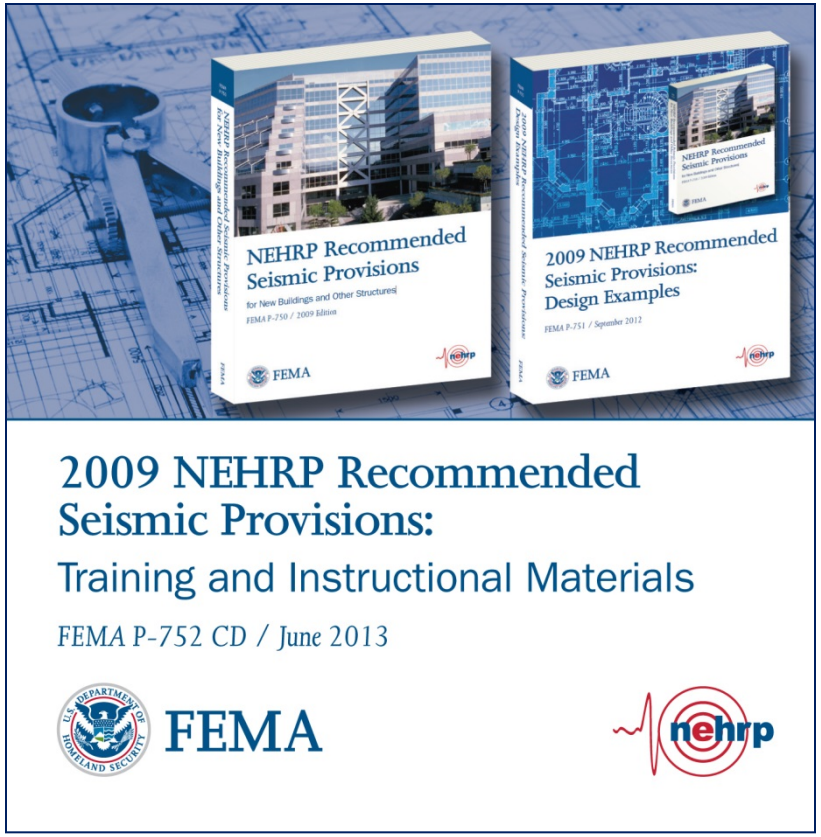


15

NONLIN and EQ-Tools Software for Earthquake Engineering Education

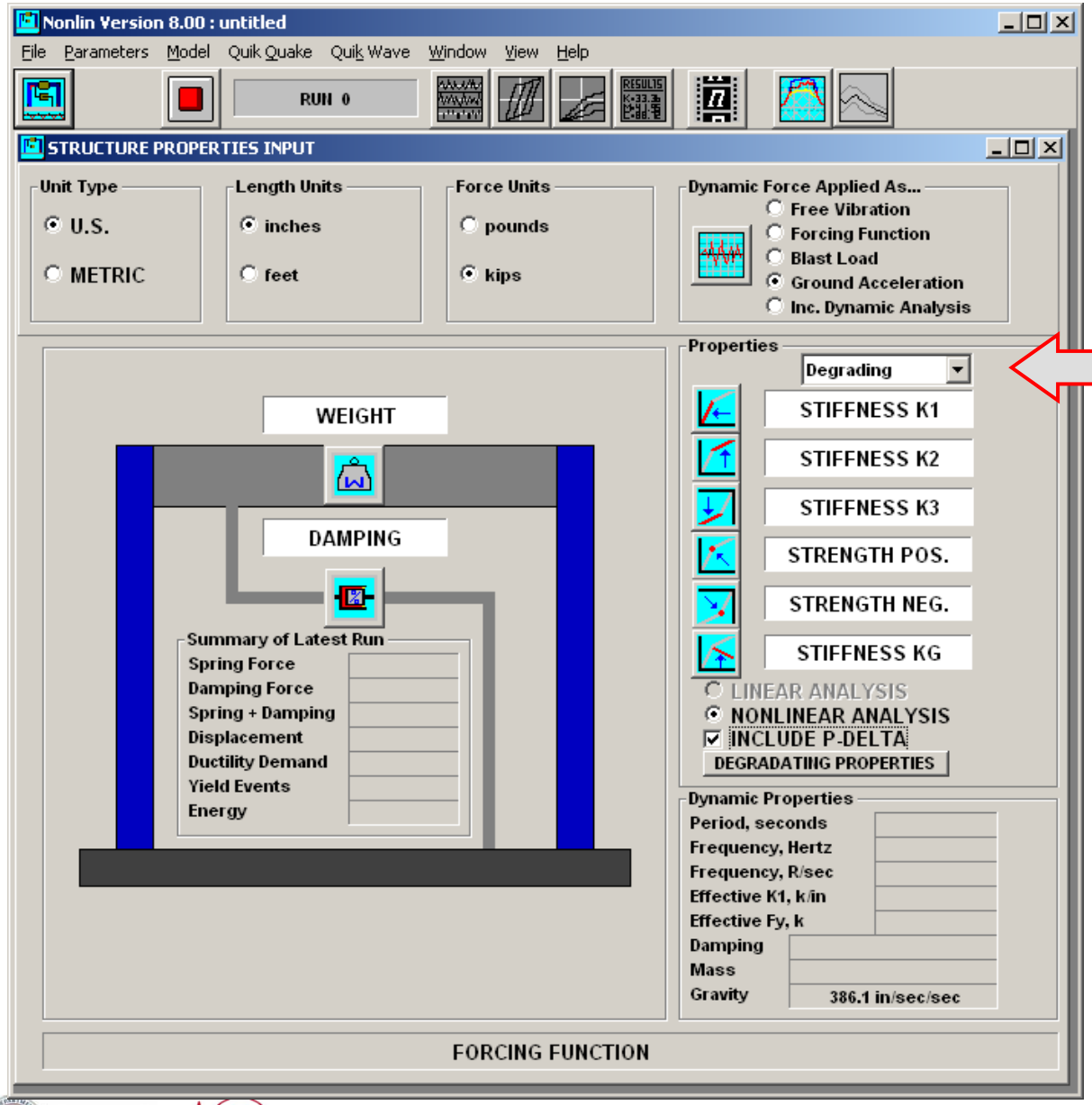
Finley A. Charney, Ph.D., P.E., Virginia Tech,
Department of Civil and Environmental Engineering

NONLIN: Version 8.0

- **Nonlinear Dynamic Analysis of SDOF Systems**
- **Incremental Dynamic Analysis of SDOF**
- **Nonlinear Dynamic Analysis of Simple MDOF Systems**
- Elastic and Inelastic Response Spectrum Analysis
- Fourier Amplitude Spectrum Analysis
- Modal Analysis of Simple Proportionally Damped Systems
- **Modal Analysis of Simple Non-proportionally Damped Systems**

Items in **BOLD** indicate significant updates since Version 7

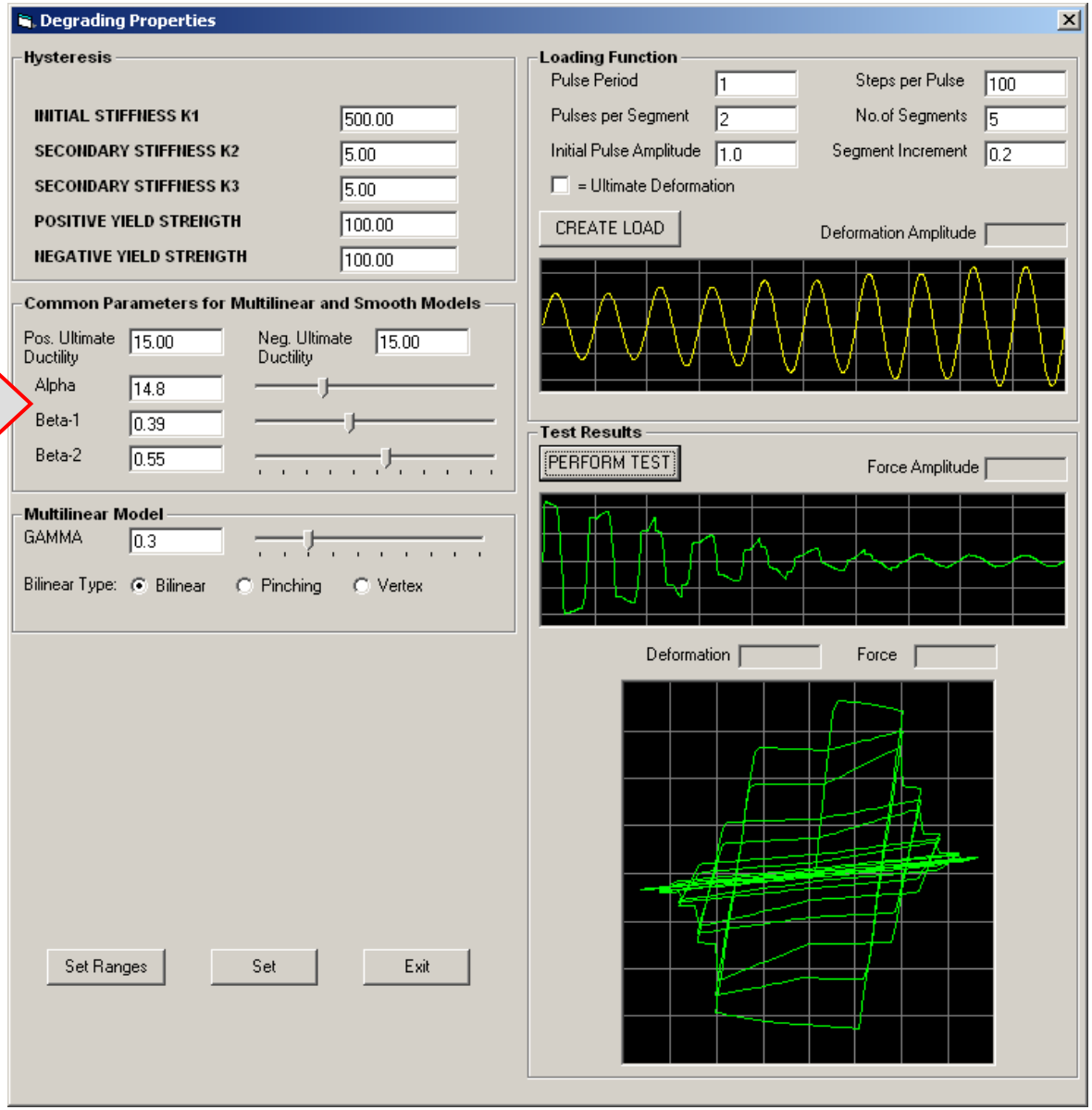
SDOF Analysis Tools



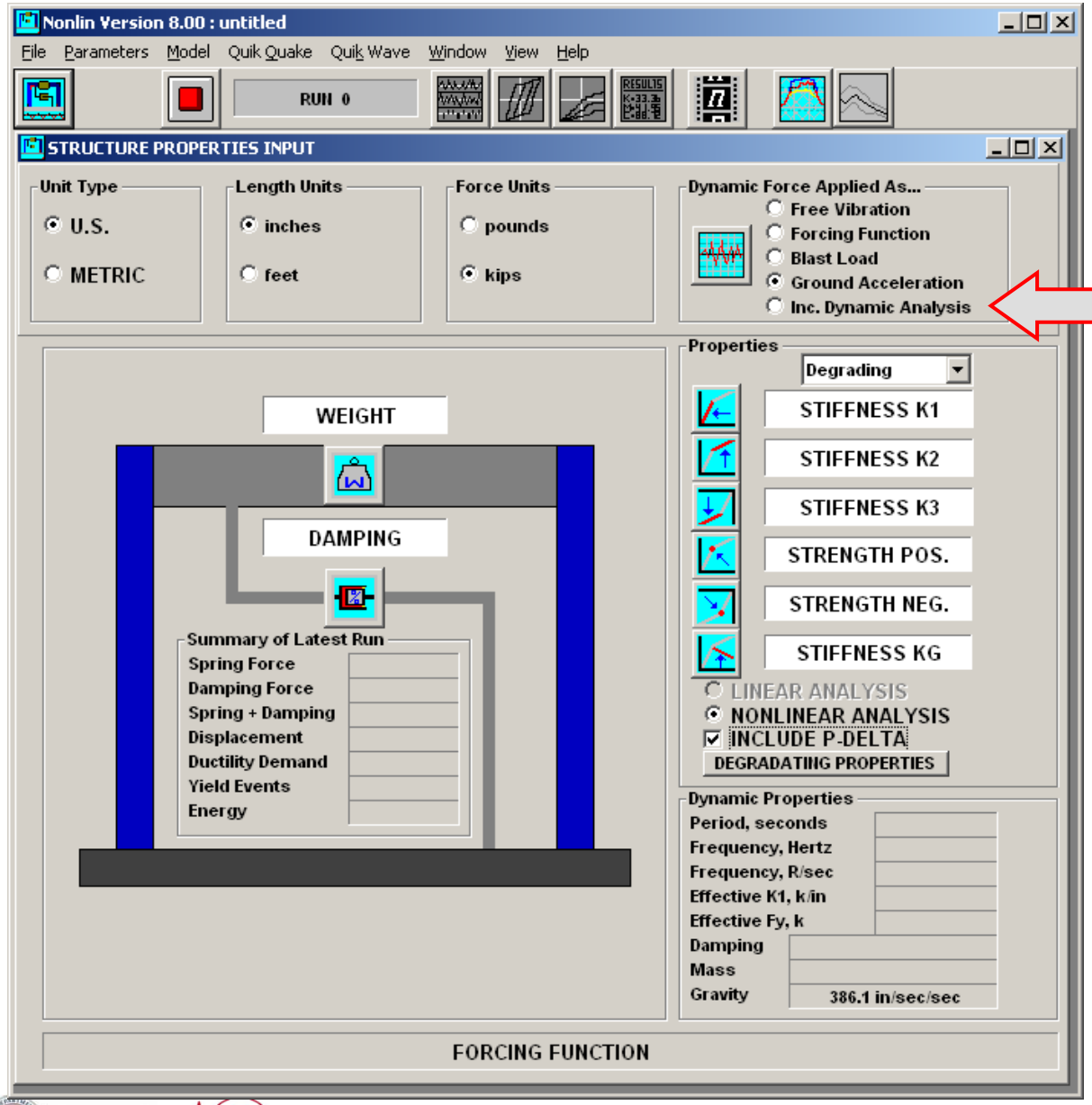
New degrading Strength and Stiffness model
(Sivaselvan and Reinhorn)

Degrading Stiffness and Strength Model

Properties set Interactively. Properties can be "tested" before use.

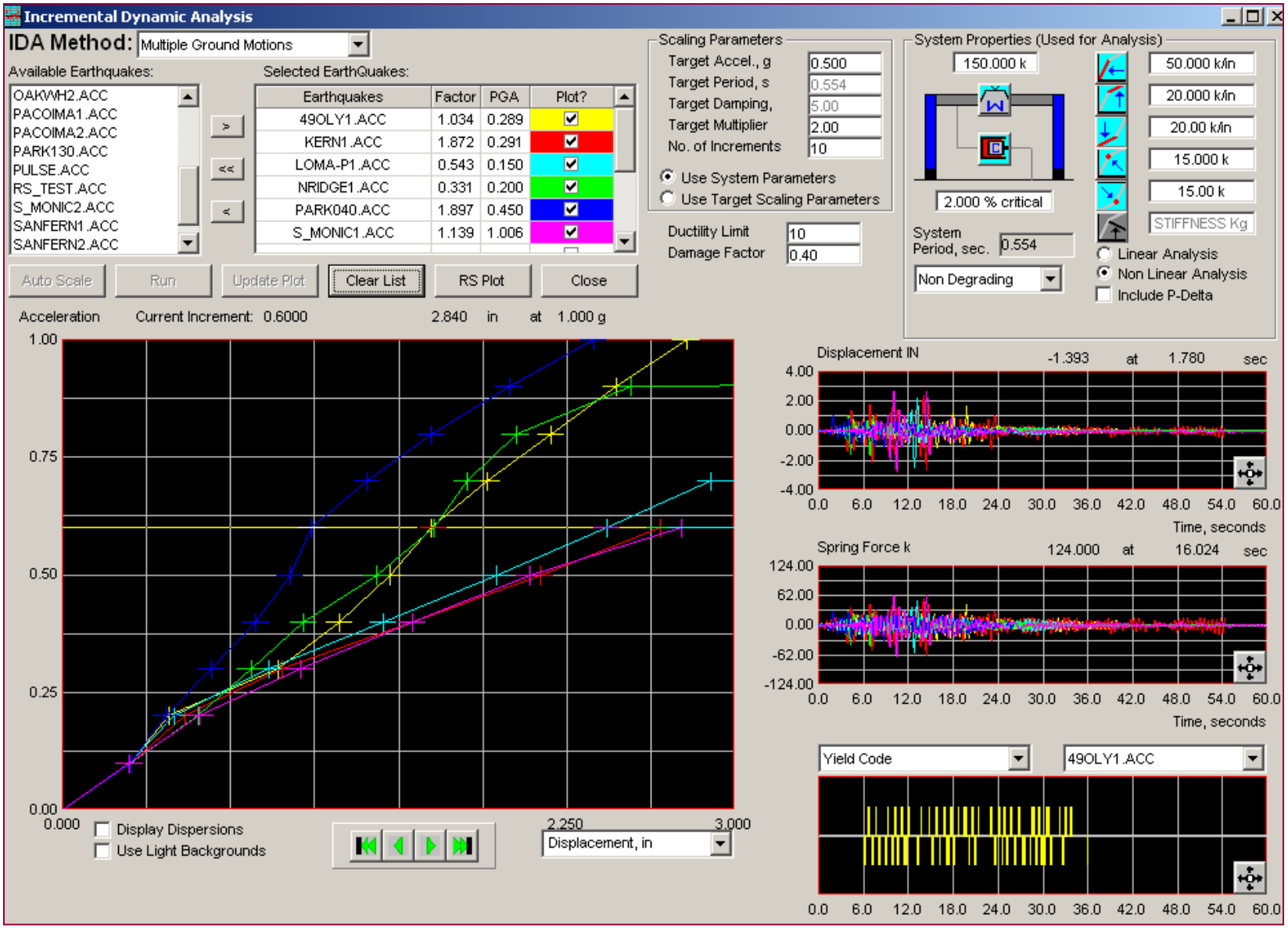


SDOF Analysis Tools: IDA

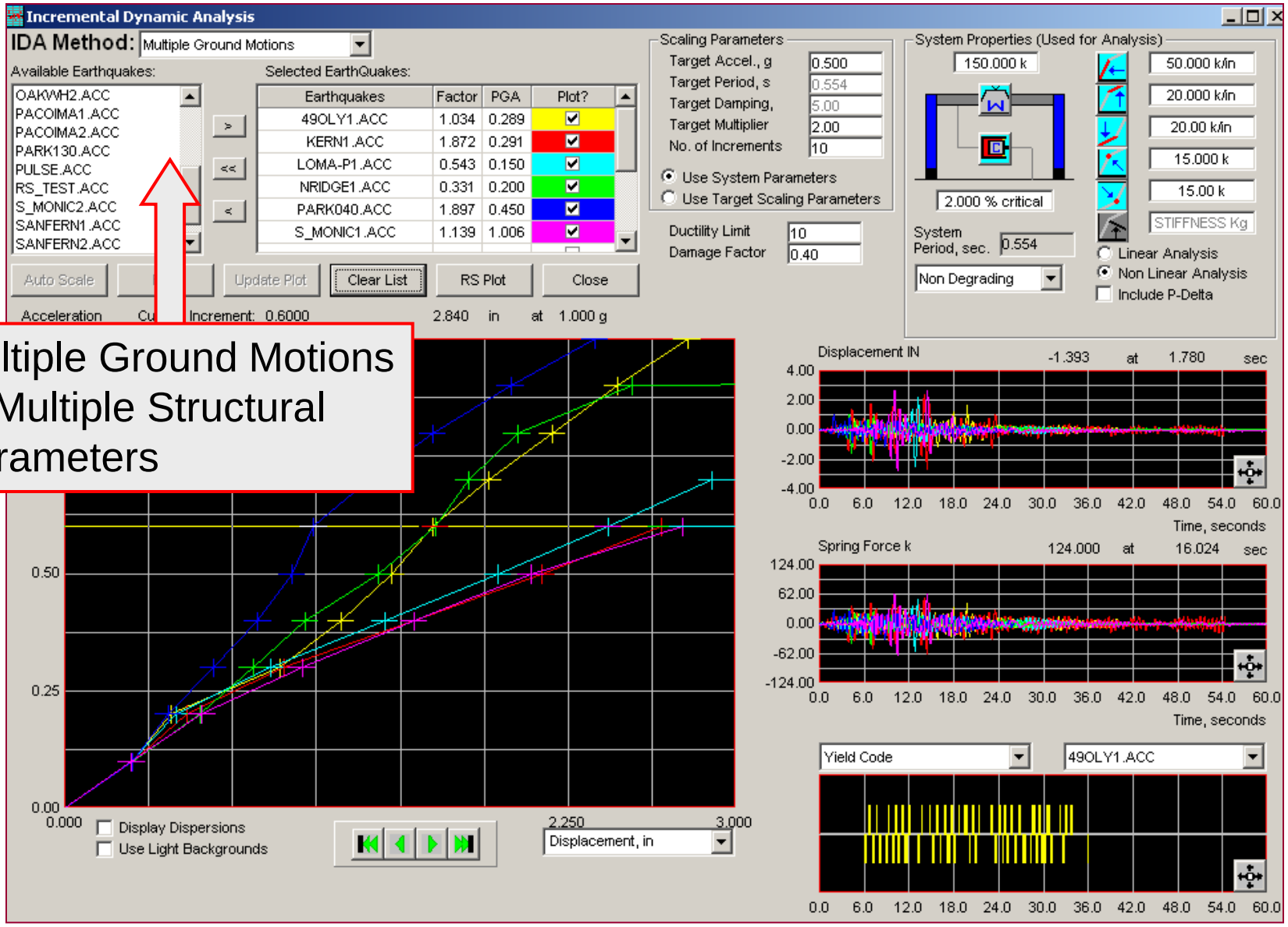


Incremental Dynamic Analysis

Incremental Dynamic Analysis

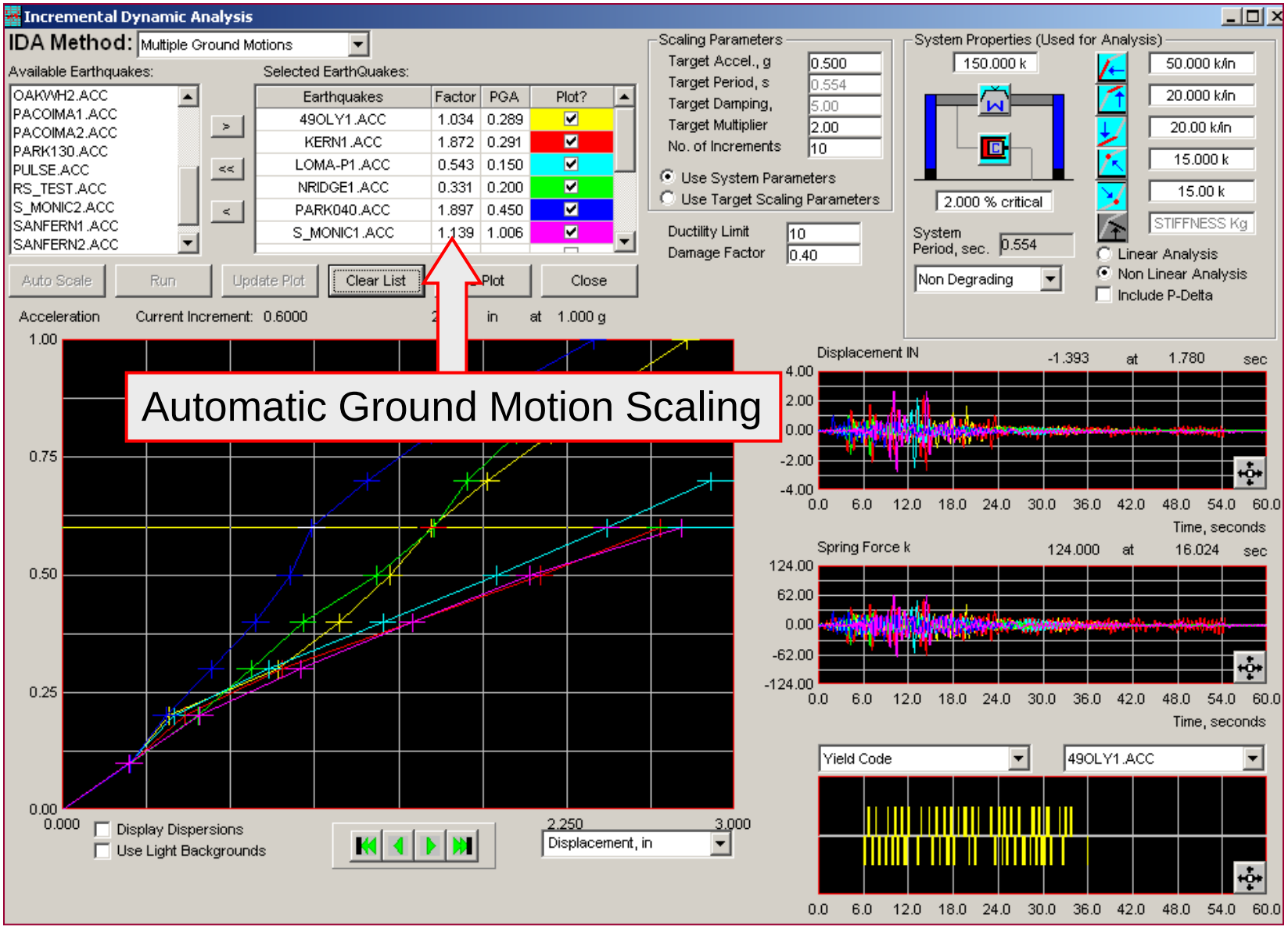


Incremental Dynamic Analysis (2)

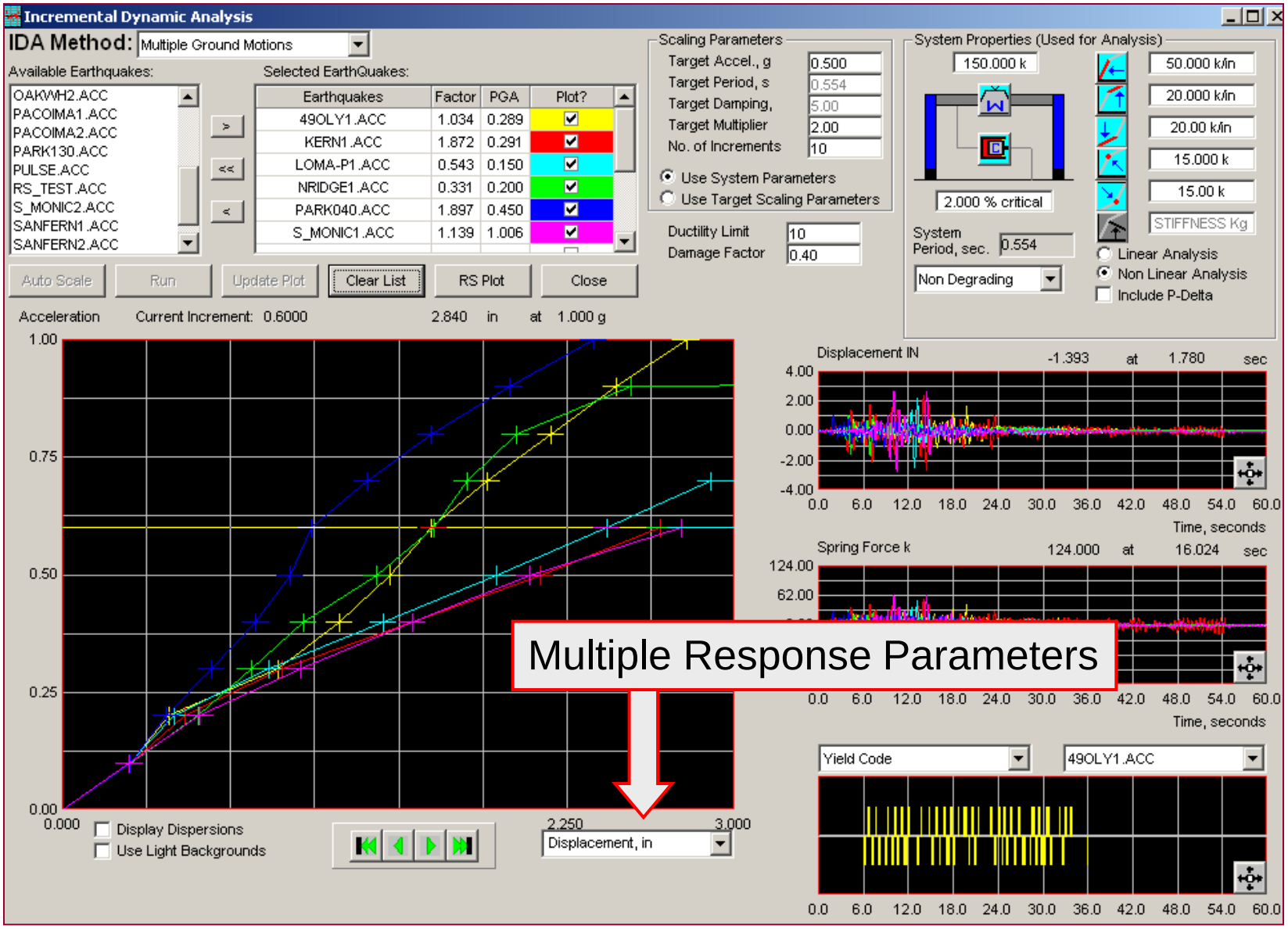


Multiple Ground Motions or Multiple Structural Parameters

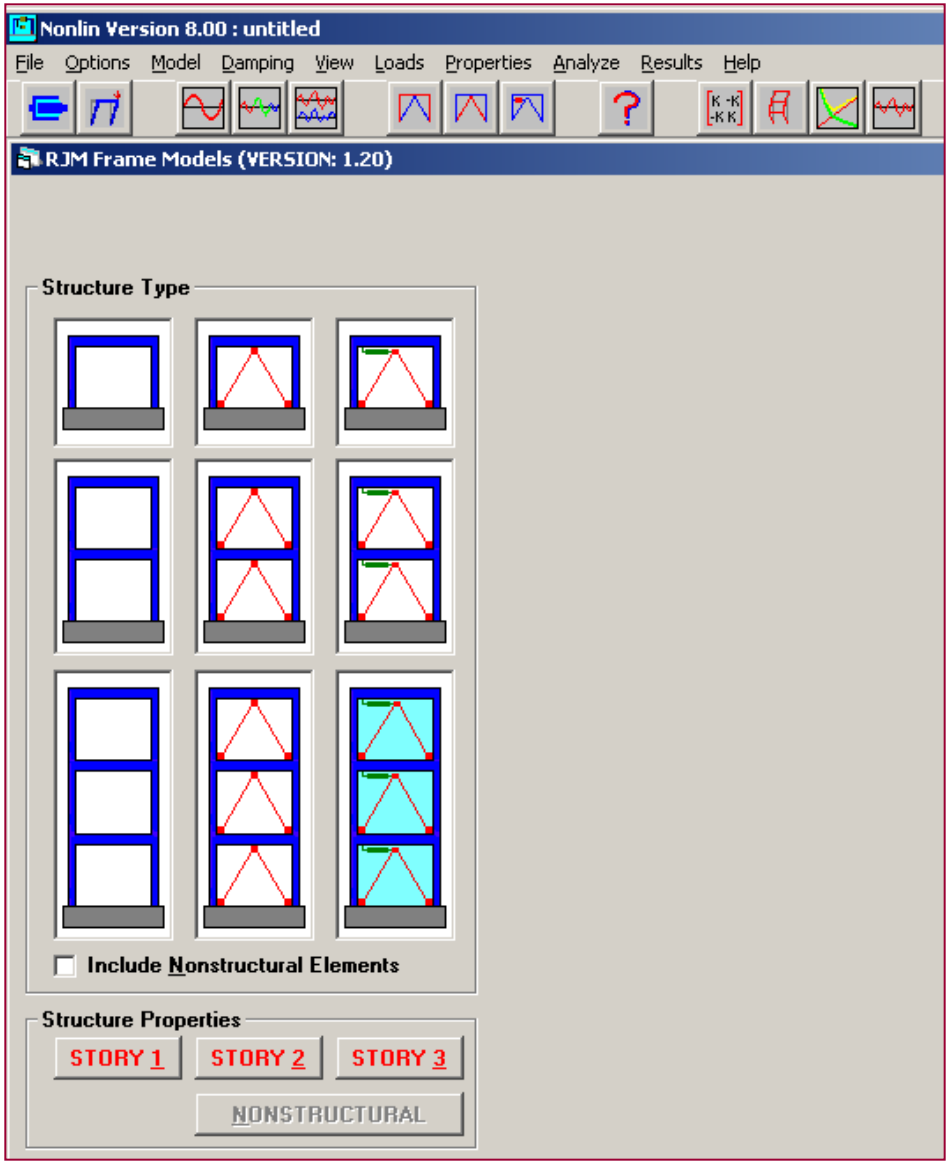
Incremental Dynamic Analysis (3)



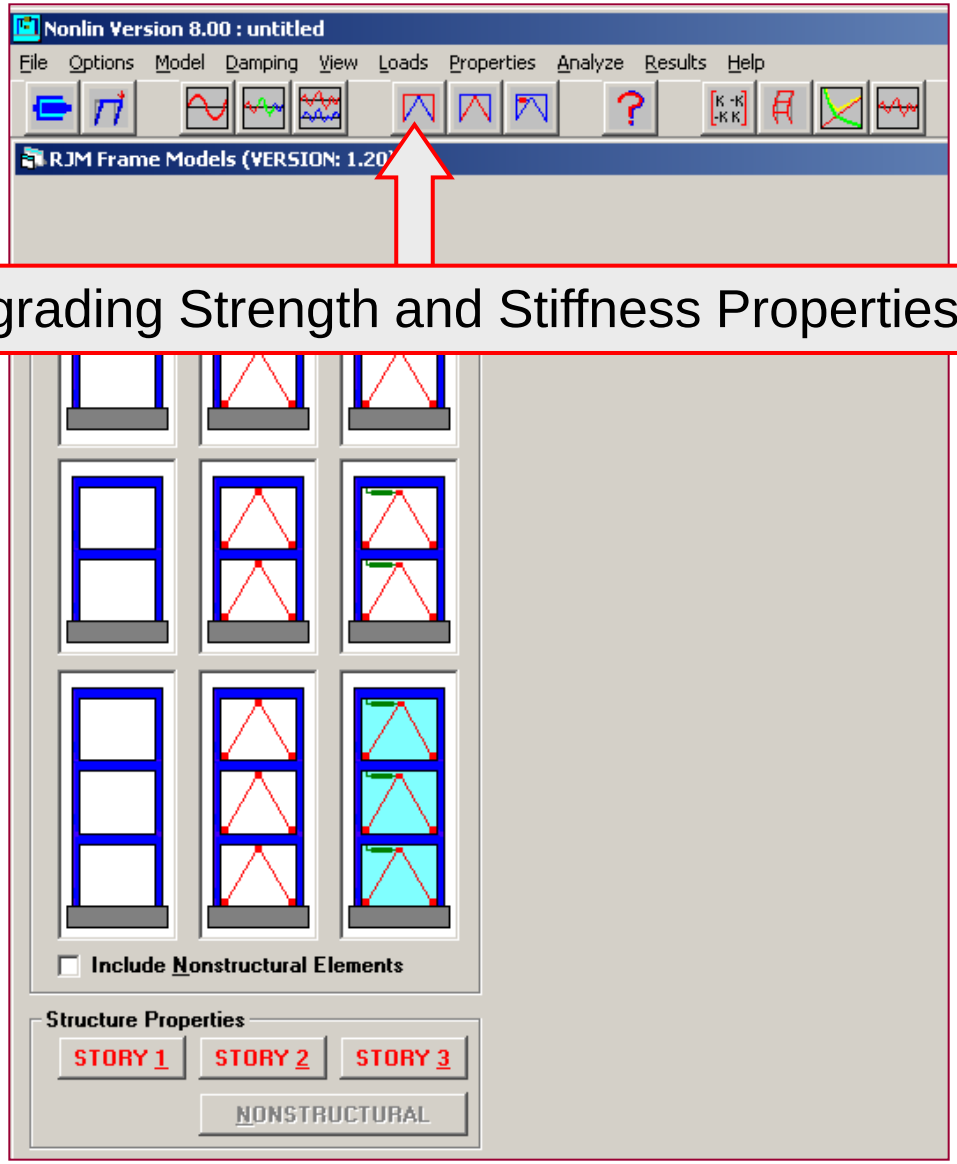
Incremental Dynamic Analysis (4)



New Multi-Story Model

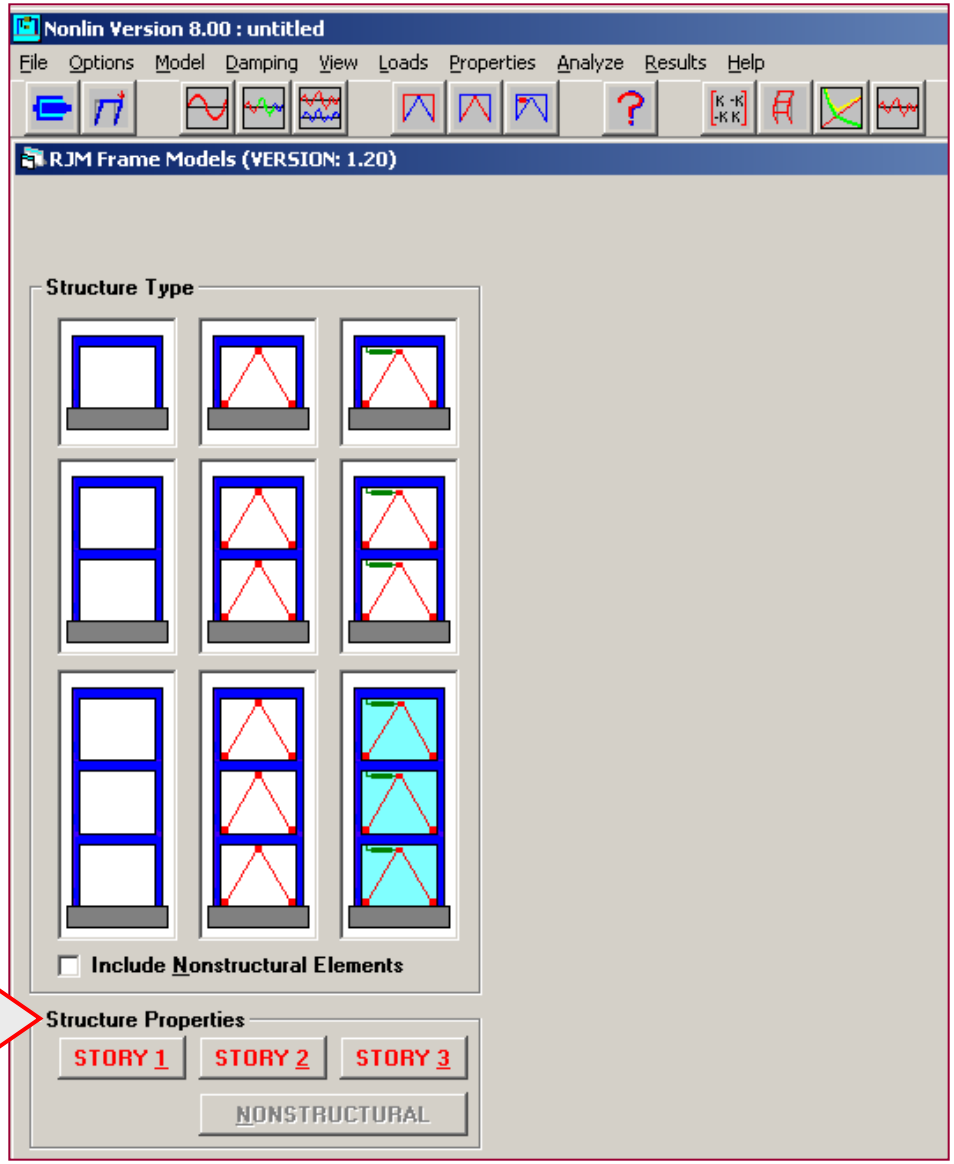


New Multi-Story Model (2)



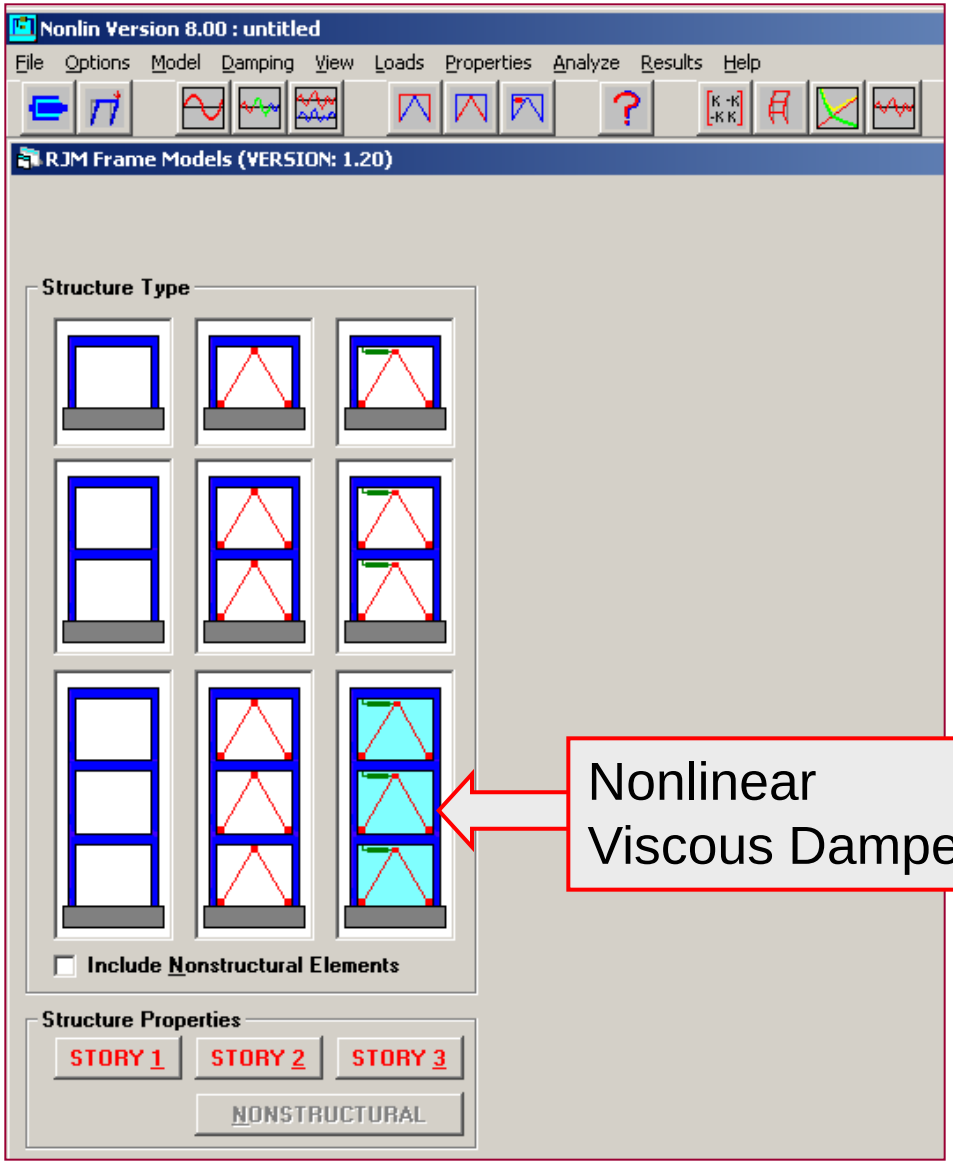
Degrading Strength and Stiffness Properties

New Multi-Story Model (3)



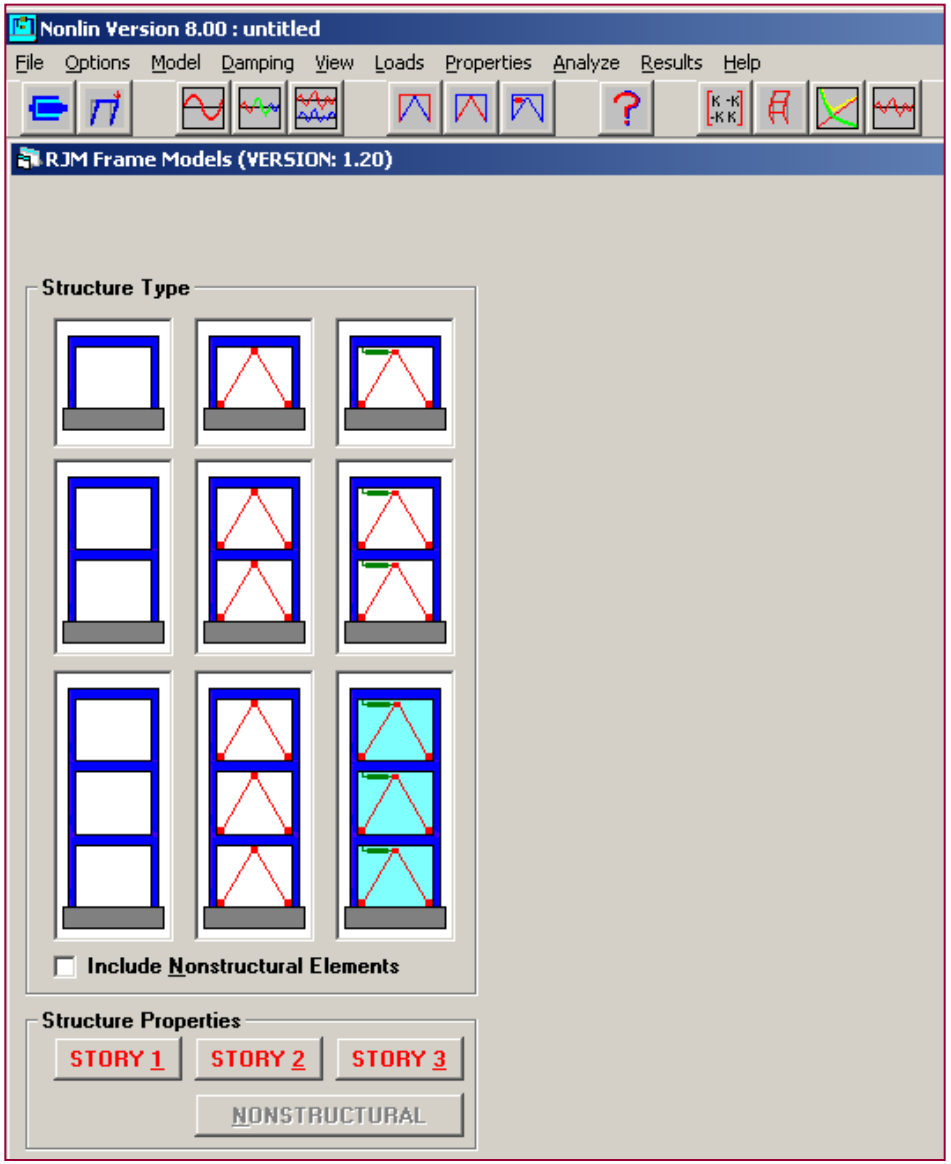
Structural and Nonstructural Properties

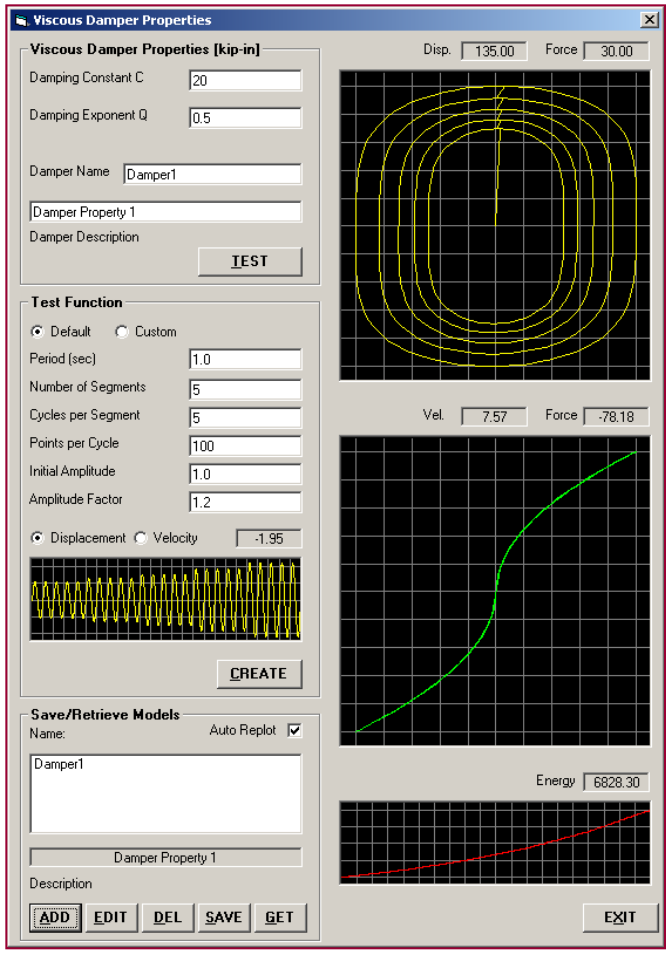
New Multi-Story Model (4)



Nonlinear
Viscous Dampers

New Multi-Story Model (5)





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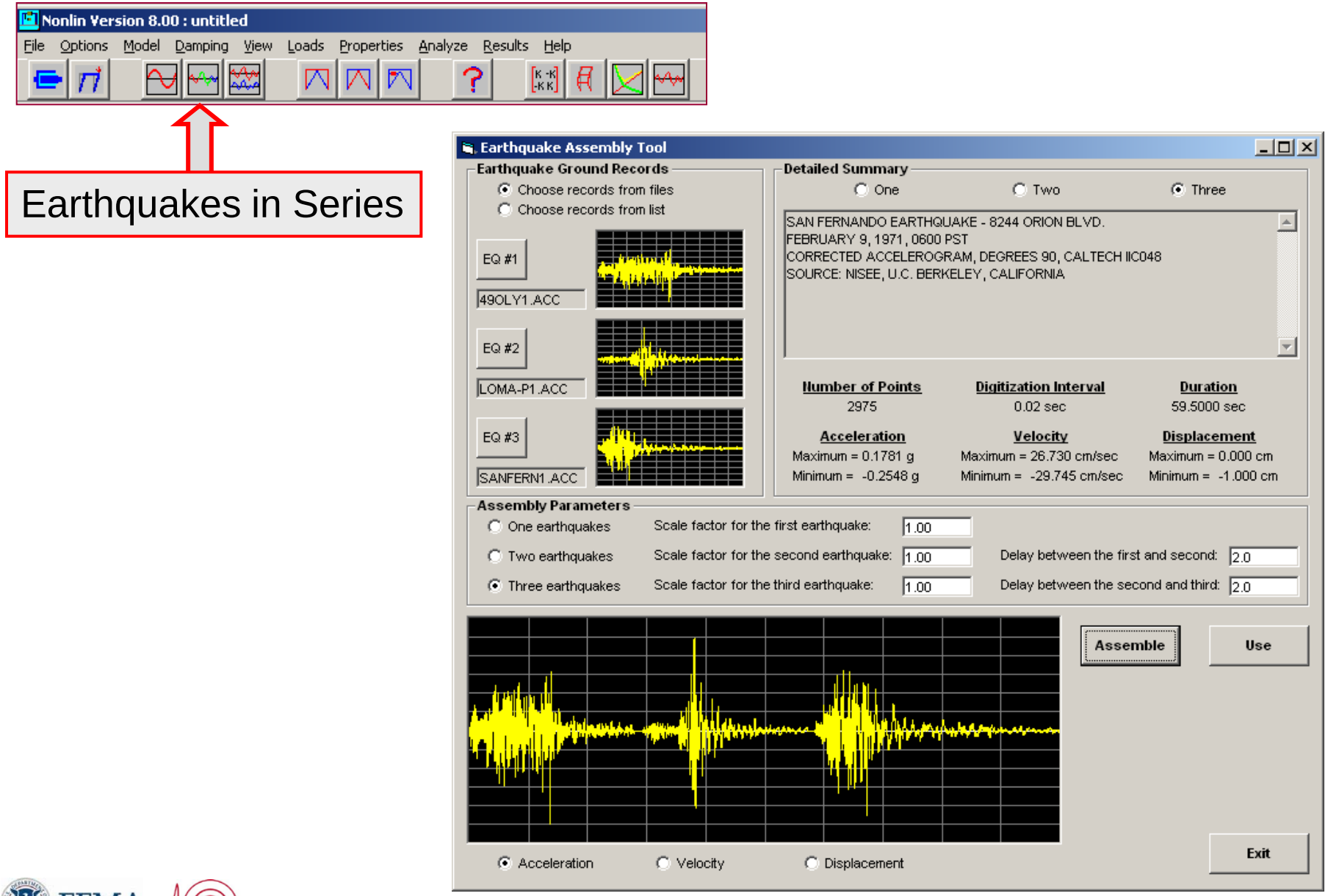
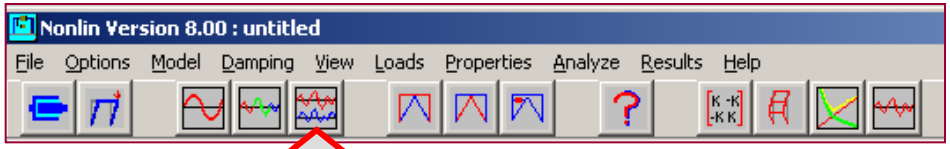
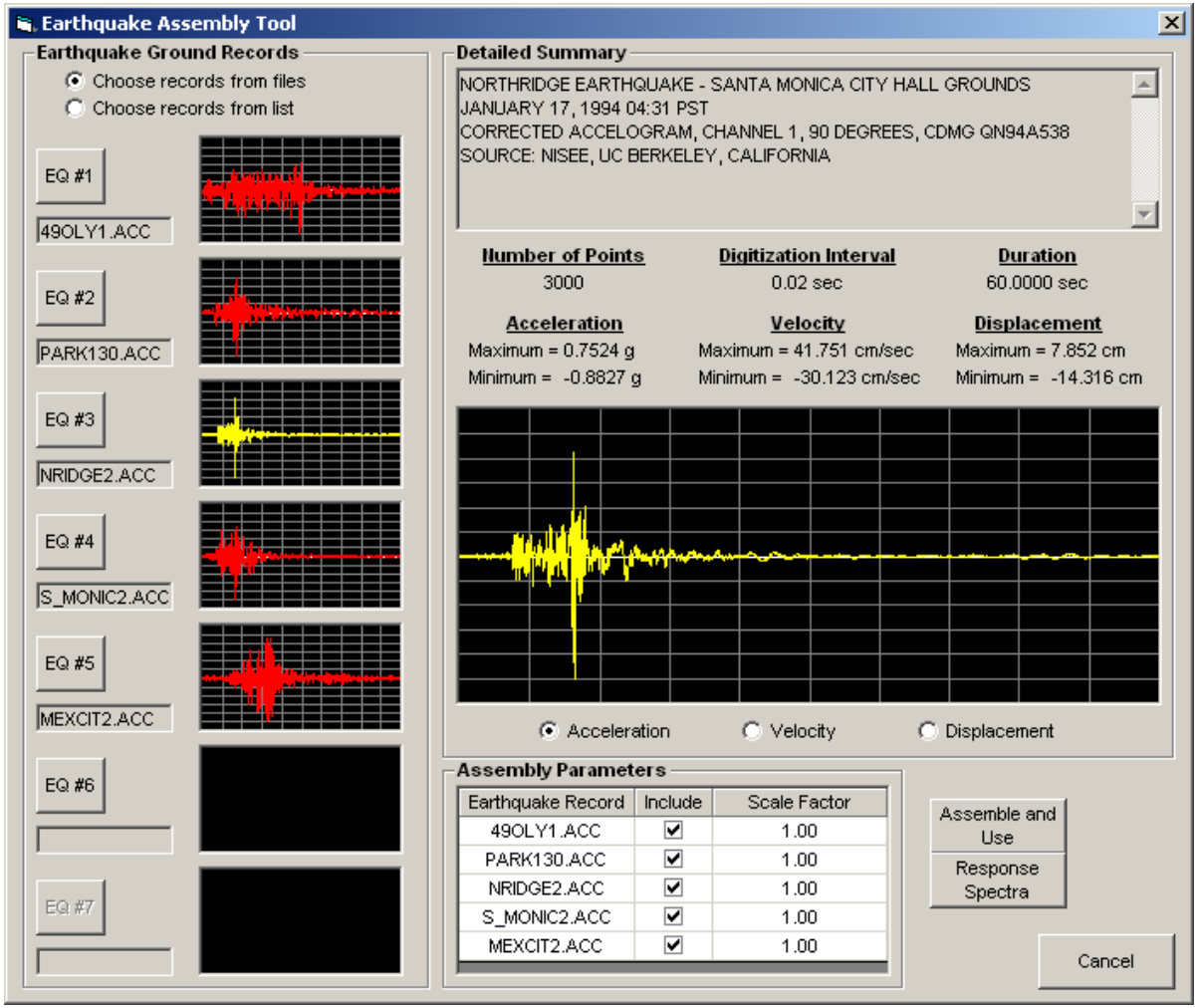


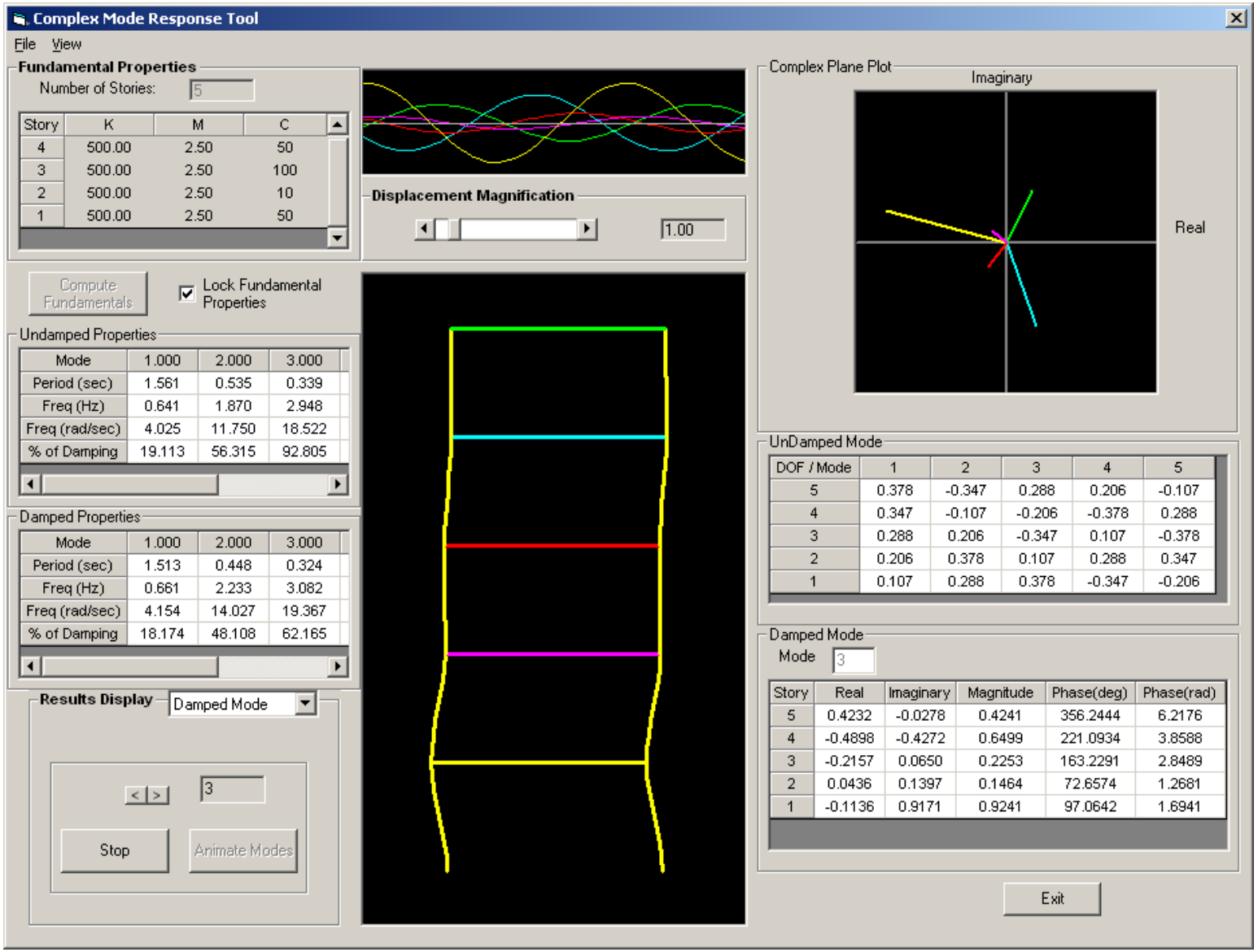
New Multi-Story Model (7)



Earthquakes in Parallel



New Nonproportional Damping Tool



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- Site Response Tools

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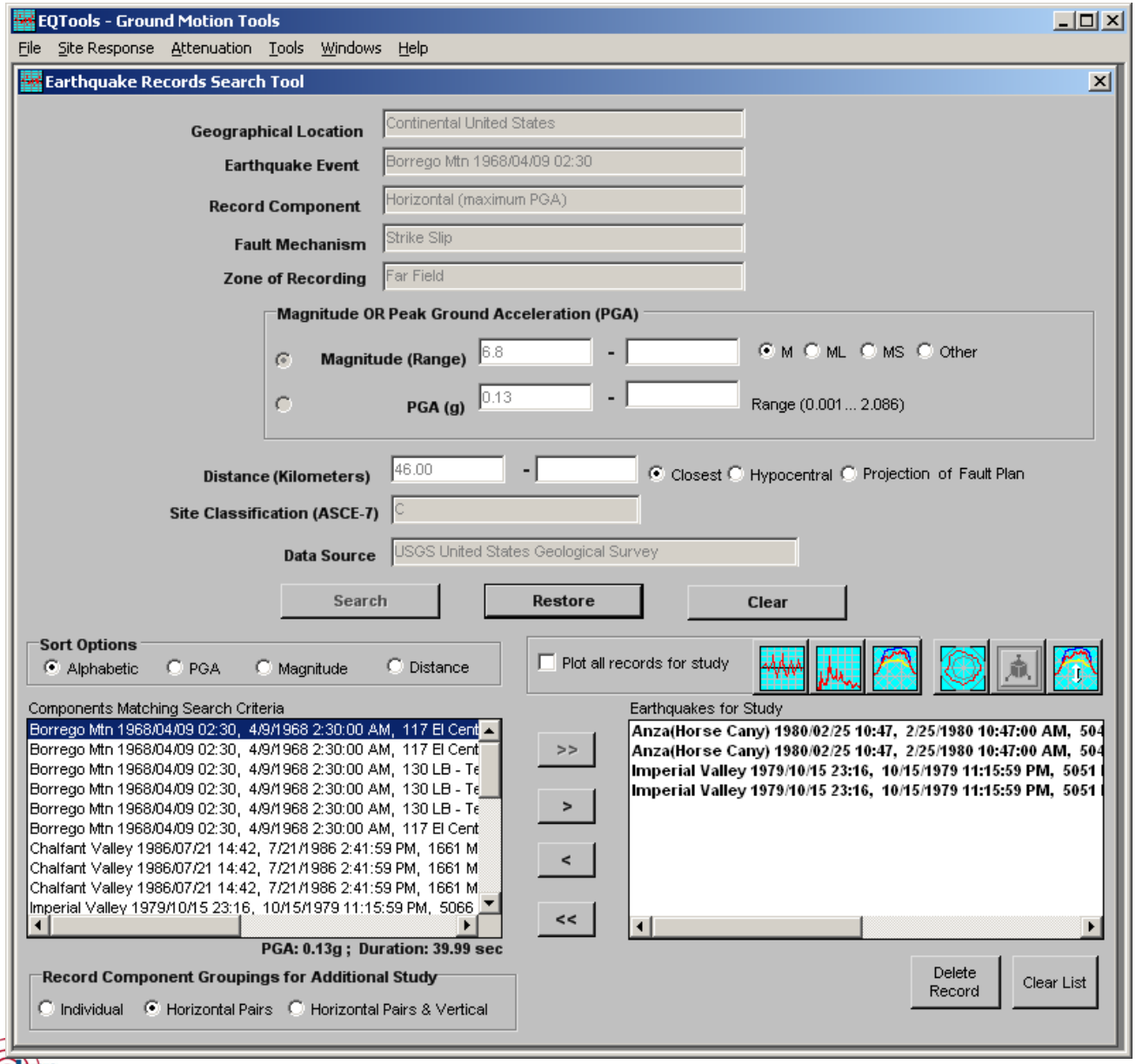
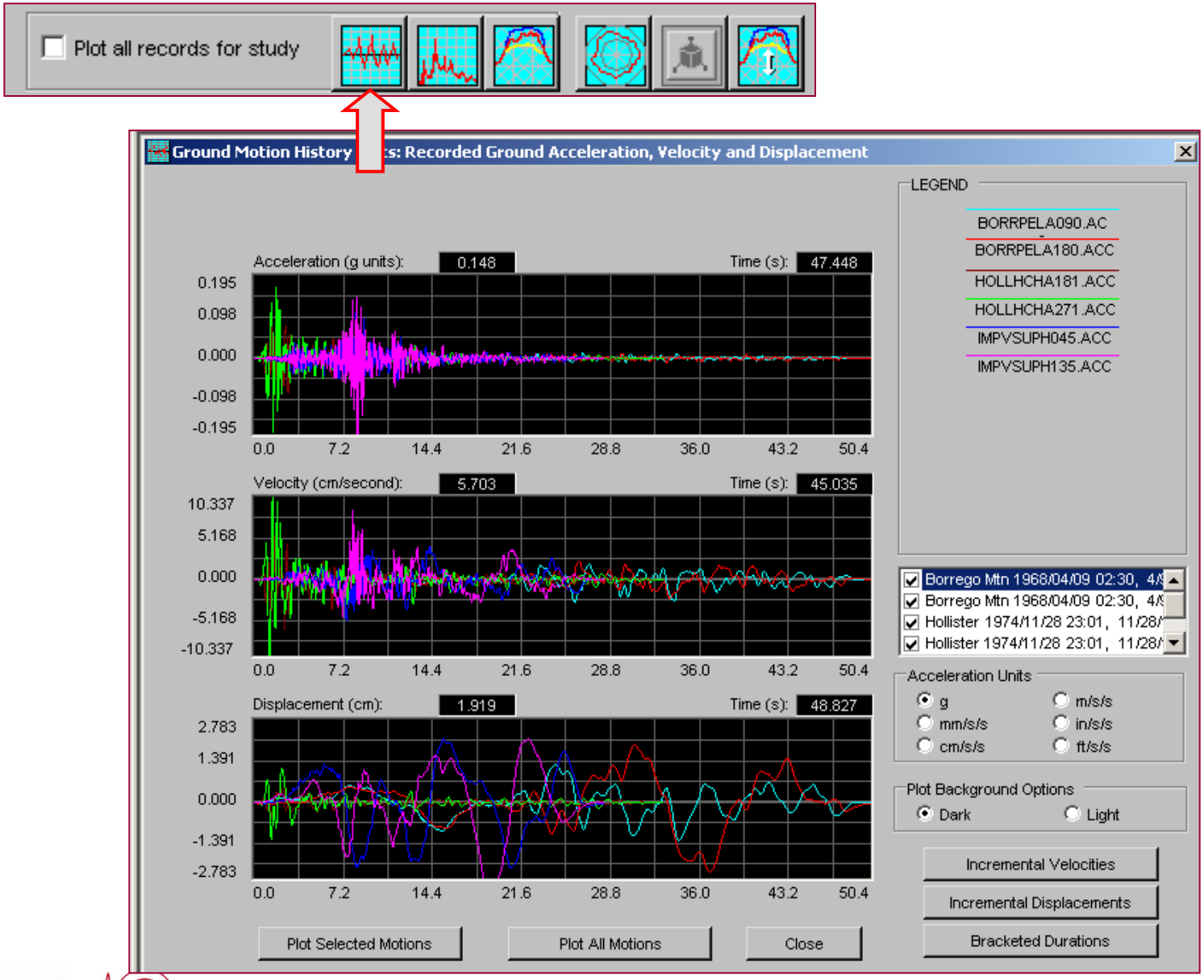
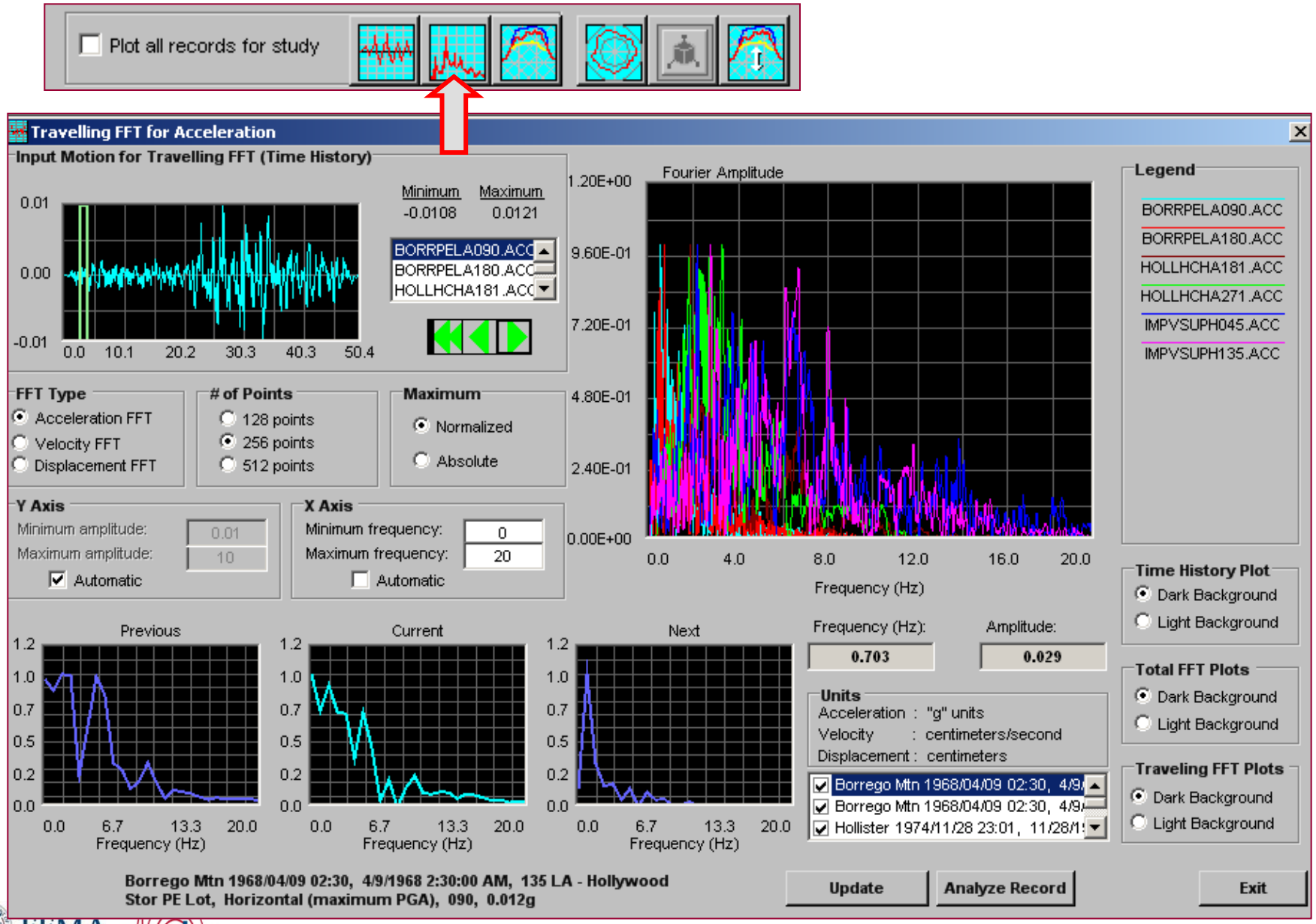
EQ-TOOLS Search Engine and Control Panel



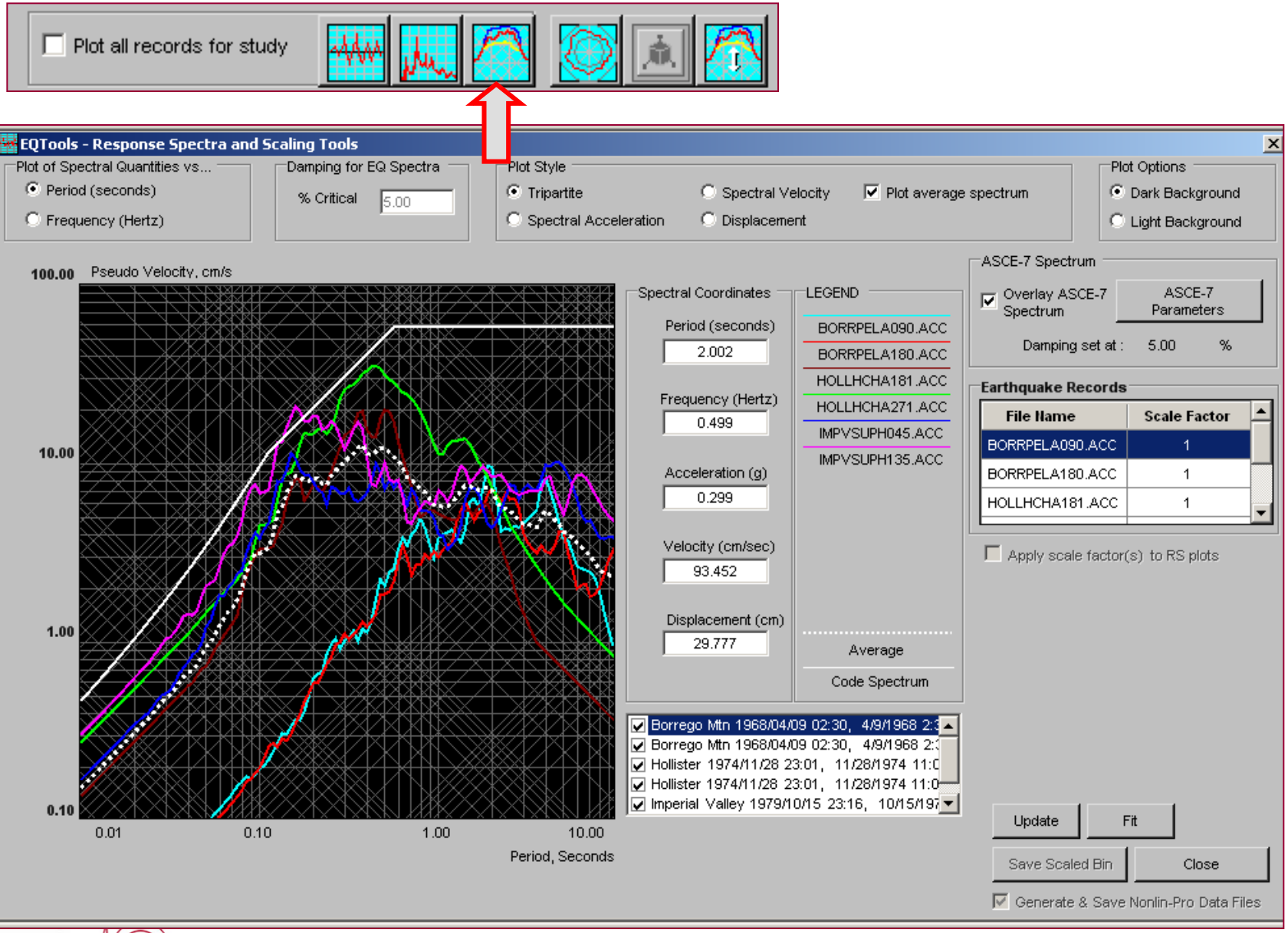
Ground Motion Analysis Tool



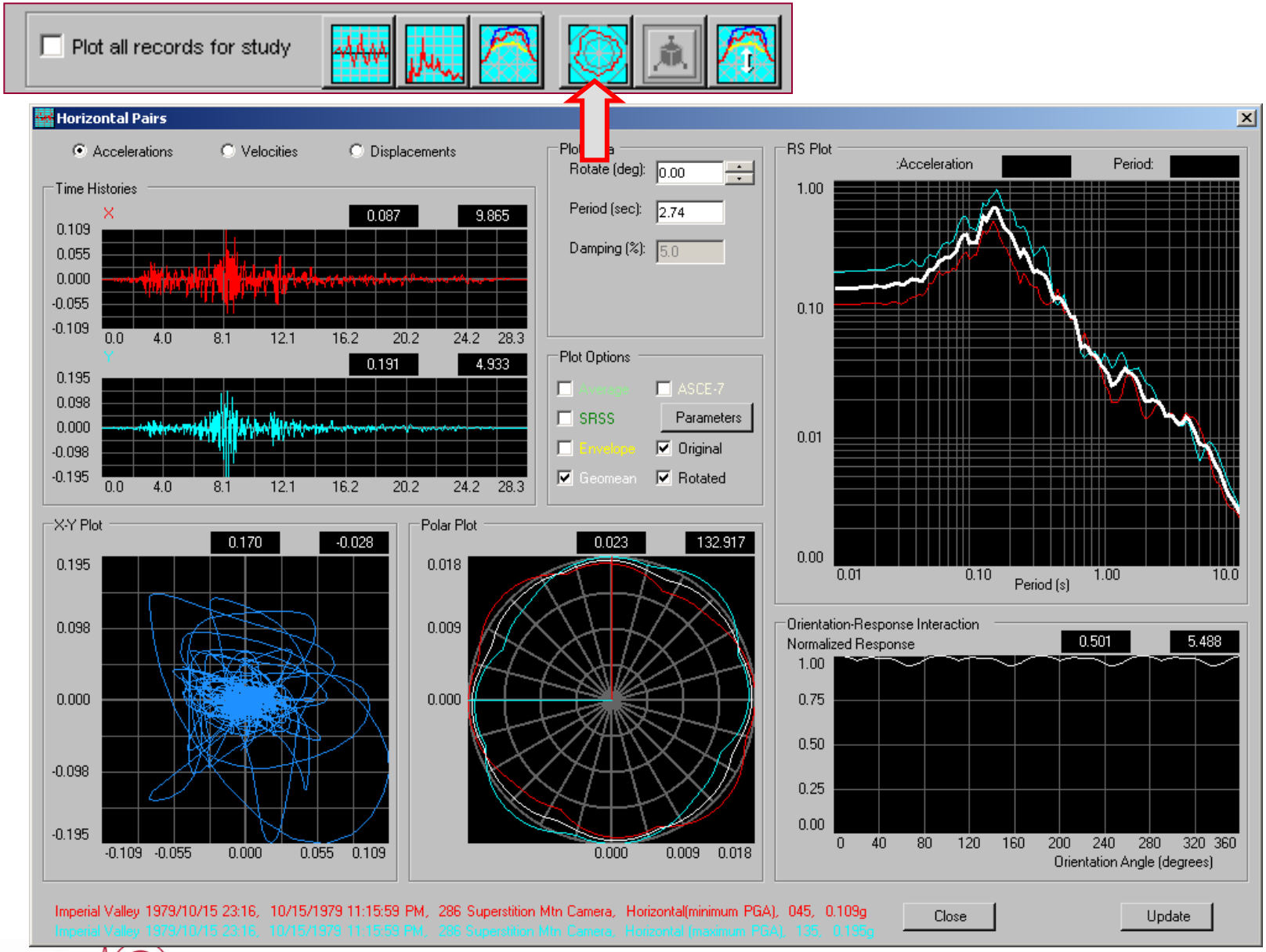
Fourier Amplitude Spectra Tool



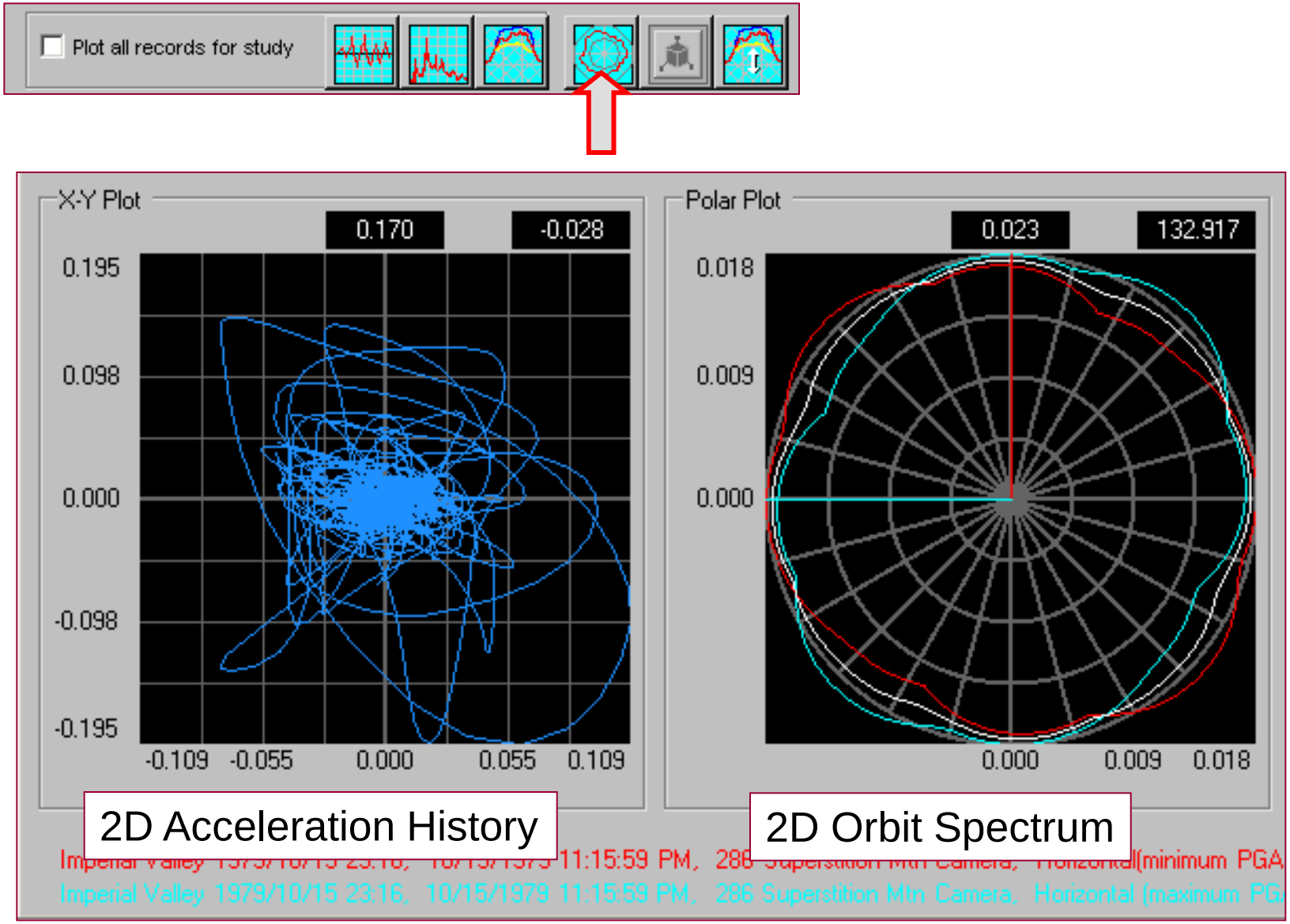
Response Spectrum Tool



Horizontal Components Tool



Horizontal Components Tool (2)



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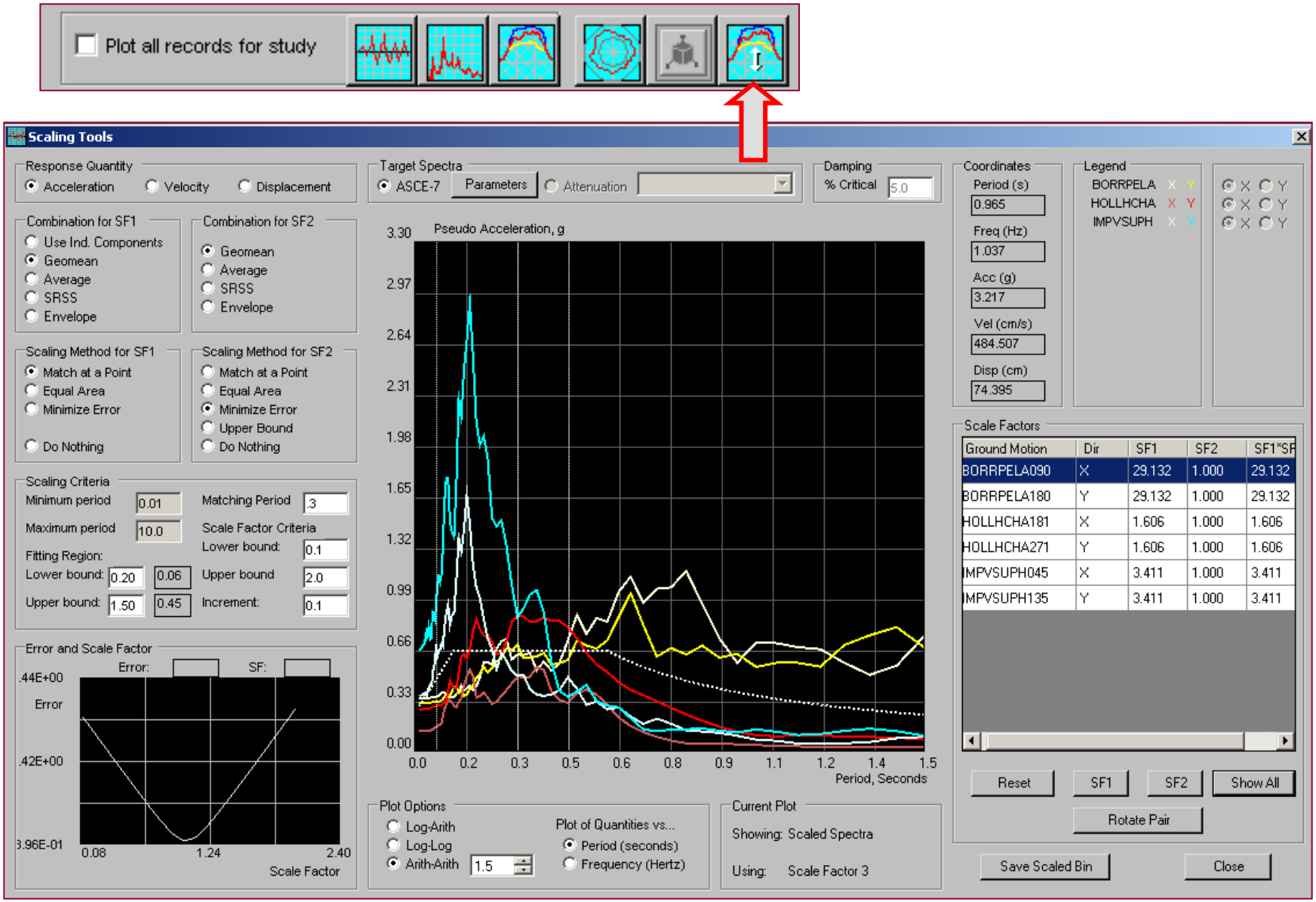

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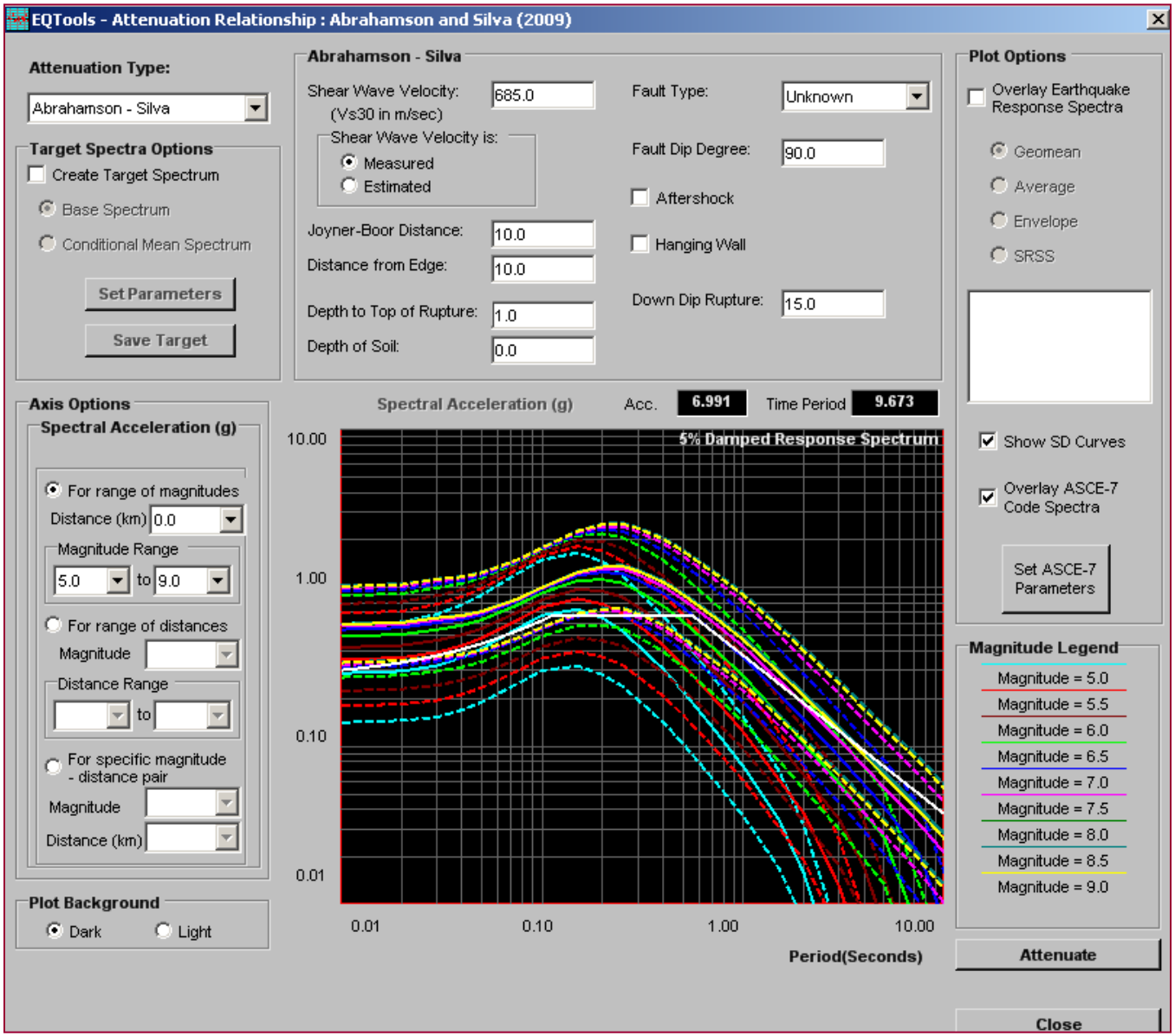

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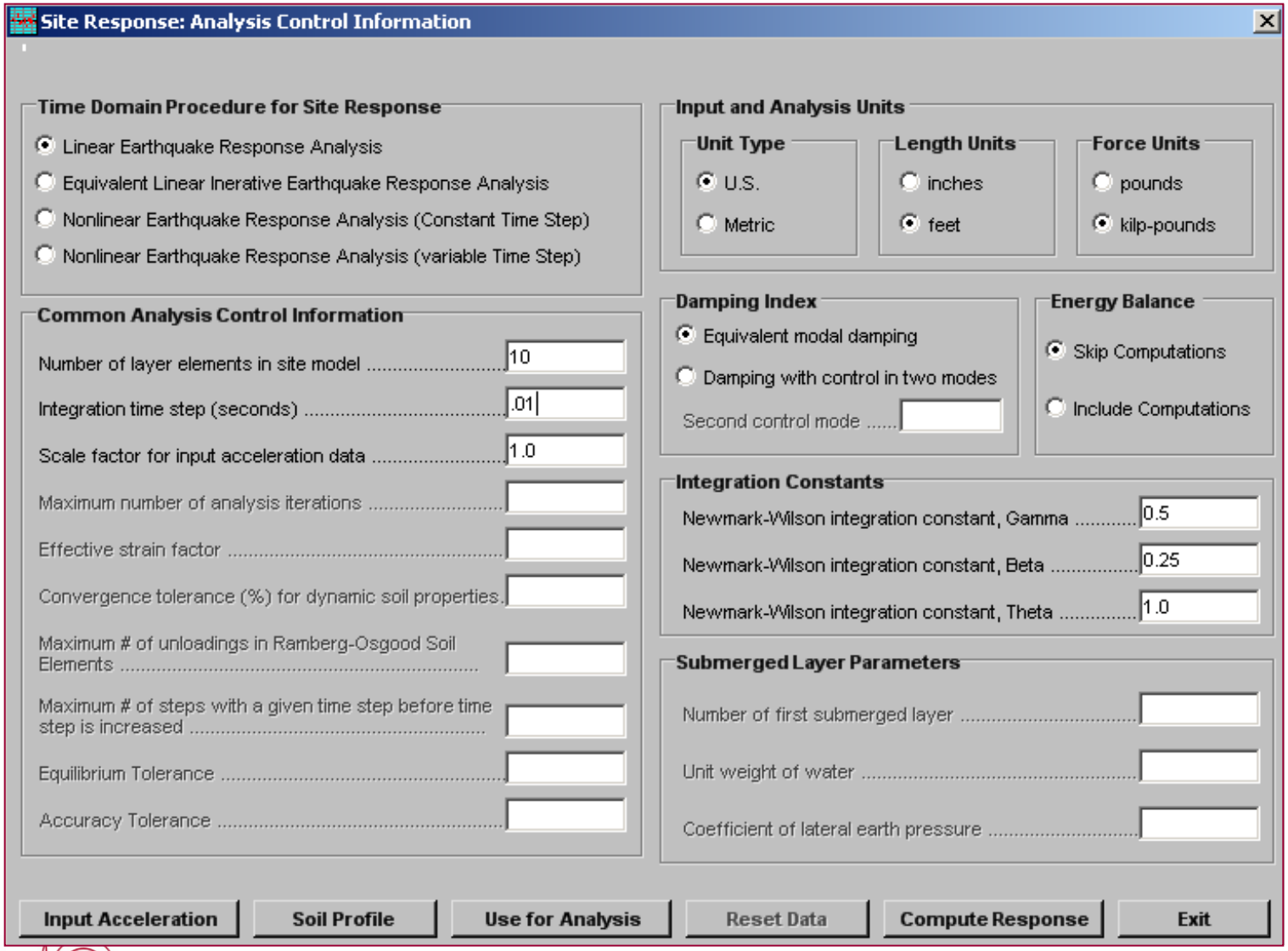

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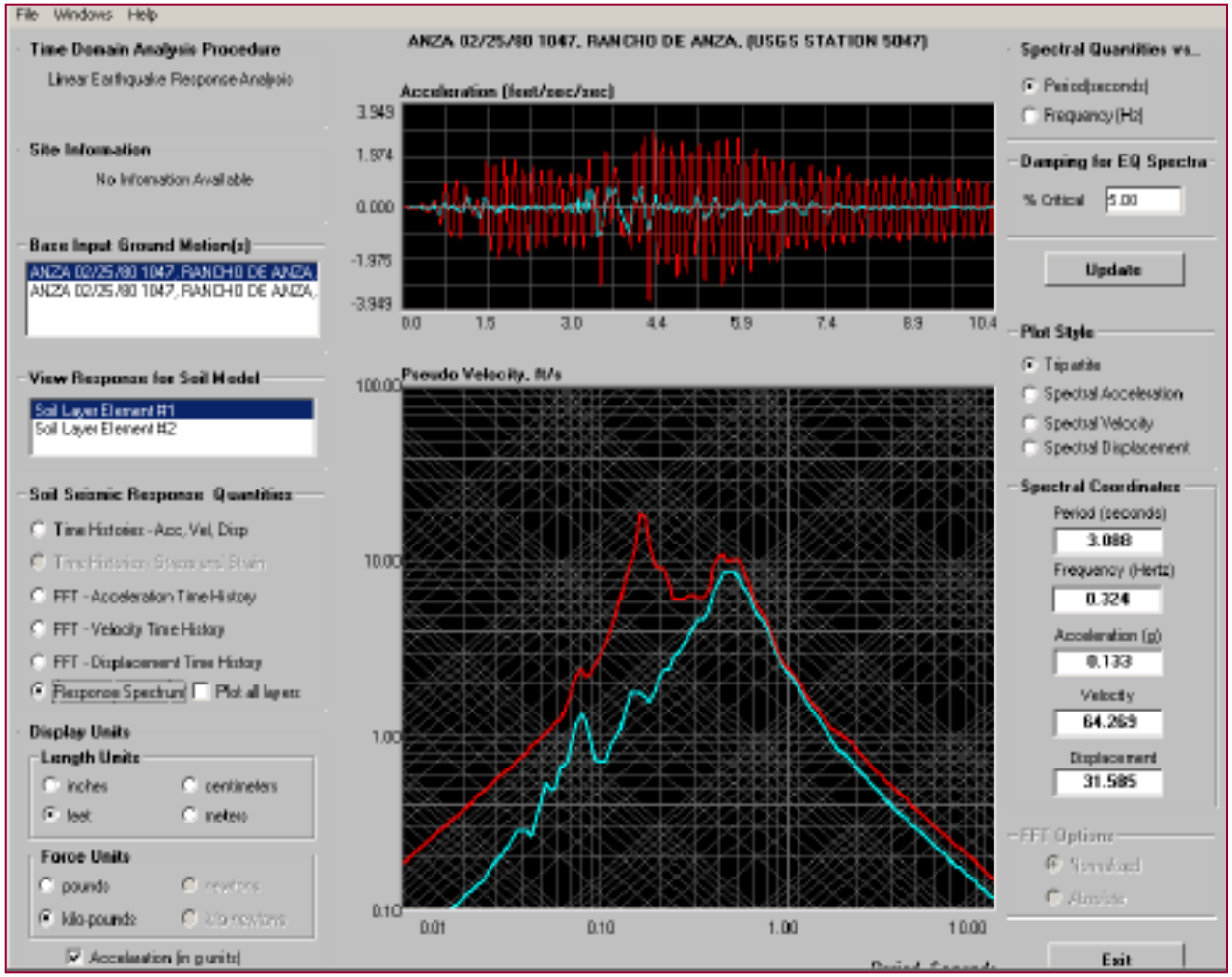

Modified ground motion may be saved for further analysis in EQ-Tools

Access to Programs Through NEES Hub

- NONLIN and EQ-Tools are available as online tools through NEEShub: http://nees.org/
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- Use of tools may require Java plugin (automatically provided by NEEShub)

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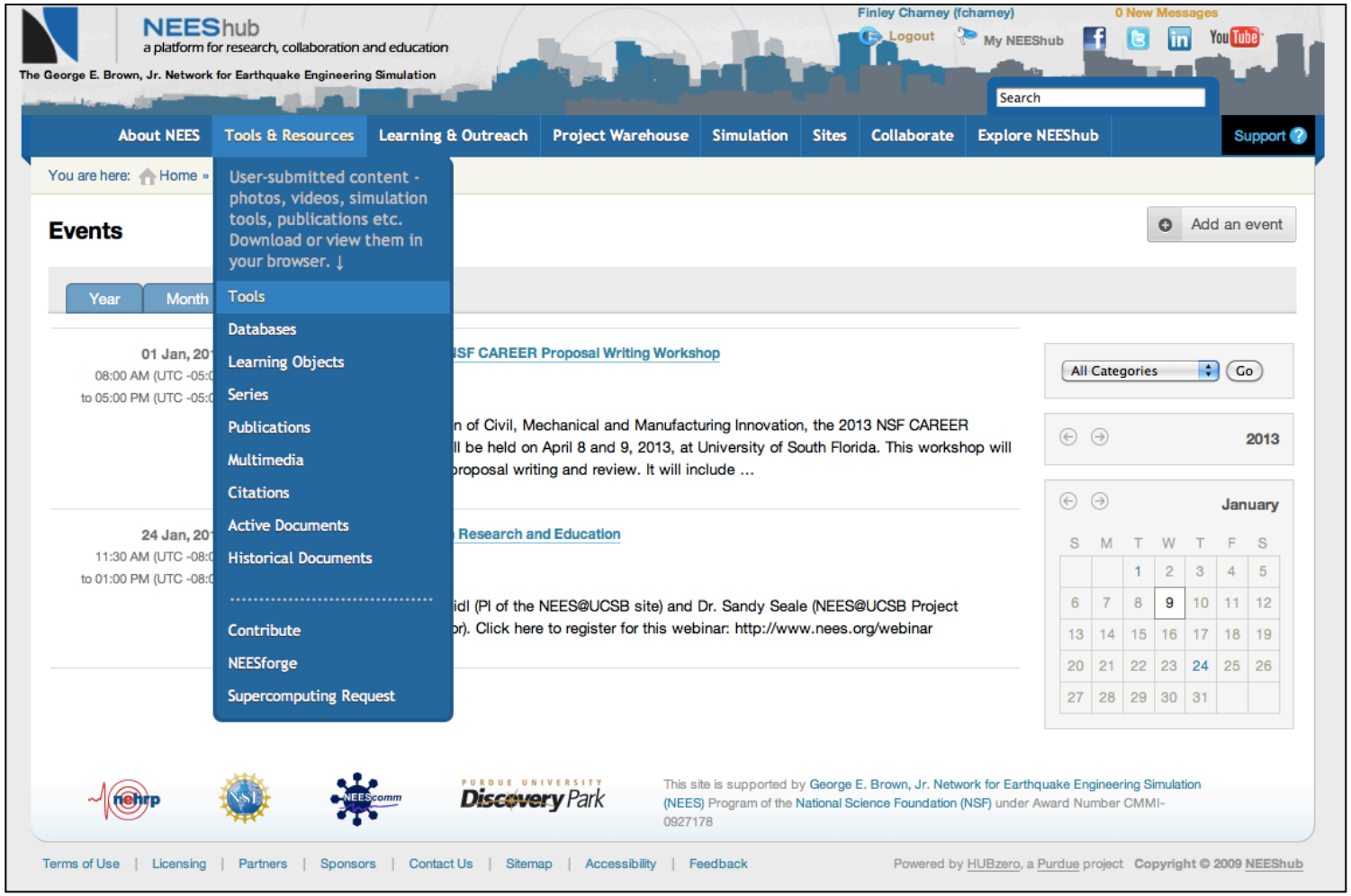

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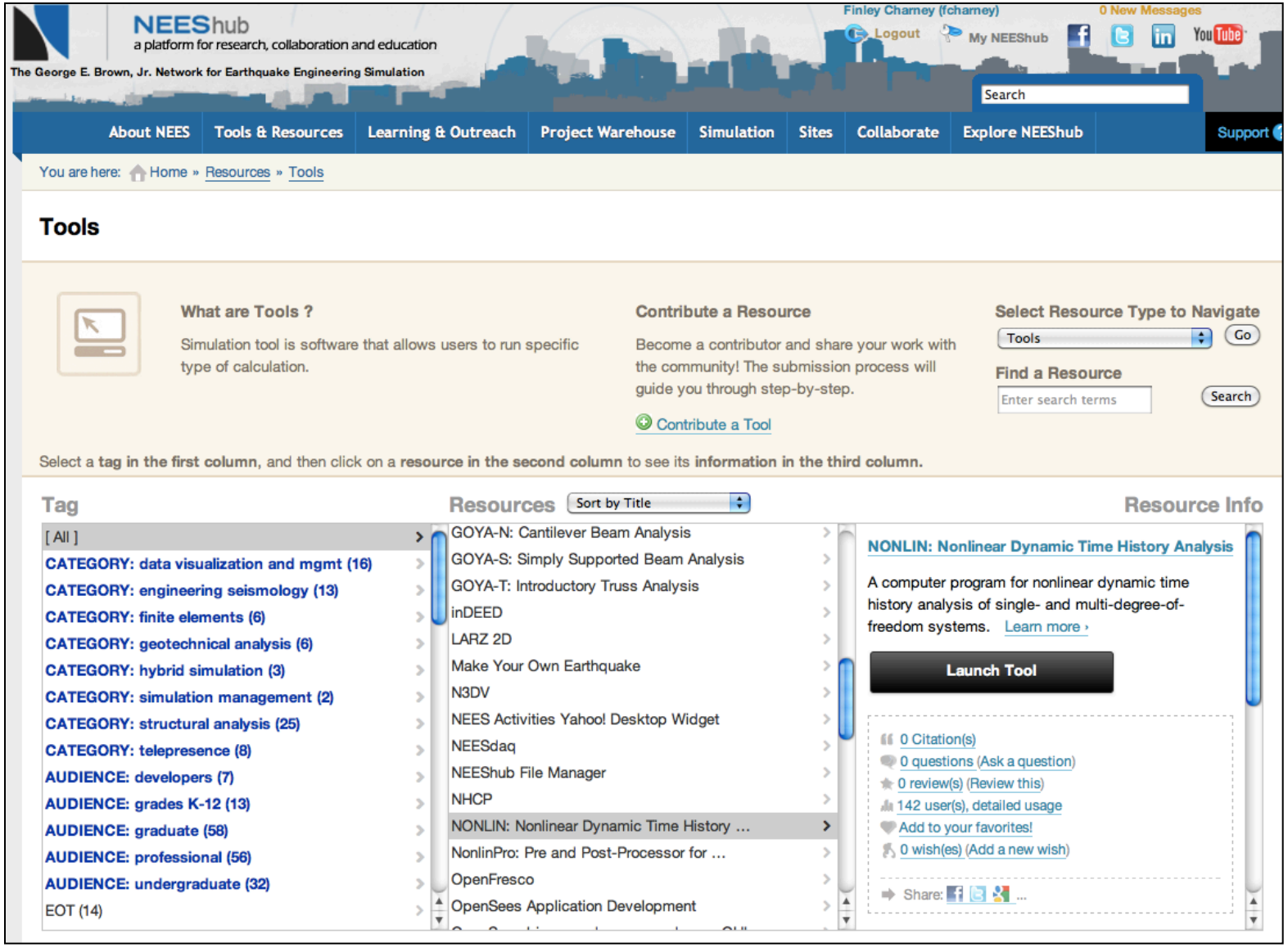

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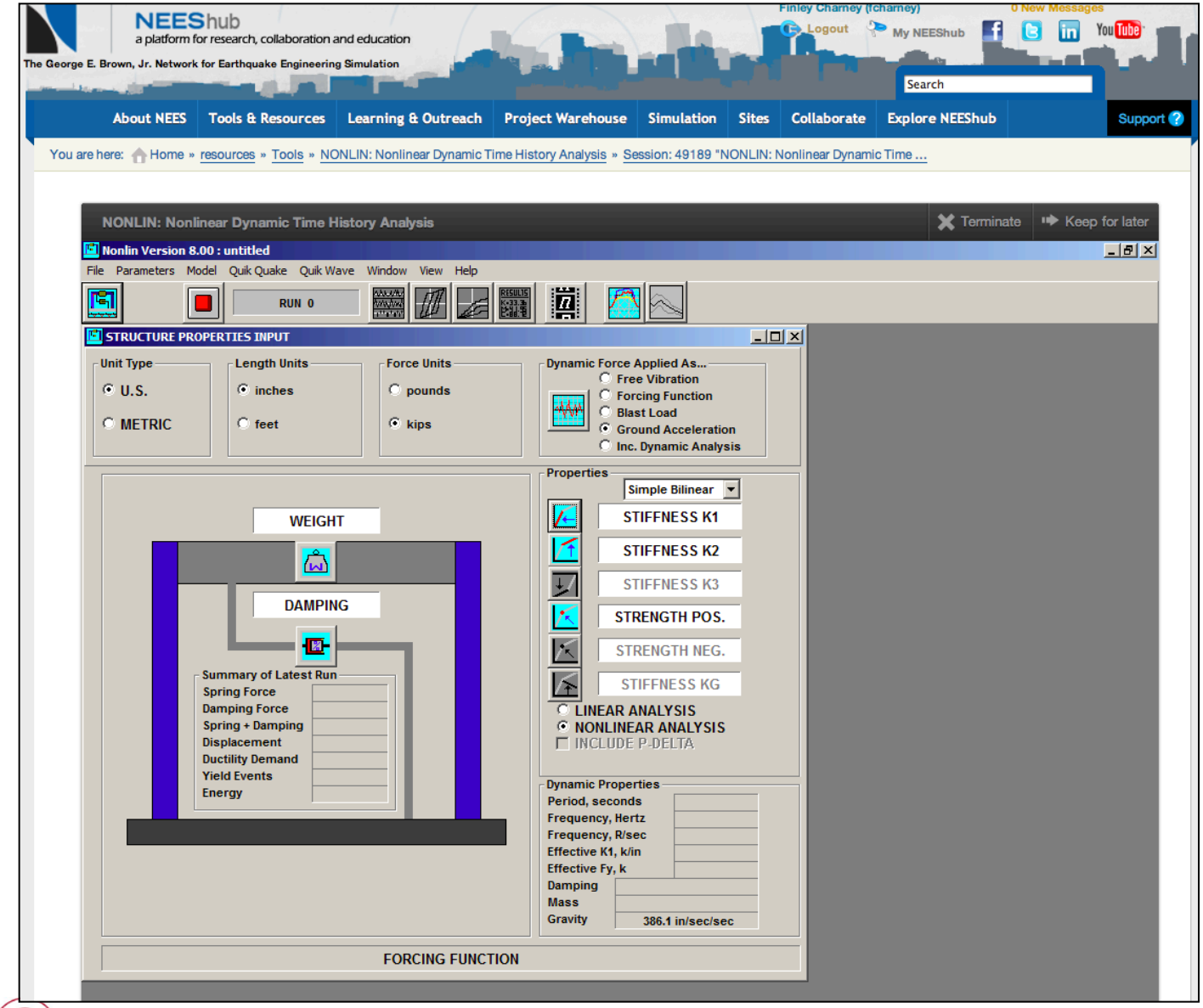

Questions

15

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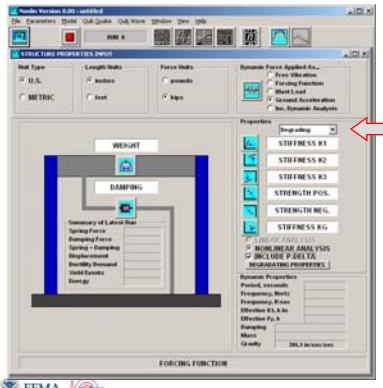

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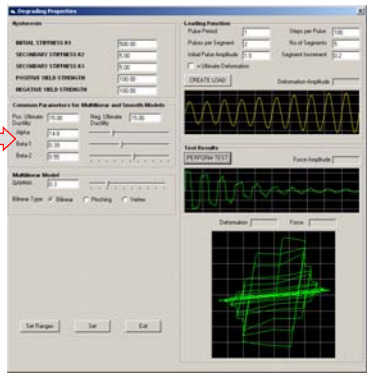
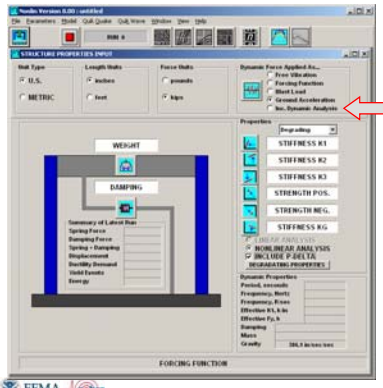
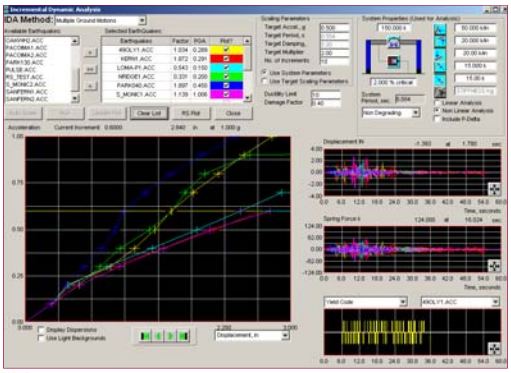


SDOF Analysis Tools: IDA

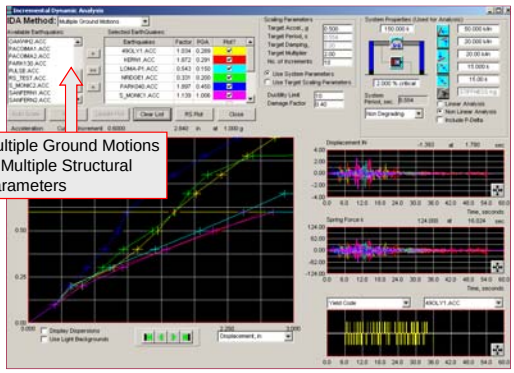


Incremental Dynamic Analysis

Incremental Dynamic Analysis

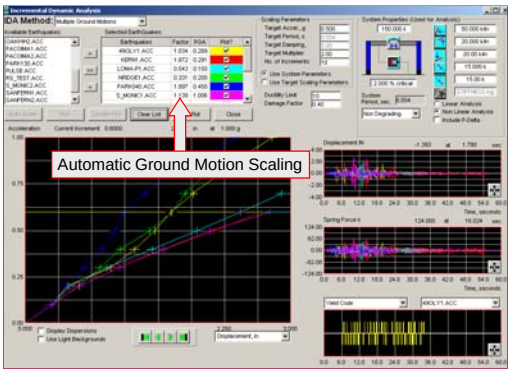


Incremental Dynamic Analysis (2)



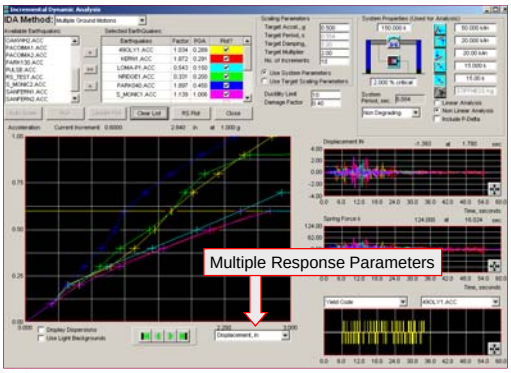
Instructional Material Complementing FEMA P-751, Design Examples NONLIN and EQ-Tools 7

Incremental Dynamic Analysis (3)



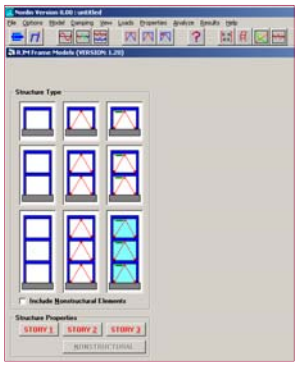
Instructional Material Complementing FEMA P-751, Design Examples NONLIN and EQ-Tools 8

Incremental Dynamic Analysis (4)



Instructional Material Complementing FEMA P-751, Design Examples NONLIN and EQ-Tools 9

New Multi-Story Model



New Multi-Story Model (2)

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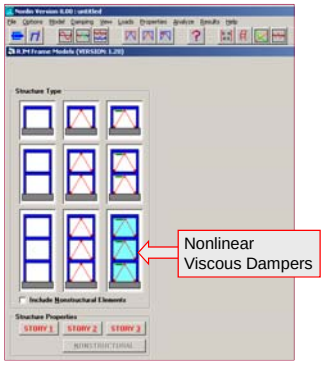
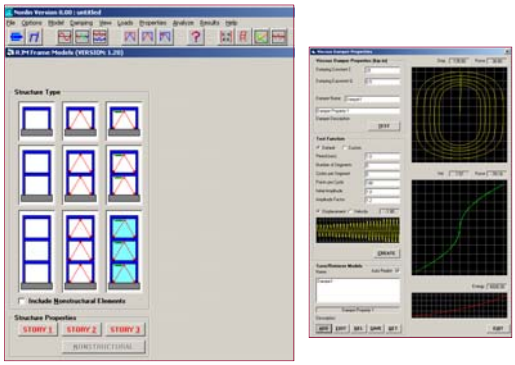
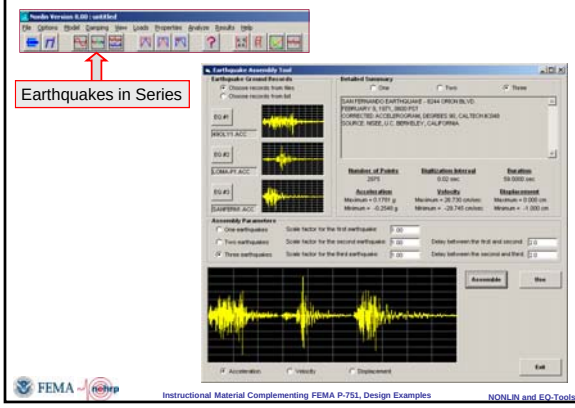


New Multi-Story Model (5)



New Multi-Story Model (6)



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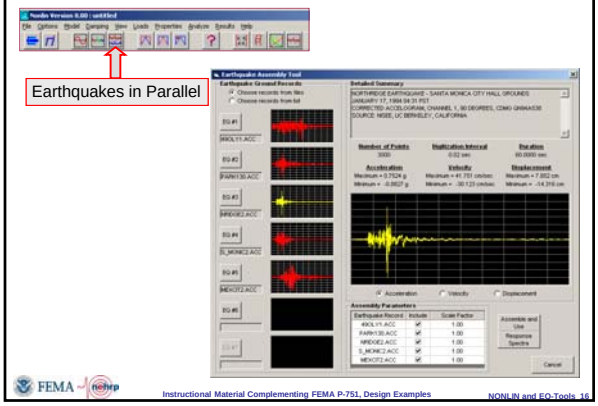
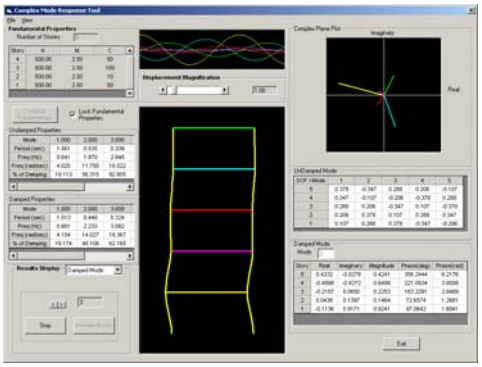


New Nonproportional Damping Tool



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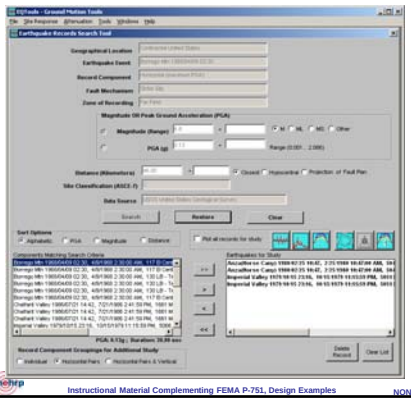
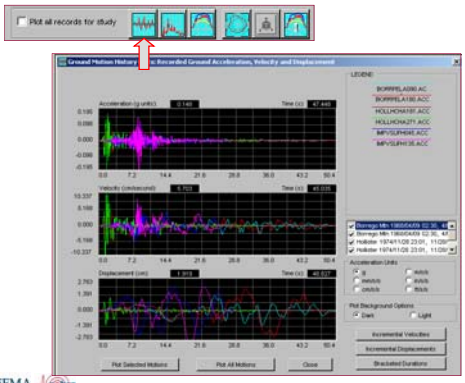
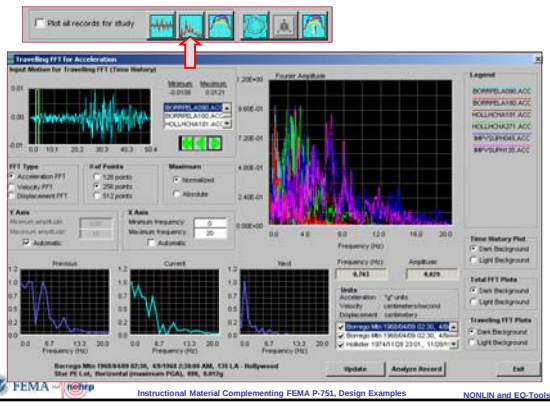


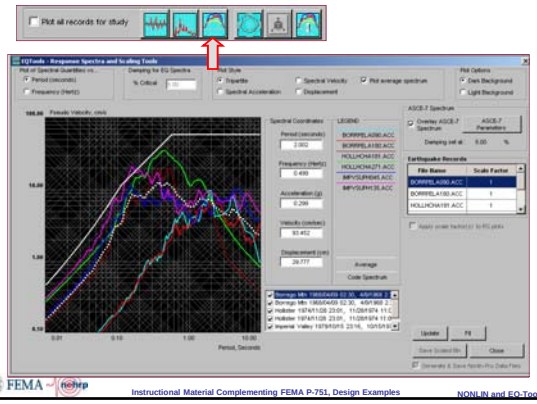
Ground Motion Analysis Tool



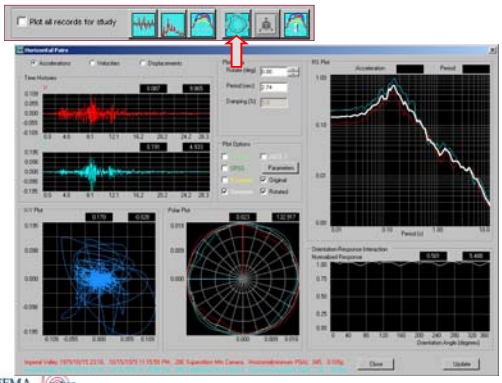
Fourier Amplitude Spectra Tool



Response Spectrum Tool



Horizontal Components Tool



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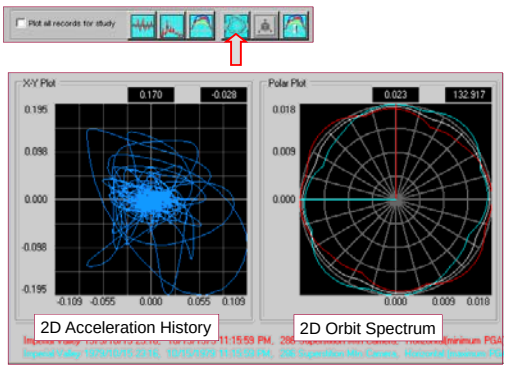
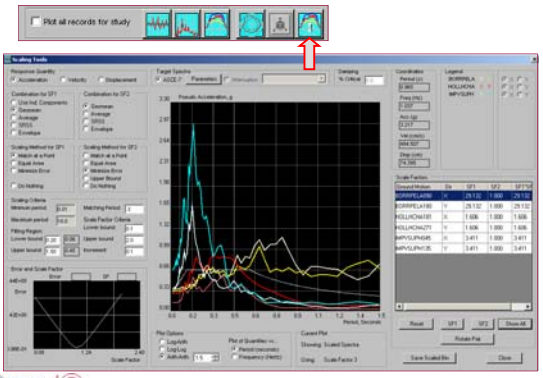


Ground Motion Scaling Tool



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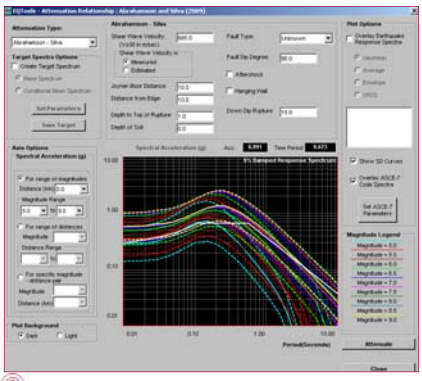
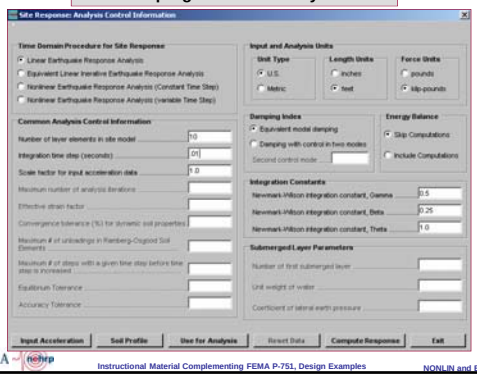
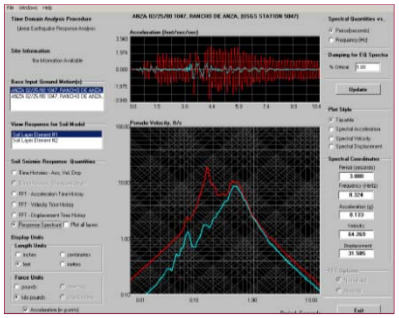


Site Response Analysis Tool

Based on program "Waves" by J.D. Hart



Site Response Analysis Tool



Modified ground motion may be saved for further analysis in EQ-Tools

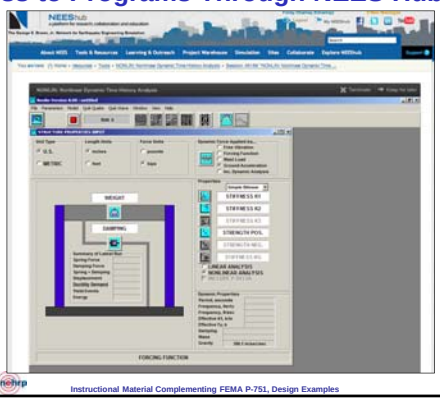
Access to Programs Through NEES Hub

- NONLIN and EQ-Tools are available as online tools through NEEShub: http://nees.org/
- Users must register with NEEShub before using the tools.
- Use of tools may require Java plugin (automatically provided by NEEShub)

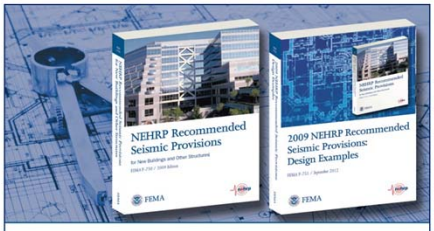
Access to Programs Through NEES Hub (2)

Access to Programs Through NEES Hub (3)

Access to Programs Through NEES Hub (4)



Questions



2009 NEHRP Recommended Seismic Provisions:

Training and Instructional Materials

FEMA P-752 CD / June 2013

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15

NONLIN and EQ-Tools Software for Earthquake Engineering Education

Finley A. Charney, Ph.D., P.E., Virginia Tech,
Department of Civil and Environmental Engineering

FEMA

Instructional Material Complementing FEMA P-751, Design Examples

NONLIN and EQ-Tools 1

Title slide.

NONLIN: Version 8.0

- **Nonlinear Dynamic Analysis of SDOF Systems**
- **Incremental Dynamic Analysis of SDOF**
- **Nonlinear Dynamic Analysis of Simple MDOF Systems**
- Elastic and Inelastic Response Spectrum Analysis
- Fourier Amplitude Spectrum Analysis
- Modal Analysis of Simple Proportionally Damped Systems
- **Modal Analysis of Simple Non-proportionally Damped Systems**

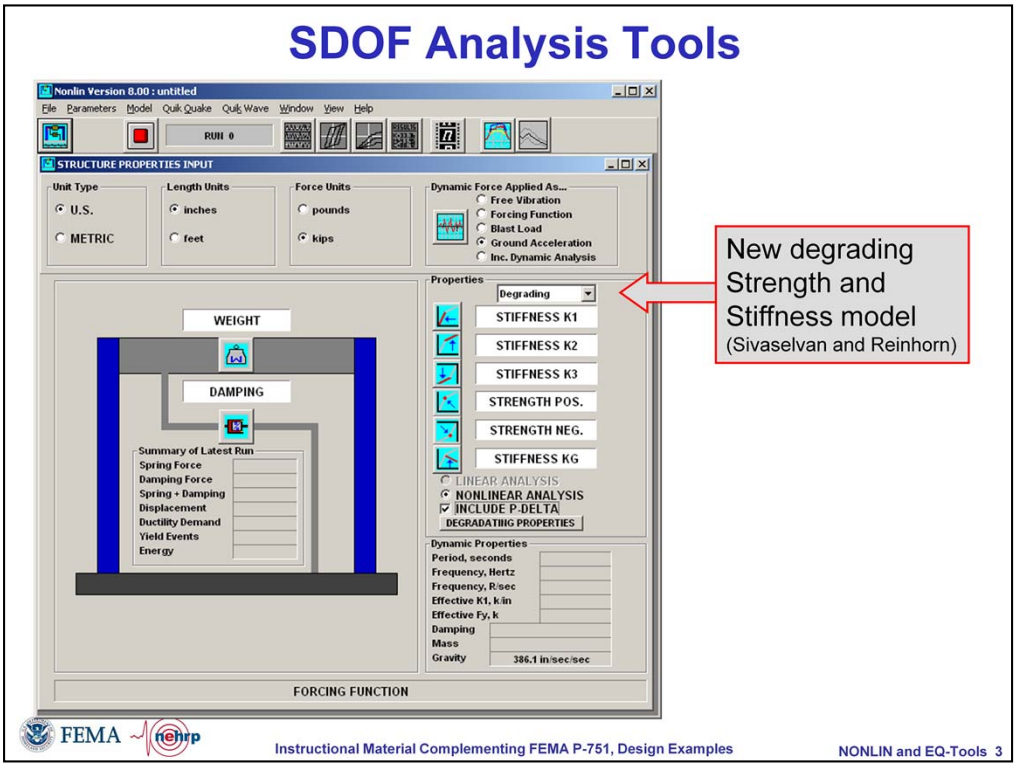
Items in **BOLD** indicate significant updates since Version 7

FEMA nehrp Instructional Material Complementing FEMA P-751, Design Examples NONLIN and EQ-Tools 2

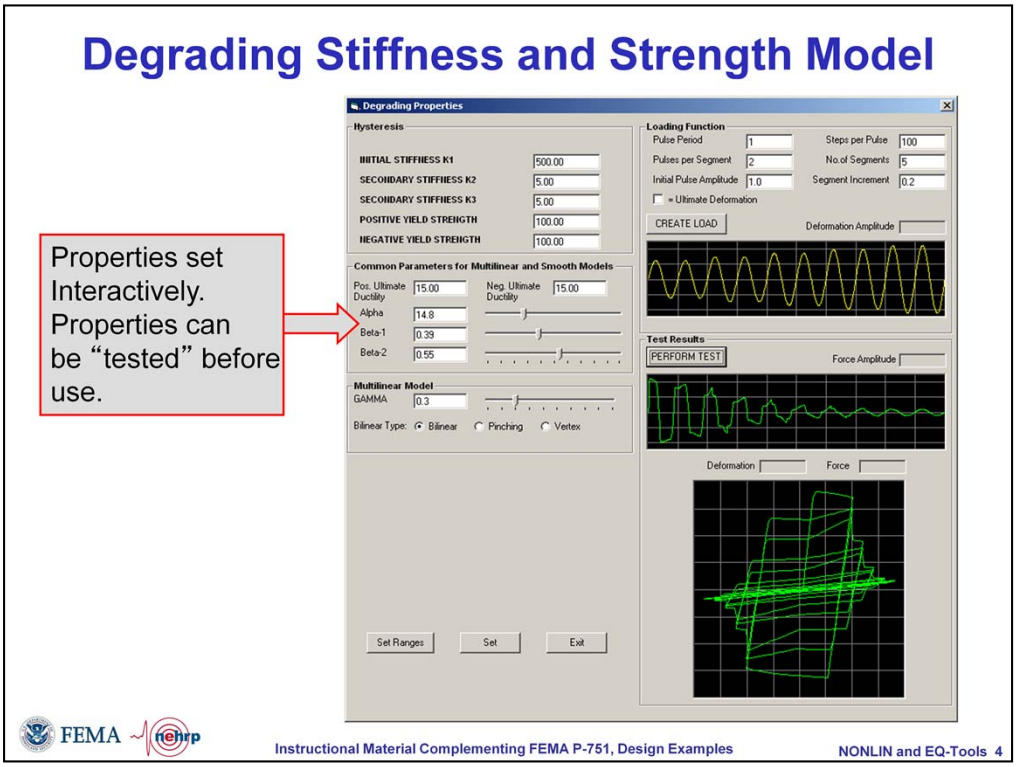
This presentation provides some of the key features of the educational computer programs NONLIN and EQ-Tools. These programs were developed by Dr. Finley Charney. Most of the funding for development of the programs was provided by FEMA. The programs are available from NEES Hub as described at the end of the presentation.

NOTE: It would beneficial for the instructor to demonstrate the programs "Live" during the presentation.

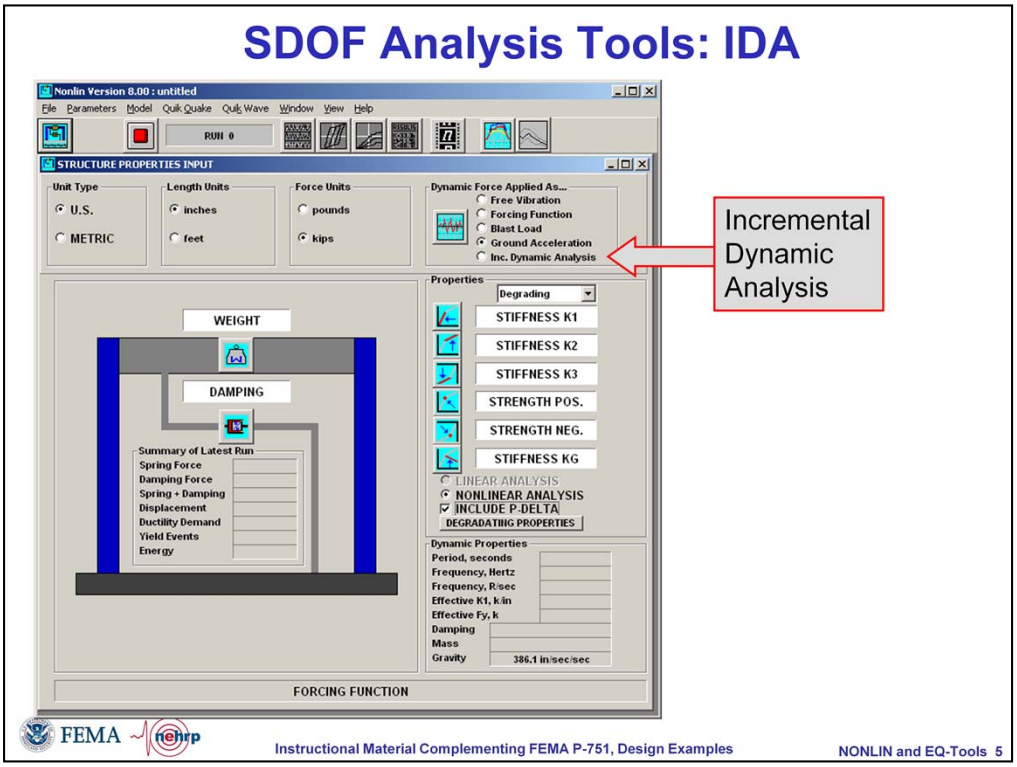
NONLIN was originally developed for the Earthquake Engineering part of the FEMA Multihazard building Design Summer Institute (MBDSI) that was held for many years at the Emergency Management Institute in Emmitsburg, Maryland. The program proved to be very effective in teaching the basic concepts of structural dynamics, and is included on the CD for that purpose. The companion program, EQ-Tools, was also developed for the MBDSI. The MBDSI training course was discontinued in 2002, but both NONLIN and EQ-Tools have been continuously updated.



NONLIN provides tools for linear or nonlinear response history analysis of Single Degree of Freedom (SDOF) systems. A large variety of loading functions are available, including dozens of pre-recorded ground motions. In addition to the original bi-linear model, the latest version of the program provides a sophisticated degrading stiffness and strength model.

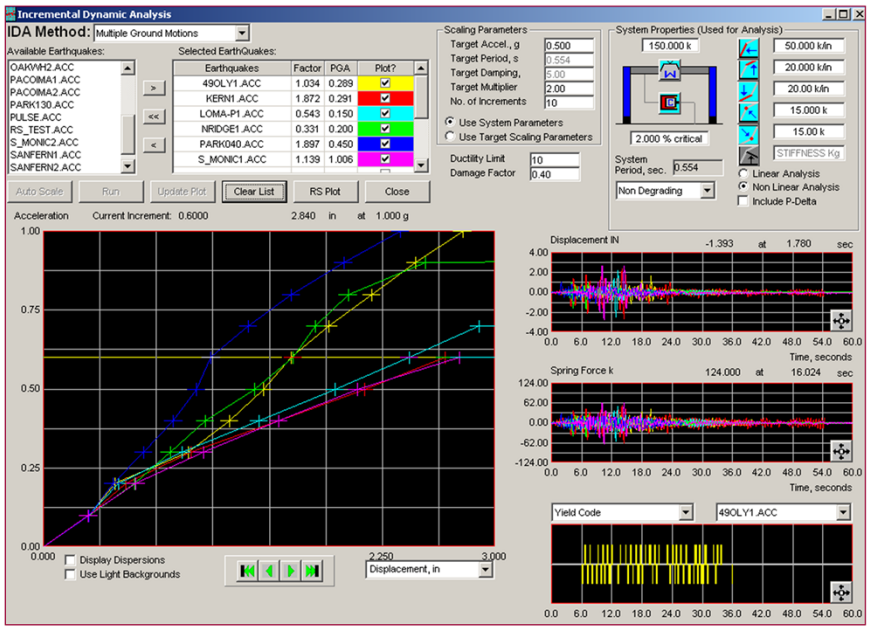


For the degrading model, the parameters can be set and then exercised interactively before using in the analysis.



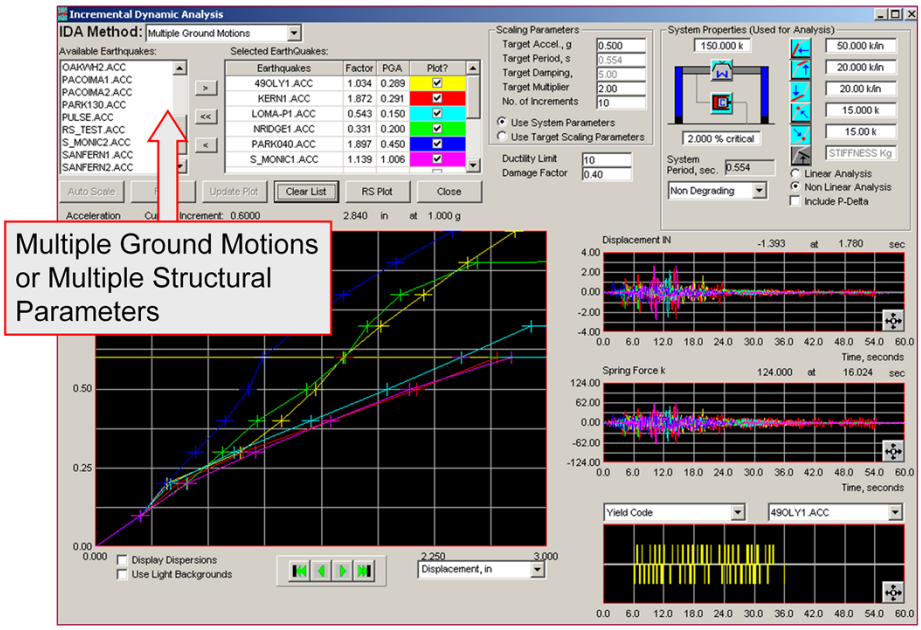
NONLIN also offers Incremental Dynamic Analysis (IDA). IDA analysis is useful in research, and is utilized heavily in the FEMA P-695 Methodology.

Incremental Dynamic Analysis



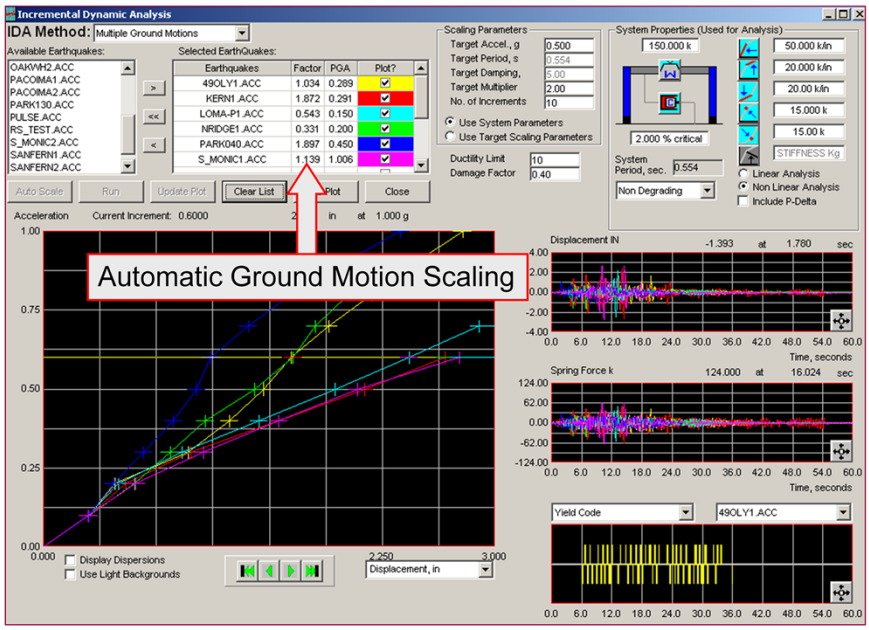
This screen shows the basic IDA analysis window, together with results from an IDA analysis of a single structure subjected to six different ground motions.

Incremental Dynamic Analysis (2)



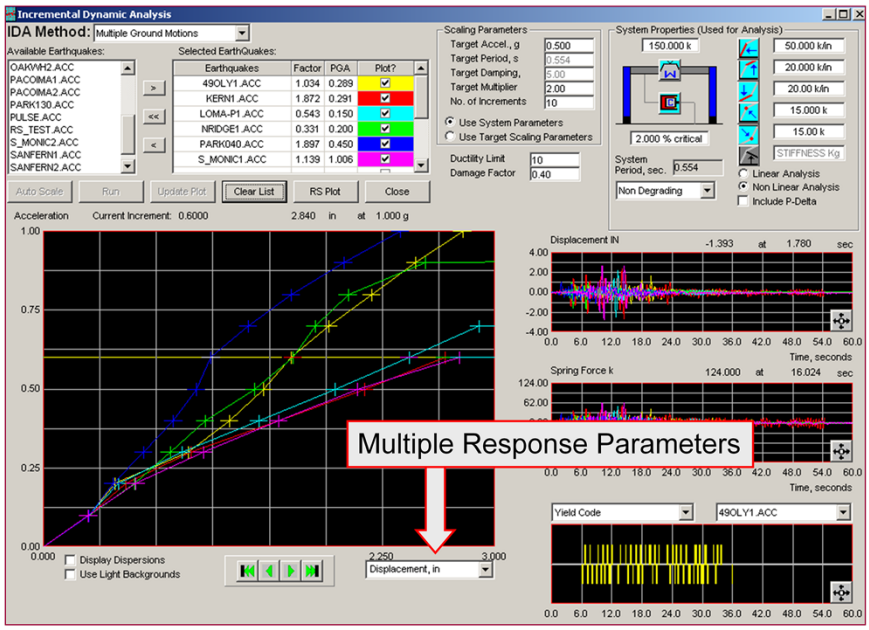
In addition to running multiple ground motion IDA, one can select a single ground motion and test the influence on a variation of structural parameters (e.g. damping).

Incremental Dynamic Analysis (3)



In IDA analysis it is necessary to scale the ground motions, and this is done automatically by the program (using single point spectrum matching).

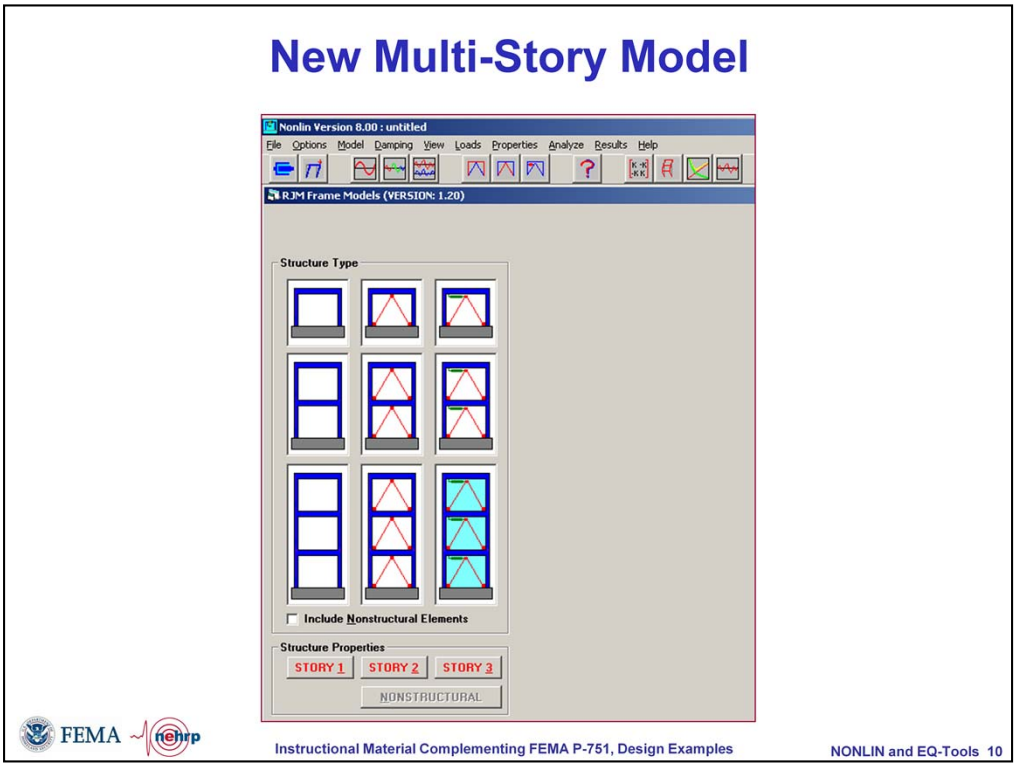
Incremental Dynamic Analysis (4)



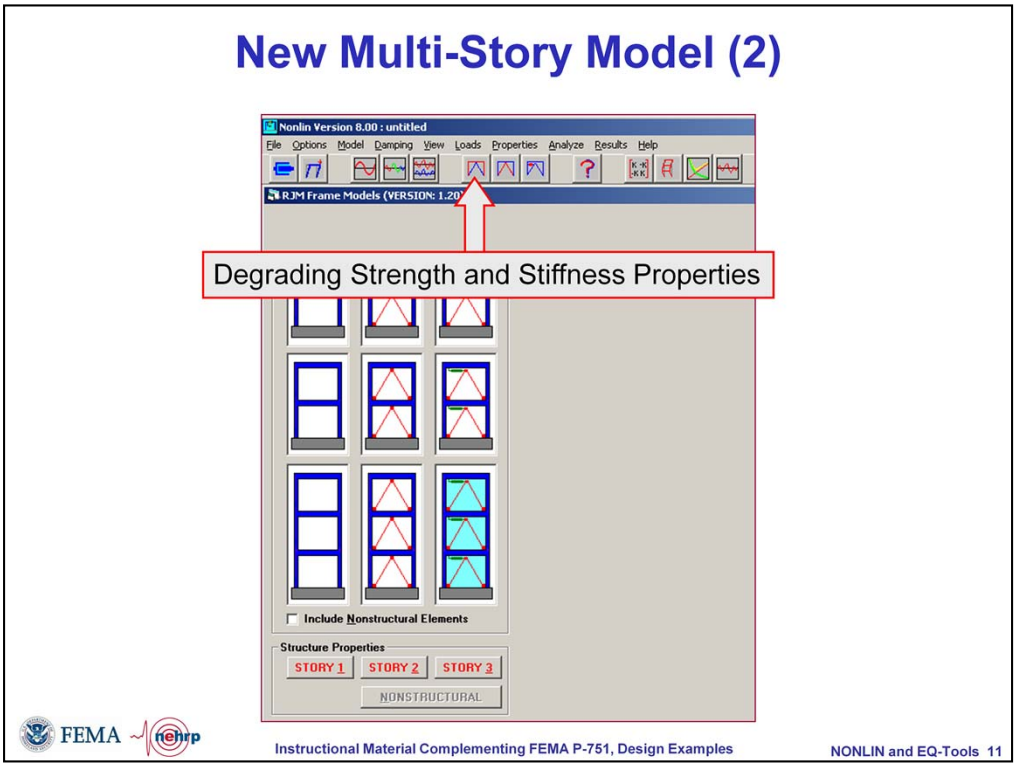
Instructional Material Complementing FEMA P-751, Design Examples

NONLIN and EQ-Tools 9

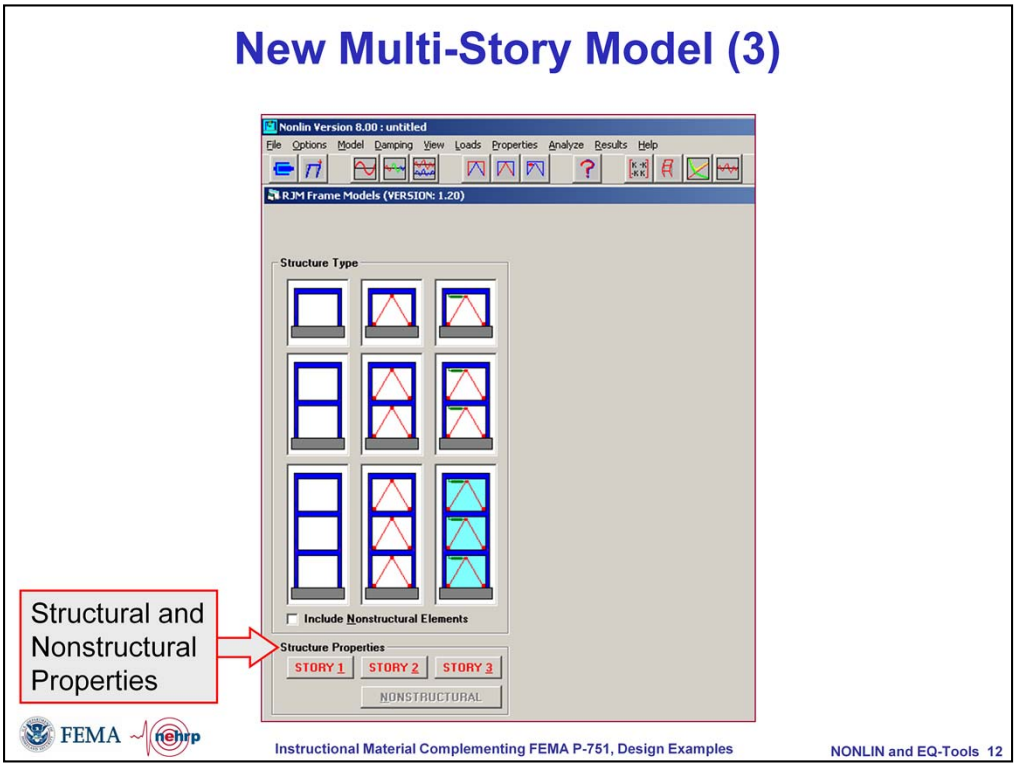
Various response parameters (damage measures) can be used to assess the performance of the structure.



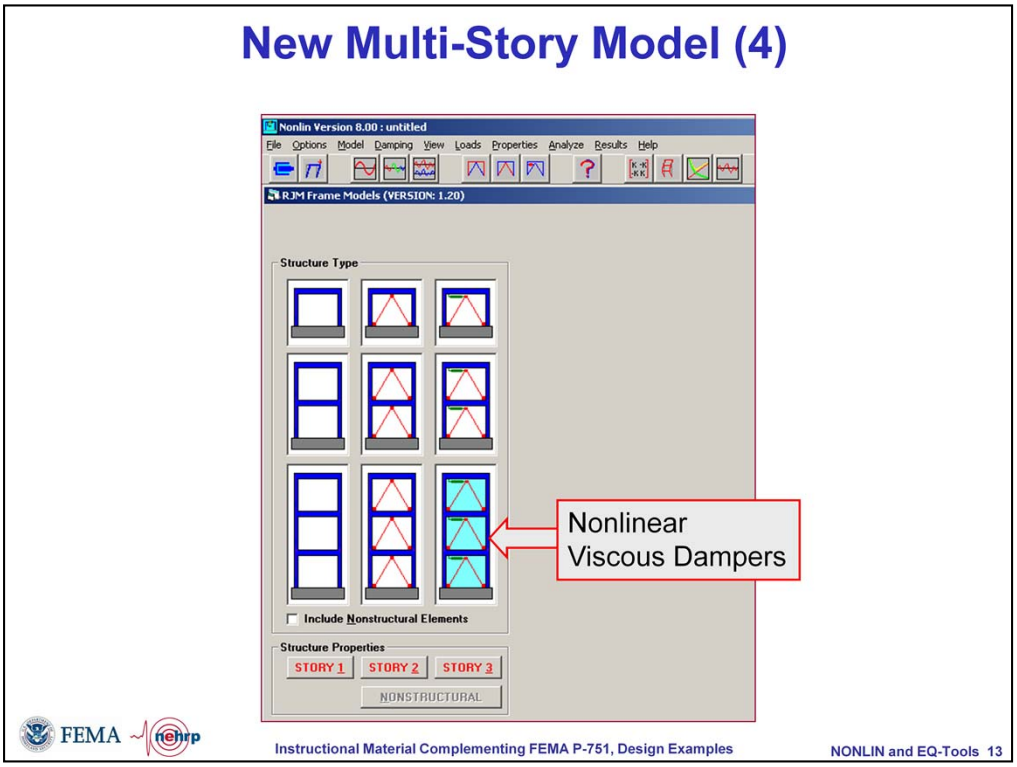
One of the key features of the new version of NONLIN is a simple MDOF model.



As with the SDOF model, degrading strength and stiffness properties may be set.

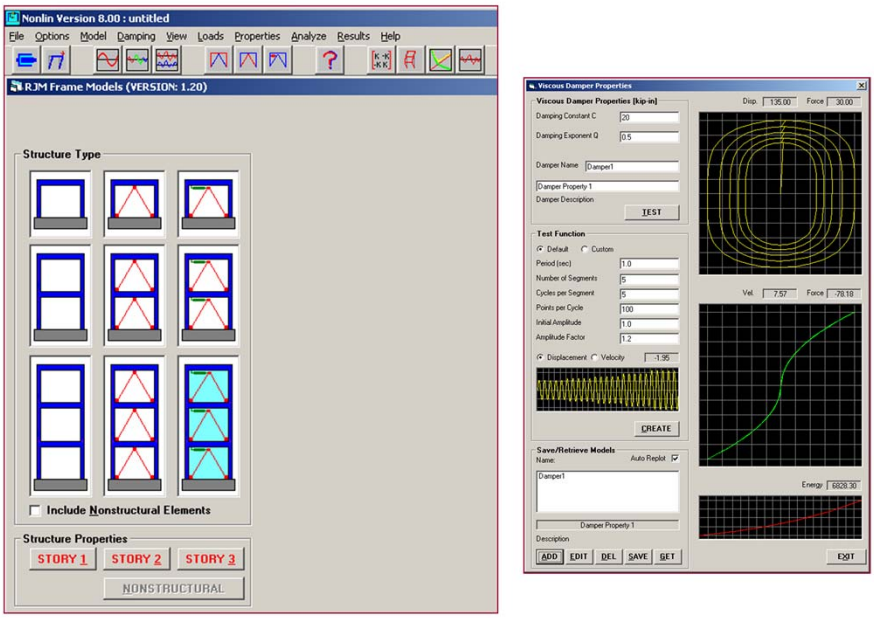


Nonstructural properties (to represent gravity framing or other components) may be included in the analysis.



The program also has the capability to model added damping, including nonlinear viscous damping.

New Multi-Story Model (5)



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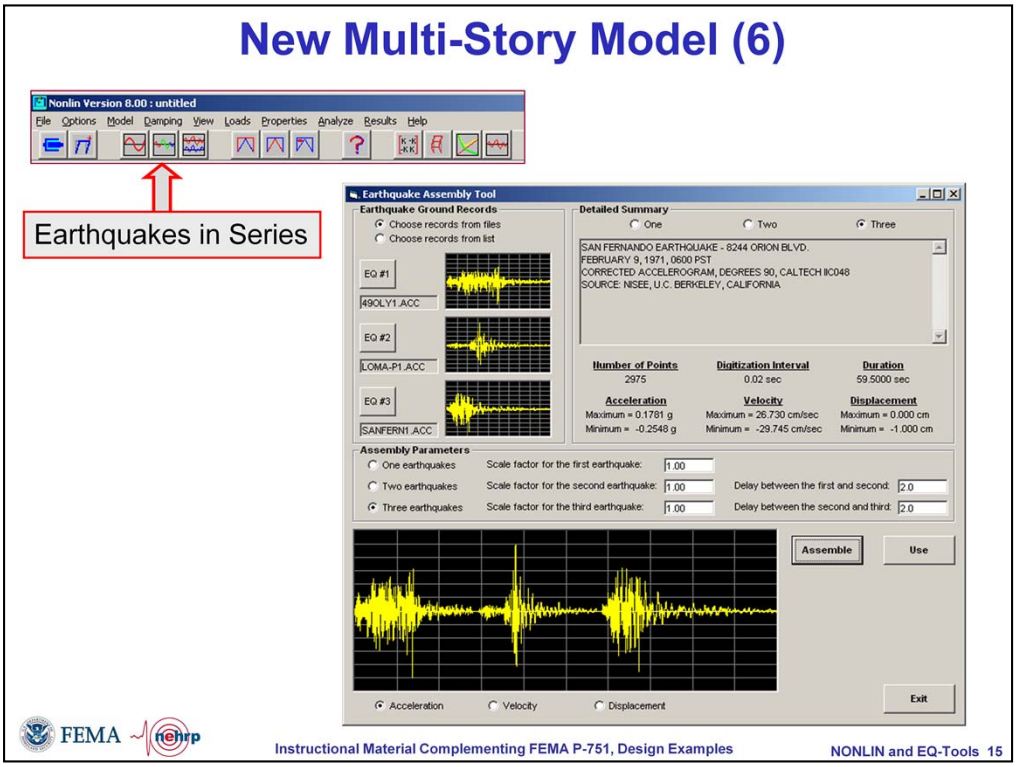
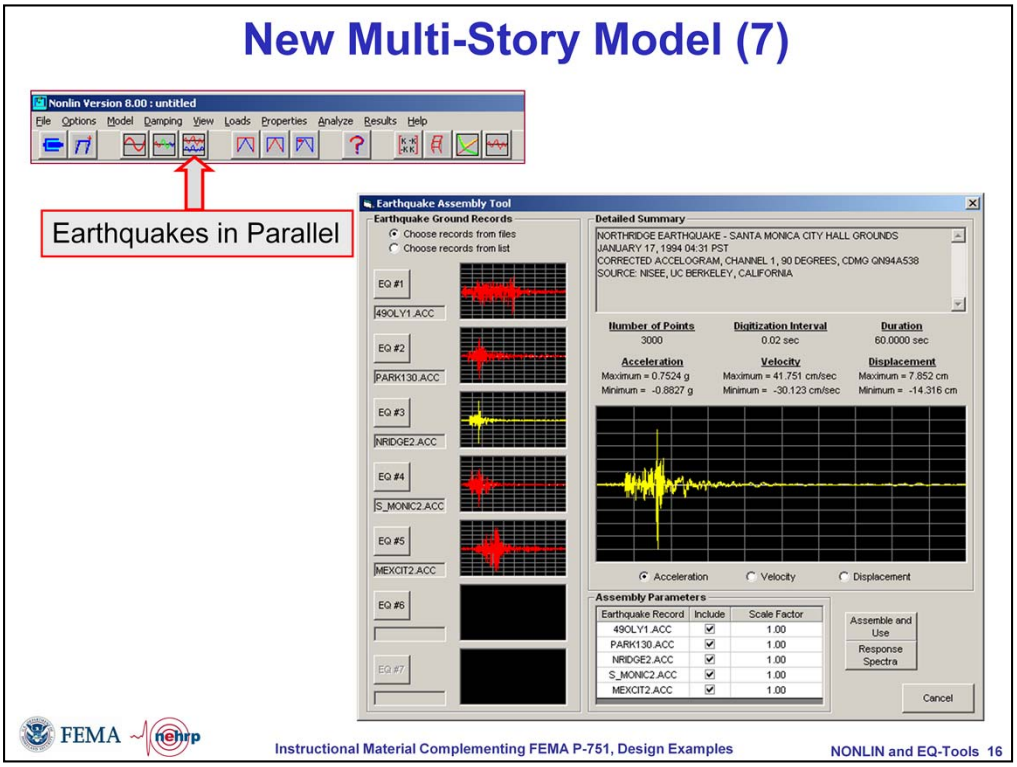
NONLIN and EQ-Tools 14

This screen shows the behavior of a selected nonlinear viscous damper.

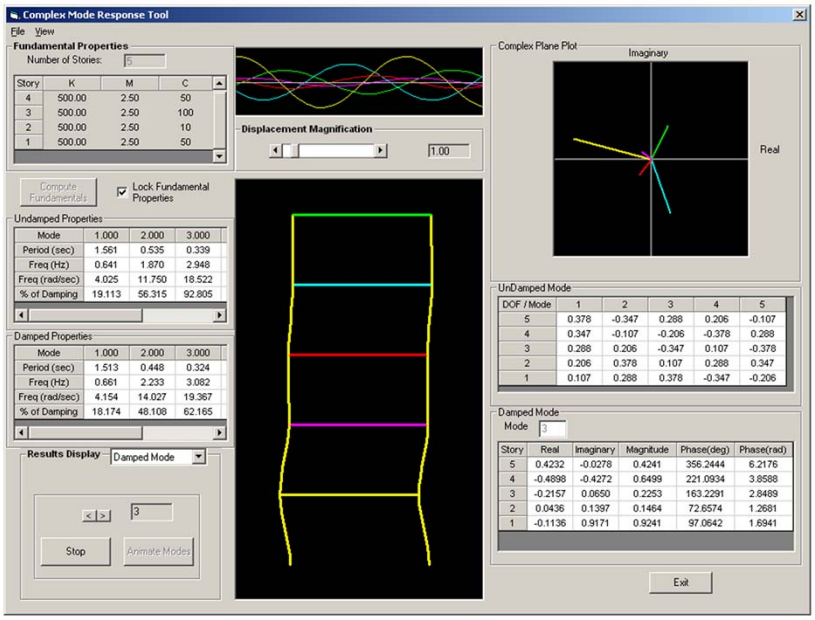


The structure may be subjected to a single earthquake or to a series of earthquakes (representing a main shock followed by aftershocks).



A structure can also be evaluated for a suite of ground motions, as in ASCE 7 Chapter 16.

New Nonproportional Damping Tool



FEMA nehrp Instructional Material Complementing FEMA P-751, Design Examples NONLIN and EQ-Tools 17

NONLIN also provides an interesting new tool to study the dynamic behavior of a structure with nonclassical (nonproportional) damping. The animated mode shapes are particularly interesting, as the change in phase along the height can be easily seen. Note: This tool for illustrating nonproportional damping is separate from the MDOF tool shown in slide 14, which is limited to a maximum 3 stories.

EQ-TOOLS: Version 3.0

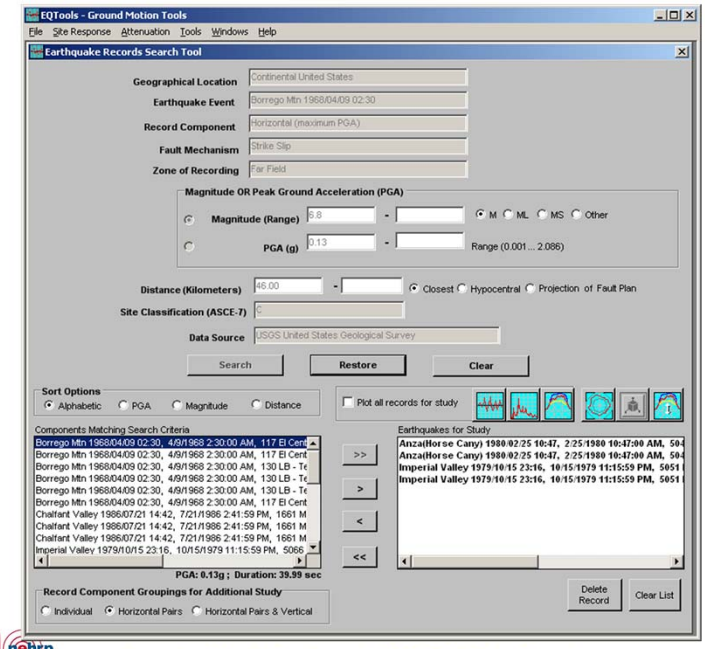
- **Ground Motion Search Engine**
- Ground Motion History Analysis
- Linear Response Spectrum Analysis
- Fourier Amplitude Analysis
- **2D and 3D Ground Motion Evaluation Tools**
- **Ground Motion Scaling**
- **Ground Motion Attenuation Relationships**
- Site Response Tools

Items in **BOLD** indicate significant updates since Version 2

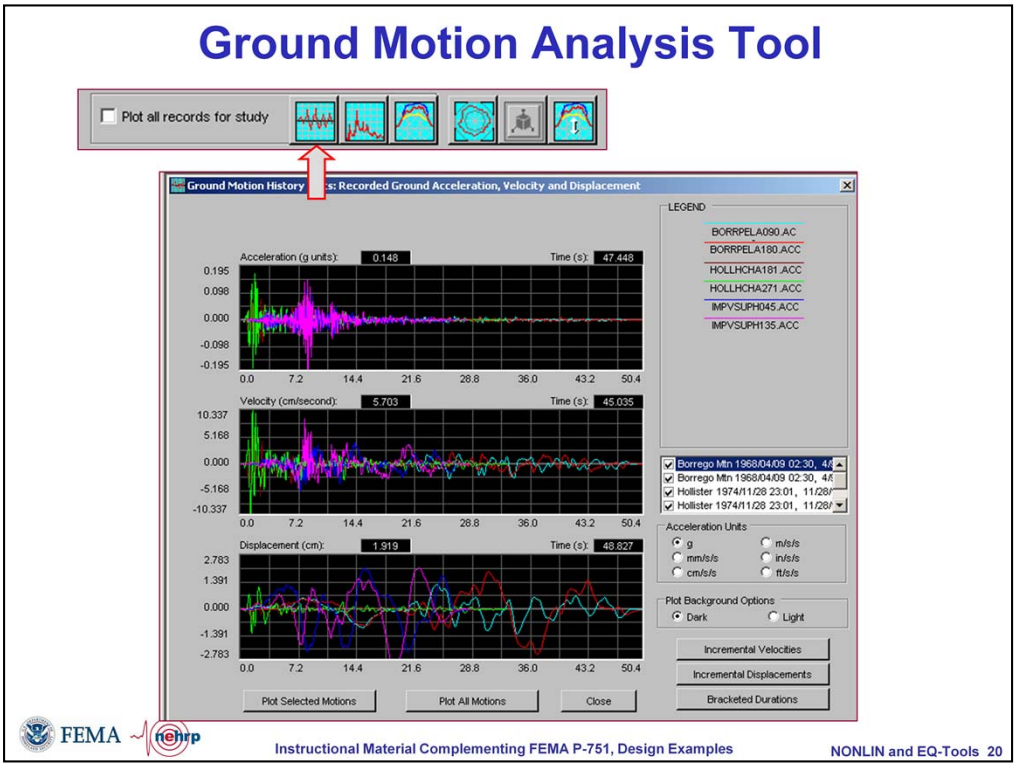
FEMA nehrp Instructional Material Complementing FEMA P-751, Design Examples NONLIN and EQ-Tools 18

The following slides describe some of the features of the new version of EQ-Tools.

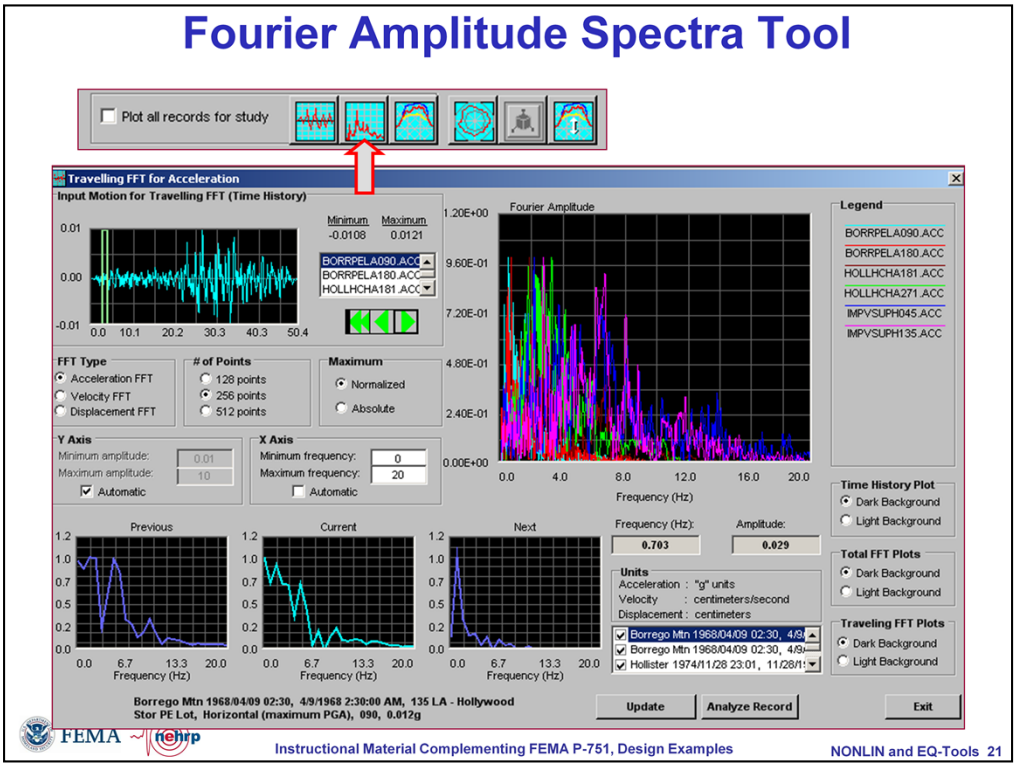
EQ-TOOLS Search Engine and Control Panel



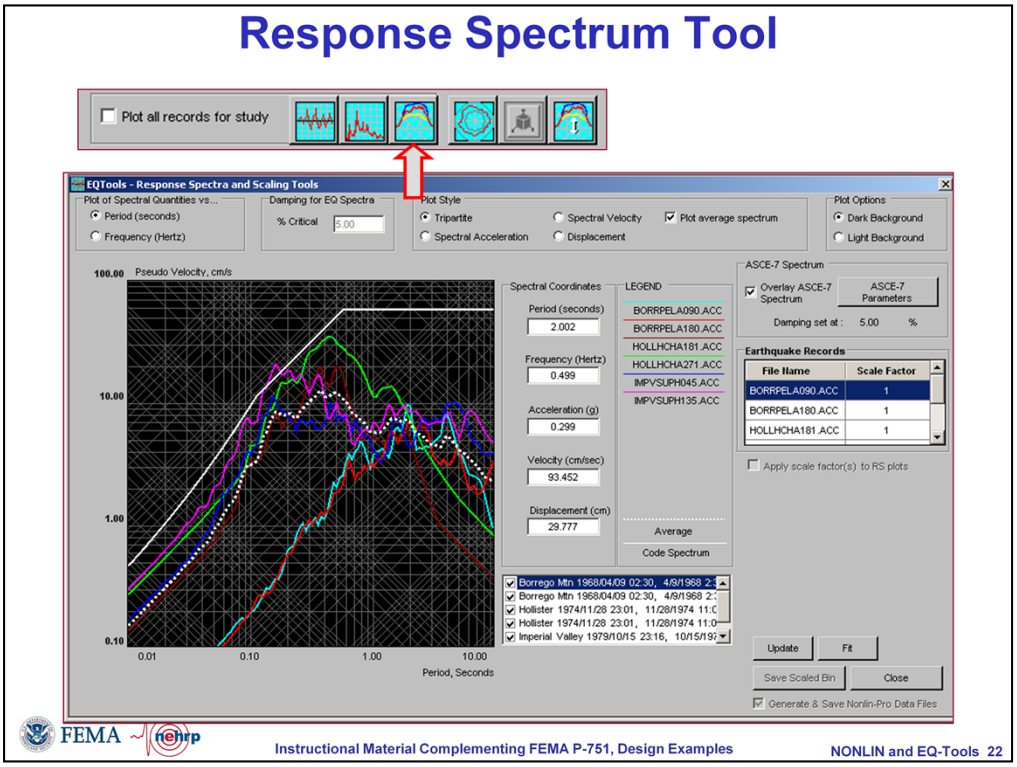
One of the main features of EQ-Tools is to evaluate ground motion acceleration records. A large number of records is provided with the program, and suites of records can be developed using a variety of search parameters.



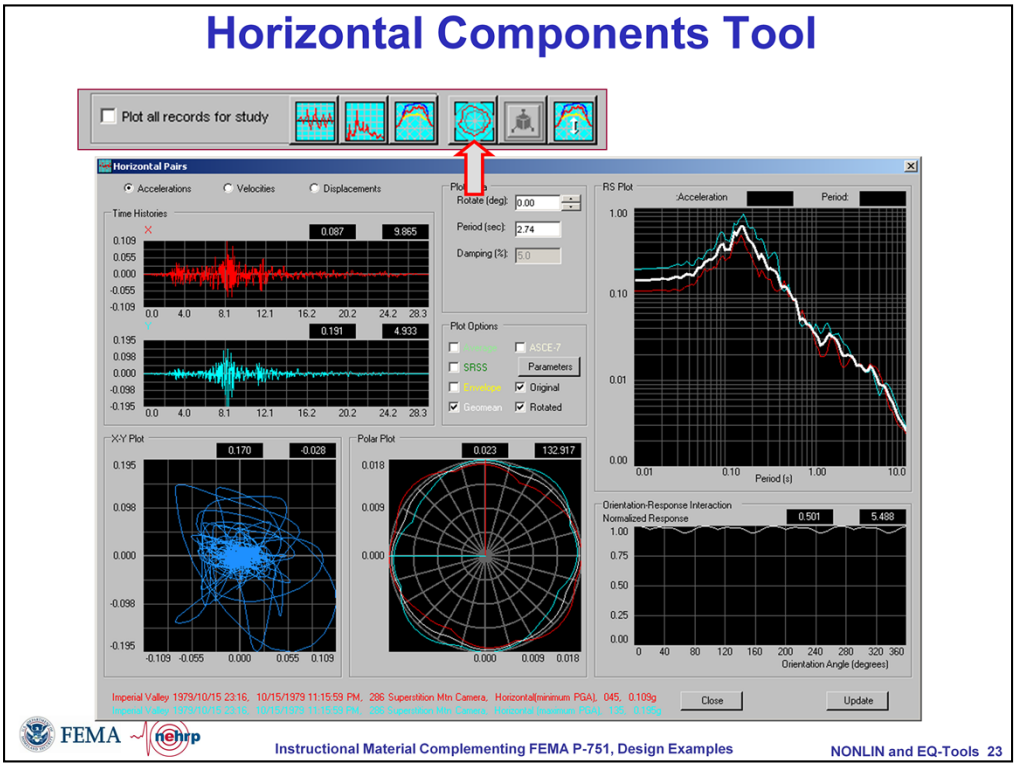
This slide illustrates the results of the ground motion record plotting tool, comparing the ground acceleration, velocity, and displacement histories of six recorded ground motions.



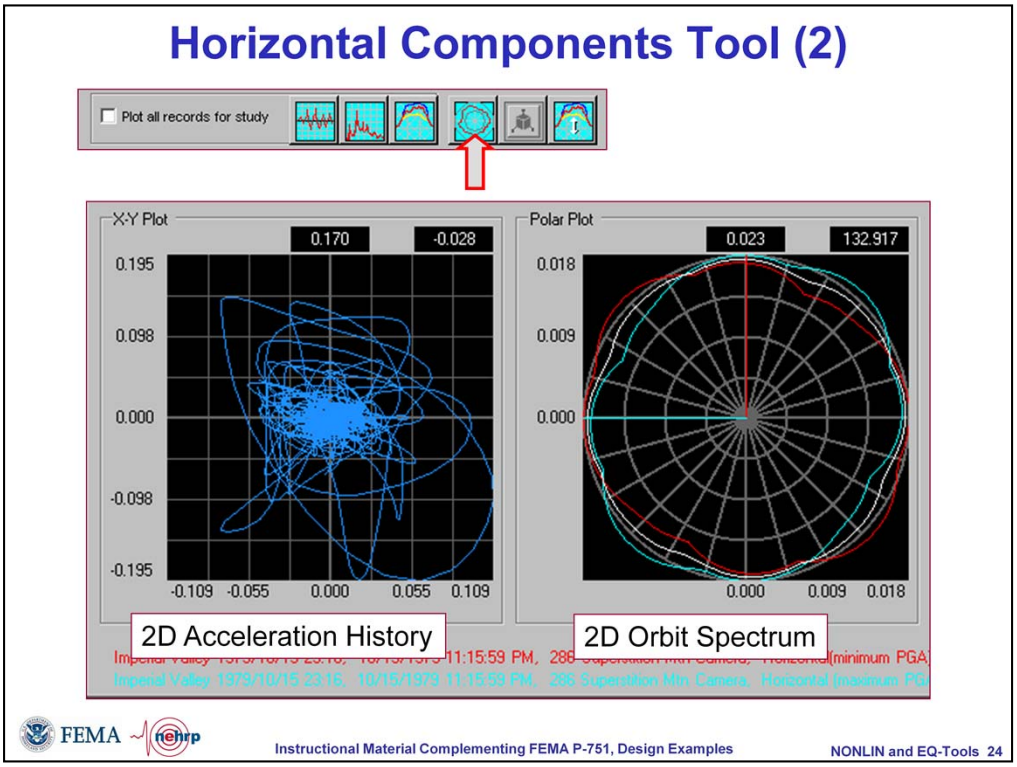
The program provides the capability to plot Fourier Amplitude spectra of the ground motions. The small plots on the bottom allow a "traveling" FFT in which the change in frequency content can be determined as a time window is passed through the record.



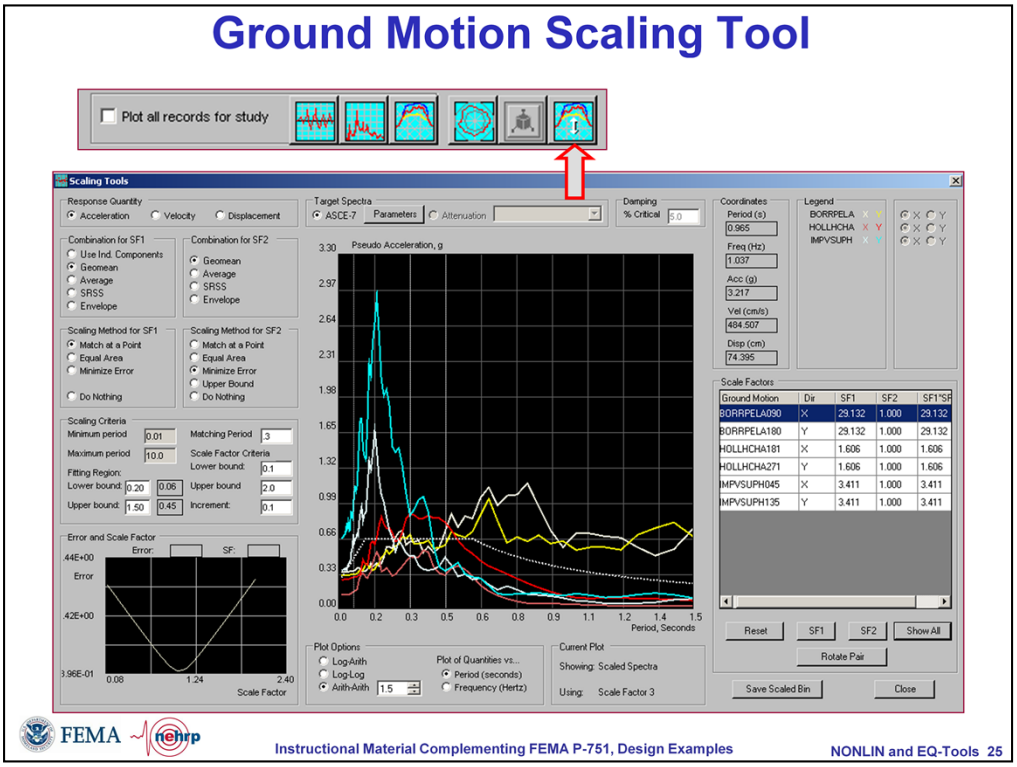
The program has a large variety or response spectrum plotting tools, including the tripartite spectrum shown here. Ground motion spectra, average spectra, and code spectra can be plotted simultaneously.



The two horizontal components can be plotted together vs time, or as an X-Y plot. Polar spectra (two rotated components plus geomean at a selected period) are also provided.



This is a close up view of the X-Y plot and the polar spectra plot.



EQ-Tools provides a large number of ground motion scaling tools. Dozens of scaling options are available, including a method that satisfies the requirements given in ASCE 7-05 and ASCE 7-10.

Ground Motion Attenuation Relationships

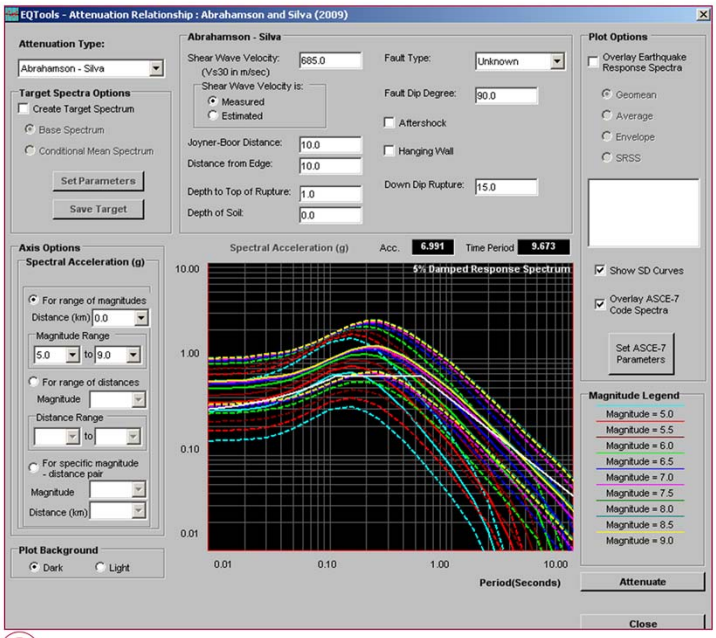
- Older (Project 97) relationships and newer PEER
- NGA Relationships
  - Abrahamson and Silva
  - Boore and Atkinson
  - Campbell and Bozorgnia
  - Chiou and Youngs
  - Idriss

Relationships may be used as targets for scaling

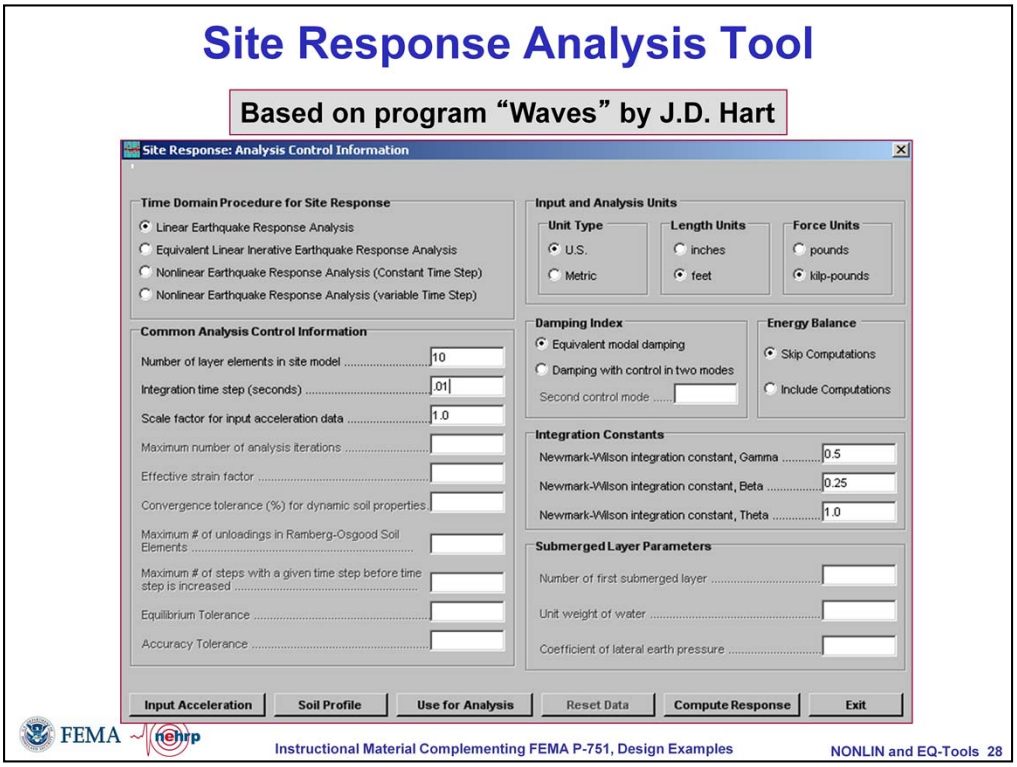
Conditional mean spectra development

A key feature on EQ-Tools is the ability to plot a variety of ground motion attenuation relationships. More than a dozen such relationships are available.

Ground Motion Attenuation Relationships

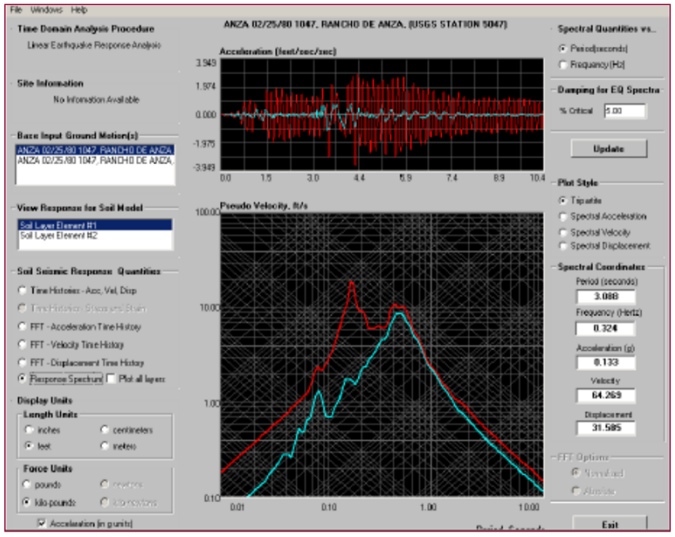


This screen shows the results of a computation that produces a variety of ground motion spectra based on the Abrahamson-Silva relationship. Different spectra are provided for different Magnitude measures (ranging from 5 to 9).



EQ-Tools also provides the capability to perform site analysis, wherein the effect of a soil profile can be investigated. The base of the soil layer is shaken with a given ground motion record, and new acceleration histories and spectra are provided at each soil layer. Both linear and nonlinear soil can be modeled.

Site Response Analysis Tool



Modified ground motion may be saved for further analysis in EQ-Tools

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NONLIN and EQ-Tools 29

This slide shows the results of a site analysis.

Access to Programs Through NEES Hub

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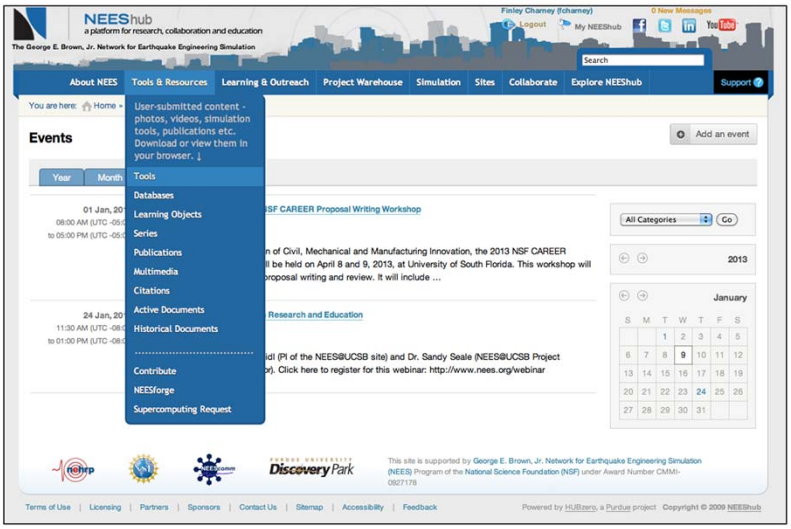
- Users must register with NEEShub before using the tools.
- Use of tools may require Java plugin (automatically provided by NEEShub)

Access to NONLIN and EQ-Tools is provided by NEES-Hub. (This slide needs to be completed)

Access to Programs Through NEES Hub (2)



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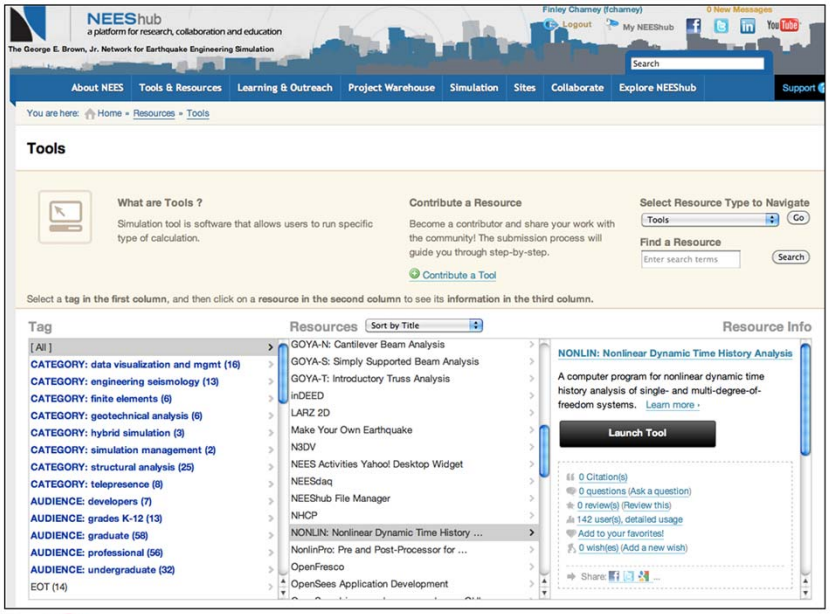
Instructional Material Complementing FEMA P-751, Design Examples

31

NEEShub Screen showing the dropdown Tools menu.

Access to Programs Through NEES Hub (3)



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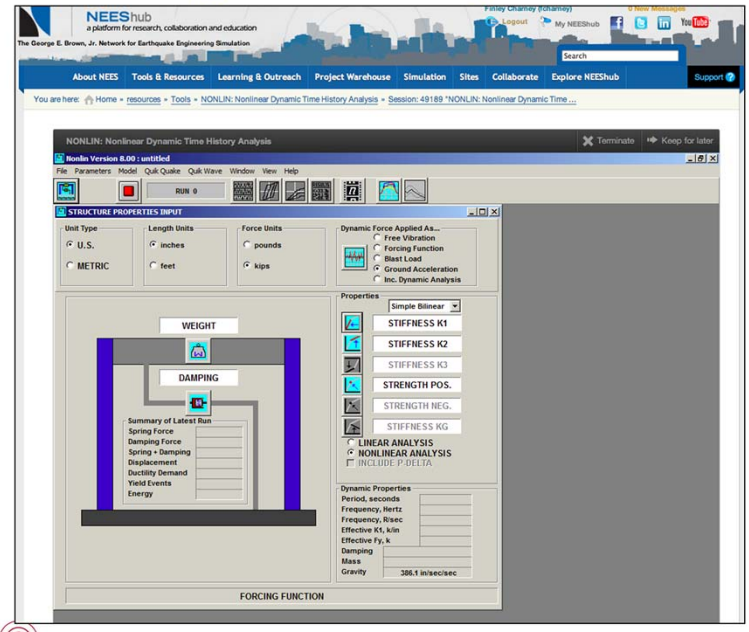
Instructional Material Complementing FEMA P-751, Design Examples

32

NEEShub Screen showing NONLIN “Launc Tool” option.

Access to Programs Through NEES Hub (4)



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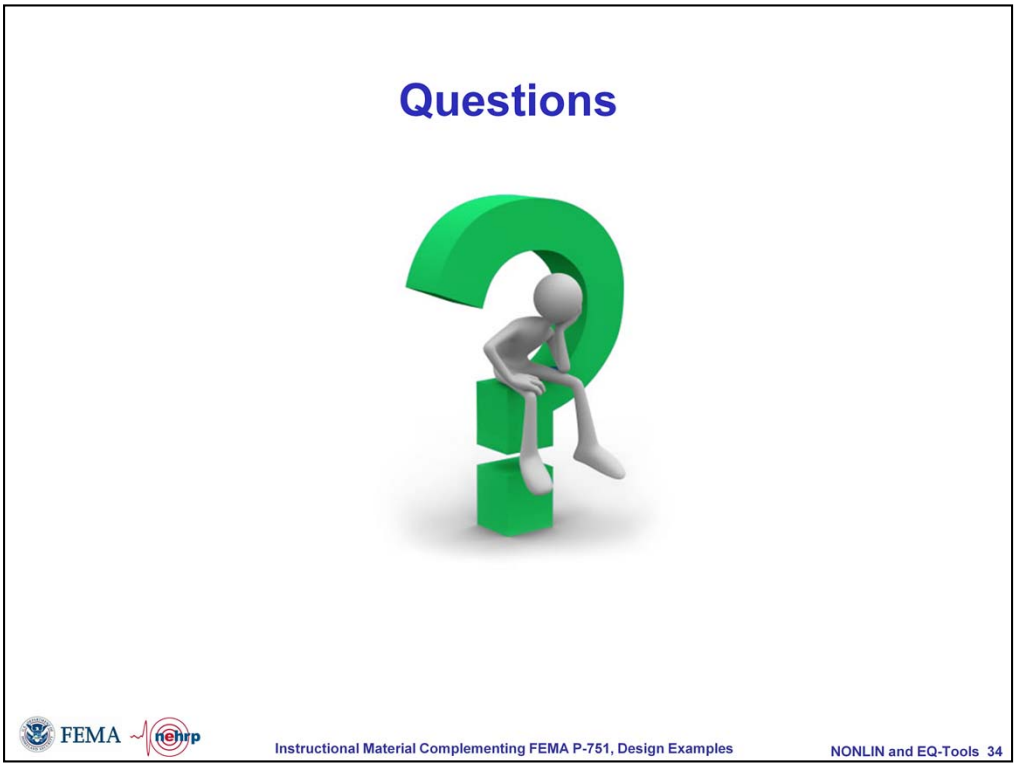
Instructional Material Complementing FEMA P-751, Design Examples

33

NONLIN running within the NEEShub online environment.



A slide to prompt questions from the participants.