HIRENASD Analysis Using MSC NASTRAN OpenFSI and CFD++

1st Aeroelastic Prediction Workshop
Honolulu, Hawaii
April 21-22

Beerinder Singh (Metacomp)

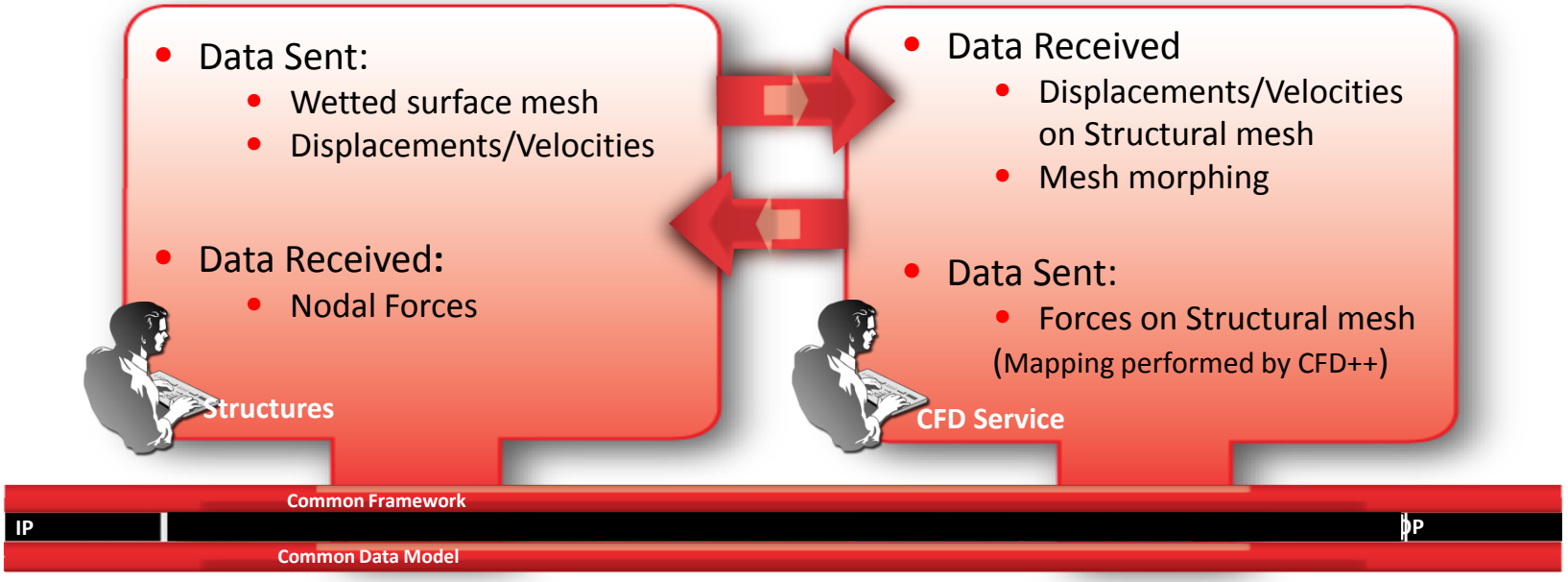
Jack Castro (MSC)

Agenda

- Solution Approach
- Setup
- Results Discussion
- Runtimes
- Lesson's Learned/Next Steps

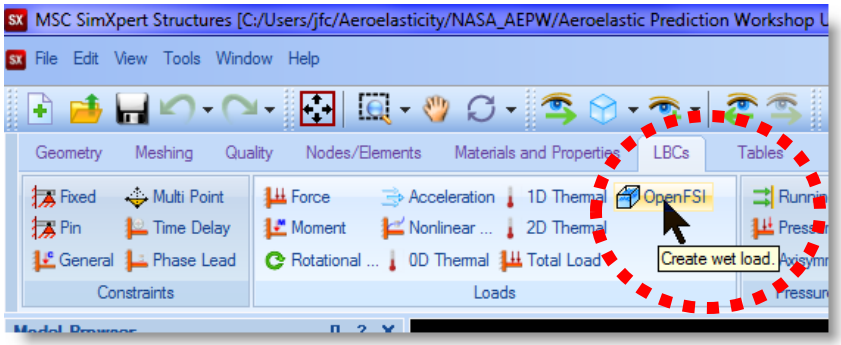
Solution Approach

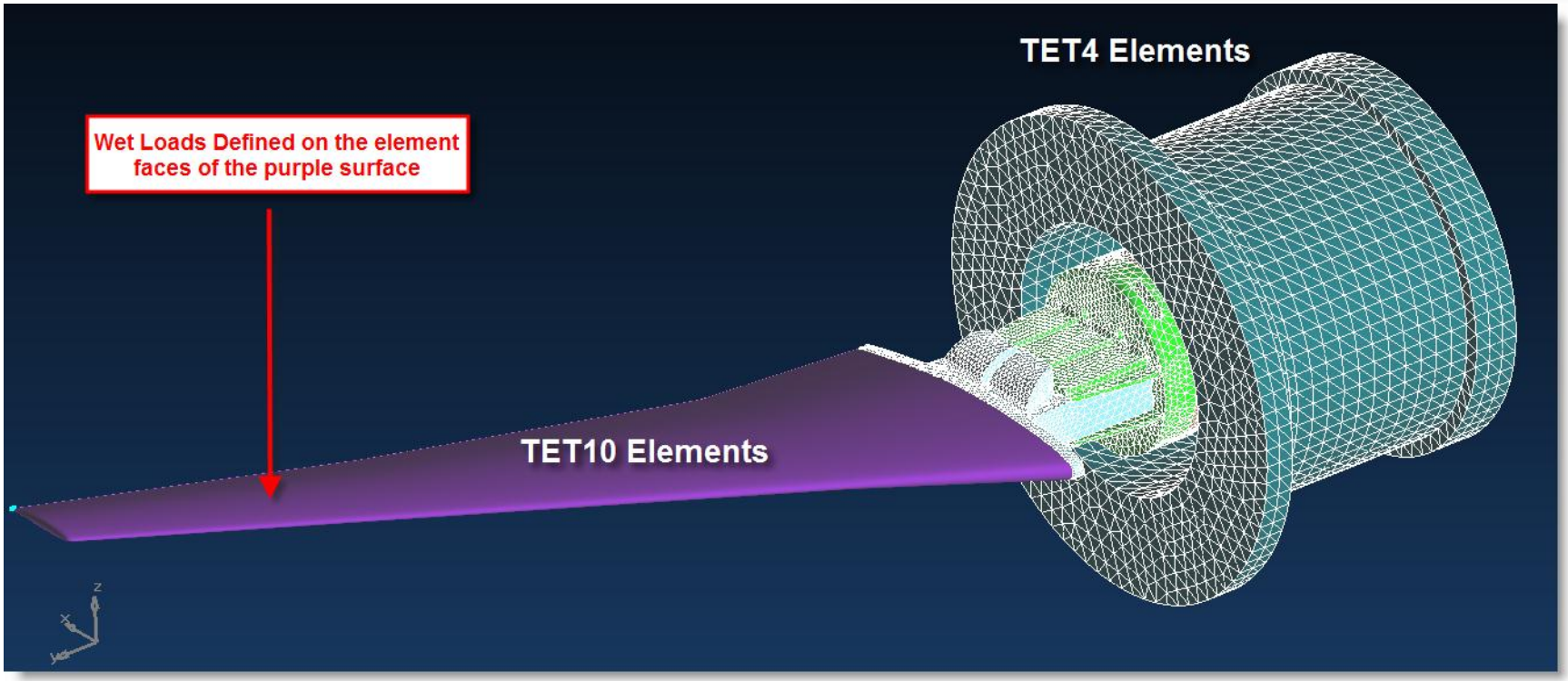
- **MSC Nastran OpenFSI Service**
  - **Co-simulation with CFD++**
  - **Structural FSI -- Forces and Displacements/Velocities**
  - **Static/Steady or Transient/Unsteady linear/nonlinear solutions**
  - **Available in MSC Nastran SOL 400**



MSC Nastran Setup

- SOLution 400
- Define “WetLoad”
  - Wetload →WetSurf→WetElm





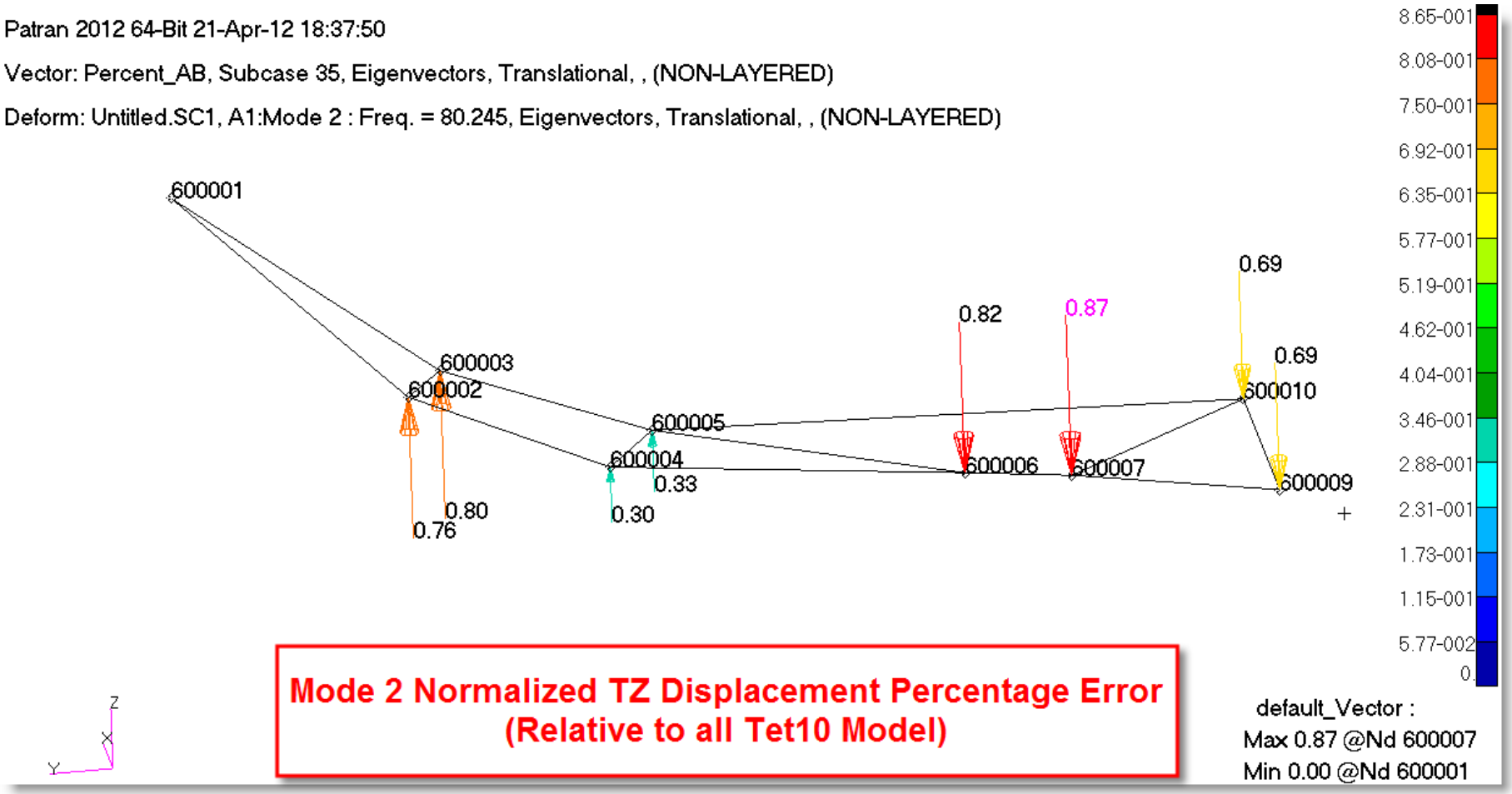
MSC Software

Metacomp Technologies

Tet4/Tet10 Combined Model Mode Comparison

Mode	All Tet10	Tet4/Tet10 Wing	Experiment
1B	25.550	25.560	26.015
2B	80.245	80.931	78.635
1FA	106.193	110.994	
3B	160.349	165.228	166.250
4B	241.995	250.552	245.002
1T	271.884	272.926	265.885

Tet4/Tet10 Combined Model Mode Comparison



Mode 2 Normalized TZ Displacement Percentage Error (Relative to all Tet10 Model)

MSC Software

Metacomp Technologies

MSC Nastran Setup

```
CONNECT SERVICE FSISRV1 'metacfd.openFSI'

SOL 400
CEND
SPC = 1
smethod=element
set 1 = 600001 thru 600007, 600009,600010
SUBCASE 1
   DLOAD = 1001
   ANALYSIS = NLTRAN
   NLSTEP = 1
   IC=101
BEGIN BULK

FSICTRL FSISRV1 EXPLICIT 1

$ damping
param,g,0.2
param,w3,495.7 $ 2*pi*78.9
$
$ 78.9 hz = period of 0.01267
$ 5 periods = .0634 sec
$ 500 steps
NLSTEP  1       .0634
        general 25      2       0
        fixed   500

INCLUDE 'tet4_mc.dat' $ structural model
INCLUDE 'hirenasd_TIC_Case159-nospc.dat' $ transient initial conditions

DLOAD   1001    1.      1.      21
$ wet load is TLOAD1,21
TLOAD1   21      2                      3
$ the table below will apply all the wet load at time zero
TABLED1 3
        0.0     1.      10000.  1.      endt

$ OPENFSI LOADING
$!
WETLOAD         2       2 FSISRV1
$!
WETELMG  6047539   TRIA6                                          +
+         347720  285770  347719  291761  291762  347762
WETELMG  6047540   TRIA6                                          +
+         318165  318184  350517  323786  323784  323744
WETELMG  6047541   TRIA6                                          +
+         273334  273535  273517  276408  276411  276307
WETELMG  6047542   TRIA6                                          +
+         350517  285005  350518  289430  289428  350589
ETC...

ENDDATA
```

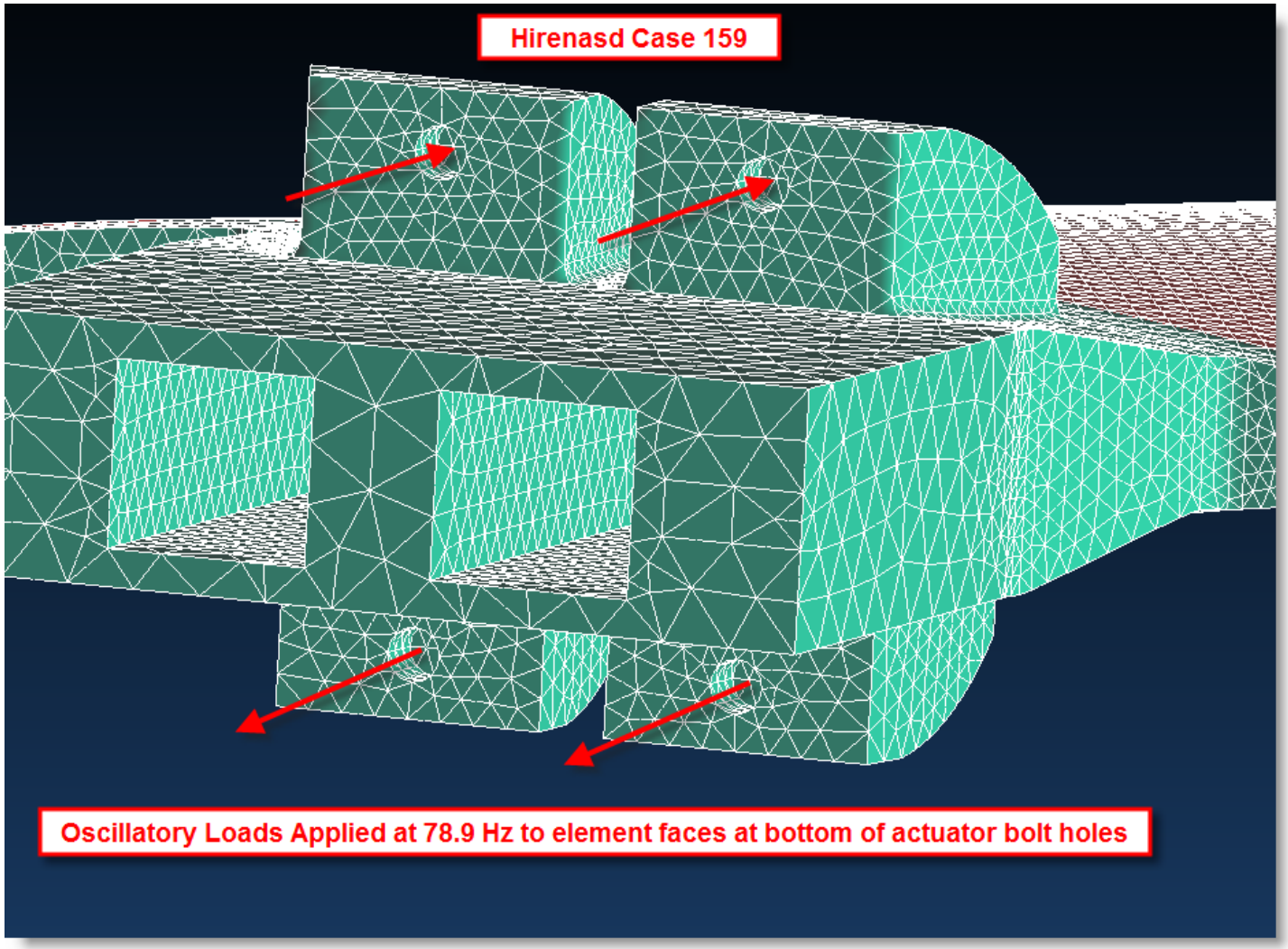
TRIA6 element face topologies on wetted elements

MSC Software

Metacomp Technologies

Oscillatory Load Setup

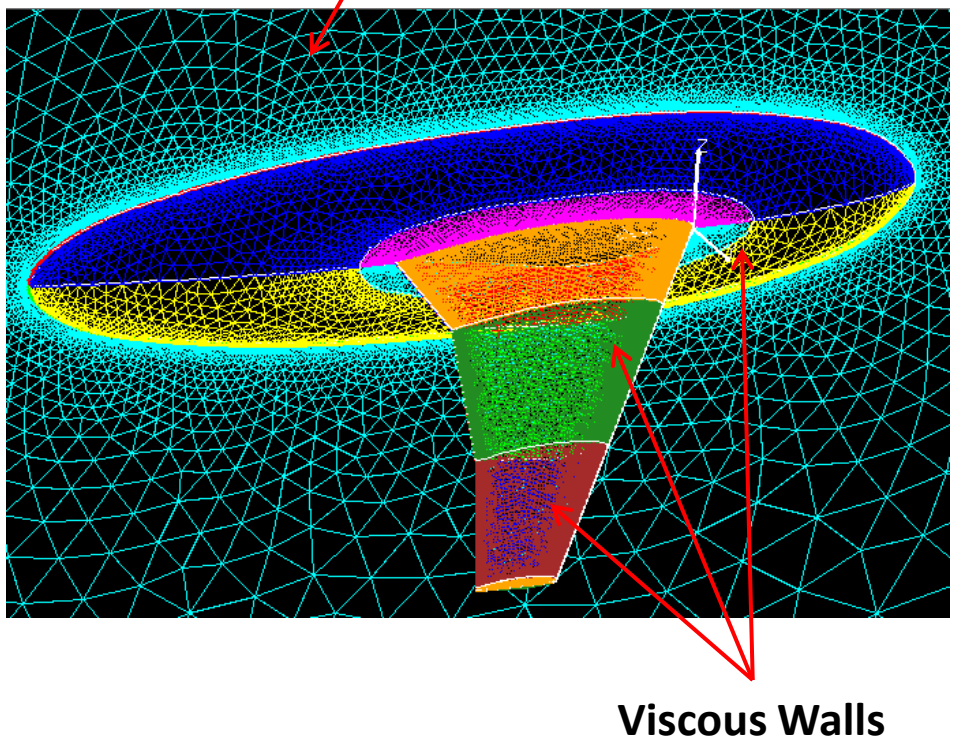
Case 159: Oscillatory Loads Scaled to obtain ~ 2.4mm vacuum steady state amplitude at node 600001



MSC Software

Metacomp Technologies

CFD++ Setup

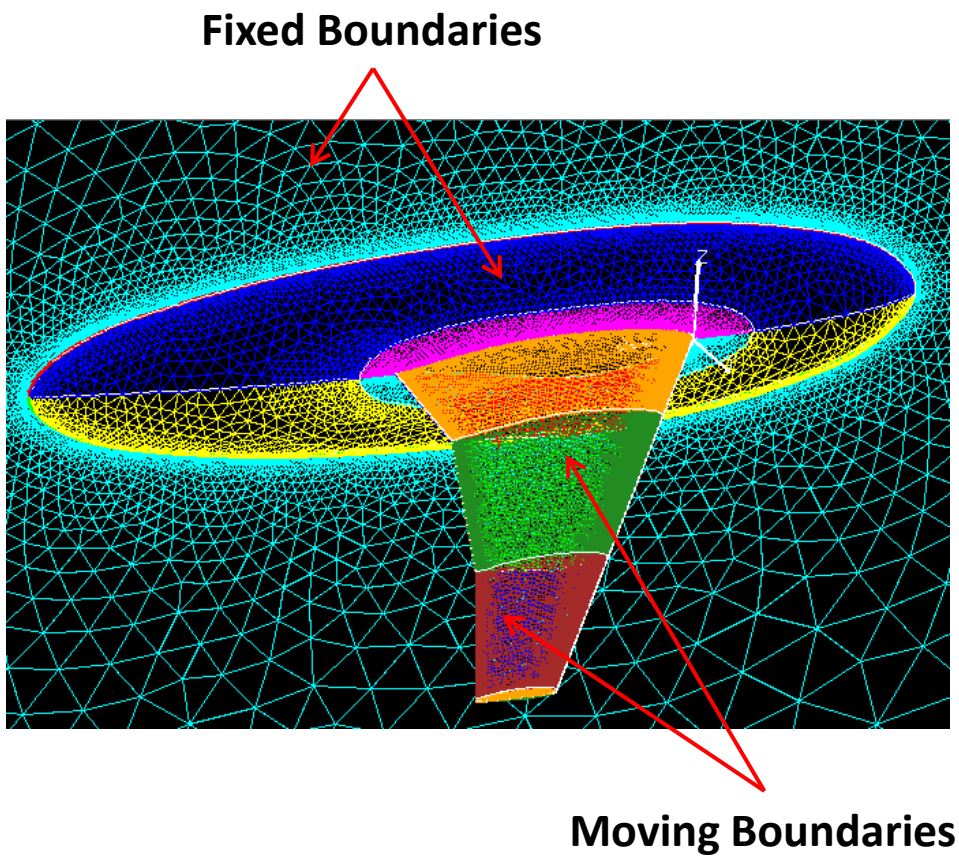


- RANS
- Turbulence model:
  - 2 equation realizable k-ε
  - Solve to wall for all grids
- Fluid: Nitrogen
- Steady case: coupled every 100 CFD steps
- Transient case
  - dt = 1.268e-4 sec (~100 steps/cycle)
  - 15 sub-iterations
  - Explicit FSI coupling

MSC Software

Metacomp Technologies

CFD++ Setup (Morphing)

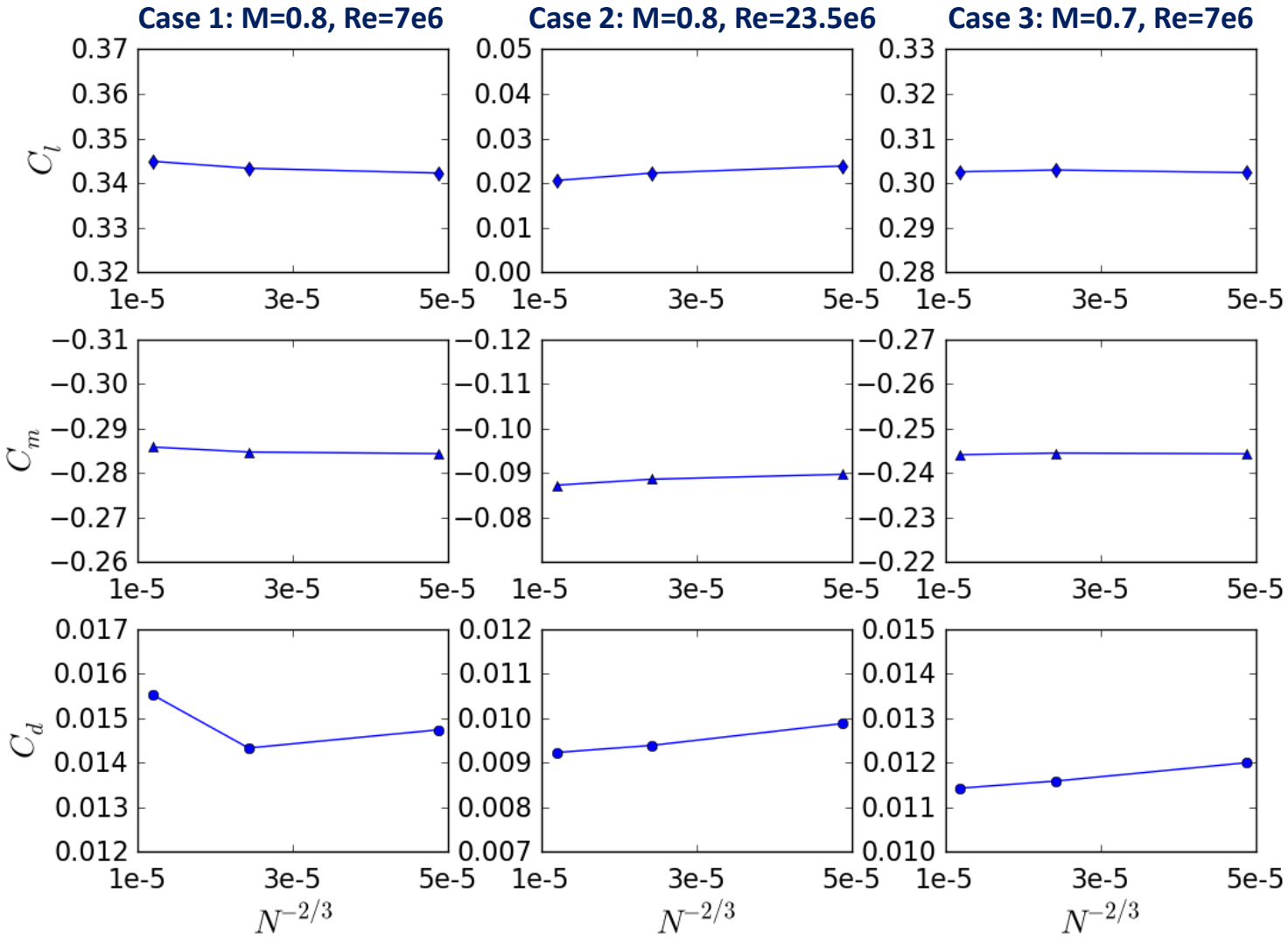


- Wing – moving
- Fuselage, Symmetry – Fixed
- Morphing restricted to a box around the wing/fuselage combination.

MSC Software

Metacomp Technologies

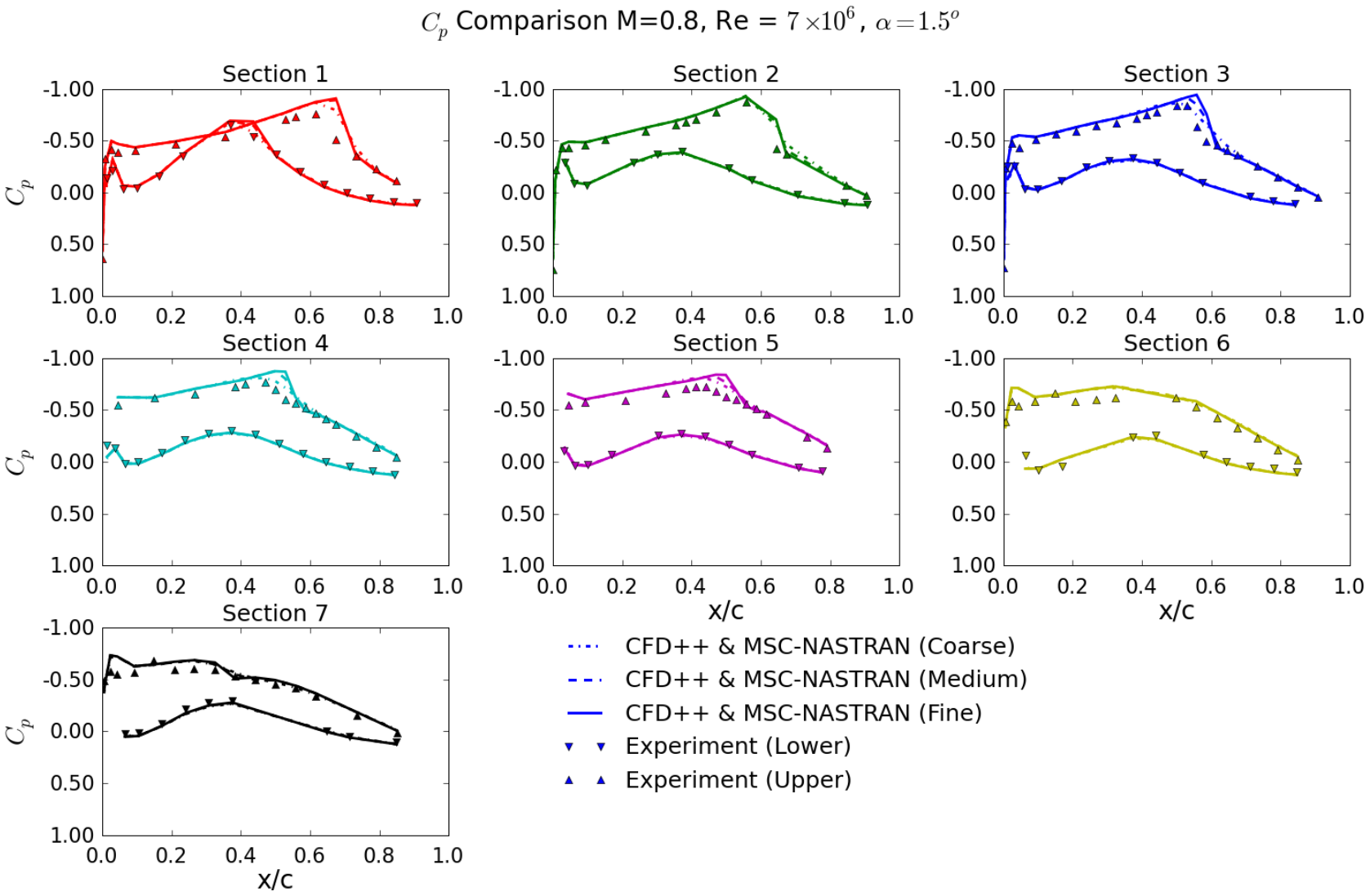
Grid Convergence



MSC Software

Metacomp Technologies

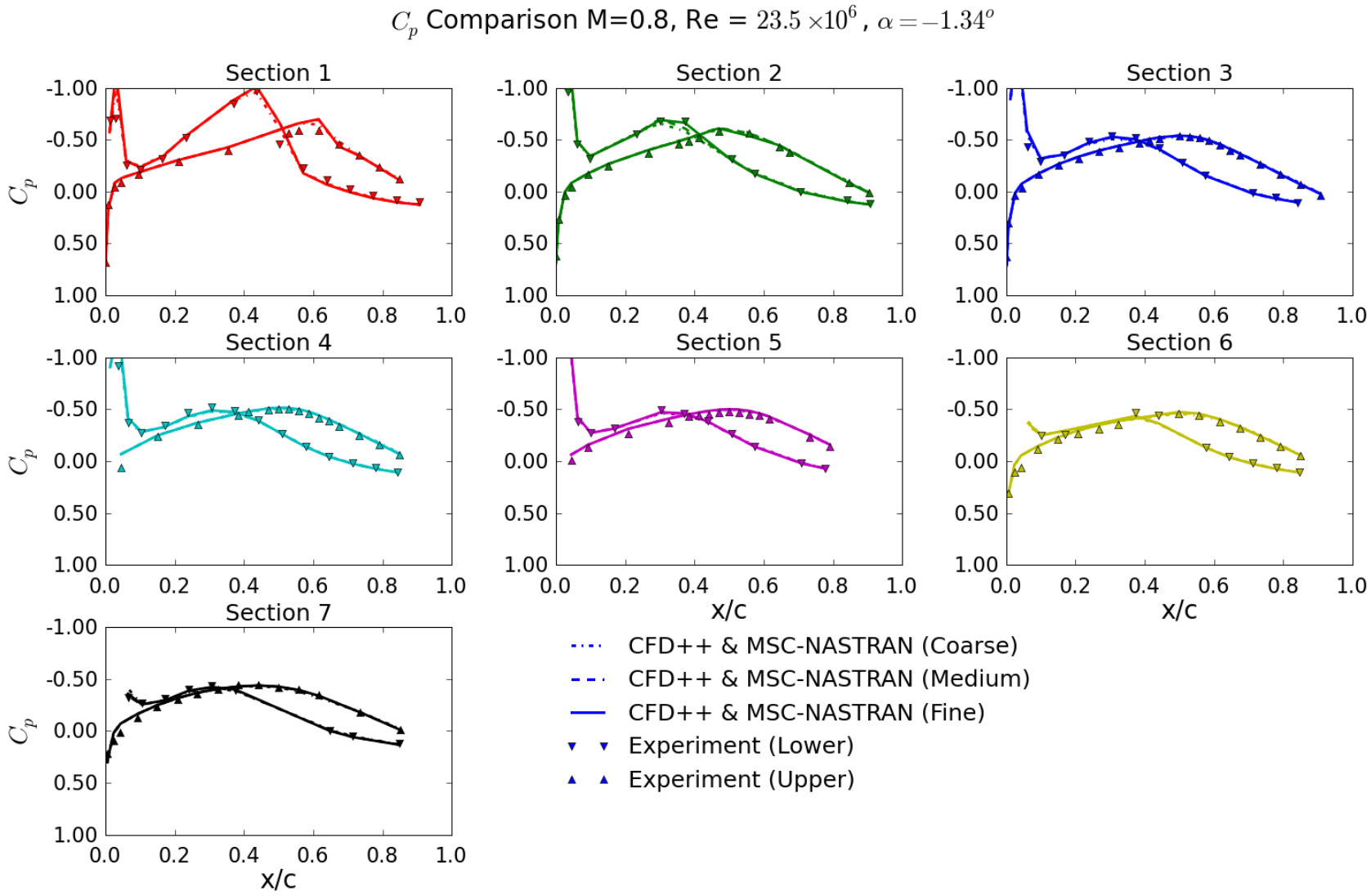
Steady State: Case1



MSC Software

Metacomp Technologies

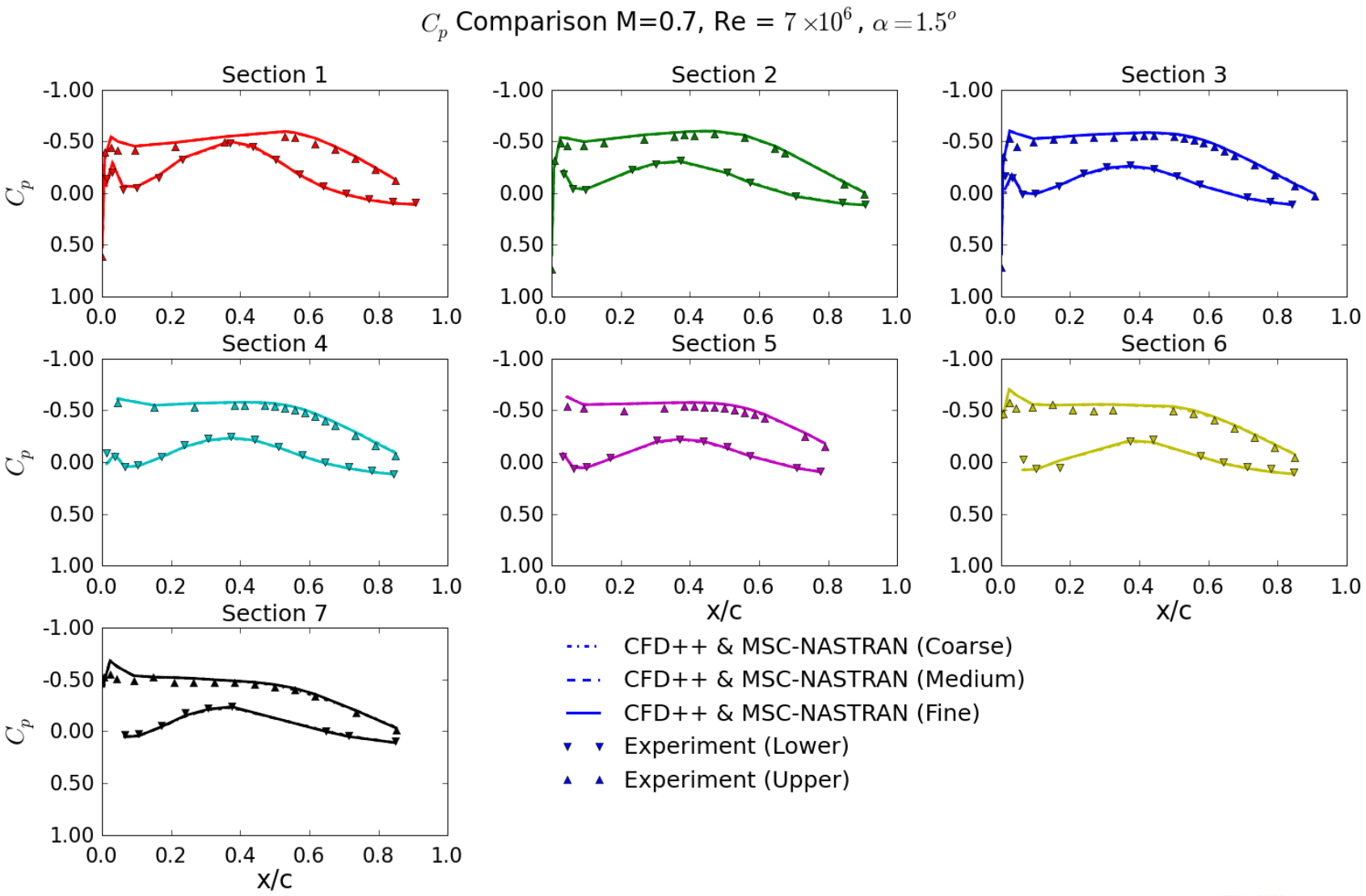
Steady State: Case 2



MSC Software

Metacomp Technologies

Steady State: Case 3



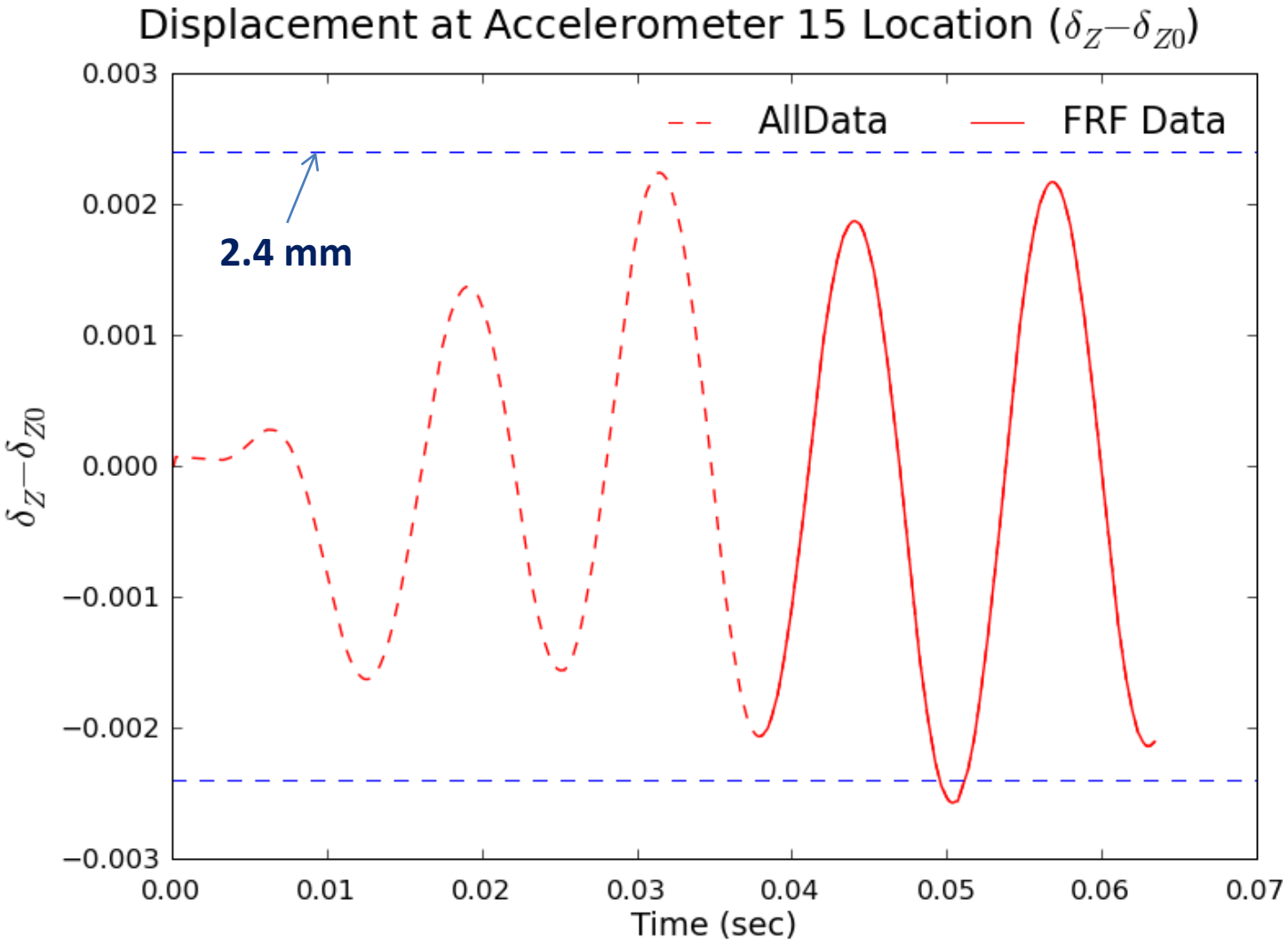
MSC Software

Metacomp Technologies

Transient Results

- **Transient: Plots of Cp phase and magnitude w.r.t the displacement at Accelerometer 15**
  - **Oscillatory mechanical loads excite the wing**
  - **For the coupled analysis we had difficulty in determining the mechanical load amplitude to get the exact displacement amplitude seen in the experiment**
  - **This is also complicated by the fact that the excitation was at the second mode frequency (resonance)**
  - **Time to reach steady state was too large to allow fully coupled simulation. 20% structural damping added. (we had limited time access to the compute cluster)**

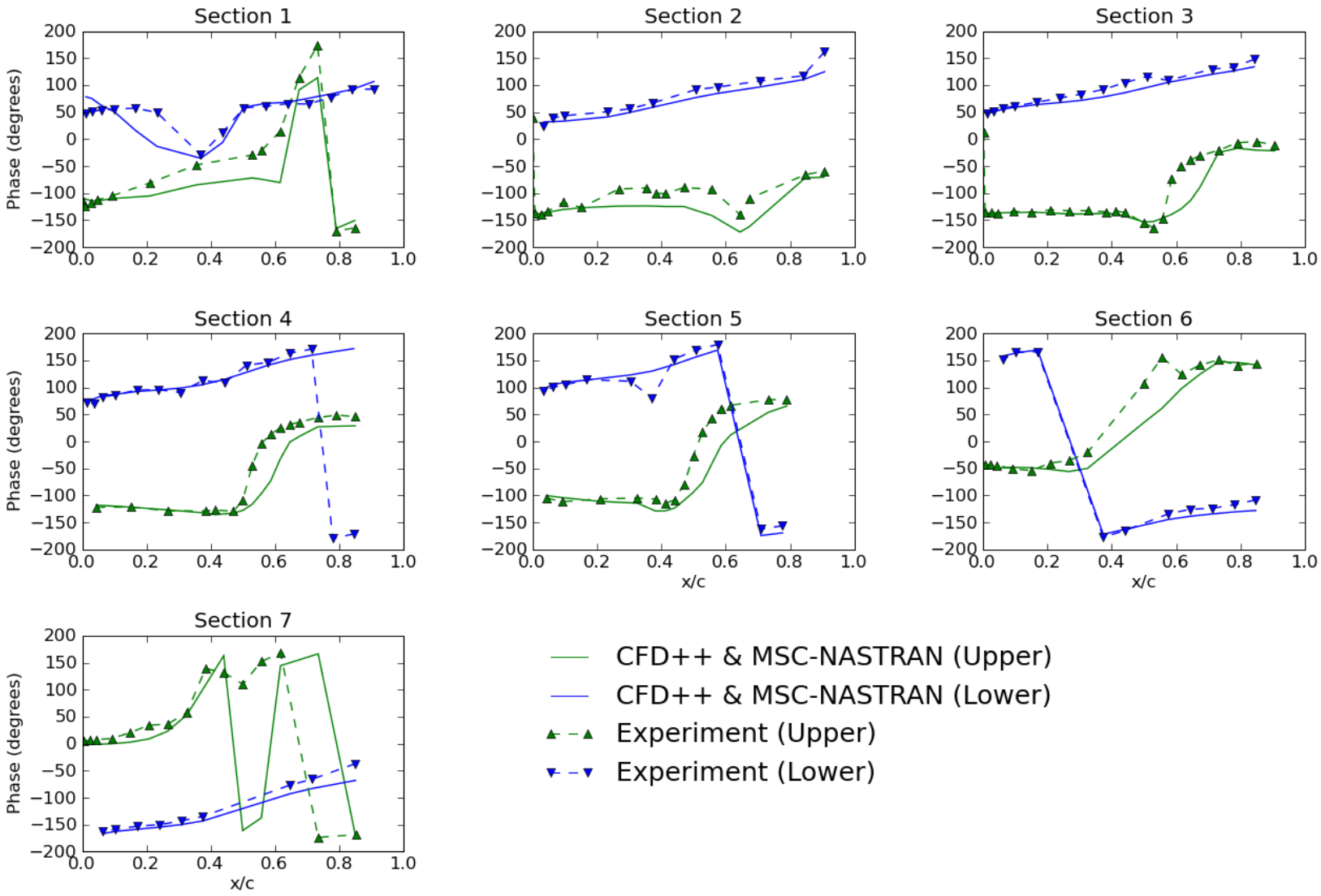
Unsteady: Case 1 (Coarse)



MSC Software

Metacomp Technologies

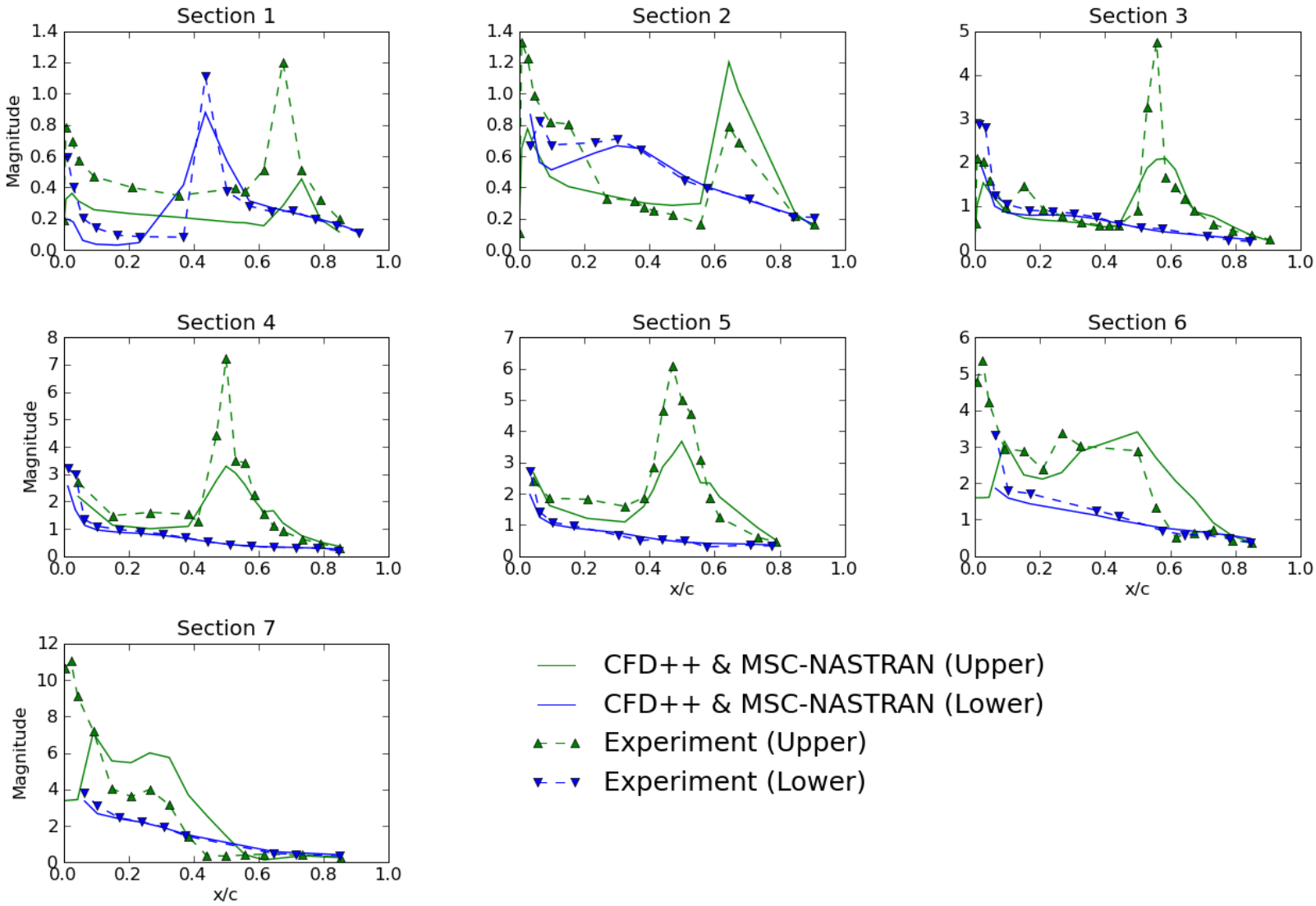
Transient Cp Phase: Mach=0.8, Re=7e6, α=1.5°



MSC Software

Metacomp Technologies

Transient Cp Mag.: Mach=0.8, Re=7e6, α=1.5°



MSC Software

Metacomp Technologies

Hardware and Run Times

- **CFD++: 2.1 GHz AMD Opteron cluster with 24 CPUs and 128 GB per node.**
- **NASTRAN: 3.4 GHz Intel i7 CPU with 64 bit Windows and 16 GB RAM.**

	Coarse	Medium	Fine	Coarse (unsteady)
No. of processors CFD/Morphing	96/48	240/48	240/48	192/48
Single step time (s) CFD/Morphing/ MSC-NASTRAN	9 /60/90*	24/415/90*	75/2600/90*	40/60/90*
Steady Run Time (hrs) 5 coupling steps	1.46	4.0	14.15	---
Unsteady Run Time (hrs) 500 steps				26.4

*Some uncertainty on the Nastran step time

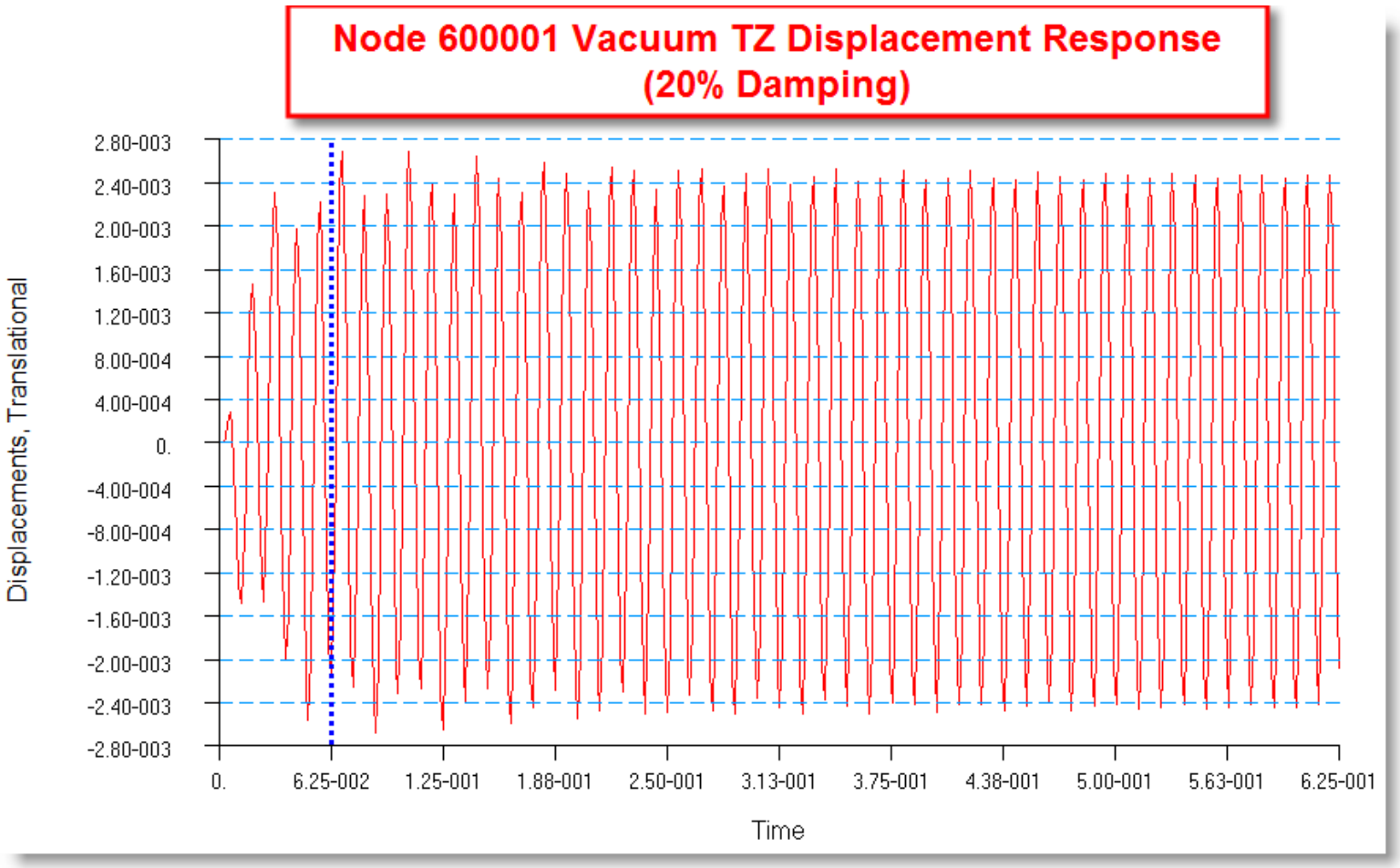
MSC Software

Metacomp Technologies

Results Discussion

- General coupling approach with full CFD++ and MSC-NASTRAN models
- Good comparison with experimental data for all steady cases
- Case 1: shock-like structure at inboard sections not present in experimental data
- Transient case:
  - Phase trends ok but shifted a bit aft for upper surface
  - Upper surface magnitudes do not match as well
    - Influence of mode 1
    - Not at steady state oscillation
    - Too much structural damping

Lessons Learned/Next Steps



Would have preferred to run the coupled analysis much longer to get improved steady state results

MSC Software

Metacomp Technologies

Lessons Learned/Next Steps

- **Transient run times extensive because of time required to reach steady state**
  - **Run MSC-NASTRAN stand-alone until steady state**
  - **Use zero-crossing displacement and velocity as initial condition before starting coupled run**
  - **Reduce structural damping to more reasonable levels**

Thank You

- **Beerinder Singh**
  - 818-735-4880, ext. 259
  - bsingh@metacomptech.com
- **Jack Castro**
  - 425-891-3177
  - jack.castro@mscsoftware.com

MSC Software

Metacomp Technologies