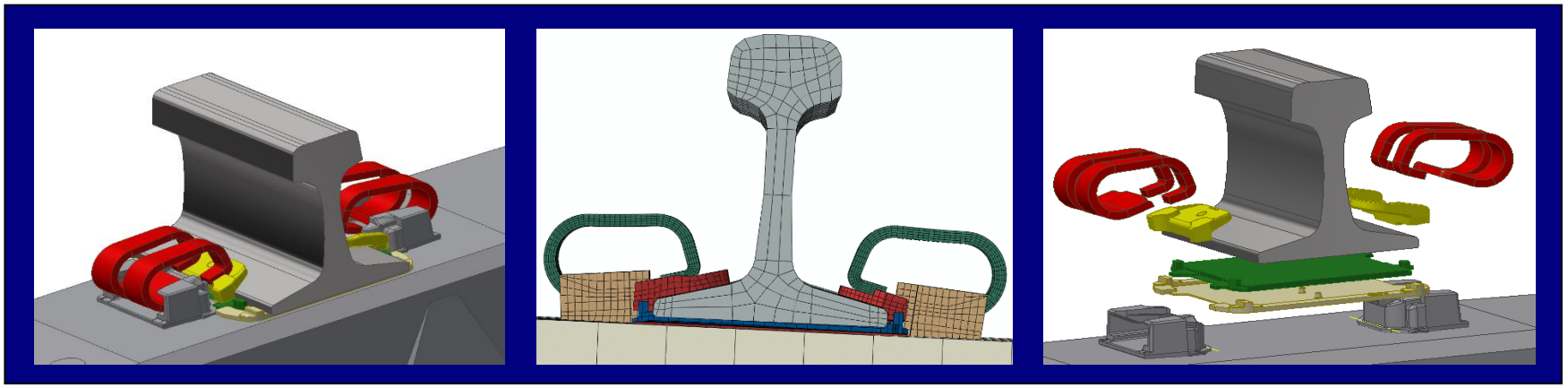
Development of a Track Component Response Tool (I-TRACK)



Joint Rail Conference – JRC 2014

Colorado Springs, CO

4 April 2014

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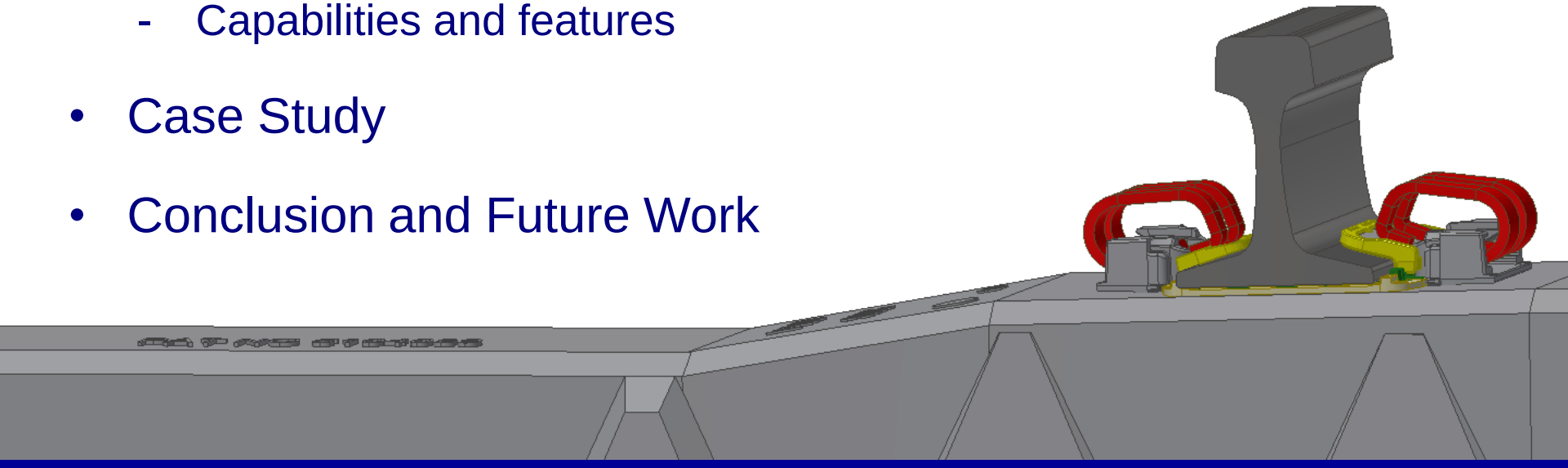
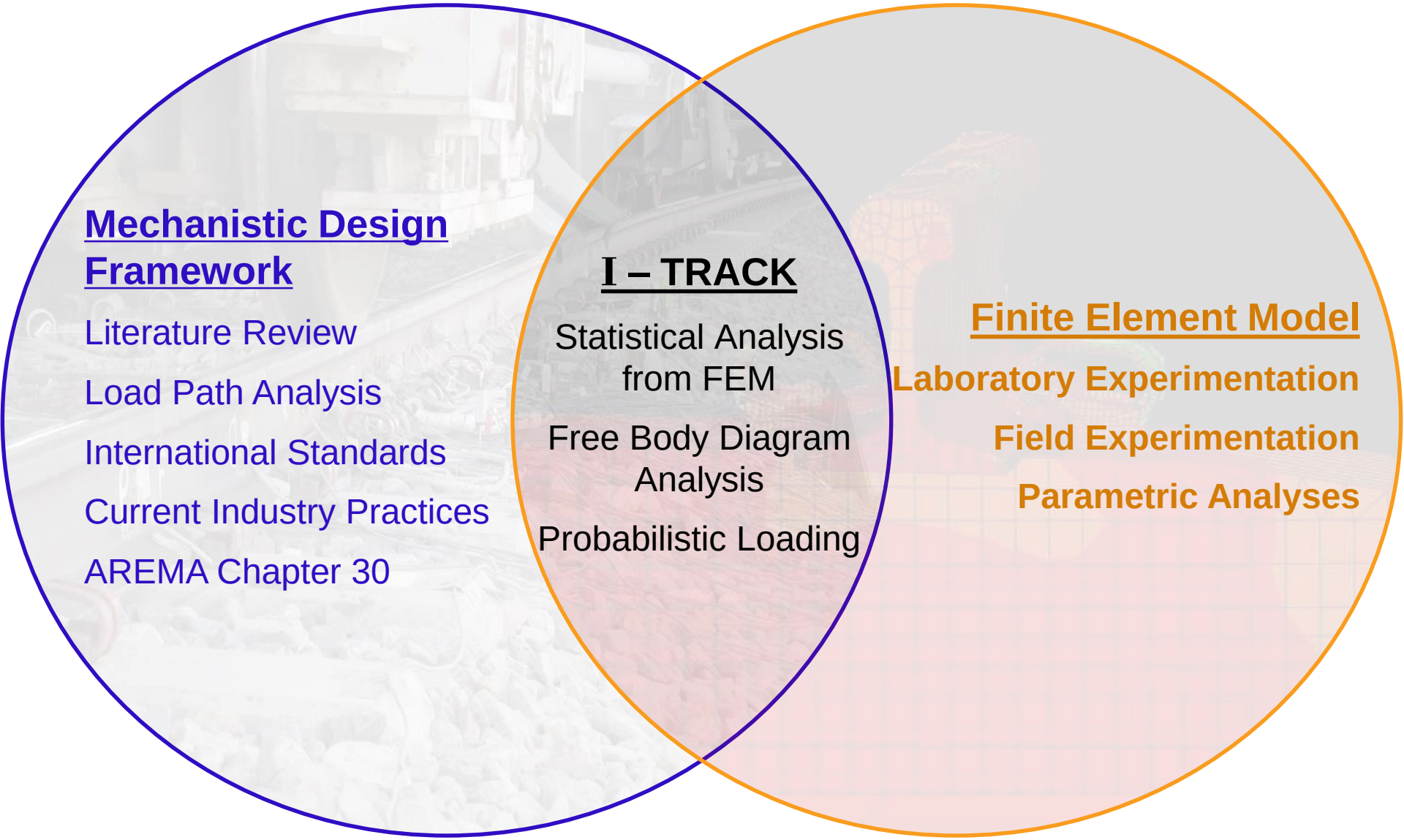
Federal Railroad Administration

Outline

- Motivation to Develop I-TRACK
- Characterization of I-TRACK
- Radial Basis Function Neural Network
- Project Phases
  - Capabilities and features
- Case Study
- Conclusion and Future Work

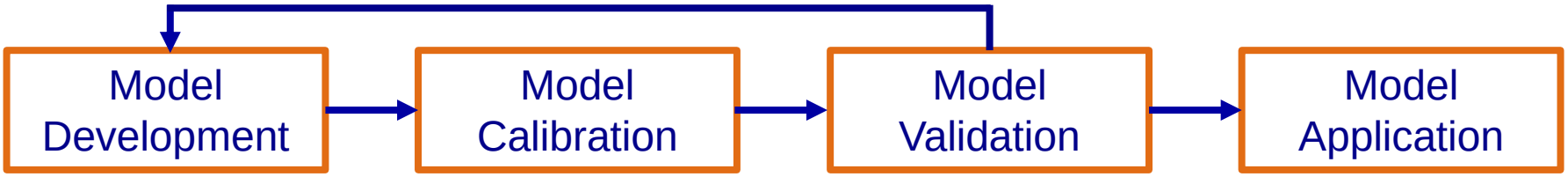


FRA Tie and Fastener Research Program
Overall Project Deliverables

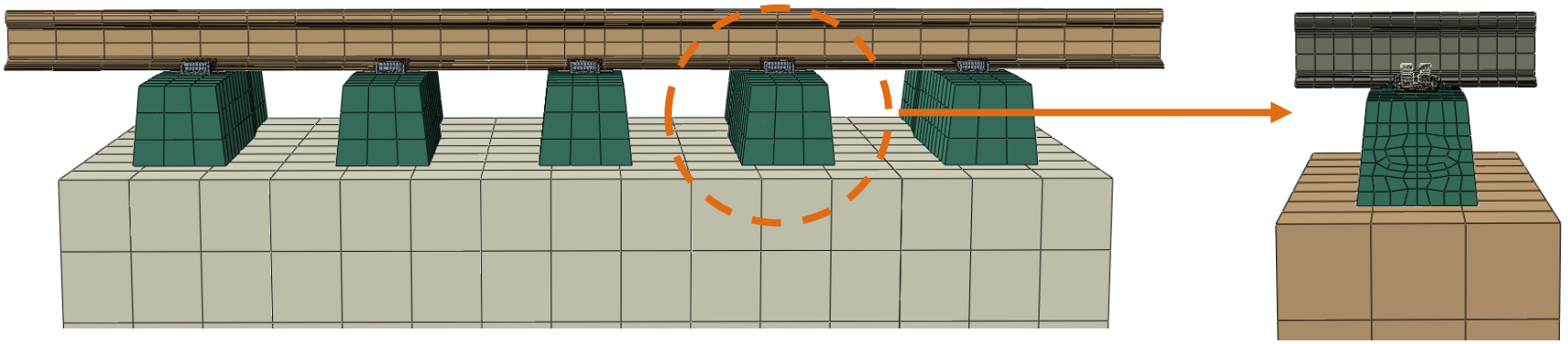


UIUC Finite Element (FE) Model

- UIUC has developed a comprehensive concrete crosstie and fastening system FE model to simulate and gain understanding on the track structural system, components interaction, frictional behavior, and load distribution



- Two models are used to simulate the track behavior (including substructure support)
  - **Global model**: five crossties and simplified fastening systems
  - **Detail model**: single crosstie and fastening system

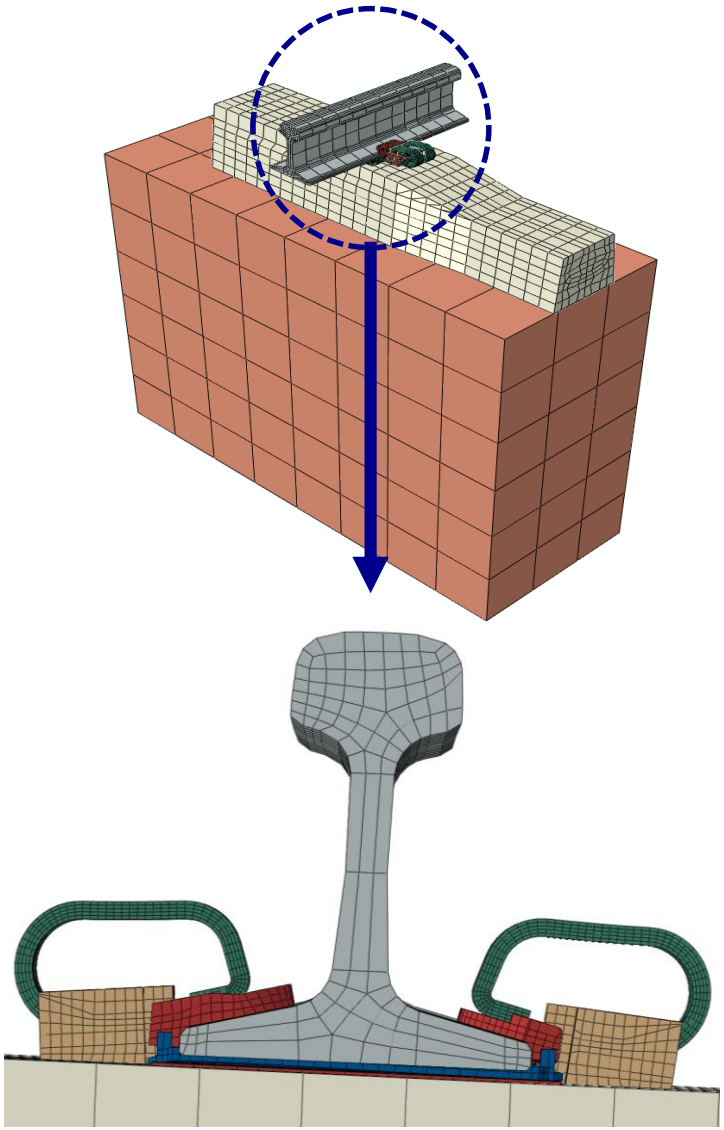


Global Model

Detailed Model

Motivation to Develop I-TRACK

- FE models provide a powerful tool to accurately represent loading environments, support conditions, and component interactions to obtain the system and component level behavior
- Accessibility and computational limitations are factors that make the use of the FE model impractical for the general user
- I-TRACK was developed to overcome FE model limitations and provide users with quick access to track components responses with a good level of flexibility
- **Objective: develop a tool to assist improving the design of components and help railroad track engineers assessing the conditions, safety, and expected performance of the track structure**

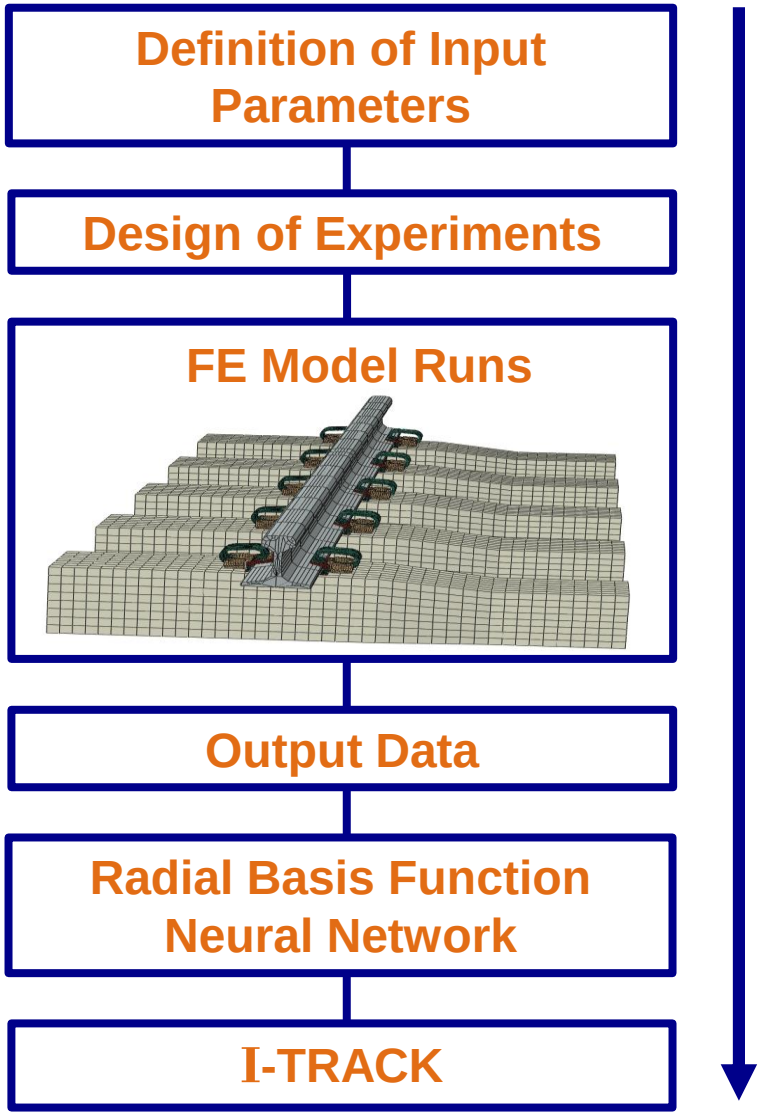


UIUC FE Model (Chen et. al.)

Characterization of I-TRACK

- I-TRACK is a software based on statistical analyses of the UIUC FE model
- A neural network model was developed to predict track components responses based on user defined inputs (e.g. wheel loads, material properties, etc.)
- No proficiency in computer coding or knowledge in FE modeling is required from the user when using I-TRACK
- Practicality, adaptability, and statistical model reliability were the three main factors taken into consideration when developing the tool
- Microsoft Excel was the platform chosen to embed the initial versions of the model due to its wide spread use, flexible functionality, and ease of use

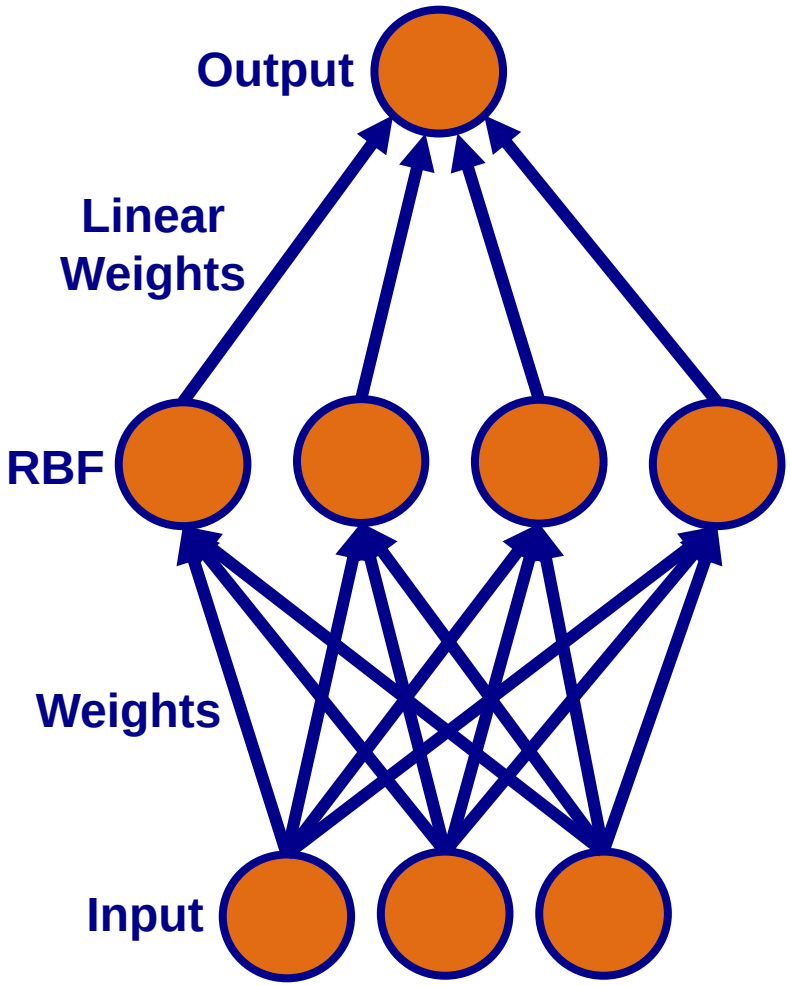
Development of I-TRACK



I-TRACK Statistical Model

Radial Basis Function Neural Network

- I-TRACK statistical model was developed using a Radial Basis Function Network (RBFN) approach
- RBFN is an artificial neural network that uses radial basis functions as activation functions
- RBFN gives zero error for the training data. FE model outputs will generate the same values when the same inputs are used as the Design of Experiments that was originally used
- Model was trained using 95 sets of input-output values and tested with 16 runs extracted from the FE model
- Average error in all outputs is below 20% and maximum error is below 30%

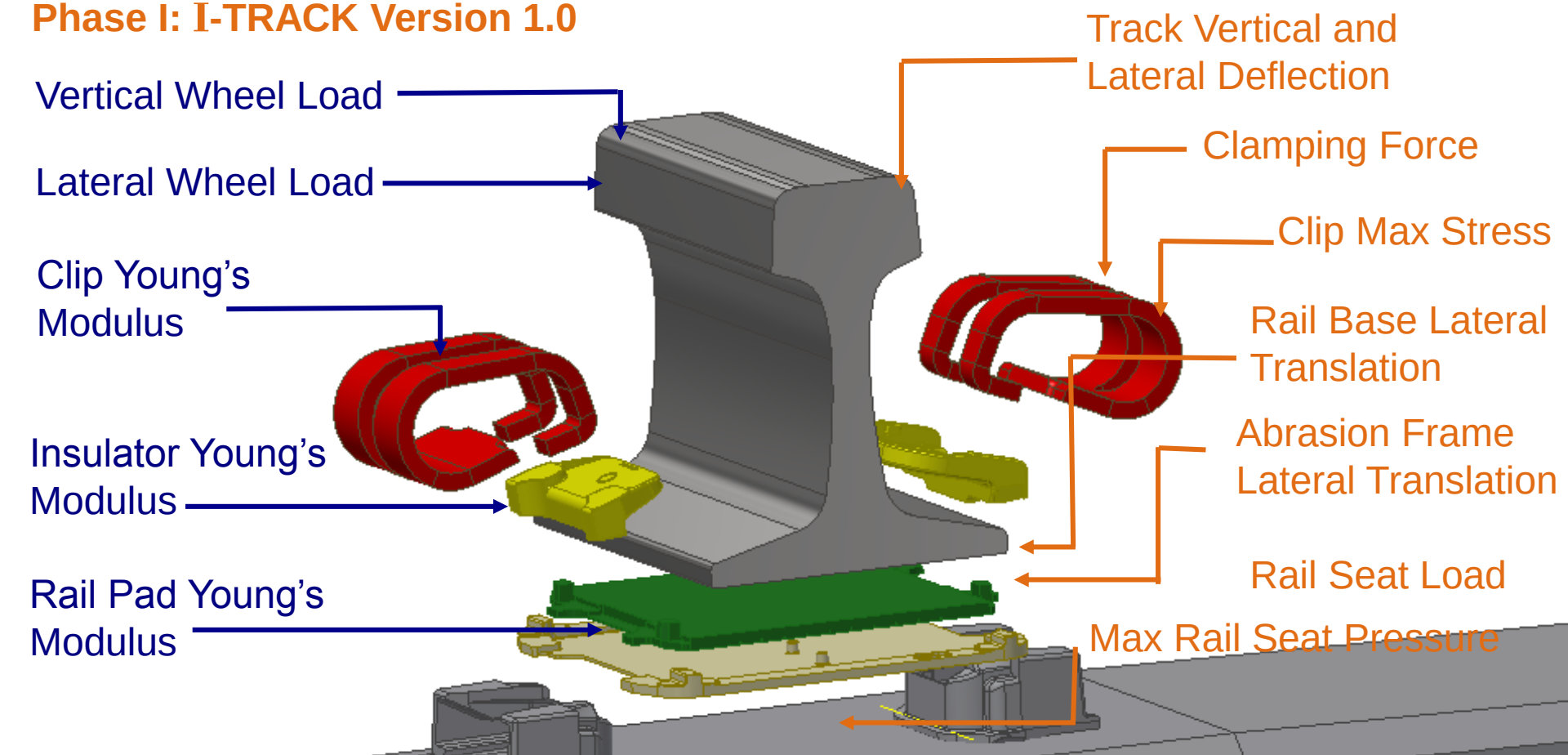


Representation of a RBFN

Project Phases

- The development of I-TRACK follows a systematic process. The project was divided in 3 phases, which add additional complexity and analysis capabilities
- Goal: expedite the development of I-TRACK, test the model accuracy and functionalities on a continuous basis, and provide interim utility to end users

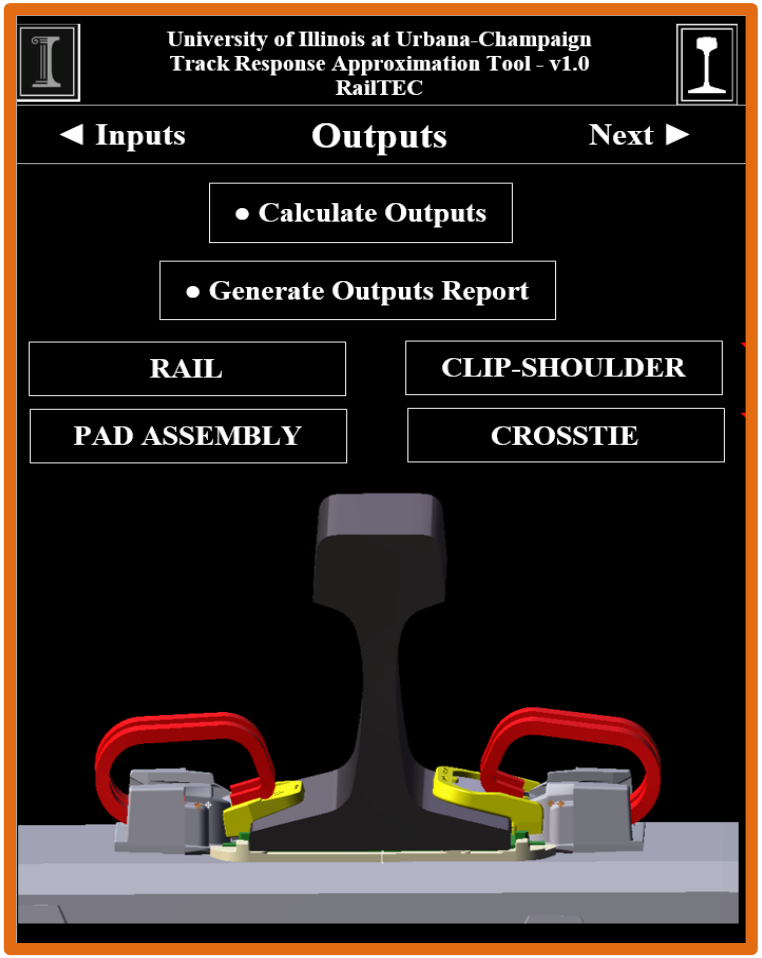
Phase I: I-TRACK Version 1.0



Functionalities and Features

- I-TRACK Versions 2.0 and 3.0 will allow users to modify a larger number of inputs (interface interactions, support conditions, components geometry) and will provide additional output parameters

- **Main Functionality and Features**
  - Simplified user's interface
  - Tutorial
  - Selection of baselines
  - Selection of inputs
  - Generation of Inputs vs Outputs graphs
  - Analysis Report
  - Prediction of possible failure modes



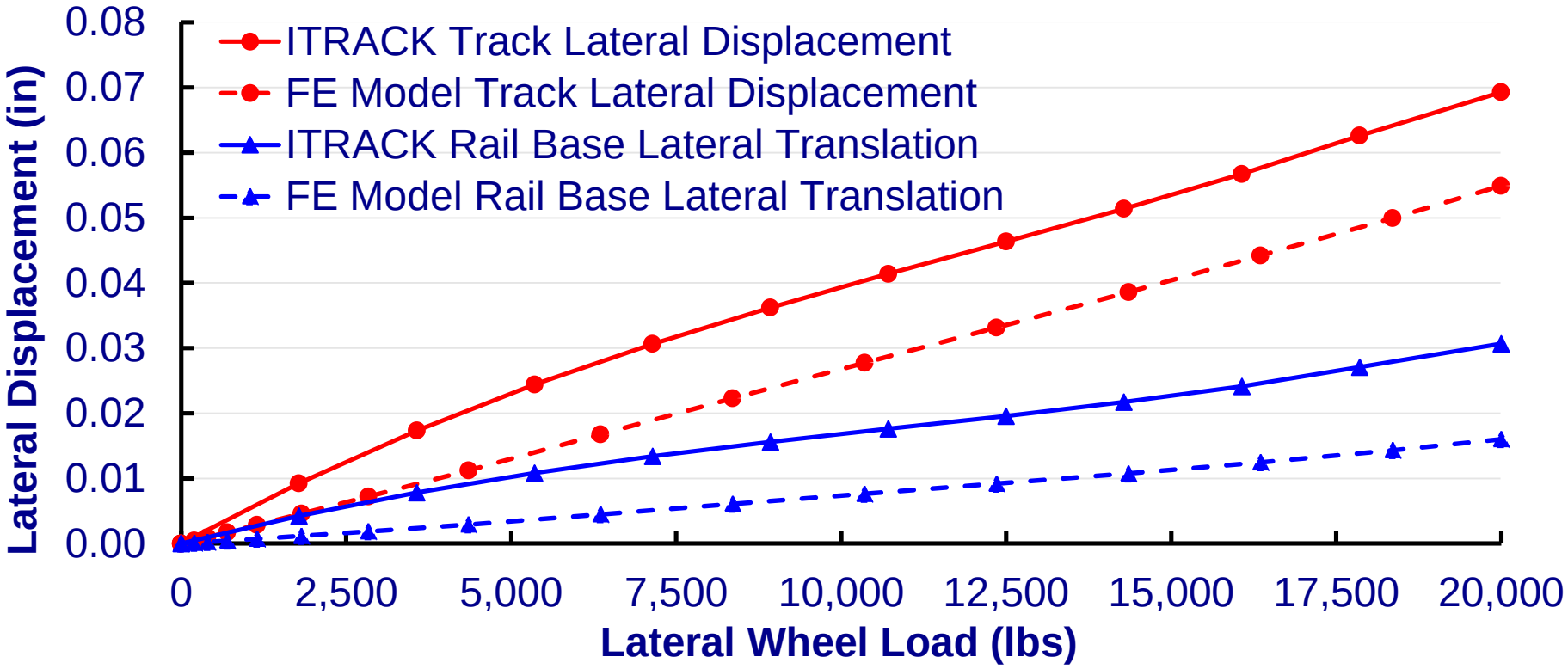
Overview of I-TRACK Case Study

- **Purpose:** validation of I-TRACK's results when compared to the FE model outputs
- **Test Case:**
  - Simplified framework for a rail pad assembly mechanical behavior study using I-TRACK
  - Test the accuracy and present the usefulness of this tool in the development of improved design methodologies for fastening system components

Inputs	Magnitude
Vertical Load (lbs)	30,000
Lateral Load (lbs)	7,500
Insulator Young's Modulus (psi)	440,000
Rail Pad Young's Modulus (psi)	7,500
Rail Pad Poisson Ratio	0.49
Clip Young's Modulus (psi)	23,000,000

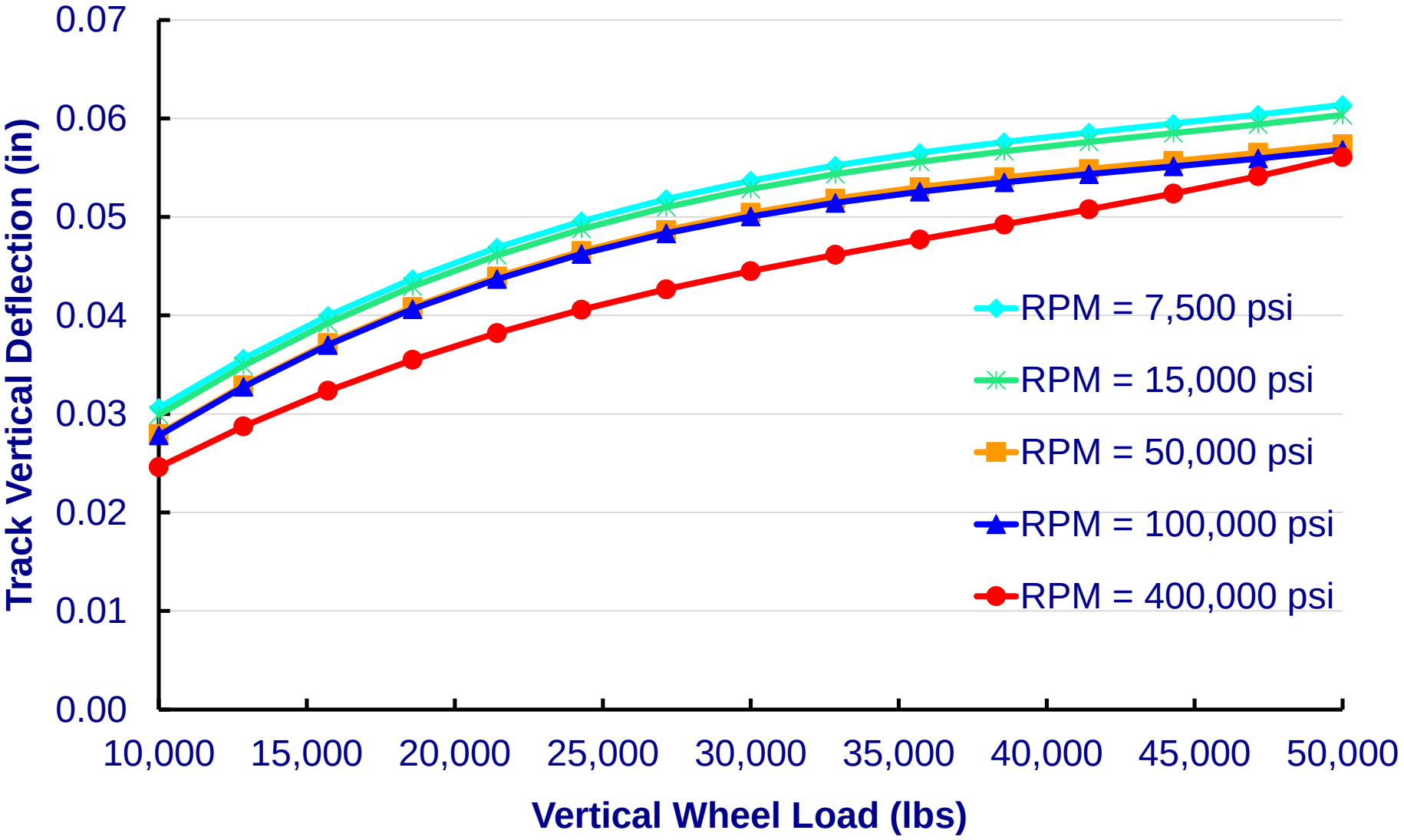
Magnitude of inputs used to conduct the case studies

Comparison of FE Model Results

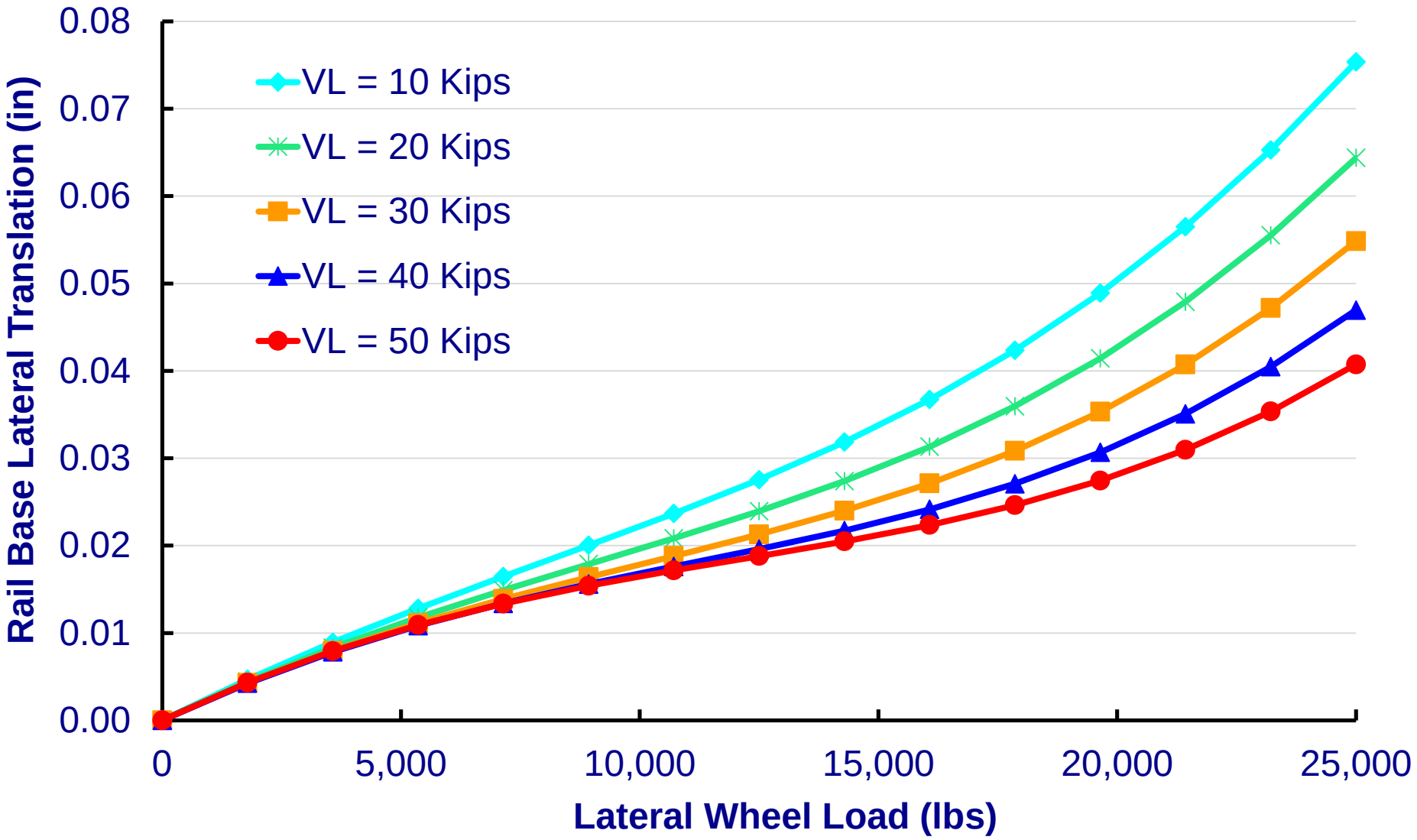


- Good agreement was found between results, with magnitude of displacements close to each other.
- I-TRACK successfully captured the FE model behavior with R^2 value equal to 0.98
- Error is present for all the simulated data due to the amount of variables in the system and reduced number of experiments used to develop the statistical model

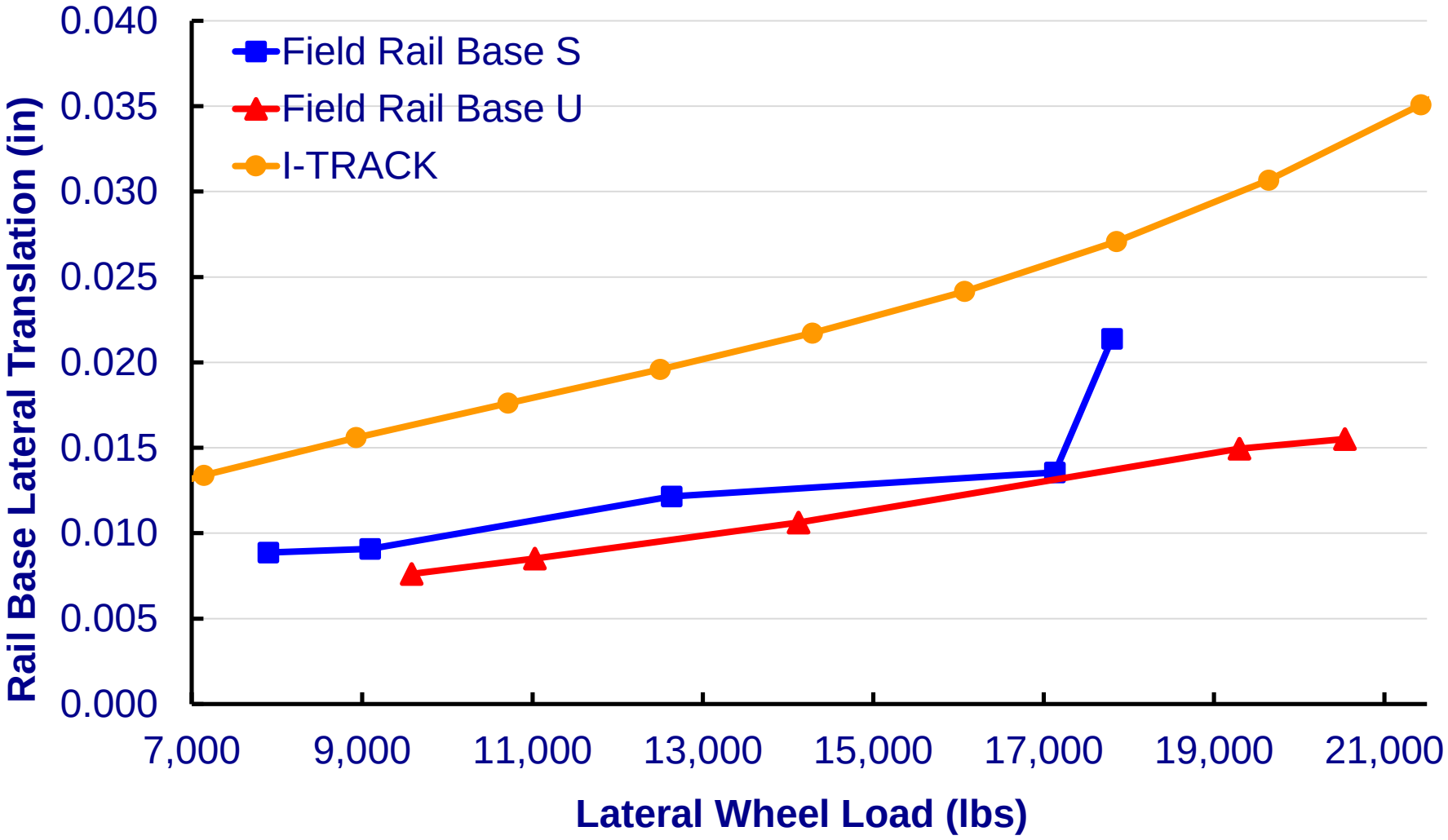
Effect of Rail Pad Modulus (RPM) on Track Vertical Deflection



Effect of Vertical Load (VL) on Rail Base Lateral Translation



Comparison Between Field Data and I-TRACK Results



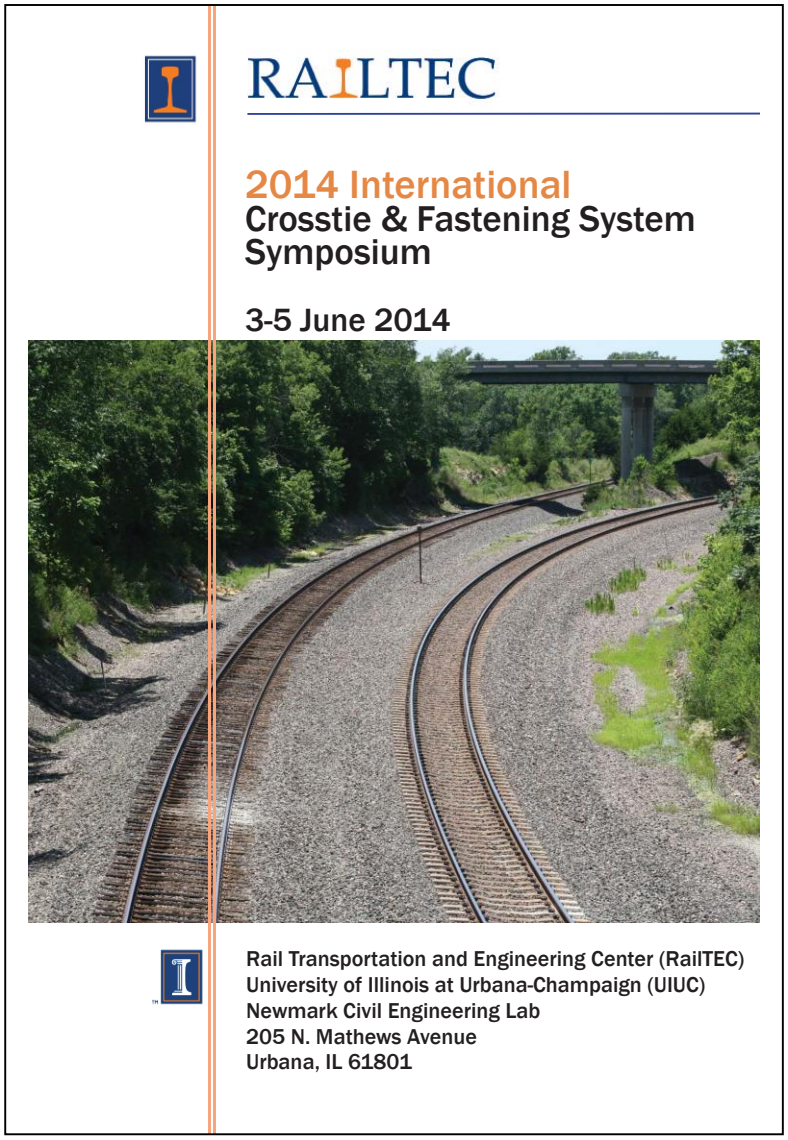
- Field results from freight train consist (40 kips axle load)

Conclusions and Future Work

- The development of a tool based on FE model results using RBFN demonstrated satisfactory results
- Accurate correlation between I-TRACK results and FE Model outputs was found
- Field data has presented similar behavior to the statistical model results. This is a strong indication of I-TRACK's accuracy and reliability
- A systematic investigation of track and components responses using this tool proved to be viable
- I-TRACK is still on its early stages, but it is a prospective tool to assist the development of mechanistic design practices focused on component performance

Hosting 2014 International Crosstie and Fastening System Symposium

- Co-organized by: **AREMA Committee 30 (Ties), Railway Tie Association (RTA)**
- ***Three day conference with presentations, discussions, and a technical tour***
- **Focus → state of the art in timber, concrete, and composite crosstie and fastening system design, performance, research, modeling, and inspection**
- **3 - 5 June 2014** – Sessions on UIUC campus
  4 June 2014 – Technical tour to UIUC Research and Innovation Laboratory (RaIL) and voestalpine Nortrak facility in Decatur, IL
- Strong domestic and international participation; addressing topics including:
  - *Laboratory and Field Testing*
  - *Component and System Modeling*
  - *Automated Inspection Technologies*



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Questions or Comments?

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Thank you!