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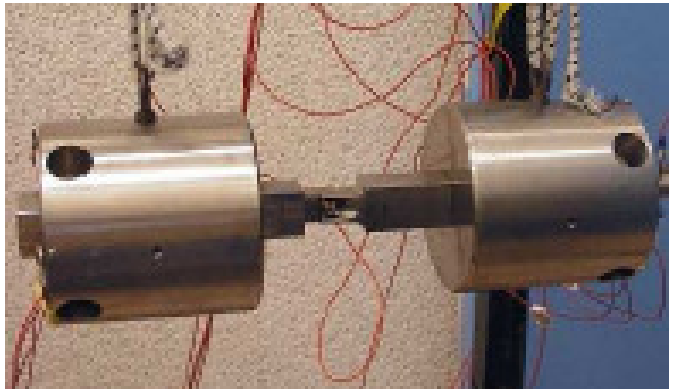
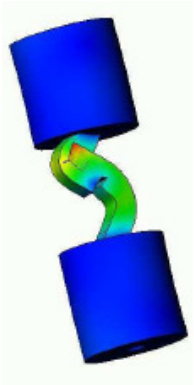
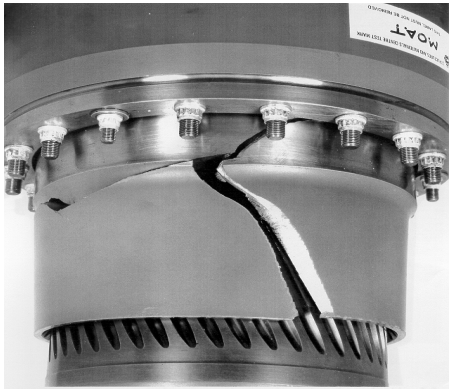
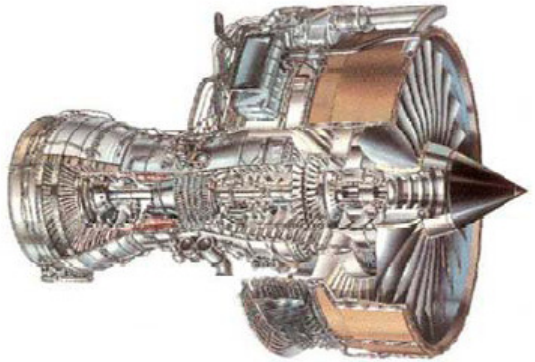

Project 4: **Potential of analytical and experimental model reduction techniques**

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U.S. DEPARTMENT OF ENERGY | NNSA

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Project Introduction

- **Given a real industrial Structure, reduction techniques are necessary to enable large linear/nonlinear computations**

- **Different methods (analytical and experimental) shall be investigated concerning the feasibility and effectiveness to predict nonlinear dynamic responses**

- **Main Tasks:**
  - Basic **validation** of the available linear FE models against test data
  - **Analytic model reduction** of components
  - **Experimental model reduction** of components
  - **Nonlinear modelling** with reduced models
  - **Model correlation** with experimental data

Benchmark FE structure: overview

Substructure 1: knuckle

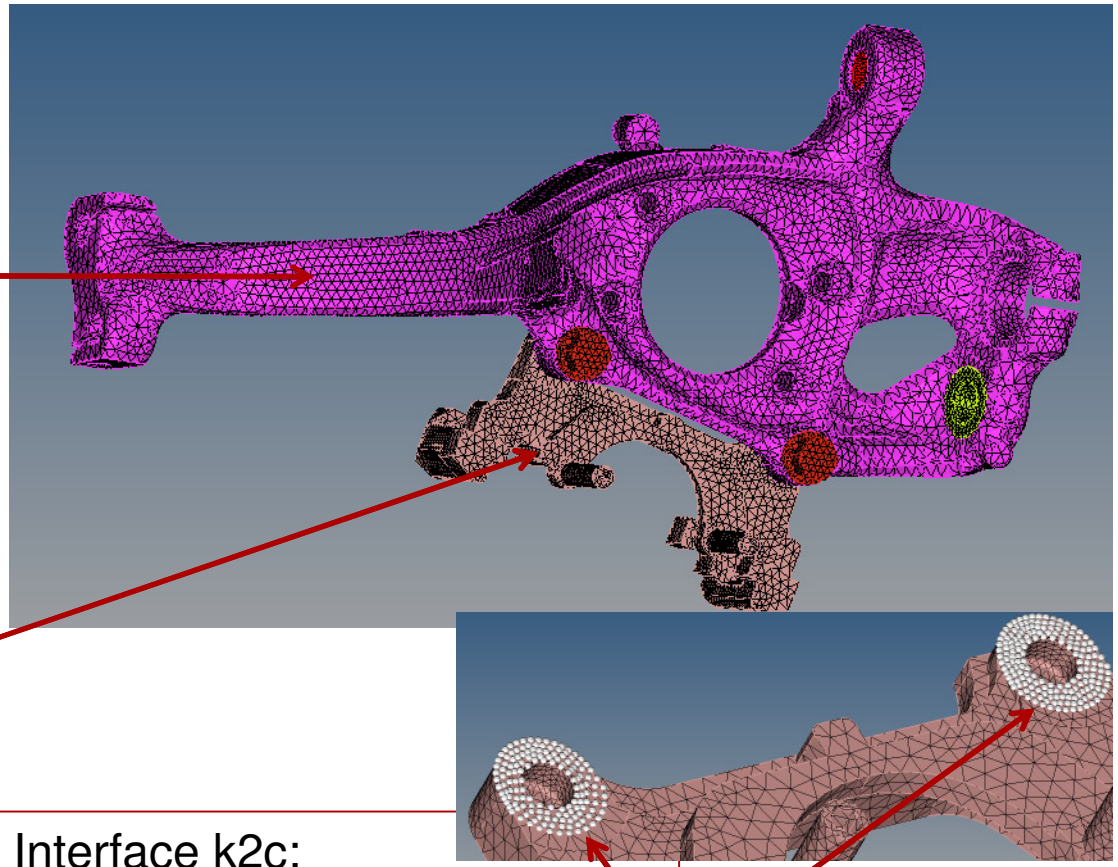
Eltype = tetra10
#elements = 81.9k
#nodes = 108k

E-mod = 70k [N/mm^2]
Nu = 0.31 [-]
Density = 2.7e-9 [t/mm^3]

Substructure 2: carrier

Eltype = tetra10
#elemets = 23.5k
#nodes = 41k

E-mod = 190k [N/mm^2]
Nu = 0.26 [-]
Density = 7.3e-9 [t/mm^3]

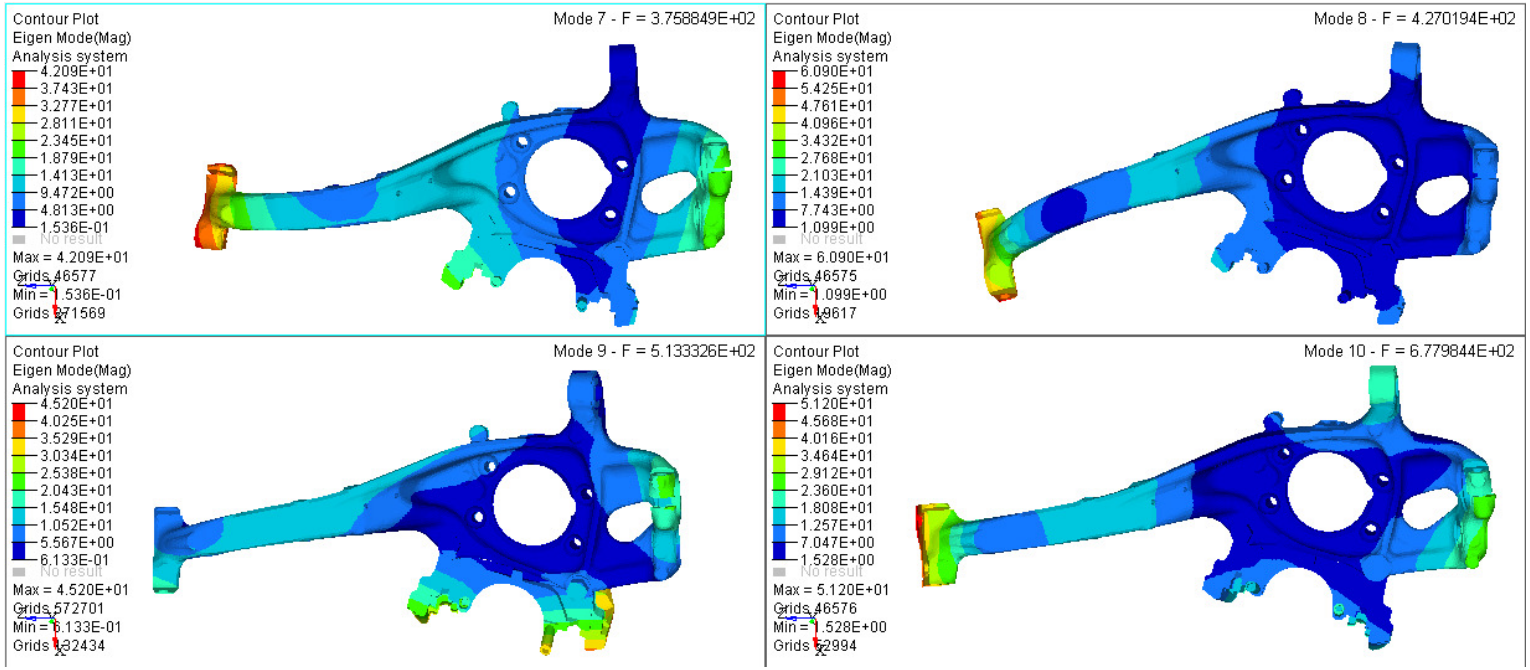


Interface k2c:

Conforming mesh at interface
#interface nodes = 476

Validation of linear Structure (I)

- Analytical results: Eigenshapes and eigenfrequencies (linear)



Validation of linear Structure (II)

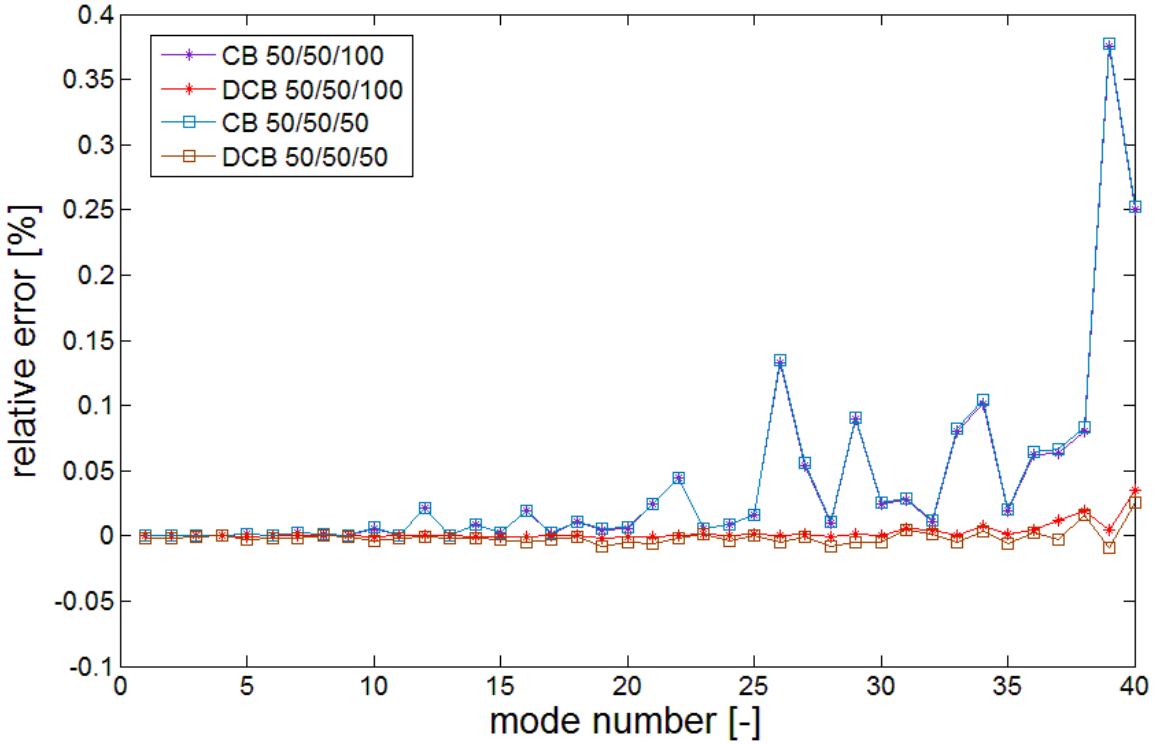
- Experimental results: Eigenshapes and eigenfrequencies

Model reduction techniques

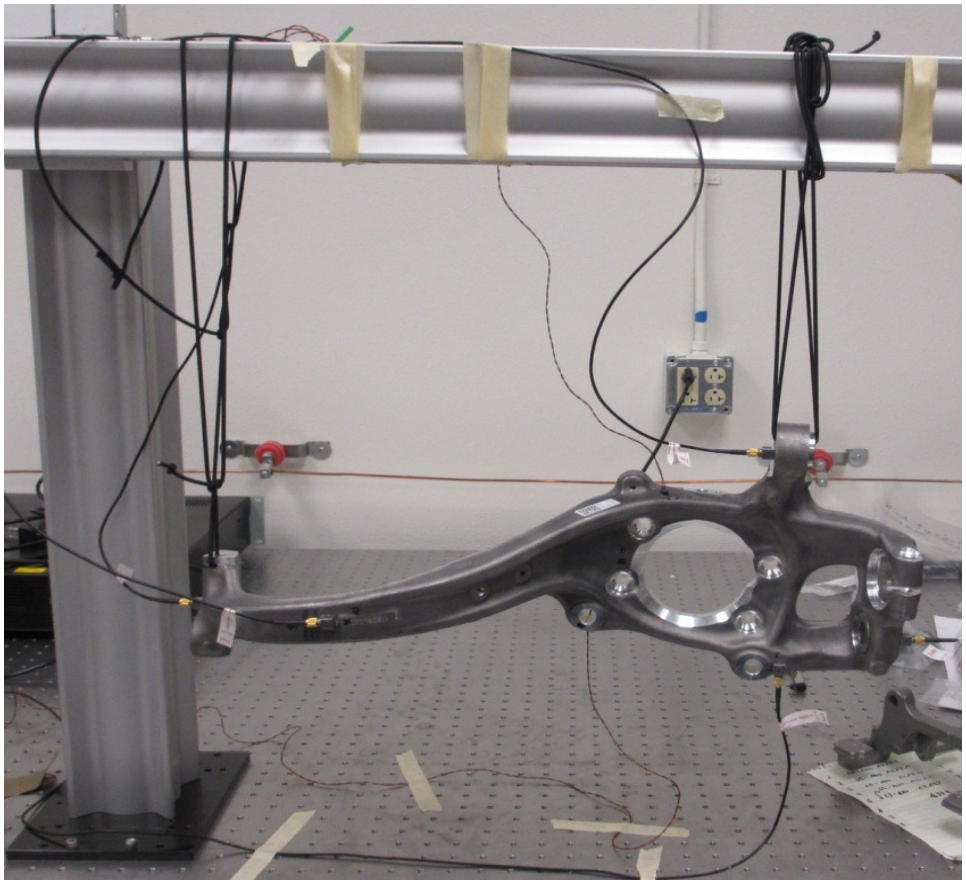
- Two methods were implemented during the Summer School:
  - **Classical Craig-Bampton** (ref. Craig&Chang)
  - $X = [\Phi\_fixed\_interface\ \Psi\_c]*[\eta; u];$
  - **Dual Craig-Bampton** (ref. Rixen)
  - $X = [-G\_res*B^T\ \ \Phi\_free\_interface\ R\ ]*[\lambda; \eta; \alpha]$
  - → linear Interface modes

Analytical reduction of Components

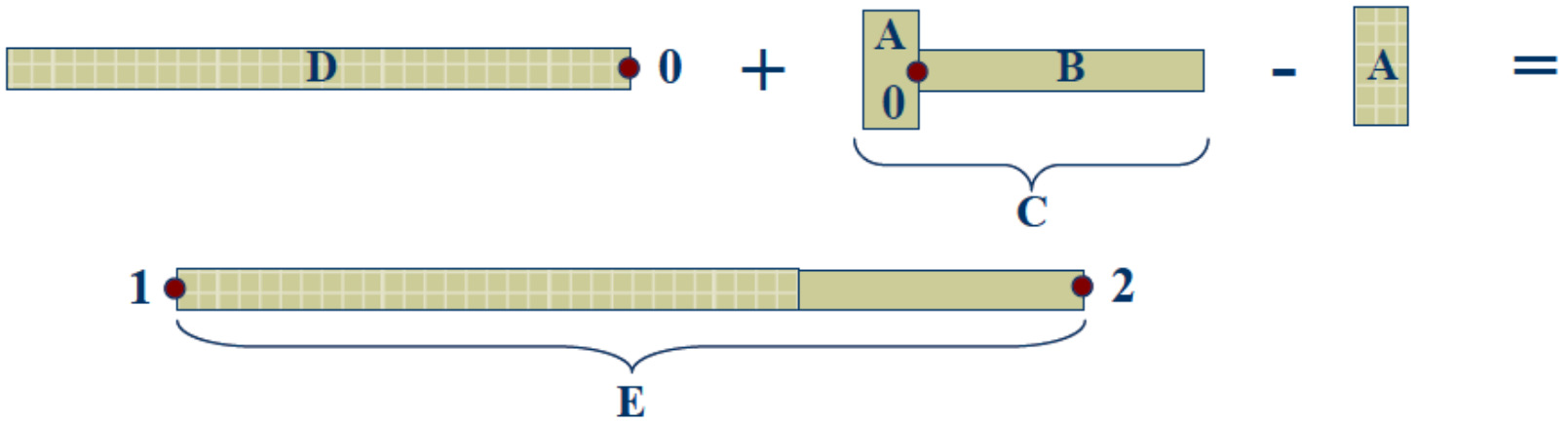
- Performance CB vs. DCB



Experimental model



Transmission Simulator Approach

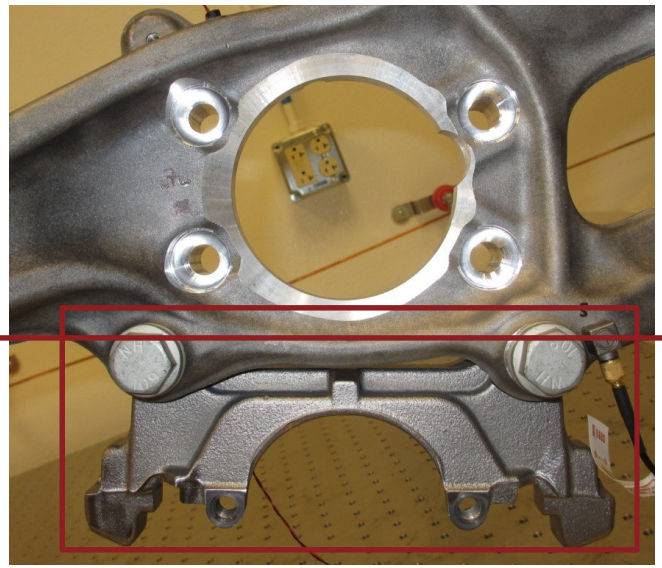


- Measure $C_{Exp} = A_{Exp} + B_{exp}$
- Substraction: $C_{Exp} - A_{FE} = B_{Exp}$
- Couple B_{exp} to D_{FE} or D_{exp} to obtain E
- Measure E_{truth}
- Compare results

Application

A

B



A

C

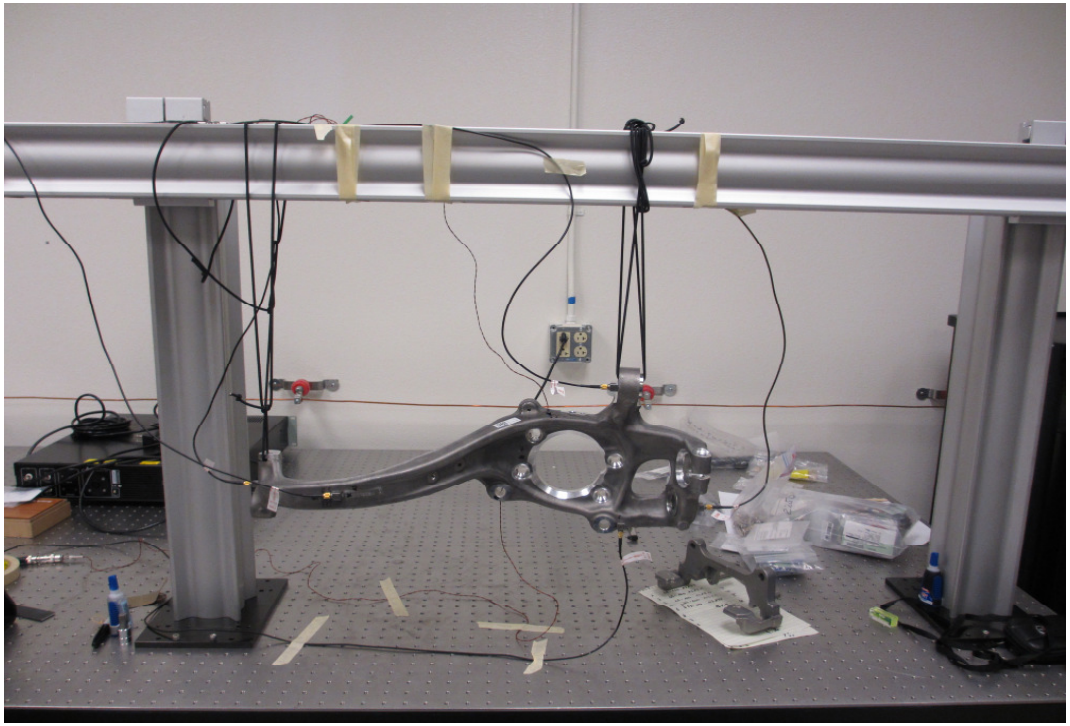
- A: Transmission simulator
- B: Brake knuckle
- C: Assembly trans. sim. + knuckle
- D: Brake carrier
- E: Assembly carrier + knuckle

Testing Approach

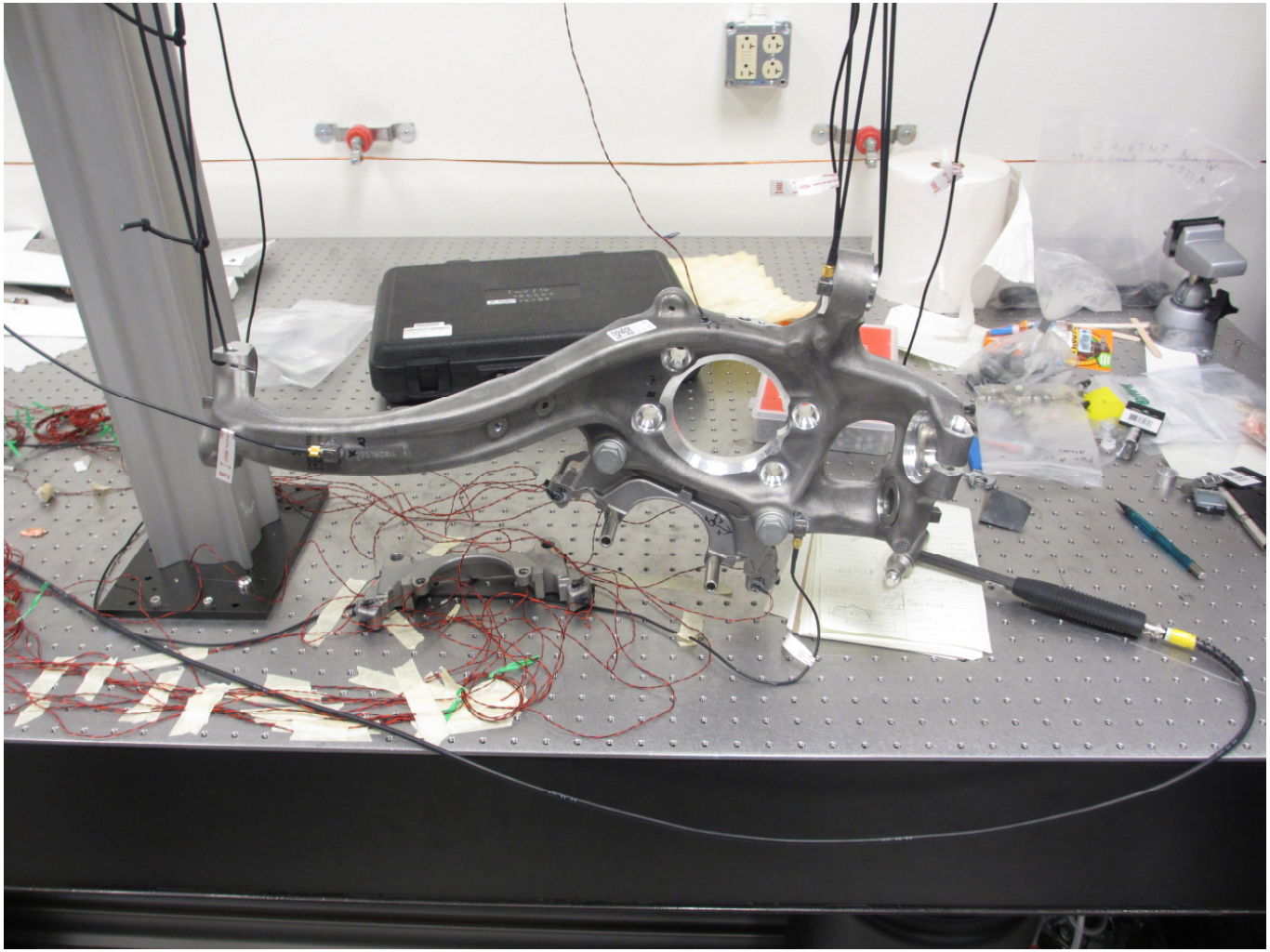
- Excitation Method: Impact Hammer (PCB 06C05)
- Measurement Method: Accelerometers (PCB 352A24s, Endev 65-100s)
- DAQ and Collection Software: NX-Ideas
- FEM Model/accelerometer locations calculated from model supplied by Audi
- Hit in line of accelerometers, either directly on with a cap or as close as possible
- Free-Free boundary
- Collected FRF Coherence/Auto Spectra to 2000Hz

Bare Knuckle

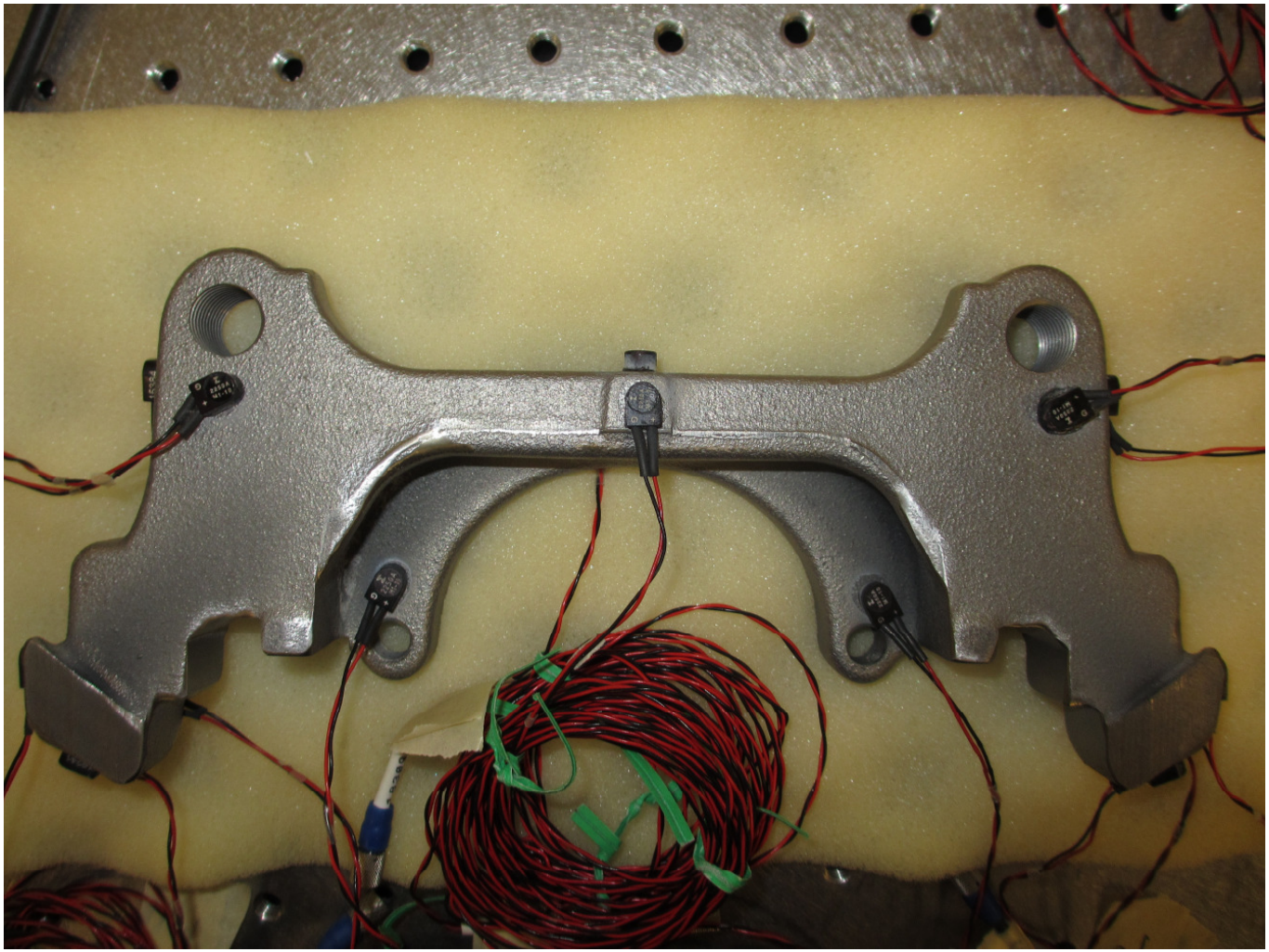
- Typically used 1.5-2x the accelerometers “theoretically” needed
- This figured to 5 Triaxial and 2 Uniaxial for the Knuckle alone



Knuckle + Carrier (6 extra accels)



Transmission Simulator



TS+Knuckle