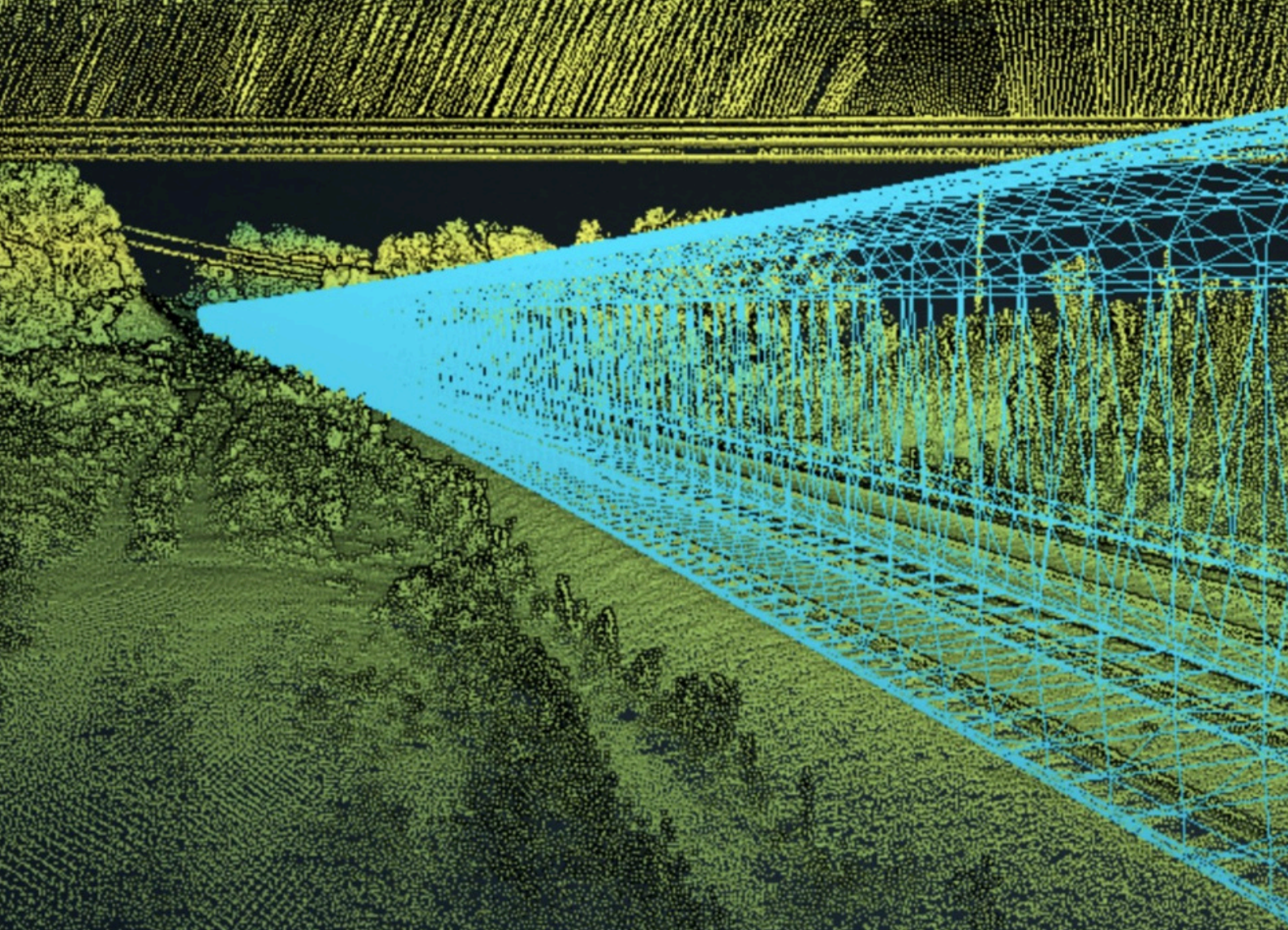


CORDEL CONNECT

Structure Infringements

Network-scale identification of structure infringements from LiDAR — comparing captured geometry against client-defined rolling stock profiles and kinematic envelope requirements to flag clearance risk across the corridor.

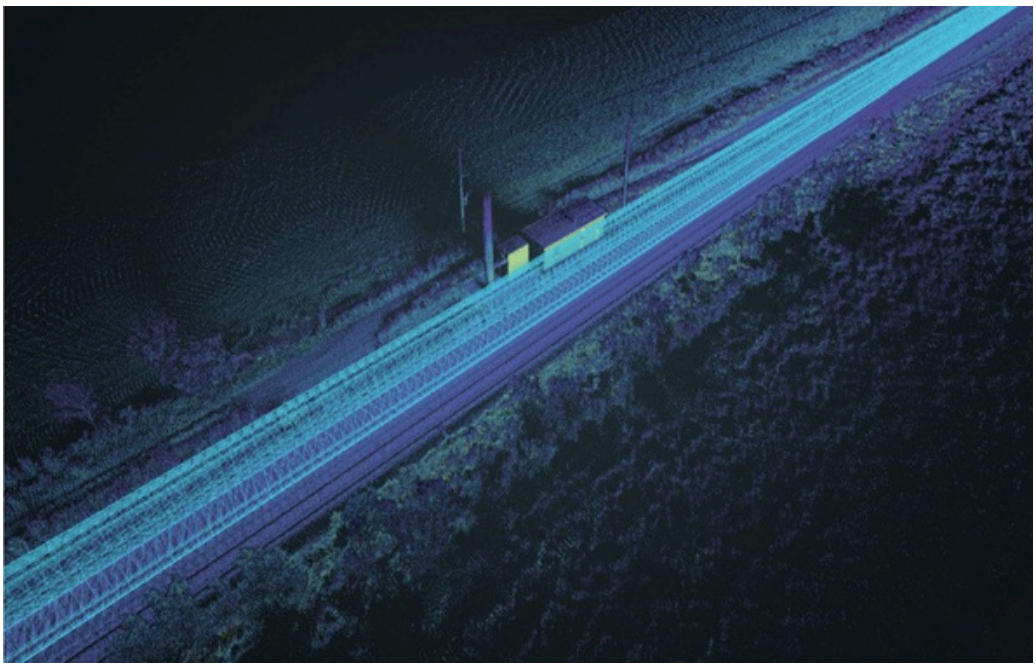
Information

Summary

Rail networks must ensure all structures along the corridor clear the space required for safe train operation. This space includes the physical train footprint and the kinematic envelope - the maximum area a vehicle may occupy considering suspension movement, track curvature, cant, and dynamic tolerances.

The Structure Infringements (StrInf) solution provides an automated method for identifying objects that encroach on the kinematic envelope. Using Cordel captured data and/or BYOD (Bring Your Own Data) the solution uses sophisticated AI to analyse the surrounding environment and compares detected objects against client-defined rolling stock profiles and kinematic envelope requirements.

Infringing structures are recorded with associated positional data and visual artefacts and plotted geospatially on the client network. This allows infrastructure managers to identify potential clearance risks across large sections of network and investigate them within the Cordel platform.



Structural infringements can be reviewed against client provided locomotive profiles

What does this module do?

This solution detects encroachments inside one or more of the outlines defined below, and generates a corresponding infringement ticket with relevant metadata.
Kinematic envelope: The area representing the maximum considered range of occupancy of the rollingstock, taking into account all track and rolling stock movement tolerances. This zone is sometimes referred to as the Kinematic or E Infringement priority.
K+P1: This refers to the specific area located between the KE and the P1 boundary, which lies outside the KE. It is important to note that this area is distinctly positioned beyond the limits of the KE, marking a clear boundary between these two points. This zone is sometimes referred to as the Base Operating or P1 Infringement priority.
K+P2: This denotes the region situated between K+P1 and K+P2. This area serves as the intermediate space connecting these two points, highlighting the zone that lies directly between K+P1 and K+P2. This zone is sometimes referred to as the Maintenance or P2 Infringement priority.
K+PN: This denotes the region situated between K+P2 and K+PN. This area serves as the intermediate space connecting these two points, highlighting the zone that lies directly between K+P2 and K+PN. This zone is sometimes referred to as the K400 or PN Infringement priority.

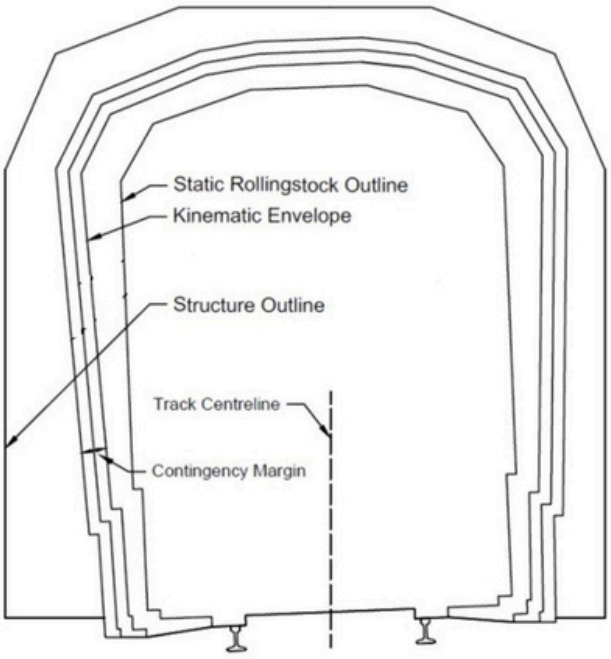


Figure 7-1 shows a static outline rotated to match design superelevation.

The structure outline is not rotated with the track. It is aligned with the top of rail or high rail in curved track.

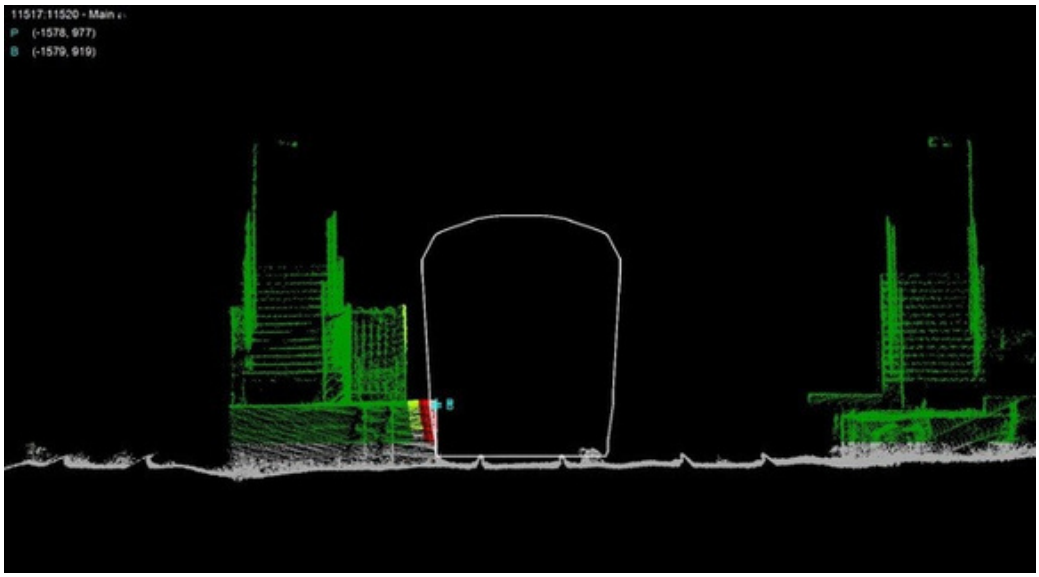
The structure outline shown is for curved track, this is wider on the low rail side

A diagram that shows the relevant outlines

During implementation the client supplies their rolling stock profile(s) specifications and their kinematic envelope requirements. Cordel generates several kinematic envelopes that account for track geometry (e.g. end throw and centre throw where the track is curved). The kinematic envelopes are saved as pre-defined envelopes in a library.

Data is segmented, nominally into 1 m cross-sections (though cross-section depth is configurable to suit client requirements) and processed by Cordel AI. This involves classifying the point cloud and positioning data against the network. This solution automatically selects the appropriate kinematic profile based on the location and radius of the cross-section (radius is often segmented into a range).

Cordel's AI algorithm then analyses each cross-section by comparing the kinematic envelope and the client defined zones of encroachment to the objects that surround them. Where objects are found to be within the zones of encroachment and/or the kinematic envelope an infringement is generated, and this solution records the zone closest to the kinematic envelope being infringed upon, the location of the infringement, the measurement of the infringement (i.e. how far into the zone/envelope the object has been detected) and how close to the kinematic envelope the infringement is.



Structural infringement cross-section

Cordel Clearances Payload Data

.CSV Reports

`*StrInf.csv`

QA Videos

`_Kinematic_Inf.mp4`

.PLY Polygon Files

`*_kinematic_profile.ply`

.PNG Image Files (per infringement)

`_kinematic_profile.ply`

.LAZ Files

`10047_75_MLSPCD_20250411_b33a`

Accessed through the Mission Viewer, users can download a range of outputs included as standard in this solution.

.CSV Reports

The Structure Infringement solution includes one .CSV report. This report includes the standard information contained in all Cordel generated .CSV files — such as positional information, capture details, mission information and links to the Cordel Connect platform.

The Structure Infringement Report

`*StrInf.csv`

The data contained in this report centres on measurements of objects found to be within or close to the kinematic envelope.

Column Name	Details
`Plate`	The reference plate applied to the cross section assessment
`Radius`	The measurement of the curvature of the track from the track centreline. In this report, -1 represents a straight (tangent) track.
`Aspect`	The radial direction [Left, Right, Tangent]
`Cant`	The measurement of the vertical distance/sloping height between the two rails.
`InfringementOutline`	The zone where the infringement is detected [typically Kinematic, Base Operating, Maintenance]
`InfringementMeasure`	The measurement in mm that the infringing object is found to be within the encroachment zone or kinematic envelope.
`ClearanceFromKinematic`	The distance between the infringement and the kinematic envelope in mm

Column Name	Details
`InfringementSide`	The side the infringement has been detected on [Up, Down]
`HorizontalOffsetFromCentreline`	The horizontal offset measurement from the track centreline to the infringement point in mm
`VerticalOffsetFromAvgRailHeight`	The vertical offset measurement from top of the railhead to the infringement point in mm
`InfringementPriority`	Based on the kinematic envelope and encroachment zones, the priority represents the proximity to the kinematic envelope. Infringements found closer to the kinematic envelope are considered a higher priority [E, P1, P2, PN]
`InfringementClassification`	The classification of the object that has caused the infringement [NeverClassified, Conductor, Building, Lowvegetation, MediumVegetation, HighVegetation]

A number of standard Cordel columns are also included in this report such as:

- Recording Information: Time, Date, LIDAR Sensor, positional reference (Lat/Long/Alt, TrackCode, Track Position, etc...)
- Solution Artefacts: Image references, LiDAR URL, Mission URL, Assessment version number

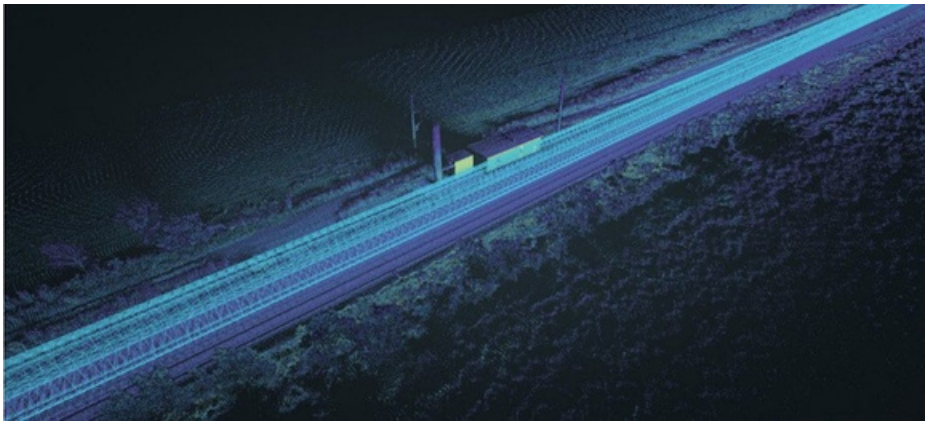
Visual Tools

Report Graphing Tool

NA — The Report Graphing Tool is not applicable to this solution.

LiDAR Viewer

Using the kinematic profile .PLY file provided, users can view the applied kinematic envelope in the point cloud viewer and evaluate kinematic infringements with greater context.



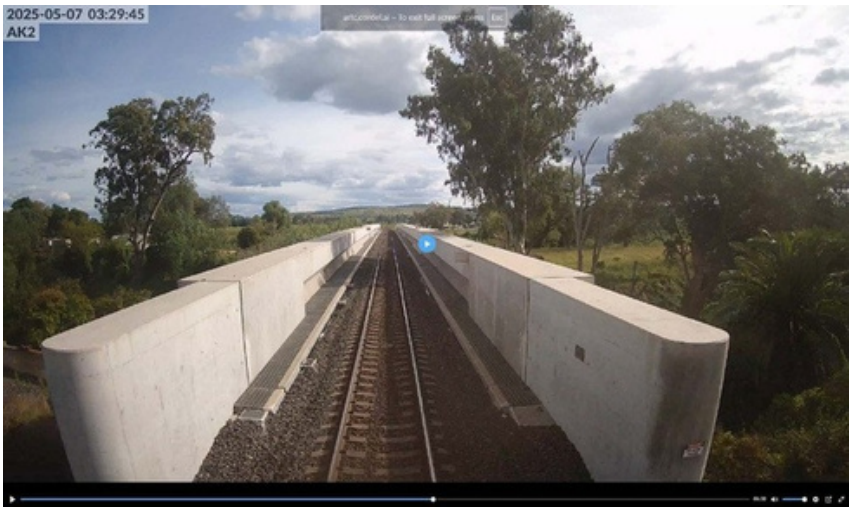
LiDAR point cloud showing a structure



LiDAR point cloud showing the kinematic envelope

Forward Facing Video

The video footage captured by Cordel hardware is a powerful tool when conducting digital assessments of potential kinematic infringements, allowing users to digitally review structures along the corridor.



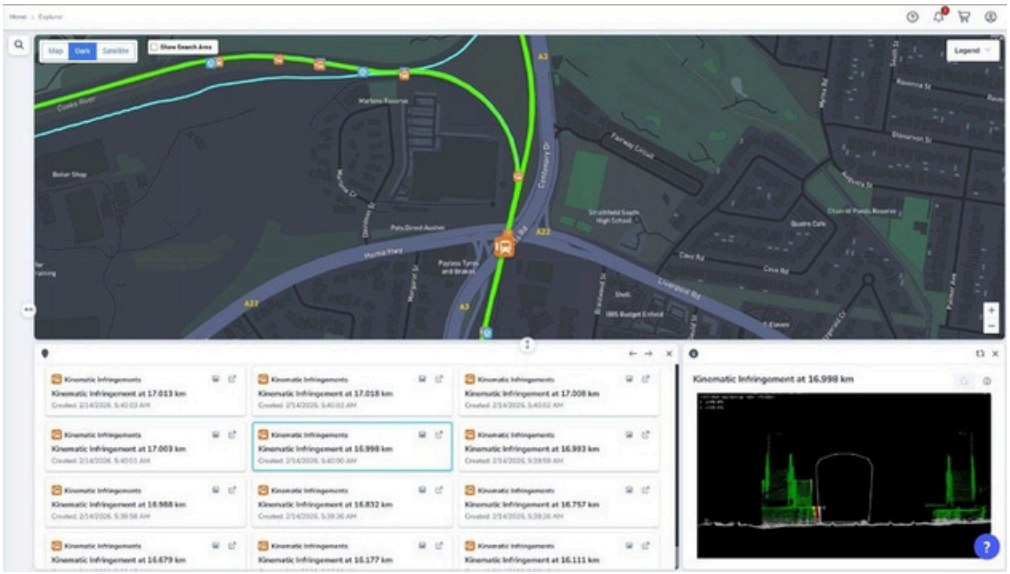
Forward Facing Video footage that shows a structure

Infringements: Explorer

The Explorer page delivers a high level understanding of the volume of infringements — and where they are located on the client's network. Structural Infringements are displayed on the Explorer page with an appropriate marker. Where there are several infringements, these are grouped together, allowing users to quickly identify areas that have multiple issues.

Each infringement also has a corresponding infringement in the search results section, which includes information such as the location, infringement type, and capture date and time.

The 2-D cross-section for each infringement is colour coded based on the Kinematic Envelope Zones and linked to the ticket card and the map marker, as well as the video footage that corresponds to that section of the network. Any time a user selects an infringement ticket, the relevant cross-section and video is displayed to give additional context and visual information.



Kinematic Infringements shown on Cordel Connect Explorer

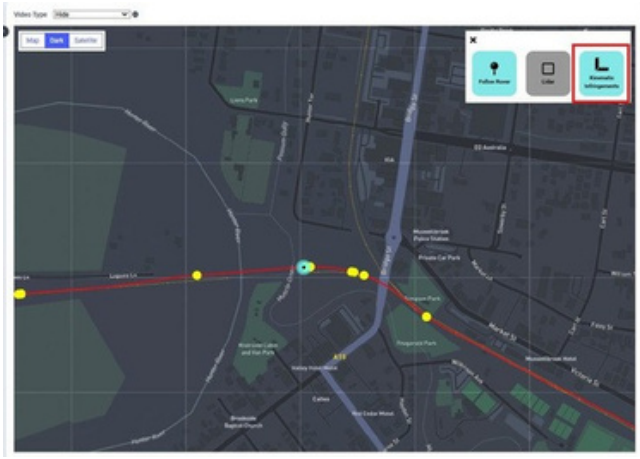
Infringements: Mission Viewer

Where a more granular investigation is required, users can review infringement details on the Mission Viewer page using a range of intuitive tools. The elements on this page are synced geospatially, allowing users to 'drag and drop' the rover marker to the area of interest — and view the relevant data for that location.

Map Layers: Report Heatmap Layer

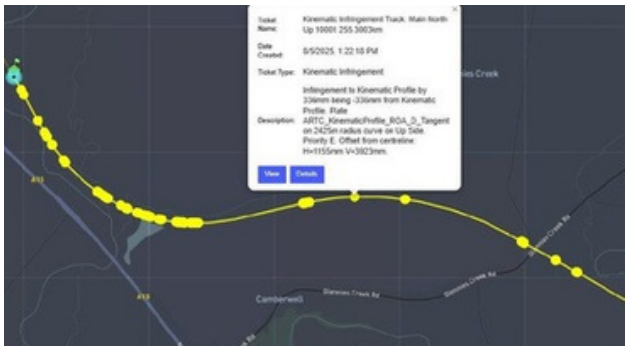
NA — The Heatmap Layer is not applicable to this solution.

Map Layers: Kinematic Infringement Layer

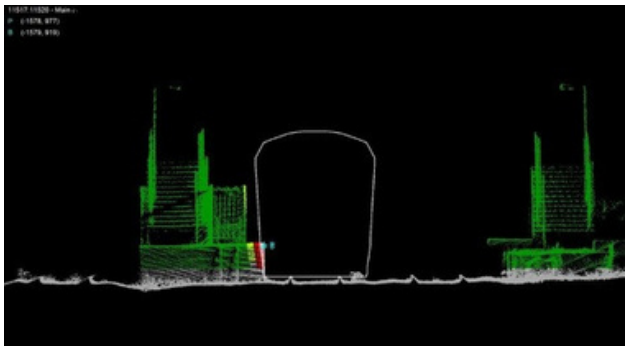


View infringements as a map layer in Mission Viewer

Kinematic Infringement Details



View infringement cross sections or infringement details

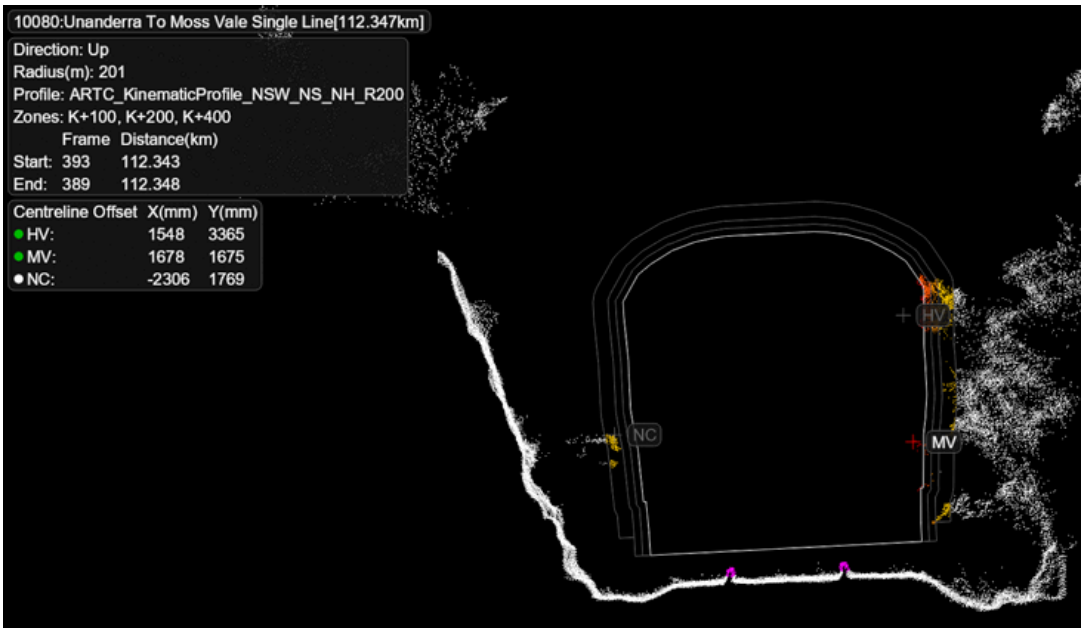


Structural infringement cross-section

Structure Infringement QA Video

Each 1 meter 2D cross-section is 'stitched together' and presented in the Structure Infringement solution as a QA video. This QA video is synced to the Network Model and can be reviewed in the Mission Viewer by selecting the "Kinematic Infringements" video type.

Users can view the QA video in full screen mode, and this artifact is also available for download as part of the standard payload data.



Structure infringement QA video cross-section sample

QA Video: Meta Data and Legend

Column Name	Description
Track Code Track Name Location (mi/km)	The track code the infringement exists on; The name of the track the infringement exists on; The distance along the track the infringement exists (in km or miles depending on configuration)
Profile Name	The name of the kinematic profile used in this assessment. The selected profile is displayed in white as the inner most profile in the QA video
Kinematic Zones of Encroachment	The encroachment zones the assessment uses to detect structural infringements inside of. These zones are displayed in grey around the kinematic profile.
Quick Check Box	An box shown in pink outside the encroachments zones used to visually check for infringements quickly, at a high level.
Infringing - normal	Points shown in green that infringe on one or more of the kinematic zones and/or the kinematic profile
Infringing - outlier	Outliers are determined by a clustering algorithm. A cluster is 3 or more points within a 0.1m area. So outlier points are groups of 1 or 2 points that sit alone and are 0.1m away from any other points.
Not infringing - under XX rail plane	Points shown in orange that are detected below the selected rail plane
Non infringing - outside XX Kinematic Zone	Points shown in grey that are detected outside the outer most kinematic encroachment zone.