2023

Extreme Heat Taskforce Final Engineering Report

REVIEWERS & AUTHORS

Neil Andrew

Peter Blakeman

Peter Dearman

Andrew Went

Sir Douglas Oakervee CBE FREng

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- **These Items have not been included.**

1.0 Glossary of Terms

AC Unit	Air Conditioning Unit
ADD	Automatic Dropping Device
S&T	Signalling & Telecommunications
AIS	Asset Information Services
ASC	Area Signalling Centre
AWAC	British Rail Mk3a and Mk3b Catenary (American Wire and Cable)
BCE	Business Critical Equipment
BWA	Balance Weight Anchor
Cat 1 and Cat 1A	The 2 highest categories of UK track based on speed and annual tonnage. Typically, over 100mph and 20 million gross tonnes per annum. Cat 1A is 125mph of any tonnage.
CEO	Chief Executive Officer
CM&EE	Chief Mechanical & Electrical Engineer
CP6	Control Period 6 Network Rail's plan for 2019 to 2025
CRT	Critical Rail Temperature
CWR	Continuously Welded Track
DEAM	Regional Director of Engineering & Asset Management
D&P	Distribution & Plant
ECML	East Coast Main Line
ECR	Electrical Control Room
E&P	Electrification & Plant
EPME	Electrification an& Plant Engineer
ELT/Board	Executive Leadership Team / Network Rail Board of Directors
FEA	Finite Element Analysis
FTN	Fixed Telecommunication Network
GIS	Geographic Information System
GSM-R	Global System for Mobile Communications – Railway
HS1	High Speed Train 1 Railway

IME	Infrastructure Maintenance Engineer
IMDM	Infrastructure Maintenance Delivery Manager
INSIGHT	Visualisation and Analysis Software applied to asset data.
LADS	Linear Asset Decision Support – Software Tool
MST	Maintenance Scheduled Task (as generated by the Ellipse Maintenance Management system)
NRHS Ltd	Network Rail High Speed Ltd
NR OCR	Network Rail Overhead Conditions Renewals
NRT	Neutral Rail Temperature (U.S. equivalent of SFT)
NW&C	North, West and Central Region
OLE	Overhead Line Equipment
PE Jumper	Potential Equalizing Jumper
PLPR	Plain Line Pattern Recognition
PTA	Public Transport Authority of Western Australia
RBM	Risk Based Maintenance
REB	Relocatable Equipment Building
RC	Return Conductor (on OLE)
RCM	Reliability Centred Maintenance
R&D	Research & Development
ROC	Route Operational Control Centre
S&T	Signalling & Telecommunications
SFT	Stress Free Temperature
S&C	Switches and Crossings
SRE	Safety Related Event
TA	Network Rail's Technical Authority
TfNSW	Transport for New South Wales
TME	Track Maintenance Engineer
TRL	Technology Readiness Level
TSMP	Track Stability Management
UTU Train	Ultrasonic Test Unit Train
WCML	West Coast Main Line

2.0 Panel Chair's Foreword

Network Rail is known as one of the safest railways worldwide but during the extreme heat experienced on the !8th and 19th July 2022 abnormal measures were adopted to ensure passenger safety. However, these measures were both inconvenient and disruptive for customers. Concerned over the level of service disruption and with extreme heat being predicted to become a frequent event in the coming years due to global warming, Andrew Haines, OBE of Network Rail, on the 20th July launched the Extreme Heat Taskforce (EHTF). Its purpose to examine how the levels of resilience of the network could be improved to tolerate these changing weather patterns as well as considering how other countries, which already cope with extremes and wide ranges in temperature, manage. A copy of the NR press announcement of the EHTF can be found in Appendix A.

On the 19th July Andrew Haines invited me to lead the Engineering investigation as part of the EHTF Review.

On the 26th July I received a Draft Brief for the exercise from NR's Martin Frobisher OBE, Group Safety and Engineering Director, Technical Authority. A copy of the Brief can be found in Appendix B.

Given that the railway is a complex system and embraces many branches of engineering, with the agreement of the Group Safety and Engineering Director, Technical Authority I invited Peter Dearman, Andrew Went, Neil Andrew and Peter Blakeman to assist me in their various areas of expertise. Their curriculum vitae can be found in Appendix C along with my own.

It was subsequently agreed that, given the breadth and extent of the task required, in addition to the Initial and Final report called for in the brief there should be an interim report. Those reports were to be submitted in November 2022, February 2023 and August 2023 respectively. This extended period also took account of the fact that all members of the panel were engaged on a parttime basis due to their other commitments. The most important point was that each of these reports contained the Panel's emerging conclusions and recommendations based on the information and facts available at that time, allowing Network Rail to adopt and, where possible, implement them progressively. This was especially important to be better prepared for the summer of 2023. Network Rail adopted many of these changes. Engineering standards were re-issued with changes which will deliver greater resilience.

To fully understand the approach, the review has taken to reach its final recommendations, this third and final report is best read in conjunction with the Initial Report submitted in November 2022 and the Interim Report submitted February 2023. The Initial and Interim Reports have been appended to this Final Report to provide a complete understanding of the whole review and how the observations and recommendations have developed. This staged approach to the delivery of our findings has enabled NR to progressively implement the changes advocated. The Initial and Interim Reports served the Review well by provoking meaningful discussion and debate which has strengthened the final recommendations of the Review. However, because they were very much working documents unlike this the final report, they were not independently proofread. Therefore, I apologise for any typos, grammatical or spelling errors in the earlier reports. For completeness both these earlier Reports have been included in Appendix E and F.

Although there was no formal call for evidence, I am extremely grateful to the large number of Network Rail officers and staff from all levels and regions who gave freely of their time and their candour with which they have responded to our enquiries. A list of those NR staff who were interviewed can be found in Appendix D. The initial interviews arranged by Network Rail were recorded by the company but later this was dropped. In addition to the formal meetings various of the Standards and Specifications have been reviewed the more recent editions having been prepared by the Technical Authority. As may be expected the number of performance records and analyses is vast and not accessible to those not in Network Rail employ. The Board Minutes (redacted copies) for the years 2022 and 2023 have been studied but no published minutes of the Executive Leadership Team meetings have been found in the public domain or made available. Therefore, this report by necessity has largely been based on both anecdotal and speculative evidence.

I am extremely grateful for the time, insight and substantial contribution each member of the engineering team has made in preparing the three Reports produced during this enquiry without whom these could not have been achieved. Throughout the review Arup have provided administrative support without which progress would have been impossible. The substance, findings and clarity of all the reports would not have been possible without that level of cooperation. Lastly, my thanks to Professor Andrew McNaughton who undertook the challenging task of proofreading the Final Report.

Given the importance of the findings and recommendations in this report it was agreed with the Group Safety and Engineering Director, Technical Authority that the Report and its recommendations should be made the subject of an independent peer review. This review was undertaken by Robert Clarke CEng FICE, James Collinson CEng FIMechE and Andy Merritt. Initially Prof. Andrew McNaughton had been invited to lead the peer review but unfortunately this was not possible due to a conflict of interest. The comments and views expressed in those peer reviews have been carefully considered and after discussion some of our final recommendations were modified. My fellow members of the review panel and I are most grateful for the valuable contribution made by the peer reviewers in finalising this Report.

Throughout this report I refer to the conclusions and recommendations of the Review. These conclusions are mine and reached with the support of my colleagues forming the Review Panel. Discussions with the Panel Members were both constructive and challenging. All the Panel members have confirmed that they agree with the Report as presented.

Any errors or omissions in this report are all mine.

Sir Douglas Oakervee CBE FREng

August 2023

3.0 Introduction

At the outset of this Review Andrew Haines provided an additional briefing to the written draft brief provided by The Group Safety and Engineering Director. The essence of the CEO's message was that the Business Model currently adopted by NR was the right one, but some of its dynamics were not functioning properly and it would be helpful if this review could discover why and where this was the case. Further, when the question as to why the recommendations of several other independent reviews had been accepted by NR but not implemented, he indicated that there appeared to be a bias towards the status quo which has resulted in a less constructive and creative tension between the TA and Regions than the operating model envisaged.

Therefore, our investigation was steered towards consideration of the cultural and behavioural effects highlighted by the CEO's concern. We have seen clear evidence of lack of knowledge about the condition of the infrastructure assets leading to decisions about the need for precautionary service restrictions. That low level of asset condition knowledge has been seen alongside a maintenance regime which seeks only compliance with the essential safety parameters, not attending to those measures which secure reliability and longevity. This led us to consider that investigation and comparison with equipment specifications and operational practices in overseas rail administrations was a lesser priority, NR assets are not at the best condition that should be expected taking account of age. The loss of resilience in the NR network has therefore been seen to result from maintenance condition.

It is recognised that the act of devolving powers to the regions in 2019 was a precursor to Government's intention, set out as part of the Williams/Shapps Review, to bring about the biggest change to the UK's railway network since its privatisation in 1994 by the creation of Great British Railways (GBR). The review panel accepted in general the current business model set out in the Network Operating Model V2. However, several of the recommendations in this Report suggest that some refinements are needed to improve the dynamics within and between parts of the NR organisation.

Throughout the changes brought about by devolution and the eventual establishment of GBR, Network Rail has remained passenger focussed since the Company was established in 2002. This was confirmed by Network Rail's then

CEO, John Armitt CBE FREng, when he delivered the Hinton Lecture to the Royal Academy of Engineering on the 1st October 2002. Further, it was clear in the lecture that to achieve Passenger Focus, engineering must play a leading role together with operations.

When the review panel embarked on their journey the verbal evidence gathered clearly indicated that there was a measure of disconnect between the commercial, operations, engineering and safety disciplines across the company and particularly within the Regions. That which concerned the panel most was the claim that the voice of the Engineer was neither being heard, nor properly represented through the various levels of management.

On the 13th September 2023 in the Group Safety and Engineering Director forwarded his commentary on the previous iteration of this report which indicated that over the past 6 months many changes have been made in line with the initial and interim recommendations by this panel. Most importantly the voice of the Chief Engineer and his discipline Engineers is now heard by the CEO through regular meetings. The ELT similarly receive regular updates from the TA Engineers.

At the start of this review, it was established that the Regional DEAMs in collaboration with the TA were conducting an in-depth investigation to draw up plans for their own Regions to better prepare for and manage summer temperatures in 2023, in anticipation of a repetition of the 2022 extreme heat. The Review was pleased to have been given the opportunity to work with NR staff on this exercise.

It was clear from the outset of this review that network wide knowledge of asset condition was neither understood nor routinely measured. It was also apparent that whilst there is strong commitment to and emphasis on compliance in delivery. Deeper investigation reveals that the major emphasis of what has been described as a “compliance regime” emphasises those measures applying to safety limits only. Consequently, the level of maintenance being undertaken was found wanting. Compliance with maintenance procedures and preservation of asset whole life operational performance are not measured and are certainly not compliant.

Our investigation has brought the panel to a view that there is in some parts of the organisation a lack of understanding of the maintenance needed compounded by inadequate records and resources constraints. Consistently in every part of Network Rail, and at all organisational levels restricted and inadequate availability of possession access to the railway has been emphasised as the primary concern.

Our comments and recommendations are both challenging and demanding, especially given the constraints on access and even more so the cost pressures exerted through CP6 and shortly CP7. Nonetheless, it is the opinion of the reviewers that positive change in the attitude towards maintenance is essential if Network Rail is to continue to operate the safest railway in the World, particularly in the extreme weather conditions forecast in the future.

It has emerged from the discussions the review team have had with a range of diverse staff that under the present contractual arrangements NR has with its customers, the TOC'S and FOC's, they are required to respect the contracted rights of access whether the train paths cited are used or not. One of the unintended consequences of this arrangement has an adverse effect on planning and ability to conduct routine and necessary maintenance and the general stewardship of the railway's assets. The orthodoxy of the privatisation model in operation since 1994 is that commercial and financial penalties between NR and the train operators will ensure a balance in managing access to the infrastructure. Regardless of any views on the reliance on what is in effect an unregulated market solution, it is obvious that the correct balance has not been achieved. It must surely be an objective for Great British Railways to bring a more rational and sustainable approach, recognising that the running of a few more train paths at the cost of poor reliability and expensive premature renewal is not in the national interest.

Further, the financial and resource bandwidth limiting the extent of maintenance possible would appear to be governed by the monies afforded for the Control Period agreed by HM Treasury. The panel has noted the Network Rail view that at present there is not the capacity to fully and quickly adopt all the recommendations of multiple internal and independent reports all of which have made important recommendations to secure the safe operation of the railway.

Disappointingly it is unlikely that either access or the rate of progress with adoption of recommendations for change can be resolved within the current industry framework and Control Period financial settlement. We must hope for change which the delayed restructuring that the creation of the GBR could bring.

In assessing and advocating the changes needed to overcome the perceived problems, the review has continued for a period of thirteen months and has been able to observe the network and the engineering approach to maintenance, renewals and replacement throughout the four seasons of the year spanning 2022 and 2023. A draft of our anticipated final recommendations was included in the interim report on 7th April 2023. The TA and the Regions took note of the findings and progressively adopted many of the recommendations. Following the latter submission, the TA organised a workshop on 24th May with senior staff including the NW&C, Southern and Eastern Region DEAMs, engineers and others representing safety and architecture. The team subsequently met with Andrew Haines, Martin Frobisher and Jake Kelly on the 30th May. As a result of these two meetings further work to refine elements of the report was provoked, in addition we were requested to submit our recommendations in a format like that used by the Rail Accident Investigation Branch. These changes and additions are fully reflected in this final report.

In recent years Government has chosen to invest heavily in new rolling stock to upgrade rail services and in doing so also to improve safety and reliability meeting the aspirations of passengers. To ensure this new stock can operate to its potential is yet a further important reason for the railway infrastructure is to be maintained to an improved and more appropriate standard.

The EHTF engineering team has concluded that to have a railway achieving high standards of safety and reliability, together with the ability to increase capacity, thus allowing it to play an important role in supporting and growing the UK's economy, much is needed to be done by way of renewals and enhancements. However, this alone is not good enough, for if the assets now in place are not properly maintained to an acceptable standard, then degradation of the existing infrastructure will result. Eventually degradation will demand more premature investment in renewals and enhancements before many assets have reached their expected life. These matters need urgent and effective action as failure to exert proper Asset Stewardship will undoubtedly drive excessive and inappropriate expenditure on unplanned renewals; indeed, it is evident that this is already the case.

Further, when considering these issues, it must be appreciated that the foundation on which the railway runs, and the fundamental track alignment, has existed for 150 years or more. That is a testament to those great railway engineers of the Victorian and Edwardian eras. Nevertheless, the infrastructure should not be expected to function reliably or even safely under the pressures from 21st century tonnage, frequency and train speeds without proper inspection and maintenance. This is where sometimes Key Performance Indicators can be misleading if not considered against the bigger picture and future expenditure. During this review, we were provided with records of the compensation payments made to the TOCs and FOCs in accordance with Schedule 8 for the years 2019, 2020 and 2021. It was clear that a percentage of those payments were the result of inadequate maintenance. This would suggest that more thorough maintenance would have been cost effective and certainly less disruptive.

As indicated earlier, the Review Panel soon came to the realisation that the challenge was far wider than anticipated under the initial draft remit. It would not adequately address the issues if assessment were limited to the equipment specification targeting extreme heat alone. Instead, our initial examination indicated that there was a lack of knowledge together with out of date records of the condition of the assets, especially those relating to the existing track and the overhead line assets.

The ethos of this Report therefore is to flush out those critical areas that need to be addressed to allow the maintenance teams, aided by modern technology, to improve reliability, maintain safety standards and be more efficient and cost effective. Britain has reasonable claim to having the safest railway in the world, but in the face of forecast increase in temperatures and extreme weather conditions action is needed if that status is to be protected.

The initial remit for this report requested a comparison with international best practice. As the panel comprises of individuals, railway companies around the world were not inclined to cooperate and therefore each member has reflected upon their experience in Japan, Canada, USA, Hong Kong and Australia. Simon Lane also assisted the panel by drawing upon his experience in Singapore and Australia. It was subsequently acknowledged that Network Rail as a member of both the Union Internationale des Chemins de fer (UIC) and European Infrastructure Managers Group maintaining also less formal contact with other international rail organisations. Whilst there is undoubtedly more that can be learned from international best practice without direct access to the information required the panel members considered it more appropriate to concentrate their efforts on how best to improve maintenance and asset management here in the UK. With the agreement of the client the remit was modified to reflect the foregoing.

However, the Review has noted that some countries within the European Union this summer experienced extreme temperatures exceeding 40ºC have deemed it appropriate to close some lines on the grounds of safety.

Whilst the EHTF review team acknowledges that it has found it necessary to make a significant number of recommendations, earlier in these comments is recognition that the limitation of the funding settlement from government limits the capacity for action. It is also understood that Network Rail is a significant national organisation with extensive assets and a large workforce but is nonetheless required to operate within a funding envelope which dictates a limited bandwidth for its activities. In acknowledgment of this predicament the reviewers have already indicated priorities within the recommendations made here in such a way as to ensure the level safety and resilience needed to function effectively in extreme weather conditions. It is noted that NR has a great many recommendations stemming from a large number of reports. The actions in response to all those recommendations, including those made here must be gauged by comparative risk assessment. The EHTF team do not have access to all active recommendations, neither would it be appropriate to comment here on the relative importance between them, that is squarely for NR to judge.

The review team fully recognise the benefits of the renewal and replacement programme of railway assets. But the accompanying point cannot be stressed enough; renewal and enhancement alone is no substitute for a well-managed maintenance programme. Fully effective maintenance will serve to ensure that assets are able to function for their predicted life span and beyond and thus achieve optimal cost effectiveness.

4.0 Executive Summary

The remit of the EHTF has been to investigate the specific issue of the effect of extreme heat. What has been seen through these investigations is that the extreme heat during Summer 2022 exposed weakness in resilience of the infrastructure and cautious/risk adverse decisions by Network Rail engineers. Whilst the heat exposed process weakness and provoked actual engineering failure, underlying those symptoms are causes which indicate under achievement in maintaining the condition of the infrastructure and knowledge of that condition. Although it may seem outside the remit for this report to comment so heavily on maintenance, it is the root cause of loss of resilience which needs to be addressed.

The review team has worked closely with Network Rail to modify and improve engineering specifications. This review has removed unnecessary caution from the specification. Network Rail engineering standards were revised and reissued prior to summer of 2023.

This Review has not attempted to duplicate the work undertaken by Lord Robert Mair following the Carmont Derailment and as contained in his Report entitled “The Management of Earthworks” which was published in February 2021. However, consideration has been given to track formations on embankments. Hot and dry summer weather causes widespread desiccation the impact of which is worse for elastic clays, which dry out causing shrinkage and then heave when the heavy rains follow. This could, in the long term, cause changes in the track geometry.

We are pleased to have been able to work with the TA and DEAMs, and their teams, during the whole period of this Review. We have observed the adoption of some of our earlier recommendations along with the outcomes of their own “star chamber” style review, which has enabled a more robust plan to be put in place for the summer of 2023. However, this has yet to be put to the acid test for, fortunately, the extreme temperatures experienced over much of Europe did not reach our shores. That is no cause for complacency for much more work is required to secure asset wide resilience needed to ensure the network can be operated under all extreme weather conditions.

The Review has been greatly assisted by the workshops that have been held with engineering groups and the DEAMs. Hopefully this will allow the recommendations contained in this report, once accepted by the senior management, to be owned by those individuals and groups who assisted in formulating the recommendations and allow them to be fully embedded into the working practices, standards and specifications.

It is recognised that good progress has been made in many areas since devolution but, as is often the case when disciplines are decentralised, some important things can be lost or forgotten. These shortcomings can be key but are better illustrated in the chapters dealing with technical matters. Whilst by necessity specifications are required to be modified to suit the unique requirements of each Region and/or Route, the basic physics of engineering remains unchanged. Whilst the devolved organisation no longer encourages “command and control” from the centre, the Technical Authority must be seen and understood by all to be the Authority for the whole Network rather than just an advisory body. One of the unfortunate ramifications this has had is that engineering and maintenance are not considered holistically. As an example, the Panel has observed new standards issued over the last 2/3 years, together with guidance modules, relating to the periodic inspection of assets and the introduction of the Risk Based Maintenance (RBM) regime. Whilst being comprehensive in terms of process, the concern is that they must also be comprehensible to the artisans, junior engineers and particularly to Delivery Unit TMEs, SMEs and E&PMEs. Without a stable maintenance baseline and without adequate training for all the above employees it is difficult to understand how the current state of the assets will be improved. This important issue is dealt with in greater detail in the technical sections of this report.

In his 2018 report "Engineering Capability Review of Network Rail" Professor Andrew McNaughton described the need for a clear line of sight from the Chief Engineer in the Technical Authority through the DEAMs in the Regions to the Maintenance Engineers in the Routes. The EHTF panel fully endorse Professor McNaughton's views. Various interviews undertaken with Engineers at every level of the NR organisation have brought forward views that make clear engagement in that engineering chain is not as it should be.

It is a strong recommendation that under the leadership of the Group Safety and Engineering Director a more formal understanding of the engineering structure that embodies that line of sight should be set in place. This will require engagement with and from the Chief Engineer, the TA Heads of discipline, the DEAMs, Regional Engineers and Maintenance Engineers. Stakeholders in this will include Route and Regional Directors, support from the hard line on the organisation chart is critical to securing the creation of meaningful dotted line connections within the whole engineering community. The aim is better engagement among engineers at all levels in fulfilment of the recommendations of the 2018 McNaughton Report, culturally embedding a clear and defined line of delegated authority from Chief Engineer to all engineers within NR.

In summary, the Engineering Final Report serves to bring this Review to a close - which has proved fascinating, and I believe necessarily reached beyond the scope originally anticipated by the initial remit included in Appendix B. The reason for the scope being extended beyond the brief was a necessary consequence of the need to investigate where the functional dynamics were not performing as expected by the CEO.

This has then enabled presentation of recommendations that the Review team believes are necessary for NR to achieve the level of resilience essential for the network to operate in all extremes of weather. These are dealt with in much greater detail in the technical chapters of the Report but in headline are as follows: -

• A revision of some of the standards and specifications to cover higher ambient temperatures above 40°C.

• Improved and fully validated records of asset condition, especially relating to Critical Rail Temperature

• Improved asset stewardship information and plans embracing whole life of the asset including maintenance.

• A maintenance regime that provides economic and proactive maintenance rather than merely safety compliance.

• Developing a programme that provides sufficient safe access to undertake the volume of preventive maintenance necessary involving both physical access and the use AI together with vehicle based remote data acquisition and video inspection where applicable.

• Changes to and enhancement of the operational dynamic within Network Rail as it relates to engineering throughout the whole organisation and in the Regions, including the interrelationship between asset management and operations, to bring proper engineering governance from the DEAM over maintenance delivery.

As was stated in the initial Report whilst engineering and operations are two separate disciplines, they are intrinsically entwined to provide a safe, predictable and efficient railway. To accord with that need, both Simon Lane, responsible for operations EHT Report, I and the rest of my team have worked closely throughout this whole exercise and where applicable have generally reached a common view.

5.0 Observations

NR is responsible for the care and operation of the national rail infrastructure. A defining feature of railway infrastructure is that the passengers place their physical safety directly in the hands of the service provider.

The delivery of train services is a complex interaction between people and machines, but undeniably the foundation of the whole undertaking is physical 'engineering' of assets the maintenance and management of which can only adequately be performed by technically trained staff and qualified engineers.

It follows that the role of engineering expertise is vital to the care for, upkeep and responsible operation of that infrastructure. The history of railways in Great Britain graphically illustrates the risks and consequences when disaster strikes, the long-established process of judicially led public enquiries provide a record of organisational and personal shortcomings.

Engineers throughout the organisation will have reporting lines which place them in positions which deliver, in their daily work, outcomes determined by the local requirements of the business. This will place their direct reporting line, the creation of their objectives and determination of their payment and reward, in the hands of Managers who have backgrounds and expertise outside of the engineering discipline.

With devolution has come a cultural expectation of greater autonomy. The review team does, in principle, accept that the goal of delegating technical authority to an appropriate level within the organisation ensuring the individual has the proven professional training and competence capable of allowing them to discharge that responsibility. To achieve this level of delegation there must be effective support and engineering guidance from both the Technical Authority and the DEAMS.

The review team in speaking with the more junior members of the engineering and maintenance teams, ignoring and putting aside individual complaints, were not convinced they had easy access to senior staff with experience and ability to provide a guiding mind necessary to ensure best practice. Clearly to achieve this there needs to be training, support and mentorship for front line staff. As the devolution programme matures, we are confident that all the foregoing will be delivered through the TA and the regional DEAMS.

Because of recent discussions with senior management the review team is beginning to have a degree of confidence that the engineering competence, experience and expertise required to maintain any engineering asset will develop. However, it must be understood that those qualities must be appropriately manifest in all levels of maintenance activity, from the artisans to the senior decision makers. Without fully competent engineering leadership the activities within the field of maintenance tend towards process box ticking applied by routine.

Network Rail Standards set out mandatory requirements, guidance and indication of best practice. The undoubtedly well intentioned this formatting of standards in that way has not in practice brought about the desired result. Mandatory issues are clearly observed, normally met with compliance, occasionally with derogation being sought. The status of guidance is that adoption is discretionary. Guidance is less frequently not observed. Take up of best practice is very rare. There is presently no effective mechanism by which this might be improved.

Any specific regional requests for modifications needed to accord with local conditions should be agreed with the TA, properly registered, with the appropriate regional officer being accountable for the action. It is said by some that this is what happens but from verbal evidence gathered others would not concur with that view. Ad-hoc arrangements appear to be in place which can also vary between Regions. The way specifications and standards are drawn up and amended by peer review is of concern for, whilst this may be convenient and cosy, the process lacks any positive tension. The Review strongly advises that serious consideration to introducing positive and independent tension.

The fact that NR records are poor in several areas, especially in relation to CRT for track, conductor stretch in the OLE wires and the dangerous state of so many of the D&P buildings, is a matter of fact. For a good number of these buildings the purposeful remedial measures need to commence within the next 12 months. The major concern the Review has, as previously mentioned, is the lack of awareness and understanding by NR of the condition of its assets across the Network. This situation has been exacerbated in recent times with the necessary changes to the rules governing track access.

It has been made clear to us that the maintenance teams are frequently jumping from one emergency to another rather than conducting a planned maintenance programme as expected. There are examples where the records on the Ellipse Programme show work having been done for a whole section rather than localised remedial work. The Ellipse system is not designed to record and report in sufficient granularity to give confidence that maintenance is being achieved to both the standards and frequency required.

The other key reason why so little is known about the condition of the assets is because management has become reliant on a compliance based regime of examination which may be regarded by some as a box ticking exercise. As was stated in the Interim Report there is confusion between compliance and risk management which needs to be resolved. Whilst both are closely aligned, a compliance regime with established rules and statutory regulations helps protect the business from a variety of unique risks while risk management protects the organisation from risks that could lead to non-compliance a major risk itself. Therefore, when applied to asset maintenance compliance can pass a system or component that is likely to fail before the next inspection. Evidence of the failure of the compliance only regime to 'put passengers first' is the annual increase in asset failure in Periods 4 and 5 due to hot weather. This is before extreme conditions were experienced. In the last five years Schedule 8 payments (some measure of customer impact) due to attributed weather effects has risen by 280% in addition to the 63% increase in general infrastructure failure payments.

Without adequate asset condition information and with tracking only of the achievement of safety compliance senior management will believe that all is well with the system, whereas it is not for the asset condition has not been held within operational tolerances.

Clearly the funding in CP6 and that recently approved for CP7 is founded on an assumption that a competent and safe system exists only needing funding for continuation of current levels of routine maintenance, combined with a volume of renewal and enhancement. Far more than this is required across the Network if asset condition is to be lifted to the required level of sustainability and resilience, protecting reliable operation in all weather conditions, extreme or otherwise. The improvement in asset condition needs to reduce the not infrequent failures in signalling and OLE which are costly to repair, and which entail associated compensation payments. With the anticipated creation of GBR an opportunity would seem possible to more effectively manage operational risk, better balancing hours available for train service running and time available for infrastructure maintenance.

Therefore, to put matters to rights funding beyond that afforded by HM Treasury through CP6 & 7 will almost certainly be necessary.

Rolling stock has progressively moved from periodic maintenance to reliability centred maintenance regimes combining the best of periodic, usage-based and condition-based maintenance. This has taken half a generation of trains to achieve with considerable engineering effort to define optimum interventions. Infrastructure needs to follow the same rigour to implement RBM on a railway with 150 years of legacy. Asset Stewardship indicators should provide indication of the positive balance between preventive and reactive maintenance, only with that balance exposed will the effect of risk based maintenance be assured.

NR has made progress with development of a RBM regime. It is acknowledged that RBM can be very powerful in allowing unnecessary tasks being removed from maintenance scheduling, instead placing more emphasis on preventive work and reducing the risk of repeat failure. The NR RBM regime must be held under review as it evolves to protect against unintended consequences from abandonment of apparently unnecessary tasks without monitoring to confirm that results.

From two Regions we have been made aware of concerns about the effectiveness of self-assurance in capital investment works delivered by external contractors. Poor quality work, and uncorrected snagging from installation has fallen to maintenance teams for remedial action. This has been highlighted as a burden, a drain and a distraction which takes away resource from maintenance core activity. All such remediation it is argued, should be dealt with and closed out by the capital project. Indication has been that there is a trend towards capital programmes reducing and even stopping altogether the “informed client” inspection of finished work, relying solely on self-assurance by the contractor. This exposes a weakness in that by the point of agreement of handover between the implementation project and NR Asset Management and Maintenance Engineers, the contractor may well have de-mobilised leaving the maintenance organisation with a fait accompli workload and with no resource availability to deliver the work.

The most important programme Network Rail has in hand is “Modernising Maintenance.” The improved productivity envisaged by this programme is considered to be essential to deliver effective maintenance of the railway infrastructure. The evidence provided to the review team has indicated that the programme has reached a stage of early implementation. It goes without saying that getting this right is crucial to embedding a proper preventive maintenance programme (including through Risk Based Maintenance), balancing whole life cost, safety, sustainability, reliability and resilience. NR clearly has plans to have a workforce that is both competent and has all skills needed within each team. This is a change programme of both great importance and great complexity, as with RBM monitoring and review over the long term will be essential.

To ensure these teams function efficiently and their work is meticulously planned they must be allowed adequate access periods onto the track to complete the works as planned. To achieve this there is need for an increased reliance on modern technology. Already NR has a substantial squadron of drones that need to be employed efficiently, alongside greater and more structured routine use of measuring systems on service train as well as the new dedicated fleet, specifications for which are currently in development. This will better inform the maintenance teams as to the condition of the various assets and enable them to quantify the cost of ineffective reactive intervention, leading then to the ability to realistically plan preventative maintenance. DEAMs should be expressing 'customer pull' by owning the asset inspection plan for their Region, deploying and using TA approved systems that are compatible with standards. This must integrate with a service provided by Asset Information Services that satisfies the five regional plans, maximising the economies of scale and support of a central function.

With service train data and new measurement trains planned, the numerous inspection systems mounted on each train can gather continuous live data. This will ensure that NR have a detailed understanding of its assets. However, there is a danger for there is the risk of maintenance managers and engineers being drowned in a mass of information that will not be used. Therefore, in parallel with this new development it is necessary to align, filter and process the data to provide meaningful information that enables the various teams to undertake the appropriate work. The algorithms/programmes needed to achieve this need to be available as soon as possible.

The DEAMs must define the optimum business process for their Region. Technology is only the enabler; effective maintenance outcomes, and a reliable asset in consequence, is the objective. NRHS management of HS1 demonstrates the benefit of using technology to plan preventative work rather than using it to manage the asset closer to failure.

The predetermined and agreed comprehensive plans generated jointly by the Regions, WRTF and the TA and needed to be resilient in the face of the weather conditions for Winter, Spring, Summer and Autumn and must be introduced in good time for each season. The view of the EHTF is that a more collaborative working relationship between the WRTF and the climate change team should be created, for the former should be feeding off the material generated by the[19] latter.

6.0 Conclusions

If the technical recommendations including the agreed prioritisation, accepted and adopted, together with favourable consideration being given to the various observations made, it should be possible to overcome the degradation that exists and have an affordable preventative maintenance programme in place. Once achieved then the level of resilience needed to operate the railway both safely and efficiently in all extreme weather conditions (not just high temperatures) will be possible.

It is hoped the Recommendations in this Report will not only be accepted but be fully embedded into Network Rail's specifications, standards and working practices.

7.0 Acknowledgements

I am most grateful to the Chief Executive, Andrew Haines OBE, and the Group Safety and Engineering Director, Martin Frobisher OBE, for affording me and my colleagues both total freedom to interface with any of NR's employees and open access to any document requested. Likewise, we appreciate the candour of all those we have interviewed for it has enabled us to properly understand some of the real challenges faced by the engineering teams across the network to maintain the infrastructure.

As was the case with the previous Reports I am indebted to the experts who, along with myself, form the Reviews engineering team namely, Peter Dearman, Neil Andrew, Andrew Went and Peter Blakeman, together with NR graduates Shahab Fazal and Damiano Acerbi who have supported us.

In addition, I should like to thank Lord Robert Mair CBE for his time discussing matters relating to the earthworks across the network in general and his Review of Earthworks Management following the tragic train derailment at Carmont on 12th August 2020.

I am also grateful to Simon Lane, appointed by Andrew Haines to look at the operation aspects for the Extreme Heat Taskforce, with whom we have had a meaningful liaison throughout this review. This has helped ensure that the importance of the interface between operations and engineering was properly understood.

It has been a privilege to be invited to undertake this Review and an education into the challenges faced by all at Network Rail to have the world's oldest railway perform to meet the demands of the 21st Century.

Sir Douglas E Oakervee CBE FREng, August 2023

8.0 Summary of Recommendations

Each of the subject matter sections (Track, Overhead Line Equipment, Power & Distribution and Support Functions) in the body of the report contain discipline focussed specific recommendations. In those subject matter sections can be found the reasoning behind the recommendations.

This appendix for convenience brings together all those recommendations but seeks at this stage to do no further rationalisation, they are presented as set out in the main body of the report. It is however noted that such a rationalisation will ultimately be possible, where for example systemic process issues are identified.

Recommendations applying to Track.

1. The Regional DEAM's and Infrastructure Director's to set out a strategy that deliver, as far as reasonably practicable, a policy of zero unmitigated track buckles. This should incorporate the investigation of all recent incidents with a Hazard Score of 50 or greater to ensure key lessons have been adopted.

2. Any future incident with a score of 50 is to be formally reported and subject to root cause analysis with a review by an internal, independent, panel consisting of the TA and SO and Chief Engineer.
3. The Responsibility and accountability for the oversight of Hot Weather preparedness across the network needs to be clearly defined and agreed. The role of regional teams, IME'S, DEAM's and the TA, alongside the approach to the management of assurance and associated escalation, must be set out and applied consistently across all 5 Regions.

4. The role of the TA, specifically the WRCCA, in providing national assurance as to key route preparedness cannot be overlooked. The TA, alongside the System Operator, shall own the wider assessment of preparedness for key routes and, through the Executive Leadership Team provide a national view of the networks availability and capability.

5. Examine how 2022 CRT sites were evaluated and ensure measure/mitigations are in place to
   (a) rectify the risk prior to the on-set of future hot weather and, if not addressed
   (b) confirm resources are available to undertake necessary hot weather inspections
   (c) The output of this review to be approved and signed off by the Regional Infrastructure Engineer, DEAM and Chief Engineer

6. Review of the national stress database and, as a priority on Cat 1a and 1and 2 sites, assess the available stress data and verify that the risk of buckle has been managed appropriately through the application of standards and network restrictions.

7. Undertake detailed inspection of timber bearer S&C layouts with a line speed of 60 mph or above and Implement strengthening of the asset in accordance with current track standards.

8. Plan and implement the replacement of track structures with poor buckle resilience. This specifically includes timber bearers in Cat 1 and Cat 1a track. - Routes should produce their prioritised plan to confirm and restore SFT at track stability risk sites (braking areas, gradients, poor fixation, and S&C) such that the age of records is less than 10 years. This to reduce the number of S&C sites to match the resource available.

Resources experienced and competent in the restoration of stress within S&C will be required.

9. Use track stability and vehicle dynamics modelling to update the risks associated with specific vehicle types and amend speed restriction instructions accordingly.

10. Increase the use of remote monitoring of track temperature using existing fixed measurement systems/portable devices that are easily deployed for the forecast risk period.
11. The overall condition of the asset being operated close to actionable limits results in a wider lack of asset resilience. Comparing the approach taken by the maintenance teams for HS1 it is evident that, for the track asset, the maintenance teams undertake interventions earlier. Review the intervention triggers for the higher categories of line and develop a 365 strategy, by route, that address network resilience through all periods. It is recommended that a review of actionable, 1 Month activities (M1), is instigated as part of a wider asset performance regime. This should evaluate the regions response to the pro-active management of critical repairs and its ability, of the maintainer, to address critical defects. In parallel a review of work activities that need to be undertaken, as part of maintenance tasks, should be reviewed to ensure the right work activities and priorities are being undertaken. It should be noted that this is not only applicable to track.

Recommendations applying to Overhead Line Equipment

1. OLE maintenance in <u>FULL</u> compliance with module B10 of NR/L3/ELP/27237 should be implemented across the Network.
   Module B10 to be reclassified as “red” mandatory requirement.
   Any variance on periodicity to be justified as a deviation, and only adopted following Engineering endorsement by the standard owner, the TA head of discipline.

The maintenance instruction module B10 of NR/L3/ELP/27237 to be reviewed and rewritten updating the requirements to make the requirements applicable under Condition Based, Reliability Centred or Risk Based Maintenance regimes, whilst placing clear obligation to deliver basic maintenance adjustment, lubrication and like for like replacement of worn components.

Changes to be made to the recording of work in ELLIPSE to give full visibility of maintenance shortfall and/or backlog. The masking of what has been done/not done under the cover of single B10 MST will be stopped to improve visibility and quantification of the achieved maintenance activity.

2. Refocussing of maintenance attention will need to be accompanied by a remediation plan to replace worn components like for like. This is a mid-life remediation of dilapidation by heavy maintenance, not renewal.

   The remediation phase may need to be tackled by engagement of contracted labour. Steps to securing funding authority and engagement with the supply chain to be actively pursued.

3. Maintenance Engineers teams junior level Technician Engineer posts should be unfrozen and filled.
   Much of what needs to be achieved in mitigating risk during weather extremes and in the comprehensive rehabilitation of the OLE requires engineering investigation and analysis. The holders of these posts will be key to undertaking that work.

4. The TA has the formal authority within NR to mandate standards and where necessary set corrective actions against non-compliance with those standards. The line of sight engagement between Heads of Discipline within the TA and engineers of the individual disciplines throughout NR must be improved and formalised fostering a culture which supports the Head of Discipline to be the guiding mind, consolidating widest possible adoption of identified best practice.

5. To compliment the indicators reported on operations safety and operations performance, the TA should present routinely an asset stewardship report with indices to confirm to the ELT/Board that whole life asset condition is being protected across the network.
   It is noted and welcomed that this has been actioned following the initial report.

6. A strategic plan for asset data and information technology with a clear link to the business vision should be developed. I recommend that the TA should be the owner and responsible for delivery against that plan.

7. Access for OLE maintenance is across most of the network inadequate. The reaction to this is one of resigned acceptance among those charged with the responsibility who present a clear position that they are disempowered from any action available to them, nor is there seemingly recourse to support by which to gain that empowerment. It is recommended that an NR ELT level sponsor is nominated to lead an initiative under an appropriate ELT remit to restore access availability across the whole electrified network for OLE wire run maintenance, based on the 15 minutes per span every 4 years which is the generally accepted minimum.

8. Recommendations for summer preparedness

Recognising that it will take multiple years to remediate maintenance condition throughout, some emergency measures need to be actioned to mitigate risk as much as possible. The following two recommendations address actions to apply to as many overlaps as possible for each overlap not rehabilitated to Module B10 operational condition.

All overlaps not in date with Module B10 maintenance complete should be surveyed. Using the temperature of the day at time of survey and measurement of the radial displacement angle, cantilever frames on the first two registrations both sides of the overlap to be assessed.
An adjustment plan to be calculated for each of those cantilevers/registrations and associated balance weight stacks or Tensorex to restore settings appropriate to the 38°C position.

Note that these measures will improve resilience but must not be interpreted as any more than expedient risk reduction, this is not adequate action to address the extent of dilapidation.

9. Recommendations for wider climate resilience

The remediation and re-establishment of the maintenance regime will necessarily entail bringing the OLE back to acceptable registration (position of the wire geometrically corrected compared to rail position).

Maintenance of that geometry is the best guarantee of resilience in high winds. There will however remain some sections of lines where high wind speeds create higher risk of de-wirement. A re assessment of the topographically adjusted wind speeds based on current met office wind speed predictions should be conducted. Only locations where that re-assessment confirms significant exceedance of the OLE design wind speed should any extra precautions/train speed restrictions be applied.

Recommendations applying to Distribution and Plant

1. Remote continuous temperature monitoring with pre-set alarm levels for alerting response staff.
   Various views have been expressed about the need for this, but it remains the view of the EHTF that critical operational equipment should be monitored for high temperatures.

2. Carry out suitability assessment of existing REB AC units regarding the current heat output loads, likely ambient temperatures relative to its position, shading and environment. The TA need to be tasked with creating and overseeing the adopted methods of carrying this out.
   The assessment process outlined should be selectively applied to locations where risk is greatest. This is likely to be applied to large REB locations housing critical interlockings and central control centres.

3. Carry out energy usage assessment at each site, to establish if savings can be made by changing the cooling system. This should be coupled with an

evaluation of the PSP total power usage with a view to incorporating the Level Crossing REB loadings into it.

4. When Level Crossing power supplies are lost during a heatwave due to the area DNO supply failing and the railway signalling power supply is sufficiently backed up with standby power resource, the railway has to cease working as the level crossing become an extreme H&S risk. There has been a general reduction in the power demand by signalling equipment in recent years and there is sufficient headroom on the signalling power system in each area to add the level Crossings power supply into it and abandon the DNO supplies. However, as the reduction in power usage will vary from one signalling powered 'string' to another, the recommended assessment of power should be carried out first to confirm the level of headroom. This recommendation should bring about a reduction of service abandonment risk in extreme heat periods because of the temperamental nature of DNO supplies during extreme weather events.

5. The TA should carry out study of how improvements can be made to the lineside building insulation, heat venting using best practice methodology learned from other hot countries railway methods to reduce the energy usage. Australia uses double skinned walls and roof with rotating air outlet vents and shading to stop the build-up of heat and avoids using AC units, completely by selection of appropriate internal equipment that can tolerate the expected ambient temperatures. The Buildings & Architecture TA have a 'wrap' panel design for existing lineside buildings that could reduce energy usage and improve NR's Carbon Footprint. It could be cost effective to some sites, if a time framed energy usage assessment were carried out.

   Noted that the initial response was that this would be a responsibility for the Route Director. Whilst that is noted the EHTF view is agnostic on who leads, the action remains an EHTF recommendation.

6. Develop a strategy for having the responsibility of maintenance that provides NR with value for money, maximise cost efficiency for failure repair and minutes delay costs and minimises energy usage. Utilising RBM methods of targeting maintenance interventions where needed, with a focus on extending useful life of aging cooling equipment, would improve the risk to the operational railway.

The role of the E&P maintenance team as first line maintainer be formally acknowledged and properly resourced. There can be up to 14 days delay between a failure and response by the contracted service provider. Without adequate resourcing in the E&P maintenance teams, places vulnerable operations critical systems at risk.

7. Consider making the IMDM accountable for the delay attribution of any Lineside building cooling system failure, so that the Responsibility, Accountability, the net delay attribution costs are all in the same domain. The best choice skill set operatives of combining the summer preparedness checks with the lineside building's pre-summer electrical system checks has to be the economically logical choice.
   Links to 5 above
8. Deploy Smart room stats to minimise energy usage on dual forced air/ AC cooling system that cannot be interfered with by visiting maintenance or signal testing staff. If high noise levels being generated by the chosen cooling system are necessary, the design should couple the smart device with a PIR to reduce the air flow during these visits.

9. Each route should have two or three 'F' Gas refrigeration trained operatives that can carry out repairs and the rapid replacement of AC units. This should be on a Depot-to-Depot arrangement for sharing specialised resources. Links to 5 & 6 above.

10. The relationship between the specification of operational temperature of equipment and the specification of the installation environment ventilation/cooling plant should be reviewed. It should be more clearly established that the asset owning Engineer for the equipment/system to be protected has interdisciplinary sign off responsibility for the proposed environmental controls.

11. The use of polymer based troughing for high voltage cable installations to be reviewed. The aim of this review is to assess whether presently product approved troughing types afford adequate protection in the event of lineside fires.

12. The Buildings and Architecture asset portfolio is a large and varied mix of operations critical equipment enclosures with stations, depots, and

commercial properties. Whilst investment in stations, depots and commercial properties can in almost all circumstances be matched to a positive business case, the less high-profile equipment enclosures are, in that context a straightforward liability. This will inevitably bias investment decisions towards stations, depots, and commercial properties at the cost of overall condition in the operational locations.

Consideration should be given to creating a ring fence effectively creating two separate asset portfolios with separate ring-fenced budgets. Whilst financing will never be comfortably available for every need, such a measure will guard against increasing expenditure on assets judged to have positive business benefit being at the expense of increased building and enclosure dilapidation and increased railway operational performance risk.

Recommendations applying to Support Services

1.The DEAM responsibilities includes the specification for regional asset information requirements, to ensure asset condition is known for heat related risks. Updating this is an urgent requirement in advance of the forthcoming investment of over £750m in these systems. Importantly the Regional Infrastructure Director's endorsement needs to include implementation plans to ensure integration with the business processes within local Engineering and Asset Management teams. The Regional specification and implementation plan requires strong and influential input from the Delivery Unit Maintenance Engineers enabling full use of approved information systems at depot, route, and regional level. It is the TA responsibility to ensure that approved systems provide the accuracy, repeatability, and resolution to enable users to comply with standards and is suitable for the application of intelligent analytical processing.

2. Review the prioritisation of access and minimum levels of schedule compliance for infrastructure monitoring vehicles, with due regard to the increased importance of vehicle borne inspections in preference to personnel on track. This to specifically include routes where observation of dynamic stability of track is restricted.

3. Use the currently fitted In-Service Train systems to plan and evaluate maintenance of OHLE as a priority. Eliminate existing barriers to data availability. Evaluate the use of all In-Service Train data to enhance and supplement the data available from the dedicated monitoring fleet to meet the requirements of the regional DEAM/Infrastructure Director asset information specifications.

4. Information specific to extreme heat should be extracted from existing data, processed, and presented to maintenance teams in a consistent and easily usable format. Synchronised video, track geometry, ballast profile and SFT information should a selectable output from systems for 'at risk' locations. This to ensure that the risk at vulnerable sites is identified and managed in accordance with the standards, and that the use of all data captured is optimised.

5. Critically review output from the NDT and Track Stability research with a view to implementation of outputs with defined benefits to safety and performance of track in extreme heat. Identity and plan the approvals and revised standards required to ensure the benefits are realised at the vulnerable asset locations. Review FRA research and methods for UK application. Periodically (min 30 months) review overseas research into hot weather railway operations for applicability and benefit.

6. The Extreme Temperature - Key Route Strategy engineering inputs are reviewed by the DEAM to verify the extent of asset vulnerability, and the maintenance response to the vulnerability is input by the Infrastructure Director (monitoring, resources, and local impact assessments) to ensure that in the event of extreme heat <u>excess</u> disruption to train services is less than 10% reducing to 5% by the end of CP7.

7. Ensure WRCCA teams offer <u>tactical</u> support to routes with formal guidance embedded in the 'business process' at a local level. The selection and application of weather forecasts and monitoring at route level including guidance on the local application of ambient temperature, solar gain, and air movement with respect to component temperatures will ensure Key Route Strategies optimise operational performance.

8. Formally evaluate the use of Drones (Unmanned Aerial Vehicle's - UAV's) to assess vulnerable sites, complimenting if required the information processed in recommendation 4.

9.0 Recommendations in The RAIB Format

Access Strategic Objectives

To improve access available for infrastructure maintenance by increased industry wide dialogue including the Regulator and DfT supported by the following:

- Make plain throughout NR that at the highest level there is recognition that with current access the infrastructure cannot be adequately inspected and maintained.
- Reverse the resigned acceptance and complacency in the management of maintenance delivery through visible leadership from the most senior level in NR.
- New and innovative ways of delivering maintenance tasks and improved productivity in limited access are urgently required – This is pre-cursor to Modernising Maintenance.
- The Modernising Maintenance arrangements to proceed to implementation only when those pre-cursor arrangements are in place.
- Earliest possible replacement of the antiquated ELLIPSE system with a new Maintenance planning tool which extends beyond simple scheduling and record keeping and which links to planning and access optimisation.
- To set a robust policy setting out the requirement for and securing priority planning of train path access for on train inspection systems, consistent with those systems being the primary inspection method.

Access **Priority 1**				
Recommendation		Action Owner	Timescale for completion	Timescale for review
TRK 12	Undertake detailed inspection of timber bearer S&C layouts and adjoining plan line, with a line speed of 60 mph or above	DEAM IME TME	3 months Immediate	3 months

	and Implement strengthening of the asset. *Objective is to improve condition and resilience to extreme heat.*			
SRT 2	Review the prioritisation of access and minimum levels of schedule compliance for infrastructure monitoring vehicles, with due regard to the increased importance of vehicle-borne inspections. *Objective is to recognise that the virtual elimination of patrol inspection with trains running raises the criticality of vehicle-borne condition assessment for safe operation and resilience.*	Systems Operator DEAM/TA input	4 months	6 months
OLE 7	The balance of the train plan and the need for maintenance access to be adjusted to provide whole wire run planned access *Objective is to provide sufficient routine access to enable approximately 15 minutes of working time on every span of OLE once every 4 years*	ELT level owner *Cross industry stakeholders* *ORR* *DfT*	6 months	3 months

Access **Priority 2**				
Recommendation		Action Owner	Timescale for completion	Timescale for review
TRK 13	Plan and implement the replacement of track structures with poor buckle resilience on Cat 1a,1 and 2. *Objective is to concentrate interventions to remove reduce buckle risk on high category lines*	IME TME	12 months	6 months
TRK 14	Routes to produce their prioritised plan to confirm and restore SFT at track stability	TA DEAM IME	12 months	6 months

	risk sites. The age of records to be less than 10 years. *Objective is to secure robust correlation between the CRT records and the physical SFT setting of the track at risk sites*	TME		
D&P 13	Buildings and Structures to be given higher priority for access to carry out lineside building inspections. *Objective is for NR B&C to reduce the backlog of 578 overdue structural examinations.*	Regional Engineers Delivery Unit Planning Managers Works Delivery	12 months	24 months

Asset Stewardship Strategic Objectives

The strategic objective is to improve the preservation of asset condition, operational performance and full life durability. In support of that strategy recommendations cover:

- Objective measurement of asset condition made visible throughout the organisation (asset stewardship dilapidation indices produced during the period of outsourced maintenance are examples).
- The ownership and objectives of asset management must be re-stated placing the primary responsibility to secure best whole life durability and resilience of existing assets.
- Increased Engineering oversight and direction of maintenance delivery; Asset Managers to have increased focus on maintenance and securing of full asset life.
- The objectives of NR maintenance to be lifted above safety compliance only. Henceforth compliance to maintenance operational tolerances to be given equal managerial priority.
- A pro-active maintenance regime delivering reliability, availability, operational performance, resilience and protection of whole service life must be fully implemented.
- Creation of Region wide plans setting the strategic and tactical Route based actions for rehabilitation of the infrastructure to sustainable maintenance

condition, taking account of age, specification and current condition/dilapidation of assets, traffic tonnage, rolling stock type and speed.

- To nurture and encourage Engineering leadership in the management of the physical railway assets, securing a balanced relationship in the Engineering and Asset Management organisations giving greater confidence that engineering professional judgement is the foundation of all asset management process.

Asset Stewardship Priority I				
No.	Recommendation	Action Owner	Timescale for completion	Timescale for review
TRK 5	Examine 2022 CRT sites and ensure measures /mitigations are in place to remove risk prior to onset of hot weather. *Objective is to target intervention based on known CRT risk sites reducing the need for action on days of extreme heat*	TA DEAM IME TME	3 months	3 months
TRK 6	Review the national stress database and , as a priority on Cat 1A, 1 and 2 confirm that the risk of buckle has been mitigated. All other Categories of line are to be completed after the priority routes have been assessed. *Objective is to reduce the need for service affecting restrictions*	DEAM IME TME	3 month. (cat 1a/1 and2) 6 months (remaining routes)	3 monthly
OLE I	Full OLE wire run maintenance must be carried out meeting maintenance compliance. *Objective is to restore and maintain OLE within Maintenance tolerance throughout its life*	Regional DEAM *Regional E&P Engineers* *Route Asset Managers E&P* *Maintenance E&PME*	Immediate	3 months

OLE 5	Asset Stewardship report to be presented routinely to the NR ELT *Objective is to make visible the condition of the assets through a quantified evaluation of maintenance compliance*	Group Engineering and Safety Director *Regional DEAMs*	Immediate	6 months
OLE 8	Future summer preparedness to include adjustment of OLE overlap geometry including two spans on both sides of the overlap span *Objective is to improve maintenance compliance of all overlaps to 38°C setting*	Regional DEAMs *Regional E&P Engineers* *Maintenance E&PME*	12 months	12 months
D&P 18	The poor condition of lineside buildings and housings for operational HV Electrical and S&T equipment should be rectified. Rain water ingress is a major concern in a large number of locations. *Objective is to bring the lineside building estate to a standard suitable and fit for purpose*	B&A TA Route Directors B&C Works Delivery Engineers	12 months	12 months

Asset Stewardship Priority 2				
No.	Recommendation	Action Owner	Timescale for completion	Timescale for review
TRK7	Undertake detailed inspection of timber bearer S&C layouts and adjoining plan line, with a line speed of 60 mph or above and Implement strengthening of the asset *Objective is to improve resilience of track around and through S&C*	IME TME	6 months	6 months
TRK 8	Routes to produce prioritised plan to confirm and restore SFT at all track stability risk sites; location with a stress record greater than 10 years *Objective is to provide high confidence in the co-relation between records and physical SFT*	DEAM IME TME TA	12 months	6 months
OLE 2	Develop and implement a plan for OLE dilapidation recovery *Objective is action to quantify the resource and funding required to return all OLE to maintenance tolerance compliance*	Regional DEAMs *Regional E&P Engineers* *Route Asset Managers E&P*	12 months	6 months
D&P 13	Carry out structural inspections as per the required structural inspection regime for all buildings and structures including any backlog. *Objective is to remove the backlog of the 578 outstanding structural inspections.*	Regional DEAMs B&C Works Delivery Engineers	12 months	3 months
D&P 2	RBM Methods should be applied to air cooling systems setting a maintenance as part of a strategy to extend the life of the plant. *Objective is to focus maintenance activity on the highest risk locations.*	Regional DEAMs EPMEs B&C Works Delivery Engineers	12 months	12 months

Asset Stewardship Priority 3				
No.	Recommendation	Action Owner	Timescale for completion	Timescale for review
D&P 1	Continuous Remote temperature monitoring with alarms to be provided for all S&T Lineside buildings. *Objective is for NR to react more speedily to cooling system failures. Data gathered will in longer term inform the development of improved design and improved asset management decisions.*	B&A TA D&P TA Regional DEAMs EPMEs	12 months	3 months
D&P14	Where UPS have been installed to address poor DNO supply reliability, the capacity of ventilation and cooling to be reviewed to verify that the thermal burden of the UPS is tolerable. *Objective is to reduce the operational risk of UPS systems with over temperature cut-outs.*	Route Directors Regional DEAMs Signalling Engineers D&P Engineers	3 months	3 months
D&P 15	A greater level of redundancy should be a requirement for design & replacement of HVAC equipment in locations housing vital operating systems. *Objective is to minimise the operational risks to the S&T equipment during temperature extremes.*	B&A TA Route Directors Regional DEAMs	12 months	12 months
D&P 3	Carry out an energy usage assessment for each lineside building location to establish whether a business case can be made for heating and/or cooling enhancements. *Objective is to enforce a reduction in NRs carbon footprint and remove the past power supply status-quo of lineside building energy consumption.*	Route Engineers E&P Maintenance Engineers	12 months	12 months

Process and Standards Strategic Objective

The Strategic objective is to increase the effectiveness and application of Engineering and Maintenance process and standards. This to prevent the drift of infrastructure asset condition towards actionable limits (safety compliance minimum standard) with the associated loss of resilience and operational performance.

This will involve measures to invigorate the creation, application and observance of processes and standards which together empower and nurture high quality maintenance delivery and innovation. The resulting objective will frame revised working arrangements that transition the infrastructure to a sustainable maintained condition making the railway more reliable, more resilient, more operationally flexible and able to achieve full design life.

- Re-focus and drive Asset Managers throughout the organisation, engineering leadership must be empowered and crucially must be organised with clear lines of engineering accountability from the front line to the DEAM and Chief Engineer. The delivery processes and procedures must then balance the hard organisational line with the technical accountability line.
- Delivery of availability, resilience, operational flexibility and reliability must be elevated in the priorities of Asset Engineers. The sustainable and resilient condition of an asset needs to be clear in the standards and directly linked to expected design life and performance. The assessment of the sustainable and resilient condition needs to be directly available from the inspection and condition monitoring processes.
- Maximisation of asset life and lowest whole life cost is the first objective of Asset Managers, accountability requires clarity and prominence in their personal objectives and performance measures.

- Prudence in renewal demand must be a component of regional processes. Life extension and resilience enhancement measures need to be fully explored in a balanced assessment.
- Processes that review high levels of unplanned work (indicating loss of control) and the effectiveness of maintenance tasks are required to reduce repeat faults and the consequential reactive and costly repeated tasks. This to drive efficiency through competence and innovation.
- The process of assessing and implementing research and emerging knowledge requires focus and urgency.

Process and Standards Priority 1				
Recommendation		Action Owner	Timescale for completion	Timescale for EHTF review
TRK 1	Heat related incidents with a score of 50 or above shall be formally reported, root cause analysis undertaken and reviewed by an internal independent, panel with recommendations/actions cascaded within 2 weeks *Objective is to undertake mandatory investigation of all buckle events and set out the Zero tolerance to buckle risk*	TA DEAM IME	Immediate	3 months
TRK 1	The Regional DEAM's and Infrastructure Director's to set out a strategy that delivers a policy of zero unmitigated track buckles.	DEAM IME TME	6 months	3 months

	Objective is to elevate the perceived importance of CRT registers and management of buckle risk throughout Maintenance and Engineering			
OLE 1	Maintenance instruction module B10 of NR/L3/ELP/27237 to be revised. *Objective is to prevent adoption of risk based maintenance obscuring the need for OLE to be mechanically maintained and routinely reset to maintenance tolerances*	CM&EE	6 months	3 months
SRT 1	Critically review output from the NDT Stress analysis project and confirm the viability of the technique for practical application. Implement a high priority project to convert from a proven concept to application. *Objective is to accelerate validation of rail stress records at minimum cost, access, and resource.*	TA DEAM active pull	Immediate	3 months

Process and Standards Priority 2				
Recommendation		Action Owner	Timescale for completion	Timescale for EHTF review
OLE 1	Amend the instructions of recording of OLE B10 MST *Objective is to prevent ELIPSE recording that the MST is complete, until the whole wire run has been inspected and all work arising has been closed*	CM&EE *Regional DEAMs* *Regional E&P Engineers*	Immediate	3 months
SRT 3	Use currently fitted In-Service Train systems to inspect and evaluate Track and OLE. Eliminate existing barriers to data availability. *Objective is to identify conditions that result in Track and OLE degradation and failure.*	Systems Operator TA	4 months	6 months
SRT 5	Critically review Track Stability research with a view to implementation of outputs. Define benefits to safety and performance of track in extreme heat and plan implementation. *Objective is to focus research on defined benefits to extreme heat performance, and timely application.*	TA	3 months	3 months
SRT 6	Key Route Strategy to be fully verified. The DEAM to review engineering inputs to verify the extent of asset vulnerability. The maintenance response to the vulnerability to be approved by the Route Infrastructure Director (monitoring, resources, local impact	DEAMS Route Directors	6 months	6 months

	assessments, and planned operational restrictions). *Objective to ensure that an extreme heat event results in unplanned disruption to train services less than 10% reducing to less than 5% by the end of CP7.*			
SRT 4	Develop specific analysis of currently available track geometry and video data to identify buckle risk conditions. Synchronised video, geometry, ballast profile, ballast disturbance and SFT information to be available to the maintenance engineer. *Objective is to ensure that risk is identified and managed in accordance with the standards, and that the use of all data captured is optimised.*	Chief Engineer Asset Information Systems	12 months	12 months
SRT 7	WRCCA teams to offer formal guidance embedded in the 'business process' at a local level. Definition of how ambient temperature forecasts, solar gain, and air movement are used to predict component specific temperatures is required by maintenance engineers. *Objective is to ensure consistency in the management of extreme heat risk across Network Rail*	TA Systems Operator	12 months	None
D&P 2	Lineside building standards to be revised to require that the specified ventilation and or cooling systems provide protection appropriate to	B&A TA B&C Works	12 months	12 months

	the equipment housed in the enclosure recognising ambient temperature and solar gain of the building. *Objective is to provide guidance on calculation of sizing & selection of the ventilation and cooling system plant.*			
D&P 10	Procedures to require that where sensitive operational systems equipment is housed in lineside buildings, the ventilation and cooling plant proposed for lineside buildings should be subject to interdisciplinary sign off by both the building and systems designers. *Objective is to install cooling systems in lineside buildings that respect the required duty and cooling needs of the operational equipment housed and accounting for the extreme weather operational risks*	B&A TA Signalling and Telecom Engineers TA	12 months	12 months

Process and Standards Priority 3				
Recommendation		Action Owner	Timescale for completion	Timescale for EHTF review
OLE 9	Review topological wind speeds for all routes based on latest meteorological data. *Objective is to ensure that precautionary speed restrictions are applied only where blow off risk is genuinely exposed.*	CM&EE *Regional DEAMs Route Directors*	24 months	None
SRT 3	Use intelligent analysis of images and data to determine angular and longitudinal displacement to predict OHLE condition at critical locations in advance of extreme heat events. *Objective is to use technology to predict asset condition for resilience.*	TA	12 months	12 months
SRT 5	Review FRA research and methods for accelerating the application of research in the UK. Ensure that all research has a timebound application plan including any required trials, approvals, and changes to standards. Periodically (min 30 months) review overseas research into hot weather railway operations for applicability and benefit. *Objective is to accelerate the application of emerging knowledge and implementation at the working level.*	Technical Authority	12 months	None
SRT 8	Evaluate the use of Drones (Unmanned Aerial Vehicle's - UAV's) to assess vulnerable sites,	Technical Authority	6 months	6 months

	complimenting the information available from train-borne systems. *Objective is to improve asset condition assessment to plan preventative work for resilience.*	Asset Information Services DEAM (active pull)		

Organisational Dynamics Strategic Objectives

Including Competence and Technical Capability

Strategic objective is to create within the NR organisation a robust engineering hierarchy which makes clear that Engineers in Regions, Routes and in Maintenance have a traceable route of responsibility to the NR company Engineer and ultimately the Chief Engineer. That should be understood by all to be their professional line. Regional and Route Managers must have clear authority boundaries recognising that professional line.

The Technical Authority must be empowered to set national engineering minimum limits and accepted standard practices which are mandatory. In support of the Regions the TA must then provide professional expert guidance on application in specific cases, crucially including authority to vary from those mandatory requirements.

The intent of the TA role must be both to avoid unsafe or unsustainable acts or designs and to minimise waste and risk through unnecessary “preferential engineering” of solutions.

- The relationship between the TA and the Regional DEAMs must be clarified, the intended organisational authority levels should define that relationship.
- The degree of autonomy, capability and accountability in the Regions is urgently in need of clarification including documentation of delegation of authority from the Group Engineering Director/Chief Engineer to the DEAMs
- Primary responsibility, authority and accountability for maintenance must be clearly vested in the DEAM. Engineering must assert its role as guiding mind for Network Rail’s maintenance and inspection activity recognising that all asset management has to be based on high quality maintenance.
- The Chief Engineer and the DEAMs must be recognised as a peer group, the senior level of Engineers in the company. The views of that peer group are vital to decision making over the operation of the Railway and accordingly the influence of those views within the ELT must be improved.
- The Chief Engineer should be accountable to the Exec and Board for overseeing the career development of competent professional engineers across the company. The intent of this requirement is to secure the

sustainability of a safe, performing and affordable railway system through the availability of engineers in key posts capable of exercising sound engineering judgement, within a framework of accepted good practice, and of contributing to continuous improvement.

- Greater prominence must be given to Engineering at ELT level. There is presently inadequate visibility of the assets beyond the implied influence on train service performance. The underlying condition and rates of dilapidation must be made more prominent.
- The Operating model for the Regional and Route organisations must clarify that Maintenance Engineers in the Delivery units and Route Engineers are accountable on engineering and technical matters to the Regional Engineers, the DEAM and the Chief Engineer heads of engineering discipline in the TA.
- All staff in managerial positions through the organisation must recognise and respect the engineering accountabilities to which they and their dedicated engineering teams are committed. Executive leadership and vision will inevitably be rooted in the ELT.

Organisational Dynamics **Priority 1** **Including Competence and Technical Capability**				
Recommendation		Action Owner	Timescale for completion	Timescale for EHTF review
TRK 1	Heat related incidents with a score of 50 or above shall be formally reported, root cause analysis undertaken and reviewed by an internal independent, panel with recommendations/actions cascaded within 2 weeks *Objective is to provide rigorous assurance that all high risk incidents are promptly investigated an to provide clarity that there is zero tolerance to buckle events*	TA DEAM IME	Immediate	3 months
TRK 2	The Responsibility and accountability for the oversight of Hot Weather preparedness across the network is to be clarified, with key responsibilities and duties defined and agreed. *Objective is to put in place arrangements for proper engineering oversight of the application of weather related precautions*	TA SO DEAM	6 months	3 months
TRK 3	Undertake a review of mandated competencies for all staff managing critical assets and identify areas of weakness *Objective is to identify requirements for additional skill or competence training for track teams, and confirm that TME/IME level post holders and above are suitably competent*	TA DEAM	6 months	6 months
OLE 4	Operational Model to be adjusted to secure Technical Head has authority throughout the organisation	Group Engineering	3 months	3months

	Objective is to make clear that Engineers throughout the organisation are technically accountable to the company Technical Head	and Safety Director		
SRT 1	The DEAM to be accountable for the specification and quality of regional asset condition information. DEAM's and Regional Infrastructure Directors to endorse the forthcoming investment of over £500m in asset information systems and assure the competence of staff to use new systems. TA to be responsible for approval of systems to provide the accuracy, repeatability, and resolution to enable users to comply with standards, and their suitability for intelligent analytical processing. *Objective is to assure accountability for asset condition information, and the use of systems for resilience and safety management at the working level. Enabling Modernising Maintenance through technology.*	DEAMs and Regional Infrastructure Directors. TA and AIS support	4 months	6 months
D&P 7	Maintainer to have responsibility and accountability for operational failures caused by temperature or water ingress in lineside enclosures. *Objective is for the operational impacts to be clearly attributed to the building condition*	Regional DEAMs	3 months	3 months

Organisational Dynamics Priority 2 **Including Competence and Technical Capability**				
Recommendation		Action Owner	Timescale for completion	Timescale for EHTF review
TRK 4	Review current National and Regional strategies for operating in Hot Weather and ensure a level of consistency; particularly around regional boundaries. *Objective is to confirm that strategies are engineering based assessments and that precautions are consistent in their application*	DEAM IME TME	18 months	12 months
OLE 3	OLE Engineering technician posts in E&PME teams to be filled *Objective is to make available adequate engineering support is available within the E&P maintenance units*	Regional DEAMs Route Directors	9 months	12 months
D&P 6	E&P/D&P resource to be reviewed. First line failure & response in the event of extreme heat affecting lineside building cooling systems failures to be specifically considered. *Objective is to balance the number of plant trained operatives with multiple simultaneous failures of cooling systems during extreme heat events.*	Route Engineers E&P Maintenance Engineers	12 months	24 months

Organisational Dynamics Priority 3 **Including Competence and Technical Capability**				
Recommendation		Action Owner	Timescale for completion	Timescale for EHTF review
D&P 9	Economic and performance evaluation of in-house F Gas trained maintenance staff to be undertaken to examine the case for wider adoption *Objective determine if the in house arrangements in Doncaster and Peterborough Depots offer positive benefits elsewhere*	Route Asset Managers E&PME	12 months	12 months

10.0 Technical Reports

10a Overhead Line Equipment

Introduction

This part of the report will cover the traction Overhead Line Equipment (OLE) assets. Prominent in their direct effect on train operation in summer 2022 (and previous years) have been the traction OLE failures. Some less visible aspects of the overall E&P Asset inventory are covered in a separate section on fixed plant and power supply.

2022 performance

Whilst it is tempting to concentrate on the July 18th/19th, the days of highest recorded temperatures, the number of failures in the two days alone is not the whole picture. The UK experienced hot weather throughout June, July and August. OLE failures across those three months were numerous and indicate vulnerability to high temperature.

The pattern showing that failures occurred over the days following the high temperatures is an important indication of the effect of high temperatures and the way in which equilibrium is restored as temperatures then reduce. The mechanical movement back to equilibrium can be seen to continue to cause failures into September.

Appendix 2 presents details of the population of OLE incidents across the months of June, July and August, together with some more specific information about the results of investigations of cause.

There are many mechanisms of OLE failure; those related to the effects of high temperature are worthy of description.

What causes OLE to fail

In the context discussed here, catastrophic failure of the OLE is characterised by wires parting or geometrically distorting, commonly but not always resulting in entanglement with train pantographs.

Typical OLE damage near Birmingham International

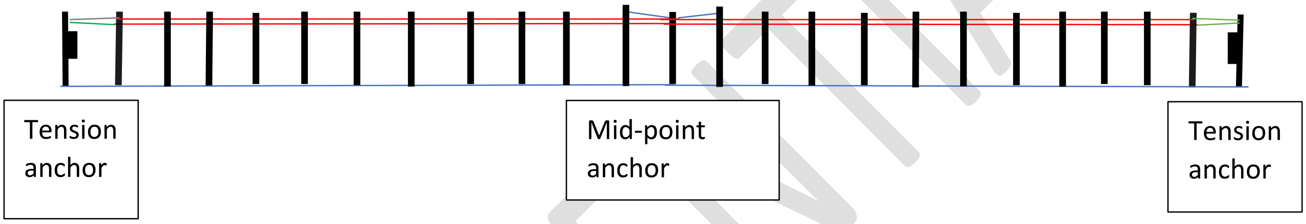
There are many issues which can be the precursor to such failures. Described here are the major mechanisms of failure most likely to be the result of high temperatures. First though there is a little about the laws of physics to clarify.

OLE contact wire, catenary and other conductors are metal (copper, copper alloy or aluminium) and have a positive coefficient of expansion with temperature. Copper has an expansion coefficient of 16.5µm/m.K). A unit of overhead wire run is known as a tension length and may be up to 1600m and each tension length is tensioned in two half sections. The temperature range of BR era OLE is -18°C to + 38°C. If a half tension length of wire is exactly 800m long at its lowest operating temperature it will expand to 800.739m at its highest. The automatic tensioning system must be able to accommodate that range of movement. Once the tensioning system stops absorbing the along-track movement the wire spans will begin to soften and sag, and the registration supports may also progressively become mechanically overloaded.

Some sections of OLE are constructed with fixed tension conductors having no arrangements for temperature compensating automatic tension control. Fixed tension OLE was installed widely until the late 1960s although it has never been adopted for line speeds over 75mph. At high temperatures fixed tension equipment demands speed restrictions and ultimately service suspension at temperatures lower than apply for OLE which incorporates automatic tension control; it will not move along track but rather will progressively deepen the sag at mid span as the temperature rises. Eventually that sag will become sufficiently great to cause the live wire to come into contact with the roofs of passing trains.

Configuration of OLE

As noted above wires are built in tension lengths. A normal tension length will be up to 1600m long, will have auto tension anchors at both ends, and will be fixed anchored at its mid-point.



A wire run tension length.

Wires are overlapped where one tension length abuts the next to allow pantographs to transition smoothly.

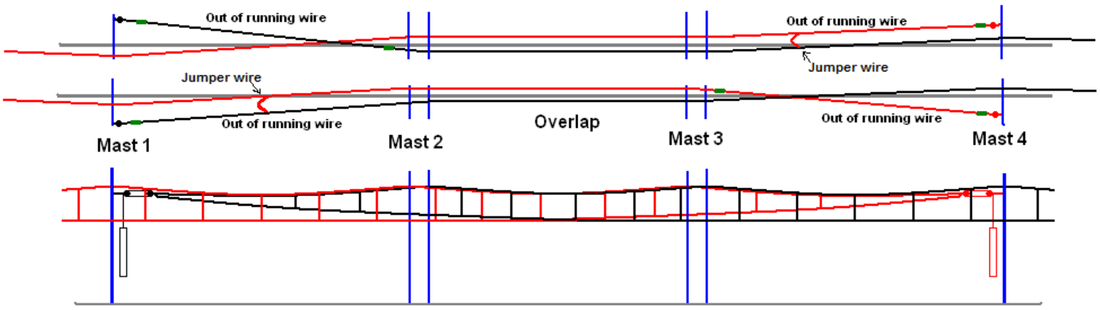
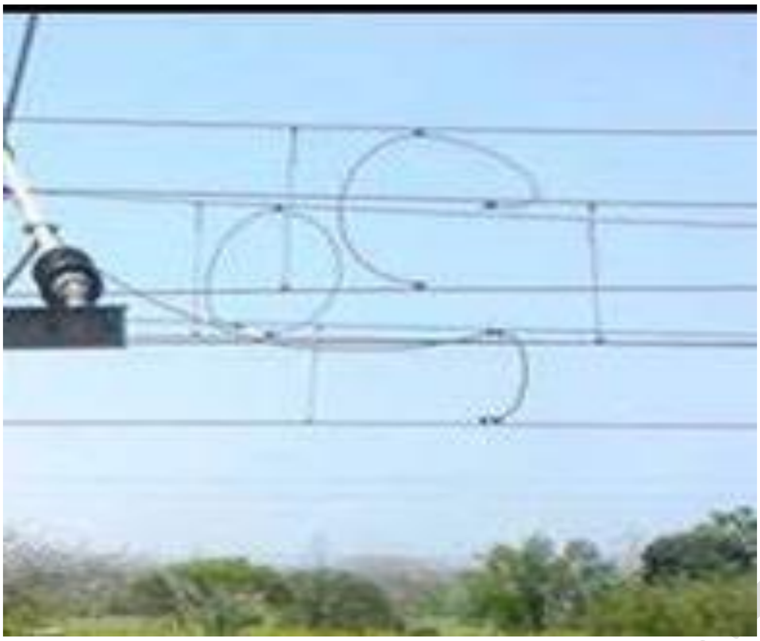


Figure 2 A standard Overlap arrangement

At these overlaps there must be conductors known as jumper cables which provide electrical continuity. These jumper cables must have sufficient available flexibility and movement to accommodate the up to 1.4m range of difference as the two wires that they connect together move across the temperature range.



Picture 1 Overlap Jumper cable

The OLE registration assemblies must accommodate the range of radial movement required as the wire expands. Thas movement imparts a rotation of the registration assemblies, which is a complex issue. There will be between 12 to 15 registration points between the fixed end of a half tension length and the auto tension termination at the overlap. Whilst the registrations towards the fixed end will experience little radial movement, those at the overlap will experience the full range of movement. The length of the registration support must be great enough to allow sufficient rotation without pulling the wire out of registration tolerance, and to avoid placing too great a tensile load on the components, particularly the steady arm beyond the capability of the fitting.

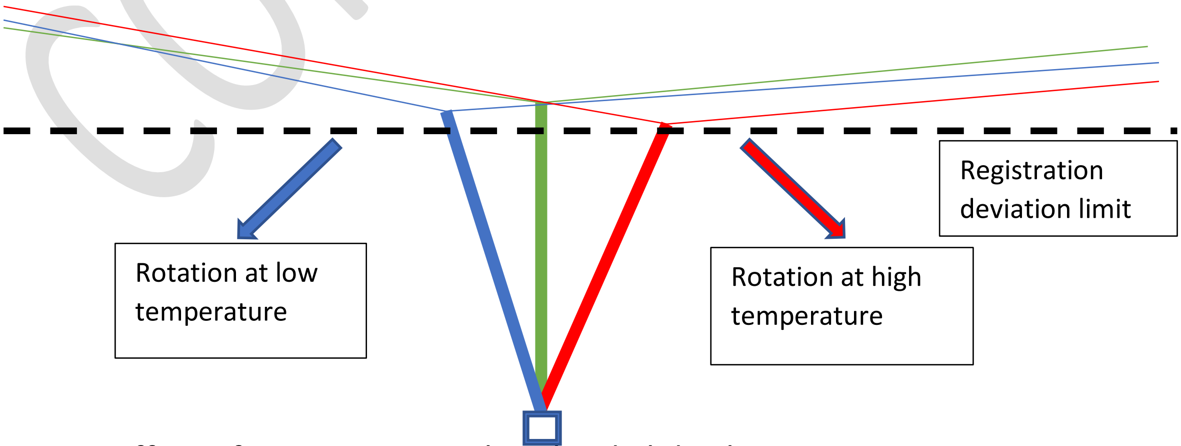


Figure 3 Effect of temperature related radial displacement

However, over time wire, particularly copper wire, will stretch. This is plastic deformation and individual wire runs will stretch at different rates. If the stretch is not taken out there will be a bias towards the tension end of the wire. The arms will all be drawn around towards the weights, and, at the extremity of available movement due to temperature the wire, will move outside the stagger deviation limit. This will pull the wire off the pantograph and will result in a "hook-over" de-wirement.

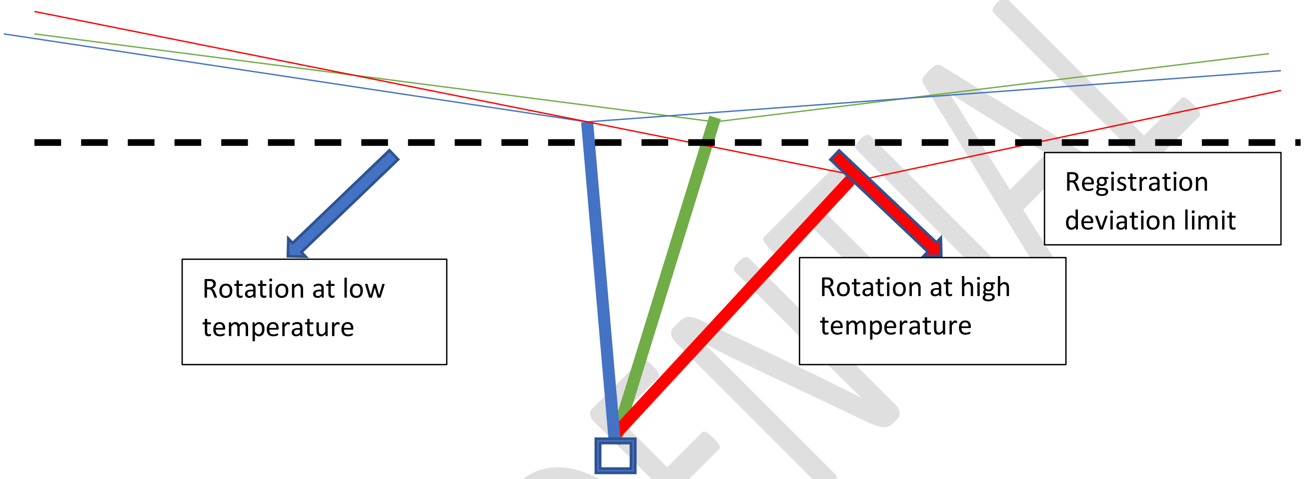


Figure 4 Effect of stretch "biasing" the radial movement allowance towards the tension end

Picture 2 Overlap cantilevers both showing along track offset towards the tension assemblies. Note that the noses are moving towards each other.

When temperature is extreme

Well maintained OLE will move to the limits of available movement and will remain within operational tolerances. However, if wire stretch has not been removed, or steady arms and registrations have not been adjusted back to the centre of the temperature range, the equipment will become vulnerable to loss of tension and a risk of hook-over de-wirement.

Furthermore, the moving hinges and clevis fittings which hold the weight and loads of the wire and assemblies and allow radial movement of the supports need to be free to move, adequately greased and within wear tolerances. The extra tensile load occasioned by sticking mechanical parts will increase the tendency for wire to stretch and can cause tensile failure of wire, fittings or insulators. Hinges and clevis links not lubricated and not replaced when worn will place loads on the system components which they were not designed to bear. These forces will be sufficient to cause tensile fracture of steady arm clevises and contact wire clamps and if ceramic insulators are placed in bending load due to seized hinges they will simply break.

Without maintenance attention to jumper cables and the electrical connections these jumpers provide can cause failure of the wire where the jumper is connected. Over time conductivity worsens due to ageing, degrading the connecting surfaces. Heating and cooling due to cyclic loading will weaken the wire. Mechanically the jumper position must be adjusted to compensate for stretch and tension redistribution. Otherwise, at extreme temperature the connections will be placed at greater mechanical tension as the differential movement of the wires attempts to stretch the jumper cable. Already weakened by ageing clamps under high load will fail and hang foul of passing pantographs.

Even if none of those conditions provoke failure, as the wire loses tension it becomes mechanically less stiff. Passing pantographs will experience much higher dynamic forces, potentially sufficiently high to cause pantograph failure. The forces unleashed will also propagate through the OLE and that may cause fatigue and tensile failure of the wire, clamps, dropper clips or ceramic insulators.

What is good maintenance?

All OLE should be inspected and maintained cyclically. BR mk.1 and BR mk.3 systems were specified for a 4 yearly cycle on lines over 75mph, 6 yearly for all others, newer systems at 6 yearly throughout. The inspection should be used to determine the need for stretch recovery and re-adjustment of registration setting. The work then carried out should be those adjustments, replacement of worn fittings and components, lubrication of all moving hinges clevises and connections, adjustment of jumpers and replacement of jumper clamps.

Maintenance is not defect repair; defect backlogs should not be allowed to build to the point where the access time for essential OLE maintenance is needed to be used in dealing with the increasing number of defects. The 4 or 6 yearly essential maintenance should not be sacrificed to free time for defect rectification.

Network Rail now has in place a maintenance instruction for OLE (Module B10 NR/ELP/L3/27237) which details these measures. Compliance with module B10 should be a fundamental requirement.

Who tracks OLE maintenance?

In his interview with the task force the CM&EE explained that the general position of the OLE estate of Network Rail is that access time and resource availability is limiting the attention that OLE is for most routes limited to site specific defects and rectification and repair on failure. He also noted that even with that focus there is a defect backlog which is in general growing across all Regions.

His comment was that if all that can be done is compliance rectification and fix on fail, the equipment condition will become increasingly dilapidated over time until the whole system is bordering at the point of failure. Without proper maintenance it cannot deliver the reliability the railway needs. Furthermore, equipment that should in the large part last 40 to 60 years will need renewal much earlier.

The effect this level of maintenance will have on the operation of the system in extreme climatic conditions will inevitably be harmful. BR era systems were specified to be capable of operation up to 38°C. Unmaintained, it is debateable what the upper limit will now be, but a reduction well below the design maximum temperature will certainly be the effect. Missing two or more cycles of maintenance will likely leave some wire runs with the reduced upper range below 28°C and vulnerable to mechanical failure when movements due to high temperature are experienced.

The CM&EE noted that the specification for the UKMS OLE system now used for all new installations has an upper temperature limit of 40°. But he specifically noted that no OLE system is maintenance free, failure to deal with conductor creep due to stretching plasticity will as surely degrade those modern systems as it has all of its predecessors.

Conclusions for OLE

The evidence clearly shows the OLE failed in multiple locations due to the high temperatures. Those failures did not all occur on the highest temperature days - many occurring in the days following. This is consistent with the effects of stressing the OLE wires and components and compromising the dynamic performance of the OLE/pantograph interface.

It is widely the case that the full range of maintenance work has not been undertaken, work associated with stretch recovery across most of the main line network has been the victim of access and resourcing constraints. Auto-tension weights have been adjusted, but that does not address the exposure of the wire and fittings to along-track movement and radial load on cantilevers beyond the design and capability of the components; and ignores the need for lubrication to allow free movement of the cantilever assemblies.

The capability and experience of the OLE maintenance teams has suffered due to experienced and senior people from the teams having taken early retirement during the various downsizing initiatives, leaving inexperienced teams, some without sufficient people with suitable experience to mentor and nurture their development.

Access constraints are a major cause for concern. OLE is a mechanical system; without proper maintenance attention the mechanical system will deteriorate and ultimately fail.

Appendix 1 presents OLE failures throughout the period of high temperatures across the months of July and August 2022. In the table it will be noted that ELLIPSE records present a picture that maintenance was 100% compliant. As will be set out later, ELLIPSE records for OLE maintenance are unreliable.

The performance of the OLE across NR throughout the summer months of 2022 indicated a general trend of loss of asset condition with a likely cause being inadequate preventive maintenance intervention. Module B10 of NR/L3/ELP/27237 is a derivative of the BR maintenance standards known as EO1 and EO2, which, respectively, set out the requirement for routine track patrol inspections and intrusive preventive maintenance.

The high number of incidents with originating cause of failure to OLE in the vicinity of overlap spans and the long overdue timing of maintenance intervention adds weight to the conclusion that the poor performance in Summer 2022 was in large part caused by general maintenance non-compliance.

What has changed?

Maintenance of the whole infrastructure has become increasingly pressured over the post privatised period. Those pressures result from many diverse directions but access constraint, the drive to reduce OPEX cost and loss of experience and competence in the maintenance organisation are the most significant.

Over several years the requirement for patrolling all mainlines every 4 weeks was identified as highly demanding of resources and considered by many to be of debatable value. What emerged from that debate was a revised requirement - a risk-based approach was introduced. This allowed extending the periodicity from 4 weeks to 6, 8 and as much as 12 weeks depending on assessed criticality. It is worth noting that this change was further necessitated as red zone working restriction became more widespread and, with the recent move to remove people from open running lines. most if not all patrolling has become a possession only activity. However, OLE patrol inspections are very ineffective at night.

Visual inspection by patrol seeks to identify:

- damaged or broken components or assemblies
- displaced droppers or jumper connections
- excessive radial movement of registration assemblies and low (less commonly high) auto-tension weight stacks
- security of traction bonding cables
- vegetation within and outside the railway boundary
- work in construction sites or businesses such as scrap yards neighbouring the railway to which the 25kV conductors might present electrical hazards.

Risk based patrolling was an entirely logical development. It is clear to all who have considered this that patrol inspection yields variable results. The outcomes, compromised by visibility, the difficulty of checking bonding cables against schedules or drawings and the need to look out for trains, limit the effectiveness of patrolling inspections; so a risk-based reduction in frequency is sensible.

There are encouraging prospects for replacing visual inspection by patrolling with data and video gathered from trains. Developments in video-based pattern recognition will increasingly replace visual inspection and improve identification of problems beyond what can be seen by eye from track level. It is however surprising to note that there appears to be no discernible direct connection between the need for these technology systems and the development work being progressed. Other sections of the report cover the detail of these technical developments; suffice here to note that neither the delivery objectives nor the timebound urgency to mitigate the effect of reduced visual patrolling of OLE is visible in the overall implementation strategy.

Access Constraints

All Regional Engineering teams have raised the point that access is constrained. Hands on inspection and remediation requires track possession and electrical isolation. The planning and delivery of OLE maintenance is problematic and demands new thinking. Notably the Wales and West Region has several initiatives in active progress. There is recognition that the proper maintenance of the new electrification on the GWML must be established and integrated into the routine of operation on the Region. The need to resource the hands-on high-level inspection work has been recognised and an arrangement has been put in place with the NR OCR team, which provides machines and manpower for maintenance work. An interesting development undertaken has been the development of a lubrication tool making possible the application of grease using insulated poles from track level. The Region has plans to improve the resilience of the OLE between Paddington and Airport Junction.

Solving the availability of competent resources alone is however only one challenge. All Regions have reported that access constraints are a severe limitation on maintenance delivery. NW&C in particular has determined through a detailed study that with current restricted access the average time available for maintenance of a span of OLE is limited to 5 minutes every 4 years. Many years of experience across electrification maintenance has shown that 15 minutes every 4 years is the need.

OLE Maintenance

Traction OLE is a mechanical system and components within the system will wear and fatigue with age and use. In general, higher speed of train operation will occasion more wear than a lower speed due the energy and magnitude of movement imparted by each passing pantograph. The greater the number of pantograph passages, the greater will be the wear on mechanical linkages. The magnitude of mechanical wear is therefore directly in proportion to the speed and number of trains operating on the line. Any risk-based approach to the mechanical maintenance of the OLE might reasonably conclude that the 4 yearly cycle applicable to the East and West Coast Main Line fast lines can be considerably eased for the line from Witham to Braintree in Essex for example. Line speed is barely half that on ECML and service patterns are incomparably different, yet it would seem that risk-based maintenance consideration has been applied to both in exactly the same way.

The connecting moving parts of an OLE system are, for the most part, simple hinges and hook and eye fittings. Most are metal castings and lubrication of these moving parts within the OLE is by grease. The predicted rate of wear, and therefore the predicted service life, depends on effective lubrication both to reduce surface attrition and for hinges to protect freedom of movement. No lubricant will provide indefinite protection weather and pollution will wash off and contaminate the lubricant. Essentially this is a time related maintenance need.

There are some maintenance tasks which are therefore time critical. Module B10 of NR/L3/ELP/27237 sets out these tasks. The time critical task will always be that of lubrication. Even a wire run of OLE above a line over which no trains run will nonetheless require attention to replenishment the grease. Whilst wear and fatigue will not feature, the wire may stretch, and if so, it may also need adjustment if it is to remain in operational specification.

Wire runs with high speed and high numbers of pantograph passages will require wear of moving parts to be inspected, replacing worn components accordingly. Fatigued cables will need to be sought out by hands-on inspection and replaced, and of course the adjustments must be made to restore the wire run to operational specification.

Risk Based Maintenance

The traditional approach to maintenance across all industries is time based interventions with a defined scope. The inherent anomaly with an entirely Time Based Maintenance (TBM) regime is that there is no factoring of the effect of usage; systems are maintained at the same periodicity regardless of the operational demand placed on them. For railway infrastructure that demand varies both in line speed and tonnage. TBM in its simplest form will give rise to the same interventions on a line with line speed below 75 mph and 10,000 pantograph passages per annum as will be undertaken on a line with 125mph line speed and 50,000 pan passages per annum.

Some differentiation has been embodied in maintenance requirements over time recognising that for lower speed and lower tonnage lines, longer periodicity can apply. However, interventions remain time based and without variation of the scope.

What underpins the TBM approach is a view on rates of wear, attrition, corrosion and drift of adjustment. Whilst the precise evaluation of the rate at which those degradations occur has historically been judgment based, there is no question that each is a factor requiring attention. For systems such as OLE where access for hands-on intervention is limited, it makes sense to group the whole system into one intervention event. It will be the case that some components will be maintained and adjustments made before their individual critical point of degradation is reached but the cost and complexity of access justifies dealing with the whole at the periodicity of the most rapidly degrading item, thereby maximising reliability and availability.

In recent years many industries have moved from TBM to Condition Based Maintenance (CBM). It is obvious that if maintenance intervention is to be planned and undertaken based on condition, some mechanism to allow monitoring and evaluation of condition must be set in place. CBM has been implemented successfully by many industries, most notably perhaps in aircraft engine maintenance. Modern trains are maintained on condition based regimes. To make the transition data acquisition and gathering, together with information management systems must be comprehensive, robust and secure.

Within NR Risk Based Maintenance (RBM) has been introduced. RBM is clearly not the same as CBM. RBM has been introduced without robust and secure data/information systems. Whilst those systems are notionally being developed, none are complete, and none are comprehensive. This then leaves RBM to be applied based for the most part on the judgement of individuals. In making that judgement what is the individual assessing? There are three areas of change that can be considered; to change the period between interventions, to change the method or nature of the work at the time of the intervention and to change the scope of the intervention.

In the interviews with all engineers across Maintenance, Asset Management and with the TA two points are clear. It is universally understood that all maintenance must be achieved within the available access - which is defined by the priority to maximise train service delivery with no counterbalancing weight given to the need for asset maintenance. Maintenance costs are regarded as too great and are subject to pressure to reduce. RBM may have had more balanced intensions as conceived, but it is nonetheless adopted as a vehicle to legitimise reduction of planned maintenance scope.

The role of Ellipse

The NR ELLIPSE system is now almost 20 years old. It allows maintenance work to be scheduled, tracked and closed out. A Maintenance Scheduled Task (MST) is the transactional unit within ELLIPSE. MSTs are raised by the system and closed once the specified task is complete. Ellipse data is used for many purposes, among which is the tracking of maintenance output. However, as a simple scheduling system ELLIPSE offers no insight into effectiveness.

RBM is applied to vary scope and method of work within an MST. It would appear to be the case that those changes to scope and method are un-moderated. Therefore, whilst tasks within a particular intervention may be altered or indeed dropped completely, the MST will be raised against the description of the historic interpretation of task. However, what will be planned is the reduced RBM scope. With that reduced scope completed the MST is closed as 100% complete, creating the impression that the equipment is fully maintained and compliant with condition expectations embodied in the historic maintenance requirement.

The impact of this cannot be overstated. It creates an impression that all is well. The infrastructure will appear to be well and comprehensively maintained. In the specific area of OLE maintenance, interviews with practitioners revealed a clarity of view that preventive maintenance was extremely limited, and yet ELLIPSE continues to record 100% completion of the MST which records that maintenance activity.

Taken alongside the dominance of the exceedance compliance regime it is inevitable that much of the infrastructure is operating on the margins of failure and therefore extremely exposed at times of climatic extreme. This leads to increased demand for enhancement and early renewal funding and drives an understandable lowering of the threshold at which the organisation concludes service restriction is prudent.

A concentration on safety compliance and defect rectification has become the norm. Whilst compliance interventions seem broadly to be achieved, defect repairs are not, and there is a substantial backlog. There is a widespread view among maintainers and engineers alike that a compliance and fix on fail regime will keep the system "safe". That may well be correct, but achievement of safety in operation is not the only objective of maintenance, reliability. Resilience and longevity are matters of equal importance. OLE does not present risks analogous to derailment inherent in the track. Safety risk from OLE de-wirement is greatest from the heavier registration components breaking through driving cab or passenger windows or being shed onto a passenger platform. Currently those are thankfully very infrequent events. This appears to have brought about an attitude which regards OLE failure in the "lesser" category of performance risk, and therefore tolerable. In general, those involved in OLE engineering and OLE maintenance understand the significance of not tackling module B10 maintenance but regardless of that understanding the maintenance is not planned and not delivered. Various lines of reasoning have been presented as to why this is so. The main issues discussed have been access time, diversion of resource on to lucrative isolation service provision to projects and to reductions in operative numbers. Particularly the OLE Technician level engineering support to Maintenance Engineers has been highlighted. This is an issue which appears to be affecting all Maintenance Engineers across the disciplines. The standard model for Maintenance Engineers includes at least two engineering technicians, office based. Those posts languish as vacancies, presumably as a of cost saving measure. Without those junior Engineers, the maintenance Engineer is impossibly placed to undertake the range and number of surveys and detailed investigations that the assets demand.

In the absence of periodic maintenance attention, the equipment deteriorates more rapidly into the need for early renewal, imposing unreliable performance, greater cost and disruption.

In Japan the way in which OLE is maintained is unlike any European practice. Robust OLE is built. There is no preventive maintenance carried out, but no OLE wiring, insulator or registration assembly is left in service for more than 15 years. From day one in service, there is renewal programme at work. They base their target on renewing the whole on a 12 year cycle. 12 years of 50 weeks and 5 nights a week gives 3000 nights over which the renewal must be achieved. So however, many wire runs there are, 1/3000 must be renewed each night. That renewal entails removal of all the OLE from mast face outwards including all the wires, droppers etc. insulators and cantilever assemblies. New or refurbished OLE is built and set to as new settings. Because the teams do this every night, they get very polished at it, and being Japan, the quality is excellent.

That illustrates the effective life that should be expected without preventive maintenance. With module B10 preventive maintenance consistently carried out UK should be able to plan for 40 years life before the level of renewal carried out at 15 years in Japan is needed. Japan shows us that we should expect around a third of that life without module B10 intervention. It would appear that there is a belief that the entirely renewal based approach adopted in Japan can also deliver the whole life duration which UK expects, clearly it cannot.

A remediation plan is needed if reliable and more resilient performance is to be restored. That remediation plan will comprise measures to restore maintenance condition across much of the network. It is likely that the remediation will stretch across several years. It is urgent that the equipment built in CP5 is now actively placed under a module B10 maintenance regime, without that the performance of that equipment will deteriorate, and its useful life will be reduced.

Conclusions

1. OLE across the network is not in a maintained condition.
   This leads to a general loss of performance reliability.
   That loss of performance reliability is accentuated at the extremes of operational range such as summer temperatures or high winds.
2. Visibility and stewardship of the asset condition is poor.

The advance in dilapidation of the OLE is progressing unseen and unchecked.

The notable loss of reliability is eroding confidence in the infrastructure leading to draconian precautions in climactic extremes.

The life if the assets is being progressively reduced which will lead to unnecessary premature renewal.

3. CM&EE (and whole of TA) is not able to act with authority.

   There is thus no effective guiding mind to highlight shortcomings and prompt intervention.

   Insufficient independent review of stewardship is undertaken.
4. Risk Based Management is not balanced.

   Safety and service performance are reported by the System Operator.

   The fundamental performance of the maintenance function is not monitored; both response and repair are seen through a train service performance lens but the maintenance output is invisible.

   Asset stewardship is not tracked and therefore not monitored; whole life cost is thus not protected.
5. Maintenance Engineers have available insufficient Technician Engineer level support.

   The analysis, survey and investigation to set the plan for maintenance requires engineering input; the Maintenance Engineer cannot be effective as a one-man organisation.
6. There is no strategic plan for technology development and deployment.

   Within the business various systems and data collection technologies are being developed. There is no plan which links those developments to business benefit or organisational efficiency objectives.

Recommendations

Recommendation OLE 1

OLE maintenance in FULL compliance with module B10 of NR/L3/ELP/27237 should be implemented across the Network.

Module B10 to be reclassified as “red” mandatory requirement. Any variance on periodicity to be justified as a deviation, and only adopted following Engineering endorsement by the standard owner, the TA head of discipline.

The maintenance instruction module B10 of NR/L3/ELP/27237 to be reviewed and rewritten updating the requirements to make them applicable under Condition Based, Reliability Centred or Risk Based Maintenance regimes, whilst placing clear obligation to deliver basic maintenance adjustment, lubrication and like for like replacement of worn components.

Changes to be made to the recording of work in ELLIPSE to give full visibility of maintenance shortfall and/or backlog. The masking of what has been done or not done under the cover of a single B10 MST will be stopped to improve visibility and quantification of the achieved maintenance activity.

Recommendation OLE 2

Refocussing of maintenance attention will need to be accompanied by a remediation plan to replace worn components like for like. This is a mid-life remediation of dilapidation by heavy maintenance, not renewal. The remediation phase may need to be tackled by engagement of contracted labour. Steps to securing funding authority and engagement with the supply chain to be actively pursued.

Recommendation OLE 3

Maintenance Engineers teams junior level Technician Engineer posts should be unfrozen and filled. Much of what needs to be achieved in mitigating risk during weather extremes and in the comprehensive rehabilitation of the OLE requires engineering investigation and analysis. The holders of these posts will be key to undertaking that work.

Recommendation OLE 4

Changes in working arrangements will need to be made to consolidate and secure the TA with full authority to act as Engineering guiding mind for Network Rail, it is not acceptable that the standards owner can be seen to be ignored.

Recommendation OLE 5

To compliment the indicators reported on operations safety and operations performance, the TA should present routinely an asset stewardship report with indices to confirm to the ELT and Board that whole life asset condition is being protected across the network. It is noted and welcomed that this has been actioned following the initial report.

Recommendation OLE 6

A strategic plan for asset data and information technology with a clear link to the business vision should be developed. It is recommended that the TA should be the owner and responsible for delivery against that plan.

Recommendation OLE 7

Access for OLE maintenance is inadequate across most of the network. The reaction to this is one of resigned acceptance among those charged with the responsibility who present a clear position that they are disempowered from any action available to them, nor is there seemingly recourse to support to gain that empowerment. It is recommended that a NR ELT level sponsor is nominated to lead an initiative under an appropriate ELT remit to restore access availability across the whole electrified network for OLE wire run maintenance, based on the 15 minutes per span every 4 years metric which is the generally accepted minimum.

Recommendation OLE 8

Recognising that it will take a number of years to remediate current maintenance condition throughout, some emergency measures need to be actioned to mitigate risk as much as possible. Overlaps which are part of a wire run not yet rehabilitated to sustainable maintenance condition should be surveyed. Using the temperature of the day at time of survey and measurement of the radial displacement angle, cantilever frames on the first two registrations both sides of the overlap to be assessed. Adjustment should be calculated and carried out for each of those cantilevers/registrations and associated balance weight stacks or Tensorex, together with wire geometry through the overlap span, to restore settings appropriate to the 38°C position.

Note that these measures will improve resilience but must not be interpreted as any more than expedient risk reduction, this is not adequate action to address the extent of dilapidation.

Recommendation OLE 9

This recommendation is to secure wider climate resilience. The remediation and re-establishment of the maintenance regime will necessarily entail bringing the OLE back to acceptable registration (position of the wire geometrically corrected compared to rail position). Maintenance of that geometry is the best guarantee of resilience in high winds. There will however remain some sections of lines where high wind speeds create higher risk of de-wirement. A re assessment of the topographically adjusted wind speeds based on current met office wind speed predictions should be conducted. Only locations where that reassessment confirms significant exceedance of the OLE design wind speed should any extra precautions such as train speed restrictions be applied.

The view from the Regions

Wales & West

Discussions with the Regional E&P engineering team on 3rd October 2022 centred on the OLE failure at Hayes on the GW main line on the morning of 19th September 2022, the day of Queen Elizabeth’s funeral. The disruption on that day was particularly damaging reputationally although that was not the prime concern of our meeting.

Factually the failure was parted wires with entanglement with a pantograph. The damage was in the section of the main line between Paddington and Airport Junction, electrified with the BR Mk3 OLE system supported by 4 track head span structures. Failure of the head span at what was likely the originating location of the failure propagated the effects to all 4 lines, closing the GWML route to all traffic.

All the trains involved in the immediate incident (two class 800 IEP trains and one class 387 train) were equipped with pantograph and front facing cameras and yet the recorded video images from every one of those cameras were either lost or otherwise not available. The loss of that crucial evidence made detail evaluation impossible. Furthermore, the damaged components and wires were all disposed of as scrap without being safeguarded and retained for forensic examination, nor were they photographed, so that evidence trail also went cold.

When the system opened to traffic a second incident occurred closer to London. Some suspicion has been raised that this may have been related. It is the Task Force view that the symptoms and photographic evidence are more suggestive of failure due to excessive movement towards the adjacent tension anchor overloading a steady arm fitting. This second incident was only revealed when service reopened, the site likely remaining protected because trains were stopped on the 19th.

One profound difference of view must be noted. The Regional E&P Engineer does not accept that any link is proven between hot weather and the GWML incidents in
summer 2023. That view is noted and it is acknowledged that there is no direct evidence to substantiate the conclusion. Investigation on site and component recovery was not of a standard to support detailed post repair review. Nonetheless, the view from the EHTF remains that the circumstantial indications are that the high temperatures provoked excess movement due to wire expansion. The equipment, already out of adjustment for along-track movement through long standing inattention to maintenance, was subjected to localised high mechanical stress. OLE stressed in this way will take several days to move back to equilibrium and resulting failures are likely to emerge as that movement redistributes tension along the spans. The BRmk3 equipment between Airport Junction and Paddington is not in good maintenance condition and it remains the EHTF view the excess movement was enough to provoke component, assembly and cable failures at locations of incipient damage, wear and fatigue.

NW&C

NW&C E&P team undertook an in-depth study: NW&C Contact Systems, High Level Wire Run Maintenance Study, (Module B10 NR/ELP/L3/27237)

In the report of that study is an analysis that concludes that at each maintenance cycle each span of OLE (the wire over one track between consecutive supports) should be given 15 minutes attention on average once every 4 years. Alarmingly their assessment is that with currently available access the maximum that can be achieved is 5 minutes.

The summary of that report is reproduced here:

For some E&PMEs, contact systems as a discipline is secondary to their core experience in Plant & Distribution (P&D). That places a reliance on having a strong overhead line team around them. Assurance checks via audits and engineering verifications have highlighted that some EPME's require coaching and support. This is a key role for Route and Regional Engineers.

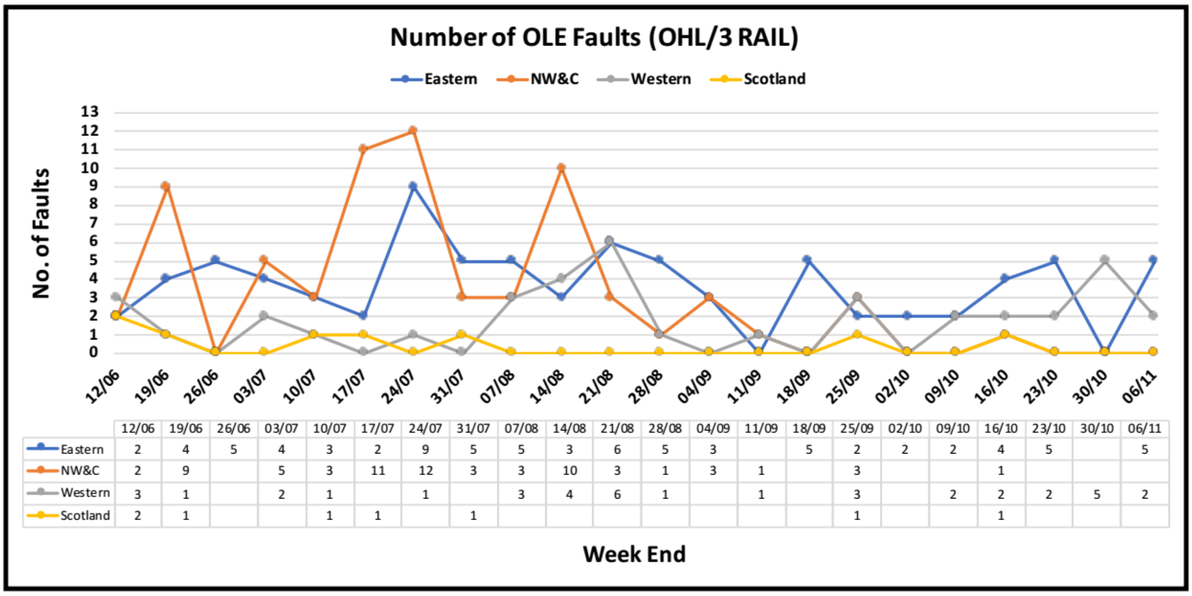
To make any effective changes within a large organisation at a local level can be very challenging and can take time to convince others that any changes are for the best. It is the intended purpose of this document to help inform why changes have to be made and to provide E&PME's and Section Managers, those who hold the day to day responsibility for the assets, with the ability to demonstrate to the business why preventive maintenance is essential. Effective maintenance will demand more and longer access windows to facilitate sufficient productive time.

Whilst a few maintenance teams are planning more than a single shift per wire run, it is recognised that planning for more access to complete maintenance will stretch some teams that are already at full capacity within roster flexibility and available staff competencies. More and better planned time on site per wire run will naturally lead to more efficient and effective maintenance and will afford greater capability for defect removal, which in turn will improve reliability.

OLE failures, recorded over summer 2022 (Information provided by Network Rail)

		Number of OLE Faults (OHL/3 RAIL)				(Dewirement, Wire down)			
Week Start	Week End	Eastern	NW&C	Western	Scotland	Eastern	NW&C	Western	Scotland
06/06/2022	12/06	2	2	3	2				
13/06/2022	19/06	4	9	1	1				
20/06/2022	26/06	5							
27/06/2022	03/07	4	5	2					
04/07/2022	10/07	3	3	1	1				
11/07/2022	17/07	2	11		1				1
18/07/2022	24/07	9	12	1		1	1	1	
25/07/2022	31/07	5	3		1	1			
01/08/2022	07/08	5	3	3		2			
08/08/2022	14/08	3	10	4					
15/08/2022	21/08	6	3	6					
22/08/2022	28/08	5	1	1					
29/08/2022	04/09	3	3						
05/09/2022	11/09		1	1					
12/09/2022	18/09	5				2			
19/09/2022	25/09	2	3	3	1				1
26/09/2022	02/10	2							
03/10/2022	09/10	2		2					
10/10/2022	16/10	4	1	2	1				
17/10/2022	23/10	5		2		2			
24/10/2022	30/10			5					
31/10/2022	06/11	5		2					
	Total	81	70	39	8	8	1	1	2

Weekly distribution of OLE failures (note the decline over the period into September)



The table below covers OLE incidents in Eastern, NW&C and Western Region.

Date	Incident description	Overlap proximity	B10 date	B10 %	Investigation
Eastern Region					
03/08/2022	Registration arm detached on the Up line at E160/16 - failed strut insulator at E160/16.	Yes	19/03/18	100%	The incident has an SRE completed. The failed porcelain strut insulator has been sent for analysis.
18/07/2022	Section 155 on the up main tripped at 1648. 1V68 reports wires down over both lines, 1V68 has suffered a broken windscreen. CCIL 2516697.	No	15/11/20.	100%	The incident has an SRE completed. The failed porcelain hook insulator has been sent for analysis.
30/07/2022	12:06 - 1E11 reports OLE is drooping on the down Main at E496/13. Tripped again 11:02, closed 11:04, no trains in section. Section 158 tripped at 10:04, closed 10:07 no electric trains in section. All circuit breakers tripped at both ends. CCIL.2522968. Failed insulator on the top tube at E496/13. Insulator is still intact on mast but has detached from the top tube, which has caused the wires to sag. Both insulators replaced on E496/07 and E496/13	No	26/03/18.	100%	The incident has an SRE completed. The failed porcelain hook insulator has been sent for analysis.
19/07/2022	146 sections tripped on its own at 16.02 & reclosed 16.05 nothing in the section. A tripping and then phone from OLE to say wires have parted at E423/01 only a few strands holding the wire up. Section 145.#145 & 146 sections tripped at 10.55 & not reclosed, 9M22 passed through the section. Damaged catenary wire	Yes	12/06/22.	100%	The incident has an SRE completed. The RC sagged in extreme heat reducing electrical clearance to catenary.
14/07/2022	OHL is sagging on the Down Clacton C/S of Hockley Crossing in the area of CO1119. 2F23 confirmed OHL sagging in the area of BC07/01. 1N12 was cautioned at 5-7mph, reports that the OHL is sagging over a section	Yes			No

	of 4 droppers, all OHL is in place however cautioning, nevertheless. BLOCKED on the Down Clacton. OHL Staff ETA - 10:40.				
31/07/2022	Section 628 tripped. Triple dish is sheared causing balance weights to hit the ground and distort the feed wire/droppers on the down slow only. F 064/09 Switch 628/2	Yes			The incident has an SRE completed. The failed insulator has been sent for analysis and report is available.
North West & Central Region					
10/07/22	Littleton Cap & Pin Insulator Failed (Stafford DU)	Yes	12/07/17 Not in date		SRE has been produced and sent to Regional Team
11/07/22	Gorton Sagging OLE & Short Circuit Trips	No	13/03/15 Not in date		No
19/07/22	Garston Freight Terminal Hook-over	Yes	19/07/02 Not in date		Safety Related Event Report produced
19/07/22	Hest Bank AWAC Failure	Yes	30/05/18 Not in date		Safety Related Event Report produced
19/07/22	Hay Fell Jumper Failure	Yes	20/12/18 Not in date		Safety Related Event Report produced.
19/07/22	Winson Green Click Splice Failure – Near BB01/37	Yes	30/01/18 Not in date		Safety Related Event Report produced
19/07/22	Cross City North near Erdington Station, high temperature caused balance weight bottom out and extreme along track movement. One of jumpers caught the pan and caused damage to the pan. Area requires Stretch Recovery.	No	02/12/18 Not in date		Awaiting initial Safety Related Event Report from E&PME
19/07/22	Long Buckby Cap & Pin Insulator Failure	No	17/03/22	100%	green film over the insulator, it is yet unclear what the film may be but we suspect it could be the remnants of a balloon. The insulator has been quarantined to be sent off for forensic analysis to better understand the cause.
20/07/22	Chorley Tunnel Catenary Parted	No	New asset		Safety Related Event Report produced.

15/08/22	Cross City Lines Low BWAs & Tight Jumpers – Butlers Lane Station. OLE reported an PE Jumper very taught due to high temperature. Area requires Stretch Recovery	No	15/02/17 Not in date		Awaiting report
14/08/22	Longsight Goods Lines ADD & Sagging OLE	Yes	30/10/18 Not in date		Awaiting report
Western Region					
05/07/22	Parted drape jumper at Tilehurst	Yes	New Asset		Construction error failed due to along-track movement
02/07/22	Parted drape jumper at Maidenhead	Yes	New Asset		Construction error failed due to along-track movement

10b Track

Introduction

This section looks at the extent of track asset across the GB Network, managed by Network Rail (NR) through its 5 devolved regions and how it performed through the extreme heat events of 2022/23.

NR are responsible for over 20,000 miles of track, split across the 5 devolved regions. In examining and reporting on the hot weather period of 2022/23, the review has focused on the following areas:

- Approach to maintenance,
- Access to and analysis of infrastructure monitoring,
- The application of applicable standards that are deployed to the management and operation of its infrastructure,
- Approach to future tools and
- Wider global activities that would assist NR in addressing future challenges.

Through this investigation discussions have been held across the central and regional leadership teams and has included interviews with TME's and IME's, at the delivery end of track management, as well as the broader DEAM's and their track management team who look at the longer-term renewal and maintenance strategy.

This has provided an insight into how NR manages track through hot weather. It has provided a broader understanding of the regional and national structure and the challenges/opportunities this presents, differences in regional approaches to managing the physical asset and how local systems are being implemented to establish and imbed new ways of working. It also provides a platform from which the challenges faced by NR are identified and has shaped the final recommendations and priorities.

2022 Performance

Through the summer period of 2022 a total of 23 buckles were reported; with13 occurring during the extreme heat days of the 18th and 19th July and are summarised in Table 1. The remaining 10 buckles occurred through May (1 number), June (1 number), July (5 number) and August (3 number).

The analysis of the buckle reports shows that of the 23 reported incidents 15 occurred within, or near, S&C. Of the remaining 8 incidents 1 occurred close to a long timbered bridge, 1was next to a pedestrian level crossing, 1was on an embankment, three were on at grade track and had unknown CRT/Stress levels, 1 was within jointed track with inadequate joint regulation and un-consolidated ballast and the final buckle occurred because of ballast shortage.

Region	Route	Total No of Events	On CRT Register		Track Type		
			Yes	No	Plain line	S&C	Within 100m of S&C
Wales & West	Western	3		3		2	1
	Wales	1		1	1		
Southern	Sussex	1		1		1	
	Kent	5	2	3	1	3	1
	Wessex	1		1			1
Northwest & Central	Northwest	2		2		2	
	Central	2	2		1		1

Eastern	East Midlands	4		4	2	1	1
	Anglia	1	1			1	
	North & East	3		3	3		

Table 1

Assessing the individual buckle events, using reports provided by Network Rail, Track Standard NR/L2/TRK/001/mod14 – Managing track in hot weather. This standard, which has since been subject to a recent review and re-issue, sets out the approach that should be applied prior to the onset of hot weather. It defines the maintenance activities that should be undertaken prior to the start of the hot weather period, calculation of the Critical Rail Temperature (CRT) and mitigations that should be applied during this period.

Buckle Mechanisms and Triggers

In undertaking this review consideration of the factors that cause track to buckle needs to be understood as well as the standards and strategy that NR take in preparing for summer.

Heat alone, and the associated expansion of rail, is not the only factor that causes track to buckle; consideration must also be given to a range of factors and triggers, principally:

- Ballast and the level of consolidation around sleepers and bearers
- Ballast condition, in particular the volume of contamination from either slurry/wet beds (due to failing formation) or general ballast age/degradation. The lack of free drainage and ability for track to shed water must also be considered; particularly around embankments were weakening of the formation and slopes can further reduce the ability for the track system to resist movement.
- Ballast profile and volumes, particularly within the cribs/ space between sleepers/bearers and at the ends/shoulders.
- Drainage and the ability to remove water; particularly the ability to reduce the long-term effects of degradation to ballast and formation.
- Sleeper/Bearer condition, type, and age, and bearer/sleeper pads
- Rail – age, type, and stressing history and levels

- Clips and pads, particularly the ability to retain the toe load on the rail and the condition of pads between the baseplate and sleeper.
- Alignment – vertical and lateral, the propensity for faults and the number of repeat alignment failures.
- Changes in rail section and transition zones.
- Adjustment switches condition and setting.
- Transition zones between structure and condition e.g. run on/off bridges and embankments.
- Track Speed, frequency of service and axle loading.

The key risk areas for buckle sites are set out in NR/L2/TRK/001-mod 14 'Managing track in hot weather'. Examining the detailed reporting for each of the 23 sites, not just the 13 on the extreme hot weather day, the primary deficiencies were found to be a one or a combination of:

- Wood bearers on S&C, shallow depth switches combined with shortages of ballast and low SFT in adjoining plain line.
- Poor ballast support and volume of ballast.
- Voiding of track particularly on run off from fixed assets e.g., bridges or level crossings.
- Joint regulation and low stress temperature

Extreme Temperatures

Understanding the vulnerability of the track should be understood to ensure longer term resilience. Good asset management acknowledges that the individual assets may perform the same function equally well but that there may be underlying differences in the asset design, age, condition. This has a direct impact on their susceptibility to a range of hazards, not just heat, and should be recognised if undertaking a vulnerability assessment.

Where more modern track forms exist, e.g., UIC60 or 56 on concrete sleepers with 300mm+depth of ballast and with higher quality track geometry, the current stress ranges of 27˚C could and should be increased to accommodate a higher stress range of up to 30 ˚C. However, with the noticeable changes to the seasonal range of temperatures within the UK, the wider impact of climate change, and the historic parameters by which track has been maintained it is also recommended that the current maximum and minimum ranges, within which track is installed and maintained, is re-examined. The setting of a new upper bound, 30˚C, should be balanced against a raised lower threshold to manage the risk of rail breaks during periods of cold weather.

To apply this across the wider network the quality of the track componentry, in conjunction with the capture, analysis and distribution of asset information need to be reviewed and tested. Through Control Period 6 NR has progressed with the roll out of its Intelligent Infrastructure (I.I) programme which is targeted towards a proactive predict and prevent regime. The aim is to capture and analyse data regularly, in line with track categories, and to use this to improve a route/region prioritisation and planning of work.

The systems that are currently employed across the network do collect a range of critical data which is then delivered to the regions maintenance teams through a range of IT systems including the 'Linear Asset Data support tool (LADs) and the Asset Data Storage (ADS); these are associated with the I.I programme. Terabytes of data from systems, such as PLPR, Track Internal and the forward-facing video, is captured monthly for the Cat 1A and Cat 1 Lines, or 23% of the current network, and is distributed to the various maintenance teams to undertake critical maintenance activities. This information can, in theory, be accessed by the regional teams and analysed to identify trends, vulnerable sites and future planned maintenance activities.

Maintenance

The accountability for the monitoring, planning and physical delivery of activities, for hot weather, sits within the 5 regions and their Regional Maintenance Teams: with the ultimate, day to day, responsibility sitting with the delivery unit IME and TME teams.

Discussions held with IME's and TME's on Eastern Region, Northwest and Central and Wales and West provided an insight into how plans and programmes of work are identified to target high-risk areas of infrastructure; these are also locations that experienced buckles during 2022/23 and specifically the extreme days in July.

Each team described the infrastructure under their control, the activities they sought to undertake to prepare for hot weather and the challenges they face in delivering key tasks. They also shared insight into activities they are applying to help monitor and react to changing asset conditions and access challenges.

A common theme was the restrictions in red zone access and the ability to monitor track under a physical load. In all discussions the teams had found and developed solutions that allow them to understand the physical temperature on the rail. However, a solution to understand the displacement of the track is yet to be developed though, it is understood, that this is under review as part of a separate NR procurement process.

On HS1, the NRHS Ltd maintenance teams linked to Southern Region but operating under its own standards, technical authority and safety management systems as a separate legal entity, provided access to standard (C-02-OS-01-2001 issue 8 – January 2022, Network Rail (High Speed – NRHS) Ltd Weather 365), which sets out the processes and tasks that the maintenance teams undertake on HS1 infrastructure in preparation for Summer, Autumn and Winter. This included:

- The number of sites with a low Stress-Free Temperature; although this appears not to be linked directly to sites where natural stress reduction/loss is a factor.
- Associated locations of plain line with poor ballast volumes and/or condition
- S&C layouts with low volumes of ballast within cribs and locations were the positioning of point motors, stretcher bars and back drives limited ballast placement.
- Location of high-risk embankments
- Locations of geometric alignment faults which, when combined with the above, created a further risk of sudden track movement.

The approach to the management of hot weather by NRHS on HS1, is more prescriptive than seen on other routes. Regulatory and safety risk, held by HS1 Ltd, deploy a different range of standards that are aligned to European high speed rail networks.

It is evident that the actioning of geometric faults is triggered at a higher level than on other routes and is understandable when considering the line speeds of passenger services. However, on review it is worth considering how this approach could be applied to corresponding/equivalent categories of lines nationally.

Further the approach, applied by NRHS Ltd, also defines when post review assessments are undertaken therefore providing a regular review of the network's performance, the identification of performance and productivity trends and activities to be factored into future planned maintenance.

Discussions with maintenance teams and DEAMS on the ECML, WCML and WML indicated that the ability for the maintenance teams to actively address critical areas of intervention, and effectively monitor degradation rates, is becoming increasingly pressured due to a range of factors.

On the core main lines, the frequency of monitoring trains has resulted in the regular re-direction of pre-planned maintenance activities to address identified faults. This may indicate that there has become a practice of maintaining to safety, rather than maintenance limits. It is accepted that immediate action faults, which have or risked the imminent imposition of a speed restriction needs to be addressed as a priority. However, the inability for maintenance teams to actively address longer term asset condition e.g., SFT levels, will, in the medium to long term impact on the networks ability to address extreme temperature ranges.

Risk Based Management (RBM) and Reliability Centred Maintenance (RCM

RBM and RCM) has been mentioned frequently by NR colleagues through the course of this review.

This change from national 'Command and Control' to devolved 'Risk Based Management' is a structured change and targets the benefits of route-based engineering decisions to benefit operational performance and customer experience.

For Track the following standards have been reviewed in order to understand how RBM/RCM have been implemented within NR:

Ref	Issue	Compliance	Document
NR/L2/MTC/10622	12	6/6/2020	Process for the creation of new or revised maintenance regimes using Reliability Centred Maintenance
NR/L2/TRK/7014	2	5/3/2022	Standardised Risk Based Maintenance Regime (RBM) for the Inspection and Maintenance of the Permanent Way
NR/L2/TRK/7014 - module 1	1	5/3/2022	Implementation and Assurance of Standardised Risk Based Maintenance
NR/L3/OPS/021/01 Module 1	1	7/9/2019	Autumn Management
NR/L3/TRK/1015 Module 3	1	4/6/2022	Inspection for RBM Regimes
NR/L3/TRK/7012	1	6/3/2021	Critical Rail Temperature Management for Projects

The standards set out the approach to implementing and assuring RCM across the network. Documentation reviewed details the minimum requirements and deliverables for:

- Asset Inspection
- Competencies
- Frequency and validation of Train Borne Inspection and coverage.
- Work Bank evaluation and review
- Assurance – particularly in relation to compliance monitoring
- Inspection and examination frequencies by track category

Applying the above methodology and thinking Network Rail needs to ensure that each route is maintained at an agreed level. Each category of line needs to adopt a strict maintenance regime that ensure condition data is obtained at fixed frequencies, analysis is undertaken to monitor degradation rates and interventions are planned and delivered. This should include the undertaking of fixed seasonal maintenance tasks of which hot weather preparedness is clearly one.

The people employed to undertake these activities should have clearly defined and tested levels of competency. The application of monitoring and assessment systems, to examine degradation rates, need to be accessible and operated by qualified teams in the regions; and then assessed regularly as part of an independent, internal, assurance process, applying a system Verification and Validation methodology.

Access

During early meetings the Regional Engineering teams raised a concern that access to the network is constrained, in part because of red zone prohibition.

It is recognised that Hands on inspection and remediation requires track possession and associated electrical isolation, and, considering safety concerns, this is being restricted to nighttime or weekend possessions.

What is currently missing from data capture is the ability to actively monitor or record the physical displacement of the track vertically and longitudinally; this would previously have been captured through on-site inspections as traffic passes over the infrastructure.

Further the link between asset data, its collation/analysis and Meteorological data, and its use in critical decision-making process/activities on the lead to and through hot weather periods is not clear.

It is unclear how this programme is being co-ordinated and what resources are being deployed to review outputs.

Regional v National view

A relationship does exist between the Network Standard holder, Technical Authority (TA), and the responsible Regional Individuals. Track standards are owned by the TA and, from correspondence, are briefed to all regions and senior engineers who then cascaded to the 'front line teams.

However, on review the relationship/organisational structure within the 5 regions is different. Wales and West/NW&C and Scotland have a similar approach with the DEAM having a core central team and fixed relationship with the various Infrastructure Maintenance Engineers within the Routes. LNE and Southern have a different structure with what appears to be, less direct relationship with the Routes. From discussions with the TA, in particular the

Chief Engineer, this ranging approach creates challenges particularly regarding the actioning and closing out of Special Instruction Notices (SIN).

Routes manage to the standards set although, from evidence provided, the interpretation of the standard differs. Reviews are undertaken, prior to the onset of the Hot Weather Period (HWP), to ensure the network is prepared and that risk sites are identified, and management process defined. Meetings held with maintenance delivery teams demonstrates that each area has a different approach to managing its infrastructure. This is not necessarily a negative, however the cascade of knowledge and lessons appears not to be occurring, certainly not at a consistent level.

International Perspective

The UIC has, over recent years, reviewed the effects of Global weather changes and examined the impact this is having on existing and new rail networks. From this work and other recent studies, it concluded that track systems will need to tackle wider temperature ranges, and potentially for longer durations. This is combined with the need to operate more frequent services to meet future demand. Approaches that are being taken variously include:

- The adoption of improved monitoring systems fixed and mobile, in conjunction with competency training for key staff.
- Improved temperature forecasting for planning of rail works.
- Undertaking route specific Vulnerability Assessments identifying sites that are unable to accommodate higher temperatures.
- Application of higher SFT for key routes
- Application of AI techniques to identify critical asset component changes.
    - Ballast, cribs, and shoulders
    - Changes in vertical displacement, particularly known areas of alignment faults or structural transition zones
    - Remote monitoring of high-risk buckle sites, with real time capture to control centres.
    - Remote monitoring of high-risk structures – thermal expansion of bridges

Within North America the aim of the FRA is to lead, nationally, an innovation programme that looks to ensure the development of systems/tools that will deliver a long-term resilient network. It has a national approach to delivering the longer-term network resilience and developing systems/methodology to tackling a growing range of track, operational and user issues.

Since 2021 specific studies have been progressed to develop new tools, systems, and approaches to address hot weather challenges. Current research and development projects, which are being supported and led by a range of USA operators, infrastructure owners and the FRA are looking closely at how stress levels in CWR can be assessed pro-actively using GIS and satellite technology, temperature changes can be accurately measured on a real time basis.

In Australia a review of track standards from Transport for New South Wales (TfNSW) and Inland Rail was examined to assess their approach to the management of track and determine differences to current UK methodology.

The selection of standards reviewed demonstrated a clear and detailed approach to the management of their network before and through the hot weather period and appears more prescriptive than NR. The point at which the network owner implements restricted service operation is defined nationally and by specific route. Further the approach to managing the asset is clearly defined as is the competency of the staff undertaking the work.
Standards employed by the infrastructure owner appear not to be based on safety minima. The approach taken is that the network is expected to achieve a level of operational availability and quality. For summer it specifically sets out:

- Preventing misalignments including the approach to controlling track adjustment, stress management and adjustment, impact of track stability and geometry, track anchor methodologies, rail adjustment and management of
- Pre summer planned maintenance and the approach to applying speeds in relation to track stability.
- Application of local maintenance instructions to disturb track during summer periods.
- Application of speed restrictions when the air temp is high or forecast to be high; applies to air temperature above 35℃
- Reporting of misalignments and the level of review; in principle by the Chief Engineer

Recommendations

These are set against the four areas of Process and Standards, Access, Asset Stewardship and Organisational Dynamics.

Process and Standards

TRK 1

Heat related incidents with a score of 50 or above shall be formally reported, root cause analysis undertaken and reviewed by an internal independent, panel with recommendations/actions cascaded within 2 weeks.

TRK9

The Regional DEAM's and Infrastructure Director's to set out a strategy that delivers a policy of zero unmitigated track buckles.

TRK 11

Develop a series of TQ metrics which allows greater evaluation of the asset's resilience to extreme temperatures.

TRK 12

Undertake detailed inspection of timber bearer S&C layouts and adjoining plan line, with a line speed of 60 mph or above and Implement strengthening of the asset.

TRK 13

Plan and implement the replacement of track structures with poor buckle resilience on Cat 1a,1 and 2.

TRK 14

Routes to produce their prioritised plan to confirm and restore SFT at track stability risk sites. The age of records to be less than 10 years.

TRK 5

Examine 2022 CRT sites and ensure measures /mitigations are in place to remove risk prior to onset of hot weather.

TRK 6

Review the national stress database and, as a priority on Cat 1A, 1 and 2 confirm that the risk of buckle has been mitigated. All other Categories of line are to be completed after the priority routes have been assessed.

TRK 7

Undertake detailed inspection of timber bearer S&C layouts and adjoining plan line, with a line speed of 60 mph or above and Implement strengthening of the asset.

TRK 8

Routes to produce prioritised plan to confirm and restore SFT at all track stability risk sites; location with a stress record greater than 10 years.

TRK 10

The Responsibility and accountability for the oversight of Hot Weather preparedness across the network is to be clarified, with key responsibilities and duties defined and agreed.

TRK 3

Undertake a review of mandated competencies for all staff managing critical assets and identify areas of weakness.

TRK 4

Review current National and Regional strategies for operating in Hot Weather and ensure a level of consistency, particularly around regional boundaries.

Access

TRK9

The Regional DEAM's and Infrastructure Director's to set out a strategy that delivers a policy of zero unmitigated track buckles.

TRK 11

Develop a series of TQ metrics which allows greater evaluation of the asset's resilience to extreme temperatures.

TRK 12

Undertake detailed inspection of timber bearer S&C layouts and adjoining plan line, with a line speed of 60 mph or above and Implement strengthening of the asset.

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Plan and implement the replacement of track structures with poor buckle resilience on Cat 1a,1 and 2.

TRK 14

Routes to produce their prioritised plan to confirm and restore SFT at track stability risk sites. The age of records to be less than 10 years.

Asset Stewardship

TRK 5

Examine 2022 CRT sites and ensure measures /mitigations are in place to remove risk prior to onset of hot weather.

TRK 6

Review the national stress database and, as a priority on Cat 1A, 1 and 2 confirm that the risk of buckle has been mitigated. All other Categories of line are to be completed after the priority routes have been assessed.

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Undertake detailed inspection of timber bearer S&C layouts and adjoining plan line, with a line speed of 60 mph or above and Implement strengthening of the asset.

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Organisational Dynamics

TRK 10

The Responsibility and accountability for the oversight of Hot Weather preparedness across the network is to be clarified, with key responsibilities and duties defined and agreed.

TRK 3

Undertake a review of mandated competencies for all staff managing critical assets and identify areas of weakness.

TRK 4

Review current National and Regional strategies for operating in Hot Weather and ensure a level of consistency, particularly around regional boundaries.

Engineering Standards, structure, and application

This report has also drawn against the following NR standards and briefings that have been access through the Network Rail team or the National Standards Register

NR Ref	Issue	Title	Compliance Date	Comments
NR-L2-TRK-001	22	Inspection and Maintenance of Permanent Way	4th June 2022	
NR-L2-OHS-019		Safety of people on or near the line	3 September 2022	
NR-L3-TRK-3011	3	Management of Rail Stress and Critical Rail Temperature	26 August 2008	Update on TME process for updating National Register
NR-GN-TRK-7001	1	How to manage exceptionally hot weather	1st March 2005	
NR-L3-OPS-021-09	1	Management of structures during Adverse weather	7th September 2019	
NR-L3-TRK-3012	2	Management of hot weather precautions (track)	26th August 2008	
NR-L2-TRK-001-Mod14	7	Managing Track in Hot Weather	4th September 2021	
NR-L2-TRK-001-mod 15	6	Managing Track in Cold Weather	2nd February 2013	
NR-L2-OPS-021	8	Weather – Managing the Operational Risks	7th September 2019	
NR-L3-OPS-045	3	National Operating Procedures	6th June 2020	
NR-L2-TRK-038	3	Train Bourne Recording	4th September 2021	
NR-L2-TRK-035	1	Track Asset Management Strategies	4th September 2021	
NR-L2-TRK-001-mod11	11	Track Geometry – inspections and minimum actions	4th June 2022	

The standards that are employed by Network Rail set the effective minimum parameters by which the track system should be inspected, maintained, and renewed. These documents, particularly those identified above, have been developed over numerous years and, where updated, have taken cognisance of events to mitigate future risks

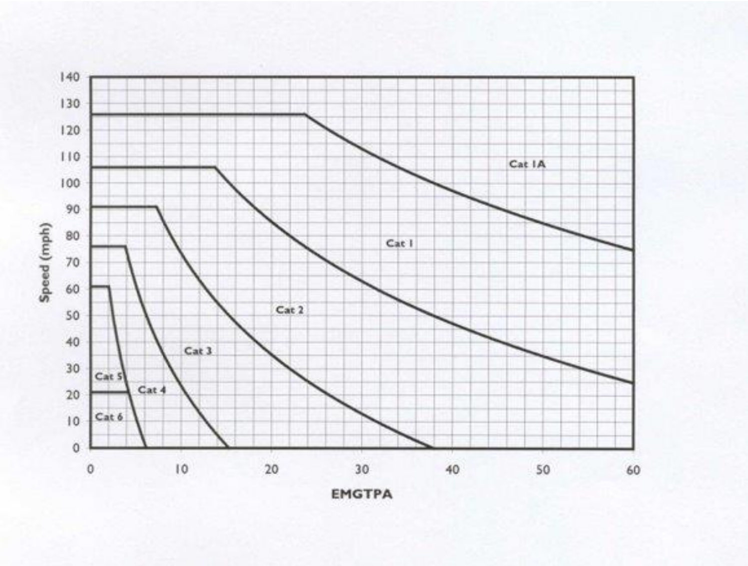


Figure 3

It also sets out the track categorisation through which asset and renewal policies are developed. Figure 3 shows the effect speed and tonnage have on track quality and therefore the system componentry.

The categorisation of track is a complex subject governed by strict European Legislation standards and detailed calculations. The overarching principle is that each line of route is assessed on 3 key factors:

• The speed required on the line – considers the current and predicted future traffic flows

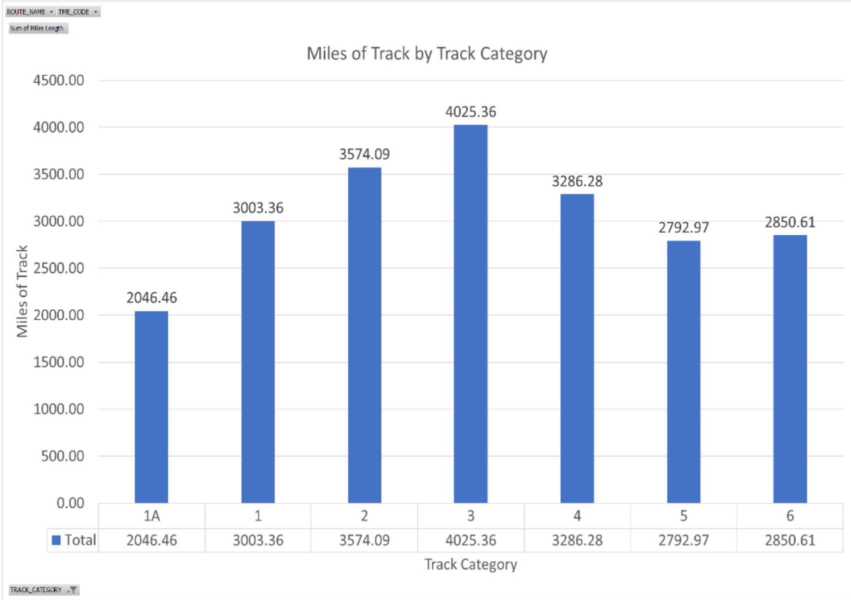
• The annual tonnage moved over it – type and consist of traffic, particularly freight

• The equivalent tonnage on it n- or Equivalent Million Gross Tonnes per Annum (EGMTPA) and is a measure of the annual tonnage carried over a section of track and relates to the variations in track damage that is caused by the range of rolling stock.

Through this process the track is assigned a category from 1A to 6 based on a function related to EMGTPA. Category 1A is the highest - 125mph or higher and Category 6 is the lowest – 20mph and below.

From Network Rail colleagues the current split of track categories is set out in the table below

Track Category	Sum of Miles Length
1A	2046.46
1	3003.36
2	3574.09
3	4025.36
4	3286.28
5	2792.97
6	2850.61
Grand Total	21579.13



Requirements and standards relating to the design, maintenance renewal and inspection of the track vary according to usage and speed. This affects materials used such as sleeper types, switches, crossing types and the depth of the ballast required. It defines the overall track quality bands. It is a complex process which is designed to always ensure system safety.

Track categories are reviewed at least annually and updated as necessary to consider new train timetable services and revised freight traffic flows. Sidings normally have slow moving traffic and are frequently restricted to a maximum speed of 5mph.

Critical to the deployment of these standards and procedures is the availability of reliable and accurate data, through which, the teams can review and plan appropriate work to mitigate any form of asset failure. This therefore requires the delivery of regular visual and geometric data to allow the regional maintenance teams to pro-actively plan and implement maintenance/renewal activities.

In relation to the extreme heat events of 2022 this requires the capture and delivery of accurate asset information using remote and train borne monitoring systems to ascertain information pertaining to:

- Geometry condition
- Degradation profile
- Areas of ballast deficiency
- Missing fixings

Using the above data, alongside wider asset information of track type, rail age, stress records, sleeper/bearer type and condition will, in theory, allow the routes/regions to make an accurate assessment of the network at times of extreme stress, not purely hot weather. Against the current standards, which as previously stated are effectively do-minimums, would in, most cases, allow the network to operate with specific, localised restrictions in place.

What is evident from the initial examination of reported buckles and route closures, is that the components, within the key routes, are of an age/type and condition, including geometric, that would likely trigger a buckle.

10c Distribution and Plant Infrastructure affecting S&T Systems

The Extreme Heat Task Force has published an initial report which set out areas of concern over the condition and suitability of lineside enclosures and buildings, the specification and design of ventilation and cooling systems and the maintenance/repair of the ventilation and cooling plant. The report explained the distinct options for protecting lineside infrastructure and the associated power supplies and back up batteries.

More detailed investigation including engagement with the engineers in the Technical Authority and in the Regions followed. An interim report presented the outcomes of that engagement setting out some conclusions and recommendations.

The interim report described a complex and intricate set of interfaces in the management of lineside enclosures and buildings. The Extreme Heat Task Force has examined how vulnerable electronic systems and high voltage plant and cables are protected from the effects of high temperatures.

Operationally critical infrastructure is housed in various types of bespoke lineside enclosures, dedicated buildings and shared station or other operational buildings. Primary concern concentrates on vulnerable components and

systems that fall within the scope of the infrastructure discipline expert (e.g., Signal Engineer, Telecoms Engineer). That equipment might be housed in a location case (LOC) at trackside, a larger relocatable equipment building (REB), modular building at trackside or in a more substantial building such as a room in a control centre, station, or depot. Equipment in many locations is provided with ventilation or air conditioning cooling plant. The stewardship responsibilities for the potentially vulnerable systems and the operating environment of those systems calls for clear accountability for each location to maintain operating temperature within defined limits.
The final report was first released in draft and Network Rail has commented on many of the recommendations contained in that version which has required an independent Peer Review to take place and issue steering statements as to whether the recommendations should stand as written or be changed to provide an exacting objective. These recommendations are included in this report with prioritisation and an indication of the area of deficiency, whether Access, Asset Stewardship, Organisational Dynamics, or Process & Standards.

Signalling power supplies must deliver high reliability. Much of the railways in Great Britain have 650V lineside power distribution systems, some with standby diesel generators. These generators provide automatic emergency back-up to DNO (Distribution Network Operator) supplies which only have the reliability associated with domestic household supplies. Not all the signalling equipment is powered from the lineside 650V signalling power supply and some Level Crossings are powered from DNO sources only.

Signalling systems are controlled via a data system increasingly over fibre optical carrier systems. Network Rail has a nationwide telecom system comprising cables, telecommunications equipment, and radio systems. Equipment owned by NR is housed in telecom centres, signalling relay rooms, lineside equipment buildings (FTN Nodes) and telecom REBs. These installations contain equipment requiring protection from extremes of temperature.

The Extreme Heat concerns:

Signalling equipment and Business Critical Equipment **(BCE)**

Modern signalling equipment has an upper operational temperature of 65°C. Older electronic systems installed from the late 1980s to 2010, have a lower operational limit of 45°C. The 45°C maximum working temperature also applies to most of the batteries on which the systems rely. REBs and some location cases, particularly in remote rural locations, have older battery back-up systems, trickle charged from the 110V signalling supplies. The temperature range of those systems is uncertain.

Any installation which includes temperature sensitive equipment will require cooling. Many sites are equipped with air conditioning plant. Over many years the responsibility for maintenance and asset management of air conditioning plant was unclear and varied from site to site. In recent years that has been rationalised and most installations are now part of the maintenance E&P portfolio and Route/Regional E&P Asset Manager responsibility. Exceptions remain for large installations in joint user locations where there are offices or large control centres; these fall within the building services group. See Recommendation D&P 7.

The NR maintenance organisation has approximately 12,000 small to medium size fixed air conditioning installations within its portfolio.

Monitoring and Analysis

Temperature monitoring is the common to most industries and utilities and as such the cost of monitoring is relatively low. Business Critical Equipment should be temperature monitored and intelligent analysis applied to determine the specific characteristics of the enclosure or building in respect of solar radiation, air movement and ambient temperature. This would inform the hierarchy of protection risk assessment. Subject to criticality, additional monitoring such as fans could give alarms before the temperature rises. See Recommendation D&P

What causes Air Conditioning (AC) units to fail?

The initial report identified common causes of AC Units failure, plus the reasoning behind the need for an AC unit size assessment to all lineside buildings utilising a cooling system. The earlier reports (initial & Interim) also dealt with how most AC unit failures are managed and repairs actioned, with many suffering delays and requiring the intervention by the D&P/E&P sections with portable AC units. This reflects their capacity as first line faulting teams and thus best placed to overcome the overheating REBs under their maintenance obligations for operational equipment being put at risk. Two depots on the ECML have now taken over the AC unit and cooling system maintenance themselves, taking over the NR B&C Small Works contracts in those areas, bringing about a faster response to cooling system repairs and a more efficient and cost-effective way of working.

Recommendation of how Cooling System maintenance should be managed.

Each of the D&P depot units consulted identified a need for refrigeration F gas training, a competence structure that supports Network Rail having refrigeration F Gas Licences, to enable reductions in delays in repair of AC Units, the demand for portable AC units, A further benefit should be to improve response times during critical high temperature periods - when general AC contractors are at their busiest.

NR has tried an alternative approach; fan blown (forced air) systems. This achieves a high number of air changes per hour and therefore is expected to hold air temperature inside an enclosure at the ambient air temperature outside. Well-designed installations are successful.

There is commercial grade of cooling systems available that use both forced air and air-conditioning cooling methods, which have a longer life expectancy, but the initial purchase cost is greater than the domestic variants in use in lineside buildings. However, a retrofitted series of lineside buildings along the Cambrian Coast route have not been satisfactory. Repeated failures of the fans, sea air corroding the signalling equipment terminations, the tripping of the localised power supplies due to debris and the resulting busbar flashovers have all been seen.

The predicted temperature increases to 2050 with 3 yearly extreme events giving a gradual increase of ambient temperatures to 44.5°C, will expose risk for the older systems specified for maximum 45°C.

Recommendation for selecting the type of cooling system needed.

There is a need to focus on where forced air cooling should be used in the future, The geographical location, type of equipment housed and quality of the air in the immediate area should all be taken into consideration before deciding to adopt forced air cooling.

An engineering policy should be developed to inform of the methods that must be considered in equipment temperature control and protection. That policy should consider lifetime energy demand and whole life cost. It should include a clear recommendation about monitoring cooling systems installed to protect vital installations. The hierarchy of selecting the type of cooling should include.

1. Shading and reflecting
2. Passive Ventilation
3. Forced Ventilation
4. Climate Control (AC)

This is to minimise energy costs, maintenance complexity and risk of failure to maintain temperature. See Recommendations D&P 2 and 3.

Batteries and higher working temperatures

Many signalling REBs and location cases house batteries. As currently specified, batteries are vulnerable to high temperatures which shorten lifespan. Extreme temperatures above 40°C can cause complete failure of some battery types. Batteries are rated to operate up to 45°C but as batteries age the risk of premature failure due to high temperatures will increase.

Temperatures in location cases REB enclosures are typically at least 15°C higher than the ambient air temperature due to the solar heat gain when in direct sunlight.

Anglia Route had battery failures in 2022 and choose to carry out a wholesale change with batteries that had a much larger capacity (approximately double the size). It is not clear why the decision was made to double the capacity but it

was likely to have been largely financially driven, with a smaller per unit cost of the larger battery. It should be noted that there were no reported battery failures in Anglia during the extreme heat in July.
The Technical Authority has an initiative to research and develop new battery technology more suited for railway operations. The initiative was also researching smart battery chargers. These initiatives should incorporate Anglia Route's experience and determine the optimum type, capacity and charging method for resilience.
A similar experience of having no battery failures during the extreme heat days was apparent to the telecoms discipline, particularly with regards the FTN sites. Its sites use telecom sized batteries which are always much larger than those used for signalling applications and incorporate sophisticated smart battery chargers. Clearly, both disciplines should share common research and development with a focus on the required railway environment.

Solar reflecting systems for Location cases and REBs and where it should be deployed.

Lumur AG15 solar reflecting protection has been proven to keep the internal temperatures in location cases to a lower level and at the extreme heat level, when the external ambient air temperature reaches 35° - 40°C, a reduction of approximately 15°C is apparent internally. This will assist in keeping within the operating temperature parameters of most electronic equipment housed in location cases and REBs when AC units are failing to cope with the extreme temperatures now being experienced. The Lemur AG15 system is expensive and a cost indicator of £500 per location case and £2500 per REB has been reported. The system has been extensively employed in all regions in England and Wales (Scotland remains unknown). It appears that much work still needs to be carried out for appropriate protection to be in place for future extreme temperature events.
In W&W Region, some REB roofs have been painted white and it has been reported that is seems to have the same temperature lowering effect as the Lemur AG15 system. This should be confirmed, and a specification produced.
Evaluation as to the best options for protecting signalling equipment from solar gain needs to be developed with cost-benefit guidance for the various building types for both shading and shielding (Australian style) and reflective coating.

Distribution Lineside Cabling and its containment during extreme heat

There have been a few lineside fires during the extreme heat of the 2022 summer and there is nothing abnormal about the initiators of such incidents. However, reports about the intensity of the lineside fires being exacerbated by the composite polymer troughing route sections are of concern. Polymer troughs are now in extensive use throughout the network.

The continued use of this type of trough and its constituent make up should also be reviewed by the Telecom TA, which oversees trough specification. The aim of this review is to assess whether the present product specification conforming troughing types afford adequate protection in the event of lineside fires.

Loss of DNO supplies to some key operational locations.

During the July 2022 extreme heat, modern signalling power supplies proved robust. However, the robustness of signalling power supplies highlighted the items of signalling and telecom related equipment at level crossings, not supplied from the signalling power supply system, which suffered failures. Level Crossing equipment i.e., barriers, lights and yodels, CCTV cameras are only powered from a localised DNO supply, which when lost, stops the railway. UPS systems have been installed to overcome the fragility of some DNO supplies, which in turn have added to the heat loading of the AC systems in the LC REB - which have failed to have sufficient cooling capacity resulting in the UPS systems prematurely shutting down due to their internal protection cut-out. See Recommendation D&P14.

When signalling power supplies were upgraded to the robust system that is now in use today, the equipment at level crossings was left out because of the potential additional heavy loadings.

Since the advent of LED signal lights and, generally, the reduction of power requirements for all the active signalling equipment that is now in use, there may be scope to consider (where appropriate given peak current requirements) Level Crossing power supply loading in the power supply 'chain' fed from the Signalling PSPs.

Recommendation for AC Unit size assessment.

There needs to be a simple method of calculating the cooling load of each lineside building. This is needed to make an appropriate working 'thermal load' assessment of the existing Air conditioning unit fitted to the lineside building. The accountable persons for the maintenance of AC units fitted to lineside building need to be aware that they have sufficient additional cooling capacity to deal with extreme heat days, without over stressing the AC unit and causing premature failure. See Recommendation D&P15.
The hierarchy of simplicity and energy cost can then be applied to determine the need for passive, forced or AC cooling.

Buildings and Architecture concerns

The Extreme Heat Task Force had meetings with NR Buildings and Architecture asset managers,
responsible for a vast array of buildings and structures.
Recent focus in making the public facing elements 'all user' friendly and dealing with the effects of the extreme wet weather to many buildings, has left non-public facing buildings exposed.
The 'wakeup call' was the incident that occurred at Godington in Kent, where water ingress caused a catastrophic failure of a 3rd Rail DC circuit breaker. The cascade effect of conductive ionised air resulted in the DC module melting throughout along with the suite of circuit breakers. There were two staff injuries, fortunately minor in nature but with an ORR prosecution and fine resulting. It is now a priority for B&A staff to deal with any water leaks immediately. There have been many long-standing water ingress issues in lineside modules and major operational electrical buildings, not least of which was at Kenton Substation where a temporary water ingress tarpaulin arrangement was in place for 7 years.
The B&A asset managers explained that of the 18,000 lineside building in their maintenance portfolio, 50% were classified as in a poor condition. Initiatives to overcome this had led to a sectionalised 'Wrap' solution being developed that literally wraps around and over the existing modular building and prevents leaks and at the same time improve its insulation. Due in part to the £45k cost, take up has been limited. See Recommendations D&P 10,13 and 18.

Recommendations for Lineside Building Improvement.

There is inevitably a bias in investment decisions towards stations, depots, and commercial properties at the cost of overall condition in the operational locations.
Consideration should be given to creating two separate asset portfolios with separate ring-fenced budgets. Whilst financing will never be comfortably available for every need, such a measure will guard against increasing expenditure on assets judged to have positive commercial or customer benefit being at the expense of increased building and enclosure dilapidation and increased railway operational performance risk.
Determining the risk though temperature monitoring is essential to quantify the requirements of individual enclosures and buildings.
The TA should carry out study of how improvements can be made to the lineside building insulation, heat venting using best practice methodology learned from other hot country railways' methods to reduce energy usage. Australia uses double skinned walls, louvres and roofs with rotating air outlet vents and shading to stop the build-up of heat and avoids using AC units completely by selection of appropriate internal equipment that can tolerate the expected ambient temperatures.
It was noted in the initial response that implementation would be a responsibility for the Route Director.

Other Meetings held after the publication of the Initial and Interim Reports.

The Signalling Telecommunications and E&P Discipline Meeting

It was noted that for the large part there was little impact on direct equipment performance during the high temperature period and that signalling, and telecommunications equipment installed over recent years, has been specified and tested to a higher temperature range. What failures were recorded in July 2022 were seen in equipment built to older less robust standards. However, there were examples of DNO power supply failures, principally affecting level crossings, and there was much activity across the maintenance organisations to keep ventilation and cooling plant in effective operation.

There is a steady increase in installation of battery back-up supplies for infrastructure systems.
It is, however, essential that batteries are maintained and protected against high temperatures. All batteries are at their core chemical energy stores, and the chemistry can be significantly harmed by overheating. So, effort was seen to be needed to improve designs with a focus on protection for battery installations, particularly those at lineside; that protection being a combination of better enclosures and smart charging facilities.

The Signal, Telecommunication and E&P Engineers had no significant concerns about the responsibilities for asset stewardship in the current organisational model. What was less clear was how the linking of appropriate specification for ventilation and cooling installations is secured against the specification of the equipment needing the protection. There also remains concern over the maintenance, repair and replacement of ventilation and cooling plant. Whilst this is in principle all covered under service contracts managed and administered by the Building and Architecture group, in practice the slow response within those contracts dictates that it falls by default to the local E&P maintenance team to provide first response. This was acknowledged to be an area where better clarity of responsibility would reduce vulnerability. See Recommendations D&P 6 and 9.

Resulting from the meetings and a subsequent meeting with all members of the TA and DEAMs, the recommendations for P&D affecting S&T were updated.

The Final Recommendations applying to Distribution and Plant, with prioritisation - Priority 1 *(3 to 6 months)*, Priority 2 (*6 to 12 months)* and Priority 3 *(greater than 12 months).*

Note: There have been several iterations of recommendations during the process of the gradual evolution of this report. A few have been clarified and no longer form part of this final report, but numbering remains consistent with the draft final report.

D&P 1 Continuous Remote temperature monitoring with alarms to be provided to all S&T REBs.

Asset Stewardship Priority 3

Objective is for NR to react faster to cooling system failures. Data gathered will in the longer term inform the development of improved design and improved asset performance, especially for RBM.

D&P 2 Lineside building standards to be revised to require that the specified ventilation and or cooling systems provide protection appropriate to the equipment housed in the enclosure recognising ambient temperature and solar gain of the building.

Asset Stewardship Priority 2; Process & Standards Priority 2

Objective is to provide guidance on calculation of sizing and selection of the ventilation and cooling system plant.

D&P 2 RBM Methods should be applied to air cooling systems setting a maintenance regime as part of a strategy to extend the life of the plant.

Asset Stewardship Priority 2

Objective is to focus maintenance activity on the highest risk locations.

D&P 3 Carry out an energy usage assessment for each lineside building location to establish whether a business case can be made for heating and/or cooling enhancements. **Asset Stewardship Priority 3**

Objective is to enable a reduction in NRs carbon footprint and remove the past power supply status-quo of lineside building energy consumption.

D&P 6 E&P/D&P resource to be reviewed. First line failure and response in the event of extreme heat affecting lineside building cooling systems failures to be specifically considered.

Organisational Dynamics Priority 2

Objective is to balance the number of plant-trained operatives with multiple simultaneous failures of cooling systems during extreme heat events.

D&P 7 Maintainer to have responsibility and accountability for operational failures caused by high temperature or water ingress in lineside enclosures.

Organisational Dynamics Priority 1

Objective is for the operational impacts to be clearly attributed to the building condition.

D&P 9 Economic and performance evaluation of in-house F gas-trained maintenance staff to be undertaken to examine the case for wider adoption. Cost and rapid response benefits to be considered.

Organisational Dynamics Priority 3

Objective is to determine if the in-house arrangements in Doncaster and Peterborough Depots offer cost and performance benefits elsewhere.

D&P 10 Procedures to require that where sensitive operational systems equipment is housed in lineside buildings, the ventilation and cooling plant proposed should be subject to interdisciplinary sign off by both the building and systems designers.

Process & Standards Priority 2

Objective is to install cooling systems in lineside buildings that respect the required duty and cooling needs of the operational equipment housed therein allowing for extreme weather operational risks.

D&P13 Carry out structural inspections as per the required structural inspection regime for all buildings and structures including any backlog.

Asset Stewardship Priority 2; Access Priority 2

Objective is to remove the backlog of the 578 outstanding structural inspections.

D&P 14 Where UPS have been installed to address poor DNO supply reliability, the capacity of ventilation and cooling to be reviewed to verify that the thermal burden of the UPS is tolerable. **Asset**

Stewardship Priority 3

Objective is to reduce the operational risk of UPS systems with over temperature cut-outs.

D&P 15 A greater level of redundancy should be a requirement for design and replacement of HVAC equipment in locations housing vital operating systems.

Asset Stewardship Priority 3

Objective is to minimise the operational risks to the S&T equipment during temperature extremes.

D&P18 The poor condition of lineside buildings and housings for operational HV Electrical and S&T equipment should be rectified. Rainwater ingress is a major concern in many locations.

Asset Stewardship Priority 1

Objective is to bring the lineside building estate to a standard suitable and fit for purpose. Priority 1

Observations and Conclusions

In the extreme temperature days in July 2022, there was a marked improvement of the reliability and operational effectiveness of the cooling equipment to lineside buildings, as more thorough checks were made to the cooling systems. This, coupled with the widespread installation of LEMUR AG15 solar reflecting coverings to the vulnerable signalling equipment housed within unshaded location cases, meant that were considerably less Signalling and Telecom system failures during the extreme heat events in all regions.

In the last 20 months, Airedale International has supplied and fitted a further 40 of the NR approved 'TCU Range' of Cooling systems and replaced a further 5 split AC units. It attended at 260 sites that needed repairs caused by a variety of faults, however the lack of timely filter changing and loss of the refrigerant F gas feature high in the list of causes. The TCU range of cooling systems combines mechanical and air conditioning, the latest of which will cope with temperatures up to 40ºC. Therefore, more work is necessary to develop cooling systems that are extremely energy conscious and designed to operate at a range of temperatures that the housed equipment will tolerate. In the past the requirements specifications have been set with human comfort in mind.

Eastern Region is very large and complex, covering mainline routes of the ECML, MML and much of the TransPennine along with Anglia. The number of repairs and replacement AC systems to lineside buildings carried out by the competent NR staff in Doncaster and Peterborough Depots needs to be analysed and compared to other areas where dependency on portable AC units, and contractors to carry out repairs and replacement is high.

Western Route saw a considerable improvement due to the new infrastructure brought about by the Great Western Electrification, with much of the signalling system being renewed with the latest electronic modules being far more tolerant of higher temperatures (65ºC). This was compared with legacy signalling modules with a maximum operating temperature of 45ºC; albeit these tend to stop functioning at 40ºC, but recover after cooling down. In total, Western saw only 7 failures where portable AC units had to be deployed whilst waiting for the specialist air conditioning contractor to carry out the necessary repairs or replacement (Airedale International). Western Route carries 12 portable AC units for fast response whilst waiting for the specialist contractor, although the Western Mainline is generally served by fan cooled equipment in REBs which tend to be more reliable.

Wales Route, in contrast the Western Route, had a marked difference in the failure rates and the numbers of portable AC units that needed to be deployed during July 2022. E&P staff attend faults reported by signalling staff to deploy portable AC units. July 2022 saw an increase of 23 portable AC units over and above the 62 AC units awaiting replacement subject to quotation costs and purchase orders being granted to Airedale International. The Cambrian coast fan blown conversion cooling systems to REBs experience was stated earlier in this report and will not be repeated.

Southern Region provided the Wessex Route cooling system PPM records, which showed a total of 450 AC units needing to be maintained. 179 of these were Airedale units greater than 15 years old (there were also 9 other that are ‘old’ and in need of replacement from other manufacturers) with no spare parts available for these. Since the hot weather in 2019, 111 AC units have been replaced; and as the efficiency has fallen off from some of the AC units in a few other locations, 21 second/back up units have needed to be fitted to supplement the cooling output. Over the last year many more have been changed in preparation for hot weather in 2023.
Southern Region accounts for a large percentage of the 18000 lineside buildings that are maintained by the B&C Work Delivery units.

With the advent of Risk Based Maintenance likely to be rolled out with increased efficiency, life prolongation and cost effectiveness as benefits, the

recommendations stated in this report should be actioned as soon as practicable.
The resourcing levels at each NR depot for plant competent personnel is extremely limited and usually comprises one or two technicians. Attending potentially +200 buildings for summer preparedness checks is not credible and, just as the experience in most depot areas has shown, these checks are spaced out through the year. Unless there is a change in the maintenance contracting strategy, this will continue. As the ambient temperatures continue to rise and extreme heat events become more frequent, legacy signalling and telecom equipment will be at higher risk of failure, so summer preparedness must be given a higher priority than it is today for these lineside buildings.

Transport Authority, Western Australia Specification: Equipment Rooms, Shelters, Enclosures, Cable Access Ways 8880-700-003 Rev 5.01 (2019)

7. Heating Ventilation and Air Conditioning

The type of climate control equipment to be installed will depend on the type of equipment being housed inside an equipment location case/enclosure or shelter (i.e., active or passive equipment).

7.1.1 Equipment Shelters and Enclosures

Equipment Shelters and enclosures should be passively cooled where possible, i.e., by means of convection or by fans only. The design of the equipment shelter shall allow for the passive dissipation of the heat load generated by all current and future equipment that is to be installed in the shelter. All location cases are to have a minimum IP rating of 56 as per AS 1939.
In addition to these requirements, the effects of solar radiation on the shelter shall be taken into consideration when calculating heat loads, assuming a daily peak solar radiation level of 1100 Watts/m2 in the design calculations. Maximum temperature inside the Equipment Shelter and Enclosure should not exceed 55 ºC.
In the determination of maximum internal temperature rise, it should be recognised that the worst-case situation for solar radiation may occur when it is incident upon a side wall rather than the roof and the highest ambient air temperature in the locality concerned may occur as late as 1600 hours.

Alternatively, where specified by PTA, or where required by the heat loading of the equipment to be installed, the Equipment Shelter shall include an air conditioning system which shall be provided in accordance with the requirements detailed in Section 7.2.

7.2 Active Climate Control

Refer to PTA Specification 8803-000-007, which outlines the active climate control requirements for Equipment rooms. Enclosures and Shelters, however, are covered in this section.
It should be noted that no air conditioning system/units are permitted to be installed above any PTA equipment and racks.
Air conditioning units and their associated drains shall be positioned such that in the event the drain becomes blocked the condensate overflow cannot flood or drip onto any equipment within the room.

Australian Track Corporation Specification ESC-07-03 Version 1 (2009) Small Buildings, Location Cases, Terminal Cases and General-Purpose Cases

3.1.9 Ventilation

3.1.9.1 Thermal Characteristics and Design

The thermal characteristics of buildings and location cases shall be designed to limit the dynamic range of temperature within the building to within plus 5 degrees Celsius of the external temperature throughout the entire year.
The thermal design shall consider the power dissipated by the equipment installed in the building and the location of the building.
All ventilation in respect of buildings and location cases shall be passive. Air-conditioning is not to be used to achieve the thermal requirements of buildings and location cases.
Roof ventilation shall be provided in all equipment rooms and where provided, generator rooms.
Vents in walls and doors may be required to meet thermal requirements.

In some environments the building fitted ventilation may be insufficient. In such cases sunshades may be provided.
Independent certification will be required relative to the buildings and location cases to verify conformity with the requirements of this specification.

3.1.9.2 Ventilation to buildings

Roof ventilation shall be provided by means of at least one (1) rotary roof ventilator model IVR LTV 200 or equivalent per room and installed in accordance with the manufacturer's recommendations.
Where the floor area of an equipment room exceeds 12 square metres, a minimum of two (2) ventilators shall be installed. These ventilators shall not be placed directly above equipment or equipment racks. The ventilators shall be ducted through the ceiling lining and shall include a removable insect mesh screen fitted to the ceiling.
Buildings with floor area of ten (10) square metres or less shall include two (2) 300mm x 250mm vermin and insect proof vents located in the wall opposite the door at a height 150mm below the ceiling level. A single vent shall be provided in the lower section of the door. This vent shall have a minimum size of 0.03 sq. metres, be waterproof and filtered to minimize the entry of dust.

3.1.9.3 Ventilation to Generator Rooms

Roof ventilation shall be provided in generator room by means of one (1) rotary roof ventilator model WR8 or equivalent. A thermal extraction fan shall be installed as an integral unit in the rotary roof ventilator to exhaust air during operation of the diesel generator unit. It shall be IP56 rated and wired from the lighting circuit with an in-line switch for emergency isolation. The switch shall be located adjacent to the interior light switch and appropriately labelled. The roof ventilator and thermal extraction fan are to be installed in accordance with the manufacturer's recommendations.
The Contractor shall carry out a test on site to confirm and prove that the generator will run at 75% of its full load for twenty-four (24) hours without any malfunction. Vents provided in the generator room shall have fixed metal blade louvres and external fixed wire insect screens.
Special attention shall be given to ensuring that the vents are weather and insect proof.
Fixed aluminium louvres, 600 mm wide x 930 mm high, with framed opening and internally fitted wire insect screens shall be installed in the generator room.

Two (2) of the louvres shall be installed 350 mm from the floor and the other two (2) installed 350 mm down from the ceiling.

3.1.9.4 Sunshades

Over roof sunshades may be installed by the Contractor to assist in achieving and maintaining the thermal characteristics of the equipment building. Where this is the case, the sunshade shall be designed to a W65 wind load rating and be installed by the Contractor complete with approved specifications and drawings.

Building Works

The steel frame and support structure shall be hot dipped galvanised to AS1650, with the galvanising to take place after fabrication. The roof over shall be Colourbond metal roofing to AS1562 and be at least 200 mm clear of the highest point of the building roof line and protrude 1000 mm (minimum) outside the building walls on all sides.
The fall on the sunshade shall be 100 mm from front to back and drain away from the track.

10d Support Functions – Rolling Stock and Train Performance

Introduction

This report considers how the principal railway engineering disciplines of Track, Traction Power and Signalling and Telecoms are supported and should be read in conjunction with the specific reports. The report builds on the Initial Report (dated November 2023), Interim Report (dated February 2023), Network Rail response to the Interim Report, and subsequent interviews and review meetings.

The definition and identification of Critical Rail Temperature for vulnerable track assets is fundamental to hot weather preparation and performance. The standards that are developed and issued by the TA define the minimum asset condition criteria, these are then applied by the maintenance teams to identify sites of weakness and risk in hot weather. Through this approach the region identifies and manages the sites using a combination of manual, remote and automated capture of asset condition. Similarly, OLE has vulnerable locations where excessive thermal movement can result in failure.

In recent years the safety driven reduction in 'red-zone' working has reduced access for manual inspection and assessment of dynamic movement. This requires regions to transition to a more automated and remote inspection and monitoring strategy. There is planned investment in new systems for remote and automated inspection.

This report considers the opportunities for support to maintenance teams with asset condition information, weather resilience assessment and research to improve operational performance in hot weather. The review of train performance reveals a repeated cycle of delay and cancellation in hot weather confirming a general lack of resilience even before the occurrence of extreme events.

Asset Information (including AIS and Intelligent Infrastructure)

The EHT investigation considers the information required to:

1) Prepare for extreme heat with preventative maintenance intervention

2) Engineering information required to inform the Key Route Strategy, and

3) The asset condition assurance required at the time of an extreme heat event to minimise operational restrictions.

The AIS monitoring fleet of 12 trains is operated centrally and will be supplemented by 3 Switch and Crossing Inspection Vehicles currently under development on Southern and Eastern. Investment in a new fleet and inspection systems of over £500m is underway with central procurement.

In 2022 there was no specific set of data that is captured or processed to directly assist with planning of extreme heat preparation and, in addition, no data was specifically captured to benchmark any changes before and after the extreme temperature. Asset information is not currently directly linked to the 'business process' of managing extreme heat. However, data that is regularly captured by the current fleet could be processed and analysed to determine geometric deterioration, ballast loss, lateral alignment and repeat defects which, if overlayed with known physical data, such as bridges, S&C and SFT, provides insight into high-risk locations. The SFT records are also not validated regularly enough to provide an integrated view of stress, geometry and ballast conditions at vulnerable sites.

Collection of Data

The responsibility and priority for regional operations team to guarantee train paths and access to assure the asset inspection and management plan needs to be clarified in the devolved organisation. The infrastructure monitoring fleet needs sufficient access and priority to recover from any failure to capture data on schedule. Priority over passenger and freight operations may be required to assure asset condition. See Recommendation SRT 2.

<u>Plain Line Pattern Recognition (PLPR) cameras for imaging at 125mph with automated</u>

Defect Analysis

Improving overall data capture, many service trains fleets now include vehicles that are fitted with approved systems to provide asset information on track and OLE condition. These trains are operated by a range of franchises, access to this data appears to be constrained by the complex commercial arrangements between manufacturers, owners, and operators. See Recommendation SRT 4

The Taskforce considers that co-operation on the use of this data is consistent with ROGS Section 6 Regulation 22. Any barriers to the availability of this data (commercial or logistical) should be eliminated as a matter of urgency.

Consistency and accuracy of asset condition monitoring is essential for Risked Based Maintenance implementation.

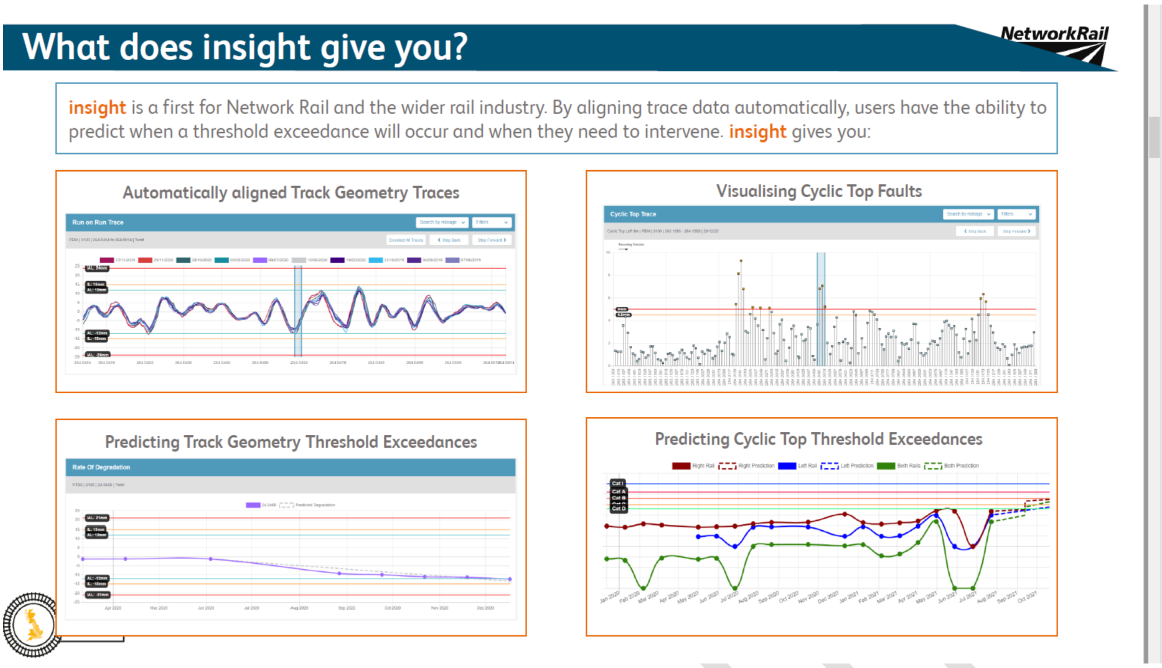
Processing and Use of Data to provide Information.

Existing data captured on dedicated inspection vehicles is not fully utilised. Valuable information is not being processed and made available to local teams and work planning processes. For example, access to PLPR data is inflexible in the vicinity of S&C. Ballast profile and synchronised video and geometry information, available for all track (including S&C) and OHL assets on a regular basis for all Cat 2, Cat 1, and Cat 1A lines, provides a reasonable short term objective that will inform preventative work and the Key Route Strategy. See Recommendation SRT 5

The application of intelligent processing of the existing data needs to include heat resilience related parameters to derive lateral stiffness, misalignments, voiding and ballast profile. This, linked directly to reliable SFT data, will reduce the risk of failure to identify and mitigate CRT sites. For OLE, poorly adjusted and adversely changing geometry can be identified by analysis of seasonal change.

It is important to develop clear requirement specifications on this information as a matter of urgency to avoid unnecessary cost and duplication in the planned investment in new equipment and vehicles.

The use of the processed information at the depot level is essential. This requires the training, knowledge, and experience to apply the information to track and OHL assets. The application of intelligent analysis to support improved decisions is limited by the variations in age, local conditions, track structure, OHL design and asset type. Engineering knowledge and experience will be required until technology is able to ‘learn’ site and asset specific parameters sufficient to assure safety, and plan preventative intervention. The LADS (Linear Asset Decision Support) system did not become embedded in the maintenance process and the anticipated predictive benefits were not realised; this failure is typical of software system roll-out in many large enterprises. The application of the replacements system INSIGHT needs to be ‘pulled’ by the customer (DEAMs and Route Directors) to support cost effective asset performance. Regional Executive level review of the transition is required.



Investment, Regional Requirements Specification, Capability and Transition

The forthcoming investment in new systems will, the Task Force believes, set the direction of asset information for the next 15 plus years. It is important that the regional 'customer pull' for these systems is well defined and backed up with the capability and capacity to implement the systems, learning from previous failures by ensuring that the focus is on maintenance outcomes and embedding change in the 'business process'. Mature embedded systems are essential to realise the benefits of 'modernising maintenance' and RBM.

There is a high risk that the investment becomes focussed on trains, technology, and data rather than maintenance outcomes and passenger experience. Currently the outputs of these systems are not formally configured and approved to prepare for and manage extreme weather resilience.

The importance of the £500m investment is not reflected in the Engineering team's capability at a Regional and TA level. The underpinning engineering and detailed knowledge of the systems requirements is being undertaken by the equivalent of less than 4 full-time roles (December 2022). Given the cost, importance, and reliance of the routes on these systems, the transition requires significant short-term engineering leadership and capability to ensure that 'Intelligent Infrastructure' is validated and embedded in the 'business process'. Fully developed DEAM and Infrastructure Director plans are needed to ensure that successful implementation at route and depot level dominates the prioritisation of resources and funding in the planned investment.

The ‘customer pull’ from the Regions, Routes and Maintenance teams requires clear definition. The current envisaged centralised ‘big bang’ approach to procurement of new systems appears to be at odds with the devolved structure and the specific requirements of regions covering variability in traffic, asset type, geography, access, and operational risk. Fully developed plans to undertake training, piloting and migration to new systems require stage gates of customer acceptance at the DEAM/Infrastructure Director level to assure transition.

The TA and Regional DEAM/Infrastructure Director roles in Intelligent Infrastructure and new Asset Inspection Systems.

In anticipation of the large investment, the DEAM and the Infrastructure Director (responsible for all maintenance activity) provide vision, leadership and ownership of the asset information requirements specification for the region. These requirements need to project forward 10 and 20 years to anticipate and enable flexibility in adoption of new technology. See Recommendation SRT 1.

Formal migration from ‘as is’ to the ‘to be’ state with achievable milestones and resources identified is needed as for any other large investment. The TA needs to provide subject matter experts in the asset, relevant standards and approved systems to support the DEAM/Infrastructure Director in specification and implementation. Some examples of implementation such as the NW&C initiative on OLE information and work on the S&C Inspection Vehicles need to become typical of all regions. Importantly this needs to be by sharing and collaboration to avoid the cost of duplication and unnecessary diversity of technology.

The large CAPEX and OPEX cost of these systems and their operation warrants regional ownership of the specification. Importantly, TA validation and approval of all systems is needed to ensure that they meet the accuracy and repeatability anticipated in the standards.

The analysis of data alone does not provide sufficiently 'intelligent information' unless it is underpinned by the understanding of track, OLE and vehicle dynamics that may vary by asset type, line speed and traffic. Engineering properties need to be asset specific and location specific to ensure the experience of traditional evaluation methods is embedded in more automated analysis. Expertise in the new technologies and innovation will be required alongside engineering knowledge. Failure to fully resource and plan implementation risks delay and repeated failure in realising the benefits of the investment.

Investment in Vehicle and Systems - Regional Asset Information with consistent Engineering Assurance.

The devolved structure provides opportunity for a phased approach to the selection of systems and platforms and prove implementation though local management of the changes.

Two Regions (due to the differences in asset type and geography) - Scotland and Southern - provide the opportunity to implement dedicated regional monitoring and inspection platforms in a relatively short timescale, with DEAM and TA support, to pilot full implementation of specific systems. The systems on these vehicles need to be approved by the TA to ensure compatibility with the standards and engineering specifications. Driving innovation in the standards to reflect emerging technology and engineering evaluation techniques is essential.

The remaining three regions provide a mixture of line categories. Procurement of systems to address the high-speed requirements should be fully coordinated with sharing of vehicles to achieve economies of scale and compatibility of measurement. Importantly the use of in-service passenger vehicle systems needs to be fully implemented where appropriate.

The high-speed fleet is then supplemented on a regional basis with systems that are interchangeable with the dedicated vehicles in Scotland and Southern (economies of scale in maintenance of the fleet). This approach allows overlapping deployment to cover short term unavailability due to maintenance and calibration.

The specification of vehicles needs to allow capacity to trial and validate new and emerging technology and implement R&D outputs alongside existing systems. The typical 40-year life of vehicles needs to be compatible with the 4 or 5 generations of new technology that will need to be deployed.

A fully devolved model for the infrastructure monitoring fleet would not realise the economies of scale and may lead to variation in application of engineering standards and the increased cost of systems diversity. Consideration should be given to a hybrid approach with regional requirements specification supported by centrally approved 'common' systems (TA) directly related to GB and international standards. The visualisation tools required should be identified at the regional level with common systems for key safety and resilience related information. The systems should meet the requirements of the regional plans but be common and consistent in terms tolerances, resolution and repeatability to assure track geometry, rail defects, location reference and trend analysis.

The AIS operating model needs to reflect the devolved requirements but realise the economies of scale, resilience and assurance that underpin a central service. The level of resource in the TA to support this transition is presently inconsistent with the task of approval of systems and support to implementation at the regional level.

Specific Systems for Improved Assessment and Management of Heat Resilience.

The opportunity for the wider market to engage with NR and deliver an enhanced and improved level of asset knowledge is a significant opportunity. Careful consideration should therefore be given to how the asset will need to perform in future decades and what data is captured to inform future operational decisions. Through the work of the EHTF the following areas of capture should be considered:

- In-service vehicle data for asset management and maintenance.
- Ballast level and profile measurement.
- Voiding - localised support and lateral stiffness of track assessment.
- Lateral alignment - high resolution run on run analysis as temperatures fluctuate.
- Geometry/Video of all S&C assets.
- OLE - balance weight position (ambient temperature related).

- OLE - registration (variations of longitudinal position, angular displacement with temperature). See Recommendation SRT 9.
- OLE - video of jumper wire (tensioned or slack).
- Portable track stability monitoring (voiding and lateral movement)
- Conductor rail wear, positioning, and longitudinal movement detection at ramp ends.
- Conductor rail insulator pots misplacement and height adjustment.
- Drone use to identify, plan and manage potential CRT sites. See Recommendation SRT 11.
- Direct link between the Rail Stress database and track geometry/video.
- Intelligent processing of track geometry data to identify track stability risk.
- Portable 'intelligent' rail temperature sensors with ambient to rail temperature prediction.

Research, Development, and Innovation

There are three track projects with high relevance to Extreme Heat.

1. NDT (Non-Destructive Testing) Stress Measurement – The Taskforce is awaiting confirmation of the practical feasibility of this development. Although a potential 'gamechanger' it unlikely to provide practical solutions before the end of CP7. See Recommendation SRT 3.

2. Factors Affecting Track Stability. This has potential to update both the management and definition of CRT sites and the contribution of different vehicle types to the risk of buckling. Focussing the project on deliverables that directly link to proven vehicle parameters used within accepted vehicle models and standards is essential to delivering operational benefits. Freight and other vehicles with improved suspension will directly benefit with reduced restriction to operations. As identified in the Extreme Heat Interim report, the Federal Railroad Administration in the USA is looking to apply similar research. See Recommendation SRT 6.

3. Track Buckle Detection (eliminating watchmen) is in the development and prototyping stage. The understanding, identification, and where possible elimination of potential track instability is an essential pre-requisite to deploying these systems. In 2022 less than 50% of the buckles that occurred were identified before the event. Risk identification needs to be the priority to ensure this emerging technology is deployed at vulnerable locations.

Consideration should be given to a review of the research of other railway administrations every two years to ensure that Network Rail is able to focus expenditure and innovate best practice from around the world. See Recommendation SRT 10.

A practice once widespread in the Network Soutth East area of British Rail, the management of rail temperature by either reflective coating or heat dissipation, is not currently in the reported projects. Some research in this area is evident in the USA and Germany; the benefits of this are encouraging at around 7 degrees centigrade rail temperature reduction.

Intelligent rail temperature sensors with 'learned' site specific prediction can link to WRCCA approved forecasts have the potential to create a consistent to approach CRT management. This will require innovation leadership from NR to ensure that specifications meet minimum standards and communicate directly with NR systems.

Rolling Stock - Passenger and Traincrew Heat-Stress

In terms of passenger heat stress, the specification of the HVAC systems to BS EN11329:2016 assumes the UK to have a temperate climate and along with Ireland has the lowest designed range in Europe within the standard for extreme temperature – minus 15^{o}C to plus 33^{o}C. This figure needs to be reviewed in the light of projected future heat events.

Key Train Requirements (KTR) identify the need for battery or auxiliary power to maintain cooling fan operation for 90 minutes, but they do not define specific values on maintaining temperature to prevent heat stress.

Consideration should be given to NR Operations being provided with declared engineering status of passenger trains before entering service on extreme temperature forecast days. This should include the condition of HVAC systems, the status (including minimum fuel) of auxiliary systems on trains, and completion of heat related failure checks prior to operation in extreme temperature. This would reduce the consequences of any train failure or stranded trains due to infrastructure failure.

WRCCA & Engineering Inputs to Key Route Strategy and Train Performance

WRCCA – Seasonal and Weather Resilience

Fundamental to operating in extreme heat is defining how assets will be affected. For the Technical Authority this includes specific values that may be included in product specification, standards, and approvals. For the regional engineering and maintenance teams this includes the specific temperatures, solar gain parameters, geographical and regional effects to plan for, and allow site specific assessments to be as robust as possible.

WRCCA have provided guidance that is now included in procurement and the acceptance of new products. This when included in renewal and enhancement will provide improvement in resilience over time.

The table below identifies the WRCCA strategic objectives for resilience.

Strategy and Planning	Capability and Training	Standards and Processes	Information and Intelligence	Investment in resilient assets
Strategic planning and investment in the railway system is shaped by long term climate change adaptation plans.	Rail industry has a high level of adaptive capacity, and all staff know their role in creating a resilient railway	Climate change adaptation and resilience is integrated into core business processes	Technology and data deliver safe operations and information to analyse vulnerabilities and performance	Resilient infrastructure, buildings and rolling stock enable a safe and efficient railway in adverse and extreme weather.

Our investigation has revealed that at the route and local level the adaptive capacity of maintenance teams is low and challenged by other changes in access, experience, and resource levels. Further iteration of strategic advice will be wasted unless knowledge is used tactically as part of the business process. Direct guidance on the how specific assets is affected by ambient temperature, solar gain and air movement is needed to assure consistency of engineering evaluation and for input to intelligent monitoring systems.

Fundamental to operating in extreme heat is defining how assets will be affected. This is a combination of assessment of the effects of forecast temperatures on railway assets (WRCCA), minimum requirements for asset condition (TA standards), accurate information on regional asset condition (DEAM), and the maintenance operations (Infrastructure Director). This directly informs the Key Route Strategy and operations. 2022 performance was as follows. See Recommendation SRT 7.

Train Performance – July 2022

The Extreme Heat days of 18th July to 20th July 2022 were forecast several days in advance; this allowed execution of the route strategy for the Regions affected. Robust engineering assessment and infrastructure condition information provided essential input to the operational plan to ensure customers were aware of the revised operational timetable and that this worked successfully.

The actual performance compared to plan gives indication of the maturity and accuracy of asset information, local temperature impact assessments and the validity of the Key Route Strategy.

Analysis of the performance information further illustrates the need for information on vulnerable assets and the mitigation plan to be improved. The difference between planned and actual requires further analysis to establish the root cause. The following table is from the 19th of July 2022.

19th July 2022 – Trains Run			
Region/Route	Planned Trains (Compared to same day in week earlier)	Actual Trains (Compared to same day in week earlier)	Excess Disruption
ECML (Long Distance)	69%	9%	-60%

GTR (TLink,Southern,GN)	51%	44%	-7%
WCML (Long Distance)	84%	25%	-59%
West Midlands (incl WCML suburban)	68%	41%	-27%
NATIONAL	79%	64%	-15%

The Engineering and Maintenance Operations input to the Key Route Strategy requires investigation within the Region and specific shortcomings addressed. It is noted that significant excess disruption on WCML was the result of an off-track event.

The planned reduction of services of around 20% to 30% was consistent with the age and type of asset in the Regions. The excess disruption was the result of shortcomings in the Key Route Strategy consistent with uncertainty of asset condition and resilience, and the accuracy of route/line temperature prediction of the vulnerable asset sites.

The WRCCA teams have undertaken considerable work in evaluating and supporting the strategic works to alleviate flooding and earthworks. Extreme heat events require more tactical support of local maintenance and engineering teams, including guidance in the application of forecasts. Direct engagement with local teams is needed to support assessment of the effects of ambient temperatures, air movement and solar gain in the prediction of rail temperature. Formalisation is required of factors that are to be assumed in seasonal preparation and input to the Key Route Strategy. This support should increase confidence in assessment leading to minimum operational impact without compromise to safety. See Recommendation SRT 8.

Hot Weather and Extreme Heat - Costs of Train Cancelation and Delay

This is considered in two parts.

1. The general resilience of the NR assets to hot weather overall. This looks at the excess delays and cancellations in Period 4 and Period 5 compared to an average period (excluding winter and summer peaks), using Schedule 8 payments.
2. The planned reduction in services on an Extreme Heat Day. This reflects the tolerance to operating above the planned temperature limits for a route in Schedule 4 payments.

The overall resilience of the asset is reflected in the unplanned interruption to services in hot rather than extreme conditions. The lack of 'headroom' between asset condition and failure is consistent with the increased disruption. This is confirmed with respect to hot weather in the 280% increase in weather attributed Schedule 8 costs in Periods 4 and 5 and the 63% increase in infrastructure schedule 8 cost in those periods.

The total excess for three of the last four years (excluding Covid impact) is £130m; see table below:

Excess Delay and Cancellation Cost in Periods 4 and 5			
Year	Weather Attributed £m	Infrastructure £M	Total Excess Cost £M
2018	9.9	20.8	30.7
2019	13.4	35.5	48.9
2022	18.9	31.5	50.4
total	42.2	87.8	130

Note - These costs do not include the cost of resolving the failure.

Av. schedule 8 – Weather - Estimated to be £2.5m/period.

Av. schedule 8 - Infrastructure - Estimated to be £23m/ period (all factors).

Each region will include known vulnerable assets and assets where the condition is not known or verified. The location and quantity of these assets and uncertainty of condition results in planned cancellations. The Extreme Heat event of 18th and 19th July 2022 resulted in the cancellation of 7737 trains, a reduction of 19% compared to normal summer services. This resulted in an estimated Schedule 4 planned cost exceeding £30m for the 2 days in Schedule 4 costs alone. (This is based on the average cancellation cost per train of £4000).

The cost of delay and cancellation is consistent with the reported condition and level of asset resilience identified in the Initial and Interim reports. The level of cost (which does not include costs of rectification) justifies targeted investment to eliminate specific track and OLE conditions, raising the level of resilience above minimum requirements.

Recommendations for Engineering Support

SRT I
The DEAMs to be accountable for the specification and quality of regional asset condition information. DEAMs and Regional Infrastructure Directors to endorse the forthcoming investment of over £500m in asset information systems and assure the competence of staff to use new systems.
TA to be responsible for approval of systems; to provide the accuracy, repeatability and resolution to enable users to comply with standards, and their suitability for intelligent analytical processing.
SRT 2
Review the prioritisation of access and minimum levels of schedule compliance for infrastructure monitoring vehicles with due regard to the increased importance of vehicle-borne inspections.
SRT 3
Critically review output from the NDT Stress Analysis project and confirm the viability of the technique for practical application. Implement a high priority project to convert from a proven concept to application.
SRT 4
Use currently fitted in-service train systems to inspect and evaluate track and OLE. Eliminate existing barriers to data availability.
SRT 5
Develop specific analysis of currently available track geometry and video data to identify buckle risk conditions. Synchronised video, geometry, ballast profile,

ballast disturbance and SFT information to be available to the maintenance engineer.

SRT 6

Critically review track stability research with a view to implementation of outputs. Define benefits to safety and performance of track in extreme heat and plan implementation with respect to vehicle type specific risk.

SRT 7

Key Route Strategy to be fully verified. The DEAM to review engineering inputs to verify the extent of asset vulnerability. The maintenance response to the vulnerability to be approved by the Route Infrastructure Director (monitoring, resources, local impact assessments, and planned operational restrictions).

SRT 8

WRCCA teams to offer formal guidance embedded in the 'business process' at a local level. Definition of how ambient temperature forecasts, solar gain, and air movement are used to predict component specific temperatures is required by maintenance engineers.

SRT 9

Use intelligent analysis of images and data to determine angular and longitudinal displacement to predict OLE condition at critical locations in advance of extreme heat events.

SRT 10

Review FRA research and methods for accelerating the application of research in the UK. Ensure that all research has a timebound application plan including any required trials, approvals, and changes to standards. Periodically (min 24 months) review overseas research into hot weather railway operations for applicability and benefit.

SRT 11

Evaluate the use of drones (unmanned aerial vehicles - UAVs) to assess vulnerable sites, complimenting the information available from train-borne systems.

SRT 12

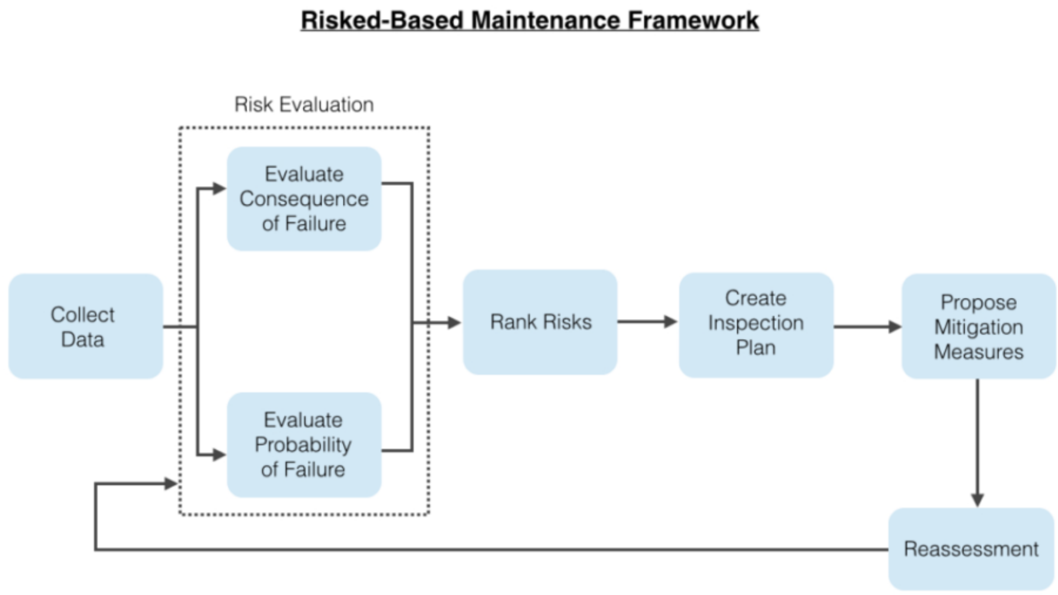
Undertake detailed inspection of timber bearer S&C layouts and adjoining plan line, with a line speed of 60 mph or above and Implement strengthening of the asset.

Risk Based Maintenance (RBM)

The adoption of risk-based maintenance introduces a process that identifies opportunities to reduce the number of tasks that add little or no value to the performance of the asset. In this regard it is analogous with the deployment of 'lean' in other industrial sectors to reduce cost and enhance quality. Application to railway infrastructure provides opportunity to improve the effectiveness and quality of maintenance, based on well-developed understanding of failure modes and robust asset condition information. The rigorous application of RBM to resilience in extreme heat, for example track buckle risk, will ensure that accurate and up to date asset information is used in the assessment of critical rail temperature. Track stability modelling can then identify the mitigations required in terms of operational restrictions with defined factors of safety.

Theory of Application

The theoretical stages are:



- **Collection of data**: Once the risk is identified, data of all sorts including details of the risk, its effects, and mitigation is collected.
- **Risk evaluation:** At the evaluation stage, the risk and its consequences are quantified to be measured.
- **Rank risks:** The data obtained from the quantification of risk probability and its consequences is combined to determine the 'total risk'. Total risk is then compared with predetermined levels of risk which indicates whether a risk is acceptable or not.

- **Creating an inspection plan:** If the risk is not found to be within acceptable levels, a plan is developed to inspect the system via condition-based monitoring.
- **Propose mitigation measure:** To mitigate the risk, a proposal is planned via condition based monitoring and predictive maintenance approach.
- **Reassessment:** Once the proposal is developed, it is assessed for legal and regulatory requirements. If it does not match the criteria, the plan is developed once again; otherwise, the maintenance proposal is put into place.

This approach is successful in managing assets that operate in defined conditions and in this basic form may be used simply for the prevention of operational failure.

This approach can be applied to Railway Rolling Stock where the ability to inspect for failure modes can be evaluated with detailed data collected in the controlled environment of the maintenance facility and fleet performance. As with other mechanical systems over the last 3 decades progressive changes to acceptable tolerances have improved cost, reliability, and maintenance intervals.

Application on Railway Infrastructure

Risk based maintenance for railway assets needs to consider the challenges for application:

1. Safety – unlike some other sectors, the existing railway infrastructure has failure modes that could result in multiple injuries and fatalities. Known as Wrong Side Failures the asset may fail to an unsafe condition that could result in derailment or collision.
2. Asset life – many railways asset have a life of 20-40 years on higher speed lines. The condition of the asset may not be fully inspected for many years due to the limitations of inspection techniques.
3. Variability – track components for example have a wide range of loading conditions, age, and type. This may require the failure mode assessments to be specific to location and route.
4. Asset history and condition Information – the data is required to be current, consistent, and accurate.

Specify the objectives of the RBM regime.

Network Rail manages a highly diverse portfolio of assets in terms of age and type with many variables from geographical and environmental factors to load type and volume.

The asset is also required to perform over time with the age of track asset often in the range 20-40 years even on principal routes.

RBM needs to consider not only the short-term failure risk but also importantly the risk of significant reduction to asset life and the consequent disruption and cost of premature replacement.

The generic process is set out in NR/L2/MTC/10662. The purpose and definitions are broad and could be interpreted to already include extreme heat resilience in the general performance definition. Intent could however be clarified with specific requirements being set out for sustainable asset condition and resilience. The specification of risk-based maintenance for long term assets such as track needs to consider the diversity of asset type, age and loading to ensure that safety, reliability, and asset life are not compromised. For example, operational tolerances that affect fatigue of rail and attrition of ballast on higher speed track needs specific evaluation due to the exponential increase in degradation rate that high dynamic forces produce. Specifically, the FMECA needs to define conditions that increase degradation rate or reduce resilience as a failure mode with specific mitigations.

Control and the Competence of Risk Assessment

In terms of 'sustainable operational limits' within RBM, these will need to be applied using the product specification and modelling of failure and degradation modes to identify the tolerances and inspection criteria required. This requires the professional engineering evaluation of the component and the actual operating conditions.

The definition of standards and specifications relating to 'safe operation limits' requires professional engineering evaluation and ongoing review based on the range of operational conditions and any failure investigations.

A fundamental requirement of successful implementation is that the existing regime is 'in control' using accurate asset information, with predictable levels of work and work arising. Maintenance regimes with high levels of unplanned and reactive work need transition support to provide the 'headroom' for change. This is acknowledged within the standard and requires close attention.

Implementation of risk-based maintenance at a route or local level requires a professional evaluation of risk and review of the impact of any changes. Where the consequence of failure is or increases the likelihood of a Wrong Side Failure (WSF) any change needs to be formally approved. For Signalling (Train Control) systems this would be an engineer licenced to the appropriate level within IRSE. For other assets the approval of change would require a similarly competent and approved professional engineer.

The training and competence module within NR/L2/MTC/10662 needs to include specific technical competence in the evaluation of extreme heat risk with specific expertise in failure modes within the discipline modules. For example, NR/L2/TRK/7014 sets out the engineering process for track in adopting and reviewing RBM changes. The additional engineering resource required to support the TME/IME through an implementation needs to be identified (this will vary with Track Category, age and condition) and in place before the RBM Lead and Facilitator commence the process.

RBM for Climate Change Resilience

The application of RBM can be used to reduce risk of failure to deliver the planned train services for defined extreme heat conditions.

Extreme temperature becomes a defined failure mode within the RBM programme with a specific checklist within NR/L2/MTC/10662 modules. Resilience becomes an integral part of the 'business process' supported by asset information and mitigating actions. For OLE this checklist will include specific inspection information on the longitudinal position of components with respect to ambient temperature (jumper tension and registration arm angular rotation) over time.

As identified in the theoretical process and Network Rail standards for the application of RBM, the essential elements are collection of data and then competent evaluation by trained and appointed technical staff. Correctly applied RBM would identify and address the shortfalls in asset knowledge, competent resource, and access for mitigation measures that resulted in the unplanned disruption to services in July 2022 and previous summer periods.

RBM implementation for track buckles is complex. As set out in NR/GN/TRK/8001/040, this includes 105 process steps of which 79 are the responsibility of the TME/SM covering 10 failure modes resulting in a buckle and potential for derailment. Each process step requires a working knowledge of on average 7 standards. Dedicated and technically competent support to the TME is needed to implement change.

APPENIX A

Press Release Issued by Network Rail on 20th April 2022

Consequently, the Chief executive of Network Rail Andrew Haines OBE issued the following press statement: - The review will consider four key areas, each led by an independent expert in their field. Three of these areas will be focused on gathering insights from other countries and making comparisons with international rail networks that are more used to dealing with extreme heat and fluctuations in temperature. Andrew Haines, chief executive of Network Rail, said: "The weather we've experienced this week has put a huge amount of pressure on our infrastructure, our staff and our passengers, and with extreme weather events becoming more frequent as our climate continues to change, we've got to pull out all the stops to make our railway as resilient as possible. "That's why I've decided to commission this taskforce, spearheaded by leading global experts, whose considerable experience in their fields both in the UK and across the world will arm us with the guidance we need to make our railway resilient in the face of climate change for generations to come." Dame Julia Slingo FRS, former chief scientist at the Met Office and a world renowned expert in climatology, will examine the likelihood of more frequent extreme hot weather events in the UK and how high-quality, detailed and timely weather forecasting can be maximised by Network Rail to mitigate the impact of heat on its infrastructure. Dame Julia recently led a weather action task force focussed on equipping Network Rail with a better understanding of the risk of rainfall to its infrastructure. Sir Douglas Oakervee will draw on his 60 years of experience in engineering to investigate options to ensure the railway infrastructure can continue to function 2 safely and reliably during very hot weather. This work will particularly focus on the performance of track and overhead line equipment as they are the two most common causes of delays and disruption in hot weather. Sir Douglas has served as chair of Crossrail and HS2 and is a former president of the Institution of Civil Engineers. Simon Lane, former Managing Director and CEO of railways in Melbourne and New South Wales respectively, will explore operational standards, policies and practices which could allow services to continue to operate safely and without highly limiting speed restrictions in extreme heat. Mr Lane, who has experience in leadership roles in the UK and Singapore, has particular knowledge from his work in Australia not only of the challenges railways face in very high temperatures but also the challenge of running railways in a climate where there is a wide variation between the highest *and coldest temperatures. Mr Lane previously led a review for the government of Victoria following a period of extreme weather in 2009. Anthony Smith, chief executive of the independent transport watchdog Transport Focus, will examine how Network Rail communicates with passengers in the run-up to and during periods of extreme weather, as well as in its planning for disruptive events. Mr Smith has more than 20 years' experience leading Transport Focus as it took on representing bus and road users as well as rail passengers. He has contributed to recommendations to the rail industry and the government on how the pandemic affected rail passengers and the Williams Shapp's rail reform white paper amongst other topics.*

Appendix B.

Draft remit for extreme heat task force Engineering Workstream Issued to Sir Douglas Oakervee on 26th July 2022

Introduction: *Hot weather events cause significant disruption to the railway. Track, overhead line and signalling assets are at risk of overheating or permanent damage at high temperatures. Very hot days (such as in 1976, 2003, 2019 and 2022) have caused widespread disruption and can, in certain situations, place passengers at risk. The 10 hottest days have occurred during this century and temperatures approaching 45C are predicted to occur by 2050. 3 The record-breaking days of the 18th and 19th July 2022 saw multiple infrastructure failures. Some lines were closed for the day; for some others, services were suspended because of the scale of the disruption. For many journeys the railway could not offer a viable service. This disruption subsequently affected 20 July 2022 as well. A task force has been convened by the CEO of Network Rail to understand how the railway's response to hot weather can be improved covering forecasting, infrastructure, operations and passenger information. Primary objective of the Extreme Heat Task Force The primary objective of the EHTF is to identify, based on international best practice, the practical steps the railway can take to improve its resilience to very high temperatures. This to identify the costs and likely benefits of investment, and the benefits to passengers and freight users. Engineering workstream objectives Provide recommendations to Network Rail to improve the service to passengers and freight users in extreme hot weather: To identify world-wide engineering best practice for management of railway infrastructure during extremes of hot weather. To recommend how Network Rail will be able to adopt this best practice. Network Rail's framework for assets is described by our engineering standards. The task force is to undertake an independent review of this framework. Is it effective for controlling the risks we manage? Does it deliver the optimum safe service to passengers? Are there areas where our engineering standards are overly risk averse? How might we optimise these standards? Do we manage track, power systems and assets in a sufficiently integrated and effective way? Or do we need greater coordination? To identify assets vulnerable to extremes of hot weather and to recommend engineering solutions which will* *provide greater resilience. To review Network Rail's funding proposal for CP7 i.e., the funding control period from 2024-2029. Does this contain sufficient funding for hot weather climate change resilience? 4 To review Network Rail's long-term plans for control periods 8,9 and 10. Do these plans address the long-term trend of hotter summers? Required outputs Task force outputs to be delivered to Group Director Safety and Engineering Initial report Within 12 weeks to provide an initial report describing the following: Initial findings and early recommendations Areas of focus for the task Confirmation of the final deliverables Confirmation of publication date for the final report Final Report Within 6 months to provide a final report, detailing the findings and recommendations of the Task Force. To support Network Rail with the publication of a media release describing the findings of the Task Force. To provide statements to the media in support of the publication of the report. Programme resources It is anticipated that a project team will be required to support this task. Resources can be provided through the Network Rail managed services framework contracts. Steering meeting There will be a regular steering meeting for this engineering workstream. Initially at a frequency of every 2 weeks. The frequency will then be adjusted according to needs. The engineering steering group will be attended by: Sir Douglas Oakervee (chair) Martin Frobisher, Network Rail Group Safety and Engineering Director Gareth Evans, Network Rail National Technical Head – Track 5 Martin O'Connor – Network Rail National Technical Head – Overhead line contact systems Lisa Constable – Network Rail lead for climate change adaption Key members of the task force project team The task force chair will also be required to attend a wider programme meeting which brings together the chairs of the 4 workstreams. This will be needed to ensure alignment between the workstreams. Ongoing Support Task force chair to provide regular review of the task force recommendations. To check if Network Rail is implementing the recommendations as intended. Management of the Review The management of the whole Review covering all disciplines is the responsibility of Oliver Bratton, Director Network Strategy & Operations. In turn the engineering review group is supported by Martin Frobisher, Group Safety & Engineering Director, Technical Authority.*

Appendix C.
Panel Members Curriculum Vitae.

Sir Douglas E Oakervee CBE, FREng, Hon. FICE, Hon. D Eng, Hon.FAPM, Hon FCInstCES, FICE, FIMechE, FHKIE, FASCE. Douglas has had a distinguished career as a Civil Engineer and has vast experience of delivering major projects. These have included his role as Chief Tunnel Engineer of the Hong Kong Mass Transit Railway Authority, then Senior Resident Engineer and later Construction Manager for the tunnelled sections of the Railway in North Kowloon and the Tsuen Wan Extension. He went on to set up his own company, undertaking in Hong Kong the Tai Po Gas Reforming Works and associated submarine pipelines, the Eastern Harbour Crossing, and the Kwun Tong By-pass and in the UK in JV with the Babtie Group Ltd (now Jacobs) the Jubilee Line Extension from London Bridge to Waterloo including Southwark Station. In1991 he was appointed to the Hong Kong Airport Authority as Project Director and was wholly responsible for planning, design, procurement, and construction of the new Hong Kong International Airport on a man-made island in the South China Sea. In the UK, he became Director of P O's London Gateway Port in 2004 and from December 2005 Executive Chairman of Crossrail Ltd, until his retirement in May 2009. In July 2009, he was appointed Chairman of Laing O'Rourke Construction (Hong Kong) Limited and in parallel was the Non-Executive Chairman of High Speed Two Limited (HS2) from April 2012 until December 2013. He then undertook consultancy work in both the UK and the Far East. In 2019 The Prime Minister invited him to review of HS2 which resulted in the "Oakervee Review". He has since conducted several minor reviews for The Department of Transport. In 2003 he was installed as The Institution of Civil Engineers' 139th President and has been awarded the Institution's prestigious Gold Medal in 2008, previously he had been awarded both the Baker Medal and The Telford Medal. He was until December 2010 Chairman of Engineers Against Poverty and in June 2011 was elected as the International President of the Lighthouse Club, the charity supporting the Construction Industry. In 2013 Heriot-Watt University conferred upon him the Honorary degree of Doctorate in Engineering. He is a visiting Professor to the University of Leeds He was awarded the OBE in 2000 CBE in 2010. and the Kt in 2022. In 2010 he was inducted into the HKIE "Hall of Fame" and in 201 was elevated to Hon. Fellow in the Institution of Civil Engineers. He was elected President of the Smeatonian Society of Civil Engineers 2019-2020.

Peter Dearman FREng CEng FPWI FIET FIMechE

Peter Dearman is a career Railway Engineer with a background in railway traction electrification. Trained by British Rail he has over 50 years of practical railway engineering and operational experience. Qualified in Electrical and Mechanical Engineering he has worked in senior management positions for more than 30 years. Career History 1970-1974 Apprentice trained at British Rail Stratford depot. 1974-1978 Worked as a maintenance Technician on the British Rail Great Eastern lines dealing with 25 kV high voltage switchgear and protection and control systems. 1978-1983 Design and implementation of work associated with the conversion of the Great Eastern lines from the dual voltage 6.25 kV/25 kV to the standard 25 kV system. 1983-1986 British Rail HQ responsible for the specification and contract procurement of electrification supervisory control and data acquisition systems. 1986-1988 Deputy Electrification Engineer for British Rail Eastern Region. Responsible for all new works and maintenance activities on the high voltage distribution systems on the Eastern Region traction network. 1988-1993 Electrification Engineer East Coast Main Line. Responsible for Commissioning the ECML traction system, establishment of the electrification fixed equipment maintenance depots, and operation of the electric traction network between London, West Yorkshire, Edinburgh and Glasgow. 1993-1994 Worked within the British Rail privatisation unit, producing the structure of the new arrangements for the privatised railway. 1994-1996 Initially working for RailTrack as Production Manager East Coast Main Line. Responsible for operation of the route, including all signalling staff, and the management of the circa £200m maintenance contracts. On completion of a re-organisation of the RailTrack structure in late 1995, assumed responsibility for the development of the train protection strategy. Developed the Train Protection Warning System (TPWS) managing the technical development of the system, and the complex industry wide negotiation to bring about its implementation. 1996-1998 Managing Director Infrastructure Maintenance for Jarvis Rail. Full business responsibility for the Jarvis rail maintenance business unit, with a seat on the Jarvis Rail Board. Circa 3000 staff and annual contract value circa £250m. 83 1998-2002 Atkins Rail. Engineering Director for the West Coast Main Line Overhead Alliance. Responsible for all Engineering design and co-ordination of the upgrade of the WCML electric traction system. 2002-2004 Atkins Rail, Director of Electrification. Seat on the

Board of Atkins Rail with responsibility for the Electrification business. Circa 175 designers and consultants with an annual turnover of £12.5m. 2004-2006 Network Rail. Infrastructure Maintenance Manager for the Network Rail Great Northern Area. 1300 staff covering all railway infrastructure maintenance between London and York, all of Lincolnshire and South Yorkshire. 2006-2009 Network Rail. Managing a major programme of organisational change, restructuring the £1.3 bn annual budget, 17000 strong workforce. 2009-2010 Restructuring Network Rail track renewal programme. Created an engineering design team within Network Rail to "in-source" all S&C design. Redefined the end to end process of track renewal assessment and creation of build-up of the annual track renewal plan. 2010-2013 Head of Network Electrification: Network Rail. Formulating the programme for the major programme of electrification. Negotiation with DfT and setting the programme for engineering development which defined OLE Series One, Series Two and the Master Series, and defining and setting to work on the Route Traction Power strategies and the building of the Grid feeder points across the network. Instigated the National Electrification Safety Improvement Programme (NESIP) including definition of the electrical safety Lifesaving Rules, "Test Before Earth" and "Test Before Touch". 2013-2015 Engineering Director: Systra UK. Responsible for consolidating the position of Systra in the UK and Northern Europe. Recruited a team in the UK to support the work on CrossRail, where Systra provided 80 staff, mixed ex-pat French and UK recruits. Supported ABC in the tendering exercise for the EGIP project in Scotland. Following the success of that tender, established the Systra design team which were a sub-contract part of the ABC delivery team. Worked with the Electrification Project Director for the Banedanmark electrification programme. Provided advice and helped define the project programme and structure. Recruited commercial and technical advisers and designers into the programme from UK and from France. 2015 3 Month period with Atkins. Supporting Atkins to improve the focus on delivery and quality of the Rail Engineering business. Advisor to the newly appointed MD of the Transport sector during the organisational transition which brought both the Road and Rail businesses into a unified Transport division. 84 2015-2018 Electrification expert: Bechtel. Working within the delivery partner team on the GWRM programme. Leading the engineering team to deliver the electrification of the GW main line. Engaged in refining management of design, system engineering, construction and commissioning. 2018- Independent Consultant. Currently engaged in: • Network Rail/DfT Challenge Panel offering support to major programmes including Trans

Pennine Route Upgrade, Northern Powerhouse Rail, Midland Main Line Electrification and the Traction Decarbonisation Network Strategy. • Advising the rail operator/owner Metrolinx (Ontario Canada) on the development of the Engineering and Asset Management organisation as Metrolinx progresses a $90 billion investment programme to create a 21st century transport network for Toronto. • Sitting member of a Royal Academy of Engineering panel as part of the NEPC advising government on the decarbonisation of the national economy, with specific interest in the development of green electrical supply capacity and the role of hydrogen • Past President of the Permanent Way Institution.

Neil Andrew BSC Hons (Aeronautical Engineering) CEng MIET

Joined British Rail in 1992 after an early career with GEC-Alstom Turbine Generators as a project engineer responsible for final assembly and test of large electrical machines up to 1000MW. Working at the Railway Technical Centre in Derby, became Operations Director for Railtest (later Serco Railtest Ltd) in 1996 managing the ongoing testing of railway infrastructure and the validation and testing of rail vehicles as part of the acceptance process. In 1999, became the Technical Director of Balfour Beatty Rail with specific responsibility for innovation in track inspection and maintenance techniques. Six years later established Balfour Beatty Rail Technologies Ltd, this resulted in a range of innovations that have been adopted in the UK and overseas including video inspection of track, switch monitoring, PU injected track and resulting in new products such as the tubular stretcher bar and the TruTrak optical track geometry system. From 2014, as General Manager of Balfour Beatty Rail Engineering and Technology Solutions, became responsible for all the engineering teams in Balfour Beatty Rail in the UK and overseas, including three hundred staff of all disciplines. Working in Singapore, Malaysia, Hong Kong, and the USA. In 2019, established Interactive Rail Solutions Ltd, a 'niche' consultancy working with two previous colleagues, focused on railway engineering and asset management. As a consultant works with the University of Leeds, Institute of High-Speed Rail and Systems Integration to develop 'state of the art' rail infrastructure and vehicle testing facilities. Other recent project includes working with Network Rail to develop improved management of cast crossings on the East Coast Route.

Andrew Went BSc Hons, CEng, FICE FIPW

I am responsible for the strategy and growth of the Arup's Rail business in the UK, India, Middle East and Africa Rail Business, as well as our engagement within the global high speed rail market. I have extensive experience in transport and civil engineering, focussing on rail maintenance, scheme concept development, major project implementation and commissioning. I am currently working alongside colleagues and delivery partners on the East West Rail project, helping to develop its route along the Central section between Bedford and Cambridge. Prior to Arup, I worked with British Rail, Railtrack and Network Rail, where I led the development of asset renewal strategies across the UK. I have also developed renewal and delivery programmes and new fleet specifications for the Department for Transport and was involved in developing the High Speed 2 network, in my role as Head of Route Engineering and Stations. I am very interested in the transition towards zero carbon railways in the UK and abroad.

Peter Blakeman CEng MIET

Peter's experience includes leading Electrical Safety Improvements, particularly the NSCD (Negative Short Circuiting Device) through its development, trials and roll out throughout the DC 3rd Rail areas. This followed playing a leading role in the National Electrical Safety Improvement Programme for the DC third Rail area of Network Rail and identifying many areas requiring improvement to reduce the incidence of Electrical accidents on the DC railway. Peter also served as a Senior Validation & Verification Engineer for Network Rail's Infrastructure Projects which gave him a wide knowledge of the individual capabilities of Network Rail's electrification Engineers throughout the country. Peter has extensive railway design, installation, and construction experience of electrification and plant, including both AC and DC traction supply systems. During the London Tilbury and Southend Re-signalling Scheme, Peter was the responsible Engineer and Project Manager for the OLE constructional works needed for the remodelling of terminus and many junction areas. He also has played a key role in Network Rail Infrastructure Projects NSCD Roll out works in Wessex, Kent and Sussex NSCD Trials in the London area, Wessex & Kent The National Electrical Safety Improvement Programme DC report and its recommendations.

Appendix D.

Network Rail staff interviewed during Initial Review many of whom were interviewed again on subsequent occasions throughout the whole review period.

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Location	Org	Who	Role
Southern		Sian Thomas	DEAM
Wales & West		Jane Austin	DEAM
		Nick Millington	Route Director Wales & Borders
NW&C		Kamini Edgley	DEAM
Eastern		Andrew Murray Roger Griffiths	DEAM Chief Engineer
Centre	AIS	Kevin Hope Chris Johnson	
S&C monitoring	AIS	Mark Chestney Mark Quinn Brendan Rice	
Safety Taskforce		Rupert Lown Nick Millington	Chief Health and Safety Officer Director Safety Task Force
Centre	STE	John Edgley	Chief Track, S&C Engineer
		Brian Tomlinson	Chief Systems Engineer
		Martin Jones	Chief Engineer
		Brian Whitney	Engineering Expert

Technical Authority	Chief Mechanical & Electrical Engineer Phillip Doughty	29th September 2022
GW Region	Regional E&P Engineer David Hewings Contact Systems Engineer Daryl Tiddy Route Asset Manager	3rd October 2022

	Nia Watkins	
NW&C Region	Dean Chauke Reginal E&P Engineer Michael Dobbs Contact Systems Engineer Anthony Chan Ram West Midlands	3rd October 2022
	Dean Chauke Regional E&P Engineer Michael Dobbs Contact Systems Engineer Paul LeFevre E&PME Carlisle	14th October 2022
Eastern Region	Andy Gardiner Regional IME (E&P) Sean Hill E&PME Doncaster	3rd October 2022

Location / Region	**Org**	**Who**	**Role**
Southern	Engineering & Asset Management	Sian Thomas	DEAM
		Paul Percival	Head of Engineering (Signalling)
		Martin Kearney	Section manager (D&P)
		Richard Stone	Team Leader (D&P)
		Aston Boyd	Working Supervisor (D&P)
		Roy Harvey-Gardner	EPME
		James Rundle	IME (Eastleigh)
		Deborah Clements	Section manager D&P
		James Rice	Assistant EPME
Wales & Western	Engineering & Asset Management	Jane Austin	DEAM
		Robert McClelland	EPME (Wales &Western)
		Jonathan Beynon	Section Supervisor (D&P)

		Duncan Barclay	Principle Technical Officer (D&P)
		Thomas Gilbertson	Principle Technical Officer (OLE)
		Heimo Nieminen	Assistant EPME
		Will Jones	Assistant S&T Maintenance Engineer
		Lee Yelland	S&T Maintenance Engineer
Eastern	Engineering & Asset Management	Andrew Murray	DEAM
		Roger Griffiths	Chief Regional Engineer
		Adrian Moss	Route Asset Manager (Signalling)
		Adam Lowery	Regional Engineer (S&T)
		Sean Harris	EPME (Doncaster)
		Geoffrey Vande Velde	Principle Technical Officer (D&P)
		David Everson	Principle Engineer (D&P York)
		Stephen Collins	Regional Telecoms Asset & Performance Manager
NW & Central	Engineering & Asset Management	Kamini Edgley	DEAM
		David Weir	Principle Technical Engineer (Telecoms)
Centre	STE	John Edgley	Chief Track, S&C Engineer
		Martin Jones	Chief Engineer
		Brian Whitney	Engineering Expert (Track)
		Phil Doughty	Chief mechanical & Electrical Engineer
		James Dzimba	Chief Control, Comms & Signalling Engineer

Rob McIntosh – Regional Managing Director -Eastern

Tim Shoveller - Regional Managing Director – North, West &Central

Martin Frobisher -Group Safety & Engineering Director -Technical Authority

Lisa Constable - Weather Resilience and Climate Adaptation Strategy Manager

Dr Brian Haddock – Head of Extreme Weather Resilience Taskforce

Appendix E

Interim Report submitted on01/02/2023.

Not Included

Appendix F

TA’s Response to Interim Report received on03/05/2023.

Not included

Appendix G

Initial Report Submitted on 27/11/2022

Not Included

Appendix H

TA’s Response Received on 08/01/2023.

Not Included