Transport for London

London Underground Limited

New Tube for London: UIP2344

Document Number: **NTfL-2344.1.1-LUL-RPT-00066**

NTfL Operations and Maintenance Concept (OMC)

		Signature	Date
Prepared by	Refer to individual Volumes and Parts.		
Reviewed by	Refer to individual Volumes and Parts.		
Approved by	[redacted] Head of Operational Upgrades & Asset Development	[redacted]	22nd July 2016
Authorised by	[redacted] Director of Asset & Operational Support	[redacted]	22/July/16

© Copyright 2009 London Underground Limited. All rights reserved.

Revision	Date	Summary of Update					
		Volume 1 Part 1	**Volume 1 Part 2**	**Volume2 Part 1**	**Volume 2 Part 2**	**Volume 2 Part 3**	**Volume 2 Part 4**
Issue 1	26/02/16	First issue	First issue	First Issue	First Issue	For information only	Work in progress not included
Issue 2	15/04/16	Various content updates Issue 2	Various content updates Issue 2	Minor updates Issue 2	Minor updates Issue 2	First Issue	First issue
Issue 3	20/07/16	Various content updates Issue 3	Various content updates Issue 3	Minor updates Issue 3	Minor updates Issue 3	Minor typographical corrections Issue 1	No changes

Issue 3 constitutes a minor update of the OMC. The changes are described on the following page.

© Copyright 2009 London Underground Limited. All rights reserved.

V1,P1:
- Typographical changes further to alignment review.
- Completeness matrix and development plan updated
- 'Open issues' section for future resolution created.

V1,P2:
- Minor typographical changes
- Command and Control organisation chart updated in section 4.1.1.

V2,P1:
- Changes to the Control Centre Staffing model; GOA2 roles now reflect GOA1 [redacted]
- Amendments to the Interoperability sections.
- Changes to align with the URS
- Addressed inconsistencies and minor typographical changes

V2,P2:
- Change to address inconsistencies in the use of the phrase 'Zone of Protection'
- Minor typographical changes
- To align the OMC with the URS

V2,P3:
- Minor typographical corrections to Issue 1

V2,P4:
- No changes.

© Copyright 2009 London Underground Limited. All rights reserved.

Transport for London

London Underground Limited

NTfL OMC Volume 1 Part 1

Executive Summary and Introduction to the OMC

		Signature	Date
Prepared by	[redacted] Consultant, Operational Upgrades and Asset Development	[redacted]	20/7/16.
Reviewed by	[redacted] Upgrade Delivery Manager	[redacted]	20/7/16

Revision	Date	Summary of changes
Issue 1	26/02/16	First issue
Issue 2	15/04/16	[redacted] acronym corrected. Executive summary update. Writing Style (Tense) section moved to GOA2 and [redacted] concepts. Change control process section added. Completeness matrix and development plan updated.
Issue 3	20/07/16	Typographical changes further to alignment review. Completeness matrix and development plan updated. 'Open issues' section for future resolution created.

© Copyright 2009 London Underground Limited. All rights reserved.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

© Copyright 2009 London Underground Limited. All rights reserved.

Executive Summary

The NTfL Programme is a key element of the TfL Business Plan, aiming to continue the LU programme to upgrade ageing assets and to respond to current and forecast increases in passenger demand. Whilst doing this the programme is also maximising the opportunity to take a step forward in reliability; this is in order to deliver a truly world class service for our customers.

This OMC sets out, conceptually, how the upgraded NTfL lines will be operated and maintained to achieve the goals and objectives that established the business need for the programme.

The scope of the technical upgrades to the NTfL lines concerns the integration of new fleet, signalling systems into the existing infrastructure along with a new common control centre. Therefore, this OMC is primarily concerned with alterations to operational processes and maintenance practices that are directly affected by these technical changes.

The OMC also informs the wider business of changes to operations and maintenance allowing business systems and processes to be developed to enable the transformation.

The OMC is structured into two Volumes and six Parts.

Volume 1 contains overarching information: an introduction to the OMC document and the plan for its on-going development. Part 2, the Vision and Transformation Statement explains the future vision for NTfL and provides an overview of the various operational and maintenance components.

The Vision Statement also describes the purpose of operational change on NTfL, focusses on delivery of two of TfL's Strategic Objectives for NTfL:

- **Increase Capacity** – providing transport capability commensurate with forecast passenger numbers;
- **Improve Railway Safety and Reliability** – increasing passenger perception of safety whilst reducing system 'downtime';

In driving towards the goal of increased capacity the chief change is the number of trains operating per hour (Tph) during peak periods. This measure must be achieved consistently, throughout the peaks, whilst maintaining the recovery margins, rather than being achieved as a 'one-off'. Achieving these frequency objectives will require increased levels of operational automation. [redacted]

Improved maintenance practices support the drive towards the NTfL goal of increased reliability of the service. Discrete KPIs will be set in detail for maintenance in advance of the implementation of new processes, but at this conceptual level it is the overall reliability that guides the development of new practices.

While delivering these objectives the programme must remain cognisant of the fact that improvements must be performed economically and efficiently to ensure the lowest overall whole-life cost.

Volume 2 contains concept level descriptions of operations under each of the new automation levels and maintenance for the fleet and the signalling and control systems.

Using and amalgamation of existing practice, established strategies and creative vision the Operational Concepts describe the application of operational processes under Grade of Automation 2 (GOA2) [redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

The Fleet and Depot Maintenance Concept and the Signalling and Train Control Maintenance Concept establish a vision for a transformative maintenance regime for NTfL utilising a condition base maintenance approach. Heavily dependent on system selection, the concepts at this time propose the principles and philosophy of this approach to maintenance.

The OMC is a dynamic, live document. It will be reviewed and updated as the business need is translated from a concept to a realised system. Ultimately, once the technical solution is known, the OMC will support the development of Rule Book and Maintenance Regime updates.

A completeness matrix in Volume 1 Part 1 Section 8 illustrates the current status of the OMC in terms of its overall content. It is supported by a development plan in Volume 1 Part 1 Section 9, which sets out a path to robustly populating the OMC through a holistic approach and in line with key programme milestones and the realisation of levels of detail necessary to build a robust concept, particularly in relation to the maintenance regime.

© Copyright 2009 London Underground Limited. All rights reserved.

1 Introduction

In 2023 the first of the NTfL Rolling Stock will be delivered to London Underground, marking the beginning of a 15 year, £16bn Programme, to deliver comprehensive modernisation to the Piccadilly, Waterloo & City, Bakerloo and Central Lines.

These lines date from the early 20th century and currently utilise rolling stock and signalling systems introduced between the early 1970s and the mid-1990s. The NTfL programme will deliver circa 250 new trains, a state of the art signalling system and a common control centre to enable modern automated operating models that will transform the day to day operations and maintenance activities of the business.

Such technical and procedural enhancements will achieve essential business and customer benefits in capacity, capability, reliability and environmental comfort.

2 Purpose of the NTfL Operations and Maintenance Concept (OMC)

The OMC for NTfL describes strategically how the future upgraded underground lines will be operated and maintained in order to deliver the proposed business benefits of the NTfL programme.

It is developed at the concept stage of the programme lifecycle and is used to derive new and validate existing User Requirements. The System Definition Requirements, from which the technical solution will be designed, must satisfy the User Requirements and therefore provide the required operational and maintenance solution. The OMC will be used to verify requirements and validate proposed technical solutions throughout the programme lifecycle.

The OMC also informs the wider business of changes to operations and maintenance allowing business systems and processes to be developed to enable the transformation.

Where the underground lines are being upgraded whilst providing continuous passenger service, the OMC also describes how the operations and maintenance of these lines will be performed during the migration from one technical system to another.

The OMC is a dynamic, live document. It will be reviewed and updated as the business need is translated from a concept to a realised system. Ultimately, once the technical solution is known, the OMC will support the development of Rule Book and Maintenance Regime updates.

This document supersedes, the Deep Tube Railway Operations and Maintenance Concept 2020 [DTP-UIP1973-1.1-RPT-00011]. It ensures that there is an effective understanding between those designing the upgraded assets and systems of the NTfL railway and the Operations and Maintenance community that will use them to deliver the post-upgrade service.

3 Scope of the NTfL OMC

The scope of the technical upgrades to the NTfL lines concerns the integration of new fleet, signalling systems into the existing infrastructure along with a new common control centre. Therefore, this OMC is primarily concerned with alterations to operational processes, maintenance procedures and the supporting organisational structure directly affected by these technical changes.

However, the overall operation and maintenance of the 4 lines is integrally related to the wider LU system as well as third party interfacing lines. While these operational and maintenance interfaces are outside the scope of this programme it is necessary to identify any impacts from, or on these

© Copyright 2009 London Underground Limited. All rights reserved.

interfaces, that may affect the achievement of the NTfL business benefits. Examples of these interfaces would be passenger flow management at stations or civil infrastructure maintenance.

Such interfaces will be described within this OMC and logged in the NTfL programme interface register.

4 The NTfL OMC in Context

This Operations and Maintenance Concept is one of a suite of documents that define the NTfL system and programme. As shown in Figure 1 the Operations & Maintenance Concept, along with the Customer Concept, Engineering Vehicles Concept and the Sponsors Programme Requirements form the Sponsors remit for NTfL. The Operations and Maintenance Concept is owned and updated by the NTfL Operational Upgrades and Asset Development Team.

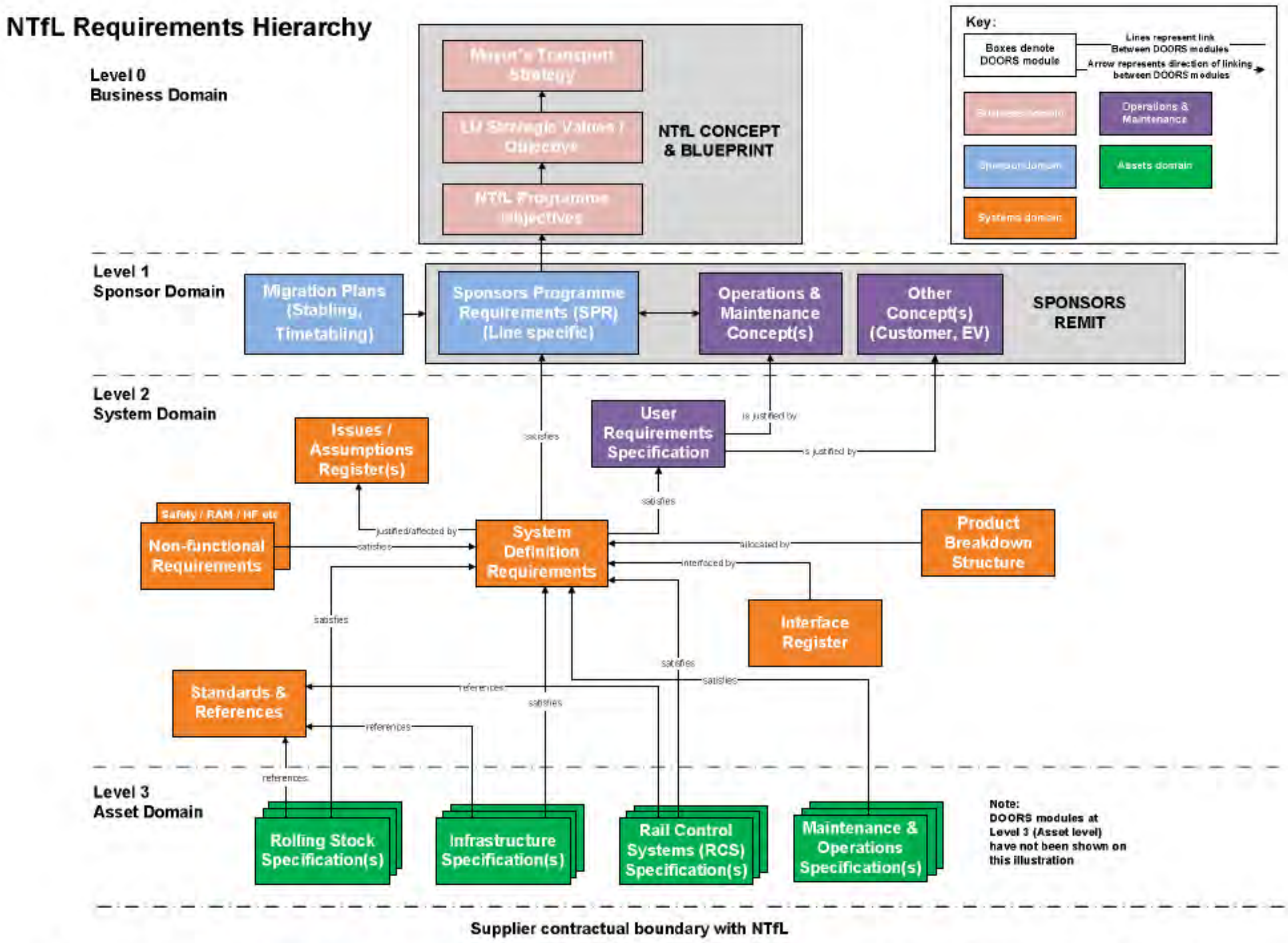


Figure 1: Illustration of the NTfL OMC within the programme requirements hierarchy

Although it has been developed after the User Requirements Specification (URS) this version of the Operations and Maintenance Concept provides context for the URS and drives its overall completeness.

© Copyright 2009 London Underground Limited. All rights reserved.

5 NTfL OMC Structure

The Operations and Maintenance Concept itself is structured into a number of 'Volumes' and 'Parts' (referred to as OMC Volume or OMC Part when referenced individually) as shown in below.

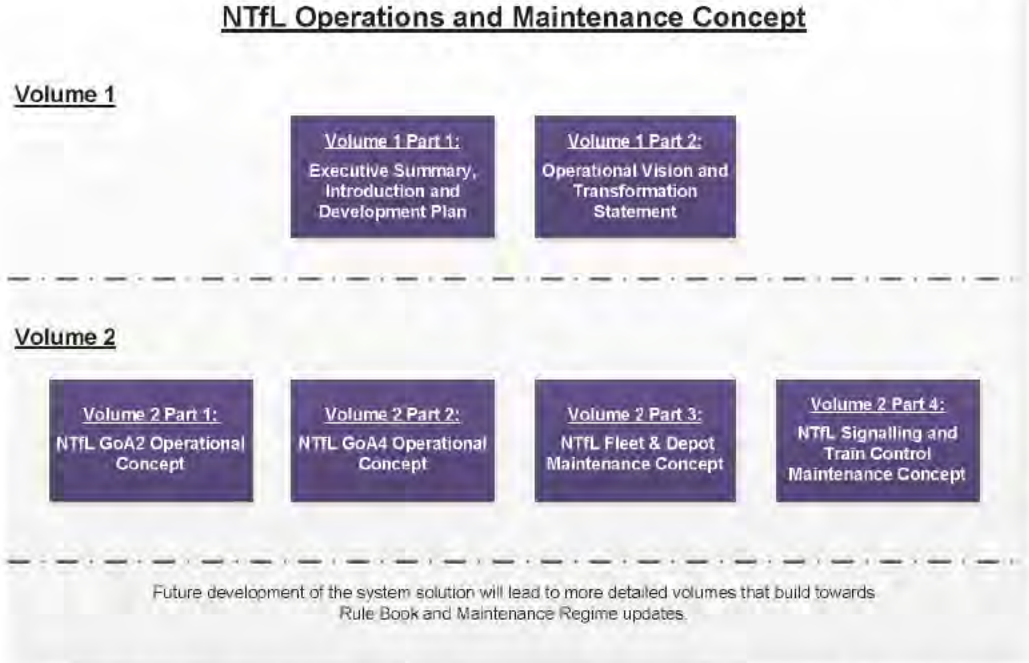


Figure 2: Operations and Maintenance Concept document structure

This structure provides clarity of content, accessibility to specific subject areas and provides a strong basis for further development.

Volume 1 contains overarching information: an introduction to the OMC document and plan for its on-going development, as well and the future vision and overview of the various operational and maintenance components.

Volume 2 contains concept level descriptions of both operations under each of the new automation levels and the maintenance concepts for fleet and the signalling and control systems.

As well as enabling the definition of User Requirements the concept will drive the development of detailed operational and maintenance procedures as well as Line Emergency Plans. Over the course of the programme additional volumes of the OMC will build on the emerging technical solution to add greater levels of detail, ultimately defining changes to the Rule Book and Maintenance Regime.

6 Configuration Management of the NTfL OMC

The OMC is a configuration managed document that will evolve with the progress of the NTfL programme. Elements of the existing Volumes require greater development and future volumes are dependent on a greater level of system development. As such the OMC will be updated and re-released on a planned basis aligned to programme milestones to incorporate new developments as the project evolves. All releases will be issued under Sponsor Instruction.

© Copyright 2009 London Underground Limited. All rights reserved.

7 Governance of Volumes and Parts

The overall OMC will be approved & authorised as a single entity when it is changed and/ or updated. However, various parts of the OMC have differing authors and reviewer requirements. As such they will have individual "Prepared by" and "Reviewed by" cover pages. The detail for this governance is as follows in Table 1:

OMC Part	Part Title	Prepared by	Reviewers, Approvers and Authorisers
Overall OMC sign off	Operations & Maintenance Concept	Operational Development Managers	Reviewed by: Upgrade Delivery Manager Approved by: Head of Operational Upgrades & Asset Development Authorised by: Director of Asset & Operational Support
Volume 1, Part 1	Executive Summary and Introduction to the OMC	Operational Development Manager	Reviewed by: Upgrade Delivery Manager
Volume 1, Part 2	Operational Vision and Transformation Statement	Operational Development Manager	Reviewed by: Upgrade Delivery Manager
Volume 2, Part 1	NTfL GOA2 Operational Concept	Operational Development Manager	Reviewed by: Upgrade Delivery Manager
Volume 2, Part 2	[redacted]	Operational Development Manager	Reviewed by: Upgrade Delivery Manager
Volume 2, Part 3	NTfL Fleet & Depot Maintenance Concept	Operational Development Manager	Reviewed/Approved by: Head of Fleet JNP Head of BCV Fleet
Volume 2, Part 4	NTfL Signalling and Train Control Maintenance Concept	Operational Development Manager	Reviewed by: Incident Response & Command Manager Head of Signals Maintenance SSR BVC Area Infrastructure Manager Head of Signal - JNP

Table 1: Review and approvals required for various OMC Parts

It should be noted that the OMC is a single document. Therefore **full sign off of every OMC Part is required for all version updates**. This includes any OMC Parts that have not undergone any change in content.

© Copyright 2009 London Underground Limited. All rights reserved.

8 Current Baseline Status

This OMC is a live document, subject to development and change. This will occur both as the operational concept itself matures and as the technical solution becomes realised. Changes will be driven from within the programme and potentially also from external stakeholders.

This Baseline (Issue 3) represents the current maturity of the OMC, in line with the current programme lifecycle stage and available information in relation to programme requirements and the maturity of the technical system solution.

To fully understand the status of this OMC Issue, a completeness matrix (Figure 3: OMC completeness matrix below) has been developed and included here. This matrix defines the elements that need to be incorporated to the overall OMC, whether or not they are relevant to particular OMC Parts and the percentage complete relevant to the current programme maturity level (lifecycle stage and availability of information.)

It is important to note that the elements do not represent particular chapters within the OMC but topics that need to be addressed. For instance, the GOA Concepts address the various modes of operation within the Processes chapters, not as specific individual chapters themselves.

This matrix will be updated as the OMC is updated, and completeness may vary as the lifecycle progresses and new information becomes available.

For ease of reference, a summary table of all currently 'open issues' (decisions or choices not yet taken, not yet able to be taken or not yet able to be confirmed) from all Volumes of this OMC are given in Appendix A of this Part. These open issues constitute the on-going OMC development work.

© Copyright 2009 London Underground Limited. All rights reserved.

	Executive Summary & Introduction to the OMC		Vision and Transformation Statement		GoA2 Operational Concept		[redacted]		Fleet and Depot Maintenance Concept		S&TC Maintenance Concept	
	Applicable	% Complete	Applicable	% Complete	Applicable	% Complete	Applicable	% Complete	Applicable	% Complete	Applicable	% Complete
Document												
Structure												
Overall OMC structure	Y	100%	N/A		N/A		N/A		N/A		N/A	
Structure of individual OMC Part	Y	100%	Y	100%	Y	100%	Y	100%	Y	100%	Y	100%
Integration of operations concepts	Y	100%	Y	100%	Y	100%	Y	100%	N/A		N/A	
Integration of maintenance concepts	Y	100%	Y	100%	N/A		N/A		Y	100%	Y	100%
Consistency of format and style	Y	100%	Y	90%	Y	90%	Y	90%	Y	90%	Y	90%
Governance												
OMC governance process	Y	100%	N/A		N/A		N/A		N/A		N/A	
OMC governance responsibilities	Y	100%	N/A		N/A		N/A		N/A		N/A	
Change request approval process	Y	90%	N/A		N/A		N/A		N/A		N/A	
Alignment												
Programme alignment												
Alignment of FBS to OMC	Y	90%	Y	90%	Y	100%	Y	100%	Y	100%	Y	100%
Alignment of operational architectures to OMC	N/A		N/A		Y	75%	Y	90%	Y	100%	Y	100%
Alignment of other architectures to OMC	N/A		Y	90%	Y	75%	Y	90%	Y	100%	Y	100%
Alignment of URS to OMC (Gap analysis)	N/A		Y	100%	Y	100%	Y	100%	Y	100%	Y	100%
Alignment of other reqs sets to OMC (Gap analysis)	N/A		Y	50%	Y	tbc	Y	tbc	N/A		N/A	
POTIC analysis interface	Y	10%	TBC	-	TBC	-	TBC	-	Y	TBC	Y	TBC
Content												
Whole System												
High level principles of Operation	N/A		Y	100%	N/A		N/A		N/A		N/A	
High level principles of Maintenance	N/A		Y	100%	N/A		N/A		N/A		N/A	
Whole NTfL system	N/A		Y	80%	Y	100%	Y	100%	Y	100%	Y	100%
Alignment between concepts within OMC	N/A		Y	95%	Y	100%	Y	100%	Y	100%	Y	100%
Interfaces with wider TfL System (station operations, 3rd party lines, infrastructure maintenance etc.)	N/A		Y	20%	Y	30%	Y	30%	Y	10%	Y	10%
Interface with Customer Concept	N/A		Y	35%	Y	35%	Y	35%	N/A		N/A	
Interface with EV Concept	N/A		Y	40%	Y	100%	Y	100%	Y	0%	Y	0%
Interface with 3rd parties	N/A		Y	10%	Y	10%	N/A		Y	0%	Y	0%
Modes of operation												
Normal Mode	N/A		Y	80%	Y	100%	Y	100%	Y	0%	N/A	
Abnormal Mode	N/A		Y	80%	Y	100%	Y	100%	Y	0%	N/A	
Degraded Mode	N/A		Y	80%	Y	100%	Y	100%	Y	0%	N/A	
Emergency Mode	N/A		Y	80%	Y	100%	Y	100%	Y	0%	N/A	
Operational and Maintenance needs through Technical Migration												
Current Operations (applicable Rule Book references)	N/A		Y	90%	Y	100%	Y	100%	N/A		N/A	
Current Maintenance (applicable Maintenance Regime references)	N/A		Y	75%	N/A		N/A		Y	100%	Y	50%
End state Operations	N/A		Y		Y	100%	Y	100%	N/A		N/A	
End state Maintenance	N/A		Y		N/A		N/A		Y	100%	Y	100%
Migration of operations	N/A		Y	10%	Y	25%	Y	25%	N/A		N/A	
Migration of maintenance	N/A		Y	10%	N/A		N/A		Y	40%	Y	20%
Operational Lifecycle												
Planning operations & maintenance	N/A		Y	50%	Y	50%	Y	50%	Y	70%	Y	40%
Delivering operations & maintenance	N/A		Y	90%	Y	80%	Y	80%	Y	40%	Y	40%
Service performance analysis	N/A		Y	30%	Y	30%	Y	30%	Y	30%	Y	30%
Implementing improvements	N/A		Y	0%	Y	0%	Y	0%	Y	0%	Y	0%
Line Specific												
Bakerloo line (all modes, all states)	N/A		N/A		Y	75%	N/A		Y	50%	Y	50%
Central line (all modes, all states)	N/A		N/A		Y	75%	Y	75%	Y	50%	Y	50%
Piccadilly line (all modes, all states)	N/A		N/A		Y	90%	Y	90%	Y	50%	Y	50%
Waterloo & City (all modes, all states)	N/A		N/A		N/A		Y	90%	Y	50%	Y	50%

Notes
Completeness is measured relative to the level of detail appropriate for the current stage of the programme lifecycle
OMC content is subject to maturity of information available at the time of writing.
Completeness is measured relative to the maturity of currently available information.
The content of the OMC is subject to change as the programme develops and technology solutions are realised.
Completeness will therefore be re-assessed as information becomes available and following approved change requests.

Figure 3: OMC completeness matrix

© Copyright 2009 London Underground Limited. All rights reserved.

9 Development Plan

The completeness matrix (Section 8) defines a number of areas of the OMC which require further development. Figure 4: NTfL OMC Development Plan on the following page sets out a programme for continuing to develop the OMC to reach full maturity as a concept. Additionally it shows how the OMC becomes a driver for the development of line specific plans in preparation of operational readiness.

Issue dates for the OMC are based on programme milestones that are considered likely to need an update to the OMC, i.e. requirements changes for the S&TC ITT necessitating updates to the OMC. This way the Operational Upgrades team can continue to develop the OMC but minimise changes impacting the program through multiple re-issues.

This plan is an accurate representation of the proposed development of the OMC at the time of this baseline Issue, but will be updated as the OMC is updated for subsequent issues.

© Copyright 2009 London Underground Limited. All rights reserved.

Notes:
Issues are driven by the need to update as specified. Ongoing development within the Operational Upgrades Team will align to these drivers to minimise revisions.
Dates for issue are approximate and subject to Programme changes.
"Further ISSUES" driven by technical or programme change will need a schedule of update dates. These are to be determined in advance of ISSUE 4 and included within the OMC development plan at that point in time.
* Dates for drivers need to be confirmed.

Figure 4: NTfL OMC Development Plan

© Copyright 2009 London Underground Limited. All rights reserved.

10 POTIC Considerations

POTIC is included in the Programme Blueprint and summarises the operational states through the migration stages.

11 Consultation

In alignment with the Governance structure for the OMC, consultation was undertaken as shown in Figure 5 below.

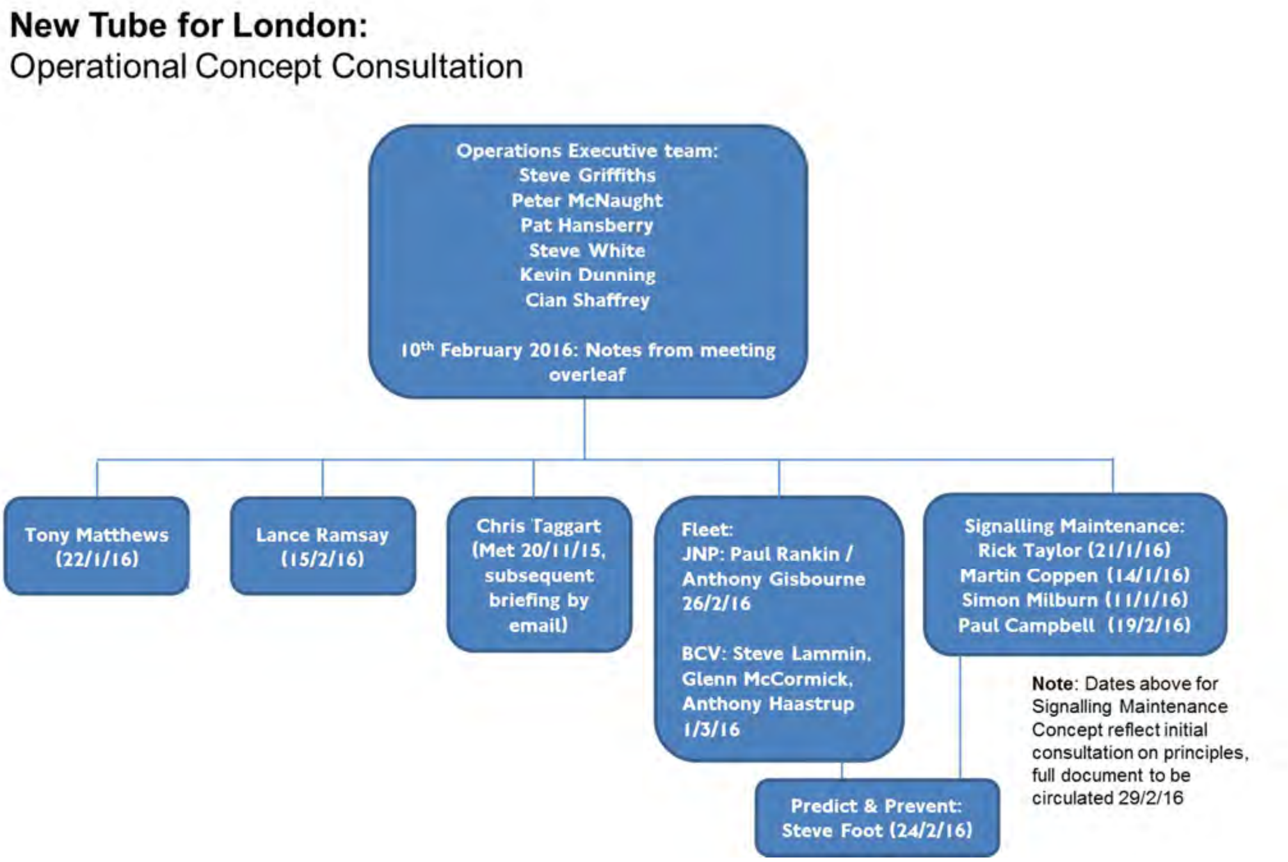


Figure 5: NTfL Operational Concept consultation mapping

© Copyright 2009 London Underground Limited. All rights reserved.

12 Appendix A – Currently 'open Issues' (taken from all volumes of the OMC)

The following table highlights the main OMC 'open issues'. Work is on-going to close these out. The substantial update of the OMC planned for February 2017 provides the next opportunity to formally close issues out and add new ones in progressive levels of detail.

Section	Open issue	Notes:
V1P1	**Executive Summary and Introduction to the OMC**	
OC Leadership Consultation Minutes in Issue 2	Need a proper strategy for crewing on the NTfL lines, given it's not been fully considered for the District line post 4LM and subsequent NTfL West London changes (SW)	Dependent on Operations Readiness Plan development and implementation
OC Leadership Consultation Minutes in Issue 2	Given the "every second counts" nature of the railway, we needed to influence customer behaviour through design, to ensure we can maximise the benefits of the project (SG)	On-going but cannot be closed until design work is complete
V1P2	**Operations Vision and Transformation Statement**	
Section 3.3	Operating principle 9: Manage performance Performance management details are a work in progress, reference the development plan Volume 1 Part 1 Section 10.	February 2017 OMC update will provide next substantial update
Section 4.1.1	Unlike operational roles, maintenance roles are dependent on a mature architecture and geography of the system solution, and therefore cannot be defined at this time. No significant alterations as currently proposed. Some roles are identified in relation to the control centre.	Dependent on architecture development process
Section 4.2	Development of interfaces with NTfL in all operational states is on-going.	Issue 4/ Feb 2017 will update
Section 6	Where the underground lines are being upgraded whilst providing continuous passenger service, the OMC will describe how the operations and maintenance of these lines will be performed during the migration from one technical system to another. The detail of this element of the OMC will be developed in alignment with the development plan in Volume 1 Part 1 of this OMC.	This may no longer be required for all stages –on-going for Feb 17 review
V2P1	**GOA2 Operational Concept**	
Section 3.2.5.8	Once the train is in place, the Train Operator shuts down the train and exits. [Note: If ATP is present in the depot, the Train Operator may leave the train in Automatic – this will be refined during the detailed design phase.]	Dependent on final Depot strategy in this area as part of on-going governance

© Copyright 2009 London Underground Limited. All rights reserved.

Section	Open issue	Notes:
Section 3.2.7.3	[redacted]	This cannot be determined at this point though design development is ensuring that flexibility is maintained
Section 3.3.2.5	[redacted]	This is likely to be resolved by 2018. It is managed by the New Trains Programme
Section 4.1.1.6	[redacted] a solution may be required to manage the Operational Control of those features, which at the point of this document's authorship, is not determined.	For future resolution

© Copyright 2009 London Underground Limited. All rights reserved.

Section	Open issue	Notes:
V2P3	**Fleet and Depot Maintenance Concept**	
Concept further development and update	This version of the concept has been developed prior to critical input of the detailed Train Maintenance Plans that will be received and analysed from the Rolling Stock supply chain forming part of the submission pack received back in the Invitation to Negotiate (ITN) process. As a result a large number of assumptions have been made of Fleet Maintenance strategy and Depot facilities based on recent experience. These assumptions are planned to be revised in late 2016 following the analysis of specific information directly related to the NTfL train. It should therefore be noted that a major revision of this concept is planned at this point.	A substantial OMC update is planned for Feb 2017. This will further detail the issue as decisions are taken to close it out
6.2	For seasonal Maintenance, the Sandite Trains are required to continue at Hainault and Ruislip Depots and may also be required at the other upgraded depots. A Future strategy for provision of Rail Adhesion Trains to replace the legacy trains (Central & Piccadilly Line Provision) will need to be agreed to ensure that this provision it continues following completion of the upgrade.	Dedicated workstream established managed by Peter Turrell (S&SD)
9.8.5	The full strategy for stores management will be outlined in a subsequent version of this concept.	A substantial OMC update is planned for Feb 2017
14.9	OPO, CCTV & CSDE are integrated systems impacting both Rolling Stock Maintenance and Stations Maintenance however they have been allocated for provision by the Rolling Stock supplier. There are significant lessons to learn in terms of defining future maintenance strategy and more development work and stake holder engagement is planned thought 2016 to accurately define maintenance principles to confirm in line with the requirements of this concept.	A substantial OMC update is planned for Feb 2017. This will further detail the issue as decisions are taken to close it out.

© Copyright 2009 London Underground Limited. All rights reserved.

Section	Open issue	Notes:
V2P4	**Signalling and Train Control System Maintenance Concept**	
4.2.2	It is recognised that the suggested architecture for NTfL's Operational Control Centre deviates from this arrangement by placing the line Control Room in a separate location from the signalling control equipment. This is currently being termed as a 'campus' arrangement. Whilst there are benefits associated with the adoption of this arrangement, careful consideration will need to be given to the location of the control system equipment. If the Control Room is placed a significant distance from the control system then the maintenance organisation will need to provide coverage at both the Control Room and the Control system locations if TTS targets are to be met. In addition, it is likely that call depot facilities will need to be provided adjacent to the equipment room(s) which allow for the requisite incident response coverage. Clearly the introduction of additional staff & 'call depot' facilities will erode some of the benefits that would be expected from a Control Room / Control system combined in one place (or separate within a reasonable distance).	A substantial OMC update is planned for Feb 2017. This will further detail the issue as decisions are taken to close it out – e.g. when the Control Centre Design Package is let.
General	Organisation charts to be updated further to design development particularly regarding the Fleet structure, S&TC and the Control Room	This will be updated at the end of the Competitive Development Phase.

© Copyright 2009 London Underground Limited. All rights reserved.

1213 Appendix B: Operational Concept leadership consultation meeting notes

	Note / Action (Originator)	Response / Comment	Owner	When	Status
1	Sign off required for Operational Concept document by the end of February	Meeting booked with Kevin Dunning for final review and his approval of documentation on 25th February	[redacted]	26th Feb '16	Complete
2	Are we specifying the RVAR 3 second door chime? (SW)	Specified within regulatory compliance. Should a change to the regulations or a concession be granted after the Victoria line trial, we've specified that LU can make the change to tone duration without reliance on the manufacturer.		Complete	Complete Assumed compliance with applicable standards
3	Note that todays' management structure will change and Concept documentation will need to change to reflect (CS)	Update as required, liaise with Trains Programme through established meetings		On-going	Complete Development plan
4	[redacted]	[redacted]		26th Feb '16	Complete – and on-going interface / development with Train programme

© Copyright 2009 London Underground Limited. All rights reserved.

	Note / Action (Originator)	Response / Comment	Owner	When	Status
5	[redacted]	Pass to Sponsor for consideration	[redacted]	End March '16	Inclusion for crowd management considered at network level but not required for GOA2. Concept describes "if" at GOA2.
6	[redacted]	Sponsor to note / consider concern	[redacted]	End March '16	Complete
7	Train Diagnostics should be routed to the Control Centre rather than Line Performance Centres - this will ensure trains can be routed to where they need to go for maintenance and the centralisation of resource allows greater efficiency and flexibility (SW)	The slide presented at the meeting doesn't fully reflect the position in the Fleet & Depot Concept, which is that a Control Centre-based Train Doctor will receive live information; however more detailed data needed for analysis related to "Predict & Prevent" will be received at the Line Performance Centres.	[redacted]	Complete	Complete
8	Include the changes to the FSA made prior to issue of ITN in the slide pack (SW)	Update slides	[redacted]	26th Feb '16	Complete

© Copyright 2009 London Underground Limited. All rights reserved.

	Note / Action (Originator)	Response / Comment	Owner	When	Status
9	Endorse the approach of having a single Control Centre (all)	Note	[redacted]	N/A	Complete and in concept
10	Maximum flexibility of staff and breaking down of cultural boundaries between lines should be pursued - this drives a solution that ultimately houses Control of all lines on a single floor, with removable dividing walls (PMc)	Update Concept	[redacted]	26th Feb '16	Complete
11	[redacted]	[redacted]	[redacted]	End June 2016	Complete – may change if C4 proposal is adopted. Managed by Control Centre workstream
12	Need to ensure trains in automated depot / siding stabling areas can be accessed for minor maintenance tasks (e.g. Changing a bulb on a headlight). This is currently problematic at White City. (PMc)	Include in Concept	[redacted]	26th Feb '16	Complete and in concept

© Copyright 2009 London Underground Limited. All rights reserved.

	Note / Action (Originator)	Response / Comment	Owner	When	Status
13	We'll ask what experience Signalling & Train Control suppliers have of 1st line Maintenance in the pre-qualification exercise. (DW). Signalling OEMs do carry out this elsewhere in the world (SW) Difficult to see how it would work for us given the inherent link to other assets they wouldn't maintain (PMc)	Note	[redacted]	N/A	Complete - in concept
14	The view in the room was that suppliers' value creation is in the product development rather than on the ground doing maintenance. There needs to be a philosophy of developing long term relationships with OEMs, to ensure they're incentivised to develop the products to continuously improve performance. LU should not become "Design Authority by default". (SG)	Needs to be considered in Signalling & Train Control procurement. Provide a timetable to return to Exec with key decisions in the run up S&TC "Invitation to Negotiate" issue.	[redacted]	End March '16	Complete - in concept
15	As a result of 4LM, we have multiple repair capabilities for Signalling equipment and the view was that we would be better served with a single facility. We need a single "Centre of Excellence" for signalling maintenance, carrying out any in-house 2nd line maintenance tasks - ensuring best use of resource. (SW)	Consider in S&TC Maintenance Concept	[redacted]	End March '16	Complete - in concept
16	[redacted]	[redacted]	[redacted]	Complete	Complete - in concept
17	Confirm whether we'll specify time to site and time to fix times with S&TC requirements (SW)	COMPLETE - Time to site of 10 mins & 12 to Fix included in Concept.	[redacted]	Complete	Complete

© Copyright 2009 London Underground Limited. All rights reserved.

	Note / Action (Originator)	Response / Comment	Owner	When	Status
18	[redacted]	[redacted]	[redacted]	On-going	Complete - in concept
19	[redacted]	[redacted]		On-going - include in Bak / Cen appendixes to concept	In open issues at Concept issue 3
20	The Directors discussed the issues surrounding 4LM and in particular Neasden and the escalation of costs associated with the upgrade re-working the facilities, rather than undertaking greenfield build. (All). Clarify point on depot locations remaining the same, but that rebuilds of the facilities are comprehensive	Depot Concept already reflects this, change wording on slide		Complete	Complete and in concept
21	Given the "every second counts" nature of the railway, we needed to influence customer behaviour through design, to ensure we can maximise the benefits of the project (SG)	Note		On-going	In open issues at Concept issue 3
22	Need to understand when the big Operational decisions are needed and make sure they're made in a timely way - NTfL merits a slot at the Operations Exec meeting (SG / KD)	Get NTfL slot on monthly exec agenda		End March '16	Complete

© Copyright 2009 London Underground Limited. All rights reserved.

Attendees:

[redacted] [redacted] [redacted] [redacted]
[redacted] [redacted] [redacted] [redacted]
[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

Transport for London

London Underground Limited

NTfL OMC Volume 1 Part 2

NTfL Operations Vision and Transformation Statement

		Signature	Date
Prepared by	[redacted] Consultant, Operational Upgrades and Asset Development	[redacted]	20/7/16
Reviewed by	[redacted] Upgrade Delivery Manager	[redacted]	20/7/16

Revision	Date	Summary of changes
Issue 1	26/02/16	First issue
Issue 2	15/02/16	High level principles of maintenance updated to align with RAMS based approach. Levels of Maintenance and Predict & Prevent sections added. Geographic change section updated to incorporate LPC and maintenance elements. Transformation overview of Fleet and Depot Maintenance and S&TC Maintenance added. Maintenance elements incorporated throughout, including acronyms, descriptions, checklist and development plan. GOA acronym corrected.
Issue 3	20/07/16	Minor typographical changes/ Changes to the Control Centre Staffing model; GOA2 roles now reflect GOA1 as opposed to [redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

TABLE OF CONTENTS

© Copyright 2009 London Underground Limited. All rights reserved.

LIST OF TABLES

LIST OF FIGURES

© Copyright 2009 London Underground Limited. All rights reserved.

Summary

This Operations Vision and Transformation Statement provides an overview of the vision for operations and maintenance following upgrade of the NTfL lines.

The NTfL Programme is a key element of the TfL Business Plan aiming to continue the LU programme to upgrade ageing assets and to respond to current and forecast increases in passenger demand. Whilst doing this the programme is also maximising the opportunity to take a step forward in reliability; this is in order to deliver a truly world class service for our customers.

The Vision statement focusses on delivery of two of TfL's Strategic Objectives for NTfL:

- **Increase Capacity** – providing transport capability commensurate with forecast passenger numbers;
- **Improve Railway Safety and Reliability** – increasing passenger perception of safety whilst reducing system 'downtime';

In driving towards the goal of increased capacity the chief change is the number of trains operating per hour (Tph) during peak periods. This measure must be achieved consistently, throughout the peaks, whilst maintaining the recovery margins, rather than being achieved as a 'one-off'. Peak values are between 27 and 33 Tph dependant on the line.

[redacted]

Improved maintenance practices support the drive towards the NTfL goal of increased reliability of the service. Discrete KPIs will be set in detail for maintenance in advance of the implementation of new processes, but at this conceptual level it is the overall reliability that guides the development of new practices.

A set of operating and maintenance principles are established within this Vision describing a high level view of the way in which NTfL intend to operate and maintain the four lines post upgrade. They are relevant to the operation of the depots and stabling facilities as well as giving consideration to the protection of people who are working on or near the running lines, the depots or other operating hazards such as electrification equipment. It also considers contractors, passengers and other members of the public.

The principles provide guidance to future development of the OMC and subsequent processes and practices, as well as providing confidence to programme stakeholders that the concept is being developed to deliver operations and maintenance in accordance with their expectations.

This Statement looks at the impact of change on NTfL and the wider LU network. The people change aspects are common across the lines and are therefore described in some detail here. The main focus of this is the change in command and control structure will transition to a Railway Manager and a Railway Controller (RC). The latter having direct interaction with the control system, thus combining the traditional roles of Service/Line Controller and Signaller.

Subsequently an overview of the Transformation is presented, summarising the detail of the individual concepts that form the OMC Volume 2. The exception to this is the overview of GOA1 with new train. This transformation is largely correlated to current operations and maintenance changes are captured in the Fleet & Depot Maintenance concept (OMC Volume 2 Part 3). Therefore no discrete Part of the OMC is required.

© Copyright 2009 London Underground Limited. All rights reserved.

Finally this Vision seeks to address the considerations of migrating from an existing system to a new system of operations. It will describe how the operations and maintenance of these lines will be performed, retaining continuous service, as the technical systems are migrated.

© Copyright 2009 London Underground Limited. All rights reserved.

1 Introduction

The overall OMC sets out, conceptually, how the upgraded NTfL lines will be operated and maintained to achieve the goals and objectives that established the business need for the programme. This part of the OMC provides an overview of the vision for operations and maintenance following upgrade of the NTfL lines. By describing the business need and objectives it provides context and justification for the proposed operational changes.

The document assesses the impact of these changes both on the existing NTfL lines and the interfaces to the wider system and third parties. It then summaries the transformation that will occur through operational grades of automation and enhanced maintenance practices. It Provides context for Volume 2 of this OMC which describes these concepts in more detail.

Finally the document discusses the operational migration that must occur to keep the lines running throughout the technological upgrade.

2 Programme Background

The NTfL Programme is a key element of the TfL Business Plan aiming to continue the LU programme to upgrade ageing assets and to respond to current and forecast increases in passenger demand. Whilst doing this the programme is also maximising the opportunity to take a step forward in reliability; this is in order to deliver a truly world class service for our customers.

Aligned to the Mayor's Transport Strategy and TfL's Strategic Objectives the four goals of NTfL are to:

- **Increase Capacity** – providing transport capability commensurate with forecast passenger numbers;
- **Improve Railway Safety and Reliability** – increasing passenger perception of safety whilst reducing system 'downtime';
- **Improve Customer Experience** – enhancing the travelling environment;
- **Reduce Whole Life Costs** – improving value for money through investment.

These goals are supported by a set of core Programme Objectives which are as follows:

Enable Business Transformation	[redacted]
Increase Capacity	To deliver increased line capacity to meet rising demand for services, address crowding and congestion on the network and reduce customer journey times.
Improve Railway Reliability	To achieve a step-change in railway reliability performance to rival leading world metros through a more complete understanding of inherent asset reliability and the interaction of assets with staff and customers in service.

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]	[redacted]
Improve Customer Experience	To improve the overall customer experience of deep tube services through the introduction of a new generation of trains, higher levels of automation and line service volume and quality enhancements.
Reduce Whole-Life Costs	To achieve the uplift in line capacity economically and efficiently through the specification of all aspects of the complete railway system to ensure the lowest overall whole-life cost.
Provide Air Cooling	To enhance the customer environment through the introduction of saloon air cooling on deep tube trains.
Managing Rising Platform Temperatures	To design solutions that consider fully the energy impacts of increasing capacity and performance in the constrained deep tube environment that when implemented will minimise energy consumption, enable energy recovery and maintain acceptable station temperatures.
Asset/System Renewals	To replace life-expired train systems and rolling stock assets with modern equivalents which deliver higher train performance, increased capacity and a reduction in journey times.

Table 1: NTfL Programme Objectives

3 The Vision

3.1 Operational Objectives

In driving towards the goal of increased capacity several changes to the four lines will be implemented. Chief among these is the number of trains operating per hour (Tph) during peak periods. This measure must be achieved consistently, throughout the peaks, whilst maintaining the recovery margins, rather than being achieved as a 'one-off'. The objective for each of the lines is as follows:

NTfL Line	Piccadilly	Bakerloo	Central	W&C
Peak frequency objective	**33 Tph**	**27 Tph**	**33 Tph**	**27 Tph**
Note: figures for the Piccadilly, Bakerloo and Central lines are for the central part of each line at peak hours. Outer sections require lower train frequency. W&C line frequency is for the whole line. Full details are set out in the 'NTfL Programme Concept and Blueprint' document [Reference 9]				

Table 2: Peak frequency objectives for the NTfL lines at final state of upgrade

Achieving these frequency objectives will require increased levels of operational automation. [redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

[redacted]

3.2 Maintenance Objectives

Improved maintenance practices support the drive towards the NTfL goal of increased reliability of the service. Discrete KPIs will be set in detail for maintenance in advance of the implementation of new processes, but at this conceptual level it is the overall reliability that guides the development of new practices. These overall targets are detailed as follows:

System	Overall reliability target for system
Rolling Stock	120,000 km mdbf
Signalling and Train Control	Defined for each ATC functional group, reference Volume 2 Part 4 Section 4.4

Table 4: Overall system reliability targets

3.3 High level principles of operation and maintenance

The following operating and maintenance principles provide a high level view of the way in which NTfL intend to operate and maintain the four lines post upgrade. They are relevant to the operation of the depots and stabling facilities as well as giving consideration to the protection of people who are working on or near the running lines, the depots or other operating hazards such as electrification equipment. It also considers contractors, passengers and other members of the public.

The principles, although grouped differently, are aligned to the Functional Breakdown Structure [Reference 10]. They will provide guidance to the on-going development of the OMC and operating and maintenance practices that will be enacted post-upgrade.

It should be noted that the development of these principles is impartial to the level of automation of the operational railway.

Operating Principle 1: Manage the safe movement of trains

The movement of all trains will be managed in a safe manner throughout the operating lines, in transition from depots and stabling areas and within the depots themselves. This applies throughout the operational lifecycle incorporating scheduling train movements, assuring safe route in advance of movements and executing movement instructions.

Operating Principle 2: Safely operate trains

All trains will be operated in a safe manner whether controlled manually or automatically. This principle applies to all trains on the NTfL lines, in all operating modes such as when rescuing a

© Copyright 2009 London Underground Limited. All rights reserved.

stranded train or managing service during a signalling system failure. Safe operation also includes all activities associated with train preparation and transition into passenger service.

Operating Principle 3: Manage boarding and alighting of train services

Boarding and alighting of train services will be managed in such a way that all passengers and staff are able to use the transport system without risk to their health and safety. This applies to the stopping of trains in the correct location, supervision of passengers boarding and alighting, provision of communication and the safe departure of trains following boarding and alighting.

Operating Principle 4: Manage special running conditions

In the event of abnormal or degraded operations, planned and unplanned changes to the service plan or individual train missions will be enacted ensuring continued safe operation at all times.

Operating Principle 5: Detect and manage emergency situations

Railway systems (both technical and procedural) shall be designed to ensure that any incidents or emergency situations can be managed both safely and efficiently. Standard incident management protocols will apply, mirroring the Gold, Silver and Bronze command and control structure used by the emergency services, as implemented on the LU network today.

Operational procedures and controls will enable appropriate manual override of automated operations when it is safe and appropriate to do so. Protocols will be designed to minimise risk of human error.

Operating principle 6: Protect people from hazards

Staff, passengers and members of the public will be kept safe from known hazards, this includes safe procedures for switching off traction current, application of protection zones for planned work on or near running lines and keeping non-railway employees safe from moving trains when entering railway controlled infrastructure or property.

Operating principle 7: Communicate with customers

Customer communication is essential to the effective movement of passengers to their destination and management of emergency situations. It occurs both visually and audibly, both in real-time and when triggered by pre-defined criteria, additionally two-way communications occur between passengers and staff.

Wherever possible the provision of customer information is automated. Live announcements using a public address system take precedence over automated announcements.

Operating principle 8: Manage and control traction power

Centralised traction power control will enable quick co-ordination between railway operations and power control. Efficient use of power ensures that the system is never in a condition where demand for power exceeds supply. This ensures the risk of loss of traction current and consequently stranded trains is minimised. Co-ordinated controls are especially important during emergencies in terms of providing safe movement for people both by bringing trains to stop in stations for evacuation purposes or by enabling the safe movement of people (passengers, staff or emergency services) on foot.

Operating principle 9: Manage performance

The systems to provide operational intelligence concerning how the service is performing, in order to enable immediate as well medium to long term service decisions. *[Performance management details are a work in progress, reference the development plan Volume 1 Part 1 Section 10.]*

Maintenance Principle 1: Reliability

© Copyright 2009 London Underground Limited. All rights reserved.

The maintenance regimes for the system, asset and components will be developed to provide high reliability rates of the overall system, thereby enabling the delivery of the required service performance. The system will feature inbuilt redundancy for safety signalling and service affecting components, eliminating single points of failure wherever practicable.

Maintenance Principle 2: Availability

The maintenance regimes for systems, assets and components will be based on a 'predict and prevent' model, to assure high levels of system availability, which will enable the delivery of the required service performance. Maintenance will be scheduled to maximise service availability, whilst high levels of redundancy will afford teams time to respond to, and rectify failures, without affecting the on-going operation of the railway.

Maintenance Principle 3: Maintainability

The capability and capacity to deliver the required availability and reliability will be assisted by both a system and procedures that are designed for ease of maintenance. It is essential that faults can be identified easily and that faulty equipment can be changed quickly and efficiently. This will be complemented by a maintenance model that seeks to extend the time between planned maintenance activities as far as possible, without increasing the risk of failure to the signalling system. Enabling features will include a strong human factors focus and supporting training regimes.

Maintenance Principle 4: Safety

The system itself and its maintenance procedures will be designed to ensure that hazards associated with maintenance activities are either eliminated entirely or are reduced as low as reasonably practicable (ALARP).

© Copyright 2009 London Underground Limited. All rights reserved.

Under this arrangement there is no second-line maintenance involvement other than the equipment passing through the 'in-house' maintenance facility which is being used as a 'staging-point' to facilitate the recording and storage of defective items prior to Supplier collection and following their subsequent return.

4.1.3.5 Suppliers Whole Life Support

Major Assets such as Rolling stock and Signalling & Train Control require a vital level of support from the supplier throughout their life to support operation and therefore a long term support arrangement with the supplier. This level of support is defined for each asset but may include

- Technical authority, General Engineering Support & Advice
- Materials Provision, Overhaul or Part Overhaul of components
- Long Tern Obsolescence Support

4.1.4 Maintenance approach: Predict and Prevent

London Underground is current developing a future maintenance strategy driven by the principle of "Predict and Prevent" as shown in the diagram and summary below:

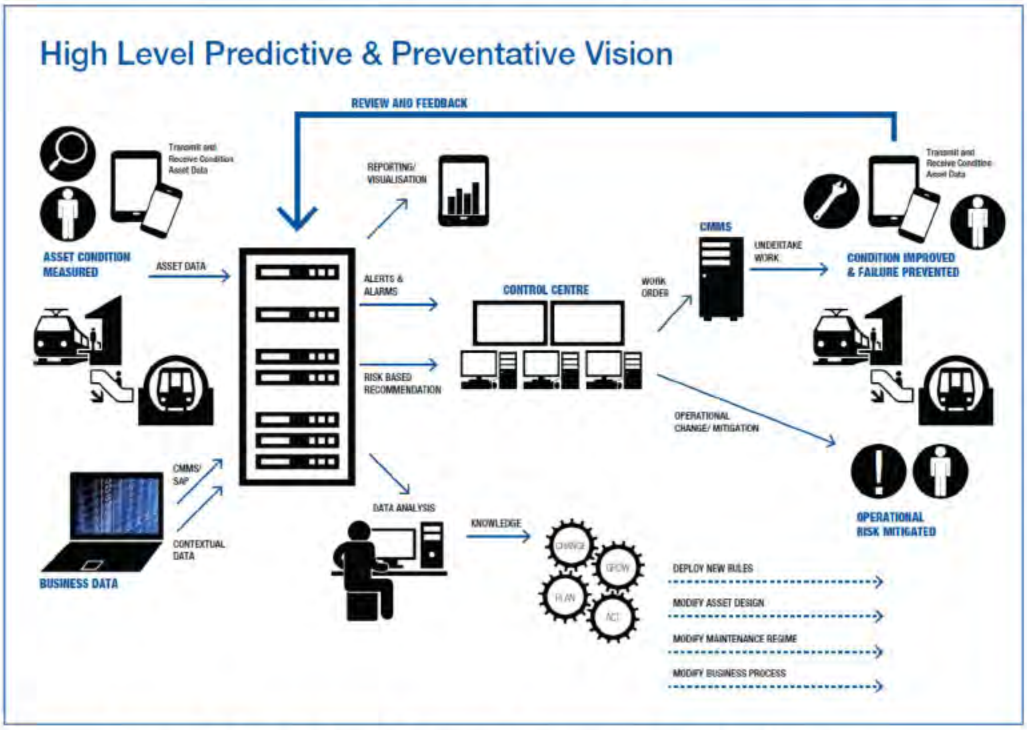


Figure 3: Predict and Prevent approach to maintenance

4.1.4.1 Monitoring Sources, Data Capture & Storage

The strategy functions on the principle whereby the sources of asset data (from Condition Monitoring and manual inspection) are integrated and analysed together with other relevant contextual sources. Other data sources include work history, cost, external factors like weather/temperature (i.e. data warehouse is represented by the large black rectangle in the diagram).

© Copyright 2009 London Underground Limited. All rights reserved.

4.1.4.2 Data Analysis

From this data (and with the suitable analysis tools) the following can be undertaken to enable:

a) Visualise and report on the data

b) Create alarms/alerts and risk based recommendations for the business to respond. This response may be work (i.e. planned or rapid response) on the asset as well as operational changes to mitigate the risk from the asset whilst it exists. Feedback of information on the work done etc. is fundamental to the learning process. We want to reduce the occurrence of alarms/alerts and increase the risk-based recommendations i.e. we become more predictive.

b) Use historic data to develop knowledge and understanding of assets and the effectiveness of our maintenance regimes.

4.1.4.3 Improved Asset Performance

The analysed data is then used to enable the implementation of the following improvements at asset performance to enable a predictive approach to be implemented including:

- Effective use of asset data to improve the maintenance and management of our assets
- Change and enhancement maintenance regimes
- Applying a systems approach to the assets which make up our network
- Implement the business change to make the benefits sustainable.

4.1.5 Operational Process

[redacted]

4.1.6 Technical

Technological change will be required to enable the new operational structure and process models. This will impact both the fleet and the signalling and control systems. Design of this technology will be governed by the System Definition Requirements which must satisfy the User Requirements Specification that is derived from the three sponsor level concepts (this OMC, the Customer Concept, and the EV Concept.)

4.2 On the wider LU system

Interface analysis is in progress and a series of workshops has been held in coordination with the NTfL Interface Manager. Interfaces include: station control, station control, power control, wider infrastructure management, rules and 3rd party interfaces. This analysis is examining these in normal, abnormal, degraded and emergency modes.

It is expected that this will be completed and added to the OMC at Issue 4.

4.3 On other operators/third parties

[Interoperability considerations such as grade of automation and train frequency have been made where the NTfL lines interface with other LU lines in OMC Volume 2 Parts 1 & 2. Interface analysis to be performed to validate that this captures all third party interactions.

© Copyright 2009 London Underground Limited. All rights reserved.

5 The Transformation

[redacted]

[redacted]

5.1 GOA1 with new train

The new train will be introduced onto the Piccadilly and Bakerloo lines and will be manually driven, using the existing Trainstop / Tripcock signalling protection, until the Signalling system is fully Upgraded as part of the Programme.

As a result of the introduction of new Rolling Stock, customers will benefit from:

- Improved passenger comfort
- Real Time customer information
- Air Cooling
- Greater Accessibility
- Improved ambience
- Increased capacity

Key enablers for the Programme are:

- Operational staff will be trained and competent to make use of the new assets as they become available
- Depots will have all facilities required for the maintenance of the new train available prior to the arrival of the first train.
- All additional stabling capacity to be provided by the Programme will be available prior to the first train arriving on the network, to ensure that the legacy rolling stock can be retained for service longer than would otherwise be the case; in order to maintain service levels should the new trains be unavailable.
- Maintenance staff will be trained to perform all maintenance functions on the new train and will be supported by a skilled internal engineering team with extensive technical knowledge of the train.
- The trains will feedback key information about its' status & health to a centralised point from where technically capable staff can ensure reliable operation.

5.2 GOA2

Completion of the Signalling Upgrade works will facilitate the move to single Operational Control Centre, which will ultimately control all 4 NTfL lines. Trains will be automatically controlled by signalling system but will have a driver present.

The operational staff based in the OCC will be multi-skilled in Signalling, Control and Communications roles. As a result, a greater level of efficiency and consistency will be achieved

© Copyright 2009 London Underground Limited. All rights reserved.

through staff flexibility and service recovery will be enhanced through the utilisation of improved control system functionality.

The speed and capacity benefits of the Upgrade will be realised at this stage along with a majority of the reliability benefits. As a result, timetable changes will take place following the Signalling commissioning to exploit the capability uplift and to deliver journey time improvements.

Concurrently with this activity, the Signalling and Fleet Maintenance staff will be trained to support the new equipment in full.

A detailed description of the process changes for GOA2 is included in Volume 2 Part 1 of this OMC.

[redacted]

5.4 Fleet & Depot Maintenance

Alongside the introduction of new rolling stock the duty cycle of the railway will be significantly expanded with both service frequency and hours of operation increased. Therefore there will be a smaller window of opportunity for maintenance. Availability of a reliable fleet will be paramount.

The new maintenance regime will make full use of modern condition monitoring and inspection technologies to deliver maintenance according to condition. As much as possible a production line methodology will be realised via a flexibly designed depot layout.

This ethos will derive a maintenance approach that delivers the key business objectives of the future maintenance function:

- Reduced whole life cost
- High asset and service reliability
- Efficient use of resources
- Consistent, predictable and high levels of asset availability.

First line maintenance will be performed 'in-house'. Staff performing this work will be trained in the maintenance of the fleet, signalling the depot and use / maintenance of depot equipment (as

© Copyright 2009 London Underground Limited. All rights reserved.

appropriate) prior to assets being brought into use. Therefore, this will enable a smooth transition from old stock to new, with the aim of delivering high quality maintenance from the start.

A detailed description of the Fleet and Depot Maintenance concept can be found in Volume 2 Part 3 of this OMC.

5.5 Signalling and Train Control Maintenance

In conjunction with the introduction of new trains, a new signalling system will be commissioned to enable the capability to operate the lines under Automatic Train Operation or Automatic Train Control in alignment with their planned Grade of Automation.

Effective asset management of the RCS will be a critical element in ensuring that the lines continue to function at their optimum performance levels. This includes a reduction in service affecting failures, minimised maintenance interventions and reduced time to repair.

The new system will have inbuilt design to reduce service affecting failures: minimised trackside equipment which is located as far from trackside as possible, inbuilt redundancy eliminating single points of failure risk, and inbuilt emerging technologies enabling the remote reporting and diagnosing of faults.

The maintenance regime employed, similarly to the Fleet Maintenance regime will reduce the number of planned, periodic maintenance interventions. Condition monitoring will be used extensively to enable preventative maintenance without service interruption. Additionally any planned maintenance will be based on usage and or likelihood of imminent failure.

The maintenance regime employed will deliver the same key business objectives as mentioned in Section 5.4.

Similarly all staff will be trained in the new maintenance procedures and the performance of maintenance itself. With the emergence of simulation and virtual reality technology there is the opportunity to develop a 'system wide' S&TC training facility which retains the core equipment of a traditional training facility but provides a virtual railway system which the equipment interacts with.

A detailed description of the Signalling & Train Control Maintenance Concept can be found in Volume 2 Part 4 of this OMC.

6 Migration

[Where the underground lines are being upgraded whilst providing continuous passenger service, the OMC will describe how the operations and maintenance of these lines will be performed during the migration from one technical system to another. The detail of this element of the OMC will be developed in alignment with the development plan in Volume 1 Part 1 of this OMC.

© Copyright 2009 London Underground Limited. All rights reserved.

7 Abbreviations

The following abbreviations are used in this document:

Table 7: Abbreviations	
Abbreviations	Definition
4LM	SSR Upgrade Programme
ACA	Asset Condition Assessment
ACCAT	Adhesion Controller Condition Assessment Tool
ADC/ADO	Automatic Door Closing/Opening
AGS	Asset Group Strategy
ALARP	As Low As Reasonably Practicable
ATC	Automatic Train Control
ATMS	Automatic Track Monitoring System
ATO	Automatic Train Operation
ATP	Automatic Train Protection
ATR	Automatic Train Regulation
BCV	Bakerloo, Central & Victoria (Lines)
BTUK	Bombardier Transportation United Kingdom
C&I	Control & Information
Cat 1	Category 1
CBTC	Communication Based Train Control
CCTV	Closed Circuit Television
CIS	Customer Information System
COTS	Commercial Off The Shelf
CRMS	Cable Route Management System
CSDE	Correct Side Door Enable
DISI	Defective In Service Instructions
DP&E	Depot, Plant & Equipment
DRM	Duty Reliability Manager
DSIM	Duty Signalling Incident Manager (BCV, SSR)
EMS	Energy Management System (also known as Building Management System)
EOT	Electrical Overhead Travelling crane
EP	Electro Pneumatic
FFCCTV	Forward Facing CCTV
FSA	Fleet Support Agreement
GOA	Grade of Automation (See definitions)
HMF	Heavy Maintenance Facility
HMI	Human Machine Interface
HVAC	Heating, Ventilation and Air-Conditioning
IT	Information Technology
ITN	Invitation To Negotiate
JNP	Jubilee, Northern & Piccadilly (Lines)

© Copyright 2009 London Underground Limited. All rights reserved.

Kms	Kilometers
L0-7	Level 1 to 7 maintenance interventions – see also 0
LIM	Lead Incident Manager (BCV, SSR)
LPC	Local Performance Centre
LRU	Line Replaceable Unit
LU	London Underground
LUCC	London Underground Control Centre
LUL	London Underground Limited
M	Metre
MDBF	Mean Distance Between Failure (Also MDBSAF – see definition of SAF)
MIG	Maintenance Introduction Group
Mph	Miles per hour
[redacted]	[redacted]
MSA	Manufacture and Supply Agreement (MSA)
MTBF	Mean Time Between Failure
NDF	No Defect Found
NTfL	New Tube For London Programme
OCC	Operational Control Centre
OCS	Operational Control System
OMC	Operations & Maintenance Concept
Operations (ASSETS)	Maintenance Management Team within the Operations Directorate
OPO	One Person Operation
OPO (T)	One Person Operation Tube
PA	Public Address
PCRO	Power Control Room Operative
PEA	Passenger Emergency Alarm
PED	Platform Edge Door
PKS	Staff Protection Keyswitch
PNR	Personal Needs Relief
POTIC	Process, Organisation, Technology, Information and Culture
PPP	Public Private Partnership
PTI	Platform Train Interface
RAM	Reliability, Availability, Maintainability
RC	Railway Controller
RCO	Railway Control Organisation
RCS	Railway Control System
RCU	Railway Control User
REW	Railway Engineering Workshop
REW	Railway Engineering Workshop
RM	Railway Manager
S&TC	Signalling & Train Control

© Copyright 2009 London Underground Limited. All rights reserved.

S&TCS	Signalling and Train Control System
SAF	Service Affecting Failure
SCADA	Supervision Control and Data Acquisition
SCD	Short Circuiting Device
SER	Signalling Equipment Room
SIM	Signalling Incident Manager (JNP)
SMM	Signalling Maintenance Manager
SOP	Saloon Operating Position/ Shunters' Operating Panel
SSR	Sub-Surface Rail
STECO	Steering Committee (Fleet OPERATIONS (ASSETS) led)
T/Op	Train Operator
TCMS	Train Control and Monitoring System
TfL	Transport for London
TMR	Train Maintenance Regime.
TNA	Training Needs Analysis
TpH	Trains per Hour
TSR	Temporary Speed Restriction
TTF	Time To Fix
TTS	Time To Site
UAM	User Acceptance Manager
URS	User Requirements Specification
[redacted]	[redacted]
VEID	Visual Electronic Information Device
VLU	Victoria Line Upgrade
VMI	Vehicle Maintenance Instructions (Process Instructions)
VMP	Vehicle Maintenance Processes
W&C	Waterloo & City (Line)
WSP	Wheel Slide Protection
WTT	Working Timetable
ZIM	Zonal Incident Manager (JNP)
ZMM	Zonal Maintenance Manager (JNP)

© Copyright 2009 London Underground Limited. All rights reserved.

8 Definitions

The following terms are used in this document:

Table 8: Definitions	
Term	Definition
Normal Operations	"State of normal running of the railway incorporating minor disturbances and delays to the service in traffic hours and operations in non-traffic hours"
Abnormal Operations	"State of continuing railway operations with specific, planned changes to its configuration or equipment (such as special events, engineering works in traffic hours or within station public areas).
Degraded operations	"State of continuing railway operations with significant equipment failures" (such as track, train related failures and communication failures)
Emergency Operations	"State of the railway in response to a major safety or security related event. Introducing contingency plans at a moment's notice".

9 References

The following documents are referenced in this document:

Table 9: References		
Ref.	**Document ID**	**Title**
International Standards		
1.		
2.		
3.		
4.		
London Underground		
5.		
6.		
7.		
8.		
New Tube for London Programme		
9.	NTfL-2344.2.2-LUL-RPT-00035	New Tube for London Programme Concept Blueprint
10.	NTfL-2344.2.2-LUL-DWG-00020	NTfL Functional Breakdown Structure
11.	NTfL-2344.1.1-LUL-RPT-00032	The "New Tube for London Operational Model and User Requirements Executive Summary"
12.		

The reference numbers in the above table can be used as a Cross-Reference in the main body of the text to link references to the correct entry in this table.

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

Appendix B – Description of Assets

Introduction

The following tables contain high-level descriptions of the essential characteristics of each of the railway asset area. Each characteristic has been classified according to the 'MoSCoW' system, as follows:

Must The characteristic is essential to the operation of the upgraded railway
Should The characteristic adds value and is necessary in order for the upgraded railway to be operable in the optimum manner
Could The characteristic is desirable to enhance the operability of the railway
Will not The characteristic is not delivered by the upgrade.

A MoSCoW rating has been given for the three key stages of the NTfL upgrade, and where applicable, shown for current, pre-upgrade operations, as follows:

Current Legacy trains - manually driven by Train Operators in driving cabs, protected by legacy track-side signalling, under the control of legacy train control systems.
GOA1 New NTfL Tube Stock trains manually driven by Train Operators in driving cabs, protected by legacy track-side signalling, under the control of legacy train control systems.
GOA2 NTfL Tube Stock trains with movement controlled by Automatic Train Operation (ATO), protected by Automatic Train Protection (ATP) systems, with a Train Operator in a driving cab responsible for closing customer doors and initiating the start of automatic train movements. Critical elements of the new Railway Control System (RCS) present; NTfL lines controlled from a single NTfL Operational Control Centre (OCC)
[redacted] [redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

Transport for London

London Underground Limited

NTfL OMC Volume 2 Part 1

NTfL GOA2 Operational Concept

		Signature	Date
Prepared by	[redacted] Operational Development Manager	[redacted]	21/7/2016
Reviewed by	[redacted] Upgrade Delivery Manager	[redacted]	20/7/16

Revision	Date	Summary of changes
Issue 1	26/02/16	First issue
Issue 2	11/04/16	Explanation of document style added to Introduction along with some minor refinements to phraseology throughout document.
Issue 3	20/07/16	Minor typographical amendments Changes to the Control Centre Staffing model; GOA2 roles now reflect GOA1 [redacted] Clauses and content aligned with Requirements [redacted] Additions made to Bakerloo line Interoperability

© Copyright 2009 London Underground Limited. All rights reserved.

TABLE OF CONTENTS

© Copyright 2009 London Underground Limited. All rights reserved.

© Copyright 2009 London Underground Limited. All rights reserved.

LIST OF FIGURES

© Copyright 2009 London Underground Limited. All rights reserved.

1 INTRODUCTION

1.1 Summary

[redacted]

[redacted]

[redacted]

The NTfL railway in GOA2 is characterised by:

- An increase in peak train services from 24 to at least 33 trains per hour (TpH) in the central section of the Piccadilly line;
- ATO on the Piccadilly and Bakerloo lines
- Migration from legacy ATO to NTfL ATO on the Central line, maintaining peak train services to at least 33TpH;
- An increase in peak train services to from 22 to 27TpH on the Bakerloo line;
- [redacted]
- A new signalling and control system;
- A new Operational Control Centre incorporating all four lines
- Off-train PEA awareness;
- [redacted]
- Early prediction of and rapid recovery from disruption;
- Improved flexibility allowing service to be maximised when the railway is degraded;
- More robust assets providing greater reliability and availability;
- Use of off-train data transmission to enable continuous monitoring of asset performance information and targeted, pro-active maintenance planning;
- The provision of more timely, targeted and beneficial customer information;
- A railway capable of operating 24hour passenger services;
- Engineering hours and traffic hours consistent with the current network practices;

© Copyright 2009 London Underground Limited. All rights reserved.

- Bi-directional signalling for train recovery.

The content of the document is an amalgamation of existing practice, established strategies and creative vision. In this context, the document depicts a potential state of the NTfL post upgrade and provides the basis for consultation, ongoing conceptual design and development of user requirements. It should be read in conjunction with the User Requirements Specification, which contains explicitly, the user's needs for GOA2 operation.

© Copyright 2009 London Underground Limited. All rights reserved.

1.2 Scope & Structure

This document is written from the end user perspective and provides a description of future NTfL operational practice operating in GOA2 from 2026 onwards on the Bakerloo, Central and Piccadilly Lines.

The scope of this document is:

- The Operational Organisation Structure and staffing model at GOA2
- The operational processes and techniques that are adopted to manage the service in normal, abnormal, degraded and emergency conditions
- The procedures for managing interoperability of NTfL trains with other lines and train services.

The structure of this document is:

- Section 1 *Introduction* - contains an Executive Summary that highlights the salient points of NTfL GOA2 operation.
- Section 2 *NTfL Operational Organisation Structure* - illustrates the Operational Organisation's structure.
- Section 3 *NTfL Railway Processes* - describes the operational processes and procedures used to deliver the service.
- Section 4 *Interoperation* - describes the operation of interoperable areas within the NTfL railway.
- Section 5 *Appendix 1* - contains supporting information and context for content within Sections 2 - 4.

1.3 Style

This document is intended to provide a vision of Train Operations post upgrade in GOA2, but with variances that suit the operation of the upgraded railway in order to: enable the service for capacity uplift (as highlighted above in section 1.6); maximise the benefits from new technology; [redacted] It is therefore written in the present tense from the perspective of someone describing the railway post upgrade. This was the most effective way found to describe how LU will operate systems that have yet to be designed. Where something has been referred to in the past tense – it is describing the railway before the upgrade and will reflect today's operation of the railway.

Operational Procedures that are no different from what is carried out on today's railway can be found in the Operational Rule Books. These can be located electronically in *The Management System* library http://onespace.tfl.gov.uk/lu /OSSRB/default.aspx. Where relevant the specific Rule Book and section have been referenced.

© Copyright 2009 London Underground Limited. All rights reserved.

2 NTFL RAILWAY – OPERATIONAL ORGANISATION STRUCTURE

2.1 The Railway Control Organisation (RCO) in GOA2

2.1.1.1 The organisational structure for command and control of the GOA2 railway is shown in the diagram below.

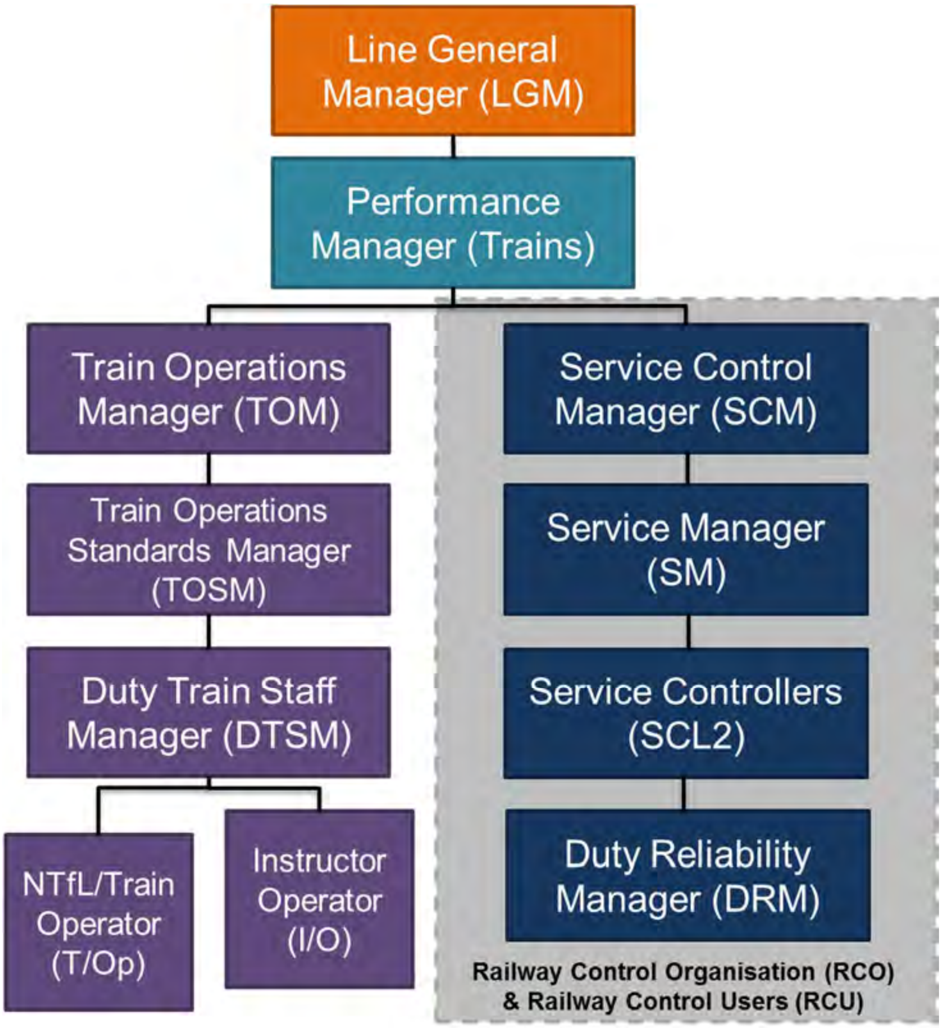


Figure 1 – GOA2 Operational Organisation

2.1.1.2 The role of the Line General Manager and Performance Manager is not covered within the concept documentation. In GOA2 Train Operations and the management of Train Operators will reflect the structure in place today, which is outside of the scope of the project. ; It is assumed that when Service Control staff migrate to NTfL

© Copyright 2009 London Underground Limited. All rights reserved.

GOA2 the Line Information Specialist's (LIS) role will merge with the Service Controller (SCL2). Detailed information on the roles that support Train Operations and Service Control can be found in Appendix 1 section 5.1. [redacted]

2.1.2 Train Operator

2.1.2.1 [redacted]

2.1.3 NTfL Train Operator

2.1.3.1 [redacted]

- monitor the guideway and the PTI on the approach to a Station stop
- monitor the opening of train doors, and intervene automatic door opening if necessary
- monitor the safety of customers boarding and alighting
- initiate closing of the train doors, once dwell time has elapsed and when safe to do so;
- initiate platform departure of the train,
- monitor the safety of customers at the PTI until the train has fully departed the platform;
- intervene and take appropriate action if they observe a potentially hazardous situation and liaise with the responsible RCU, Metropolitan Line Service Control and station staff if assistance is required;.
- manage the handling of PEAs;
- assist when evacuating passengers and recovering the train in the event of an incident.

© Copyright 2009 London Underground Limited. All rights reserved.

2.2 Train crew accommodation

2.2.1 Piccadilly Line

2.2.1.1 There are four train crew accommodation and relief locations for Piccadilly line Train Operators: Northfields, Acton Town, Arnos Grove and Cockfosters.

2.2.2 Rayners Lane to Uxbridge

2.2.2.1 [redacted]

2.2.3 Central line

2.2.3.1 There are five train crew accommodation and relief locations for Central line Train Operators; West Ruislip, White City, Leytonstone, Loughton and Hainault.

2.2.4 Bakerloo line

2.2.4.1 There are two train crew accommodation and relief locations for the Bakerloo line Train Operators; Elephant & Castle and Queens Park.

3 NTFL RAILWAY PROCESSES

3.1.1 Introduction

3.1.1.1 This section describes the processes used by the Operational Organisation to deliver, maintain and, where necessary, recover the train service in normal, abnormal, degraded and emergency conditions, whilst ensuring the safety of customers and staff at all times.

3.1.1.2 The processes described have been developed in response to the functional design undertaken in the feasibility stage of the project, and aim to identify how the various railway functions will be delivered by the Operational Organisation, utilising new and upgraded assets.

3.1.1.3 The structure of this section (3.2 to 3.8), therefore, mirrors the NTfL Functional Breakdown Structure, to ensure consistency and clarity of understanding. [Note: the User Requirements Specification is also structured in this way]

© Copyright 2009 London Underground Limited. All rights reserved.

3.2 Train Movements

3.2.1 Scheduling Train Movements

- The railway's control system schedules train movements for each day. As inputs, it takes account of the following:
- The active Working Timetable (WTT)
- Forthcoming maintenance tasks scheduled by maintenance planning tools (e.g. Maximo and Ellipse) , providing requests for particular train sets to be at specified maintenance facilities within a stated time-frame
- The availability and location of rolling stock, determined by maintenance activity and depot management
- A list of ad-hoc train movement requests made by the responsible RCU.

3.2.1.1 The schedule states the times and locations of individually-identified trains over the planned-for period using the basis of the Working Timetable to:

- Set routes for trains
- Schedule the train's route and trip into and out of service from Depots and stabling locations
- Generate movement authorities for trains
- Highlight potential conflicts between planned movements and Train crew scheduling
- Schedule empty stock-balancing train trips.

3.2.2 Controlling Train Movement – Automatic Operation

3.2.2.1 The train's movement and systems operate automatically other than where it is specifically described within this concept.

3.2.2.2 Each train is given authority to move (movement authority) by the signalling system, which commands each train to motor, coast and brake, thus enabling Automatic Train Operation. .

3.2.2.3 All necessary settings and controls to the NTfL infrastructure, for example, setting routes necessary for the scheduled train movements are applied automatically.

3.2.2.4 The train travels automatically between stations. The railway's control system continuously monitors each train's location and ensures it is adhering to line speed, which includes all local speed restrictions. The train's target speed (the speed in which the signalling system determines the train needs to be at in order to maintain the service plan) along with confirmation of ATO, is presented to the Train Operator, as information.

© Copyright 2009 London Underground Limited. All rights reserved.

3.2.2.5 Continuous automatic corrections to the running of trains to maintain the Timetable and/or other operating parameters are applied to deliver the service plan and ensure, to as far that is reasonably practical that gaps between trains are even, in order to provide a consistent service along the .line. Relevant information pertaining to the condition of the service is presented to RCUs in the Operational Control Central (OCC), enabling situational awareness if a manual intervention is required in order to correct inconsistencies in the service and get it service back to its normal running pattern.

3.2.2.6 These corrections may take the form of instructing trains to coast/motor to increase/reduce inter-station run-times and extending dwell-times, within pre-defined parameters, to even out headways between trains.

3.2.2.7 These corrections are applied automatically and in most circumstances invisible to Train Operators when the train is moving between platform stops, unless the train is held in the tunnel for an extended period. Train Operators are presented with the dwell time for each station stop, which supports timely departure. If the train is held, extending the dwell, the Train Operator is made aware. Passengers are kept abreast of changes to services that may impact their journey. .

3.2.2.8 ATP automatically brings trains to a halt within the tolerance of each designated platform stopping point.

3.2.2.9 The Train Operators responsibility for each station stop is covered in section 3.3 Customer Movement.

3.2.2.10 The Train Operator is able to override and inhibit automatic train movements, e.g. to prevent the train from leaving a platform in response to an observed unsafe condition.

3.2.2.11 The Train Operator is able to directly apply the train's emergency brake, and in these circumstances, the railway's control system cannot restart that train's movement The Train Operator must initiate restarting the train when they are satisfied it is safe to do so.

3.2.2.12 Trains can be routed in a non-normal direction to aid the recovery of trains, or in the event of a serious failure which prevents the train from moving forward in the normal direction (See section 3.2.12).

3.2.3 Controlling Train Movements – Manual Operation

3.2.3.1 When it is necessary for an Attending Operator to directly control the movement of the train, the Train Operator puts the train into Manual Mode and uses the Traction Brake Controller to command the train to motor, coast and brake.

3.2.3.2 Trains can only be permitted to move in Manual Mode when authorised by the responsible RCU.

© Copyright 2009 London Underground Limited. All rights reserved.

3.2.3.3 When a train is operating in Manual Mode, it is identified as such to RCUs in the OCC.

3.2.3.4 If automatic train protection (ATP) is available, i.e. signalling and train control is functioning correctly, indication of the presence of a movement authority and target speed at which the train is to be operated are provided, the Train Operator observes this information and keeps the train at or below the indicated target speed and within the limit of the movement authority.

3.2.3.5 If the train exceeds the target speed, a warning is provided and if the over-speeding continues, or exceeds a predefined limit, the ATP will bring the train to a halt. Similarly, if the Train Operator attempts to move the train beyond its movement authority, the ATP will bring the train to a halt. In both cases, the infringement is detected which raises an alarm to the responsible RCU.

3.2.3.6 If ATP is not available, the Train Operator drives the train by line of sight, observing the roadway ahead of the train, and bringing it to a halt before any obstructions.

3.2.3.7 Indications are provided on the train's exterior to inform observers that the train is not under signalling control and may therefore move when and where it is not expected to.

3.2.3.8 The Train Operator is able to view platform and stabling berth stopping positions from the train's driving position (described in section, 3.2.4).

3.2.3.9 In certain circumstances it is necessary to move a train beyond its movement authority when the ATP is still operational, for example, in order to couple two trains together (see section 3.2.13), or to move a train into a maintenance facility.

3.2.3.10 In these circumstances, the Train Operator must first ensure that their train is at a halt and then seek authorisation from the responsible RCU before proceeding. Once authorised, the Train Operator moves the train as described in section 3.2.14.

3.2.4 Platform stopping positions

3.2.4.1 There are two methods that assist the Train Operator to stop the train within the tolerance of the platform stop when the railway is degraded and trains are driven manually. These are:

- infrastructure mounted chevron signs that are viewed against fixed markers on the train at the operating position when the Train Operator is seated, provide the Train Operator with a visual target to aid stopping within the platform's tolerance;.
- an additional stopping accuracy detection system, which may utilise the in-cab monitors to provide the Train Operator with a visual indication that assists them to stop the train at the correct position. [Note: It is envisaged this system will be the primary method to support the train operator stop the train in the correct position and within the reduced stopping tolerance if PEDs are present and

© Copyright 2009 London Underground Limited. All rights reserved.

therefore, may not be applicable to GOA2.]

3.2.5 Transfer the train to a stabling location or siding (inc emptying the train)

3.2.5.1 Prior to a train entering the depot or sidings to stable, passengers are detrained by the Train Operator or station staff. Information visible from the platform, informs staff that the train terminating requires detraining.

3.2.5.2 On train customer information informs passengers that the train is terminating.

3.2.5.3 The Train Operator leaves the cab and assists platform staff to detrain any remaining passengers, and ensures the entire train is clear of customers and any lost property. Controls within the saloon close all doors per car, facilitating the detrainment of passengers while ensuring no-one else can board the train.

3.2.5.4 Note: when a train is due to reverse in service via a siding without laying over (i.e. remaining there for an extended period of time), staff are not required to attend and detrain customers. Audio/visual messaging informs customers that the train is terminating at this station and they must alight from the train. However, since the train will not be stabled in the siding and will shortly return to the station (albeit on a different platform), there is no risk of customers being stranded in Sidings if they do not alight. [Note: in the event that the return move is delayed, saloon CCTV on the train can be used by the Train Operator to check whether any customers have remained on the train].

3.2.5.5 Once the train is clear of passengers and all passenger doors are closed the Train Operator returns to the cab. The train is operated in Automatic mode and moves away from the platform onto the depot reception road.

3.2.5.6 If the Depot or Sidings are signalled for ATO, the train automatically enters its designated berthing location.

3.2.5.7 If the Depot or Sidings are locally controlled, the train stops at the signalling boundary where the Train Operator changes the driving mode from Automatic to Manual Mode. Once authority to proceed is given to the Train Operator, the train is driven manually into its designated berthing location.

3.2.5.8 Once the train is in place, the Train Operator shuts down the train and exits. [Note: If ATP is present in the depot, the Train Operator may leave the train in Automatic – this will be refined during the detailed design phase.]

3.2.5.9 More information on depot operations can be found in Vol 2 Part 3 NTFL Fleet & Depot Maintenance Concept

3.2.6 Staff access depot or sidings

3.2.6.1 Access to the depot is strictly limited to trained and licensed staff wearing the correct personal protective equipment. The Train Operator uses the official walking route to access the train. Where crossing the track is necessary, safety measures

© Copyright 2009 London Underground Limited. All rights reserved.

are in place to protect people. To make crossing the track safer, a physical barrier is used to separate people and trains. Access to the drivers cab is via modified access platforms. [Note: In order to access sidings in tunnelled sections, traction current must be removed.]

3.2.6.2 When the depot is signalled for ATO it is envisaged that people and train movements are segregated, as are maintenance and stabling locations. Train movement within stabling areas is automatic, but movement in and out of maintenance areas is in Manual Mode. Train access across track is via bridges to platforms, enabling the Train Operators to board trains safely in areas where trains are moving automatically.

3.2.7 Staff Access to the train

3.2.7.1 The train is equipped with a driver's cab and cab-side doors.

3.2.7.2 For GOA2 operation, the Train Operator's duties are carried out from a partitioned cab, which is accessed via a cab side door, or when in tube sections where the cab is in tunnel, via the leading set of passenger saloon doors and the J-Door.

3.2.7.3 [redacted]

3.2.7.4 Access to the train's cab and operating position at crew change locations is through the cab-side door.

3.2.7.5 At stabling locations and in depots access to the train's cab is through the cab side door via staff access platforms.

3.2.7.6 At a number of locations on NTfL lines, the train is greater in length than the platform and the cab will be in the tunnel. Under normal circumstances the Train Operator is not expected to have to leave the cab but if access is required at these locations, it is through the J-Door and leading passenger saloon doors.

3.2.8 Train preparation for service

3.2.8.1 [redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

3.2.8.2 Note: The Train's Operating Environment allows for simplified preparation. It is easily accessible, with minimal time required to set up ready for Operation; incorporating Human Factors best practices and lessons learnt from recent LU Rolling Stock upgrades.: The features and controls are intuitive and allow for quick adjustment; they include a fully adjustable chair and footrest. Other features are included to meet the expectations of the Train Operator such as: cupholders, sunblinds, storage space for belongings, temperature and air flow controls, controls for task lighting, enhanced sightlines, intuitive and ergonomic controls and instruments, minimal ambient noise.

3.2.8.3 A facility at the operating position will be provided for the Train Operator to notify the RCS that the train is now under operator control. Other "logins" are kept to a minimum.

3.2.9 Transfer of train from stabling site to station stop

3.2.9.1 When ATO is present at stabling locations, including depots, movement of the train is consistent with the mainline and initiated when movement authority permits, by the Train Operator. On leaving the stabling site, the train automatically travels to the first designated platform where the train stops and the saloon doors automatically open.

3.2.9.2 When ATO is not present at stabling locations, movement of the train is under manual control of the Train Operator onto an ATO transfer location; this allows the train to be enabled for automatic operation.

3.2.10 Non–stopping platforms

3.2.10.1 Due to certain operational requirements, it occasionally becomes necessary to prevent trains from stopping at a platform (or platforms). This can be due to an incident or safety risk, a planned closure of a Station or platform for maintenance activities, or an asset failure [Note: See section 3.5.2 – Programme Platform/Station Skip]

3.2.10.2 If a train approaches a platform it is not due to stop at and the route through or ahead of the platform is not clear, the train comes to a halt before any part of it enters the platform road. This is to prevent a train halting in a platform either partially or fully without the customer doors opening; which is undesirable, as it causes confusion to customers, who may attempt to board or alight from the train, or operate Passenger Emergency Alarms (PEAs).

© Copyright 2009 London Underground Limited. All rights reserved.

3.2.10.3 Once the route through and ahead of the platform becomes clear, the train is instructed to automatically move through the platform.

3.2.10.4 The train traverses non-stopping platforms at the appropriate speed. This is to mitigate risks caused by a fast moving train passing close to customers at the edge of the platform.

3.2.10.5 The Train Operator receives an automated notification informing them that the Station or a platform is closed.

3.2.10.6 An automated announcement notifies the customers on the train of the Station or platform closure and that the train will not be opening its doors to allow passengers to board or alight.

3.2.10.7 The train's external information displays change to reflect that the train is not stopping, to inform passengers on the platform when at the previous open platform, of the next available station stop.

3.2.10.8 If the train is not stopping at a terminus platform, the previous open platform becomes the terminus point, which is reflected by the train's Customer Information.

3.2.11 Movement of engineers' vehicles and alien trains

3.2.11.1 Engineers' vehicles are fitted with the NTfL ATP system, enabling them to run under signalling protection on NTfL lines. They are manually operated and depending on type, may need to operate at a reduced speed compared to passenger trains.

3.2.11.2 Stabling berths to accommodate over-length engineers' vehicles are provided in the Piccadilly and Central line depots. [Note: certain reversing sidings on the Piccadilly and Central lines are also able to accommodate trains of this length].

3.2.11.3 Some vehicles that cannot be equipped with NTfL ATP, for example some road-rail vehicles and legacy stock, are occasionally required to run on NTfL lines. These vehicles are only able to run inside an engineering possession.

3.2.12 Non-normal direction movement of trains

3.2.12.1 It occasionally becomes necessary for a train to be moved for a limited distance in the 'wrong' or non-normal direction. This can occur at any location on the railway and is usually in response to a serious failure or incident that prevents trains from continuing in the planned direction of travel, and therefore risks customers being stranded on trains in tunnels for an extended period of time.

3.2.12.2 In these circumstances a RCU arranges protection (see section 3.5.3) so the non-normal direction of movement can take place.

3.2.12.3 All trains are prevented from entering the area in which the movement is taking place and the train undertaking the movement is prevented from leaving it.

© Copyright 2009 London Underground Limited. All rights reserved.

3.2.12.4 In addition, the train immediately to the rear of the zone of protection is brought to a halt; the Train Operator is instructed to secure their train from movement, which they do from the Train cab. As a result the Train illuminates an external indicator continuously at both ends and extinguishes the Headlights. This informs staff in the train's vicinity that it cannot move unless the Train Operator enables it to move.

3.2.12.5 This train then provides a physical barrier that protects any other train from entering the area..

3.2.12.6 The responsible RCU defines the location of which of the non-normal direction movement will be completed (the Limit of Movement).. This is communicated to the Train Operator. Note: All Train cabs are fitted with operational radios which provide secure voice and one-to-many communication. In addition, Train Operators carry hand held radios that offer the same functionality as the Train's operational radio which are linked to the train's operational radio.

3.2.12.7 Note: A Train Radio failure requires a second person on each train, as required by Railway Operating procedures. If a second person cannot be provided, the alternative is to suspend the service.

3.2.12.8 The Train Operator is then instructed to operate the Wrong Direction Move lighting, displaying red tail lights at the rear and both head and tail lights at the non-normal direction leading end.

3.2.12.9 Remaining in Automatic and under signalling protection, the Train Operator then instructs the affected train to move to the limit of move. While the train is moving, the Train Operator sounds a continuous series of short whistle blasts to alert anyone on or about the railway that it is moving in the non-normal direction.

3.2.12.10 Once the non-normal direction movement has been completed, the Train Operator is instructed to resume normal direction operations.

3.2.12.11 The protection can then be lifted, and the train to the rear can be instructed to switch back to automatic movement.

3.2.12.12 If signalling protection cannot be provided by the railway's control system, resulting in points that are unable to be secured, a Wrong Direction Move Person in Charge is appointed, who will need to secure the points by scotch and clip and use the legacy procedure, including appointing a Hand Signaller and using a WDM form as per the procedure described in Rule Book 5 Section 3.

3.2.13 Rescuing Stranded Trains – General Principles

3.2.13.1 The use of continuous automated asset condition monitoring and remote fault-finding and fault-rectification has rendered it extremely unlikely that trains become stranded between Stations with customers on board.

© Copyright 2009 London Underground Limited. All rights reserved.

3.2.13.2 However, it is recognised that such a situation could still arise and therefore, the following section sets out the various procedures to be undertaken to rescue stranded trains.

3.2.13.3 A strategic plan for recovering the stalled train is developed by the responsible RCU. This may be the Service Controller in charge of the area in which the train has become stalled, or it may be the Service Manager who takes charge.

3.2.13.4 In most instances, one or more DRMs will attend and assist the Train Operators with the actual recovery on site in response to, and under the strategic guidance of, the RCU in charge of the recovery. Station staff may also assist with the procedure.

3.2.13.5 The RCO adjusts the service and/or individual train trips and to provide the optimum service to customers on the rest of the line. This may include suspending the service on part of the line and applying procedures from the Line Emergency Plan which may involve implementing an emergency Timetable – for more information on see OMC Reference Data and section 3.5.13.

3.2.13.6 Evacuation of customers is detailed in section 3.3.7 – 3.3.8.

3.2.14 Rescuing Stranded Trains – Coupling trains together

3.2.14.1 NTfL trains are fitted with coupling devices at each end of the train, which allows coupling and train recovery on all areas of the railway.

3.2.14.2 A stranded train can be recovered using an assisting train to either push or pull the stranded train to a suitable location. Trains must be coupled together to achieve this.

3.2.14.3 Having ensured that no other trains are in the area, the responsible RCU arranges protection (Section 3.5.3) to prevent any other trains from entering the area.

3.2.14.4 Prior to recovering the stranded train, whenever possible and therefore in most circumstances, passengers are detrained from the assisting train onto an empty platform.

3.2.14.5 To recover a train the assisting train proceeds under signalling protection towards the stranded train, up to full line speed, until it no longer receives movement authority. Once the limit of movement is reached, the Train Operator receives authority from the RCU, puts the assisting train into Manual Mode and proceeds towards the stranded train. A yellow light at each end of the train's exterior flashes, denoting the train is being driven in Manual Mode and without signalling protection.

3.2.14.6 The Train Operator on the stranded Train secures and immobilises it by applying the train's brakes to ensure is does not roll when the assisting train couples to it.

3.2.14.7 The assisting Train Operator checks the exterior of the stranded train for the indication that it is secured, and checks the alignment of both trains' couplers.

© Copyright 2009 London Underground Limited. All rights reserved.

3.2.14.8 Images from Forward Facing CCTV targeted directly at the front of the train, can be selected from the in-cab monitors, providing the Train Operator on the assisting train an alternative perspective of the couplers.

3.2.14.9 If passengers remain on the stranded train, an RCU can trigger pre-determined customer information from the OCC, to the train, keeping passengers abreast of the procedure. The Train Operator on the stranded train is available to reassure passengers, and make regular Public Address announcements in order to keep passengers informed of progress. Remote Public Address is also available from the OCC. Similarly, on the assisting train, if passengers remain on board, pre-determined customer information can avoid the Train Operator's use of the PA, unless they are required to do so specifically.

3.2.14.10 The assisting Train Operator moves the train towards the stranded train and couples the trains together.

3.2.14.11 Confirmation of coupling is notified to the Train Operator at the operating position of the assisting train and to the responsible RCU at the OCC.

3.2.14.12 Communication between the Train Operator at each operating position is via the Train Radio or the Cab to Cab handset, the latter allowing for private conversation to take place between the Operators, if passengers remain on either train. Hands-free Cab to Cab communications can be selected, which allows the Operators to converse, without having to physically hold the handset.

3.2.14.13 Coupling of the trains transfers where permitted by the underlying defect, control of the brakes on the rescuing Train from the defective Train.

3.2.14.14 Movement of coupled trains is limited to manual.

3.2.15 Rescuing a stranded train - pushing out with an assisting train

3.2.15.1 If the stranded train is to be pushed by the assisting train, the Train Operator from the stranded train moves to its leading end.

3.2.15.2 Once at the leading end, the Train Operator establishes the method for applying the brakes of the coupled trains in an emergency, and sets up a secure communication channel with the Train Operator on-board the assisting train.

3.2.15.3 When both Train Operators are satisfied that the procedure can commence, the assisting train is put into Manual Mode. The stranded train is put into a mode that permits the train to be recovered.

3.2.15.4 The Train Operator on the stranded train contacts the responsible RCU, confirms the location of the planned limit of movement for the coupled trains and requests authorisation to proceed. When authorised, the Train Operator on the stranded train observes the road ahead and instructs the assisting Train Operator to proceed.

© Copyright 2009 London Underground Limited. All rights reserved.

3.2.15.5 The assisting train is driven in Manual Mode and the assisting Train Operator controls the movement of the coupled trains.

3.2.15.6 If the stranded train contains passengers, the Train Operator on the assisting train shunts the stalled train into the next available platform, stopping in a position that allows the passengers to be detrained.

3.2.15.7 The train is taken out of service and recovered to an appropriate location.

3.2.16 Rescuing a stranded train - pulling out with an assisting train

3.2.16.1 If the stranded Train is to be pulled by the assisting train the Train Operator secures and immobilises it and moves to the leading end.

3.2.16.2 The Train Operator in the adjacent cab of the stranded train establishes the method for applying the brakes of the coupled trains in an emergency, and sets up a secure communication channel with the Train Operator on-board the assisting train.

3.2.16.3 When both Train Operators are satisfied that the procedure can commence, the assisting train is put into Manual Mode, the stranded train is put into a mode that permits the train to be recovered.

3.2.16.4 The Train Operator on the stranded train contacts the responsible RCU, confirms the location of the planned limit of movement for the coupled trains and requests authorisation to proceed.

3.2.16.5 The train is driven in Manual Mode and the assisting Train Operator controls the movement of the coupled trains. If the stranded train contains passengers, the stalled train is pulled into a position that allows the passengers to be detrained and the passengers are detrained onto the next platform available.

3.2.16.6 The train is taken out of service and recovered to an appropriate location.

3.2.17 Rescuing stranded legacy Tube Stock

3.2.17.1 The New Tube Stock is capable of recovering legacy Tube Stock, which for GOA2 (and fleet migration on the Piccadilly and Bakerloo in GoA1), is pertinent throughout the migration of the Central line's rolling stock, via a portable interface coupler. [Note: Throughout the migration phase, the portable couplers may need to be placed at strategic locations along the Line.]

3.2.18 Recovery of a gapped train

3.2.18.1 A train is said to be "gapped" when it stops in such position that it is sitting over a gap in the traction current conductor rails, and none of its current pick-up shoes are in contact with the live rails.

© Copyright 2009 London Underground Limited. All rights reserved.

3.2.18.2 The layout of traction current conductor rails and the configuration of current pick-up shoes on the train have been designed to minimise the risk of trains becoming gapped.

3.2.18.3 A train can become gapped, however, in the event of it losing some of its pick-up shoes due to, for example, striking obstacles on, or near the track.

3.2.18.4 Batteries on the train may enable up to a minimum of 50 meters of slow speed self-powered movement when crushed laden or 200m when empty on level gradient.

3.2.18.5 When moving under self-power the train normally remains in Automatic Mode, maintaining signalling protection (self-powered movement is also available when the train is driven manually). All self-powered train movements require authorisation will be enabled by the Train Operator.

3.2.18.6 The train will provide the Train Operator with an indication at the operating position that it is moving under its own power.

3.2.18.7 The Train Operator and a responsible RCU are aware of the train's self-powered capacity.

3.2.19 Recovery from a failure in the supply of traction current

3.2.19.1 If it becomes necessary to switch off traction current when trains are operating in customer service, every attempt is made to work all trains in the affected section into platforms and bring them to a halt, or to allow them to work clear of the affected section before current is switched off

3.2.19.2 Occasionally, however, this is not possible due to an emergency or a failure of the power supply.

3.2.19.3 The on/off status of traction current power supply in every current section is interlocked with the signalling and train control, but can be overridden to enable the movement of trains in the affected section. In the event of traction current being switched off, or lost, the RCS brings to a halt any train approaching the dead section, which can safely be stopped before any part of it enters the dead section.

3.2.19.4 The RCO are aware of the status of traction current in each section; when it is switched off, or lost, the responsible RCU receives a notification. When the train loses traction current the Train Operator receives an on-board notification.

3.2.19.5 Trains already moving in the section when traction current is lost are automatically instructed to coast until they reach the platform stopping point at the next station, provided they have sufficient inertia and a movement authority.

3.2.19.6 If a train is moving between a station and the end of the dead section, and providing it has a movement authority and sufficient inertia, it coasts into the next live section. Providing the train is in Automatic, once it is has picked up traction power again, Movement Authority is confirmed to the Train Operator and the train re-starts.

© Copyright 2009 London Underground Limited. All rights reserved.

3.2.19.7 If movement authorities are not available, or a train has insufficient inertia to reach the next station, the train is braked to a stand.

3.2.19.8 If a train comes to a halt in the dead section without reaching a station, the train's batteries have sufficient capacity to maintain those services on-board which are essential to customer safety and comfort for a minimum of two hours. The status of the power sources is presented to the Train Operator and to the responsible RCU enabling strategic decision making on how best to use remaining power. This is essential to enable operational staff to determine the train's capacity to move under Self Power, without compromising the ability to maintain essential systems.

3.2.19.9 These services include:

- Saloon emergency lighting
- Train Radio
- Remote public address system
- Passenger emergency alarms, including the ability to listen into PEAs at the OCC
- Train secure indication
- External lighting and display systems,
- Recording and on demand transmission of CCTV images
- Saloon ventilation
- Sufficient control functionality to enable train to resume automatic operation on restoration of traction power
- Sufficient control functionality to enable self-powered movement
- Fire detection
- Saloon interior digital customer information displays

3.2.19.10 If a train has come to a halt in the dead section, but still has a movement authority the responsible RCU or Railway Manager may take the decision based on a dynamic risk assessment, to use the power from the train's batteries to move it closer to the station under the advice of Service Control.

3.2.19.11 The Train Operator initiates self-powered movement from the operating position.

3.2.19.12 This action impacts on the amount of time the essential services on the train can be maintained. The decision is therefore based on a dynamic risk assessment, determined by the capacity status of the train's batteries, the proximity of the train to the nearest station, and the predicted time to recovery of traction power.

3.2.19.13 In the event that loss of traction current is likely to persist for a significant period of time, and trains are stranded in tunnels without movement authority or sufficient

© Copyright 2009 London Underground Limited. All rights reserved.

battery power, the responsible RCU may take the decision to evacuate customers on foot to the nearest platform or evacuation point.

3.2.20 Recovery from a failure of the signalling system

3.2.20.1 In the event of a failure of the wayside or centrally located signalling system, the RCS raises an alarm to the responsible RCU indicating the affected section of the railway.

3.2.20.2 All trains in the affected section detect the loss of signalling control and immediately brake to a halt; where possible further trains are prevented from operating into the affected area. .

3.2.20.3 Communication between customers on the train and the Train Operator, and CCTV feeds from the train to the in-cab monitors are unaffected by signalling systems failures. Therefore, it remains possible for Train Operators to communicate with customers on affected trains to provide them with reassurance and instructions, and to monitor conditions and customer behaviour on-board trains.

3.2.20.4 A record of the last logged position of each train is retained for Service Control staff. If the system cannot recover, without human intervention, a procedure is put in place to recover the trains. [Note: This could be one of a number of recovery procedures available to the RCU but without signalling protection the movement of trains will be in Manual Mode.]

3.2.20.5 When the failure has been rectified, signalling communication is re-established with all trains in the affected area, and gathers information about their actual locations. This is automatically cross-referenced with the record of the trains last known location, with any discrepancies raising an alarm to Service Control staff.

3.2.20.6 In the event of being unable to establish signalling control of individual trains, the response is the same as for recovery of a non-communicating train.

3.2.20.7 Once ATC has established the location of, and control over all trains in the affected area, the RCU authorises automatic working to re-commence.

3.2.20.8 If the failure has affected a significant number of trains, the sequence in which they re-start is automatically staggered to prevent overloading and tripping out the traction current system.

3.2.21 Recovery of a non-communicating train

3.2.21.1 In the event of a failure of train-borne signalling equipment on an individual train an alarm is raised to the Train Operator and the responsible RCU.

3.2.21.2 As a precaution, the train brakes to a halt; the signalling system imposes a buffer zone around the last known position of the train to protect from collisions and if possible, any further trains from entering the affected section.

© Copyright 2009 London Underground Limited. All rights reserved.

3.2.21.3 If the failure of the train-borne signalling cannot be rectified, as there is no protection, the train is recovered in a Manual Mode and driven by line-of-sight at low speed, until it has re-established communication with the signalling system, or if this is not possible, to the nearest suitable stabling location.

3.3 Customer Movement

3.3.1 Introduction

3.3.1.1 This section deals chiefly with the movement of customers on and off trains, and with evacuation of customers from trains.

3.3.1.2 Upgrades to Station operations are outside of the scope of the NTfL project, therefore the movement of customers around Stations, and Station Operations other than the provision of customer information on platforms, are not dealt with in this document.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted].

© Copyright 2009 London Underground Limited. All rights reserved.

3.3.3 Close door and train runs out

3.3.3.1 The monitoring of the PTI is consistent with attended operations on ATO lines across the LU network and is managed by the Train Operator during platform departure and arrival.

3.3.3.2 Platform based cameras transmit pictures to OPO CCTV monitors at the operating position, enabling the Train Operator to view the full length of the Platform-Train Interface (PTI). The Train Operator is able to select between images from OPO CCTV and in-car CCTV cameras, enabling visibility of individual saloon doorways, if PTI incidents occur. However, they would be primarily using the OPO CCTV to monitor the PTI.

3.3.3.3 Note: Images from the OPO, headwall and platform CCTV camera are available to RCUs in the OCC enabling situational awareness of train's in platforms, improving the timely dispatch of trains, and assisting with recovering services, when the railway is degraded.

3.3.3.4 The Train Operator is provided with an indication of the dwell time, and a countdown indication to the point where they receive movement authority and departure can be initiated. When the dwell time expires, the Train Operator will be provided with an audible alert and visual indication.

3.3.3.5 Note: Passenger loading information is reported to the OCC on a per bogie, per car and whole Train basis. Enabling situational awareness during incidents and helping to improve dwells by managing passenger movements to lower loaded areas of the Train and platforms.

3.3.3.6 Once movement authority is received the Train Operator checks to confirm the PTI is clear from hazards and therefore safe.

3.3.3.7 The Train Operator closes the passenger doors.

3.3.3.8 The Train Operator initiates the train's departure from the platform.

3.3.3.9 If the dwell is extended beyond what is predetermined within the service pattern the Train Operator and the responsible RCU in the OCC is notified.

3.3.3.10 When departing the station, OPO CCTV images are provided at the operating position enabling the Train Operator to monitor the PTI, up until the point the train is entirely clear of the platform.

[redacted]

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

3.3.5 Saloon doors failing to open/close

3.3.5.1 The train automatically sends an alert to the Train Operator and the OCC if a there is a defective door. [Note: This is separate from a failure to open or close doors due to an obstruction, in this circumstance, an alert will only be sent after the number of instances exceeds a pre-set tolerance. This is to be developed further during design.]

3.3.5.2 If the train doors fail to open or prove closed, and in the event of failure of the Correct Side Door Enabling (CSDE) doors operation is achieved by the emergency door open switch. The train cannot be moved and the emergency brakes are applied if the emergency open switch is activated.

3.3.5.3 Individual train doors can be taken out of service by the Train Operator, if they become defective. Customer information advises passengers at the doorway that the doorway is out of service and to move to a different one.

3.3.5.4 If the Train cannot close and interlock all doors, the Train Operator will not receive a *doors closed visual* indication and the train will not generate movement. To clear an obstacle preventing door closure, the Train Operator can choose to either re-open or close all doors, or selectively re-open and close the individual doors failing to close and lock. Outside Door Indication Lights (ODIL) are fitted on both sides of

© Copyright 2009 London Underground Limited. All rights reserved.

each car, which when illuminated inform operational staff from the platform that a saloon door is not closed.

3.3.5.5 In the event of a fault that results in doors failing to close and lock, the door interlock system can be cut out, enabling train movement.

3.3.6 Customer Evacuation – General principles

3.3.6.1 This section details the way in which customers can be evacuated from trains at various locations on the railway, in the event of a serious incident or emergency.

3.3.6.2 In the event of a serious incident or failure leading to trains becoming stranded in tunnels, the RCU in charge of the incident (usually the Service Manager) assesses conditions on-board trains, including saloon temperatures and loading, which are reported by trains to the RCU in the OCC. This information provides context to the decision to evacuate customers from trains. The Train Operator will feed information back to OCC, informing them of status of passengers on board the train. This informs the response to the incident.

3.3.6.3 In almost every case, it is desirable that customers are assisted to evacuate by members of staff. However, it is recognised that in extreme cases, this may not always be possible. Therefore, provisions are also made in this section to safeguard customers in the event that they self-evacuate from trains.

3.3.7 Customer Evacuation

3.3.7.1 If a train is stranded at a platform, and powered door control is unavailable, staff on the platform use manual controls on the exterior of the train to release at least one set of saloon doors allowing customers to alight.

3.3.7.2 If powered door control is unavailable, the Train Operator accesses door controls in the vicinity of each doorway allowing them to manually open the saloon doors.

3.3.7.3 If a train is stranded in a tunnel, and traction current is still available, the quickest and safest way for staff to reach it is by travelling on another train. Otherwise, staff must walk along the track to the stranded train(s), having taken suitable safety precautions.

3.3.7.4 Customers are evacuated both by transferring them directly to an assisting train, via the end-doors, or to the track via the detrainment device and escorted to an assisting train, platform or evacuation point.

3.3.7.5 The train’s end doors (M-Door) remain unlocked and accessible to staff from the exterior. [Note: The open/closed status of the rear M-Door is reported to the Train Operator at the active cab. Opening the rear M-Door initiates an alarm in the drivers cab and the train cannot move automatically.]

© Copyright 2009 London Underground Limited. All rights reserved.

3.3.7.6 Trains are equipped with detrainment devices at both ends to enable staff and customers to get safely from the train to the track (and vice versa) or to an assisting train.

3.3.7.7 Detrainment devices are not accessible to customers, but can be deployed and re-stowed by a single, trained member of staff.

3.3.7.8 When the detrainment device is deployed, lighting on the train illuminates the device, and the area of track at its base.

3.3.7.9 Trains carry a short-circuiting device at each end, to be used by attending staff to prevent accidental recharging of traction current, once it has been switched off to allow staff and customers to walk along the track.

3.4 Managing the Service

3.4.1 Managing the Service and Staff – General principles

3.4.1.1 This section details routine operations which require the intervention an RCU or Train Operator.

3.4.1.2 In cases where an RCU needs to make changes to the automated running of the railway, for whatever reason they are provided with decision support information. This information takes the form of validation checking of proposed changes to the active service plan, for example, allowing the RCU to understand the potential impact of their proposals and then either continue with the change, or adopt an alternative course of action.

3.4.1.3 A channel for secure one to one voice communications between all operational staff is available across the NTfL network.

3.4.1.4 A channel for one-to-many voice communications encompassing all operational staff is available across the NTfL network.

3.4.2 Edit a train's route/path

3.4.2.1 The RCU also has option to cancel and amend the route and destination of individual trains in response to observed, reported or predicted changes to operational conditions. This includes routing a train to a different branch due to customer demand, taking a train out of service before the planned end of its mission and routing it to a stabling location. This is required, for example, if that train has become defective and cannot complete its mission.

3.4.2.2 Detrainment of customers when a train is taken out of service also applies to scheduled detrainments at, for example, the last Station before a train enters a stabling location at the end of its current trip (see section 3.2.5).

3.4.2.3 If it is necessary to change the route / destination of a train, the RCO changes the train's path to an alternative path within the active Timetable. The new path is

© Copyright 2009 London Underground Limited. All rights reserved.

communicated to the train. The Train Operator is made aware by an in-cab alert and the information is communicated to them. The appropriate announcements are made to customers, and destination displays and if applicable the running number on the train are changed without the need for action by the operator.

3.4.2.4 Note: The Train Operator can manually set or change the Train's Destination Indicator and Running Number from an interface provided at the operating position.

3.4.3 Stepping Back

3.4.3.1 Stepping Back is a planned timetabled event where Train Operators are booked to "step back" to a later train at a reversing platform. This technique is used to provide a higher level of service than otherwise possible if each Train Operator took the same train out which they brought in, due to the time it takes to change ends. Trains are not renumbered in stepping back.

3.4.3.2 The Train Operator shuts down the train, leaves the cab, and activates an indication they are clear. The Train Operator waiting at the other end of the train is provided with an indication informing them what mode the train is in, that the rear cab is clear and that he/she may now open up the cab at their end of the train.

3.4.3.3 The Train Operator permits the train to be routed for its reverse or onward journey.

3.4.3.4 The train's reverse route will not clear until the rear cab is confirmed clear and the leading end of the train is fully active.

3.4.3.5 Stepping back on the current railway occurs at Arnos Grove on the Piccadilly line and Elephant and Castle on the Bakerloo line. [Note: Despite a low TpH at Arnos Grove (11Tph), Stepping back increases the speed in which the service can be recovered, reducing turnaround times to 2 minutes.] Stepping back on the Central line only takes place during closures and can be carried out at White City or Liverpool Street.

3.4.3.6 [redacted]

3.4.4 Reforming the Service

3.4.4.1 Reformations are used to recover disrupted service patterns and late running. If a train is sufficiently delayed that it is now running in the timetabled path of a subsequent train, its running number is changed, at a suitable location (usually at a Crew relief point), to that associated with the path in which it is actually running. The Train's running numbers are changed automatically, as they receive the new path allocated to it.

3.4.4.2 The subsequent train may be re-numbered to avoid having two trains with the same running number. The process is repeated, as appropriate, until the service is again running to timetable.

© Copyright 2009 London Underground Limited. All rights reserved.

3.4.4.3 The RCO can renumber trains but it is the responsibility of the DTSM to ensure that Train Operators are on the trains in which they are rostered to operate.

3.4.5 Code Amber

3.4.5.1 Code Amber is an operational procedure that is used to hold trains in platforms when an incident or failure occurs.

3.4.5.2 The responsible RCU can apply this function with great flexibility using signalling controls.

3.4.5.3 The RCU chooses to apply Code Amber, as applicable, to:

- all trains on the line
- all trains on either road
- all trains within a specific area
- multiple trains
- individual trains

3.4.5.4 ATC then moves the trains into platforms, if they are not already standing at one, and ensures that they do not depart until the Code Amber is lifted.

3.4.5.5 If a train is prevented from moving into a platform, it is held as near to the platform as signalling permits and an indication is sent to the RCU to take the appropriate action.

3.4.5.6 Train Operators are automatically alerted within the zone of Code Amber, that the procedure has been applied.

3.4.5.7 Real-time disruption messaging is automatically transmitted to affected trains and Station information systems.

3.4.5.8 If it becomes necessary for the responsible RCU to permit specified trains to move out of platforms without lifting Code Amber, the RCU overrides the command for individual trains.

3.4.5.9 When Code Amber is lifted, if a number of trains in the same traction current section have been held, the sequence in which they re-start is automatically to prevent overloading and tripping out of the traction current system.

3.4.5.10 Code Amber functionality is available at all times**.**

3.4.5.11 The RCU can choose remove Code Amber to the same level of granularity as it is applied.

© Copyright 2009 London Underground Limited. All rights reserved.

3.5 Managing Special Running Conditions

3.5.1 Managing Special Running Conditions - General principles

3.5.1.1 This section details railway processes used to manage non-normal events which do not require an emergency response.

3.5.2 Programme Station/Platform skip

3.5.2.1 When non-stopping becomes necessary, an RCU selects the appropriate platform, station or group of platforms, and closes it/them either indefinitely, or for a period of time which they can specify.

3.5.2.2 The RCU can override the non-stop instruction for a selected train, or trains. This may be used, for example, when an empty train is used to take staff to a worksite on a closed platform.

3.5.2.3 It is also possible to prevent an individual train from stopping at all platforms between two designated points on the line. This is generally used for empty stock movements, e.g. transferring a faulty train to a maintenance facility.

3.5.2.4 An automated notification is sent to the Train Operator if a station or a platform is closed.

3.5.3 Providing protection for persons on the track

3.5.3.1 The word “protection”, when used in an operational context, refers specifically to protection from moving trains. Therefore, providing protection in an area entails ensuring that no trains are able to move into or within that area. Such an area is known as a Zone of Protection.

3.5.3.2 Zones of Protection are usually enforced by the signalling system.

3.5.3.3 However, a Train Operator can enforce a Zone of Protection immobilising a train behind the area in which the protection is required.

3.5.3.4 In this circumstance, the Train Operator immobilises their train, ensuring it cannot move until the train is re-enabled for movement by that Train Operator. The immobilised train then prevents any other trains moving into the zone from the rear.

3.5.3.5 This does not protect staff on the track from a train undertaking a non-normal direction movement (see section 3.1.12). However, since an RCU or Train Operator must obtain authorisation from the responsible RCU before accessing the track or permitting others to access the track, and a non-normal direction movement must also be set up and authorised by the responsible RCU, this provides an operational control to manage that risk.

© Copyright 2009 London Underground Limited. All rights reserved.

3.5.3.6 The responsible RCU can also remove movement authority. Trains operating in ATO within and approaching the Zone of protection are prohibited from moving by the signalling.

3.5.3.7 Depending on location, the responsible RCU can also set and hold points or close a track such that any approaching train is routed away from the Zone of Protection.

3.5.3.8 When a Zone of Protection has been set up, all other RCUs are able to see, the physical limits of the protected area, and the identity of the responsible RCU.

3.5.3.9 The RCU communicates the extent of the Zone of Protection to the Train Operator via the operational radio.

3.5.3.10 A Hand-signaller can be put in place to prevent a train from being manually driven into the Zone of Protection.

3.5.3.11 Only a responsible RCU can lift the protection and permit trains to run again once they have received confirmation from staff on site that it is safe to do so.

3.5.4 Providing protection for persons on the track (Staff Protection Key Switch)

3.5.4.1 At certain locations, a Zone of Protection can be established by use of a Staff Protection Key Switch (PKS). This is a physical switch which can only be operated when a unique key is inserted in it, and which interfaces with signalling and train control. . A PKS can be operated by any member of staff requiring access to a clearly specified and delineated section of track, provided they have first contacted the responsible RCU and requested permission to operate the switch. The RCU must first ensure that no trains are in, or approaching the area. When the PKS is operated, the signalling prevents any train from entering the area associated with the switch.

3.5.5 Responding to a track defect

3.5.5.1 [redacted]

3.5.5.2 If a potential track defect is detected by the Train Operator, the RCO may request for Train Operators to be vigilant, while the Train travels through the vicinity of the suspect defect.

© Copyright 2009 London Underground Limited. All rights reserved.

3.5.5.3 If a track defect is confirmed a temporary speed limit may be imposed on all trains running through the area until the defect is rectified by the Maintenance organisation.

3.5.6 Response to a Train Overrunning its Movement Authority

3.5.6.1 The most likely cause for a train overrunning its movement authority is poor wheel/railhead adhesion, causing the train to slide past the point at which the signalling system intended it to stop. In this circumstance, the Train Operator is aware the train is out of the platform stopping tolerance and an alarm is raised to the responsible RCU.

3.5.6.2 At platforms if the train overruns and is within one car length the Train Operator can set the train back to within the correct stopping tolerance.

3.5.6.3 If the train overruns by more than one car length and as long as the route ahead of the train is clear, the RCU is able to cancel the Station stop, instigate automated announcements to customers both on the train and at the Station, and authorise the RCS to move the train on to the next Station, or as far as the signalling permits.

3.5.6.4 If the train has stopped short of the correct position and cannot be realigned, the Train Operator can open the train's doors where the train is, allowing passengers to board and alight. A through gang-way train improves the movement of passengers throughout the train.

3.5.6.5 The train can be moved back into place with a non-normal direction move.

3.5.6.6 In certain circumstances, for example if a train overruns the stopping point at a terminal or reversing location, the Train Operator may be required to move in Manual Mode control back to the stopping point.

3.5.7 Response to miscellaneous train generated alarms

3.5.7.1 The train transmits data to the OCC and Depot regarding the "health" of the train. The train constantly transmits data, this will allow an RCU in the OCC the ability to respond to disruption of potential sources of delay in a timely manner.

3.5.7.2 More information is detailed in Vol 2 Part 3 NTfL Fleet & Depot Maintenance Concept.

3.5.7.3 For GOA2 the train system notifies the Train Operator, the responsible RCU and a maintenance representative in the OCC of any relevant train system defects. If necessary the train may apply the safety brakes (if the failure relates to a safety system).

3.5.7.4 Where possible, the train will take the necessary steps to resolve the problem without human intervention.

© Copyright 2009 London Underground Limited. All rights reserved.

3.5.7.5 A HMI is present at the train's operating position which is reflected in the OCC for the responsible RCU and maintenance representative to support the Train Operator and respond to a train fault. Where possible the train will indicate any fault to the Train Operator and staff in the OCC.

3.5.7.6 The information the Train Operator receives is concise and relevant, and employs Human Factors best practices such as prioritising information to manage workload, in accordance with operational needs. They are limited to information that only they can take action to address, or which improves their situational awareness, avoiding distraction from higher priority tasks, such as supervising the PTI or monitoring the route ahead.

3.5.7.7 When an on board system failure occurs the Train Operator is notified by an audible and/or visible alarm and possibly also by the application of the safety brakes (if the failure relates to a safety system).

3.5.7.8 As far as reasonably practicable all faults shall be detected, recorded and reported by the train.

3.5.7.9 The train's maintenance strategy makes use of remote asset condition monitoring, self-monitoring and self-diagnosis. Real-time data aids the rectification of on train faults, assisting fleet maintenance and enhancing reliability.

3.5.7.10 [redacted]

3.5.7.11 Note: More information and the current DISI can be found in The Management System library.

3.5.8 Operate and inspection Train – without track access

3.5.8.1 On occasion it is necessary to inspect an area of track or tunnel. In most circumstances this will be carried out by a Train Operator driving through the affected area at reduced speed and reporting anything they might see.

3.5.8.2 The Train Operator puts the train into Manual Mode which allows the train to be driven at a reduced speed should they choose to do so, or to easily stop the train at a particular point of interest (e.g. to inspect a set of points) while maintaining ATR around the inspection area.

3.5.9 Operate an inspection Train – with track access

3.5.9.1 When required the train will be used to transport staff to locations along the railway in order to carry out track inspections.

© Copyright 2009 London Underground Limited. All rights reserved.

3.5.9.2 In this instance, the train identified to carry out the inspection will pick up the required staff from a platform relevant to the location where the inspection is to be carried out. The staff enter the cab through either the cab-side door (if available) or the leading set of passenger doors and then via the J-Door.

3.5.9.3 If the specific location requiring inspection is unclear and therefore a large area of track requires inspection, the Train Operator puts the train in Manual Mode, enabling the train to be operated under the control of the Train Operator at a speed that enables them to inspect the area. Because there is signalling protection the train is cable of being manually driven at full line speed. [Note: If signalling is unavailable the train is restricted to 16KpH.]

3.5.9.4 Otherwise, the train remains in Automatic, and moves to an appropriate location.

3.5.9.5 At the inspection location the train is put into Train Secure mode and immobilised.

3.5.9.6 To access the track, the inspection staff open the M-Door (tunnel section) or Cab Door (open section) and exit the train, using handrails and tread plates, to get to track level.

3.5.9.7 Once the inspection staff are back in the train, or in a place of safety, the Train Operator confirms to Service Control that all staff are clear of the track and safe. The train is put into Automatic mode, and continues to the next available station where normal operation commences.

3.5.10 Responding to low adhesion

3.5.10.1 LU's predictive Condition Monitoring system (ACCAT) will be in continuous all year round operation to manage performance and implement a range of mitigations in areas subject to variations in adhesion. The system will be managed by the adhesion controller (Operations Engineer in the OCC)

3.5.10.2 To assist trains meeting the braking performance required the train is fitted with Wheel Slide Protection (WSP) and an automatic sanding facility which will deposit sand automatically on the rail head when the train detects wheel slide. Sand levels are reported remotely to the condition monitoring system and may be reported to the Train Operator only, when sand levels reach a certain level.

3.5.10.3 In addition dedicated trains will dispense Sandite (thick paste adhesion improver active for a number of hours) during the leaf fall season (October – December) when adhesion levels in certain areas are subjected to significant degradation. The operation of these trains will be timetabled and co-ordinated by the adhesion controller. On the eastern branches the limited open sections will have other fixed means of dispensing Sandite.

3.5.10.4 Either the adhesion controller (Manually)or the OCC (Automatically) have the ability to increase or decrease the acceleration and braking profiles used by ATO trains in an individual section or sections of the line depending on the environmental conditions affecting the track as assessed by the predictive condition monitoring

© Copyright 2009 London Underground Limited. All rights reserved.

system. It is possible to set different braking profiles on different sections of track. The brake rate will be adjusted by the adhesion Controller in consultation with the Service Control staff.

3.5.11 De-icing train

3.5.11.1 Each train has sleet brushes to remove snow/ice deposits that have accumulated on the conductor rail. In GOA2 these are manually controlled by the train operator, on instruction, following the observation of snow/ice.

3.5.11.2 A proportion of the fleet has a de-icing fluid dispensing capability that works by means of laying the fluid directly on to the conductor rail head as a preventative measure while the train is running at line speed in ATO as normal. The laying of the de-icing fluid is switched on by the OCC or by the Train Operator. Whoever turns on the de-icing will be responsible for turning it off. There is an inhibiting device to stop de-icing in tunnel sections. De-icing activation control from the OCC is assisted by the use of weather reports and information from dedicated line side weather stations.

3.5.11.3 The de-icing levels are reported to the condition monitoring system available in OCC and are only reported to the Train Operator once levels drop below a certain level. Levels are replenished by the train maintenance staff in dedicated quick refill facilities located in each depot to assist quick refill in periods of high risk

3.5.11.4 Service de-icing trains are scheduled in the timetable to ensure the correct allocation of de-icing trains on the NTfL Piccadilly line railway. The OCC manages de-icing fluid levels to ensure coverage of the fluid across the line and protecting fluid levels in any given traffic period to avoid service disruption from trains being removed from service for refilling de-icing tanks

3.5.11.5 The traction package on the train is resistant to the risk of stalling when operating selected in ice/snow conditions.

3.5.11.6 All key track points are fitted with thermostatically controlled point heaters with. The current status and condition is reported to the OCC in addition to Depot and stabling locations where conductor rail heating strips are fitted.

3.5.12 Turning traction current on and off

3.5.12.1 The London Underground Power SCADA system enables RCUs to directly switch off and enable the switching on of traction current in a consistent manner in any section across the whole of the line. When an RCU switches off traction current, the system automatically applies a lock to inhibit the section from being switched back on by Power Control Room (PCR) staff without the authorisation of the responsible RCU [Note: this lock can be overridden by PCR staff, if necessary, provided the correct operational checks and controls have been applied].

© Copyright 2009 London Underground Limited. All rights reserved.

3.5.12.2 Platform equipment enables staff at Stations to directly switch off traction current in their area in an emergency.

3.5.12.3 The Power SCADA provides a safety critical data feed, allowing all RCUs to know, with absolute confidence, the on/off status of every traction current section.

3.5.12.4 If a traction current section has been switched off to allow staff to access the track, for example to attend a Person Under Train Incident (PUTI), the responsible RCU can, depending on the location of the PUTI, remotely open traction current section switches in order to sub-divide the traction current section, allowing it to be partially re-charged in order to move stranded trains and provide some service to customers while the incident is being dealt with.

3.5.12.5 Traction current is always switched back on by an operative in the London Underground Power Control Room. However, the switch on must first be authorised by the responsible RCU in the NTfL Control Centre. Note: the responsible RCU must first reset the automatically applied inhibit.

3.5.13 Partially suspending the service

3.5.13.1 A partial service suspension occurs when a failure means it is necessary to prevent trains from being routed to a destination, or onto a branch, while maintaining as good a service as possible on the rest of the line.

3.5.13.2 Where this occurs the customer information is automatically updated and broadcast on trains and at Stations.

3.5.13.3 The RCO applies procedures from the Line Emergency Plan which may involve implementing an emergency Timetable on sections of the line not affected by the suspension – for more information on the existing Line Emergency Plan see OMC Reference Data.

3.5.13.4 All decisions regarding train movements must take into account Train crew duty schedules and provides the RCO with contextual information highlighting potential conflicts between planned movements and crew scheduling requirements.

3.5.13.5 Within the suspended section, the responsible RCU has the option to halt all trains, or to allow trains to continue to move, if possible, until they have cleared the suspended area or worked into platforms.

3.5.14 Setting a temporary speed restriction (TSR)

3.5.14.1 If a track, or other defect, necessitates that trains run more slowly than normal through a section of track the responsible RCU is able to set a speed restriction in any area of track.

3.5.14.2 The permitted speed that can be set and the geographical area in which the restriction applies, is defined by the RCU, and is not restricted by the system.

© Copyright 2009 London Underground Limited. All rights reserved.

3.5.14.3 TSRs are normally set as a first response to a reported track defect of rough-ride, or in response to a request from the maintenance organisation and are only lifted once it is proven that it is safe to do so.

3.6 Manage the Service in an Emergency

3.6.1 General Principles

3.6.1.1 For GOA2 Standard incident management protocols continue to apply, mirroring the Gold, Silver and Bronze command and control structure used by the emergency services, remaining consistent with Rule Book 2. Incidents are categorised from 1-3 depending on their severity. The command structure is dependent on the level of incident.

3.6.1.2 In an emergency, members of the RCO and Train Operators are able to override automated operations, provided they have the sufficient level of authorisation within the system and subject to operational procedures and controls that include a dynamic risk assessment, which may be conducted by Senior Operating Officials who are not part of the RCO.

3.6.2 Code Red

3.6.2.1 In an emergency, it may become necessary to immediately bring trains to a halt, regardless of their location. This is known as 'Code Red'.

3.6.2.2 It is usual practice to apply Code Red across the whole of a line as a first response, however, RCUs are able to select sub-divisions of the line in which to apply Code Red, if time allows.

3.6.2.3 The RCU chooses to apply Code Red, as applicable, to:

- the whole line
- specified sections of the line
- specified groups of trains
- individual trains.

3.6.2.4 When a Code Red is applied all affected trains are immediately braked to a halt, and holds them where they have stopped.

3.6.2.5 Trains at platforms are not allowed to depart, and if a train has already closed its doors, the Code Red application causes them to re-open.

3.6.2.6 Train Operators within the zone of a Code Red are automatically alerted that the procedure has been applied.

3.6.2.7 A message is automatically broadcast to customers on trains and at Stations.

© Copyright 2009 London Underground Limited. All rights reserved.

3.6.2.8 If it becomes necessary to move individual trains to places of safety while the Code Red is in force, the responsible RCU(s) are able to select trains and permit them to move to a specified point.

3.6.2.9 When the nature and affected location of the emergency has been identified, the responsible RCU(s) can, if applicable, lift Code Red from unaffected sections of the line while it remains in force elsewhere.

3.6.2.10 The RCU can choose to remove Code Red to the same level of granularity as it is applied.

3.6.2.11 When a Code Red is lifted, the automatic working of trains resumes without the need for further operator action.

3.6.2.12 The start-up sequence of trains in each traction current section is staggered to prevent the electrical system being overloaded by the current demand from multiple trains at the same time.

3.6.3 Fire/Smoke detection inside a train

3.6.3.1 When the train detects fire/smoke, an indication of which detectors have been activated, along with CCTV images of the affected area is provided to the Tran Operator. The Train Operator contacts the RCO to confirm receipt of the alarm. The train continues to proceed to the next available platform stop. The responsible RCU receives an alarm and an indication of which detectors have been activated. If required, the RCU triggers emergency customer information to the train.

3.6.3.2 The Train Operator maintains the ability to inform and reassure passengers using the PA or trigger pre-determined messages. The Train Operator, if possible, responds to passengers who may have activated a PEA.

3.6.3.3 The responsible RCU contacts the Station in advance to notify them and to prepare for a possible train fire.

3.6.3.4 The responsible RCU also contacts the LUCC to notify them and request the attendance of the emergency services at the station in advance.

3.6.3.5 When the train detects smoke in the passenger saloon, it shuts down the heating and cooling but maintains air ventilation on a car by car basis.

3.6.3.6 A Code Amber is automatically applied to the incident train, and to any train standing at or approaching the station to the rear.

3.6.3.7 The ventilation systems on the incident train and in the tunnel are automatically adjusted to maintain a supply of clean air, as far as possible, without fanning any fire present.

© Copyright 2009 London Underground Limited. All rights reserved.

3.6.3.8 If a train has already left the Station to the rear, it is stopped in the tunnel in readiness for a non-normal direction movement away from the incident train, if that becomes necessary.

3.6.3.9 When the incident train reaches the next Station and the saloon doors are opened, an evacuation message triggered by the RCU is automatically broadcast to customers.

3.6.3.10 If a fire is found, the service may be partially suspended while the emergency services deal with it.

3.6.3.11 Once the incident has been dealt with, the smoke detector resets, and the responsible RCU lifts the Code Amber, and automatic control of the affected trains resumes.

3.6.4 Fire/smoke detection exterior to a train

3.6.4.1 [redacted]

3.6.4.2 The responsible RCU receives an alarm and an indication of which detectors have been activated.

3.6.4.3 Depending on whether corroborating reports have been received from the Train Operators, customers or station staff, the responsible RCU may take the decision to detrain customers from the train standing at the Station to the rear, and run it empty through the affected area while the Train Operator observes the route for indications of fire.

3.6.4.4 If a fire is found, the service may be partially suspended while the emergency services deal with it.

3.7 Communication with Customers

3.7.1 General Principles

3.7.1.1 This section includes the provision of service and travel information to customers, both in real-time and when triggered by pre-defined criteria; and with two-way communications between customers on trains and staff.

3.7.1.2 Wherever possible the provision of customer information is automated. This is to ensure that messages are standardised and consistent with all other information and that messages are delivered to customers by both audio and visual means [Note: information is relayed by both audio and visual means, unless otherwise stated].

© Copyright 2009 London Underground Limited. All rights reserved.

3.7.1.3 The Customer Information System interfaces with existing Station Management Systems (SMS) and provides them with data feeds to ensure that information given to customers on Stations is as timely and accurate as that given on trains.

3.7.1.4 Live announcements made by the Train Operator, RCU or a member of station staff using a public address system (PA), either at a Station or on a train, take precedence over automated announcements. This ensures that if an emergency announcement is being made, it is not cut off by less urgent routine messages.

3.7.2 Communication with customers on the train

3.7.2.1 Customer information provided by the systems on the train is primarily automated and managed centrally by RCUs thereby improving the timeliness and consistency of information across trains that are in service.

3.7.2.2 Audio and visual customer information is provided to passengers on the train where possible via Visual Electronic Information Displays (VEIDs) and saloon loudspeakers.

3.7.2.3 VEIDs enable pictorial information, enhancing the messages provided to passengers in the event of a delay, disruption and when applicable in an emergency and so, helping to manage operational responses.

3.7.2.4 The Customer Information System requires little or no input from the Train Operator, but functionality is retained that allows them to:

- trigger “one-shot” messages - these are generic and can be applied ad-hoc dependant on the situation;
- make Public Address (PA) announcements;
- keep informed of customer and real time disruption information active on their train.

3.7.2.5 If the automated system fails the Train Operator can trigger disruption messages, as a back-up.

3.7.2.6 Line maps and diagrams are in the traditional paper format, allowing for maintainability.

3.7.2.7 All disruption information is provided in real time and distributed to trains by a responsible RCU located within the OCC. Information can include: disruption to journey interchanges, destinations, Stations; facilities; information pertaining to emergency and degraded operational scenarios and major events.

3.7.2.8 Customer information can be sent to individual trains, groups of trains and all trains.

3.7.2.9 Automated Real Time Information is provided that replicates the 30 and 90 second messages which Train Operators have traditionally provided via the PA in the event of a short term delay.

© Copyright 2009 London Underground Limited. All rights reserved.

3.7.2.10 “One shot” messages can be sent to individual trains by an RCU, replicating the functionality available to the Train Operator.

3.7.2.11 The Train Operator is able to select an “Out of Service” function which triggers specific customer information content and inhibits door controls to prevent the Train Operator accidently opening them.

3.7.2.12 Out of Service mode can be trigged through the RCS when a Train is being, or has been, removed from passenger service or is being used as a non-passenger carrying test train.

3.7.3 Making announcements to the train

3.7.3.1 The Train Operator has a Public Address (PA) facility at the operating position, enabling communication to passengers on board the train. A PA made by the Train Operator takes precedence over all other automatic information provided to passengers.

3.7.3.2 Remote PA is available to enable communication from the OCC to individual, multiple and all trains, overriding all other information provided to passengers. The Train Operator can override the remote PA.

3.7.4 Passenger Emergency Alarm (PEA) – General functionality

3.7.4.1 PEAs do not require an Operator to attend and re-set them locally. PEAs are cleared from the train’s operating position.

3.7.4.2 PEAs are fitted with covers to reduce malicious and accidental activations.

3.7.4.3 PEAs remain active at all times unless the Train is shut down, allowing passengers that may have been accidently over carried into stabling areas to contact the Train Operator.

3.7.5 A PEA is activated and the Train is stationary

3.7.5.1 If the train doors are already open, they remain open. Time Delay Closing is suspended.

3.7.5.2 If the train doors are closed but the train has not departed, the train doors will remain closed until the Train Operator re-opens them.

3.7.5.3 On departure, if the train is within station limits, and no PEDs are present, activation of a PEA will apply the Emergency Brake (see section 3.6.7)

3.7.5.4 The train does not depart the platform until all active PEAs are cleared by the Train Operator.

© Copyright 2009 London Underground Limited. All rights reserved.

3.7.5.5 Activation of a PEA prompts an audible alarm notifying the Train Operator, whilst visual information enables its location within the train to be ascertained. The alarm is silenced when the PEA is acknowledged.

3.7.5.6 The Train Operator is presented with CCTV images of the area around the activated PEA on in-cab monitors, which assists them to determine what response is required. If necessary, to improve situational awareness, they scroll through the in-car CCTV images, via the in-cab monitors, providing an alternative perspective.

3.7.5.7 CCTV images of the area around the activated PEA are available to the Train Operator until it has been cleared. CCTV images are stored on the train and can be downloaded to support incident investigation. Each CCTV image is identifiable by Car Number, camera location, date and time.

3.7.5.8 If multiple PEAs are activated CCTV images for the next PEA are presented as each PEA is cleared, this prevents different CCTV images being presented to the Train Operator each time an alternative PEA is activated.

3.7.5.9 Note: PEAs do not require the Train Operator to leave their cab in order to clear. The Operator is able to clear PEAs from the cab if they are confident the PEA does not require investigation in the saloon.

3.7.5.10 The Train Operator acknowledges the PEA from the operating position and communicates with the passenger audibly via the talkback facility.

3.7.5.11 The active PEA initiates an alert in the OCC. The responsible RCU is able to listen in to the communication between the Train Operator and passenger. If the Train Operator requires additional assistance, the responsible RCU arranges it.

3.7.5.12 If the Train Operator is required to leave the cab and investigate further, they secure the train and exit via the J-Door into the passenger saloon, otherwise if possible; they can exit the cab via the cab-side door and walk along the platform.

3.7.5.13 White PEA status indication lights on each car, enable platform staff to determine the location of the active PEA. The lights extinguish when all of the PEAs in that car are cleared.

3.7.5.14 PEAs are cleared one at a time from the operating position. Once all PEAs are cleared, the Train Operator indicates that the train can be handed back to the control of the RCS. The Train Operator is given authorisation to initiate normal platform departure.

3.7.6 The train is outside of station limits and in motion

3.7.6.1 Activation of the PEA prompts an audible alarm in the cab notifying the Train Operator and visual information enables its location within the train to be ascertained.

© Copyright 2009 London Underground Limited. All rights reserved.

3.7.6.2 The Train Operator will not see CCTV images of the PEA unless the train is stationary.

3.7.6.3 The Train Operator acknowledges the PEA and communicates with the passenger(s) audibly via the talkback facility.

3.7.6.4 The PEA can be cleared by the Train Operator, if they ascertain by talking to the customer that no assistance is required, or that the train does not need to be held at the next station.

3.7.6.5 The passenger doors open at the next available Station stop, and remain open until all PEAs have been cleared.

3.7.7 PEA Brake

3.7.7.1 PEA Brake (PEAB) is still present at locations where there are no PEDs, and will bring the train to a halt when a PEA is activated when the train is leaving a Station, provided some part of the train is still in the platform. The Train remains braked in the position it has stopped, until the reason for the PEA is identified and the incident is resolved. Train movements are managed around the incident and the service is regulated if the incident causes a delay. Code Amber may be applied within the affected zone of the incident – see section 3.4.5.

3.7.7.2 The procedure for responding to the PEA is that if the train is stopped in a platform is described in section 3.6.5. Through gangway trains enable easier access to an on train incident. Platform based staff may be required to assist with an on Train incident.

3.7.7.3 Throughout sections where PED installation is complete, the PEAB is not active and the train is considered to be in motion and continues to the next available Station stop, where the PEA will be handled.

4 Interoperability

4.1 Piccadilly line interoperability

4.1.1 Rayners Lane to Uxbridge

4.1.1.1 NTfL trains operating on the Piccadilly Line between Rayners Lane and Uxbridge run on track operated by the Metropolitan Line, and controlled from the Sub-Surface Railway (SSR) Control Centre at Hammersmith, therefore, the Piccadilly line service adheres to the Met line's Rules and Procedures.

4.1.1.2 [redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

4.1.1.3 Primary responsibility for signalling control, traction current and management of incidents, transfers to the Metropolitan Line Service Controllers once the train has left South Harrow, Westbound. The exact location is indicated by a trackside marker.

4.1.1.4 Once past this point, any call made by the Train Operator to Service Control using the train radio is automatically routed to the SSR Control Centre at Hammersmith.

4.1.1.5 On returning Eastbound, the reverse situation applies and control passes back to the NTfL Control Centre when the train is on the approach to South Harrow, with the exact location, again, indicated by a trackside marker.

4.1.1.6 [redacted]

4.1.2 Barons Court to Acton Town

4.1.2.1 The Piccadilly and District Lines run parallel to each other between Barons Court and Acton Town.

4.1.2.2 Responsibility for signalling control, traction current and management of incidents on the Piccadilly Line in this area remains with the NTfL Control Centre.

4.1.2.3 Responsibility for signalling control, traction current and management of incidents on the District Line operating as far as Turnham Green, remains with the SSR Control Centre.

4.1.2.4 Once District Line trains leave Turnham Green, Westbound, Primary responsibility for signalling control, traction current and management of incidents affecting them, transfers to the NTfL Control Centre. The exact location is indicated by a trackside marker.

4.1.2.5 On returning Eastbound, control for District Line trains passes back to the SSR Control Centre when trains are on the approach to Turnham Green.

4.1.2.6 Note: At the time of writing, it is proposed that District Line trains returning to Ealing Common Depot are taken out of service at Turnham Green, but due to the time constraint imposed by the need to maintain headways for District Line trains routed in service to the Richmond/Wimbledon branch, the out of service trains will be checked to ensure all customers have alighted at the old Chiswick Park Westbound platform.

© Copyright 2009 London Underground Limited. All rights reserved.

4.1.3 Acton Town to Ealing Broadway

4.1.3.1 [redacted]

4.1.3.2 District Line trains work to Ealing Broadway and reverse there in order to transfer to Ealing Common Depot. Conversely, a certain proportion of District Line trains leaving Ealing Common Depot work to Ealing Broadway and reverse Eastbound to Acton Town and then towards Turnham Green, where they enter service.

4.1.3.3 Primary responsibility for signalling control, traction current and management of incidents for all trains in this area is with the NTfL Control Centre.

4.1.4 Transfers to and from other lines

4.1.4.1 In addition to the areas of interoperability described above, it is possible for trains to transfer between the Piccadilly and other lines at three locations. These transfers normally only involve Engineers' vehicles. The locations are described below.

4.1.4.2 Trains can transfer from the Northbound road of the Northern Line to the Eastbound road of the Piccadilly line at King's Cross.

4.1.4.3 Trains can transfer to the Victoria Line from the Eastbound road of the Piccadilly line and from the Victoria Line to the Westbound road of the Piccadilly line at Finsbury Park.

4.1.4.4 Trains can transfer from the Eastbound road of the District Line to the Eastbound road of the Piccadilly line (and vice versa), and can also transfer from the westbound road of the Piccadilly line to the westbound road of the District line at Hammersmith.

4.2 Bakerloo line interoperability

4.2.1.1 NTfL trains operating on the Bakerloo line between Queen's Park and Harrow & Wealdstone run on track operated and controlled by Network Rail, therefore, the Bakerloo line service adheres to the adheres to Network Rail Rules and Procedures contained in the "Working Over Books"..

Note: It is expected, that because NTfL trains will be running under the control of existing Network Rail signalling, some functionality available to the Operator throughout the London Underground operated area, will be limited. Further detail will be elicited throughout the design phase, once we have a greater understanding of how NTfL assets are likely to perform.

© Copyright 2009 London Underground Limited. All rights reserved.

4.2.1.2 Similarly to the Piccadilly line between Rayner Lane and Uxbridge, because of the mixed operation of LU Tube Stock and Network Rail surface stock and the different floor height and door spacing, it is not possible to install PEDs. [redacted]

4.2.1.3 Bakerloo line serving stations remain owned and managed by Transport for London (TfL).

4.2.1.4 Incidents affecting the service beyond Queen's Park are dealt with in the first instance by Network Rail incident response, which is not covered within this document but can be found in the Network Rail Rule Book http://www.rssb.co.uk/standards-and-the-rail-industry/the-rule-book/new-digital-rule-book-manuals

4.2.1.5 In the situation where an incident does occur, the Bakerloo line RCO is notified. Due to the time it can take for Network Rail incident manager to attend and resolve the incident, it can be more effective for the incident to be managed by the NTfL RCO and supported by LU staff.

4.2.1.6 The NTfL OCC maintains visibility and awareness of the entire Bakerloo line service and as it does on the rest of the line, manages the train's health status and condition of LUL assets.

5 Appendix 1: Supporting information

5.1 Roles Supporting Train Operations

5.1.1.1 The current arrangement of the NTfL management structure is mirrored consistently on each line. The Performance Manager Trains (PMT) is responsible for the operational running of the railway on their respective line. They are supported by **Train Operations Managers (TOM)** whose role is to manage their assigned depot(s). They are responsible for people management activities including Train Operator utilisation, working with trade unions, effective attendance and disciplinary issues. The TOM manages and is supported by two types of Duty Manager:

- **Duty Train Staff Managers (DTSM)** provide effective Train Operator performance and deployment, to maximise customer benefit on behalf of the Train Operations Manager. They ensure Train Operators are able and appropriately allocated to perform their duties to requirements and maintain or recover the operating schedule. They have accountability for managing Train Operators and ensure shift coverage. They run the train crew depot desk in accordance with LU regulations, including monitoring the train crews and liaising with service control during a service disruption. They look after the welfare of train crews and the utilisation of spare crew to ensure the effective deployment of resources to minimise disruption to train services.
- **Train Operations Standards Managers (TOSM**) are accountable for people

© Copyright 2009 London Underground Limited. All rights reserved.

management activities on behalf of the Train Operations Manager (TOM). Their primary role is to support the TOM to ensure that performance targets are achieved. They are accountable for staff engagement and implementing change and face to face delivery of key company messages. They are also accountable for monitoring competence management of relevant staff and the effective management and utilisation of Instructor Operators.

5.1.1.2 **Train Operators** are the Line's resource, and are located at one of the various Train Crew depots. Train Operator training consists of a mix of simulator based activities in order to gain familiarisation with the stock, and practical exercises taking place in a train on "the road" or in the depot depending on what competency the Train Operator is required to demonstrate in order to pass out and become available for rostered duties. The main T/Op accountabilities are: Operational and safety tasks; Customer Care and Communication. Train Operators do not have user rights to the RCS and are not, therefore, considered to be RCUs.

5.1.1.3 **Instructor Operators (I/O)** are Train Operators Instructed to carry out the Line based training for all Train Operators and all other staff are a deemed necessary to hold a Train Operators license. I/Ops perform, when rostered the duties of a Train Operator

5.1.1.4 The **Service Manager (SM)** functions as the team leader during each shift and is responsible for:

- The strategy for operating the railway safely and in compliance with standing performance targets.
- Decisions that are required to maximise the service that is delivered during periods of disruption and to recover the service following periods during which acceptable levels of performance has not been delivered, or has not been possible.
- The effectiveness of the Service Control team and of its individual members.
- The Service Manager SM is able to make decisions about service delivery without the need to gain approval from a higher authority. The SM is responsible for the resolution of issues during periods of perturbation.
- The SM monitors the condition of the railway, reviews start-up problems (equipment failures, staffing issues, etc.) and determines the level of potential disruption to the scheduled service.
- The Service Manager is supported by Service Controllers, who perform the tasks traditionally associated with both the signalling and line control functions.
- During periods of disruption the SM co-ordinates and directs the work of the SCs and of other delivery focused personnel whether in or outside of the OCC.

5.1.1.5 Service Controllers (SC) are responsible for:

- Monitoring the movement of trains through the area over which they have

© Copyright 2009 London Underground Limited. All rights reserved.

control.

- Identifying potential or actual decline in, or loss of, acceptable service performance.
- Determining or assisting with developing strategies to recover the service.
- Implementing measures to recover acceptable levels of service.
- Responding to railway operating incidents and co-ordinating the response or working in collaboration with the Service Manager and carrying out instructions when necessary.
- Manually controlling train movements that are not directed by the automated system.
- Managing traction current and signalling equipment issues that affect the safe movement of trains.
- The new control system provides an effective range of tools that allow SCs to control the railway and the various sub systems during normal, abnormal, degraded and emergency operational modes.

5.1.1.6 **Duty Reliability Managers (DRM)** are line based, reporting to the SM, and has accountability for:

- Proactive management and support to Train and Station staff during incidents and events
- Responding to incidents on site, on behalf of the Service Manager
- Active and on-site monitoring of the effects of all incidents and disruptions to the normal operation of the train and station service
- Acting to ensure that safety is maintained for customers and staff on the railway
- Investigating and reporting on incidents, failures and delays, including conducting fact-finding interviews and taking witness statements
- Providing incident reports, detailing root causes, to enable business performance improvement and to meet legislative and corporate reporting requirements.
- Providing emergency cover for SCs in the OCC.

There are usually two DRMs are present at all times, and are based at strategic locations around each NTfL line. . The base locations for DRMs are equipped with standard IT equipment to enable them to prepare incident and investigation reports. When not attending incidents, or present at their base location, DRMs are expected to travel around the area of the railway for which they are responsible. This is to facilitate maintaining specialised railway knowledge, to build familiarity and collaborative working practices with station staff, and to provide customer service. The SM instructs the DRM(s) to attend incidents and events, as necessary. Additionally, DRMs are competent to use the S&TCS, and may be deployed to the

© Copyright 2009 London Underground Limited. All rights reserved.

OCC to assist the SCs in the event of an emergency or major incident. In this role, they are qualified to work on any NTfL line.

5.2 Train crew management

5.2.1 Train Crew Duty Allocations

5.2.1.1 Train Crew duty allocations are generated through SAP and are given to 'rostered' Train Operators a minimum of 28 days in advance of the duty. Pool Operators are notified of allocations on the Thursday of the preceding week prior to the duty. During normal service operation, the desk is operated by a DTSM who manages any perturbations in the service and for example; a Train Operator's Personal Needs Relief (PNR). During service disruptions, they will ensure that there is a Train Operator for each train by liaising with the Service Controller as the service is reformed. This process is aided by the Train Operator Coverage Plan (TOCP) which assists Service Control to optimise the available trains and Train Operator utilisation.

5.2.2 Train Operators booking on for Duty

5.2.2.1 Train Operators book on for duty with the Duty Train Staff Manager (DTSM). Operators book on at staggered times throughout the day, from the start of traffic to the close of traffic. Some Operators remain on duty throughout the night to facilitate late stabling, running 24 hours tube services, sleet working overnight and the earliest possible running of trains at the start of the traffic day.

5.2.2.2 The DTSM is responsible for ensuring that Train Operators are available for all timetabled movements with crew issues detected by TOCP. Although Service Control personnel are automatically notified via data available at the control desk, the DTSM is responsible for informing the Service Manager if attendance or similar issues will affect the ability to deliver a service.

5.2.2.3 Train Operator shift patterns are allocated via a roster. Each week of the roster has a set of predetermined duties and rest days. Provision is made to cover annual leave, sickness, welfare and disciplinary issues. Once a Train Operator is given a position within the roster they will continue to move in a chronological order, week by week from that position.

5.2.2.4 Each train operator duty is broken down into the running number of the trains to be operated, during the working day, together with book on/off time, times and locations at which the operator is to commence operating each train, and the times of meal reliefs.

5.2.2.5 At the start of their duty the Train Operator books on with the DTSM, confirming their fitness for duty. If the Train Operator is required to bring a train into service from a siding or depot they receive information about the train's location. This includes the road number and leading car numbers.

© Copyright 2009 London Underground Limited. All rights reserved.

5.2.2.6 Time is built into the start of each duty to enable Train Operators to carry out administrative tasks, receive management instructions, updates about the service, read notices and other publications.

5.2.3 London Underground Train Operator Coverage Planning (TOCP)

5.2.3.1 TOCP is an LU system used by the DTSM and accessed via LU's SharePoint site. The TOCP system interfaces with SAP and enables each Train Operator's location and trip details to be viewed online. It also shows the location of spare operators, each crew member's latest finishing times and their required meal reliefs. Service Control access the TOCP in a read only state which assists them to proactively rectify the service in a way that is simpler for the DTSM to crew because they have sight of remaining duty times for each Train Operator.

5.3 Timetables

5.3.1.1 London Underground makes changes to permanent Working Timetables (WTTs) for a number of reasons, for example but not limited to:

- Changes to customer demand
- Changes to asset capabilities
- Changes needed in consequence of other interfacing operators' changes

5.3.1.2 Changes to WTTs, are effected through the Train Service Change Process. This document outlines the two year timescale for specification, development, approval, compilation and introduction of timetables and their associated staff duty schedules. Temporary timetables for part-line closures are issued as a Timetable Notice (TTN) via a separate process.

5.3.1.3 The timetables are produced in "book" form and also as a data file, using the "Common User Format" (CUF) for use on computerised control systems. The CUF file is then converted to the appropriate format for the various control systems present across LU. This task is usually undertaken by the local Asset Performance Control & Information (AP C&I) teams, however in the case of the Central line LU Scheduling Services, who compile the timetables and duty schedules, also complete this conversion process. CUF files are converted to the format supported by the RCS.

5.3.1.4 The Piccadilly and Bakerloo line WTTs change on set Sundays in May and December only, in line with National Rail timetables. In the case of the Bakerloo line, this is to co-ordinate with the inter-operation of London Overground services, in the case of the Piccadilly line; this is to co-ordinate with the inter-operation with the Sub-Surface lines, which in turn inter-operate with National Rail services in various locations. Any changes outside of these dates are constrained by ensuring use of identical timetable paths in interoperable areas. Working Timetable changes on the Central and Waterloo and City lines can take place at any time, but are normally

© Copyright 2009 London Underground Limited. All rights reserved.

done on Sundays, partly to minimise any consequences of any problems arising from the change.

© Copyright 2009 London Underground Limited. All rights reserved.

6 References

The following documents are referenced in this document:

Table 1 – References		
Ref.	**Document ID**	**Title**
International Standards		
1.	UGTMS	UGTMS - Urban Guided Transport Management System
2.	IEC 62290-1	Railway applications – Urban guided transport management and command/control systems
3.	RSSB – (GE/RT8000)	RSSB – Rule Book
4.		
London Underground		
5.	N/A	London Underground Rule Books
6.		
7.		
8.		
New Tube for London Programme		
9.	NTfL-2344.1.1-LUL-RPT-00032	New Tube for London Operational Model and User Requirements Executive Summary
10.	NTfL-2344.1.1-LUL-RPT-00066	OMC Vol 1 Part 2 Operational Vision and Transformation Statement
11.	NTfL-2344.1.1-LUL-RPT-00066	OMC Vol 2 Part 2 NTfL [redacted] Operational Concept
12.	NTfL-2344.1.1-LUL-RPT-00066	OMC Vol 2 Part 3 NTfL Fleet & Depot Maintenance Concept
13.	LiveLink ref: NTfL-2344.4.5-LUL-DOC-00002	RCS Restatement Description
14.	NTfL-2344.1.1-LUL-RPT-00055	NTfL Customer Concept
15.	NTfL-2344.1.1-LUL-RPT-00032	The "New Tube for London Operational Model and User Requirements Executive Summary"
16.	NTfL-2344.2.2-LUL-DWG-00020	NTfL Functional Breakdown Structure
17.	TBC	OMC Reference Data

© Copyright 2009 London Underground Limited. All rights reserved.

7 Consultation

The following people were consulted in the preparation of this document:

Name:	Job Title:	Comments received:
[redacted]	Head of Operational Upgrades and Asset Development	27/01/16
	Upgrade Delivery Manager	12/12/15
	Lead Operational Development Manager	12/12/15
	Lead Operational Development Manager	12/12/15
	Operational Development Manager	12/12/15
	Operational Development Manager	12/12/15
	Operational Development Manager	12/12/15
	Operational Development Manager	12/12/15
	Operational Development Manager	12/12/15
	Head of Engineering, NTfL	No comment
	Principle Engineer, Systems	16/12/15
	Lead Signalling Principles Design Engineer	08/02/16
	Programme Delivery Engineer, RCS	No comment
	Programme Delivery Engineer, Rolling Stock	08/02/16
	Project Engineer, Rolling Stock	08/02/16
	Project Engineer, Rolling Stock	08/02/16
	Project Engineer, Rolling Stock	08/02/16

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]	Project Engineer, Rolling Stock	08/02/16
[redacted]	Lead Control Systems Project Engineer	No comment
[redacted]	Programme Delivery Engineer, Systems Integration	No comment
[redacted]	Programme Delivery Engineer, Infrastructure	No comment
[redacted]	Lead Sponsor NTfL Programme	No comment
[redacted]	Human Factors Delivery Manager	08/02/16
[redacted]	NTfL Lead Systems Performance Engineer	08/02/16
[redacted]	Embedded Engineer, RCS	08/02/16
[redacted]	Engineer, Signals and C&I	08/02/16
[redacted]	Lead Project Engineer, Infrastructure	08/02/16
[redacted]	NTfL Engineering Safety Manager	08/02/16
[redacted]	Systems Safety Engineer	08/02/16
[redacted]	Engineer, Systems Integration	08/02/16
[redacted]	Signalling Principles Design Engineer	08/02/16
[redacted]	Senior Project Manager	08/02/16
[redacted]	Customer Strategy Manager	08/02/16

© Copyright 2009 London Underground Limited. All rights reserved.

Transport for London
London Underground Limited

NTfL OMC Volume 2 Part 3

New Tube for London Fleet & Depot Maintenance Concept

		Signature	Date
Prepared By :	[redacted]		
	Asset Development Manager	[redacted]	11/4/16
Checked By :	[redacted]	[redacted]	
	Head Of Fleet BCV		15.4.16
Checked By :	[redacted]	[redacted]	
	Head of Fleet JNP		11/04/16

Revision	Date	Summary of changes
Draft A	18/12/2015	1st Draft for initial review and discussion
Draft B	02/02/2016	2nd Review for Review and discussion
Version 1	15/04/2016	First Issue

© Copyright 2009 London Underground Limited. All rights reserved.

TABLE OF CONTENTS

© Copyright 2009 London Underground Limited. All rights reserved.

© Copyright 2009 London Underground Limited. All rights reserved.

© Copyright 2009 London Underground Limited. All rights reserved.

© Copyright 2009 London Underground Limited. All rights reserved.

TERMS OF REFERENCE

The purpose of the Fleet & Depot Maintenance Concept is to describe how new or altered assets will be maintained over their lifespan. This is produced to provide:

- Consistency with corporate investment strategy for this asset group
- Consistency with the Business Plan and investment for related projects outside NTfL.
- Early involvement of Operations (Assets) in the design process.
- A common and effective understanding between designers and Operations (Assets)
- The asset is designed to fit and function within the proposed/expected maintenance environment.
- An aid to the Design Teams to allow understanding of the context of use which enables them to check the users understanding of what is being provided.
- This Fleet & Depot Maintenance Concept provides high-level maintenance objectives and assumptions to ensure alignment between the New Tube for London Upgrade Programme (NTfL), Sponsor and London Underground Operational Areas.
- This will provide Fleet Management, Project Management and Sponsorship teams with a common point of reference and baseline assumptions.

CONCEPT FURTHER DEVELOPMENT AND REVISION

This version of the concept has been developed prior to critical input of the detailed Train Maintenance Plans that will be received and analysed from the Rolling Stock supply chain forming part of the submission pack received back in the Invitation to Negotiate (ITN) process.

As a result a large number of assumptions have been made of Fleet Maintenance strategy and Depot facilities based on recent experience. These assumptions are planned to be revised in late 2016 following the analysis of specific information directly related to the NTfL train. It should therefore be noted that a major revision of this concept is planned at this point.

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

1 OVERVIEW & INTRODUCTION

1.1 NTfL Fleet Maintainability Objectives

Ensuring that the new Rolling Stock procured under New Tube for London (NTfL) Programme delivers world class maintainability and performance is critical to optimising the future whole life costs of the Piccadilly, Waterloo & City, Bakerloo and Central Lines. From the Programme requirements specification, the business objectives of the future maintenance function are stated as:

- Reducing Whole Life Cost
- High asset and service reliability; with the opportunity for continual improvement
- Efficient use of resources
- Consistent, predictable and high levels of asset availability.

The Rolling Stock must, where practicable, be maintained according to its condition with maintenance tasks planned to prevent failure in service.

To ensure that the new train (which is equipped with modern technology) can achieve the targeted high level of reliability and overall service performance demanded ,requires alignment of the design, the development of the Depot and the development of skills of the maintenance teams to ensure that the standard of high levels of quality and performance necessary can be achieved.

A supplier developed Train Maintenance Regime, making full use of modern condition monitoring and automated inspection technologies, will drive a predictive and condition based maintenance regime that ensures inspections are undertaken when they are required and where they add value to ensure the drive towards maintenance efficiency.

1.2 The Future Railway Duty Cycle

[redacted] This together with a larger fleet of more technically advanced trains will result in maintenance being scheduled into a smaller window of availability and drives the requirement for a train that that is designed for efficient maintainability minimising maintenance production time.

Productivity of the Depot is paramount for successful delivery of upgrade benefits. An overarching requirement upon the Depot design is to ensure that facilities are designed to be as flexible as possible to eliminate (or minimise) train movements during any planned intervention.

Guidance from Operations (assets) shall be sought to identify the optimal location for facilities, for example train wash plants located on reception or exit roads from Depots. The final design will cater for different types of maintenance being carried out on specifically designed maintenance roads as close to a production line methodology as possible.

Up to 90% of the NTfL fleet will be required to support the peak service train declarations, excluding any hot spares. In principle, this means a low number of trains available (between 3 and 10 depending on fleet size) on each line will be available at Depots during the days for longer planned interventions (e.g. wheel turning, door examinations, exams & programme lift) and casualty repairs. It should be assumed that there will be 2-5 trains of hot spares on each line. [redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

1.3 The Commitment to Safety, Quality & Efficiency

With the decision to retain first line maintenance of the new trains in house, the development of maintenance team skills to rise to the challenge of new technology is a fundamental part of the overall strategy for the introduction of these fleets. The introduction of the NTfL fleet must drive exceptional levels of maintainability that put the availability of the NTfL fleet into "World Class" performance.

The organisation has a fundamental commitment to the safety and efficiency of our teams undertaking maintenance. The facilities needed for the next generation of Rolling Stock must enable best practice in the development of production facilities, human factors and safety of operation in line with legislation including:

- Electricity & Work
- Working at Heights
- Human factors including taking into account the working environment

2 REQUIRED RELIABILITY, AVAILABILITY, MAINTAINABILITY PERFORMANCE

A declared strategic objective of the NTfL programme is improved railway reliability while increasing railway capacity, reducing journey times, lowering life cycle costs and improving customer experience. To ensure these objectives are achieved NTfL are following the general guidelines of EN BS 50126 Railway Applications – The specification of Reliability, Availability, Maintainability and Safety (RAMS) and EN BS 50128 Railway Applications – Communications, signalling and processing systems: Software for railway control and protection systems.

A RAM Strategy (NTfL-2344.2.2-LUL-PLN-00007) has been produced to outline the process by which the RAM requirements for the NTfL programme are determined and the RAM activities undertaken by NTfL and its Suppliers to achieve them.

[redacted]

The RAM Strategy includes consideration of:

- Customer influences
- Staff influences
- Traction and Auxiliary Power
- Platform / Train Interface equipment
- Railway Control System (Signalling & Train Control plus Operational Control)
- Rolling stock
- Track & Civils
- Station infrastructure
- Operational influences

The RAM Strategy considers all modifications associated with the future upgrades and how such changes will influence the overall Railway Level RAM performance. A RAM Management Plan

© Copyright 2009 London Underground Limited. All rights reserved.

(NTfL-2344.2.2-LUL-PLN-00011) has also been produced that provides a detailed description of the RAM activities applicable to the NTfL Programme scope, which takes the project from the System Requirements (phase 4) through the Apportionment of System Requirements (phase 5) stage and into the preliminary design (phase 6).

The RAM Management Plan outlines the arrangements for the detailed Reliability, Availability and Maintainability (RAM) requirements for the NTfL Programme and as such covers the following:

- Description of RAM Roles and responsibilities within the NTfL Programme organisational structure
- Identification of RAM requirements and tasks that need to be carried out for each identified line of route
- The NTfL Programme RAM approach follows the general principles of BS EN 50126

The aim of the detailed RAM activities identified within the RAM Management Plan is to assess the design specification against the RAM requirements and targets.

The RAM work detailed within the RAM Management Plan is intended to influence the overall operational reliability of the railway and therefore the RAM activities specifically include consideration of all factors that may affect service performance. This includes not only failure of hardware but also operational and maintenance issues that may contribute to reliability. Detailed targets are presented within the RAM Management Plan for all routes (lines) along with formal classification and acceptance criteria for each phase of the project [redacted] All NTfL suppliers are required to follow the general principles and practices defined within the RAM Management Plan as applicable to their specific system equipment.

3 LEVELS OF MAINTENANCE LEVELS (DEFINITION)

There are various types of maintenance interventions expected to be undertaken on the train. It is recognised that there are different, often interchangeable, terms are used to describe the various levels of maintenance intervention. For this reason, and to promote a common recognition of the terms used throughout this document, these interventions have been categorised into three levels; first-line, second-line and third-line.

In the context of this document first-line has been sub-divided to encompass response and corrective maintenance activities, whilst second-line and third-line Maintenance is used to describe the particular pathways taken in the repair and overhaul of equipment 'returned from the train following a first-line maintenance intervention. The table below indicates where each type of maintenance intervention lies in respect of first-line, second-line and third-line. A set of definitions is also provided for clarification purposes.

© Copyright 2009 London Underground Limited. All rights reserved.

Category		Maintenance Activity
1st Line Incident	1st Line Response
	1st Line Corrective
1st Line Preventive	Planned, Periodic Maintenance
	Preventive Corrective
	Component Wear Analysis
2nd Line Maintenance	'In-house' Overhaul & Repair
3rd Line Maintenance	'Out-sourced' Overhaul & Repair

Maintenance Intervention Categorisation

3.1 First-Line Maintenance (Definition)

First-line maintenance has been sub-divided to form two distinct categories of maintenance activity; first-line incident and first-line preventive.

3.2 First-line Incident (Definition)

'Incident' comprises both 'first-line response' and 'first-line corrective' maintenance activities and is primarily associated with the diagnosis and rectification of those faults and failures which are, or have the potential to become, Service Affecting Failures (SAF's) on any train across the fleet during its current or next service cycle.

It is necessary here to make the distinction between 'first-line response' and 'first-line corrective' activities. These have been defined as a function of those activities that are undertaken while a train is in service as "Incident" and those activities that are undertaken on a fault on a train in the depot as "Corrective.

3.3 First-line Preventive (Definition)

Preventive Maintenance relates to the planned, periodic maintenance activities seen as necessary to ensure the continued and effective operation of the system and identified by the Train Maintenance Regime.

The extensive use of condition monitoring and automated inspection will enable direct information to more intelligently target the maintenance regime based on asset condition rather than periodic intervals.

3.4 Second-Line Maintenance (Definition)

Second-line maintenance describes the process for repair and overhaul of whereby equipment, returned following a first-line maintenance intervention, is sent to an 'in-house' facility equipped with the capability of undertaking the work. Traditionally, the full repair and overhaul of legacy train equipment has been undertaken utilising London Underground's Railway Engineering Workshop (REW) based at Acton works. Once overhauled, this equipment is subsequently returned to Depot stores on each line ready to be refitted to a train as replacement component/module.

© Copyright 2009 London Underground Limited. All rights reserved.

3.5 Third-Line Maintenance (Definition)

Third-line maintenance is considered to be the repair/overhaul of equipment returned from a first-line maintenance intervention which is undertaken by the Supplier or a nominated sub-contractor with Supplier involvement. Under this arrangement there no second-line maintenance involvement other than some (e.g. on board signalling equipment) passing through the Underground's 'in-house' maintenance facility which is being used as a 'staging-point' to facilitate the recording and storage of defective items prior to Supplier collection and following their subsequent return

As modern Train systems have evolved so the equipment involved has tended more toward the adoption of 'black box' technology (hereafter referred to as Line Replaceable Units or LRU's). This approach facilitates quick fault diagnosis and rectification at a first-line maintenance level, allowing units to be replaced without the need for rectification at component level. However, due to its specialised nature any further examination of returned equipment often requires the use bespoke diagnostic and testing rigs.

In some cases it has been found to be more expedient to return defective Line Replaceable Units (LRU's) directly back to the Supplier for repair and overhaul. This ensures that failed equipment is restored to a serviceable state as quickly and cost-effectively as possible. The 'direct first-line to third-line' approach may also be dictated by the conditions of the supply contract and subsequently prohibits the opening of an LRU through the immediate invalidation of its warranty.

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

4.3 Fleet Maintenance Training Plan

The development and evolution of staff skills is fundamental to the successful implementation of the NTfL maintenance strategy. The principle of the NTfL training philosophy (NTfL-2344.1.1-LUL-RPT-00007) and Rolling Stock Whole Life Technical Support Life Cycle for New Tube for London - NTfL-2344.1.1-LUL-RPT-00044 reflects this strategy including the adoption of the strategy for early embedding of maintenance technical staff into the Programme and supply chain.

The Training Philosophy supports the use of a number of options to facilitate the delivery of training and enables greater cooperative working between LU and the Supplier to achieve "Right First Time" delivery of training prior to any assets being brought into use.

4.3.1 Rolling Stock Training

An NTfL training philosophy has been written to provide a structured approach to all aspects of the training of the maintenance workforce up to the post training delivery review encompassing preparation, delivery and management of training material, facilities, documentation and resources. This document has set out the scope of the training that the Suppliers training team will deliver to LU trainers, who will then train the front line Maintenance staff in order to provide a trained and competent workforce.

To support the training strategy, a training-working group has been formed to support the development of requirements with the key stakeholders. An NTfL training plan will follow once more detailed dates for fleet introduction and Depot build sequence is known.

A training needs analysis must be undertaken for all staff to ensure that the training can be developed and targeted at the right audience. This analysis will also assist in aligning any recruitment that is being undertaken for future readiness.

It should be assumed that when initial NTfL tube stock training occurs that it will require the permanent daytime use of one NTfL Tube Stock train at the earliest opportunity with the capability to stable new trains at each Depot for parallel training. Training facilities are to be specified to ensure that they will satisfy the requirements.

These arrangements must be integrated with Operational Staff Training to ensure that a comprehensive plan is developed that ensures that the need for new train availability for service and training needs are both satisfied. Training facilities are to be specified to ensure that they will satisfy the requirements.

Whilst legacy training activities are often carried out on maintenance trains, recent experience of S-stock has identified that there is a requirement for more 'power-on' time for maintenance and fault-finding. For this reason it should not be assumed until fully clarified with the design of NTfL train that a maintenance train can be used for training and a dedicated train must be allocated for the duration of the training plan. NTfL Tube Stock training will include the following courses:

The vehicle awareness course will consist of an overview of the vehicle, which will be aimed at non maintainers such as Cleaning Supervisors and other Depot Admin staff.

© Copyright 2009 London Underground Limited. All rights reserved.

Planned maintenance training will consist of safety isolations followed by preliminary generic practical skills tuition and then practical training on each system using the VMIs.

A systems overview course will aid systems understanding with respect to individual components, system function and maintenance requirements.

Shunting training will be delivered during initial training for all train maintenance staff who will undertake this task as part of their role.

Call Point training will be undertaken to ensure that the response to managing faults on trains in service minimises service impact with effective step-by-step instructions to allow Call Point personnel to overcome defects and symptoms of degraded operation of trains in passenger service in the early days of introduction.

Series train update (refresher) courses to cover any changes to the systems training and planned maintenance training as a result of design changes / modifications made to the series trains.

Work Arising training on the Vehicle Maintenance Procedures (VMPs) and aspects of inspection, removal and post renewal functional testing.

Fault finding training will consist of in depth system theory, general fault finding techniques, training in the use of the fault finding guides for each rolling stock system, and practical test exercises in fault finding on the trains themselves.

'Specialist Engineer Training' to provide skills to manage technical and incident investigations.

4.3.2 Depot Signalling Training

Training will need to be undertaken for those staff located in the Depot who are controlling the movement of trains in any Depot where the signalling system is installed, upgraded and modified. This training must include both the operation of stabling areas and movement of trains into and out of maintenance facilities.

4.3.3 Depot Facilities Equipment Training

Training is required for all equipment delivered as part of the Depot upgrade including those inside the Rolling stock supplier's scope and all equipment covered in the Depot and Infrastructure scope.

4.3.4 Operational & Information System Training

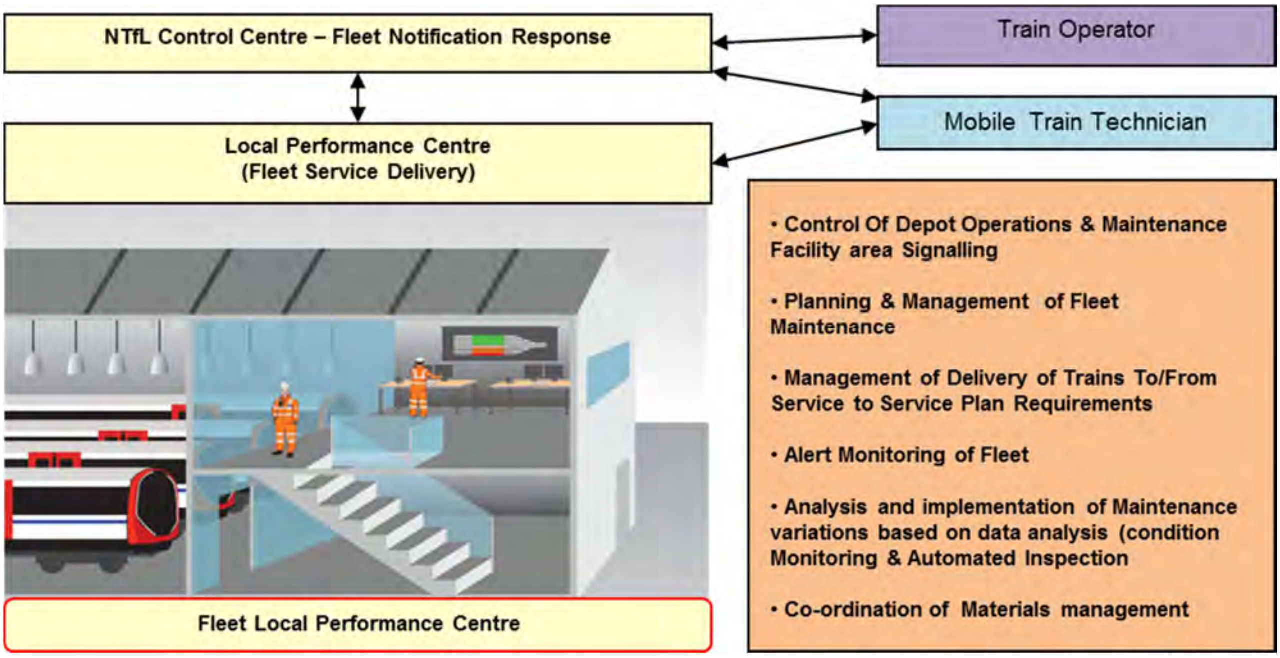
Various systems will be introduced as part of NTfL such as condition monitoring, automated Inspection and functionality with the Operational control system relevant to fleet operations. Training must be provided on all systems to ensure that staff can fully utilise and realise the benefits. This needs to be delivered as a fully integrated package.

4.4 NTfL Fleet Operations Management

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]



4.4.2 Event Management

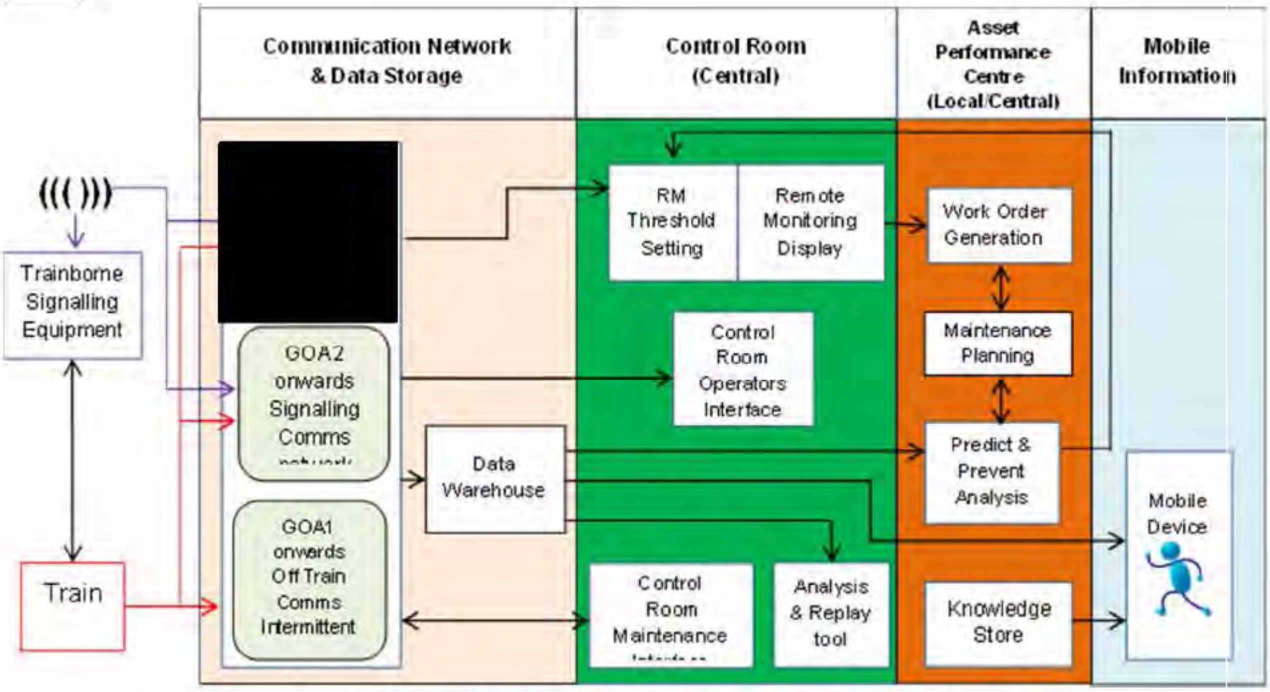
Mobile train technicians are positioned strategically on each line to assist with specific rolling stock issues and are directed by the OCC. Their primary role is to support the event management process giving on-site technical support. Management will be aligned to the Defective In Service Instructions (DISI) or new equivalent with a decision making tool used by the Service Control Staff based in the Line Control room/OCC. A simple hierarchy similar to the following existing DISI instructions is recommended:

- Remain In service
- Remain in Service to Depot
- Withdraw From Service

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]



Example of Data Communication Paths GOA1-[redacted]

The NTfL systems will have the capability to raise work orders on the LU Enterprise Resource Planning (ERP) system with priorities defined using a condition basis that enables the probability/ severity of the event to be categorised and an appropriate maintenance intervention defined. Status of adverse weather consumables including de-icing fluid, sanding hopper level and screen wash level will be available as part of the condition monitoring system and prioritised as alarms and/or alerts are raised to the Line Control Centre /OCC and LPC.

4.5 NTfL Fleet Asset Maintenance Management

4.5.1 Maintenance Planning

The Local Performance Centre includes the planning and control of asset maintenance. The integration of this function to the overall Railway Control Organisation provides continuous visibility of asset status and availability and is a major contributor to the delivery of consistent and resilient services.

© Copyright 2009 London Underground Limited. All rights reserved.

Planning of maintenance is undertaken by the LPC utilising the TfL network standard systems (2015 - JNP Maximo, BCV Ellipse). The NTfL programme are not directly delivering upgrades to the maintenance planning systems ,however a modern and capable Enterprise Resource planning System (ERP) must be operation in readiness for the introduction of the new train. This is to enable the functionality delivered by condition monitoring and automated inspection together with the New Train Maintenance Regime to be fully realised.

The ERP system used must be based on Industry best practice systems and must integrate all key functions. Materials management must also be integrated into the capability of the standard network systems used.

The main production activity of the LPC is the planning and delivery of the Asset Maintenance Plan (AMP) to achieve the operational Service Requirements. The AMP contains information on the maintenance requirements of the fleet and the capacity of each maintenance facility of the railway. This information is current, and forecast as far as far as can confidently be predicted. The LPC also holds a record of past maintenance tasks and those planned.

Maintenance tasks can be planned quite a way into the future but it is important that the plan be flexible to maximise its robustness to events. The defining details of a task (such as the exact time and location) are only added to it as the time for its execution nears.

The schedule can be changed at any time as circumstances demand, although this becomes progressively undesirable as it might disrupt the planned usage of trains.

The Plan reflects the loading of both planned and reactive maintenance activity onto maintenance capacity including the consideration of facilities, Plant, Human resources, Spares and Materials. If the new proposed (Train Maintenance Plan) (TMP) does include a significant condition based analysis to avoid regular planned activities, then a likely key change is the need to be more reactive (for general maintenance as well as 'faults') and this is a key step change from current planning arrangements.

The Local Performance Centre (LPC) is updated with the status of maintenance work-in progress and completed such that it continually reflects the availability of maintenance capacity and any change in the planned availability of assets. Local and Mobile Fleet Maintenance staff will make extensive use of handheld electronic devices to manage work orders and to view Work Instructions and other key information.

4.5.2 Flexibility in Maintenance Planning

When the execution of maintenance work diverges from the plan and as a consequence the availability of the maintenance facility capacity changes then the LPC will use the tools available to amend and adjust the works schedule.

[redacted]

[redacted]

With planned levels of enhanced operation and the likely removal of the inter-peak period rolling stock, maintenance will have to be concentrated in the remaining periods of availability. This is likely

© Copyright 2009 London Underground Limited. All rights reserved.

to mean that the remaining night and weekend periods, where lower frequency services remain in operation, will be the most productive for the execution of maintenance. Step Changes in existing planned maintenance will be required prior to stock introduction.

[redacted]

4.6 NTfL Fleet Information and Data Management

The use of remote monitoring and risk based maintenance regimes has the potential to significantly improve the asset performance and whole life costs.

To fully exploit the opportunity afforded by the NTfL Tube Stock on-board condition monitoring system, NTfL shall provide suitable communication and IT infrastructure (fixed and wireless), both in the Depot and across the lines, to efficiently capture all available train data for timely analysis at Asset, Line and Network levels.

At the introduction of the Train in GOA1 the likely use of intermittent data transmission may impact the timely download of data. The collective use of IT and on-board electronic systems will allow operations to move towards predictive failure prevention and, as a result make more efficient use of staff resources. The NTfL upgrade teams shall assume that a high specification network link is required for access by all on-site computers used by both staff and suppliers.

A Modern method of Tagging (using latest technology) is to be adopted by Operations to improve stores and materials processes, to ensure efficient operations and in particular to ensure effective stock management under the MSA/FSA obligations. This solution will be required to track

© Copyright 2009 London Underground Limited. All rights reserved.

component utilisation, serialised component configuration and component storage across all main Depots.

4.7 NTfL Fleet Reliability and Performance Management

System performance under the Manufacture and Supply Agreement (MSA) and Fleet Support Agreement (FSA) is likely to be managed via a joint LUL / supplier DRACAS/FRACAS process which will start before the train enters service. This will be set up to monitor and analyse each defect and ensure that an agreed responsibility for resolution is agreed. The Majority of the new train equipment can be interrogated via the TCMS or stand-alone specialist equipment (laptops). This approach shall necessitate a step change in staff skills, but should reduce fault-finding time and instances of 'NDF' compared to legacy stock.

5 NTFL - DEPOT OPERATIONS MANAGEMENT PRINCIPLES

5.1 Key Principles

The movement of trains in Depots will change significantly as a result of the planned increases in automation. Key operations principles include:

There shall be safe operation of train movements within the Depot area.

[redacted]

Ensuring that the injection rates for service and ramp down from service can be managed in a timely manner.

It is recommended that from GOA2 service uplift that the operation of powered operated points is introduced for all depot routes covered by regular train movements. Th is eliminates the need for staff to manually operate each point on the ground. The Human factors and human error issues around the continued used of Ground Shunting, particularly where the operational workload of train movements will increase with enhanced service levels is a concern.

Ensuring that all movements including those required for maintenance are enabled and supported by the upgrade.

[redacted]

If necessary Train paths starting in sidings shall preferably be scheduled to stable at the end of that service period in a major Depot, with a view to supporting a 3-day frequency of Automatic Train Washing, and the Exam maintenance cycle.

Trains are to be presented for service, having passed any remaining elements of pre-service inspection, within maintenance tolerances, and railed with at least one pair of shoes on a conductor rail. [redacted].

All NTfL trains, at all locations shall be capable of being stabled with at least one pair of shoes on conductor rails, to enable cleaning, pre service checks, and unassisted entry into service. Traction current feeds to all major Depots and sidings are normally continuously "on" 24 hours a day to enable train movements, testing, and supplies for lighting, heating and compressors.

© Copyright 2009 London Underground Limited. All rights reserved.

Traction sectionalisation and alternative feed arrangements are to be agreed with Fleet Operations (Assets) to facilitate planned maintenance and incident management.

Alternative operating procedures will be put in place from time to time to cope with abnormal conditions, for example:

- Service disruptions leading to stock imbalance
- Stabling of excess trains (i.e. emergency stabling)
- Use of Depots for service reversing
- Use of overtime and unscheduled shifts (e.g. Late Turn) to address unplanned demand.

5.2 Principle of Operation - Fleet Introduction to Automated Operation

5.2.1 Depot Operations at Fleet Introduction (GOA1)

At Fleet introduction the operational arrangements and boundary agreements for train movement remain as they are today with the split between Depot Control and Service Control Management at the main line boundary. Stonebridge Park Depot on the Bakerloo Line is operated by a control tower and power worked points, Waterloo Depot on the Waterloo & City line is managed by the dedicated Line Control System, and the remaining Depots are operated with handwork points utilising ground shunters up to the Depot outlet.

5.2.2 Depot Operations at Signalling Upgrade to ATO (GOA2)

It is the Operations recommended strategy for the whole depot area to be fully signalled at this stage in readiness of service uplift. Signalling must at least extend far enough into stabling areas to support the required ramp up and ramp down of service taking into consideration the full operability of the Depot.

[redacted]

5.2.3 [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

5.3.2 Maintenance Facilities

[redacted]

5.3.3 Track & Infrastructure Maintenance

[redacted]

6 NTFL TUBE FUTURE TRAIN MAINTENANCE REGIME

Note: As of March 2016, the full set of maintenance interventions are part of the information expected to be received back for bid evaluation, together with the supplier's assessment of maintenance facilities required for the train and associated equipment.

© Copyright 2009 London Underground Limited. All rights reserved.

A recent Train Maintenance regime similar to that from 09 Tube Stock and S-stock is shown in Appendix H as a reference point only to show the expectation of what should be significantly improved upon with the new train.

There is a clear expectation that the new train maintenance regime will be more advanced than any current existing fleet and the existing maintenance regimes will not be used as a basis of future.

The NTfL Tube Stock Train Maintenance Regime (TMR) (and Train Maintenance Plan) is to be developed by the supplier who will act as the Technical design authority. The new train maintenance regime must make full use of modern condition monitoring and automated inspection technologies, that will drive a predictive and condition based maintenance regime ensuring that inspections are undertaken when they are required and where they add value to ensure the drive towards maintenance efficiency. The LU NTfL Rolling Stock Project Team, Maintenance Representative and Fleet Maintenance Sponsor shall jointly agree a process to validate the VMI's with respect to safety, tooling, maintainability, content and periodicity.

The TMR and VMS are to be approved by the LU Professional Head of Rolling Stock, supported by the Fleet Maintenance Sponsor who shall assist in determining the TMR suitability compared to industry best practice. The strategic objective for NTfL tube stock maintenance is to establish a preventative and risk-based regime, which reduces the amount of reactive work to a minimum. Planned maintenance will be balanced as far as possible with modular examinations where reasonably practicable.

6.1 Levels of Train Maintenance

There are some key assumptions about the future maintenance regime :

- **Condition Monitoring & Automated Inspection** – This is not a level of physical maintenance, but the use of monitoring and inspection technologies to report, analyse and confirm rolling stock status and condition. This will enable the optimisation of planned maintenance interventions and to "predict & prevent" failures, thereby enabling interventions prior to them causing impact to the service and damage of the asset. The analysis of data undertaken in the LPC will utilise specific technical resources to support data analysis (not a fully 'automated' process). This will lead to the need to adopt a flexible and proactive approach to subsequent on-train activities (to replace before failure rather than investigate after a failure as exists in todays fixed interval maintenance). The Condition Monitoring and Automated inspection Solution must operate as an integrated package to support the efficiency of the maintenance regime.

[redacted]

- **General Inspection & Repair** – The maintenance strategy supports the use of condition based data driving the timing of general inspection activities with a significantly extended interval that is achieved today.

The approach for routine maintenance activities is to 'balance' all non-overhaul activities into General inspection so that they can be delivered within a maximum of 1 shift without the need to move the train; with fleet resource requirements calculated to support this demand.

© Copyright 2009 London Underground Limited. All rights reserved.

With maintenance intervals extending significantly the wear rate of consumables such as shoe wear may be a future factor in prescribing the periodicity of inspections. The bid evaluation stages must consider this carefully in order to optimise the maintenance regime

The more complex and extensive levels of general inspection and repair (particularly door systems) may necessitate a workload that exceeds a single shift of work; however this is dependent upon the reliability of the systems, NTfL Stock maintainability and the best use of staff. It should be assumed that some activities will, take one long shift and an door general inspection will require with an estimated duration of two shifts.

- **Heavy Maintenance -** The new train will require heavy maintenance to service, maintain and replace heavy equipment that involves the separation of car body from bogies and the removal of bogie mounted or underframe equipment**.**

It is anticipated that the intervals requiring this activity will be extended and optimised as far as is practical however there will be an additional activity to routinely subject components samples to condition assessment between overhauls such that overhaul frequencies can be continually altered and extended.

- **Component - Off Train Module Overhaul** - Components and modules removed from the train will require overall, repair and replacement to form the spares stock for the train. Serialised spares shall be managed to ensure that traceability and the history of parent / child components is maintained throughout component life.
- **Mid-life 'heavy' Overhaul** of the NTfL train may be required. Consideration must be given to these major overhauls, internal and external refurbishment if these are undertaken in an internal or external facility. This heavy overhaul should combine obsolescent component replacement throughout the train in accordance with the Obsolescence Plan.
- **Wheel Turning** - On-condition turning of Wheelsets shall be undertaken to optimise the wheel life and maximize the lifting periodicity, this is assumed to start as an 18 monthly-planned activity (based on recent Analysis on optimizing wheel turning frequencies)
- **Cleaning-** Train Cleaning will be conducted in line with current best practice, frequencies and regime. Appendix F gives details of a notional cleaning regime that represents best practice in LU Fleet Operations. Maintaining the current standard of cleaning will result in an increased labour demand owing to the increased number of cars in the new fleet.
- **Underframe Cleaning** - It is envisaged that under frame cleaning will remain due to a potential increase in gearbox oil leaks and sander use, although track borne grease contamination should reduce owing to the application of on-train 'stick lube'. An additional HVAC cleaning activity will be adopted for NTfL Tube Stock, requiring dedicated depot cleaning road facilities.
- **Sanding:** Refilling the sanding system sand boxes will be a new maintenance activity not encountered on current tube stock fleets. Calculations concerning sand dispensation and maintenance intervals required to refill the sand-boxes are given in SSR document SUP-PSGC0007-SSL-RPT-00016, Issue 3 for S-Stock; however, further work is required to map this to NTfL stock. The sanding equipment refill rate could vary from between 60 days in low risk areas to 7 days on in the leaf fall vulnerable areas of the Piccadilly and Central Lines in autumn.

© Copyright 2009 London Underground Limited. All rights reserved.

6.2 Additional Items

Note: Depot upgrades should not introduce gauge infringements that prevent movement of pre-existing LUL stock, including heritage stock that may need to be repaired.

For seasonal Maintenance, the Sandite Trains are required to continue at Hainault and Ruislip Depots and may also be required at the other upgraded depots. A Future strategy for provision of Rail Adhesion Trains to replace the legacy trains (Central & Piccadilly Line Provision) will need to be agreed to ensure it continues following completion of the upgrade.

© Copyright 2009 London Underground Limited. All rights reserved.

7 MAINTENANCE ARRANGEMENTS INITIAL, MIGRATION AND END STATES

7.1 Maintenance Arrangements Summary Table (Balanced Option)

Legacy & Depot	Initial State	Migration State		NTfL Stock
	Legacy Fleet	Legacy Fleet	New Train	New Train
Piccadilly Line (East End) Cockfosters Depot	Train Preparation Exam Shed Day/Modular Maintenance Programme Lift Minor Overhaul Heavy Overhaul Casualty Maintenance Interior & Exterior Cleaning Underframe Cleaning De-icing Replenishment	Train Preparation Exam Shed Day/Modular Maintenance Programme Lift Minor Overhaul Heavy Overhaul Casualty Maintenance Interior & Exterior Cleaning Underframe Cleaning De-icing Replenishment	Pre-Service Inspection/Walk Through General Inspection & Repair Heavy Maintenance Wheel Turning Interior & Exterior Cleaning Underframe Cleaning De-icing Replenishment Sanding Replenishment	Pre-Service Inspection/Walk Through General Inspection & Repair Heavy Maintenance Wheel Turning Interior & Exterior Cleaning Underframe Cleaning De-icing Replenishment Sanding Replenishment
Piccadilly Line (West End) Northfields Depot	Train Preparation Exam Shed Day/Modular Maintenance Programme Lift Minor Overhaul Heavy Overhaul Casualty Maintenance Interior & Exterior Cleaning Underframe Cleaning De-icing Replenishment Wheel Turning	Train Preparation Exam Shed Day/Modular Maintenance Programme Lift Minor Overhaul Heavy Overhaul Casualty Maintenance Interior & Exterior Cleaning Underframe Cleaning De-icing Replenishment	Pre-Service Inspection/Walk Through General Inspection & Repair Heavy Maintenance Wheel Turning Interior & Exterior Cleaning Underframe Cleaning De-icing Replenishment Sanding Replenishment	Pre-Service Inspection/Walk Through General Inspection & Repair Heavy Maintenance Wheel Turning Interior & Exterior Cleaning Underframe Cleaning De-icing Replenishment Sanding Replenishment

© Copyright 2009 London Underground Limited. All rights reserved.

Legacy & Depot	Initial State	Migration State		NTfL Stock
	Legacy Fleet	Legacy Fleet	New Train	New Train
Ruislip Depot (West End)	Train Preparation Exam Shed Day/Modular Maintenance Programme Lift Minor Overhaul Heavy Overhaul Casualty Maintenance Interior & Exterior Cleaning Underframe Cleaning De-icing Replenishment Wheel Turning	Train Preparation Exam Shed Day/Modular Maintenance Programme Lift Minor Overhaul Heavy Overhaul Casualty Maintenance Interior & Exterior Cleaning Underframe Cleaning De-icing Replenishment Wheel Turning	Pre-Service Inspection/Walk Through General Inspection & Repair Heavy Maintenance Wheel Turning Interior & Exterior Cleaning Underframe Cleaning De-icing Replenishment Sanding Replenishment	Pre-Service Inspection/Walk Through General Inspection & Repair Heavy Maintenance Wheel Turning Interior & Exterior Cleaning Underframe Cleaning De-icing Replenishment Sanding Replenishment
Hainault Depot (East End)	Train Preparation Exam Shed Day/Modular Maintenance Programme Lift Minor Overhaul Heavy Overhaul Casualty Maintenance Interior & Exterior Cleaning Underframe Cleaning De-icing Replenishment	Train Preparation Exam Shed Day/Modular Maintenance Programme Lift Minor Overhaul Heavy Overhaul Casualty Maintenance Interior & Exterior Cleaning Underframe Cleaning De-icing Replenishment	Pre-Service Inspection/Walk Through General Inspection & Repair Heavy Maintenance Wheel Turning Interior & Exterior Cleaning Underframe Cleaning De-icing Replenishment Sanding Replenishment	Pre-Service Inspection/Walk Through General Inspection & Repair Heavy Maintenance Wheel Turning Interior & Exterior Cleaning Underframe Cleaning De-icing Replenishment Sanding Replenishment

© Copyright 2009 London Underground Limited. All rights reserved.

Legacy & Depot	Initial State	Migration State		NTfL Stock
	Legacy Fleet	Legacy Fleet	New Train	New Train
Bakerloo Line (North End) Stonebridge Park Depot	Train Preparation Exam Shed Day/Modular Maintenance Programme Lift Minor Overhaul Heavy Overhaul Casualty Maintenance Interior & Exterior Cleaning Underframe Cleaning De-icing Replenishment	Train Preparation Exam Shed Day/Modular Maintenance Programme Lift Minor Overhaul Heavy Overhaul Casualty Maintenance Interior & Exterior Cleaning Underframe Cleaning De-icing Replenishment	Pre-Service Inspection/Walk Through General Inspection & Repair Heavy Maintenance Wheel Turning Interior & Exterior Cleaning Underframe Cleaning De-icing Replenishment Sanding Replenishment	Pre-Service Inspection/Walk Through General Inspection & Repair Heavy Maintenance Wheel Turning Interior & Exterior Cleaning Underframe Cleaning De-icing Replenishment Sanding Replenishment
Bakerloo Line South End (London Road)	Train Preparation Casualty Maintenance Interior & Exterior Cleaning	Train Preparation Casualty Maintenance Interior & Exterior Cleaning	Pre-Service Inspection/Walk Through Interior Cleaning General Inspection & Repair De-icing Replenishment	Pre-Service Inspection/Walk Through Interior Cleaning General Inspection & Repair De-icing Replenishment
Waterloo & City Line Waterloo Depot	Train Preparation Casualty Maintenance Interior & E Shed Day/Modular Maintenance Interior & Exterior Cleaning Programme Lift	N/A as planned blockade so no operation migration		Pre-Service Inspection/Walk Through General Inspection & Repair Heavy Maintenance Interior & Exterior Cleaning Underframe Cleaning

Key NTfL Depots and Maintenance Roles per line

© Copyright 2009 London Underground Limited. All rights reserved.

7.2 Migration of Legacy Stock Maintenance Regimes

It is likely that the current maintenance frequencies of exam and shed day activities on 73TS, 72TS and 92TS will continue to be optimised up to the point of fleet replacement.

Leading up to and during disposal, the 73TS, 72TS and 92TS Fleet Managers shall assist the NTfL CPD Team in the detailed planning of disposal activities such as spares retention and the scrapping sequence for their respective fleets. Furthermore, the Fleet Managers shall pro-actively seek cost saving opportunities during stock disposal with the support of the Sponsor.

Extension of Programme Life (and other maintenance) periodicities should be undertaken where it can be demonstrated that the assets continue to function safely and without risk to operational performance. These activities support the overarching AAMP objective to minimise residual asset value at the point of disposal whilst enabling LU to recoup the maximum sale value. Contingency plans should exist to deal with unforeseen delays to the new stock delivery.

7.3 Migration Maintenance Arrangements

As part of the depot feasibility report, a description of several potential migration maintenance arrangements is given.

With the exception of the Waterloo & City Line, which will be closed to facilitate the line upgrade, full operational service and maintenance capability must be maintained in the other depots during the migration phase. Once the project progresses to the chosen solution, this report will be updated with those maintenance arrangements. In summary each, of the migration options are shown below:

1) Modification of Existing Depot Facilities, whilst the Depot remains operational for maintenance of the existing fleet.
2) Modification of the existing Depot Facilities, whilst removing the capability for maintenance from that Depot for existing maintenance. (Not Bakerloo Line)
3) The Early feasibility Option proposed By AECOM (1 with Additional Maintenance facilities) (Piccadilly Line Only)
4) Construction of a new maintenance facility on existing depot footprint whilst existing depot facilities remain operational for the existing fleet
5) Construction of a new maintenance facility on existing depot footprint whilst removing the capability for rolling stock maintenance in that depot. (Not Bakerloo Line).

7.3.1 Piccadilly Line - Cockfosters and Northfields Depots

The Piccadilly Line will be the first location to maintain the new NTfL Rolling Stock,, although Ruislip is likely to be the delivery and initial commissioning and testing location for the initial trains.

During migration, the Piccadilly Line will be served by both by 73TS and NTfL Rolling Stock. This means there will need to be sufficient facilities to deal with maintaining both sets of trains until the rollout is complete. The CPD team will manage the overall introduction, testing and commissioning of the new trains in parallel with decommissioning and disposal of the legacy Tube stock.

7.3.2 Waterloo & City Line - Waterloo Depot

It is proposed that the Waterloo and City Line is shut for upgrade works and introduction of the new fleet. Therefore the existing fleet will cease operations within the existing facilities and the maintenance of the new train will be undertaken in the new commence in the upgraded facilities once the line has re-opened.

© Copyright 2009 London Underground Limited. All rights reserved.

7.3.3 Bakerloo Line - Stonebridge Park Depot

During migration, all levels of 72TS planned and corrective maintenance shall continue to be undertaken at Stonebridge Park Depot, with the new NTfL train introduced alongside the existing fleet. This means there is a need for sufficient facilities to deal with maintaining both sets of trains until the rollout is complete. The CPD team will manage the overall introduction, testing and commissioning of the new trains in parallel with decommissioning and disposal of the legacy Tube stock.

7.3.4 Central Line – Hainault and Ruislip Depot

During migration, all levels of 92TS planned and corrective maintenance shall continue to be undertaken at Hainault and Ruislip Depots with the new NTfL train introduced alongside the existing fleet. This means there will need to be sufficient facilities to deal with maintaining both sets of trains until the rollout is complete. The New Train project team will manage the overall introduction, testing and commissioning of the new trains in parallel with decommissioning, stripping and scrapping of the legacy Tube stock.

8 END STATE MAINTENANCE ARRANGEMENTS

As of early 2016 there are a number of main options for the concept of Depot operation that are under consideration for future operation. These options are split between self-sufficiency of the Bakerloo and Waterloo & City Lines and a greater range of options for the Central and Piccadilly Lines.

8.1 Bakerloo Line

8.1.1 Stonebridge Park

The Bakerloo Line remains a self-contained operation at end state using the NTfL materials distribution network, with component overall undertaken remotely.

Whilst in theory the line is connected to the Jubilee line and will be connected in future to the Metropolitan Line via the Metropolitan Line Extension at Watford, it is considered as inefficient and impractical to move the trains to another facility on the network for normal Planned and casualty maintenance. The line will use a central materials distribution network with component overhaul undertaken at a central location, independent of Stonebridge Park Depot.

The Depot will therefore include the facilities required to undertake the following activities on the 36 planned new NTfL trains :

- Pre-Service Inspection/Walk Through
- General Inspection & Repair
- Heavy Maintenance
- Wheel Turning
- Interior & Exterior Cleaning
- Underframe Cleaning
- De-icing Replenishment
- Sanding Replenishment

© Copyright 2009 London Underground Limited. All rights reserved.

8.1.2 London Road Depot

London Road will operate as a light Satellite Depot able to undertake light maintenance up to underframe module replacement. The exact number of roads will need to be modelled however is estimated that 3 Pitted roads will be required for this activity. The stabling area outside the maintenance facilities will operate as manually driven signalled sidings. The facilities are required to undertake the following activities at London Road

- Pre-Service Inspection/Walk Through
- Interior Cleaning
- General Inspection & Repair
- De-icing Replenishment

8.2 Waterloo & City Line

8.2.1 Waterloo Depot

The severe space and logistics movement constraints of the Waterloo and City Line mean that the operation at end state must be self-contained using the NTFL materials distribution network and with component overhaul undertaken remotely an offsite location. The Depot will therefore include the facilities required to undertake the following activities on the 5-7 planned new NTfL trains. Any wheel turning that is required to be undertaken will require the wheel sets to be removed and sent away from Waterloo Depot for Turning.

- Pre-Service Inspection/Walk Through
- General Inspection & Repair
- Heavy Maintenance
- Interior & Exterior Cleaning
- Underframe Cleaning

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

9 NTFL TUBE STOCK – DEPOT MAINTENANCE FACILITIES

9.1 Lessons Learned From Recent Fleet Introduction

Experience first identified during S-stock introduction has shown that the low solebar height prevents adequate visibility and access to the bogie mounted and under frame equipment from the

© Copyright 2009 London Underground Limited. All rights reserved.

existing side pitted roads. Although the NTfL solebar height is similar to existing stocks the problem remains due to existing deficiencies in side pit width and dimension in particular.

For this reason, all Depots roads that will be used for routine maintenance or casualty inspection will be upgraded to Swimming Pool type roads where new roads are constructed. Where existing side pits and centre pits remain, these must take account of human factors for those undertaking maintenance. Changes to working practices and implications for Health and Safety must be considered as part of this fundamental change. Protection against falling from height through an open door is an issue that needs to be mitigated on swimming pool roads.

Maintainability and Human Factors studies have identified that the optimum distance between adjacent Swimming Pool pit roads is 3 metres between car-bodies – this distance allows un-hindered movement of most Mobile Access Platforms (MAPs) and the tooling between adjacent roads during examinations. It should be noted that the Depot facilities should be designed to minimise the use of MAPs where possible, for example provision of permanent access platforms for Door examinations will eliminate inefficient and costly maintenance.

The NTfL Tube Stock bogies are not likely to be designed to be mechanically retained when the train is lifted. As a consequence of the permanently coupled through-gangway design, potentially with articulation, this could result in the process of lifting a train being is a lengthy procedure – risking lost service if the maintenance activity takes longer than a few hours. NTfL lifting systems must therefore be specified to avoid the practice of manually securing the bogies to the underframe for lifting. Suitable products would include under-wheel lifting systems, bogie jacking systems or bogie drop systems.

The introduction of S-stock as a long fixed formation train has identified significant challenges in visibility while moving a train over facilities such as the fixed wheel lathe. These types of issues must be considered as part of the development of each facility and solutions found where appropriate e.g. used of CCTV to aid positioning operations.

Recent initiatives have been implemented on LU Depots to introduce Lean practices, in particular the 5S methodology (Sort, Segregate, Standardise, Shine and Sustain). NTfL should ensure that special storage and floor markings are reinstated after intrusive works. Project teams shall work jointly with Depot UAM's to identify opportunities when specifying racking, tooling and general storage locations.

© Copyright 2009 London Underground Limited. All rights reserved.

9.2 Summary of New Depot Facilities Required for NTfL Tube Stock

The new train will require a range of modified and new maintenance facilities to facilitate its maintenance. These include:

Facility	Current Equipment	Mechanism For Upgrade / Change	New Facility/ Equipment	Additional Requirements notes
Heavy Maintenance Facility	Piccadilly Line & Bakerloo Line Lifting shop with overhead crane for single car lift on to move car to car stands Central Line & Waterloo & City Line 2 car synchronised lifting Jacks with Overhead crane Hainault/Ruislip	New rolling stock designed as fixed car formations with inter-car gangways semi permanently coupled not designed to be easily split	"PIT STOP" Modular component Replacement Targeted module/component replacement in a specific area of train	Whole train synchronised lifting either by jacks or in floor lifting system (Train Static In Shed) or Component drop (Train moved to defined position) In floor lifting systems or jacks Must lift the train under each wheel and have built in car stands to secure the car and then enable the bogie to be lowered. Space requirements to enable equipment to be removed from side of train with fork lift/plant
			Overhaul Facility Access to whole train for removal/replacement of components	Whole train synchronised lifting either by jacks or in floor lifting system In floor lifting systems or jacks Must lift the train under each wheel and have built in car stands to secure the car and then enable the bogie to be lowered. Component Drops NOT to be used for this activity Space requirements to enable equipment to be removed from side of train with forklift/plant

© Copyright 2009 London Underground Limited. All rights reserved.

Facility	Current Equipment	Mechanism For Upgrade / Change	New Facility/ Equipment	Additional Requirements notes
General Exam and Inspection Facility	Roads with Centre Pits & Roads with centre and side pits	New modules components on the train that require removal	Modified Central Underframe & Side Access Roads	Existing pitted Maintenance Facilities in the depot reused for defined NTfL tube stock Tasks These roads have between 1.9m and 2.4m space between car bodies
			New Central And Side Access Roads with enhanced space between trains for worksite and materials efficiency and management	New roads typically "Swimming pool pits". Designed for centre and side pit access with a minimum of 3 m between trains Exact number of Swimming pool pits depends on rolling stock design and safety human factors considerations
Cleaning Facility	Above solebar Platform roads in depot with current rails into the sheds		Facilities to ensure access to both sides of the train to maximise production	Longer train length or alterations to floor height. Many cleaning roads do not enable access to both sides of the train.
	Underframe Cleaning Road	Centre Pitted Road	Centre Pitted Road	Underframe inspection should be automated
	Automated Train Wash	Requirement to fulfil; exterior cleaning targets	Similar facilities to Today Cleaning of specific items such as fans/ducting etc. may be needed.	Current located in Cockfosters , Hainault Stonebridge Park and Waterloo depots Location carefully considered in new installations to maximise throughput of trains while entering / exiting depot

© Copyright 2009 London Underground Limited. All rights reserved.

Facility	Current Equipment	Mechanism For Upgrade / Change	New Facility/ Equipment	Additional Requirements notes
Door Maintenance Facility	Periodic Inspection Facility	New train	Equipment to facilitate maintenance of NTfL doors	
	Overhaul Facility	Increased door size and mass on New train.	Dedicated facility to remove and manipulate NTfL door	
Adverse Weather Facilities	Sandite Facilities Currently only in Neasden , Ruislip and Hainault Depots	Characteristics of future line upgrades result in Sandite treatment being proposed	Equipment to handle IBC for loading to train and or pump's to load in to Sandite hoppers	
	Sanding Facilities Only currently installed in Neasden Depot in Preparation operation of S-stock in ATO	Increase brake rates introduced for ATO may result in on train Sanding on Future Fleets	Sanding silo and multiple distribution points in suitably identified locations in depot	Exact requirement to be developed and then revised following in service experience of S-stock in ATO 2018 approx. Thought very likely on Piccadilly Lines and Central Line less likely on Bakerloo Line
	De-icing facilities currently in all depots	Modern practice and minimising cycle time into the depot during high risk periods	Multiple filling points should be considered as best practice	
Screen Wash Facilities	Currently used on S-stock	Incorporate lessons learned from S-Stock experience	Learned best practice for filling device	

© Copyright 2009 London Underground Limited. All rights reserved.

Facility	Current Equipment	Mechanism For Upgrade / Change	New Facility/ Equipment	Additional Requirements notes
Underfloor Wheel Lathe	Currently in Some Depots	In situ wheel Turning reduces Maintenance Burden. Bi annual skimming of wheels		
Store Facilities	Traditional Depot stores facility	Need to consider more efficient storage methods and storage of new sensitive electronic components	New modern stores and materials management	Need to ensure adequate storage for both migration between old and new and final states Operations will consider as part of future materials strategy.
General Office Facilities	Many offices still traditional and contain separate offices	Need to promote open plan and interaction between all parties on site	Convert or construct new open plan offices to create depot hub	
Staff Amenities	Accommodation, lockers , mess facilities, toilets & showers , canteen , security , cleaners facilities , training facilities, visualisation room	Facilities introduced and upgraded to modern standards	Facilities maintained and upgraded for new depots	Adequate provision for requirements needs to be made for new facilities and new ways

© Copyright 2009 London Underground Limited. All rights reserved.

Facility	Current Equipment	Mechanism For Upgrade / Change	New Facility/ Equipment	Additional Requirements notes
Power Supplies	Existing power supplies	Needs to upgrade power for trains that enhanced power supplies including air conditioning etc.	Upgraded power supplies	
Shore Supplies	Existing shore supplies	New to upgrade supplies for higher power requirement of train	Upgraded shore supplies	Roof structures may need to be strengthened to facilities improved supplies. Consider use of battery back-up to reduce reliance on shore supplies.
Battery Charging Facilities	Legacy Fleets requires dedicated battery charging rooms	Introduction of New Fleet	Objective for new fleet not to require regular battery charging between replacement	Should regular be required a facility will be required and this must also include transportation of batteries to and from trains
Pit Bridging Boards	Boards designed to specified structural load requirements	Upgrade to new facilities	New equipment for revised pit design	
Air Supplies	Clean ,dry compressed air supply provided for air bake testing and also for pneumatic tools	Upgrade to new facilities		Depot upgrade to considered redundancy of compressed air supplies where possible
Car parking	Car Parking traditionally restricted in Most Depots	Depot Upgrade	Additional parking	As a result of an Increased number of personnel on site as a during and post upgrade additional parking should be considered

© Copyright 2009 London Underground Limited. All rights reserved.

Facility	Current Equipment	Mechanism For Upgrade / Change	New Facility/ Equipment	Additional Requirements notes
Crane – overhead	Cranes providing facility to lift equipment from roofs , from track level and from floor level	New equipment Lifting requirements for new rolling stock and for modern human factors requirements	New cranes should:- Be a minimum of 10 tonne capacity on a travelling gantry. Have twin gantry cranes provided with movement restrictions to avoid clash and interlocked with traction power	Requirement for cranes even with in floor, on floor lifting systems /jacks remains. Exact capacity depends on maintenance requirements of new train
Depot Protection system (DPS)	A variety of systems in some depots	Depot upgrade and in particular increased levels of depot automation.	Interlocked systems to segregate maintenance areas from operational areas within the depot	Future systems to in particular enforce controlled safe handover between maintenance areas and operational areas of the depot.
Depot Access Road Pedestrians , vehicles & Emergency Access & for emergency appliances	Road access. Where required arrangements for second or alternative emergency access must be maintained	Alternations to depot as part of upgrade	Access Requirements need to be both maintained and improved to modern standards. Methods for controlling vehicle speed in depots must be incorporated	Segregation of people from vehicles where possible. Particular consideration to movement and reverse movements of large goods vehicles in depots must be considered.
Length Of Shed	Shed length acceptable for existing train lengths	New Rolling Stock introduction	Extended train lengths requiring extended shed facilities	
Depot Lighting	Traditional light with varied condition	New standards and technical analysis	Improvements made in lighting levels improve visibility and safety particularly in confined areas.	Efficient lighting is a clear requirement

© Copyright 2009 London Underground Limited. All rights reserved.

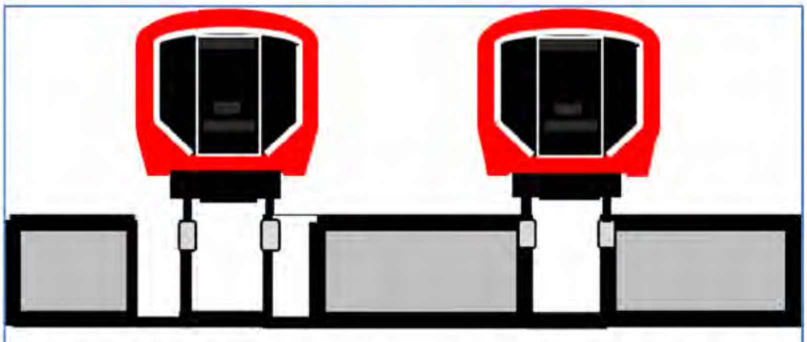
Facility	Current Equipment	Mechanism For Upgrade / Change	New Facility/ Equipment	Additional Requirements notes
Track Standards	Many depots to be upgrade have legacy track formations	Upgrade of depot, introduction of new control systems and better whole life cost management of track spares	track formations designed to modern standards	

9.3 General Inspection & Maintenance facility

The most versatile maintenance type of facility on both existing and future Depots is the General Inspection & Maintenance Facility (Pitted Maintenance Roads). This enables a range of regular inspection and lighter component and modular replacement maintenance activities to be undertaken. The activity range extends to the use of manipulation equipment to assist in the manipulation of bulky or heavier components and modules. Critical to the facility is the need to create an efficient human factors driven working environment for the maintenance activities that are going to be undertaken.

9.3.1 Modification of Existing General Exam & Inspection Facilities

The future suite of Depots facilities may include the re-use of the existing Depot pitted facilities that can continue to undertake some tasks with either no or limited modification. The length of these roads, centre pit depth, side pit depth/ width, space between roads, lighting, drainage, materials movement logistics, worksite management and other enabling activities such as shore supplies will affect the practicality of future re-use of these facilities for NTfL tube stock. In particular the space between roads is likely to remain restrictive to optimising maintenance production and limit the scope of activities where these roads can be re-used.



General Inspection Centre & Side Pitted Facility

General Inspection Centre Pitted Facility

© Copyright 2009 London Underground Limited. All rights reserved.

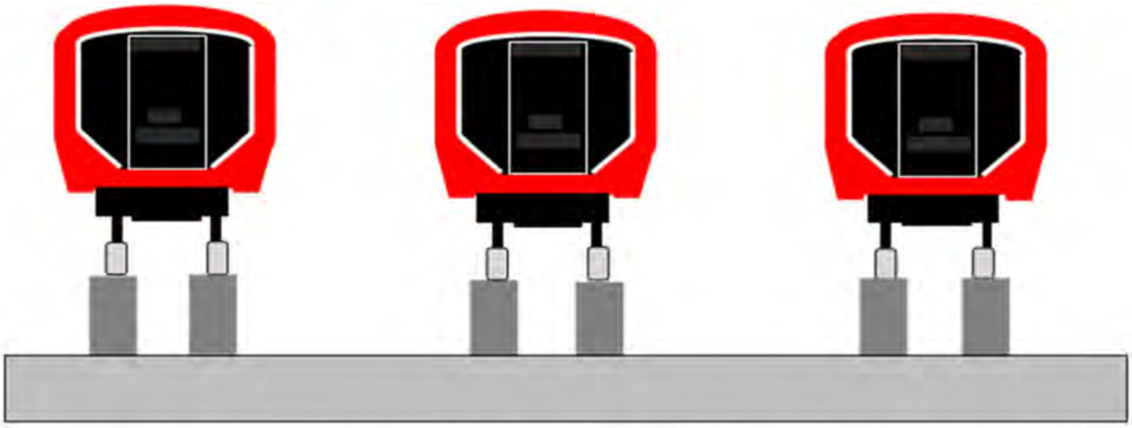
Note: It is essential that the method of safety protection e.g. working at height can be implemented in a timely manner.

Example of an existing Centre & Side Pitted Road at Stonebridge Park Depot on the Bakerloo Line. Existing space between trains is 2.4m between car bodies (1.7m between side pits in this example although typically on the Piccadilly Line this is reduced to 1.9m

9.3.2 New Pitted Maintenance Facilities (e.g. Swimming Pool Type)

The future strategy for General Inspection & Maintenance Facilities includes the use of newly designed pitted facilities to undertake those maintenance activities that require pitted facilities, but which cannot be undertaken in the existing facilities due to the factors outlined in the previous section.

Swimming Pool Pitted roads are not an explicit operational requirement for these facilities, however the opportunity to develop new facilities with good underframe and side access is likely to result in this being the chosen design. This type of pit is not without disadvantages and in particular the issue of Working at Heights can be exacerbated by the use of these facilities and this issue needs to be carefully managed. The additional space between roads (minimum of 3m) will be challenging as it is likely to reduce the overall number of available Maintenance Roads within the Depot so the need for space and capacity needs to be carefully modelled.



Example Cross Section of a typical modern "Swimming Pool Pit Facility provides improved access to the underframe and side of the train below solebar and increased working space between trains

© Copyright 2009 London Underground Limited. All rights reserved.

Example of the newly constructed swimming pool pit roads At Neasden depot for S-stock. Note the increased height from the mobile platform to ground level. The minimum space between trains is 3 metres

9.4 Heavy Maintenance Facility

Heavy Maintenance Facilities are required when large components and modules of the train need to be removed or replaced using dedicated equipment. The introduction of the NTfL tube stock results in the need to significantly upgrade these facilities. This is primarily because the new train is of a fixed formation with the potential use of articulation (i.e. it cannot be routinely split easily). In addition the available space means that the underframe is the primary position for the location of heavy modules and equipment including HVAC and train-borne signalling which would need to be removed. For reference, the existing facilities split the train into either single cars where they are then lifted using an overhead crane or lifted as two cars using mobile lifting jacks (Central Line & Waterloo & City Line only). It is recognised that the strategy for heavy maintenance facilities involves two specific areas:

- Rapid Modular Component Replacement
- Overhaul Facility

Existing Heavy Maintenance Facility at Cockfosters Depot with a single car lifted on Car Stands and bogie removed

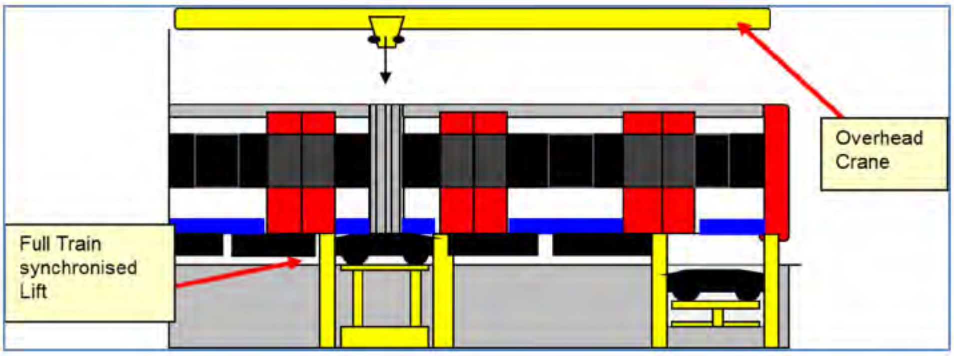
© Copyright 2009 London Underground Limited. All rights reserved.

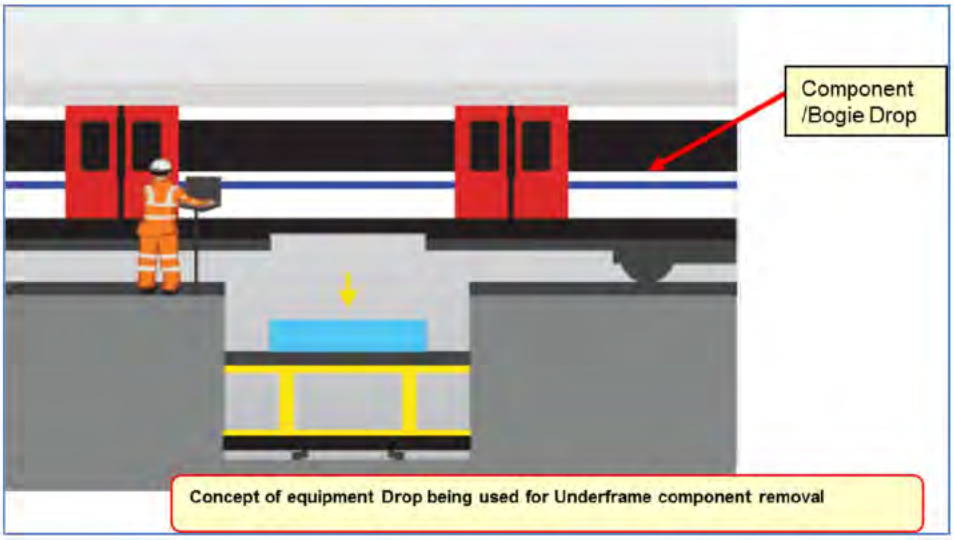
9.4.1 Casualty Maintenance Activity Lifting - Rapid Modular Component Replacement

The purpose of this facility is to remove, replace or access large and/or heavy component/modules in a specific targeted area of the train outside the normal heavy maintenance regime. Therefore the requirement is for the train to re-enter service with the principle of minimising the production down-time by ensuring rapid utilisation of the maintenance facility. For the scope of this facility, the train can either be lifted (whole Train Synchronised lift) with the train fixed in position within the maintenance road, or the train moved to the required position and the component removed and replaced by using a drop system. London Underground has recent experience of introducing lifting systems but has not thus far used dedicated component/bogie drops, although these are used extensively in other railway operations both in the UK and across the world.

Experience of lifting systems has identified that there can be a considerable set up time (2 man hours for 4 cars of 09TS) in chaining bogies prior to lifting (NTfL tube stock would require the same process), therefore lifting systems that lift under wheel for example, eliminate this activity and significantly reduce set up time.

For the bogie drop/component drop to be effective, the activity of movement of the train to position the target section of the train, as well as its impact on other shunting moves within the maintenance facility and operational depot area has to be fully considered. In moving part of the train outside the shed, the protection of those inside the shed from the weather and temperature extremes outside it must also be considered.

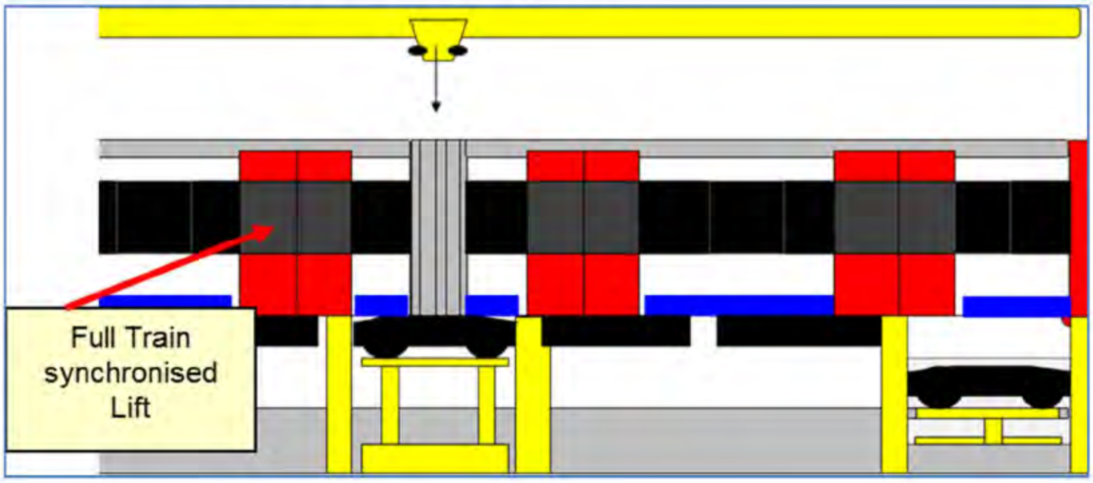




© Copyright 2009 London Underground Limited. All rights reserved.

9.4.2 Overhaul Facility

Where heavy equipment removal and replacement activity is to be undertaken across multiple locations along the train the whole train synchronised lift must be the preferred facility for this activity. Typically a train may be in this facility for a longer period of time, therefore the set up time must remain minimised so as to reduce wasted time in the maintenance operation and the lifting principles as described above remain applicable.



An example of the Whole Train Synchronised lifting system in operation at Neasden. The lift supports the bogie underwheel as well as supporting the car body. The bogie can then be lowered with the car body supported. Note the space under, and around the train to create an efficient worksite. When fully retracted the lifting system is flat to the floor and creates a level access flat road, that is a dual purpose road.

9.5 Cleaning Facilities

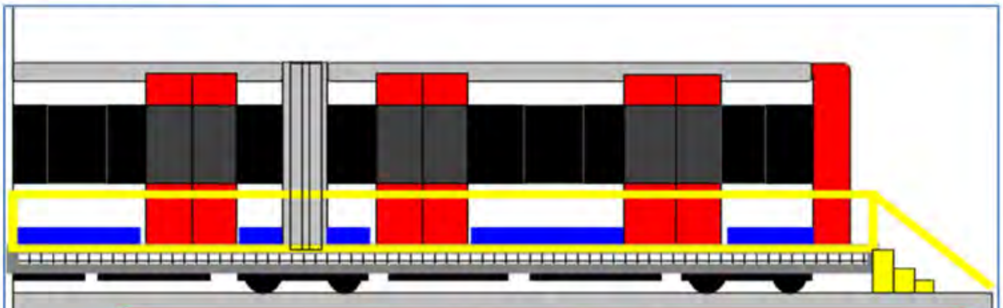
The new train will require a range of cleaning facilities and the intention to continue undertaking on train litter picking activities both in service and in stabling areas [redacted] should be noted.

9.5.1 Above Sole-bar Cleaning facilities

To facilitate the cleaning of the NTfL Tube Stock, above sole-bar level dedicated cleaning roads are to be used to facilitate the more advanced interior cleaning, exterior hand cleaning and graffiti removal from the train. To maximise efficiency and production all cleaning roads must provide

© Copyright 2009 London Underground Limited. All rights reserved.

platform level access to both sides of the train, and be designed for the equipment and processes required to undertake this activity. Drainage must be specifically incorporated into the design of this facility. Dedicated Cleaning roads must have the functionality for isolating the traction current supply in the cleaning facility area.



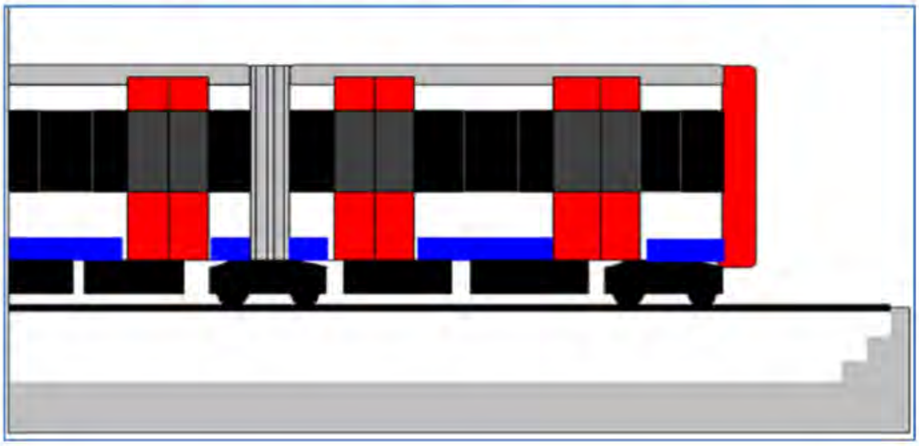
Dedicated Cleaning Platform Road

Platform cleaning Road at Northfields Depot

9.5.2 Underframe Cleaning Road

The operating environment of London Underground makes the requirement for underframe cleaning a very necessary activity and this will continue thought the life of the NTfL Train. Currently this is typically an activity undertaken on a 56 day cycle (6 weeks) and has remained a very manual activity with unsuccessful efforts to automate it not being successful. Eliminating this manually based activity, that puts cleaning teams in a dirty, cramped environment is a clear operational requirement a for the new fleet, and this should be investigated further. Should new methods of automation not be practicable, a dedicated road with good drainage that is easy to clean must be developed.

© Copyright 2009 London Underground Limited. All rights reserved.



9.5.3 Ventilation System cleaning

The build-up of dust in rolling stock Ventilation System equipment fans and ducts has proved very challenging with recent fleets.

For the Central Line Fleet a dedicated single road with ventilation cleaning plant system is in operation. More recent fleets have not got a dedicated plant system and are continuing to refine and develop smaller equipment manipulated to the train in a pitted road. Ensuring that these facilities remove dust in a way that prevents it being ejected in to the working environment of the Depot has proved difficult and therefore solutions are required for NTFL Tube Stock.

A solution must to be found to ensure that NTfL tube stock ventilation ducting is kept clean with dust removal in a safe an efficient way. To address this, there are specific requirements in the Rolling Stock Tender to ensure that there is both access to equipment on the train and to reduce build- up of dust and dirt on critical surfaces; but this is unlikely to fully eliminate the need for cleaning.

9.5.4 Automatic Train Wash

Automatic Exterior Train washes exist on each line to facilitate the cleaning of trains in a 3-4 day cycle. Train washes must be located at a position in the Depot that has the highest frequency of trains entering and leaving the depot. With specific cleaning targets to be achieved, the existing train washes will need to be modified, where necessary, to accommodate the new train. The train Washes are currently located at:

- Piccadilly Line - Cockfosters Depot
- Bakerloo Line – Stonebridge Park Depot
- Central Line – Hainault Depot x2 (East & West) & Ruislip
- Waterloo & City Line – Waterloo Depot

© Copyright 2009 London Underground Limited. All rights reserved.

Waterloo & City Depot Underground Wash Plant

The existing train washes are largely life expired and should be replaced with new facilities in each depot. It is recommended to install train washes in either end of double ended depots.

Where existing train washes are reused careful consideration must be given to ensure they are fit for purpose for long term use. Note : it is anticipated that as the profile of the new train is similar, the train washes can be used simultaneously with the existing and new fleets, possibly with minor changes to the brush arrangements.

New train washes must be considered.

9.6 Wheel Turning Facilities

The wheel profile on NTfL tube stock will require a machining operation to restore it to the designed profile.

Dedicated wheel turning facilities are an absolutely essential facility for the operational of NTfL tube stock on all lines. The Piccadilly Line (73TS) and Bakerloo Line (72TS) tube stocks do not have effective Wheel Slide Protection (WSP) and as a result suffer significantly from casualty wheel flat issues. It should be noted and the Bakerloo Line in particular does not have on site wheel turning facilities.

The introduction of the new train with efficient WSP (on those lines where WSP is not already fitted) is likely to significantly reduce the number of casualty wheel flats (particularly during the autumn leaf fall period); however wheel turning remains a vital maintenance activity. This has been endorsed by recent analysis that strengthened the engineering case behind a cycle of regular wheel turning (bi-annually approx.) to restore the wheel profile to “new” condition. This has positive benefits for not only wheel life but also rail life.

The NTfL strategy for facilities is therefore to manage a limited number of casualty wheel turning events in addition to regular planned turning cycle of the entire fleet. This in turn makes a strong case for a dedicated facility for this activity since there is going to be a constant cycle of wheel turning production. There are two options for wheel turning facilities:

9.6.1 Fixed Wheel Lathe

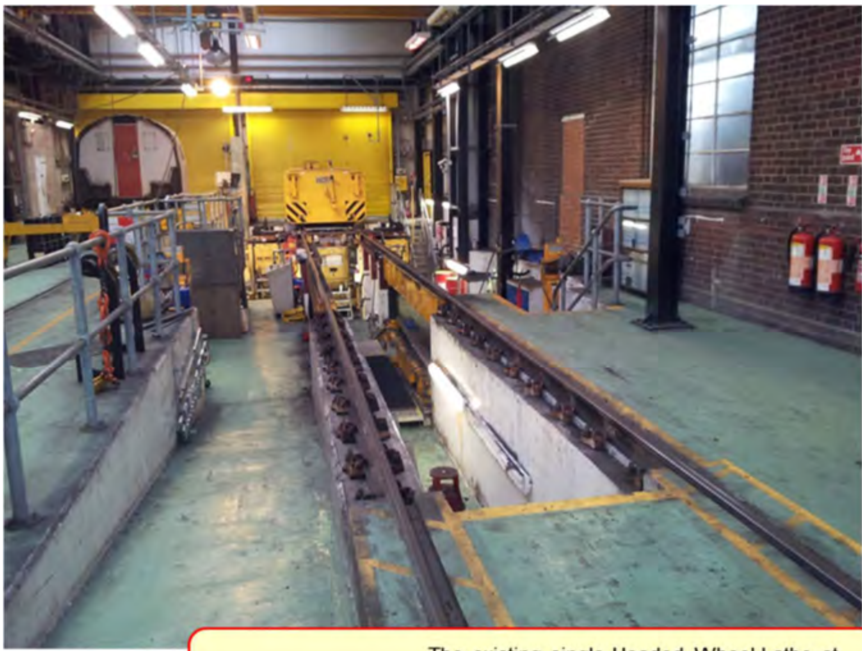
A fixed wheel lathe is one in which the train is not dismantled and is moved over a dedicated facility to restore the wheel to its new condition.

Considering the frequency of wheel turning a dedicated fixed wheel lathe is recommended operationally for NTfL tube stock maintenance, as it avoids the need to undertake a separate lifting activity prior to the commencement of wheel turning process. To maximise production efficiency the

© Copyright 2009 London Underground Limited. All rights reserved.

wheel lathe must be double headed and enable all wheelsets of the train to move over it. In addition it aids the collection and removal of swarfe during the wheel turning process.

Working in an exposed shed environment must be considered as part of this strategy.



The existing single Headed Wheel Lathe at Northfields Depot on the Piccadilly line

9.6.2 Mobile Wheel Lathe

A Mobile Wheel Lathes is where the train is lifted on synchronised jacks and then the wheel lathe is moved underneath the train to restore the wheel to the desired profile.

An Example of a Mobile Wheel Lathe in a non- London Underground Depot

© Copyright 2009 London Underground Limited. All rights reserved.

Example of a Mobile Wheel Lathe in operation at Ruislip Depot on the Central Line

Mobile wheel lathes have recently been used in a number of London Underground Depots as an alternative to a fixed underfloor wheel lathe and it is recognised that in some locations, space constraint's mean that they are the preferred option.

In consideration of their use with NTfL tube stock, the production time for lifting activity to ready the train for wheel turning must be considered together with the feasibility of their use where under wheel lifting is used. Practical use has also highlighted that swarfe needs to be carefully managed in their operation. The expected frequency of wheel turning also means they are likely to need a dedicated road, so use of the heavy Maintenance Facility is likely to cause scheduling conflicts.

9.7 Door Maintenance Facilities

Doors are critical components that exist in high numbers on the train and traditionally maintenance has been an annual inspection activity (activity 3 times longer on recent new fleets) with a 4-5 year overhaul cycle. The maintainability of recent fleets that have been introduced to London Underground has resulted in an increase in the production time for door maintenance, due to the amount of dismounting and reassembly required which adds no value to the overall maintenance being undertaken. Typically each train will spend a complete week per year undergoing door maintenance.

It still remains the case that dedicated facilities are required to undertake this activity. Within these maintenance roads, some maintenance tasks are completed with the assistance of manipulation equipment and plant to reduce the level of human movement of doors.

9.7.1 Periodic Door Inspection Facilities

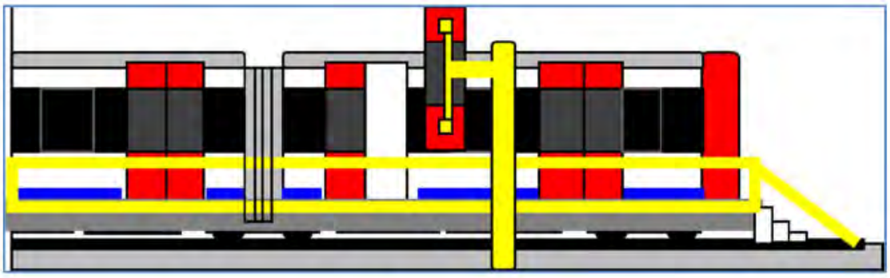
For the more frequent periodic door maintenance activities, good access to the upper and lower door areas is essential. Mobile access platforms have often been used for this activity, however they require manipulation to move into the correct position so a fixed and dedicated facility is required for an activity that will be part of a constant production cycle.

9.7.2 Overhaul Door Maintenance Facilities

The more intrusive door maintenance activities result in complete removal and manipulation of the door and associated equipment.

© Copyright 2009 London Underground Limited. All rights reserved.

With door size and mass possibly increasing, it is anticipated that dedicated equipment is required to manipulate the door; this, in addition to the space required around the train to undertake this activity.



9.8 Adverse Weather Consumable Re-fill Facilities

NTfL tube stock will have equipment to mitigate the impacts of poor adhesion, winter weather and dirty windscreens. All of these require consumables, which in turn will need management and refilling to ensure safety and service performance is maintained. Refilling is required to be undertaken quickly and efficiently for all trains to ensure rapid refill production rate of all required trains in the fleet (Target 8 mins per train). These consumable levels will be monitored remotely with an appropriate threshold for alarm notifications in addition to physical indications on the train. [redacted]

Winterisation Facility Constructed at Neasden Depot for Sanding and De-icing refill for S-Stock

9.8.1 De-icing Refilling Facility (Not W & C)

Approximately 30-40% of the NTfL tube stock fleet will be fitted with the capability to lay an anti–icing fluid on the positive and negative conductor rails to prevent the formation of ice and snow in winter conditions.

The size of tank specified for NTfL is similar to that on S-Stock, which has a which has a fluid laying duration of approximately 9 hours., In high risk periods trains may need to be cycled through the de-icing facilities rapidly to ensure the fluid continues to be dispensed across the line.

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

To facilitate rapid refilling of de-icing tanks in both the planned and reactive maintenance cycle, a target fill rate of 450/l min has been specified to the rolling stock suppliers.

The facility must consider turning of the train (on appropriate lines) and have the capability to refill the de-icing tank regardless of train orientation. The working environment of the maintenance staff must be considered to ensure it is acceptable. The number of required de-icing facilities for the NTfL lines must be carefully calculated to meet operational requirements.

9.8.2 Sanding Refill Facility (Not W & C)

Sanding will be fitted on every NTfL train, with sand hoppers fitted on multiple locations along the train. The rate of sand usage will have a significant impact on the type of facilities required and will vary on each Line. For lines with heavy sand usage, Central Line & Piccadilly Lines, there will be the requirement for dedicated facilities to rapidly replenish hoppers on multiple locations along the train.

For the Bakerloo Line, where sand usage is likely to be much lower, the use of mobile bowsers may be considered. This approach is similar to the approach taken on the Sub-Surface lines (Metropolitan vs. District Line). The maintenance working environment must be considered to ensure it is acceptable.

9.8.3 Screen Wash Refill

A Mobile bower used on any general maintenance in the Depot will fill the Screen Wash tanks. It should be noted Screen Wash Refill has presented unexpected problems for S-stock in that there was no automatic cut off system when the tank was full, hence the liquid continued to overflow when being refilled. A Low fill pressure method of operation had to be developed to overcome these issues.

9.8.4 Sandite Refill Facility (not Bakerloo or W & C)

On the Central Line and possibly the west end of the Piccadilly Line), Sandite Trains will operate during the autumn leaf fall period. (This notes/ assumes that the eastern end open section of the Piccadilly line is short and is treated with Sandite by infrastructure based methods.

These dedicated trains will require Sandite hoppers to be refilled at regular intervals during the leaf fall seasons and requires a location in the depot where this task can be undertaken. Based on existing operation this consists of a platform where the International Bulk Container (IBC) that contains the Sandite can load the hoppers. It should be noted that Sandite has a limited life and will harden when left within a short number of hours.

9.8.5 Stores Facility

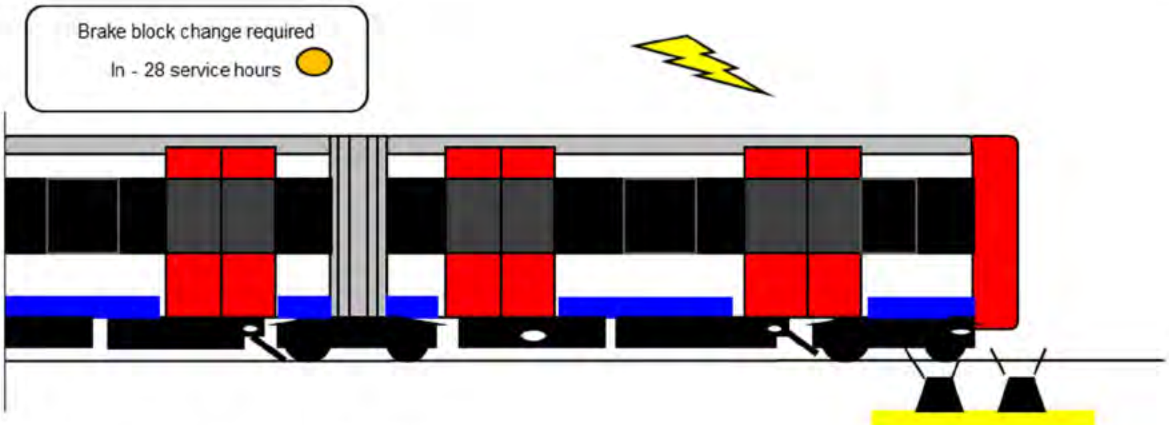
The full strategy for stores management will be outlined in a subsequent version of this concept. It is currently envisaged that there will be a large central stores location (separate from depot locations and located at Acton) with each Depot holding the key spares for its planned and casualty maintenance operation. Delivery to and from the central store will be undertaken on a “Just in Time” principle. The planned stores and management arrangements will be consistent with the agreements for suppliers operations under the FSA and MSA arrangements.

© Copyright 2009 London Underground Limited. All rights reserved.

9.9 Automated Inspection Equipment

Automated inspection equipment is likely to be used as part of the future Maintenance Strategy. It is similar to the requirements for facilities such as the train wash, in that the location of the equipment will be critical to ensure that the required number of trains can pass over it at the required frequency.

[redacted]



9.10 Workshop & Special Facilities

Further work will be undertaken for the next revisions of the concept to review the requirements for workshop facilities required in new depots in line with the emerging train maintenance regime and arrangements agreed for component overhaul.

9.11 Depot Security

Each Depot must be equipped and operated as a secure facility. Authorised personnel must present a valid pass and safety induction certificate at a security gate to enter a Depot. All other pedestrian and vehicular access is subject to a security procedure at a manned or monitored entry point.

CCTV must be extended and expanded across internal / external areas of the depot to ensure protection as part of the new operational model.

9.12 Depot Safety Systems

Protection Systems are installed in modern depots to warn staff of train movements in and out of shed roads. There are currently no Depot Protection Systems installed at any NTfL Depot sites. Therefore, introduction of an audible and visual warning system (plus physical train obstruction or indication) linked to train movement will be required to continue to reduce the risk of injury or death in a Depot to ALARP.

The Depot Contractor is to examine the feasibility for providing audible and visual warning of train movements in and out of maintenance sheds. The warning could be activated from wheel detection switches (treadles) upon the approach of a vehicle towards the particular shed road on which it is to run or via local driver activated switches for exit from particular Depot roads.

© Copyright 2009 London Underground Limited. All rights reserved.

The Depot Protection System is to enhance the current depot rule, (which requires trains to stop before entering a shed) by installing a local stop/go light linked to the roller shutter door and an audible/visual warning system on that road.

10 ESTIMATED NUMBER OF FACILITY TYPES FOR EACH NTFL END STATE OPTION

An estimate of the number and types of critical facilities has been made in the tables below and referenced to the options identified in section 8.3. It will be noted again that this estimate has been derived without specific evidence or modelling and is a general estimate based on similar ranges consistent with experience from the introduction of recent new fleets.

Central & Piccadilly Line Variations (Balanced Strategy)	Piccadilly Line		Waterloo & City Line	Bakerloo Line		Central Line	
Facility	Cockfosters Depot	Northfields Depot	Waterloo Depot	Stonebridge Park Depot	London Road	Hainault Depot	Ruislip Depot
HMF Casualty	1	1	1	1	1	1	1
HMF Overhaul	1	1	0	1	0	1	1
Modified General Exam & Inspection Road	6	6	1	3	0	6	6
New General Exam & Inspection Road	4	4	0	3	1	4	4
Cleaning Road (Above solebar)	3	3	0	4	1	3	3
Underframe Cleaning Road	1	1	Shared	1	0	1	1
Automatic Train Wash	1	0	1	1	0	1	0
Door Road - Periodic Inspection	1	1	Shared	1	0	1	1
Door Road - Overhaul	1	1	Shared	1	0	1	1

© Copyright 2009 London Underground Limited. All rights reserved.

Central & Piccadilly Line Variations (Balanced Strategy)	Piccadilly Line		Waterloo & City Line	Bakerloo Line		Central Line	
Facility	Cockfosters Depot	Northfields Depot	Waterloo Depot	Stonebridge Park Depot	London Road	Hainault Depot	Ruislip Depot
Fluid Replenishment - De-icing	5	5	N/A	3	1	5	5
Fluid Replenishment - Sanding	5	5	N/A	3	0	5	5
Fluid Replenishment –Screen Wash	Any	Any	Shared	Any	1	Any	Any
Wheel Turning Facility	1	1	0	1	0	1	1
Specialist Road - Ventilation System Cleaning	1	0	0	1	0	1	0
Specialist road - Sandite Refill Facility	0	1(TBD)	N/A	0	0	1	1
Automatic Inspection Equipment	1	1	0	1	1	1	1
Central & Piccadilly Line Variations (Main Depot & Satellite per line)							
HMF Casualty	1	1	1	1	1	1	1
HMF Overhaul	2	0	0	1	0	0	2
Modified General Exam & Inspection Road	6	6	1	3	0	6	6
New General Exam &	4	4	0	3	1	4	4

© Copyright 2009 London Underground Limited. All rights reserved.

Central & Piccadilly Line Variations (Balanced Strategy)	Piccadilly Line		Waterloo & City Line	Bakerloo Line		Central Line	
Facility	Cockfosters Depot	Northfields Depot	Waterloo Depot	Stonebridge Park Depot	London Road	Hainault Depot	Ruislip Depot
Inspection Road							
Cleaning Road (Above solebar)	3	3	0	4	1	6	6
Underframe Cleaning Road	1	1	Shared	1	0	1	1
Automatic Train Wash	1	0	1	1	0	1	0
Door Road - Periodic Inspection	1	1	Shared	1	0	1	1
Door Road - Overhaul	2	0	Shared	1	0	0	2
Fluid Replenishment - De-icing	5	5	N/A	3	1	5	5
Fluid Replenishment - Sanding	5	5	N/A	3	0	5	5
Fluid Replenishment - Screen Wash	Any	Any	Shared	Any	1	Any	Any
Wheel Turning Facility	1	1	0	1	0	1	1
Specialist Road - Ventilation System Cleaning	1	0	0	1	0	1	0
Specialist road - Sandite Refill Facility	0	1	N/A	0	0	1	1

© Copyright 2009 London Underground Limited. All rights reserved.

Central & Piccadilly Line Variations (Balanced Strategy)	Piccadilly Line		Waterloo & City Line	Bakerloo Line		Central Line	
Facility	Cockfosters Depot	Northfields Depot	Waterloo Depot	Stonebridge Park Depot	London Road	Hainault Depot	Ruislip Depot
Automatic Inspection Equipment	1	0	0	1	1	0	1
Central & Piccadilly Line Variations (Centralised Heavy Depot at Ruislip)							
HMF "PIT STOP"	1	1	1	1	1	1	1
HMF Overhaul	0	0	0	1	0	0	4
Modified General Exam & Inspection Road	6	6	1	3	0	6	6
New General Exam & Inspection Road	4	4	0	3	1	4	4
Cleaning Road (Above solebar)	3	3	0	4	1	3	3
Underframe Cleaning Road	1	1	Shared	1	0	1	1
Automatic Train Wash	1	0	1	1	0	1	0
Door Road - Periodic Inspection	1	1	Shared	1	0	1	1
Door Road - Overhaul	0	0	Shared	1	0	0	4
Fluid Replenishment - De-icing	5	5	N/A	3	1	5	5

© Copyright 2009 London Underground Limited. All rights reserved.

Central & Piccadilly Line Variations (Balanced Strategy)	Piccadilly Line		Waterloo & City Line	Bakerloo Line		Central Line	
Facility	Cockfosters Depot	Northfields Depot	Waterloo Depot	Stonebridge Park Depot	London Road	Hainault Depot	Ruislip Depot
Fluid Replenishment - Sanding	5	5	N/A	3	0	5	5
Fluid Replenishment - Screen Wash	Any	Any	Shared	Any	1	Any	Any
Wheel Turning Facility	0	0	0	1	0	0	3
Specialist Road - Ventilation System Cleaning	1	0	0	1	0	1	0
Specialist road - Sandite Refill Facility	0	1	N/A	0	0	1	1
Automatic Inspection Equipment	1	1	0	1	1	1	1

11 CORRECTIVE MAINTENANCE AND REPAIR STRATEGIES

11.1 Corrective Maintenance Assumptions

Train reliability represents the greatest risk to satisfactory Depot design and train availability. Although contractual targets exist within the NTfL rolling stock specification and contract, the potential for variation that comes with the reality of in service performance will have to be considered.

Where assumptions associated with train reliability are sensitive with respect to decision-making, it is proposed that benchmarking of facilities required for similar modern rolling stock should be undertaken as far as possible. Before the trains enter service, reliability modelling will be based upon sub-system reliability design data supplied by the supplier.

Assumptions may be necessary to develop Depot road capacity models on contingency reliability forecasts, for example; the traditional LU fleet reliability has been very poor at introduction, whilst

© Copyright 2009 London Underground Limited. All rights reserved.

the reliability contractual targets of 50,000km MBDSAF for delivery and 120,000km for fleet acceptance have been set as high targets.

It is acknowledged that all train fleets are subject to a small number of significant endemic problems/ regular failures requiring inspection or modifications throughout stock life. To this end, special consideration should be given to overprovision of some Depot facilities to balance the risk of significant service disruption. Previous evaluation for 4LM has identified that a business case evaluation supported the case for every depot to be equipped with a synchronised whole-train lifting system (paid back in avoided LCH by just two endemic once-rounds). It is expected that existing centre and side-pitted roads not converted to swimming pool roads will provide adequate provision for non-lifting inspections, modifications or 'once-rounds'.

11.2 Materials and Repair Management

Major traction and auxiliary assemblies (e.g. bogies, compressors and HVAC units) will be swapped out at the depots and sent off site for maintenance (in the same way as Single Minute Exchange manufacturing methodologies). This will ensure shorter train down-time, greater train availability and reduces the amount of required shed space.

Clean rooms are required at Depots to allow first line inspection and testing of on-board electronic modules. The purpose of the clean room is to test, rather than repair; i.e. to confirm a defect by replicating the operational conditions and save costly 'NDF' returns through the repair loop. On this basis, each clean room needs to provide:

- Heating & cooling for ambient temperature control,
- A minimum of two test benches with electrostatic discharge protection
- Space for test racks for electronic modules such as Train Borne signalling
- TCMS, Connect Radio, PIS and OPO modules. Ideally, the clean room should be located within or near the stores area so that components can be carefully controlled and sent to the repair authority or released back in to the spares stock.

It should be assumed that casualty exchange of bogie mounted equipment will be conducted at each train maintenance Depot, requiring on-site storage of casualty components, to allow 'mix and match' build of any bogie derivative for a repair within a shift.

Other heavy casualty facilities to be supported at each site include HVAC and gangway replacement. In particular, it is considered that the frequency of repairs required for HVAC (underframe mounted) will make it impractical to consider NTfL stock transfers between Depots, for the purpose of HVAC repairs necessitating underframe access and removal of HVAC at each site.

Door and gangway repairs are difficult to predict and the pressure upon fleet availability is likely to mean that at least one casualty platform road for door repairs and facilities for gangway replacement will be required at each Depot.

The NTfL implementation will require significant changes to spares, stores and specialist equipment. A strategic review of spares and storage will be undertaken across all assets, balancing on-site versus off-site holdings that will influence this requirement. The requirements for storage space for spares needs to be carefully considered in each Depot and integrated with the requirements for remote storage of spares.

NTfL will ensure the migration plan and programme will cater for the transition from existing spares and specialist equipment to the new spares and specialist equipment. Efficient use of space and storage will leave minimal unused space and storage. The migration should take into account

© Copyright 2009 London Underground Limited. All rights reserved.

synergies and efficiencies between upgrades and on-going existing requirements; providing the most efficient possible cost across Operations.

12 MAINTENANCE SUPPORT ARRANGEMENTS

12.1 Manufacturing & Supply Agreement - Warranty Key Points

The Rolling Stock Warranty period has been defined as two years following delivery of last train for each line. This is a key change resulting from lessons learned with recent Fleet introductions where each train has come out of warranty piecemeal two years after its introduction. Longer warranties (of 4 years) were considered, however following consultation with the supply chain it was felt that this would not offer value for money. LU will have all available information for component/LRU Overhaul and , so flexibility on how the overall future component strategy is managed (externally procured or managed in house), can be maintained at this point and agreed as appropriate in the future, based on the known design of the train.

13 FLEET SUPPORT AGREEMENT (FSA)

To support the NTfL tube Stock throughout its life, the following arrangements have been agreed for supplier support to London Underground:

13.1 FSA Fixed Fee Services - Service Provider to be available 24/7, 365 days per year for the following services.

Design Authority - This enables the supplier to retain long-term technical knowledge and expertise to perform as Design Authority for the New Trains. For this train, it is likely that Technical Design Authority will remain within the supplier for at least the first quarter of its life at least if not whole life. This includes managing obsolescence and can be overridden at LU risk.

Technical Information - To support Operation the supplier is required to manage the technical information for the train by maintaining the electronic library (Including documents provided by LU, including assurance submissions and (background information). Documents must be kept up to date (version control). Relevant documents will also be provided to Maximo/Ellipse

Technical Advice – To provide technical expertise during operational service of the fleet, LU has requested the following services:

- On call response for supplier expertise
- Remote and on-site support
- Access to (Original Equipment Manufacturers) OEMS
- Covers trains as they exist and contents of library

13.2 FSA Call off Services – Service Provider (SP) to be 'available' during normal business hours

Technical Investigation (Incidents and Faults) – This service is to enable for provision of the supply chain knowledge and expertise to support LU to resolve Fleet issues and includes the following:

- Undertake supplier led investigations
- Support to investigations led by LU

© Copyright 2009 London Underground Limited. All rights reserved.

- Duty to act independently (or report conflicts)
- LU not bound to use the supplier for technical expertise

13.3 FSA Engineering & Maintenance Support

This service is to enable the supply chain to support modifications, performance initiatives and maintenance efficiencies during operation of the fleet and includes:

- Advice in connection with modifications, maintenance efficiency and whole life costs
- Software modifications
- ‘Design Authority Assurance’
- Support to LU to transfer Design Authority in-house

13.4 FSA Spares Management Arrangements

The Operations intention is to manage spares supply in house with support from the supply chain where identified for bespoke items.

There is also an option for the supplier to provide spares for the first three years period post warranty (can be extended for further periods of time on a rolling basis) to ensure that the internal supply chain is established. The decision point for this service would be circa 2027.

The spares service operates on the following principles :

- No obligation on LU to buy
- No minimum quantities
- Detailed priced Bill of Materials (“BoM”) provided at contract under MSA
- MSA Whole Life Cost Warranty controls pricing
- 12 month minimum warranty on new items / parts & labour on repairs
- Service Provider manages spares warranty claims arising under MSA or FSA.

Consumables are excluded. service provider

LU is responsible for stock levels and the supplier is responsible for delivering them within stated lead times.

14 FLEET & DEPOT MAINTENANCE TEAM INVOLVEMENT TO NTFL

14.1 Maintenance Introduction & Readiness

A separate paper (Rolling Stock Whole Life Technical Support Life Cycle for New Tube for London NTfL – 2344.1.1-LUL-RPT-00044) has been developed to describe the process of knowledge transfer and how it uses dedicated resource to ensure long term benefit.

An overview of the key principles of this approach is shown below.

14.2 Operational Upgrades & Asset Development Team

The Operational Upgrades & Asset Development Team (OU&AD) has a core team embedded into the NTfL programme. From an Fleet & Depots perspective this team will serve as the day to day

© Copyright 2009 London Underground Limited. All rights reserved.

interface between the Programme and the wider maintenance community. The team should be considered as the 'first point of contact' with Operations (Assets). Where the team has delegated authority from the various asset disciplines then it will provide direct input into the programme. If not, then OU&AD will subsequently ensure that the appropriate representation is provided to the programme.

In order for this approach to be effective it is the responsibility of the programme to ensure that its sub-programmes and projects plan effectively for when maintenance involvement is necessary. It is imperative that sufficient notice is given to allow the designated maintenance representatives to plan for the necessary time.

itIt is expected that each project will embed into their schedule all activities which involve input from the maintenance organisation. The maintenance organisation will subsequently require that projects needs are 'rolled up' by the programme and are presented to the OU&AD team on a rolling one month 'look-ahead' basis. This look-ahead should provide clear information on what the planned activity is and what asset groups are affected.

14.3 Embedded Maintenance Operations Support to NTfL

Extensive experience and lessons learned of London Underground fleet introduction over the past 25 years has shown opportunities for embedded joint working and clearly defined Operations to CPD responsibilities must be taken early and proactively. This is to ensure both successful fleet introduction and handover in the project delivery phase in addition to ensuring that expert long term internal knowledge is developed to ensure high performing long term maintenance capability.

The embedded team approach is therefore recommended for NTFL, ensuring that internal LU Operations knowledge is integrated within the project team and supply chain throughout the project life cycle, leading to a strong self-sufficient capability at the end of the warranty phase and a long term reduction in reliance of the supply chain. Some areas of this support will also have the benefit of being able to provide the supply chain with London Underground engineering service expertise to assist in the "right first time" completion of key work stream deliverables as part of the process of sharing information.

The clear clarification of these activities will ensure that the process of proactive involvement and responsibility is understood and committed to and agreed by both the LU CPD and Operations asset organisations (BCV & JNP).

The implementation of embedded Operations teams within the project, supplier and even sub supplier organisations throughout the project life cycle has the objectives of ensuring knowledge and skills are thoroughly transferred from LU operational experience to the project to influence the design phases. The specifically includes :

Ensuring knowledge and skills are transferred from the Supply chain to the LU Operations Asset teams.

Ensuring activities that require Operations support, knowledge and approval (including development of manuals and depot processes), are organised to achieve "Right First Time delivery".

Ensuring the whole process of maintenance introduction and readiness is integrated.

Ensuring LU Operations has sufficient engineering management of the train through its' whole life.

Ensuring that the Handover process is achieved thoroughly and promptly, with the main deliverables achieved on a staged basis, with Operations as part of the integrated team.

© Copyright 2009 London Underground Limited. All rights reserved.

14.4 Phases/Activities of embedded support

Defining Requirements - The key activity completed for this stage is the completion of the maintenance user requirements. These have been drawn up utilising expertise from around the organisation that are relevant for Rolling Stock Technical Specification, Manufacturing Services agreement (MSA) and the Fleet Support Agreement (FSA). The Operational Upgrades and Asset Development team has co-ordinated this exercise within Operations.

Bid Assessment - At this stage there is wider involvement from Operations asset teams to ensure that the maintenance analysis of the bids is undertaken with input from key subject matter experts within the organisation. This operational input is fundamental at this stage to ensure that the preferred solution is chosen for a strong whole life relationship of forty years.

Design Phases - Embedded Operations support builds on from requirements definition and bid assessment phases by incorporating critical maintenance engineering technical expertise into the design phases. This is considered to be a fundamental requirement in ensuring that the optimal maintainability solution is achieved, and that operational experience and lessons learned are embedded in to this process.

In particular, the capability of the supplier to demonstrate how design for maintainability is considered and developed in this stage, is an important element to making this stage successful and provides insight relevant to the subsequent maintenance demonstration. This should include consideration of human factors for train maintenance.

This will ensure, with a degree of confidence, that the user requirements have been fully reflected in the detailed design. The Mandatory Asset Iinformation Deliverables (MAID) will be further reviewed at this stage and a plan will be produced to outline how phasing of critical information throughout the delivery phase can avoid a “Bow Wave” of information at the planned point of handover.

- **Construction & Testing -** Facilitating the embedding of the Operations teams during the construction and testing phases is aimed at developing the core understanding of physical design and operation and maintainability of the train. This phase in particular requires involvement of the Engineering, Maintenance Introduction and Training teams, to ensure they develop the necessary depth of understanding and knowledge. In particular this involves how local information relates to how the system performs in the real world.

- **Maintenance Demonstration -** To ensure that maintainability performance can be physically achieved, the supplier is required to demonstrate the maintenance capability of the train. The involvement of Operations asset teams for this phase ensures a comprehensive assessment can be undertaken, that ensures that the train can be well maintained in the operational environment. It is also an important validation of both the Train Maintenance Regime and Vehicle Maintenance instructions. It should also be noted that this phase is equally important in ensuring that the depot upgrade requirements meet the capability of the train.

- **Fleet Delivery & Introduction -** The full mobilisation and support of both the embedded team within the project and the wider Operations organisation will be implemented for this phase to ensure integrated and effective change to the operational railway.

When the impact of the project becomes live to the operational railway, the level of Integration and Development of a “ONE TEAM” approach will be fundamental in ensuring this introduction is achieved with minimum impact to the operational railway. Learning lessons from earlier projects will ensure that the performance of the introduced fleet achieves its defined targets, with the Operations asset organisation capable of leading and driving the continued asset performance with the contracted support from the supplier.

© Copyright 2009 London Underground Limited. All rights reserved.

The comprehensive Asset Performance Readiness Plan together with stakeholder agreement will be critical in ensuring successful delivery throughout the introduction phase. As previously outlined, the activities required to deliver the MAID will be fully supported and actively managed during this phase, to ensure that a successful handover process is implemented.

A range of Operations asset teams will ensure the introduction of the new train through asset introduction and into to immediate high performance. In particular the teams directly involved in training and developing the competence and capability of front line maintenance staff are of key importance and priority.

- **Training Support -** Training will be critical to ensuring all staff are competent to work on the new Train and On Board Signalling. Using in-depth knowledge gained from involvement NTfL Programme will allow the embedded teams to assist in the development of Training Needs Analysis (TNA) and to feed back into the training requirements and maintenance course production. Their use has been seen to be particularly beneficial in assisting in the development of operational rules which are traditionally not provided in the Supplier 'train the trainer' training packages, but are necessary to embed as part of end-user training delivery.

- **Assurance -** Supporting the project with Operations (Assets) staff early in the process will enable maintenance acceptance requirements to be clearly defined ensuring a smooth handover, also giving assurance and confidence that Operations (Assets) are ready to accept and maintain the new system.

- **Management of Warranty & Handover -** The involvement and embedding of Operations teams throughout the project lifecycle is intended to significantly assist the process of comprehensive and prompt handover through the continuous identification and correction of issues at an early stage including acceptance of all documentation. The role of the Procurement and Commercial teams in ensuring that the key deliverables are achieved prior to delivery are also critical for successful completion of this phase. From project inception, the active, embedded representation from Operations will ensure that that the upgraded railway meets the defined operational needs and performance levels whilst the organisation is migrated to a world class railway.

Successful completion of handover and achieving world class steady state operation will be achieved through ensuring that the long term asset support arrangements are in place, both in terms of those provided by the supply chain and those implemented internally. These are critical factors and Itit will be by these measures that the success of the embedding process upgrade will be assessed.

14.5 Assets and Facilities Acceptance

Assets shall be designed and managed in such a way as to improve safety and performance and minimise commercial risk in the long term.

14.6 Depot Plant & Equipment

All plant and equipment procured as part of the Upgrade shall be accepted as fit for purpose by the nominated Maintenance Representative for Operations Depot, Plant and Equipment (DP&E). Whole life cost of ownership, repair and maintenance must be a key consideration when specifying equipment. Standardisation of equipment across the NTfL upgrades is preferable in order to rationalise the number of overall contracts that need to be managed by the DP&E team.

© Copyright 2009 London Underground Limited. All rights reserved.

Training for DP&E staff will be the responsibility of the NTfL Upgrade Programme (Project Managers), and fit for purpose Operational and Maintenance instructions will be required as part of the handover process. The design life of each asset should be specified on an asset-by-asset basis, based upon an optimum balance between initial and whole life cost. Long life assets (expected to be used for all of the train fleet life) should be nominally designed to last for 40 years.

14.7 Facilities & Premises Assets

All of the Depots on the London Underground (LU) network are equipped with an Energy Management System (EMS) of differing technology types and functions. An upgrade to the building EMS should be evaluated at the time of Depot Upgrade to identify whether synergy of upgrade scope will result in a positive business case for upgrading the whole EMS.

Any new EMS should be set up to allow Depot staff to track faults and optimise energy use by regulating the heating and/or lighting. Any lighting or heating systems not centrally controlled should incorporate a local control, for example motion sensors, lux level sensors and time switches on pit lighting to reduce energy consumption.

It is acknowledged that the NTfL Depot Upgrade scope does not cover renewal of legacy assets unless upgrade is directly required to support the introduction of the new fleets. Where synergies or efficiencies can be identified in replacement of life-expired or failing assets outside the NTfL scope, the Sponsor may request delivery of works by the NTfL project management, subject to access to necessary funding with no adverse impact to NTfL programme delivery. The Depot Upgrade project teams shall consult with the Maintenance Representative and Sponsor representatives to identify acceptable boundaries (tidemarks) for scope enhancements. A balance will be sought to avoid starkly contrasting standards within adjacent Depot facilities whilst avoiding cost escalation.

14.8 Signalling & Control Assets

It shall be assumed that Fleet operations will be responsible for the first line maintenance inspection of on-train signalling equipment (as per the VLU, SSR & JNUP strategy). A Depot based test rig is required in a clean, temperature-controlled environment for the test of modules removed from the train. Additionally, the NTfL signalling requirements will include the provision and fitment of trackside signalling equipment upon a (nominally) 500m maintenance test track within each of the three Depots for the use of the maintainer following on board signalling unit replacement. These facilities are required to diagnose, confirm and record the nature of defective equipment before it is sent to the repair authority. The second line support and supplier management strategy will be covered in the NTfL Signalling Maintenance Concept.

14.9 OPO CCTV & Correct Side Door Enable

OPO, CCTV & CSDE are integrated systems impacting both Rolling Stock Maintenance and Stations Maintenance however they have been allocated for provision by the Rolling Stock supplier. There are significant lessons to learn in terms of defining future maintenance strategy and more development work and stake holder engagement is planned thought 2016 to accurately define maintenance principles to confirm in line with the requirements of this concept.

14.10 Interface Assets

Train Cab Simulators are maintained a C&I asset. Where the simulator needs to be modified, it is the responsibility of the asset that enacts the change to ensure costs are provisioned. Implementation of changes should be coordinated with Signals & C&I Operations (Assets). Operations (Assets) would manage the changes via the CRS (Change to Rolling Stock) process for

© Copyright 2009 London Underground Limited. All rights reserved.

physical changes to the cab environment (for example cab seats). Where Cab Simulators are maintained away from Depot's or Fleet maintenance sites, the supporting infrastructure will be maintained by Stations Operations (Assets).

14.11 NTfL Maintenance Representative and Stakeholders

Depots are comprised of a large number of assets that are managed by three management groups; these are: Depot, Plant & Equipment, Facilities and Premises. Appendix G is references the relevant User Maintenance Representative for the key assets. Lead Operational Representatives are nominated to represent the Depot production and management teams – these Senior Operations (Assets) Fleet management staff have been embedded in the trains and Depot upgrade project teams to deliver fleet domain knowledge and operational experience. They also ensure that engineering or operational designs and solutions are practical, workable and acceptable to the Fleet organisation.

Whilst the nominated Operational Representatives are responsible for representing Operations (Assets) interests for Operation and Maintenance, it is the NTfL project responsibility to ensure that the relevant Sponsor is involved with any business case evaluations regarding whole life cost. Furthermore, where changes to the Operations (Assets) are materially impacted by NTfL project change (for example, changes to operating efficiency or maintenance contracts), the Depot Sponsor should be engaged to support whole life cost evaluation and budget provision.

© Copyright 2009 London Underground Limited. All rights reserved.

APPENDIX A - CURRENT MAINTENANCE LEVELS & DESCRIPTIONS

Type	Description
Check	Visual check of system integrity or performance, to look for damage, defects and loose or contaminated equipment and fittings
Casualty maintenance	A maintenance task undertaken outside of a planned maintenance regime to identify the cause of and rectify a fault, for example replacement of a flatted wheel.
Condition maintenance	A maintenance task undertaken to confirm the continued fitness for use of a piece of equipment, e.g. Non-Destructive Testing.
Intrusive maintenance	An activity which includes interference with the operation of a system or equipment, including adjustment of clearances, cleaning, dismantling and changing of components
Kilometres run	The distance a train travels. When used in a train maintenance context it shall include both running in and out of passenger service.

Maintenance	Description
Level 1 Train Preparation	Inspection requiring a functional test of specified (mainly safety) equipment in advance of every continuous period of 24hours that the train is available for passenger service.
Level 2 Examination	Examination and service of specified equipment, including train underside from a pit, at interval determined by TMR
Level 3 Shed Day	Inspection, service and on-train maintenance of specified equipment at intervals determined by TMR
Level 4 Programme Lift	Inspection, service and maintenance of specified equipment including exchange of equipment, normally involving separation of car body from bogies, at intervals determined by the TMR
Level 5 Minor Overhaul	Inspection, service and heavy maintenance of specified equipment including replacement of equipment involving separation of the carboy from the bogies defined by the TMR
level 6 Heavy/Major/half-life Overhaul	Inspection, service and major maintenance of specified equipment involving the separation of carboy from bogies and major renewal of equipment and fittings

© Copyright 2009 London Underground Limited. All rights reserved.

Level 7	Replacement of equipment requiring off-train maintenance such as compressors on a time cycle independent of the parent train inspection
Post maintenance testing of trains	The combination of tests and checks to assure that a train has been re-assembled correctly and systems are operating as designed.

© Copyright 2009 London Underground Limited. All rights reserved.

APPENDIX B - PICCADILLY LINE FLEET 1973 TUBE STOCK MAINTENANCE ASSUMPTIONS

(Extracted From Approved 2015 Train Maintenance Regime)

Level	QP / PI	Activity	Period	Tolerance	Estimated average duty
1	QP.73.01	Train Preparation	24 hours	n/a	455 Km
2	QP.73.02	Exam	400 service hours	+20 hours	8373 Km
3	PI.73.18.11.01.TF	Air conditioning test	21 calendar days	+ 3 days	9551 Km
3	PI.73.16.00.C	Underframe clean	60 calendar days	+28 days	38203 Km
3	QP.73.21	MAR and battery check	90 calendar days	+28 days	38203 Km
3	PI.73.31.15.OP	Inspection of yolk welds on truck sides	Condition Assessed	+28 days	59649 Km
3	PI.73.11.01.I2	Traction motor brush check	105 calendar days	+28 days	47754 Km
3	QP.73.10	Cab Air conditioning	365 calendar days	+28 days	76406 Km (Assuming 168 service days)
3	QP.73.12	Traction Module	5000 service hours	+300 hours	114610 Km
3	QP.73.16	Ambience module	365 calendar days	+28 days	114610 Km
3	QP.73.17	Auxiliary module	252 service days	+28 days	114610 Km
3	QP.73.14	Functional System Test module	252 calendar days	+28 days	114610 Km
3	QP.73.13	System Service module	252 service days	+28 days	114610 Km
3	PI.73.31.03.C	Grid clean	252 calendar days	+28 days	114610 Km
3	QP.73.11	Door module	365 calendar days	+28 days	155087 Km (Assuming 341 service days)
3	PI.73.19.04.04.RR	Compressor cylinder head-change	491 calendar days	+28 days	223762 Km
3	QP.73.15	Major Service	547 calendar days	+28 days	229219 Km (Assuming 504 service days)
3	QP.73.19	De-Icing module	365 calendar days	+28 days	155087 Km (Assuming 341 service days)
3	QP.73.28	Armature carbon brush tensator spring replacement	1460 calendar days	+105	620348 Km (Assuming 341 service days)
3	QP.73.29	Armature bearing greasing	730 calendar days	+56 days	310174 Km (Assuming 682 service days)
3	QP.73.27	Rocking link replacement	1095 calendar days	+84 days	465261 Km (Assuming 341 service days)
4	QP.73.24	Ground Wheel Lathe	730 calendar days	+56 days	310174 Km (Assuming 682 service days)
4	QP.73.04	Programme Lift	4.5 calendar years	+ 6 months	697891 Km
4	QP.73.04	Wheel-set Overhaul	4.5 calendar years	+ 6 months	697890 Km
5	QP.73.06	Heavy Overhaul	9 calendar years	+ 12 months	1395781 Km

© Copyright 2009 London Underground Limited. All rights reserved.

APPENDIX C - BAKERLOO LINE FLEET 1972 TUBE STOCK MAINTENANCE ASSUMPTIONS

(Extracted From Approved 2015 Train Maintenance Regime)

Level	QP/PI or Standard	Activity	Frequency	Tolerance	Facilities
1	RSE-ST-04001	Train Preparation	24 Hours	Nil	
1		Litter Pick /	As required	Nil	
1		Sweep and Dust	24 Hours	Nil	
2	RSE-ST-04002	Cab AHU filter change	14 Days	+ 5 Days	
2		Examination	28 days	Nil	
3	E6823	Battery Maintenance	6 Weeks	7 Days	
3		Traction and Aux Maintenance	18 Weeks	+ 28 Days	
3		Winterisation and Summerisation	26 weeks	+ 18 Days	
3		Shed Day	36 weeks	+ 28 Days	
3		Door Maintenance	52 Weeks	+ 36 Days	
3		Static Converter cleaning	2 years	+ 28 Days	
4		Programme Lift	2.5 Years	+ 6 Months	
4		Safety critical relays	4.5 Years	+ 6 Months	
4		Static converter filter and earth Test	4.5 Years	+ 6 Months	
5		Mini Overhaul	7 Years	+ 9 Months	
5		Heavy Overhaul	9 years	+ 12 months	

© Copyright 2009 London Underground Limited. All rights reserved.

7		Compressor overhaul (TBC38Z)	3 Years	+ 6 months	
7		Compressor overhaul (3HC43)	4 Years	+ 6 Months	
7		Traction Motor overhaul	6 Years	+ 12 Months	
7		Motor Alternator overhaul	6 Years	+ 12 Months	
7		Static converter overhaul	10 Years	+ 12 Months	
		Wheelset Ultrasonic Axle Testing	4.5 Years	+ 6 months	
		Routine Brake Test	3 Years	0 Days	
		Standard clean	14 days	3 Days	
		Under-frame clean	9 Weeks	6 Days	
		Under-seat clean	36 weeks	+ 10 Days	
		Train Wash	N/A		

© Copyright 2009 London Underground Limited. All rights reserved.

APPENDIX D - CENTRAL & WATERLOO & CITY LINES – 92 TUBE STOCK MAINTENANCE ASSUMPTIONS

(Note: Extracted From Approved 2015 Train Maintenance Regime)

Level	QP/PI or Standard	Activity	Frequency	Tolerance	Facilities
1	RSE-ST04001 Level 1	Train Preparation	24 Hours	0 hours	
2	RSE-ST 04001 Level 2	28 Day Exam QP02	26 Days (Service Days)	+ 2 Days (Service Days)	
3	To supplement E6823 Level 3	Batteries QP06	2 Month (61 Days)	+ 18 Days	
3	E6823 Level 3	Modular Maintenance Modules [4] QPMM1-QPMM6 [Central] QPMM5 – QPMM6 [W&C]	Yearly (365 days)	+ 90 Days	
3	To supplement E6823 Level 3	Door Maintenance QP16	Yearly (365 days)	+ 36 Days	
3	To supplement E6823 Level 3	Door Bond Inspection QP35	Yearly (365 days)	+ 36 Days	
3	To supplement E6823 Level 3	Door Interlock Inspection QP37	Yearly (365 Days)	+ 36 days	
3	To supplement E6823 Level	Door Force Gauge & Gapping QP45	Yearly (365 Days)	+ 36 days	

© Copyright 2009 London Underground Limited. All rights reserved.

Level	QP/PI or Standard	Activity	Frequency	Tolerance	Facilities
	3				
3	To supplement E6823 Level 3	Air Conditioning Maintenance QP08 Heat & Ventilation check QP46	Yearly (365 Days)	+ 36 days	
3	To supplement E6823 Level 3	ATO/ATP check & Emergency Brake Release Test MY84c	Yearly (365 Days)	+ 36 days	
3	To supplement E6823 Level 3	Compressor Service AP04 (Central Line Only)	2.5 Years (913 Days)	+ 3 months (91 days)	
4		Programme Lift	6 Years (2190 Days)	+ 6 Months (+183 Days)	
5		Minor Heavy Overhaul	12 Years (4380 Days)	+ 1 Year (365 Days)	
5		Door Overhaul	14 Years (5110 Days)	0 Days	
6		Major Heavy Overhaul	18 years (6570 Days)	+ 2 Years (730 Days)	
7		Motor Overhaul	4.5 Years	+ 6	

© Copyright 2009 London Underground Limited. All rights reserved.

Level	QP/PI or Standard	Activity	Frequency	Tolerance	Facilities
			(1643 Days)	Months (183 Days)	
		Motor Light Overhaul	As Required		
7	E6340	Wheelset Overhaul	6 Years (2190 Days)	+ 6 Months (183 Days)	
		Gearbox Overhaul	8 Years (2920 Days)	0 Days	
		Compressor Overhaul (Central Line)	5 Years (1825 Days)	+ 6 Months (183 Days)	
		Compressor Overhaul (W&C)	1.5 Years (548 Days)	+ 55 Days	
	Additional Maintenance	Light Tube Replace	3 Yearly (1095 Days)	+ 4 Months (122 Days)	
		Bogie Fixing Check QP52	6 Monthly (183 Days)	+ 18 Days	
		NDT Schedule QP53 (No current Activities)	6 Monthly (365 Days)	+ 36 Days	
		Gearbox Oil Change QP31	Yearly (365 Days)	+ 36 Days	
		Intercar Barrier QP49	Yearly (365 Days)	+ 36 Days	
		Windows Security	3 Months	+ 9 Days	

© Copyright 2009 London Underground Limited. All rights reserved.

Level	QP/PI or Standard	Activity	Frequency	Tolerance	Facilities
		Checks QP19 (Waterloo & City Only)	(91 Days)		
		Gearbox & Motor Security Checks QP55	14 Days (Service Days)	3 Days (Service Days)	
	Train Radio	Planned work carried out by Connect LU Fleet Staff Replace LRU	Yearly (365 Days)	+36 Days	
		Cleaning – Major Clean (Interior)	21 Days	+ 3 Days	
		Cleaning – Underframe Clean	20 Weeks (140 Days) (Service Days)	+ 14 Days (Service Days)	
		Cleaning Train Wash	3 Days	+ 0 Days	

© Copyright 2009 London Underground Limited. All rights reserved.

APPENDIX E - NTFL TUBE STOCK - MAINTENANCE INTERVENTIONS AND SUPPORTING FACILITIES

Piccadilly Line – Cockfosters Depot

Activity	NTfL Frequency / S-Stock equivalent frequency	Overhaul?	Initial State for 1973 ts	Existing Facility For 1973 ts Maintenance	Requirement For Migration 1973 ts	Requirement for Migration NTfL ts	Full NTfL ts GOA1	Full NTfL ts GOA2 (On Board ATC)
Pre Service check	24hrs		73	Any	73	ntfl	ntfl	ntfl
Balanced Exam A,B and C	25,000 kms		73	Centre Pitted roads with Shallow side Pits	73	ntfl	ntfl	ntfl
Underframe Clean	50,000 kms		73	Road 46 - (Centre Pitted Road with Shallow Side Pits Centre- Pitted road min)	73	ntfl	ntfl	ntfl
Modular Shed Exam	150,000 kms		73	Centre Pitted roads with Shallow side Pits	73		ntfl	ntfl
Annual Door Maintenance	150,000 kms		73	Road 52 - (Centre Pitted road) with Shallow side Pits	73	ntfl	ntfl	ntfl
2 Yearly Exam	300,000 kms			N/A			ntfl	ntfl
Sand filling	Reactive			N/A				ntfl
De Icer filling	Reactive		73		73	ntfl	ntfl	ntfl
De Icer Removal	Annual					ntfl	ntfl	ntfl
Screen Wash refill	8 days			N/A		ntfl	ntfl	ntfl
HVAC Clean	300,000 kms		73 Cab Only	N/A	73 Cab Only	ntfl	ntfl	ntfl
Wheel Turning	18 monthly			N/A			ntfl	ntfl
Planned lifting Light	762,000 kms	Y	73	Lifting Road (53 & 54 Road)	73	ntfl	ntfl	ntfl
Planned Lift Heavy	1524,000 kms	Y	73	Lifting Road (53 & 54 Road)	73	ntfl	ntfl	ntfl
Traction Brake Controller Overhaul	762,000 kms	Y	73	Centre Pitted/ Centre Pitted roads with Shallow side Pits	73	ntfl	ntfl	ntfl
Planned HVAC Removal	1905,000 kms	Y		N/A		ntfl	ntfl	ntfl
Gangway Overhaul / Intercar Jumper	1270,000 kms	Y		N/A	73	ntfl	ntfl	ntfl
Coupler / Semi Perm Coupler Overhaul	1270,000 kms	Y	73	Centre Pitted/ Centre Pitted roads with Shallow side Pits		ntfl	ntfl	ntfl
Planned Door Overhaul	1524,000 kms	Y		Road 52 - (Centre Pitted road) with Shallow side Pits	73	ntfl	ntfl	ntfl
Casualty repair above floor	Reactive		73	Centre Pitted/ Centre Pitted roads with Shallow side Pits	73	ntfl	ntfl	ntfl
Casualty repair below floor	Reactive		73	Centre Pitted/ Centre Pitted roads with Shallow side Pits	73	ntfl	ntfl	ntfl
Casualty Door removal	Reactive		73	Road 52 - (Centre Pitted road) with Shallow side Pits	73	ntfl	ntfl	ntfl
Small and Large Raft removal	Reactive			N/A		ntfl	ntfl	ntfl
Propulsion software updates	2286,000 kms	Y		N/A	73	ntfl	ntfl	ntfl
Seating Overhaul (Saloon, T/Op)	1524,000 kms	Y	73	Cleaning Shed Road A Flat Road	73	ntfl	ntfl	ntfl
Exterior Lighting (OSDIL / De Icer)	1524,000 kms	Y	73	Centre Pitted/ Centre Pitted roads with Shallow side Pits	73	ntfl	ntfl	ntfl
De Icing tank overhaul	1524,000 kms	Y				ntfl	ntfl	ntfl
Casualty repair HVAC	Reactive					ntfl	ntfl	ntfl
Train Wash	4 days		73	Train Wash on Depot Entry/Exit coackfosters End of Depot	73	ntfl	ntfl	ntfl
Train Hand bash	TBC		73	Cleaning Shed Roads B & C	73	ntfl	ntfl	ntfl
Floor Polish	TBC		73	Cleaning Shed Roads B & C	73	ntfl	ntfl	ntfl
Glazing Descale	75,000 kms		73	Cleaning Shed Roads B & C	73	ntfl	ntfl	ntfl
Litter pick	24hrs		73	Any	73	ntfl	ntfl	ntfl

Piccadilly Line – Northfields Depot; Waterloo & City Line – Waterloo Depot

Activity	Northfields: Initial State for 1973 ts	Northfields: Initial State for 1973 ts	Northfields: Requirement For Migration 1973 ts	Northfields: Requirement for Migration NTfL ts	Northfields: Full NTfL ts GOA1	Northfields: Full NTfL ts GOA2 (On Board ATC)	Waterloo: Overhaul?	Waterloo: Initial State for 1992 ts	Waterloo: Existing Facility For 1992 ts Maintenance
Pre Service check	73	Any	73	ntfl	ntfl	ntfl		92	Any
Balanced Exam A,B and C	73	Centre Pitted roads with Shallow side Pits	73	ntfl	ntfl	ntfl		92	
Underframe Clean		N/A	73	ntfl	ntfl	ntfl		92	
Modular Shed Exam	73	Centre Pitted roads with Shallow side Pits	73		ntfl	ntfl		92	
Annual Door Maintenance	73	Road 17 - (Centre Pitted road) with Shallow side Pits	73	ntfl	ntfl	ntfl		92	
2 Yearly Exam		N/A			ntfl	ntfl			N/A
Sand filling		N/A				ntfl			N/A
De Icer filling	73	De-Icing refilling undertaken on XX Road	73	ntfl	ntfl	ntfl			N/A
De Icer Removal				ntfl	ntfl	ntfl			N/A
Screen Wash refill		N/A		ntfl	ntfl	ntfl			N/A
HVAC Clean	73 Cab Only	N/A	73 Cab Only	ntfl	ntfl	ntfl		92 Cab Only	N/A
Wheel Turning	73	Wheel lathe 20 Road	73	ntfl	ntfl	ntfl			N/A
Planned lifting Light	73	Lifting Road (20 & 21 Road)	73	ntfl	ntfl	ntfl	Y	92	Lifting Road
Planned Lift Heavy	73	Lifting Road (20 & 21 Road)	73	ntfl	ntfl	ntfl	Y	92	Lifting Road
Traction Brake Controller Overhaul	73	Centre Pitted/ Centre Pitted roads with Shallow side Pits	73	ntfl	ntfl	ntfl	Y	92	
Planned HVAC Removal		N/A		ntfl	ntfl	ntfl	Y		N/A
Gangway Overhaul / Intercar Jumper		N/A		ntfl	ntfl	ntfl	Y		N/A
Coupler / Semi Perm Coupler Overhaul	73	Centre Pitted/ Centre Pitted roads with Shallow side Pits		ntfl	ntfl	ntfl	Y	92	
Planned Door Overhaul		Road 17 - (Centre Pitted road) with Shallow side Pits		ntfl	ntfl	ntfl	Y		N/A
Casualty repair above floor	73	Centre Pitted/ Centre Pitted roads with Shallow side Pits	73	ntfl	ntfl	ntfl		92	
Casualty repair below floor	73	Centre Pitted/ Centre Pitted roads with Shallow side Pits	73	ntfl	ntfl	ntfl		92	
Casualty Door removal	73	Road 17 - (Centre Pitted road) with Shallow side Pits	73	ntfl	ntfl	ntfl		92	
Small and Large Raft removal		N/A		ntfl	ntfl	ntfl			N/A
Propulsion software updates		N/A	73	ntfl	ntfl	ntfl	Y	92	N/A
Seating Overhaul (Saloon, T/Op)	73		73	ntfl	ntfl	ntfl	Y	92	
Exterior Lighting (OSDIL / De Icer)	73	Centre Pitted/ Centre Pitted roads with Shallow side Pits	73	ntfl	ntfl	ntfl	Y	92	
De Icing tank overhaul				ntfl	ntfl	ntfl	Y		N/A
Casualty repair HVAC		N/A		ntfl	ntfl	ntfl			
Train Wash		N/A						92	N/A
Train Hand bash	73	Roads 18 & 19	73	ntfl	ntfl	ntfl		92	
Floor Polish	73	Roads 18 & 19	73	ntfl	ntfl	ntfl		92	
Glazing Descale	73	Roads 18 & 19	73	ntfl	ntfl	ntfl		92	
Litter pick	73	Any	73	ntfl	ntfl	ntfl		92	

Bakerloo Line – Stonebridge Park Depot

Activity	Overhaul?	Initial State for 1972 ts	Initial State for 1972 ts	Requirement For Migration 1972 ts	Requirement for Migration NTfL ts	Full NTfL ts GOA1 (If Used)	Full NTfL ts GOA2 (On Board ATC)
Pre Service check		72	Any	72	ntfl	ntfl	ntfl
Balanced Exam A,B and C		72	Centre Pitted roads with side Pits	72	ntfl	ntfl	ntfl
Underframe Clean		72	Road 32 Road - Centre Pit road with Side Pits Nomiated for underframe clenaing	72	ntfl	ntfl	ntfl
Modular Shed Exam		72	Centre Pitted roads with side Pits	72		ntfl	ntfl
Annual Door Maintenance		72	Road 31- Centre Pitted road side Pits	72	ntfl	ntfl	ntfl
2 Yearly Exam					ntfl	ntfl	ntfl
Sand filling							ntfl
De Icer filling		72	De-Icing refilling undertaken on 45 Road	72	ntfl	ntfl	ntfl
De Icer Removal					ntfl	ntfl	ntfl
Screen Wash refill			N/A		ntfl	ntfl	ntfl
HVAC Clean		72 cab only	N/A	72 cab only	ntfl	ntfl	ntfl
Wheel Turning			N/A		ntfl	ntfl	ntfl
Planned lifting Light	Y	72	Lifting Road (37 & 38 Road)	72	ntfl	ntfl	ntfl
Planned Lift Heavy	Y	72	Lifting Road (37 & 38 Road)	72	ntfl	ntfl	ntfl
Traction Brake Controller Overhaul	Y	72	Centre Pitted roads with side Pits	72	ntfl	ntfl	ntfl
Planned HVAC Removal	Y		N/A		ntfl	ntfl	ntfl
Gangway Overhaul / Intercar Jumper	Y		N/A	72	ntfl	ntfl	ntfl
Coupler / Semi Perm Coupler Overhaul	Y	72	Centre Pitted roads with side Pits		ntfl	ntfl	ntfl
Planned Door Overhaul	Y		N/A	72	ntfl	ntfl	ntfl
Casualty repair above floor		72		72	ntfl	ntfl	ntfl
Casualty repair below floor		72		72	ntfl	ntfl	ntfl
Casualty Door removal		72			ntfl	ntfl	ntfl
Small and Large Raft removal			N/A		ntfl	ntfl	ntfl
Propulsion software updates	Y		N/A		ntfl	ntfl	ntfl
Seating Overhaul (Saloon, T/Op)	Y	72		72	ntfl	ntfl	ntfl
Exterior Lighting (OSDIL / De Icer)	Y	72	Centre Pitted/ Centre Pitted roads w th Shallow side Pits	72	ntfl	ntfl	ntfl
De Icing tank overhaul	Y	72		72	ntfl	ntfl	ntfl
Casualty repair HVAC			N/A		ntfl	ntfl	ntfl
Train Wash		72	Train Wash on Road 21 Depot Exit Road	72	ntfl	ntfl	ntfl
Train Hand bash		72	Roads 39,40,41 42,43 &	72	ntfl	ntfl	ntfl
Floor Polish		72	Roads 39,40,41 42,43 &	72	ntfl	ntfl	ntfl
Glazing Descale		72	Roads 39,40,41 42,43 &	72	ntfl	ntfl	ntfl
Litter pick		72	Any	72	ntfl	ntfl	ntfl

Central Line – Hainault Depot; Ruislip Depot

Activity	Hainault: Overhaul?	Hainault: Initial State for 1992 ts	Hainault: Existing Facility For 1992 ts Maintenance	Hainault: Requirement For Migration 1992 ts	Hainault: Requirement for Migration NTfL ts	Hainault: Full NTfL ts GOA2 (On Board ATC)	Ruislip: Initial State for 1992 ts	Ruislip: Initial State for 1992 ts	Ruislip: Requirement For Migration 1992 ts	Ruislip: Requirement for Migration NTfL ts	Ruislip: Full NTfL ts GOA2 (On Board ATC)
Pre Service check		92	Any	92	ntfl	ntfl	92	Any	ntfl	ntfl	ntfl
Balanced Exam A,B and C		92	Centre Pitted roads with Shallow side Pits	92	ntfl	ntfl	92		ntfl	ntfl	ntfl
Underframe Clean		92	Road 46 - (Centre Pitted Road with Shallow Side Pits Centre- Pitted road min)	92	ntfl	ntfl		N/A			
Modular Shed Exam		92	Centre Pitted roads with Shallow side Pits	92		ntfl	92		92		ntfl
Annual Door Maintenance		92	Road 52 - (Centre Pitted road with Shallow side Pits	92	ntfl	ntfl	92		92	ntfl	ntfl
2 Yearly Exam			N/A			ntfl	No	N/A		ntfl	ntfl
Sand filling			N/A		ntfl	ntfl	No	N/A		ntfl	ntfl
De Icer filling		92	De-Icing refilling undertaken on 55 Road	92	ntfl	ntfl	ntfl	De-Icing refilling undertaken on 36 & 37 Road	ntfl	ntfl	ntfl
De Icer Removal					ntfl	ntfl				ntfl	ntfl
Screen Wash refill			N/A		ntfl	ntfl		N/A		ntfl	ntfl
HVAC Clean		92 Cab Only	N/A	92 Cab Only	ntfl	ntfl	92 Cab Only	N/A	92 Cab Only	ntfl	ntfl
Wheel Turning			N/A			ntfl	92	N/A	92	ntfl	ntfl
Planned lifting Light	Y	92	Lifting Road (63 & 64 Road)	92	ntfl	ntfl	92	Lifting Road (51 .52 & 53 Road East)	92	ntfl	ntfl
Planned Lift Heavy	Y	92	Lifting Road (63 & 64 Road)	92	ntfl	ntfl	92	Lifting Road (51 .52 & 53 Road East)	92	ntfl	ntfl
Traction Brake Controller Overhaul	Y	92		92	ntfl	ntfl	92	Centre Pitted/ Centre Pitted Roads with Shallow side P ts	92	ntfl	ntfl
Planned HVAC Removal	Y		N/A		ntfl	ntfl		N/A		ntfl	ntfl
Gangway Overhaul / Intercar Jumper	Y		N/A		ntfl	ntfl		N/A		ntfl	ntfl
Coupler / Semi Perm Coupler Overhaul	Y	92			ntfl	ntfl	92	Centre Pitted/ Centre Pitted roads with Shallow side P ts	92	ntfl	ntfl
Planned Door Overhaul	Y			92	ntfl	ntfl	92	N/A		ntfl	ntfl
Casualty repair above floor		92		92	ntfl	ntfl	92		ntfl	ntfl	ntfl
Casualty repair below floor		92			ntfl	ntfl	Yes		ntfl	ntfl	ntfl
Casualty Door removal		92			ntfl	ntfl	Yes		ntfl	ntfl	ntfl
Small and Large Raft removal			N/A		ntfl	ntfl	92	N/A	92	ntfl	ntfl
Propulsion software updates	Y	92		92	ntfl	ntfl	92	N/A	92	ntfl	ntfl
Seating Overhaul (Saloon, T/Op)	Y	92	Cleaning Shed Road A Flat Road	92	ntfl	ntfl	92		92	ntfl	ntfl
Exterior Lighting (OSDIL / De Icer)	Y	92	Centre Pitted/ Centre Pitted roads with Shallow side Pits	92	ntfl	ntfl	Yes		92	ntfl	ntfl
De Icing tank overhaul	Y	92				ntfl					ntfl
Casualty repair HVAC					ntfl	ntfl		N/A		ntfl	ntfl
Train Wash		92		92	ntfl	ntfl	No		No	TBC	TBC
Train Hand bash		92	Cleaning Shed Roads A, B & C	92	ntfl	ntfl	TBC	N/A	TBC	TBC	TBC
Floor Polish		92	Cleaning Shed Roads A, B & C	92	ntfl	ntfl	TBC	N/A	TBC	TBC	TBC
Glazing Descale		92	Cleaning Shed Roads A, B & C	92	ntfl	ntfl	TBC	N/A	TBC	TBC	TBC
Litter pick		92	Any	92	ntfl	ntfl	TBC	N/A	TBC	TBC	TBC

© Copyright 2009 London Underground Limited. All rights reserved.

APPENDIX F - NOTIONAL TRAIN CLEANING REGIME (GOOD PRACTICE)

Types of Clean	No of Units per Week	Frequency	Shift
Pre-Service	All service trains	24 Hourly	Days/Nights
Deep Cab Cleans	40	2 Weekly	Days
Seat Well Cleans	10	15 weeks	Days
Standard Clean	60	14 Days	Nights
MSS Clean	70	Weekly	Nights
Modular (+ "I" Clean)	60	14 Days	Days
Under frame	10	15 Weekly	Nights
Exterior Wash Manual	30	2.5 Weekly	Days/Nights
Exterior Wash Auto		3 Days	Days
In Service Litter Pick	All service trains	Daily	Days/Lates
Paper Re-cycling	All service trains	Daily	Days/Lates/Nights
Siding Accommodation	7 nights	Nightly	Nights

© Copyright 2009 London Underground Limited. All rights reserved.

APPENDIX G - BASELINE OF EXISTING FLEET & DEPOTS OPERATION

1. The Current Fleet & Depots Operation - Initial Migration State

1.1 Current Fleet Organisation

The current Fleet organisations for the NTfL lines to be upgraded are run as separate operations. The Bakerloo, Central and Waterloo & City Lines are organised under the BCV grouping, with the Piccadilly Line under the JNP grouping.

The history of the organisation over the last fifteen years resulted in BCV and JNP being operated as separate commercial asset management companies while the Public– Private Partnership (PPP) was in operation. This period of operation has resulted in differences in asset management approach, structure of support services and asset management support systems before those organisations re-migrated to closer relationships back within the TfL group of companies.

1.2 Current Train Maintenance Regimes

The existing Train Maintenance Regimes (TMR) give details of the preventative, supplementary, cleaning and testing activities planned for each stock. For the purpose of capacity modelling, a summary of the current key levels of maintenance is shown in Appendix A. Activities, frequencies and facility requirements for 73TS (Piccadilly Line), 72TS (Bakerloo Line) and 92TS (Central & Waterloo and City Lines) Stock are given in Appendix B, Appendix C & Appendix D.

© Copyright 2009 London Underground Limited. All rights reserved.

1.3 Current Depot Operations

1.3.1 Current Train Movement Summary

The current headway injection to service rate from NTfL Depots based on the current peak (as of December 2015) is as follows:

Line	Location	East End of Depot	No	West End OF Depot	No
Piccadilly Line	(East) Cockfosters Depot	East to Cockfosters AM -	22	West to Oakwood AM	12
		West From Cockfosters PM	22	East From Oakwood PM	12
	(West) Northfields Depot	East to Northfields AM	24	West To Boston Manor AM	10
		West From Northfields PM	24	East From Boston Manor PM	10
Central Line	(East) Hainault Depot	To Grange Hill	7	To Hainault -	27
		From Grange Hill	7	From Hainault	27
	(West) Ruislip Depot	East to Ruislip Gardens AM	8	West To West Ruislip AM	9
		West From Ruislip Gardens PM	8	East From West Ruislip PM	9
Bakerloo Line	Stonebridge Park Depot	To Stonebridge AM	12		
		From Stonebridge PM			
Waterloo Depot	Waterloo Depot	To Waterloo AM - 5 From Waterloo PM - 5			

© Copyright 2009 London Underground Limited. All rights reserved.

1.4 Piccadilly Line Fleet Maintenance Operation

Northfields Depot – Existing Maintenance Facilities & Function				
Road Number	Location	Current Road Type & Length (m)		Current Function / Notes
1	Maintenance Shed	Centre Pit	129	General Maintenance Used for Track Recording Train
2	Maintenance Shed	Centre Pit	129	General Maintenance
3	Maintenance Shed	Centre Pit	129	General Maintenance
4	Maintenance Shed	Centre and Shallow Side Pits	129	General Maintenance
5	Maintenance Shed	Centre and Shallow Side Pits	129	General Maintenance
6	Maintenance Shed	Centre and Side Pitted Calibrated Road	129	General Maintenance
7	Maintenance Shed	Centre and Side Pitted Calibrated Road	129	General Maintenance
8	Maintenance Shed	Centre and Shallow Side Pits	129	General Maintenance
9	Maintenance Shed	Centre Pit	129	General Maintenance
10	Maintenance Shed	Centre and Shallow Side Pits	129	General Maintenance
11	Maintenance Shed	Centre and Shallow Side Pits	129	General Maintenance
12	Maintenance Shed	Centre Pit	129	General Maintenance
13	Maintenance Shed	Centre Pit	129	General Maintenance
14	Maintenance Shed	Centre Pit	129	General Maintenance

© Copyright 2009 London Underground Limited. All rights reserved.

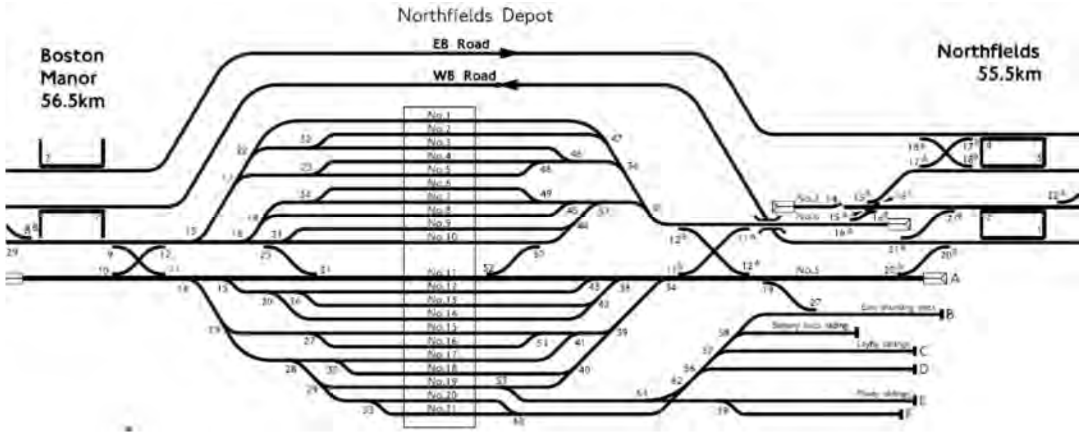
15	Maintenance Shed	Centre Pit	129	General Maintenance
16	Maintenance Shed	Centre Pit	129	General Maintenance
17	Maintenance Shed	Centre Pit	129	Door Road Brakes Overhaul
18	Cleaning Road	Above solebar Cleaning Road	129	Door Road , General interior clean , Deep interior clean Platform currently only on one side of train so only interior cleaning is possible
19	Cleaning Road	Above solebar Cleaning Road	129	Door Road General interior clean Deep interior clean, Exterior clean - Hand bashing
20	Lifting Shed & Wheel Lathe	Overhead Crane Lifting Road	113	Heavy Overhaul Brakes Overhaul, NDT Testing
21	Lifting Shed	Overhead Crane Lifting Road	113	Heavy Overhaul Brakes Overhaul, NDT Testing

The 1973 Tube Stock (86.5 trains) is maintained between the two Depots located at the eastern end (Cockfosters) and the central western side (Northfields), with the fleet maintained under the management of the JNP team. Both Depots are equipped to undertake all levels of maintenance. There are some modular maintenance activities that are focused at either Northfields & or Cockfosters to balance efficiency. Equipment overhauls are undertaken at a centralised overhaul workshop run by London Underground at Acton, called the Railway Engineering Workshop (REW) and also by other external suppliers. There is currently a life extension project in progress for the fleet that has included a bogie project and floor covering replacement and extended bogie overhaul. There may be further life extension projects leading up to fleet replacement.

1.4.1 Northfields Depot

Northfields Depot is located on the western side of the Line on the Heathrow Branch. It is a double-ended Depot with a central complex of facilities that is unique, in that the Depot facilities extend across the entire width of the Depot. Its general layout is shown in the diagram below:

© Copyright 2009 London Underground Limited. All rights reserved.

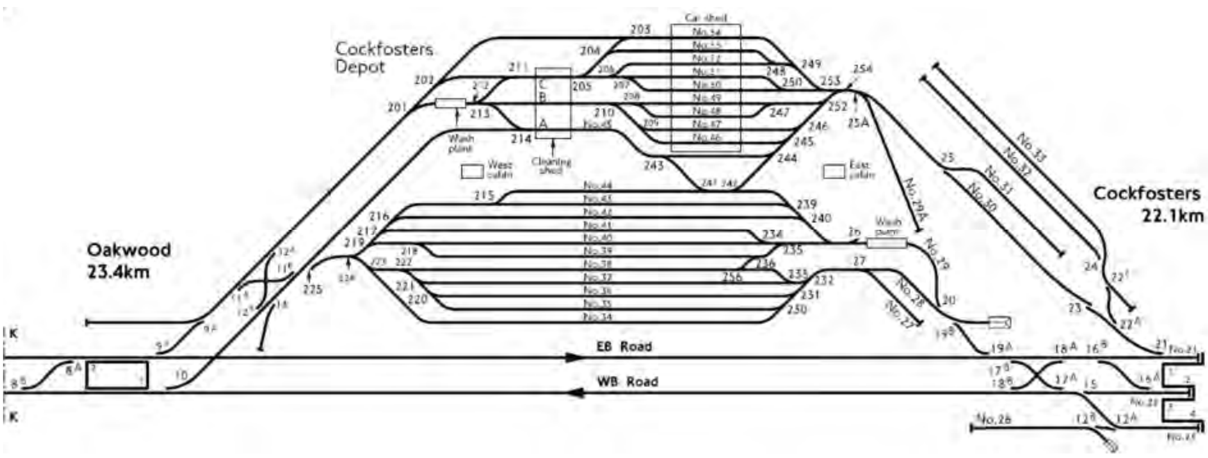


Train movements are currently controlled by hand worked points using a ground shunter past the inlet/outlet roads, which are trailing when exiting the Depot. The heavy maintenance facilities (currently 20 & 21 roads) include a two road lifting facility with an overhead crane to facilitate a single car lift on to car stands. Road 20 also has a single headed underfloor wheel lathe to undertake planned condition turning in addition to casualty wheel turning. There are two dedicated above solebar cleaning roads (18 Road – single sided & 19 Road - double sided).

The remaining seventeen roads are a mixture of centre-pitted roads with no side pits and centre pitted roads with shallow and narrow side pits from which general exam and inspection activities are undertaken. Road 17 has a dedicated crane to facilitate door maintenance and overhaul. Space between pitted roads is typically 1.9m between carbodies. Number 1 road is currently used for the maintenance and stabling of the Track Recording train, new Asset Inspection Train and is also used to stable trains from other parts of the network that have been transferred for testing on the South Ealing test track. The full summary of facilities is shown in the following table:

1.4.2 Cockfosters Depot

Cockfosters Depot is located at the eastern end of the Line and is a double ended Depot with a defined separate triple train length stabling area (30 berths) and an area containing the maintenance facilities consisting of a central shed and separate cleaning shed. Its general layout is shown in the diagram below.



Train movements are currently controlled by hand worked points using a ground shunter past the inlet/outlet roads, which are trailing when exiting the depot.

© Copyright 2009 London Underground Limited. All rights reserved.

The Heavy maintenance facilities (53 & 54 road) include a two road lifting facility with overhead crane to facilitate a single car lift onto car stands. Within this facility there is currently a configuration to undertake a bogie overhaul project on 73TS, which includes a bogie jig and a welding plant.

The remaining seven roads in the main shed are a mixture of centre-pitted roads and centre pitted roads with shallow and narrow side pits from which general exam and inspection activities are undertaken. Road 46 is generally dedicated as an underframe-cleaning road. . Typical space between pitted roads is 1.9 m.

There is a separate dedicated cleaning shed (Roads A, B & C). Road A is configured as a flat road and has been recently used as the facility for flooring replacement on 73TS. Of the remaining two above solebar cleaning roads only one is used for cleaning. The full summary of facilities is shown in the following table.

There is an automatic train wash with water harvesting system located at the east end of the Depot (Cockfosters end) to support the requirements for exterior train cleaning. De-icing refill is undertaken on a multiple number of outside roads including 45 road.

Cockfosters Depot – Existing Maintenance Facilities & Function				
Road Number	Position	Current Road Type & Length (m)		Function / Notes
46	Maintenance Shed	Underframe Cleaning Road	129	Underframe clean
47	Maintenance Shed	Centre and Deep Side Pits	129	General Maintenance Door faults, Brake faults, Traction faults, Auxiliary faults and any other faults that do require access using side pits as agreed with an ATM and the DDM
48	Maintenance Shed	Centre Pit	129	General Maintenance
49	Maintenance Shed	Centre Pit	129	General Maintenance
50	Maintenance Shed	Centre and Side Pitted Calibrated Road	129	Compressor replacement Door faults, Brake faults, Traction faults, Auxiliary faults and any other faults that do require access using side pits as agreed with an ATM and the DDM. Manipulator within the centre pit to remove items such as compressor

© Copyright 2009 London Underground Limited. All rights reserved.

Cockfosters Depot – Existing Maintenance Facilities & Function				
Road Number	Position	Current Road Type & Length (m)		Function / Notes
51	Maintenance Shed	Centre and Side Pitted Calibrated Road	129	Compressor replacement Door faults, Brake faults, Traction faults, Auxiliary faults and any other faults that do require access using side pits as agreed with an ATM and the DDM. Manipulator within the centre pit to remove items such as compressor.
52	Maintenance Shed	Centre and Shallow Side Pits	126	Door Exam , Door Overhaul , Door faults, Brake faults, Traction faults, Auxiliary faults and any other faults that do require access using side pits as agreed with an ATM and the DDM.
53	Lifting Shed	Overhead Crane Lifting Road	118	Heavy Overhaul , NDT Testing , Brakes Overhaul
54	Lifting Shed	Overhead Crane Lifting Road	118	Heavy Overhaul , NDT Testing, Brakes Overhaul
A	Cleaning Shed	Flat Road	n/a	Currently used for overhaul of components, e.g. seat exchange.
B	Cleaning Shed	Above solebar Cleaning Road	n/a	General interior clean , Deep interior clean Exterior clean - hand bashing
C	Cleaning Shed	Above solebar Cleaning Road	n/a	General interior clean, Deep interior clean , Exterior clean - hand bashing

1.5 Waterloo & City Line Fleet Maintenance Operation

The Waterloo and City line fleet maintenance operation is managed under the Central Line BCV fleet management team.

The asset wear cycle is not high, however, it has a significantly higher number of direction changes compared to other lines and this for example, means that cab equipment suffers greater wear than is experienced on other lines.

1.5.1 Waterloo Depot

The five 1992 Tube Stocks that are captive to the Waterloo and City line are maintained in the tightly constrained Waterloo Depot. It has equipment to undertake all levels of maintenance but does not currently have a wheel lathe. Wheelsets that require turning are removed and transported to REW.

© Copyright 2009 London Underground Limited. All rights reserved.

Waterloo Depot consists of two maintenance roads (roads 2 & 3) which are located closest to the Depot staff facilities and pedestrian entrance to the Depot.

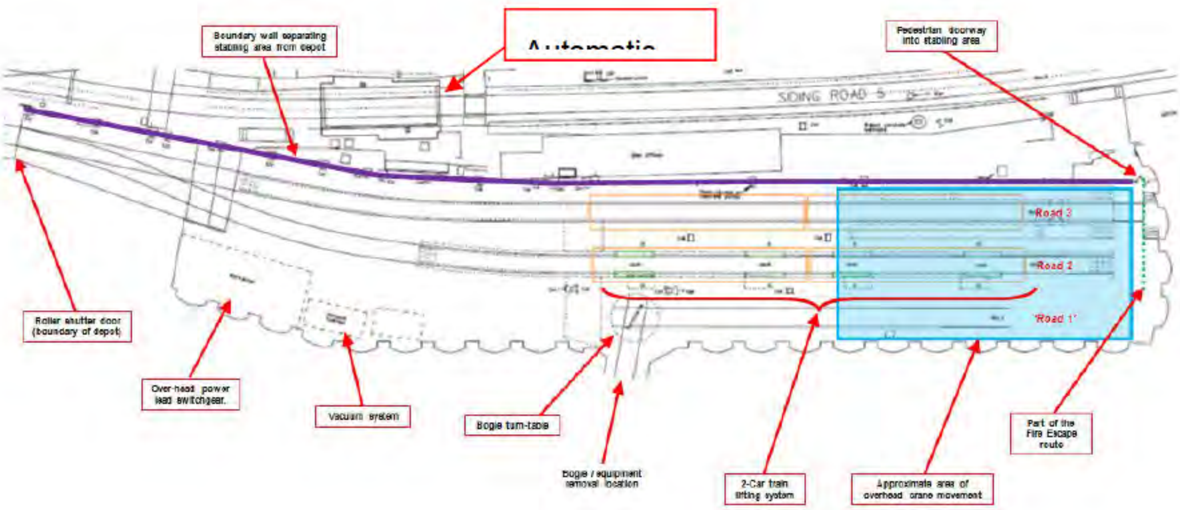
Both maintenance roads have centre pits which give staff access to the underside of the train for light maintenance tasks and inspections. The pit on road 3 is of sufficient length to gain access beneath a full train (i.e. a 4-car unit) but the pit on road 2 is only long enough for a 2-car unit.

Road 3 has side pits to both sides of the train of sufficient length for access to a single car only. Road 2 has an in floor lift installed that has the capability to undertake a 2-car synchronised lift of a unit to enable bogies to be removed. The trains can be split into individual cars if necessary to access the couplers and other inter-car equipment.

There are 2 overhead cranes to manipulate bogies or heavy equipment over the area of roads 2 and 3 (coverage is broadly from the end wall up to 2-cars along the Depot, i.e. under the higher, pitched roof section). These cranes enable components to be moved to the area closest to the Depot staff facilities (road 1) where there are further cranes / a bogie turn-table to allow components to be moved up and out of the Depot on the back of a lorry.

The Depot has Mobile Access Platforms (MAPs) available which can be positioned to enable access for door maintenance or to gain access to the side of the train. There is a vacuum system located on the area of road 1 to allow interior cleaning. An automatic train wash is located on road 5, with other routine activities such as litter picking and interior train cleaning are undertaken on stabling roads 5 and 6.

Over-head power leads (jumpers) are provided to power the trains when stabled on roads 2 and 3. The switchgear and supply equipment is located at the northern end of road 1.



General Layout of Maintenance Facilities at Waterloo Depot

Waterloo Depot – Existing Maintenance Facilities & Function

© Copyright 2009 London Underground Limited. All rights reserved.

Road Number	Position	Road Type & Length (m) Current		Current Facility Capability Function / Notes
1	Maintenance Shed	Flat Road with Bogie Turntable	n/a	
2	Maintenance Shed	2 - Car synchronised Lifting Road	50	Heavy Planned & Casualty Maintenance.
3	Maintenance Shed	Centre and Deep Side Pits	63	General Maintenance & Inspection.
5	Automatic Train Wash Road	Automatic train Wash		

1.6 Bakerloo Line

The Bakerloo Line fleet is managed under the BCV Fleet management team

1.6.1 Stonebridge Park Depot

The 36 1972 Mark II tube stocks that operate the Bakerloo Line are maintained from Stonebridge Park Depot a single ended Depot. It is located at the central northern end of the line which is LU owned and operated but connected to the Network Rail controlled main line infrastructure section known as the "Watford DC" Lines outside the Depot limits. The infrastructure reverts to London Underground ownership North of Queens Park.

All levels of planned and casualty maintenance including programme lift and overhaul are undertaken within the Depot. Component overhauls are undertaken centrally at REW with support from other external suppliers. The Depot operation today is not able to undertake wheel-turning activities on site and therefore trains have to be lifted and wheel sets sent to the REW for this task to be completed.

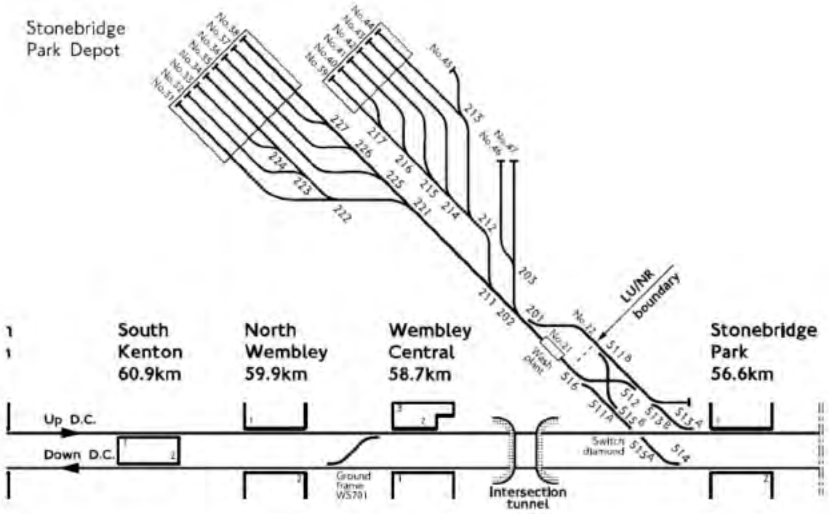
There is additionally the first phase (2015) of a life extension overhaul programme to undertake weld and corrosion repairs to the fleet. This overhaul is being undertaken at REW Acton with the trains being moved by rail or by road using a newly constructed transfer ramp in the Depot. There may be a second overhaul phase that includes RVAR modifications before the NTfL programme, but the scope and extent of this overhaul is still under discussion and development.

The Bakerloo Line is physically connected to the Jubilee Line at Baker Street, however obtaining paths for moves between other maintenance locations around the network entails a long transfer time and is difficult to plan. Train movements are currently controlled by a tower within the Depot which operates powered points. These interface with the Network Rail Signalling Centre. Depot maintenance facilities comprise of two main sheds consisting of an eight-road maintenance shed and a six road cleaning shed. The heavy maintenance facilities (37 & 38 road) include a two road lifting facility with overhead crane to facilitate single car lift on to car stands.

The remaining six roads in the main shed are all centre-pitted roads with deeper and wider side pits that undertake general exam and inspection activities with a typical space between the roads of 2.4m. Road 32 is generally dedicated for underframe-cleaning road and 31 road is dedicated to door maintenance and overhaul.

© Copyright 2009 London Underground Limited. All rights reserved.

There is a separate dedicated above solebar cleaning shed consisting of six roads (Roads 39-44) and an automatic train wash to support the requirements for exterior train cleaning on 31 road. Note: The Bakerloo Line does not currently have the capability for wheel turning facilities on site and this has caused severe challenges to maintenance delivery.



Stonebridge Park Depot – Existing Maintenance Facilities & Function				
Road Number	Road	Current Road Type & Length (m)		Function / Notes
31	Maintenance Shed	Centre and Deep Side Pits	116	Door Exam , Door Overhaul Door Rd Mobile Access Platforms are used.
32	Maintenance Shed	Underframe Cleaning Road	116	Underframe clean Access to the under frame to remove dirt.
33	Maintenance Shed	Centre and Deep Side Pits	116	General Maintenance
34	Maintenance Shed	Centre and Deep Side Pits	116	General Maintenance
35	Maintenance Shed	Centre and Deep Side Pits	116	General Maintenance

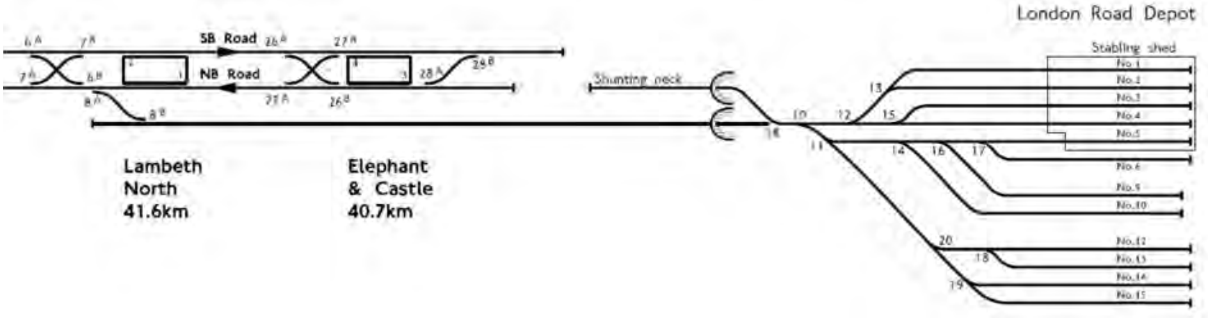
© Copyright 2009 London Underground Limited. All rights reserved.

Stonebridge Park Depot – Existing Maintenance Facilities & Function				
Road Numbe r	Road	Current Road Type & Length (m)		Function / Notes
36	Maintenanc e Shed	Centre and Deep Side Pits	11 6	General Maintenance
37	Lifting Shed	Overhead Crane Lifting Road	11 6	Heavy Overhaul , NDT Testing , Lifting roads are also used for weld repairs etc.
38	Lifting Shed	Overhead Crane Lifting Road	11 6	Heavy Overhaul , NDT Testing ,Lifting roads are also used for weld repairs etc.
39	Cleaning Shed	Above solebar Cleaning Road	n/a	Gentle interior clean Deep interior clean Exterior clean - hand bashing Inside Carriage Cleaning
40	Cleaning Shed	Above solebar Cleaning Road	n/a	
41	Cleaning Shed	Above solebar Cleaning Road	n/a	
42	Cleaning Shed	Above solebar Cleaning Road	n/a	
43	Cleaning Shed	Above solebar Cleaning Road	n/a	
44	Cleaning Shed	Above solebar Cleaning Road	n/a	Graffiti cleaned on Road 44 as it has drainage

1.6.2 London Road Depot

London Road Depot has limited older maintenance facilities generally not up to modern standards and is only used as a location for level 1 maintenance - train preparation, daily interior cleaning and emergency casualty investigation. Points within London Road Depot are hand-worked and manually operated by a ground shunter past the shunt neck.

© Copyright 2009 London Underground Limited. All rights reserved.



1.7 Central Line

The 1992 Tube Stock (87 trains) are maintained between the two Depots located at the eastern end (Hainault) and the western End (Ruislip). Both Depots are equipped to undertake all levels of maintenance however some activities are focused at either Ruislip or Hainault. REW and other external suppliers undertake equipment overhauls. There is currently (2015) a significant life extension project planned to improve reliability and extend the life of the fleet until replacement with the NTfL fleet.

1.7.1 Hainault Depot

Hainault Depot is located at the Eastern End of the Line on a circular section of the Central Line known as the Hainault Loop. It is a double-ended Depot with a defined separate double length stabling area (30 x berths) and area containing the maintenance facilities consisting of a central shed and separate cleaning shed. Its general layout is shown in the diagram below.

Train movements are currently controlled by hand worked points using a ground shunter past the inlet/outlet roads, which are trailing when exiting the Depot.

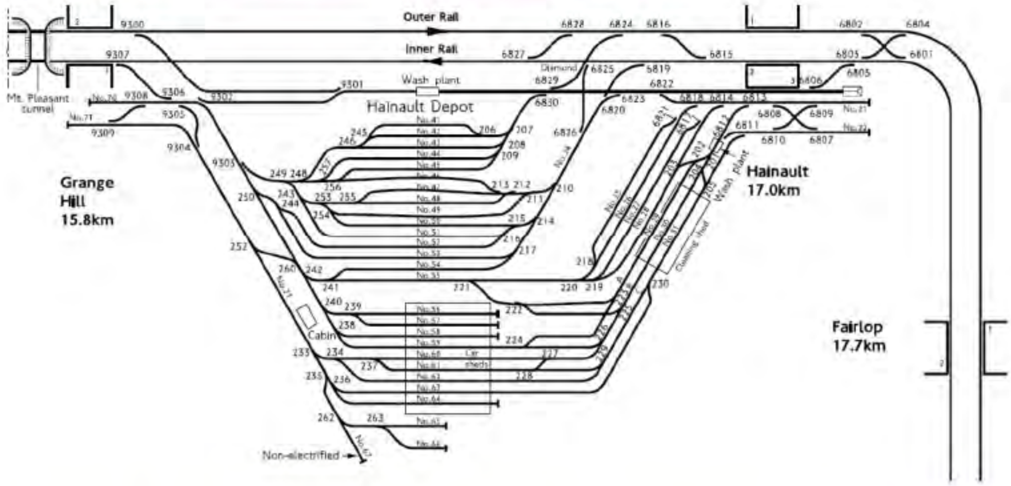
Within the main shed the heavy maintenance facilities (60 road & 44 road) include a two road lifting facility with overhead crane and on floor synchronised jacks to facilitate double car lifting under body with bogies strapped

The six roads 57 – 62 are a mixture of centre-pitted roads and centre pitted roads with wider and deeper side pits that undertake general exam and inspection activities. Roads 60 & 61 are currently calibrated roads. Typical space between pitted roads is 1.9 m

Road 56 is a dedicated vacuum plant facility built to resolve the design issues of dust build up in the ventilation ducting of 92 TS, which have also been experienced on subsequent fleets. There is a separate dedicated cleaning shed (Roads A, B & C) that are all configured as above solebar cleaning roads within all activities of this type currently undertaken at Hainault for the whole fleet.

There are two exterior automatic train washes located at both the East and West ends of the Depot to support the requirements for exterior train cleaning. De-icing refill is undertaken on 55 road. The full summary of facilities is shown in the following table. The east end 1962TS Sandite train is operated, refilled and maintained from Hainault during the leaf fall season from September – December.

© Copyright 2009 London Underground Limited. All rights reserved.



Hainault Depot – Existing Maintenance Facilities & Function				
Road Number	Position	Road Type & Length (m) Current		Function / Notes
56	Maintenance Shed	Enclosed Vacuum Road	133	Deep interior clean and cleaning of ventilation system
57	Maintenance Shed	Centre and Deep Side Pits	133	General Maintenance including Car Heights, auto coupler height setting, Traction faults, Auxiliary faults and other faults
58	Maintenance Shed	Centre and Deep Side Pits	136	General Maintenance including Car Heights, auto coupler height setting, Traction faults, Auxiliary faults and other faults
59	Maintenance Shed	Centre Pit	133	General Maintenance including Gearbox oil changes, battery set changes, compressor changes, Sandite train refilling, and motor checks , Door faults, brake faults, and any faults that do not require side pits
60	Maintenance Shed	Centre and Side Pitted Calibrated Road	133	General Maintenance including , Exam, battery maintenance, compressor maintenance , Traction faults & Auxiliary faults
61	Maintenance Shed	Centre and Side Pitted Calibrated Road	133	General Maintenance including , Exam, battery maintenance, compressor maintenance , Traction faults & Auxiliary faults

© Copyright 2009 London Underground Limited. All rights reserved.

Hainault Depot – Existing Maintenance Facilities & Function				
Road Number	Position	Road Type & Length (m) Current		Function / Notes
62	Maintenance Shed	Centre Pit	133	General Maintenance including Gearbox oil changes, battery set changes, compressor changes, Sandite train refilling, and motor checks , Door faults, brake faults, and any faults that do not require side pits
63	Lifting Shed	Overhead Crane , Synchronised Jacking Road	133	Maintenance requiring heavy lifting including Wheel set changes, Bogie pressing, Planned motor changes, in brief all heavy lifting. Flashed over motors, all heavy lifting or items that require a bogie to be dropped.
64	Lifting Shed	Overhead Crane , Synchronised Jacking Road	133	Maintenance requiring heavy lifting including Wheel set changes, Bogie pressing, Planned motor changes, in brief all heavy lifting. Flashed over motors, all heavy lifting or items that require a bogie to be dropped.
A	Cleaning Shed	Above solebar Cleaning Road	n/a	Gentle interior clean , Deep interior clean Exterior clean hand bashing
B	Cleaning Shed	Above solebar Cleaning Road	n/a	Gentle interior clean , Deep interior clean Exterior clean - hand bashing
C	Cleaning Shed	Above solebar Cleaning Road	n/a	Gentle interior clean Deep interior clean Exterior clean - hand bashing

1.7.2 Ruislip Depot

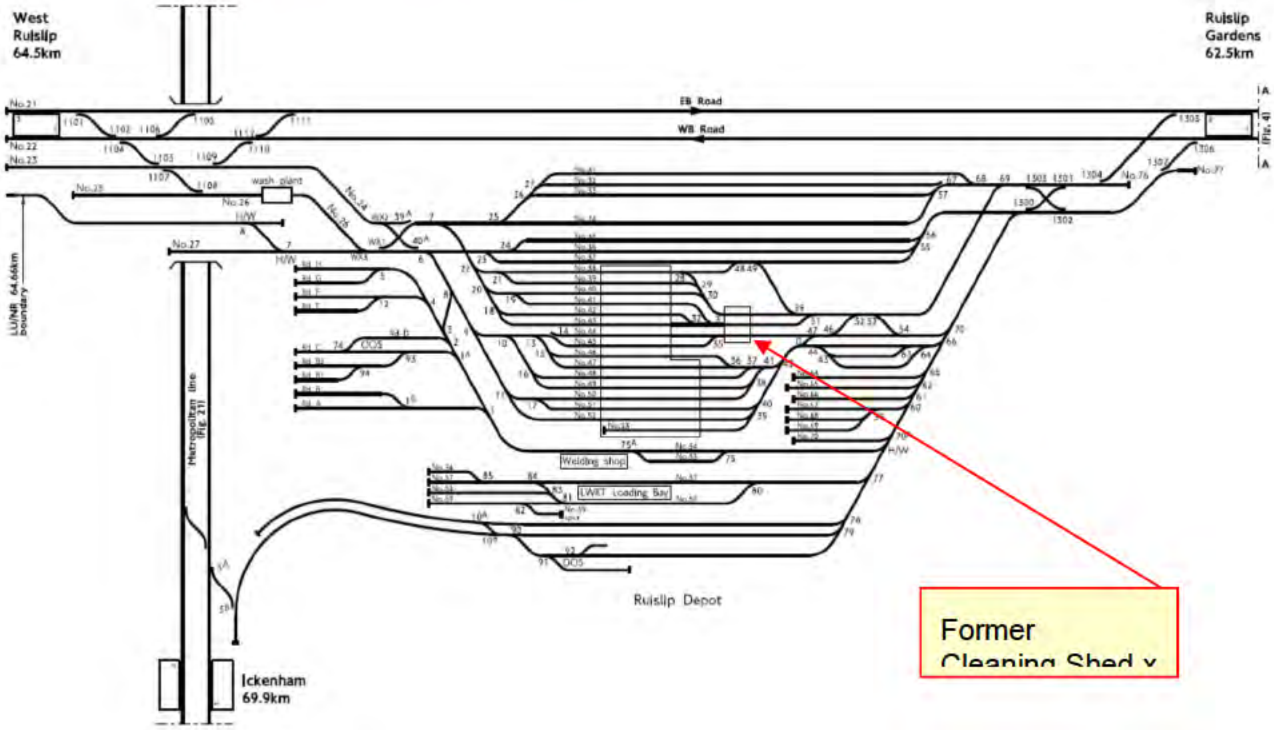
Ruislip Depot is located at the Western End of the Line and is a double-ended Depot with a defined separate 24 berth stabling area (up to 4x trains per road) and an area containing the maintenance facilities consisting of a central shed a separate cleaning shed.

The Depot is also the major hub on the network for engineering trains and the use of facilities and operation of the Depot is split between the Central Line and that of Transplant (LU Engineering Trains Unit).

To facilitate engineering train movements outside of the Central Line the depot is connected to the Metropolitan & Piccadilly Lines via a link to the West of the Depot. It also has a link to Network Rail infrastructure on the "Chiltern Main Line" at West Ruislip.

The general layout is shown in the diagram below:

© Copyright 2009 London Underground Limited. All rights reserved.



Train movements are currently controlled by hand-worked points using a ground shunter past the inlet/outlet roads, which are trailing when exiting the Depot.

The eastern end heavy maintenance facilities (51,52 road & 53 road) are used for 92TS maintenance and include a three road lifting facility with an overhead road lifting facility with overhead crane and on floor synchronised jacks to facilitate double car lifting under body with bogies strapped. Wheel turning is undertaken in this facility with the use of a mobile wheel lathe Mobiturn located in (51 Road) and is operated under a lifted train.

The western end heavy maintenance facilities (51, 52 & 53 roads) are utilised for the heavy maintenance of the transplant engineering fleet and are not available for use by 92TS operations.

The remaining seventeen roads in the main shed are a mixture of centre-pitted roads and centre pitted roads with deeper and wider side pits that undertake general exam and inspection activities. Four roads 39, 44, 45 & 46 are dedicated to transplant and not available for 92TS maintenance use. Typical space between pitted roads is 1.9 m.

The former cleaning shed cleaning shed consists of three roads that have recently been modified in preparation of utilisation for ATC modification to S-Stock and as a result they are not used for 92TS maintenance.

The transplant area next to the Depot is the main distribution site used by Track Partnership for preparing, loading and unloading materials transported to worksites by the Engineers Train fleet.

There is an automatic train wash with water harvesting system located at the east end of the Depot at the West Ruislip end to support the requirements for exterior train cleaning.

The west end 1962TS Sandite train is operated, refilled and maintained from 37 road during the duration of the leaf fall season September – December ,with de-icing refill undertaken on 37 road.

© Copyright 2009 London Underground Limited. All rights reserved.

Currently some of the London Underground Heritage fleet is also stabled at Ruislip Depot. There is an ATC test track across the length of Road 31 (nearest stabling road to the main line).

Ruislip Depot – Existing Maintenance Facilities & Function (1)				
Road Number	Position	Road Type & Length (m) Current		Function / Notes
38	Maintenance Shed West	Centre Pit	133	Project Road / Body End Repair Road
39	Maintenance Shed West	Centre Pit	133	Not Available for use. Used by Transplant and not available for Central Line Fleet.
40	Maintenance Shed West	Centre Pit	133	General Maintenance and Casualty activities where side pit not required including : On Days – Gearbox Maintenance, oil change & Battery Maintenance On Nights – Under frame Clean
41	Maintenance Shed West	Centre Pit	133	General Maintenance and Casualty activities where side pit not required including. On Days – Gearbox Maintenance, oil change & Battery Maintenance On Nights – Motor Skim
42	Maintenance Shed West	Centre Pit	133	General Maintenance and Casualty activities where side pit not required including , oil change & Battery Maintenance
43	Maintenance Shed West	Centre Pit	133	General Maintenance and Casualty activities where side pit not required including Gearbox Maintenance, oil change & Battery Maintenance. Compressor changes
Ruislip Depot – Existing Maintenance Facilities & Function (2)				
Road Number	Position	Road Type & Length (m) Current		Function / Notes
44	Maintenance Shed West	Centre Pit	133	Not Available for use Used by Transplant and not available for Central Line Fleet.

© Copyright 2009 London Underground Limited. All rights reserved.

45	Maintenance Shed West	Centre Pit	133	Not Available for use Used by Transplant and not available for Central Line Fleet.
46	Maintenance Shed West	Centre and Shallow Side Pits	133	Not Available for use Used by Transplant and not available for Central Line Fleet.
47	Maintenance Shed West	Centre and Deep Side Pits	133	General Maintenance Exam, battery maintenance, Door maintenance, QP maintenance Traction Faults, Auxiliary Faults and other faults that require side pit access to get to side covers on trains etc.
48	Maintenance Shed West	Centre and Deep Side Pits	133	General Maintenance Exam, battery maintenance, Door maintenance, QP maintenance Traction Faults, Auxiliary Faults and other faults that require side pit access to get to side covers on trains etc.
49	Maintenance Shed West	Centre and Deep Side Pits	133	General Maintenance where a side pit is required including Exam, battery maintenance, Door maintenance, QP maintenance. Traction Faults, Auxiliary Faults and other faults that require side pit access to get to side covers on trains etc.
50	Maintenance Shed West	Centre and Deep Side Pits	133	General Maintenance where a side pit is required including Exam, battery maintenance, Door maintenance, QP maintenance. Traction Faults, Auxiliary Faults and other faults that require side pit access to get to side covers on trains etc.
51	Lifting Shed West	Centre Pit	119	Not Available for use Used by Transplant and not available for Central Line Fleet.
52	Lifting Shed West	Centre Pit	119	Not Available for use Used by Transplant and not available for Central Line Fleet.

© Copyright 2009 London Underground Limited. All rights reserved.

53	Lifting Shed West	Flat Road	n/a	Not Available for use Used by Transplant and not available for Central Line Fleet.
47	Maintenance Shed East	Centre and Deep Side Pits	131	General Maintenance where a side pit is required including Exam, battery maintenance, Door maintenance, QP maintenance. Traction Faults, Auxiliary Faults and other faults that require side pit access to get to side covers on trains etc.
48	Maintenance Shed East	Centre and Deep Side Pits	131	General Maintenance. Only calibrated road so primarily used for PLSW – coupler heights etc. Exam, battery maintenance, Door maintenance, QP maintenance Traction Faults, Auxiliary Faults and other faults that require side pit access to get to side covers on trains etc.
Ruislip Depot – Existing Maintenance Facilities & Function (3)				
Road Number	Position	Road Type & Length (m) Current		Function / Notes
49	Maintenance Shed East	Centre and Deep Side Pits	131	General Maintenance where a side pit is required including Exam, battery maintenance, Door maintenance, QP maintenance. Traction Faults, Auxiliary Faults and other faults that require side pit access to get to side covers on trains etc.
50	Maintenance Shed East	Centre and Deep Side Pits	131	General Maintenance where a side pit is required including Exam, battery maintenance, Door maintenance, QP maintenance. Traction Faults, Auxiliary Faults and other faults that require side pit access to get to side covers on trains etc.
51	Lifting Shed East	Mobile Wheel Lathe Overhead Crane , Synchronised Jacking Road	116	Mobiturn Road Only This road uses Synchronised and Standalone Jacks

© Copyright 2009 London Underground Limited. All rights reserved.

52	Lifting Shed East	Overhead Crane , Synchronised Jacking Road	115	Heavy Overhaul and Gearbox Project Road
53	Lifting Shed East	Overhead Crane , Synchronised Jacking Road Centre Pit	109	Casualty Wheels and F/O Motor, casualty tasks that require lifting etc.
A	Former Cleaning Shed			Not Available For Use
B	Former Cleaning Shed			Not Available For Use
C	Former Cleaning Shed			Not Available For Use

© Copyright 2009 London Underground Limited. All rights reserved.

APPENDIX H - TRAIN MAINTENANCE REGIMES FOR RECENT NEW FLEETS (09TS & S-STOCK)

Level	Activity	Period	Back Stop Frequency	Notes / Facilities
0	Condition Monitoring & Automated Inspection	Continuous		
1	Pre- Service Check		24 Hours	
2	'A/B/C Exams	25,000 km	80 days	
	A' Examination Train systems	75,000 km	240 days	
	'B' Examination Train systems	75,000 km	240 days	
	'C' Examination Train Systems	75,000 km	240 days	
3	X/ Y Exams	150,000 km	480 days	
	X' Examination Train systems	300,000	960 days	
	'Y' Examination Train systems	300,000km	960 days	
	SCD testing		5 years	
	Doors Maintenance	150,000 km	480 days	
	Lubrication (e.g. gearbox oil change)	150,000 km	480 days	
4	Bogie light overhaul			
	Z6 Overhaul Bogie overhaul light	762,00km		
5	Minor overhauls			
	Z4 Overhaul Propulsion clean	508,000km		
	Z9 Overhaul Brake valves	1,143,000km		
	Z18 Overhaul Propulsion software reload	2,286,000km		
	Z24 Overhaul – Reservoir replace	3,048,000km		
	Z25 Overhaul DC link Capacitor replace	3,175,000km		

© Copyright 2009 London Underground Limited. All rights reserved.

Level	Activity	Period	Back Stop Frequency	Notes / Facilities
6	Heavy overhauls			
	Z10 Overhaul Intercar equipment	1,270,000km		
	Z12 Overhaul - Heavy overhaul, bogie overhaul heavy	1,524,000km		
7	Serialised module equipment overhauls OFF train			
	Z6 Overhaul Motors and compressors	762,000km		Rotating Machines needs lifting Roads
	Z15 Overhaul HVAC and CCTV	1,905,000km		HVAC & CCTV replacement
	Z5 Overhaul Battery replacement	5 years		
N/A	Cleaning			
	Daily clean	24 hours		
	Train wash 7 days	7 days		
	Standard clean	14 days		
	Modular clean	56 days		
	Underframe clean	50,000km		

Note: A, B and C Exams are balanced examinations. Each contains all of the 25,000Km tasks and a third of the 75,000Km tasks. Every 25,000Km either an A, B or C exam is carried out in the order of A, then B and then C.

X and Y Exam are balanced examinations. Each contains all of the 150,000Km tasks and a halfa half of the 300,000Km tasks. Every 150,000Km either an X or a Y exam is carried out in the order for X and then Y.

Z6 Overhaul – Rotating machines (needs lifting roads)

Z15 Overhaul – HVAC and CCTV replacement (needs roof access)

Z5 Overhaul – Battery replacement

© Copyright 2009 London Underground Limited. All rights reserved.

APPENDIX I - MATRIX OF DEPOT ASSETS AND MAINTENANCE REPRESENTATIVE RESPONSIBILITIES

Depot Asset area	Nominated Maintenance Representative
Access platforms	OPERATIONS (ASSETS), Depot, Plant & Equipment (Fleet)
Grit blast cabinet type Euro 7 PF	OPERATIONS (ASSETS), Depot, Plant & Equipment (Fleet)
De-icing	OPERATIONS (ASSETS), Depot, Plant & Equipment (Fleet)
Caustic dosing system	OPERATIONS (ASSETS), Depot, Plant & Equipment (Fleet)
Energy management	OPERATIONS (ASSETS), Depot, Plant & Equipment (Fleet)
Running cables and man safe systems	OPERATIONS (ASSETS), Premises (Stations)
Shutter doors	OPERATIONS (ASSETS), Depot, Plant & Equipment (Fleet)
Wheel lathes, swarfe conveyor, crusher & shunter	OPERATIONS (ASSETS), Depot, Plant & Equipment (Fleet)
Welding equipment BCV	OPERATIONS (ASSETS), Depot, Plant & Equipment (Fleet)
High vacuum & explosion suppression plant	OPERATIONS (ASSETS), Depot, Plant & Equipment (Fleet)
Grease system	OPERATIONS (ASSETS), Depot, Plant & Equipment (Fleet)

© Copyright 2009 London Underground Limited. All rights reserved.

Battery chargers	OPERATIONS (ASSETS), Depot, Plant & Equipment (Fleet)
Treadview	OPERATIONS (ASSETS), Depot, Plant & Equipment (Fleet)
Talgo wheel monitoring equipment	OPERATIONS (ASSETS), Depot, Plant & Equipment (Fleet)
Local exhaust ventilation systems	OPERATIONS (ASSETS), Depot, Plant & Equipment (Fleet)
Ladders and pit boards (Portable)	OPERATIONS (ASSETS), Depot, Plant & Equipment (Fleet)
Chimneys	OPERATIONS (ASSETS), Premises (Stations)
Drains, foul and surface water (including Pit)	OPERATIONS (ASSETS), Premises (Stations)
Sumps and interceptors	OPERATIONS (ASSETS), Premises (Stations)
Track (within buildings)	OPERATIONS (ASSETS) Track & Signals Line Manager
Passenger and Material Lifts within Depots	OPERATIONS (ASSETS), Premises (Stations)
Lead Maintenance Representatives	
Piccadilly Line	OPERATIONS (ASSETS), Asset Development
Central Line	OPERATIONS (ASSETS), Asset Development

© Copyright 2009 London Underground Limited. All rights reserved.

Bakerloo Line	OPERATIONS (ASSETS), Asset Development
Waterloo & City Line	OPERATIONS (ASSETS), Asset Development
Depot Plant, Equipment, Facilities & Premises	OPERATIONS (ASSETS), Asset Development

Depot Asset area	Nominated Maintenance Representative
Structures and fabric	OPERATIONS (ASSETS), Premises (Stations)
Heating	OPERATIONS (ASSETS), Premises (Stations)
Lighting	OPERATIONS (ASSETS), Site Services (Fleet & Trains Division)
Ventilation	OPERATIONS (ASSETS), Premises (Stations)
Electrical control panels (All) ventilation systems	OPERATIONS (ASSETS), Premises (Stations)
Fireman's switch	OPERATIONS (ASSETS), Premises (Stations)
Air conditioning & ventilation	OPERATIONS (ASSETS), Premises (Stations)
Gas services	OPERATIONS (ASSETS), Premises (Stations)

© Copyright 2009 London Underground Limited. All rights reserved.

Water services	OPERATIONS (ASSETS), Premises (Stations)
Ground maintenance – vegetation control	OPERATIONS (ASSETS) Track & Signals Line Manager
Graffiti removal	OPERATIONS (ASSETS), Site Services (Fleet & Trains Division)
Secure perimeter	OPERATIONS (ASSETS) Track & Signals Line Manager
Depot security	OPERATIONS (ASSETS), Site Services (Fleet & Trains Division)
Public address system	OPERATIONS (ASSETS), Site Services (Fleet & Trains Division)
Electrical services	OPERATIONS (ASSETS), Premises (Stations)
Lightning conductors	OPERATIONS (ASSETS), Premises (Stations)
Statutory Inspection	OPERATIONS (ASSETS), Depot, Plant & Equipment (Fleet)
In-service testing of in-service electrical equipment	OPERATIONS (ASSETS), Depot, Plant & Equipment (Fleet)
Compressed air	OPERATIONS (ASSETS), Depot, Plant & Equipment (Fleet)
Lifting and moving equipment	OPERATIONS (ASSETS), Depot, Plant & Equipment (Fleet)
Train washing system	OPERATIONS (ASSETS), Depot, Plant & Equipment (Fleet)
Foam arch system	OPERATIONS (ASSETS), Depot, Plant & Equipment (Fleet)

© Copyright 2009 London Underground Limited. All rights reserved.

All cleaning equipment	OPERATIONS (ASSETS), Depot, Plant & Equipment (Fleet)
Effluent control	OPERATIONS (ASSETS), Depot, Plant & Equipment (Fleet)

© Copyright 2009 London Underground Limited. All rights reserved.

Transport for London

London Underground Limited

NTfL OMC Volume 2 Part 4

Signalling & Train Control System

Maintenance Concept

		Signature	Date
Prepared by	[redacted] Operations (Assets) Development Manager	[redacted]	6/4/2016
Checked by	[redacted] Head of Signals (JNP)		15/4/16
Checked by	[redacted] BCV Infrastructure Manager		06/04/2016.
Checked by	[redacted] Incident Response & Command Manager		12.4.16.
Checked by	[redacted] Head of Signals (SSR)		8-4-16.

© Copyright 2009 London Underground Limited. All rights reserved.

Document History

Revision	Date	Summary of changes
Rev. A	11/03/2016	Draft Version – issued for internal review
Rev. B	15/03/2016	Draft Version – updated to reflect removal of GOA3
Issue 1	15/04/2016	Issued following draft review

© Copyright 2009 London Underground Limited. All rights reserved.

TABLE OF CONTENTS

© Copyright 2009 London Underground Limited. All rights reserved.

© Copyright 2009 London Underground Limited. All rights reserved.

© Copyright 2009 London Underground Limited. All rights reserved.

1 SUMMARY

The New Tube for London (NTfL) programme will provide extra capacity through the renewal of ageing assets by delivering a coordinated series of line modernisations on the Bakerloo, Central, Piccadilly and Waterloo and City lines.

NTfL will deliver new rolling stock and signalling assets. The new trains, operating in conjunction with the new signalling system, being capable of automatic train control (ATC) operation facilitating a more frequent and reliable service.

With the addition of modernised train depots, up-rated power supplies, and optimised track layouts, the NTfL railway will provide London with a transport facility capable of keeping pace with an ever-growing capital city over the next 50 years.

Effective asset management of the Railway Control System (RCS) will be a critical element in ensuring that each NTfL line continues to function at its optimum performance levels. The introduction of emerging technologies built into the core of the various RCS sub-systems provides a unique opportunity for the maintenance organisation to monitor the health, diagnose faults and predict the maintenance needs of the systems in a far more pro-active way than that afforded by the systems of the past.

This capability will significantly enhance the efficiency and effectiveness of the maintenance organisation by continuing to build upon its trademark of extensive knowledge of asset performance and experience in maintenance management.

The purpose of this Maintenance Concept is to describe the maintenance vision for the Signalling & Train Control (S&TC) elements of the RCS and how they will be maintained over their lifespan.

The expected key benefits in respect to maintenance of the new S&TC assets will be a significant improvement in the reliability and maintainability of the railway as a system and therefore a reduction of the future operating costs associated with maintenance, renewals, upgrades and failure/fault rectification.

The reliability of the S&TC system will improve maintenance efficiency and reduce whole life costs because:

- The new system will be designed to minimise service affecting failures with systems designed to eliminate single points of failure.
- Equipment will be designed to be maintenance free to the greatest practicable extent. Condition monitoring will be used extensively to enable preventive maintenance without service interruption. Maintenance “down times” and repairs are expected to be very short.
- Where possible, routine maintenance will change from interval based toward effectively planned interventions based on usage / condition monitoring or predictive (likelihood of imminent failure).
- Training, diagnostics, incident response, flexibility and spares etc. will all be improved through standardised best practice across the lines in scope. Key spares will be held at critical equipment locations that present the greatest potential points of failure.
- Diagnostics and fault rectification will be simplified through the use of centralised fault reporting systems.
- The design will offer high availability via simplicity of design, the use of highly reliable components/sub-systems, redundancy and fault tolerance.
- The design will minimise the use of trackside equipment - any equipment installed on or near the track will be designed to minimise the risk of damage and will be accessible during traffic hours wherever practicable.

© Copyright 2009 London Underground Limited. All rights reserved.

1 Introduction

The purpose of this Signalling & Train Control Systems Maintenance Concept is to provide a vision as to how London Underground Operations (Assets) intend to optimise the opportunities afforded by the delivery of the new NTfL Signalling & Train Control System on the Piccadilly, Central, Bakerloo and the Waterloo & City Lines.

This document provides a high level maintenance concept which describes how LU Operations (Assets) intend to optimise the opportunities afforded by the delivery of the new NTfL Signalling & Train Control System.

The concept establishes a set of high level principles which if consistently applied in the design and implementation of the S&TC system will be instrumental in achieving LU Operations (Assets) objectives of enhancing asset performance and improving maintenance efficiency.

The document is also intended to support a common understanding which promotes the necessary alignment between the NTfL Programme and the maintenance organisation and facilitates toward achieving the common goal of meeting the Programme objectives.

From the NTfL Programme, the key business objectives are stated as:

- Asset/System Renewal
- Increase Capacity
- Introduce/Enhance Automation
- Provide Air Cooling
- Enable Business Transformation
- Improve Customer Experience
- Reduce Whole Life Costs.
- Improve Railway Reliability
- Manage Rising Platform Temperatures
- Manage Safety and Security
- Minimise Access Demand

2 DOCUMENT BOUNDARIES AND EXCLUSIONS

2.1 Document Scope

This Signalling & Train Control Maintenance Concept applies to the Signalling & Train Control system (S&TC) element of the Railway Control System (RCS) to be introduced on the operational railways of the Piccadilly, Central, Bakerloo and the Waterloo & City lines by the Capital Programmes Directorate's New Tube for London (NTfL) Programme. The document should be considered applicable for all Grades of Automation (GOA).

2.2 Document Exclusions

The S&TC Maintenance Concept does not provide specific information on the maintainability of the Operational Control System nor does it deal specifically with the supporting 'enabling' infrastructure (buildings, power supplies, CRMS etc.) expected to be installed in support of the signalling system.

© Copyright 2009 London Underground Limited. All rights reserved.

In respect of supporting ‘enabling’ assets; as the current approach toward the maintenance of them is not likely to change in future, it is envisaged that further maintenance concept documentation will not be required or provided. However, it should be recognised that any new or novel infrastructure intended to support the S&TC will ultimately have its own associated set of requirements.

In the intervening period, and in lieu of ‘expected’ infrastructure, a set of generic requirements will be provided alongside the S&TC requirements. These are intended to serve as guidance to the NTfL programme on such items such as SER’s, CRMS etc.

These generic requirements will be based upon the core principles of safety, reliability, accessibility and maintainability and should be captured by the NTfL programme prior to the tendering stage. Once an S&TC Supplier has been selected, and the extent of the supporting infrastructure clarified, then further specific technical requirements can be provided. If it is found that the future system does not utilise such infrastructure, then these requirements can simply be removed.

The S&TC Concept does not take into consideration any Depot re-signalling works which may be required to support the expected service injection rates between the main line and the Depots. The concept for the implementation of depot signalling, alongside its rationale, has been outlined in the Fleet & Depot Maintenance Concept.

The Signalling & Train Control Maintenance Concept is not intended to specify the architecture or design of the system, but does seek to influence and provide a vision of system functionality which may then be exploited to enhance the capability and efficiency of the future maintenance organisation.

The Signalling & Train Control Maintenance Concept also provides a set of fundamental maintenance principles which give essential information for use in supporting the feasibility, design & delivery stages of the RCS Sub-Programme and its associated projects. Careful application of the principles outlined in this document, throughout these lifecycle stages, should not only yield a reliable and efficient railway in the future, but also one which is safe, simple to operate and economical to maintain.

2.3 Planned revisions and how the document will be updated

The Signalling and Train Control Maintenance Concept forms the Volume 2, Part 4 component of the NTfL Operations and Maintenance Concept (OMC).

The OMC is a configuration managed document that will evolve as the NTfL programme progresses. Elements of the existing volumes, including this S&TC Maintenance Concept, will require greater development and future volumes are dependent upon a greater level of system knowledge. As such, the OMC will be updated, and re-released as required, to incorporate new developments as the programme evolves.

All releases will be executed in line with the Change process outlined in Volume 1, Part 1, Section 7 of the NTfL Operations and Maintenance Concept (OMC).

3 DESCRIPTION OF EXISTING SIGNALLING SYSTEMS

3.1 Description of pertinent aspects of the current systems

The four lines due to be re-signalled as part of the NTfL scope currently utilise diverse signalling systems. These systems are reflective of the era in which each line was last re-signalled and range from conventional systems through to railways which operate Automatic Train Control (ATC). A brief description of each line is provided below:

© Copyright 2009 London Underground Limited. All rights reserved.

3.1.1 Central Line

The Central line was re-signalled in the 1990s and utilises coded track circuits which are used to control the fleet of automatic trains. To allow for a variety of train speeds 14 different frequencies are overlaid onto track circuits. These frequencies are read by the train and from which it then determines the optimum ATO (Automatic Train Operation) driving profiles (acceleration and braking) as well as governing when emergency braking needs to be applied (Automatic Train Protection).

The majority of signal Interlocking’s on the Central Line are based upon Westinghouse’s Westrace platform. Interlocking area’s which do not utilise Westrace employ a Relay Interlocking system. These sites are predominantly located to the west end of the line.

The Central Line Control Room, which is responsible for the entire operational line, is located at Wood Lane in White City.

There is the facility to transfer rolling stock to the Metropolitan line via Ruislip depot and in Hainault there is a control tower which allows routes to be set within the Depot area.

3.1.2 Bakerloo Line

The existing signalling infrastructure on the Bakerloo Line utilises an older generation electro-mechanical type of signalling system. As a consequence the railway does not currently facilitate Automatic Train Operation (ATO). Automatic Train Protection is afforded through the trainstop / tripcock arrangement which automatically stops a train if it passes a signal displaying a stop aspect.

The Bakerloo line Control Room is located at Baker Street and is responsible for the running of the entire line from Elephant and Castle to Queens Park. The Control Room interfaces with site computers located at each Controlled area, which in turn operate ‘V’ style mechanical interlocking frames to control the signalling at ground level.

Control to the north of Queens Park, where Bakerloo trains run over Network Rail tracks, is provided through Network Rail signalling infrastructure. However, a LUL operated control tower exists at Stonebridge Park which serves to signal Bakerloo line trains locally within the Depot area.

The main Bakerloo Line Rolling Stock Depot is based at London Road, located between Lambeth North and Elephant & Castle, and is controlled by the frame at Waterloo.

3.1.3 Waterloo & City Line

The Waterloo and City line operates a twin track between Waterloo and Bank Stations. The line utilises Bombardier’s EbiScreen computer based signalling control system which interfaces with the Interlocking’s in the SER’s. In 2007, the EbiScreen system replaced the old ‘NX’ (eNtry / eXit) style push button panel as the primary operating system. The Service Control System is operated from a new control room within Waterloo Depot. There is an additional mode of control provided by the Maintainer’s panel within Waterloo SER which utilises ‘route’ push buttons. This panel serves as an emergency back-up system as well as providing the Maintainer with the capability of testing the system in Engineering Hours.

3.1.4 Piccadilly Line

As with the Bakerloo Line, the existing signalling infrastructure on the Piccadilly Line utilises an older generation electro-mechanical type signalling system. As a consequence, the railway does not currently operate Automatic Train Control (ATC).

Most of the Piccadilly Line is currently controlled from the Piccadilly and District line Control Room based at Earl’s Court. The interoperable area between Rayners Lane and Uxbridge, which serves both the Metropolitan and Piccadilly Lines, is not controlled centrally from Earl’s Court but is instead controlled by the Rayners Lane cabin.

© Copyright 2009 London Underground Limited. All rights reserved.

Piccadilly line control (except the interoperable area) is expected to be transferred under the Piccadilly Upgrade (PICCU) programme to the Griffin Rooms at South Kensington. This is expected to be completed by 2018 and will serve as an interim arrangement in lieu of the NTfL Operational Control Centre being developed.

The Piccadilly Line fleet is served by two main Depots based at Cockfosters and Northfields. These Depots are currently un-signalled and rely upon local shunting arrangements for their operation.

3.2 Current Organisational Structures

3.2.1 Bakerloo, Central and Waterloo and City Lines - Background

Under the Public Private Partnership (PPP) contract, the Metronet consortium was responsible for the maintenance of the Bakerloo, Central, Victoria, District, Circle Metropolitan and Hammersmith & City Lines. These lines were subsequently split according to whether they were 'cut-and-cover' or 'tube' type constructions. This meant the Bakerloo, Central and Victoria lines were grouped with the Waterloo & City line and became collectively known as BCV. The other lines are collectively formed what became known as the Sub Surface Railway (SSR).

Following the collapse of Metronet both BCV and SSR were taken back in house and became part of Transport for London (TFL). However, the basic Metronet structure has been retained meaning that the Bakerloo, Central and Waterloo & City Lines remain as part of a BCV group.

3.2.2 Bakerloo, Central and Waterloo & City lines – Signalling Incident Response

[Ref: Appendix 1]

Response to signalling incidents on the Bakerloo, Central & Waterloo & City lines is the responsibility of the Incident Response & Command Manager. In support of this function there is a Lead Incident Manager (LIM) who is responsible for a team of Duty Signalling Incident Managers (DSIM's). This team is based in Holborn and are directly responsible for the co-ordination and management of the line-based signalling incident response teams.

These line-based signalling teams are located at various strategically positioned depots: These response (or 'call') Depots operate a 3 shift system giving 24 hour incident coverage. Each Depot usually comprise of Technical Officers, who in turn are supported by Point Fitters and Support Technicians.

The main line-based response Depots for the Bakerloo Line are located at Waterloo and Queens Park. Signalling incident response to the north of Queen's Park is the responsibility of Network Rail.

Due to the length of the line, the Central Line operates more response Depots. These Depots are located at Loughton, Leyton, Liverpool Street, Marble Arch, West Ruislip and White City.

The Waterloo & City Line does not have a specific line-based team. Incidents on the W&C are usually covered by the Bakerloo Line response team from Waterloo and/or the Central Line response team from Liverpool St, dependent upon the location of the fault.

In addition to the line-based Depots, Signalling Technicians are based in various line Control Rooms. This important resource facilitates effective incident management between the Control Room and the line Technicians. The Central Line also employs a Control System Engineering Team comprised of eight Field Services Engineers (FSE's). This team is based in the Control Room at White City and report through to the Incident Response & Command Manager via the middle manager in charge of the team.

Similarly, the Bakerloo Line retains a small technical signalling presence in the Bakerloo Control Room located in Baker Street.

The W&C line has no Technical presence in its Control Room at Waterloo.

© Copyright 2009 London Underground Limited. All rights reserved.

3.2.3 Bakerloo, Central and Waterloo & City lines – Signalling Maintenance

[Ref: Appendix 2]

Planned, periodic Signal Maintenance on the Bakerloo, Central, Victoria & Waterloo & City lines is the responsibility of the Area Infrastructure Manager (BCV).

Supporting the Area Infrastructure Manager (BCV) are two Signalling Infrastructure Managers (SIM's). There are two SIM's, one in charge of signalling maintenance on the Bakerloo and Victoria lines, whilst the other is in charge of maintenance of the Central and Waterloo & City Lines.

Each SIM manages a group of Signalling Maintenance Managers (SMM's) who, in turn, manage maintenance teams of specialist staff across a variety of signalling grades.

Signal Maintenance teams operate out of centralised Depots, with Leyton being used by the Central Line and Lambeth North being used by the Bakerloo Line. As the infrastructure to the north of Queen's Park is the responsibility of Network Rail, Signalling Maintenance in this area is not undertaken by BCV.

W&C Line signalling maintenance, being the responsibility of the Central Line, is also covered by Leyton Depot.

It should be noted that line-based signalling response teams often come under the control of the SMM's during Engineering hours to supplement the planned maintenance capability.

3.2.4 Piccadilly Line – Background

Under the PPP, the Jubilee, Northern and Piccadilly lines (JNP) became the responsibility of Tubelines Limited. When the company experienced operating difficulties TfL became a major shareholder in the company and took overall control. Amey Ltd retains an association with London Underground and are contracted to manage the signalling incident and maintenance of the three lines.

As a consequence, the organisational model associated with signalling maintenance on JNP differs slightly from that employed by BCV.

Response for signalling incidents and maintenance on the Piccadilly Line is the responsibility of the Head of Signals (JNP). Supporting the Head of Signals are four main teams; Signal Engineering, Signal Response, Signal Maintenance and Signal Works.

Signal Engineering and Signal Works perform particular functions within the JNP organisation and are not discussed as part of this document.

3.2.5 Piccadilly Line - Signalling Incident Response

[Ref: Appendix 3]

Overall Signalling Incident Response for the Jubilee, Piccadilly and Northern Line is managed by a Signal Response Manager. Supporting this function are three Zonal Incident Managers (ZIM's). Each ZIM 'champions' a particular line but can work across all three providing flexibility in coverage.

Supporting the ZIM's are a series of incident response Depots which are essentially line based. As with the BCV structure, these response Depots are strategically located and operate a similar 3 shift system giving 24 hour incident coverage. Each response Depot is managed by a Signal Incident Manager who has responsibility for the Depot staff.

The incident response Depots on the Piccadilly Line are located at Arnos Grove, Caledonian Road and Acton Town. Control Room signalling incident response and line based failure support is provided by a small team of Technicians located at Earls Court.

© Copyright 2009 London Underground Limited. All rights reserved.

3.2.6 Piccadilly Line - Signalling Maintenance

[Ref Appendix 4]

Signalling Maintenance on JNP is managed through three Zonal Maintenance Managers (ZMM's). These ZMM's manage centralised maintenance Depots at Stratford (Jubilee), Finchley Central (Northern) and Acton (Piccadilly).

Each Depot comprises maintenance teams encompassing specialist staff across a variety of signalling grades. Although essentially line based, each Depot does have the capability of operating across 2 or more lines.

Supplementing the Maintenance Depots is a 'Point Care' team which ensure that points which are deemed to be 'Golden Assets', insofar as they are crucial to service, are '100%ed' every six months.

3.2.7 Sub-Surface Rail - Signalling Incident Response

The Sub-Surface Railway (SSR) operate the same structure for both incident response and planned maintenance as previously described for BCV, although the DSIM role has a dedicated SSR team and the locations of the response Depot naturally differ.

It should be noted that the interoperable area (Piccadilly & Metropolitan) between Rayners Lane and Uxbridge and the section between Barons Court tunnel mouth and North Ealing is the responsibility of the Sub Surface Railway.

3.2.8 Sub-Surface Rail - Signalling Maintenance

[Ref Appendix 5]

Signalling Maintenance on the Sub-Surface Railway (SSR) is the responsibility of the Head of Signals (Sub Surface Lines). In support of this role are a Signal Infrastructure Manager (North), Signal Infrastructure Manager (South) and a Cable Manager.

The Signal Infrastructure Manager (North) manages the Maintenance Depot located at Baker Street. This Depot maintains the signalling assets on the whole of the Metropolitan Line, the Hammersmith & City Line (between Hammersmith and Aldgate East) and the Circle Line (between Aldgate and Notting Hill Gate). The Baker Street Depot comprises maintenance teams of specialist staff across a variety of signalling grades. In addition, a Point Care Team (North) also operates out of Baker Street which is dedicated to improving the performance of critical points assets.

The Signal Infrastructure Manager (South) manages the maintenance depot located at Earls Court. This Depot maintains the signalling assets on the whole of the District Line, the Hammersmith & City Line (between Aldgate East and Barking) and the Circle Line (between High Street Kensington and Tower Hill). Similar to Baker Street, the Earl's Court Depot comprises maintenance teams of specialist staff across a variety of signalling grades and includes a Point Care Team (South) who work on critical points assets.

The Cable Manager role is responsible for Cable test and repair Team which, as the name implies, undertakes the periodic testing, conducts fault investigations and effects repairs on worn and damaged signal cable assets. Although primarily an SSR team, it provides a specialist function that is used by both SSL and BCV lines. This team currently operate out of Baker Street Depot.

Also under the management of the Cable Manager are two teams based at Acton Town; of these, the 'Track Support Team' are used to support the various track works and track circuit testing regimes across SSR, whilst the 'Locking Team' provides the capability for maintaining the various mechanical interlocking's left in use across LUL.

3.2.9 BCV & SSR Engineering and Signal Works

- Engineering Support

© Copyright 2009 London Underground Limited. All rights reserved.

Engineering Support for BCV & SSL is provided through the office of the Head of Engineering. This is essentially a 'matrixed' function which provides specialist engineering team resource which spans across various assets and disciplines. The organisation arrangement for Engineering support on BCV and SSL differs slightly from that of JNP where the Engineering Manager is a direct report of the Head of Signals (JNP).

- Signal Works

The majority of Signal Installation works on BCV and SSL are provided through the Signal Works team based at Acton. Most of this team form part of the Capital Programmes Directorate (CPD) rather than the Operations Directorate and therefore do not report directly to the Head of Signals (SSL), the Area Infrastructure Manager (BCV) or the Incident Response & Command Manager).

This organisation arrangement again differs from that of JNP where Signal Works is seen as a direct report to the Head of Signals (JNP).

However, there are various Signal Works functions such as track support and Point care, which are managed directly through the Signalling Infrastructure Manager (Central & Waterloo & City) and the SSL Cable Manager.

4 THE MAINTENANCE VISION FOR NTFL'S S&TC SYSTEM

4.1 Core Maintenance Principles

The four core maintenance principles on which this S&TC Maintenance Concept is based are those of Reliability, Availability, Maintainability and Safety. The NTfL programme should consistently apply each of these principles during the procurement, design and installation stages of the future system. This approach will be vital in ensuring an S&TC system that is fit for purpose, safe to maintain and will fully realise the benefits expected from such a large upgrade programme.

4.1.1 Reliability

It is a fundamental requirement that the S&TC system functions safely whilst remaining dependable and performing consistently to its specification. The design should be developed to achieve high reliability rates from the overall system via simplicity of design, the use of highly reliable components/sub-systems and fault tolerance. Safety signalling and service affecting components will need to be designed to eliminate single points of failure wherever practicable. RAMS analysis will be undertaken to ensure that the requirements of the Railway Performance Strategy is met.

A description of the desired RAM's targets for the NTfL S&TC system(s) is provided in the section entitled '**Required Reliability, Availability and Maintainability Performance'** which is contained in this document.

4.1.2 Availability

In order to mitigate against the impact of such occurrences, prime consideration will need to be given to ensuring that failures are unlikely to become service affecting and that the design of the system is sufficiently resilient so that in the event of failure the railway is able to sustain the timetabled level of service until the failing condition can be resolved.

In this respect, asset availability is a fundamental design consideration. Single points of failure should be eliminated where practicable and there should be a significant level of redundancy designed into the system which affords time for Maintenance to both respond to and subsequently rectify the failing condition without affecting the ongoing operation of the railway service.

© Copyright 2009 London Underground Limited. All rights reserved.

4.1.3 Maintainability (Fault Response)

Although a key principle of this maintenance concept is to reduce, as far as possible, the number of service affecting failures through inherent system reliability and availability, it is recognised that there will inevitably be service affecting failures that will occur over the lifecycle of the assets.

Therefore it is essential that faults can be identified easily and faulty equipment changed quickly and efficiently. Current key objectives for maintenance are biased toward achieving the 'Time to Site' (TTS) and 'Time to Fix' (TTF) requirements for first-line incidents where a fault or failure is service affecting. These terms relate to the maximum expected time for a Maintainer to arrive on site following the initial report of a fault (TTS) and the maximum time expected to resolve the service affecting issue (TTF).

Although the times allocated in both categories differ according to a variety of factors, the Current TTS and TTF times are 10 minutes and 8 minutes respectively for sites located in the centre of London. Times for the outer zones differ and have a TTS and TTF of 20 minutes in each case. It should be noted that these times are a contractual measure and do not take into account service requirements.

A fundamental principle of this concept is the emphasis on ensuring that the requisite TTS and TTF times can still be achieved during migration, with the aim to reduce these times further at end state.

The achievement of improved 'Time to Site, Time to Fix' times at end state will depend heavily upon the application of core maintenance principles being incorporated into the design of the new system. It is critical, therefore, that the following principles are recognised as part of this concept document.

- Equipment should be kept to a minimum with as much of the 'intelligent' aspects of the system (such as site interlocking's) being co-located as far as practicable.
- Wayside assets should be kept to a minimum, where required they should be readily accessible during traffic hours and positioned in a place of safety.
- Adequate access shall be provided for all new or modified equipment to allow for its maintenance, testing and replacement.
- Where local Signalling equipment rooms (SER's) are required, they should be minimum in number, allowing for the effective strategic placement of maintenance staff capable of supporting the requisite first-line 'Time to Site' response times.
- Where not already available, facilities should be provided at strategic sites nominated by the maintenance organisation which support the requisite 'Time to Site' response times. These facilities should be considered as being operable 24 hours a day and therefore should include the necessary messing and welfare arrangements.
- The Signalling & Train Control System sub-assemblies and equipment should be modular in design and construction such that defective items can be replaced by a single technician in a timely, safe and efficient manner.
- The wayside assets should be lightweight in design to ease the maintenance activity and improve removal, handling and replacement in maintenance process.
- Sufficient 'in-car' access should be provided to trainborne signalling equipment such that it allows first-line response maintenance interventions i.e. equipment resets, to be undertaken whilst a train is still in service.
- The Signalling & Train Control System should be designed to avoid the need for working at height by maintainers as far as practicable.
- Hot-swappable equipment is preferred to enable replacements to be effected without the need to power down the system. Any replaceable item should not need to be configured

© Copyright 2009 London Underground Limited. All rights reserved.

once in place.

- Where practical, quick release/access points within trim panels should be used to enable swift visual inspection of the operational mechanism.
- The Signalling & Train Control System should be designed such that access panels can be removed without the use of special tools.
- Sub-systems should be modular in design to ensure that they can be physically handled within human factors standards.
- Where system resets are required, the process should not be dependent upon the area being ‘wheels free’.
- Access to components should not be restricted by other components such that they do not need to be removed or adjusted to allow the actual maintenance activity to commence.
- A storage capability should be provided at strategic sites (nominated by the maintenance organisation) such that it is capable of holding a small amount of critical spares that support the requisite 'Time to Fix' times.
- The Signalling & Train Control System should minimise the need for specialist tools and test equipment, including software.
- Test points and/or diagnostic ports placed trackside should be positioned in such a way that they allow for the safe testing and/or monitoring of equipment operation by a maintainer.

4.1.4 Maintainability (Planned, Preventive)

The existing signalling infrastructure on both the Piccadilly and Bakerloo lines utilises the older generation electro-mechanical type signalling systems. Electro-mechanical infrastructure, by design, requires regular preventative maintenance because the mechanical components are prone to wear and have a greater probability of failure than comparable electronic systems.

Emphasis, therefore, is to be placed upon ensuring that the design of the new NTfL Signalling & Train Control system(s) seeks to eliminate entirely, or reduce significantly, the number of periodic preventive maintenance interventions required.

Where periodic maintenance is a necessity then there should be a focus on ensuring that the times between planned maintenance activities are extended as far as possible without increasing the risk of failure to the signalling system.

System design should consider equipment location to be as centralised as possible which will reduce the ‘dead-time’ associated with travelling to and from various locations to undertake planned maintenance activities.

Where planned maintenance activities are required for the new system(s) then the design should consider the following:

- New and novel equipment introduced to the railway shall be designed for reduced maintenance interventions.
- Any equipment that is required to be near the 4 foot shall be designed such that it requires minimum maintenance.
- Equipment requiring periodic maintenance should be positioned such that it is easily accessible and maintainable.
- The wayside assets should be lightweight in design to ease the maintenance activity and improve removal, handling and replacement in maintenance process.

© Copyright 2009 London Underground Limited. All rights reserved.

- Components should be designed in a way such that spares are not likely to be damaged when handling/stored, and are therefore of robust construction.
- Adequate access shall be provided to all new or modified equipment to allow for its maintenance, testing and replacement.
- Adequate task lighting to facilitate maintenance activities is provided at new or relocated P&C locations within tunnel areas.
- Maintenance activities that involve the loading or updating of software should be capable of being undertaken from a central location and not rely upon the local use of CD's, memory sticks etc.

Whilst it is understandable that development of a new S&TC system tends to become focussed on signalling maintenance tasks, the S&TC design must also consider the impact upon other asset areas within the maintenance organisation.

Previous signalling designs have often not fully considered these impacts and have experienced difficulty in gaining assurance or attaining handover of the asset into maintenance. The Programme should ensure that all works are properly assessed such that all the affected asset groups are fully identified and that the relevant Stakeholders are engaged as early as possible.

In particular, signalling designs must consider the impacts the system may have on future Permanent Way maintenance tasks and track renewal works where fixed trackside equipment, particularly those mounted on rails and on bearers, make it difficult to perform tasks such as re-railing and tamping which can lead to unnecessary increases in the time and costs required to undertake track-works. As a result the assets negate some of the benefits expected from S&TC implementation. Design of the signalling system should therefore consider the principles outlined below in respect of trackside equipment and Permanent Way works:

- Where attachment of signalling equipment and materials to the rail is necessary, the method should prevent any subsequent deterioration in the performance or condition of the rail which could result in a subsequent failure of it.
- The Signalling & Train Control System architecture and design should avoid, as far as practicable, the use of 'on-track' cabling.
- The Signalling & Train Control System architecture and design should avoid, as far as practicable, the use of track circuits.
- Where signalling equipment is attached adjacent to, or on the rails, it should be placed so to allow normal track maintenance activities, such as tamping, from being carried out.
- Where signalling equipment is attached adjacent to or on the rails, it must be placed so to allow normal track maintenance activities, to be carried out without the need for disconnection and/or reconnection.
- Components installed on or near the track, shall be suitably designed and protected to minimise the risk of damage from, as well as inconvenience to, normal trackside maintenance activities.
- Where trackside transponders are utilised by the Signalling & Train Control System then these should be designed to allow for safe and efficient replacement as well having an appropriate methodology through design and construction, ensuring they are placed back into the correct location.
- Where it is necessary to mount signalling equipment to the rails it should be connected such that it eliminates the need for the rail to be drilled.

© Copyright 2009 London Underground Limited. All rights reserved.

4.1.5 Safety

The Maintenance organisation has a fundamental commitment to the health, safety and wellbeing efficiency of all of its employees engaged in maintenance activities on the assets. The introduction of a major signalling upgrade offers a unique opportunity to ensure that the hazards associated with signal maintenance activities are either eliminated entirely or are reduced as low as is reasonable practicable (ALARP), through the implementation of effective design management.

It should be recognised that the operational railway can be a demanding environment in which to work, particularly under abnormal, degraded or emergency modes. In this regard a greater emphasis should be placed upon the system designers to ensure that the risk of human error is mitigated and the potential for accidental loss reduced.

Designs which prevent inadvertent connections from being made are seen as an important aspect in guarding against human error. As an example, the Signalling & Train Control System should be designed in such way to prevent installation of incorrect interchangeable components and electrical connections should be formed by using plug-in units as far as practicable with a single possible orientation of the unit to prevent incorrect connection.

4.2 Operational Context

The purpose of this section is to provide supplementary information that builds on the core principles already outlined in the Maintenance vision. It is intended to give a view on how the maintenance organisation intends to operate within the context of the NTfL signalling system. For reference, a full description of some of the maintenance levels outlined in this section is provided in Section 5 ‘Maintenance Levels (Definition)’.

4.2.1 General

The expected key benefits in respect to maintenance of the new Signalling & Control System assets will be a significant improvement in the reliability and maintainability of the railway as a system and therefore a reduction of the future operating cost (Opex) of any maintenance activity including renewals, upgrades and failure/fault rectification.

Emphasis is placed upon the adoption of new technology which will allow the signal maintenance organisation to become proactive in its approach rather than the traditional reactive response. In addition, technology will be able to provide signal maintenance with a greater capability to diagnose and resolve incidents in a far more efficient manner than it has previously been able to achieve.

Importance too is placed upon the use of new materials to ensure that the new system is as maintenance free as possible thus allowing a greater focus on assets which are critical to the operation of the railway.

4.2.2 The Future Vision for the Control Centre

This maintenance vision is based on the assumption that the individual line Control Rooms for each of the NTfL lines will be based at the same location. Although part of the NTfL Operational Control Centre they are expected to be separate entities and not amalgamated to form one ‘all encompassing’ Control Room.

It is envisaged that there will be a maintenance presence in each of the Control Rooms which will provide 24 hour coverage. These personnel will perform a critical role and will act as a pivotal point between the operations and maintenance teams.

Two key maintenance roles have been identified for each Control Room. These roles will cover the maintenance activities associated with the following sub-systems:

- Signalling & Train Control

© Copyright 2009 London Underground Limited. All rights reserved.

The primary Control Room role associated with the activity of maintaining the Signalling & Train Control System will be that of the 'Control Room Signal Technician' (CRST). Each Line Technician will be expected to monitor the health status of the signalling system across the whole line and ensure that everything is under control and working as desired.

As part of their general duties, each Control Room Signal Technician will also be responsible for dealing with all first-line incidents and planned maintenance activities associated with the Control Room elements of the S&TC system.

- Train & Trainborne Signalling assets

Trainborne assets, inclusive of those introduced onto the trains as part of the signalling system at GOA2, will be the responsibility of Fleet Maintenance. Due to the limited 'train to wayside' transmission capability at GOA1, it is expected that Rolling Stock event notifications which relate to the condition and health status of the trainborne systems will be sent to the Control Centre for initial processing.

This initial processing function is expected to be undertaken by Train Doctors' who are located within each of the NTfL line Control Rooms. They will also have responsibility for monitoring fleet performance whilst in operational service and in co-ordinating asset response activities with the operational control staff in the event of problems.

Once the desired train to control system transmission capability has been attained it is foreseen that the Train Doctor presence in the line Control Rooms will recede and they will become an integral part of the Local Performance Centre(s) structure.

Further information on the Fleet vision and the principles behind the use of Local Performance Centres can be obtained through the Fleet & Depot Maintenance Concept.

- Operational Control System

Responsibility for ensuring the continued operation of the Operational Control System will become the duty of the Control Room Signal Technician (CRST). The CRST will be responsible for dealing with all first-line incidents and planned maintenance activities associated with the line Control Room elements of the OCS system. The Control Room Signal Technician will also serve as an interface between train control teams and field based teams when dealing with signal related faults and incidents.

This approach represents a new approach towards the OCS Maintainer role. This function has traditionally been undertaken by Control and Information Engineers due to the specialist knowledge required for telecommunications based systems. However, with the technologies being used for signalling and the OCS systems becoming increasingly comparable, there is now the opportunity to integrate the roles of the Control Room Signal Technician and the OCS Maintainer.

In supporting this role, the Control Room Signal Technician should be provided with a dedicated OCS Maintenance Interface which allows them to undertake all the functions expected of their role in respect to monitoring OCS health status, failure diagnosis and rectification.

The Control Room Signal Technician will therefore serve as the main interface between the Operational Control staff and the Signalling Maintenance organisation when dealing with S&TC and/or OCS related faults and incidents.

Recent signalling upgrades have tended towards combining the Control Room function and signalling control system in the same building. Indeed, the Sub-surface, Jubilee and Northern lines upgrades have incorporated the interlocking's at a central location. This arrangement is seen to be ideal from a maintenance perspective as it facilities a quick response towards faulting as well as placing a significant quantity of equipment in one place allowing for an efficient use of time when undertaking planned maintenance interventions by negating the need for travelling to various sites.

© Copyright 2009 London Underground Limited. All rights reserved.

However, it is recognised that the suggested architecture for NTfL's Operational Control Centre deviates from this arrangement by placing the line Control Room in a separate location from the signalling control equipment. This is currently being termed as a 'campus' arrangement.

Whilst there are benefits associated with the adoption of this arrangement, careful consideration will need to be given to the location of the control system equipment. If the Control Room is placed a significant distance from the control system then the maintenance organisation will need to provide coverage at both the Control Room and the Control system locations if TTS targets are to be met. In addition, it is likely that call depot facilities will need to be provided adjacent to the equipment room(s) which allow for the requisite incident response coverage.

Clearly the introduction of additional staff & 'call depot' facilities will erode some of the benefits that would be expected from a Control Room / Control system combined in one place (or separate within a reasonable distance).

4.2.3 The Future Vision for Signalling Incident Response

It is envisaged that a line based 'Call Depot' strategy towards signalling incident response is likely to continue following the introduction of the S&TC system. This structure has been founded upon a set of sound organisational principles and has adapted and evolved in order to meet the stringent TTS & TTF requirements expected of London Underground. However, the adoption of a standardised signalling system across the four NTfL lines does provide the opportunity for the development of a flexible workforce capable of working across each line, with line based Depot locations being strategically selected based upon a 'four line network' basis rather than on just a 'single line' model. This approach has already been successfully adopted on both BCV and JNP and has kept operational costs down through the efficient use of the resources available.

4.2.4 The Future Vision for Signalling Preventive Maintenance

Whilst it is a core principle that the level of planned, periodic maintenance activities are likely to decrease significantly with the introduction of the new signalling systems, it remains highly likely that signalling maintenance Depots will continue to operate due to the need to maintain the point equipment on the four lines. As with the vision for incident response it is expected that standardisation of equipment will provide the mechanism towards attaining the desire to achieve maximum flexibility in the workforce.

4.2.5 The Future Vision for a 'Centre of Excellence'

Traditionally the '2nd line' repair and overhaul maintenance function has been conducted 'in-house' utilising the Railway Engineering Workshop (REW) located at Acton Works. However, various signalling upgrades have led to the development of multiple 'bespoke' facilities for the overhaul and repair of different types of signalling and train control equipment.

By their nature, these facilities have tended to become 'line-centric' and have located at various sites across the London Underground network. Whilst it is recognised that these facilities have often grown organically in order to meet specific needs, the approach doesn't represent the most efficient use of resources or lends itself towards the co-ordinated and standardised approach which ensures that serviceable spares are made readily available to the railway.

NTfL represents an opportunity to prevent any further diversification from occurring and facilitate in the attainment of the future maintenance vision of the development of a 'Centre of Excellence' which will be capable of undertaking all 2nd line signalling maintenance activities in one location.

To facilitate this vision, there will be a need to ensure that the 'Centre of Excellence' will be furnished by the programme, the capability to undertake any designated 2nd line maintenance activity. It is expected that this will comprise of manufacturers information, test rigs, diagnostic tools, software and so on.

© Copyright 2009 London Underground Limited. All rights reserved.

Despite the vision for a 'Centre of Excellence' it is recognised that it may be may be difficult to establish a contractual agreement for the maintenance of 'sealed units' with a Supplier. Moreover, it may be found to be more expedient and cost effective for repair and overhaul to be outsourced. Once the Programme progresses and the position of the potential suppliers in the marketplace are fully understood, then an informed decision can be made.

4.2.6 Desired S&TC Maintenance Functions

Figure 1 assumes a diagram of the future S&TC system for the NTfL railway. The letters A-G used in the diagram are listed below and are used to highlight desired system functionality seen as necessary to fulfil the future vision of the maintenance organisation.

Although broadly based upon the structure outlined in the Operational Concept, the diagram is not intended to prescribe any specific architecture or connectivity. It remains imperative that flexibility in system design is afforded to the NTfL programme in collaboration with its Supplier's so that a 'best fit' solution for the Underground is found.

© Copyright 2009 London Underground Limited. All rights reserved.

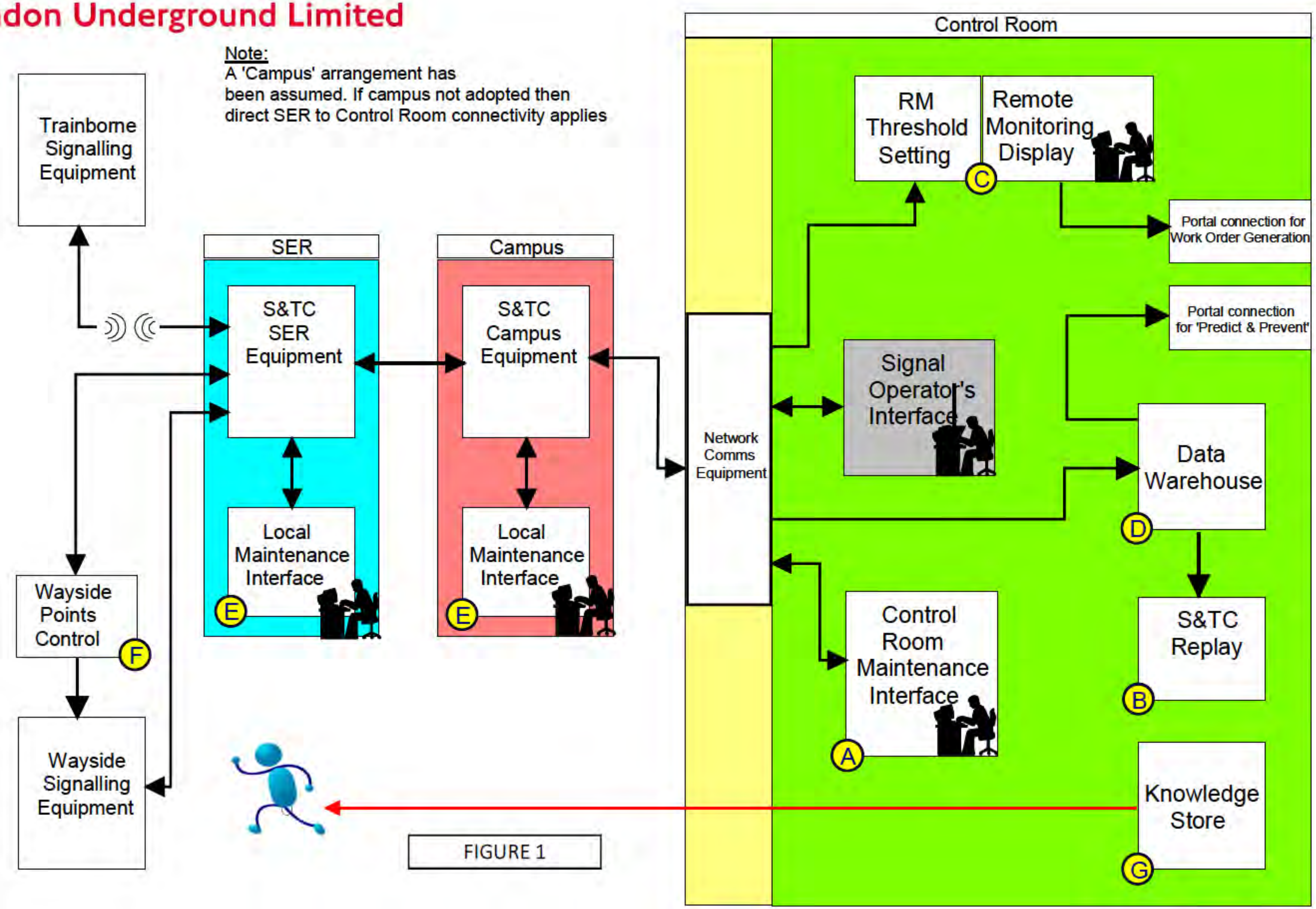


FIGURE 1

© Copyright 2009 London Underground Limited. All rights reserved.

4.2.7 Control Room Maintenance Interface

A

It is envisaged that S&TC system information is provided to a dedicated Maintainers Interface (termed hereafter in this document as the 'Control Room Maintenance Interface'). A Maintainers Interface is expected to be located in each of the line Control Rooms (Piccadilly, Bakerloo, Waterloo & City and Central lines) and positioned on a dedicated 'Maintenance desk'.

The purpose of the interface is to provide the Maintainer with the ability to monitor and interrogate the Signalling & Train Control System for each line.

- Equipment Status monitoring

In order to ensure the continuous availability of the signalling system, it will be necessary for the Signalling & Train Control System to have the capability to monitor, report and provide alerts regarding both its own health status and those of its sub-systems in 'real-time'. This capability should be applicable to any active 'on-line' systems as well as any 'stand-by' systems where redundancy has been built in as part of the overall design.

As the Control Room Maintenance Interface will essentially be used to monitor the signalling system from a line/network perspective, it should be capable of providing the health status information on all equipment associated with the S&TC Control Room, as well as the health status of S&TC equipment associated with any Control Room 'campus' or local SER's (inclusive of any communication network equipment).

Due to the need to monitor multiple sites, it should be recognised that the Control Room Maintenance Interface will need the ability to display information through the use of multiple screens or through 'software switching' capability.

It is envisaged that the interface will provide a set of highly intuitive graphical representations of the health status of the Signalling & Train Control System at both Control Room and SER level allowing a Maintainer to quickly identify a problem in the system before assessing its impact and determining the appropriate maintenance action.

- Equipment Diagnostics & Interrogation

In addition to status monitoring, the Control Room Maintenance Interface should possess diagnostic capabilities for fault-finding on all aspects of the Signalling and Train Control System. This should also include the ability to remotely interrogate the equipment at each remote site such that the Control Room Maintenance Interface is capable of providing the same diagnostic features that would be afforded to Maintainers via any Local Maintenance Interface, including the ability to interrogate any interlocking 'ladder logic' remotely.

This capability will allow fault finding and diagnostic activities to commence via the Control Room Maintenance Interface the moment a fault occurs and which can continue whilst a Maintainer travels to site. It is envisaged that in using this technology that the fault will be diagnosed before the Maintainer arrives on site allowing them to proceed directly to the rectification stage.

It is not envisaged that the Maintainer's Control Room Interface will give access for controlling the signalling system from the Control Room. However, there will be a need for the Control Room Maintainer to impose certain maintenance inhibits on the signalling system (i.e. Temporary Speed Restrictions) that ensure the safety and integrity of the railway. It is envisaged that the Maintainer's Control Room Interface will become the conduit for this critical safety function.

In order to ensure that only the maintainer can implement and remove such inhibits on the S&TC system, the Maintainer's Control Room Interface will need to be protected such that only those with 'access rights' can operate the terminal.

© Copyright 2009 London Underground Limited. All rights reserved.

Due to the amount of information expected to be drawn through this interface, it should be seen as a separate entity and realistically shouldn't form part of monitoring/diagnostic interfaces associated with other RCS sub-systems such as the OCS.

4.2.8 S&TC Replay Facility B

One of the key features when undertaking failure investigations, or when assessing alleged irregularities, is to understand the precise circumstances under which the fault or irregularity occurred. With most signalling designs being based on logical sequences, it is vital that the system has the capability to provide a 'playback facility' which will show a historical, yet chronologically accurate, reflection of the interactions and interfaces at the time of an incident.

It is envisaged that the 'playback facility' will graphically represent the railway as if it were being viewed in 'real-time', and will show the positions of each train, signal status and so on at the time of the incident.

The 'playback facility' should be considered as a function of the Maintainer's desk and be available to the Control Room of each line. Controls for setting defined dates and times to replay should be simple and intuitive and allow for immediate retrieval from the systems 'memory'. The playback facility should be capable of accessing historical information for a minimum of 72 hours after an event. Beyond this time all data should be stored in a data warehouse for future retrieval.

4.2.9 Remote Condition Monitoring C

One of the cornerstones of the S&TC Maintenance Concept is to reduce the number of Service Affecting Failures (SAF's) whilst also reducing the number of planned and periodic maintenance interventions. Whilst it could be argued that these represent two diametrically opposed needs, it is believed that a combination of reliable system design, working in conjunction with an effective asset monitoring capability, will allow the time between planned maintenance interventions to be increased whilst still being able to 'predict and prevent' failures before they have any operational impact.

The provision of an intelligent remote conditioning monitoring solution capable of capturing asset data such that it is possible to recognise a decline and/or a rate of decline in the Signalling & Train Control System condition or performance will facilitate the development of a 'just in time' maintenance intervention strategy.

With a system capable of prioritising information according to how a potential failure may criticality affect the operation of the Signalling & Train Control System, it is envisaged that assets demonstrating fault symptoms are brought immediately to the attention of the Control Room Maintainer through an appropriate alarm strategy. The Maintainer will be able to interrogate the S&TC system, allowing them to verify the problem and to assess the impacts associated with immediate asset failure. Any critical item identified can then be dealt with through the immediate dispatch of a Maintainer to site.

For non-critical items, the remote condition monitoring solution should be capable of automatically generating 'work orders' for equipment identified as requiring attention. These should naturally be sent directly to the nominated maintenance Depots but could also be potentially sent directly to Maintainers through the use of a personal mobile device.

To maximise its effectiveness, the remote condition monitoring solution should be capable of 'settable' criteria and thresholds. It is envisaged that the threshold criteria will be initially set to align with the Supplier's RAM data, but should allow for future custom settings to be inputted by the Maintainer.

As a means of developing RAM's figures that are truly reflective of the environment in which they operate, the Signalling & Train Control System should be designed so that it is capable of providing

© Copyright 2009 London Underground Limited. All rights reserved.

statistics for the operational usage of systems and equipment. This information would provide a rich information source for analysis and would allow for;

- Visualisation and reporting on the accrued data allowing for asset behaviours and trends to be identified so that the associated risks can be assessed and mitigated against,
- Creation of a rationalised set of alerts and risk based recommendations for the business to respond to,
- Use historic data to develop the knowledge and understanding of S&TC assets and the ongoing effectiveness of the maintenance regimes.

It is expected that whatever the remote condition monitoring solution will be, it should be designed and installed using LUL's Guidance Document G0213 'Condition Monitoring' so as to remain in line with the requirements of LUL's Cat 1 Standard S1213 'Condition Monitoring'.

4.2.10 Data Warehouse D

Access to historical data will be an important aspect in the establishment and verification of accurate S&TC RAM figures. Similarly, data may need to be accessible to support any future investigations such as signalling irregularities.

In this respect there will need to be a mechanism by which the recorded asset data can be stored in the longer term. It is envisaged that a large data base of information relating to the operation and behaviour of the S&TC system will be stored in a 'Data Warehouse' alongside the data drawn from other systems such as the Operational Control System (OCS) and any future [redacted] Communication connectivity.

The Data Warehouse will be a critical resource for the Predict & Prevent Programme who will able to use the information to:

- Assess asset data in order improve future maintenance and management activities,
- Implement informed changes to the maintenance regimes,
- Apply a systems approach to the assets which make up the network
- Implement the business changes which make the benefits associated with condition monitoring sustainable

Although the Data Warehouse will most likely be placed at a single location (nominally the Control Centre) it should have the capability of being accessed remotely by various users through a web-based interface.

4.2.11 Local Maintenance Interface E

The purpose of the Local Maintenance Interface is to provide the Maintainer with the ability to monitor and interrogate the on-site Signalling & Train Control System.

It is expected that a Local Maintenance Interface will be provided at all Signalling Equipment Rooms (and Campus sites, if applicable) and should be capable of providing a site specific line diagram allowing for an overview of the Signalling & Train Control System status for that area.

The Local Maintenance Interface should be capable of providing site specific equipment states and the general status for that area. It should serve as the Maintainer's main fault-finding tool and provide a significant level of diagnostic interrogation of the local S&TC system.

Unlike the Control Room Maintainer's Interface, the Local Maintainers Interface should provide a Maintainer with the ability to control the signalling in the local area to facilitate testing during Engineering Hours. In keeping with basic signalling principles, selection of a 'local operating mode' should ensure the 'locking-out' of the Control Room operation (for that site) ensuring that there is

© Copyright 2009 London Underground Limited. All rights reserved.

only one controlling entity at any given time. Once maintenance has been completed then this function can be switched out and control returned to the Control Room which in turn 'locks-out' the Local Maintenance Interface signal control capability.

4.2.12 Wayside Control Capability F

Periodic Point Maintenance requires that the final gauging is performed 'on power'. For Electro-Pneumatically (EP) operated points this does not represent a major issue as the Maintainer has the capability of operating the points locally from the trackside valves. However, this provision isn't available to electrically powered points which can only be controlled through the Control Room or through a local control terminal/panel in the SER.

With SER's becoming ever more dispersed, it means that a Maintainer may have to travel a significant distance to be able to undertake a 'powered throw' for final gauging purposes. This naturally would introduce a significant amount of 'dead-time' to the maintenance activity and thereby reduces efficiency. Moreover, the added distances involved will take the Maintainer away from visual and aural contact with their maintenance teams, increasing the risk of accidents and incidents when the points are thrown 'blind'.

To mitigate against these situations, it is envisaged that there is a means of locally controlling electrically operated points for gauging purposes whilst continuing to remain in visual and aural contact with the worksite. This would ideally be a fixed trackside installation that can be 'switched-in' for maintenance purposes and will safely 'lock-out' the Control Room and SER control capability preventing any unwanted operation. Once maintenance has been complete, then this function can be switched out and control returned to the Control Room/SER.

4.2.13 Knowledge Store G

Although not an integral part of the S&TC system, the 'knowledge store' is seen as an important element in ensuring efficient information management.

With many modern signalling systems now becoming a combination of bespoke and 'Commercial off the Shelf' equipment, technical information on systems tend to be assembled through the provision of several discrete manufacturers' technical manuals.

By their nature these manuals tend to be fairly generic and are rarely practical in the context of a broader signalling system application. Moreover, these manuals are rarely logically linked together, making it extremely difficult to quickly and efficiently pinpoint the requisite information. This becomes particularly pertinent in a failure situation. Apart from it being largely impractical to transport complete suites of technical manuals around and on-site, the extraction of the necessary information from them has become increasingly difficult, frustrating and extremely time-consuming.

To this end it is envisaged that all technical information for the signalling system (Book-wirings, Operations & Maintenance Manuals, fault finding guides, work instructions etc.) will be held in a central electronic 'knowledge store'. The 'knowledge store' can then be accessed at any site location through a suitable mobile device.

Each document would ideally be 'bookmarked' to allow efficient accessibility to other appropriate manuals/reference points/pages to assist the Maintainer and facilitate improved response times.

The system could potentially be adapted to allow limited mobile device access to Station staff , who could then utilise the information to ascertain and feedback basic status information. This could take the form of a series of 'preliminary status checklists' which, as an example, may seek such basic information as '*confirm through the touch-pad (on the mobile device) what indication lights are currently being displayed on equipment X'*.

Provision of such information would prove invaluable to the Control Centre in assessing the potential impact of a failure, whilst the feedback will also give a Maintainer, who may be travelling to site, a 'head-start' or insight into what the root cause of the problem may be.

© Copyright 2009 London Underground Limited. All rights reserved.

Provision of a centralised 'knowledge store' will also facilitate effective version control ensuring that any information being accessed by a mobile device is always up-to-date.

4.3 Required Reliability, Availability, Maintainability Performance

The New Tube for London (NTfL) programme will deliver a comprehensive, integrated series of successive line upgrades for the Bakerloo, Central, Piccadilly and Waterloo and City lines to a common set of objectives.

A declared strategic objective of the NTfL programme is improved railway reliability while increasing railway capacity, reducing journey times, lowering life cycle costs and improving customer experience.

The key components of the solution offered by the NTfL programme include:

- a lightweight and energy efficient, semi articulated train equipped with air cooling in the passenger saloons and a through corridor
- a comprehensive Communications Based Train Control (CBTC) system based upon a high performance telecommunications network
- an Operational Control System (OCS) providing comprehensive information (including fault diagnostics support and suggested failure recovery strategies) to and enabling service control from both centralised and roving staff
- integrated delivery and control of operations and maintenance
- improved control of the Platform Train Interface (PTI) to permit the automated despatch of trains
- an enhanced traction power system that maximises the energy efficiency of trains
- improvements to track quality and layout as required to deliver the specified performance

Station improvements and congestion relief schemes do not form part of the NTfL scope; there will, however, be an interface with projects charged with such deliver.

To ensure these objectives are achieved NTfL are following the general guidelines of EN BS 50126 Railway Applications – The specification of Reliability, Availability, Maintainability and Safety (RAMS) and EN BS 50128 Railway Applications – Communications, signalling and processing systems: Software for railway control and protection systems.

A RAM Strategy (NTfL-2344.2.2-LUL-PLN-00007) has been produced to outline the process by which the RAM requirements for the NTfL programme are determined and the RAM activities undertaken by NTfL and its Suppliers to achieve them. The RAM Strategy defines high level RAM targets for the Bakerloo, Central, Piccadilly and Waterloo and City lines for the [redacted] These targets are expressed as annualised rates of Service Affecting Failures (SAFs) resulting in a delay of 2 minutes or more.

The RAM Strategy includes consideration of:

- Customer influences
- Staff influences
- Traction and Auxiliary Power
- Platform / Train Interface equipment
- Railway Control System (Signalling & Train Control plus Operational Control)
- Rolling stock

© Copyright 2009 London Underground Limited. All rights reserved.

- Track & Civils
- Station infrastructure
- Operational influences

The RAM Strategy considers all modifications associated with the future upgrades and how such changes will influence the overall Railway Level RAM performance.

A RAM Management Plan (NTfL-2344.2.2-LUL-PLN-00011) has also been produced that provides a detailed description of the RAM activities applicable to the NTfL Programme scope, which takes the project from the System Requirements (phase 4) through the Apportionment of System Requirements (phase 5) stage and into the preliminary design (phase 6).

The RAM Management Plan outlines the arrangements for the detailed Reliability, Availability and Maintainability (RAM) requirements for the NTfL Programme and as such covers the following:

- Description of RAM Roles and responsibilities within the NTfL Programme organisational structure
- Identification of RAM requirements and tasks that need to be carried out for each identified line of route
- The NTfL Programme RAM approach follows the general principles of BS EN 50126

The aim of the detailed RAM activities identified within the RAM Management Plan is to assess the design specification against the RAM requirements and targets.

The RAM work detailed within the RAM Management Plan is intended to influence the overall operational reliability of the railway and therefore the RAM activities specifically include consideration of all factors that may affect service performance. This includes not only failure of hardware but also operational and maintenance issues that may contribute to reliability.

Detailed targets are presented within the RAM Management Plan for all routes (lines) along with formal classification and acceptance criteria for each phase of the project [redacted]

All NTfL suppliers are required to follow the general principles and practices defined within the RAM Management Plan as applicable to their specific system equipment.

5 MAINTENANCE LEVELS (DEFINITION)

There are various types of maintenance interventions that have to be undertaken on the Signalling and Train Control System and it is recognised that there are different, often interchangeable terms used across the network, to describe the various levels of maintenance intervention. For this reason, and to promote a common recognition of the terms used throughout this document, these interventions have been categorised into three levels; first-line, second-line and third-line.

In the context of this document, first-line maintenance has been sub-divided to encompass response and corrective maintenance activities, whilst second-line and third-line maintenance is used to describe the particular pathways taken in the repair and overhaul of signalling equipment that is 'returned from the field' following a first-line maintenance intervention. The below table (Fig 2) indicates where each type of maintenance intervention lies in respect of first-line, second-line and third-line and a set of definitions is also provided for clarification purposes.

Category	Maintenance Activity
1st Line Incident	1st Line Response
	1st Line Corrective
1st Line Preventive	Planned, Periodic Maintenance

© Copyright 2009 London Underground Limited. All rights reserved.

	Preventive Corrective
	Routine Change
2nd Line Maintenance	'In-house' Overhaul & Repair
3rd Line Maintenance	'Out-sourced' Overhaul & Repair

Fig 2 – Maintenance Intervention Categorisation

5.1.1 First-Line Maintenance (Definition)

First-line maintenance has been sub-divided to form two distinct categories of maintenance activity; first-line incident and first-line preventive.

5.1.2 First-line Incident (Definition)

'Incident' comprises both 'first-line response' and 'first-line corrective' maintenance activities and is primarily associated with the diagnosis and rectification of those faults and failures which are, or have the potential to become, Service Affecting Failures (SAF's).

It is necessary here to make the distinction between 'first-line response' and 'first-line corrective' activities. These have largely been drawn as a function of the current signal response structure which has been organised such that it offers the capability of providing 24 hour response coverage toward signalling related incidents.

As other maintenance departments do not generally need, or possess this level of coverage, the first-line response role is often fulfilled by an available Signal Maintainer who is primarily tasked with the identification of a fault.

Naturally if a fault is subsequently found to be within the Signal Maintainer's own area of expertise, then a first-line corrective action will be taken to rectify the fault.

However, due to the integrated nature of signalling systems, it may be the case that the root cause of the fault is found to be within a sub-system outside the Maintainer's area of expertise. In this instance the Signal Maintainer may attempt a first-line corrective action unless rectification is felt to be beyond their capabilities and/or limits of authority. In this event the fault will be followed up by a discipline specific person who will complete the first-line corrective action.

5.1.3 First-line Preventive (Definition)

In this context, *preventive* relates to the planned, periodic maintenance activities seen as necessary to ensure the continued and effective operation of the system.

It also relates to the activity of 'Routine Change' and as the name implies this, is the activity associated with routinely changing-out assets which are due for overhaul, as well as assets that are identified as requiring to be replaced due to excessive wear or where they have been found to be problematic.

5.1.4 Second-Line Maintenance (Definition)

Second-line maintenance describes the process for repair and overhaul when equipment, returned following a first-line maintenance intervention, is sent to an 'in-house' facility equipped with the capability of undertaking the work. Traditionally the full repair and overhaul of legacy signalling equipment has been undertaken utilising London Underground's Railway Engineering Workshop (REW) based at Acton works. Once overhauled, this equipment is subsequently returned to a centralised store ready to be returned into operational service.

© Copyright 2009 London Underground Limited. All rights reserved.

5.2 Third-Line Maintenance (Definition)

Third-line maintenance is considered to be the repair/overhaul of equipment returned from a first-line maintenance intervention which is undertaken by the Supplier or a nominated sub-contractor with Supplier involvement. Under this arrangement there is seen to be no second-line maintenance involvement other than the equipment passing through the Underground's 'in-house' maintenance facility which is used as a 'staging-point' to facilitate the recording and storage of defective items prior to Supplier collection and their subsequent return

As modern signalling systems have evolved, the equipment has tended more toward the adoption of 'black box' technology (hereafter referred to as Line Replaceable Units or LRU's). This approach facilitates quick fault diagnosis and rectification at a first-line maintenance level, allowing units to be replaced without the need for rectification at component level. However, due to its specialised nature any further examination of returned equipment often requires the use of bespoke diagnostic and testing rigs.

In some cases it has been found to be more expedient to return defective Line Replaceable Units (LRU's) directly back to the Supplier for repair and overhaul. This ensures that failed equipment is restored to a serviceable state as quickly and cost-effectively as possible. The 'direct first-line to third-line' approach may also be dictated by the conditions of the supply contract and subsequently prohibits the opening of an LRU by outside parties through the immediate invalidation of its warranty.

6 MAINTENANCE APPROACH TO NTFL MIGRATION - [redacted]

6.1 S & TC Maintenance Concept – Grade of Automation 1

First-Line Maintenance

The changes made following the introduction of the GOA1 stage are not expected to significantly alter the way in which S&TC maintenance is currently conducted today. Preliminary analysis of the signalling immunisation works indicates that there is no signalling equipment being introduced that is new and novel.

In this respect it is envisaged that the signalling maintenance structures currently being operated will remain and therefore there will be no changes in the defined maintenance responsibilities at either first, second or third-line.

However, it is recognised that the GOA1 stage may introduce additional assets which are required to facilitate operation of the new train (i.e. in-cab One Person Operation). And it is envisaged that the maintenance of these new assets will be performed by the same maintenance teams that are currently in place, unless it is found to be more expedient, from either a technical or commercial perspective, to maintain the 'specialised' elements of the system through a maintenance support contract.

6.1.1 Second-Line Maintenance

As the S&TC is not expected to be introduced at this stage of the Programme, there is no envisaged impact on the current second-line maintenance structure.

6.1.2 Third-Line Maintenance

As the S&TC is not expected to be introduced at this stage of the Programme, there is no envisaged impact on the current third-line maintenance structure.

© Copyright 2009 London Underground Limited. All rights reserved.

6.2 S & TC Maintenance Concept – Grade of Automation 2

6.2.1 First-Line Maintenance

At GOA2 it is expected that first-line incident response on the S&TC system will continue to be undertaken 'in house' using London Underground's signal staff.

A level of support will be expected from the Supplier in the first instance, which will enable the maintenance organisation to call upon the knowledge and expertise of the supply chain to support LU in resolving ongoing Signalling and Train Control issues which are not clearly understood, or which cannot be resolved through first-line maintenance intervention. It is envisaged that the level of support will be high during the first few months following the first site commissioning but will reduce as the maintenance organisation familiarises itself with the systems operation and nuances.

First-line preventative maintenance of the signalling system is also expected to be retained as an 'in-house' function. This will allow for the continuation of an effective 'whole system' maintenance regime for a system comprised of new signalling operating in conjunction with existing legacy assets such as points.

However, there may be assets in the new system which would better served through a maintenance support contract with an appropriate external Supplier. These are essentially assets where a level of specialist skill or equipment is required and may therefore not be economically viable to retain as an 'in-house' maintenance function. This approach has already been adopted on the Victoria Line system where maintenance of the radiating cable and repair of fibre optic cables has been outsourced. The extent of these assets will be known once a system architecture is defined and from where a view can be taken.

ATC equipment fitted to rolling stock is expected to be serviced by the Fleet team to the extent that the changing of line replaceable units to a fixed procedure can be carried out. The overall system and the analysis of faults, including the management of any safety signalling related software, will be the responsibility of Signals.

6.2.2 Second-Line Maintenance

As outlined in section 4.2.5 it remains the vision that following the installation post-warranty period that the repair and overhaul of S&TC equipment (inclusive of train-borne signalling equipment), is conducted 'in-house' utilising the 'Centre of Excellence. However, further information will need to be obtained from the various S&TC suppliers before a final decision can be made.

6.2.3 Third-Line Maintenance

As outlined in section 4.2.5 it remains the vision that following the installation post-warranty period that the repair and overhaul of S&TC equipment (inclusive of train-borne signalling equipment), is conducted 'in-house' utilising the 'Centre of Excellence. However, further information will need to be obtained from the various S&TC suppliers before a final decision can be made.

6.2.4 Additional Maintenance Considerations at GOA 2

Whilst the descriptions of the maintenance levels in Section 5 of this document are broadly correct, there remains a notable exception in respect of the approach adopted for third-line maintenance on the trainborne signalling equipment on the Central Line and the Victoria Line.

In this instance failed trainborne equipment that has been removed from service is initially tested utilising an LUL in-house facility, fitted with the requisite unit test-rigs and diagnostic equipment.

This approach assists with the verification of the fault as well and determining if the unit can be repaired using the in-house resource rather than being returned to the Supplier with the benefit of a higher turnaround of available spares being achieved.

© Copyright 2009 London Underground Limited. All rights reserved.

Similarly, units returned from a Supplier will be subjected to a 'soak-test' prior to being returned to service, allowing confirmation of the fix. This measure has become a necessity due to previous experiences of faulty or unrepaired equipment being returned by the Supplier and serves as a prime mitigation against defective equipment being reintroduced back into the operational railway.

In this respect, the ability to verify and soak-test test third line equipment is an important function. It is recognised that this capability will be available through the adoption of a 2nd line repair and overhaul however, it is imperative that if a 3rd line strategy towards repair and overhaul is adopted, then it will become a requirement that LU Operations (Assets) is furnished with the equipment necessary to be able undertake these pre and post-tests.

6.3 S & TC Maintenance Concept – [redacted]

6.3.1 First-Line Maintenance

[redacted]

© Copyright 2009 London Underground Limited. All rights reserved.

[redacted]

[redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

6.3.2 Second-Line Maintenance

Please refer to section 4.2.5

6.3.3 Third-Line Maintenance

Please refer to section 4.2.5

7 S&TC TRAINING REQUIREMENTS

S&TC training for maintenance personnel is expected to continue utilising the type of training facility that has already been adopted for the Victoria, Northern, Jubilee and Sub-Surface lines.

This approach provides a complementary mix of theoretical and practical training which effectively imparts knowledge of the signalling principles involved whilst also providing a high degree of practical 'hands-on' experience within in a safe learning environment.

This method has proven to be successful in developing a highly skilled workforce capable of responding to various faults conditions as well as the capability of undertaking preventive maintenance interventions across broad range of assets.

It is recognised that the emergence of simulation and virtual reality technology provides a unique opportunity to develop a 'system wide' S&TC training facility which retains the core equipment but provides a virtual railway system which the equipment interacts with. It is anticipated that the S&TC training facility will combine these elements to create an S&TC training capability that is unsurpassed in the railway industry.

A comprehensive set of requirements for the S&TC training facility has been developed by the NTfL in collaboration with Key Stakeholders from LUL's Operational Learning Department. Supporting these requirements is a 'Training Philosophy' document which provides the narrative and rationale for the preferred training approach for NTfL.

8 S&TC MAINTENANCE INVOLVEMENT IN THE NTFL PROGRAMME

8.1 Operational Upgrades & Asset Development Team

The Operational Upgrades & Asset Development Department (OU&AD) has a core team embedded into the NTfL programme. From an S&TC perspective this team will serve as the day to day interface between the Programme and the wider maintenance community. This team should be considered as the 'first point of contact' with LUL Operations (Assets). Where the team has delegated authority from the various asset disciplines, then it will provide direct input into the

© Copyright 2009 London Underground Limited. All rights reserved.

programme. If not, then OU&AD will subsequently ensure that the appropriate representation is provided to the programme.

In order for this approach to be effective it is the responsibility of the Programme to ensure that its sub-programmes and projects plan effectively for when maintenance involvement is necessary. It is imperative that sufficient notice is given to allow the designated maintenance representatives to plan for the necessary time.

In this regard, it is expected that each project will embed into their schedule all activities which involve input from the maintenance organisation. The maintenance organisation will subsequently require that projects needs are ‘rolled up’ by the Programme and are presented to the OU&AD Team on a rolling one month ‘look-ahead’ basis. This look-ahead should provide clear information on what the planned activity is and what asset groups are affected.

8.2 Maintenance Introduction Group

Following the successful use of embedded Maintainers working collaboratively with the Supplier’s on the Victoria Line Upgrade and 4LM, Operations (Assets) would be keen on adopting a similar approach on NTfL. This will be a small team (nominally 6-8 people, but actual numbers will be dependent upon NTfL’s adopted signalling migration strategy) who are drawn from those lines where NTfL Signalling & Train Control assets will be installed. Their prime function will be to provide the programme with knowledge and experience of maintenance processes.

Use of a Maintenance Introduction Group offers a personal development opportunity to those involved, as well as providing LU Operations (Assets) with a resource who will have gained a greater depth of specialist knowledge and a level of experience than that which could normally be expected from a formal training programme. A broad outline of their intended remit and the perceived benefits are provided below:

- Design and Build

Working with the Supplier’s and using knowledge and experience the Maintenance Introduction Group will be able to offer advice on the design and build to ensure maintainability of the system which will include installation, testing requirements and replacement of equipment.

- Human Factors Integration

The MIG team working with a Human Factors Specialist will ensure the signalling system meets human factor requirements for maintenance.

- Support of Factory Testing

Supporting factory testing will give the MIG team early and in-depth experience of the operational parameters of the system being provided, also allowing early feedback to the designers and input to the maintenance manuals.

- Review of Maintenance Manuals

Good quality manuals will be integral to producing maintenance procedures and instructions as well as forming the basis of training courses. The MIG team will review maintenance manuals to ensure they are correctly formatted and that they supply sufficient and detailed information to allow maintenance of the system.

- Document Review

The MIG team will be able to provide valuable input into as well as providing additional resource in reviewing the technical documentation for content and suitability for maintenance requirements.

- Involvement in Maintenance Demonstrations

© Copyright 2009 London Underground Limited. All rights reserved.

The MIG team through supporting maintenance demonstrations will allow Maintainers to practically confirm the quality of the information contained within the maintenance manuals to ensure that it meets the requirements for producing maintenance procedures.

- Training Support

Training will be critical to ensuring all staff are competent to work on the new Signalling and Train Control system. Using in-depth knowledge gained from involvement in the NTfL Programme will allow the MIG team to assist in the development of the Training Needs Analysis (TNA) and to feed-back into the training requirements and maintenance course production. Their use has been seen to be particularly beneficial in assisting in the development of operational rules, which are traditionally not provided in the Supplier 'train the trainer' training packages, but are necessary to embed as part of end-user training delivery.

The MIG team will also be capable of covering roles for those who are required to attend training in support of future NTfL commissioning's. This will allow Operations (Assets) to be able to develop a staged training delivery programme which is seen as the preferred approach toward preparing maintenance staff for the delivery of assets into service whilst ensuring that there is sufficient coverage on the operational railway. This is particularly pertinent where staged signalling migrations are implemented and where there is likely to be a mix of skills needed to deal with both legacy and new signalling systems. Installation

Installation will fall in to two categories, Infrastructure Works (e.g. new points and crossings for End State Track Layout) and S&TC system Installation, both of which will benefit from MIG team involvement whilst expanding the knowledge base of the MIG itself.

- Testing and Commissioning

The MIG team, supporting the testing and commissioning of the assets will allow LU Operations (Assets) to gain further detailed knowledge and experience of local site information and how the system performs in the real world.

- Assurance

Supporting the project with LU Operations (Assets) staff early in the process will enable maintenance acceptance requirements to be clearly defined, ensuring a smooth handover whilst also providing assurance and confidence that LU Operations (Assets) are ready to accept and maintain the new system.

- Supporting Maintenance Activities Post-Commissioning

After the first commissioning the MIG team will revert back directly to LU Operations (Assets) where they will directly support the maintenance requirements of the newly commissioned system. Their initial role will be responding to faults and failures and will also carry out preventative maintenance activities ensuring maximum availability of the new system. During subsequent section commissioning they will directly support the line based Maintainers, acting as mentors and dealing with repeat faults.

9 HANDOVER OF ASSETS INTO MAINTENANCE

The handover of assets into maintenance will be in accordance with Pathway. As part of the Pathway process, LU Operations (Assets) are key stakeholders in the development of the Pathway products involving Maintenance. In this respect, Operations (Assets) should be considered in the development of each Project's Pathway Product Management Plan (PPMP) so that it may understand its future obligations. The ongoing process for the management of these obligations should follow the requirements laid out in the future Programme level (Gate C) Maintenance Readiness Plan.

© Copyright 2009 London Underground Limited. All rights reserved.

Effective Maintenance Readiness Plans alongside the considered development and effective management of the Mandatory Asset Information Deliverables (MAID's) are expected to form the cornerstones which facilitate the efficient transition of assets into maintenance by providing specific information to each project on what maintenance will require for effective asset maintenance in future.

It is recognised that there are circumstances in which certain maintenance information (such as 'as built' drawings) cannot be made available at the time of an asset being brought into operational use. Under the Pathway structure, this would essentially mean that the requirements necessary to sign the requisite Project Completion & Handover Certificate (PC&HC) have not been met.

Under these circumstances, and where it is absolutely necessary to ensure that maintenance coverage is available once an asset has been brought into use, then an Interim Maintenance Readiness Statement should be developed and agreed between the project and maintenance well in advance of any future commissioning's. This document will serve to ensure that sufficient provisions are in place to enable maintenance to be undertaken in lieu of a set of finalised PC&HC requirements.

Interim Maintenance Readiness Statements are expected to have a 'shelf-life' associated with them which gives a project time to gather the full suite of maintenance requirements. Once this 'shelf-life' has expired, then responsibility for the assets maintenance will be returned back to the project.

10 SPARES & TOOLS

10.1 Spares - General

The provision of spares is an important aspect in the maintenance of the S&TC system. Spares need to be stored in locations that would minimise 'Time-to-Fix' times as well as being accessible to facilitate the planned, periodic maintenance of the various parts of the system.

These two differing demands necessitate a combination of both a centralised store, expected to hold a full range of spares to satisfy planned maintenance needs, and a series of 'satellite stores' capable of holding a small amount of critical spares that support the requisite 'Time to Fix' times.

Although yet to be determined through the production of the system architecture, the location of the store(s) will need to be strategically placed so as to increase accessibility on a 'round the clock' basis thereby reducing the potential for delays to the Underground in the event of a failure.

In order to reduce costs it is envisaged that 'Satellite Stores' will not be separate buildings but are instead expected to become an integral part of the equipment rooms used by the system. These will include local SER's and any Control Room SER's. The NTfL programme will need to ensure that this requirement is included in the design of equipment rooms

The quantity of spares held is an important factor, particularly for the satellite stores where space is likely to be at a premium. It is therefore crucial that the right level of spares is identified and where they are best held. To facilitate the development of this, a 'spares listing' is seen as a critical output from the NTfL programme.

10.2 Spares Listing

Identification of a logical stock profile becomes extremely important for effective stores management. The development of a spares listing forms the basis of a risk based spares strategy and must be determined through a study of the reliance of the equipment, its criticality to the functionality of the system and the present and future availability of the parts.

Naturally there is heavy reliance placed upon the Manufacturers/Supplier to provide recommendations for spares in the first instance.

© Copyright 2009 London Underground Limited. All rights reserved.

However, it is vital that these recommendations are fully considered and that the Supplier is provided with 'scoring' criteria to optimize the quality of any recommendations made to LU.

Considerations for the 'scoring' criteria are:

- Does the equipment represent a single point of failure?
- What is the likelihood of failure of the equipment based upon its most vulnerable component (reliability/redundancy)?
- How critical is the equipment to the operation of the system?
- What is the expected vulnerability of the equipment? Is it in an exposed place where damage/deterioration is likely
- What are the envisaged lead /turnaround times of supply for each item of equipment?
- Is there any contractual or warranty requirement to use the Supplier's Assets or can similar equipment be bought commercially 'off the shelf'?
- Can existing spares be used?
- Is the asset perishable? If so, what is the shelf life?

It is envisaged that under the terms of the Suppliers contract there will be a requirement to provide 'system' spares which from previous Programme's have been quantified against a contractually agreed value. It is important that the scoring criteria developed is both robust and rigidly applied because failure to do so could result in the Supplier providing uncritical, perishable and bulky expensive-to-store equipment as part of the system spares list.

10.3 Development of an Equipment 'Reliability' Database

Suggested spares are often evidenced through the Manufacturer/Supplier's Failure Mode and Effects Analysis documentation (FMEA) and RAM data. Whilst this information does provide a logical baseline on which to determine a preliminary spares list, it is quite often the case that the data will be based upon the findings of controlled factory test results and may not be truly reflective of the fault modes of equipment operating under the variable environmental conditions found 'in the field'.

In this respect it is vital that equipment failure modes are continuously monitored and recorded to build a database of actual failure trends of 'real world' equipment. Equipment should therefore be monitored on a site by site/ train by train basis to capture both generic trend data as well as being used to identify 'localised' problems.

The development of this database will become critical in determining the appropriate stock profile outside of those suggested by the Suppliers RAM data.

It is expected that the database is initially developed by the NTfL Programme and should capture RAM data once the equipment has been 'powered-up' for testing purposes, facilitating the potential to identify early mortality rates for various items of equipment.

10.4 Tools

It is imperative that maintenance activities are undertaken using appropriate tools, ensuring the equipment is effectively maintained and preventing accidental asset damage or injury to the user. An understanding of the system tasks through Human Factors task analysis, will determine what actual tooling is required to maintain the new S&TC system. This analysis should also identify what items are currently used by maintenance and a simple 'gap' analysis should then be undertaken to determine an appropriate tools listing.

© Copyright 2009 London Underground Limited. All rights reserved.

Specialist tools should also be identified by the Supplier along with the quantity required which will be determined by the staff levels and their geographical distribution.

Once developed, the tool listing will also highlight any equipment that requires specialist support, such as calibration, software licences for analytical data and so on. Similarly, the tool listing also provides the opportunity to identify any training that may need to be considered in the use and operation of tooling.

11 WHOLE LIFE COSTS

In order to maximise the expected benefits from the introduction of the new Signalling System, the NTfL programme should always consider the associated whole life cost of it to London Underground Limited.

Reductions in future maintenance costs are an important component in achieving lower whole life costs. These reductions can be attained through properly considered designs such that cost savings become an inherent part of them. This concept has already outlined several means by which appropriate designs will improve efficiency, however further consideration should also be given to the following:

- All signalling system components shall be designed to have a long life with overhaul requirements defined by the whole life cost model under full operational conditions.
- The Signalling & Train Control System should be designed such that all cables are maintenance free as far as possible.
- Cables are accessible and have convenient test points frequently located to aid 'end to end' testing.
- Where feasible, software should be bought and available to all, not limited by licence use.
- Redundant assets shall be decommissioned and removed, unless otherwise agreed with the Sponsor.
- The Signalling & Train Control System should be built to ensure the system has sufficient capacity so that any future expansion can be achieved without the need for significant equipment upgrades.

The principle to reduce Whole Life Cost forms part of the Sponsors Requirements and is a key NTfL Programme objective. Whilst it remains the responsibility of LU Operations (Assets) to manage the costs effectively once the system has been accepted into maintenance, it remains the NTfL Programme responsibility to ensure that the relevant Sponsor is involved with any business case evaluations regarding whole life cost. This requirement is to include any changes to programme scope where the LU Operations (Assets) are materially impacted; (or example, changes to operating efficiency or maintenance contracts.

12 WARRANTIES

It is recognised that there will be a warranty period associated with the S&TC system hardware and software. Management of these warranties is expected to be the responsibility of the Maintenance Organisation once the system is brought into use on the operational railway.

The terms of these warranties have, through experience, been such that they have often expired long before the associated equipment has been brought into operational use, thereby inhibiting the maintenance organisation obtaining the necessary repair or replacement of defective items of equipment, or to remedy any software errors.

To ensure that recourse (through warranty) for defective equipment or software remains available at the point of bringing into operational use, it is vital that LU Operations (Assets) are afforded time to

© Copyright 2009 London Underground Limited. All rights reserved.

review the warranty before it is agreed. The warranty should therefore provide for opportunities for amendments both from the Supplier and LUL to reflect any changes in the delivery of relevant products.

Warranties should provide absolute clarity for both the Supplier and LUL on;

- What is covered by each warranty
- What won't be covered by each warranty
- The point at which each warranty will commence
- The point at which each warranty will end

13 OBSOLESCENCE

It is a fundamental requirement that the Supplier commits to managing obsolescence so that the maintenance organisation retains the capability of ensuring a safe and reliable railway. It is therefore imperative that spares of any specialist equipment that is developed for use by the S&TC system remains available, along with a commitment to provide support on an on-going basis and throughout the expected asset life of 40 years.

However, it is recognised that the final signalling solution will inevitably involve many computer and processor based sub-systems which are expected to be bought 'commercially off the shelf' by the Supplier. Given the pace of technological advancement in this area, it would be unrealistic for a Supplier to guarantee the availability of a particular computer or processor over the requisite 40 year life span.

Whilst this could be mitigated through securing a large quantity of spares, this would be contrary to the maintenance philosophy where the emphasis is on reducing stock holdings recognised as being inherently expensive to the organisation to support.

In this respect, consideration should be given to the provision of a 'mid-life' upgrade, which will see each of the computers and other processor based equipment being replaced with modern equivalents, thus ensuring a guaranteed spares availability in future. The Supplier should be capable of recommending the point at which the mid-life equipment upgrade is undertaken based upon a combination of its RAM's figures and knowledge of the market from where it secures its COTS equipment.

14 ONGOING SUPPLIER SUPPORT

Given the specialist nature of the Signalling & Train Control system, and in particular the software developed for its operation, the maintenance organisation will often require ongoing technical support from Supplier's. It is envisaged that there will be several areas where the option to seek ongoing technical support from the Supplier(s) may be considered prudent, if not necessary, to ensure effective coverage that supports the Underground's operation from the moment the NTfL first migration area is brought into use on the operational railway.

A brief description of the expected type of support options are provided below:

14.1 Design Authority Support

This ensures that the Supplier is capable of providing long-term technical knowledge and expertise so as to continue as the Design Authority for any required changes to the Signalling & Train Control System post-warranty.

© Copyright 2009 London Underground Limited. All rights reserved.

14.2 Technical Advice Support

The purpose of this will be to provide LU Operations (Assets) with access to the Supplier's technical experts who will be able to offer advice and guidance on all aspects of the S&TC. This will be a crucial element for the first-line maintainer, particularly in the formative stages when familiarising themselves with the system. It is envisaged that there will be an on-site support capability available in the initial stages of the system being brought into use, progressing towards a remote support structure at a later date.

14.3 Technical Investigation Support

This service will be necessary in providing the maintenance organisation with the capability to call upon the knowledge and expertise of the supply chain in resolving ongoing Signalling and Train Control issues which are not clearly understood, or which cannot be resolved through first-line maintenance intervention.

Technical Investigation Support is expected to provide LU Operations (Assets) with the means by which the root causes of regularly occurring faults can be established and eradicated.

14.4 Technical Information Support

To support the maintenance organisation, the Supplier is required to manage the technical information for the S&TC by maintaining an electronic library (Including documents provided by LU, Operations (Assets) including assurance submissions and background information.

This will ensure that any book wirings, manuals and so on. are updated in line with any change in software/hardware made by the Supplier during migration, change in Grades of Automation or any other post commissioning refinements.

14.5 Engineering & Maintenance Support

This service is to enable the supply chain to support modifications, performance initiatives and maintenance efficiencies during the operation of the Signalling & Train Control System and would allow for such items as the provision of advice in connection with any recommended modifications to the system intended to improve maintenance efficiency and reduce whole life costs.

Technical support will also need to be available to cover any corrective changes, updates or amendments to the system's software. This support is expected to be available throughout the expected life-span of the system (40 years) and should provide coverage for all aspects of the S&TC system.

This would then be expected to extend to the Supplier acting as the Design Authority (and providing Design Authority Assurance therein) when implementing any agreed software/ hardware modifications.

14.6 Training Facilities Support

Ongoing technical support will be required to ensure that any S&TC training facilities developed by the Supplier for use by the maintenance organisation remains fully functional and continues to develop and evolve in line with the railway system that it should be reflective of.

In this respect there will be a need for Supplier support to undertake the diagnosis and rectification of any hardware or software faults occurring in the training system (inclusive of any simulated environments) which cannot be remedied by LU Operations (Assets). Supplier support will also be required where any future changes in the system are necessary or where there is a particular fault or scenario emerging from the operational railway which may need to be 'programmed' into the system to enhance the realism of the training facility.

© Copyright 2009 London Underground Limited. All rights reserved.

14.7 Repair & Overhaul Support

Dependent upon the selection of a 2nd or 3rd line maintenance approach, different support will be required. These are portrayed under the following scenarios:

- Scenario 1

As outlined in Section 4.2.5 it remains the vision of LU Operations (Assets) that 2nd line maintenance function will be undertaken 'in-house'. If this vision is realised then there will be a requirement to secure supplier support which can provide specialist advice to the 'Centre of Excellence' when required.

- Scenario 2

Should it be found that the vision for an 'in-house' 2nd line maintenance facility is not achievable, or that the repair and overhaul element is better outsourced as a 3rd line function then a maintenance support contract will be needed which supports this requirement for the expected lifetime of the asset.

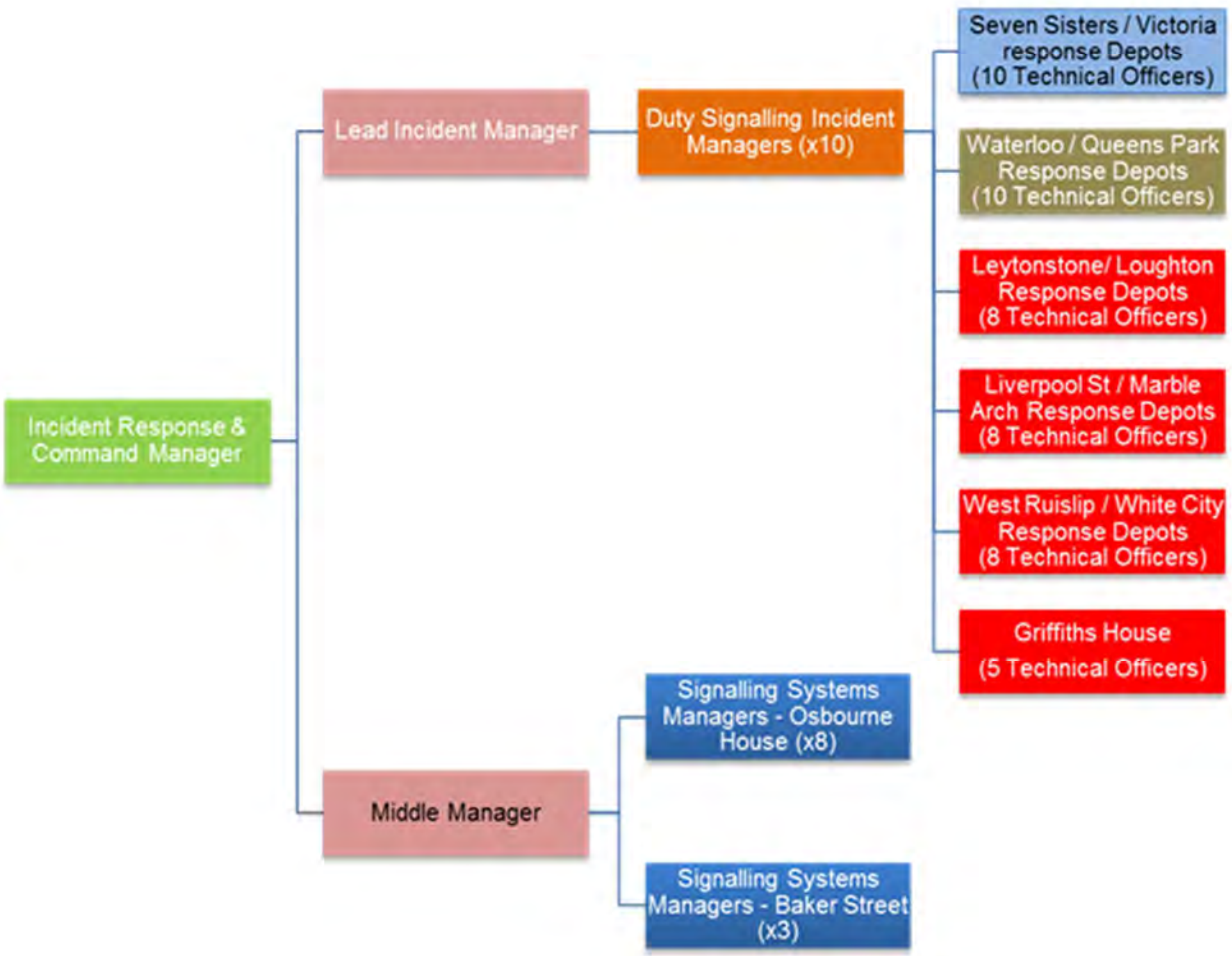
14.8 'Mid-Life' Obsolescence Support (Option)

As most S&TC systems are now processor based, there remains a risk that several of these assets may become technologically obsolete well before their expected life-cycle is reached.

An option for mitigation against this situation could be to implement a Support agreement which requires the Supplier's to 'upgrade' processor based equipment at pre-defined periods. This will ensure that S&TC capability can develop in line with future advancements in technology whilst retaining a system where obsolescence risk is eliminated.

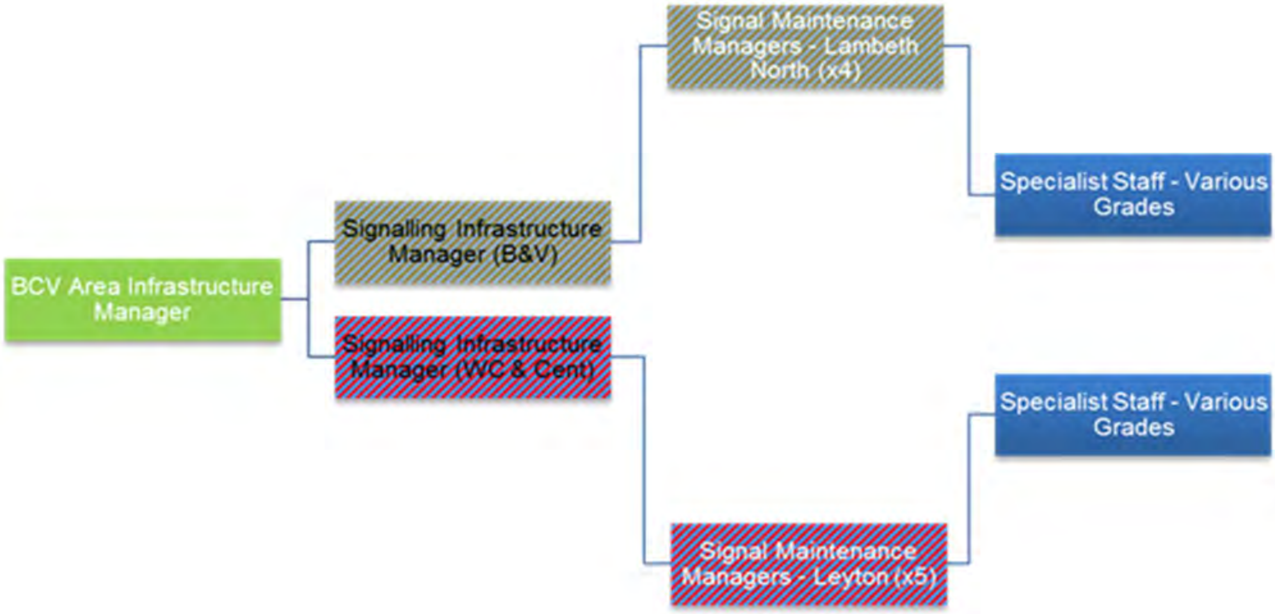
© Copyright 2009 London Underground Limited. All rights reserved.

APPENDIX 1 – SIGNAL INCIDENT RESPONSE – BCV STRUCTURE



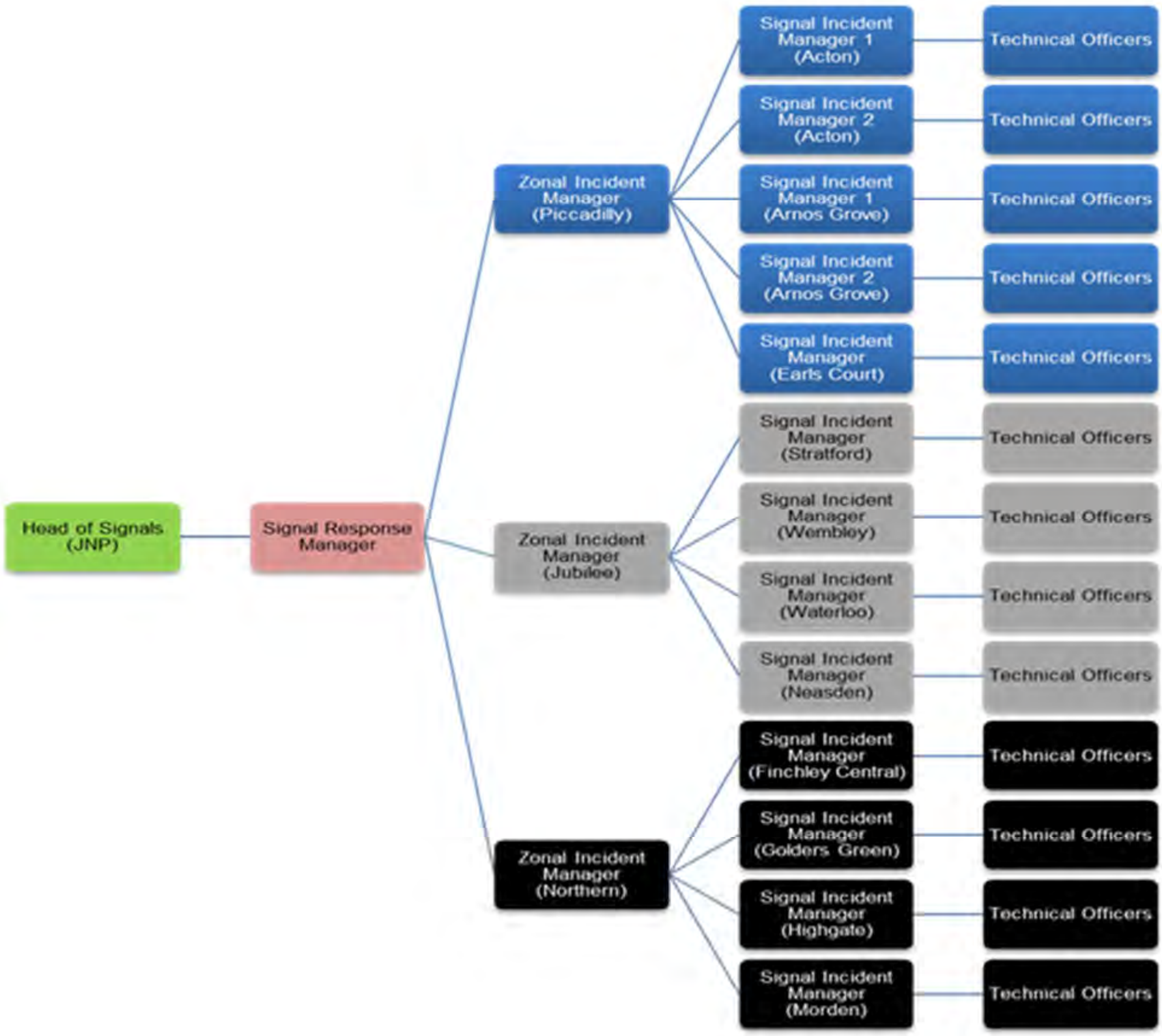
© Copyright 2009 London Underground Limited. All rights reserved.

APPENDIX 2 – SIGNAL MAINTENANCE – BCV STRUCTURE



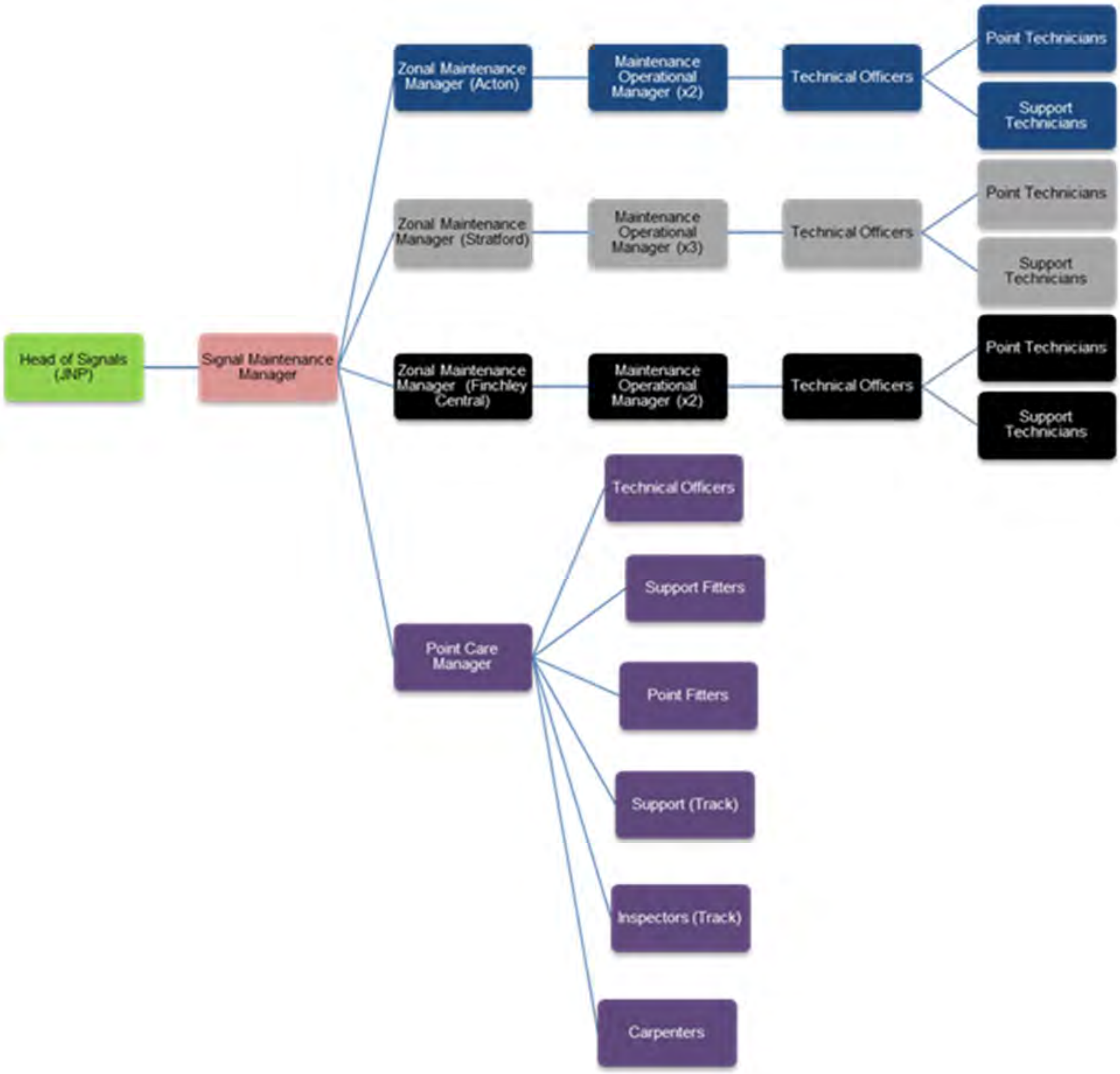
© Copyright 2009 London Underground Limited. All rights reserved.

APPENDIX 3 – SIGNAL INCIDENT RESPONSE – JNP STRUCTURE



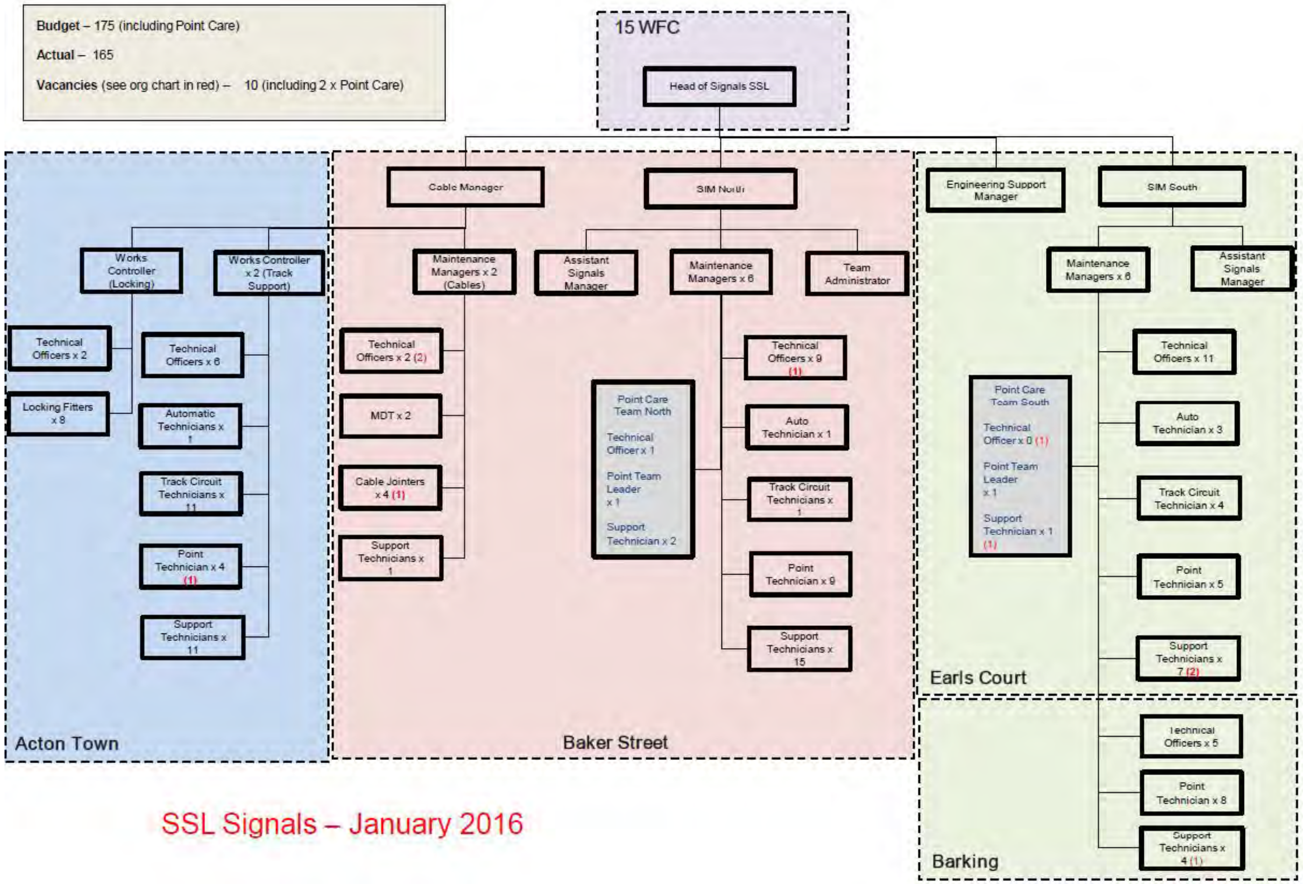
© Copyright 2009 London Underground Limited. All rights reserved.

APPENDIX 4 – SIGNAL MAINTENANCE – JNP STRUCTURE



© Copyright 2009 London Underground Limited. All rights reserved.

APPENDIX 5 – SIGNAL MAINTENANCE – SSR STRUCTURE



© Copyright 2009 London Underground Limited. All rights reserved.