Design Tools for Acoustical Materials

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Acoustical Consulting Services

Computer Modeling for Sound & Vibration

Analysis and Simulations of

- Materials
- Components
- Systems
- Complete Vehicles

For noise and/or vibration

- Airborne
- Structure-borne

Library of Analysis & Simulation Tools

- Finite Element Method (FEM)
- Boundary Element Method (BEM)
- Inverse Boundary Element Method (IBEM)
- Statistical Energy Analysis (SEA)
- Hybrid FEM / SEA Analyses
- Coupled FEM / BEM Analyses
- Acoustic Raytracing
- Poro-elastic Models (PEM)

Finite Element Method

- Typical automotive applications
  - Sheetmetal bodies
  - Engines
  - Suspensions
  - Complete vehicles
- Typical frequency range – 10 to 150 Hz
- Advantages
  - Can be integrated into CAD systems for geometry information
  - Highly accurate with sufficient number of elements (DOF)
- Disadvantages
  - High computing power needed
  - Long solution times – hours or days
  - Limited upper frequency range

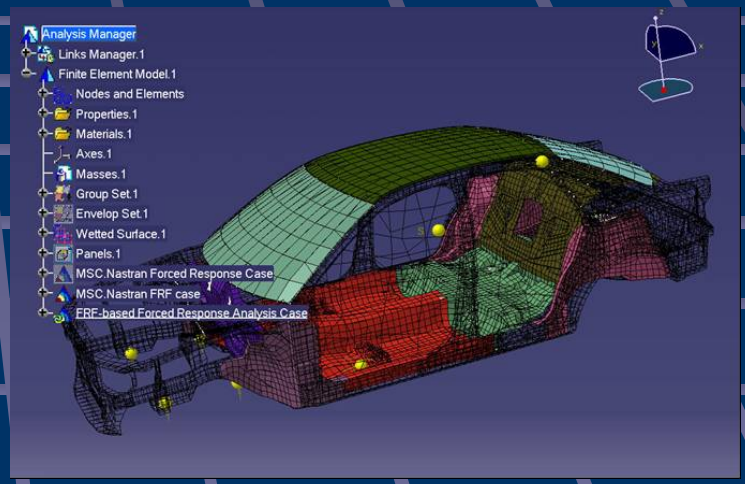


Image courtesy of LMS

Boundary Element Method

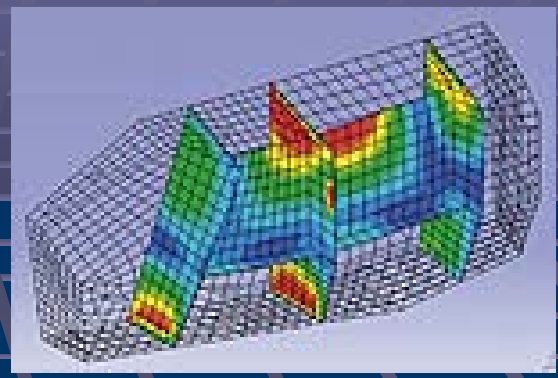


Image courtesy of LMS

- Typical applications
  - Body interior cavities & interior trim
  - Powertrains – exterior radiation
  - Tires – exterior radiation
- Typical frequency range – 10 to 500 Hz
- Advantages
  - Easier to model – only surface geometries
- Disadvantages
  - Best for solids only
  - Generally requires prior knowledge of surface velocities
  - Solution times as lengthy as finite element analysis
  - High computing power needed

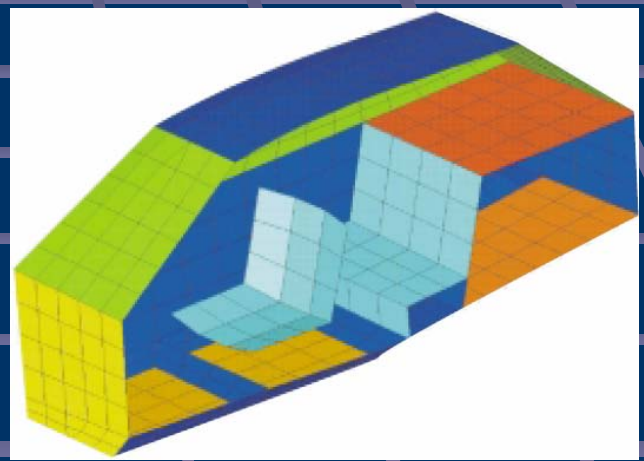
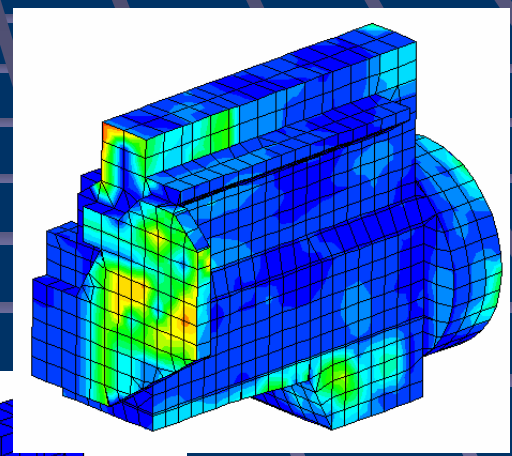


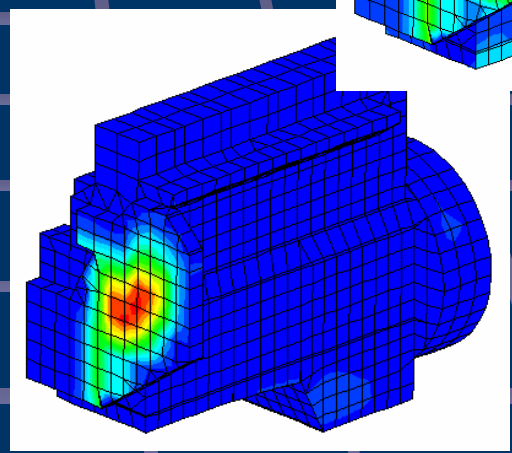
Image courtesy of ESI Group

Inverse Boundary Element Method

- Typical applications
  - Powertrains – surface velocities
  - Tires – surface velocities
- Typical frequency range – 10 to 500 Hz
  - Requires input of sound pressures at measured field points
- Advantages
  - Easier to model – only surface geometries
- Disadvantages
  - Best for solids only
  - Solution times as lengthy as finite element analysis
  - High computing power needed

Images courtesy of U. of Kentucky





Statistical Energy Analysis

- Typical applications
  - Assemblies – doors, cockpits, etc.
  - Systems and sub-systems
  - Complete vehicles – interior & exterior
- Typical frequency range – 500 to 10k Hz
- Advantages
  - Geometric detail not critical
  - Accurate to higher frequencies
  - Solution times relatively short (min.)
  - Moderate computing power needs
- Disadvantages
  - Requires structural-acoustic expertise
  - Validation testing can be complicated

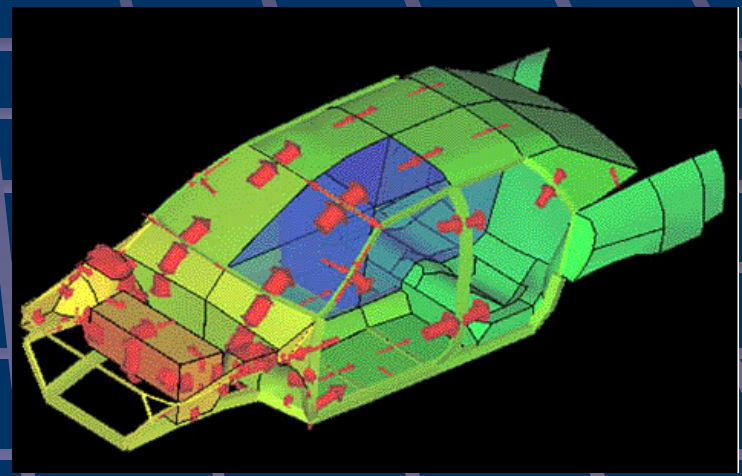
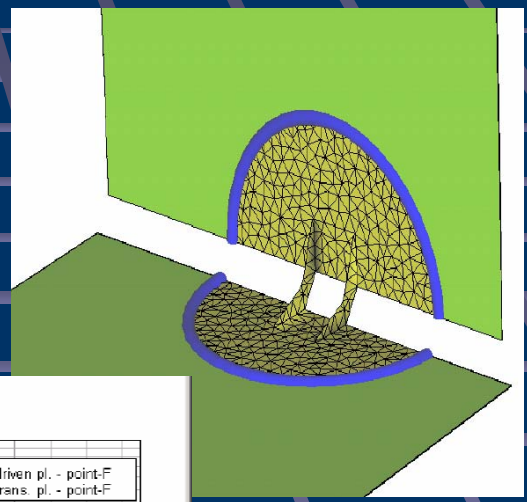
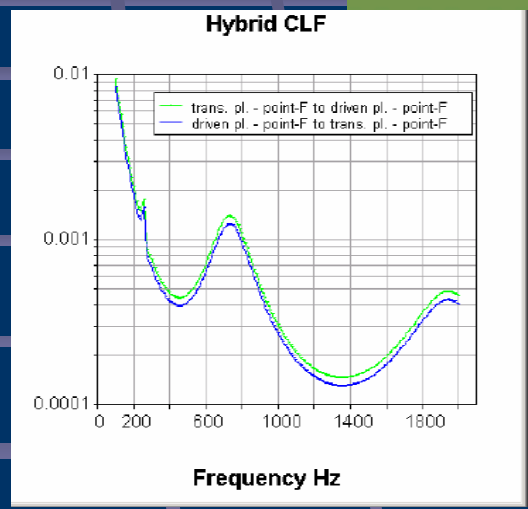


Image courtesy of ESI Group

Hybrid FEM / SEA Method

- Typical applications
  - Complete vehicle models
- Typical frequency range – 10 to 10k Hz
- Advantages
  - Nearly full frequency range
- Disadvantages
  - Emerging technology – Not much experience yet with this technology





Images courtesy of ESI Group

Coupled FEM / BEM

- Typical applications
  - Complete vehicle models
    - Structure modeled by FEM
    - Interior cavities and/or exterior spaces modeled by BEM
- Typical frequency range – 10 to 200 Hz
- Advantages
  - Easier to model interior cavities
- Disadvantages
  - Long solution times – hours to days
  - High computing power needed

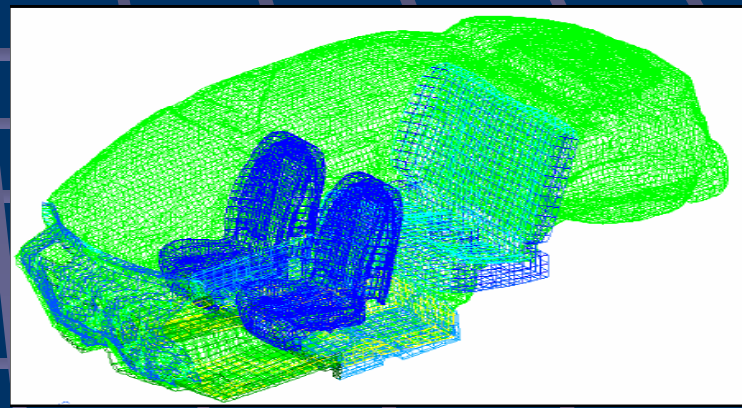
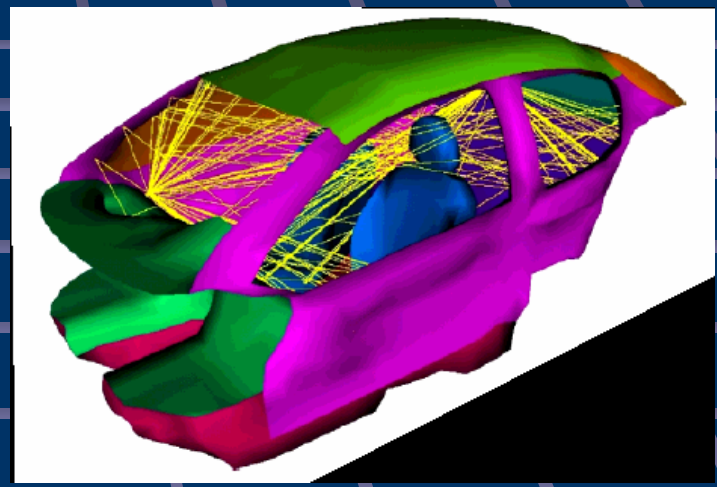


Image courtesy of ESI Group

Acoustic Raytracing Method

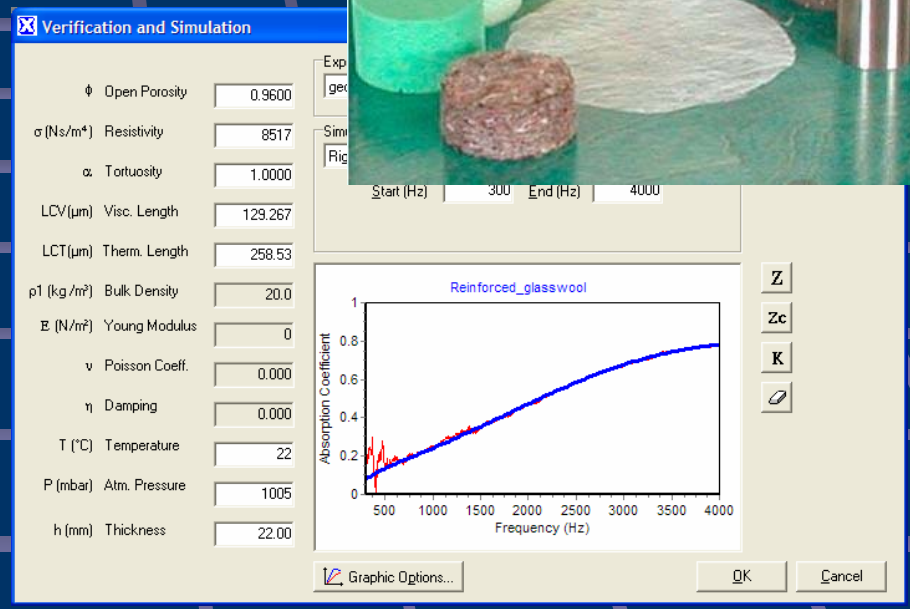
- Typical applications
  - Body interior cavities
- Typical frequency range – 20 to 10k Hz
- Advantages
  - Relatively fast solution times
  - Moderate computer requirements
  - Useful for audio design & speaker placements
- Disadvantages
  - Does not usually factor diffraction effects into predicted response
  - Sound Absorption effects only



Poro-elastic Material Modeling

- Typical applications
  - Flat, single or multilayer material models
- Typical frequency range – 100 to 10k Hz
- Advantages
  - Solves very quickly (seconds)
  - Minimal computer needs
  - Can easily simulate many material combinations
  - Can inverse calculate material parameters
- Disadvantages
  - Only flat materials at present can be modeled

Images courtesy of ESI Group



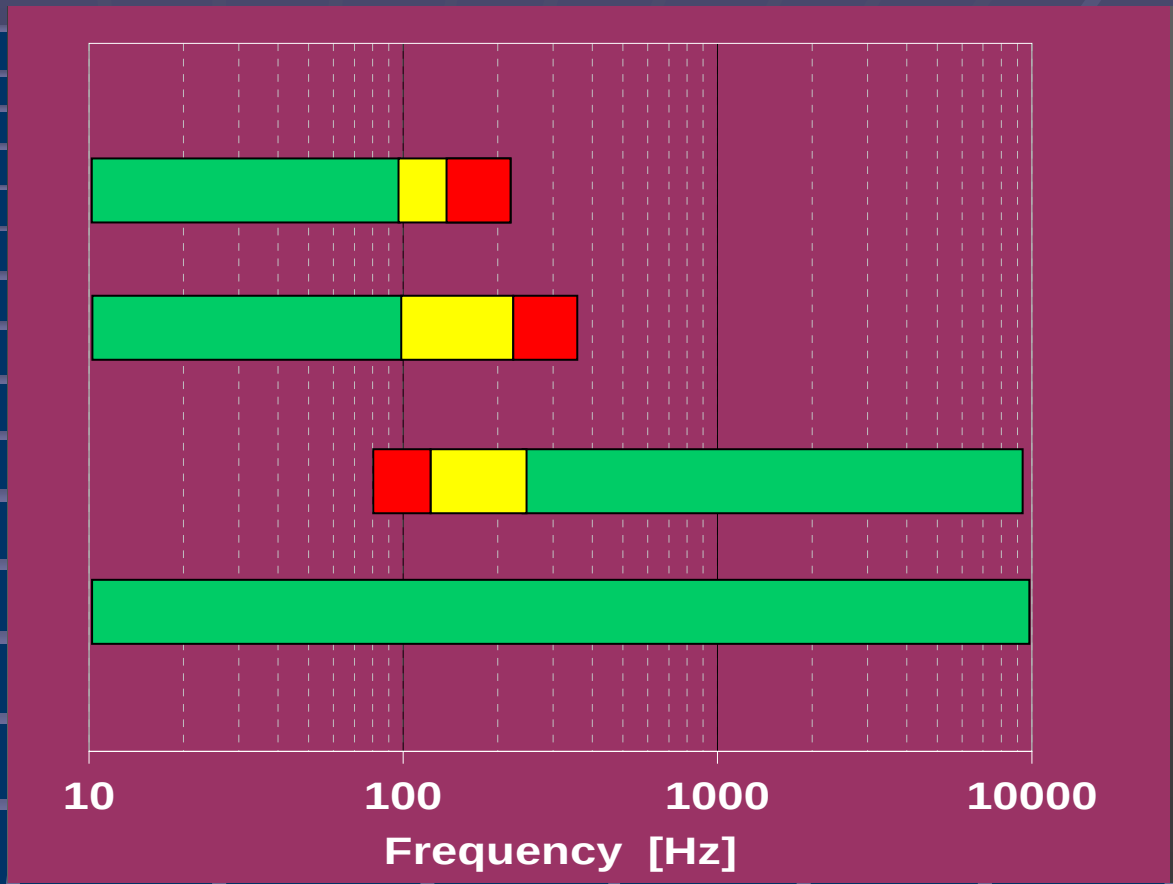
Full Vehicle Models - Frequency Ranges

Finite Element Method

Boundary Element Method

Statistical Energy Analysis

Hybrid FEM / SEA



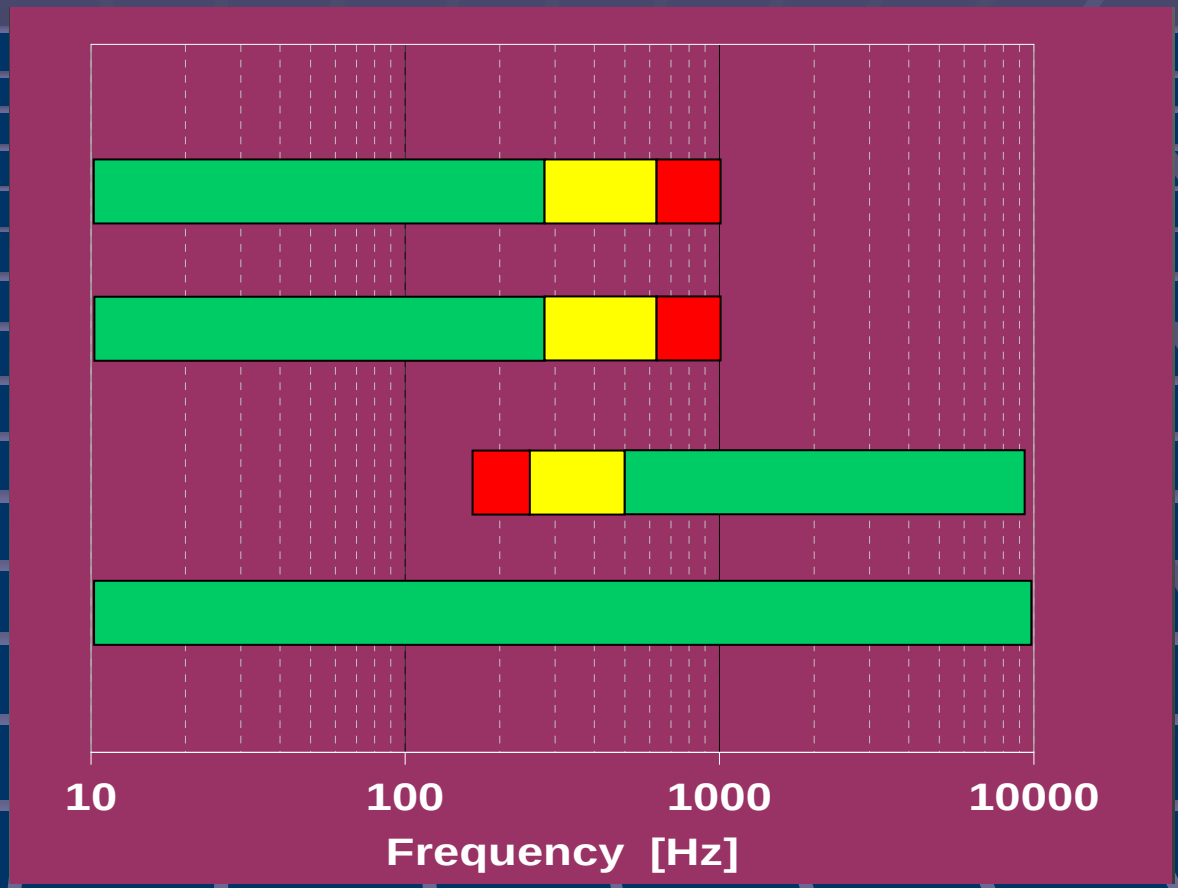
Component & System Models - Frequency Ranges

Finite Element Method

Boundary Element Analysis

Statistical Energy Analysis

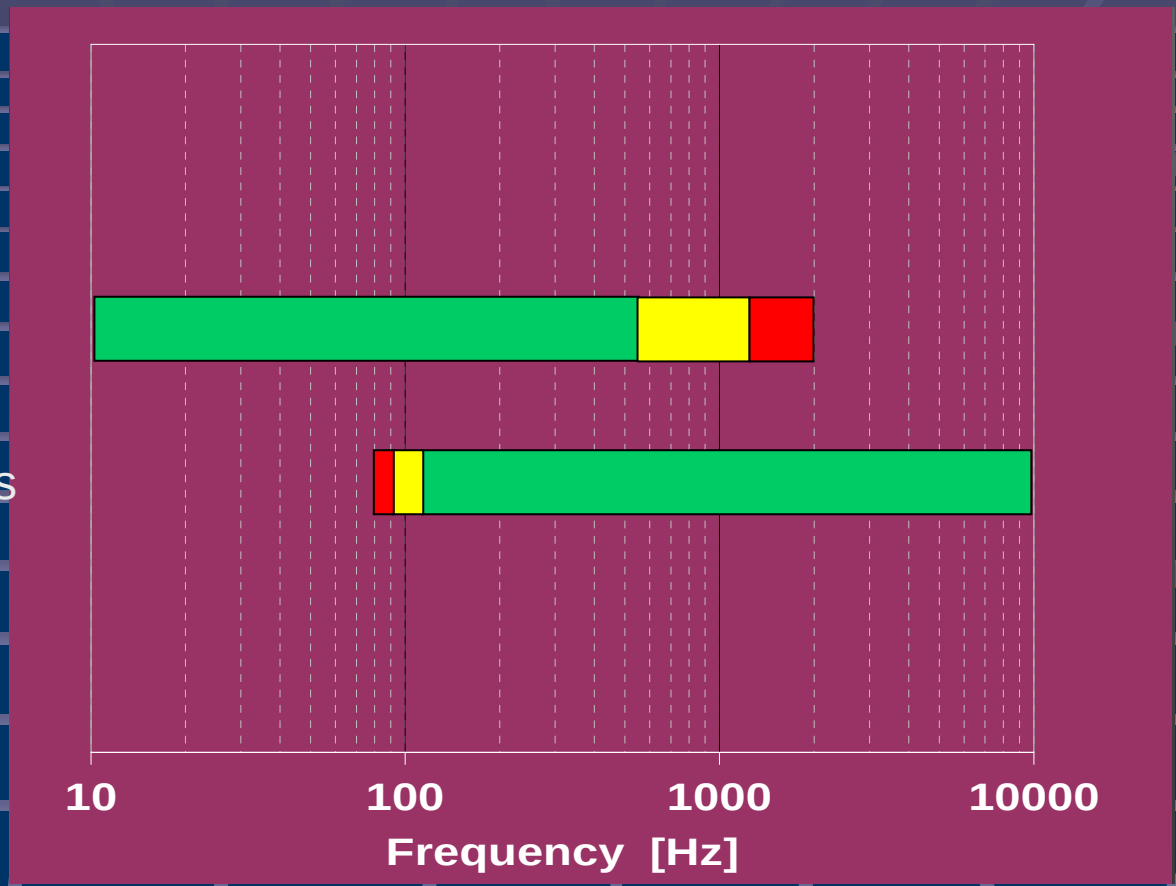
Hybrid FEM / SEA



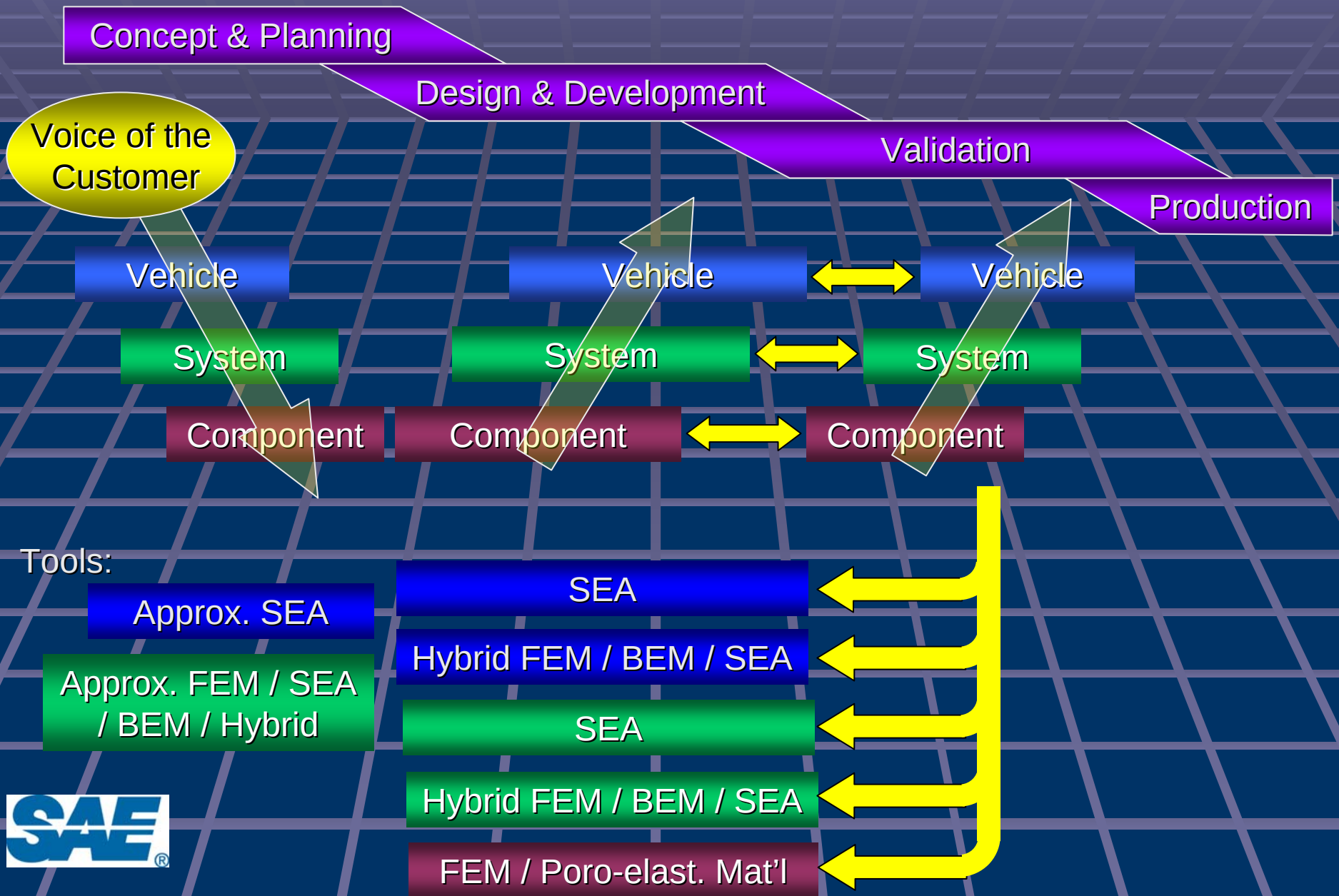
Material Models - Frequency Ranges

Finite Element Method

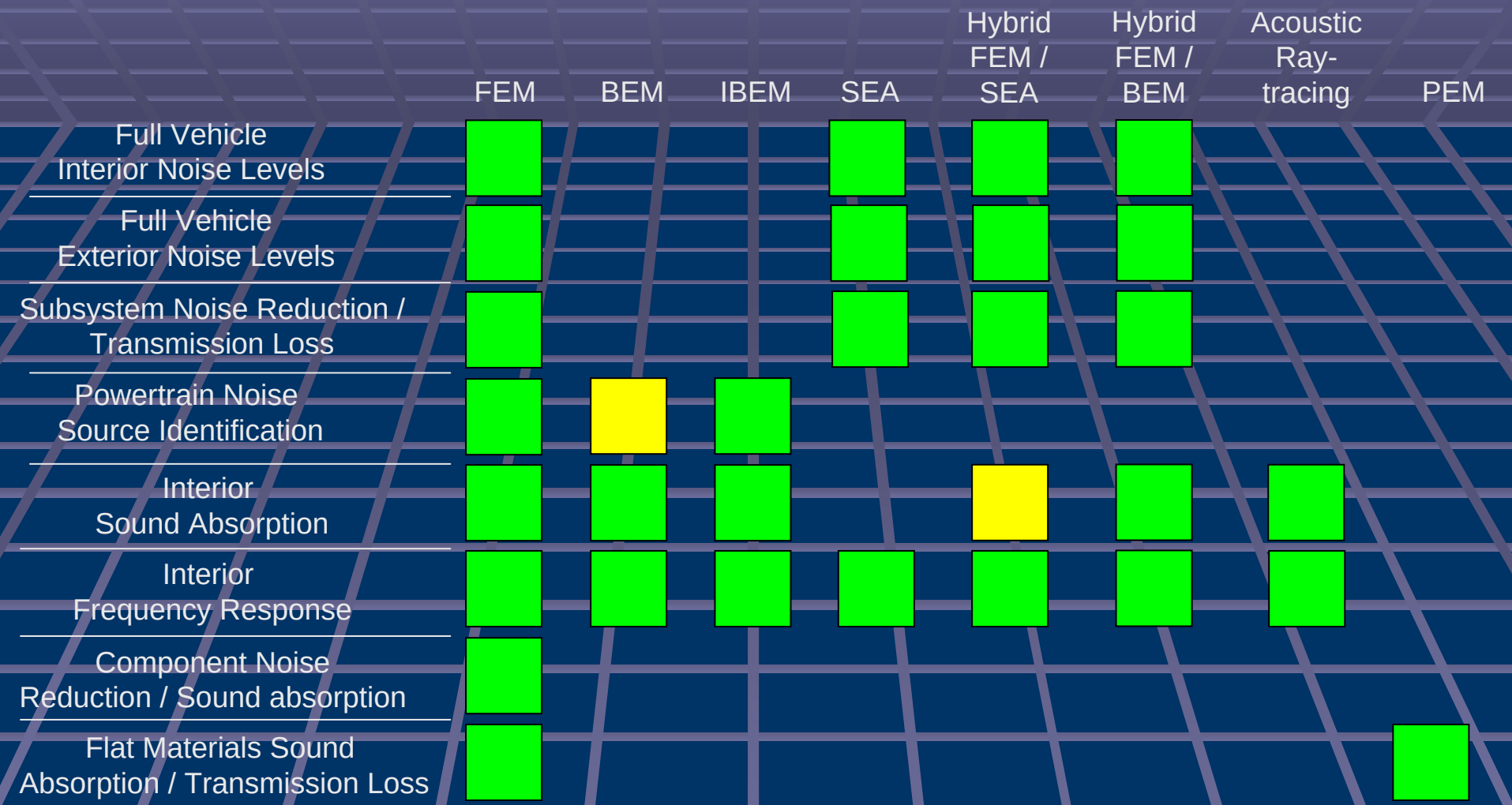
Poro-elastic Material Models



Program Development Process



Typical Application Matrix



Summary - Design Tools for Acoustics

- Overall advantages
  - Virtual prototyping / Simultaneous engineering
    - Improved initial concept development
    - Acoustic feedback during design process
    - Fewer acoustic surprises at prototype vehicle
    - Improved cost & weight control / optimization
    - Shorter development time / fewer dev. vehicles
- Modeling Trends
  - Improved analytical tools / hybrid approaches
  - Improved integration within engineering processes
  - Improved hardware & grid computing power
  - Improved software interfaces / usability
  - Optimization strategies are being adopted

Design Tools for Acoustics

Thank You