Structural Dynamics Model Update

November 1, 2011

CONTENTS

Aeroelastic Prediction Workshop Schedule

- Identified organizing committee: Dec 1, 2010

- Data Release & Workshop Kickoff: IFASD 2011, Paris

- 10 months to perform computations

- Workshop: April 2012

Activity	FY10	FY11	FY12	FY13
Form organizing committee		◢		
Workshop kick-off			▲ Kickoff at IFASD	
Config, grids, etc. available on-line	▲	▲ ▲		
Perform analysis of selected config.			▬	
Conduct 1st Aeroelastic Prediction Workshop			▲	Workshop at 2012 SDM
Update / improve CFD results / code(s)				▬
Perform comparisons, Statistical analyses				▬
Present conference papers				▲
Formulate AePW 2				▬ ▲

FY= USGovt Fiscal Year, Oct-Oct (e.g. FY12 – Oct 2011-Oct 2012)

AePW1 Prep Schedule: August 2011 – April 2012

| Activity | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. |

CFD Calculations
- Check out test cases and resolve issues
- Perform analysis for workshop
- Prepare AePW1 presentation

Experimental Data Prep
- HIRENASD
- RSW
- BSCW
- Prepare AePW1 presentation with statistical bounds

Software Development
- Prepare template
- Prepare Matlab software for user data reduction and perform sample processing
- Prepare comparative processing software
- Generate AePW1 comparisons

Computational Efficiency
- Determine request / requirement for analysts

Workshop Coordination, Communication, & Prep
- Advocacy presentations
- Abstracts due from analysts
- Coordination with AIAA
- Comp results due from analysts
- Finalize AePW1 agenda

AIAA SDTC   RTO   AFDC   ASM

Input for Event Preview; Event Preview and Registration Form available in Jan.

Analysis Components
- Update structural dynamic model
- Release next generation of grids

HIRENASD
All Configs

Telecons / Meetings
- Uncertainty analysis
- General AePW OC
- Comp. efficiency (TauBench)

Important Stuff

- Dates:
  - AePW & RTO AVT 203 Meeting: April 21-22, 2012
  - Data submission: March 21, 2012
  - Registration: same time as AIAA SDM
  - Letter of intent: November 1, 2011
  - "Final" grids & "final" structural dynamics model: November 1, 2011
- Contact:
  - AeroelasticPW@gmail.com
  - https://c3. nasa.gov/dashlink/projects/47/

Structural Dynamics Model: Plan of Action (October 2011)

- Documentation
  - Summary of Current FEM
  - Summary of published structural dynamic data
  - And summary of each of the following items
- Experimental Data Reduction of Air-off Data Sets
  - Test matrix
  - Example of
    - Time history
    - Frequency domain plot
    - Mode shapes
  - Uncertainty characterization on frequencies and mode shapes
- Finite element model modifications from "Current" to "Updated" (Updated model milestone date: November 1 upload to website)
  - Inclusion of instrumentation
  - Inclusion of full balance model
- Comparison of Modal Data (freqs & mode shapes via MAC)
  - Current AePW FEM
  - Experimental Data
  - Updated AePW FEM
- Decision Point: further FEM development or modification?

Original FEM

- HEX 8 Model, on Website
- No balance, exciter or instrumentation
- Cantilevered at root
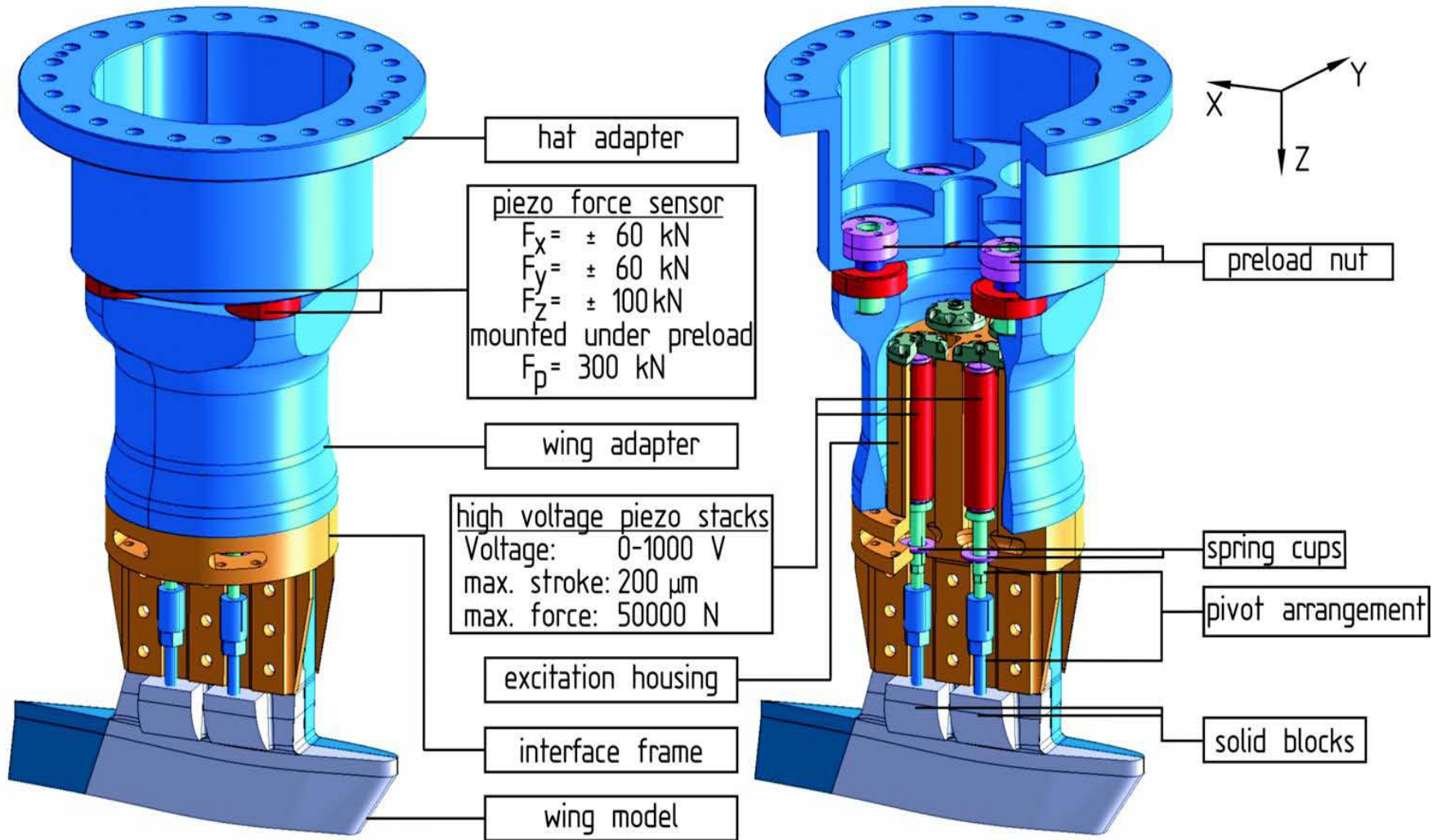
STRUCTURAL MODEL UPDATE

- HISTORY
  - Hex 20 model was converted to Hex 8. Negligible impact on modes and frequencies – substantial decrease in NASTRAN CPU time to run –10 minutes instead of 4 hours
  - Cable wiring added – using CONM and RBE3 elements (Castro)
  - Boundary conditions modified – replace cantilevered with spring elements.
  - Optimization used to attempt to match modal frequencies and mode shapes
  - Obtained Tet10 model which includes balance – connect to Hex8 model of wing. The Balance must be modified in order to join the wing and the anregung. Anregung being tet model – this has been time consuming

- October PLAN of ACTION
  - Use new TET10 model that includes balance, exciter and wing
  - Add instrumentation using CONMs and spidering
  - Modify interfaces to better represent the bolt connections
  - Modify FEM OML grids- project to IGES surface used in grid generation

hat adapter

piezo force sensor
$F_x = \pm 60$ kN
$F_y = \pm 60$ kN
$F_z = \pm 100$ kN
mounted under preload
$F_p = 300$ kN

wing adapter

high voltage piezo stacks
Voltage: 0-1000 V
max. stroke: 200 µm
max. force: 50000 N

excitation housing

interface frame

wing model

preload nut

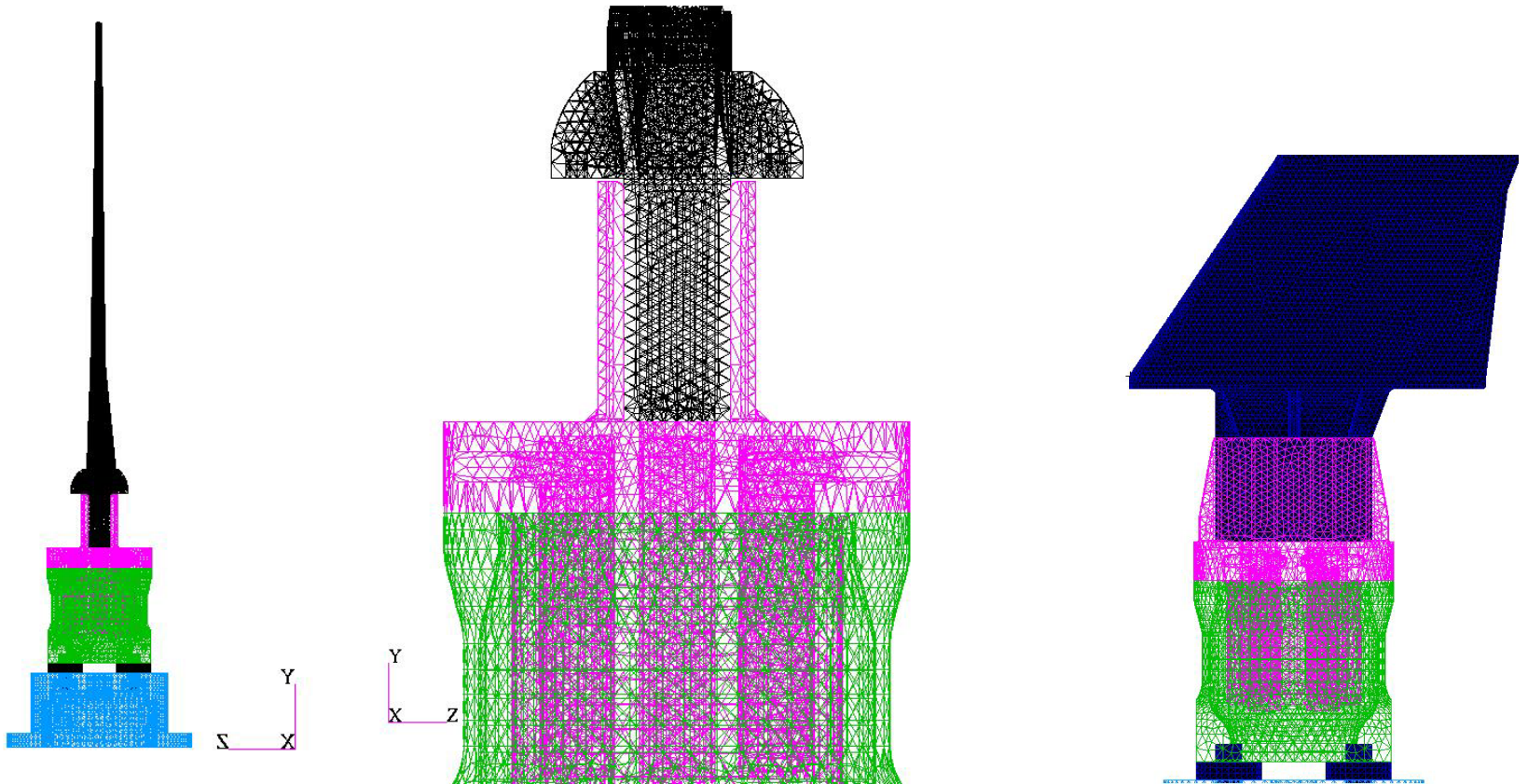spring cups

pivot arrangement

solid blocks

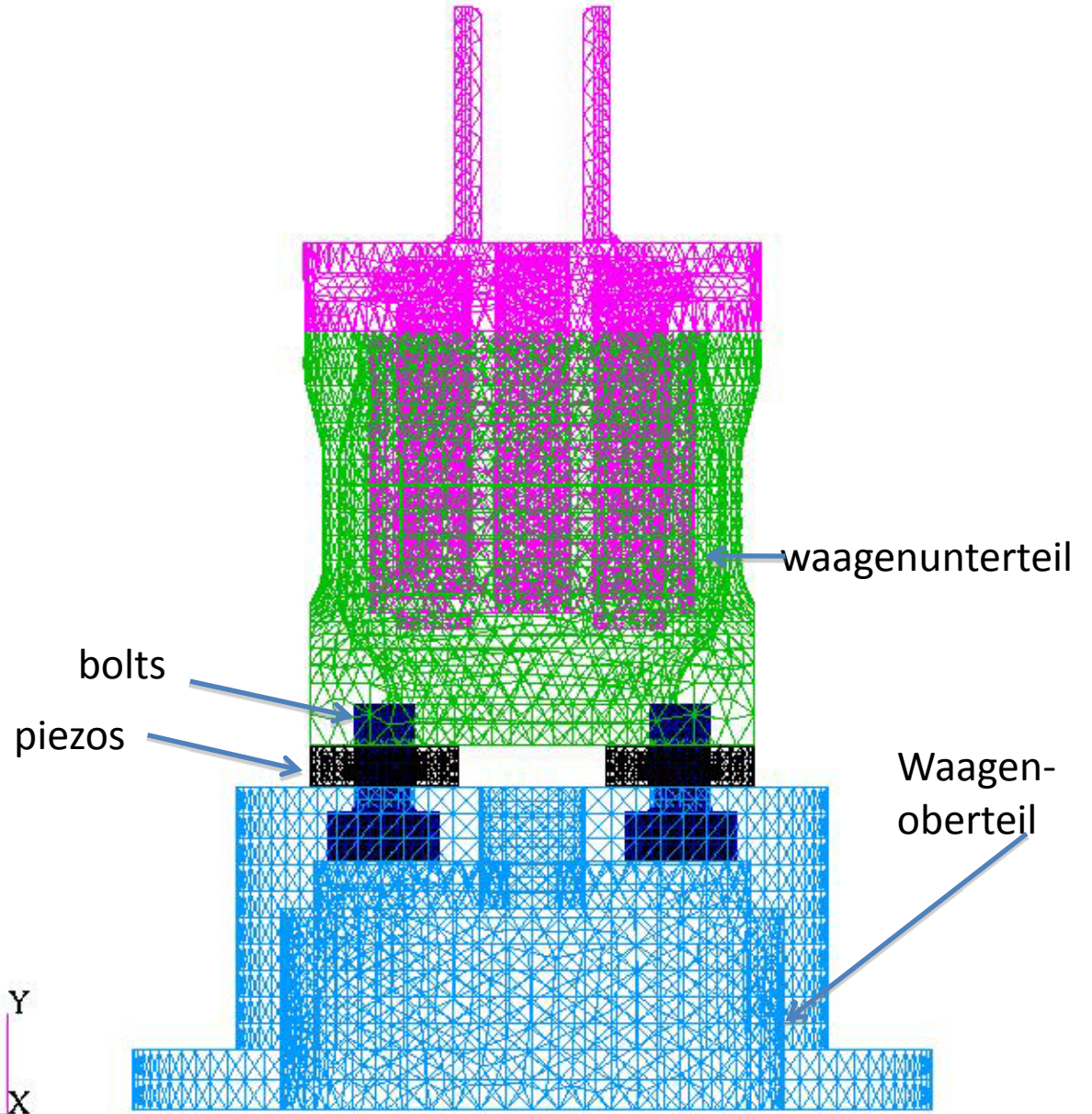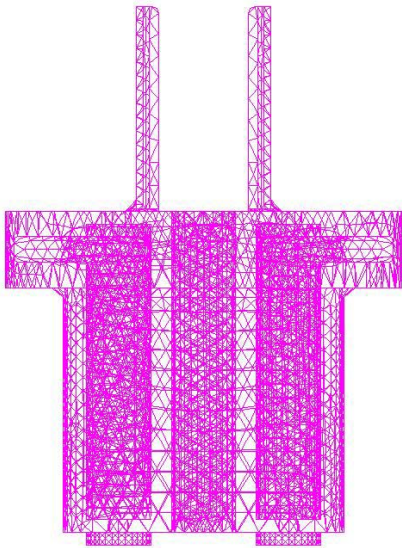A reminder of what the mounting hardware looks like

Tetrahedral Element Model

Wing: black and/or dark blue
Exciter (anregung): pink

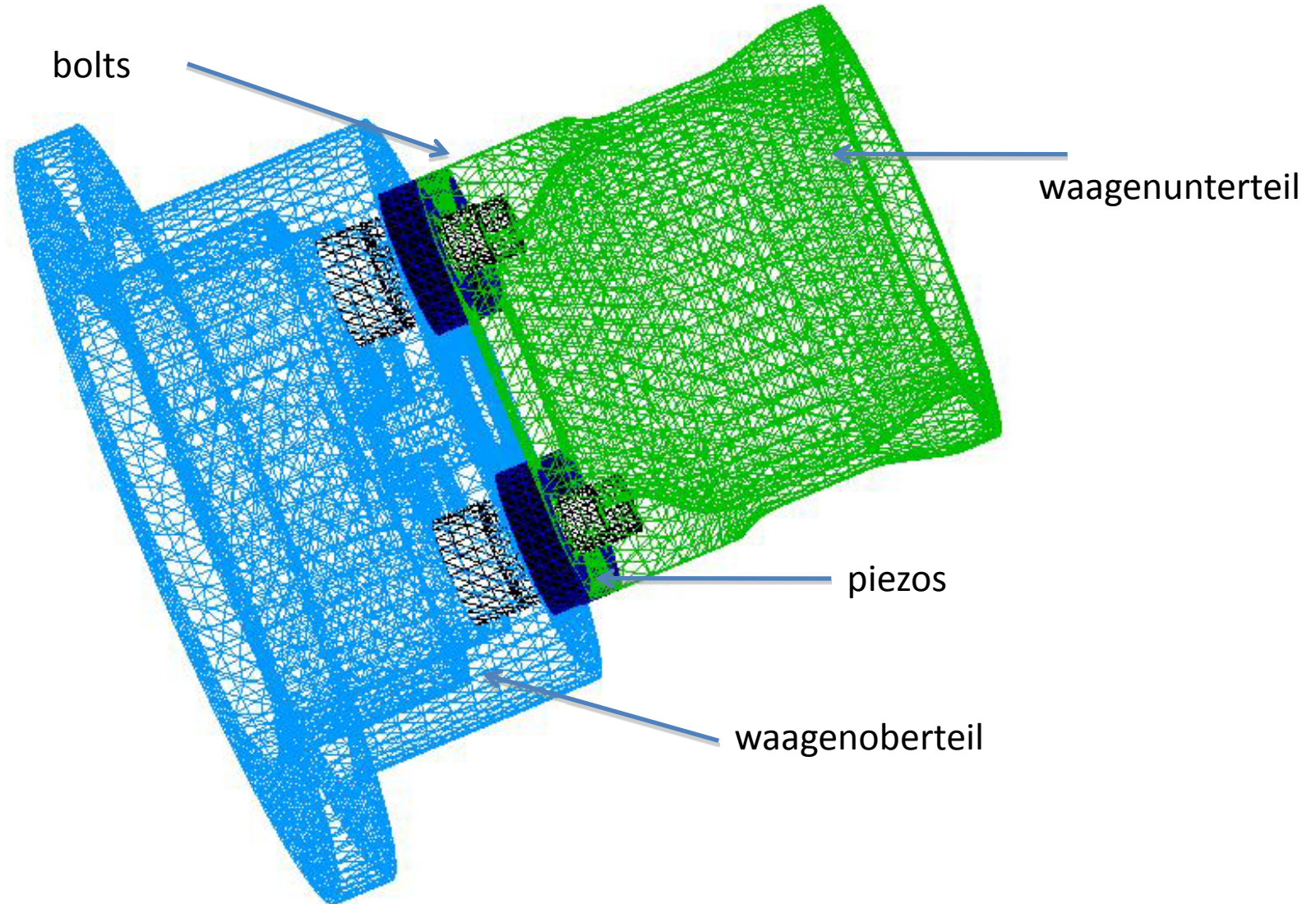# Tetrahedral Element Model

ANREGUNG
(exciter)

waagenunterteil

bolts

piezos

Waagen-
oberteil

BALANCE

bolts

waagenunterteil

piezos

waagenoberteil
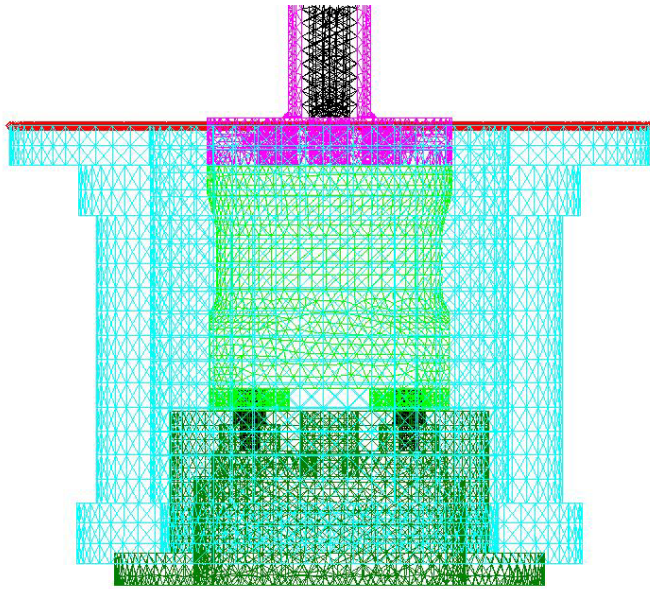
Y

X

FEM including Model Cart

Cyan is the model cart
Green are the waagenoberteil and waagenunterteil
The red grids are the locations of the SPC constraint boundary conditions

FEM as provided connects the anregung and fluegel tet using common grid points surrounding the Wing root (bottom of U and the sides)

The grids were disconnected at the wing root (bottom of "U") by renumbering the anregung grid points and regenerating the TET elements using the new grid points.

Grids at top and bottom of wing (sides in this figure) were disconnected in same manner and RBE elements were created that joined the grids at identical locations in the area covered by bolt region
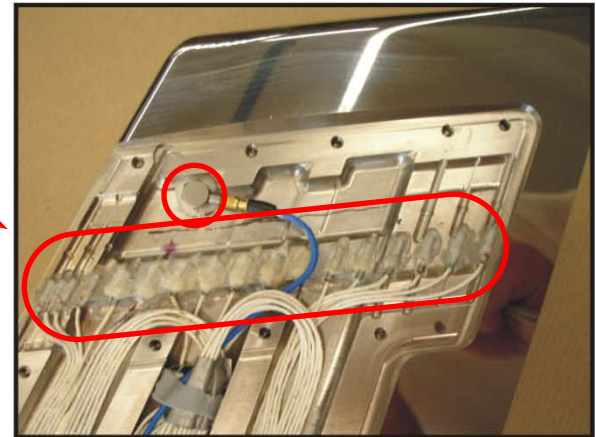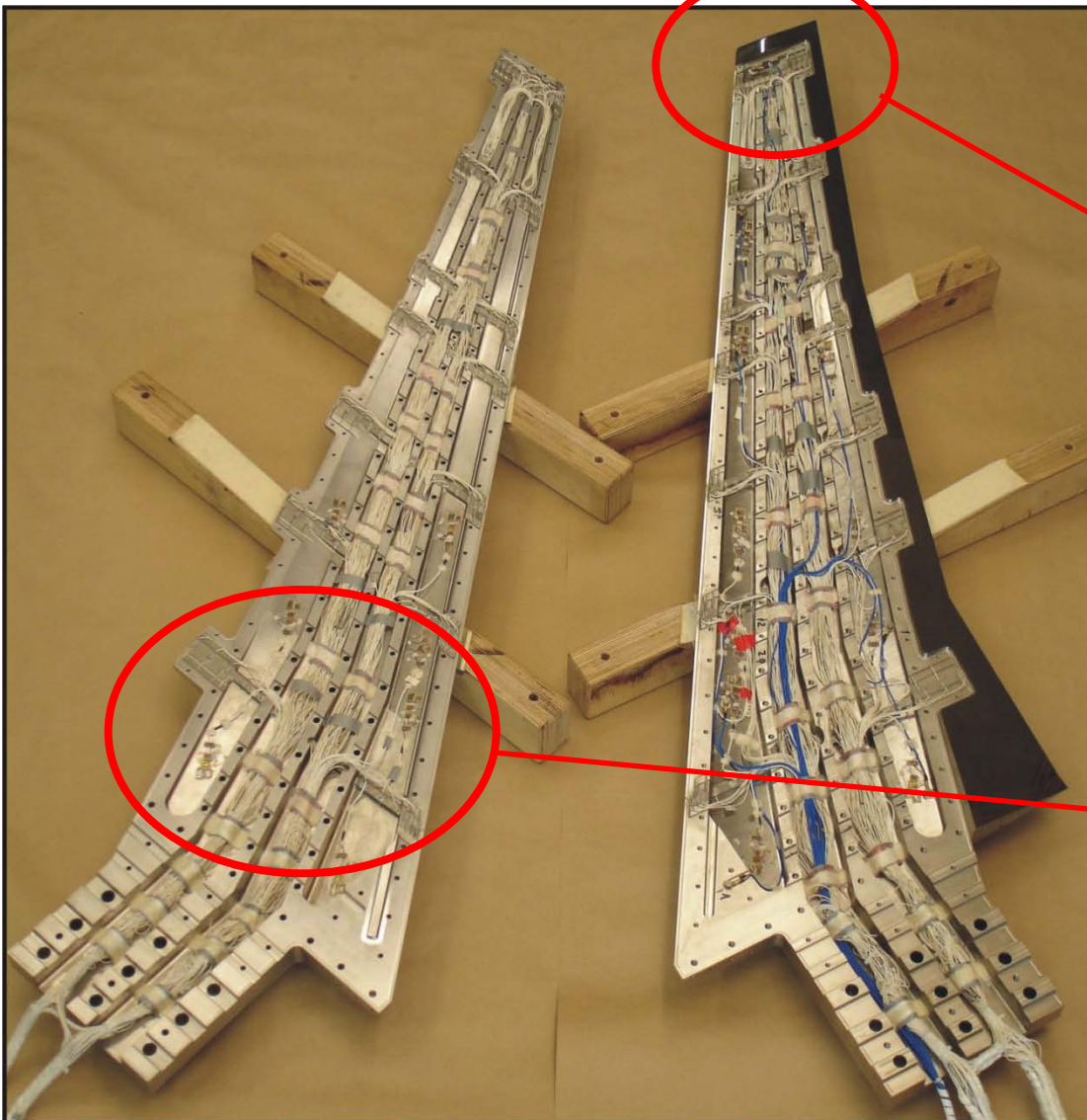
FEM plots
showing the bolted regions

The Yellow are the RBE which link the grids on the fluegel Tet and the anregung that were previously the same grid points.

The ETW Model cart has been removed from this figure.

Both TET models with and without the model cart were modified to have this bolt region connected using RBE instead of common grids.

In-situ pressure sensors and accelerometers
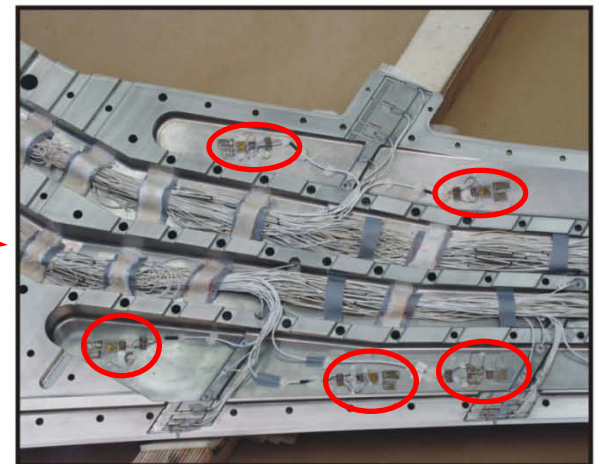
Strain gauges

Instrumentation weight within the wing that is being added to the FEM
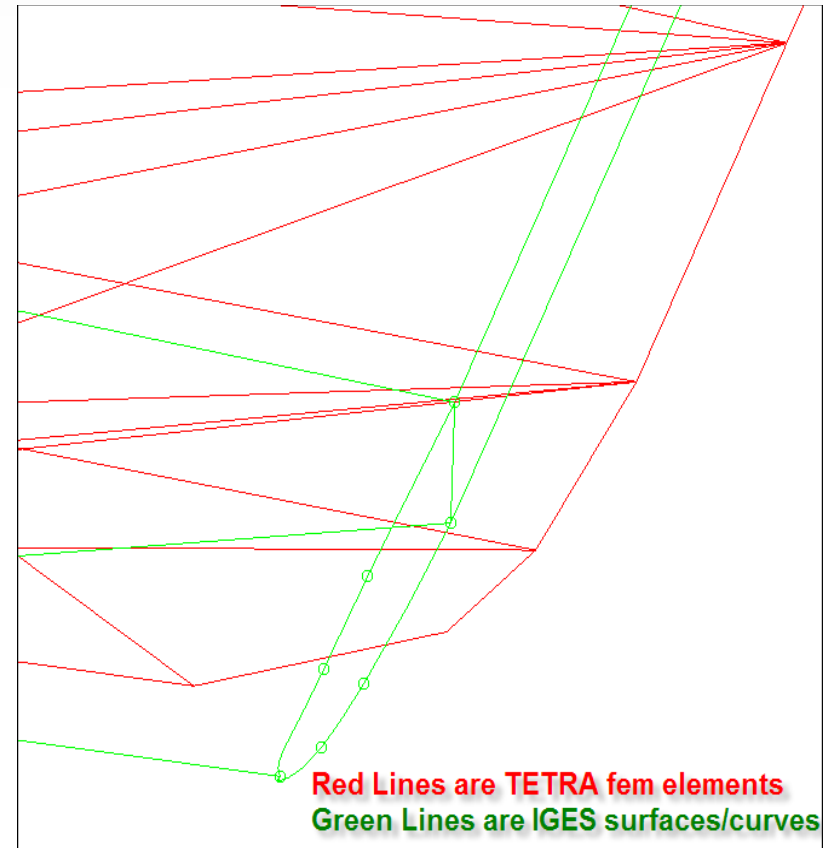
OML projection issue

- The FEM OML does NOT match the IGES OML
- FEM OML grids can be transformed from present location to an OML defined by and IGES surface.   Thanks Jack Castro for doing this for us.

Grid Projection to IGES Surface for HIRENASD model

Tip Trailing Edge Detail View

- **Problem: Geometry used to tetmesh the hirenasd model not the same as the IGES geometry used for the CFD gridding**

- **Solution: Project the wetted surface tet nodes to the IGES surfaces using a perpendicular projection to closest surface (used PATRAN: Modify/Node/Project function)**

- **Difficulties**
  - A few interior nodes were included and projected. These were identified and moved back to original locations
  - Inconsistent definition of "trailing edge" in the FEM model vs. the IGES geometry (no resolution to this issue)

Red Lines are TETRA fem elements
Green Lines are IGES surfaces/curves

Trailing edge has no thickness in FEM model but has finite thickness in IGES model

MSC Software

OML projection to IGES file details or plots go here
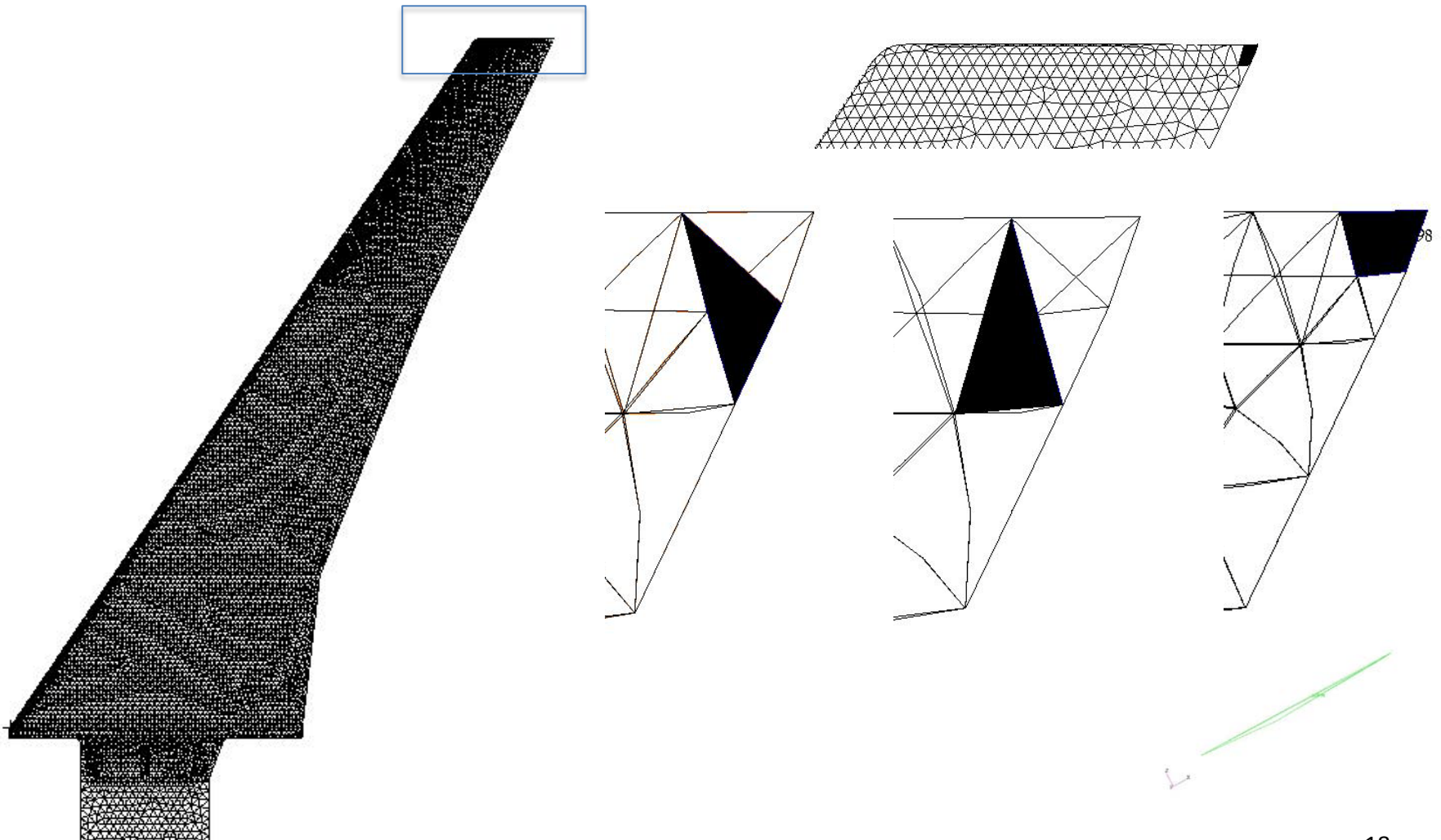
Modifications of FEM

- Start with the full Tetrahedral element FEM that includes a CAD-based model of each part
- Modify the Tet model that includes the full model of the wing, balance, exciter, and model cart
    - Add instrumentation using CONMs and spidering
    - Remove common grid point connections between exciter and wing at the base of the wing (bottom of U)
    - Remove common grid points connections at top and bottom of wing where anregung is connected to wing
    - Add constraints in bolted connection regions to connect anregung to wing
    - Project surface grids points to match the IGES OML definition
- Compare with experimental data

Validation of FEM

- Comparisons with experimental data
  - Frequencies
  - Modal Assurance Criteria
  - Leading & Trailing Edge Deflections
  - Twist distribution
  - Node lines
  - Sensor Location Displacements

- The following results are prior to the projection of the grid points onto the IGES surface modification; the difference in the mode shapes before and after IGES projection are minimal and quantified on a slide at the end of the modal comparison plots.
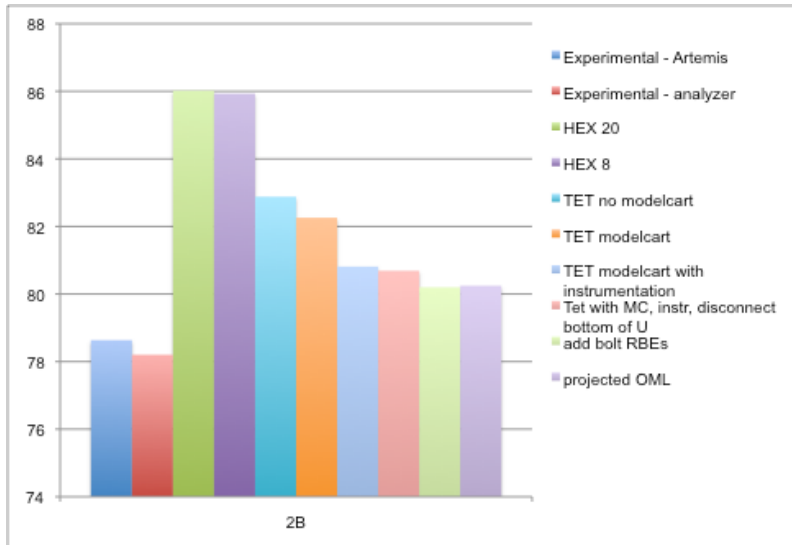
20

Methods to Extract the Mode shapes from the time histories

- Artemis – Boucke

- Analyzer – Do Frequency responses with respect to ACC15(1) and extract the magnitude and phase at the frequency desired.

- SVD – not included in this documentation

COMPARISON OF MODAL FREQUENCIES

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
	Experimental - Artemis	Experimental - analyzer	HEX 20	HEX 8	TET no modelcart	TET modelcart	TET modelcart with instrumentation	Tet with MC, instr, disconnect bottom of U	add bolt RBEs	projected OML
1B	26.015	26.250	26.541	26.534	26.249	26.217	25.618	25.604	25.542	25.550
2B	78.635	78.203	86.019	85.932	82.881	82.257	80.812	80.688	80.199	80.245
1FA			156.938	157.237	117.465	110.904	108.626	106.998	106.242	106.193
3B	166.250	166.250	189.311	189.434	170.083	163.745	161.770	161.441	160.381	160.349
4B	245.002	245.000	321.774	321.985	259.317	244.899	242.520	242.364	241.942	241.995
1T	265.855	265.781	272.859	273.443	275.120	273.055	272.295	272.182	271.718	271.844
2T			450.506	451.811	448.517	443.496	442.291	441.178	437.122	437.830
5B			496.680	497.795	380.224	360.338	356.863	356.332	354.341	354.155
2FA			422.976	423.259	280.260	256.158	252.790	252.651	252.361	252.225
3T			622.407	625.227						569.737
3FA					499.387	454.750	450.171	446.396	444.318	443.805
6B										497.802
3T										569.737
7TB										643.234

Comparison of 2B frequencies

Comparison of Modal frequencies (omit FA modes)

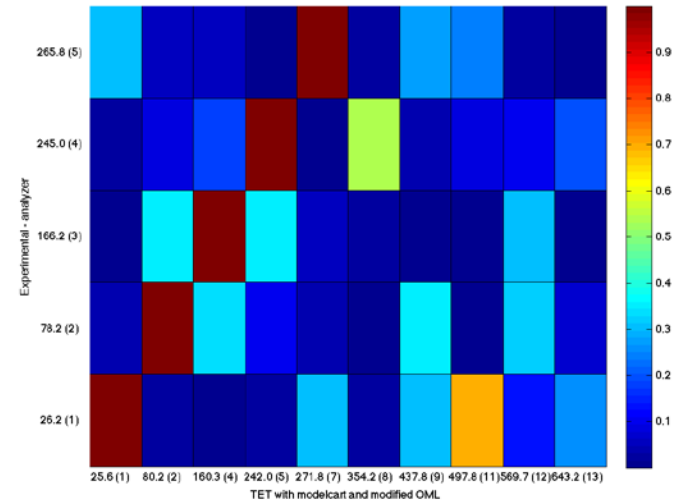Artemis Data are provided by Boucke
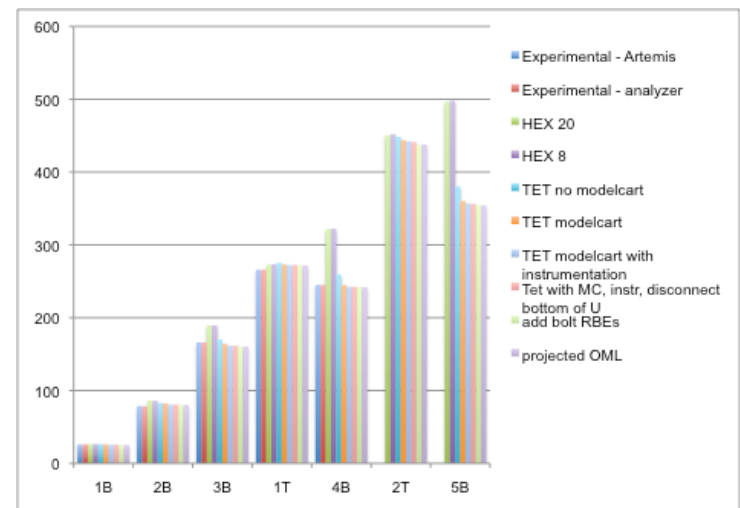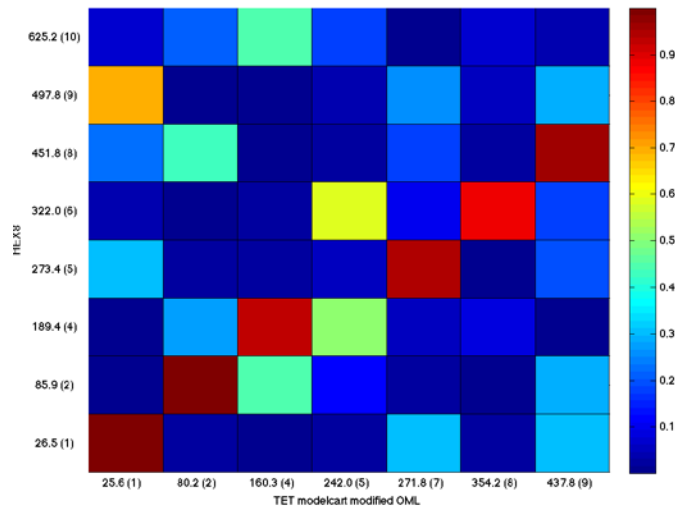
Modal Assurance Criteria
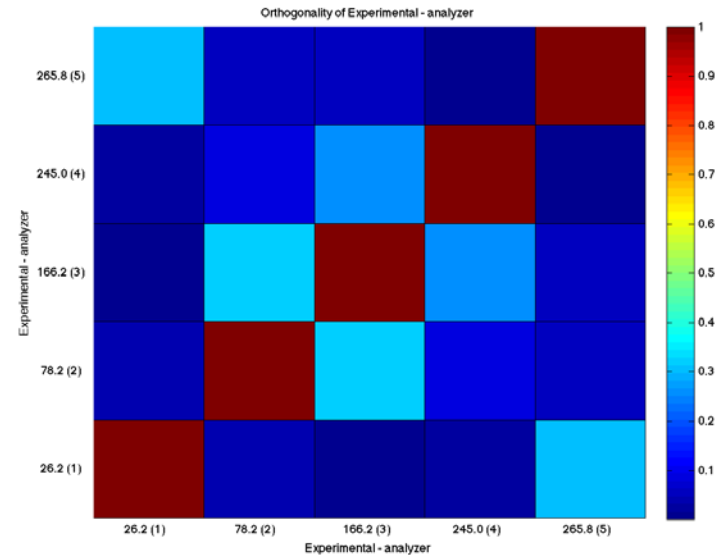

Comparison of Experimental with Hex8 wing only
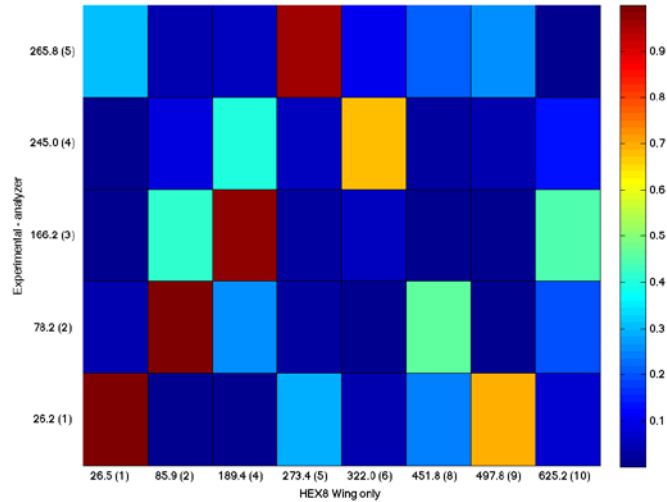
Comparison of Experimental with TET10 mode with modified OML

Comparison of HEX8 wing only and TET10 model with modified OML

Orthogonality of Experimental Data

Wing Leading Edge Deflection Comparisons 2nd bending mode

In order to compare the span-wise deflection, the flow-wise twist angle, and the node lines, the data from 9 sensor locations is extrapolated & interpolated to a uniformly spaced grid, using the matlab griddata function
Data:
9 accelerometers
Node lines:
Deflection crosses 0

Interpolated HIRENASD sensor data
Deflection of 2nd Bending Mode along Wing Leading Edge

Wing Trailing Edge Deflection Comparisons
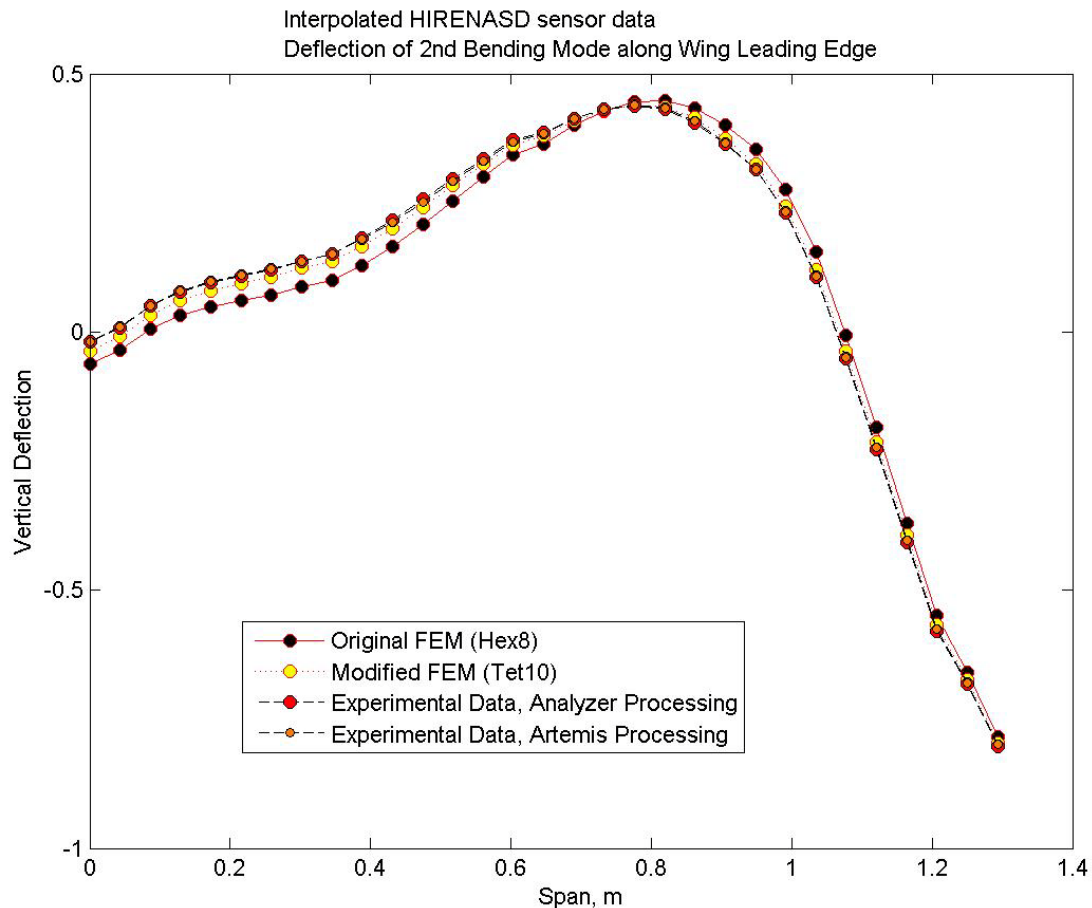# 2nd bending mode

In order to compare the span-wise deflection, the flow-wise twist angle, and the node lines, the data from 9 sensor locations is extrapolated & interpolated to a uniformly spaced grid, using the matlab griddata function
Data:
9 accelerometers
Node lines:
Deflection crosses 0

Interpolated HIRENASD sensor data
Deflection of 2nd Bending Mode along Wing Trailing Edge

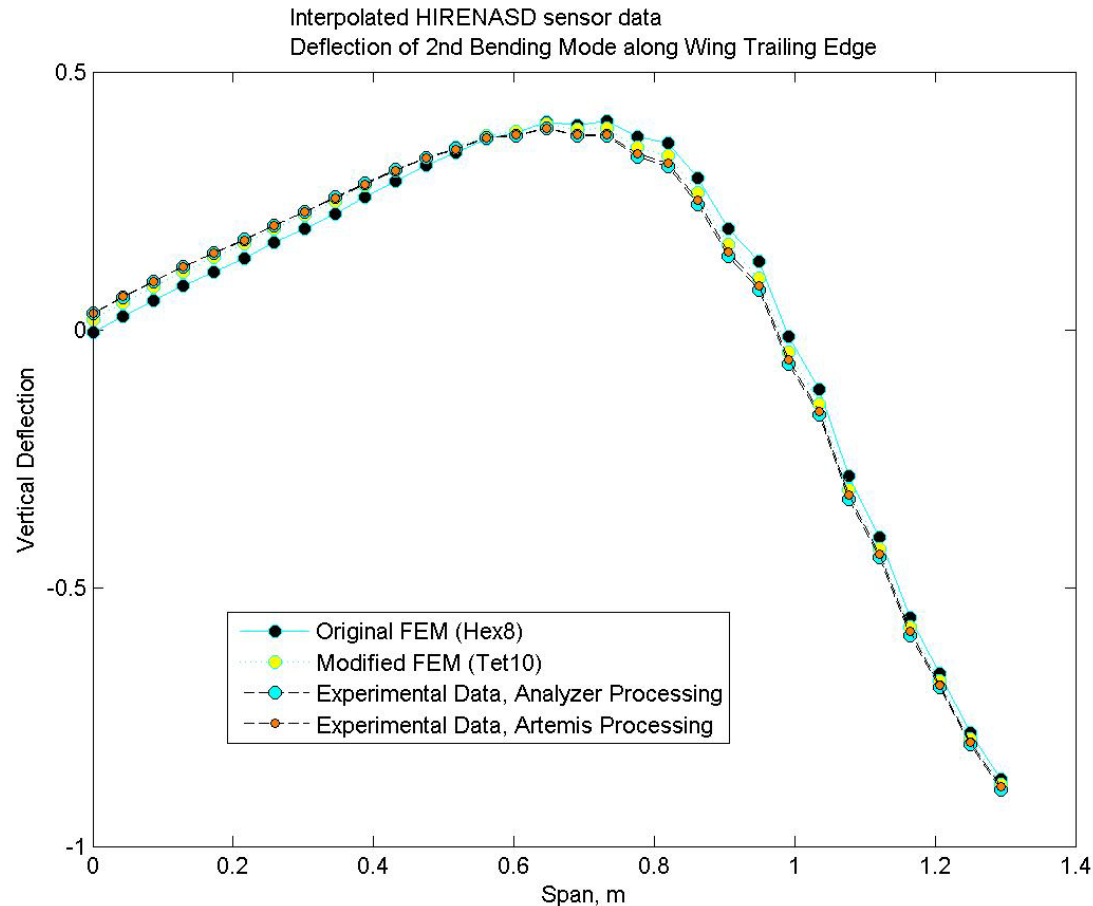# Wing Twist Angle Comparisons
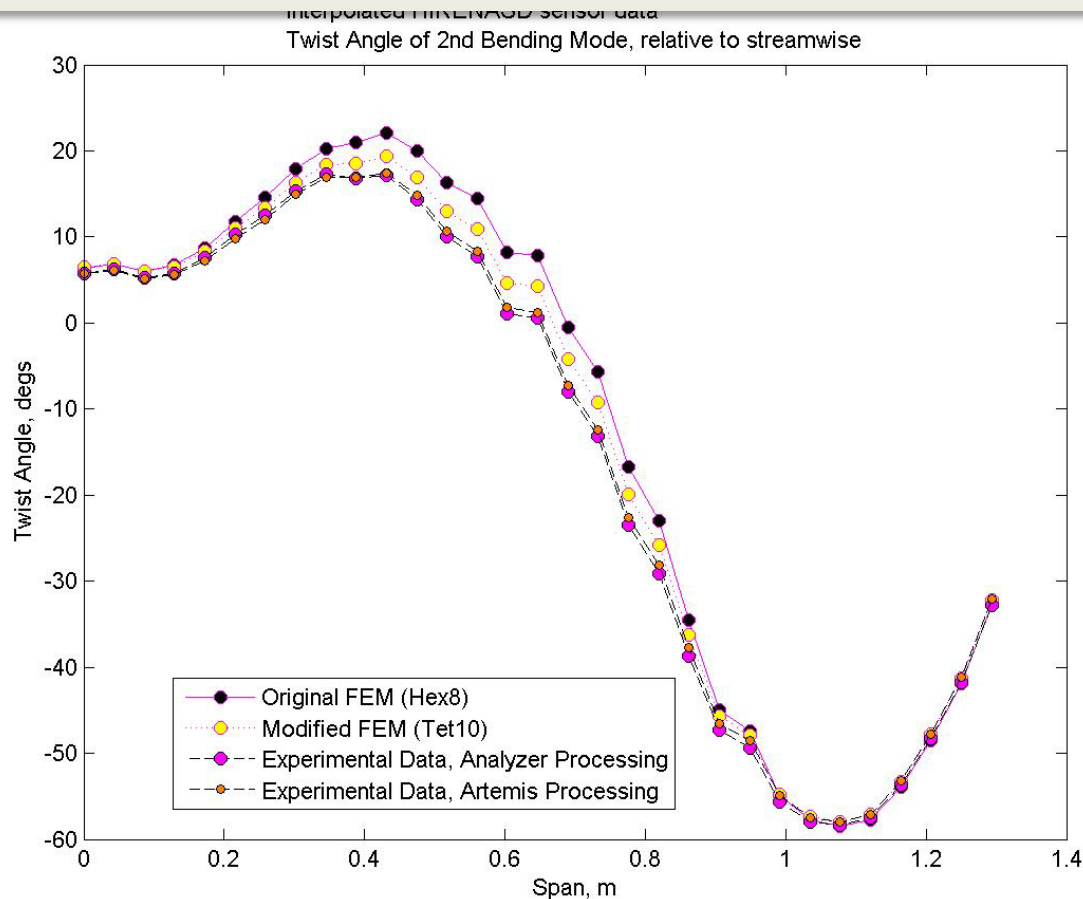## 2nd bending mode

In order to compare the span-wise deflection, the flow-wise twist angle, and the node lines, the data from 9 sensor locations is extrapolated & interpolated to a uniformly spaced grid, using the matlab griddata function
Data:
9 accelerometers
Node lines:
Deflection crosses 0

Twist Angle of 2nd Bending Mode, relative to streamwise

Node Line comparisons, 2ⁿᵈ bending mode

Data:
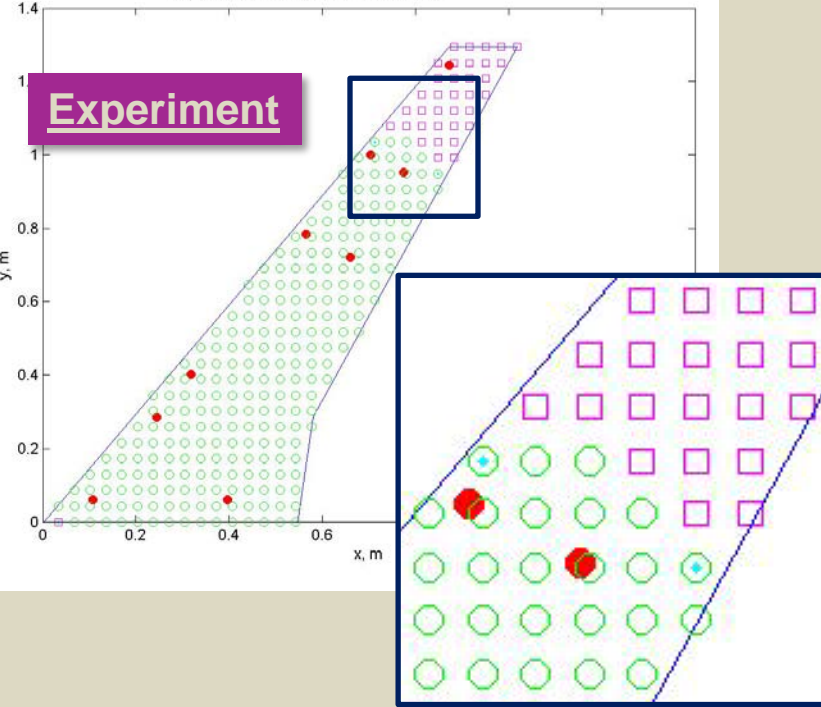9 accelerometers (red circles)
Interpolated / extrapolated to uniformly spaced points using matlab griddata function
Node lines:
Lie between magenta squares (- values) and green circles (+ values)

Original FEM

Interpolated HIRENASD sensor data, Mode at 85.9319 Hz
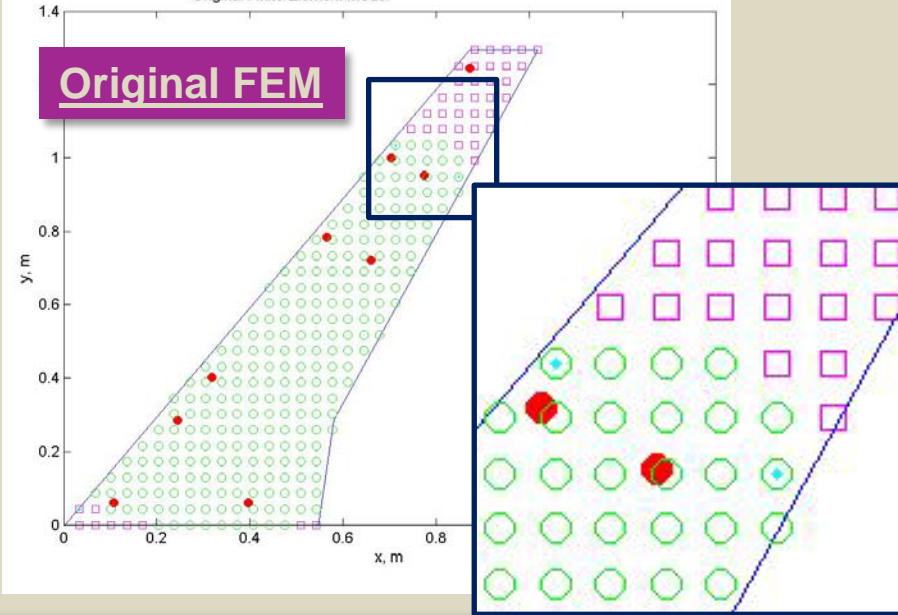Original Finite Element Model
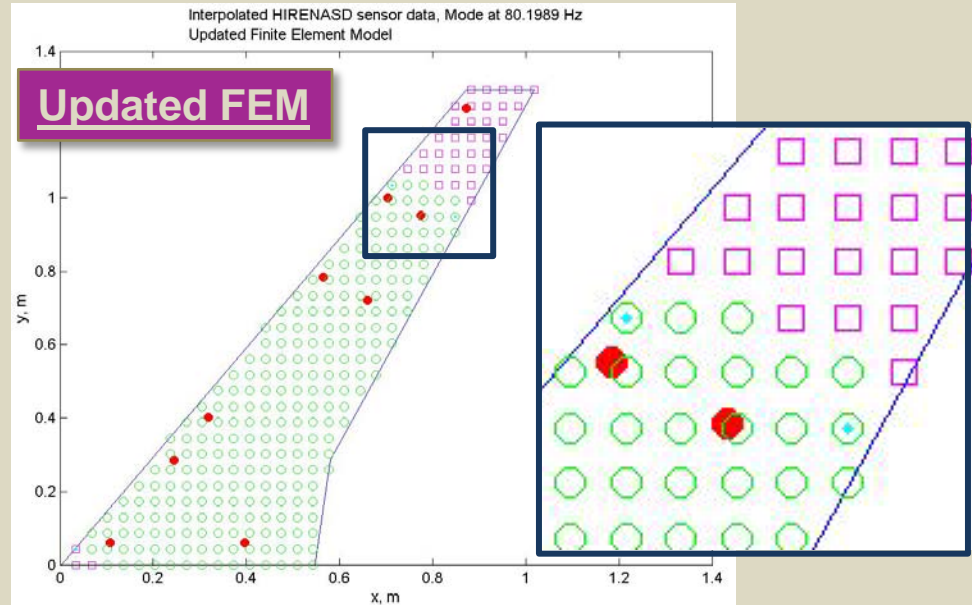
Experiment

Interpolated HIRENASD sensor data, Mode at 78.2031 Hz
Experimental Data, Analyzer Processing

Updated FEM

Interpolated HIRENASD sensor data, Mode at 80.1989 Hz
Updated Finite Element Model

Direct comparison of Mode Shape Deflections at 9 Sensor Measurement Locations

HIRENASD sensor data, only at actual Sensor Locations, 2nd Bending Mode

Radial coordinate is defined as the distance of the accelerometer from the origin,
= sqrt(xo^2 + yo^2)

Direct comparison of Mode Shape Deflections at 9 Sensor Measurement Locations

HIRENASD sensor data, only at actual Sensor Locations, 2nd Bending Mode
Experiment - Modified Finite Element Model

Radial coordinate is defined as the distance of the accelerometer from the origin,
= sqrt(xo^2 + yo^2)
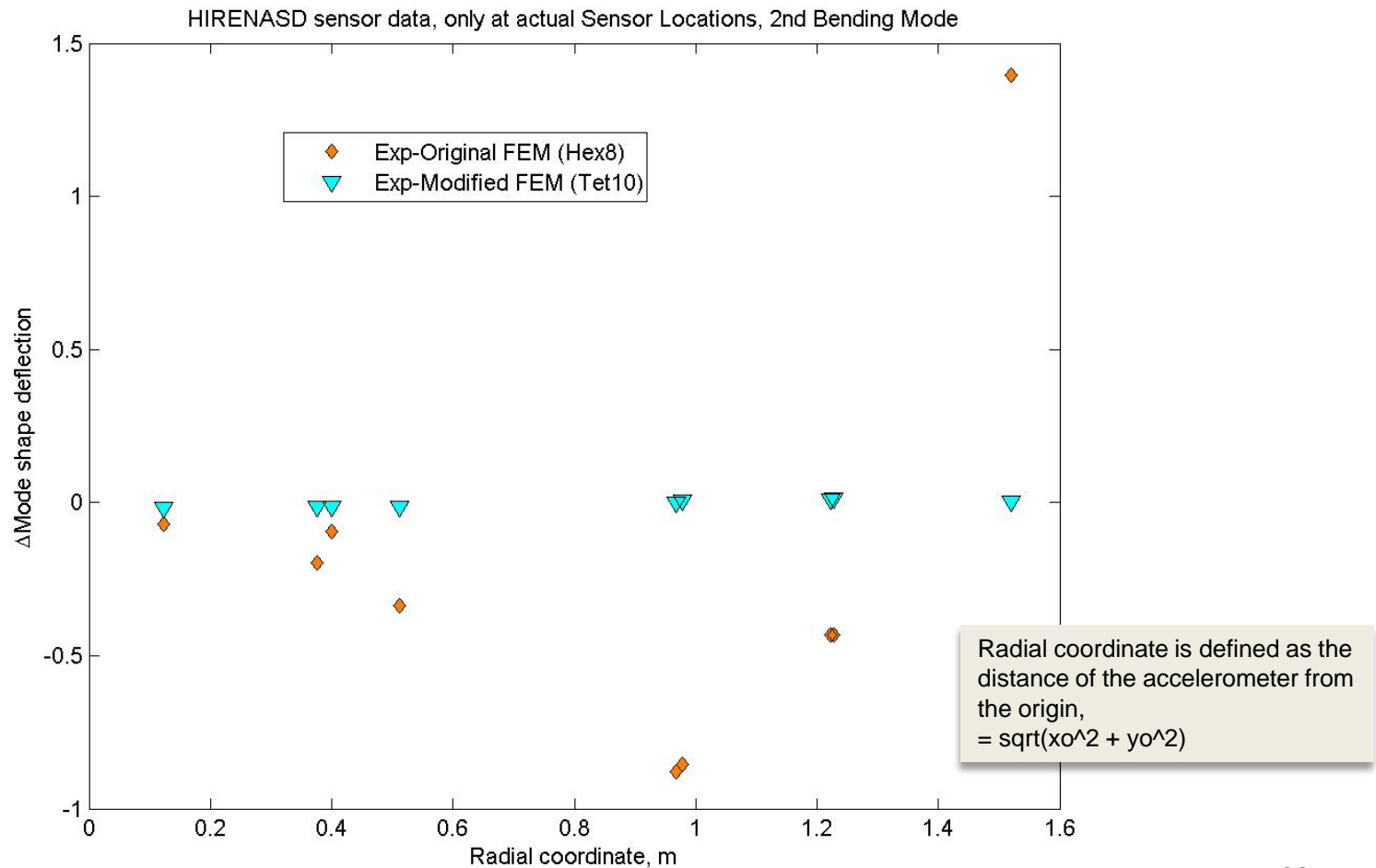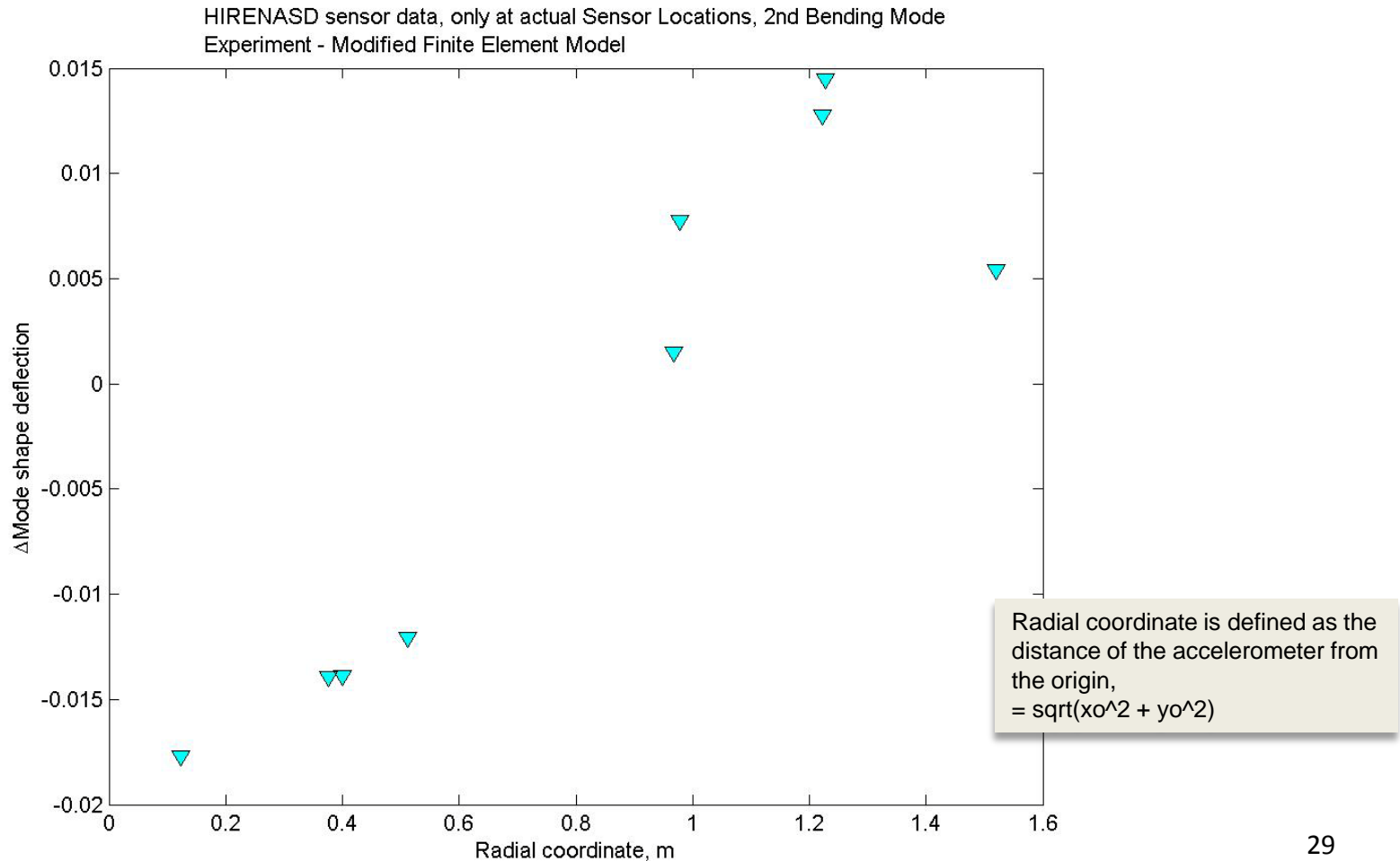
Differences before and after TSLS projection
Modal Deflection of 2nd Bending Mode

Accelerometer #	Before projection	After projection	Difference
1	0.7024	0.7003	0.0021
2	-0.2048	-0.2053	0.0005
3	-0.2068	-0.2073	0.0005
4	-0.4356	-0.4354	0.0002
5	-0.4278	-0.4277	0.0001
6	-0.1809	-0.1807	0.0002
7	-0.1092	-0.1091	0.0001
8	-0.0393	-0.0393	0
9	-0.0541	-0.0543	0.0002

Summary & Conclusions

- The fundamental FEM that served as the baseline model for the modified FEM was generated using CAD files of the hardware

- Only modifications that make physical sense were incorporated into the FEM- no tweaking or tuning using experimental data was done in the modification

- The modified FEM appears to match the frequencies and 2nd bending mode shape better than the original FEM

- The mode shape does not appear to be significantly changed, but the influence of small effects may show up in the aeroelastic analysis

- The 2nd bending mode frequency has changed by X%