What has *Vampire* ever done for me?

Is it right than an infrastructure manager is playing with vehicle dynamics?

Dr Mark Burstow

Principal Vehicle Track Dynamics Engineer

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Overview

- How and why did Network Rail get involved in vehicle dynamics simulation
- How do we use vehicle dynamics simulation?
- Challenges and success
- What for the future?

How did NR get involved?

Following the Hatfield derailment in October 2000

- Creation of WRISA cross-industry group for vehicle/track interaction
- Became V/T SIC in 2004:
  Vehicle/Track Interaction Systems Interface Committee
  - Sponsor of industry research
  - Supported by a ‘Permanent project Group’ housed within Railtrack (Network Rail)
    - “*It comprises engineers and systems specialists from across the industry with a common goal of minimising the costs to industry arising from the vehicle/track interface*”
  - Initial focus was a response to rolling contact fatigue (RCF)

Permanent Project Group became NR’s in-house specialists in vehicle/track interaction

- Vehicle dynamics research and simulation (*Vampire*)
- Only a small team

The RCF problem

In 2001 RCF was little understood

- An increasing problem since the 1970s
- Fracture mechanics models could predict crack growth, but not **where or when** it would initiate

AEA Technology Rail (*remember them?*) working on RSSB funded research

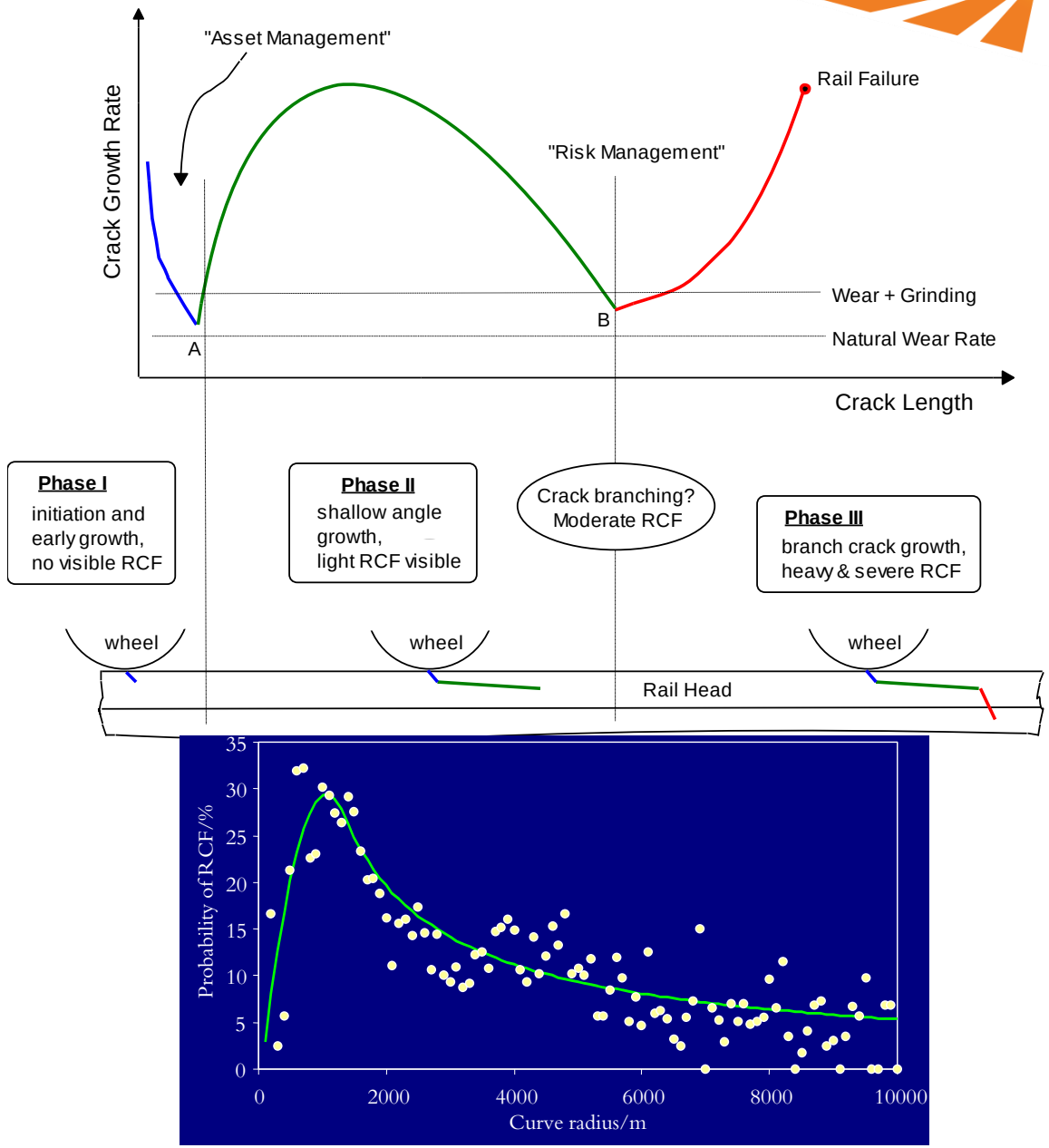
Crack initiation models were probabilistic

- No knowledge of influencing factors
- Could not predict the effects of changes in operating conditions on crack initiation

All modelling was dominated by the (vertical) contact stresses between wheel and rail

We were not able to explain 'clustering' of RCF, and why some routes were 'immune' from RCF

We lacked knowledge of the actual forces between wheel and rail



'Micro' modelling of RCF

Detailed site modelling of locations with RCF

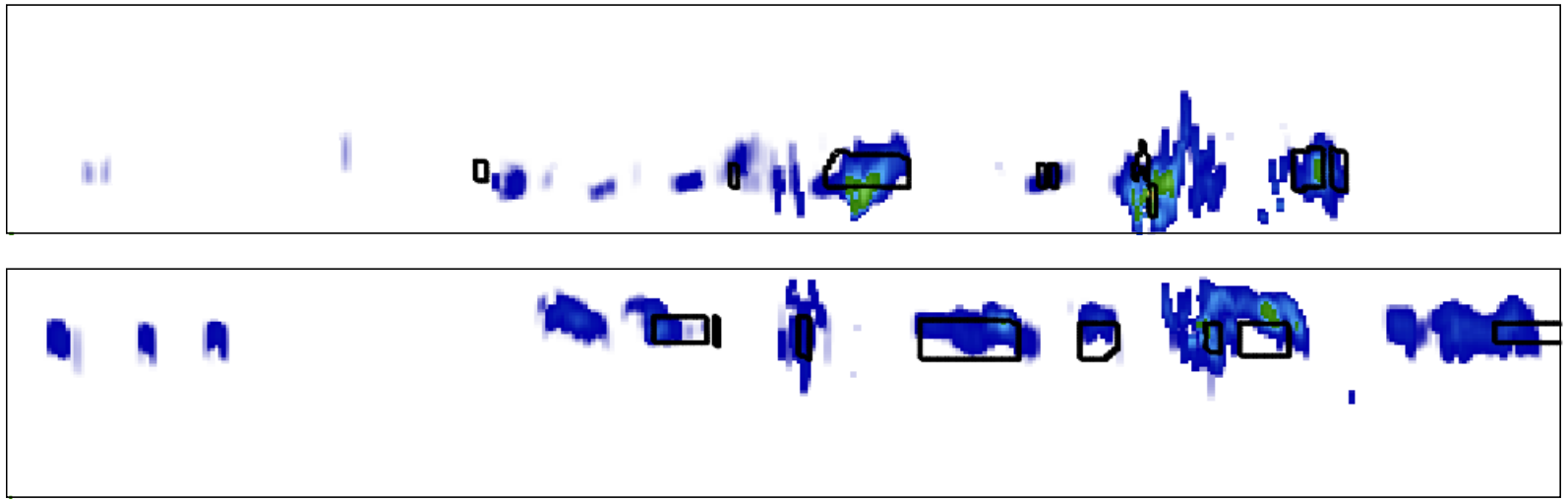
- Account for the vehicle characteristics, speed, rail and wheel shapes, track geometry and alignment
- Used *Vampire* simulations to predict the wheel/rail forces that we could not measure

Used the specialists within the 'Dynamics' section of AEATR to undertake simulations

We developed techniques to test various fatigue models against the observed damage

- Clearly showed that wheelset steering forces, not vertical forces, dominated the initiation of RCF

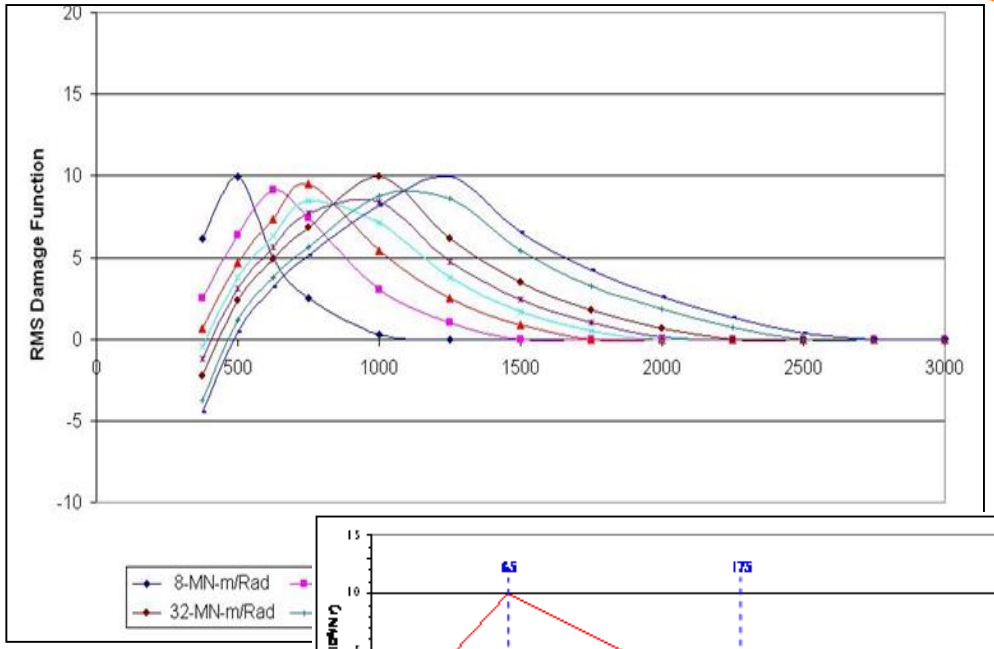
This was a giant step change in our understanding of RCF

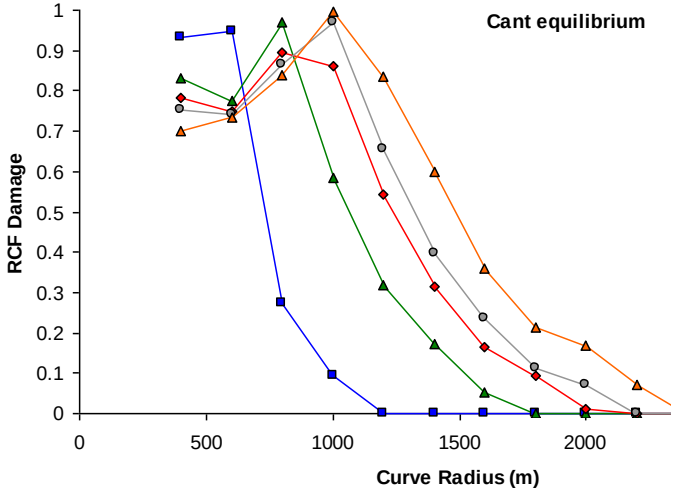


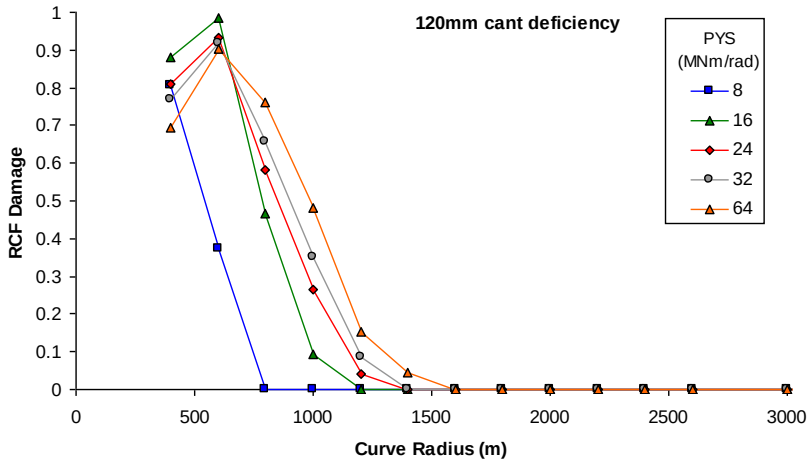
Towards a better understanding

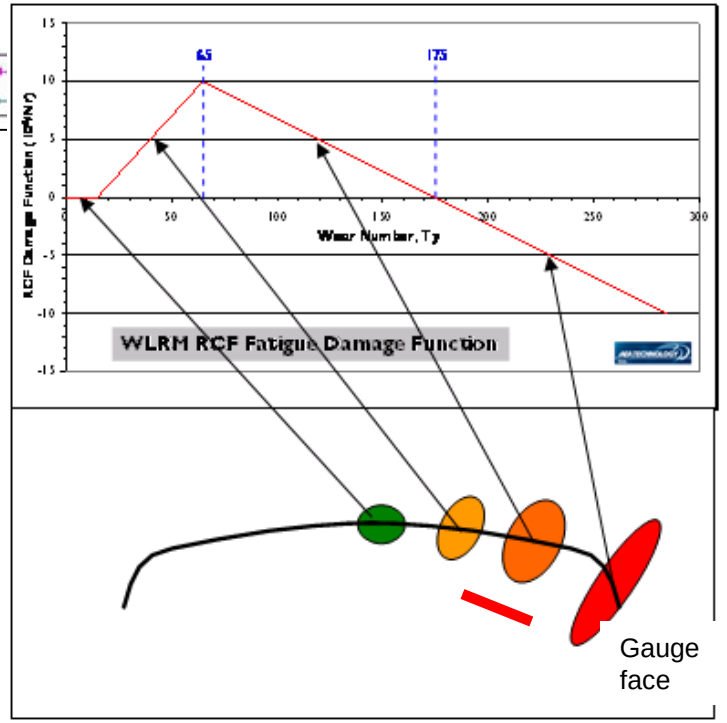
Use vehicle dynamics modelling to understand contributory factors

- Primary yaw stiffness
- Wheel/rail profile
- Curve radius
- Cant deficiency





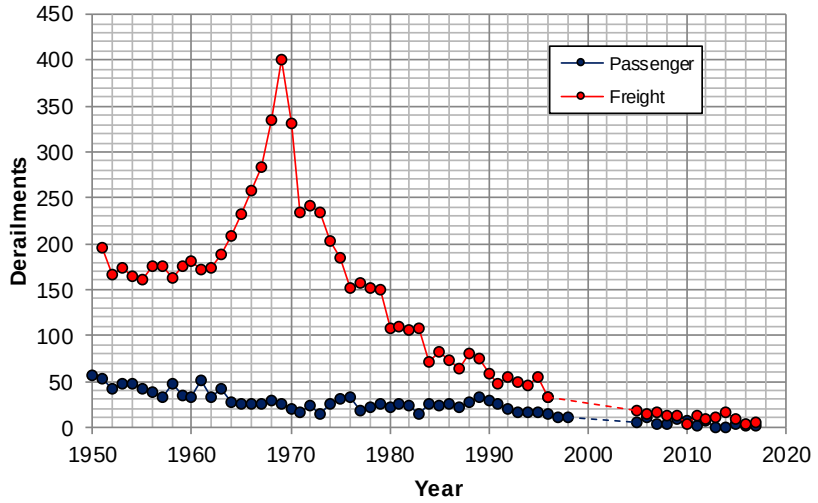




So, what do we learn from history?

Solving one problem invariably creates a new, unexpected, problem

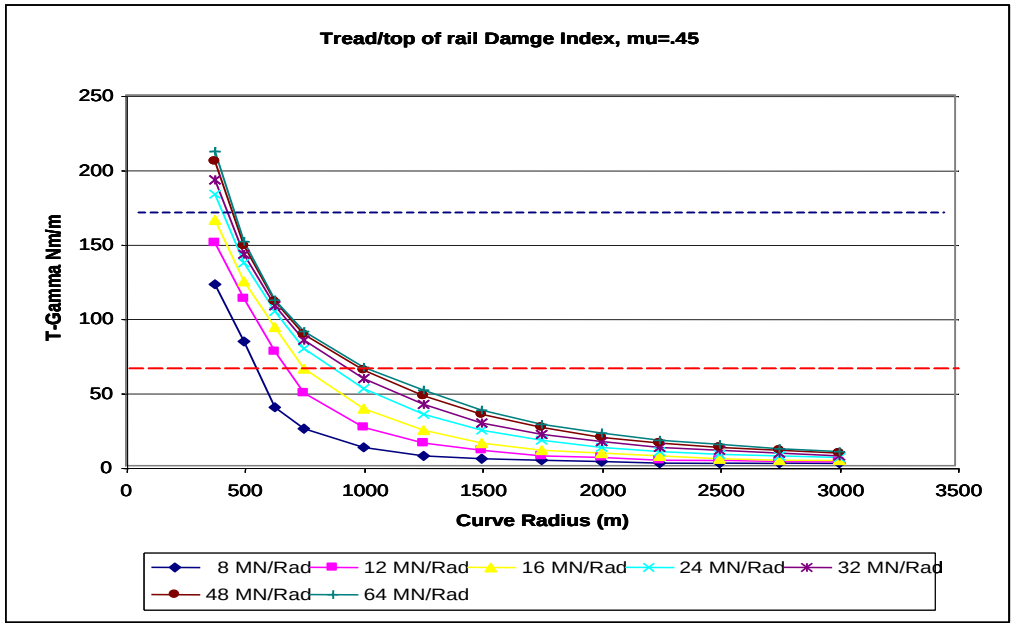
- Research into vehicle dynamics had help solve the problem of freight train derailments in the 1960s
- Allowed the development of improved vehicle suspensions
  - Improved ride
  - Reduced bogie maintenance requirements
  - Better wheel wear
  - Stiffer yaw suspensions
- But had not considered the impact of the increased wheel/rail steering forces
  - Above the fatigue threshold of the rail
  - Explains the increase in RCF since the early 1970s
  - …which the **rail metallurgist** was expected to solve!

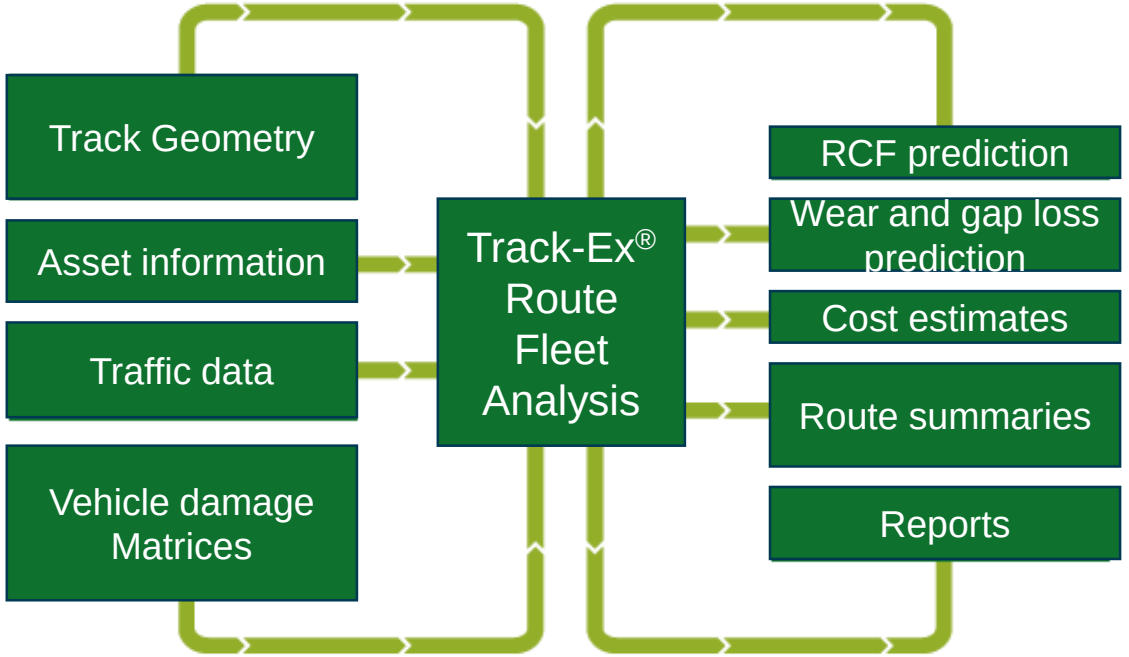


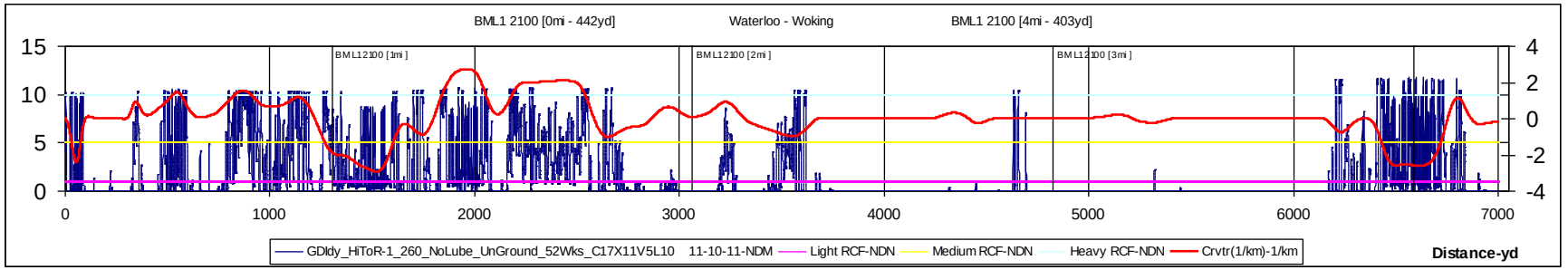
How we continue to use Vampire*: NR's* Track-Ex *tool*

Creation of software tools to help track engineers manage RCF and wear

- Based on look-up tables created from *Vampire*



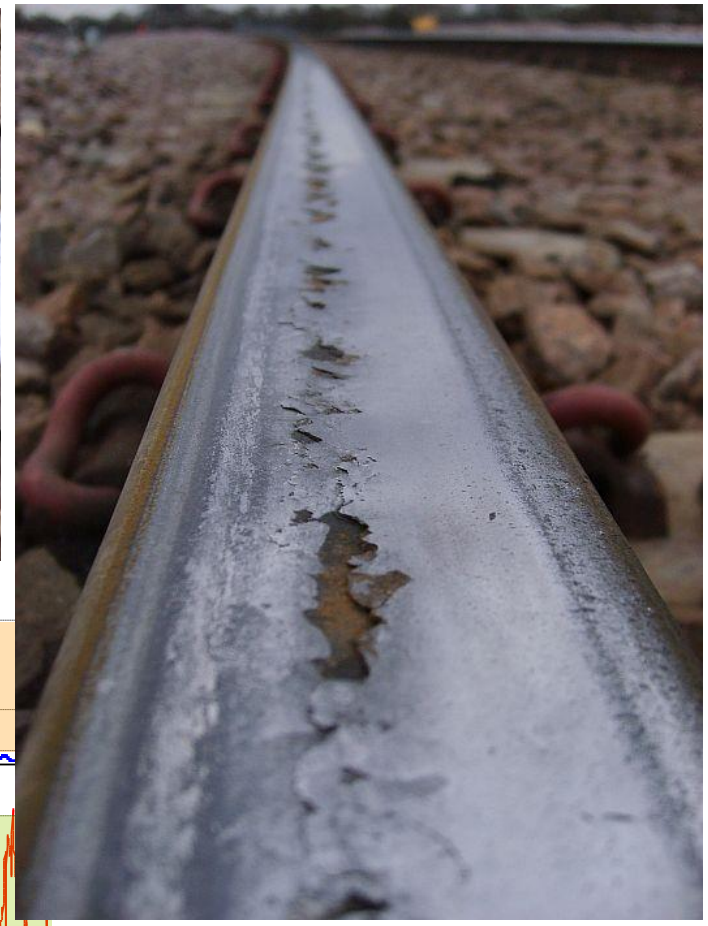


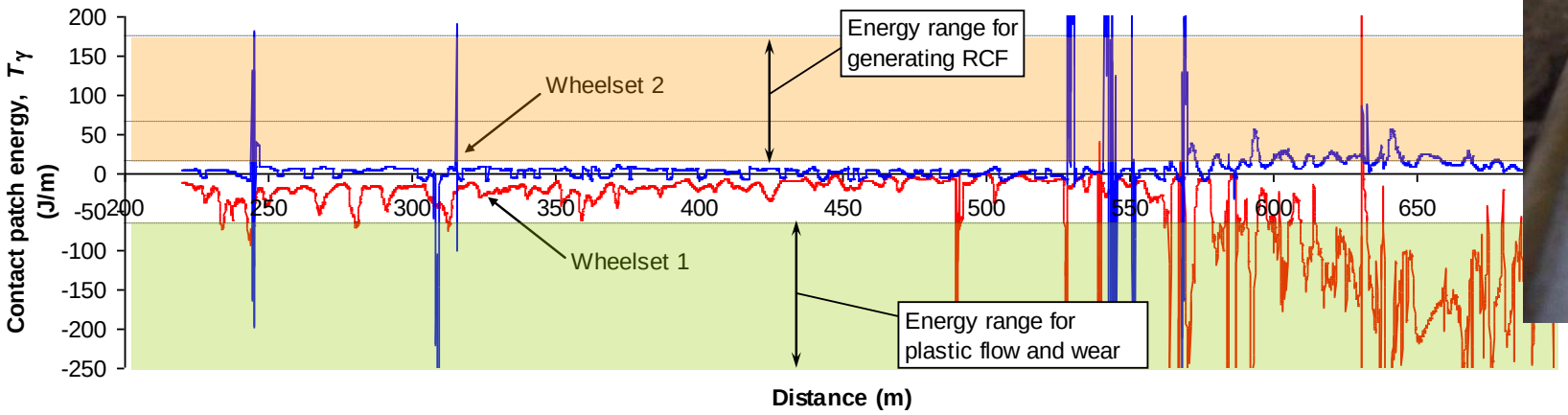


How we use Vampire *simulations – VTI research*

Other forms of track damage:

Demonstrate that surface damage on low rail of some curves is from the same steering forces as high rail RCF

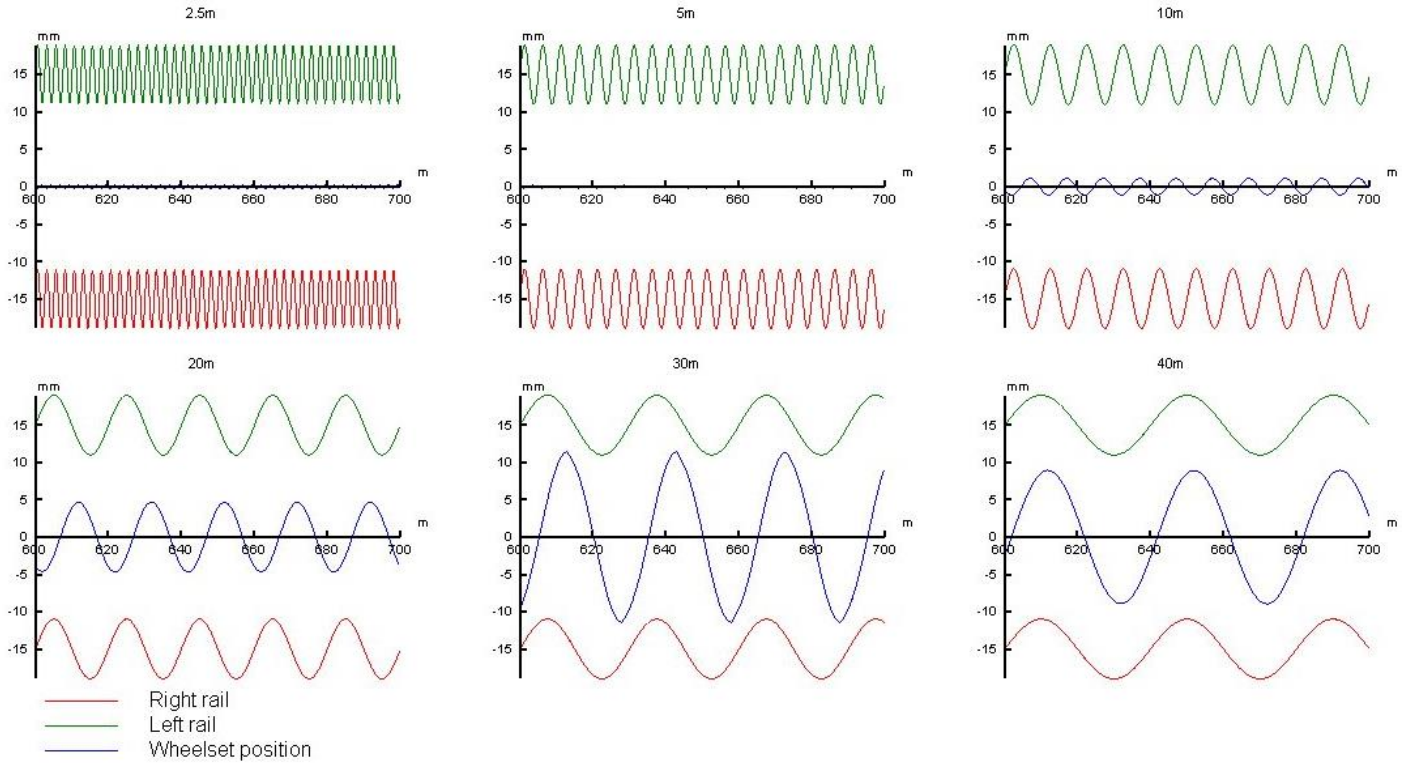


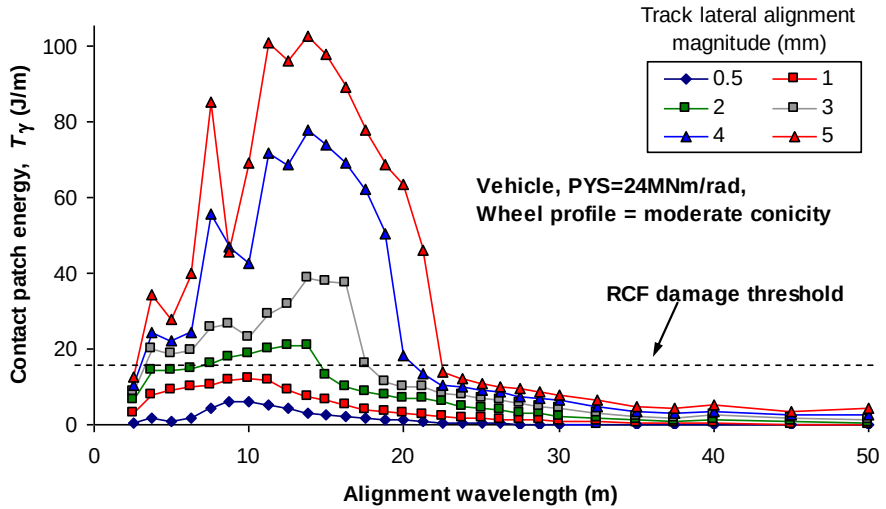


How we use Vampire *simulations – VTI research*

Factors influencing RCF

- Track alignment quality and wavelength
- Track quality is measured from amplitude, but a vehicle responds to frequency of excitation
  - Current track management does not control RCF initiation

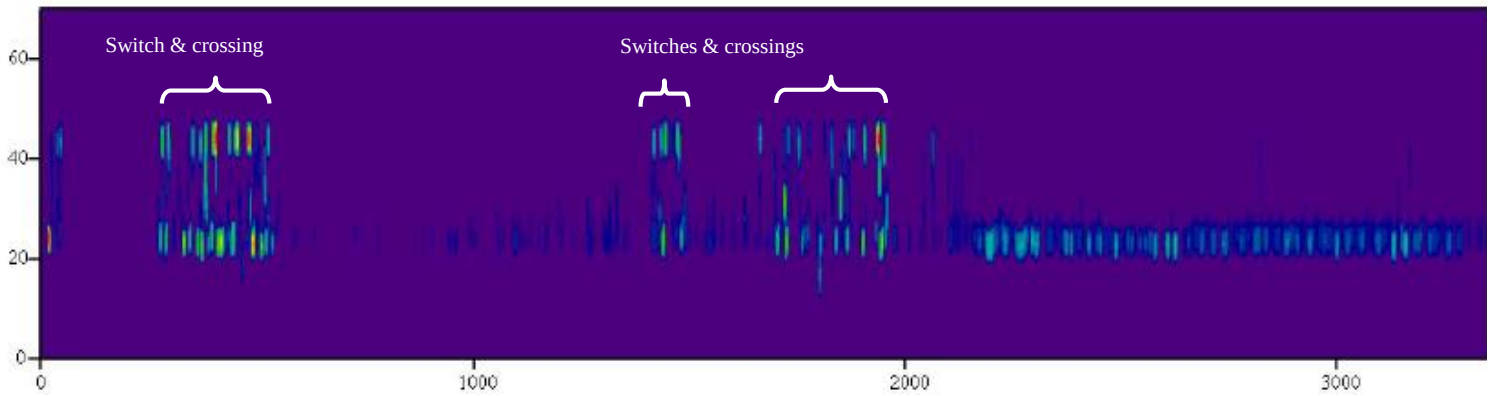


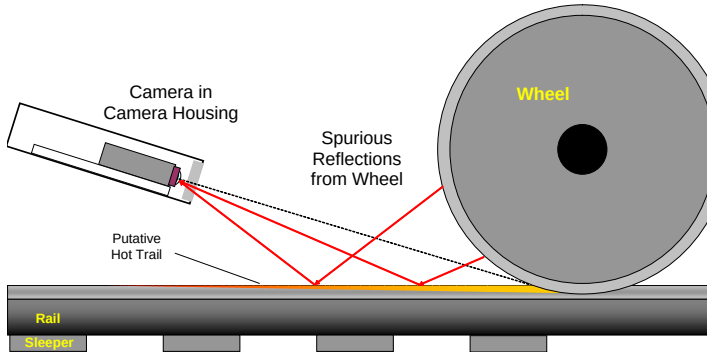


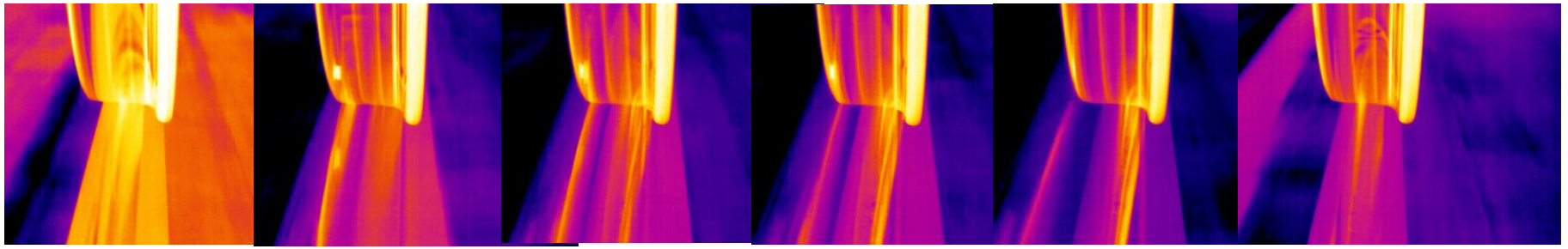
How we use Vampire *simulations – VTI research*

Experimental use of thermal imaging to detect wheel/rail contact position

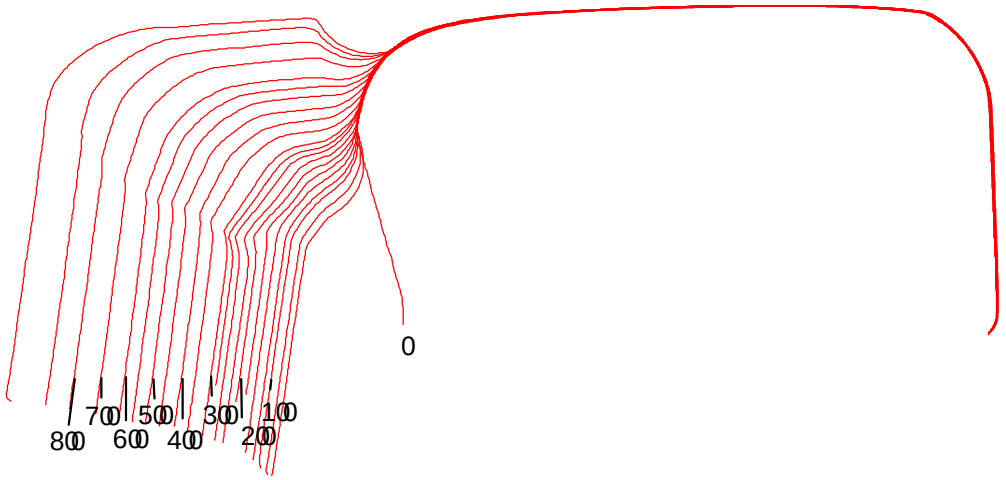
Simulations (*Vampire* and FE) to validate experimental observations of thermal traces from wheel/rail contact

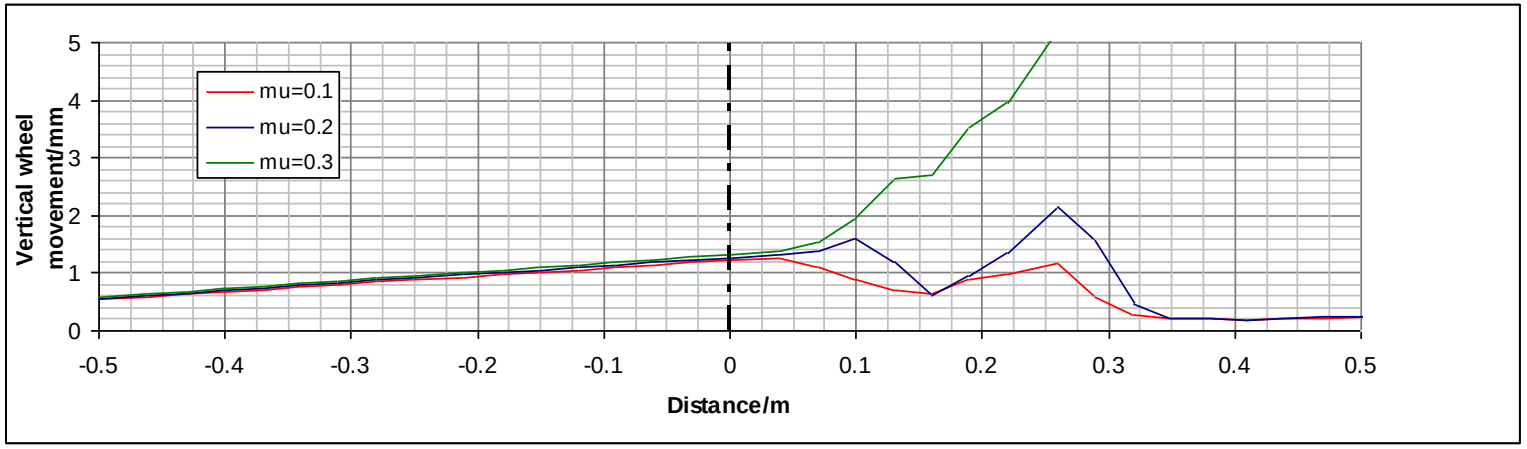






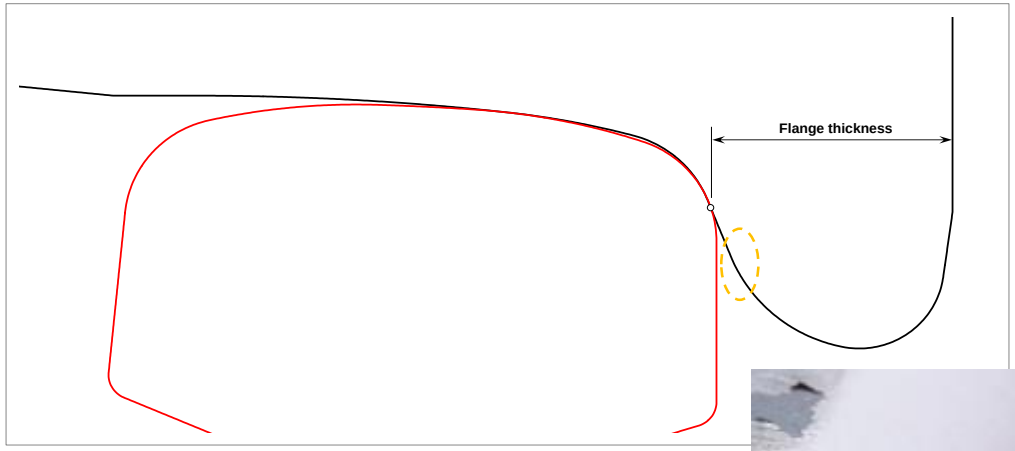
How we use Vampire *simulations – Derailment investigation*

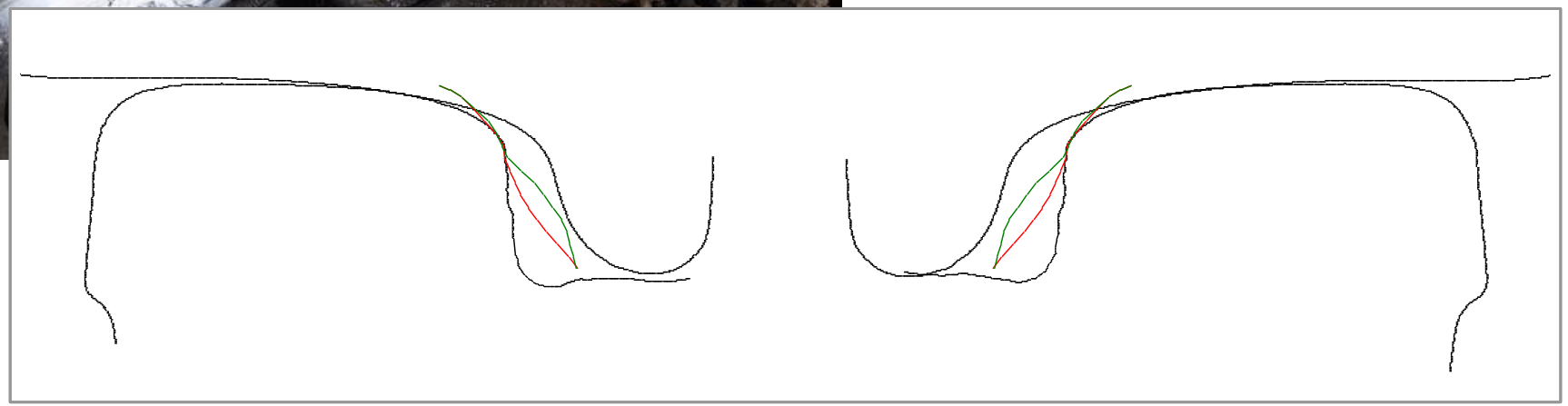




How we use Vampire *simulations – Trying to bring some science to track engineering*

Problems with track-based lubrication

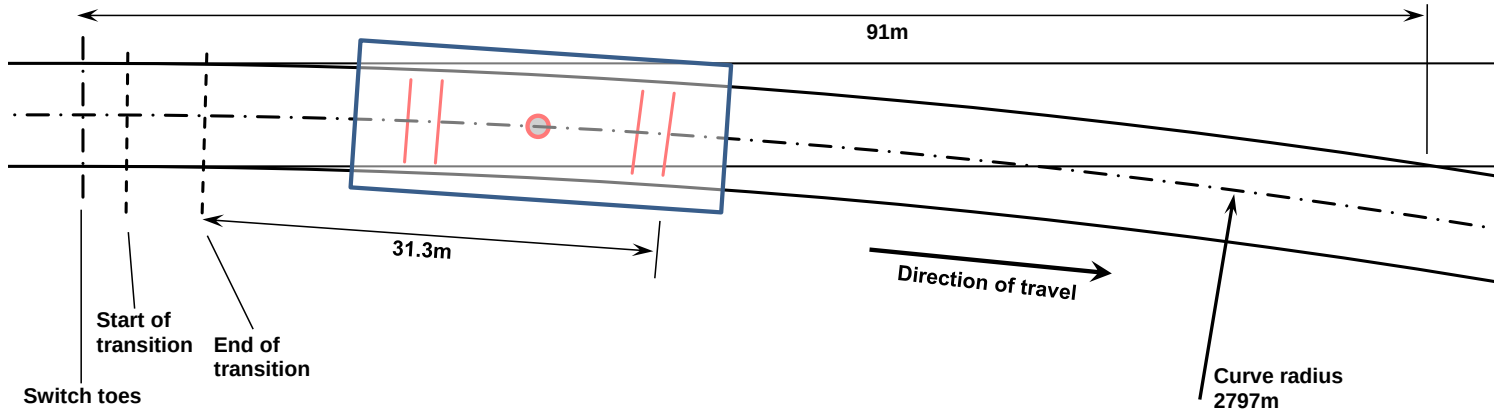


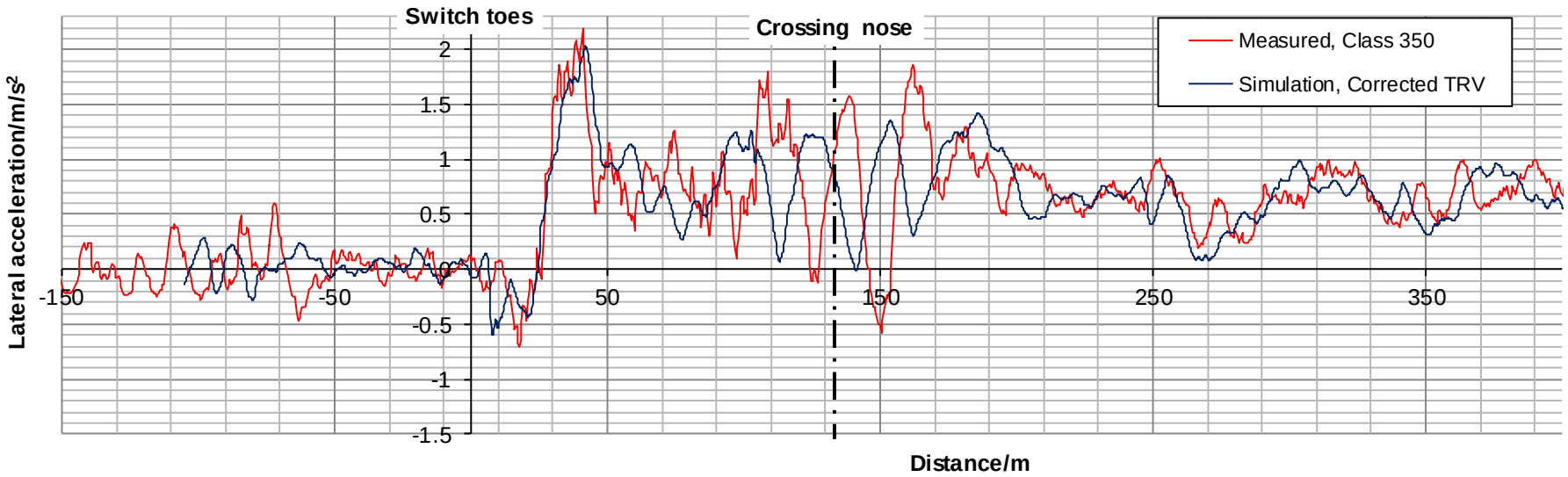


How we use Vampire *simulations – Trying to bring some science to track engineering*

Switch turnout design

- Has been largely empirical!
- No modelling to optimise wheel/rail interaction
  - Ride or wear/tear

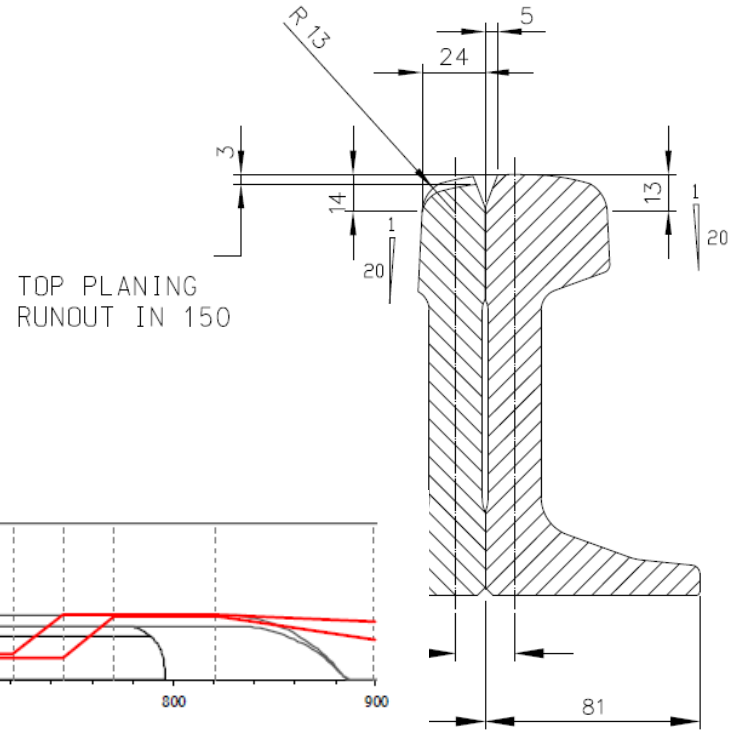


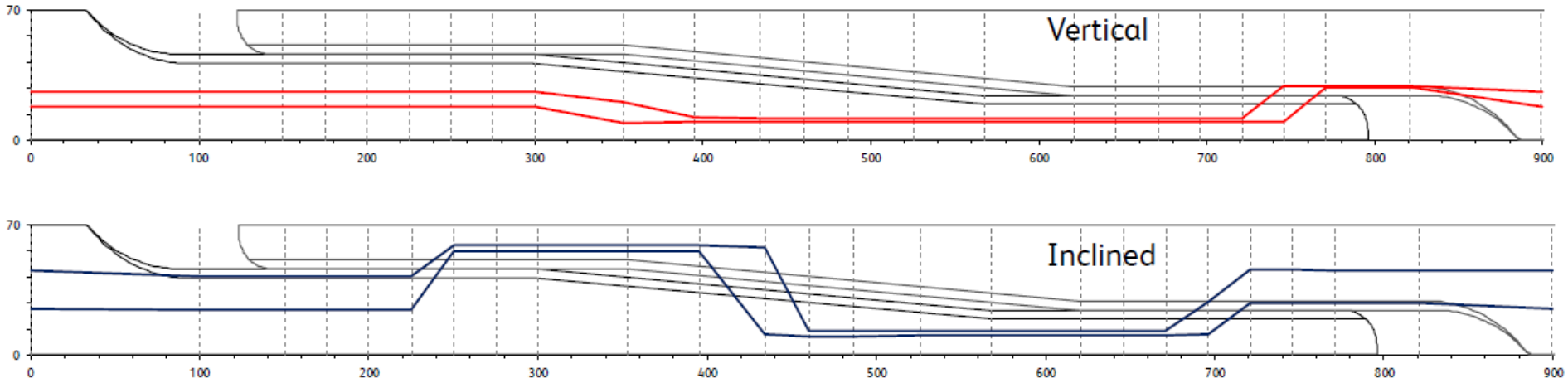


How we use Vampire *simulations – Trying to bring some science to track engineering*

Improving adjustment switch design

- Historically designed for ease of manufacture
- No consideration of wheel/rail interaction or contact paths





Challenges

Small team

- Not everyone wants to be a specialist

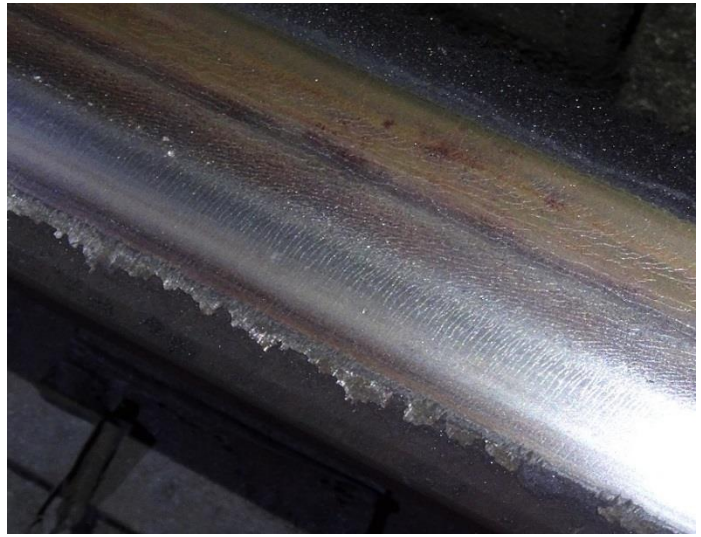
Infrastructure management

- A train is a train is a train…..
- Management by EMGTPA
  - The tonnage mindset
- Wheel/rail interaction behaviour not intuitive
- Wheel/rail forces hard to visualise, easily ignored
- New train introduction

Getting involved in projects BEFORE the vehicle/track problems start

External

- V/T SIC and cross-system co-operation
- Use of appropriate vehicle models and wheel profiles



Successes

Understanding of (some of) the causes of RCF

- Optimisation of PYS

Incentivisation to reduce track damage

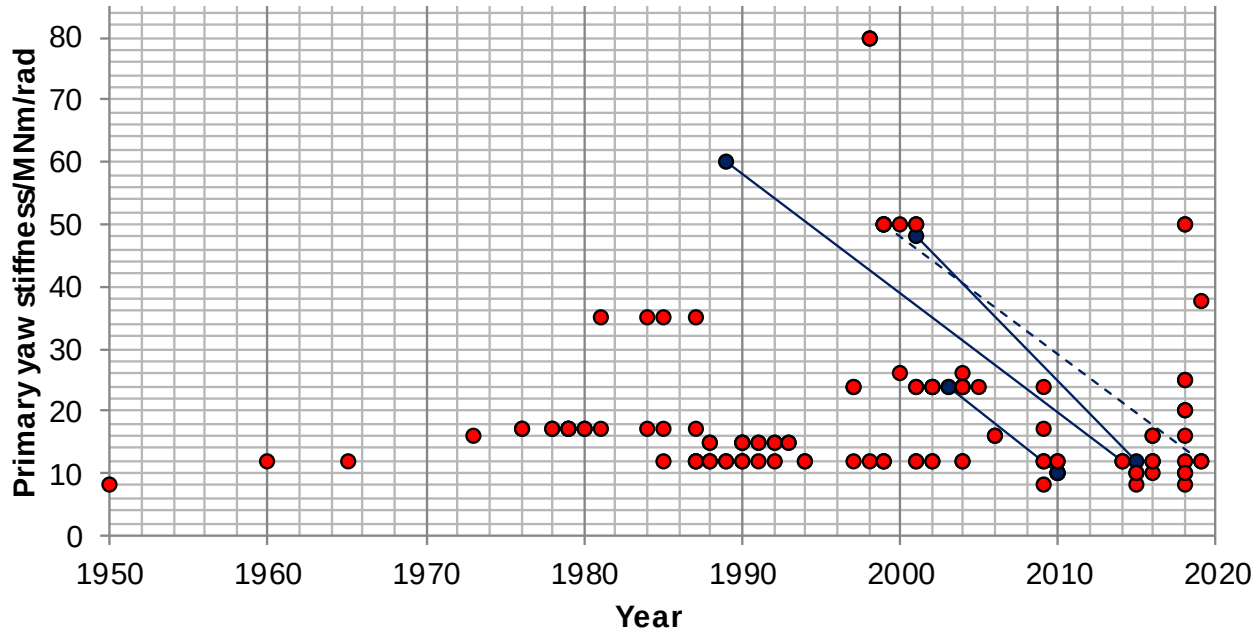
- Variable Usage Charge (VTAC)

Wheel/rail interaction accepted as part of vehicle procurement

- RDG Key Train Requirements document

Changes to track standards

- Changes to cant/cant deficiency rules (NR/L2/TRK/2049): cant deficiency is our friend!



Cant Deficiency & Rolling Contact Fatigue

Research into rolling contact fatigue (RCF) has shown that the rate of growth of RCF can be reduced significantly by increasing the cant deficiency on a curve. The effect will be greatest in curves in the 1000 m to 2500 m range where vehicles with primary yaw stiffnesses in excess of 16 MNm/radian operate. In tighter curves the reduction in RCF is less significant but sidewear can be reduced with increased cant deficiency.

Where rail life due to RCF has been found to be less than 5 years, and where whole life costs make it economic to do so, then cant deficiencies in excess of cant may be applied subject to site specific approval by the Head of Track Engineering at Network Rail HQ.

The future?

Improve track geometry maintenance: tuned to the vehicle's response to track shape

Better modelling of wheel/rail forces

- The contact patch
- Improved understanding of rail surface damage mechanisms, not just RCF

Better understanding of friction and friction modelling

- Contribution of friction to wheel/rail RCF
- Multiple-point contact
- Friction modifiers and lubricant (3rd bodies)

Can *Vampire* help us understand causes of noise?

Geometry deterioration and track stiffness

- Current models are largely empirical

New rail materials

- Need a systems approach:
  - Metallurgy, fracture mechanics and vehicle dynamics