ASD/CLAS Nonlinear Coupled Loads Analysis Capability
-
Deadbands

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Background

- 2005: NASA Mission Critical Risk Mitigation Initiative
  - Shuttle/payloads nonlinear transient coupled loads analyses (CLA) initiated
  - Simulate/investigate the impact of complex component interfaces involving deadbands
- 2005-2006: Initial Nonlinear CLAs
  - Executed with commercially available heritage tools
  - Resulted in unrealistic response time-histories
  - Dominated what can be best described as “numerical noise/chatter”
- 2006: ASD's Nonlinear CLA Capability was Investigated
  - Rigorous verification process performed
    - Resulting nonlinear time-histories were shown to be physically realizable and free of any numerical noise/chatter
    - Solution conformed to the physical parameters and constraints defined in the analysis

Background – Cont'd

- 2006: ASD's Nonlinear Solution Selected for Mission Specific Critical Risk Mitigation Analyses
  - 2006-2008: ASD performs all Orbiter/payloads nonlinear CLAs
    - STS-118, 122, 127
- 2009: ASD's Nonlinear CLA Capability Commercially Available
  - ASD/CLAS linear capability extended to include nonlinear capability
  - STS-129: Lockheed-Martin (Houston) completes the most complex Space Shuttle/payloads nonlinear CLA ever conducted for NASA
    - See ASD/CLAS Customer Success Story: Lockheed-Martin

ASD's nonlinear solver, selected by NASA and NASA's prime cargo integration contractor, is commercially available in ASD/CLAS.

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Executive Summary

This briefing presents a summary of the capability within ASD's Coupled Loads Analysis System (ASD/CLAS) to simulate deadbands.

The ASD/CLAS capability of executing nonlinear deadband interfaces between components has enabled analysts community to simulate/investigate complex interfaces between components, the most obvious being interfaces with deadbands and/or snubber type interfaces (one direction open ended deadbands).

This briefing illustrates this capability with a Shuttle/payloads nonlinear transient CLA example.

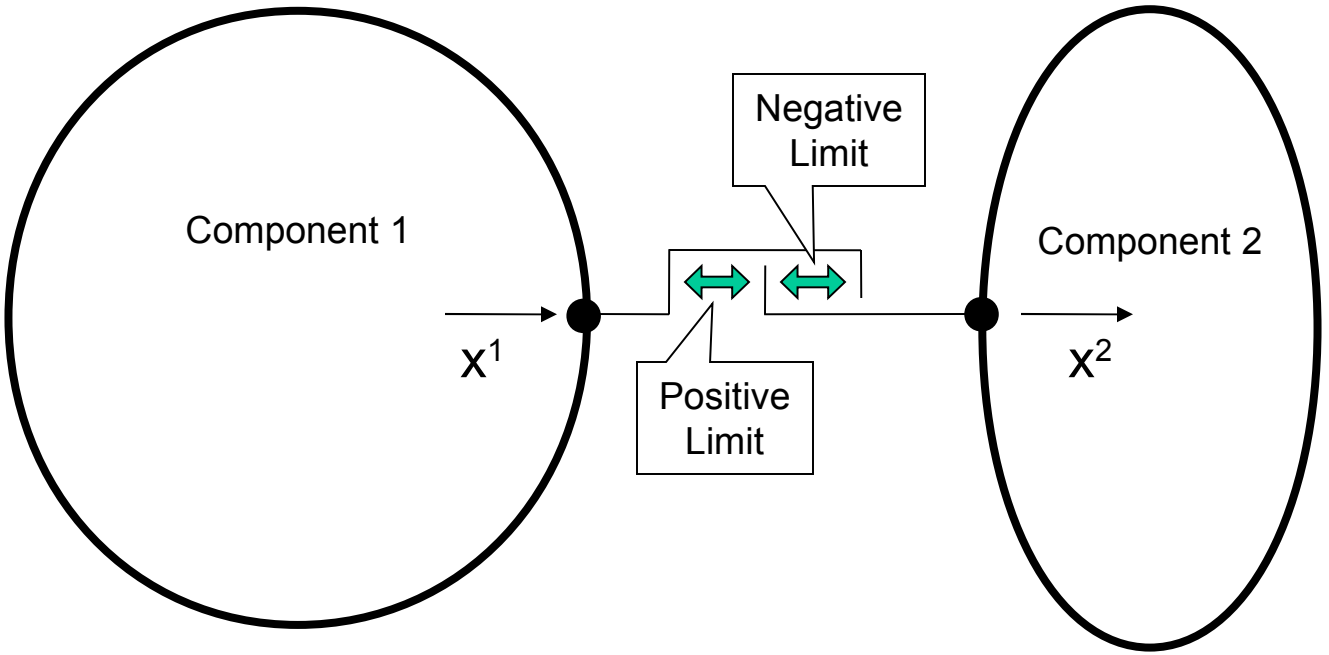
ASD/CLAS Nonlinear Capability

- With ASD/CLAS's nonlinear component interface capability, simulations involving deadbands and nonlinear springs are easily accomplished
  - Deadbands
    - Deadbands (two-sided)
    - Snubbers (one-sided deadbands)
  - Some nonlinear spring examples
    - Bi-linear springs
    - Tri-linear springs
    - Stiffening springs
    - Softening springs
    - Tension only springs (straps)
    - Compression only springs (snubbers, bumpers)
    - Combinations of the above

- Graphical depiction of deadbands and snubbers given in following charts

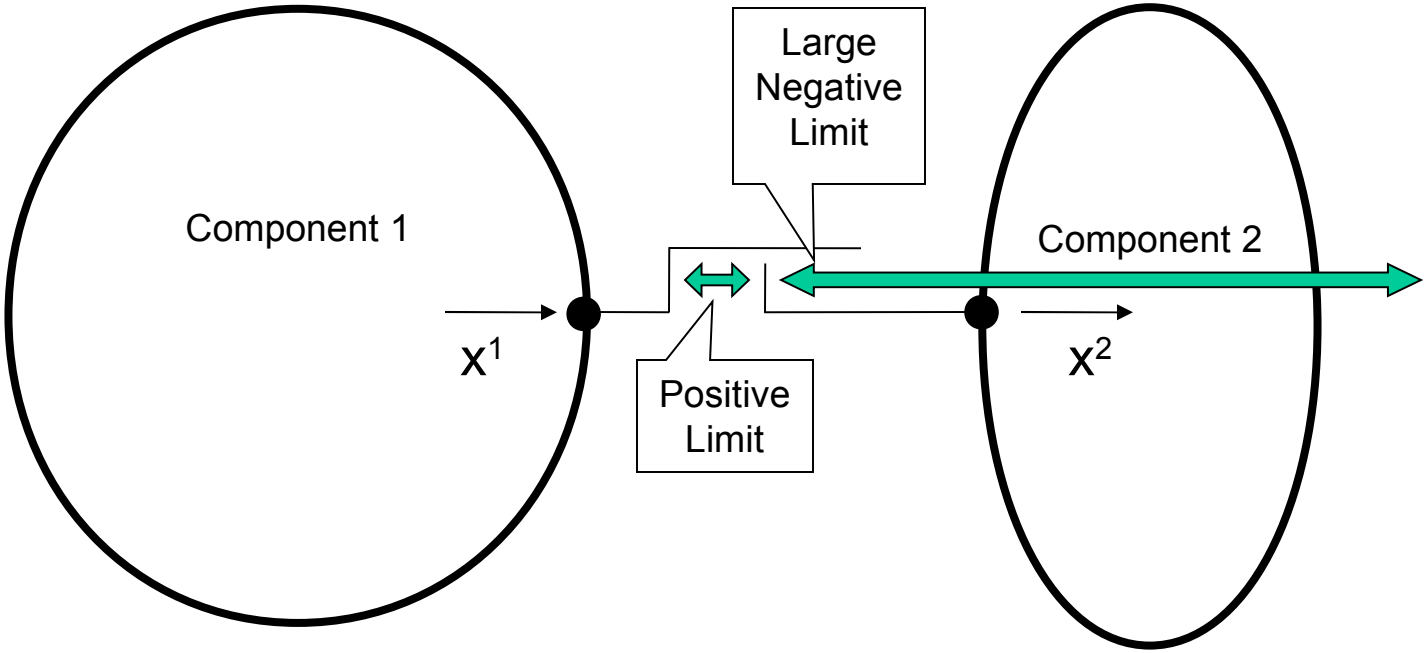
Deadband Interfaces

- ASD/CLAS deadband interface between two components' co-linear interface Degrees of Freedom (DoFs)



Snubber Interfaces

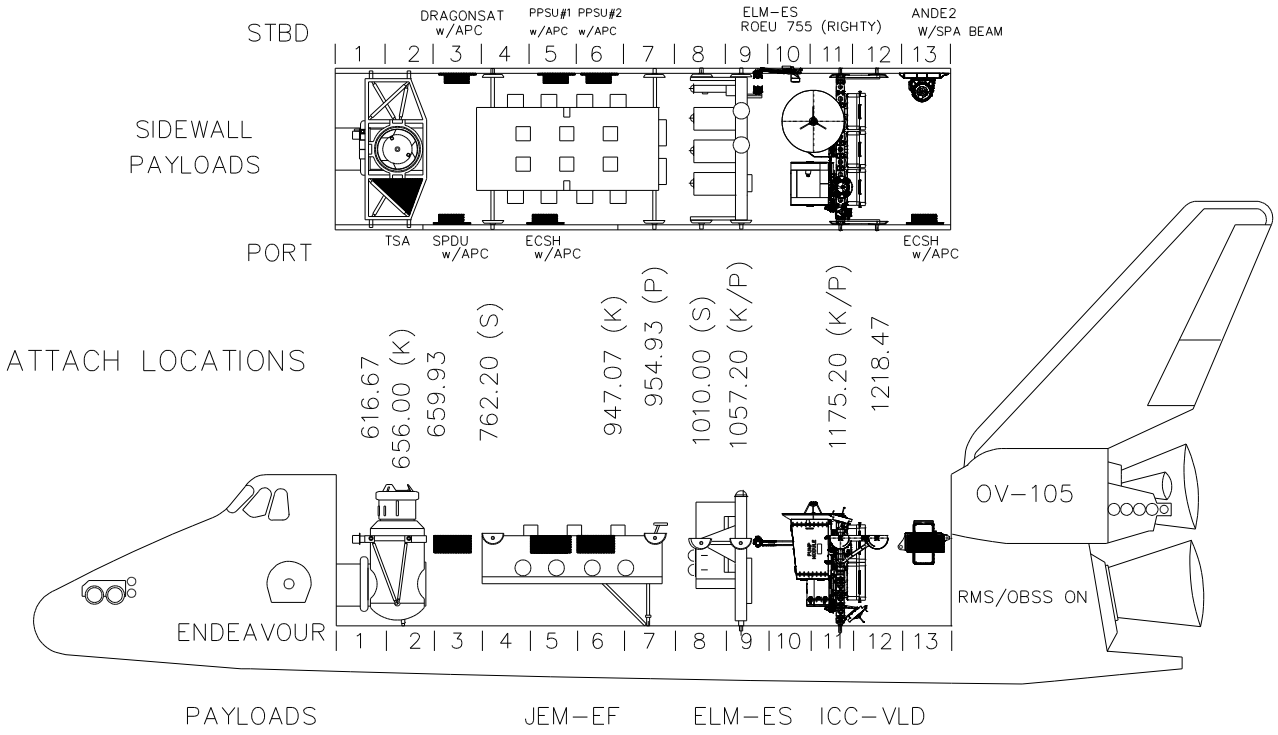
- ASD/CLAS snubber interface between two components' co-linear interface Degrees of Freedom (DoFs) with one open ended limit



Example Problem

- Analysis Objective: assess the impact of the ICC-VLD cargo deadbands on response by conducting a nonlinear transient CLA
  - Three ORUs: AFRAM/PFRAM deadbands (8 each)
  - Six Batteries: Battery FSE Kinematic Mount deadbands (9 each)
  - Total of 78 deadbands in this CLA

2J/A Cargo Bay Liftoff Configuration



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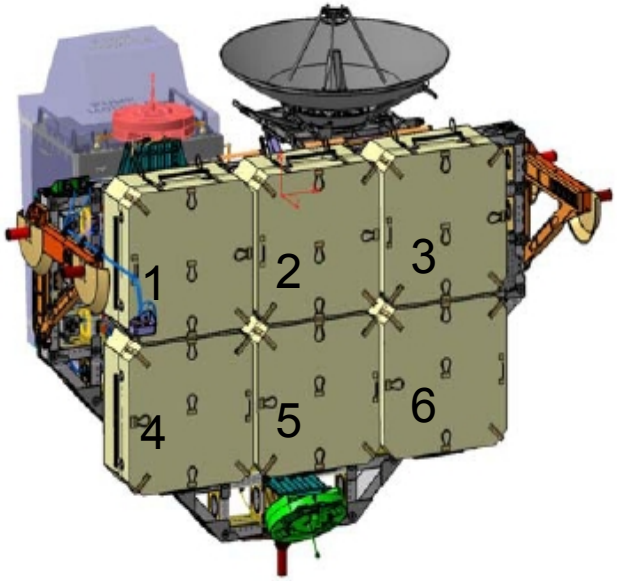
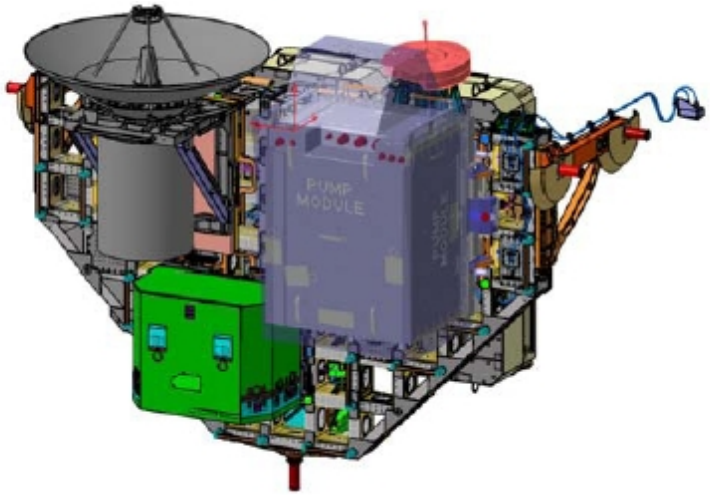
2J/A ICC-VLD Liftoff Configuration



Aft View: 6 Direct Mount Batteries



Fwd View: 3 FRAM Based ORUs
- Pump Module
- LDU
- SGANT

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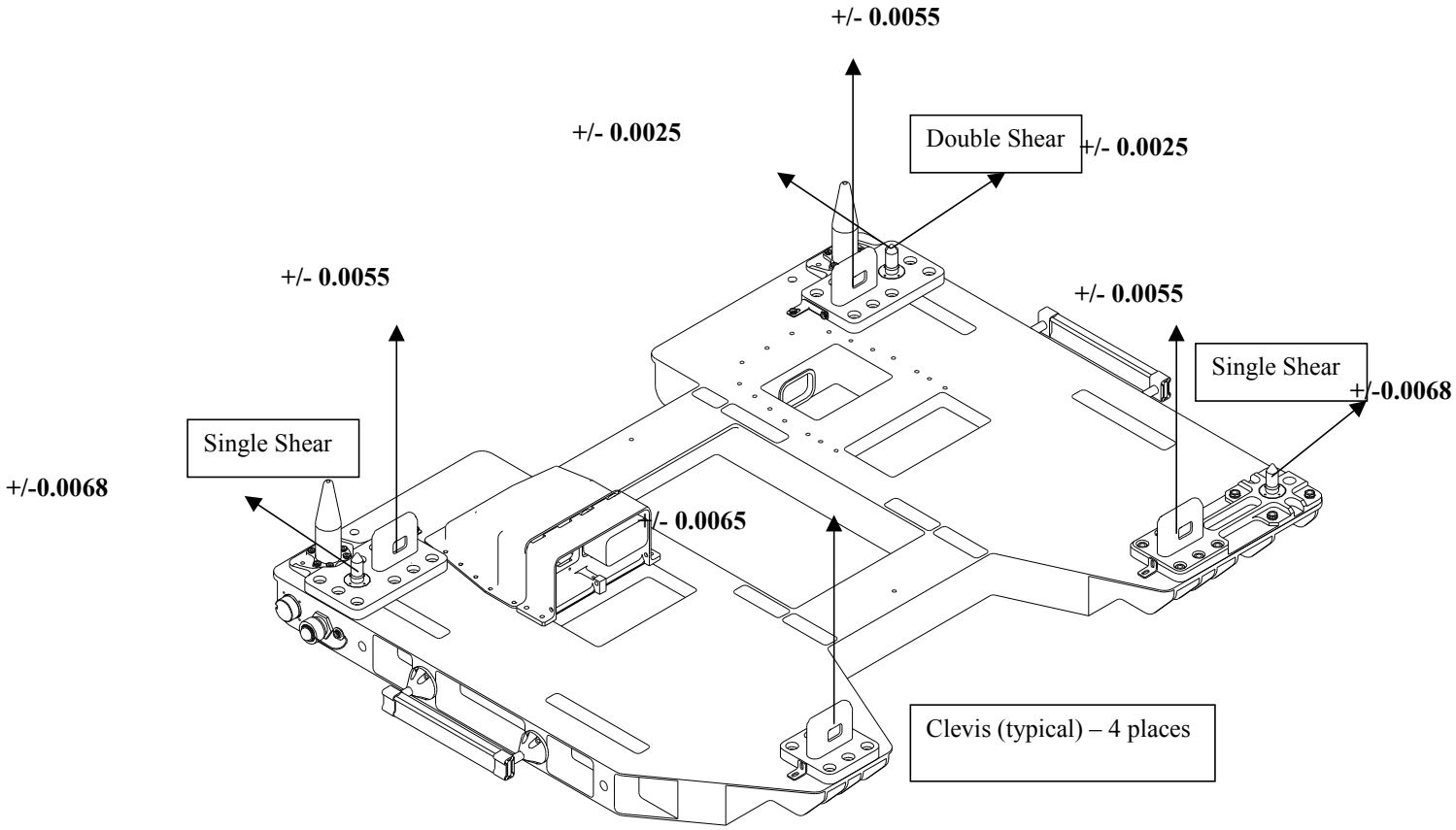
FRAM Interface Deadband Limits



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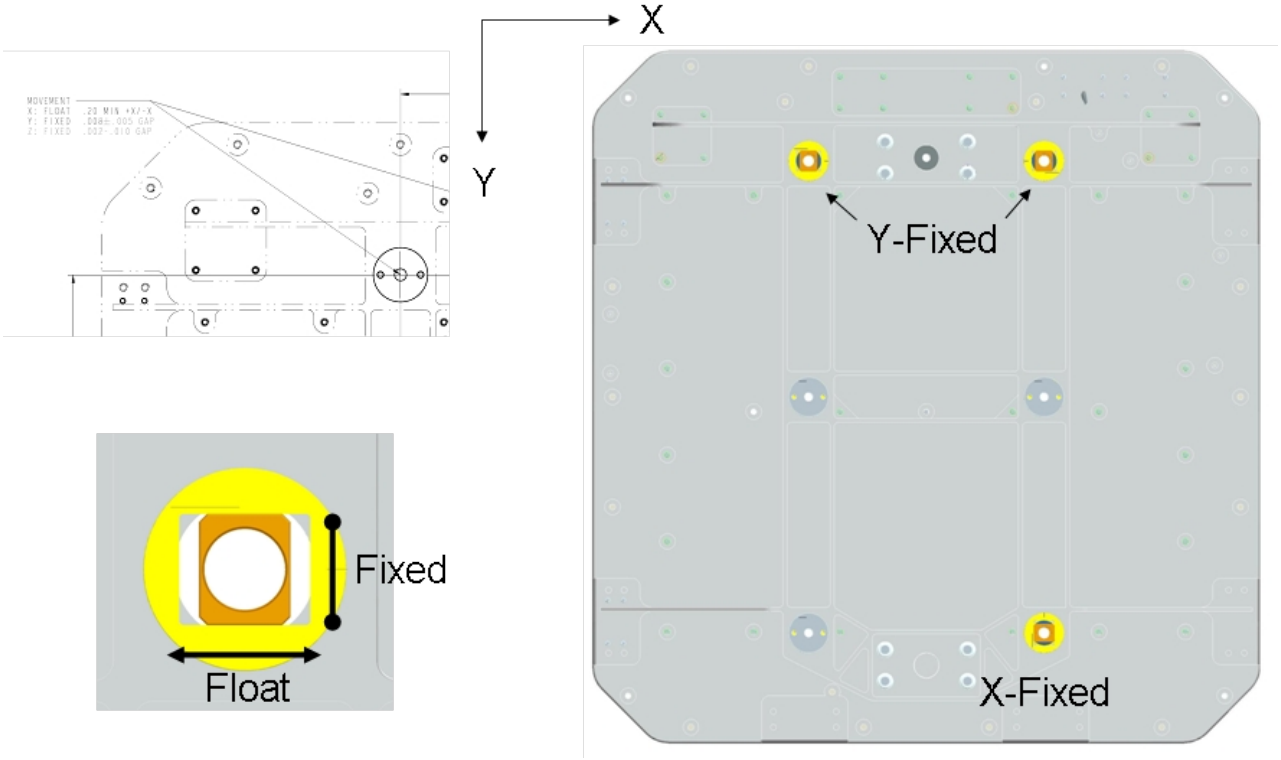
Battery FSE Kinematic Mount Deadband Limits



Fixed Shear directions (3 per Battery): **+/- 0.0064”**
Tension directions (6 per battery): **+/- 0.0025”**

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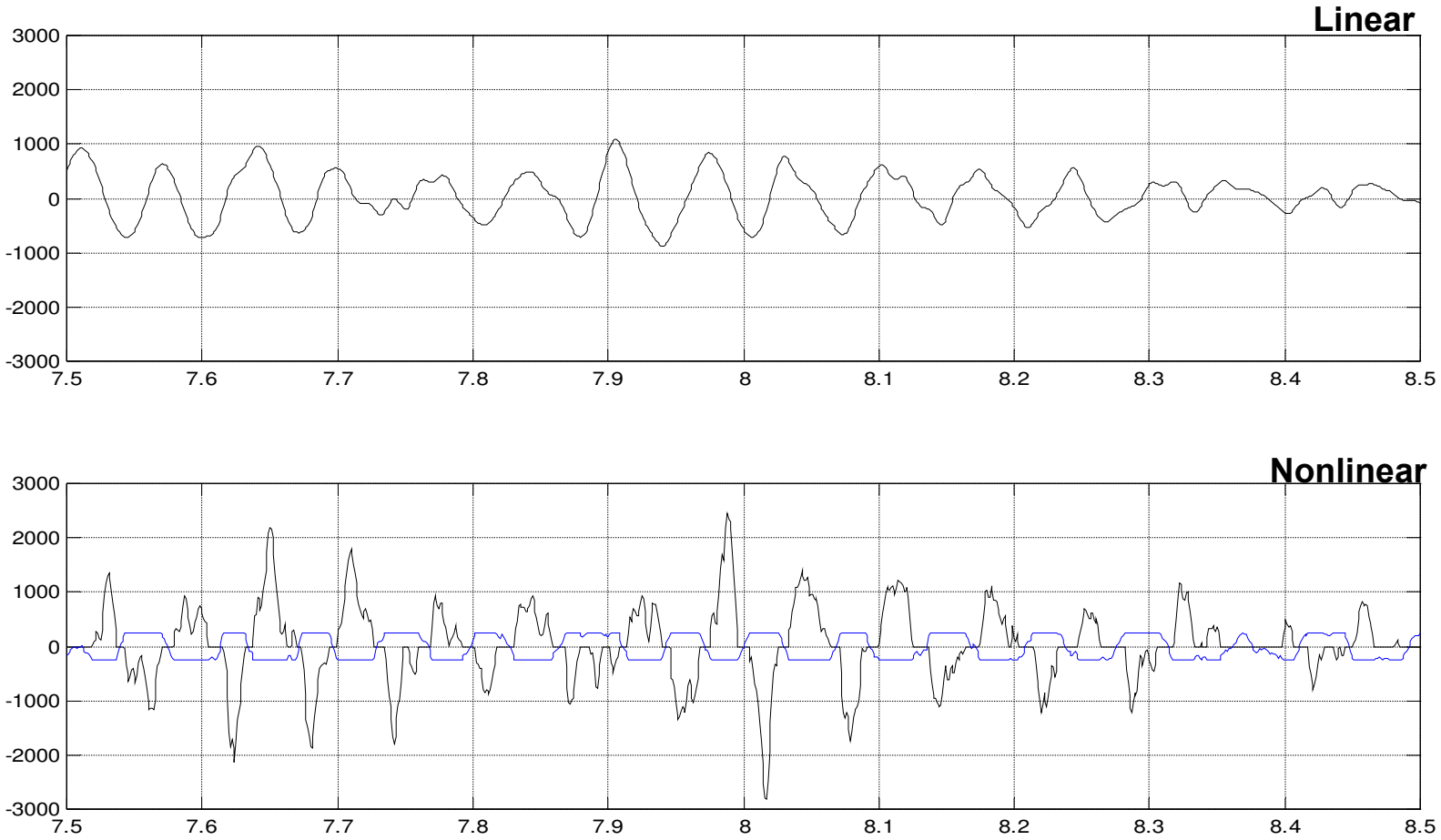
Highly Impacted Zo Shear Force - Liftoff



Battery 5: Shear Force (Node 653, Zorb) and Relative Displacement – (Blue Line x 40000)
Forcing Function: CLO1001; 7.5-8.5 second segment

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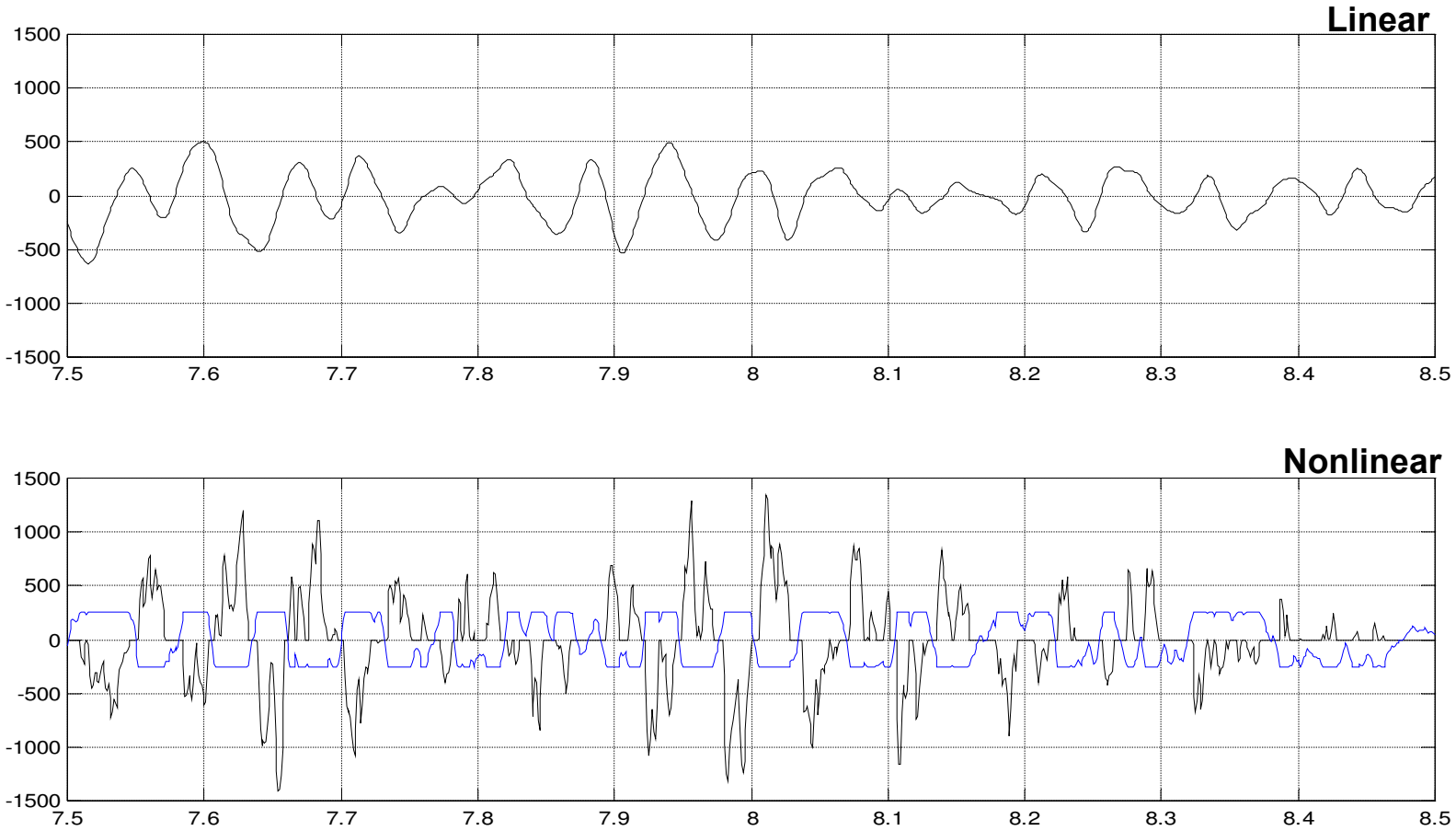
Highly Impacted Yo Shear Force - Liftoff



Battery 5: Shear Force (Node 655, Yorb) and Relative Displacement – (Blue Line x 40000)
Forcing Function: CLO1001; 7.5-8.5 second segment

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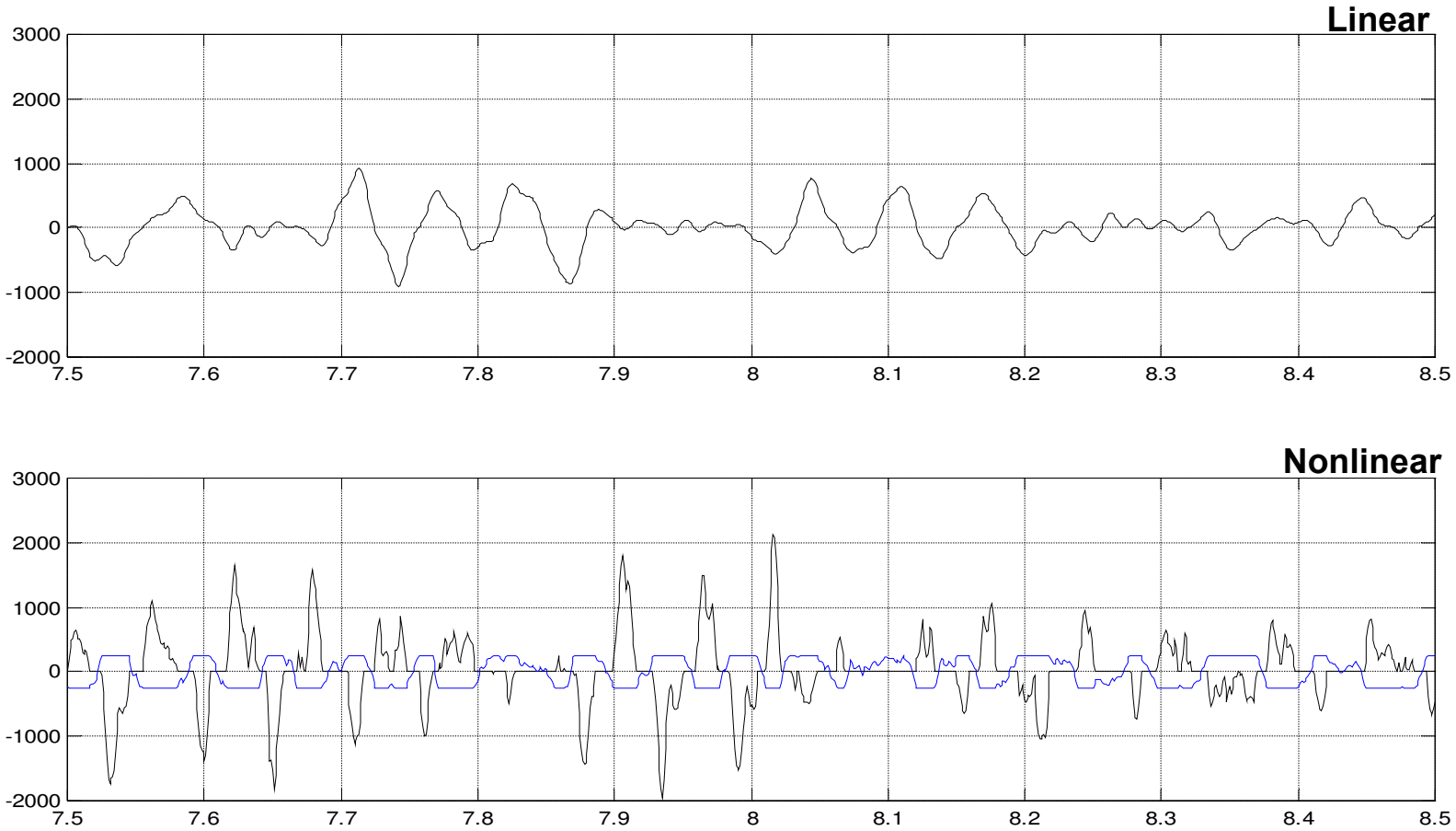
Highly Impacted Zo Shear Force - Liftoff



Battery 5: Shear Force (Node 2183, Zorb) and Relative Displacement – (Blue Line x 40000)
Forcing Function: CLO1001; 7.5-8.5 second segment

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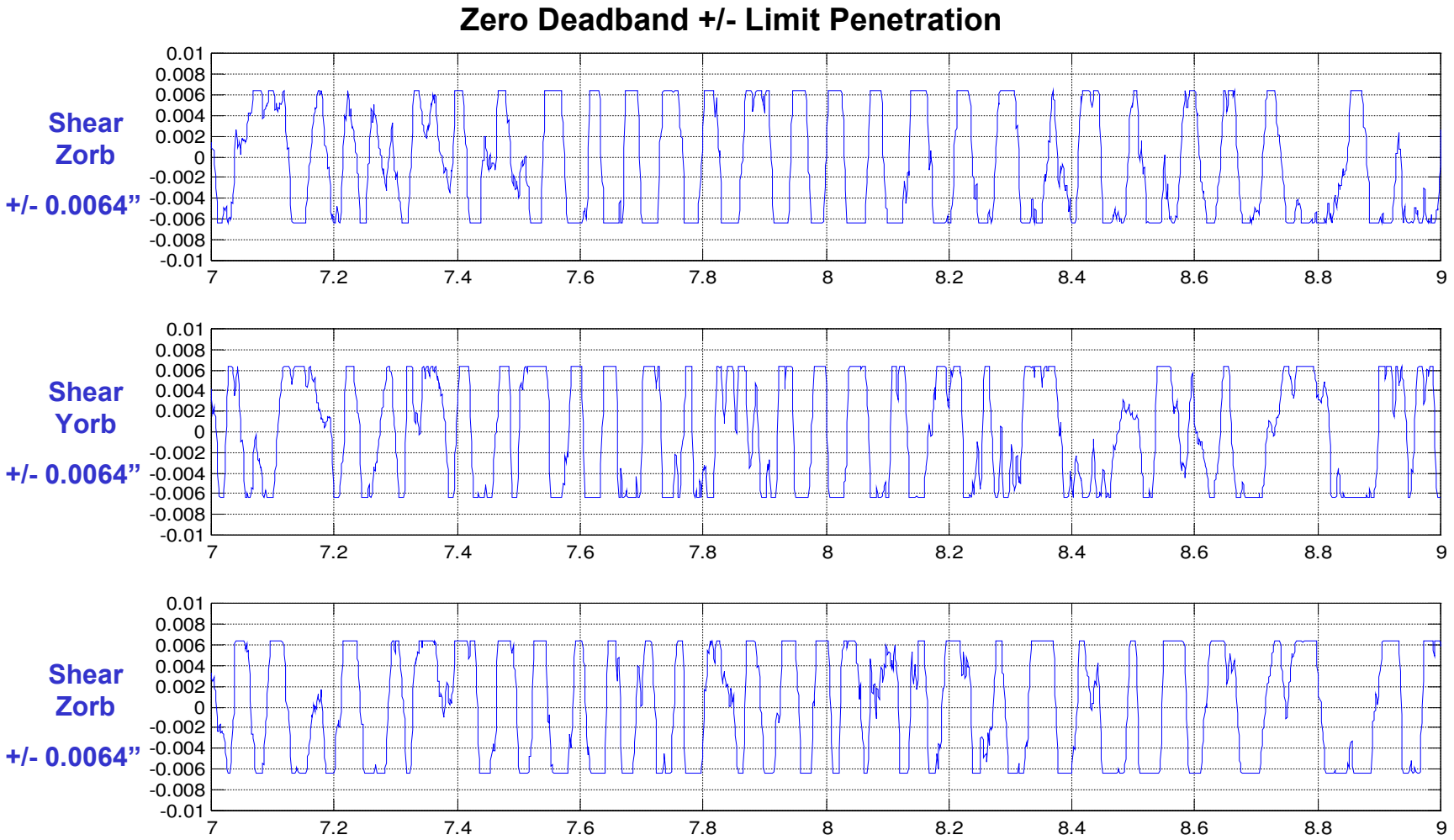
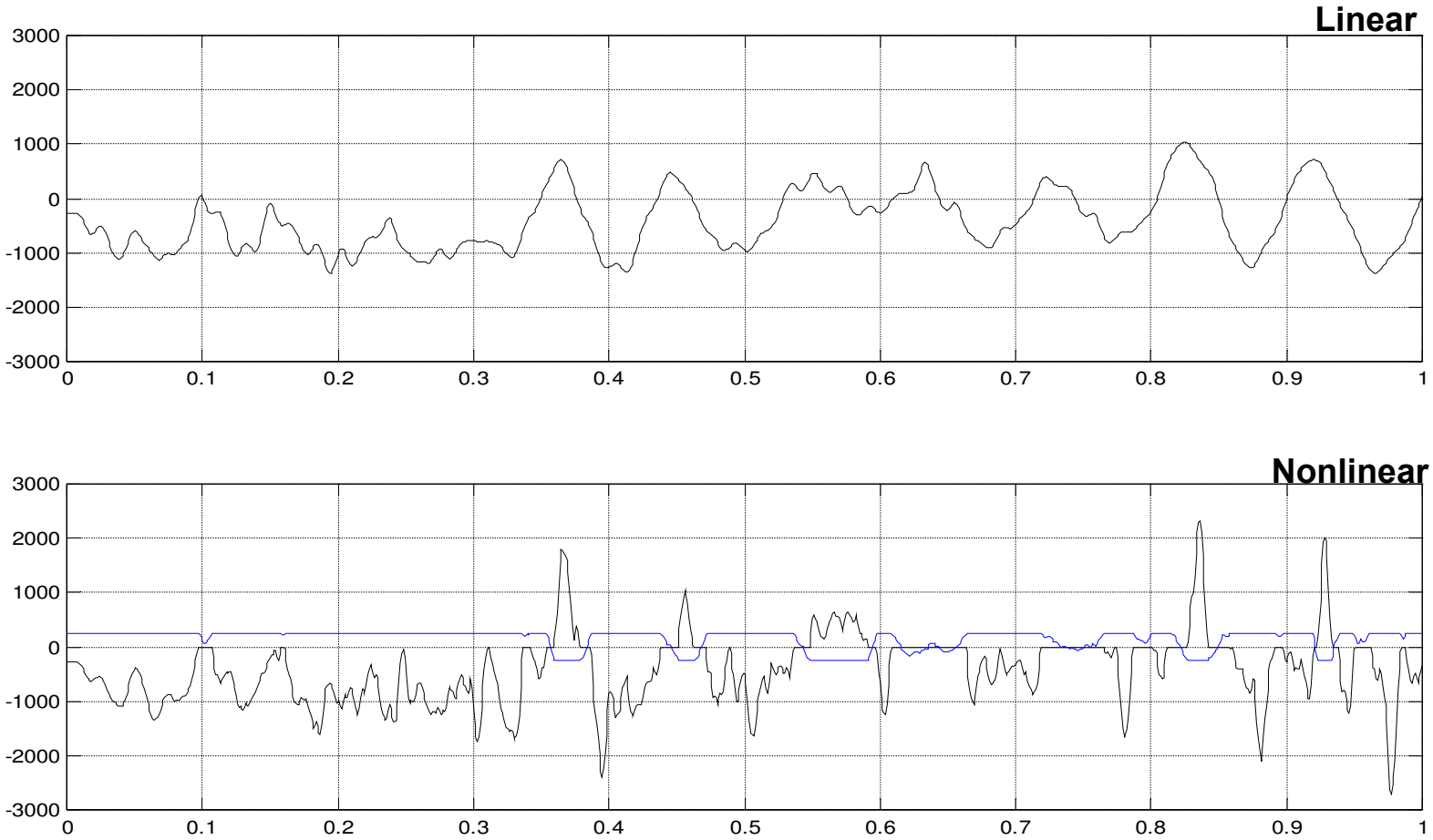
Kinematic Mounts Interface Rel. Disp. : Liftoff



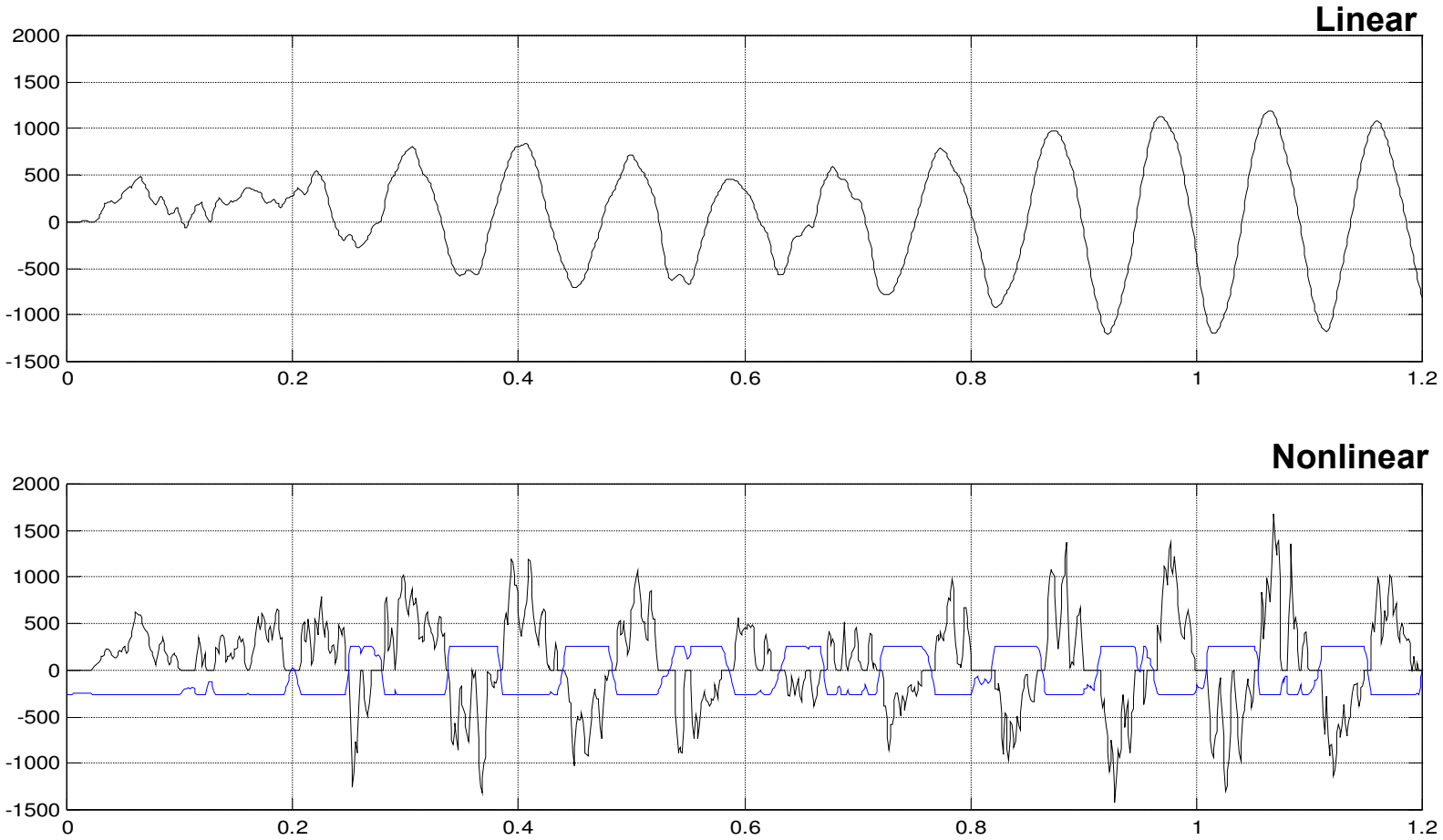
Battery 5: Kinematic Mounts Interface Relative Displacements(in) Nodes 653, 655, and 2183
Forcing Function: CLO1001; 7-9 second segment

Highly Impacted Zo Shear Force – Landing



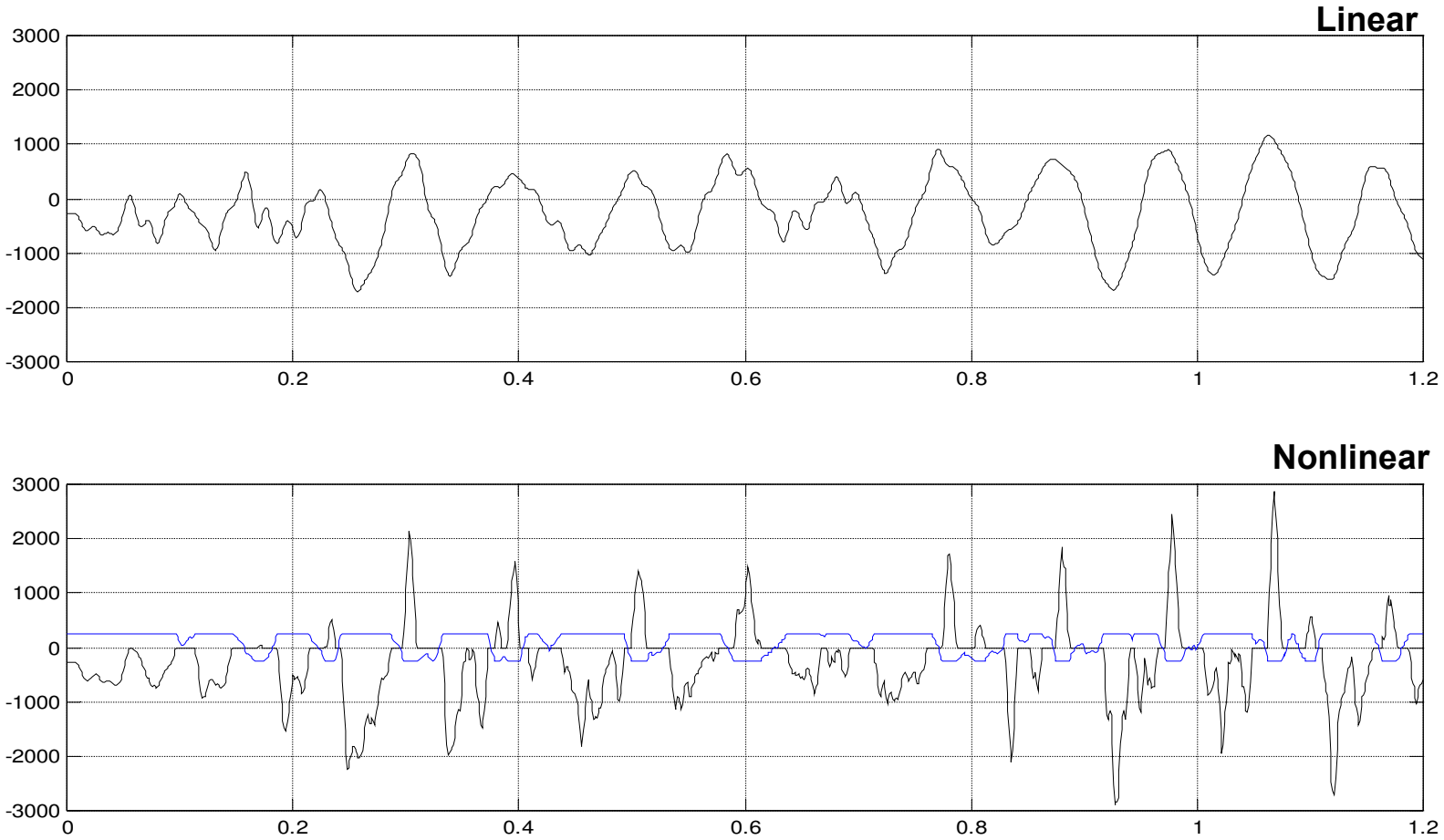
Battery 5: Shear Force (Node 653, Zorb) and Relative Displacement – (Blue Line x 40000)
Forcing Function: LG7525

Highly Impacted Yo Shear Force – Landing



Battery 5: Shear Force (Node 655, Yorb) and Relative Displacement – (Blue Line x 40000)
Forcing Function: LG7525

Highly Impacted Zo Shear Force – Landing



Battery 5: Shear Force (Node 2183, Zorb) and Relative Displacement – (Blue Line x 40000)
Forcing Function: LG7525

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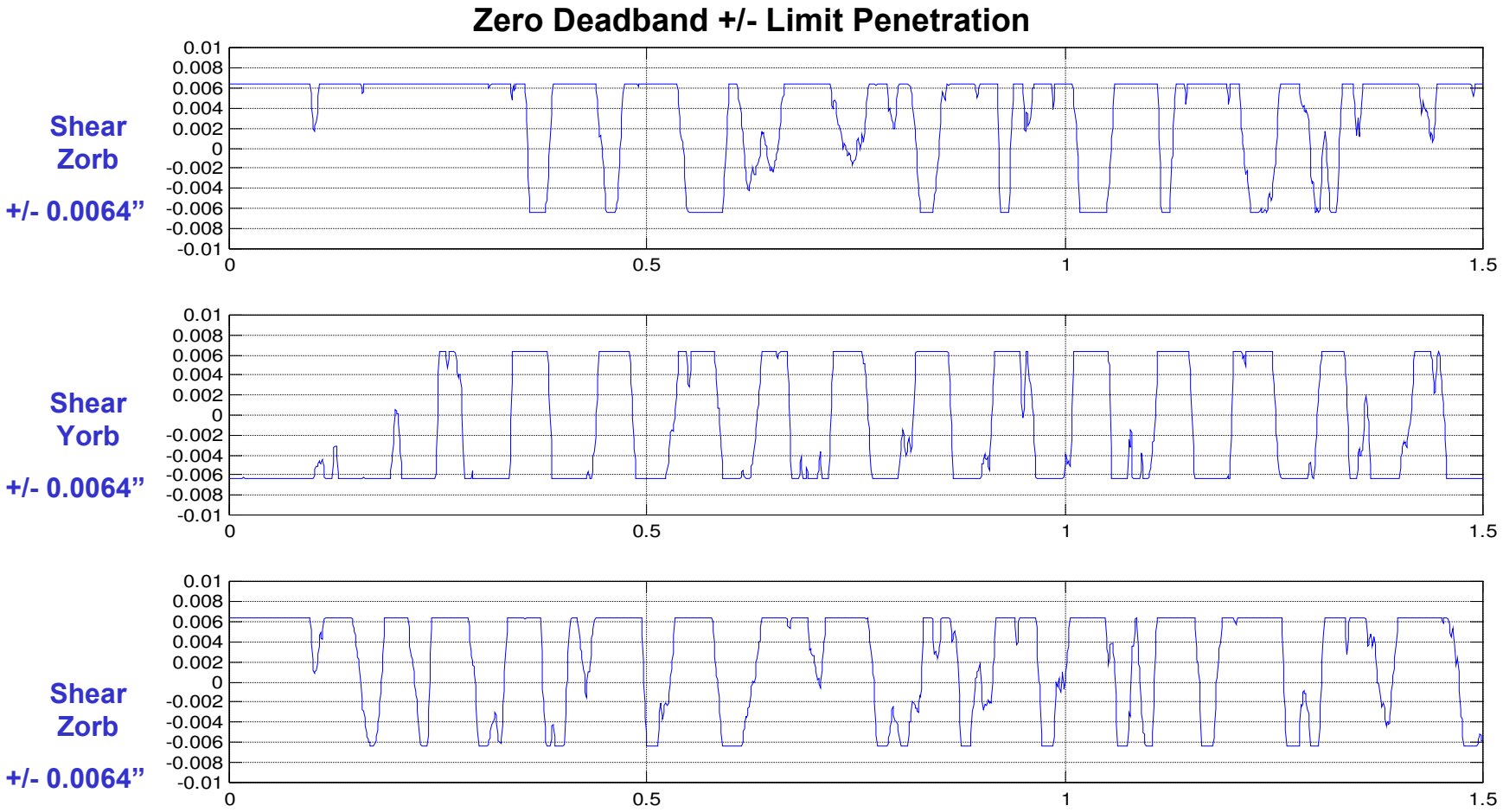
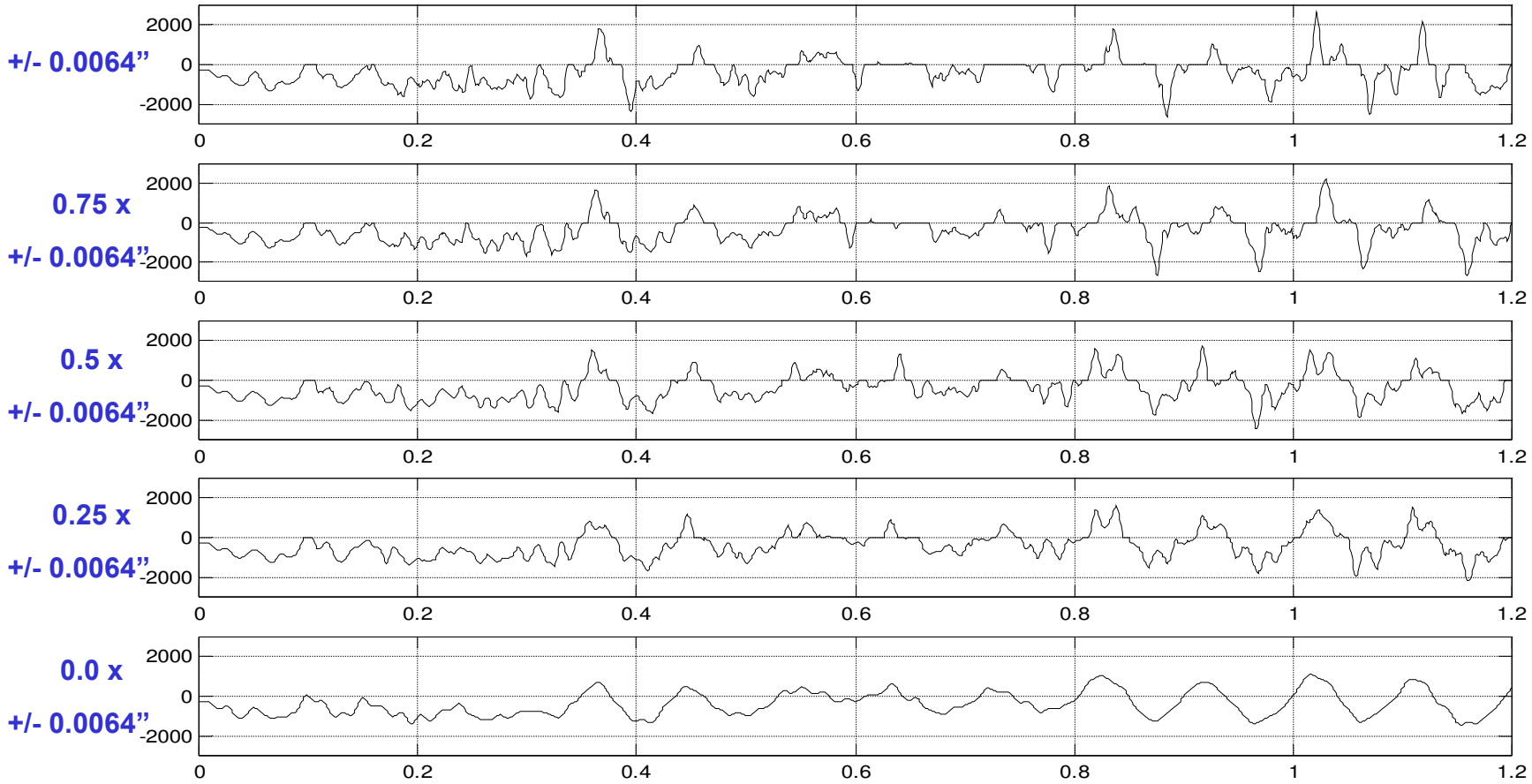
Kinematic Mounts Interface Rel. Disp.: Landing



Battery 5: Kinematic Mounts Interface Relative Displacements(in) Nodes 653, 655, and 2183
Forcing Function: LG7525

Convergence: Highly Impacted Zo Shear Force: Landing



Battery 5: Shear Force Node 653 Zorb
Forcing Function: LG7525

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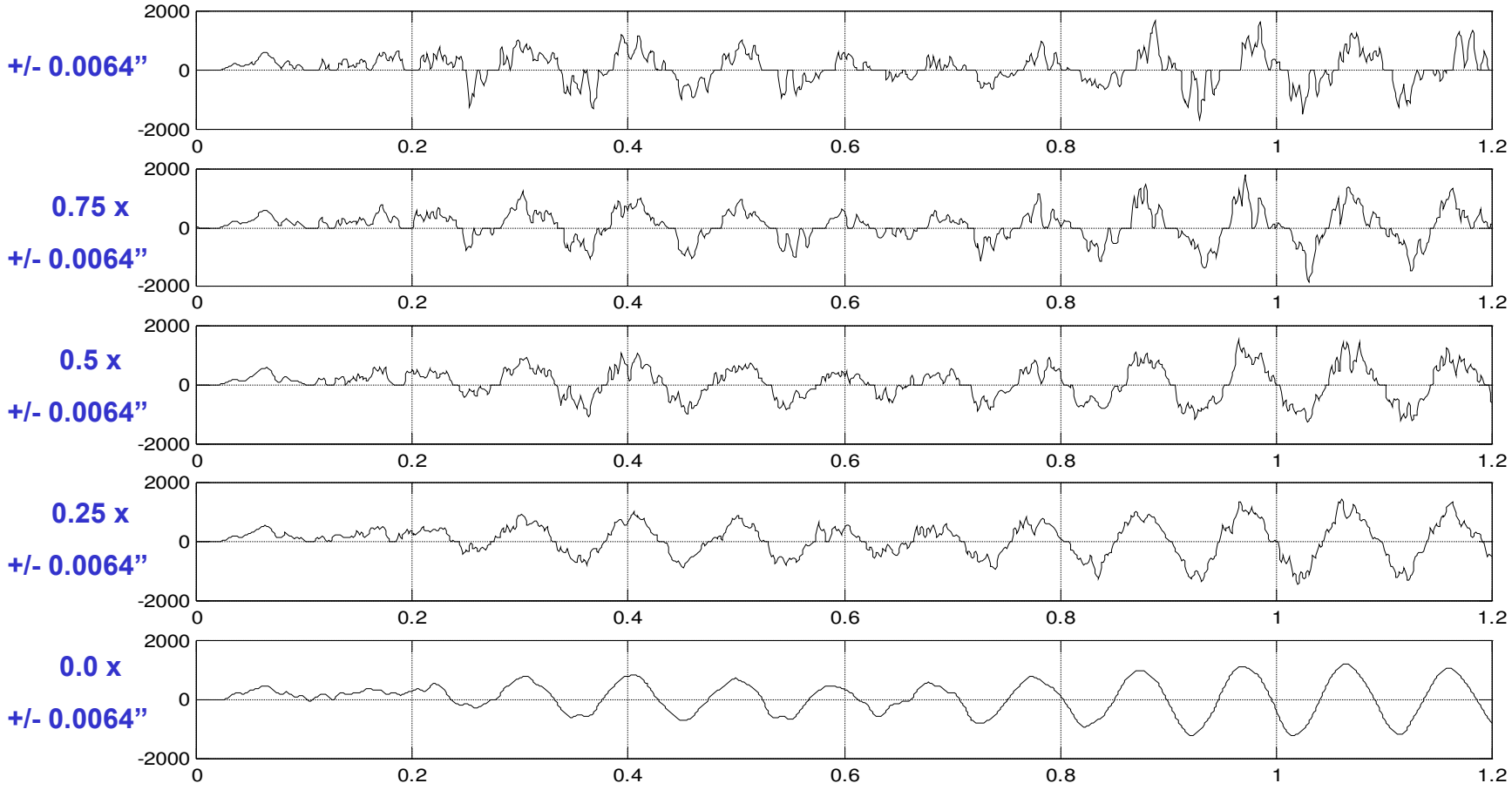
Convergence: Highly Impacted Yo Shear Force: Landing



Battery 5: Shear Force Node 655 Yorb
Forcing Function: LG7525

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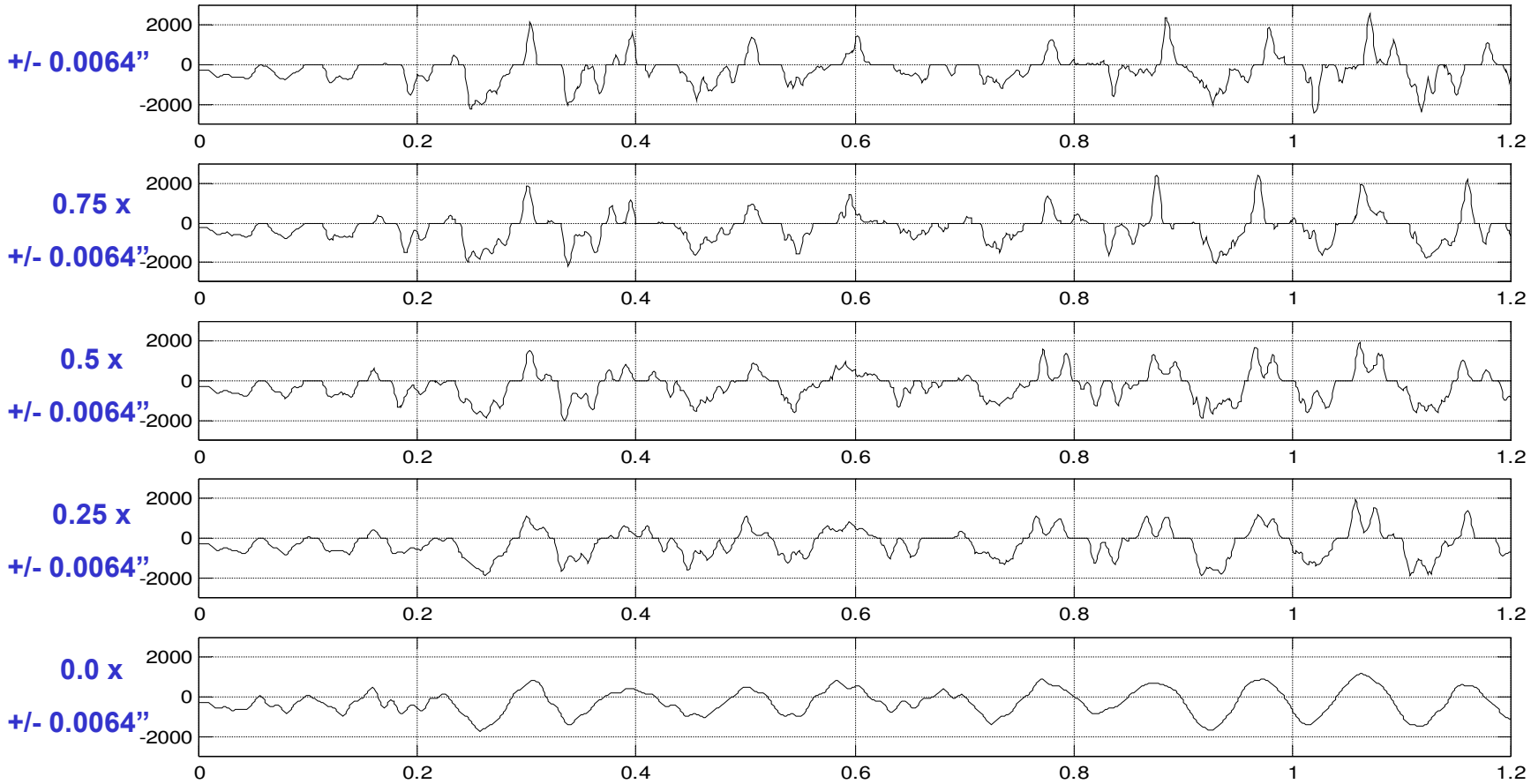
Convergence: Highly Impacted Zo Shear Force: Landing



Battery 5: Shear Force Node 2183 Zorb
Forcing Function: LG7525

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Concluding Remarks

- Nonlinear time-histories and associated relative displacements investigated
  - Nonlinear time-histories display all reasonable characteristics
    - No numerical “chatter/noise” in nonlinear time-histories
    - Zero deadband limit penetration
    - Proper phasing of nonlinear force/relative displacement
- With ASD/CLAS, simulations of joint deadbands is executed with unprecedented accuracy
- ASD/CLAS - A significant value added tool for our technical community
  - Significantly reduce risk, schedule, and cost
  - Visit www.appliedstructuraldynamics.com for more information on ASD/CLAS and licensing