OFFICE OF RESEARCH & DEVELOPMENT

2012 R&D REVIEW

Rail Neutral Temperature Measurement

U.S. Department of Transportation

Federal Railroad Administration

FRANCESCO LANZA DI SCALEA, PH.D.

University of California, San Diego

Program Area & Risk Matrix

Rail Neutral Temperature Measurement

Program Areas / Risk Factors	Trespass	Grade Crossing	Derailment	Train Collision	All Other Safety Hazards
Railroad Systems Issues					
Human Factors					
Track & Structures			X		
Track & Train Interaction					
Facilities & Equipment					
Rolling Stock & Components					
Hazardous Materials					
Train Occupant Protection					
Train Control & Communications					
Grade Crossings & Trespass					

Acknowledgements & Stakeholders

Acknowledgements

- Grant FR-RRD-0009-10-01 to the University of California, San Diego (UCSD)
- Former grad students:
  - I. Bartoli (Drexel Univ.)
  - S. Salamone (SUNY Buffalo)
- Current grad students:
  - C. Nucera
  - R. Phillips
  - T. Nguyen
  - P. Zhu

Stakeholders & Project Partners

- University of California, San Diego (grantee)
- Volpe (technical advice)
- BNSF Railway (technical advice, in-kind material donations)

Objectives

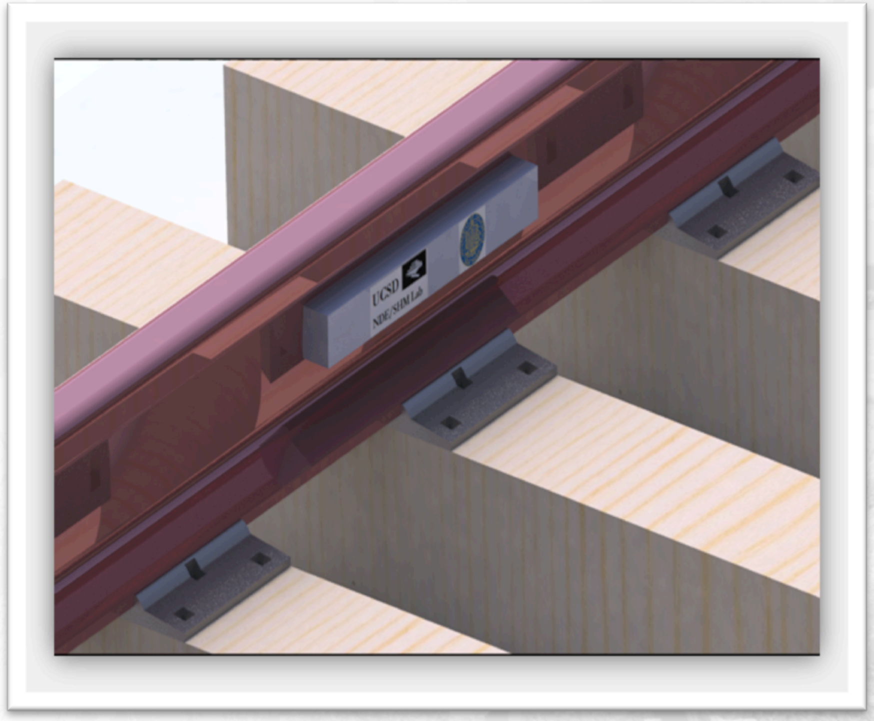
Develop a wayside system for the measurement of Rail Neutral Temperature (NT) with following features:

(1) NT measurement accuracy to within ± 5 °F.

(2) No need for reference value stress.

(3) No sensitivity to rail supports or tie-to-tie variations.

(4) No need for calibration for different rail sizes/manufacturers.



Motivations for project

- Continuos Welded Rail (CWR) can break in cold weather and buckle in hot weather.
- Current difficulty to determine the rail NT *in-situ* leads to inefficient blanket-type slow-order mandates.
- Railroads need the ability to measure rail NT and detect Imminent Buckling of CWR.
- Buckling prevention will be particularly relevant to the safety of high-speed rail.

TRAIN ACCIDENTS BY CAUSE FROM FORM FRA F 6180.54

MAJOR CAUSE= Track

Selections: Railroad - ALL
State - ALL, County - ALL
ALL ACCIDENT TYPES / All TRACK TYPES / T-ALL-Track, Roadbed and Structures
Time Frame: Dec 2006 To Oct 2011

Specific causes:	Total		Type of Accident			Reportable Damage		Casualty	
	Cnt	%	Coll	Der	Othr	Amount	%	Kld	Nonf
T001- Roadbed settled or soft	139	3.7	1	134	4	30,837,929	4.8	0	15
T002- Washout/rain/slide/etc. dmg -track	40	1.1	-	32	8	22,425,088	3.5	2	24
T099- Other roadbed defects	13	0.3	-	11	2	1,368,680	0.2	0	0
T101- Cross level of track irregular(joints)	113	3.0	1	112	-	9,652,246	1.5	0	1
T102- Cross level track irreg.(not at joints)	119	3.2	-	115	4	25,530,932	4.0	0	0
T103- Deviate frm uniform top of rail profile	18	0.5	-	16	2	3,006,268	0.5	0	0
T104- Disturbed ballast section	1	0.0	-	1	-	10,000	0.0	0	0
T105- Insufficient ballast section	5	0.1	-	5	-	718,477	0.1	0	0
T106- Superelevation improper, excessive,etc.	19	0.5	-	19	-	3,053,200	0.5	0	0
T107- Superelevation runoff improper	3	0.1	-	3	-	259,773	0.0	0	0
T108- Trk alignmnt irreg-not buckled/sunkink	62	1.6	-	62	-	14,537,127	2.3	0	1
T109- Track alignment irreg(buckled/sunkink)	143	3.8	-	141	2	57,671,350	9.1	0	3
T110- Wide gage(defective/missing crossties)	674	17.9	-	672	2	49,556,185	7.8	0	4

[FRA rail buckling video](#)

Previous Methods

- **VERSE:** Measurement of static rail stiffness
  - Requires unfastening of ~100 ft of rail
  - Requires service interruption
- **D'STRESEN:** Measurement of dynamic resonance of torsional mode of vibration at frequencies < 90 Hz
  - Can be sensitive to rail fastening/support conditions
  - Problem of tie-to-tie variation
  - Difficulty of measuring compression forces in tangent track with elastic fasteners
- **MAPS-SFT:** Measurement of magnetic permeability of steel
  - Requires calibration
  - Stress determination requires 8 scans, or at least 30 minutes
  - Slow, cannot be used in motion
- **OTHERS:** Ultrasonic Backscattering (University of Nebraska), Rayleigh Wave Polarization (Texas A&M University)
  - Still unproven

Benefits & Disadvantages

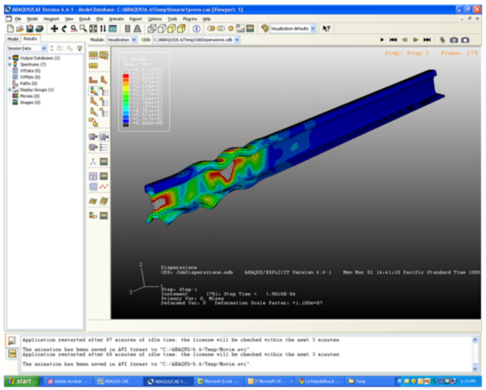
Benefits

- NT measurement accuracy to within ± 5 °F.
- No need for reference value of stress.
- No sensitivity to rail supports or tie-to-tie variations.
- No need for calibration for different rail sizes/ manufacturers (potential).

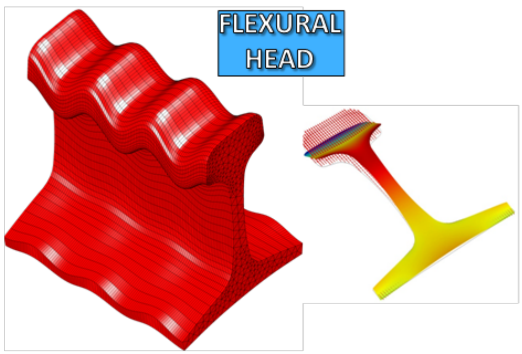
Disadvantages/Limitations

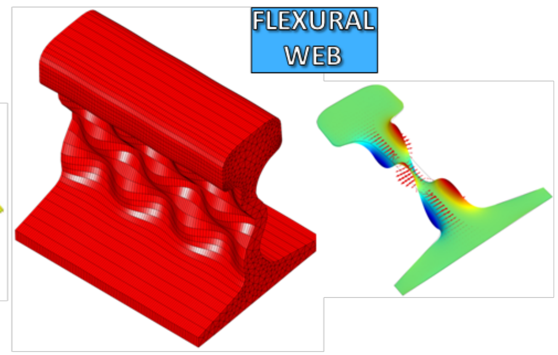
- Current UCSD wayside prototype requires multiple measurements at different rail temperatures to determine Neutral Temperature (NT).
- Measurement of rail NT in real time and in-motion will require additional development.

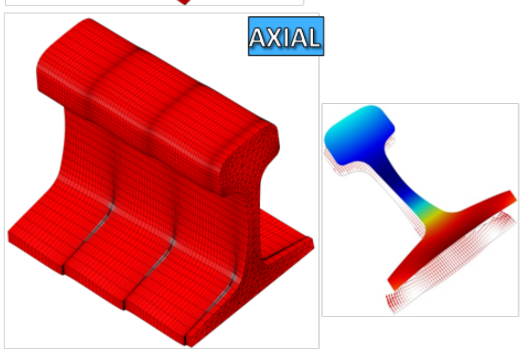
Modeling of Ultrasonic Guided Waves in Rails

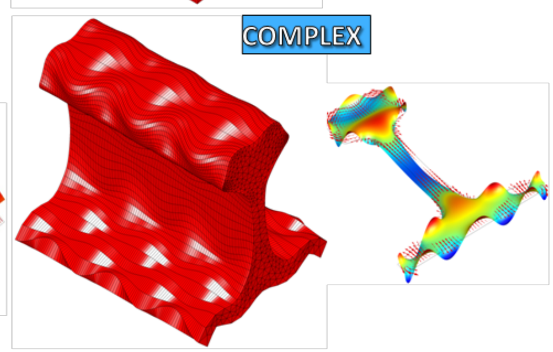


Movie Rail1



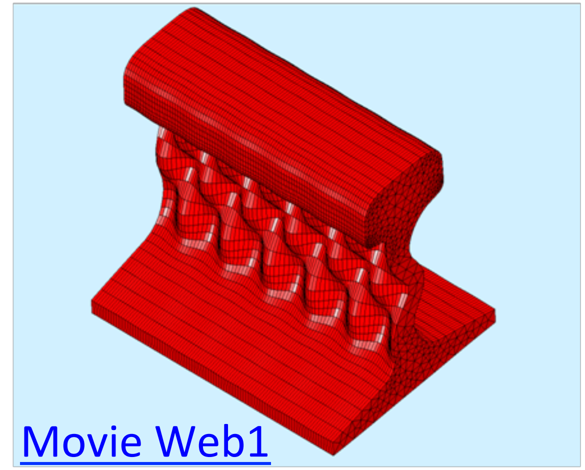




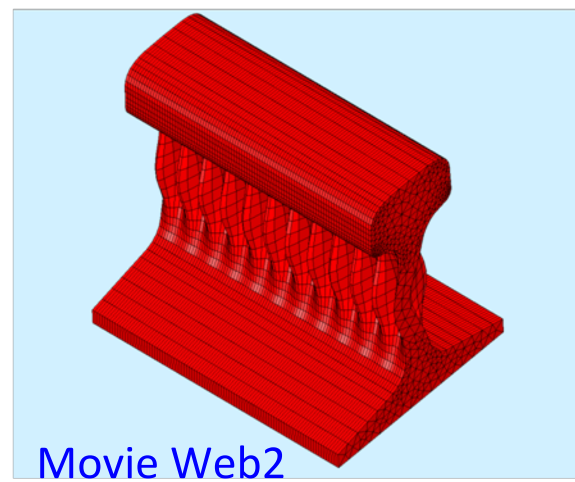


These simulations have helped identifying the correct guided wave mode and guided wave frequency for the rail NT measurement

Nonlinearity in "web modes"

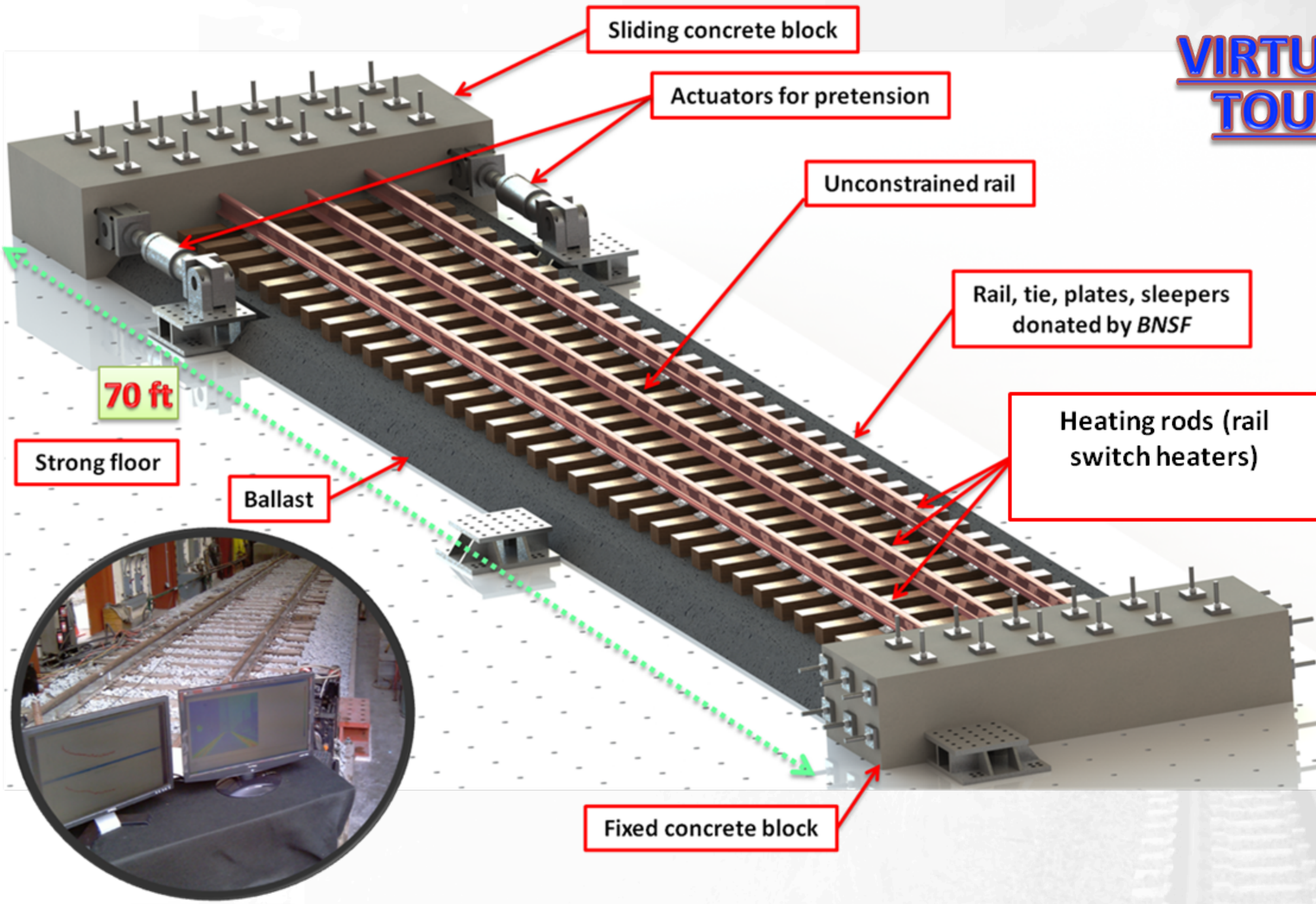


Movie Web1



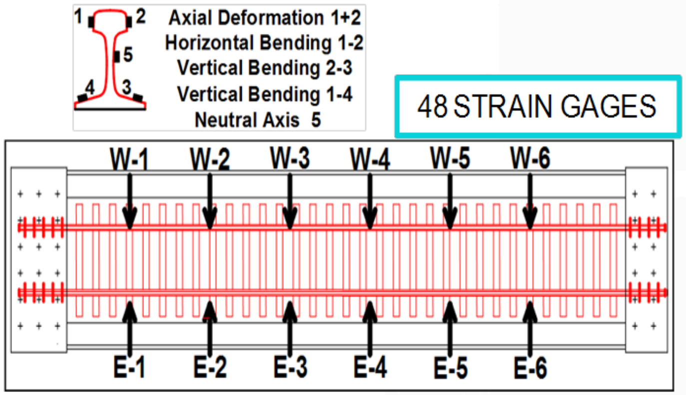
Movie Web2

The Large-scale Rail NT/Buckling Test-bed

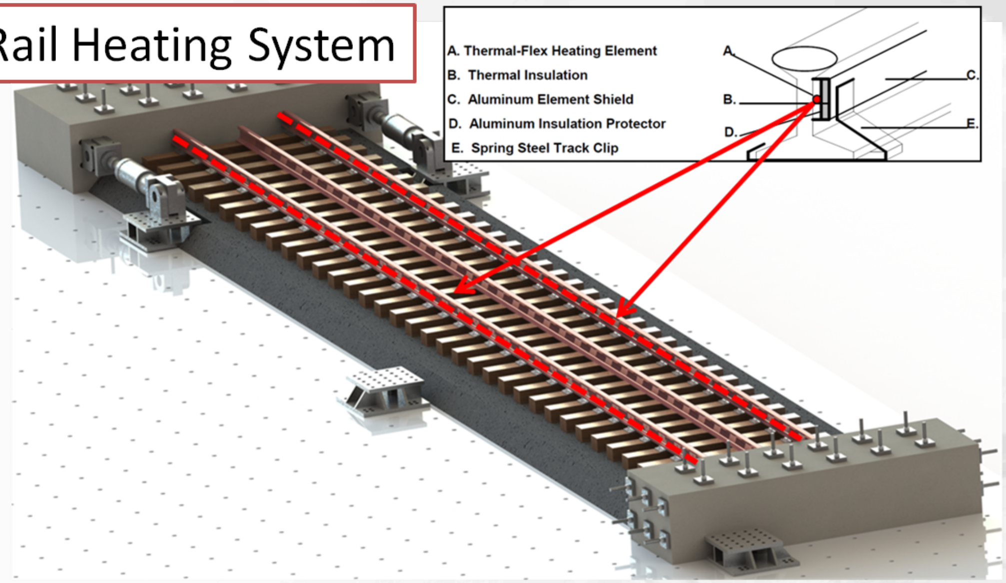


- BNSF donated materials and know-how for design and construction of test-bed
- Volpe participated with technical advice

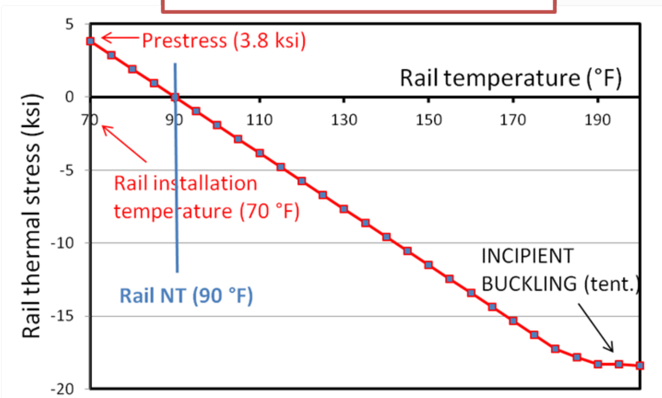
The Large-scale Rail NT/Buckling Test-bed



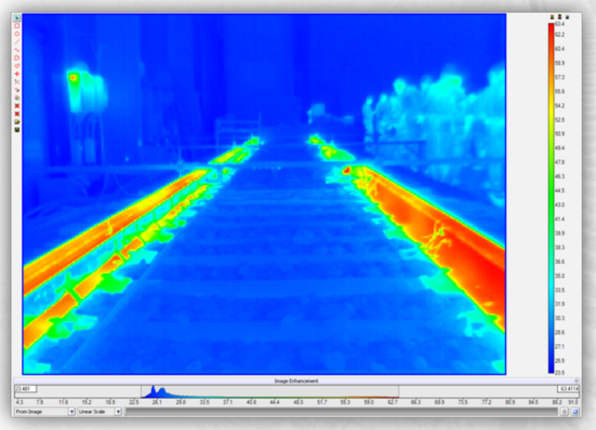
Rail Heating System



Thermal Test Protocol



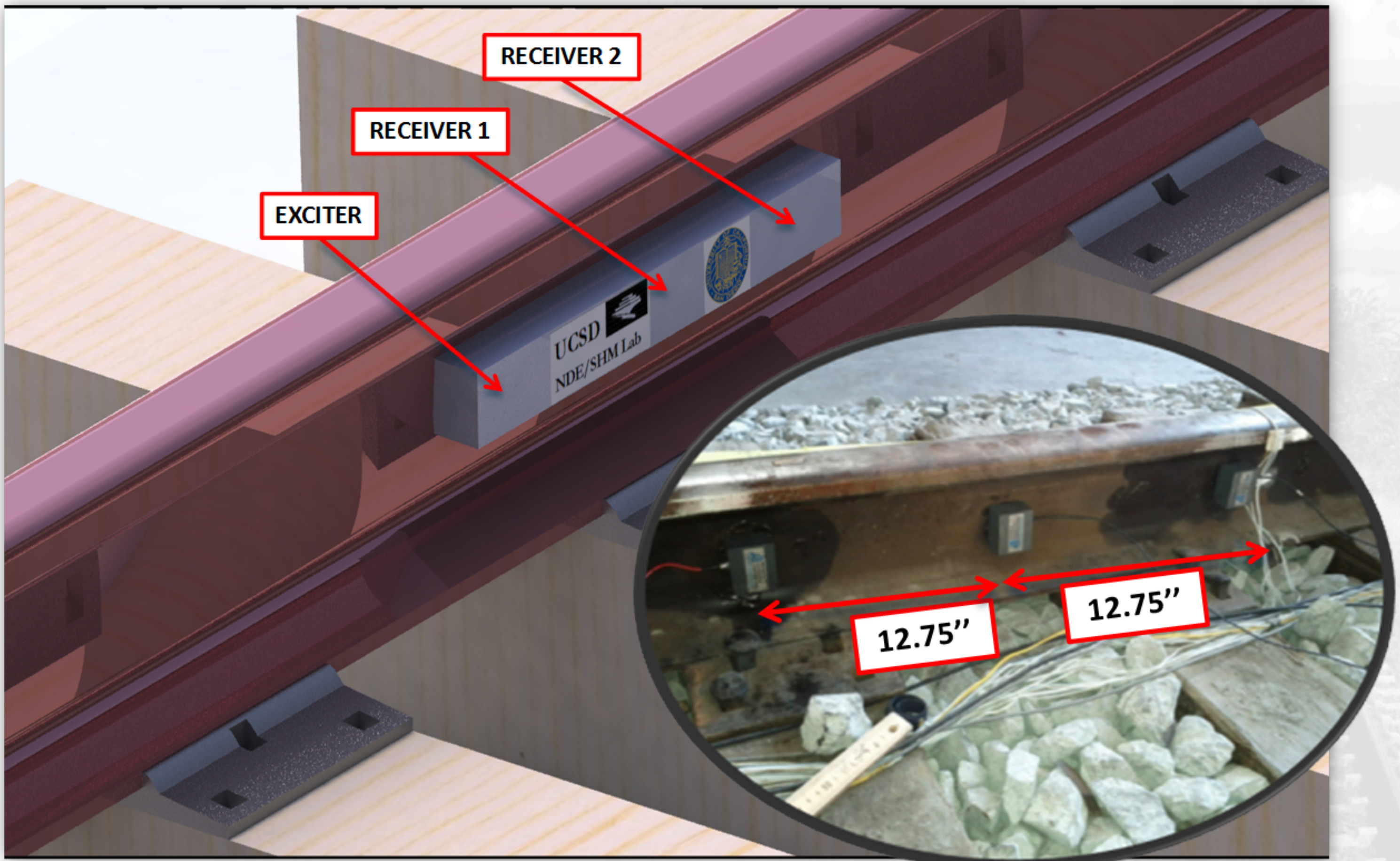
$$\sigma = -\alpha E (T - T_N)$$



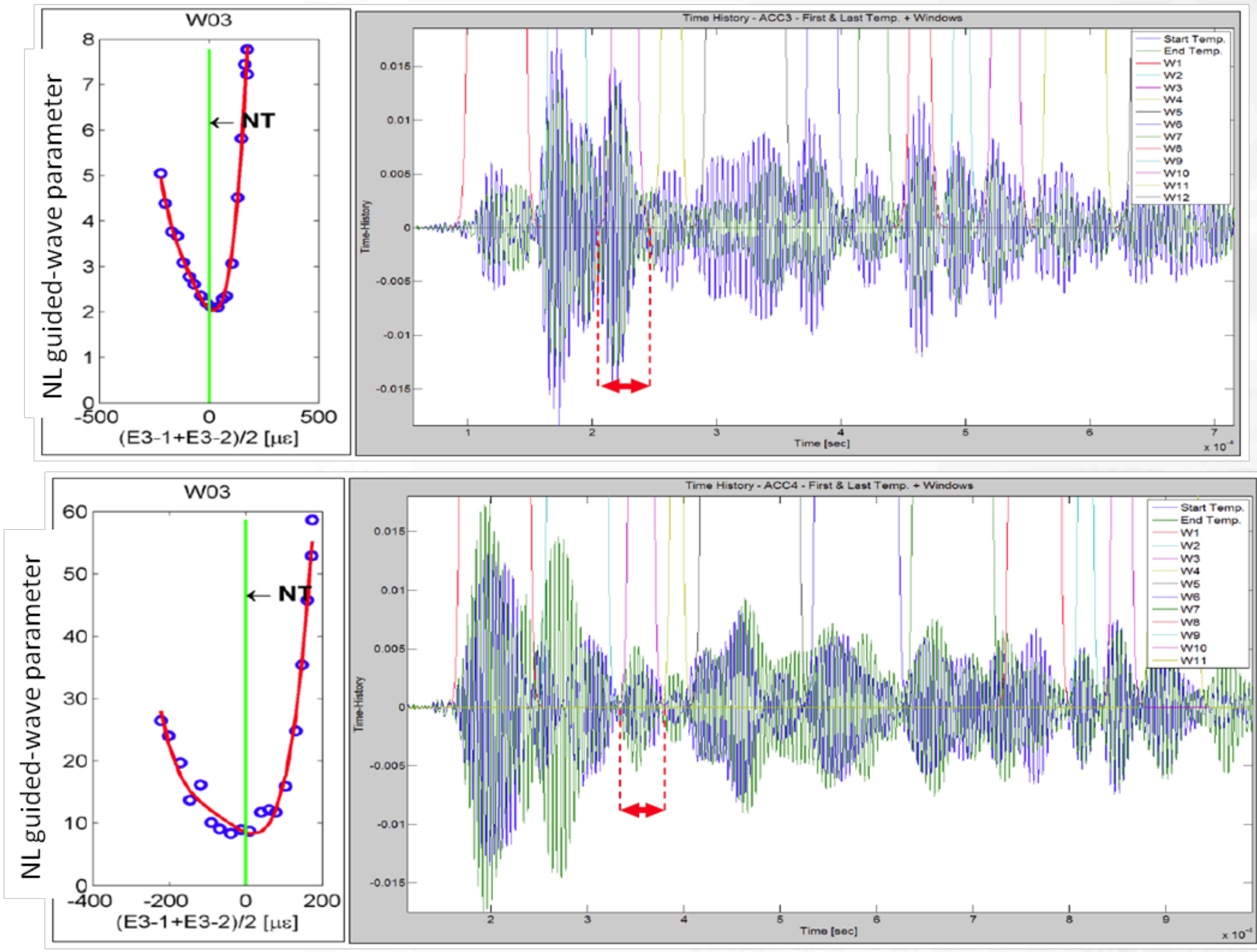
Thermal Camera

UCSD Results from Large-scale Test-bed

Transducer installation in the rail web (wayside measurement system)



UCSD Results from Large-scale Test-bed

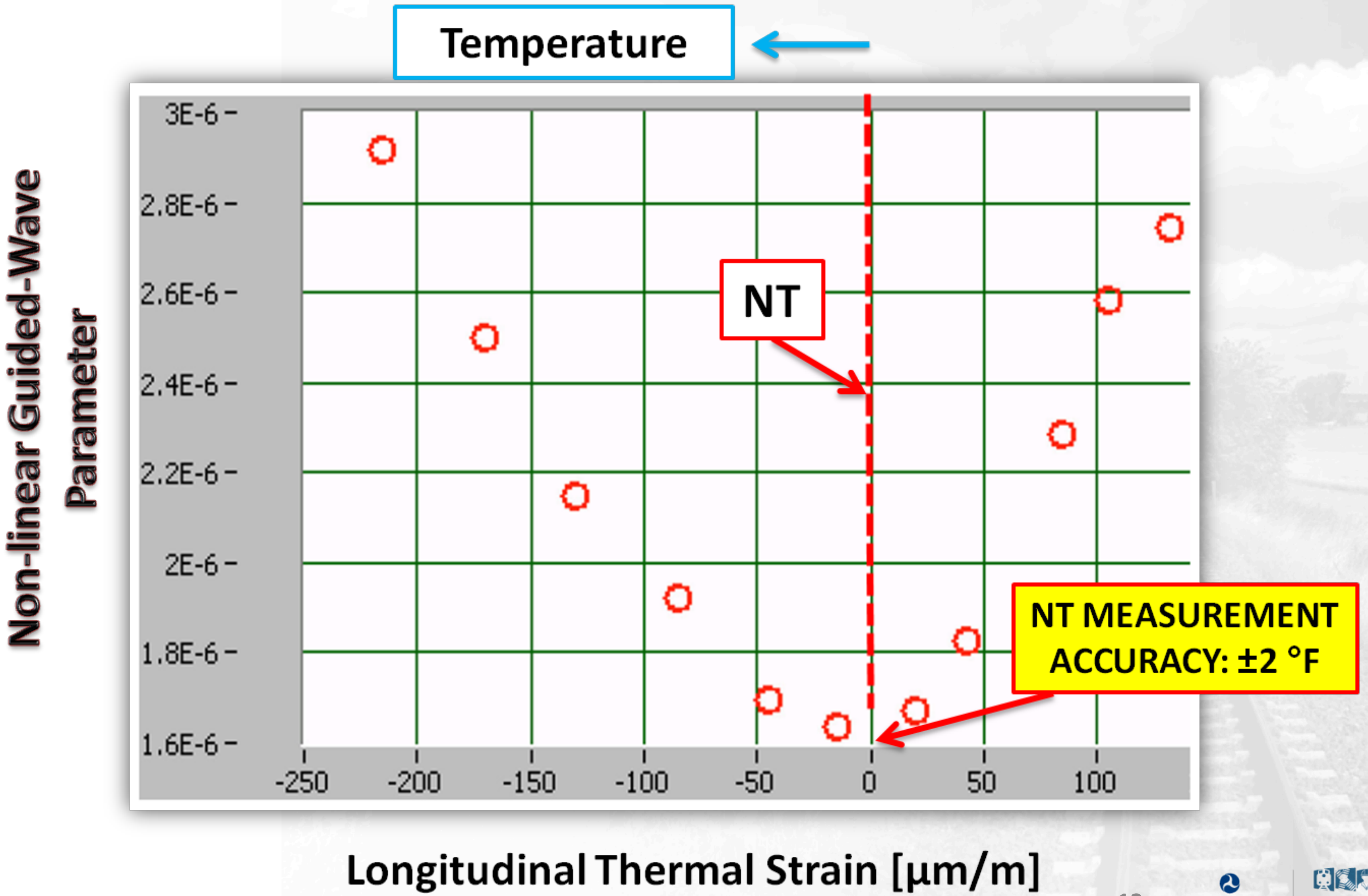


RECEIVER #1

RECEIVER #2

Same behavior consistently measured at different locations of the large-scale track test-bed

UCSD Results from Large-scale Test-bed



Summary of Results-to-Date

- The University of California, San Diego (UCSD) is developing a new technique for Rail Neutral Temperature (NT) measurement based on Nonlinear Ultrasonic Guided Waves.
- Unique Large-Scale Rail NT/Buckling Test-bed designed and constructed for development of rail NT measurement technology under highly controlled laboratory conditions.
- Simulations have identified appropriate guided mode & frequency for accurate NT measurement without tie-to-tie variation effects.
- Tests on the Large-Scale Test-bed indicate NT measurement accuracy of ±2 °F.
- Currently testing a prototype and planning demonstrations to FRA and railroads (BNSF, UP,...) before Summer 2012.
- UCSD filed a Provisional Patent Application on this technology (USPTO #61/558353, filed 11/10/2011) for planned commercialization in 2013.