Data Reduction and Its Impact on Test-Analysis Correlation

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Presentation Outline

- Overview
- Background
- Predicted and Measured Results
- Concluding remarks

Overview

Objective: Evaluate data analysis/signal processing technologies for crash applications to better quantify the accuracy of simulation results

Motivation:

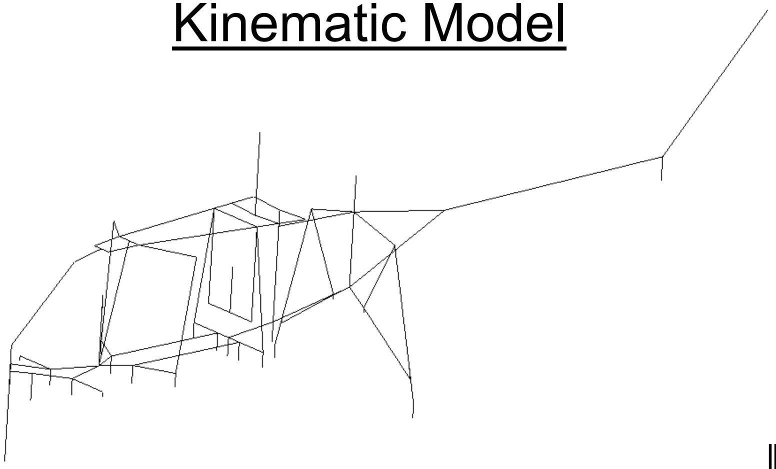
- Document modeling improvements
- Evaluate design configurations analytically
- Enable analysis to further aid certification process

Current Project Thrusts:

- Simple metallic beam and plate structures
- Representative advanced-concept, composite fuselage section

Background

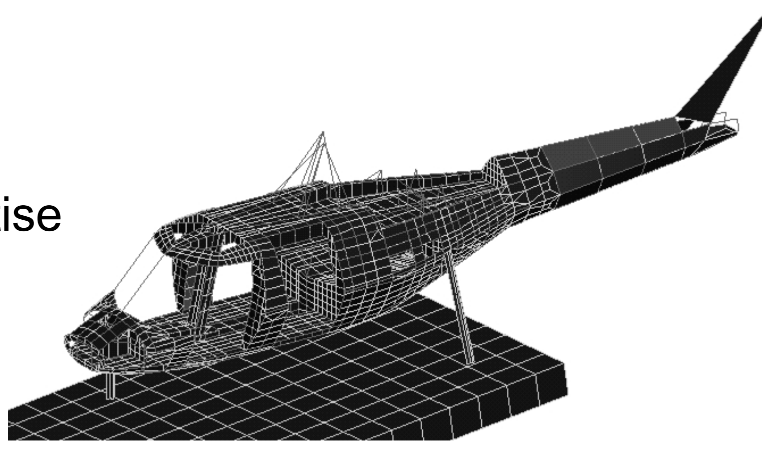
Kinematic Model



- Less than 100 nodes
- Concentrated masses, beams and 'crush' springs (based on empirical information)
- Requires numerous approximations and significant engineering judgment
- Calculates structural loading
- Computationally inexpensive

Nonlinear Dynamic Finite Element Model

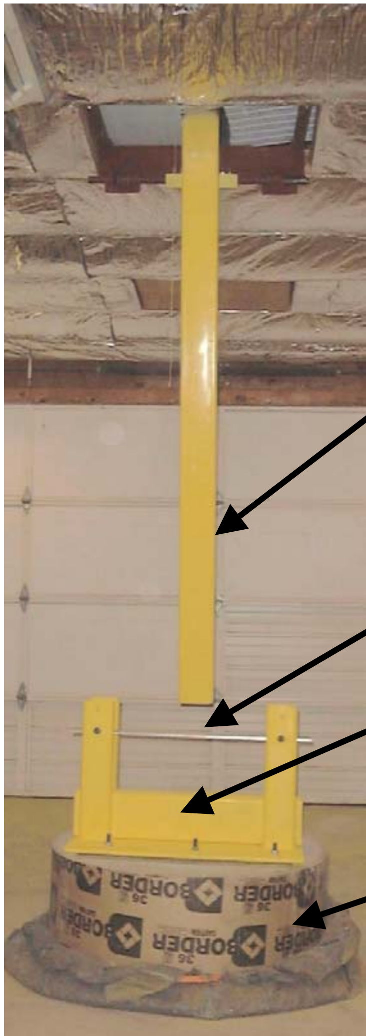
- 4,000-400,000 nodes
- Shell, beam, solid elements and concentrated masses
- Requires significant analytical expertise
- Calculates structural behavior
- Computationally expensive



Need efficient methods to reduce, evaluate, and correlate large amounts of data

Metallic Beam and Plate Tests

Objective: Evaluate test and analysis correlation methods on simple structures with “known” responses



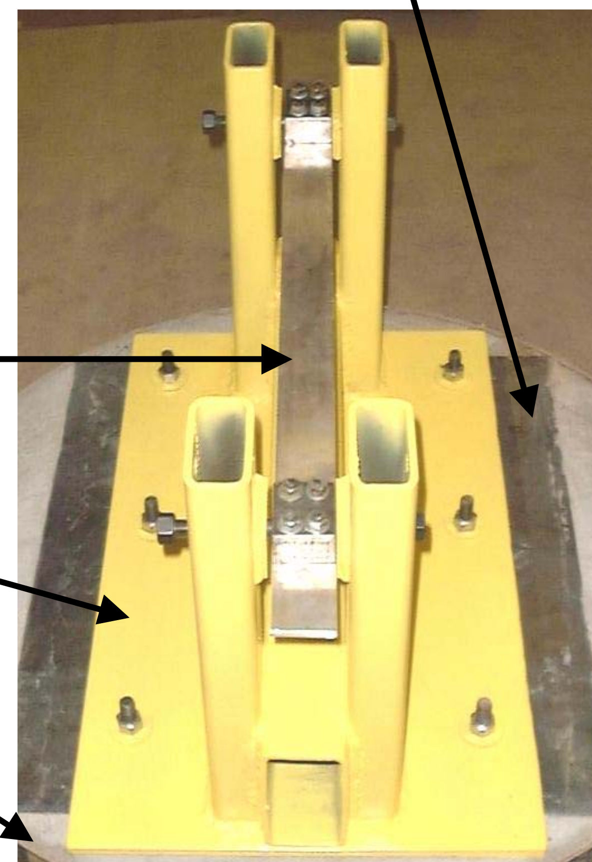
Semi-cylindrical impactor:
4 x 4 in. cross-section
24 in. long
16 lb. weight

Test beam

Test fixture

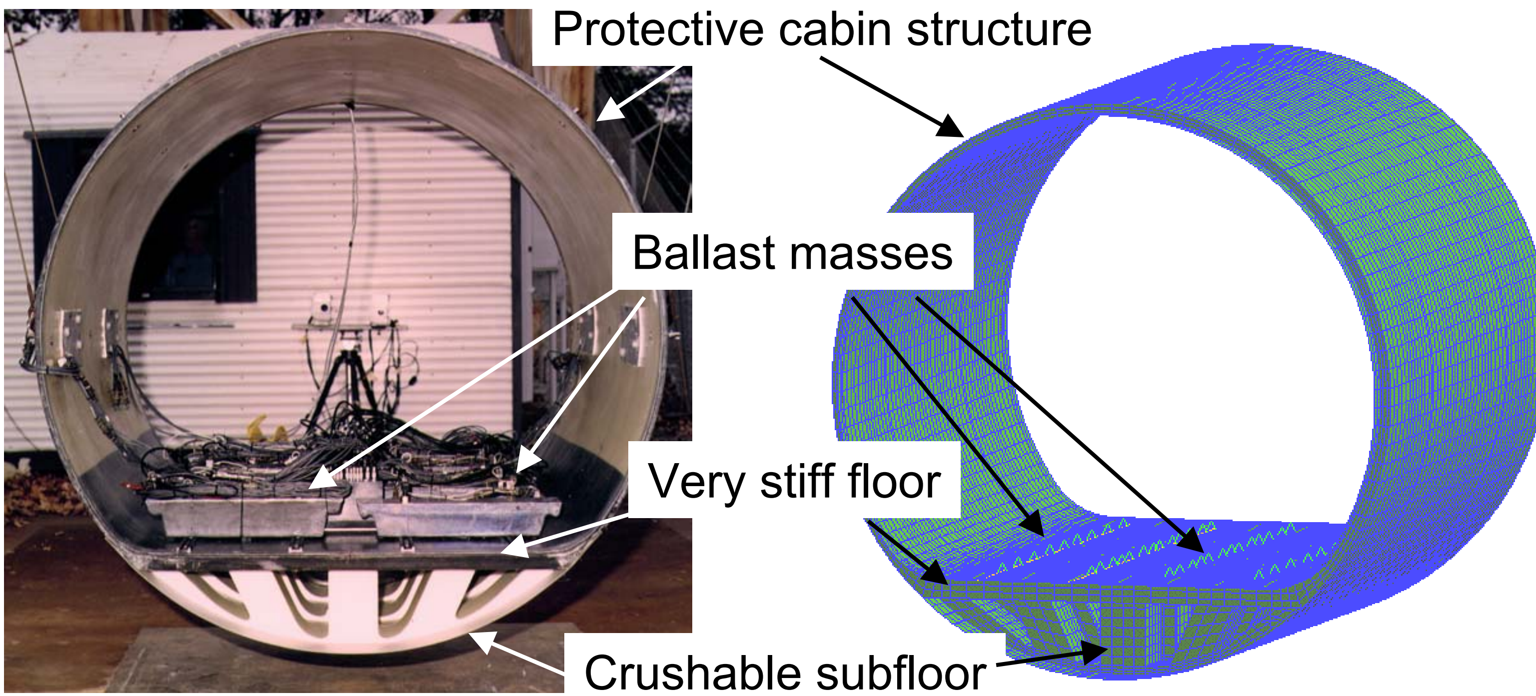
36-in diameter concrete mounting base - 1400 lb.

Imbedded steel plate provides flat mounting surface



Fuselage Section Description

Pre-test Photograph | **Finite Element Model**



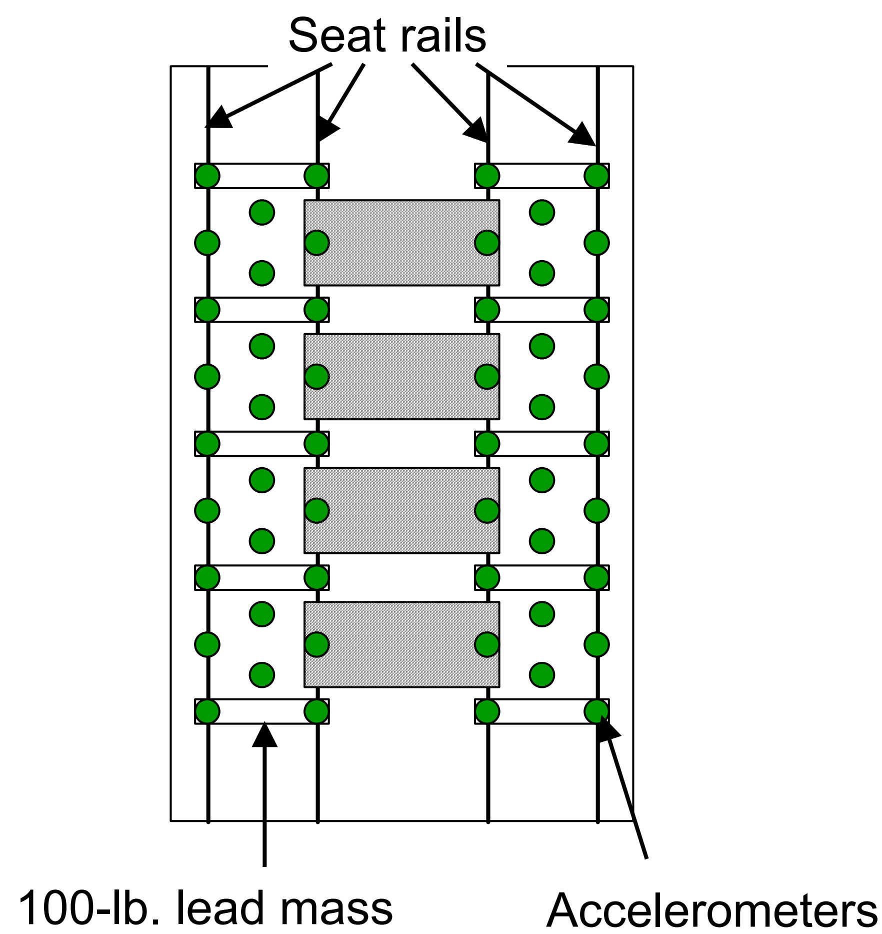
- Dimensions: 60-in. diameter x 64-in. long
- Protective cabin: Foam with laminated composite face sheets
- Ballast: Ten 100-lb. lead weights
- Stiff floor: Provides global crushing of subfloor
- Subfloor: Foam with uniform crush properties

Section Test Summary

Test Conditions

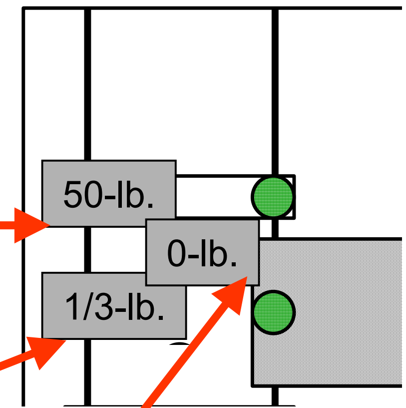
- *Designed for correlation with FEM, NOT concept evaluation*
- Impact velocity 307 in/sec
- No roll, pitch or yaw
- 16-bit digital DAS
- 10 kHz sampling rate
- 73 accelerometers

Floor Instrumentation



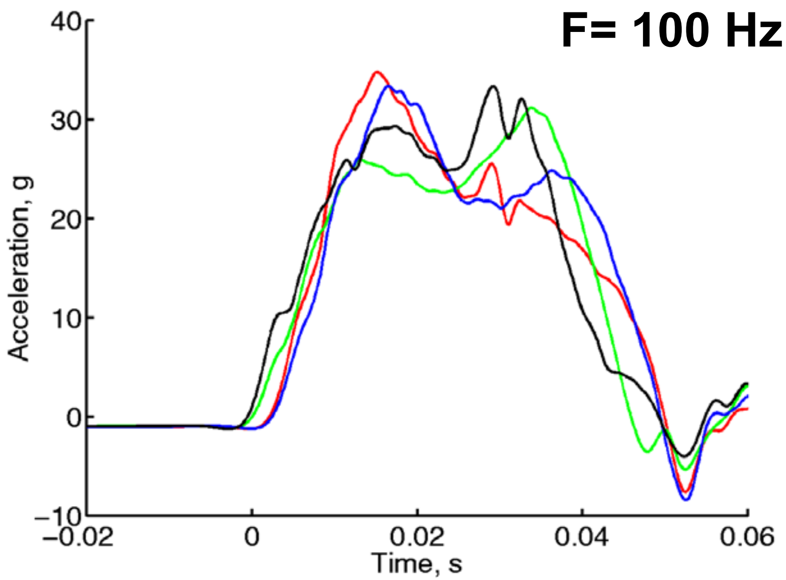
Instrumentation Details

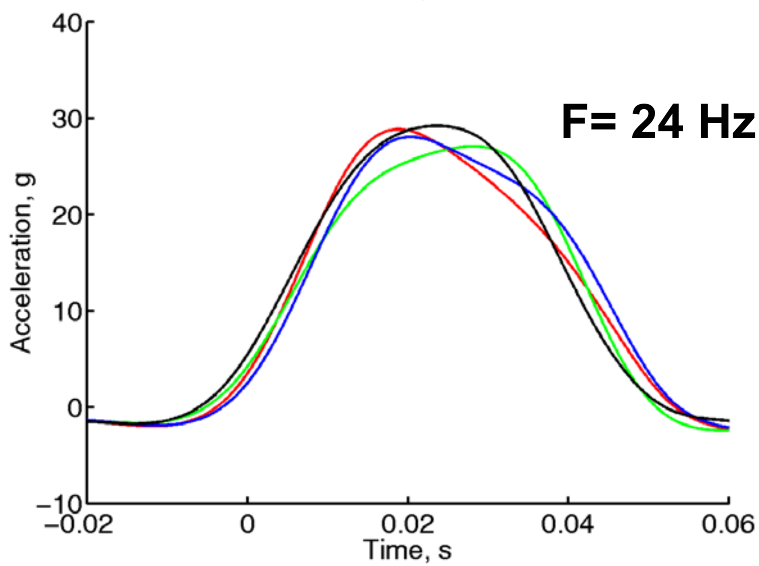
- Densely instrumented structure enabled evaluation of effect of accelerometer placement
  - Location A - attachment of lead weights to seat rails, approximated as 50-lb concentrated mass on node.
  - Location B - Attached to seat rail with mounting block, approximated as 1/3-lb concentrated mass on node.
  - Location C - Mounted on block and adhered directly to floor, no concentrated mass at node.

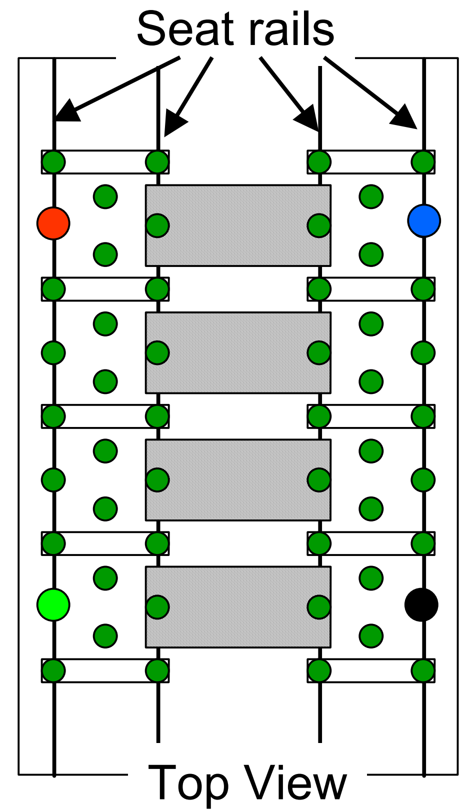


- Known:
  - Global motion of stiff floor similar at all locations.

Sample Test Data
(Symmetric locations)



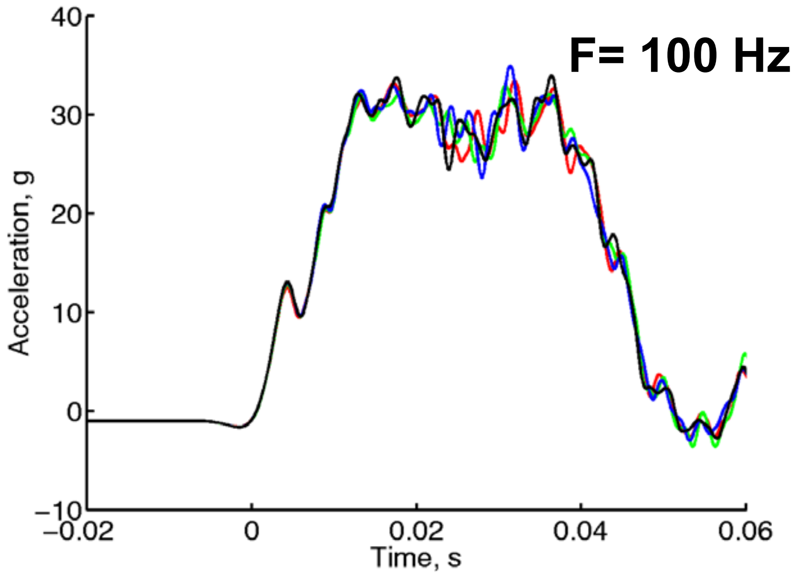


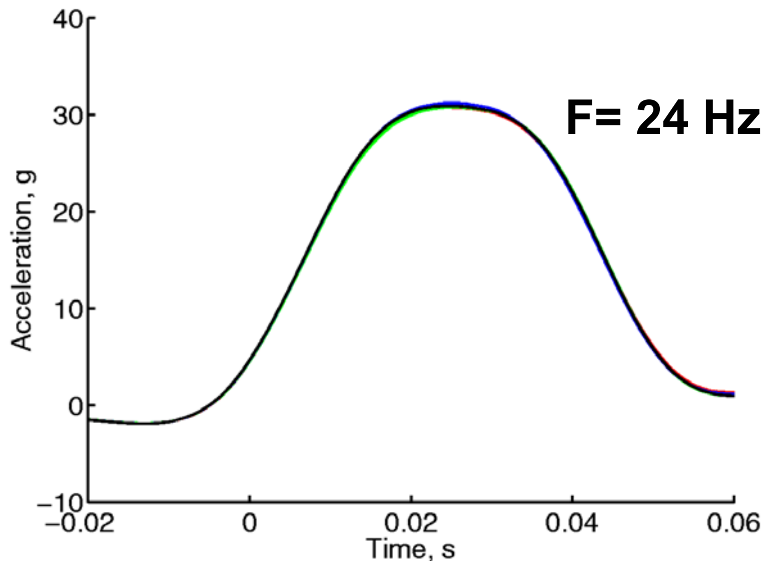


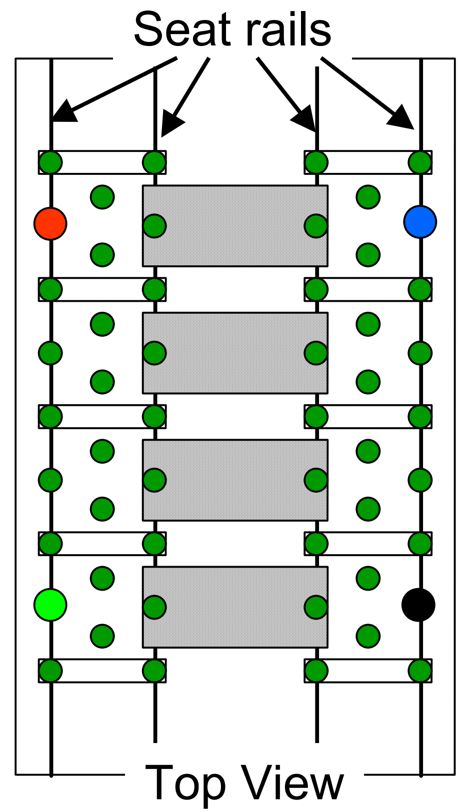
Filtering Frequency, Hz	Variation	
	Maximum	Mean
100	3.6	0.8
24	1.1	0.7

Sample Predicted Results

(Symmetric locations)



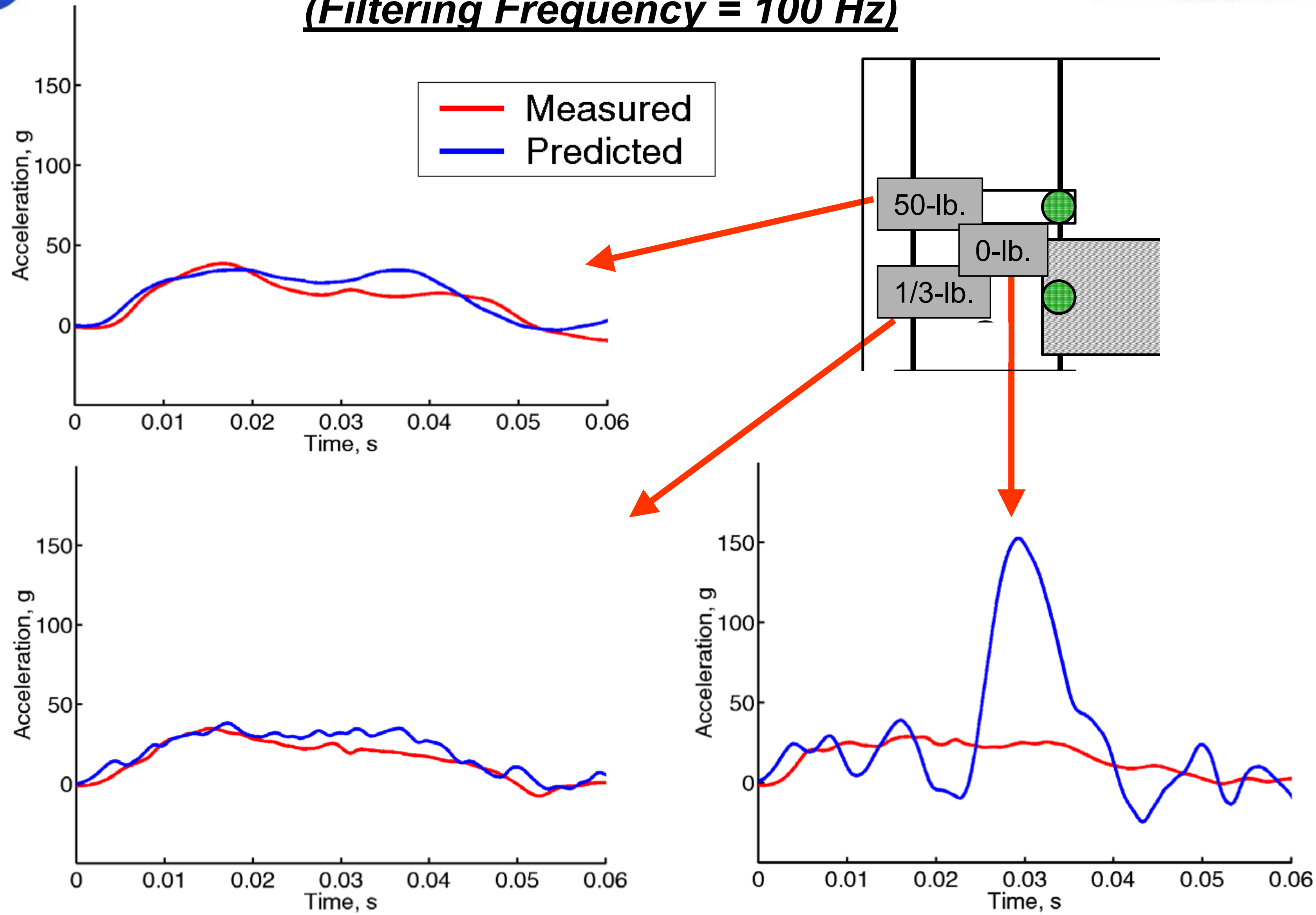




Filtering Frequency, Hz	Variation	
	Maximum	Mean
100	2.0	< 0.1
24	0.3	< 0.1

Correlation of Test Data and Predictions

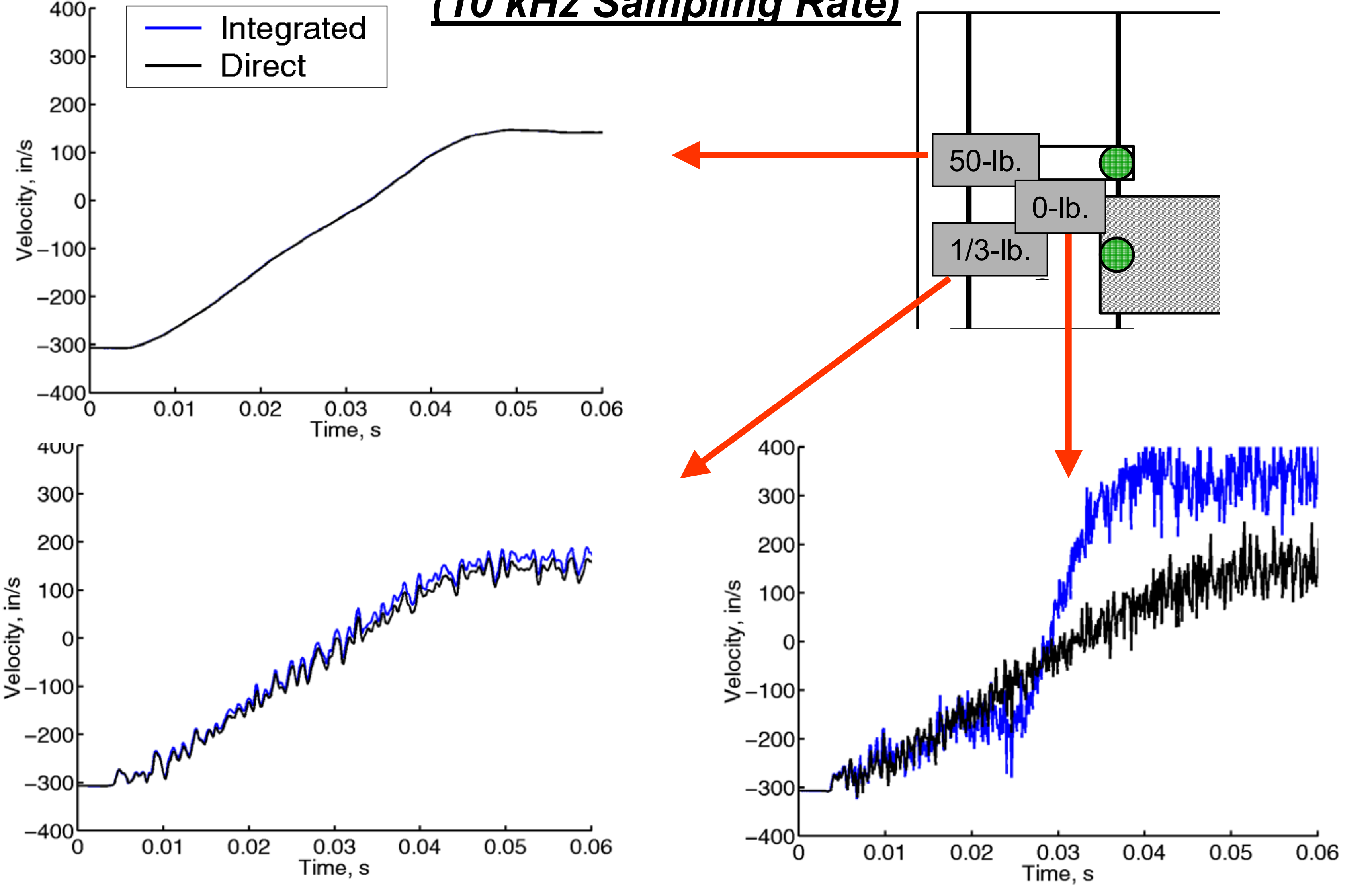
(Filtering Frequency = 100 Hz)



Why the discrepancy when no mass added to node?

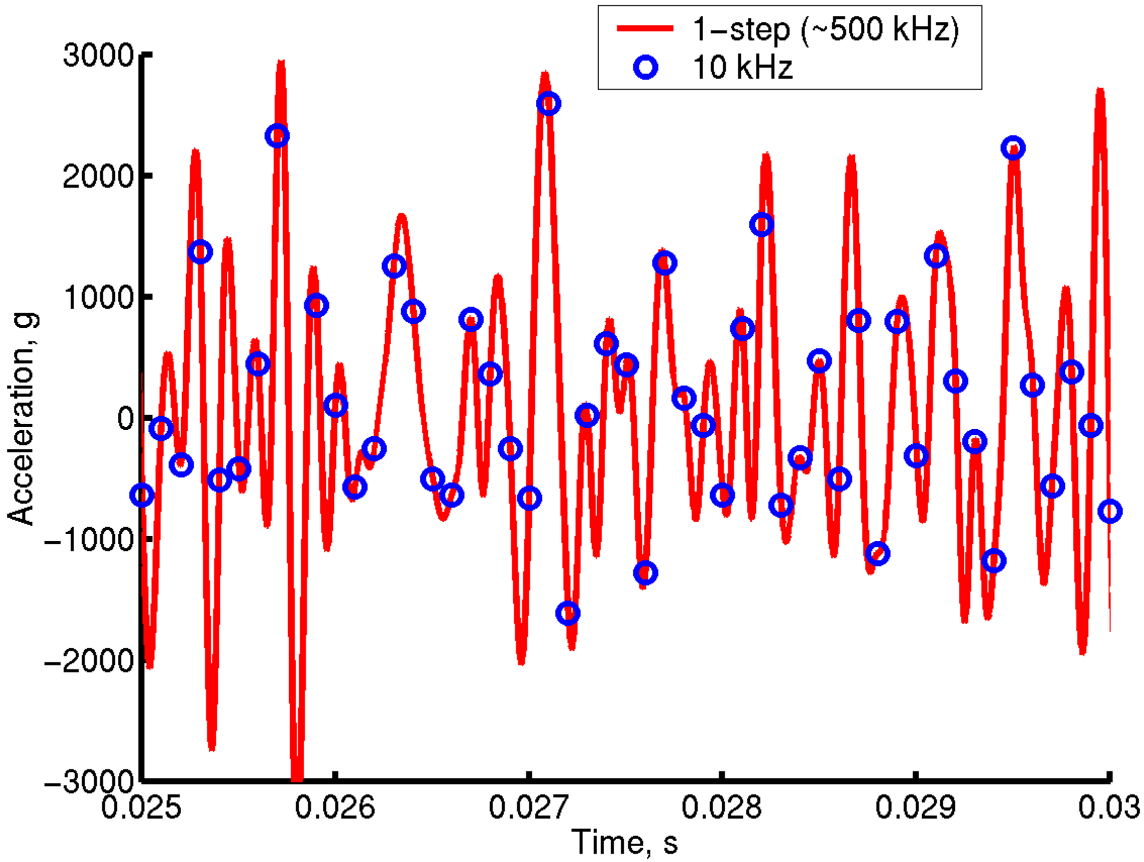
Predicted Velocities

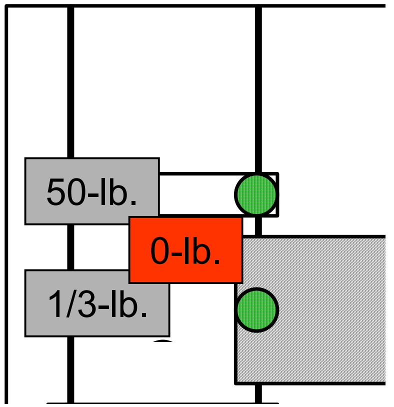
(10 kHz Sampling Rate)



“Integrated” velocities consistent with filtered accelerations, but not consistent with “Direct” velocities

Sample Time History

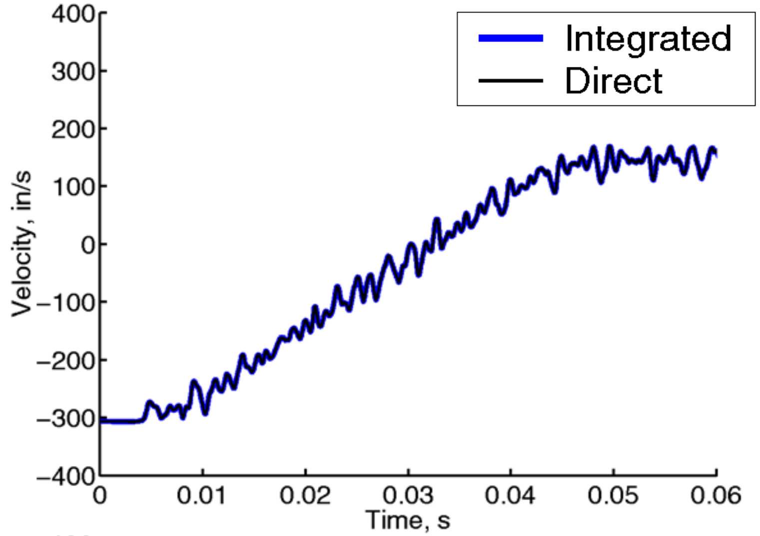


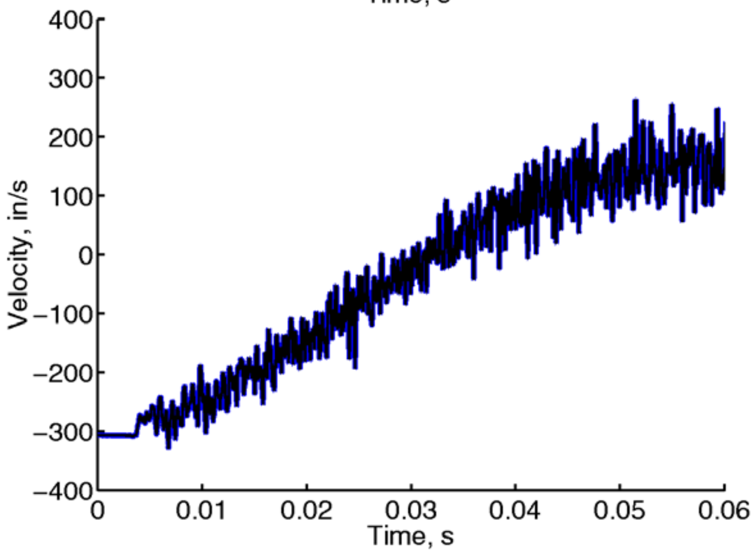


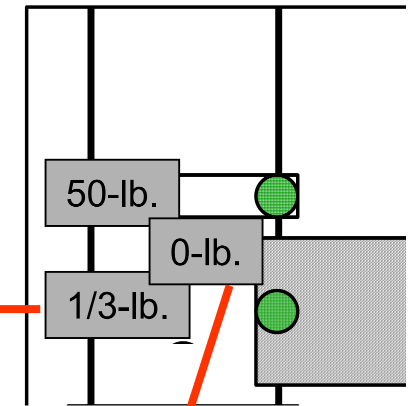
Predicted accelerations repeatable from “run” to “run”

Predicted Velocities

(1-step Sampling Rate)

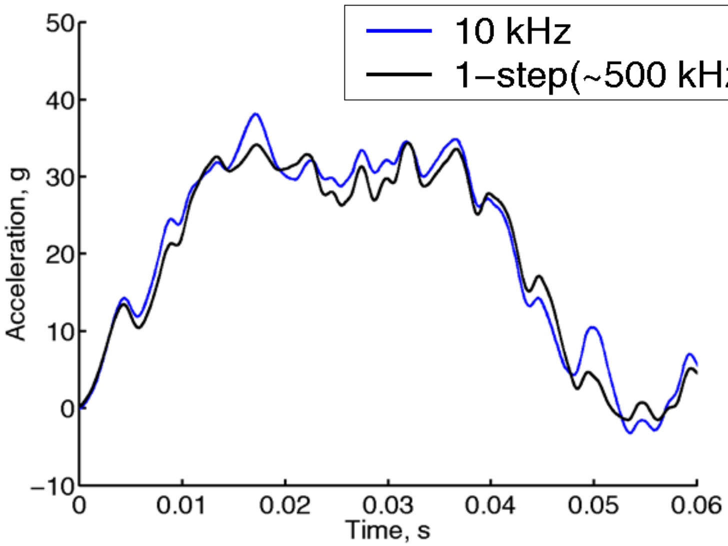


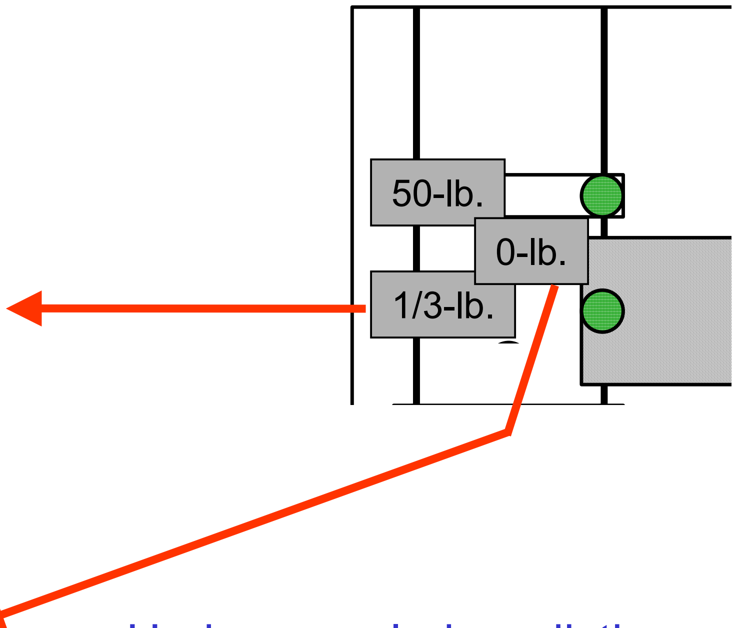


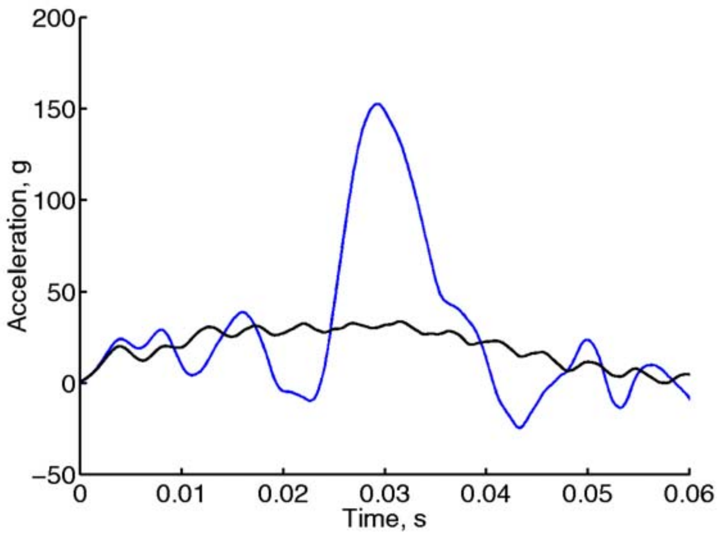


No discrepancy between "Integrated" and "Direct" velocity values for data sampled every time step.

Effect of Sampling Rate on Filtered Accelerations





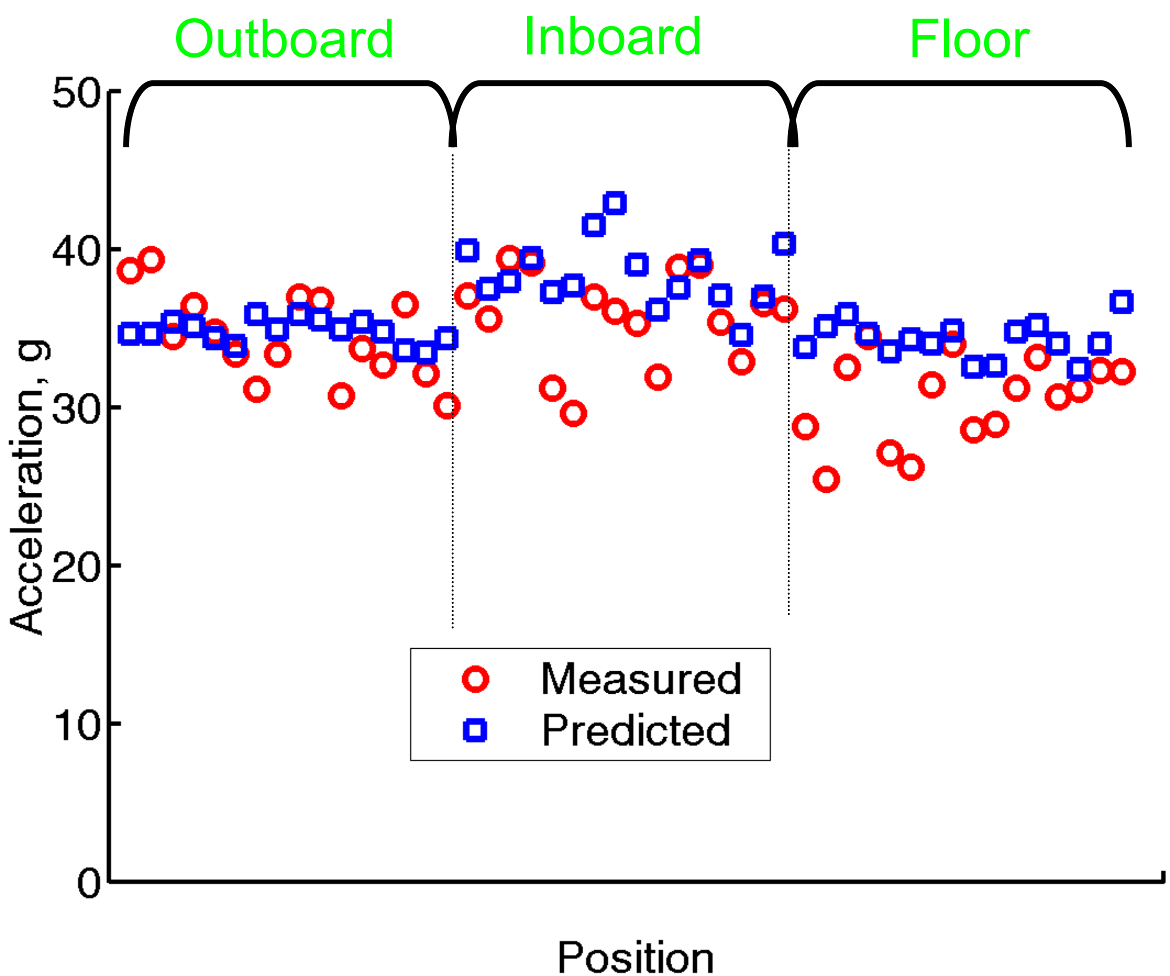


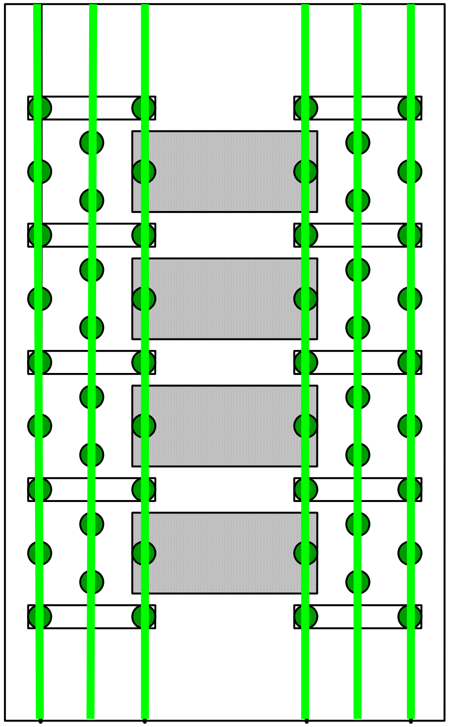
Under-sampled predictions can result in:

- unreliable and inaccurate correlations between measured and predicted
- erroneous modeling modifications

Maximum Accelerations

(Filter Frequency = 100 Hz)

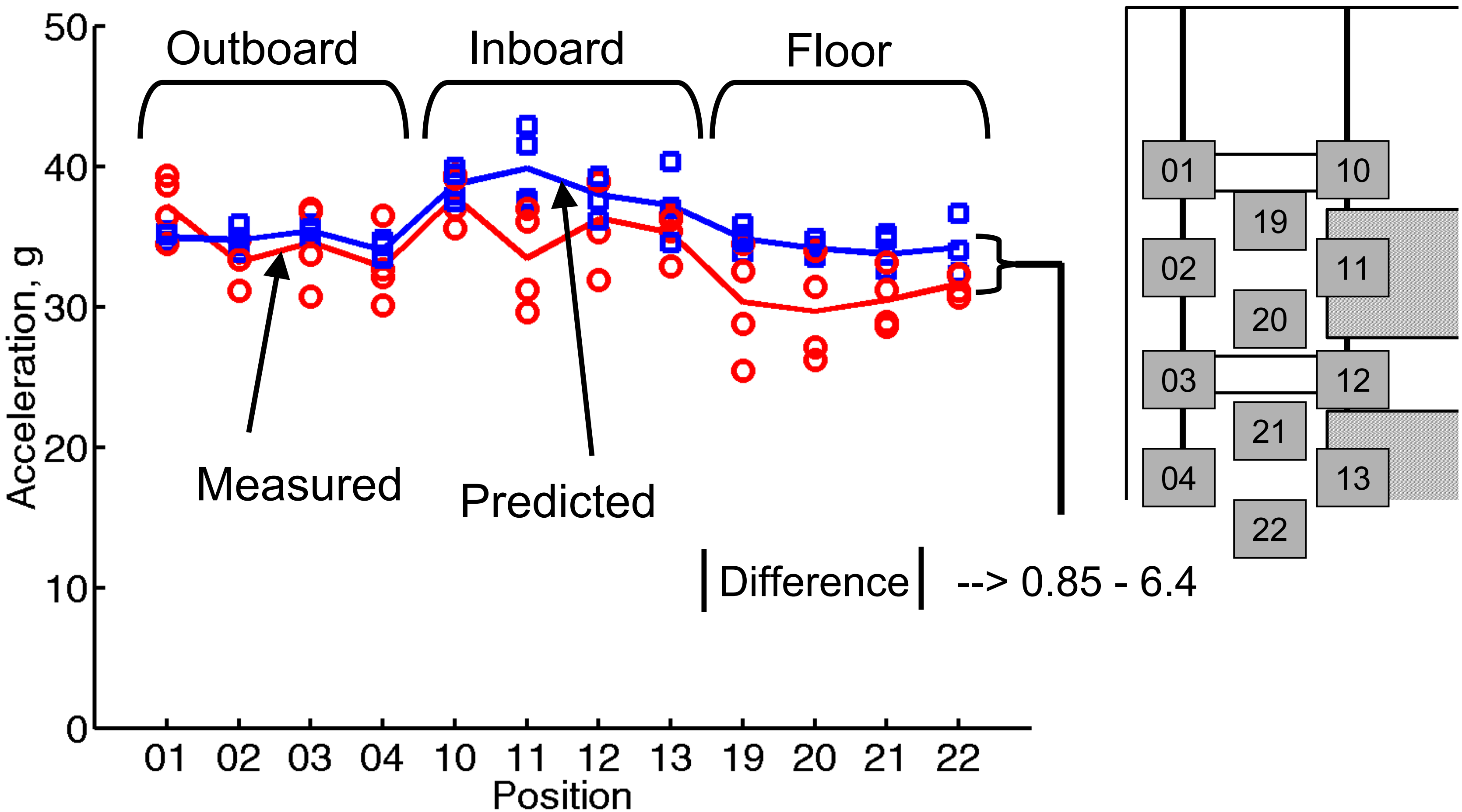




Top View

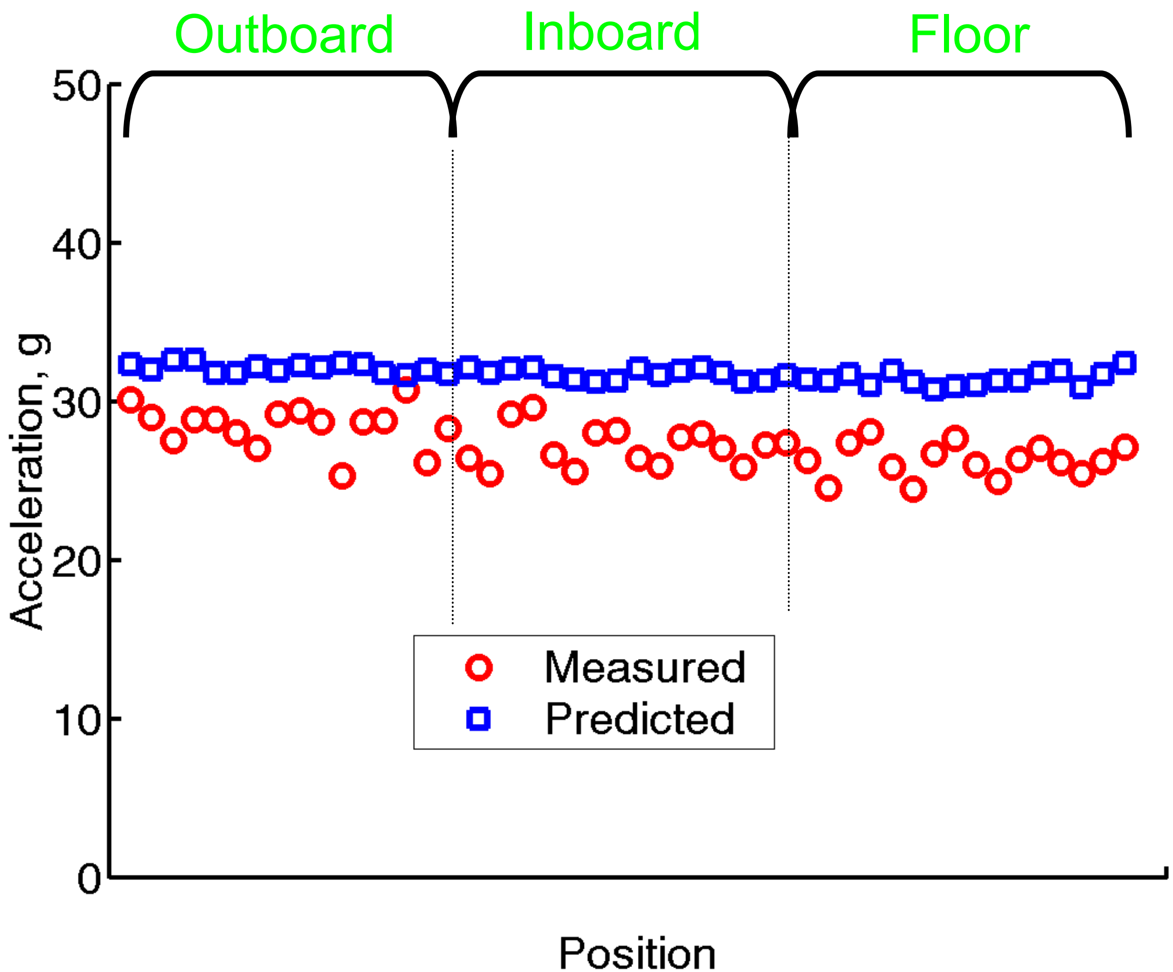
Maximum Accelerations

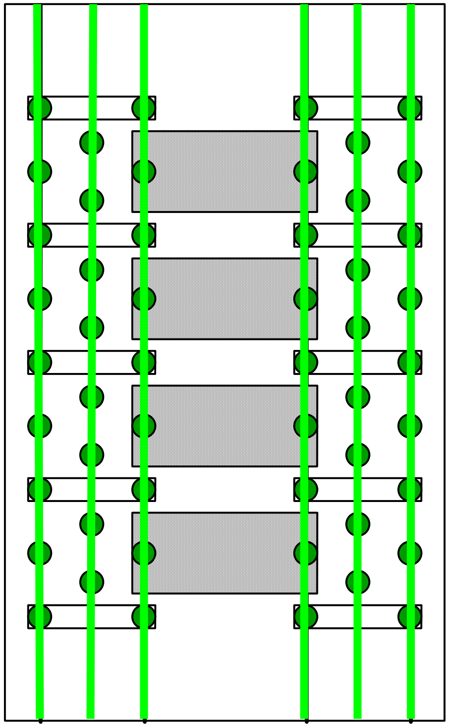
(Filter Frequency = 100 Hz)



Maximum Accelerations

(Filter Frequency = 24 Hz)

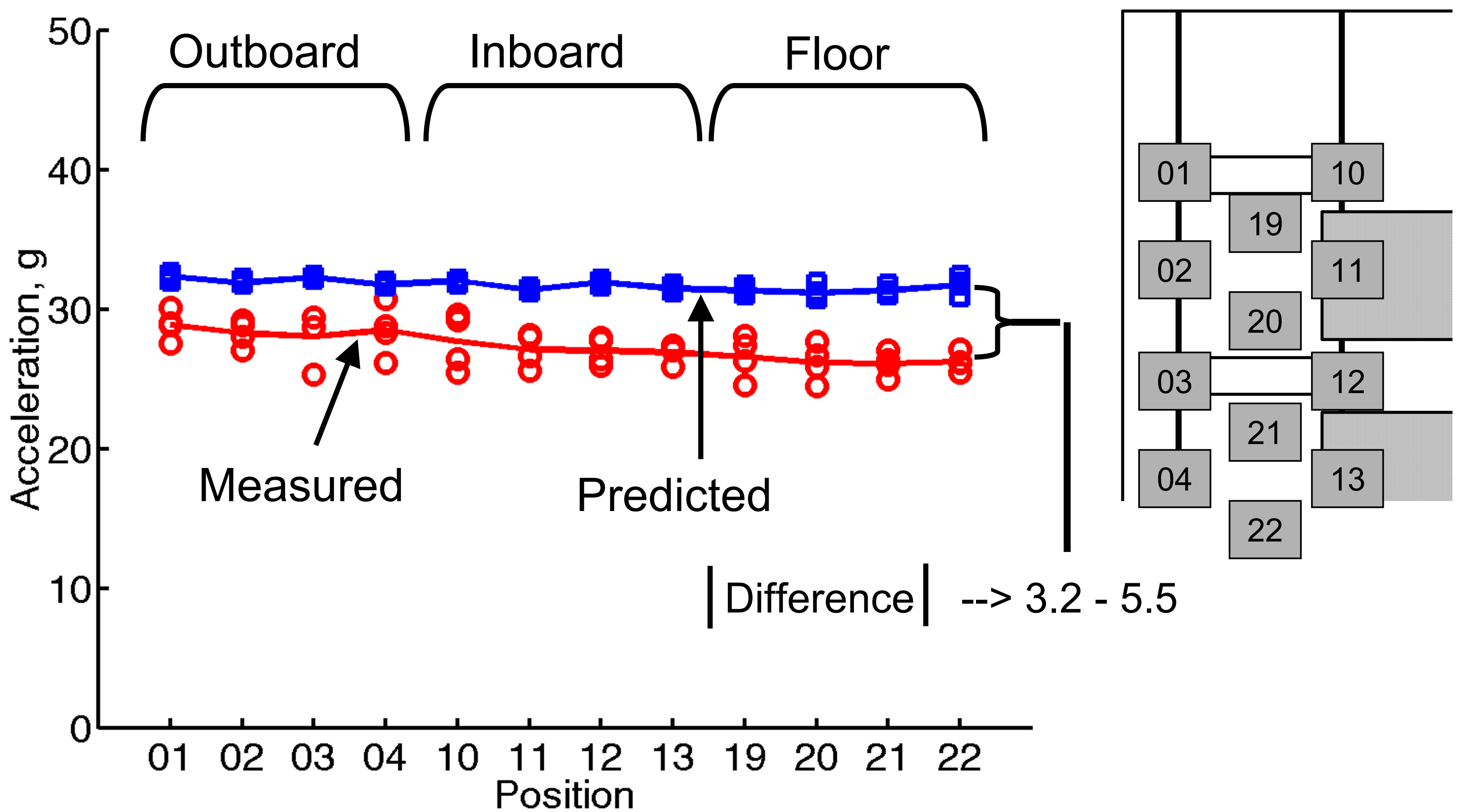




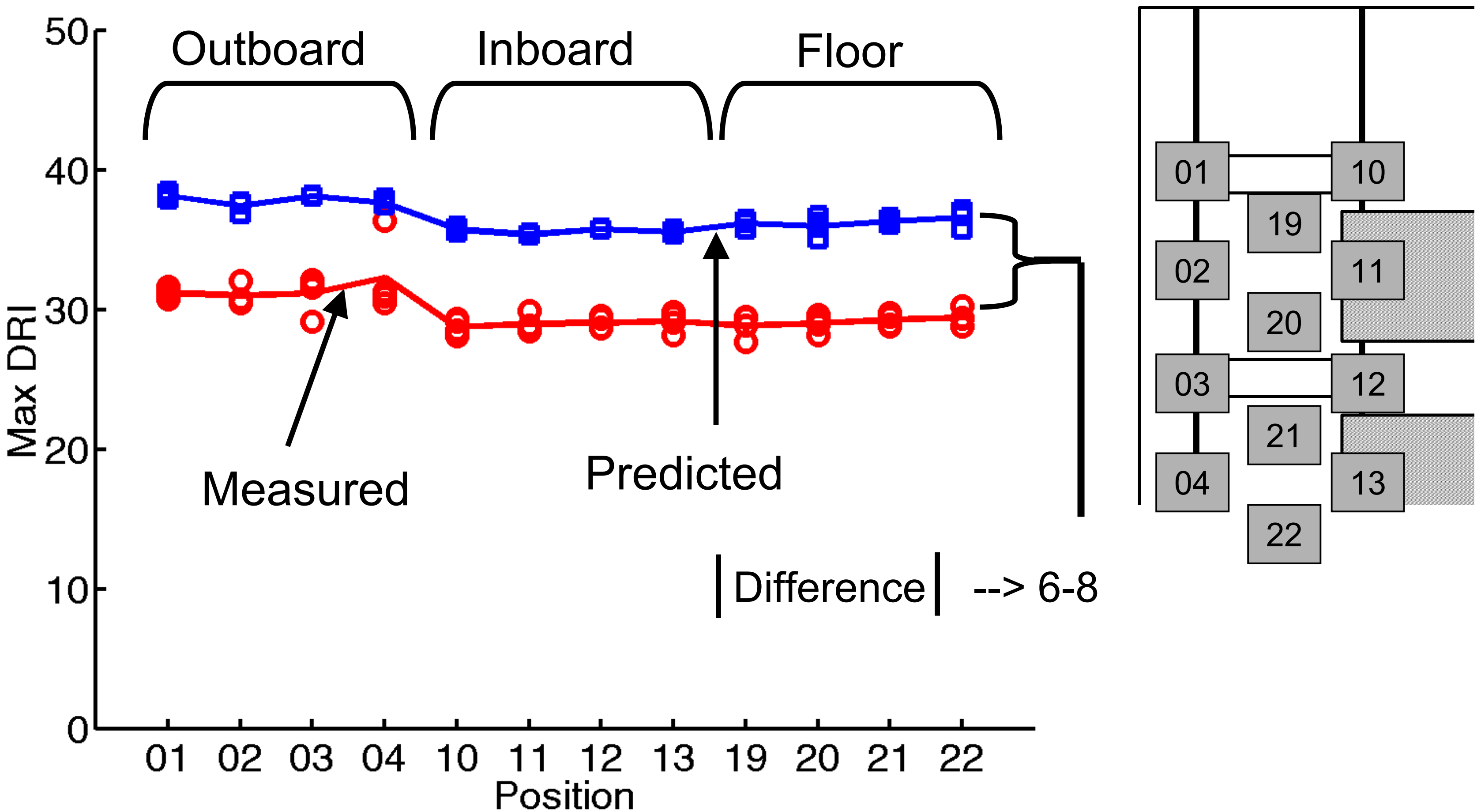
Top View

Maximum Accelerations

(Filter Frequency = 24 Hz)



1-D Dynamic Response Index (DRI)*



* DRI computed to evaluate closeness of results.
DO NOT compare with human injury criteria.

Concluding Remarks

- High channel count valuable for identifying similarities and anomalies
- Several correlation methodologies evaluated
- Filtering frequency affects correlation evaluation
- Under-sampling:
  - Readily identified
  - More likely for stiff lightweight structures
  - More prevalent when predicting at measurement points
- Presentation of all locations on one figure:
  - Valuable for global modeling accuracy
  - Highlight subtle and pronounced differences between test and analysis
  - Allow evaluation of several quantities