MEMS
Extraction & verification

What is extraction?

Simplifying a full 3D model into behavioral model

Convert FEA/BEA model (large DOFs) into computationally efficient model

Develop pre-computed energy based model that captures multiphysics

What is extracted ?

Mechanical Strain Energy of Modes of Interest (Including stress and stress gradient effects)

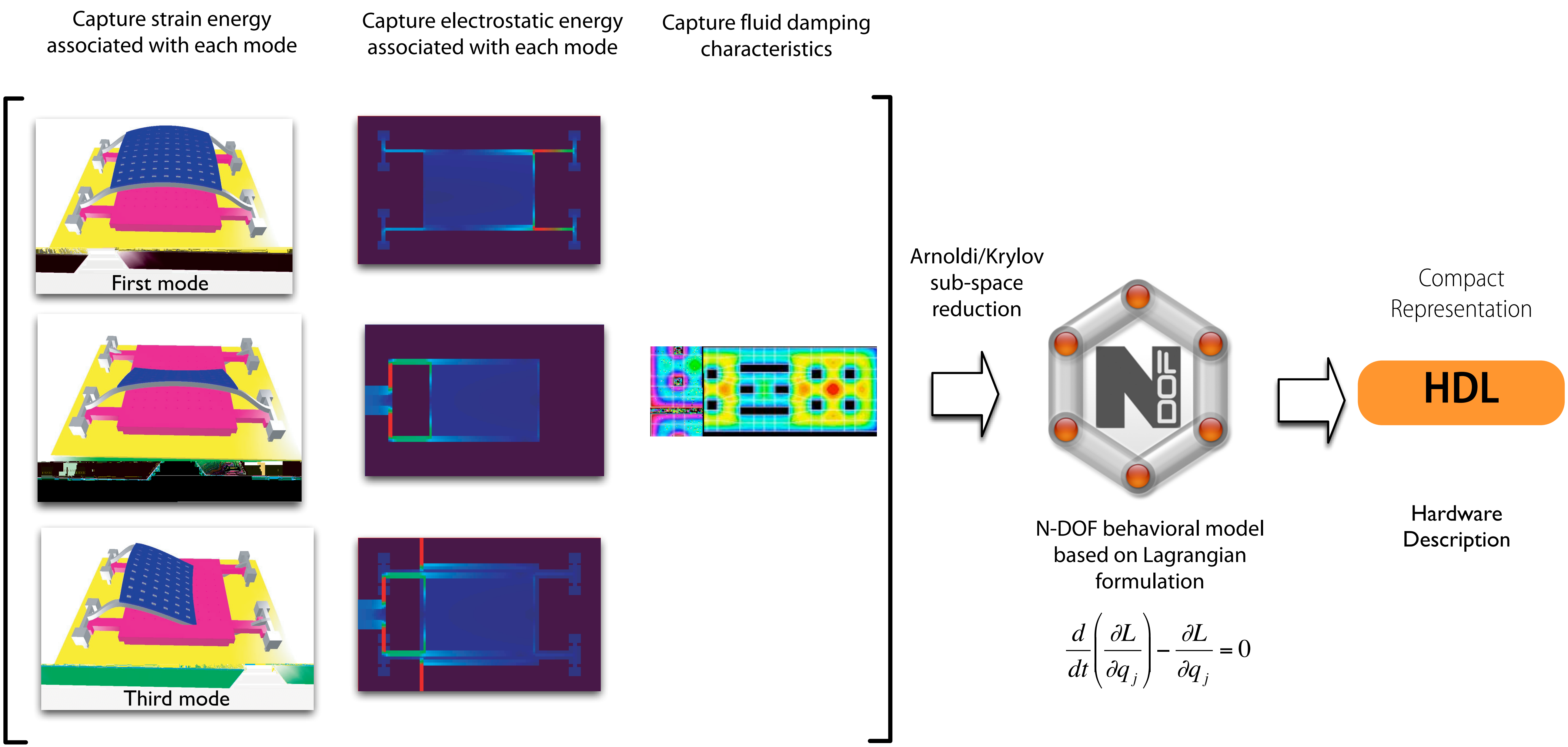
Capacitive energy

Thermal effects (deformation due to temperature change)

Fluidic Structure Interaction (due to compressive or non-compressive media)

Other dissipation sources (thermoelastic damping (v8.6.1) and anchor acoustic losses (v8.6.2))

System Model Extraction (SME)

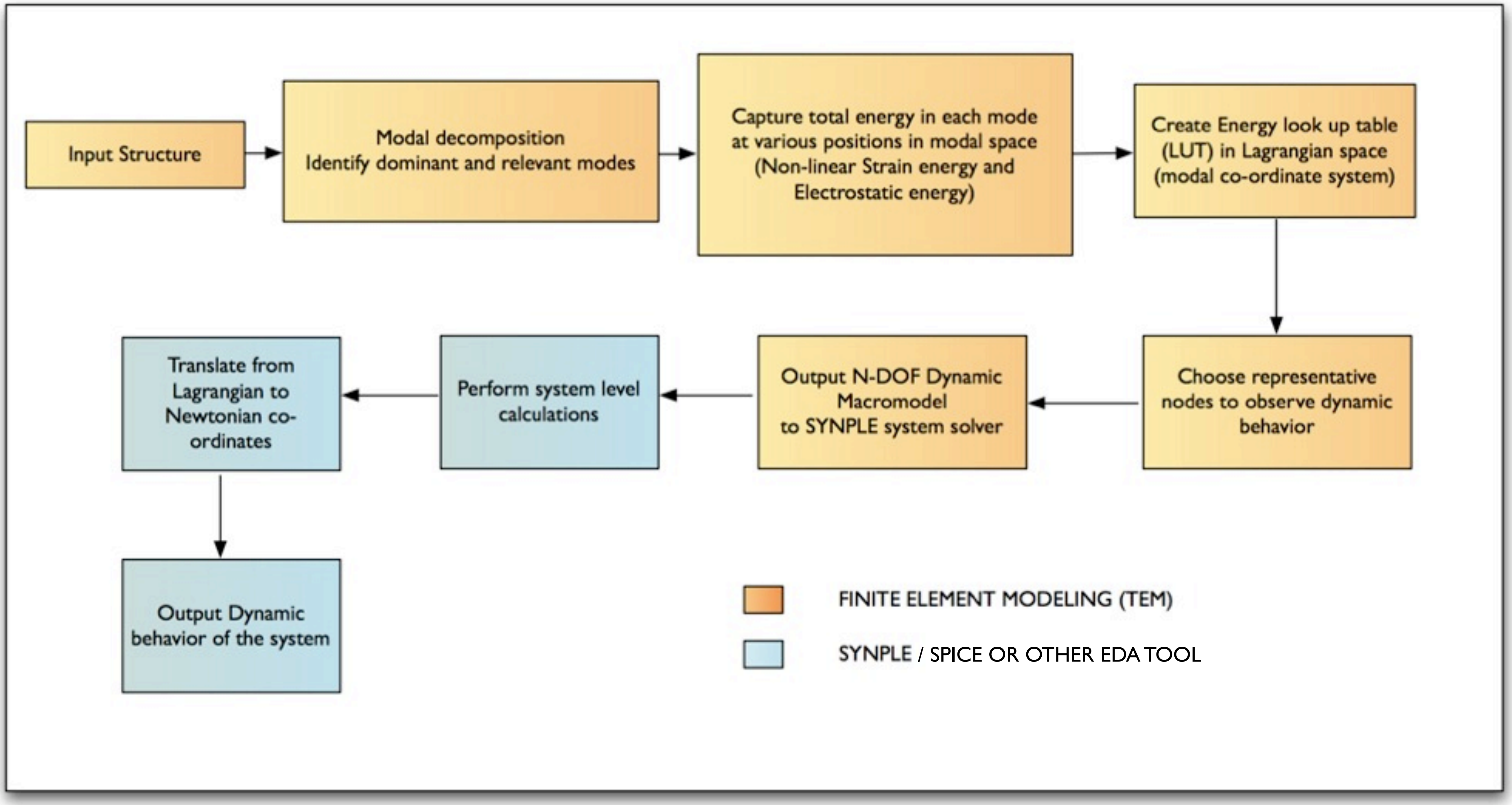


❶ Capture total energy of relevant mode (Mechanical, Electrostatic, Dissipation)

❷ Krylov/Arnoldi methods to generate Lagrangian formulation

❸ Create Compact model for system modeling

System model extraction (SME) flow chart



Summary: Convert problem from Newtonian (inertia based) to more efficient Lagrangian domain (energy based)

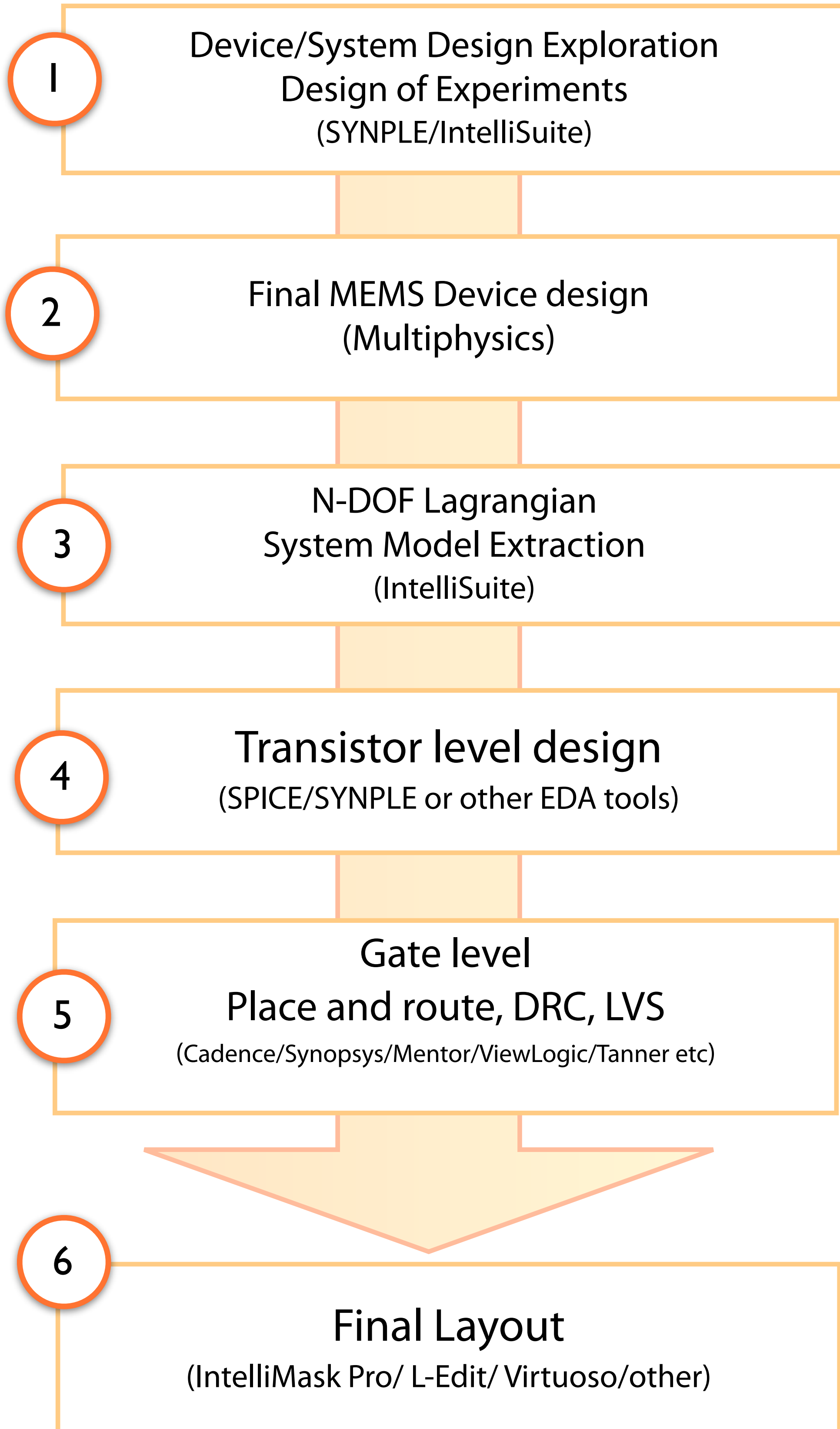
SME advantages

- Automated full multi-physics capture
- 1000 X faster than pure FEA
- Matches FEA to within 1% accuracy
- Fully capture harmonic responses
- 3D MEMS system simulation
- Device and package level extraction
- Automated VHDL/ Verilog/ SPICE generation

EDA Linker capabilities (compatibility)

- Create accurate N-DOF dynamic system model from MEMS FEA/BEA model
- Output system model into SPICE, HDL, and Simulink formats
- Compatible with EDA tools from Cadence, Mathworks, Mentor, Synopsys and Tanner
- Integrated CMOS-MEMS (SoC/SiP) compatibility

Integrated design flow for MEMS + IC



MEMS-CMOS integration design flow can be based on :

- ✓ VHDL-AMS
- ✓ Verilog-A
- ✓ SPICE netlist
- ✓ Matlab/Simulink .MEX

What is verification?

Model verification (Schematic vs 3D)

Verify schematic model and 3D model match

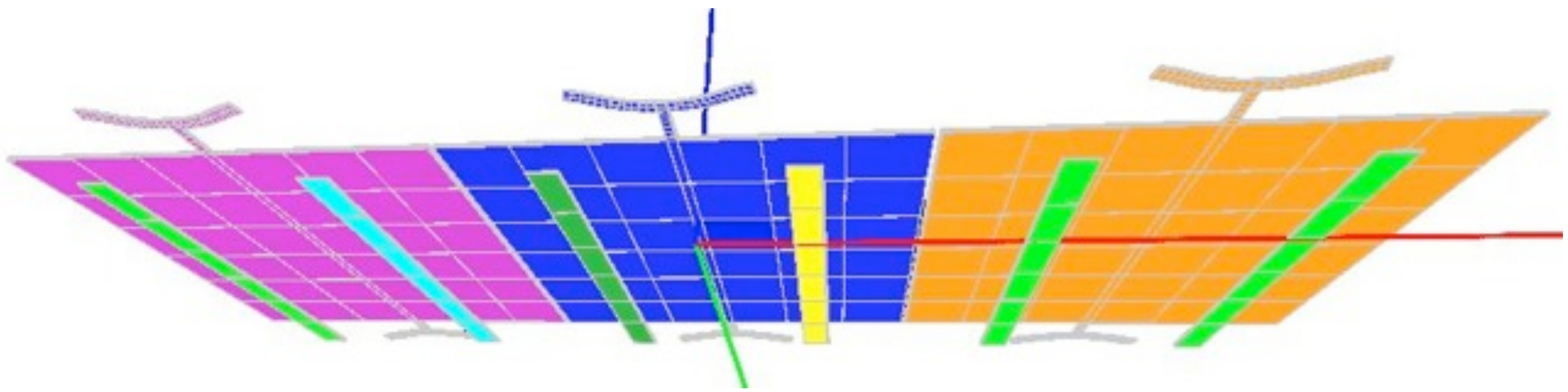
Ensure MEMS model used in circuit development is accurate

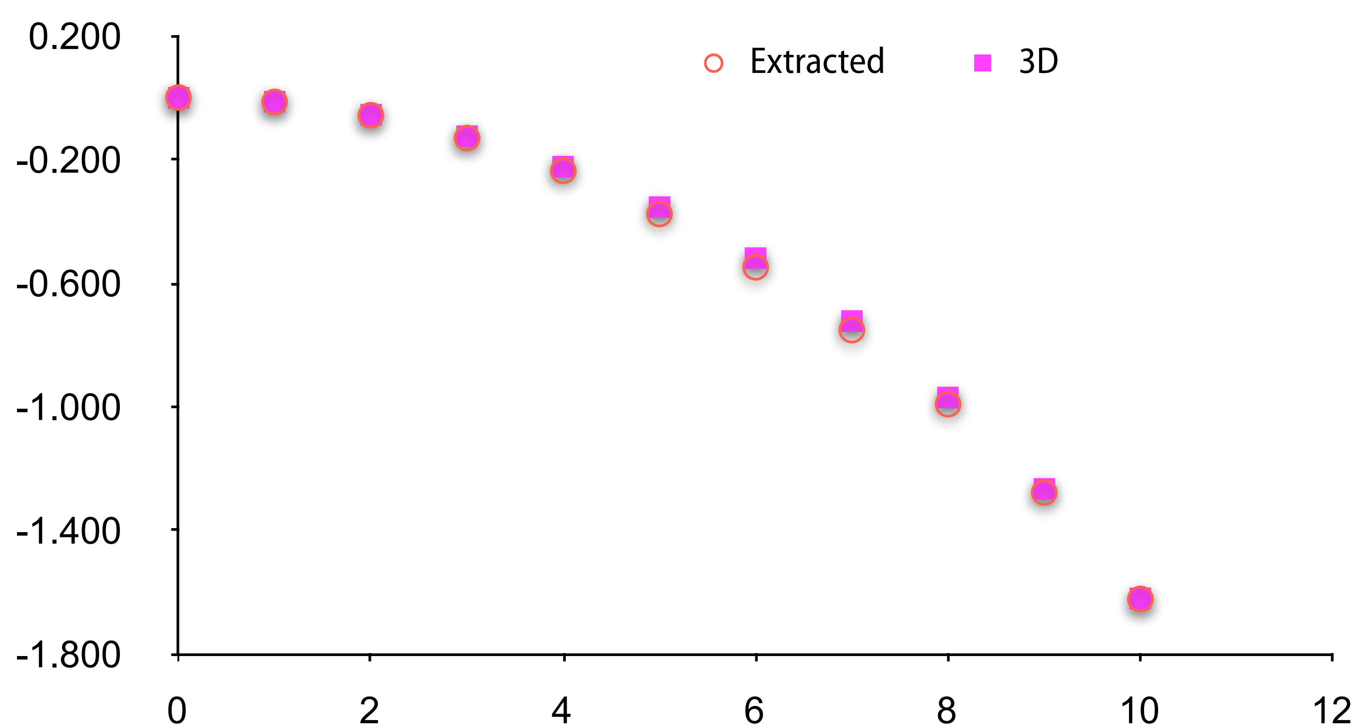
Physical verification ('Tape Out')

Verify physical layout is consistent with Design Rules

Ensure design meets manufacturability criteria

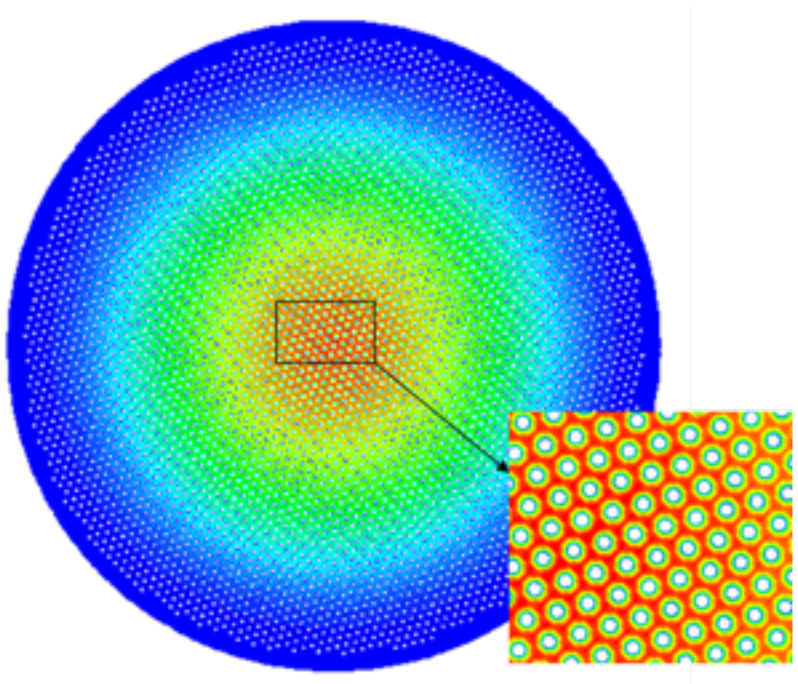
Static model verification



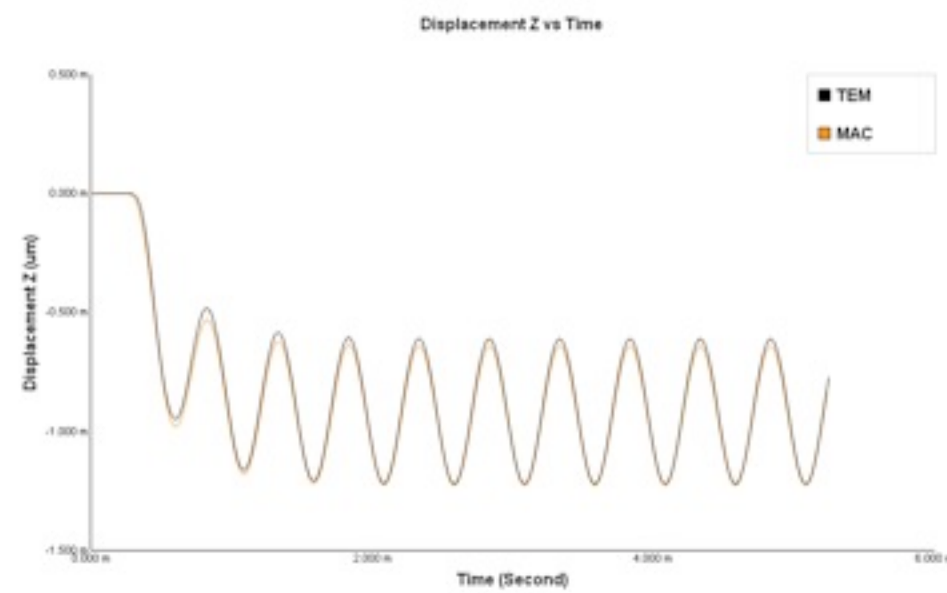


Pull-in: Schematic results vs Full 3D results

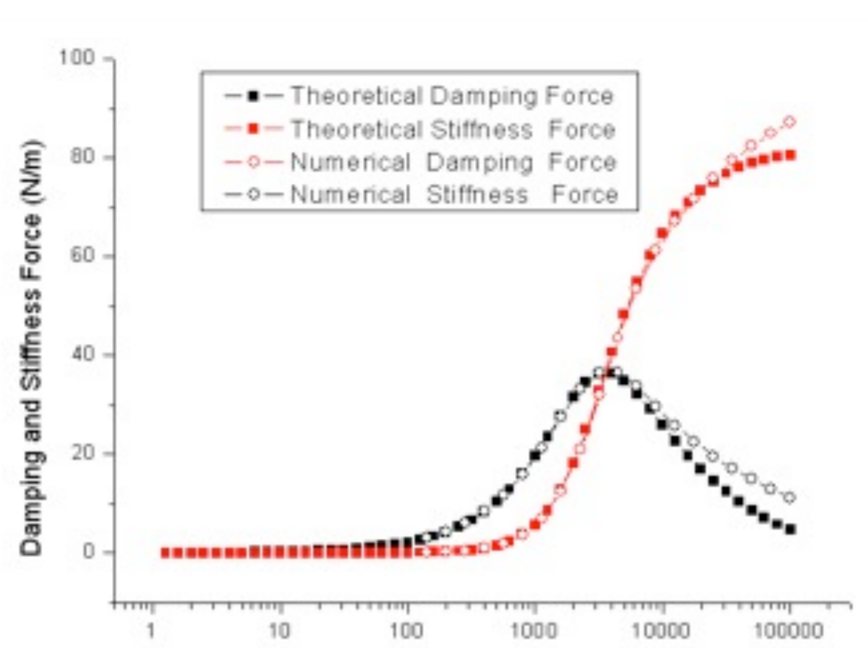
Damping model verification



Perforated condenser membrane

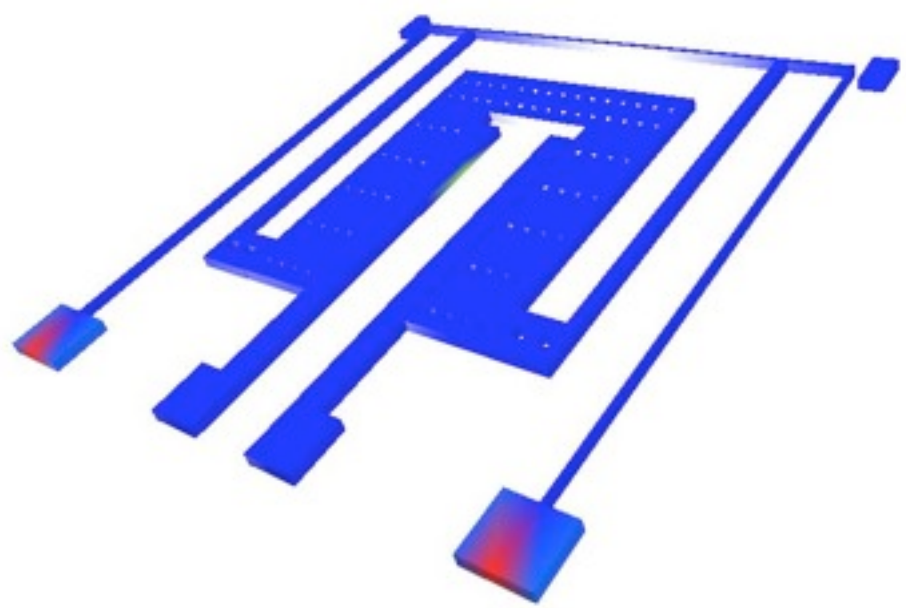


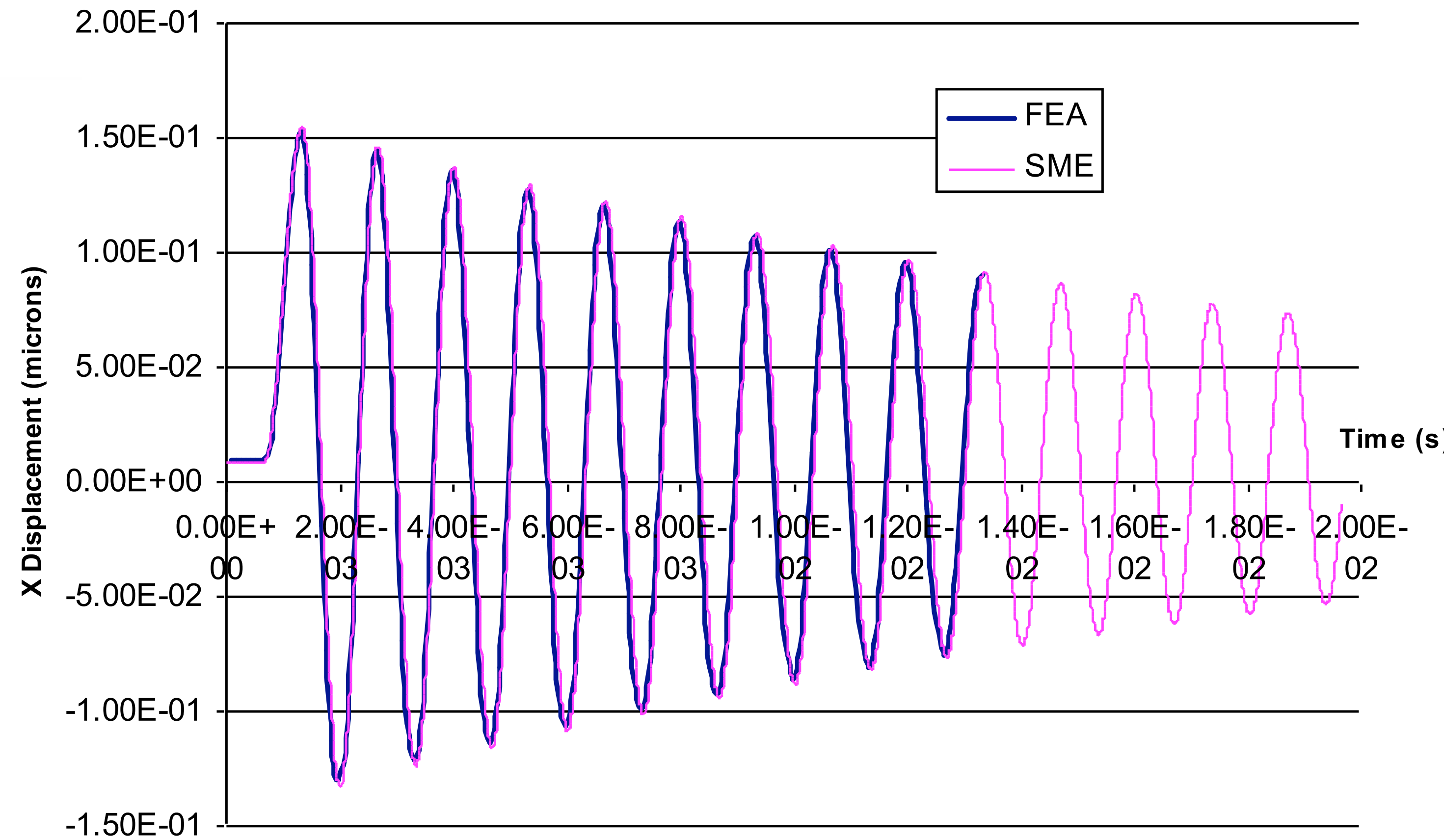
Full 3D (TEM) vs Macromodel comparison



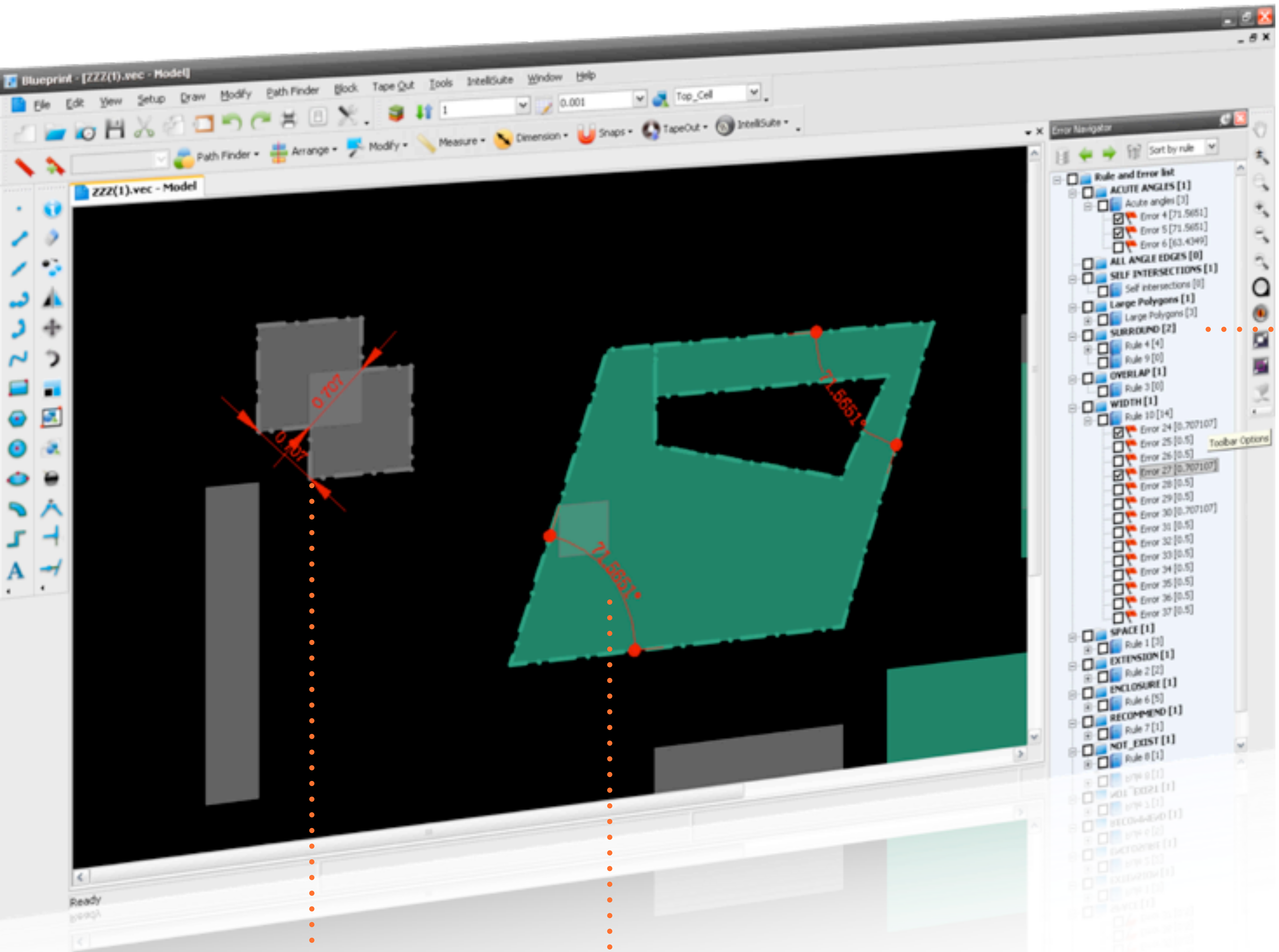
Full capture of fluidic damping and spring force

Dynamic model verification





Transient response of device: Schematic vs FEA (3D)



Tape Out

Physical verification