

# Modeling S & C

and the UoH-CTH Benchmark

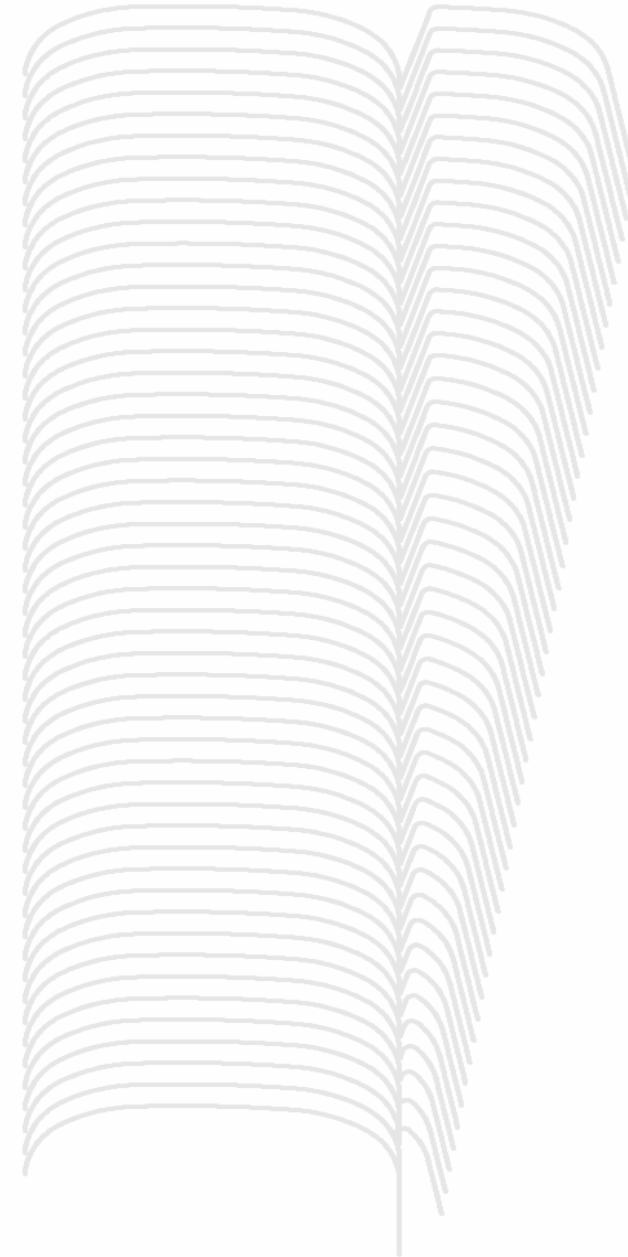
**2020 Vampire User Day**



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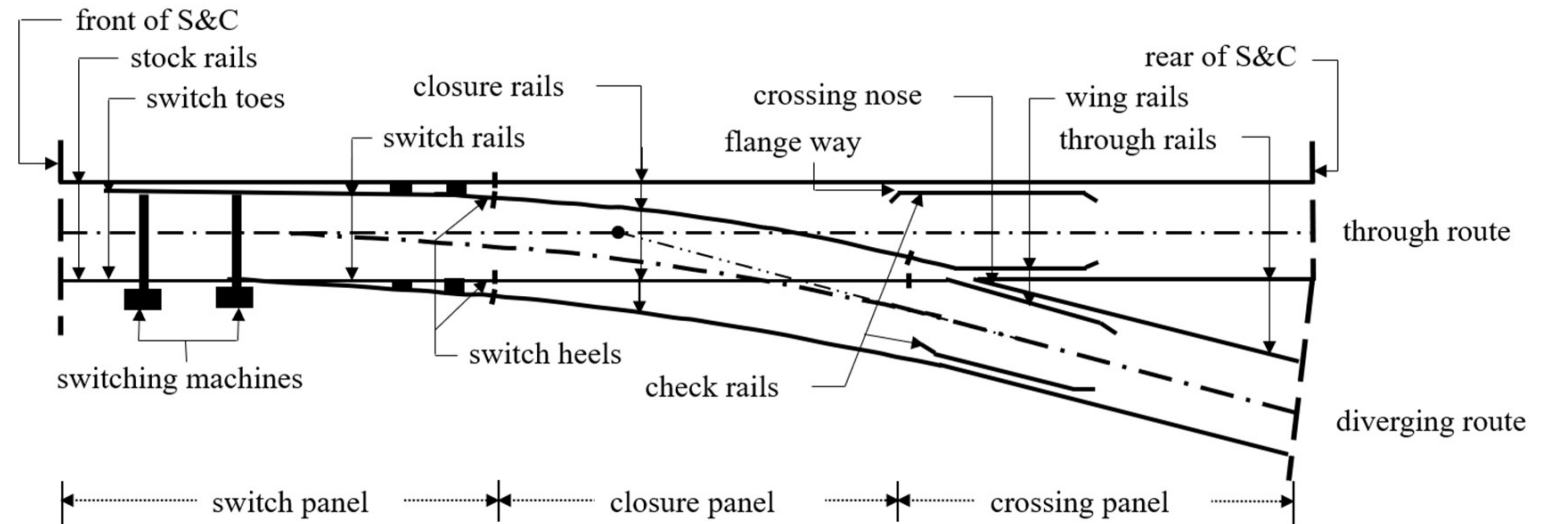
# Introduction

- Fundamentals
- Vampire Steps
  - Turnout Geometry
  - Contact Geometry
- Example Results
- Wish List



# Fundamentals

- Turnout geometry
- Variation in rail cross-sections along switch point and through crossing
- Potential relative movement of rail sections
  - Switch point versus stock rail and guard rail versus running rail
- Track stiffness variations (lateral and vertical) through switch and crossing



# Vampire Steps

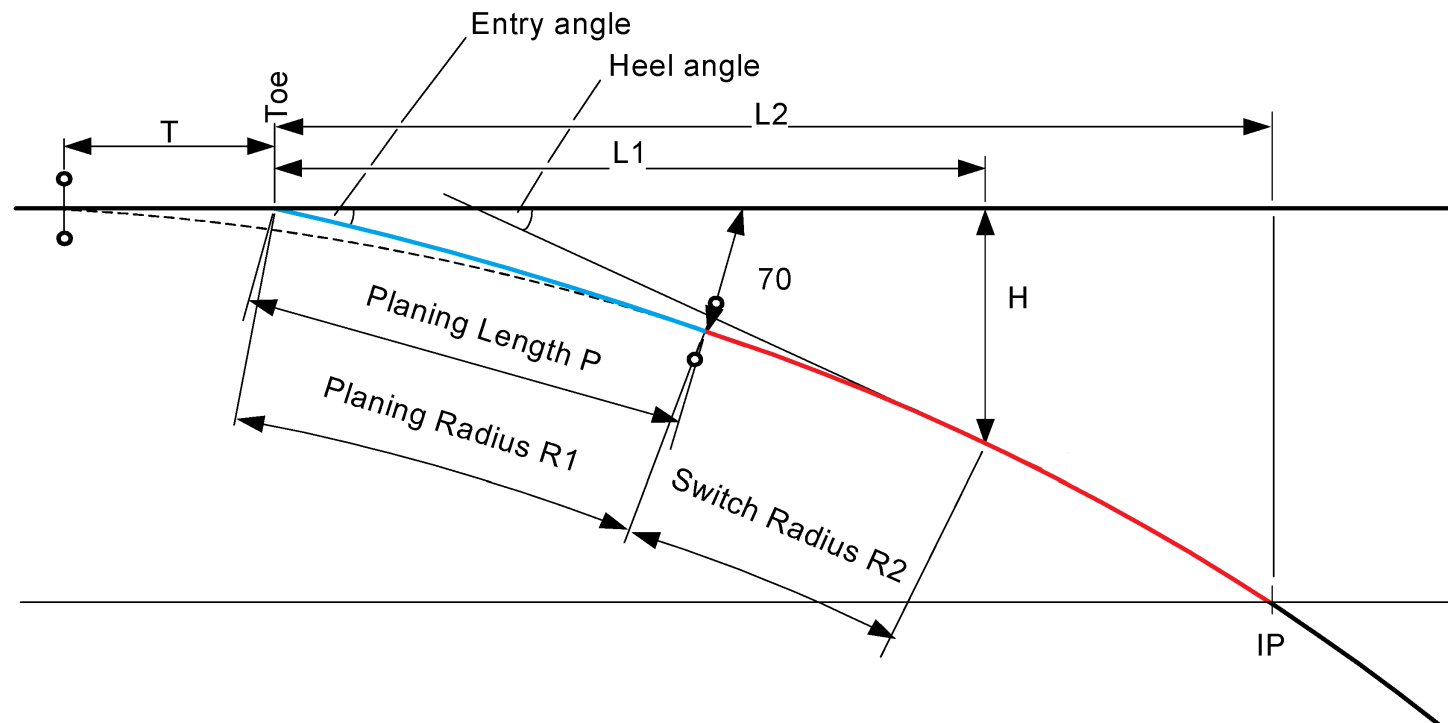
- Define turnout geometry using Track Design File
  - Represents centerline geometry of turnout
- Define switch and crossing sections as Rail Profile Files
  - Profiles as fixed left and right cross-sections
- Generate Contact Data Files
  - Geometric interaction between wheel set and rail profile sections
- Assemble Track Contact File
  - Longitudinal sequence of Contact Data Files represent contact data variation as function of position through turnout

# Geometry for Type CV 9.25 Design

## Network Rail Track Design

### Handbook NR/L2/TRK/2049

Entry angle	1 in 110.266503
Frog number	1 in 9.25
Planing length	4250 mm
Planing radius	287 251.45 mm
Switch radius	245 767 mm



- Interpretation of design geometry will likely involve some (or even significant) calculation

# Sample Design Geometry File

DESIGN

UNITS VAMPIRE

```
Left-hand 56E1-R245-1:9.25 turnout - GBR Network Rail CV 9.25 - delta = 0.001
  0.00000  0.000000  0.000000  0.000000  0.000000  0.000000  0.00000  0.00000
 49.99900  0.000000  0.000000  0.000000  0.000000  0.000000  0.00000  0.00000
** theoretical switch start
 50.00000 -1.744985  0.000000  0.000000 -9.068875  0.000000  0.00000  0.00000
 50.00100 -3.489970  0.000000  0.000000  0.000000  0.000000  0.00000  0.00000
 54.23841 -3.489970  0.000000  0.000000  0.000000  0.000000  0.00000  0.00000
 54.24041 -4.080783  0.000000  0.000000  0.000000  0.000000  0.00000  0.00000
 71.96080 -4.080783  0.000000  0.000000  0.000000  0.000000  66.50000  0.00000
 72.75080 -4.080783  0.000000  0.000000  0.000000  0.000000  45.48936  0.00000
 72.85080 -4.080783  0.000000  0.000000  0.000000  0.000000  44.06526  0.00000
 74.16080 -4.080783  0.000000  0.000000  0.000000  0.000000  41.59431  0.00000
 74.26080 -4.080783  0.000000  0.000000  0.000000  0.000000  41.50000  0.00000
 74.85680 -4.080783  0.000000  0.000000  0.000000  0.000000  41.50000  0.00000
** theoretical crossing point
**74.85780 -2.040392  0.000000  0.000000  0.000000  0.000000  41.50000  0.00000
 74.85880  0.000000  0.000000  0.000000  0.000000  0.000000  41.50000  0.00000
 75.35080  0.000000  0.000000  0.000000  0.000000  0.000000  41.50000  0.00000
 75.45080  0.000000  0.000000  0.000000  0.000000  0.000000  41.59431  0.00000
 76.76080  0.000000  0.000000  0.000000  0.000000  0.000000  44.06526  0.00000
 76.86080  0.000000  0.000000  0.000000  0.000000  0.000000  45.48936  0.00000
 77.65080  0.000000  0.000000  0.000000  0.000000  0.000000  66.50000  0.00000
999.00000  0.000000  0.000000  0.000000  0.000000  0.000000  0.00000  0.00000
```

# Sample Design Geometry File

DESIGN

UNITS VAMPIRE

Left-hand 56E1-R245-1:9.25 turnout - GBR Network Rail CV 9.25 - delta = 0.001

```
0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
49.99900 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
** theoretical switch start
50.00000 -1.744985 0.00000 0.00000 -9.068875 0.00000 0.00000
50.00100 -3.489970 0.00000 0.00000 0.00000 0.00000 0.00000
54.23841 -3.489970 0.00000 0.00000 0.00000 0.00000 0.00000
54.24041 -4.080783 0.00000 0.00000 0.00000 0.00000 0.00000
71.96080 -4.080783 0.00000 0.00000 0.00000 0.00000 66.50000
72.75080 -4.080783 0.00000 0.00000 0.00000 0.00000 45.48936
72.85080 -4.080783 0.00000 0.00000 0.00000 0.00000 44.06526
74.16080 -4.080783 0.00000 0.00000 0.00000 0.00000 41.59431
74.26080 -4.080783 0.00000 0.00000 0.00000 0.00000 41.50000
74.85680 -4.080783 0.00000 0.00000 0.00000 0.00000 41.50000
** theoretical crossing point
**74.85780 -2.040392 0.00000 0.00000 0.00000 0.00000 41.50000 0.00000
74.85880 0.00000 0.00000 0.00000 0.00000 0.00000 41.50000 0.00000
75.35080 0.00000 0.00000 0.00000 0.00000 0.00000 41.50000 0.00000
75.45080 0.00000 0.00000 0.00000 0.00000 0.00000 41.59431 0.00000
76.76080 0.00000 0.00000 0.00000 0.00000 0.00000 44.06526 0.00000
76.86080 0.00000 0.00000 0.00000 0.00000 0.00000 45.48936 0.00000
77.65080 0.00000 0.00000 0.00000 0.00000 0.00000 66.50000 0.00000
999.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
```

**Longitudinal  
position along  
the track  
(meters)**

# Sample Design Geometry File

DESIGN

UNITS VAMPIRE

Left-hand 56E1-P245-1:9.25 turnout - GBR Network Rail CV 9.25 - delta = 0.001

0.00000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
49.99900	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
** theoretical switch start							
50.00000	-1.744985	0.000000	0.000000	-9.068875	0.000000	0.000000	0.000000
50.00100	-3.489970	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
54.23841	-3.489970	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
54.24041	-4.080783	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
71.96080	-4.080783	0.000000	0.000000	0.000000	0.000000	66.50000	0.000000
72.75080	-4.080783	0.000000	0.000000	0.000000	0.000000	45.48936	0.000000
72.85080	-4.080783	0.000000	0.000000	0.000000	0.000000	44.06526	0.000000
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75.45080	0.000000	0.000000	0.000000	0.000000	0.000000	41.59431	0.000000
76.76080	0.000000	0.000000	0.000000	0.000000	0.000000	44.06526	0.000000
76.86080	0.000000	0.000000	0.000000	0.000000	0.000000	45.48936	0.000000
77.65080	0.000000	0.000000	0.000000	0.000000	0.000000	66.50000	0.000000
999.00000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

Track curvature  
( $\text{km}^{-1}$ )



# Sample Design Geometry File

DESIGN

UNITS VAMPIRE

Left-hand 56E1-R245-1:9.25 turnout - GBP Network Rail CV 9.25 - delta = 0.001

0.00000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
49.99900	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
** theoretical switch start								
50.00000	-1.744985	0.000000	0.000000	-9.068875	0.000000	0.000000	0.000000	0.000000
50.00100	-3.489970	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
54.23841	-3.489970	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
54.24041	-4.080783	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
71.96080	-4.080783	0.000000	0.000000	0.000000	0.000000	0.000000	66.50000	0.000000
72.75080	-4.080783	0.000000	0.000000	0.000000	0.000000	0.000000	45.48936	0.000000
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77.65080	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	66.50000	0.000000
999.00000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

**Kink angle  
(mrad)**

# Sample Design Geometry File

DESIGN

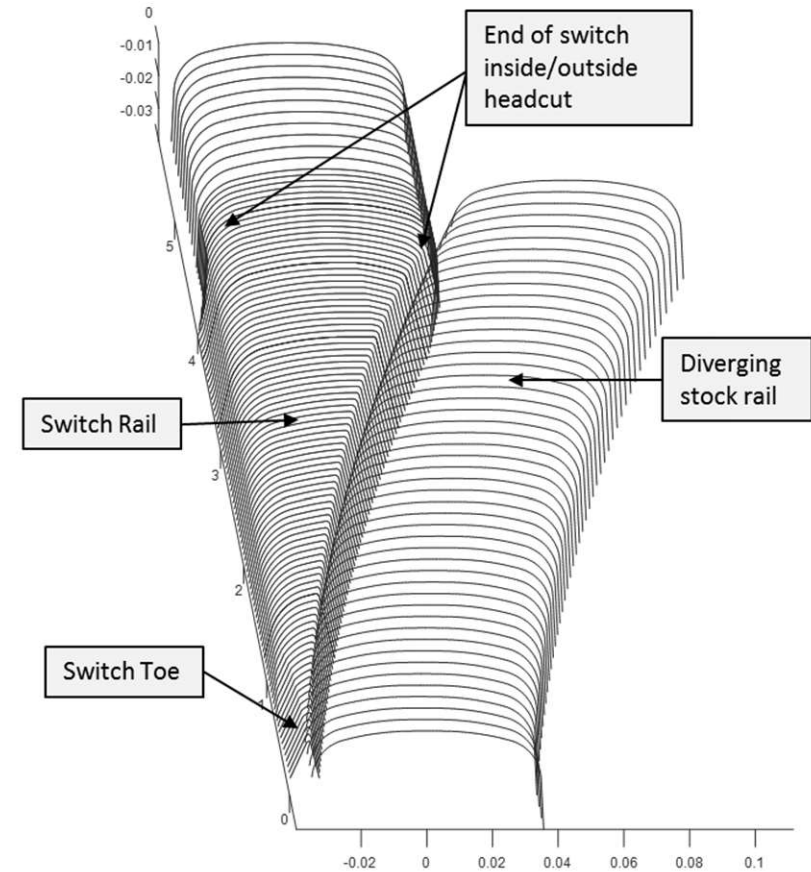
UNITS VAMPIRE

```
Left-hand 56E1-R245-1:9.25 turnout - GBR Network Rail CV 9.25 - delta = 0.001
  0.00000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
 49.99900  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
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 50.00000 -1.744985  0.000000  )00  0.000000  0.000000
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 71.96080 -4.080783  0.000000  )00  66.50000  0.000000
 72.75080 -4.080783  0.000000  0.000000  0.000000  0.000000  45.48936  0.000000
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 77.65080  0.000000  0.000000  0.000000  0.000000  0.000000  66.50000  0.000000
999.00000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000
```

**Left check rail  
clearance (mm)**

# Rail Sections

- Some significant differences compared to typical track
  - Left and right profiles may have substantially different number of points – two “rails” on one side versus single rail on other side
  - Limit data points to running surface only, reduce point density on non-running surfaces (present maximum is 1000 coordinate pairs)
  - Be careful regarding gauge values
- **Benchmark Issues**
  - Inadequate number of points in profiles (spline fit as option but requires care)
  - Need to assemble profiles from individual cross-sections (switch rail plus stock rail for example)

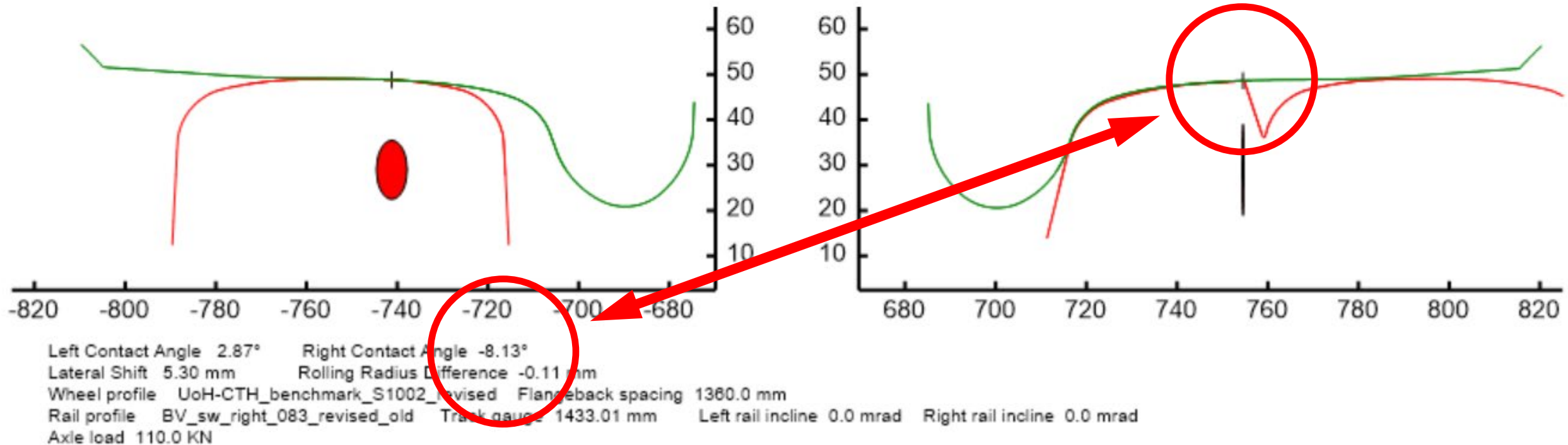


# Contact Geometry

- Calculation is comparatively simple
  - Create Task File template
  - Set up Command File to generate Task Files
  - Run Task Files using Run Control processor
  - Results need to be checked (fairly tedious “manual” process)
- **Benchmark Issues**
  - Occasional difference in left and right flange contact values using otherwise identical profiles (switch point on left versus switch point on right – sensitive to parameters for two-point contact search)
  - False contact angle at inner edge of switch point

# False Contact Angle

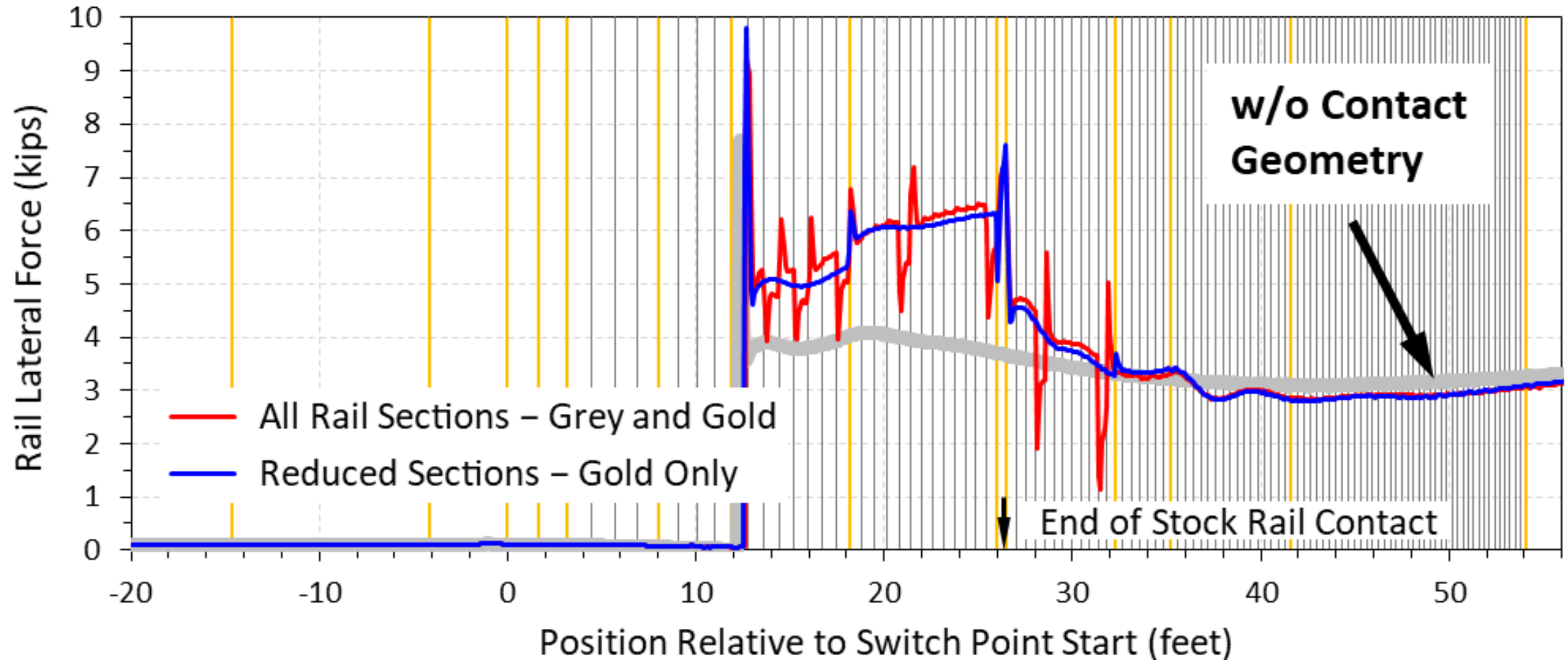
- Negative contact angle on right profile due to Vampire circular arc fit at inner edge of switch point



# Track Contact File

- Lists contact data files by longitudinal position
  - Data is linearly interpolated between files
- **How to chose relevant contact data files ?**
- Simplest option might be to use all possible cross-sections
  - Not recommended
  - Too many contact geometry files leads to interpolation issues
  - Total number of unique contact data files is limited to 200

# Effect of Contact Data Density



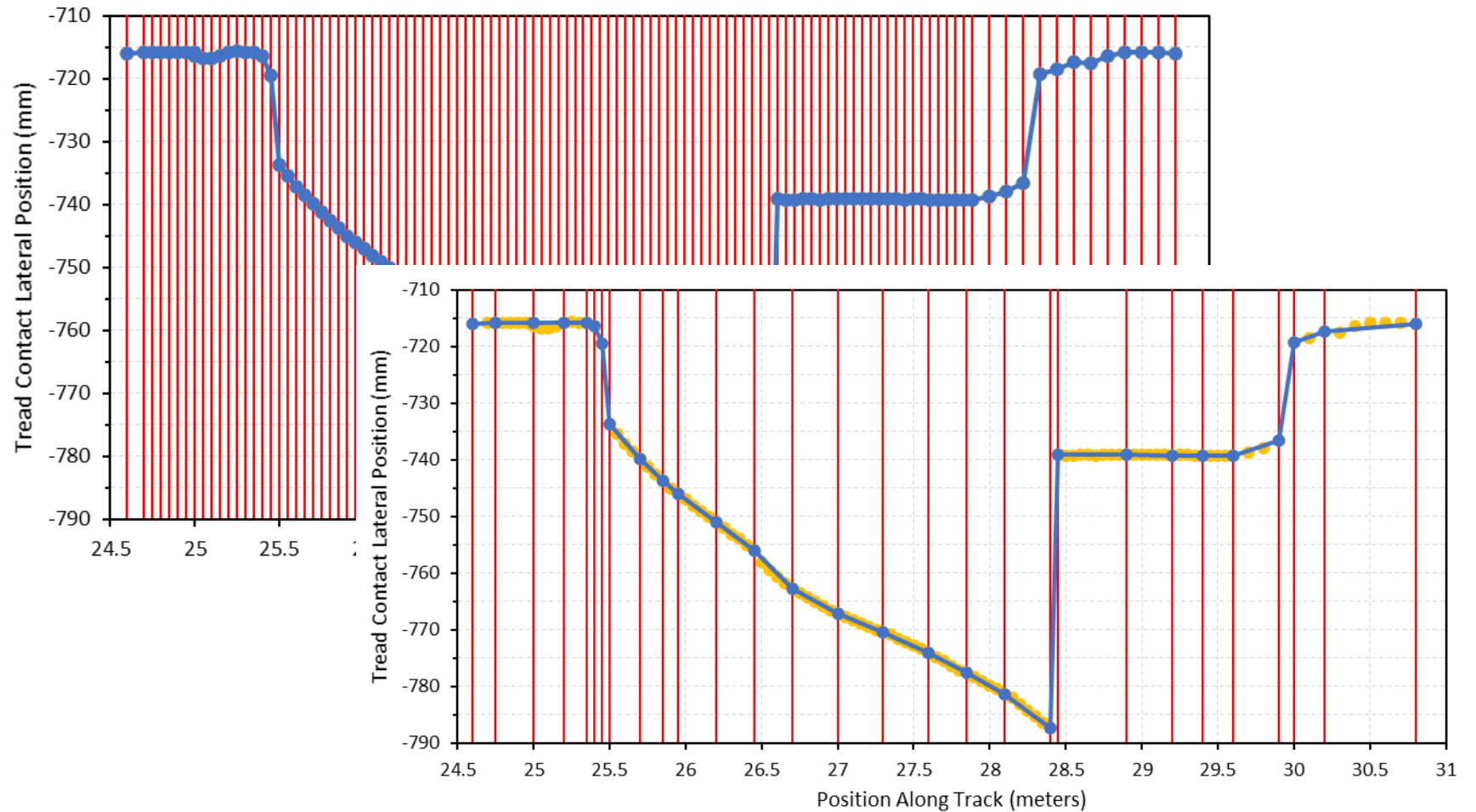
# Choosing Relevant Contact Data Files

- Limit Contact Data Files to those locations where significant changes occur in following variables
  - Rolling radius
  - Contact angle
  - Contact lateral position
- Important are results at lateral shift values relevant to actual wheel set position through switch and crossing
  - In low-speed turnouts, two-point contact is typically continuous, thus lateral shift is simple to determine
  - For two-point contact both tread and flange contact values are important



# Selecting Cross-Sections

- Interactive tool to understand cross-section choices
- Visualizes longitudinal data variation for chosen lateral shift

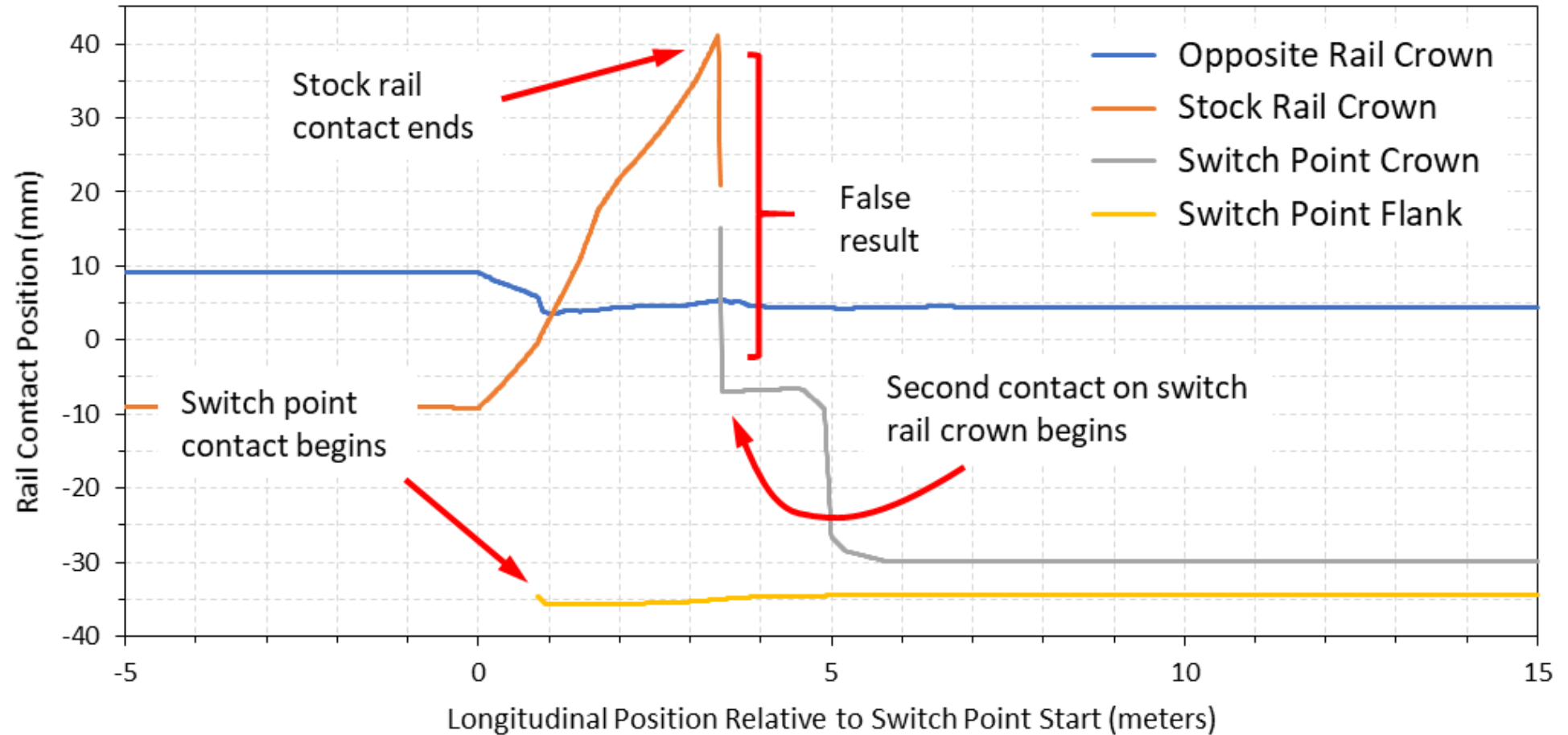


# Sample Track Contact File

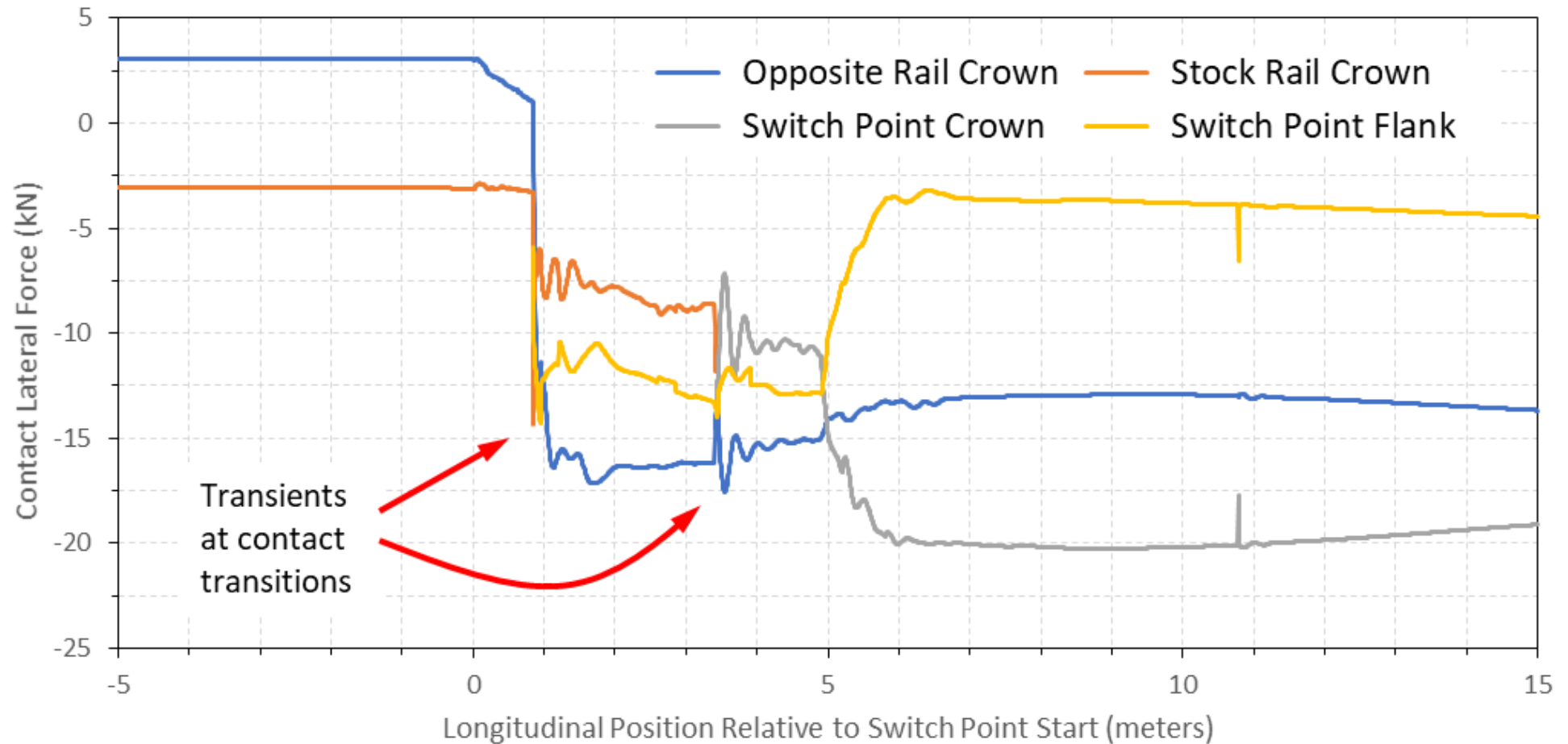
- Switch point modeled using 31 references to 29 unique files (of 118 sections calculated)

```
TRACK CONTACT
UNITS VAMPIRE
Track contact file for UoH-CTH turnout benchmark - UK switch point right w/ S1002 wheel profile
DISTANCE,CONTACTDATA
** file start
  0.0000,c:\work\turnout_benchmark\contact_geometry\UK_turnout\switch\sw_right_006_920mm_110kN
** entry switch point - right side facing direction
  49.6010,c:\work\turnout_benchmark\contact_geometry\UK_turnout\switch\sw_right_006_920mm_110kN
  49.7500,c:\work\turnout_benchmark\contact_geometry\UK_turnout\switch\sw_right_008_920mm_110kN
  50.0000,c:\work\turnout_benchmark\contact_geometry\UK_turnout\switch\sw_right_013_920mm_110kN
.
  55.0000,c:\work\turnout_benchmark\contact_geometry\UK_turnout\switch\sw_right_110_920mm_110kN
  55.2000,c:\work\turnout_benchmark\contact_geometry\UK_turnout\switch\sw_right_112_920mm_110kN
  55.8000,c:\work\turnout_benchmark\contact_geometry\UK_turnout\switch\sw_right_118_920mm_110kN
** file end
999.0000,c:\work\turnout_benchmark\contact_geometry\UK_turnout\switch\sw_right_118_920mm_110kN
```

# Example Results – Switch Entry



# Example Results – Switch Entry



# Wish List

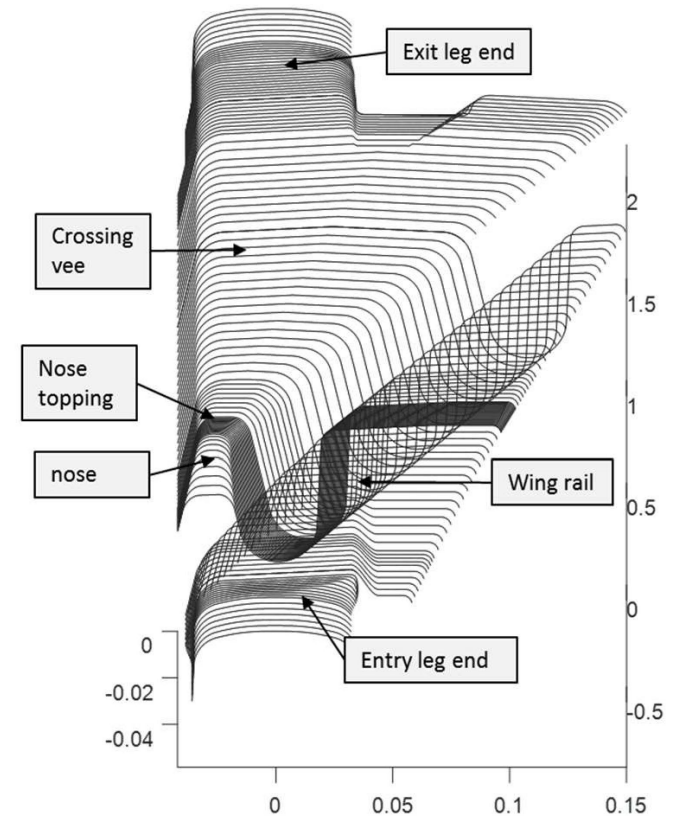
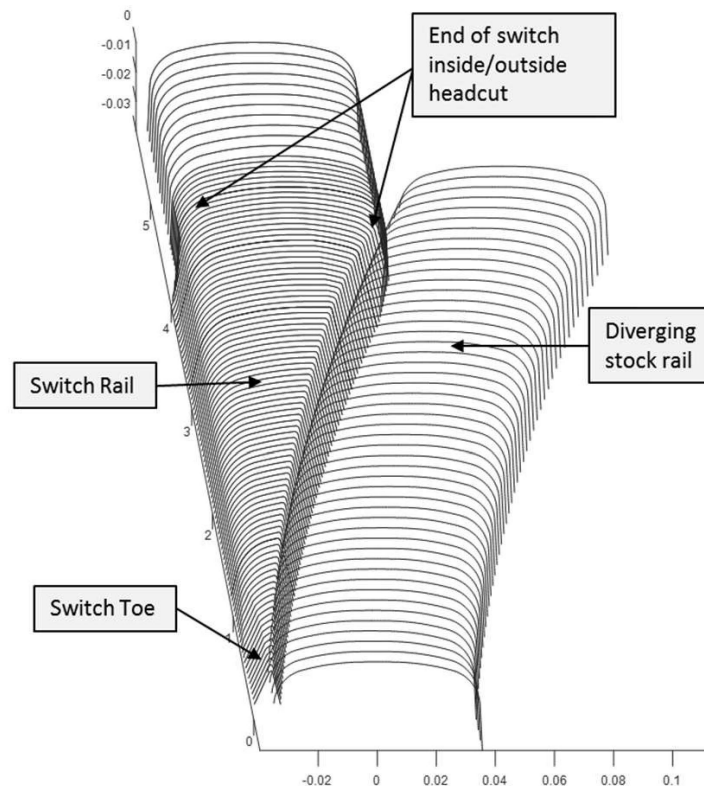
- Rail contact lateral position relative to original rail profile coordinate definition (current NL, NR, and NF mnemonics are relative to gauge point)
- Contact data interpolation for
  - Files with yaw angle results
  - Files with flange back contact
- General review of existing contact data calculation and interpolation between contact data files
- In-line contact calculation
  - Concerns regarding section-to-section effects
- Is SNC-Lavalin open to third-party utilities for Vampire ?

# The UoH-CTH Benchmark

- Modeling benchmark for S&C (Switches and Crossings)
  - Based on discussions initiated at 2020 IAVSD meeting in Gothenburg, Sweden
  - Joint leadership between University of Huddersfield (UoH) in Great Britain and Chalmers University of Technology (CTH) in Sweden
  - Modeling of two standard turnouts
- 56E1-R245-1:9.25 (CV 9.25) – Great Britain
  - Slower speed design (43 km/h diverging route) used by Network Rail
  - Intersecting geometry (kink angle at switch entry)
- 60E1-R760-1:15 – Sweden
  - Higher speed design (80 km/h diverging route) used by Trafikverket
  - Tangential geometry (no kink angle at switch entry)

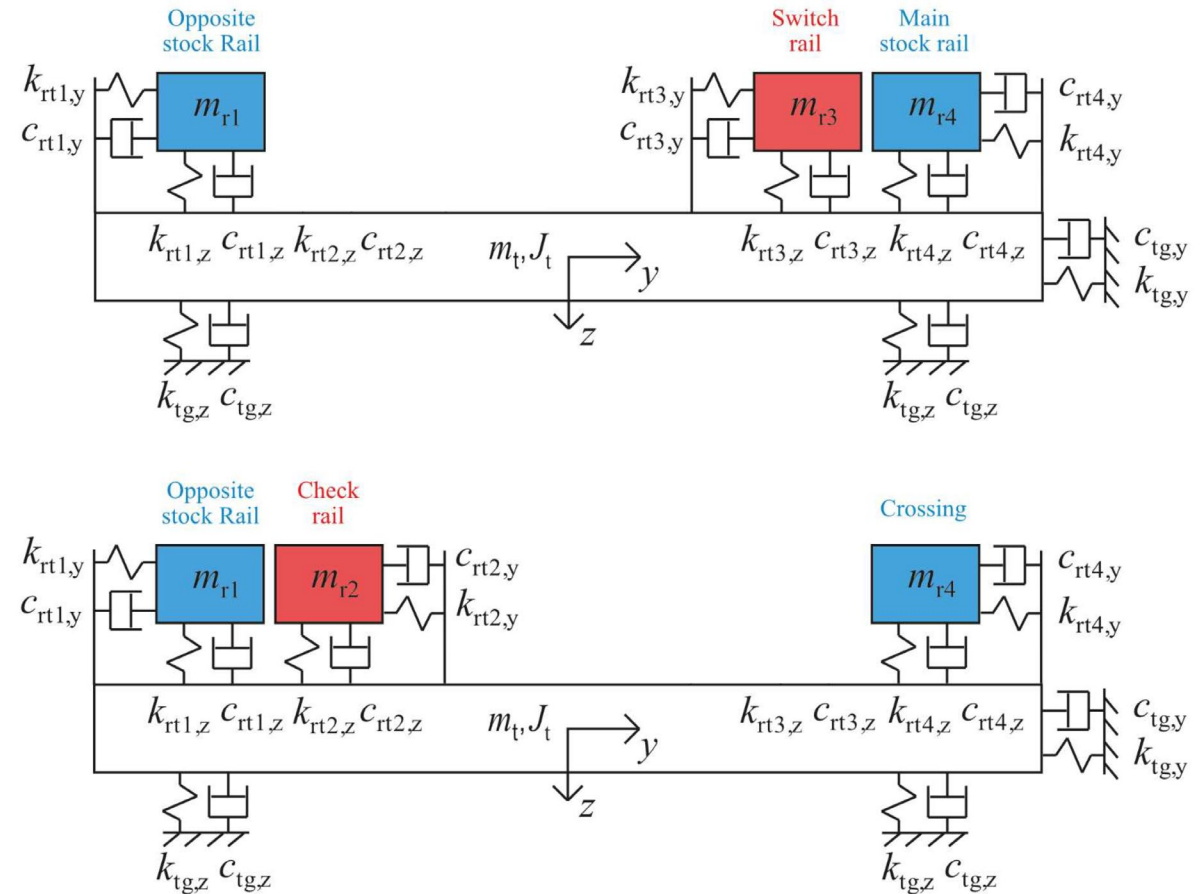
# Benchmark – Rail Sections

- Rail sections
  - Switch – stock rail, switch point, and opposite rail
  - Crossing – crossing, opposite rail, and check rail
  - Sections provided in common coordinate system **but separately**



# Benchmark – Track Model

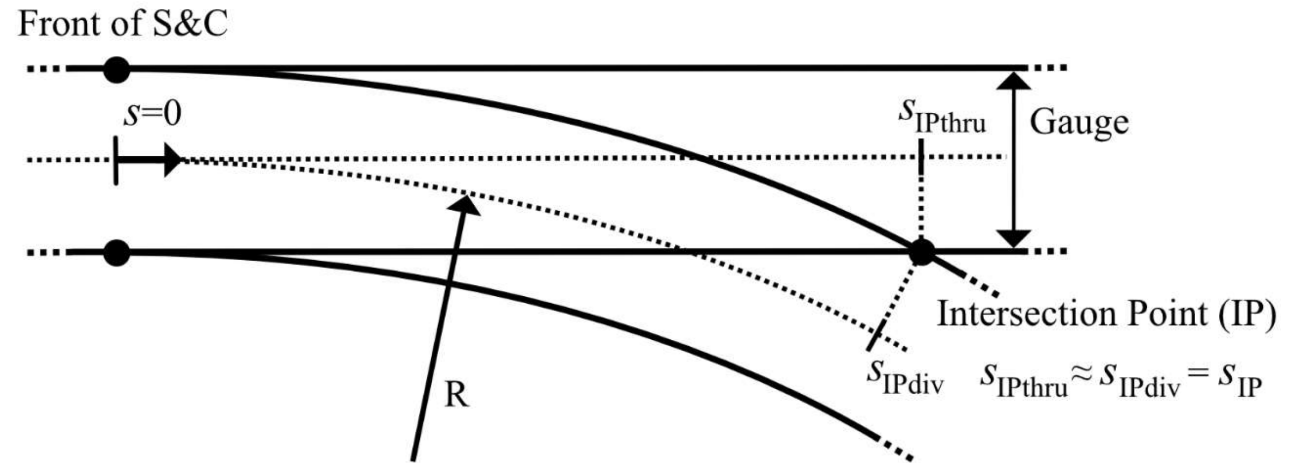
- Track modeled as sleeper (tie) and rail masses
- Masses are associated with each wheel set
- No variation in parameters along track





# Benchmark – Final Details

- Turnout geometries simplified for simulation
- Vehicle model based on Manchester Benchmark passenger coach



- Standard wheel profile
- Diverging and through route simulations for switch and crossing separately (nine cases total)

# Benchmark Status

- Roughly 20 results submitted to date
  - Covering nine codes (including multiple releases for same code)
- Results presently being tabulated
- To be accompanied by method statement in common format for each software
- Roughly 15 follow up papers in preparation
- Results to be published in early 2021 as Vehicle System Dynamics (VSD) Special Issue