NetworkRail

Rail Management Hot Topics and Developments

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Providing technical leadership

Hatfield - 12.23 Tuesday 17 October 2000

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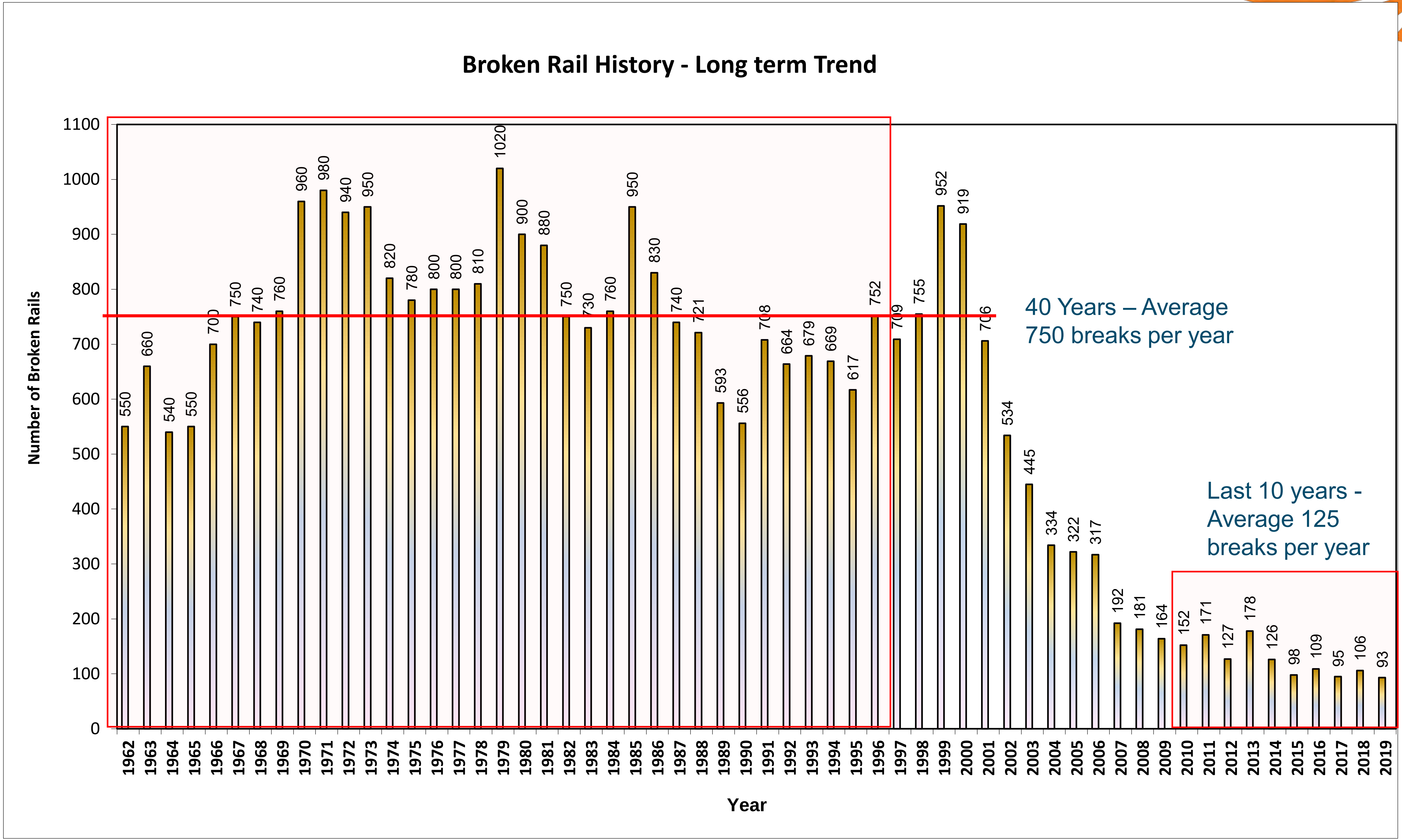
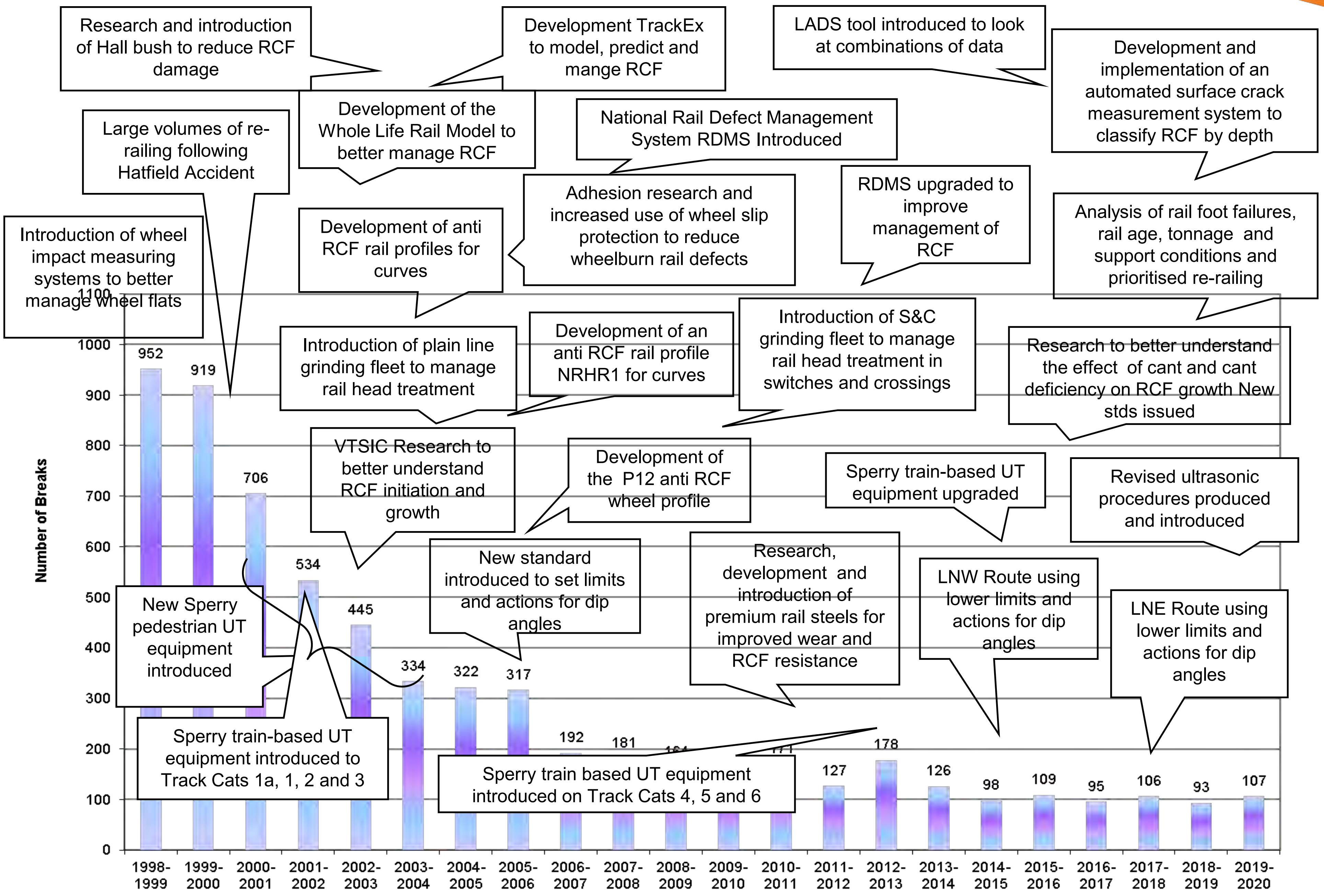


Broken Rail History - Long term Trend
Number of Broken Rails
0
100
200
300
400
500
600
700
800
900
1000
1100
550
660
540
550
700
750
740
760
960
980
940
950
820
780
800
800
810
1020
900
880
750
730
760
950
830
740
721
593
556
708
664
679
669
617
752
709
755
952
919
706
534
445
334
322
317
192
181
164
152
171
127
178
126
98
109
95
106
93
1962 1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
Year
40 Years – Average 750 breaks per year
Last 10 years - Average 125 breaks per year

Broken Rail Controls since 2000

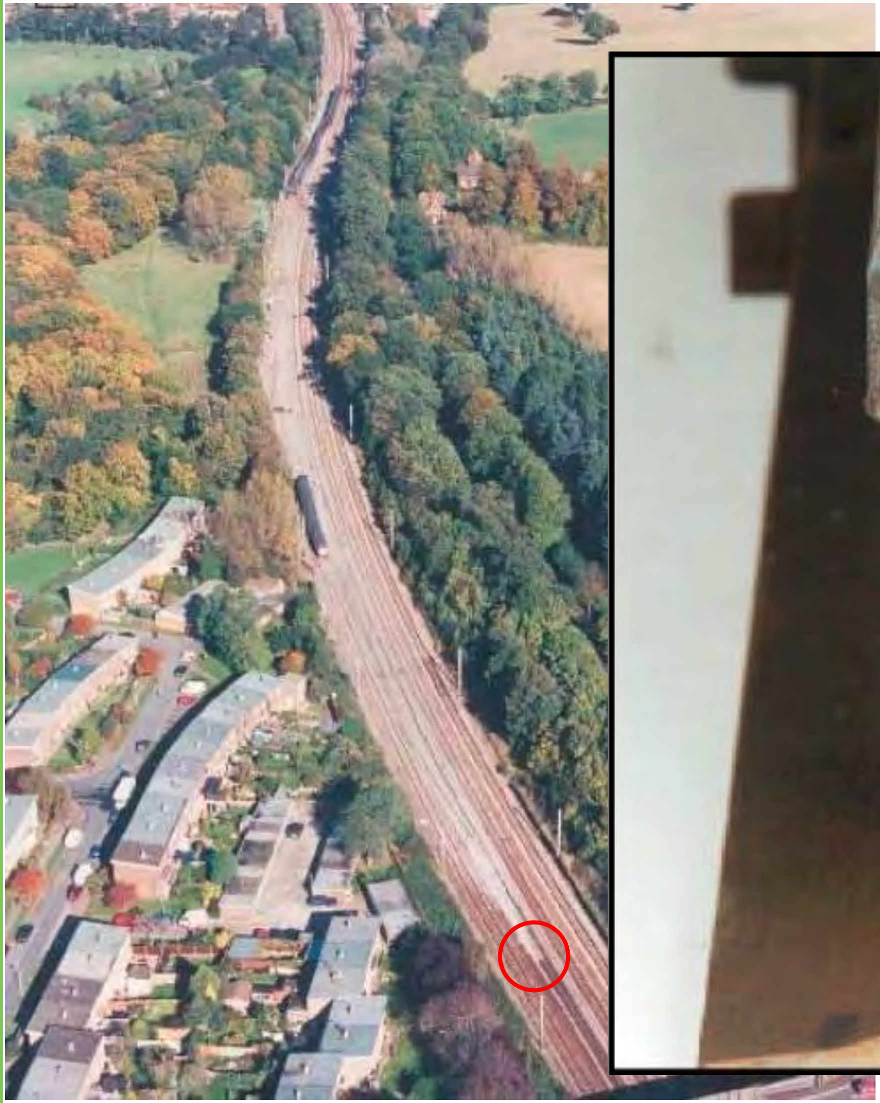


A long term continuous improvement plan based on improved monitoring and inspection, data driven analysis and understanding of root cause coupled with a large number of initiatives, developments, improved processes, updated standards and improvements to rail management.

Unfortunately there were very few quick fixes and no magic wands.

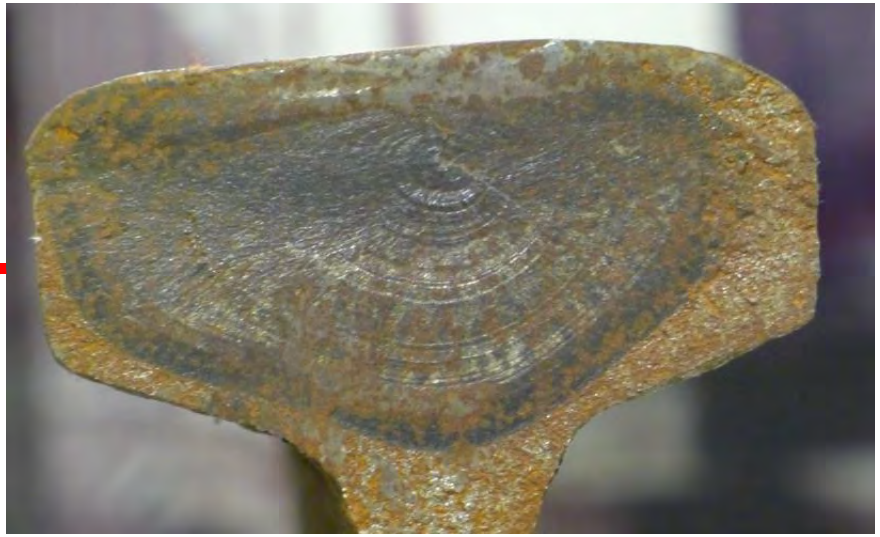
The quicker wins have already been had and further reductions become increasingly more difficult to realise

Hatfield - 12.23 Tuesday 17 October 2000



Broken Rail, RCF – 2nd January 2019 NAJ1, 2100, 2m 440yds

Broken Rail - December 2019



Broken Rail, RCF, 12th May 2020, VTB2, 1100, 19m 1078yds

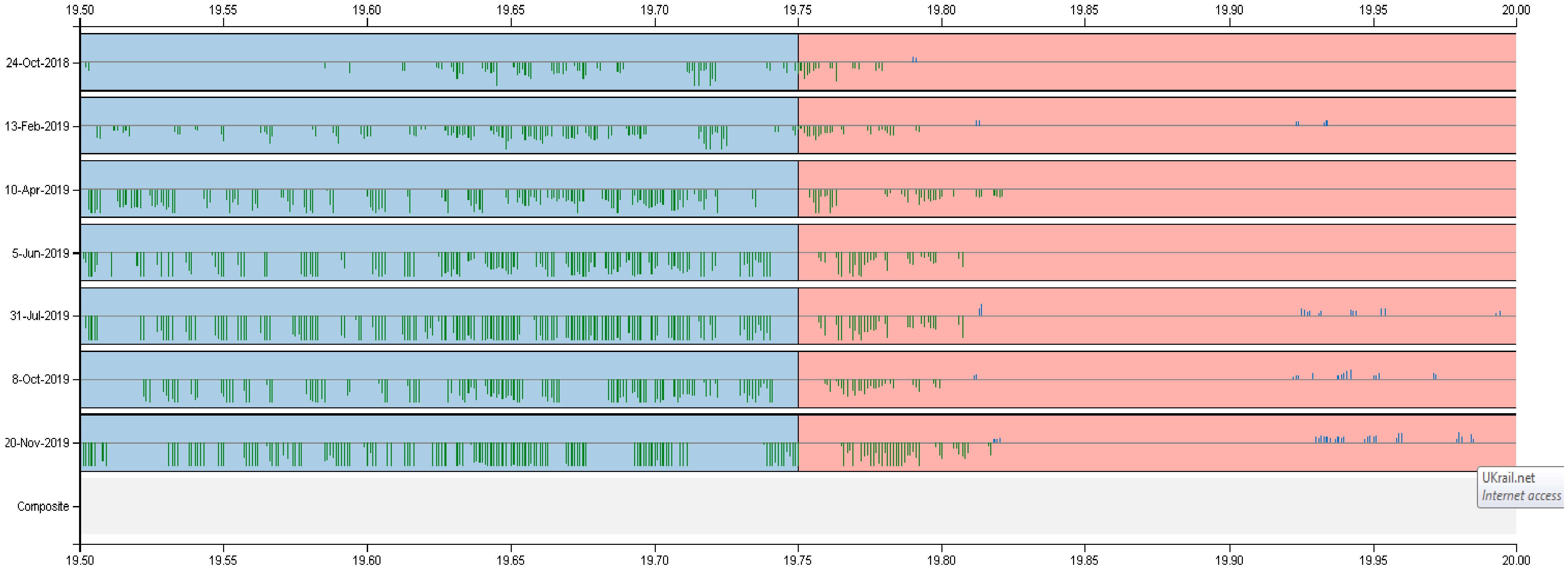
At 0635, DP track circuit failed on the Up Quarry Line, between Redhill Tunnel and Quarry Tunnel, fortunately only a single break.

OFFICIAL

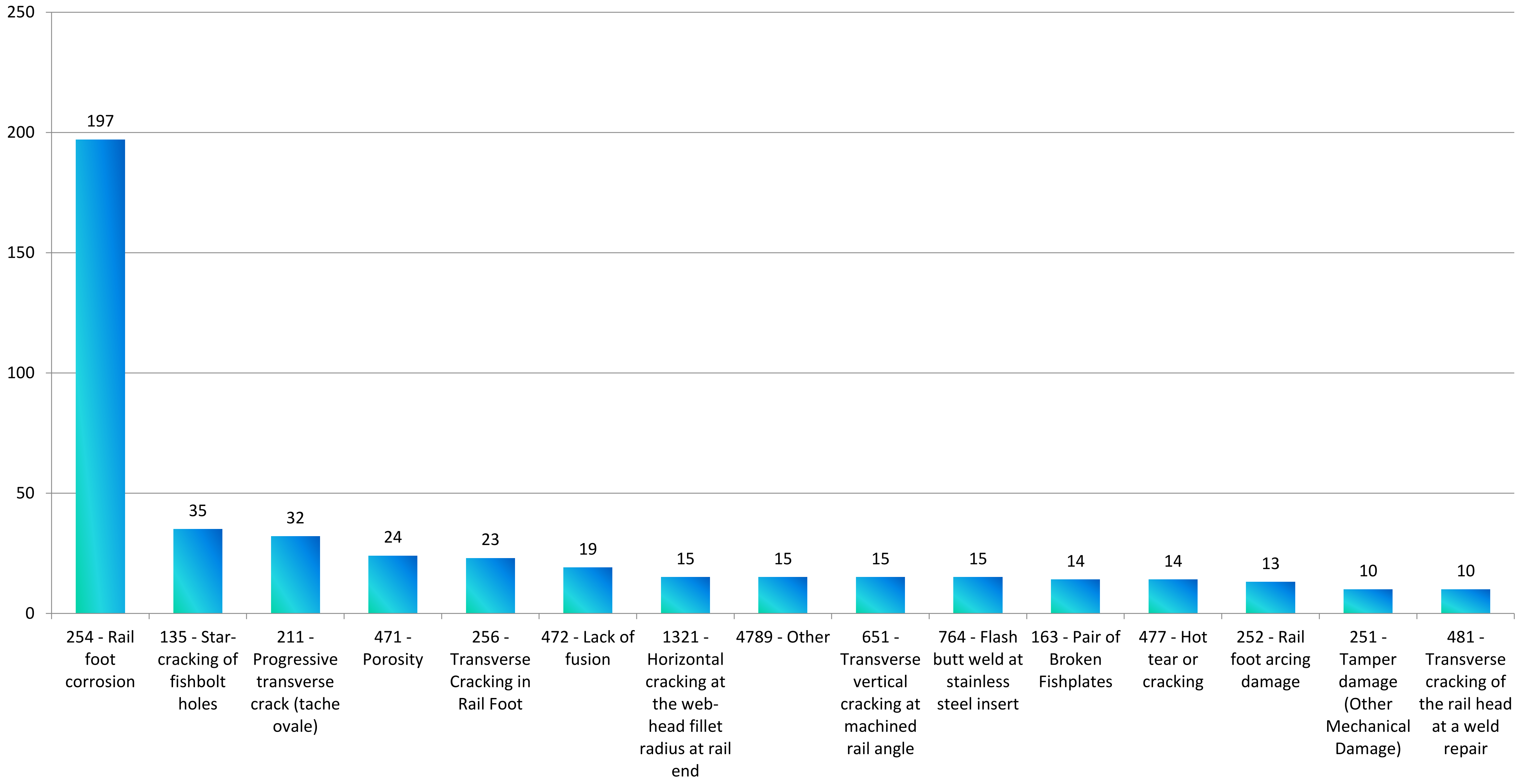
Broken Rail RCF, 12th May 2020, VTB2, 1100, 19m 1078yds

ELR:	Track Id:	From Date:	End Date:	Start Mile Post:	End Mile Post:	Display Type:
VTB2	1100	23-SEP-2018	23-SEP-2020	19.5	20	Depth

Generate Chart



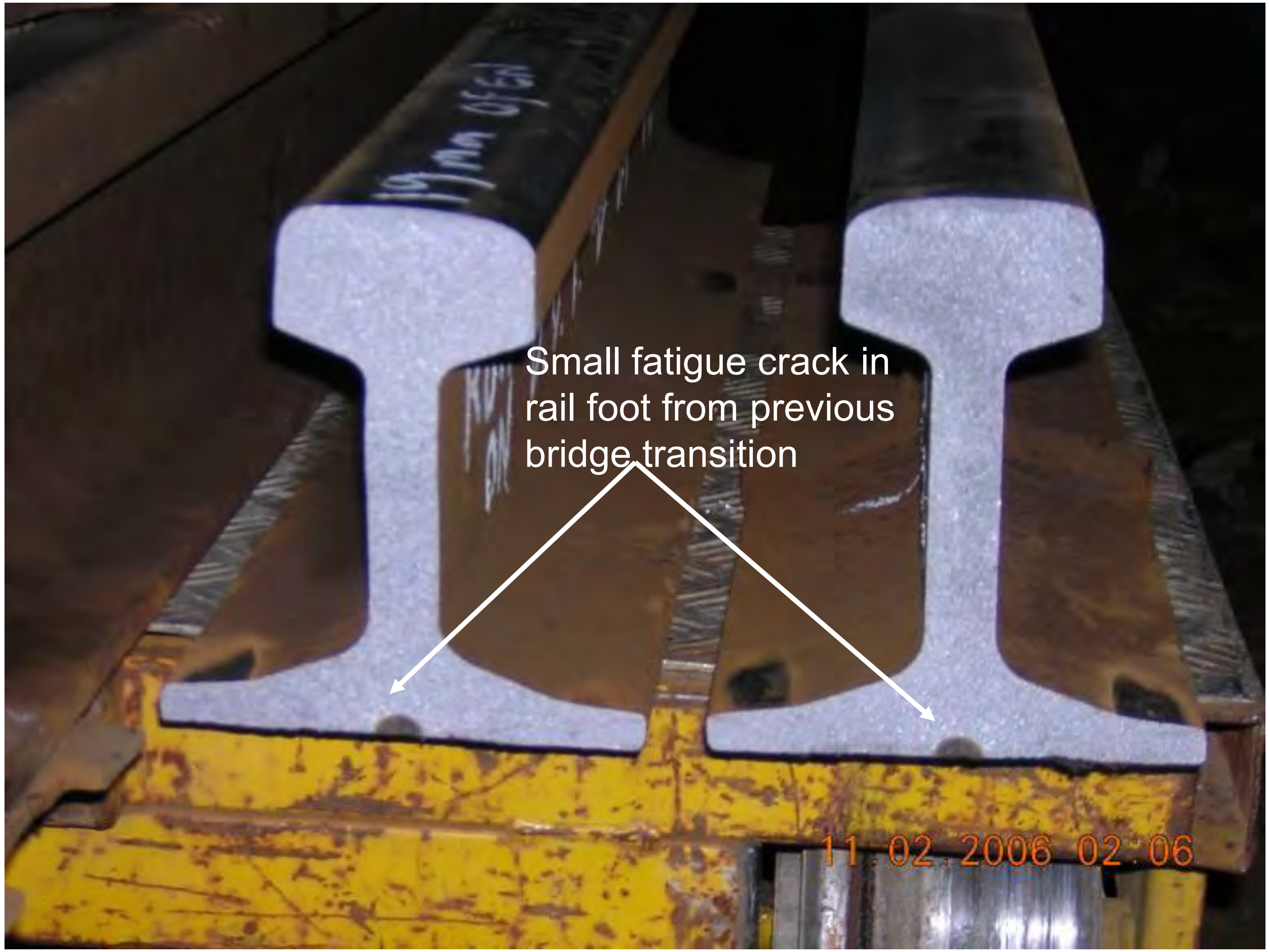
Broken Rails By Type 2013 – 2018 Top 15 by Cause



Rail Foot Failures Account For Around 50% Of Annual Breaks

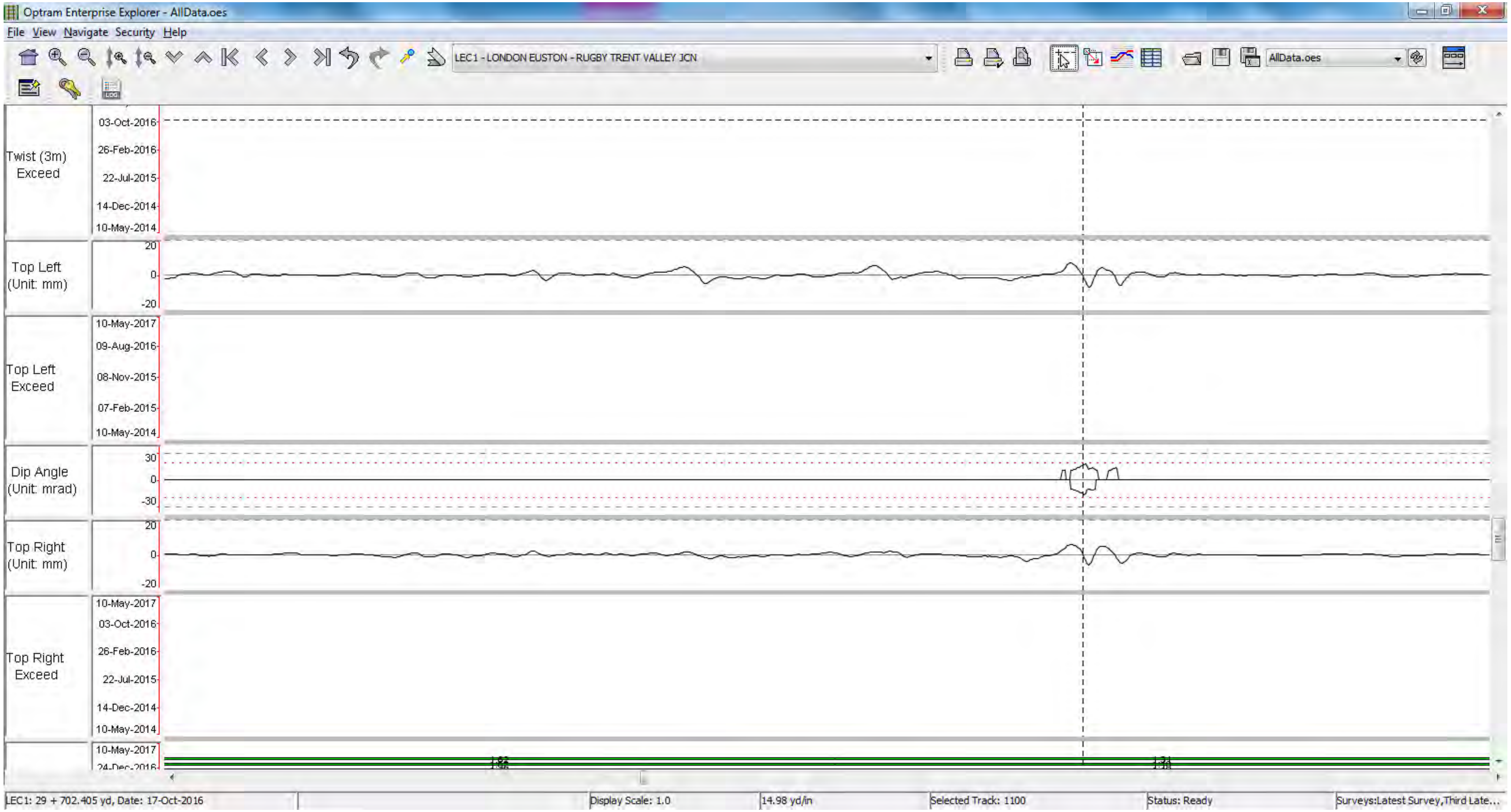
There has been a previous rail break at this location and the majority of rail breaks in the rail foot are caused by poor support conditions

Could this be found by UT?



20-04-17, LEC1 1100, 29m 700yds
Northchurch, 1980, 113A rail.
Break initiated from the rail foot due to high dynamic loading from voiding sleepers and poor support conditions
No significant defect to detect by inspection.
Need to manage the conditions where this risk exists

LEC1 1100 29m 700yds Northchurch
Dip in measured geometry trace

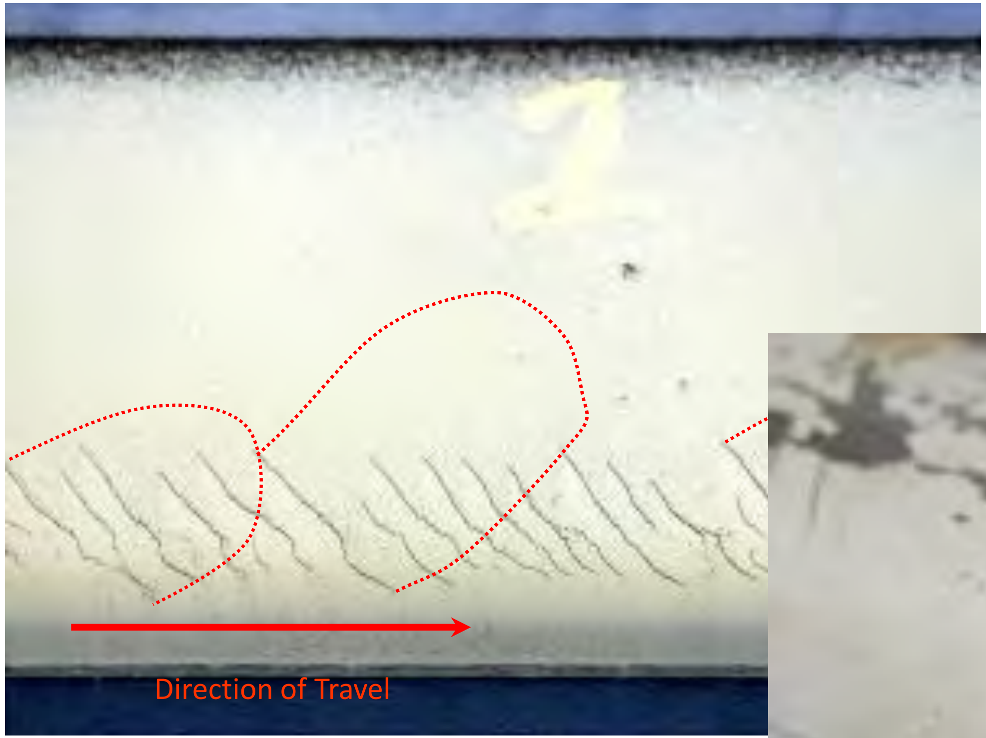


High contact stresses and an aggressive environment.

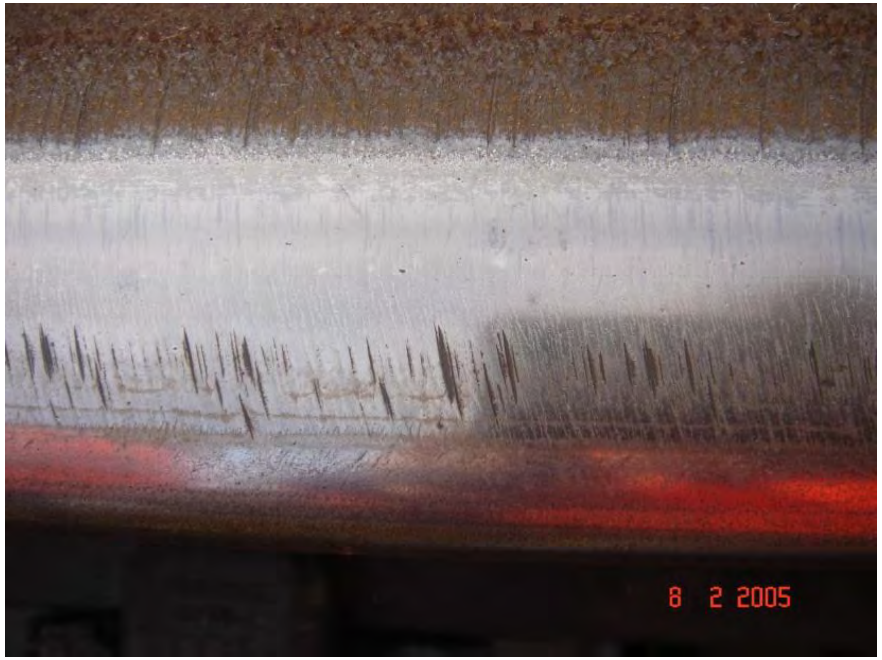
Static wheel loads from 60 to 125 kN on a small contact patch (5 pence)

125kN on 250mm^2 is around 500N/mm^2 without any lateral or longitudinal forces or the dynamic effects of the wheel in motion due to track and wheel irregularities

Severe RCF with branched transverse defect

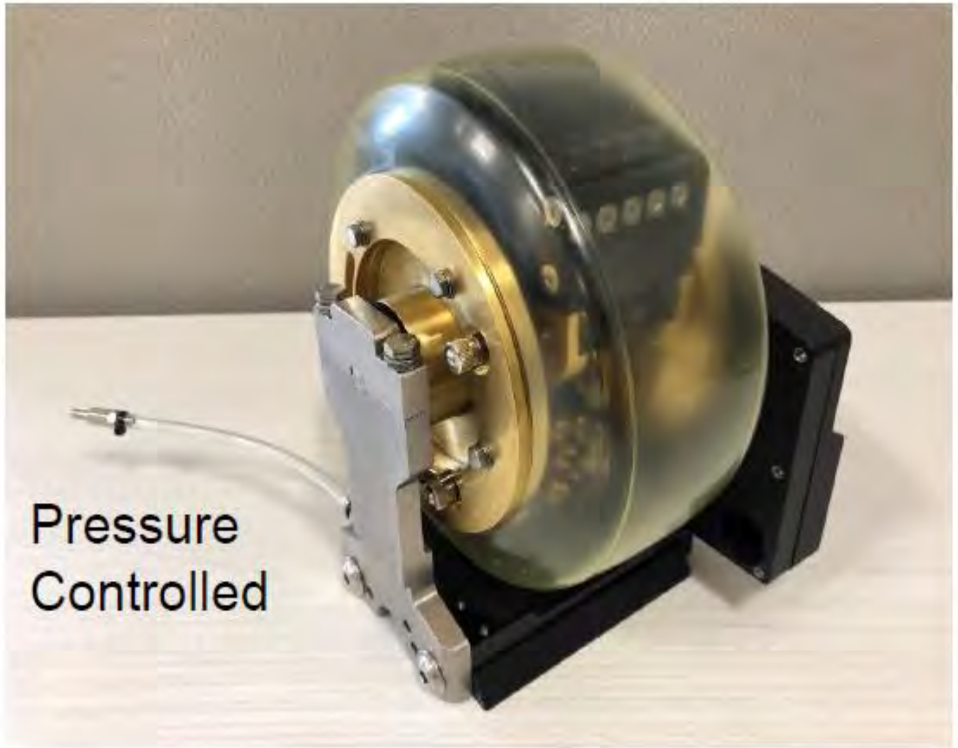


Visual Inspection and Manual Measurement of Surface Length



Surface Crack RSU

10 probes providing full coverage across rail head



Intelligent RSU with built in digital processing

RDMS Eddy Current Upgrade

http://rdms.corp.ukrail.net/rdms/page.xhtml — Rail Defects Management S...

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Network Rail BWhitney [MyOwn]

HQ

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Defects

Region	TNC	Disp.	Overdue	Due This Week	Due In 2 Weeks	Due In 3 Weeks	Due In Week > 3
Anglia	163	82	154	48	57	46	2048
East Midlands	77	32	53	5	10	5	319
Kent	61	8	49	29	15	23	376
LNE	181	67	124	23	42	34	1823
LNW North	84	39	78	35	57	69	2269
LNW South	50	43	77	18	23	29	933
Scotland	111	17	93	52	49	70	1521
Sussex	62	2	18	20	31	16	275
Wales	15		2	3	8	9	546
Wessex	104	11	164	20	42	14	533
Western Thames Valley	139	19	9	13	23	24	478
Western West	11		2	7	4	9	440

EC RCF

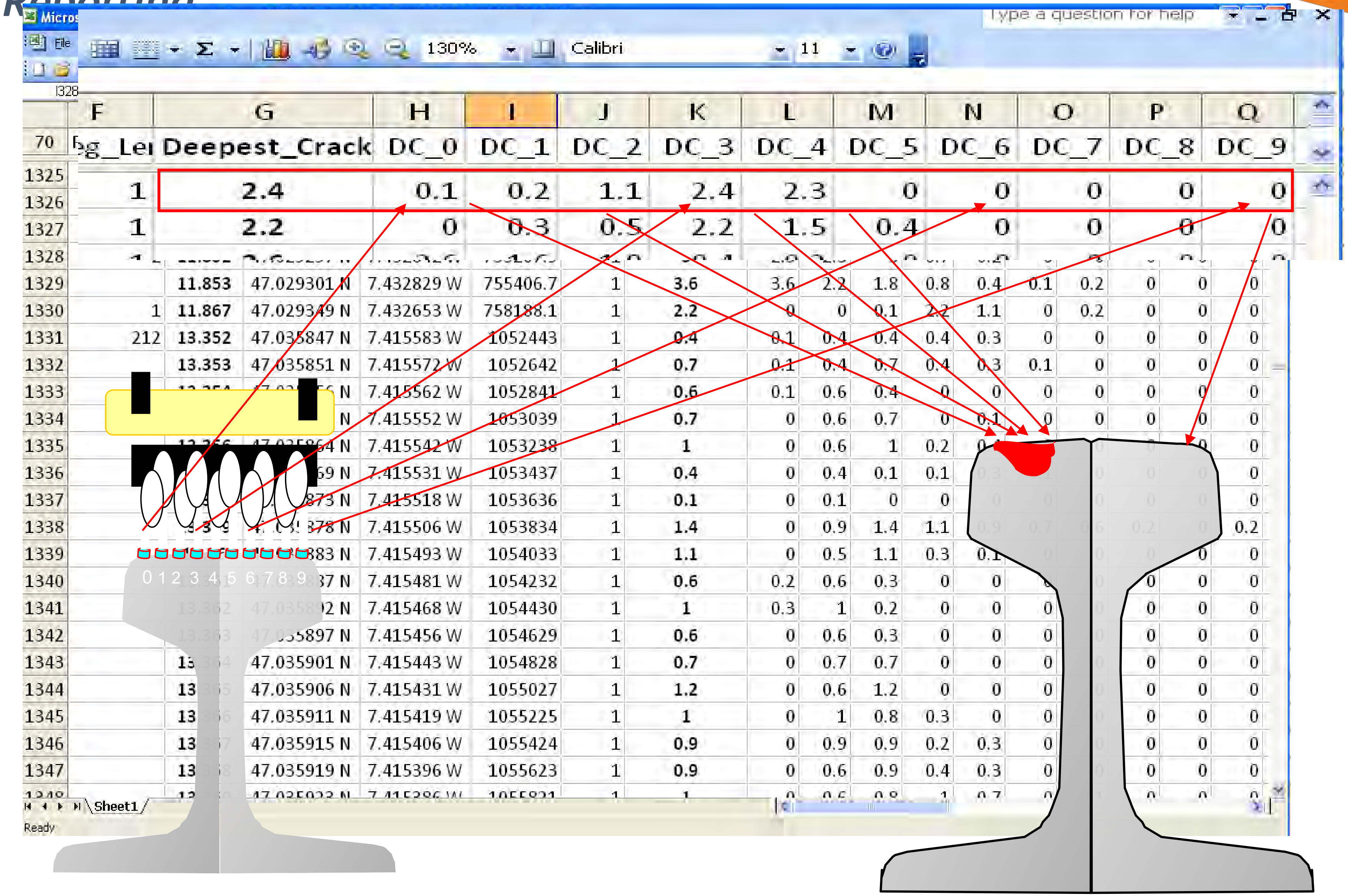
Region	Volume by Severity					Overdue for Inspection					Non compliant Inspection				
	VS	S	H	M	L	VS	S	H	M	L	VS	S	H	M	L
Anglia	2179	355	587	1616	2005	124	21	43	140	116	2010	324	528	1453	1869
East Midlands	1086	174	266	679	604	223	31	57	140	100	822	141	201	516	476
Kent	1029	215	339	843	973	153	40	62	172	147	812	162	255	592	766
LNE	3191	471	723	2176	1886	277	38	77	157	179	2817	422	631	1985	1678
LNW North	1753	277	463	1035	1227	330	47	78	106	130	1383	229	377	917	1088
LNW South	3030	413	660	1846	2611	263	43	65	152	134	2692	353	551	1610	2322
Scotland	2328	422	631	1586	1559	217	41	98	281	148	2016	356	503	1206	1212
Sussex	1266	200	333	828	1334	60	16	22	43	38	1162	180	303	757	1251
Wales	1040	180	228	567	758	200	28	45	113	107	821	149	179	451	641

Region	Planned Remediation					UnPlanned Remediation					Notifications				
	VS	S	H	M	L	VS	S	H	M	L	VS	S	H	M	L
Anglia						2179	355	587	1616	2005					
East Midlands						1086	174	266	679	604					
Kent						1029	215	339	843	973					
LNE						3191	471	723	2176	1886					
LNW North						1753	277	463	1035	1227					
LNW South						3030	413	660	1846	2611					
Scotland						2328	422	631	1586	1559					
Sussex						1266	200	333	828	1334					
Wales						1040	180	228	567	758					

Contains commands for working with the selected items. 115%

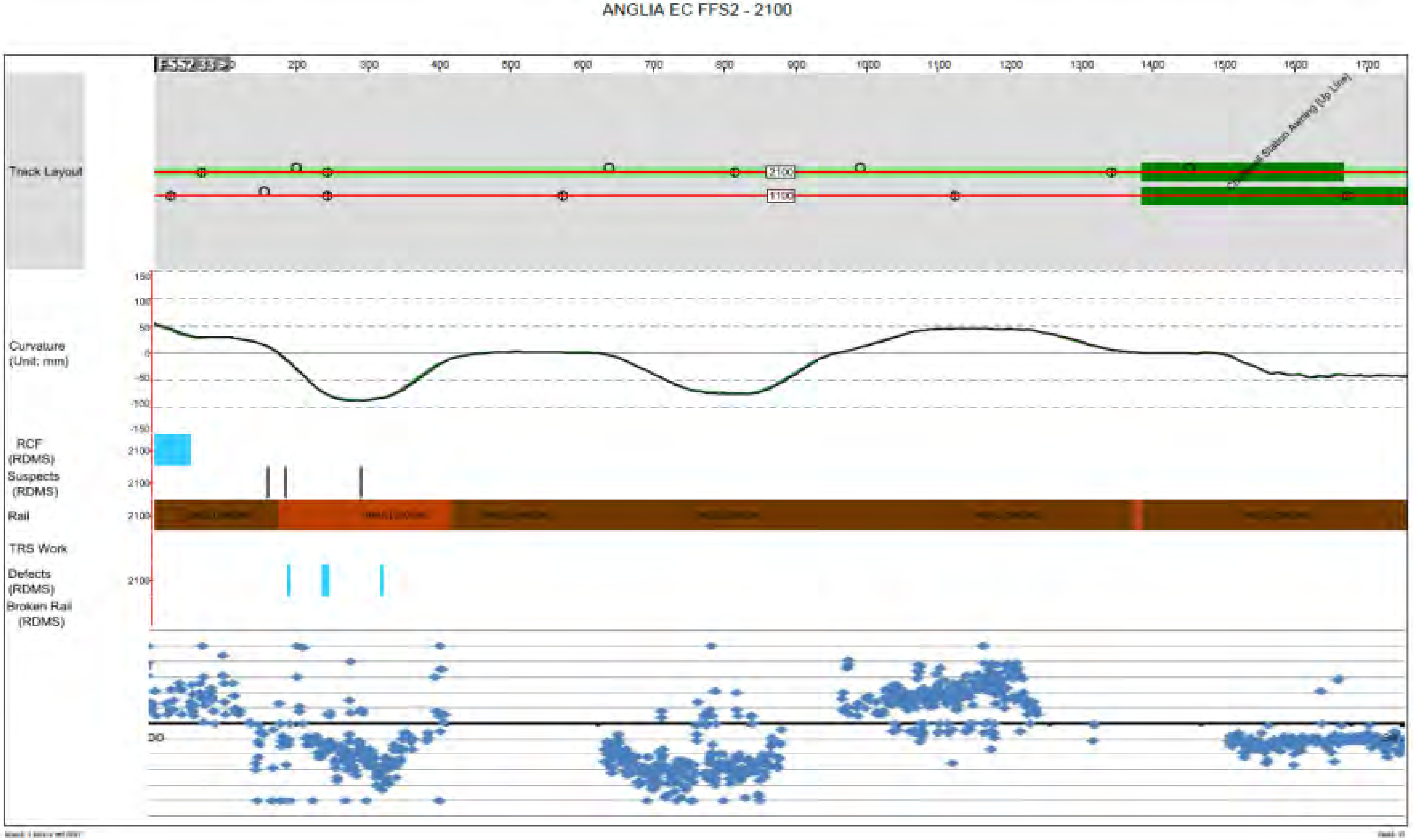
RDMS Link

Reporting



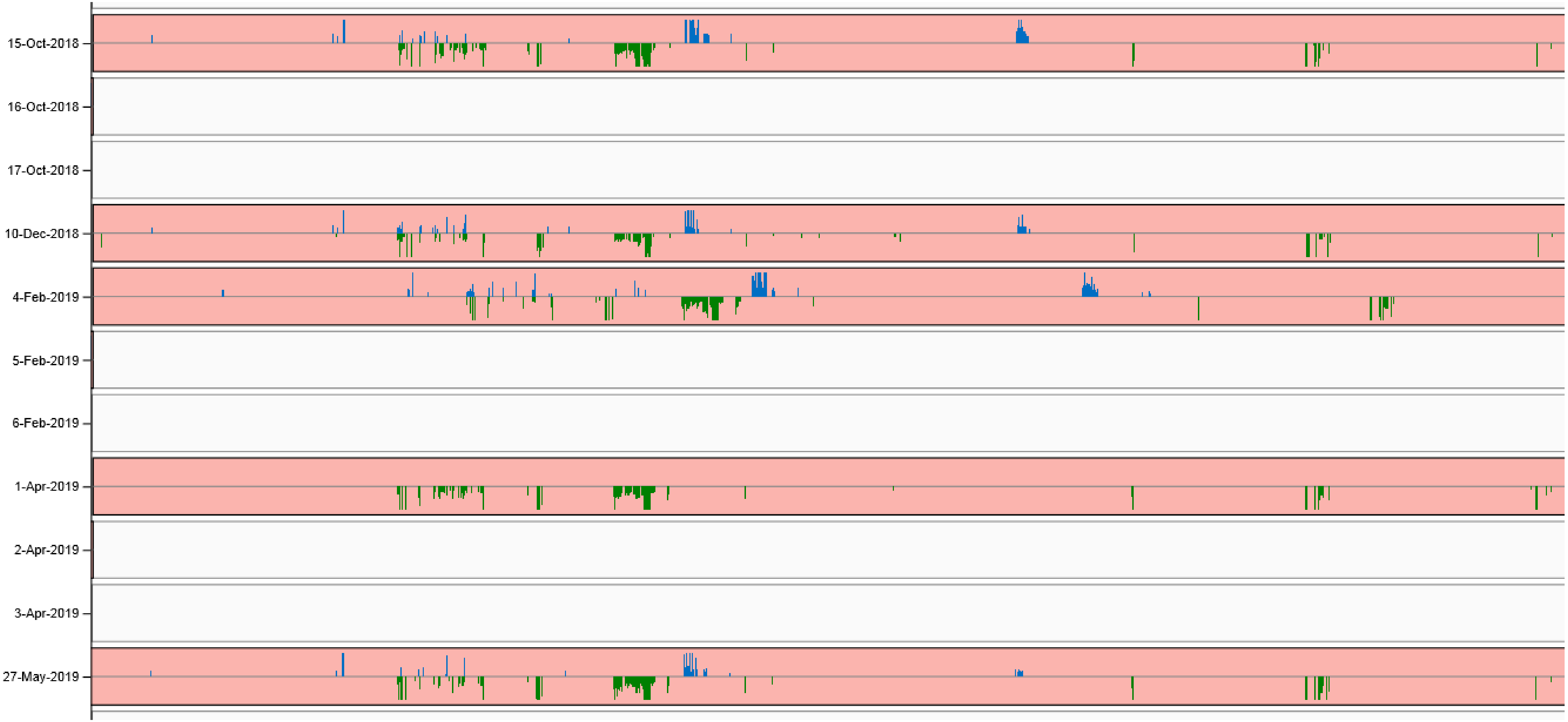
	F	G	H	I	J	K	L	M	N	O	P	Q
70	?g_Le	Deepest_Crack	DC_0	DC_1	DC_2	DC_3	DC_4	DC_5	DC_6	DC_7	DC_8	DC_9
1325 / 1326	1	2.4	0.1	0.2	1.1	2.4	2.3	0	0	0	0	0
1327	1	2.2	0	0.3	0.5	2.2	1.5	0.4	0	0	0	0

Eddy Current Data - Visualisation



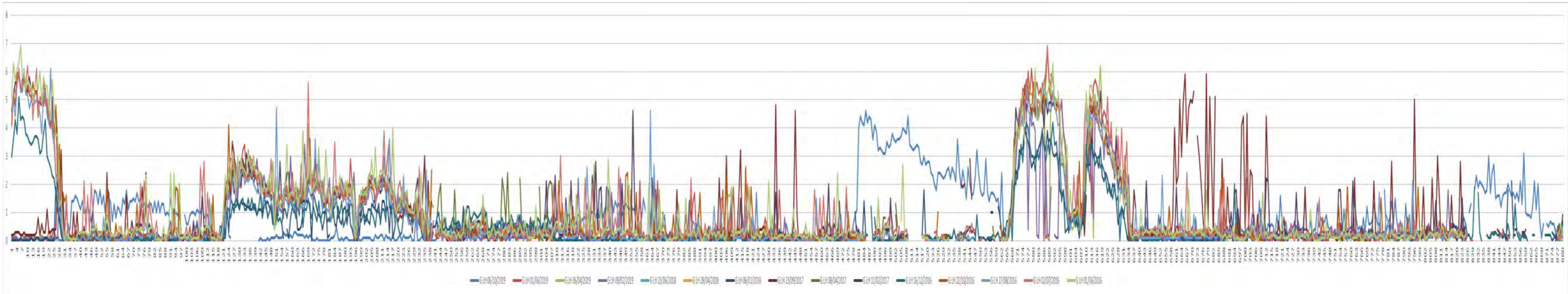
[Link to SDMS](#)

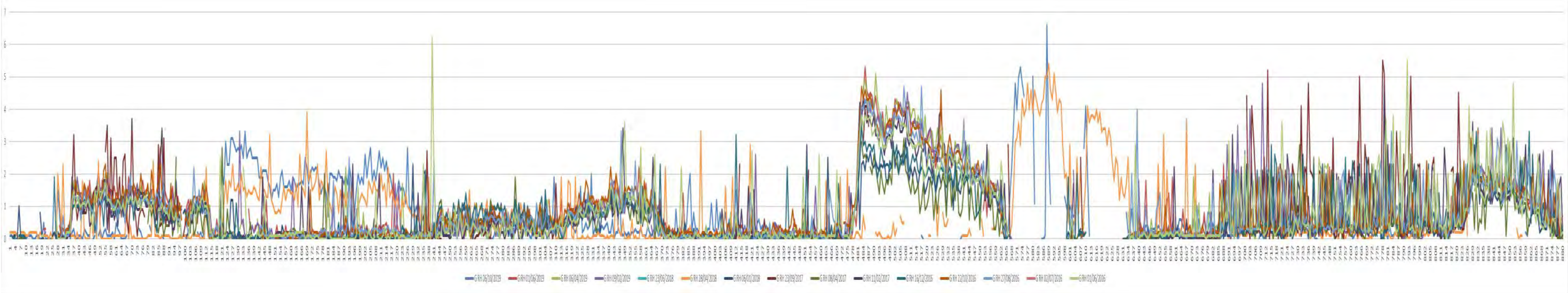
Run on Run Analysis, Repeatability, Consistency



[Link to SDMS]

Rail Profile (Sidewear) – Data Issues Left and Right rail reversal

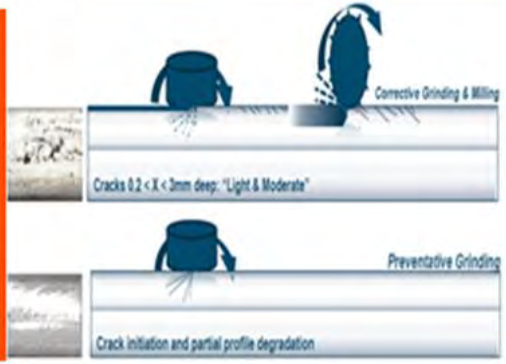




Remediation through Milling

Rail Milling Profile Management

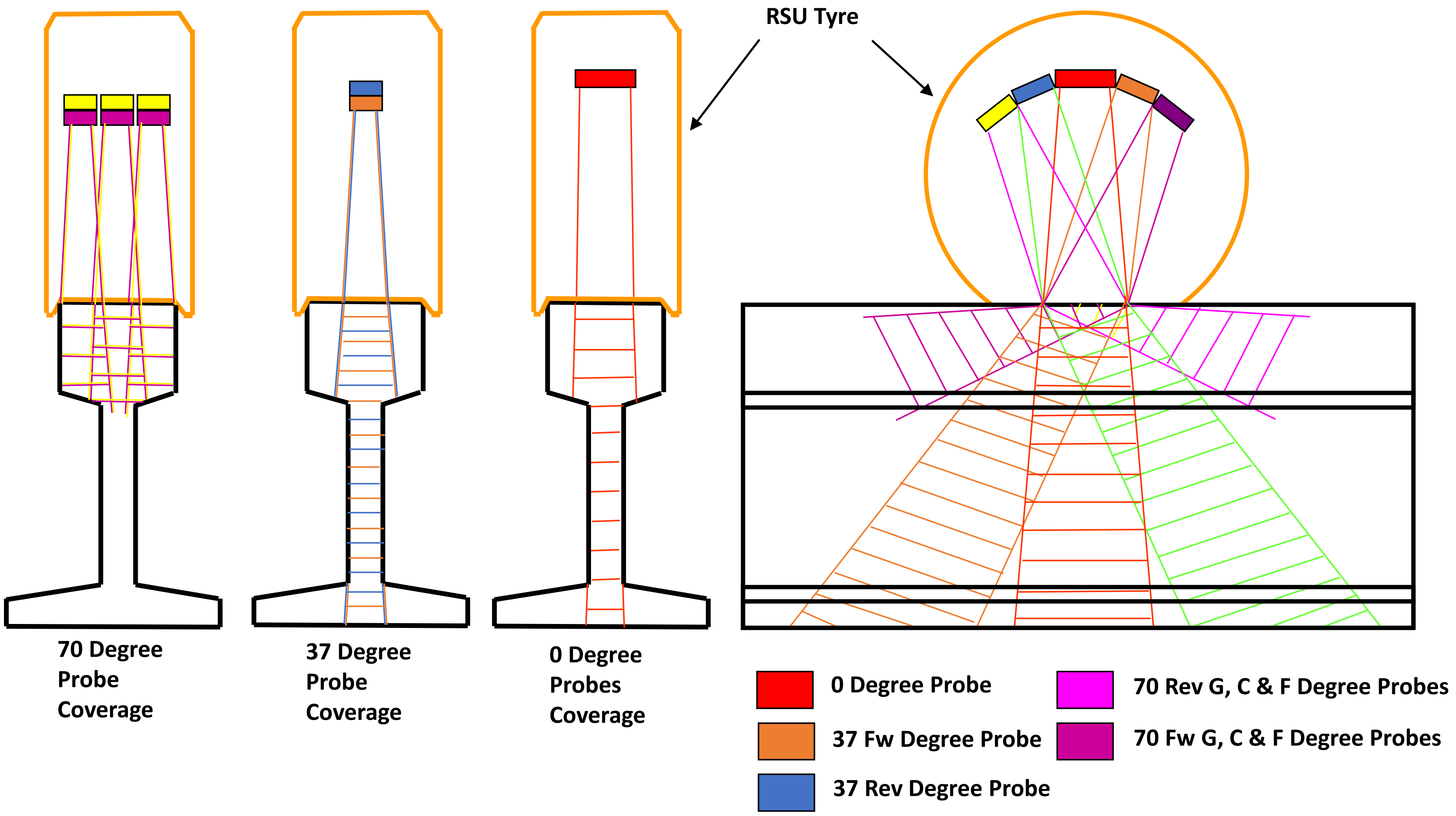
- Two Contracts agreed,
  - Schweerbau HSM 3 year service starting 07-2018
  - Linsinger Duplex procurement delivery March 2021
- Delivering rail re-profiling & defect removal = increased rail life



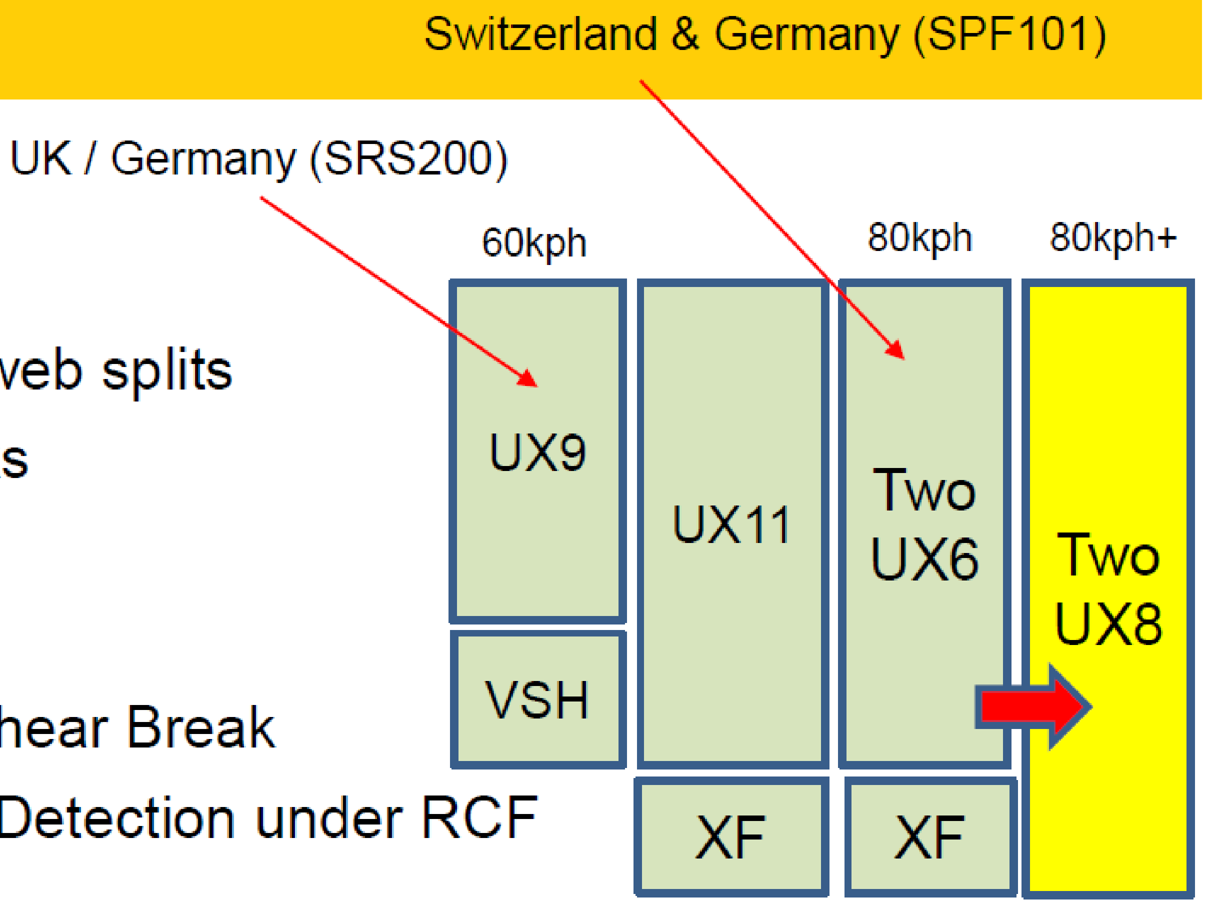
Sperry B Scan Flaw Detector

- Upgrade of existing equipment using original frame and roller search unit
- Output mirrors B Scan output from UTUs
- Can be used in A Scan mode replicating the current equipment
- B Scan equipment provides full recording of all test data
- Reduced weight as no additional flaw detector required
- Can be used with range of hand probes
- Increased battery life
- Built in GPS and encoders for accurate location
- Menu driven screen for more accurate in built defect reporting

UX9 (current UK UTU Fleet)



Ultrasonic RSUs



Core Transducers

- 0° Horizontals such as head and web splits
- 37° Bolthole cracks and base cracks
- 70° Transverse defects in rail head

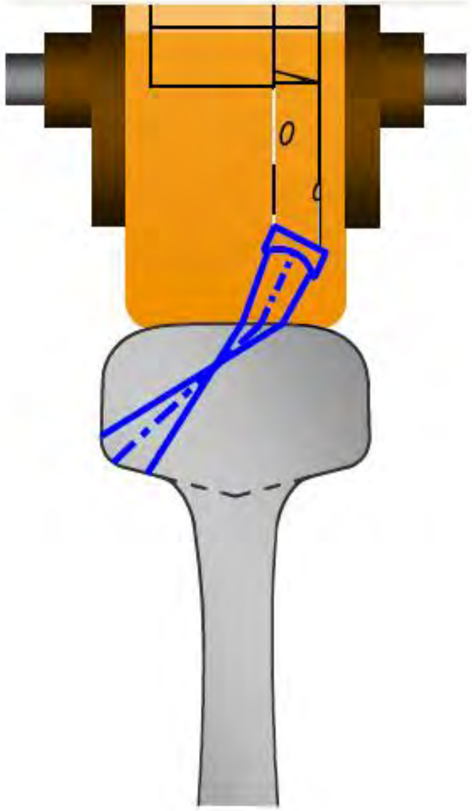
Additional Transducers

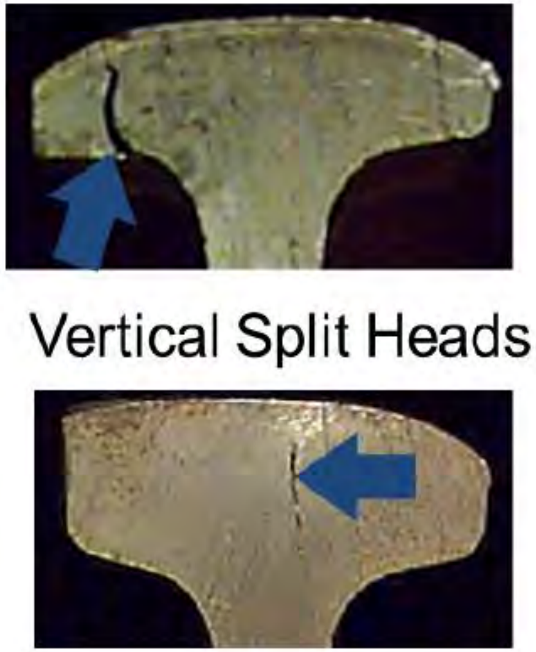
- VSH Vertical Split Head / Shear Break
- X-Fire® Improved Transverse Detection under RCF

Note: In North America both VSH/ Sidelookers and X-Fire® are essential

Porthkerry Derailment Down Vale of Glamorgan Line (VOG)
2nd October 2014

VSH / SideLooker RSU



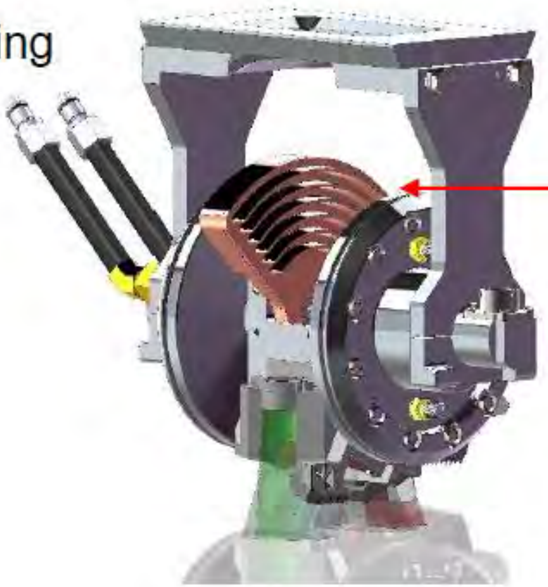


Vertical Split Heads

UX8 RSU

New for 2019

Inlet /outlet ports for cooling and heating RSU



Heat exchanger

Prototype UX8 already tested over SBB calibration track. 4500Hz PRF

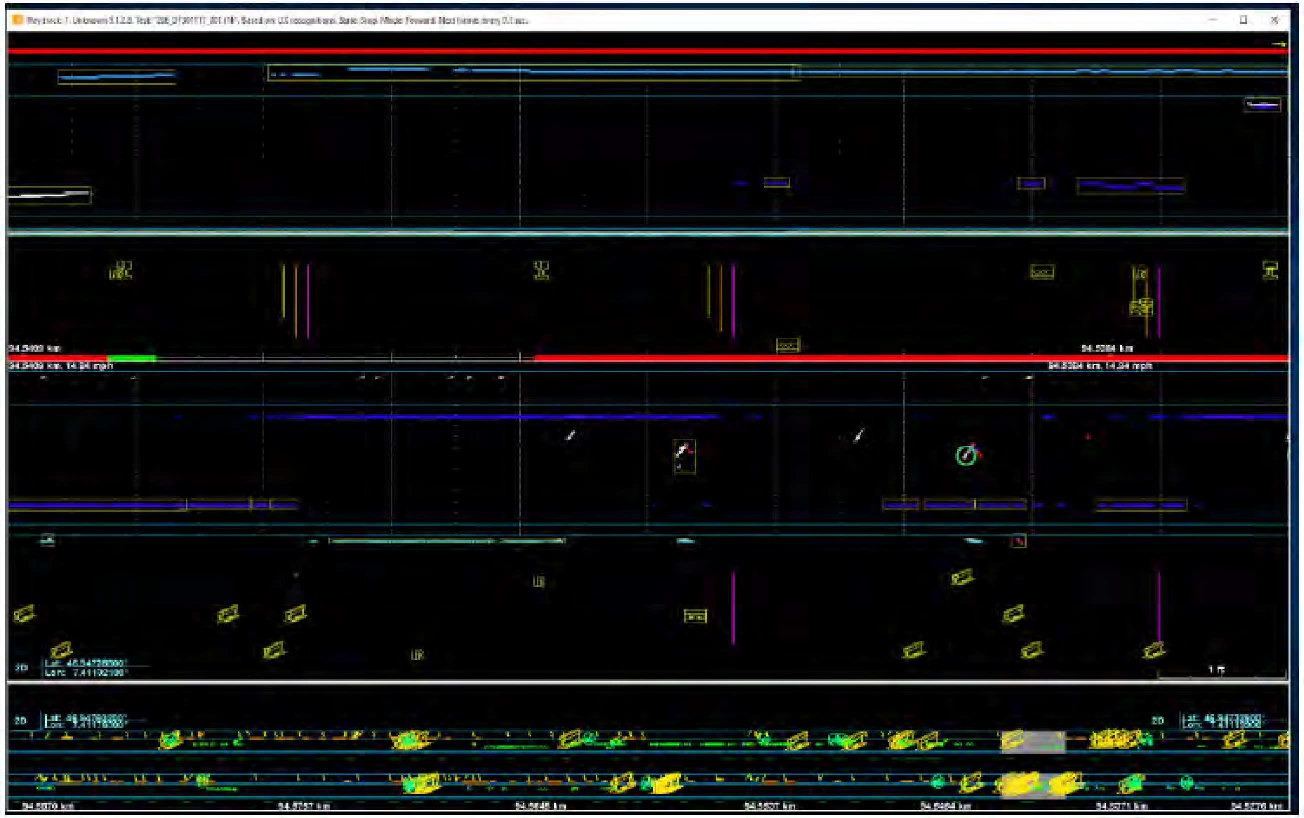
Will be deployed in Australia in Oct 2019

8 Channel Ultrasonic Highspeed RSU – Temperature Control (2019)

Synchronised Eddy Current and Ultrasonic BScan

Severity

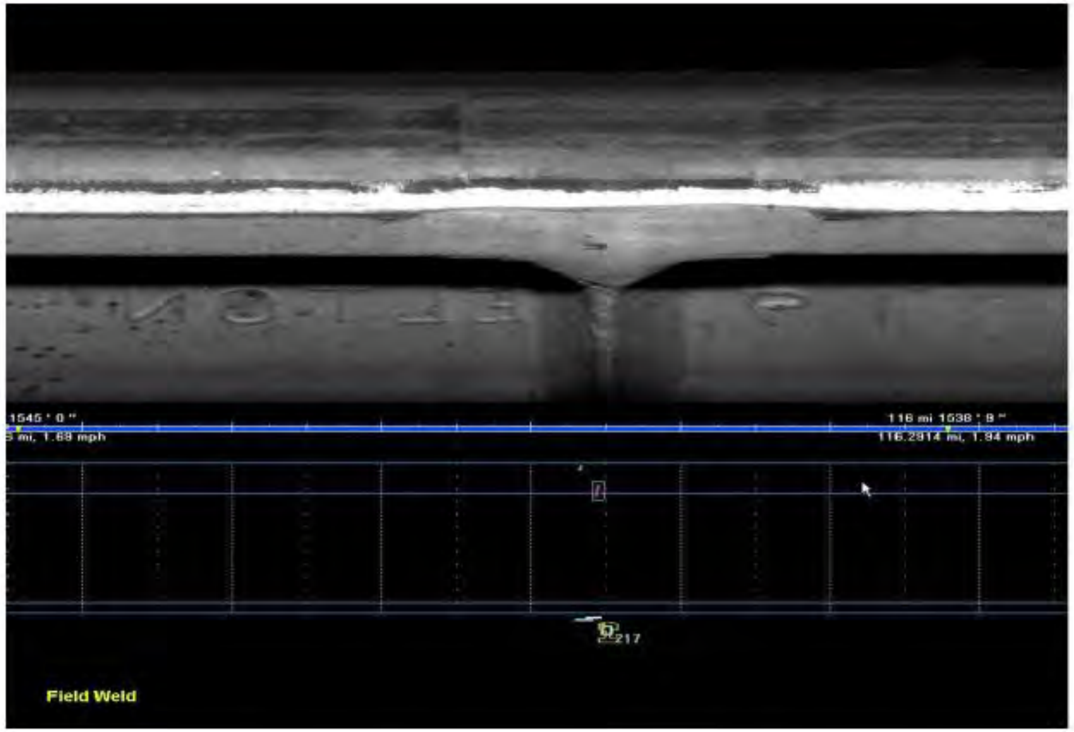
Crack depth



Analyst making decisions based on combined technologies.
(1950 only)

Vision System

Vision Hardware



Vision image is accessible to analyst from BScan

BScan Lite Dual Rail Inspection System DRIS

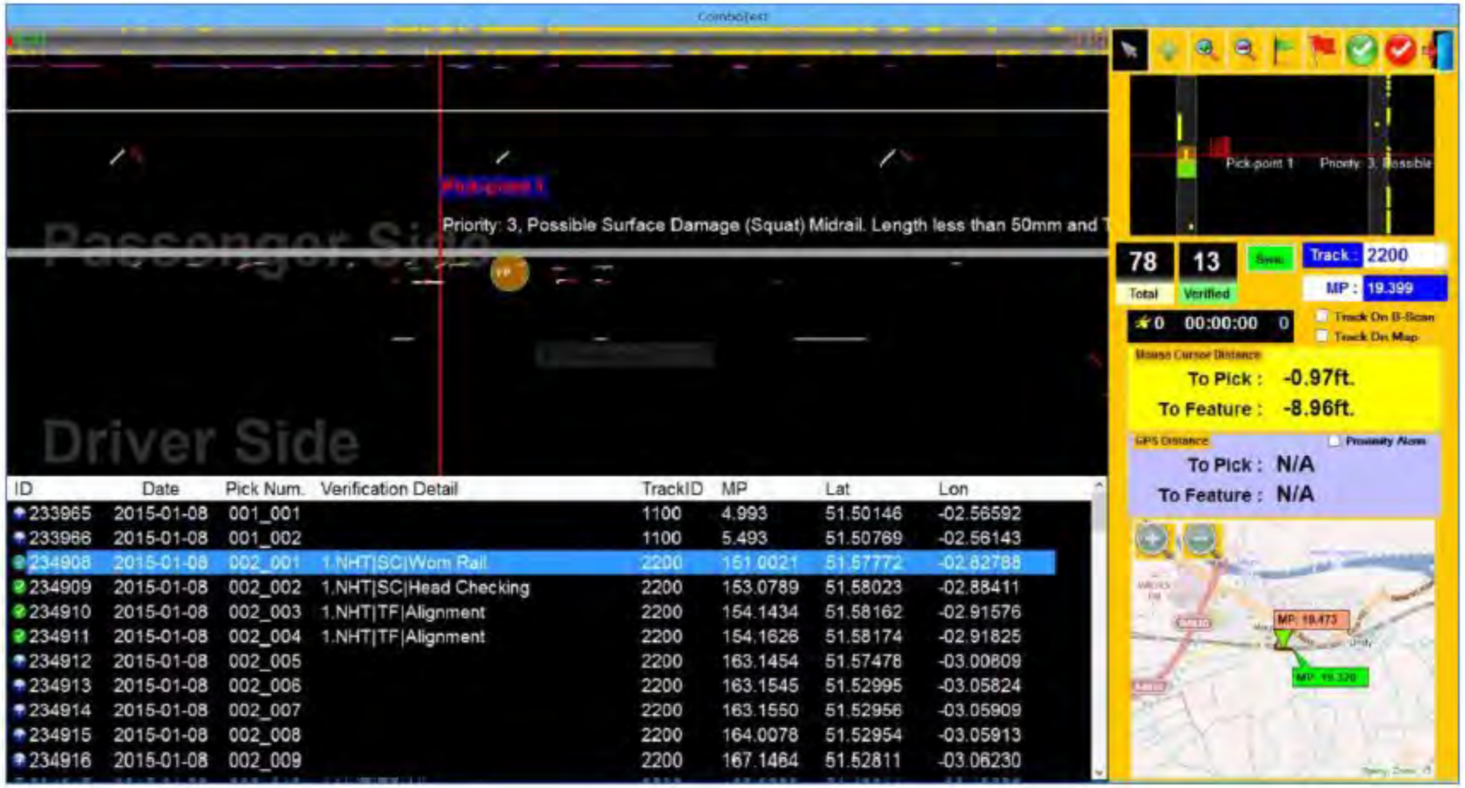
New for 2020

- 2 x UX9 RSU (Inspects Both Rails in One Pass)
- Light Weight Design Construction (Total = 47 kg)
- A Scan and B Scan Display Modes (Tablet)
- B-Scan Lite H/W and S/W Compatibility (Limited Operator Training Transfer from B-Scan Lite W.Stick)
- Offers Real-time and Offline Data Analysis
- Two Supply Configurations (Complete System or Mech and Elect + 2 x Existing NR W.Stick RSU)

SPERRY

Hand-Held verification

Multiple trials carried out to demonstrate the functionality



Combining Data – Better Information

TME	TSM	ELR	Track ID	Mile	Yard	Chain	Rail Side	Speed	Measurement Date	Rail Section	Gauge Side Wear	Gauge Side Step	Field Side Wear	Field Side Step	Head Width	Head Width Remaining	Combined Side Step	Vertical Wear	Estimated Rail Depth	Fishplate Clearance	Lip Width	Inclination Deviation	Gauge Face Remaining	Web Width	70mm - Head Width	GPS - Lat	G
TME Swansea	SWM2	1100	250	728	33.1	L	75	02-Aug-18	Br109fb	-0.2	18	0.4	17	69.8	17.8	35	4.0	154.8	10.0	0.0	-0.8	19.2	15.6145	0.2300	51.83853912	-4.431075096	
TME Swansea	SWM2	1100	250	728	33.1	R	75	02-Aug-18	Br109fb	0.0	18	-1.9	18	71.9	19.9	36	4.6	154.3	9.3	0.1	1.0	24.3	17.4868	-1.9090	51.83853912	-4.431075096	
TME Swansea	SWM2	1100	250	731	33.2	L	75	02-Aug-18	Br109fb	0.3	17	-0.2	18	69.9	17.9	35	3.9	155.0	9.7	0.0	-0.3	19.2	15.7142	0.0630	51.83852005	-4.431099892	
TME Swansea	SWM2	1100	250	731	33.2	R	75	02-Aug-18	Br109fb	-0.4	18	-1.5	18	71.9	19.9	36	5.9	153.0	8.4	0.0	0.5	21.8	17.3489	-1.9310	51.83852005	-4.431099892	
TME Swansea	SWM2	1100	250	735	33.4	R	75	02-Aug-18	Br109fb	-0.5	18	-1.5	18	72.0	20.0	36	6.1	152.7	8.2	0.0	0.9	21.8	17.4065	-1.9780	51.83850861	-4.431152821	
TME Swansea	SWM2	1100	250	739	33.6	L	75	02-Aug-18	Bs113afb	-0.5	18	0.0	17	70.5	18.5	35	3.4	155.4	10.9		-0.5	24.7	20.5534	-0.5110	51.83848953	-4.431206226	

Confirmed during verification as a 1B defect – 20mph ESR, remove within 7 days

Combinations of Defects – Increased Risk

Factors;

Known wet spot in tunnel

- Significant head and foot loss due to corrosion (rail depth recorded as 143 to 146mm, loss of around 15mm compared to a new rail, below minimum rail depth)
- Significant dip angle in plain line present for a long time (repeated dip angle in plain line 27 mrad repeated 36 times) voiding / localised head loss? Fatigue
- 1989 113A R220 rail – no coating
- 90 mph, Track Cat 2, EMGTPA
- 2 sections identified with significant reduction in rail depth / localised head loss
- Dispensation timescales, risks and mitigation?
- Consider other factors when assigning MACs and determining action timescales – dynamic loading from dip, poor support conditions, rail strength

Site Name	ELR	Track	Start Mile	End Mile	Rail	Description	MAC	Date Found	Due Date	Status	Track Cat	Line Speed	Defect Comment
Disley Tunnel	NMC1	1100	174.0760	174.0770	Right	208 - Insufficient rail depth	3T	**25-May-18**	**21-May-21**	Open	2	90	Remove rail in 3 years
Disley Tunnel	NMC1	1100	174.0750	174.0850	Right	208 - Insufficient rail depth	3L	**24-May-16**	**21-May-19(D)**	Open	3	90	Under minimum permitted rail depth

Combinations of Defects – Increased Risk

Table 2 – Minimum rail depths		
Rail section	**Minimum depth (no sidewear)** mm	**Minimum depth (sideworn)** mm
CEN60 E1 and E2 flat bottom plain line CEN60 E1 and E2 flat bottom S&C	158 162	158 + ***L*** 162 + ***L***
109 / 110A / CEN56 (113A) flat bottom 98 flat bottom / 95 and 97.5 bullhead 85 bullhead	145 131 127	145 + ***L*** 131 + ***L*** 127 + ***L***

Note:
$L = 9 - 0.5S$
Where L is the lateral head loss and S is the NR4 standard step gauge reading.

3.3 Action for rail at or below minimum permitted depth

Replace the rail within three years of the minimum depth specified in Table 2 being reached.

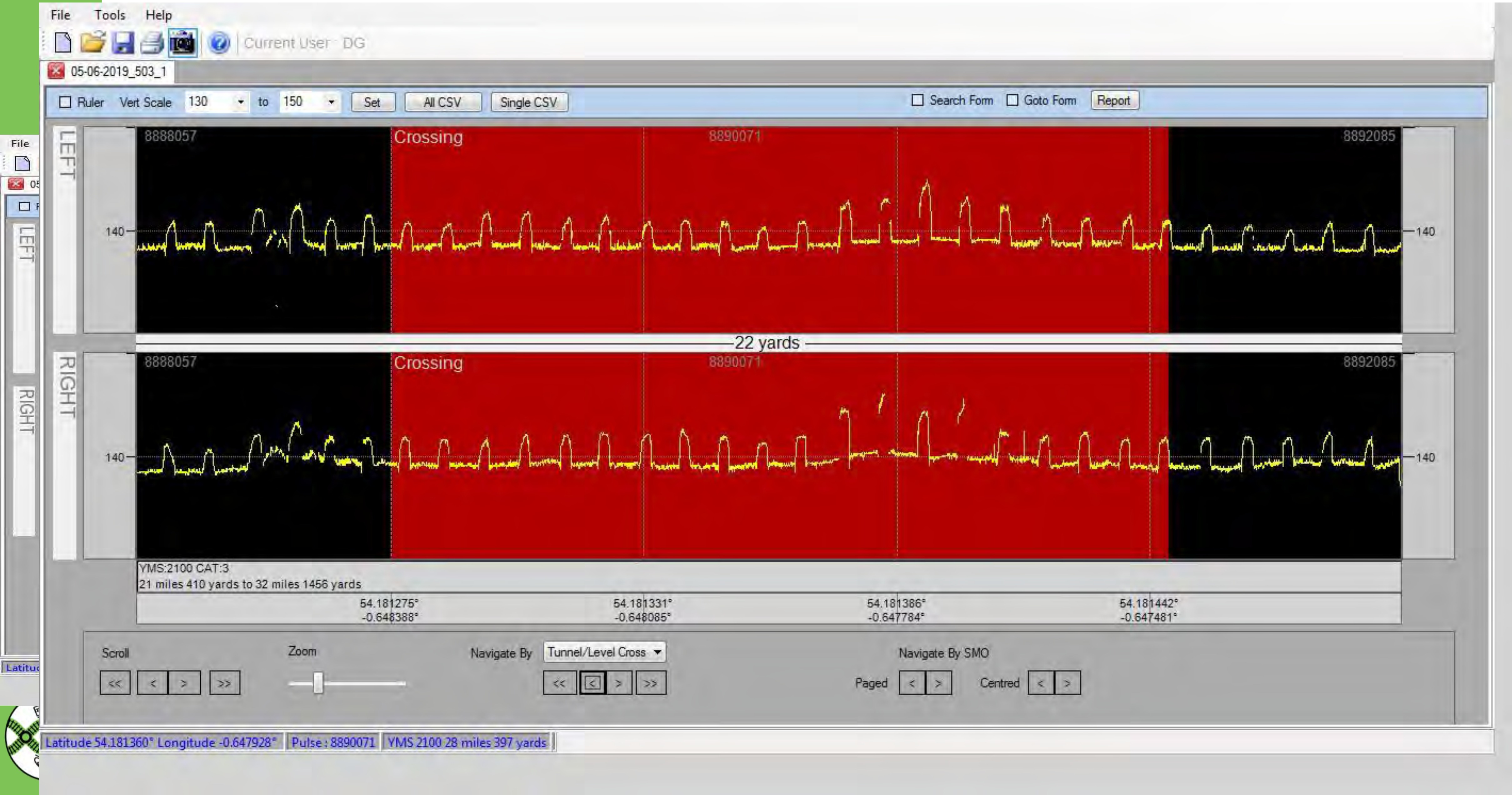
- Identified as a cracked rail by PLPR inspection 2nd September 2018
- Rail has fractured up from the rail foot and propagated along the top of the web for approximately 300mm with a significant risk of a section of the rail head breaking out
- Minimum rail depth exceeded at one location and entered into RDMS as a 3L (52 week defect), original removal date May 2017 dispensated until May 2019

Minimum rail depth reached and rail entered into RDMS in May 2018 as a three year defect due May 2021.

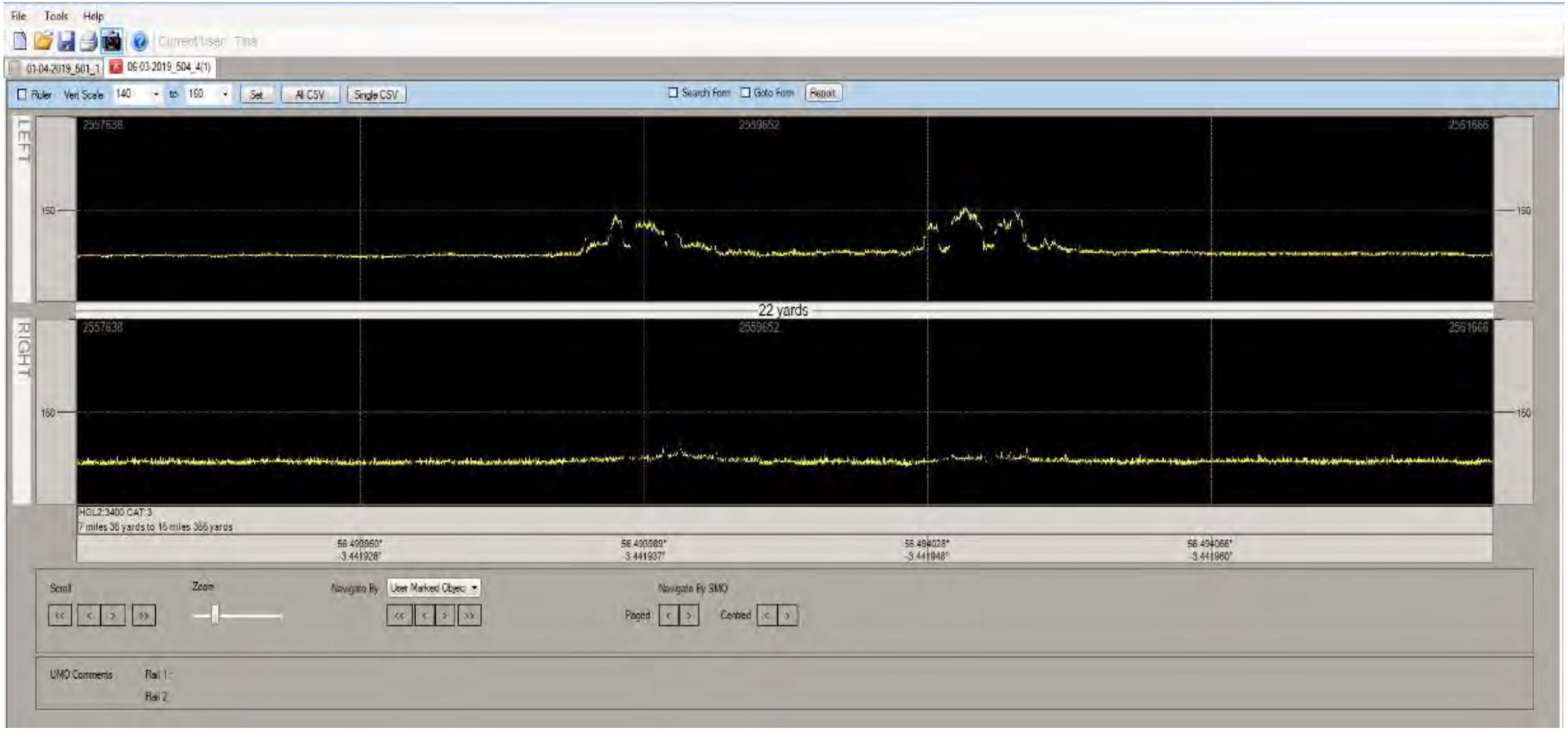
Replace the rail **within 3 years** or replace the rail in 3 years time?

Are selected **Minimum Action Codes** appropriate?

Combining Data – Rail Depth from UTUs



Combining Data – Rail Depth from UTUs



Guided Wave Ultrasonics - G – Scan Mk 2

Second generation longitudinal wave ultrasonic equipment now being trialled on LNE to screen level crossings for corrosion and potential loss of rail section.

System using a longitudinal wave and mode transformation caused by any loss of rail section anywhere in the rail rather than conventional ultrasonics which works based on a reflected signal from a specific defect or surface.

Intelligent Infrastructure Project, II, eDST

	Work Package Description	Target Reduction
Work Package A	• Track Geometry & Cyclic Top Defect Review Page • PLPR Defect Review Page • Maintenance Dashboard & Landing Page • Intervention Support & Planning Page • Track Quality & Trace Review Page	Manual Basic Visual Inspections

Work Package B	• Rail Management Defect Review Page:
	  • Rail Depth
	  • Side Wear
	  • Rail Profile Faults
	  • Rolling Contact Fatigue
	  • Rail Flaws
	  • IRJs
	  • Ballast Profile
	  • Work Specification
		Insulated Rail Joint Inspections
		Track Geometry Measurements
		Manual Rail Depth Inspections
		Rolling Contact Fatigue Testing
		Manual Ultrasonic Testing
		Side-wear Inspections

Work Package C	• Structure Gauging • Supervisor's Inspection App • Rail Stress Data - Analytics & Mobile Inspection App	Datum Plate Surveys

- The automatic identification of issues presented in the EDST
- Ability to predict where issues will occur
- Ability to prioritise workbanks
- Longer lead time to determine the desired intervention allowing for the best intervention to be selected
- Ability to make risk-based inspections
- Access to historic data across the network
- Consolidation of data for each issue in one place (EDST)

- Ability to view the location of faults through a mobile app
- Ability to view the details of planned work through mobile devices whilst at risk sites
- Ability to identify work which has been done previously and also not yet been completed

It’s not just broken and defective rails

Understanding track buckle risk

Current research activities looking at a number of areas

Modelling with University of Southampton to better understand risks and to carry out a sensitivity analysis to look at potential to review hot weather management requirements in mod 14.

Model considers a range of factors and their contribution to buckling risk.

SFT measurement

Current research activities looking at non intrusive measurement of rail stress and SFT

University of Sheffield research development to measure SFT using ultrasonic time of flight technology without the need to unclip rail.

Initial site trials at Grange sidings today in conjunction with the induction welding approval programme.

Induction Welding

Rail ends are then aligned and pushed together and held under pressure.

Simple induction coil placed around the ends of each rail.

Controlled heating of the rail ends achieved by varying frequency and power input to heat the rail ends to just below melting point.

Heating cycle typically takes around 3 to 3 ½ minutes

Temperatures can be very accurately controlled to achieve precisely the correct rail end temperature across the entire rail section.

Careful control required due to the variable thicknesses of the rail section with the head requiring more heat input than the thinner section web and foot.

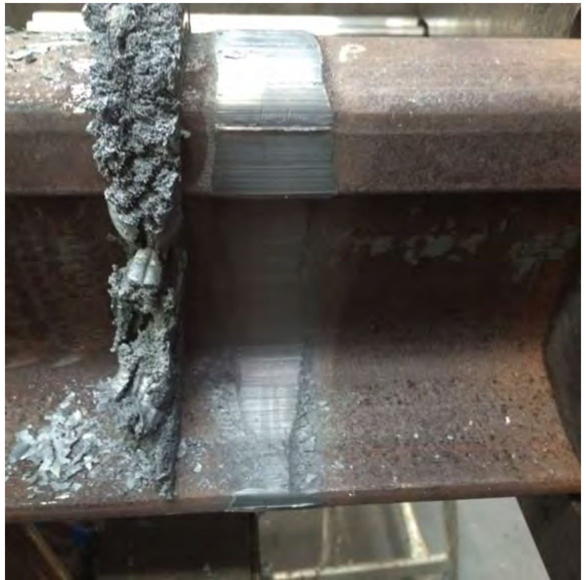
Rails are then forged together expelling the rail end material forming an upset around the weld.

The heating coil is then moved to one side and a stripping die fastened around the rail.

Stripping die is then pushed along the rail to remove the excess upset material from all round the weld.

Weld is then allowed to cool and finished by profile grinding around the head of the rail.

Grinding carried out to achieve the high degree of accuracy (+0.4 / -0.0 mm) flatness across the weld.



Initial Test Results

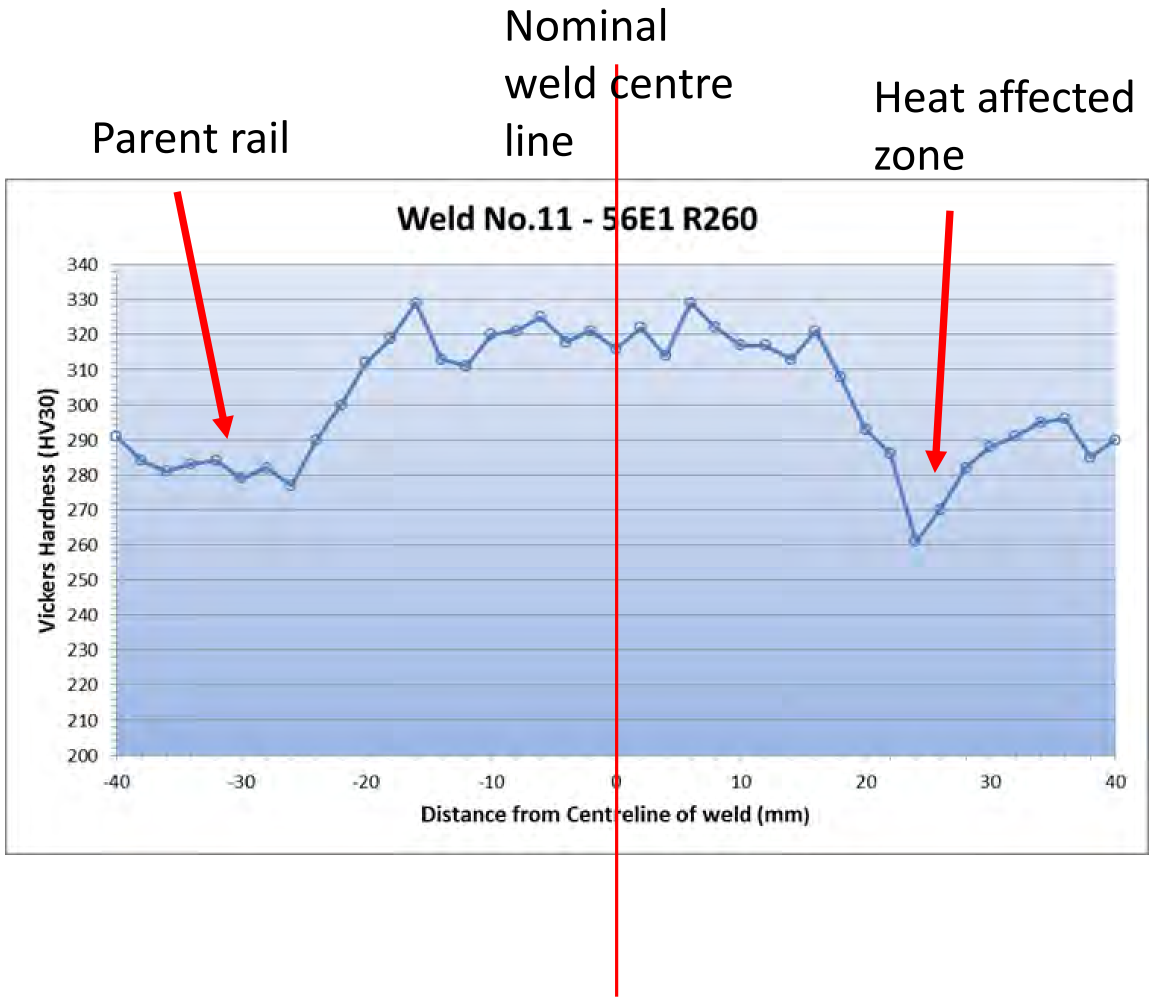
Sections through the weld machined and hardness tested from the parent rail through the weld and back into the parent rail.

Initial welds show a slightly increased but very constant level of hardness compared to the parent rail with only slight drops in hardness in the heat affected zones

Hardness survey shows no evidence of material changes around the weld fusion area.

Metallographic examination of the microstructure shows no fusion line with a homogenous structure throughout the weld.

No weld line visible with ends fully fused

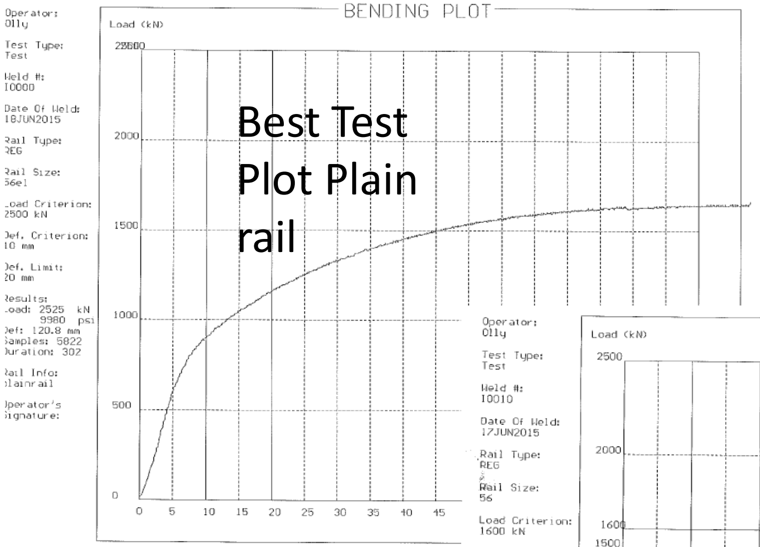


Initial Test Results

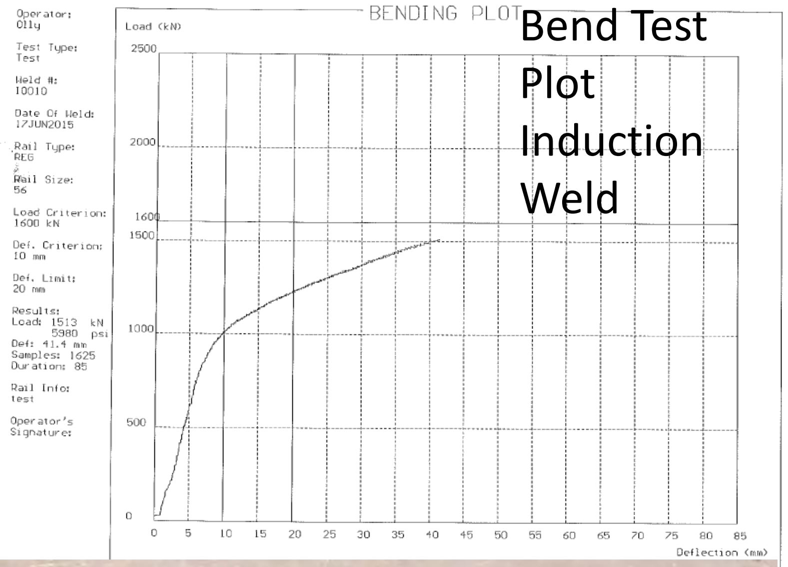
Bend tests carried out to compare the weld performance to an un-welded section of plain rail.

Welds achieving virtually the same strength as the plain rail.

Rails distorted permanently rather than breaking along the weld line.



Best Test Plot Plain rail



Bend Test Plot Induction Weld

Bend tests indicate a weld strength over 150 tonnes for 56 E2 rail

The Competition

Conventional alumino-thermic welding;

Highly portable – minimal plant required

Two man team required

Now very reliable with failure rates of around 1 in 50,000

Able to fill a gap between the rail ends without consuming a length of rail like forged welds

Easily scalable by using more welding teams as required

Typical weld time around 2 hours plus finishing time

Conventional flash butt welding;

Significant plant required to provide very high levels of electrical power required to heat the rails using resistance heating (60,000 amps)

Typical road rail vehicle around 30 tonnes, welding head large typically around 3 tonnes

Very reliable with failure rates of around 1 in 100,000

Flash butt welding consumes a length of rail during forging

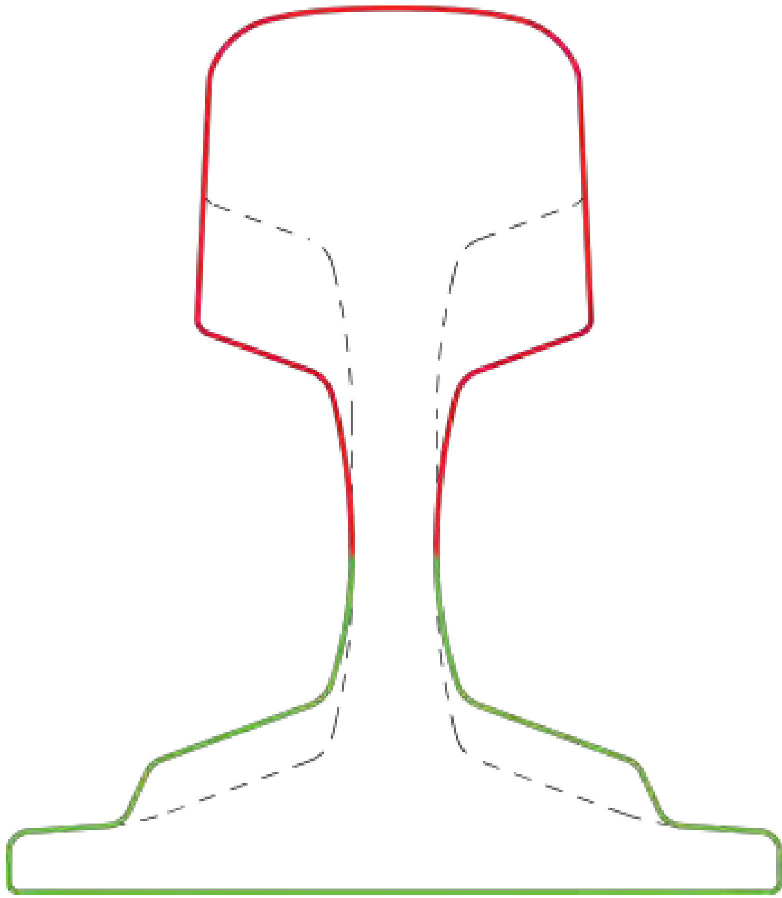
Typical weld time around 8 minutes plus finishing time

Design for Reliability – University of Huddersfield

Developed profile – result of parametric evaluation of a matrix of cross-sectional designs

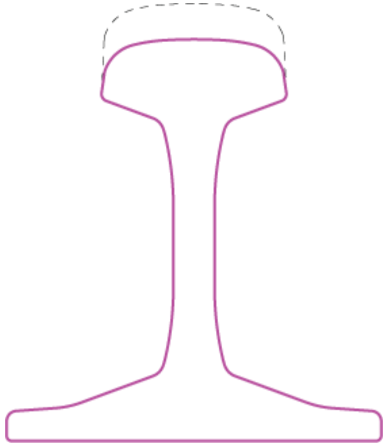
Key features compared to 60E2:

- Head & foot width, rail height, crown profile, web thickness, foot tip thickness maintained – no implications for gauge, sleeper seat, and fastenings
- Head height increased 50 % - area by ~63 %
- Foot area increased by 38 %
- Web area reduced by 31 %
- Overall increase concentrated in the head and centre of the foot, (part affecting performance and life span)
- Location of neutral axis unaltered

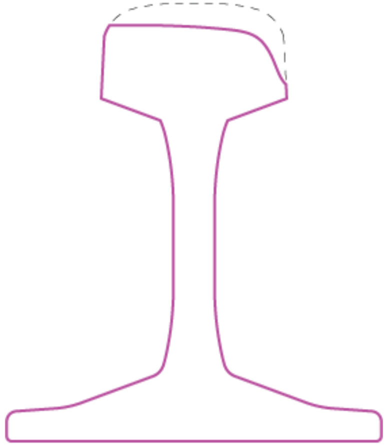


Implications of Design for Rail Wear

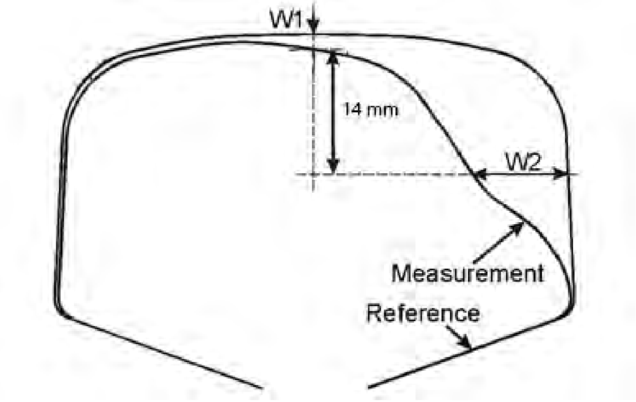
- Worn profiles of the reference 60E2



60E2 WV14

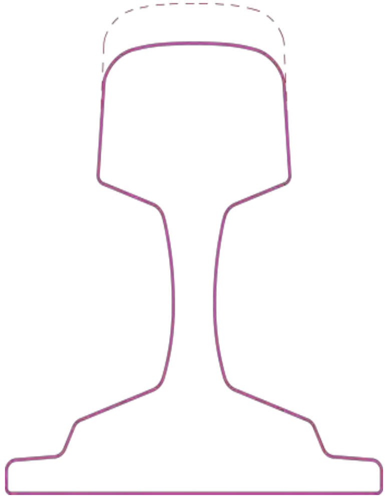


60E2 WVL14

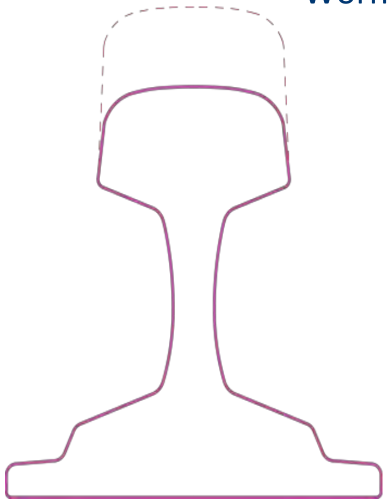


$$W = W1 + W2$$

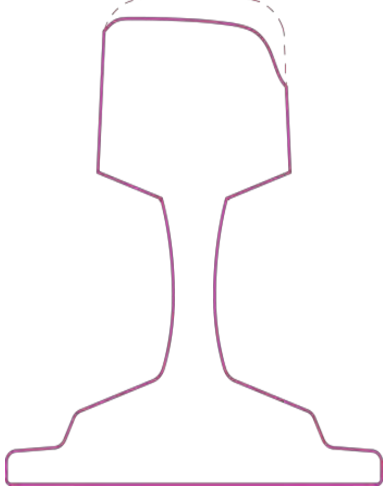
- Worn profiles of the designed HDFTO



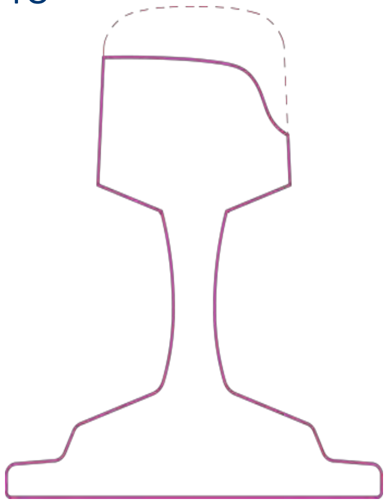
HDFTO WV14



HDFTO WV28



HDFTO WVL14



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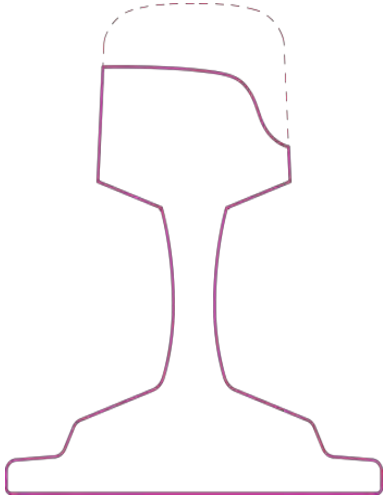
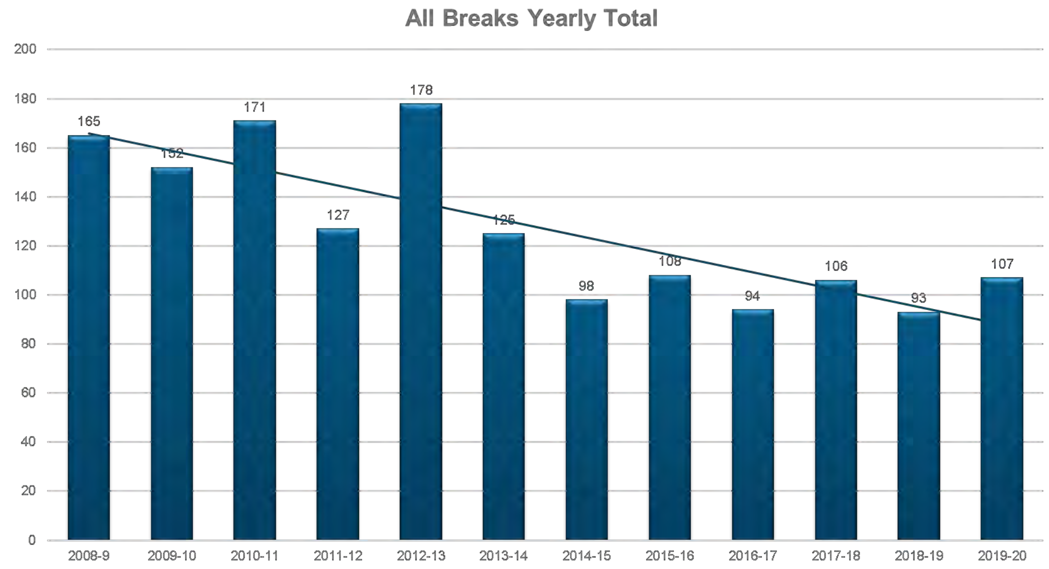
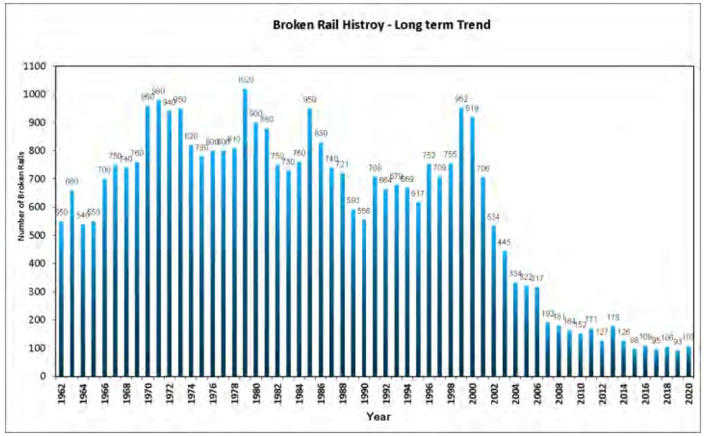


HDFTO WVL35

Record Low Numbers of Broken Rails

Still a fair comment?





Whilst we had 93 breaks in 2018 – 2019 and 107 in 2019 – 2020 we have still had two derailments due to broken rails in the last six years.

Unfortunately rails rarely fail safely and more traffic, increased tonnages, higher speeds and modern axle counter signalling systems increase the risk of trains continuing to run over broken rails before they are detected

We have not eliminated the risk, we have reduced it but a level of risk still remains.

Future targets 50 x 30 (50 breaks / year by 2030), expectations and PPF

Increased traffic volumes? Reduced access? Modern vehicles and increased RCF?

Many thanks for your time and the opportunity to present

Any Questions?

everyone
home safe
every day

Technical Authority

Providing technical leadership