



Sponsor Board 91-01 Briefing Paper

Crossrail Project Representative (PRep)

Master Operational Handover Schedule (MOHS) 2018

15 March 2018

PRep – MOHS 2018

1. Summary

The new Master Operational Handover Schedule (MOHS 2018) has been implemented, providing the baseline and schedule framework for the completion of the Crossrail Programme. It identifies the key critical milestones for energisation, testing, handover and Rail for London (RfL) post-handover testing, leading to delivery of Stage 3 Opening on 9 December 2018.

We were asked by the Joint Sponsor Team (JST) to provide an assessment of the MOHS, which we then incorporated into our 2017/18 Period 11 report. The assessment encompassed the following elements:

- The risks associated with any assumptions or omissions that underpin the MOHS;
- Planned productivity rates for critical activities, relative to historic performance;
- Risk to key milestones and implications;
- Level of float and overall time risk allowance.

From that assessment we believe that MOHS 2018 is ambitious, contains virtually no float, and relies upon the delivery of systems and stations at productivity rates that have not been reached in the past.

The principal critical path within MOHS is the Rolling Stock/Signalling dynamic testing sequence. This sequence is extremely tightly scheduled and offers very little scope for failure, without impact upon Trial Running and Trial Operations. The sequence relies upon the provision by Bombardier Transportation (BT) of Rolling Stock with proven and reliable software functionality, but a high risk remains that train software development will not keep pace with project requirements.

There are other key challenges and risks, such as the timely completion and integration of fixed infrastructure and the production of associated assurance documentation. MOHS reflects the prioritisation of those works critical to dynamic testing, but there is insufficient time for the delivery of all assets prior to the key milestones of Trial Running¹ and Trial Operations². Difficulties remain with the completion of non-dynamic testing critical systems (e.g. walkways, lighting, Low Voltage cabling), removal of temporary services such as ventilation systems, and the integration of stations.

In summary we recognise that MOHS has the support of all partners, but there is a high risk that the start dates for Trial Running, Trial Operations and Stage 3 Opening will not be achieved.

¹**Trial Running** essentially means the testing of the railway to demonstrate that it is capable of reliably meeting the requirements of the Crossrail Programme Functional Requirements and the Sponsors Requirements.

² **Trial Operations** essentially means the undertaking by the Operators of tests and trials to prepare for and demonstrate that they are capable of operating the Railway in accordance with the Sponsors Requirements and the Operators' Safety Management Systems.

2. General Review of MOHS

The new Master Operational Handover Schedule (MOHS 2018) was signed off by CRL and its partners on 16 February 2018, presented to the Joint Sponsor Team (JST) and Project Representative (Prep) on 19 February 2018, and presented to Sponsor Board on 22 February 2018. Although Stage 3, 4 and 5 Opening dates have been retained, most activities and milestones have been re-baselined. It also includes the latest plans regarding Stage 2 Opening in two phases. Figure 2 - 1 gives examples of some key dates³ which have been reset in the new MOHS, as well as the relevant delay in weeks.

Key Dates	MOHS 2017	MOHS 2018	Weeks
Traction Power Energisation Z1&2	01-Oct-17	01-Feb-18	18
Commence DT in Z1&2	01-Nov-17	25-Feb-18	17
Traction Power KG ATFS to WBP	02-Jan-18	28-Feb-18	8
ATS at WBP energised	10-Jan-18	07-Apr-18	12
Traction Power on Z3&4	04-Feb-18	10-May-18	14
Linewide SCADA available	30-Nov-17	30-May-18	26
Commence DT in Z3&4	26-Feb-18	11-Jun-18	15
HV Non Traction Power on	26-Jan-18	01-Jul-18	22
Commence Trial Running	05-Jul-18	05-Aug-18	4
Commence Trial Operations	06-Aug-18	09-Sep-18	5

Figure 2 - 1 ~ Example comparisons between MOHS 2017 and MOHS 2018

CRL has advised that the new MOHS is fully integrated and includes Network Rail (NR) On Network Works (ONW) key dates, Bombardier Transportation (BT) delivery dates⁴; and that it is supported by Rail for London Infrastructure (RfL-I) and London Underground Ltd (LUL). However, the MOHS is a 'top down' schedule, as it sets out CRL's strategic vision for delivery of Crossrail. In many cases activity durations and milestone dates have not been agreed with its Tier 1 Contractors.

Key Features

Key features of this MOHS are delays to a number of significant key dates, as well as the compression of almost all activities. There is also a significant amount of construction work to be completed during late 2018, when Trial Operations are being executed. We are aware that CRL is attempting to mitigate these issues in order to achieve Stage 3 Opening in December but we are concerned that this may not be possible in all cases.

The number of Anchor Milestones has increased; mainly to include the Handover to Infrastructure Manager (IM) dates, as well as new targets for training and safety case production. Figure A - 1 in Appendix A indicates the status of Anchor Milestones at Period 10 and Figure A - 2 indicates the status of Anchor Milestones at Period 11 following the implementation of the new MOHS. Key dates are set out in the CRL graphic attached at Appendix A, Figure A - 4.

³ DT = Dynamic Testing, KG = Kensal Green, ATFS = Auto Transformer Feeder System, WBP = Westbourne Park, ATS = Auto Transformer Station, SCADA = Supervisory Control and Data Acquisition, HV = High Voltage.

⁴ In some cases moderated by RfL.



At this time, the forecast dates sit over the [redacted] dates; meaning they are on schedule. It should be noted that the forecast curve for delivery of Anchor Milestones over the next 6 months is much steeper than the previous 6 months, requiring a significant increase in production. This aspiration to increase productivity, resulting in steepening of the forecast curve, is also prevalent across most systems and stations projects as shown in the individual project charts in Figure A - 3 in Appendix A. We are sceptical that this can be achieved.

Figure 2 - 2 indicates the Systemwide progress against the new MOHS 2018 at Period 11. The overlap of forecast dates with the MOHS 2018 [redacted], and the steepening of the forecast productivity curve can be seen in this chart.

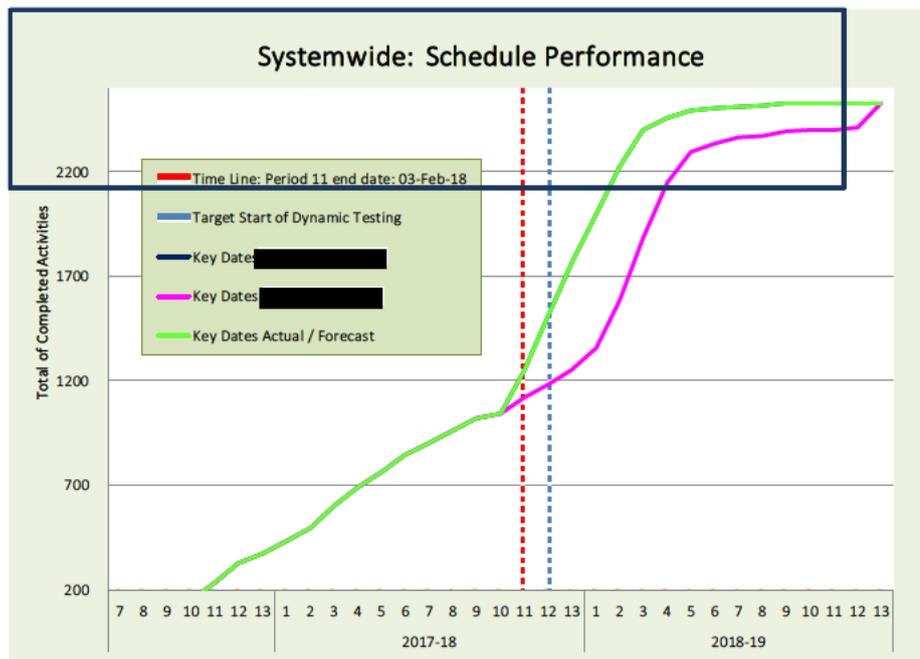


Figure 2 - 2 ~ Progress of all Systemwide Contracts – Period 11 MOHS 2018

Key Risks

The new MOHS contains a large number of assumptions and therefore risks. The key risks are:

- BT is not able to deliver the trains in accordance with its schedule;
- Tier 1 Contractors are not able to increase their productivity as required;
- Installation and testing of ventilation systems cannot be accelerated;
- Tier 1 Contractors are not able to obtain resources needed to cover peaks;
- Some stations may not be ready for scheduled non traction power-on dates;
- Phase 3 integration testing is delayed by slippages to preceding works;
- Handover Execution Plans are not agreed with IMs in time;
- Training materials, asset data and training sessions are not delivered in time;
- The production of Installation Release Notes (IRNs) cannot be accelerated back to the original forecast;
- CRL and the IMs are not able to agree Staged Completions in some locations;
- [redacted] is not able to recover recent software and SCADA slippage;
- Access to the Trace is insufficient to enable works to be completed;
- Tunnel walkways etc cannot be installed before Trial Operations;
- CRL and NR are not able to agree transition testing dates on the Great Eastern Main Line (GEML) and Great Western Main Line (GWML);

- [REDACTED] are not able to complete dynamic testing in the time allotted;
- IMs are not satisfied with the Handover verification process;
- Critical works after Handover cannot be completed in time under the RfL-I Rulebook;
- Sufficient documentation cannot be submitted to the ORR in time.

These key risks are due to assumptions built into the MOHS. Any of these has the potential to impact on the Stage 3 Opening date. This list is not exhaustive and there are many more minor risks. In light of these risks, we recommend that Sponsors consider preparations in case of a delay to Stage 3 Opening. We understand CRL is reviewing all risks across Systemwide activities and other critical paths as part of its SACR19 review.

We believe the schedule is very optimistic and extremely challenging, with many problems needing to be resolved. In addition, there is almost no schedule float to allow for any errors or mistakes

3. Specific areas affected by MOHS 2018

We have expanded upon how certain aspects of the programme are affected by MOHS 2018. They are:

- Integrated Systems;
- Dynamic Testing;
- Regulatory Approvals;
- Stations;
- Handover;
- CRL Business Plan.

3.1. Integrated Systems

Schedule compression due to ongoing delays and adherence to the Stage 3 Opening date, has progressively increased demand for access to, and occupancy of, the Tunnels and Stations. These difficulties are compounded by the need to apply additional safety controls following energisation. Despite careful scheduling, significant challenges remain with the timely completion and integration of fixed infrastructure and the production of associated assurance documentation. There is insufficient time for the delivery of all assets prior to Trial Running and Trial Operations, and MOHS reflects the prioritisation of those critical to dynamic testing. Challenges remain with the completion of non-dynamic testing critical systems (e.g. walkways, lighting, Low Voltage (LV) cabling), removal of temporary services, and the integration of stations systems to the Railway Control Centre.

Key dates in the dynamic testing phase through to Trial Operations are shown in Figure 3 - 1. These dates have remained largely unchanged during the last period while MOHS 2018 has been finalised⁵. While this might be read as indication of plan stability, it must be stressed that the MOHS as now cast contains virtually no schedule float, as the service opening date remains. Aside from the works themselves proceeding without problems, the greatest influence upon success will be the efficient management of access to the Tunnels and Stations for completion, and maximisation of productive work time. Across Systemwide, limits have been reached for the efficient

⁵ Key dates are mainly as originally presented at MOHS Period Review Meeting held on 19 January 2018.

utilisation of plant and manpower, and (with the notable exception of [REDACTED] fibre splicing and testing) increases in resources will have no significant effect upon productivity. Our assessment is therefore that it is unlikely Systemwide will meet many of its schedule dates. If the plan is not adhered to, some recovery might be possible by “trading” schedule opportunities for dynamic testing activities against installation activities, thus avoiding impact upon the current dates for Trial Running and Trial Operations. However, there is no spare time for significant rework should something go wrong, and past experience strongly suggests that completion will not be incident free.

Key Dates	MOHS 2018
Traction Power Energisation	01-Feb-18
Commence DT in Z1&2	25-Feb-18
ONW KD33 Power from KG	28-Feb-18
4 Trains ready for DT Z3&4	23-Mar-18
Fibre Backbone complete	27-Mar-18
ATS at WBP energised	07-Apr-18
Traction Power on Z3&4	10-May-18
Linewide SCADA available	30-May-18
Commence DT in Z3&4	11-Jun-18
HV Non Traction Power on	01-Jul-18
DT All Zones	02-Jul-18
Commence Trial Running	05-Aug-18
Commence Trial Operations	09-Sep-18

Figure 3 - 1 ~ Key Dates to Trial Operations

MOHS does provide opportunities for installation completion wherever this does not conflict with dynamic testing. For example while dynamic testing takes place in Zones 1 & 2, installation will continue in Zones 3 & 4; the reverse applies when dynamic testing takes place in Zones 3 & 4, with completion activities planned for Zones 1 & 2.

While much focus continues to be placed upon proving the Rolling Stock / Signalling functionality, Phase 3 integration testing at other critical interfaces must be completed before Crossrail can be shown to be fit for operation as a passenger railway. Working arrangements are being developed between CRL and RfL which will allow the completion of late activities from the time of Handover and into the Trial Running period. CRL has forecast that a wide range of activities will remain during the Trial Running period:

- [REDACTED] non-dynamic testing critical works (e.g. walkways, lighting, LV cabling);
- [REDACTED] removal of temporary works (e.g. lighting, fire main, radio, ventilation);
- [REDACTED] permanent ventilation system testing;
- [REDACTED] completion of testing;
- [REDACTED] completion of integration testing with Rail Systems;
- [REDACTED] completion of integration testing with Stations.

We are aware that RfL is showing a willingness to enter into discussion upon all completion issues and remains open-minded on how those works which do not compromise safety or reliability might jointly be concluded.

The Systemwide progress charts in Appendix A illustrate the significant increases in productivity that are necessary over the next few months, in order to achieve Stage 3

Opening on 9 December 2018. We believe it will be extremely difficult for these rates to be delivered and sustained.

3.2. Dynamic Testing

MOHS 2018 contains the latest available information from BT on Class 345 test train dynamic testing scope and progress. Based upon past performance, we have serious concerns with [REDACTED] ability to deliver software functionality to match CRL's schedule requirements.

The dynamic testing sequence forms the core critical path and MOHS shows that it is split into three distinct phases:

- Zones 1 & 2 (Early Dynamic Testing, EDT);
- Zones 3 & 4;
- All Zones.

Dynamic testing now runs between 25 February 2018 and 5 August 2018, over a total period of 23 weeks; this compares with the period of 35 weeks provided for in MOHS 2017. The reduction in dynamic testing time illustrates the schedule compression that has been incorporated into the MOHS in order to maintain the Stage 3 Opening date and highlights the critical reliance that testing is undertaken to plan, with minimal issues arising. CRL is seeking to maximise the use of the available off-site testing facilities to complement and support dynamic testing, and both BT and Siemens are focussing their integration efforts on the Crossrail Integration Facility at Chippenham, as well as at Melton test track. Ultimately, the ability to make best use of all of these facilities will come down to the availability of specialised staff, something that both contractors are seeking to address.

3.3. Regulatory Approvals

CRL has proposed key dates for the Safety Case development which are set out in Figure 3 - 2;⁶ these have been confirmed in the new MOHS. Finalisation of safety documentation relies upon documented outputs from site testing, so any further delays to dynamic testing are likely to impact the Safety Case completion and downstream securing of Regulatory Approvals.

No	Key Dates	MOHS 2018
1	Contractors submit draft ESJs to CRL	31-Mar-18
2	Safety Assessment Report (SAR) substantially complete (for AsBo)	31-Mar-18
3	Draft COS Safety Case with results from Z1&2 DT	30-Apr-18
4	Contractors submit final ESJs to CRL	30-May-18
5	CRL submit Safety Justifications to RAB-C	07-Jun-18
6	COS Safety Case submitted to RAB-C (to facilitate Handover)	30-Jun-18
7	Final COS Safety Case updated and submitted to RAB-C	31-Aug-18
8	Submit Technical File to ORR	17-Sep-18

Figure 3 - 2 ~ Engineering Safety Management Submissions for Stage 3 Safety Case

We remain concerned that the safety deliverables will be problematic to complete due to:

⁶ ESJ = Engineering Safety Justification, AsBo = Assurance Body, COS = Central Operating Section, RAB-C = RfL Assurance Board for Crossrail, ORR = Office of Rail & Road.



- Design: Slow progression through RfL's Assurance Board for Crossrail (RAB-C);
- Testing and Commissioning: There is more visibility as to what the quantum is for the safety deliverables required for this stage, but the schedule is challenging. This is also a concern to the Assurance Body (Ricardo Rail) (AsBo).

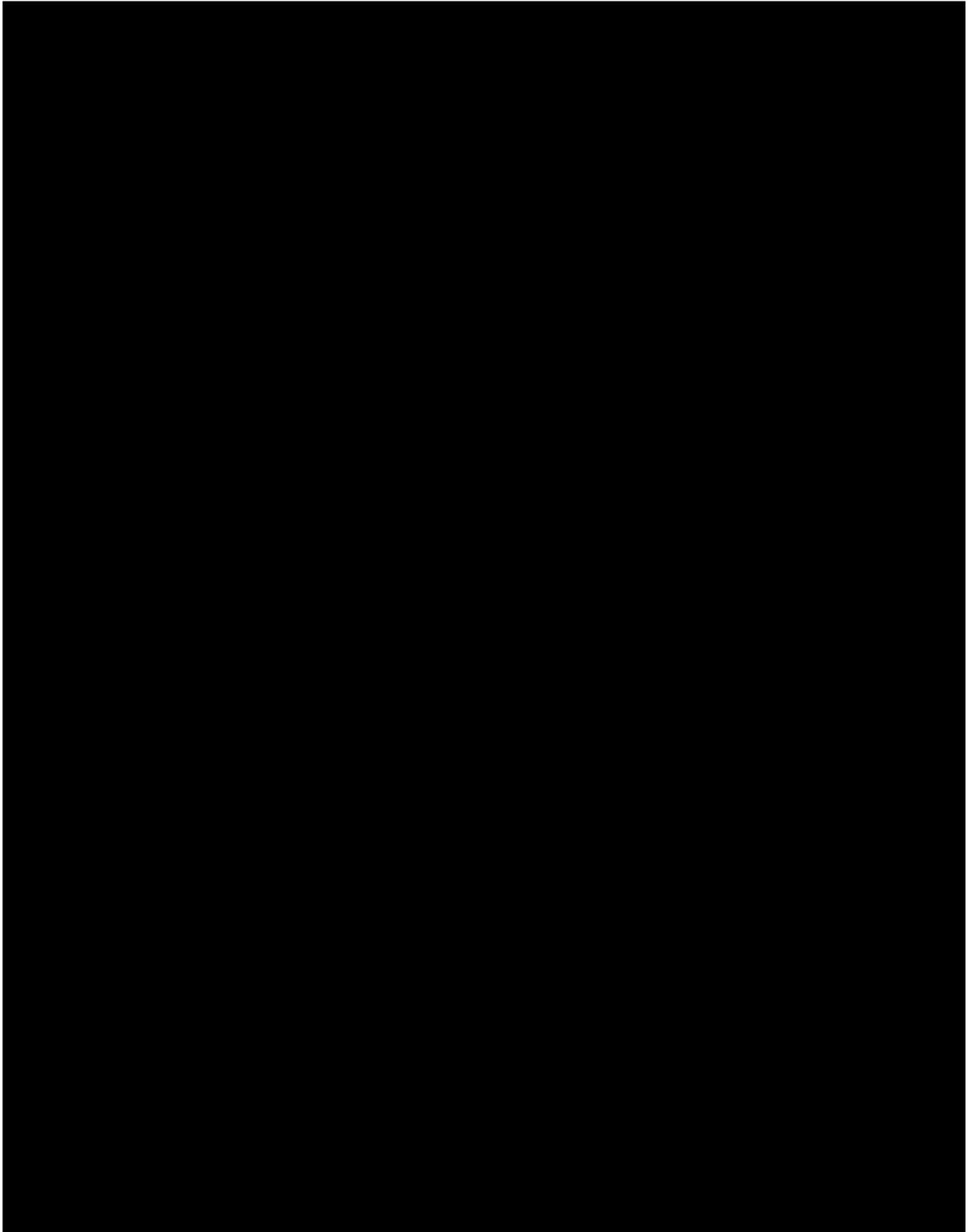
3.4. Stations

The cumulative plan and actual percentage completions, reported for all stations, have been re-baselined in Period 11. The forecast performance curves for each of the stations now show a steep increase in their gradients. We are concerned that this may reflect an "optimism bias", on the part of CRL, in the assumed rates of production that can be achieved by their respective contractors. Historically, CRL's contractors have found it difficult to achieve and sustain such high rates of production.

[Redacted]

[Redacted]

[Redacted]



The current MOHS shows an acceptance by CRL and the IMs that the Handover of an asset will be carried out in phases. There are possibly 8 assets that have been identified by CRL as requiring 'Staged Completion' plans. These plans will bridge the gap between the asset being partially made available to the IM to use, and final Handover. At each of these locations there are discussions between CRL and the IM as to what is logical to be made available and by when. CRL and the IMs have agreed to complete Handover Execution Plans for each asset by mid-March 2018, but this date is under pressure.

3.5. Handover

A key component of the Handover of assets to the IMs are the supporting material and training to be given to IM staff by the contractors via CRL. This encompasses:

- Asset Information, which includes the type of asset, number and location;
- Operations and maintenance manuals to be used for staff training and resourcing plans;
- Spares lists to enable the procurement of the necessary equipment in advance of operations;
- System training programmes.

[REDACTED] It is a matter of urgency that the safety critical elements are prioritised so that the IMs can demonstrate that they can operate the railway.

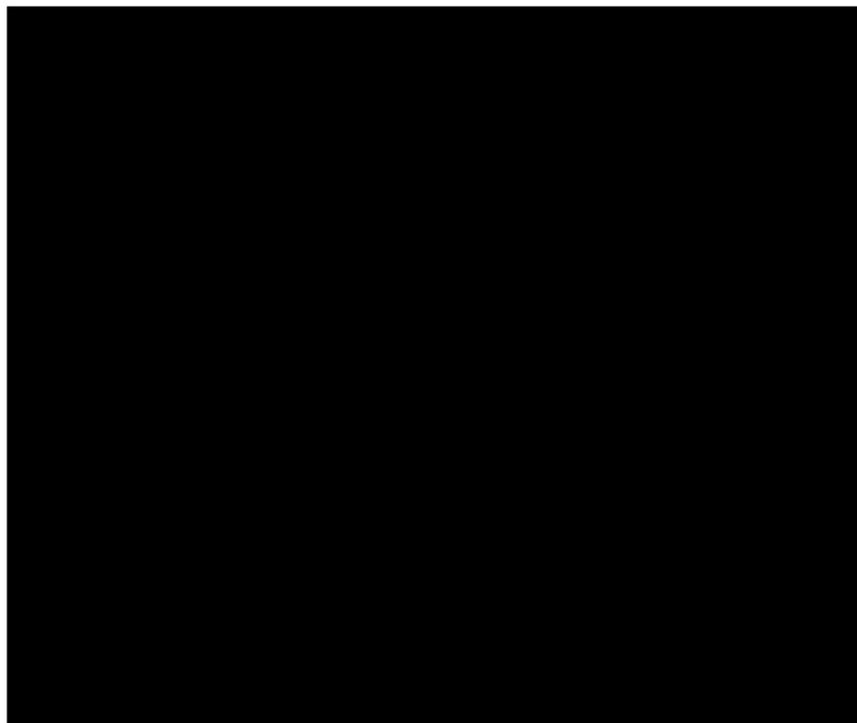
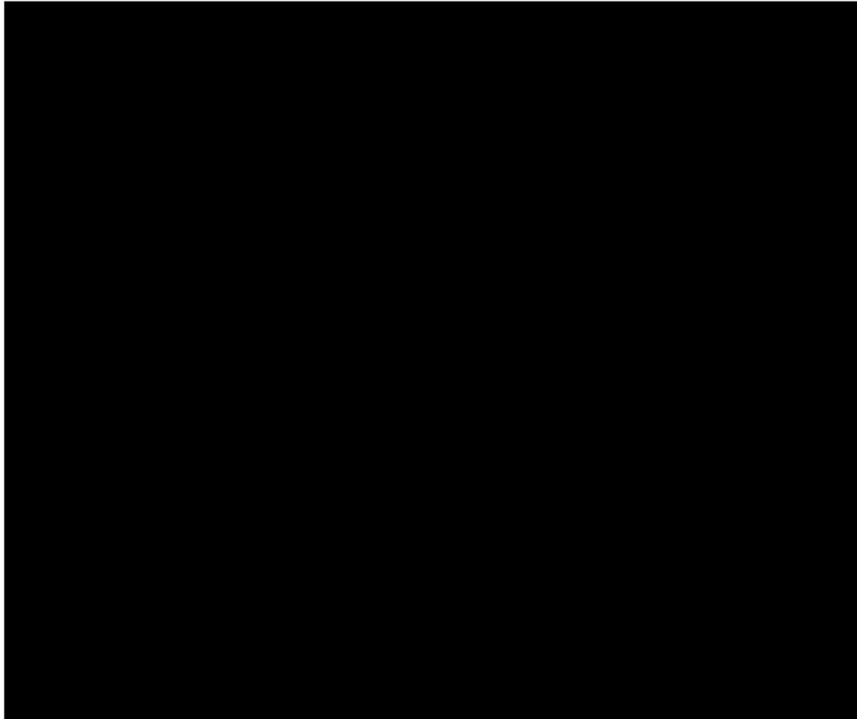
3.6. CRL Business Plan

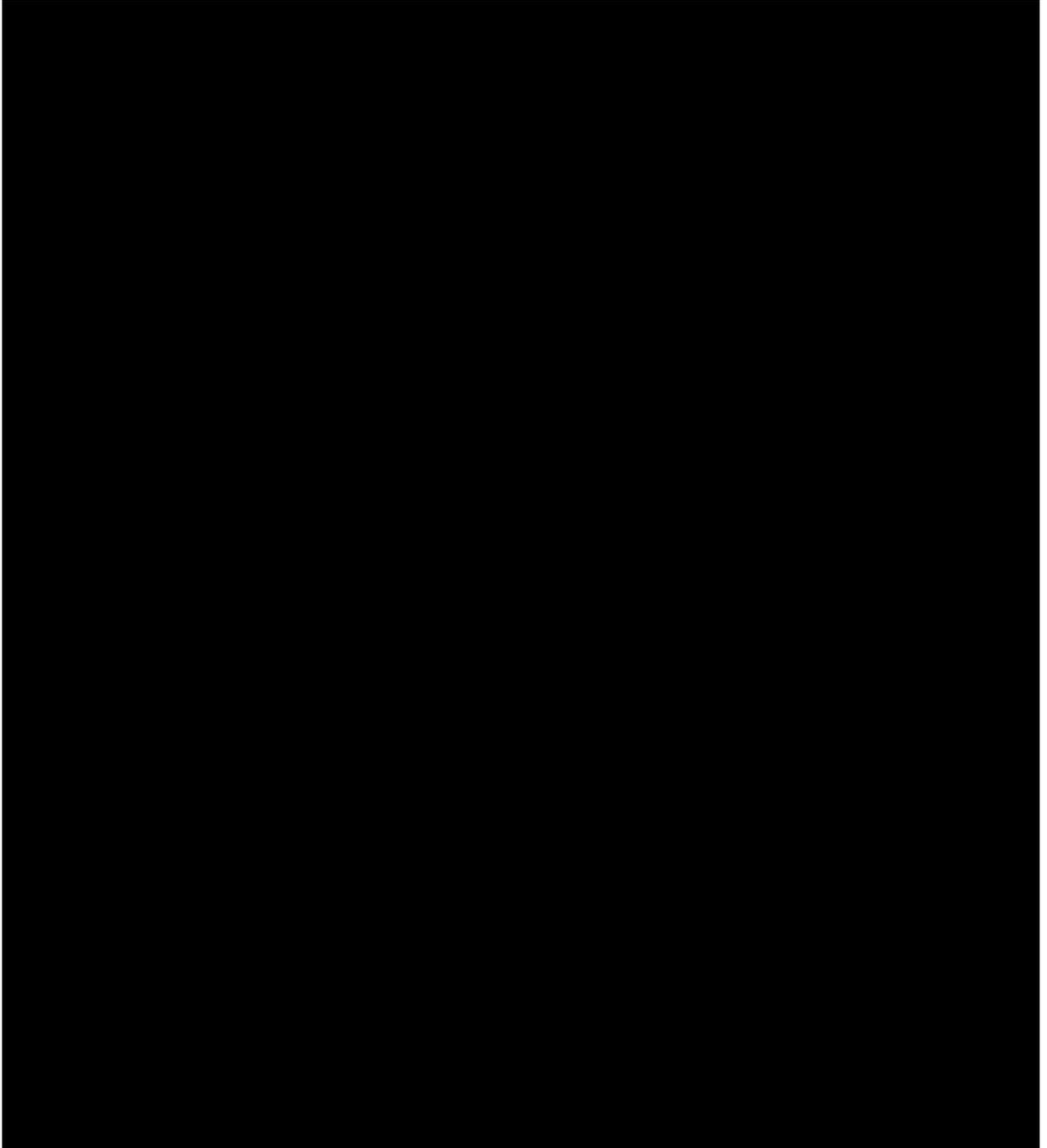
The CRL 2018-2019 Business Plan was approved by the CRL Board on 7 December 2017 and issued to PRep on 16 January 2018. The Business Plan staff structures and plans are predicated on the MOHS 2017 "Business Plan" Refresh and that Staff demobilise according to the role end dates in the Business Plan.

However, the MOHS 2017 is now out of date and hence the proposed resourcing is not properly aligned with Programme delivery. There is no evidence to suggest that the approved plan has been reviewed and aligned to the 2018 MOHS refresh nor provision or allowance included in the current Quantified Cost Risk Assessment (QCRA) to accommodate for such known risks. For instance Delivery resources are departing mid-2018 prior to when most of the works are due to be complete and before some Handover dates, notably at [REDACTED] stations. We expect the resource requirements of the new MOHS will be reflected in the Period 13 QCRA.

Appendix A Schedule and Performance

Figure A - 1 indicates the status of Anchor Milestones at Period 10 and Figure A - 2 indicates the status of Anchor Milestones at Period 11 following the implementation of the new MOHS.





JACOBS

