PROGRAMME PARTNER

INDEPENDENT REVIEW INTO LESSONS LEARNED DURING STAGE 1 TESTING AND COMMISSIONING AND BRINGING INTO USE

Document History:

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Executive Summary

Stage 1 is the progressive introduction of new Crossrail rolling stock on existing suburban services into Liverpool Street from Sheffield. The target date for start of commencement of Stage 1 was 21 May 2017. Many industry partners and contractors have been involved in developing Stage 1 and significant challenges were encountered. The date when the first Class 345 was taken into service was 22 June 2017, a month later than planned.

This review looks at lessons to be learned during Stage 1 testing and commissioning and bringing into use. The report focuses on the "right hand side of the V " and makes no mention of any specification, design or design integration activities. This is not intended to indicate that these "left hand side of the V" activities are no longer important, they are simply not the focus of this review.

There were several thousand activities that came together to achieve Stage 1 commencement. Many of these activities deviated from plan. Ultimately however, there were four activities that drove the delay. The purpose of looking at the activities that drove the delay is not to apportion blame, but rather to understand what activities need to be looked at in order to learn lessons for Stage 2. The four activities that drove the delay were:

- DOO CCTV delivery;
- TCMS Software development;
- Technical File submission; and
- Operations acceptance.

The review addresses six aspects (A to F). The scope of each aspect, and the summary of the response to that aspect is as follows:

Review Aspect A:

A review of the roles and responsibilities in Stage 1 testing commissioning and bringing to use; were these clear to all participants if not in what areas did problems exist?

Response summary

Roles and responsibilities were clear and correct. Despite textual issues with some documents, the individual roles and responsibilities were well documented.

The execution of those roles and responsibilities was not well done by all participants.

- NR failed in it's responsibility to deliver;
- CRL failed to provide leadership; and
- CRL/RfL failed to act as the systems integrator.

Review Aspect B:

An assessment as to whether there was a clear strategy and plan made available for testing and commissioning including the Class 345 train, the infrastructure, DOO, CCTV etc.

Summary Response:

There was (in 2015) a clear overall strategy for Stage 1 bringing into use. It does not appear to have been developed into a tactical plan that addressed how everything would be pulled together to deliver an operating railway. The overall planning was left to the individual contractors to sort themselves out.

There was a clear strategy and planning developed for each of the individual systems of Stage 1. Documents to support this have not been sighted for Rolling Stock.

Review Aspect C:

A review of the reporting and other communications that took place and whether this was adequate to provide the necessary transparency.

Summary Response:

CRL sits at the end of long reporting chains. There were failures in sending messages along these chains. BT knew of TCMS problems but these concerns did not make the CRL dashboards. Someone in BT knew about the problems with the Technical File submission, but that did not reach the BT dashboards. CRL knew about problems with DOO CCTV at stations but the full extent of the problem was not communicated.

A critical review of metrics is necessary to ensure the right things are being measured. This is particularly the case with software where not only the metrics, but also the management and exploitation of the software development information should also be challenged. There is a tidal wave of software dependent systems heading towards commissioning – CRL must be ready, and must be ahead of the game.

There was evidence to suggest that optimism bias, good news culture and frustrations on information sharing are all relevant issues within CRL, NR and BT. The extent to which they have contributed to the delay, or for that matter, are any different from other organisations where people interact, is questionable.

There is no evidence to suggest that anyone within CRL deliberately misrepresented known facts.

Review Aspect D:

Consideration of the clarity surrounding the requirements for the acceptance criteria for DOO CCTV and how performance acceptance could be improved.

Summary Response:

There was an objective set of test specifications for the technical set up of station side DOO CCTV. There was not an objective set of criteria for image evaluation.

The criteria described in the document "Crossrail standard for Driver Only Operation CCTV" did not include any reference images. An image grading table was provided in the test specifications but is was unclear what each grade actually meant.

In practice, the image grading table was not extensively used. A "Pass" result was determined on the basis of the "technical numbers" and an assessment of the image by the operator. There were no cases of any fail assessment by the operator (on basis of image quality) being contested by any other party. Everyone agreed that the image in question was not good enough.

Practical problems (identifying cameras, system familiarity) complicated the rectification process.

Review Aspect E:

A review of the process for creation and assembly of the evidence file in order to obtain the approval to place in service certificate (APIS) from ORR and how this process could be improved.

Summary Response:

BT has a well used and proven procedure for assembling the Technical File. In the case of the C345, however, the usual parameters around that process were changed:

- C345 is a new train type, a lot of off the shelf documentation had to be reworked, there was more to do;
- Changes and modifications late in the build process delayed Technical File completion; and
- Some requirements were missed and were only picked up late in the build.

The process would benefit from a post APIS reconstruction, within BT of the actual Technical File development timeline, to identify where difficulties arose, then review the train development processed feeding those situations.

Review Aspect F:

Consideration of the extent to which activities could reasonably have been completed earlier to reduce risk to the completion stage.

Summary Response

The activities that could reasonably have been completed earlier for Stage 1, given delays already in the train delivery, were:

- Award of contract for installation of DOO CCTV Stations;
- Completion of installation SATs;
- Confirming images on train monitor (on a test rig as part of SAT);
- Collection and review of SAT forms by CRL with subsequent involvement by CRL to sort out issues; and
- Requirements check off against new TSI's during train build.

For future stages, consideration should be given to earlier completion of:

- Planning
- Agreement on pass/fail criteria and test result sheets;
- SATs;
- Integration Testing;
- Preparation Reviews;
- Contact Lists;
- Quantitative Schedule Risk Assessment; and
- Commercial Agreements.

Contents

1 Introduction

Stage 1 is the progressive introduction of new Crossrail rolling stock on existing suburban services into Liverpool Street from Sheffield. The target date for commencement of Stage 1 was 21 May 2017. Many industry partners and contractors have been involved in developing Stage 1 and significant challenges were encountered. The date when the first class C345 was taken into service was 22 June 2017, a month later than planned.

The next delivery stage, Stage 2, is planned for 20 May 2018. This will involve a new service between Paddington (high-level) station and Heathrow airport terminals with class C345 trains running a service at 4 tph to replace Heathrow Connect Services

This review has been undertaken in order to learn lessons from Stage 1 that can be applied to stage 2 and beyond.

1.1 Context

The review addresses six aspects.

A) A review of the roles and responsibilities in Stage 1 testing, commissioning and bringing into use; were these clear to all participants if not in what areas did problems exist?

B) An assessment as to whether there was a clear strategy and plan made available for testing and commissioning including the C345 train, the infrastructure, DOO, CCTV etc.

C) A review of the reporting and other communications that took place and whether this was adequate to provide the necessary transparency.

D) Consideration of the clarity surrounding the requirements for the acceptance criteria for DOO CCTV and how performance acceptance could be improved.

E) A review of the process for creation and assembly of the evidence file in order to obtain the approval to place in service certificate (APIS) from ORR and how this process could be improved.

F) Consideration of the extent to which activities could reasonably have been completed earlier to reduce risk to the completion stage.

1.2 Approach to the Review

The approach to the review was to identify and interview key individuals within CRL/RfL, NR, BT and MTR-C. Documents were reviewed to provide background and substantiation of information provided during the interviews. In some cases, those documents have not yet been made available.

- A list of those interviews in included in Annex A
- A list of documents referenced is included in Annex B

Any issues that were raised during interviews or from document reviews were verified during subsequent discussions (to the extent possible, whist preserving the anonymity of the interviewee). There remains, however, a degree of subjectivity with every discussion. The challenge is in understanding what part of a story represents a systemic issue within the delivery mechanism, and what is an incidental anomaly.

All interviewees were very open and helpful. The active participation and assistance of NR, MTR-C, BT and CRL during the execution of this review was greatly appreciated.

1.3 Report Structure

The remainder of the report is broadly structured to follow the aspects identified for the review. Each section begins with a summary of that section. The structure of the report is as follows:

Section 2	Identifies the activities that lead to the delay in commencement of Stage 1.
Section 3	Examines roles and responsibilities, identifying where there were failures to fulfil those responsibilities (aspect A).
Section 4	Look at the strategy and panning (aspect B).
Section 5	Established a time line of events and examines the reporting and communication leading up to commencement of Stage 1 (aspect C).
Section 6	Examines the clarity of requirements and the acceptance criteria for the DOO CCTV (aspect D).
Section 7	Considers the process for pulling together the Technical File (aspect E).
Section 8	Examines what aspects could have been completed earlier (aspect F).

Recommendations have made throughout the report. Where appropriate, additional explanation has been provided for the specific recommendation. A summary of recommendations is included as Annex C.

1.4 List of abbreviations

Abbreviations

BT	Bombardier Transport
CPFR	Crossrail Program Functional Requirements
CRL	Crossrail Limited (the organisation)
DOO	Driver Only operation
MTR-C	MTR Crossrail: Operator of Crossrail services.
NR	Network Rail (The organisation)
NRCR	Network Rail Client Requirements as referenced from the Protocol
ONFR	On Network Functional Requirements
QSRA	Quantitative Schedule Risk Assessment
SAT	Site Acceptance test
TfL	Transport for London
RfL	Rail for London

2 What Happened

Stage 1 was described as bringing together two relatively independent parts of the project:

- BT via TfL; and
- On Network Works via NR.

This was also the first milestone where CRL actually had to deliver an operating service using assets delivered by different Crossrail projects. As one interviewee put it:

"The pillars are coming together in practice"

Stage 1 was not achieved on time. Commencement of Stage 1, planned for 23 May 2017, did not actually occur until 22 June 2017. In this section we examine the activities that led to the delay. The purpose of this is not to apportion blame, but rather to understand what activities need to be looked at in order to learn lessons for Stage 2 and further.

2.1 Activities driving the delay

There were several thousand activities that came together to achieve Stage 1 commencement. Many of these activities deviated from plan. Ultimately however, there were four activities that drove the delay. These were:

- DOO CCTV delivery;
- TCMS Software development;
- Technical File submission; and
- Operations acceptance.

2.1.1 DOO CCTV delivery

The installation of the DOO CCTV was "completed" on 28 February 2017. Testing of the installation was not finished until June. The delay in the testing meant that many installation problems were not discovered until MRT-C was busy with Operations Proving. There was also a number of system set up problems that distracted MTR-C. Finally, after APIS, DOO CCTV contributed to a number of outstanding problems that needed to be rectified before MTR-C could commence service. The delivery of DOO CCTV was impacted by a number of factors:

- NR had a complex contractual environment in which to implement the works. This contributed to the late start and consequential rush to complete installation.
- NR had a different interpretation of "finished" than CRL.
- CRL failed to lead the parties.
- CRL failed completely as the systems integrator.
- The DOO CCTV system was new to NR who were on a learning curve, although their installation sub contractor was well experienced in the technology.
- Testing started very late – and was conducted with exceptionally expensive test equipment – the train.
- Test specifications did not take subsystems verification as far as it could have been taken.
- Miscommunication frustrated attempts to resolve issues.
- Inexperience in system installation and set up generated a multitude of faults.

2.1.2 TCMS software

TCMS software was late. It was the last significant part of the train to be completed.

- The TCMS is a completely new concept, using IP addressing. It was developed completely from scratch in order to achieve the requirements of SIL 2. Lead time on newly developed software is often (almost always) underestimated.
- Software development is hard to measure.
- Changes were identified late in the delivery process. Some of these were related to requirements of EU interoperability directives, which had not been applicable for earlier designs. The BT team had relied on their experience, but the world had moved on. Due to the nature of the TCMS (it controls and monitors everything) – any change meant a change in the TCMS.

2.1.3 Technical file submission.

Submission of the Technical File to ORR was late.

- The C345 is a new train platform. This meant that the technical file was significantly greater challenge (in both volume and content) than Bombardier would have been used to for the introduction of a new fleet of the Electrostars (an existing train platform).
- Changes in TCMS, and other systems were completed late in the program. These changes generated additional work for the technical file. The documentation could only be completed once the mods were completed.

2.1.4 Operations acceptance

After the APIS was granted on 9 June, it took MTR-C until 22 June to commence service. A condition of the APIS was the satisfaction of the operator's safety assessment. MTR-C, as the last step in the delivery process, was left with the challenge of closing out all open issues to a level appropriate for start of service.

- The acceptance criteria of several systems was not well aligned with those of the operator.
- Systems were still in need of bedding down to an acceptable level of performance (including DOO CCTV) but also doors, PA and other systems.
- Manufacture of the trains was late. Trains (005 and 006) were delivered without a reliability bedding in period (3000 km free of service impacting faults) in order to recover the program. MTR-C was inconvenienced during Operational Proving by a number of issues with the trains that needed to be fixed. MTR-C also had to take the time to be comfortable that the trains would work reliably.

2.2 Ilford Depot

The delivery of Ilford Depot has been a complex task. It would not be appropriate to discuss the causes of the delay and not mention Ilford depot. The situation at Ilford was complicated by a number of factors including:

- Being in an operations environment;
- Project team having insufficient operations experience;
- Depot owner having less than any motivation to be cooperative; and
- Trains arriving needing significant amounts of work.

The depot was made available on time. It was not complete, nor did it have all of the facilities that were required. Roof access for example, had to be arranged by “borrowing facilities” from the depot owner. This caused logistical and program complexities that would otherwise not have occurred. That having been said, in the bigger picture, the depot was more of a distraction than a key factor driving the delay. It was just another one of those project delivery challenges that had to be met. Whilst there is evidence to suggest the distraction did make lives more difficult, it would be incorrect to identify Ilford Depot as a cause for missing Stage 1.

3 Roles and responsibilities (A)

Review Aspect A:

A review of the roles and responsibilities in Stage 1 testing commissioning and bringing to use; were these clear to all participants if not in what areas did problems exist.

Response summary

Roles and responsibilities were clear and correct. Despite textual issues with some documents, the individual roles and responsibilities were well documented.

The execution of those roles and responsibilities was not well done by all participants.

- NR failed in it's responsibility to deliver;
- CRL failed to provide leadership; and
- CRL failed to act as the systems integrator.

3.1 Definition of Roles and Responsibilities.

The CRL document "Opening stage 1 testing and commissioning Strategy" provided a clear definition of the roles and responsibilities for Stage 1. This document was last updated on 29 October 2015. The document details who is responsible for each parcel of scope associated with Stage 1. It details responsibilities for testing, what evidence is required and who must provide that evidence. An extract from this document is included in Figure 1 below.

A summary of the key testing and commissioning activities and the responsible party is given in the table below.

Activity	Responsible Party
Programme T&C Strategy	CRL
Stage 1 Testing & Commissioning Strategy	CRL
Master Commissioning Schedule	CRL
Assurance of Verification and Validation Activities	CRL
Demonstration of Compliance with CPFR, Sponsors Requirements for Stage	CRL
Specific Testing & Commissioning Plans	Bombardier, Network Rail, C828 (Volker Wessels)
Schedule of Tests	Bombardier, Network Rail, C828 (Volker Wessels)
Tester in Charge	Bombardier, Network Rail, C828 (Volker Wessels)
Dynamic Testing Planning and Logistics, including possession planning.	Bombardier
Verification and Validation, including test reports and certification; compliance with requirements	Bombardier, Network Rail, C828 (Volker Wessels)

A Stage 1 T&C Working Group will be established, reporting to the Railway Integration Authority, to co-ordinate the activities required for the Commissioning of Stage 1. A specific Terms of Reference for this Working Group will be produced.

Figure 1: Extract of management arrangements from Opening Stage 1 Testing and Commissioning Strategy Document.

3.2 Crossrail failed in leading

CRL failed in two specific aspects. These were:

- CRL/RfL failed to lead systems integration (especially for the DOO CCTV).
- CRL failed to provide overall leadership in delivery of stage 1.

The failure of CRL is demonstrated with the following examples:

- The testing of BT and NR leading up to Stage 1 was not adequately monitored. CRL failed to recognise that NR had not finished installing the DOO CCTV.
- During the Operations Proving, when problems were encountered, it was MTR-C (not CRL) that led the coordination of all parties in resolving the issues.
- Despite indications of problems with DOO CCTV, CRL failed to act.

The document "Crossrail opening stage 1 Testing and Commissioning Strategy" defines the responsibility of CRL as follows:

> "Crossrail Limited will be the System Integrator as defined in the Crossrail Project Development Agreement."

The "DOO Roles and Responsibilities" document (section 6.3) defines, the need for station validation tests as part of the Systems Integration activities. These tests confirm the correct operation of the station installation from the train cab. The responsible party for the testing is RfL(supported by MTR/BT/NR/Station Contractors). This never happened. Tests were conducted when MTR-C turned up with a train

The CRL manager for the DOO CCTV was very good at the practical aspects of installation and testing. He also showed great skill in communicating with contractors. The Operational Readiness Steering Group tracked issues but did not provide leadership

CRL would appear to have lost focus on stage one. There was no dedicated Stage 1 Manager to provide overall leadership of delivery of Stage 1. CRL failed to coordinate and manage the introduction of Stage 1.

Recommendation 1: CRL should become more focused on delivery of individual stages.

The current governance is structured around final delivery of Crossrail, with intermediate stages. This is evidenced by the current structure of the PDB as well as the lack of individual managers appointed to overview each stage. CRL governance should recognise the challenges associated with each individual stage, and specifically focus attention on achieving each stage, not just delivering individual contracts.

Recommendation 2: CRL should appoint an owner of the stage.

CRL's role of System Integrator does not fully reflect the need to have someone pulling everything together for each stage. A role, "Programme Integration Manager" should be defined with responsibility to lead planning and coordination of delivery – ensuring all parties deliver (in a timely manner) to successfully achieve the stage. The "Programme Integration Manager" should be responsible for ensuring there are no gaps between suppliers and/or

systems. The “Programme Integration Manager” should be the single guiding mind for the stage delivery and develop the plan which shows how it will all come together.

Recommendation 3: CRL needs to step up to the mark as Systems Integrator

CRL is the Systems Integrator. A named individual needs to be given the accountability. The role must drive tangible activities, not just reports. CRL, as Systems Integrator, should be guiding/directing suppliers to execute integration testing at the earliest opportunity. CRL should be arranging testing between systems and sub systems as soon as it is possible (refer also section 8). Waiting until the entire system is complete before starting integration testing looses time that CRL does not have (Recommendation 22:).

3.3 NR failed in completing their works

NR were responsible for, amongst other things, delivery of the station subsystem of DOO CCTV.

Installation of the station DOO CCTV was arguably complete by 28 February. Commencement of installation was late, in part due to the complex commercial situation in which NR found itself. This reduced the time available for the work.

The installation was completed with a compressed program. NR also made some choices on temporary installations that were not technically suitable for an operational system. There is evidence to suggest that the rush to complete the works did result in some installation issues. One estimate was 80% was fine with assorted issues on 20% of the installations.

NR did not complete SATs before 28 Feb, nor had NR completed SATs by the time BT arrived with the train, and still not even during the Operational Proving by MTR-C. The lack of a tested and stable trackside complicated train borne activities. Fault finding was made more difficult because two sides of the interface were effectively in flux.

Was testing in scope for 28 Feb?
A point of discussion was: “Did delivery for 28 Feb include testing?”

NR staff made several representations during the interviews that the NR scope did not include testing. CRL staff made several representations during the interviews that testing was included in the NR scope. Clearly, the answer to this question lay in a review of the documentation, not with opinions.

ONFR1125 states:

> “CCTV cameras which transmit images to in-cab monitors shall be provided at all station platforms where Crossrail Trains will be despatched as per Interface Control Document.”

The “Interface Control Document CRL-NR” includes the requirement for NR to “install, test and commission” the certain components of the DOO CCTV, “in accordance with the instructions provided by BT”.

An extract from Version 07 of the "Interface Control Document CRL-BR" is shown below in Figure 2 . This describes a clear responsibility for NR to "test that compliant DOO CCTV images …received at the back of a simulated train receiving antenna".

Test Description	Test Methodology	Test location/responsibility
Testing of Compliant DOO CCTV Images at pseudo-train-borne receiving Antenna	Test that Compliant DOO CCTV Images produced by the DOO CCTV Station Subsystem shall be received at the back of a simulated trains receiving Antenna, using a testing procedure defined by BT. The test equipment that replicates the unit shall also be provided by BT.	On-Network and Central Section Stations SI

Note: The IDD defined SI as NR for ONW.

Figure 2: Extract from version 07 "Interface Control Document CRL – NR "

Version 08 of the "Interface Control Document CRL-NR" provided a more detailed description of the station sub systems tests. The responsibility table, however, identifies the party responsible for testing and for test reporting as "Station Contractors". This term is neither defined in the "Interface Control Document CRL-NR", nor is it associated to NR. On face value, NR could argue that they were released from their testing obligation under version 08.

NR have never presented such an argument. Furthermore, it can be concluded from the test descriptions in version 08 that the tests described were applicable to NR stations – the reference to "day and night" and "low angle sun light" for example, are irrelevant for underground stations.

The conclusion that must be reached is, that despite the textual issues with the documents,

- The roles and responsibilities of NR were well documented; and
- Testing was included in works to be delivered on 28 February.

It should also be noted, that the table from Version 08 of the "Interface Control Document CRL-NR" was faithfully reproduced in the CRL document "Driver Only Operation CCTV – Roles and Responsibilities". The error in description has managed to propagate through the project.

Recommendation 4: Correct text errors in responsibility documents

Update the documents "Interface Control Document CRL-NR" and "DOO CCTV roles and responsibilities" to correct the textual error and remove all doubt.

The definition of what constitutes "finished" appears to have developed as a self fulfilling truth within NR. It seemed to be a case where the requirement drifted with time - enough people said it was so, and therefore it was so. It is of note that none of those interviewed, (who presented the "installed is finished" position) had read the contract (recently). Certainly none could explain where (or in what document) the scope requirements had been recorded. It was a scope description that had been passed on by word of mouth.

Recommendation 5: Be clear on what constitutes "finished"

The definition of what finished looks like should be a recurring theme in the project delivery. Ultimately, this is a clear definition of pass/fail criteria. Agree the paperwork required to demonstrate completion (the actual forms, not just the pro forma). Insist on receiving the completed paperwork as evidence of completion. There is a significant amount of effort employed in tracking progress to completion, however the definition of finished is only discussed once or twice. Be very clear on what constitutes finished, and do not be shy about going back to a contract to confirm it.

3.4 MTR-C

The role of MTR-C as operator was well defined. They fulfilled that role.

MTR-C also filled other roles. These included providing drivers for BT dynamic test runs, and providing a central voice to pull stage 1 together. It was MTR-C that organised the daily call on DOO to discuss problems, issues and progress to rectification.

The void which resulted from CRL's lack of presence was filled by MTC-C. MTR-C's lack of technical content knowledge and arguably abrupt style of communication resulted at times in strained relationships between MTR-C and NR.

The gap that existed post APIS (9 June) and start of operation (22 June) could have been significantly reduced if the acceptance criteria for the project were better aligned with the acceptance criteria of the operator. "When there were questions, CRL talked to RfL, not the operator (MTR-C)".

The role of the operator needs to be developed further in RfL CRL. MTR-C should be recognised as bringing more to the table. They are here – let the project make best use of them. There are benefits to be gained by involving the operator with:

- Definition of pass/fail criteria for handover; and
- Assessment of evidence to demonstration compliance with those handover pass/fail criteria.

This would serve to close the gap between project acceptance and start of operations.

Recommendation 6: Involve the operator in definition and assessment of handover criteria.

Develop the role of the operator – make use of MTR-C.

4 Strategy and Planning (B)

Review Aspect B:

An assessment as to whether there was a clear strategy and plan made available for testing and commissioning including the C345 train, the infrastructure, DOO, CCTV etc.

Summary Response:

There was (in 2015) a clear overall strategy for Stage 1 bringing into use. It does not appear to have been developed into a tactical plan that addressed how everything would be pulled together to deliver an operating railway. The overall planning was left to the individual contractors to sort themselves out.

There was a clear strategy and planning developed for each of the individual systems of Stage 1. Documents to support this have not been sighted for Rolling Stock.

4.1 Overall stage 1 Strategy and Plan

There was not any strategy or planning at the level of systems integration testing or delivery.

The CRL document "Opening stage 1 testing and commissioning Strategy" provided an overall strategy for bringing in Stage 1 – the big picture. This document was last updated on 29 October 2015. It identified the individual testing and commissioning plans and processes (know at that time), and detailed the test certificates and other evidence (at a generic level) that would be provided. It did not provide any detail of how the individual systems would be pulled together to deliver an operating railway.

The "CRL Stage 1 dashboard" was current (see Figure 3). It presented on a single A3, the target dates and dependencies of the major building blocks for Stage 1 - the programmatic overview. There was, however, no description of what should happen when arrows came together.

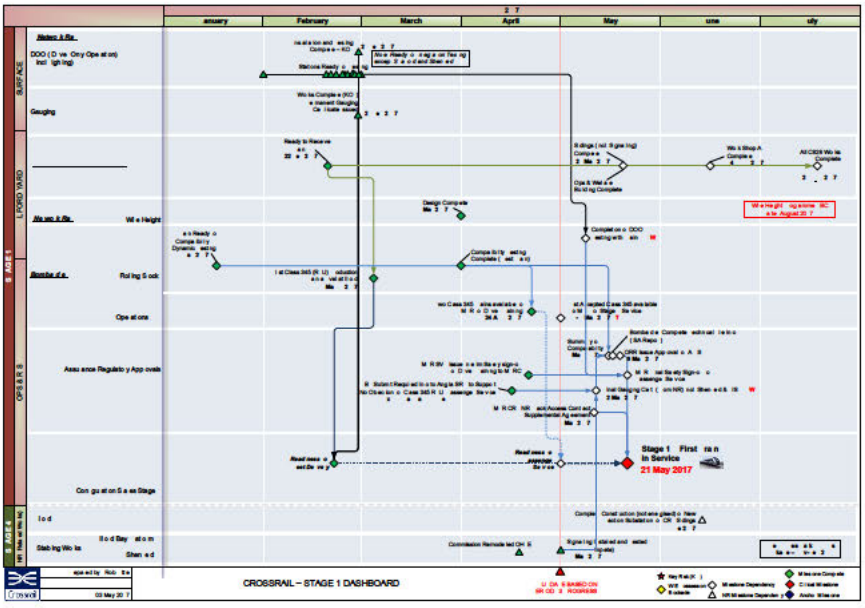

Figure 3: CRL Stage 1 Dashboard

This was a white spot in the planning. The absence of such a plan for Stage 1 was, in hindsight, a good indicator that things were not going to go well.

4.2 Strategy for testing DOO CCTV

There was a good strategy defined for the testing of the DOO CCTV Platform. The strategy was founded in the document “Crossrail standard for Driver Only Operation CCTV”. This document, released in 28 March 2013, provides a set of functional requirements for the DOO CCTV, and includes a comprehensive set of requirements for the testing and commissioning, that cover:

- Type testing,
- Train routine testing,
- Platform commissioning,
- Platform/train integration and
- Test documentation.

The strategy defined in the document “Crossrail standard for Driver Only Operation CCTV” was further developed into test specifications by BT. The BT document “DOO CCTV System IC&I Test Specification” expanded the strategy into workable test specifications for station works. A review of both documents reveals that one is quite clearly used as the input for the other.

There was a clear strategy and plan for the testing and commissioning of the DOO CCTV at stations.

The reader is referred to Recommendation 20: for further discussion on the content of SATs, and Recommendation 25: for discussion on performing integration testing earlier.

4.3 Strategy for testing trains

There was a good strategy defined for the testing of the DOO CCTV on-board. The strategy was, like the platform works, founded in the document “Crossrail standard for Driver Only Operation CCTV”. This document included requirements for the testing and commissioning related to train works.

The strategy defined in the document “Crossrail standard for Driver Only Operation CCTV” was further developed into test specifications by BT.

- The BT document “Platform DOO CCTV Generic Test Report C345” describes the testing conducted at Old Dalby.

- The BT document “DOO CCTV System On-Network Test Spec C345” and associated record sheet, further expanded the strategy into a comprehensive and well structured test specification and record sheet.

The Generic test report did contain test results (some of which had failed for reasons explained in the report). It was not possible to obtain any test records for the tests defined in the document “DOO CCTV System On-Network Test Spec C345”. It is unclear if this is due to the electronic

management of the reports, the unavailability of the reports to CRL or the tests not actually having been done.

Recommendation 7: Conduct a review of the BT test records.

BT has produced some excellent test specifications. Whilst it is expected that test records will also have been completed in a similarly professional manner, the difficulty experienced in obtaining these records during this review, and the criticality of those test results for future progress of Crossrail makes it prudent to conduct a review of the their completeness.

4.4 Strategy and plan for operations.

The MTR-C document "Stage 1 Mobilisation Project Execution Plan" contains a comprehensive description of the activities and dependencies for MTR-C Stage 1 completion. This appears to be a robust document that demonstrates that roles and responsibilities were well understood. A comparison of the MTR-C trackers with the document "Stage 1 Mobilisation Project Execution Plan" would seem to indicate that the execution plan was reasonably well followed.

There was a clear strategy and plan for the testing and commencement of operations.

4.5 Expectations about what is late

Whist this section 4.5 has only a tenuous link with Strategy and planning, the comments were so remarkable that they deserved to be included in the report. Not everyone had the same expectation regarding time. Some interviewees expressed the view that within 4 weeks could be considered as being on time. This view is a luxury the project does not have, particularly for Stage 2.

During a recent conference call with a (software) supplier, one of the suppliers casually mentioned "another 6 weeks delay" but did not appear to be particularly worried as "it was not on the critical path".

Recommendation 8: On time means "on time" – no later.

Express to all staff the importance of time being the same as the programme dates. 1 day late is still late.

5 Reporting and Communications (C)

Review Aspect C:

A review of the reporting and other communications that took place and whether this was adequate to provide the necessary transparency.

Summary Response:

CRL sits at the end of long reporting chains. There were failures in sending messages along these chains. BT knew of TCMS problems but these concerns did not make the CRL dashboards. Someone in BT knew about the problems with the Technical File submission, but that did not reach the BT dashboards. CRL know about problems with DOO CCTV stations but the full extent of the problem was not communicated.

A critical review of metrics is necessary to ensure the right things are being measured. This is particularly the case with software where not only the metrics, but also the management and exploitation of the software development information should also be challenged. There is a tidal wave of software dependent systems heading towards commissioning – CRL must be ready, and must be ahead of the game.

There was evidence to suggest that optimism bias, good news culture and frustrations on information sharing are all relevant issues within CRL, NR and BT. The extent to which they have contributed to the delay, or for that matter, are any different from other organisations where people interact, is questionable.

There is no evidence to suggest that anyone within CRL deliberately misrepresented known facts.

5.1 Timeline

The following time line was reconstructed from multiple sources. The timeline focuses on the activities that were driving the delay in commencement of Stage 1. It identifies the views of people who were involved in the process, and what was reported at various levels of the project. Milestones have been included for reference. Dates are 2017 unless otherwise noted.

Date	Event	Source
June 2016	Planned DOO testing at Harold Wood – it did not happen	MLS
Nov 2016	Planned completion of DOO at all other station – it did not happen – changed to Feb 2017	MLS
Nov 2016	Completion of DOO installation at Harold Wood.	Int
Nov 2016	Planned DOO testing at test track – it did not happen	MLS
Mid Jan	"Alarm bells start ringing" at BT. First version of TCMS software did not have level of functionality expected.	Int

Date	Event	Source
20 Jan	Train Works Project Programme shows "TCMS Software for Signalling stage 1", on page 75 of the schedule, with no delay, due to finish 7 April	TWP
25 Jan	BT Risk report defines "TCMS software bugs" as Major risk (red flag) – and stays that way through P12, P13, P01 and P02 reports.	BT
Start Feb	Planned First unit due in London with 3000 km free of service impacting faults – it did not happen	MLS
28 Feb	NR announce completion of DOO CCTV installation at all stations	Int
6 March	Unit 005 arrived in Ilford Depot. 0 km free of service impacting faults.	ORD
13 March	Operational readiness Dashboard (T-10) report infrastructure DOO CCTV complete.	ORD
20 March	DOO CCTV "On network Confidence Testing" with unit 5 performed at multiple stations – results were a mixed bag with some good images, some cameras out, some cameras misaligned and some poor images".	BT
20 March	Operational readiness Dashboard (T-9) "RfL maintenance handover requirements" set to red flag (and it stays red up until T-0)	ORD
23 March	BT report dashboard reports:- - complete submission of documents for approval: 14 April - ORR approval: 28 April	BT
23 March	BT Project Progress Report P1: - DOO CCTV complete systems test: 73 days delay –due 24 Mar	BT
30 Mar	Train available for testing DOO	Int
3 April	Operational readiness Dashboard (T-7) report "MTR-C approval of DOO CCTV" as red flag (and it stays red up until T-0)	ORD
10 April	BT report on rolling stock approvals shows significant deviation from plan against technical file submission.	BT
11 April	PDB, Ops dashboard reports: - DOO station installations as "closed"; - DOO CCTV risk forecast reduced from red to orange; and - "Assurance evidence for DOO CCTV" is red flag.	PDB
13 April	"It's all about the train" – robust discussions at Operations Steering Group meeting on delay of the Technical File submission.	Int
19 April	Operational proving commences. MTR-C note 17 platforms with DOO issues on first two nights – 9 train issues.	OPD
20 April	Unit 006 arrived in Ilford Depot. 0 km free of service impacting faults.	ORD

Date	Event	Source
20 April	BT Project Progress Report P1: - Complete submission of tech docs for authorisation: 8 May - DOO CCTV start of tests at Old Dalby : date TBA - DOO CCTV complete systems test: 114 days delay – awaiting representative TCMS release –due 5 May	BT
28 April	Operations Proving log continues to report DOO CCTV issues (as well as 45 open train issues)	OPL
Start May	TCMS becomes high risk – "but there was still a fighting chance".	Int
2 May	Operational readiness Dashboard (T-3) report - "Class 345 TCMS" appears, for the first time, as an orange flag	ORD
7 May	Clear that TCMS would not be ready on time	Int
11 May	PDB Ops dashboard reports: - "ORR issues APIS" shown as Green Flag; - "RLUs available for Stage 1" shown as green flag. All reported TCMS issues related to stage 2 and later. - "Technical File submission" forecast for 15 May	PDB
12 May	CRL expects technical file will be submitted "within a few days". Shortly thereafter, CRL is surprised by ORR's evaluation of actual progress.	Int
12 May	Train Works Project Programme shows "TCMS Software for Signalling stage 1" on page 76, with 17 days delay to finish on 16 May. Outstanding activities "Prelim validation report Document closure and ISA report"	TWP
15 May	Operational readiness Dashboard (T-1) report - "Infrastructure DOO CCTV snag list" changes to red flag - "ORR Authorisation to put in service" changes to red flag	ORD
18 May	BT Progress report states:- - Complete submission of tech docs for authorisation: 8 May - DOO CCTV start of tests at Old Dalby : date TBA - DOO CCTV complete systems test: 142 days delay – awaiting representative TCMS release.	BT
18 May	BT report dashboard reports:- - Complete submission of documents for approval: 18 May - ORR approval: 22 May	BT
23 May	Planed commencement day for Stage 1 – it did not happen	MLS
5 June	Final technical documentation submitted to ORR	Int
7 June	PDB Ops dashboard reports: - "RLUs available for Stage 1" shown as orange flag. - "Technical file submitted to ORR" shown achieved on 26 May.	PDB

Date	Event	Source
9 June	APIS received	Int
22 June	MTR-C commence service	Int

Figure 4: Timeline of reporting

Source

ORD	Operational Readiness Dashboard
OPD	Operational Proving Datasheet
PDB	Programme Delivery Board pack
BT	Bombardier documentation
Int	From Interviews
MLS	Milestone

People knew about upcoming problems before they were reported. This is only logical, as one should lead to the other. There are however, some notable anomalies that deserve closer attention. In each of the three cases discussed below there has been a failure to identify a problem and a failure to communicate the existence of problem.

5.1.1 TCMS software

Supplier	CRL

BT's was concerned over delivering TCMS in January 2017. The concern was reported as a red flag risk in the BT dashboard and risk report of 25 January; however, the BT Train Works Programme of 20 Jan did not show any potential delay.

TCMS appeared as an orange flag for the first time on the Operational Readiness T-5 Dashboard dated 18th April. The Train Works Programme dated 12 May was still predicting a finish date for TCMS Stage 1 of 16 May.

This is a case where the underlying concern, and associated risks, was not appropriately communicated. The PDB pack (train procurement dashboard) of 11 May actually showed a green flag for "RLUs available for Stage 1".

In this case, the hypothesis would be that the CRL staff receiving the report had an overly optimistic view on the severity and consequence of the problem. There was probably a level of optimism being fed from BT as well. The metrics used by CRL to track TCMS were not appropriate to clearly identify the oncoming delay.

5.1.2 DOO CCTV

The opposite situation occurs with DOO CCTV. Whereas with TCMS, the contractor (BT) had concerns yet there were no red flag at CRL, with DOO CCTV, the contractor (NR) was quite relaxed, but there were red flags at CRL.

With DOO CCTV, NR had expressed, with confidence, that the work was completed. Warnings were raised within CRL, at first, not due to functional problems with the delivery, but due to a lack of assurance documentation required for maintenance. There was an orange flag for DOO CCTV maintenance handover requirements from the T-10 dashboard of 13 March. This was upgraded to a red flag in the T-9 dashboard on 20 March 2017.

The concerns over maintenance handover should have been seen as an indication of the deeper issues concerning outstanding works, the lack of SATs and associated installation issues (where there is smoke – there is usually also fire). BT had reported failures of the DOO CCTVs in their reports of 20 March.

By 3 April, there was a red flag for MTR-C approval of the DOO CCTV. The flag was warning of MTR-C not accepting the DOO CCTV, not that the DOO CCTV was not working. Concerns over the outstanding works were only highlighted with a red flag for the DOO CCTV punch list in the Operational Readiness T-1 Dashboard of 15 May. It would appear that CRL recognised that something was wrong but failed to dig deep enough to understand the true nature of the problem. CRL failed to act.

During this period, and up until the time of preparation of this report, NR maintains that they delivered on time against their requirements. There is a clear difference of opinion on what “finished” means.

In this case, the hypothesis would be that the reporting was not sufficiently granular to reflect the developing situation – there was only one flag for DOO CCTV finished without any intermediate steps. It is also probable that the ones receiving the report in CRL did not fully grasp the implications of the situation.

5.1.3 Technical File

Supplier	CRL

The Technical File is conspicuous by the absence of any red flags. There were no concerns raised regarding the submission of the Technical File. Indeed, several of those interviewed said that submitting Technical File was "day work" for BT and that there were never concerns.

The first indication of a problem in CRL was on 13 April during an Operational Steering Group meeting, when concerns were raised over achieving regulatory approval. Reports from BT and CRL however continued reporting the imminent completion of the Technical File submission. The moving forecast date in progressive PDB packs tells the story.

- The PDB pack of 15 March forecast a Technical File delivery date of 27 March.
- The PDB pack of 11 April forecast a Technical File delivery date of 14 April.
- The PDB pack of 11 May forecast a Technical File delivery date of 15 May.
- The PDB pack of 7 June confirms Technical File delivered on 26 May.

The BT progress reports and dashboards have a similar pattern. Each successive report advises that the technical submissions will be completed shortly after the report date. The BT dashboard of 18 May reported that the Technical File submission would be completed on 18 May – the same day as the report. The forecast dates from the BT Dashboards for successive periods for the task "Complete submission of Documents for relevant Authorisations and Approvals (Stage 1)" are as follows:

- P11 BT Dashboard 26 Jan 17 Forecast Date: 11 Mar 17
- P12 BT Dashboard 23 Feb 17 Forecast Date: 30 Mar 17
- P13 BT Dashboard 23 Mar 17 Forecast Date: 14 Apr 17
- P01 BT Dashboard 20 Apr 17 Forecast Date: 08 May 17
- P02 BT Dashboard 18 May 17 Forecast Date: 18 May 17

On 12 May, CRL still expected the Technical File submission to be completed "within a few days". Shortly thereafter, the issue was highlighted (the bubble was burst) at a meeting with ORR. Reports differ as to the exact message, but it became abundantly clear that the view of ORR on the completeness of the Technical File was surprisingly different to that of CRL. Despite a report in the PDB pack of 7 June that "completion of Technical File delivery on 26 May", final submissions had only been completed 3 weeks later, around 5 June.

It would appear that no one knew exactly what was going on, every month was another surprise. The graph below is extracted from a BT report on the approval process, dated 10th April. There was a clear deviation from plan beginning on 20 February. Clearly someone in BT was aware of a problem mid to late February.

In this case, the hypothesis would be that the situation just never made it to status reports or dashboards.

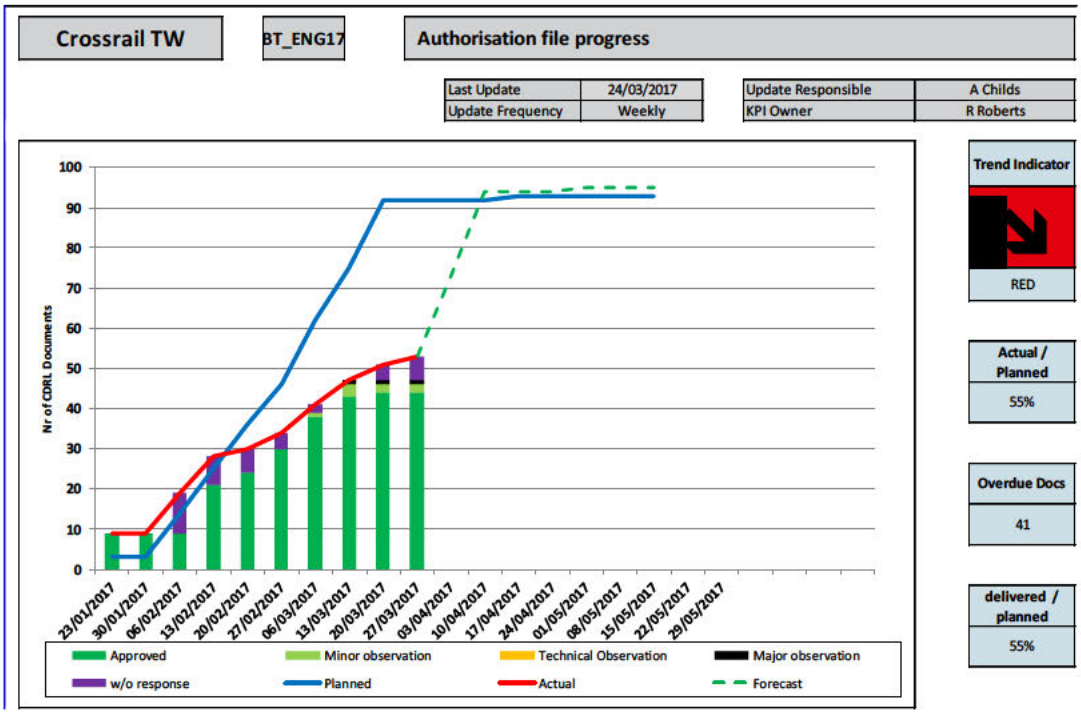

Figure 5: Technical File Submission - KPI

Source: BT report – Crossrail Rolling Stock Approvals review, 10th April 2017

5.2 Lessons from the timeline

In each of the three cases above, there was a breakdown in the reporting and communication. There was something that occurred that either prevented a message being sent, or prevented it being received and understood. In all three cases discussed above, the need for the appropriate action was missed. The cause of the breakdown could have been any one (or more) of the following:

- Problem not having been recognised (refer section 5.2.1);
- Information giving the wrong message (refer section 5.2.1);
- An overly optimistic assessment (refer section 5.2.2);
- A desire not to bring bad news (refer section 5.2.3);
- A desire to deliberately hide/not share information (refer section 5.2.4);
- Misunderstanding of the information that is given (refer section 5.2.4);
- Missing the information entirely (refer section 5.2.5);
- Clerical errors in processing information (refer section 5.2.5).

5.2.1 Metrics, software and documentation

The review confirmed that there are enough reports at CRL. There are a multitude of trackers covering all different aspects of the project delivery through diverse metrics. The fact that the delay with Stage 1 was a surprise can, in part, be traced back to the metrics that were used in tracking particular aspects of delivery. The metrics being tracked were not entirely representative of actual progress. The information (metrics) was giving the wrong message, and/or there was not a metric tracking the particular aspect of the delivery (the problem was missed).

In the case of DOO CCTV for example, the item that was reported was "DOO CCTV Complete". Had the reporting metrics been shaped to track the plan defined in the document "Crossrail standard for Driver Only Operation CCTV", then it would have been apparent that many elements of the DOO CCTV station works had not been completed. In this case, more detail (greater granularity) would have helped.

Whilst it is relatively simple to track volumes of concrete and tonnes of steel, tracking development of documents or production of software is less obvious. Tracking "Documents submitted for approval" did work, in the early stages (March – April). The BT report on the approval process highlighted an anomaly (diversion from plan) that indicated a problem was developing. It was, however, useless in the later stages (May), predominantly because target was moving (number of documents left) and amount of outstanding work was not well understood (by anyone). It is extremely difficult to track to a target, if the target is in flux.

Software is of particular interest when discussing reporting, metrics and trackers. TCMS development was not associated with a reported tracker. Software development was reported against version numbers, releases and installations. This is useful for configuration management, but not for tracking production. Two extracts from BT progress reports, shown in Figure 6 below, highlight the lack of insight. It is information, but provides absolutely no insight into the progress.

Extract from BT progress Report dated 26 January 2017: Software testing:

- In development v4.2, vBuild6.0
- VCS test rig: v4.1.30
- Train Zero: v4.1.2.30
- Train 1,2,and 4: v4.1.30
- TCMS R5.1.1 released to T18 on 19th Dec

Extract from BT progress Report dated 18 May 2017: Software testing:

- In development v4.2, vBuild6.0
- VCS test rig: v4.2
- Train Zero: v4.2
- Train 1,2,3,4 and 5: v4.1.13/ v4,2,11
- TCMS R5.1.1 released to T18 on 19th Dec

Figure 6: Software reporting from BT progress reports

The critical information necessary is:

- What release is needed?
- When it is needed?
- What functionality is contained therein? and
- What progress is being made on it's delivery?

Some of that information was buried on page 76 of the BT "Train Works Project Programme". It is hard enough clearly conveying a message on page 1 of a report, let alone page 76.

CRL must understand the "version landscape": a comprehensive overview covering all systems, that captures the planned release versions, the functionality contained therein, the planned delivery and the versions from different systems can start working with each other. This is the starting point for tracking, it is not the tracking itself.

Both software and documentation (but mostly software) are difficult to track because they are difficult to measure. One change in software may impact a single line of code or may require a complete re-write of significant sections of the code. Similarly with documentation, it can be a single sheet of paper or several volumes. Tracking against "number" only results in a limited view that is vulnerable to surprises. Only using a simple list to track changes brings the risk of surprises, should one of those changes require significantly greater effort than envisaged.

Even when there are good metrics, it is exceptionally difficult to identify exactly what the status of the product really is. The use of "sprints" in software development provides a quantity that can be tracked, but the uncertainty remains over complexity and implementation risk.

BT have implemented a suite of trackers for the TCMS development. BT track software development from different views. By looking at the same development from different angles, there is a better chance of picking up anomalies and delays.

One remarkable insight during this review was the fact that the ERTMS on board platform was also a development project. BT are using Crossrail as the vehicle to develop their Baseline 3 maintenance release 1 ERTMS platform. In the experience of the writer, there has never been a successful first time implementation of a new ERTMS platform anywhere in the world – ever. In several of the discussions with interviewees, ERTMS on board was described as "an existing product that is off the shelf".

CRL is facing a tidal wave of systems that are heavily reliant on software. The ability to track delivery of software dependent systems will only become more critical.

Recommendation 9: Review the metrics used to monitor delivery

How something is being measured is as important as what is being measured. Take a good hard look at the metrics (especially for things that can not be physically measured, like software). Check if the metric actually reflects progress. If there is only one metric for software development and it tracks % complete, then there is a pretty good chance that it is

not a real measure of progress, it is more a reflection on the optimism of the programmer. Look at how other (multiple) metrics might be used to look at that same software development process from another angle, giving a better chance of picking up problems early.

Recommendation 10: Look for leading indicators.

Even software development starts with documentation. Definition of requirements, for example is a critical first step in developing anything (including software). Identify the leading elements for the software development and consider tracking their completion to give insight into the software development process.

Recommendation 11: Review the granularity of the tracking.

The closer to the date, the more detail is required to track the event. Review the granularity of the reporting as deadlines approach. Operation will not be possible if the systems and processes are not completed to a level that can support that operation. Whilst snag lists will always be present, it is critical to understand (early in the process) what cannot be left to a snag list. Anything that can not be left on a snag list must be visible in the tracking – The granularity of the tracking should be adjusted appropriately.

Recommendation 12: Understand and use the "version landscape".

Strong configuration management is necessary. Ensure a comprehensive overview of software versions, functionality contained therein and their delivery date is understood for all software in all systems. Know which versions of different systems are required to be able to work together – this will help, amongst other things, to identify when integration tests can be started.

Recommendation 13: Get an external opinion on the impact of each change/update item

There were several lists sighted containing descriptions of changes that would be made for successive software releases. An explanation was given: "the change to version n+1 will be easier than the change to version n because there were only 5 changes instead of 7". There was no view as to how complex any of the changes might be – all were assumed to be (about) the same complexity. Having someone external to the development process look at the changes will help identify if there is a highly complex change lurking in the list.

Recommendation 14: Get under the skin of the developers

It is critical that CRL develops its own views on software development. This can be achieved by undertaking independent deep dives. The deep dive team would have "content savvy" CRL reviewers that:

- Look into the development process;
- Talk with the developers;
- Review progress of production and testing; and
- Undertake rigorous discussions with managers on risk, production and planning.

It is important to bring objectivity into the assessment. An independent deep dive team will be able to challenge the paradigms of the contractor and the day to day CRL manager. It will form a valuable contribution to reducing optimism bias in reporting.

The deep dive team should be independent of the day to day management of the supplier.. The deep dive team will not only assist CRL developing an understanding, they will also be useful in ensuring suppliers are confronted with reality.

Recommendation 15: Measure the paper not the word of mouth.

Progress should be measured against hard targets. Achieving those targets is demonstrated by documentation (test reports, design review, compliance certificates etc…). Progress reporting should be coupled with the evidence. No contractor should object to this approach, as the demonstration process is a fundamental part of the delivery obligation.

5.2.2 Optimism Bias and the Immortality Complex

Even when the message is received, it will be subject to interpretation. CRL has had some spectacular successes over the past years. It could be that CRL has been lulled into a sense of security, a belief that it will all come good in the end. When questioned if the delay in Stage 1 was a surprise, some respondents replied:

> "Yes and no. No, because we knew about the problems that were happening. Yes, because we expected that the problems would be sorted out."

One consistent comment was on optimism bias. It was in fact so consistent that one was left wondering if this really is a major issue throughout the project or if it is the most recent management scuttlebutt in the organisation. Whilst this sentiment was echoed by several of those interviewed, there is no concrete basis upon which to state that CRL has developed an immortality complex.

In any case, the delays in Stage 1 should provide a catalyst to shake out any complacency that has crept into the organisation.

Recommendation 16: Be conscious of optimism bias, challenge overly optimistic behaviour.

Management should use this opportunity to reinforce the message to CRL staff to be wary of optimism bias. Stress that risks are just as real today as last year; the only difference is there is now less time left to address them. The use of multiple metrics to track critical tasks from different angles will allow more objectivity in identifying optimism bias. Look for, and critically challenge, overly optimistic actions, for example:

- Use of P20 dates instead of P 80 dates
- Statements like: "The train will be alright"

Recommendation 17: Target running QSRA with suppliers and their CRL managers,

The QSRA process will force suppliers to look at the risks to their delivery and the impact on the programme. The use of the independent team to run the QSRAs will assist in increasing objectivity. It should confront suppliers with the reality of their delivery risk profile. QSRA should be particularly targeted at suppliers where there is limited transparency on the product delivery.

5.2.3 Good news culture

There was a consistent feeling expressed during the interviews that CRL and NR had a culture of "Good news or no News". This may be a factor in explaining why the dates for technical file submission kept creeping incrementally forward. The consistency with which this was commented seemed to indicate that this may be a credible matter to address.

Recommendation 18: Report the news: good or bad.

Express to all staff the need for accurate and factual information with which to be able to make meaningful decisions. A good news culture does not fit in the profile of delivering CRL on time.

5.2.4 Culture of sharing information

Several comments were made regarding difficulties in sharing of information within CRL, in particular, that some sections / staff are not as open with information as others might expect. The consistency with which this was commented seemed to indicate that this might be a credible matter to address.

The experience during the course of this review would support concerns that information shared by some staff is "less fluid" than from others. Documents were provided in response to requests for information, but the documents did not address the request. In one case,

- Multiple request were made;
- Documents were provided that did not reflect the information requested; and
- Explanations that were provided as to why the document did provide the information, were demonstrably incorrect (and acknowledged as such).

This could suggest a lack of access to documentation, a misunderstanding of the document content, an unclear request, a desire not to share, the information not being available or just a busy schedule.

An argument that was presented to explain this impression was that it was a reflection of a lack of justification. "If someone is asking for information on something with no clear need for it, then I can not expect people will be enthusiastic about sharing it".

Recommendation 19: Reinforce the need to be open and share project information

Express to all staff the importance of both being open with project related information to colleagues, as well as the professional courtesy of explaining why that information is useful in the first place,

Delivery of major projects relies on open and honest communications. Despite assertions from several of those interviewed that parties were lying, there is little evidence to suggest that there was ever a systematic misrepresentation of known facts.

There is evidence to suggest that the communications style of certain individuals was (and remains) abrupt, defensive and in certain cases bordering on arrogant. For example, the insistence of one interviewee that a particular activity had started on time "because it was finished on time". This insistence was despite the facts that the activity had not in fact been finished, and several colleagues had already commented on the late commencement.

There is also evidence to suggest that: in at least one case where factually incorrect information was given, the party providing the information had also been incorrectly informed.

5.2.5 Missing the information

Certain walls around the CRL offices are covered with a patchwork of RAG charts. There is the very real risk that the information telling of the next major problem will be lost in the mass. There is also the very real risk that a minor clerical error might change a red flag into a green flag.

It is all human work. That makes having the right people so incredibly important. It also means those people should be allowed to work in an environment that will allow them to excel in what they do.

Mistakes will happen, but having the right checks and balances will assist in picking up when they have happened. A healthy application of the checks and balances is necessary. Holding "feet to the fire" and having people "in the spikey chair" is critical for project delivery. The governance must push for objectivity. This, of course, is a discussion of the obvious. The key point to be taken from this section is the recommendations provided are just as relevant to picking up performance as they are to catching mistakes.

6 Clarity of Requirements and acceptance Criteria DOO CCTV (D)

Review Aspect D:

Consideration of the clarity surrounding the requirements for the acceptance criteria for DOO CCTV and how performance acceptance should be improved.

Summary Response:

There was an objective set of test specifications for the technical set up of station side DOO CCTV. There was not an objective set of criteria for image evaluation.

The criteria described in the document "Crossrail standard for Driver Only Operation CCTV" did not include any reference images. An image grading table was provided in the test specifications but is was unclear what each grade actually meant.

In practice, the image grading table was not extensively used. A "Pass" result was determined on the basis of the "technical numbers" and an assessment of the image by the operator. There were no cases of any fail assessment by the operator (on basis of image quality) being contested by any other party. Everyone agreed that the image in question was not good enough.

Practical problems (identifying cameras, system familiarity) complicated the rectification process.

6.1 DOO CCTV Test Specification

The document "Crossrail standard for Driver Only Operation CCTV" defined the strategy for the DOO CCTV testing. Test specifications were developed to address each of the stages in the defined strategy.

By way of example, the requirements for testing the transmission installation in the document "Crossrail standard for Driver Only Operation CCTV" states:

> "6.3.12 Each platform transmission installation shall be commissioned. This shall include inspecting the quality of the installation and proving the radiated signal strength is as per the design and delivers correct system operation throughout the required transmission range along the platform."

This requirement was incorporated in to the "DOO CCTV IC&I test specification". The test specification calls for testing at only two specific locations along the station edge, as shown below.

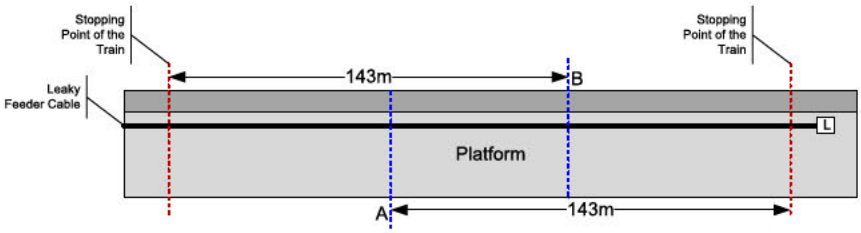

Figure 67 VHF Antenna Test Positions

Figure 7: Locations for DOO CCTV transmission tests

Bombardier developed a test rig that could be used to measure the signal strength. An antenna was to be mounted on a pole and set at a predefined distance from the leaky feeder, see Figure 8.

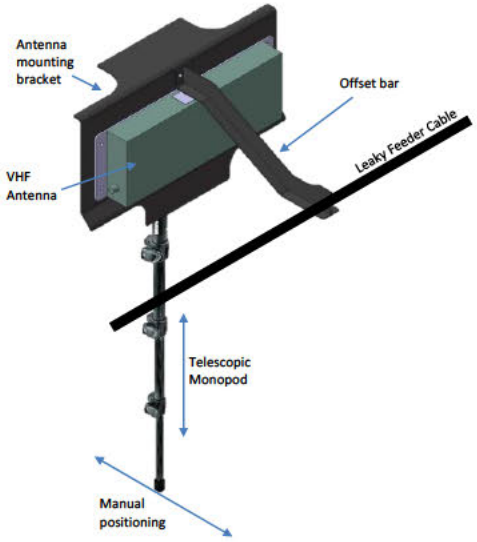

Figure 8: RF Transmission test equipment setup

The design of the test rig enabled only a static location to be tested. It was not easy, nor indeed was it required under the test specification, to move along the platform and test. Finally, the test procedure called for a spectrum analyser to be coupled to the antenna and an assessment made of the captured signal. This is not unreasonable as the test strategy document called for a measure of signal strength only. An illustration was provided to guide the testers (see figure 9 below).

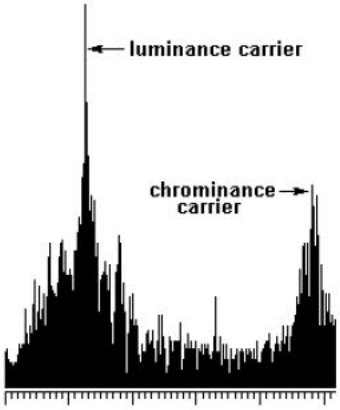

Figure 69 Single Modulated Video Signal
(Vestigal Sideband Modulated)

Figure 9: Illustration of single modulated video signal

The assessment criteria provided in the test specification concluded with a requirement that the spectrum “is of a quality judged acceptable by the RF engineer”.

The test looked at how much signal was being transmitted - it did not look at the image. It would have been a relatively simple step to provide more train borne components (the antenna is already one train borne component), and rig up an actual “train borne” monitor. If the entire rig was installed on a trolley, then the entire platform edge could easily have been tested. This approach was used – without trolley- at Harold Wood (see Figure 10).

Figure 10: Mobile test monitor used at Harold Wood

The test specification stopped too soon. It tested:

- That an image was received at the station video cabinet (before being modulated onto the RF carrier), and
- That an RF signal (which looked like a pal signal) was being transmitted from the leaky feeder.

The test specification did not consider the image that was transmitted. Adding this final test could have identified issues before the train arrived. The lack of a tested image from the station also meant that when image issues occurred on the train, they were automatically referred to the station team – there was no baseline from which to evaluate the actual cause of the problem.

Testing on the train was based on the received image. It was abundantly clear when there was a problem with a received image (see Figure 11 below).

Figure 11: Test image showing poor camera view

Note: commentary to image stated: “Manor Park platform 3 - all images displayed – camera … 3 very poor (see photo…, possible thermostat issue causing clouding).

Recommendation 20: SAT should be taken through to the functional interface.

Design testing regimes that will provide conclusive evidence of performance across the interface. SAT should not stop at the technical interface. They should be taken through to the functional interface if that is at all possible. CRL should be identifying these opportunities and making it happen (see also Recommendation 3:)

Recommendation 21: Make test rigs to reduce the need on critical resources

The use of a trolley with mobile video facilities (as opposed to just an antenna on a stick) would have identified and allowed problems to be addressed earlier. A train makes for a very expensive piece of test equipment. This comment applies equally for ERTMS beacons and every other track-train transmission interface.

Recommendation 22: Test as much as you can, as soon as you can

Arguments were put forward with all manner of reasons why testing could not be started. Much discussion was presented on the need to “wait until everything was complete before doing the SAT”. Waiting to find problems is killing in a project program. Waiting till everything is finished is a luxury that most projects do not have. Testing should be arranged as soon as possible, testing what can be tested, when it can be tested. This applies for any type of test including the FATs, SATs and Integration Testing. CRL should be searching out “meaningful chunks” and pushing suppliers to start testing them.

6.2 Pass/fail Criteria

Understanding what constituted a pass and a fail on the DOO CCTV has been the source of much discussion. The process of describing the problem is further complicated by the need for a specific vocabulary that is not in common use throughout all parties.

An Image Grading table was used to assess the quality of the image. The Image Grading table below in Figure 12 has been extracted from the document "Platform DOO CCTV System IC&I Test Specification". This table was taken from the document "Crossrail Standard for Driver Only Operation CCTV".

"A subjective assessment of image quality must grade the images at a score of 5 from the following table;

Image Grading Table		
Score	**Quality**	**Impairment**
5	Excellent	Imperceptible
4	Good	Perceptible but not annoying and does not impair task
3	Fair	Slightly annoying and does not impair task
2	Poor	Annoying
1	Bad	Very annoying
0	Unusable	Destructive

Table 6 Image Grading Table

Figure 12: Image Grading Table

At first glance, the Image Grading Table seems quite un-intuitive and bordering on abstract. This grading table also appears in ITU (International Telecommunications Union) test specifications (ITU-R.BT600 part 10) which would seem to indicate that it represents a reasonable set of internationally accepted assessment criteria. The reason an apparently vague and unintuitive set of criteria can be internationally accepted lies in the training requirements.

The ITU document ITU-R.BT600 part 10 also contain recommendations for training of assessors. An extract from ITU-R.BT600 part 10 document states:

> "Assessors should be carefully introduced to the method of assessment, the types of impairment or quality factors likely to occur, the grading scale, the sequence and timing. Training sequences demonstrating the range and the type of the impairments to be assessed should be used with illustrating pictures other than those used in the test, but of comparable sensitivity. "

There is a recognised need to calibrate the assessment bands presented in the Image Grading Table and provide training for the assessors. There is no evidence to suggest that any such calibration or training was provided for station or train testers. The conclusion to be drawn is that

the grading table, even for a subjective assessment, is far from precise enough on it's own. The assessor is asked to differentiate between:

- Not annoying;
- slightly annoying;
- annoying; and
- very annoying.

Without training and guidance, the results would be driven as much by the image, as the testers experiences in getting to work that day. Recently, a proposal was made documenting criteria in which there is a broader description provided for the Categories 5, 4 and 3 (below 3 being an immediate failure). The description was based on ITU-R.BT600 part 10. There is however, still no indication if these definitions have been discussed and agreed between the parties, nor if any form of training is to be provided.

Recommendation 23: Agree what the grades of image mean, and ensure clear direction is provided to those reporting the faults.

Make sure the interpretation of each image grade is clear. This is best achieved with the use of sample images, with images that demonstrate typical derogations. Use SAT images to provide a baseline for assessment.

Ultimately, there was not a problem in the assessment of the image - the Image Grading Table was not extensively used. The decision was mostly binary – pass or fail. A "Pass" result was determined on the basis of the "technical numbers" and an assessment of the image by the operator. There were **no cases** of any fail assessment by the operator (on basis of image quality) being contested by any other party. Everyone agreed that the image in question was not good enough. This conclusion was supported by MTR-C, CRL and NR staff that were interviewed.

Problems in rectification of the DOO CCTV was also complicated by factors beyond the technical implementation. Two examples are given below.

Example 1: System familiarity

The issues of system familiarity also played a role. The brightness of the image in the drivers cab is, in part, controlled by light sensors on the console. When those sensors are in shadow, the screen will be less bright. When the sensors are in the sun, the screen will be brighter.

There were fault reports that the two screens on the drivers console displayed different brightness. The problem was solved by placing a thumb over tone of the light sensors. The time of day and direction of the train meant that one sensor was in the sun (so screen was bright), the other sensor was in a shadow (so the screen was dimmed). The system was acting correctly as designed.

Example 2: Camera identification
There were issues related to the identification of faults.

- Multiple images appear on the on board monitors. Figure 11 provides an example of CCTV images on a train monitor.
- Initially, when faults were being reported, the operator reported the fault using the image number (left to right) as a camera reference. Hence a fault on the second image was reported as “fault on camera 2”.
- NR would attend and find no “fault on camera 2”. This occurred on multiple occasions.
- After 2 weeks, it was realised that there is not a correlation between image position on the monitor and the camera number. Image 2, might be coming from camera 4 or camera 5.
- Images on the train were then given an alphabetic code. Image A was first on the left. Image B was next then Image C etc. Faults were then reported against the alphabetic code. Hence a fault on the second image was reported as “fault on image B”.
- NR would identify which camera was associated with the reported image.
- NR would attend and, on multiple occasions, find no fault on the identified camera.
- A test run was set up with all parties on a test train in a final attempt to “sort all of this out”. The train was driven to a station, with everyone on board. When a fault was identified, all parties could observe it.
- NR examined the station equipment to rectify the fault. On several occasions, it was discovered that the cameras had not been connected to the correct port. Hence, viewing camera 2 on the test monitor in the station (fed from the video cabinet) might actually be looking at the feed from camera 3.
- Upon identification of the problem camera, the image problems were rectified in a short time.

6.3 How to improve performance acceptance

Key points to improve performance acceptance:

- Define SAT to confirm functional interfaces (Recommendation 20:);
- Ensure SATs are completed and systems aligned well before integration testing (Recommendation 22:);
- Insist on submission of completed SAT reports (Recommendation 15:;
- Take time before the testing to discuss and agree pass/fail criteria, and in particular what those pass/ fail criteria look like (Recommendation 5:).
- Take the time during testing to confirm the appropriateness of the pass/fail criteria (Recommendation 5:).
- Ensure testing uses unambiguous language (agreed between all involved parties) in the description and identification of faults.

7 Pulling the technical file together (E)

Review Aspect E:

A review of the process for creation and assembly of the evidence file in order to obtain the approval to place in service certificate (APIS) from ORR and how this process could be improved.

Summary Response:

BT has a well used and proven procedure for assembling the Technical File. In the case of the Class 345, however, the usual parameters around that process were changed:

- C345 is a new train type, a lot of off the shelf documentation had to be reworked, there was more to do;
- Changes and modifications late in the build process delayed Technical File completion; and
- Some requirements were missed and were only picked up late in the build.

The process would benefit from a post APIS reconstruction (within BT) of the actual Technical File development timeline, to identify where difficulties arose, then review the train development processed feeding those situations.

The Technical File was described as a list of validation evidence against a whole raft of test clauses derived from a standard. This was then submitted to an external body for checking and then submitted to ORR.

7.1 The process

The regulatory approvals process is well understood and well documented. The document "Guide to operating a railway from a Regulatory aspect" provides a good overview of what is required. BT have introduced new trains into service on previous occasions, so there was a well known and understood process within BT. There was no indication that NoBo or ISA resources contributed to the delay.

There were three factors that complicated the Technical File development. These were:

- The C345 is a new type of train for BT;
- Last minute changes and mods were required; and
- "New" requirements were identified quite late in the delivery process.

7.1.1 New train type

The last batches of trains before the C345, put into service by BT were Electrostars. These had being going into service for many years. Developing the Technical File was "just more of the same" with a few tweaks here and there. The C345 was a new type of train for BT, the Aventra. There were several technological developments captured in the new train, across many subsystems. This meant that certain documentation that had effectively been "off the shelf" for the Electrostars, had to be reworked (or newly developed) for the C345.

BT understood that the requirements for the Technical File would be more time consuming to complete for the C345. It is highly probable that:

- The amount of extra work involved was underestimated;
- The time required for that extra work was underestimated; and
- The validation evidence on new sub systems was not being delivered in a manner that allowed for efficient production of the Technical File.

7.1.2 Changes and Modifications

Last minute changes and mods were required to address developments in the final train design, and rectify problems. Validation of the build is the last step – testing can not be done until something has been installed to be able to be tested. Development of the Technical File needs the input from these tests. Consequently, any change or mod will require rework in the Technical File, and that rework can not be completed before that change or mod has been completed. Completion of the Technical File was impacted by late changes and mods.

7.1.3 New requirements

“New” requirements were identified quite late in the delivery process. These requirements had to be engineered into the train. Some of these were related to requirements from the EU Interoperability Directive, which had not been applicable for earlier designs. The BT team had relied on their experience, but the world had moved on. Implementing the “new” requirements led to modifications on certain systems with the consequential impact on the Technical File.

7.2 Improving the process

Clearly the greatest improvement to the process has already occurred, and that is having been through it already with a C345. The next time will not be the first time with a C345.

The process would benefit from a post APIS reconstruction, within BT and with CRL attendance, of the actual Technical File development timeline, to identify the pinch points.

Recommendation 24: Reconstruct the Technical File development timeline.

The reconstruction should identify where aspects of the BT train delivery process may need to be adjusted in response to:

- Peaks and troughs in the documentation delivery;
- Late documentation; and
- Cases where documentation had to be reworked.

8 What could have been completed earlier (F)

Review Aspect F:

Consideration of the extent to which activities could reasonably have been completed earlier to reduce risk to the completion stage.

Summary Response

The activities that could reasonably have been completed earlier for Stage 1, given delays already in the train delivery, were:

- Award of contract for installation of DOO CCTV Stations;
- Completion of installation SATs;
- Confirming images on train monitor (on a test rig as part of SAT);
- Collection and review of SAT forms by CRL with subsequent involvement by CRL to sort out issues; and
- Requirements check off against new TSI's during train build.

For future stages, consideration should be given to earlier completion of:

- Planning
- Agreement on pass/fail criteria and test result sheets;
- SATs;
- Integration Testing;
- Preparation Reviews;
- Contact Lists;
- Quantitative Schedule Risk Assessment; and
- Commercial Agreements.

8.1 Earlier completion for Stage 1 activities

In assessing the question of "what could have been completed earlier", reference should be made to the situation, as it was late in 2016. Given the existing delays with the train delivery, there was limited scope for BT to have completed the TCMS development, or the technical file earlier. These two activities were firmly tied to the train build, particularly in the last months where changes in the train drove changes to the TCMS and the Technical File. Completing the check against requirements earlier would have led to the identification of non compliances with the TSI that drove some of the late changes in the train. This could have reduced the day, but by how much is uncertain.

The station installation did have opportunities to reduce the risk to the completion of the stage. Awarding the installation contract at an earlier time would have given more time for installation. The activity that provided the greatest opportunity was completing the SATs immediately after installation was complete. Notwithstanding arguments that SAT can only be complete on a final installation, it was entirely possible to fully test each station after completion of installation. In doing so, many of the issued that frustrated the Operational Proving, and MTR-C post APIS activities could have been addressed.

If NR had completed installation on 28 Feb, commencing SAT shortly thereafter would have given almost 5 weeks advantage in sorting out installation and system issues. Use of a train monitor on a trolley would have solved even more issues.

CRL could have collected the SATs and subsequently become more involved with leading the project. This is addressed in Section 3.2 of this report.

8.2 Opportunities for future Stages

There are lessons to be learned for subsequent stages, where certain aspects can be commenced/completed earlier to provide significant de risking of the program. The focus in this section on testing does not imply that upstream activities (design reviews, gates etc) do not provide opportunities. The base assumption is that these activities have already been completed, or already scheduled.

Plans
For each stage, there must be a plan that describes how each of the individual systems will come together to deliver an operating railway (Recommendation 2:). This should be completed well in advance of the stage date.

Agreement on pass/fail criteria and test result sheets
Pass/fail criteria and other requirements for compliance demonstration should be agreed at the time the requirements are defined. It would be advantageous to review the pass/fail criteria for handover with MTR-C (Recommendation 6:) This should be done early enough to allow time to adjust commercial delivery obligations if so required. Test result sheets should be agreed at the earliest opportunity. This will ensure a common understanding of “finished“ is documented (Recommendation 5:).

SAT
SATs should be started as early as possible. Test as much as you can – as soon as you can (Recommendation 22:)! A comprehensive SAT will reduce problems downstream. Getting SATs started early will allow time for any fixes that may be needed – and result in fixes being finished early. Insist on documentary evidence to demonstrate completion (Recommendation 15:). Utilise test rigs to the extent possible to make the testing effective (Recommendation 21:). Make sure the Sat goes as far as it can to demonstrate the functional interface (Recommendation 20:)

Integration testing
Integration testing provides great opportunities to de risk delivery stages. The System Integrator should be looking for opportunities to get software modules, and/or sub systems together at the earliest opportunity (Recommendation 22:). Systems Integration then becomes a gradual process of gluing together developing systems, rather than a big (complex) bang at the completion of the development. It is not necessary to wait until the entire system is complete, if parts of that system can be tested beforehand.

Recommendation 25: Identify integration tests that can be conducted early and do them.

Understanding the version landscape (Recommendation 12:) will allow CRL to identify when elements of integration testing can be executed - even before completion of the entire system and it's associated SAT. Strong configuration management is necessary to identify and prevent incompatibilities. Leveraging that configuration management can move integration of systems to the left. CRL should be driving suppliers to conduct integration testing as early as possible (Recommendation 22:).

Preparation reviews.

Complex testing situations (e.g. dynamic testing with trains) should be examined to assess what problems could arise, and what measures are required to reduce the impact of the event. The experience from the recent dynamic testing: "When the pantograph was damaged, it cost us a week while we had to wait for one to be sent down. We foresaw problems with blown air hoses, so when one air hose did blow, we were prepared and it only cost us 10 minutes".

Contact Lists

A list detailing names, roles and contact details of all the individuals involved in the stage delivery should be prepared. This would save time while people have to look for each other.

Recommendation 26: Prepare comprehensive contact list for each stage

List names, contact details and role of everyone involved with the stage delivery.

Quantitative Schedule Risk Assessment

QSRA is a valuable tool to confront suppliers with reality of their risk profile. The earlier a QSRA is conducted with suppliers, the better chance the will be to understand what risks need the most attention.

Commercial Agreements

There were several incidents when commercial agreements lagged behind the works. Roles and responsibilities must be supported by the appropriate commercial agreement – asking someone to act is of little use if the commercial means are not in place to allow them to act. BT has reported the need for a contract change to allow testing of ERTMS between BT and Alstom systems in Charleroi as part of Stage 2. This commercial change has not yet been put in place.

NR also mentioned that the funding of certain of the On Network Works were organised from NR sources as the required agreements had not been formalised by CRL. There remain outstanding commercial agreements as of the date this report was written.

Recommendation 27: Tie down the commercial details as soon as possible.

Concluding the commercial aspects of agreements helps formalise the agreement, funds the process and removes barriers to delivery. The implementation of commercial agreements should be vigorously followed through.

Annex A: List of Interviewees

The following persons were interviewed in the course of this audit:

Crossrail		
Name	**Company**	**Position**
	CRL	DOO/CCTV Project Manager
	CRL	Chief Engineer
	CRL	Technical Director
	CRL/RfL	Operations Director
	CRL	Head of Integration
	CRL	Surface Director
	CRL	Programme Director
	CRL/RfL	Deputy Operations Director
	CRL	Regulatory Engineer
	CRL	Stage 2 Programme Integration Manager
	RfL	Deputy Director (Rolling Stock/Depot)
	RfL	Senior Project Manager Rolling Stock
	RfLi	Head of Engineering
	RfLi	Head of Infrastructure
	CRL/RfL	Operational Readiness and Testing Manager
	CRL	Program Controls Director
	RfL	Asset Engineer Coms and control
	CRL	Head of Program Risk
	CRL	Chief Engineer
	CRL	Head of Planning

Network Rail		
Name	**Company**	**Position**
	NR	Crossrail Program Director
	NR	Project Director for CRL East
	NR	Stations Program manager.
	NR	Program engineering manager.

Contractors		
Name	**Company**	**Position**
	BT	Head of Crossrail project
	MTR-C	Operations Director
	MTR-C	Managing Director
	MTR-C	Engineering Director
	MTR-C	Stage 2 Delivery Manager
	MTR-C	Head of ONFR and OSIN

Annex B: Document list

The following documents were referenced during the course of the review.

CRL Documents

- Impact on Safety and regulatory Approvals of the Crossrail Signalling Migration Strategy – Integration. Doc Number CRL1-XRL-R2-GUI-CR001-50001 V2.0 dated 23/6/17
- Driver Only Operation CCTV Roles and Responsibilities. Doc Number Q234-XRL-R1-GPD-CR001-50001, V1.0 dated 15/06/16
- Guide to operating a railway from a regulatory perspective. Doc Number: CRL1-XRL-Z-GUI-CR001-50032, V1.0, 21-01-17
- CRL1-XRL-Z-MRC-CR001_Z-50014: Minutes of meeting CRL/ORR ;7/7/17
- On Network Functional Requirements (ONFR), Document Number CRL1-XRL-08-RRS-CR001-00001 Version 6.1
- Network Rail Client Requirements (NRCR), Doc CRL1-XRL-N2-ACI-CRG04-00001 Version 7.0
- Interface Control Document between Crossrail and Network Rail. Document Number: CRL1-XRL-R1-RSP-CR001-50001
- CRL1-XRL-O6-STD-CR001-50003 Crossrail Standard for Driver Only Operation CCTV . Rev 1.0 28 Mar 2013
- Crossrail opening Stage 1, Testing and commissioning strategy CRL1-XRL-Z-STP-CR001-50021; v1, dated 29-10-2015;

NR Documents

- Telecommunications SAT Document, Brentwood Platform 1. Doc number NBW1E-ETL-REP-COS-000005, issue A01 dated 1/4/2017, signed off 12/4/2017

PDB Packs

- Period 10 - Wednesday 18th Jan 2017
- Period 11 – Wednesday 15th Feb 2017
- Period 12 – Wednesday 15th March 2017
- Period 13 – Wednesday 12th April 2017
- Period 1 – Thursday 11th May 2017
- Period 2 – Wednesday 7th June 2017

MTR-C Documents

- Staged Operating Plan: CRL1-XRL-K2-STP-CR001_Z-50002, V 2.0, dated 5 February 2016
- Staged Operating Plan: CRL1-XRL-K2-STP-CR001_Z-50002, V 4.0, dated 19 December 2016
- Stage 1 Mobilisation Project Execution Plan (MTR-PGM-GEN-PLN-0005)
- Stage 1 Tracker T-4 Final
- Stage 1 Mobilisation Tracker v3.8

- Ops proving data log (email & log): 20 April 2017
- Ops proving data log (email & log): 21 April 2017

- Ops proving data log (email & log): 22 April 2017
- Ops proving data log (email & log): 26 April 2017
- Ops proving data log (email & log): 27 April 2017
- Ops proving data log (email & log): 28 April 2017
- Ops proving data log (email & log): 03 May 2017
- Ops proving data log (email & log): 04 May 2017
- Ops proving data log (email & log): 05 May 2017
- Ops proving data log (email & log): 06 May 2017
- Ops proving data log (email & log): 06 May 2017 II
- Ops proving data log (email & log): 09 May 2017
- Ops proving data log (email & log): 10 May 2017

BT Documents

Schedules

- Q234-BMB-R1-TSC-CR001-50100 Rev 1.0: Train works programme P11/16 20 Jan 2017
- Q234-BMB-R1-TSC-CR001-50102 Rev 1.0: Train works programme P12/16 17 Feb 2017
- Q234-BMB-R1-TSC-CR001-50109 Rev 1.0: Train works programme P02/17 12 May 2017

P11 reports

- Q234-BMB-R1-TSC-CR001-50101 Rev 1.0: TWPP Level 1 P11 17 Feb 2017
- Q234-BMB-R1-RGN-CR001-50587 Rev 1.0: Assurance submissions P11
- Q234-BMB-R1-RGN-CR001-50588 Rev 1.0: Risk Report P11 25 Jan2017
- Q234-BMB-R1-RGN-CR001-50589 Rev 1.0: Dashboard P11 26 Jan 2017
- Q234-BMB-R1-RGN-CR001-50590 Rev 1.0: Prog Report P11 26 Jan 2017

P12 reports

- Q234-BMB-R1-TSC-CR001-50103 Rev 1.0: TWPP Level 1 P12 17 Feb 2017
- Q234-BMB-R1-RGN-CR001-50595 Rev 1.0: Assurance submissions P12
- Q234-BMB-R1-RGN-CR001-50596 Rev 1.0: Risk Report P12 22 Feb 2017
- Q234-BMB-R1-RGN-CR001-50597 Rev 1.0: Dashboard P12 23 Feb 2017
- Q234-BMB-R1-RGN-CR001-50598 Rev 1.0: Prog Report P12 23 Feb 2017

P13 reports

- Q234-BMB-R1-TSC-CR001-50105 Rev 1.0: TWPP Level 1 P13 17 Mar 2017
- Q234-BMB-R1-RGN-CR001-50633 Rev 1.0: Assurance submissions 1 P13
- Q234-BMB-R1-RGN-CR001-50634 Rev 1.0: Risk Report P13 22 March 2017
- Q234-BMB-R1-RGN-CR001-50635 Rev 1.0: Dashboard P13 23 March 2017
- Q234-BMB-R1-RGN-CR001-50636 Rev 1.0: Prog Report P13 23 March 2017

P01 reports

- Q234-BMB-R1-TSC-CR001-50107 Rev 1.0: TWPP Level 1 P01 14 April 2017
- Q234-BMB-R1-RGN-CR001-05662 Rev 1.0: Assurance submissions 1 P01
- Q234-BMB-R1-RGN-CR001-05663 Rev 1.0: Risk Report P01 20 April 2017
- Q234-BMB-R1-RGN-CR001-05664 Rev 1.0: Dashboard P01 14 April 2017

- Q234-BMB-R1-RGN-CR001-05665 Rev 1.0: Prog Report P01 20 April 2017

P02 reports

- Q234-BMB-R1-TSC-CR001-50110 Rev 1.0: TWPP Level 1 P02 12 May 2017
- Q234-BMB-R1-RGN-CR001-50717 Rev 1.0: Assurance submissions 1 P01
- Q234-BMB-R1-RGN-CR001-50718 Rev 1.0: Risk Report P02 17 May 2017
- Q234-BMB-R1-RGN-CR001-50719 Rev 1.0: Dashboard P02 18 May 2017
- Q234-BMB-R1-RGN-CR001-50720 Rev 1.0: Prog Report P02 18 May 2017

Other

- Crossrail Rolling Stock Approvals report, 10th April 2017.
- Q234-BMB-R1-RSP-CR001-50045 Rev 4.0 Platform DOO CCTV System IC&I Test Specification C345.
- Q234-BMB-R1-RSP-CR001-50191 Rev 1.0 Platform DOO CCTV System On Network Test Spec C345.
- Q234-BMB-R1-RSP-CR001-50191 record tracker Rev 1.0 Platform DOO CCTV System On Network Test Spec C345 test record pro forma.
- Q234-BMB-R1-CR001-50002 Rev 5.0 (3EER400018-9023).
- Q234-BMB-R1-CR001-50003 Rev 4.0 (3EER400018-9024).
- Q234-BMB-R1-CR001-50017 Rev 3.0 (3EER400019-9986): DOO CCTV EMC mgt plan.
- Q234-BMB-R1-CR001-50033 Rev 3.0: KeTech final RAMS report .
- Q234-BMB-R1-CR001-50064 Rev 8.0: (3EER400019-3713): Detailed generic Design.

Annex C: List of recommendations