.
- Investigate the possibility of using the same process for component optimization using multi External super elements.
- Investigate the possibility of using external acoustics in MD-Nastran using established process.

Conclusions - contd

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- Future Requirements
  - Ability to include sliding contact and bolt pre-load
    - Simpler set-up
  - Link to optimization tools/processes.
    - Component design optimization
    - Mass reduction
  - Ease of Use → Futher Simplify Process
    - Use External acoustics in MD-Nastran

- Working with MSC to Meet Requirements

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- For further information please contact

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