



Vision

To be the provider of choice
for advancing railway safety
and technology

Transportation Technology Center, Inc., a subsidiary of the Association of American Railroads

TTCI's Scientific Software Suite and NUCARS® Overview

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Research

- AAR Strategic Research Program
- Federal Railroad Administration Task Orders

Testing & Consultancy

- North American railroads
- Suppliers
- Other government programs
- Global rail industry – both freight and passenger

Standards

- AAR committee support
- North American rail industry suggested practices
- Compliance monitoring
- Industry data systems

Training

- Rail industry familiarization
- Hazardous material emergency response

Who / What is the AAR?

ASSOCIATION of AMERICAN RAILROADS

- ◆ Trade association of all the North American railroads including Mexico and Canada
 - Mostly focused on freight
- ◆ Has origins dating to early 1900s
- ◆ Sets performance standards and requirements for interchange of cars equipment between member railroads
 - Many of the these standards form the basis of standards used in other countries
- ◆ Funds strategic research for the railroads
- ◆ Represents railroad interests to the government





History of Transportation Technology Center (TTC)

- ◆ Formally dedicated as High Speed Ground Test Center - May 17, 1971
- ◆ Developed and operated by Federal Railroad Administration (FRA) and Urban Mass Transit Administration (UMTA), now Federal Transit Administration (FTA)
- ◆ AAR assumed care, custody, & control at TTC – October 1982
- ◆ AAR Research & Test Dept. consolidated at TTC - 1995-97
- ◆ TTCI formed January 1, 1998



- ◆ **TTCI offers a wide range of software and hardware-software combination products that accurately model and analyze rail vehicles, components, structures, and systems:**
 - Vehicle-track dynamic interaction
 - Train operation
 - Train energy consumption
 - Real-time analysis of wheel-rail contact conditions
 - Performance Based Track Geometry analysis
- ◆ **Overview provides insight into TTCI's software expertise and available products and services by market**



TTCI software for simulating and analyzing the railway environment

◆ Vehicle/Track Dynamic Interaction

- NUCARS[®]

◆ Wheel/Rail Contact Analyses

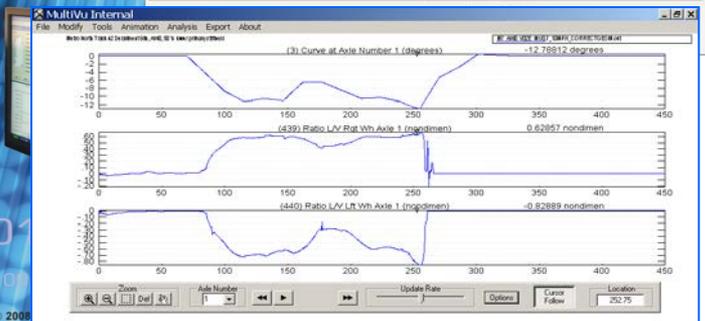
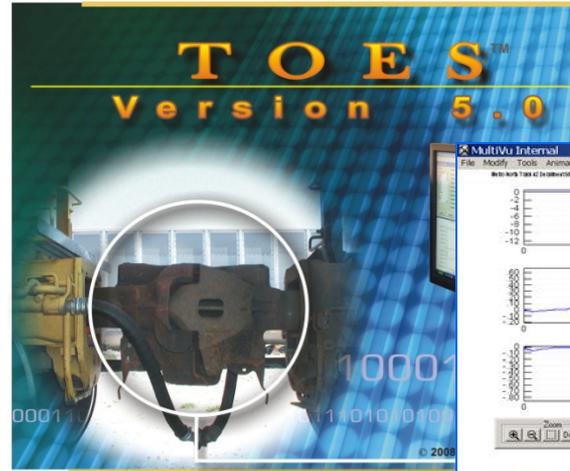
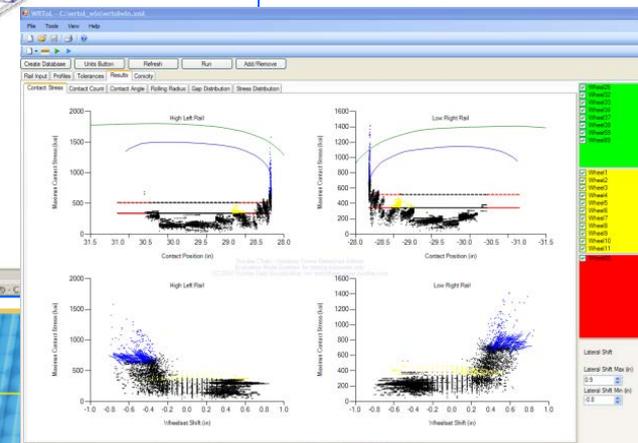
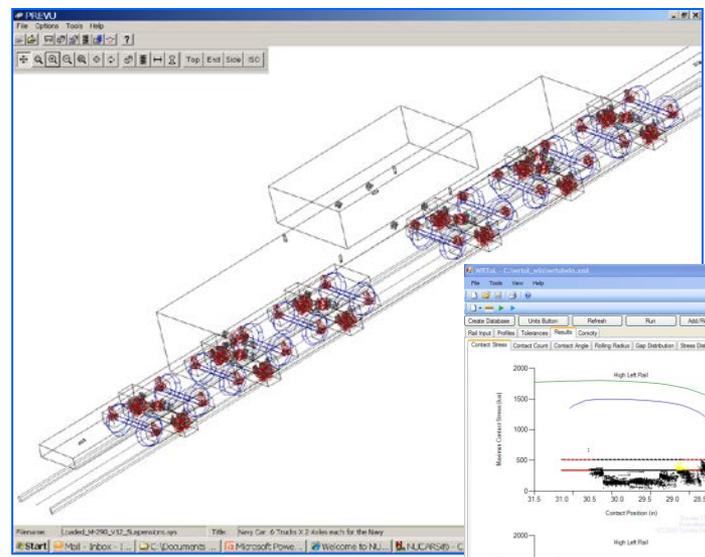
- WRCON[™]
- WRTOL[™]
- WRCIS[™]

◆ Train Simulators

- TOES[™]
- STARCO[™]

◆ Data Collection and Analysis

- MULTIVU[™]



Multi-body Vehicle/Track Dynamic Interaction Simulation

- ◆ Simulates the dynamic response of railroad vehicles to specified track conditions
- ◆ Under continuous development at TTCI since 1986
- ◆ Available under license from TTCI since 1989
 - Licensees include North American railroads and car builders, locomotive builders, component manufacturers, as well as overseas railways, car builders, and track suppliers.
- ◆ On-line calculation of W/R contact using Kalker's non-linear theory
 - Multiple overlapping contact points
 - Nearly any combination of worn wheel and rail profiles, including guard rails, and back of flange contact
 - Rail profile may change along the track
- ◆ Optional multi-body representation of track structure including rails, fasteners, sleepers, ballast, slabs, bridges
 - Simulation of failed components and changes in structure along the track
- ◆ Extensive validation with test data
- ◆ Benchmarked against other codes such as VAMPIRE[®], VOCO, SIMPACK

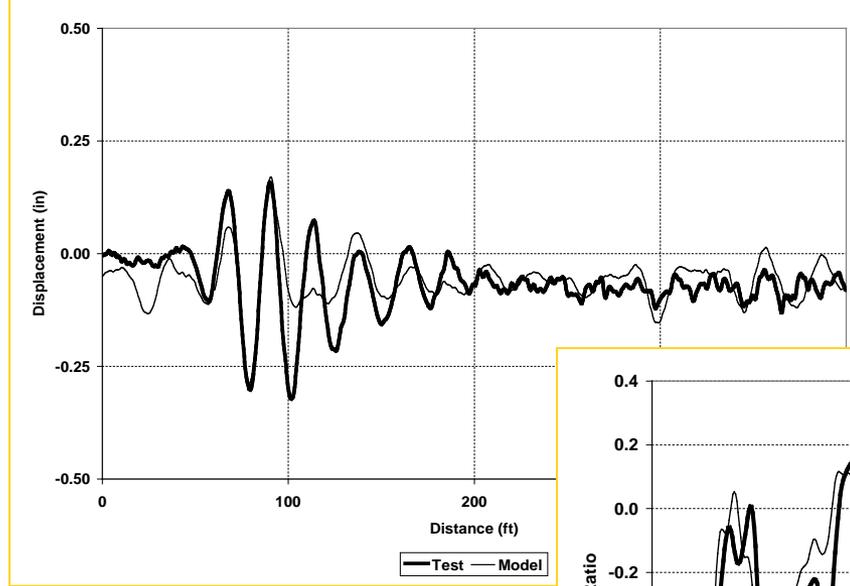
- ◆ **Analyses of vehicle/track dynamic interaction**
 - Development of new vehicles and track components
 - Vehicle certification
 - Analysis of performance problems
- ◆ **Derailment analysis and investigation of derailment mechanisms**
- ◆ **Parametric studies**
- ◆ **Evaluation of specific vehicle and track design details and defects**
- ◆ **Evaluation of wheel/rail profiles**
 - Wear and RCF
 - Switches and crossings
 - Design optimization
- ◆ **Operational and environmental conditions**
 - Vehicle Ride Quality
 - Wheel-Rail Lubrication Studies
 - Dynamic Clearance Envelope Calculations
- ◆ **Tool for learning details of vehicle/track interaction**

- ◆ **Time or Frequency Domain Models**
- ◆ **Full Nonlinear Wheel on Rail Contact Calculations**
 - Multi-point contact, flange back contact, independently rotating wheels, variable W/R friction per wheel and along track
- ◆ **Simulate Any Rail Vehicle:** Freight, Locomotive, Passenger
- ◆ **Numerous connection types:** Friction wedges, stick–slip friction, series and parallel springs and dampers, active suspension
- ◆ **Simulate All Types of Track**
 - Tangent & Curves
 - Turnouts and special trackwork
 - Track Irregularities
 - Measured track geometry
 - Track structure and flexibilities

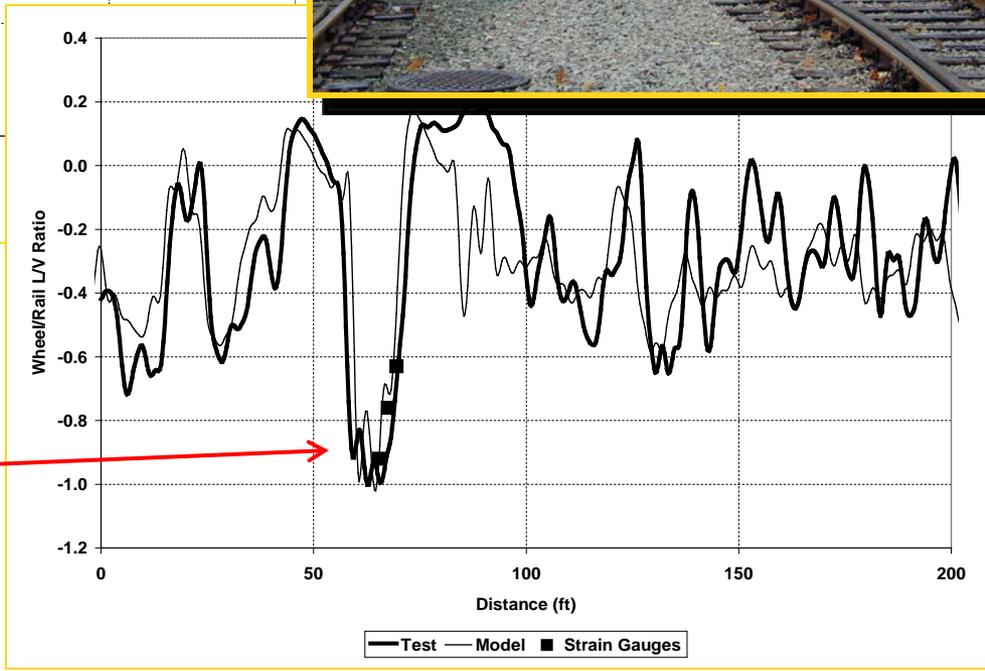


NUCARS[®] validation: Articulated LRV with independent rolling wheels

Air Suspension Vertical Deflection



L/V Ratios at Down and Out Track Perturbation (negative values indicate flanging force)

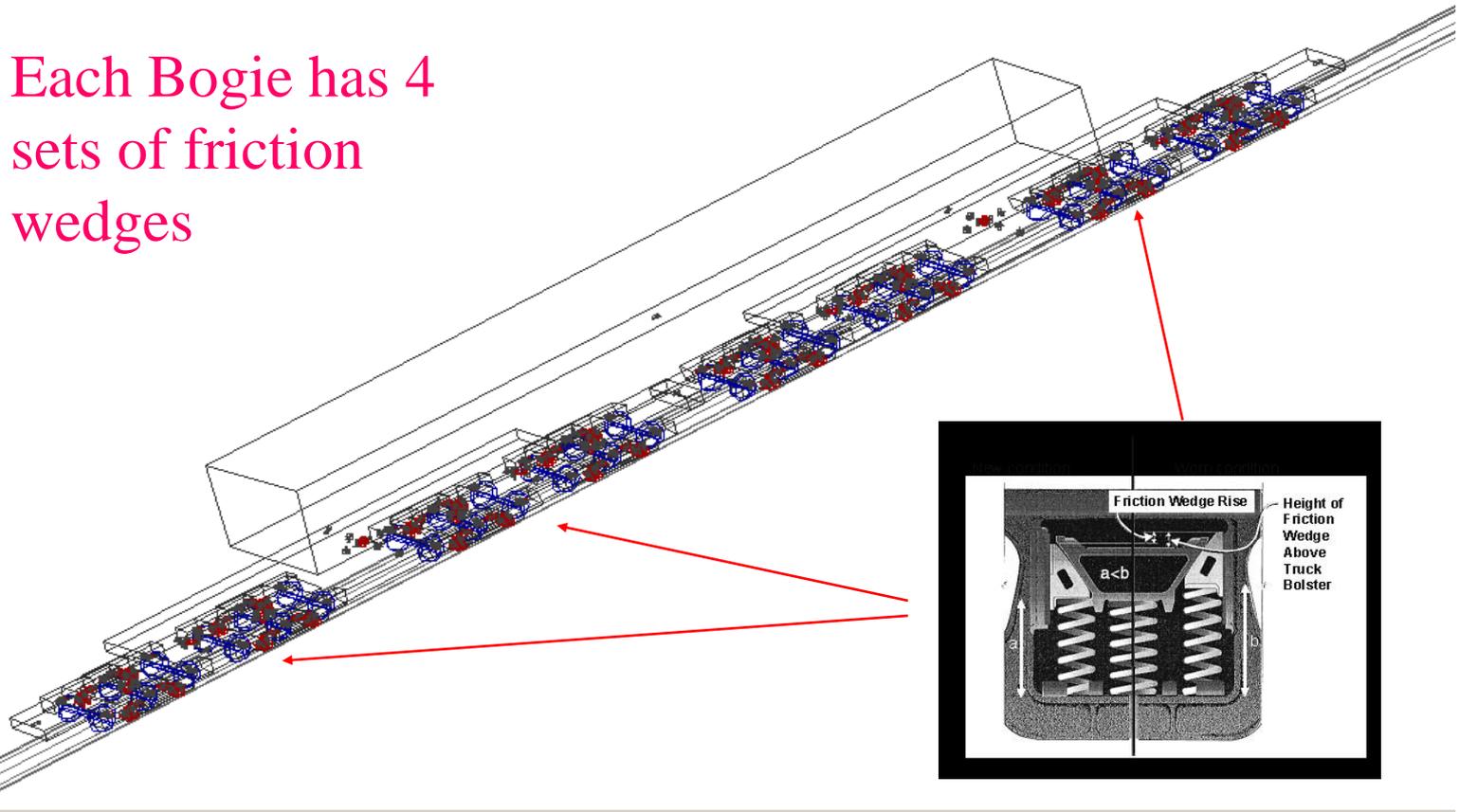




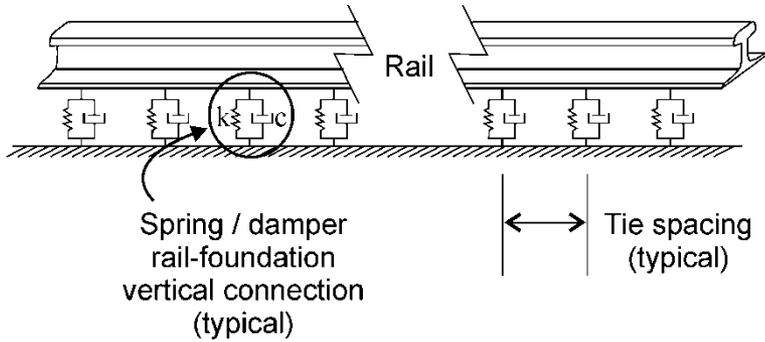
Heavy Duty Flat Car with eight 3-axle trucks



Each Bogie has 4 sets of friction wedges

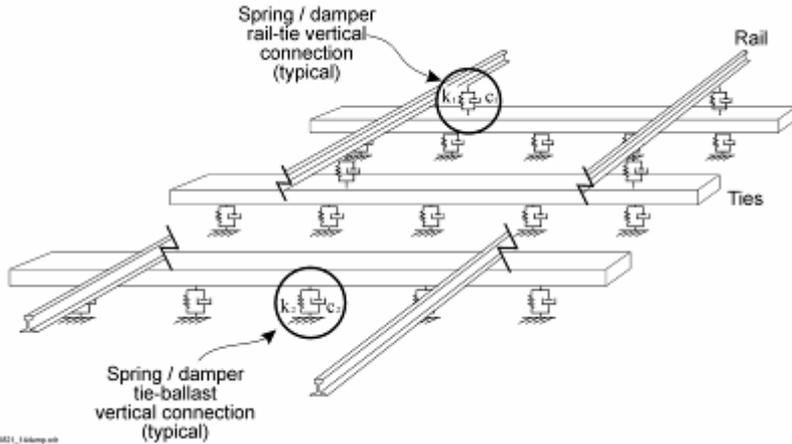
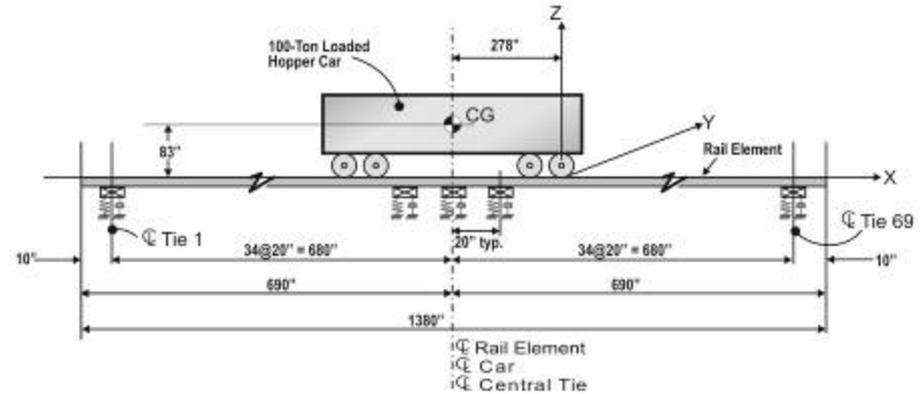


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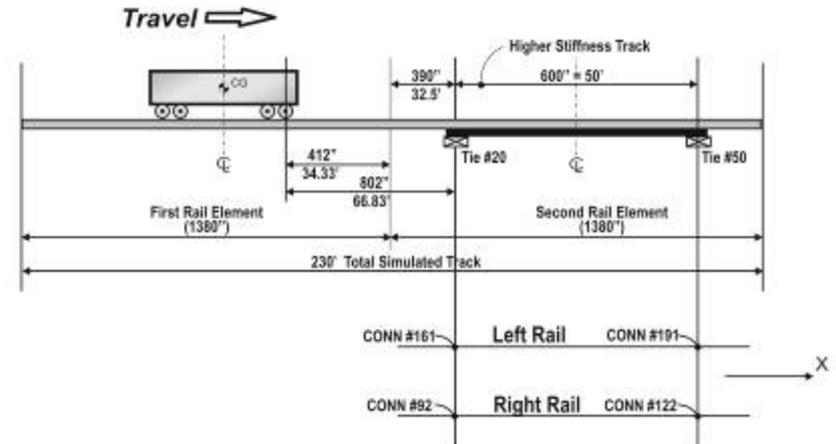
1821_13damp.cdr

Single layer track model



1821_14damp.cdr

Two layer track model



2640

Vehicle on infinite track with varying stiffness and damping





NUCARS Does...

Switches, Crossings and Track Structure

Points



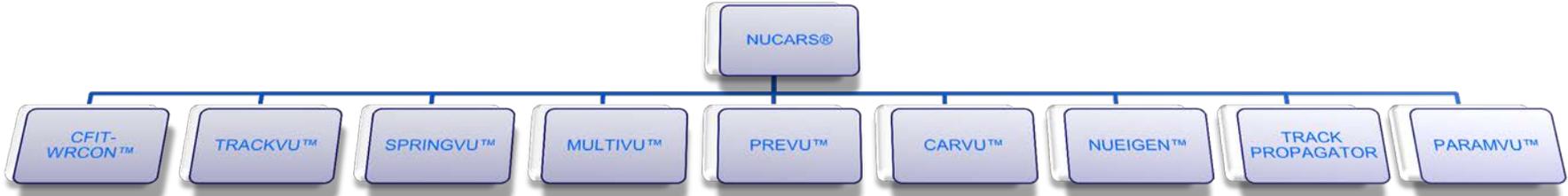
Turnout
Geometry

Frogs and
Guard Rails





NUCARS[®] Peripheral Products



A Comprehensive Suite of Applications



TOES™ and STARCO™

Typical TOES™ Applications

- ◆ Train Operations and Energy Simulator (TOES™)
- ◆ State of the art train action model developed for and licensed to AAR-member railroads
- ◆ Models the interaction of train air-brake and ECP-brake systems, intercar coupling behavior, locomotive performance characteristics, and train resistance forces
- ◆ Limited edition available to international audiences as STARCO™

- Accident or incident investigation
- Stopping distance investigations
- Coupler force monitoring
- Prediction of vehicle longitudinal accelerations
- Evaluation of train make-up strategies
- Evaluation of train handling studies
- Comparison of new track layouts
- Prediction of car fatigue damage
- Evaluation of new equipment
 - Reduced slack coupler
 - New end-of-car cushioning unit standard
 - Benefits of ECP brakes
- Train make-up
 - Placement of autoracks
 - Blocking and power placement

TOES Simulator

Train Summary

Time: 0: 1:58.000 [Speed Limit: 30] Max DraftVeh: 30-295K Max DraftVeh: 300-69K
 Tot Loc Cyls: Lac Avg BCP: Tot Car Cyls: Car Avg BCP:

24	0.00	120	20.71
----	------	-----	-------

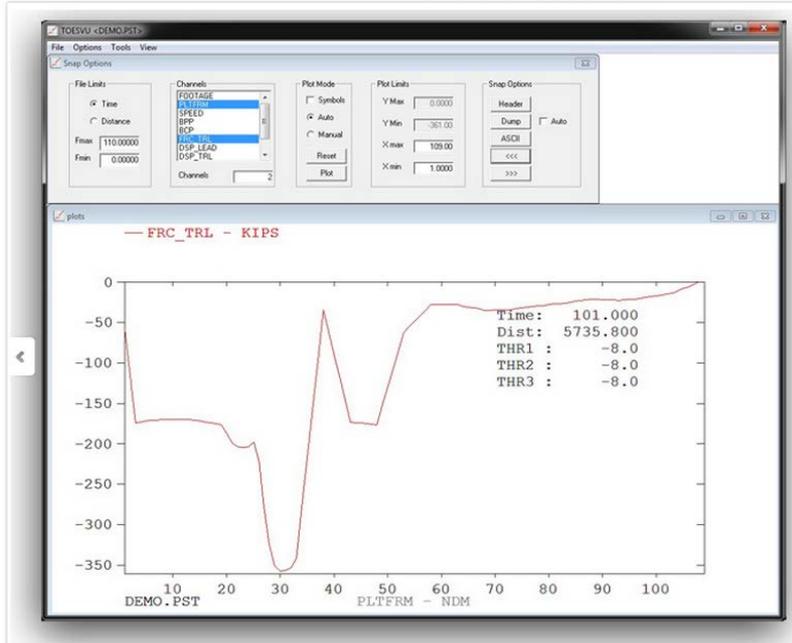
Average Train Speed: 24.15 Average Train Acceleration: -35.17

Vehicle Output

WEN	LOCATION	SPEED-mph	ACC-mph/s	GRADE	CURVE	NOTCH	FORC	AFT	BPP	BCP
1	FIRST- +54802.8	25.95	-83.23	1.0L	0.00	0	0K	-69K	000	000
10	FIRST- +55539.8	24.55	-188.5a	1.0L	0.00		-183K	-177K	000	178
20	FIRST- +56280.8	23.55	-150.2a	1.0L	0.00		-350K	-18K	000	190
30	FIRST- +56981.9	23.25	-74.4a	1.0L	0.00		67K	69K	000	208
40	FIRST- +57682.5	24.25	-28.5a	1.0L	0.00		68K	59K	000	216
40	FIRST- +58383.1	24.25	-28.8a	1.0L	0.00		68K	59K	000	218

Command Entry

```
CONTINUE COMMAND TIME CRITERION SATISFIED AT TIME 98.000
SPEED 38.951, AND POSITION 55281.7
CONTINUE COMMAND TIME CRITERION SATISFIED AT TIME 100.000
SPEED 39.959, AND POSITION 55651.8
CONTINUE COMMAND TIME CRITERION SATISFIED AT TIME 100.000
SPEED 39.959, AND POSITION 55651.8
```



Additional TTCI Software Suite Products

◆ **Train Energy Model (TEM™)**

- Analyzes fuel consumption affected by train resistance and train handling techniques
- Determines effect of varying
 - ▲ Train makeup
 - ▲ Truck type
 - ▲ Track conditions
 - ▲ Speed limits
- Not in active development

◆ **Wheel-Rail Contact Inspection System (WRCIS™)**

- On-board rail profile measurement and wheel-rail contact condition assessment (such as from track geometry car data)
- Measured profile pair analyzed against historical records to predict likely performance trends of vehicles as influenced by measured wheel-rail profiles
 - ▲ Uses embedded version of WRTOL™
- System enhancements expected in late 2015

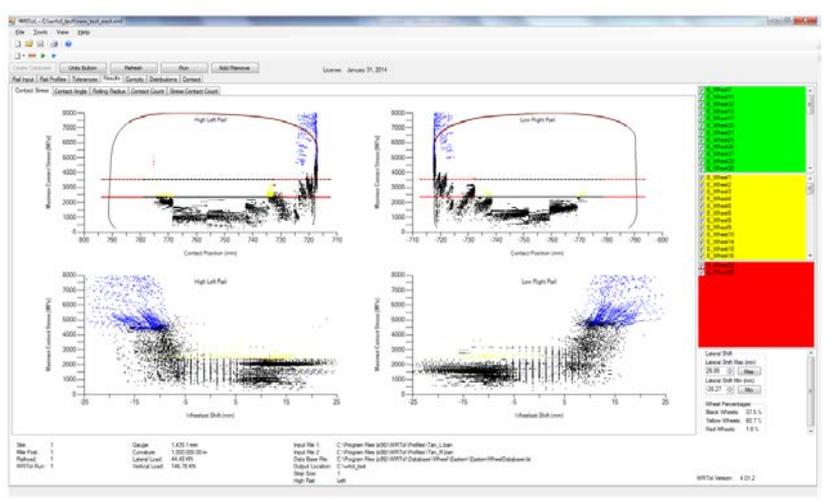
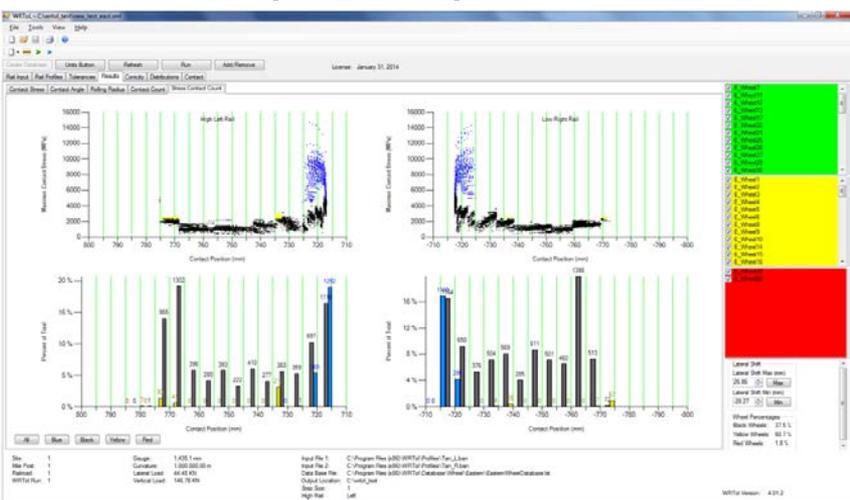




Additional TTCI Software Suite Products

◆ Wheel-Rail Tolerance (WRTOL™)

- Assesses wheel-rail contact parameters to predict vehicle performance
- Wheel-rail wear
- Rolling contact fatigue
- Analyze contact geometries of many wheelsets against a measured pair of rails, or many pairs of rail against a single wheelset
- Development planned in 2015





PERFORMANCE BASED TRACK GEOMETRY PBTG™

- ◆ **Improve and optimize track geometry maintenance**
- ◆ **Reduce track geometry caused derailments**
- ◆ **Uses Neural Networks to:**
 - Identify locations in track where combined effects of measured track geometry, operating speed and vehicle characteristics that may cause poor vehicle performance
 - Assigns track quality indices for the identified locations
 - Identify track maintenance corrective actions for each location to improve vehicle performance
- ◆ **Customized tool installed on a Railroad's track geometry measurement car**
 - Neural Networks developed for vehicles that are most sensitive to track geometry
 - Neural Networks trained using track geometry and vehicle performance data collected on the railroad





Additional TTCI Software Suite Products

◆ Rail Track Lifecycle Maintenance (RTLMTM)

- Track component deterioration calculations and economic calculations for track maintenance
- Track and traffic information maintained for any scale of interest
 - ▲ All the lines owned by a Class I railroad, down to a fictitious single mile of track created for experimental purposes
- Automated execution of any number of the models across a selected track, with result roll-up

- ◆ **Double Rail Model:** Simulation of switch points that can move relative to stock rails
- ◆ **FEA Modal Input:** Input of flexible mode shapes from FEA models
- ◆ **Different Kalker saturation curve on each contact point**
- ◆ **Ongoing improvement of W/R Penetration Model**
- ◆ **Ongoing improvement to MULTIVU data analysis package**
 - ISO 2631 (1997) ride quality including 2001 updates
- ◆ **Ongoing improvement to TRACKVU and CFIT-WRCON preprocessors**

◆ **Integrated User Interface**

- Beta version planned for early 2016

◆ **Improved curve fitting of complex rail profile shapes in switches and crossings**

- Expected for early 2016

◆ **Integrated Air Spring Models**

- Directly specify air spring parameters instead of building air spring model out of individual connection elements

◆ **Improved along Track Rail Profile Variation in W/R Penetration Model**

◆ **User definable W/R creep curves**





NUCARS® New Developments

INTEGRATED MODEL UI

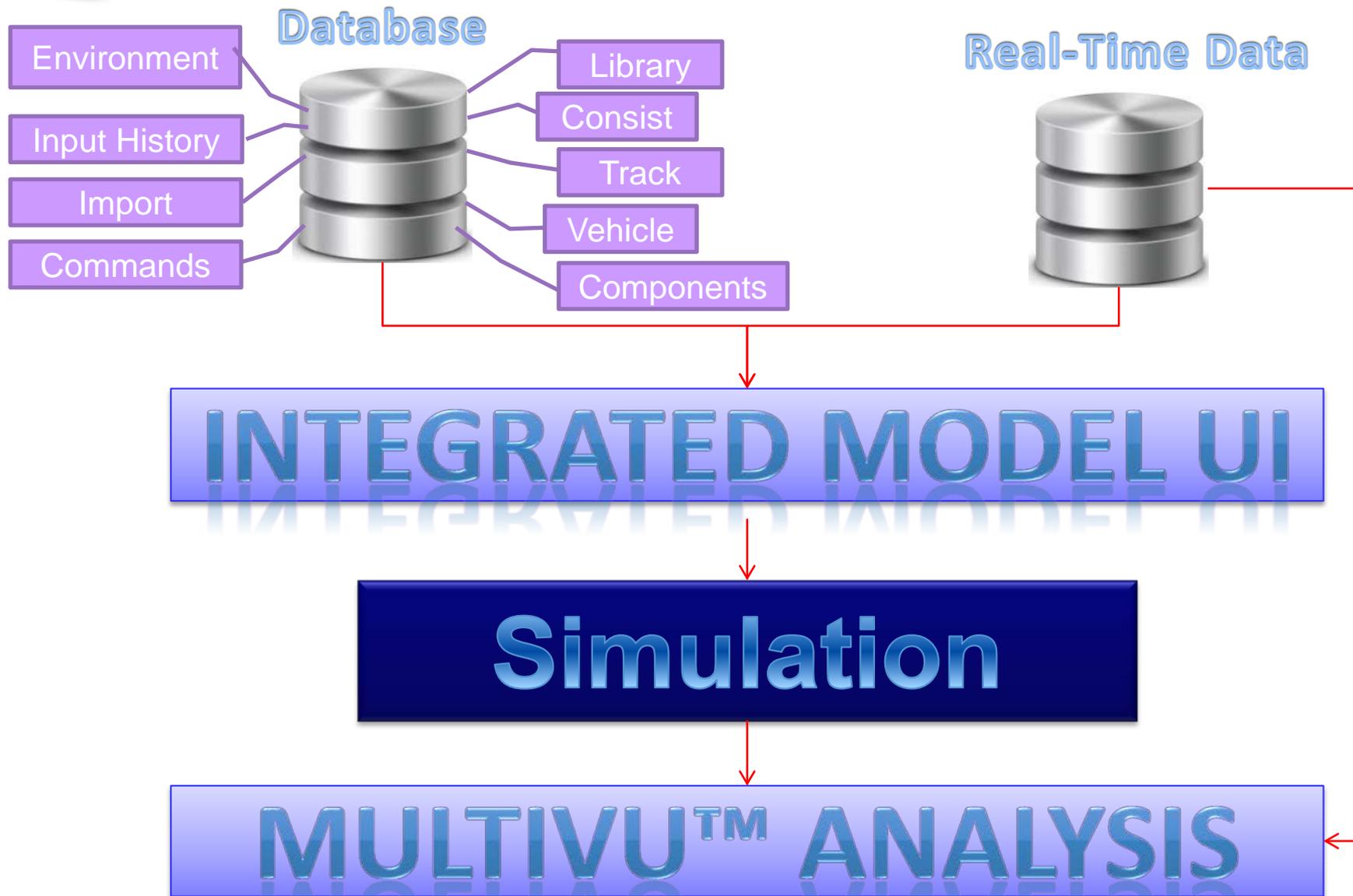
The screenshot displays the NUCARS software interface with the following components:

- Task List:** A sidebar menu with categories: SIMULATIONS (NUCARS, TOES, TEM), COMPONENTS (TRACK, VEHICLE, ENVIRONMENT, COMMANDS, INPUT HISTORY, IMPORT), LIBRARY (M-976 TRUCK, L HOPPER, IMPORT/EXPORT), and ANALYSIS (MULTIVU).
- Project Window:** A central 3D view showing a wireframe model of a rail car on a track.
- Component Properties:** A panel on the right showing details for the selected component 'FRGA_BLEB', including its description and a list of items (Body, Ground, Carbody, etc.).
- Properties:** A panel on the right showing various physical properties such as ID, Name, Description, CG equals Geomet., Center of Gravity, Geometric Center, Length, Width, Height, Mass, and Bolt Moment.
- System File:** A text window at the bottom showing the system file (.SYS) for NUCARS, including the system title and body data.

```
System file (.SYS) for NUCARS
-----
\SYSTEM TITLE
PRIIA spec bi-level car on equalizer beam trucks
\BODY DATA
16
1 'Carbody'      -498.0    0.0    129.0
```



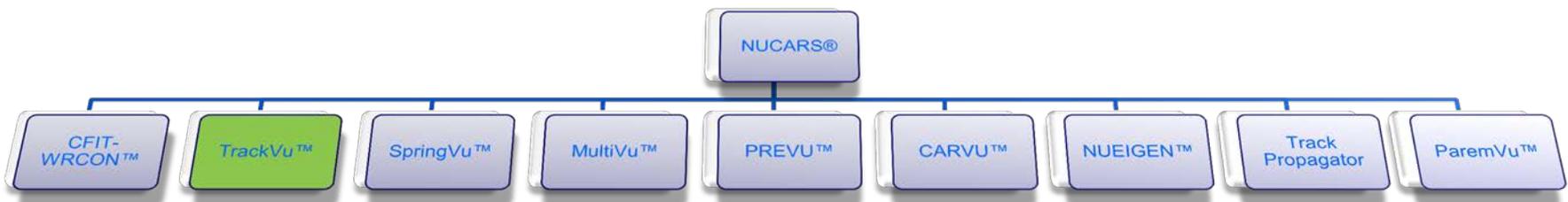
UI Data Flow



- Cluster/Cloud Services
- Enhanced Licensing Structure
- Real-time Evaluation
- Mobile Access
- Enhanced Parametric Variation
- Monte Carlo Simulations

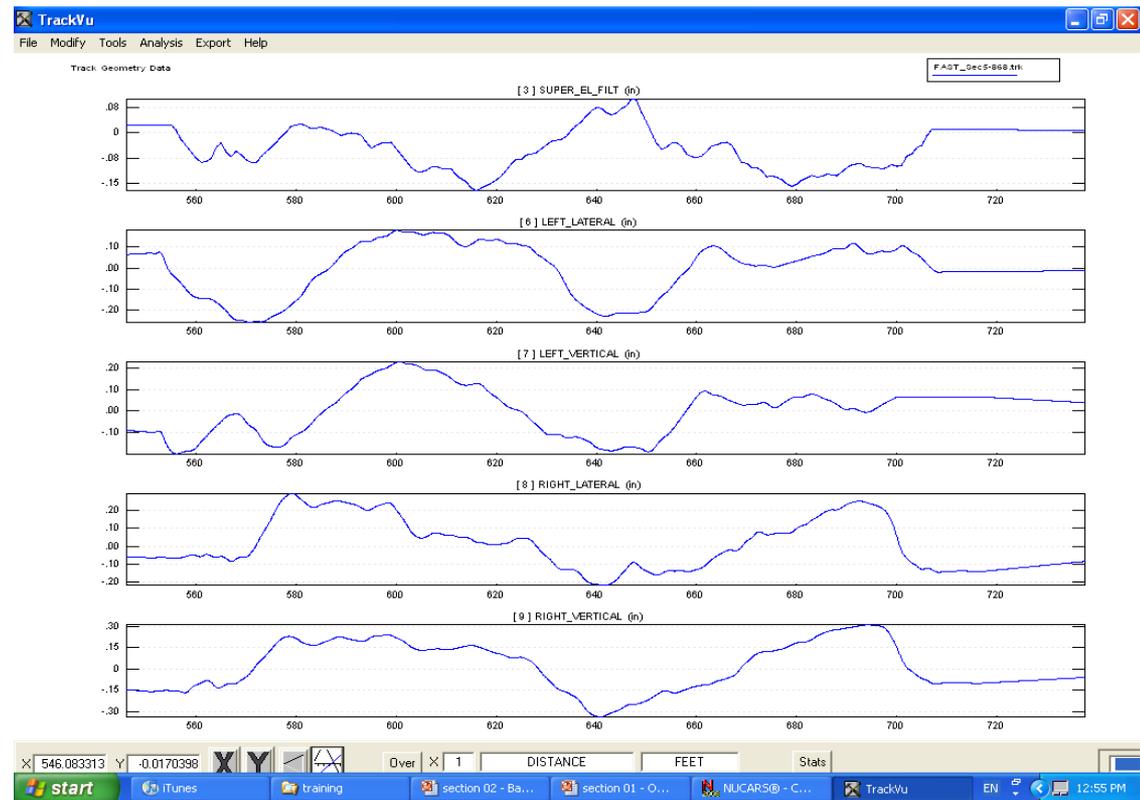


NUCARS[®] Peripheral Products



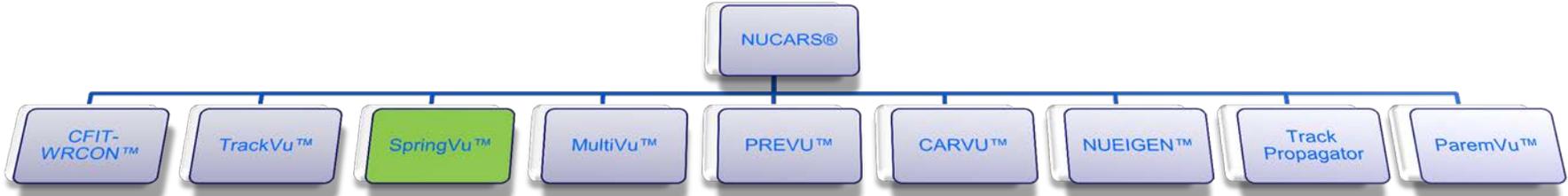
◆ TrackVu[™]

- Previews analyzes, and prepares measured track geometry for input to NUCARS



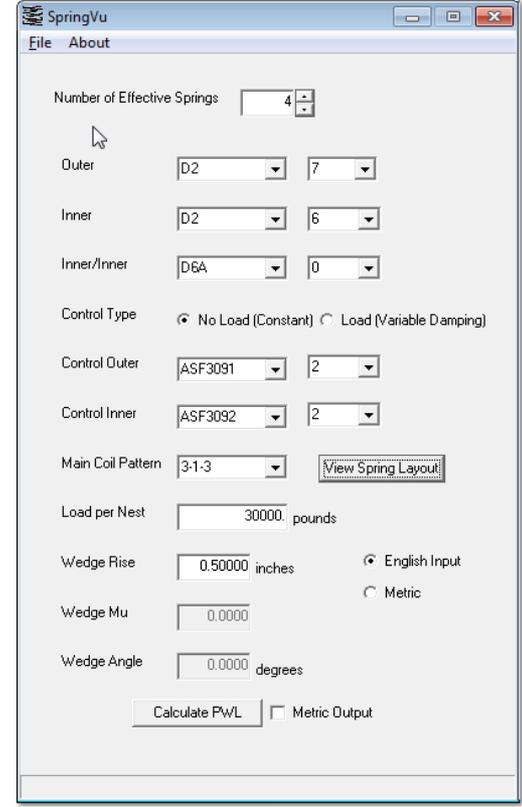
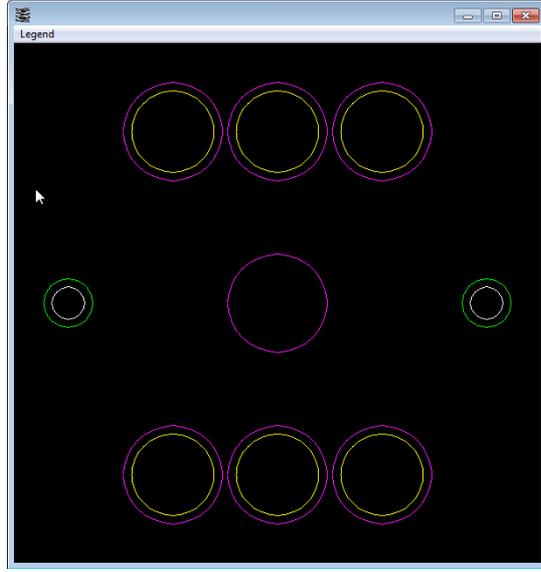


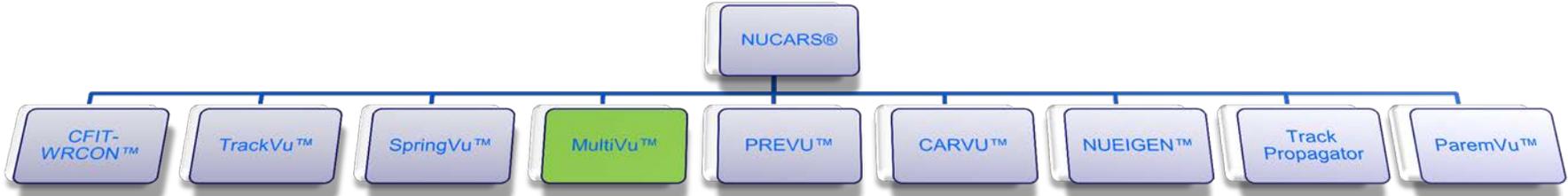
NUCARS[®] Peripheral Products



◆ SpringVu™

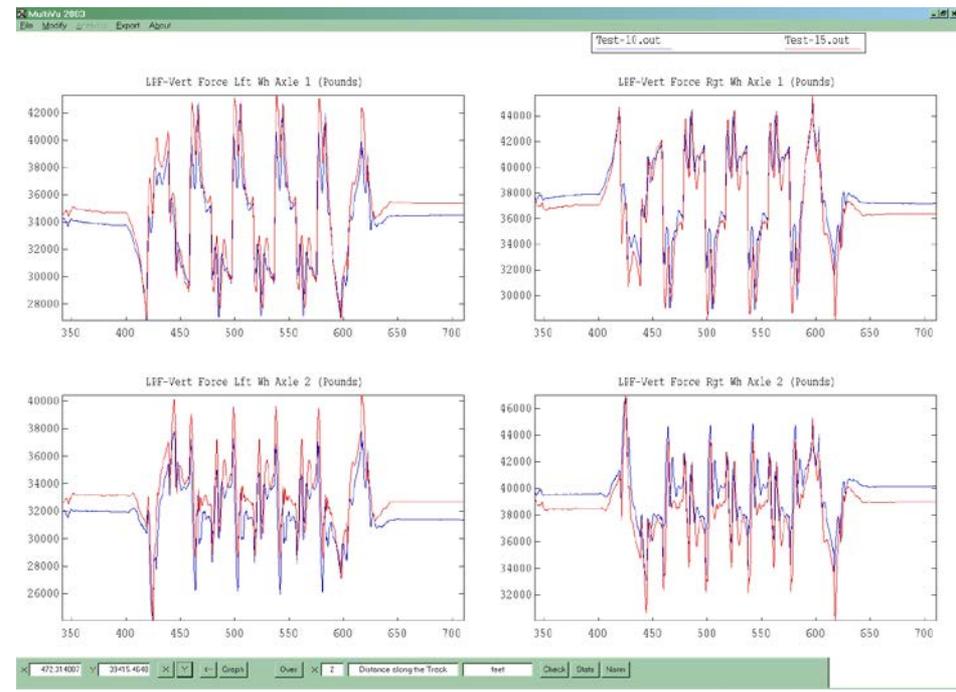
- Calculates input data for standard North American 3-piece track freight car spring groups and friction wedges





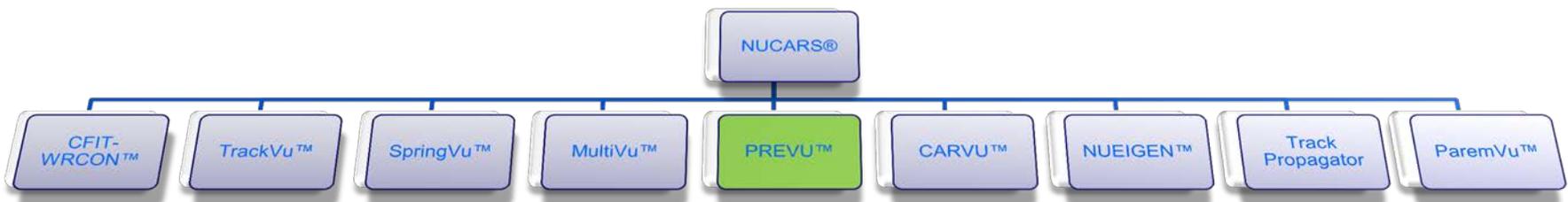
◆ MultiVu™

- A very powerful data analysis package for the analysis and plotting of NUCARS[®] output, including time domain and frequency domain analysis, digital filtering, ride quality, statistics, and conversion to other data formats.
- Most functions are also available for batch processing.
- Output data channels can also be combined and manipulated using a variety of mathematical functions.
- MultiVu™ also accepts ASCII input from other data sources, such as test data.





NUCARS® Peripheral Products



◆ PREVU™

- Preprocessor for viewing NUCARS® system files and checking their validity

Connection Report

Connection Information

#: 1 Name: Coupler to Grnd

Body 1: 1 - Full Main Body Body 2: 0 - Ground

DOF: 1 - Longitudinal Char #: Plot PWL(s)

Type: Parallel Spring/Damper

Global Position: X 36.000 Y 0.0000 Z 31.500

Relative Position: X 36.000 Y 0.0000 Z 31.500

Body Information

#: 1 Name: Full Main Body Mass: 3.01

CG Position: X -278.00 Y 0.00 Z 83.00

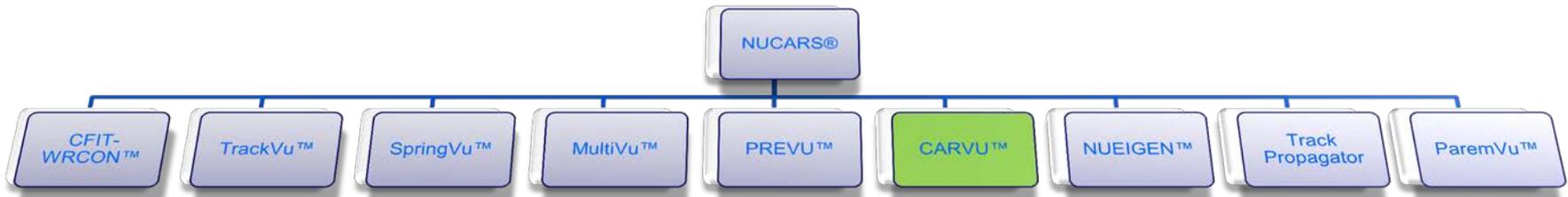
Inertia: Roll 0.63E+03 Pitch 0.16E+07 Yaw 0.17E+08

DOFs: X Y Z Roll Pitch Yaw

Title: Loaded 100T Hopper Car w/Roller Side Bearings, NUCARS 2011, Rev. 01/19/11 N

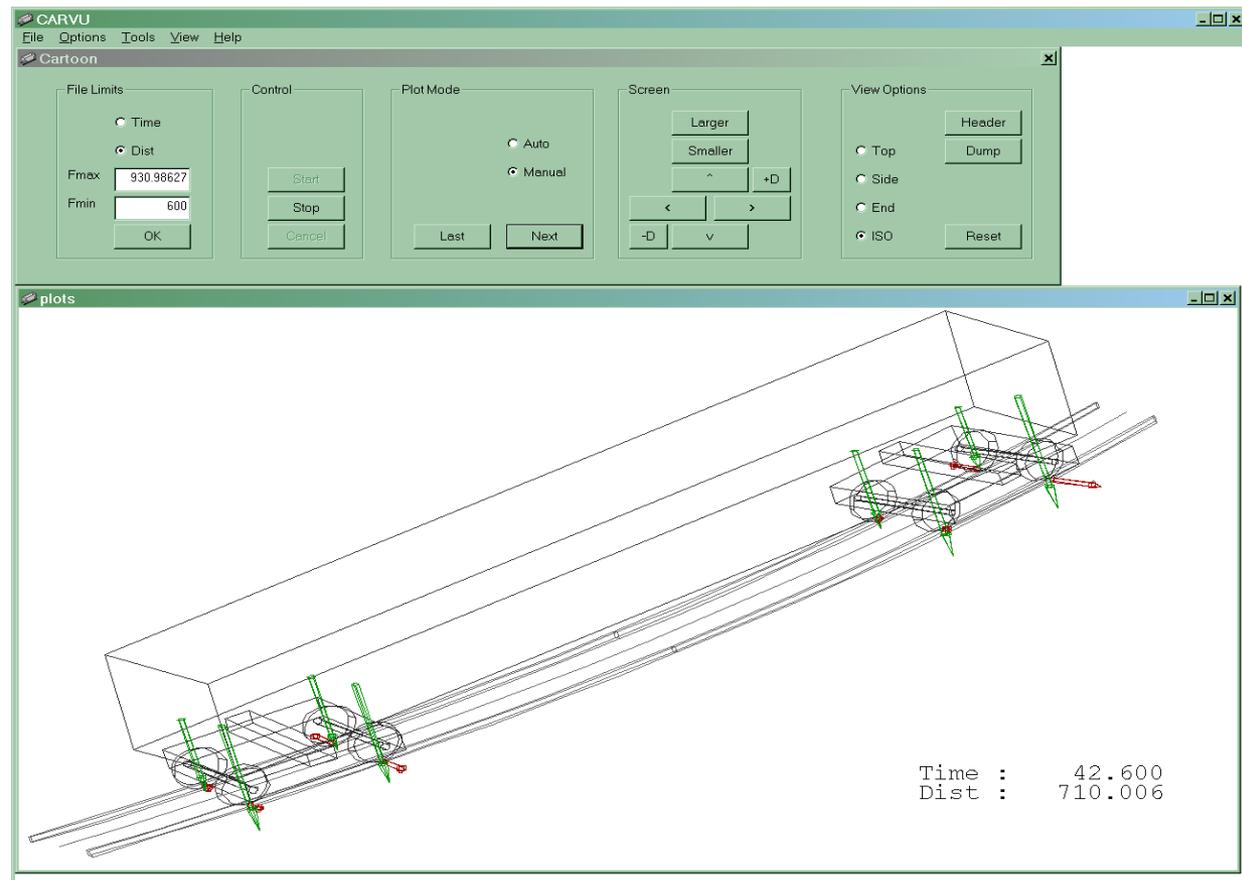


NUCARS[®] Peripheral Products



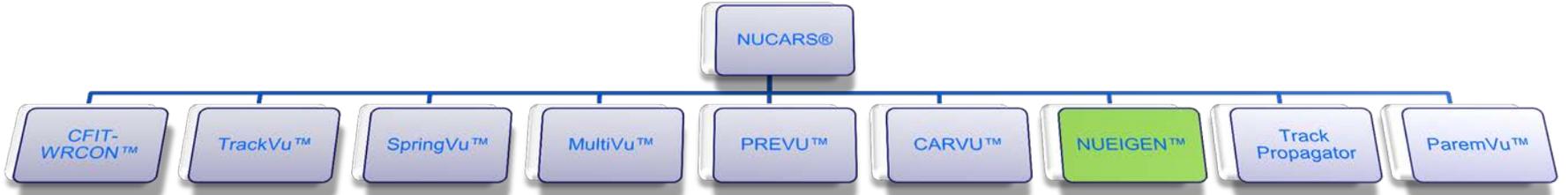
◆ CARVU™

- Animation of NUCARS[®] and NUEIGEN output, including visualization of wheel and rail forces and body motions





NUCARS[®] Peripheral Products



◆ NUEIGEN™

- Eigen-value solution for linearized systems including lateral stability (hunting)

```

Run file (.RUN) for NUEIGEN
=====
IRUN TITLE
Ehopr-23-Eig run file, velocities from 5 to 105 in 5mph increments

ISYSTEM FILE
'Ehopr-23-eig'

!CONTACT PARAMETERS
! No. of Wheelsets
4
! Wheelset Lat DOFs
44 49 54 59
! Wheelset Yaw DOFs
47 52 57 62
! Half Gage Rail Head Radius Wheel Radius Conicity Friction
29.0 10.0 18.0 0.05 0.6

VELOCITIES
! No. of Velocities
21
! Velocities
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105

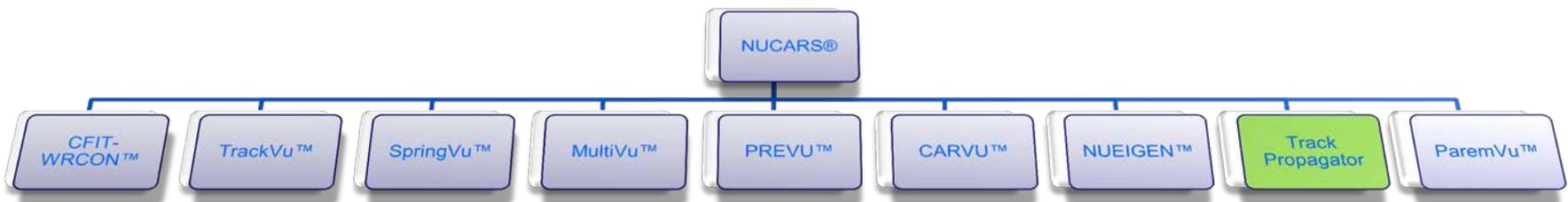
!CONTROL CONSTANTS
! Eigen Output Modal Output
1 1

MODAL OUTPUT
! Number of Modes, followed by Mode Numbers & Amplitudes
8
21 22 23 24 25 26 27 28
10. 10. 10. 10. 10. 10. 10. 10.
! Frequency(Hz) Output Step(sec) Maximum Time(sec)
0.25 0.01 20.0

```

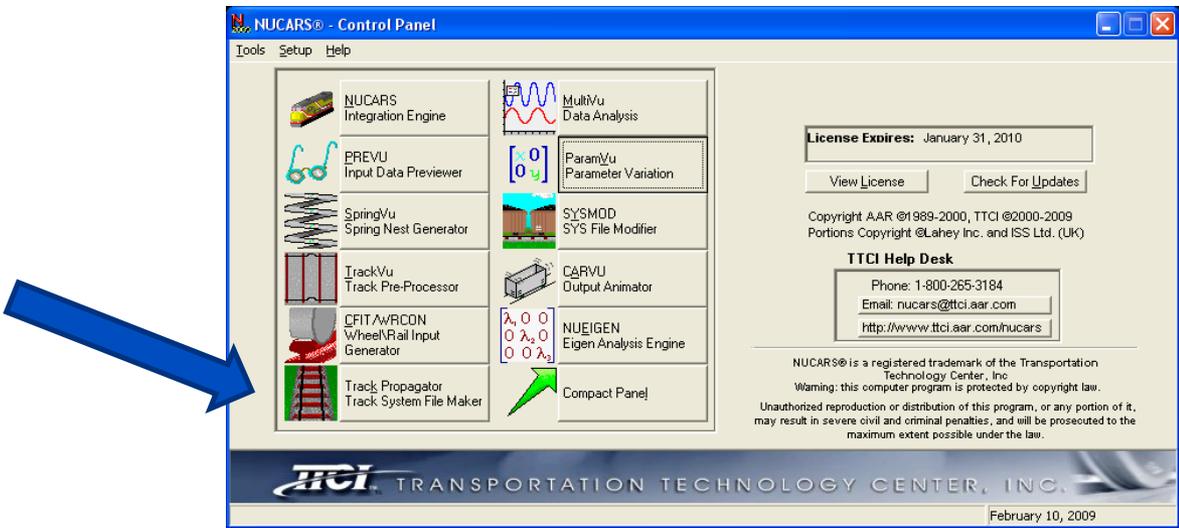


NUCARS® Peripheral Products



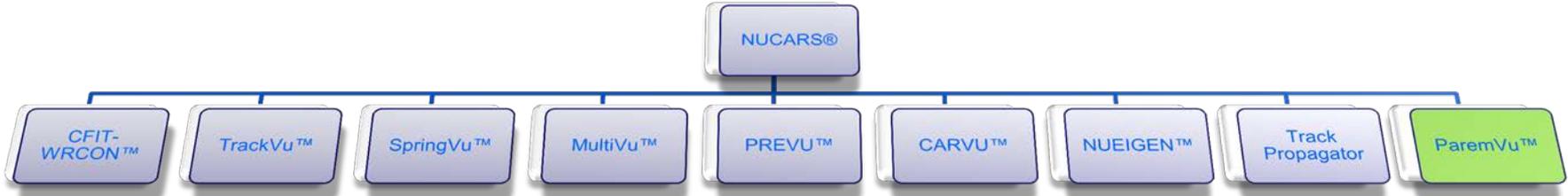
◆ Track Propagator

- For generating the track portion of NUCARS SYS files to represent flexible track structures for use with the NUCARS flexible track modeling capability





NUCARS® Peripheral Products



◆ ParamVu™

- Allow easy generation of many NUCARS input data files (SYS, RUN, ETC) with varied inputs for parameter variation simulations

Base Filename: C:\Program Files\NUCARS\sample\ParametricVariation\examp

Project Filename:

Number of Variations:

Variation 1 | Variation 2 | Variation 3 | Variation 4 | Variation 5 | Variation 6 | Va

Description: Number of Associations:

Number of Changes:

Filename String	Replacement Values
curve00_	00
curve05_	05
curve10_	10
curve13_	13
curve17_	17
curve24_	24