



# Modeling Soft Materials for Non-linear NVH Applications

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# DatapointLabs

expert material testing

Mechanical properties

Thermal properties

Flow properties

tensile  
compressive

flexural

stress-strain

Poisson's ratio

high strain rate

bulk modulus

fatigue

visco-elasticity

stress relaxation

creep

friction

hyperelasticity

thermal expansion

thermal conductivity

specific heat

PVT

rheology

# DatapointLabs

expert material testing

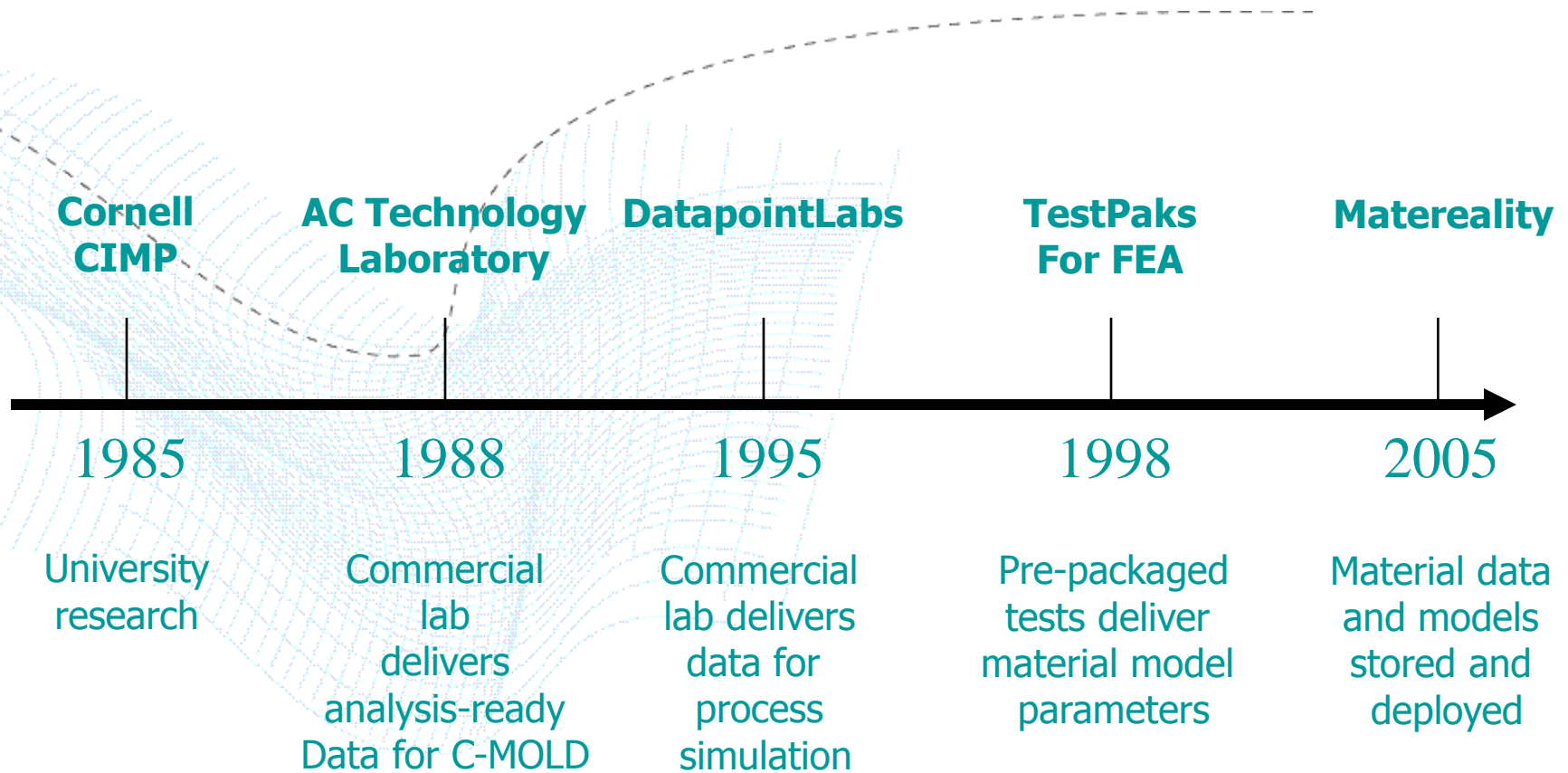
- Established 1995
- 1000 materials tested/yr
- 800 clients
- 11 manufacturing verticals
- ISO 17025 Quality System
- Globally available at

[www.datapointlabs.com](http://www.datapointlabs.com)

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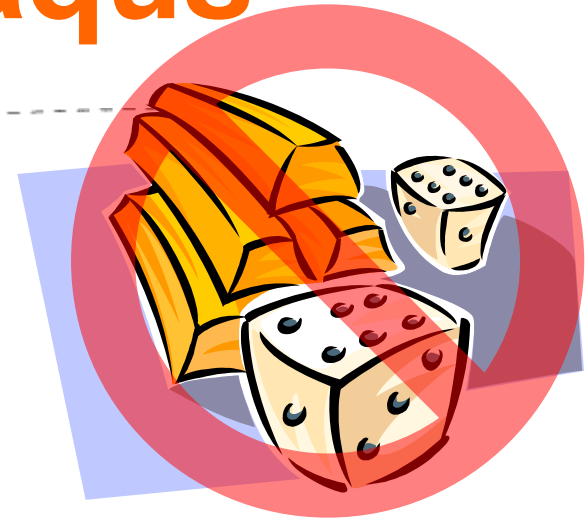
# Our history



# TestPaks<sup>®</sup> for Abaqus

- Simple to order
- Globally available
- Testing to Abaqus requirements
- Calibration of Abaqus material models
- Download via **Matereality for Abaqus/CAE**

no gamble



# Latest Innovations

- High strain rate properties to 100/s
- Non-linear elastic + plastic model-FeFp
- Equi-biaxial testing for rubber, films, foils
- 37C saline testing for *in-vivo* CAE
- Non-linear visco-elastic data for NVH
- Validated material model calibrations

# The NVH problem

- Causes noise and vibration from resonance modes
  - ◆ Noise: 20 Hz – 20KHz
  - ◆ Vibration: Lower frequencies
- Structure borne or air borne
- Interaction between components

# Real life NVH mitigation

- Use of damping components
  - ◆ bushings, seals, blankets, gaskets
- Materials are non-linear
  - ◆ rubber, felt, foam
- Materials are highly deformed
  - ◆ large strain

small components-big effects



# Why non-linear NVH

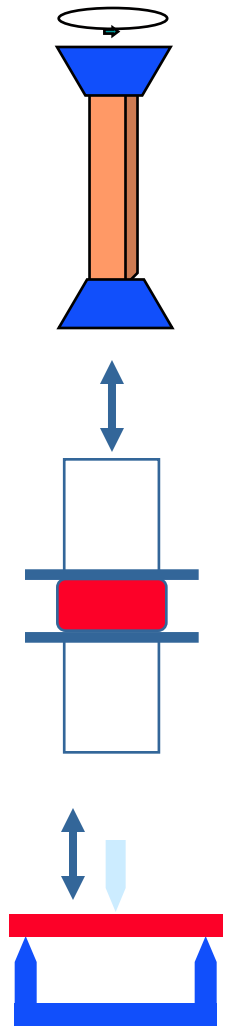
- NVH is traditionally a linear problem
- NVH mitigation components not modeled
  - ◆ Small components > big effect
- Need
  - ◆ complex material models (visco-elasticity)
  - ◆ advanced simulation (AMS+SSD)

# NVH Simulation

- Mode-based FEA
  - ◆ natural vibration frequencies
  - ◆ specific vibration patterns of the structures
- Frequencies: up to 300Hz
- Abaqus recommends
  - ◆ automatic multilevel substructuring (AMS) eigensolver
  - ◆ steady state dynamic (SSD) analysis

# Visco-elasticity

- Small strain theory
- Modulus is strain independent
- Can be superposed in time and temperature
- Valid to the non-linear visco-elastic limit



# Non-linear visco-elasticity

- Beyond the non-linear elastic limit
- Modulus is strain level dependent
- Linear visco-elastic theory may not apply
- Localized small strain visco-elastic solutions are possible
  - ◆ Visco-elastic data at each strain (Preload)

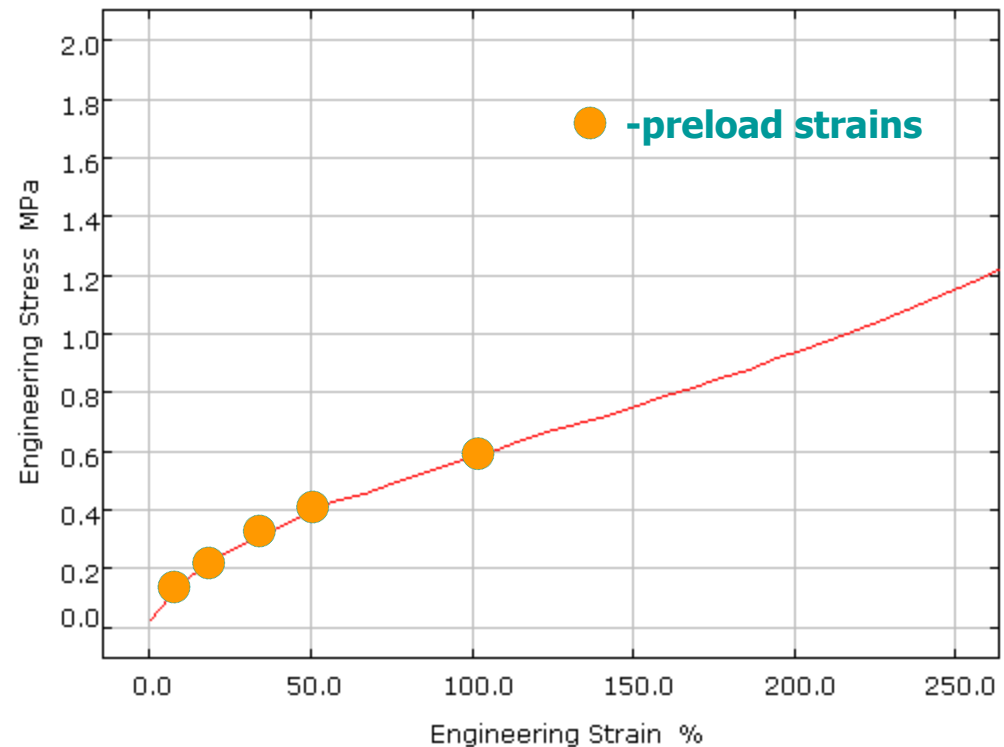
# Simplifying assumptions

- Small dynamic strains
- Localized solutions
- Limited extrapolation capability
  - ◆ No Prony series
  - ◆ No TTS

# DMA test protocol

- DMA testing
  - ◆ tensile or compressive
  - ◆ uniaxial preload strain
  - ◆ frequency sweeps at each preload strain
  - ◆ dynamic strain levels are fixed
  - ◆ temperature is fixed
- Obtain  $E'$ ,  $E''$   $f(\omega, \epsilon)$

Engineering Tensile Stress-Strain Curves

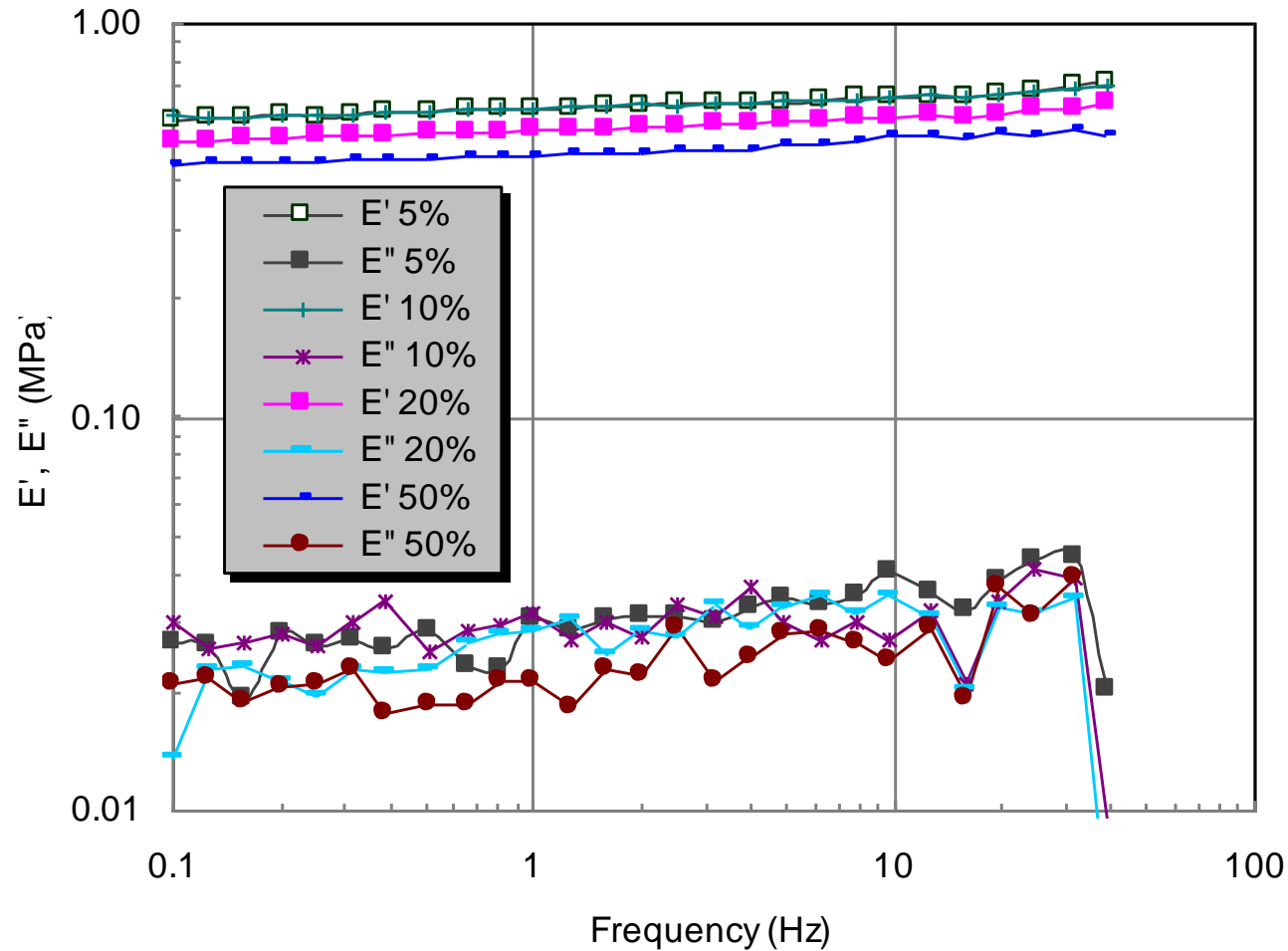


# DMA Instrument

- Bose
- Tensile or compressive
- Static Strain: 5 to 100%
- Dynamic strain: 5%
- Frequency range: 0.1-100 Hz
- Temperature: -40 to 150C

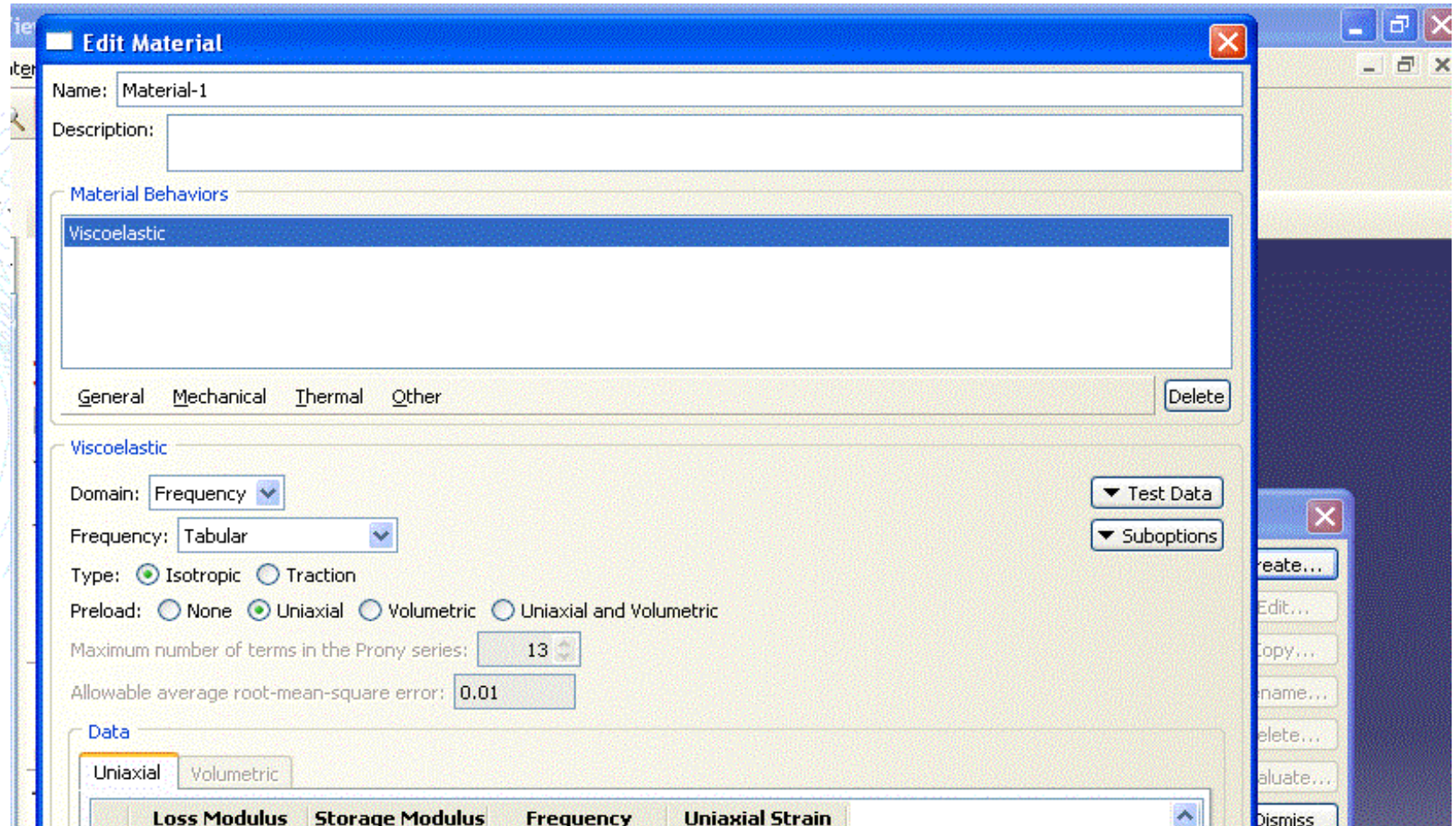


# Non-linear viscoelasticity





# Abaqus/CAE setup



# Upload to Abaqus/CAE

The screenshot displays the Abaqus/CAE interface with the 'Edit Material' dialog box open. The 'Material Behaviors' list shows 'Viscoelastic' selected. The 'Viscoelastic' section is expanded, showing the following settings:

- Domain: Frequency
- Frequency: Tabular
- Type:  Isotropic  Traction
- Preload:  None  Uniaxial  Volumetric  Uniaxial and Volumetric
- Maximum number of terms in the Prony series: 13
- Allowable average root-mean-square error: 0.01

The 'Data' section is active, showing a table with the following columns: Loss Modulus, Storage Modulus, Frequency, and Uniaxial Strain.

	Loss Modulus	Storage Modulus	Frequency	Uniaxial Strain
1	0.0268	0.5702	0.100	0.05
2	0.0263	0.5738	0.125	0.05
3	0.0191	0.5770	0.158	0.05
4	0.0280	0.5810	0.199	0.05
5	0.0261	0.5775	0.251	0.05
6	0.0272	0.5852	0.315	0.05
7	0.0259	0.5956	0.391	0.05
8	0.0286	0.5952	0.514	0.05

# More info: testpaks.com

- CAE centric materials web-site
- Focus on material modeling
- Testing for CAE / simulation
- Supported by
  - ◆ DatapointLabs
  - ◆ CAE vendors
  - ◆ Expert users

The screenshot shows the homepage of testpaks.com. The header includes the logo and tagline "material modeling solutions for the CAE community". A navigation menu lists: Home, About, DatapointLabs, Partners, Newsletter, Submissions, and Advertise. The main content area features a section titled "Good material models bring CAE closer to reality" with a sub-image of a stress-strain curve labeled "stress strain curves". Below this is a "Material Testing for CAE" section with a link to testpaks.com. A sidebar on the left offers "Buy TestPaks" options by application, software, and catalog, along with "Material Modeling Strategies" for Metals, Plastics, Rubbers, Foams, and Composites. A search bar is also present. The footer contains a "News" section with conference dates and an "Advertisements" section for matereality.

# Summary

- Major commitment to the CAE community
- Expansion into properties of all materials
- ABAQUS in-house for technical support
- Strong testing development program
  - ◆ Foam modeling
  - ◆ Biaxial film modeling
  - ◆ Crash and drop test modeling
  - ◆ Plasticity, damage, cyclic loading