

Crossrail MOHS Schedule Peer Review

A Report Prepared by Ian Rannachan

Independent Reviewer

September 2018

Issued for Use

Introduction

The following analysis comprises seven sections specifically responding to the three specific remit questions plus a general section noting other observations made while undertaking the analysis.

The sections are as follows:

Review Outline:

1. Remit and Methodology
2. Executive Summary
3. Current View of the MOHS
4. Independent Review of the 9 Critical Paths
 1. Completion of Routeway (C610)
 2. Signaling (C620)
 3. Tunnel Ventilation (C610)
 4. Radio (C660)
 5. Dynamic testing
 6. HV Non-Traction Power (C650)
 7. Traction Power (C644)
 8. SCADA & Comms (C660)
 9. SS&P Completion
5. Independent Review and Analysis of SS&P and Routeway Completion
6. Trial Running and Trial Operations
7. Response to Remit Questions
8. Other Observations

1. Remit and Methodology

The purpose of this Independent MOHS schedule review is to respond to the following questions:

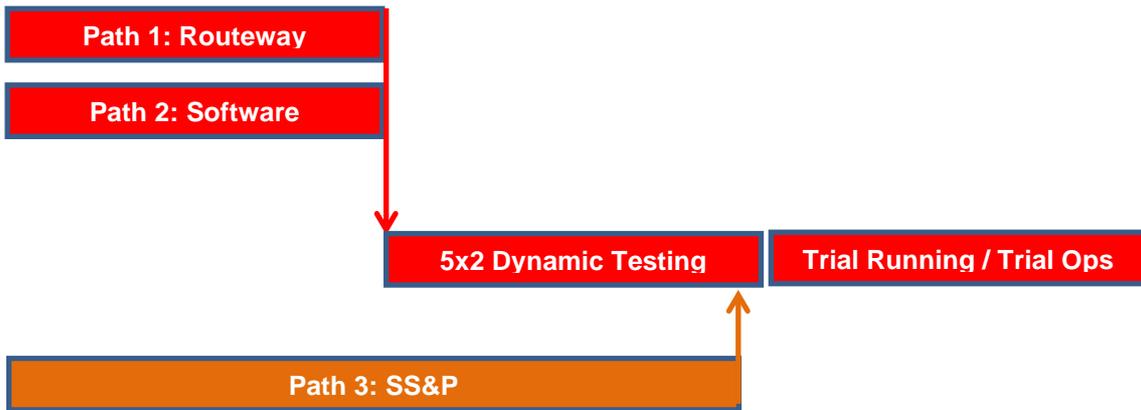
1. What confidence do you have that 21 October 2018 start of 5x2 Dynamic Testing can be achieved?
2. When do believe Stations Will Complete Phase 3 Testing?
3. Are the durations for Trial Running and Trial Operations supported by a logical plan and defined scope of trials?

The methodology used to prepare this independent review and respond to the three specific questions was to:

- Review of the current (Period 4) schedule updates, progress trackers, miscellaneous reports and analysis.
- Meet with senior project team members, project managers and planning staff. In doing so, approximately 25 specific “project” review meetings plus a number of ad hoc discussions took place.
- Focus my assessment on plans and schedules that deliver a high (P80+) level of delivery confidence.

2. Executive Summary

My view is that there are two high level critical path(s) leading to the start of 5x2 Dynamic Testing and the Start of Trial Running. Because of the schedule risks associated with each path, I am at this time unable to determine which one will ultimately be the longest “driving” path:



- Path 1 Routeway: I have low confidence that the 21 Oct 2018 date for completion of routeway to support the start of 5x2 Dynamic Testing can be achieved. My view of a date when these will be substantially complete, inclusive of testing, is the end of December 2018. Although I acknowledge that not all of these works are actually “required” to support the start of 5x2DT: there is a balance to be struck to ensure that the volume of works being moved post the start of 5x2 DT into the 5x2 DT restricted working regime is minimised. It is my view that the end of December would be a more balanced date.
- Path 2: I have low confidence that the train software (BT and Siemens) will have been sufficiently tested to support start of 5x2 Dynamic testing on 22 Oct 18. There are 27 critical tests that need to be completed to deliver a train and software that is ready to begin 5x2 Dynamic Testing. While it is true that 5x2 Dynamic Testing could begin without having completed all 27 tests this approach is likely to import risk into the subsequent four pass dynamic test plan.
- Dynamic Testing: The duration for dynamic has been established reflecting a four-pass testing scenario with an overall duration of 16 weeks. I understand that four pass Dynamic Testing has been done previously but over a considerable longer duration. I believe that a fifth path (four-week cycle) risk provision be added to this duration.
- Trial Running and Trial Operation: The durations allowed for these activities appear to be supported by defined test plans. I would agree that the addition of a four-week risk period to cover “Reliability Risk”, as shown in the “current view of MOHS in section 3, would be prudent.

- Paths 1 & 2: The combined effects of both path 1 & 2 indicate that an end of December ready to start 5x2 Dynamic Testing would be realistic and cost effective and most importantly de-risk the overall 5x2 Dynamic Testing duration.
- Path 3: My view of the dates when SS&P will be substantially complete inclusive of testing range from early December 2018 thru mid June 2019. Provided a step change can be achieved in physical installation and testing of C660 scope of works, the quantum of terminal float in this path can be increased

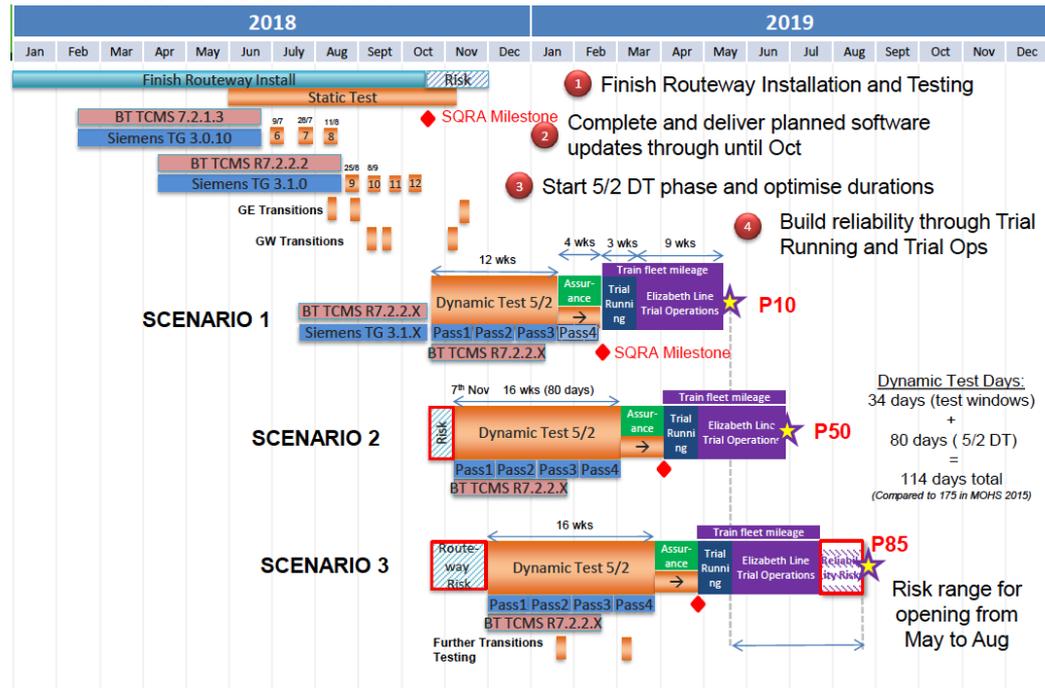
Recommendations are:

- The start of 5x2 Dynamic Testing should be delayed to 7 January 2019 start. By doing so the four pass 5x2 Dynamic Testing plan is likely to be significantly de-risked.
- Routeway to complete and fully test their works, except for SCADA testing by end of December 2018. By doing so the volume of physical works and testing left to complete in the routeway will have been substantially reduced.
- Train software (BT and Siemens) testing must complete the minimum of 27 of the 29 tests before the start of 5x2 Dynamic testing. The extra period of time that would be created by delaying the start of Dynamic Testing can effectively be used to ensure that a fully tested train is available at the start of dynamic testing.
- SS&P “PPE Free” completion dates should be re-set to deliver complete and tested works, except for C660 Phase 3 testing (Radio, SCADA, CCTV and PAVA) i.e. the contractors finish their physical works, testing and assurance.
- An action plan is required with a view to delivering a step change in C660 testing work processes and resource / supervision levels. The objective of this initiative being to target completion of C660 testing and assurance by April 2019 as opposed to June 2019.

3. Current View of MOHS

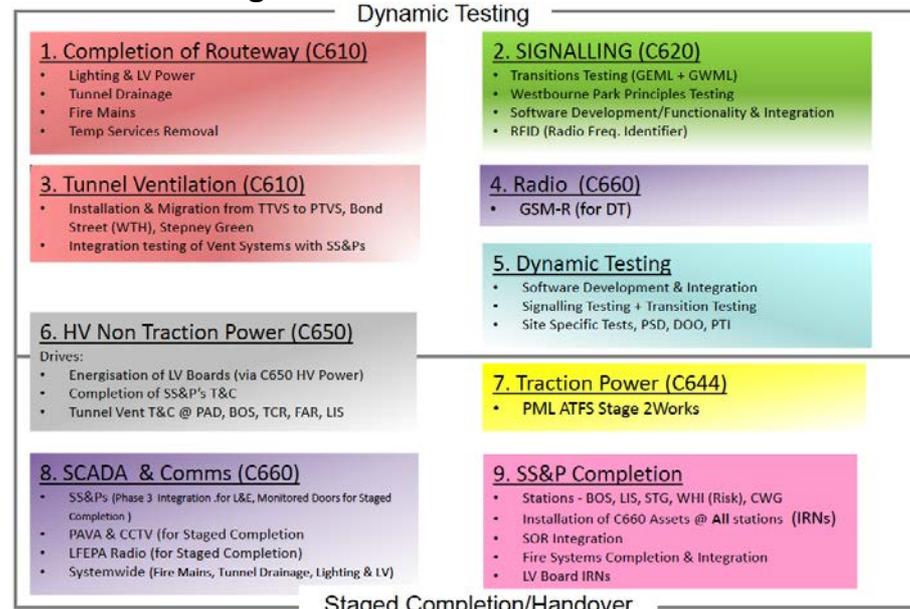
The most recent (P4) Crossrail analysis of the Dynamic Testing Critical Path(s) and risk is best depicted in the following chart:

Current View of the MOHS



It had been determined that a total of 9 schedule logic critical paths had been identified to be driving the above outcome, these paths are:

MOHS 2018 Stage 3 – Critical Paths



4. Independent Review of the 9 Critical Paths

As a starting point I have reviewed the 9 critical paths that had been identified to establish their current status and their potential to influence the scheduled outcome. In the following section I have noted, for each of the nine paths, the main facts and considerations that have enabled me to form my view of the likely schedule outcome.

- **#1 Completion of Routeway (C610)**
 - Lighting & LV Power
 - Tunnel Drainage
 - Fire Mains
 - Temp Services Removal

The objective to complete the works required to support the start of 5x2 Dynamic Testing by 21 October is under pressure. Latest forecasts by the contractors indicate that this date can be achieved, while Crossrail's project team has a view that a forecast of date around 7 November is more likely albeit with no risk/contingency provision.

My view based on volumes of physical work to go (drainage, lighting, ventilation and fire mains) plus testing, all areas where progress is well behind plan, is that a completion at the end of November plus a risk provision of four weeks is appropriate, e.g. the end of December 2018.

I recognize that the scope of work that I believe should be completed before 5x2 Dynamic Testing begins is not the minimum scope required to support 5x2 Dynamic Testing but is more a substantial completion of the works. In my view an early date moves too much work into a much more restrictive (less efficient) working regime post start of 5x2 Dynamic Testing.

There is obviously a balance to be struck in establishing the date when 5x2 Dynamic Testing should begin. The analysis for establishing this date must be informed and aligned with the date that a ready for testing train/software will be available.

Following are some comments and observation relative to the status of the works and perceived issues:

Physical Quantity Installation:

Linear commodity installation "to go rates" do not appear to support 21 Oct:

- **Lighting Luminaires:** The to go quantity is 3810, actual 5-week average is 150/wk. The required rate to complete would be 423/wk. C610 are forecasting recovery of this slippage by increasing train resources from one to two trains and increasing installation rate to 120/day.

- **LV Cable:** to go is 71km, actual 5-week average is 10.7 km/wk. Required rate to complete would be 8.9 km/wk, concern relates to Terminations and T&C
- **Tunnel Drainage:**
 - The plan and schedule for installation of pumps, completion of piping hook up and switchover/removal of temp systems unclear
 - A bulk of work to go is in cross passages, screeding to be completed by 7 Sept
- **Fire Mains:** Sector 3 BOS-TCR and BOS-PAD is dependent on BOS IRN on 30 Aug, this has not been confirmed. This is required to support 100% IRN by 11 Sept.

Issues:

- Availability of permanent power from stations to support Phase 2.2 and 2.3 testing continues to be an issue.
- The linear cable pulling tracker status reports are unclear with respect to how cable terminations are proceeding. I recommend termination tracker visibility is provided.
- Provision of Station access is an issue that has caused and will continue to cause slippages to the planned works and as such forecast completion dates must recognize this potential disruption.
- Temp Services Removal will, in the main be deferred to post 21 Oct. This strategy could become an issue if the volume of work post 5x2 Dynamic Testing becomes too great.
- Surveys are currently underway to establish the scope of works associated with rectification of damaged/blocked drainage. The volume of work to be done has not as yet been established.

C610 Linear Commodity Tracker:

Linear Commodity	Total	P04				To date (Wk 276)		Delta	To-Go
		Wk 273	Wk 274	Wk 275	Wk 276	Actual	%	P03-P04	
Cables	1,061,019	19,573	3,601	12,104	10,273	987,285	93	4	73,734
TW Completed Bays	39,559	1,544	999	2,295	2,782	23,958	61	19	15,601
Firemain	41,073	-	17	140	-	36,368	89	0	4,705
Drainage	10,478	-	-	-	-	9,337	89	0	1,141
Lighting Luminaires*	4,888	144	123	227	80	1,078	22	12	3,810

C610 IRN Dashboard:

C610 High-level IRN and Testing & Commissioning Tracker

Week: 279 14-Aug-18

Total IRN and Civil Certificates Planned

Certification Dashboard					Contract		C610						
	C610	TRK	OHLE	TVS	TWS	CMS	LVD	LGT	SGN	TPD	TFM	CPD	CLW
IRN Planned Total	748	75	140	77	36	107	76	46	16	69	49	26	81
IRN Actual Total	436	67	134	47	0	82	11	0	0	6	6	20	63
% Complete	58%	89%	96%	61%	0%	77%	14%	0%	0%	9%	12%	77%	78%

- **#2 Signaling (C620) + BT and #5. Dynamic Testing**

<p>2. Signaling (C620 + BT):</p> <ul style="list-style-type: none"> • Transitions Testing (GEML + GWML) • Westbourne Park Principles Testing • Software Development/Functional Integration • RFID (Radio Frequency Identifier) 	<p>5. Dynamic Testing:</p> <ul style="list-style-type: none"> • Software Development & Integration (C620 + BT) • Signaling Testing + Transition Testing • Site Specific Tests, PSD, DOO, PTI
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There appears to be a lack of alignment of views between the Ready to Start 5x2 Dynamic testing date being forecast BT/Siemens schedules and trackers, currently the end of September 2018, and perception of the Crossrail staff that I interviewed. Interviews indicated that there is a significant risk that full testing would not be completed by 21 October 2018.

Software release dates have been slipping and testing undertaken to date has not progressed to plan

I have a low level of confidence that full testing can be accomplished by 21 October 2018 and as such there is a risk that 5x2 Dynamic Testing could start with a Train that is not ready. The impact of this being to import additional risk to the four pass Dynamic Test plan.

Following are comments and observations supporting my views noted above:

Transition Testing (GEML + GWML):

- To date planned works have not been delivered, additional engineering works planned have only been partially successful
- Completion of transition testing is required prior to start of Trial Running (not Dynamic testing), however the works are critical possession dependent. Testing has not progressed as planned and as a result additional possessions will be required (Xmas and possible Easter)

Software Development/Functionality & Integration:

- **C620:** CBTC software 3.1.0 was to have been released two weeks ago, as yet not released.
- **BT:** to date only 12 of the minimum of 29 tests have been completed at Melton. Successful completion of minimum 29 tests prior to starting dynamic testing is expected significantly improve the chances of successfully delivering a successful four pass dynamic testing regime.

5x2 Dynamic Testing:

- Completion of C620 wayside dynamic testing in a four-pass testing regime completed in a 16 weeks overall duration would equates to the most optimistic schedule ever achieved
- Assurance: the plan is that Siemens assurance will be incorporated in Bombardier submission of evidence to ORR, 3 months has been allowed for, previously the duration for this had been 3.7 months.

Quotes to Note:

In discussing the status of C620 and BT/Siemens software development with various senior Crossrail staff the following comments were made, any one of which would be raise a red flag with respect to level of confidence and support the need to have adequate time risk provision in the schedule.

- “As it stands at this moment, it does not appear that the Train [software] and testing will not be fully completed by 21 October”
- “The signalling software (C620 + BT) design is the most complicated signalling software system ever designed”
- “The “Train” is first of a kind and is not an out of the box system”

- **#3 Tunnel Ventilation (C610)**

- Installation & Migration from TTVS to PTVS, Bond Street (WTH), Stepney Green
- Integration testing of Vent Systems with SS&Ps

Physical works, with the exception of BOS have essentially been completed and Phase 2.2 and 2.3 testing is ongoing. The volume of testing left to complete is significant as a result there is a risk that Routeway and SS&P completion work has not fully recognised potential interface impacts.

I believe that migration plans from TTVS to PTVS need more detail, especially at STG where there is a volume of work left to complete after the temporary vent system has been de-commissioned

Following are some comments and observation supporting my views noted above:

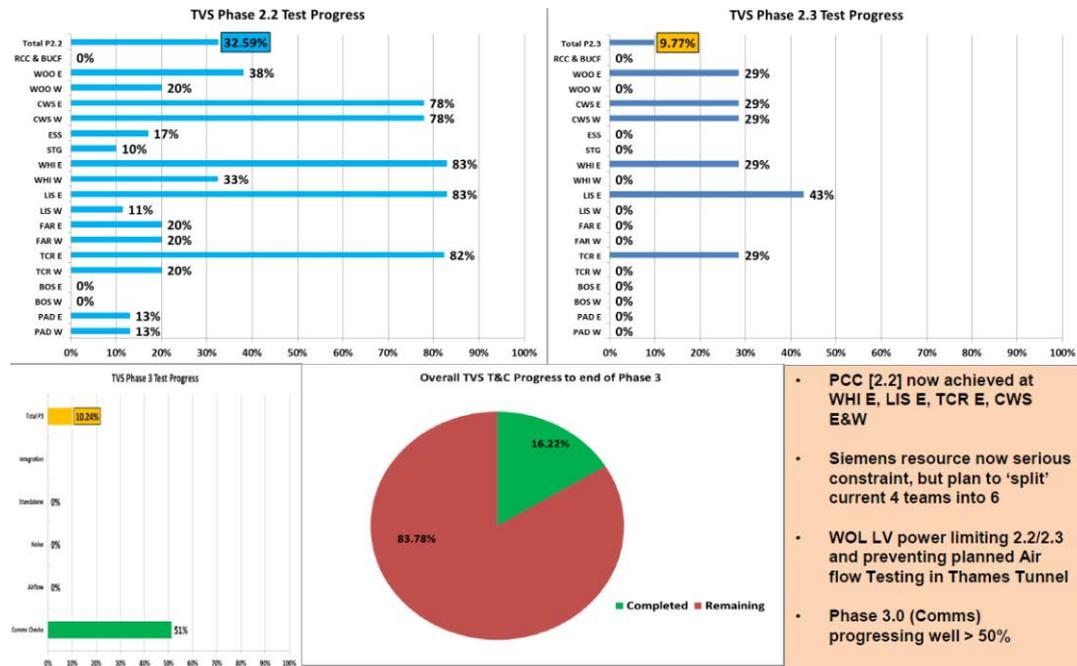
Migration from TTVS to PTVS:

- Migration is required at BOS, FAR and STG.
- The final migration (at STG) is triggered by the step down in trains (22 to 7 trains) at the start of dynamic testing (5/2 working).
- After this final migration, removal of temp vent at STG is expected to take about six weeks after which completion of STG works can progress, this is expected to take a further 12 weeks.

Integration Testing Vent Systems with SS&P:

- With the exception of BOS installation works are essentially complete.
- The lack of permanent power has impacted testing progress.
- The volume of testing to go is significant.
- I do not believe that the impact of vent system testing on “other” routeway and SS&P works has been fully recognised in the contractors’ schedules (the plan for Phase 3 integration testing with SS&P is not clear and there is a risk that the time required could be an issue)

The chart below shows status of Ventilation System Phase 2.2 and 2.3 testing, currently 16.2% complete:



- **#4 Radio (C660)**
 - GSM-R (for 5x2 Dynamic Testing)

GSM-R Radio testing required to support the start of 5x2 Dynamic testing continues to slip (from 15 October to 1 November in the last week). GSM-R testing resources have been dedicated to these works at the expense of progressing works in SS&Ps.

The completion of all C660 Phase 3 testing is currently critical path to achieving handover of SS&P. These works are resource constrained.

Physical Quantity Installation:

- GSM-R routeway completion of testing continues to slip, from 15 Oct to 1 Nov in the last week. As Radio testing resources are the limiting factor and as a result of them being dedicated to these works, slippages impact the date that SS&P testing will recommence.
- Reasons for the slippages can be attributed to three factors:
 - Primary: the lack of testing resources.
 - Secondary: the physical work not actually being complete despite IRN notice.
 - Thirdly: issues discovered during testing done to date.

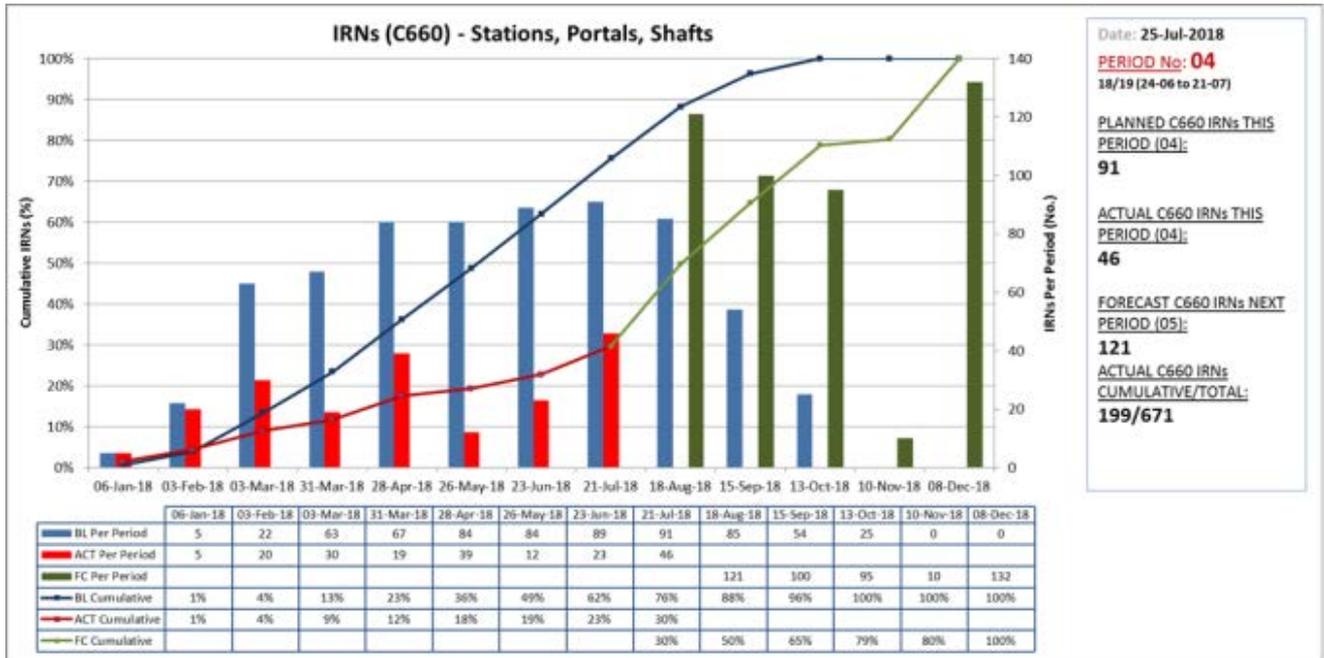
Plan Going Forward:

- Current T&C resources 16 (actual in place 8), there is an anticipation that a further increase to 22 can be achieved. A level of 22 testing resources will resource limit progress of the works.
- GSM-R Routeway will be number one priority for this resource thru the end of October at which point these resources will transition to Radio T&C works in SS&P.
- The impact of this approach is that SS&P radio testing will move the range of Radio testing completion dates from End November 2018 thru End of May 2019.

Significance of Radio systems:

- SS&P Handover or Staged Completion cannot be accomplished without radio and SCADA Phase 3 testing completion.

The C660 IRN chart and table shown below illustrates to slippage in SS&P prior to resources being redeployed to Routeway and the volume completed to date:

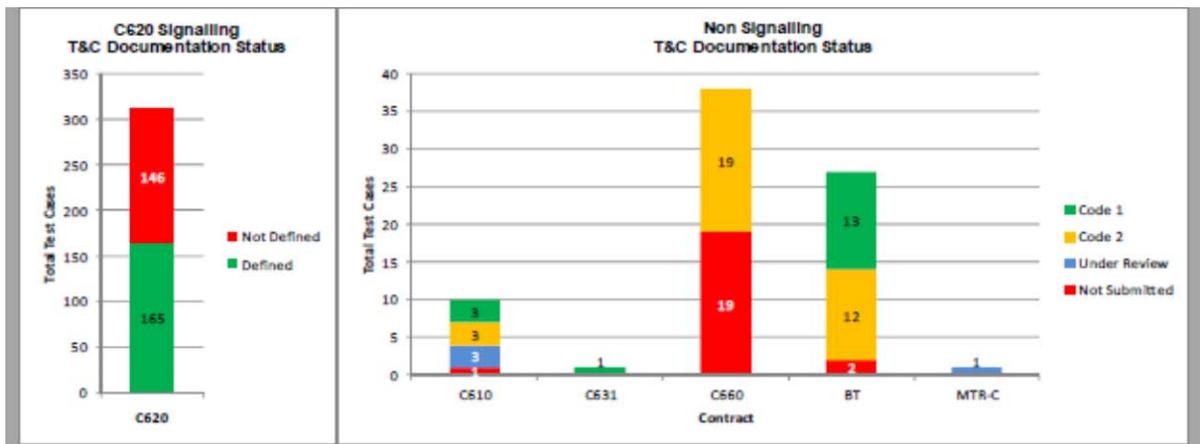
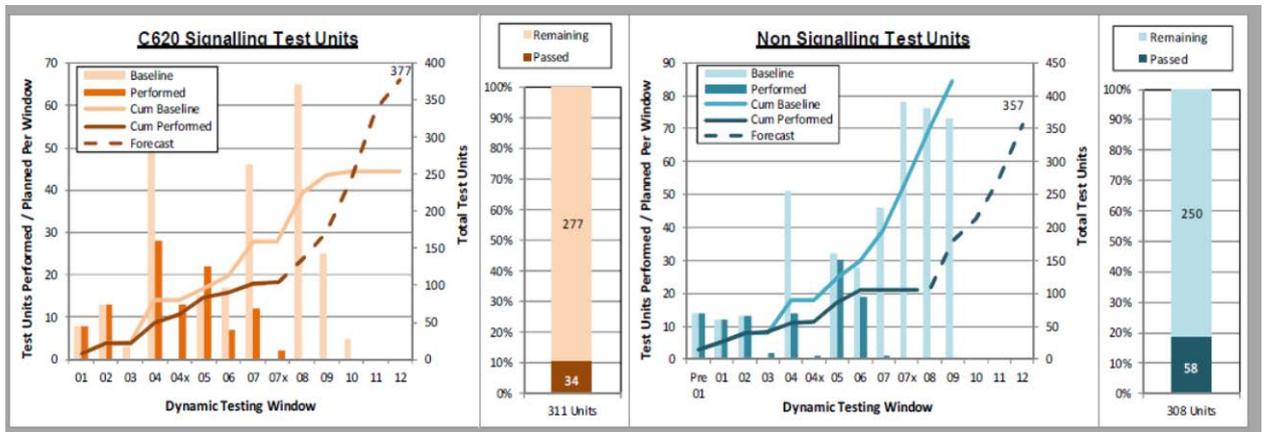


T&C % Complete		
Breakdown	% Complete	Weighted % complete
Stations	8%	5.60%
Shafts and Portals	24%	4.08%
CPs	7%	0.21%
Other	52%	5.20%
Overall % Complete		15.09%

- **#5 Dynamic testing**
 - Software Development & Integration (C620 + BT)
 - Signaling Testing + Transition Testing
 - Site Specific Tests, PSD, DOO, PTI

(See section 2. Above for comments and assessment of Dynamic Testing status and issues.)

The two charts included below provides a picture of the slippages to date with respect to C620 signalling testing in Dynamic Test windows. Progress has been well below that planned and recovery forecast appears optimistic.



- **#6 HV Non-Traction Power (C650)**
 - Energisation of LV Boards (via C650 HV Power)
 - Completion of SS&Ps T&C
 - Tunnel Vent T&C @ PAD, BOS, TCR, FAR, LIS

There has been significant slippage in energisation of HV Non-Traction Power. The MOHS schedule for completing energisation was 1 July 2018 and is now forecast for 14 September 2018. The slippage has introduced some impact to Ventilation testing. Provided the current forecast date is achieved HV Non-Traction power will not be a critical path item.

Following are some comments and observation supporting my views noted above:

- C650 had been unable to forecast energisation dates for PAD, BOS, TCR, FIS and FAR, these dates are now available.
- Critical resource shortage (cable installation, cable jointing, terminations) currently under review by ACJV.
- The non-availability of permanent power has impacted Phase 2.2/2.3 testing for SS&Ps and Tunnel Ventilation
- The current forecast is to complete energisation by 14 September to HV board. The schedules, reports and trackers support this forecast (This was planned in the MOHS for 1 July, as result of the slippage there has been impacts to testing).

- **#7 Traction Power (C644)**
 - PML ATFS Stage 2 Works

At this stage Traction Power is no longer considered to be a critical path driving item. Past slippages have been lengthy, but it appears that final testing and the balance of minor physical works can be completed in accordance with current forecasts.

Following are some comments and observation supporting my views noted above:

Traction Power:

- The physical works are essentially complete.
- Testing (Phases 2.2, 2.3 and 3.0) ongoing and forecast to complete by 27 October at PML.
- There is potentially an issue with approximately 10 OHLE switches, and there could be a replacement lead time impact of up to 12 weeks if replacement switches were found to be required.

Schedule Requirements for Traction Power are:

- Provide resilience for 5x2 Dynamic Testing
- GE main line Power Upgrade
- Crossrail Stage 4

- **#8 SCADA & Comms (C660)**

- SS&Ps (Phase 3 Integration for L&E, Monitored Doors for Staged Completion)
- PAVA & CCTV (for Staged Completion)
- LFEPA Radio (for Staged Completion)
- Systemwide (Fire Mains, Tunnel Drainage, Lighting & LV)

Completion of SCADA Phase 3 testing is a major factor that will ultimately determine SS&P Handover Dates. Currently planning for these works is being resource re-stricted resulting in forecast completion dates much later than that required to support the schedule. To date actual achievement rates of installation have been low and as yet there is no evidence of improvement.

I would recommend that a forensic analysis of the process from completion of the works thru completion of Phase 3 testing be conducted to identify pinch points and develop process improvement solutions.

In parallel to the initiative to identify process improvements a second initiative to significantly increase recruitment of SCADA testers is required. SCADA technology is widely used outside the rail industry and efforts to bring in resources from world-wide sources (including North America) is required. Part of this initiative will require designing and deploying appropriate training courses.

Following are some comments and observation relative to the status of the works and perceived issues:

- Volume of Work:
 - The volume of SCADA testing still to be done is significant
 - To date actual achievement rates do not show signs of improvement
- SS&P Handover and Staged completion cannot be accomplished without radio and SCADA Phase 3 testing having been completed.
- Stations are generally not completing I/O schedules and are not supporting progress of SCADA testing.
- I/O schedule production: STG, MES, Limmo and FIS are in good shape
- The completion of SCADA testing is currently being forecast to extend to early June 2019 as a result of anticipated testing resource limitations.

SCADA Testing Process and Resources, Step Change Required

There is a need to realise a step change in the forecast delivery rates for SCADA testing. To achieve this objective a two-pronged initiative is required

- i. The work process needs an end to end review. Works even when resourced are taking an extended time period to accomplish, the reasons for this are not clear at present.
- ii. Extraordinary steps are required to recruit, train and deploy a significantly increased the level of testing resources:
 - **World-wide Recruitment:** during August and September.
 - **Develop a Training Programme:** ready to begin training in October and November.
 - **Deploy an Increased Level of Resources:** Target to begin deployment to production work faces by December 2018.

- **#9 SS&P Completion**
 - Stations - BOS, LIS, STG, WHI (Risk), CWG
 - Installation of C660 Assets @ **All** stations (IRNs)
 - SOR Integration
 - Fire Systems Completion & Integration
 - LV Board IRNs

My assessment is that stations completion is not on the critical path but the schedule for these works have too little terminal float. As such focused efforts are required to achieve earlier completion dates and increase the available float (as noted in earlier sections successful Radio and SCADA initiatives have the capacity to support this objective).

Following are some comments and observation relative to the status of the works and perceived issues:

Stations:

- BOS, WHI, LIS and PAD all have significant physical works to complete as well as the majority of their Phase 2 and 3 testing.
- TCR, FAR have less physical works to complete but have the majority of their Phase 2 and 3 testing.
- Staged completion dates were established of for stations in an effort to focus attention to delivering stations that could effectively be used for RfL and LuL familiarisation.
- The scope of work currently being delivered as “SS&P staged completion milestones” appears to be diluting to an extent that they are less meaningful.
- Stations are not completing O&M Manuals in accordance with the plan, there appears to be O&M manual development process issues that need to be identified and addressed to break the log jam.
- To a great extent assurance “paperwork” is being planned post Stage Completion, there is a risk that the time required to complete this has been under estimated.
- Effectiveness and need for staged completions should be re-visited. Undoubtedly the dates provide focus to the contractors, however based on my assessment of the status of work they may be too early and leave too much physical work and testing to be completed. Exceptions to this appear to be WOO and WHI where some form of Staged Completion, may be advantageous.

Shafts and Portals:

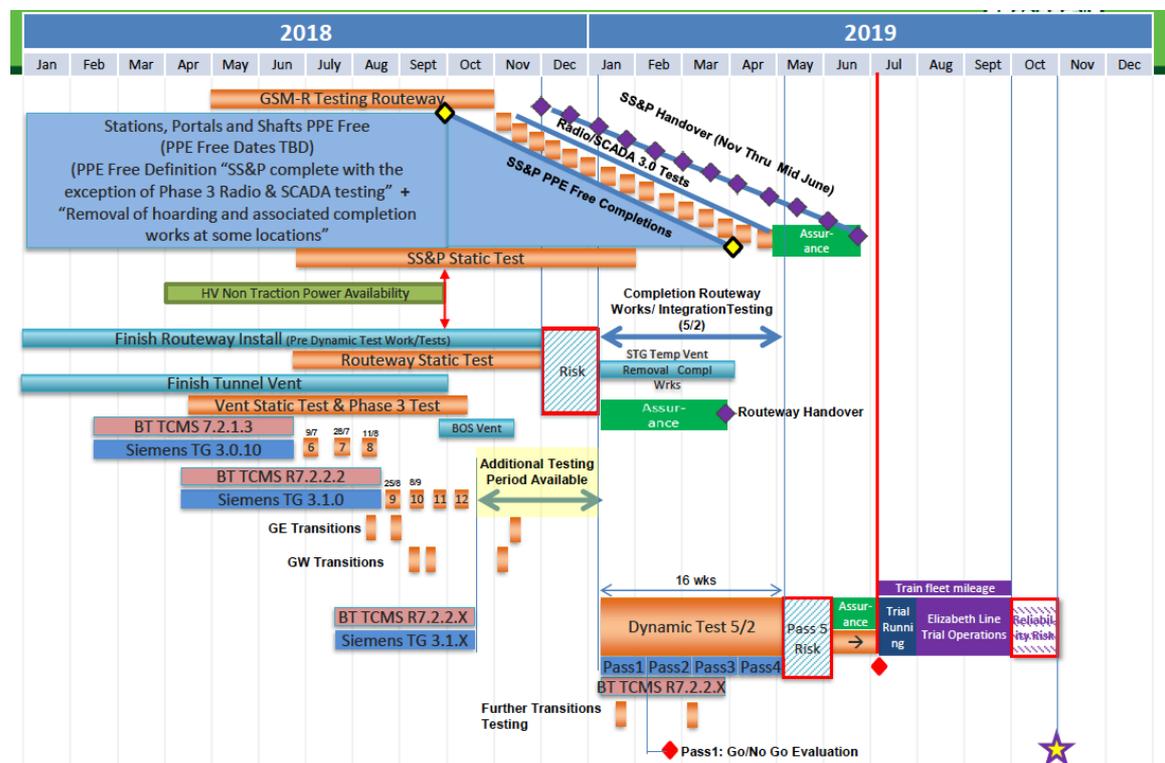
- Generally physical works are substantially complete, except STG where completion of works is reliant on removal of temp vent systems which in turn is reliant on the reduction in construction trains in the routeway post the start of 5x2 Dynamic Testing.
- T&C not progressing at planned rates.

5. Independent Review Analysis of SS&P and Routeway Completion

The chart noted below shows a summary of my assessment of the likely critical path up to and post the start of 5x2 Dynamic Testing and subsequent Trial Running and Trial Operations activities. In addition, it depicts a high-level summary of the likely completion of SS&P.

Further detail of the analysis supporting this summary is contained the three charts following this overview.

Overview of Assessed Schedule of Completion and Testing Works (MOHS)



Explanatory Notes:

SS&P: Based on my assessment of "PPE Free" dates for SS&P there is a range of completion dates from end of September 2018 through the end of March 2019. (The definition I have used for the "PPE Free" milestone is explained below)

After these completion dates I have shown assessed completions for Radio, SCADA testing and associated assurance. These completion dates are resource restrained, however as noted in earlier section of this report I have described SCADA and Radio testing recruitment initiatives that I believe can improve the completion of these works from the end of June 2019 to mid April 2019.

Completion of Routeway: based on the current status of work, analysis of contractors projected “to go” installation rates and historical performance I can see a case for these works being completed by the end of November 2018. However, I am concerned that an end of November date for the completion of these works would not adequately provide for the interface disruptions that have occurred and are highly likely to continue to occur. As a result, a completion date that would have a high level of delivery confidence would in my view be the end of December 2018. I do recognize that when setting this date, a balance needs to be struck between completing all of the work and alternatively moving some of the work into the less efficient 5x2 Dynamic Testing regime.

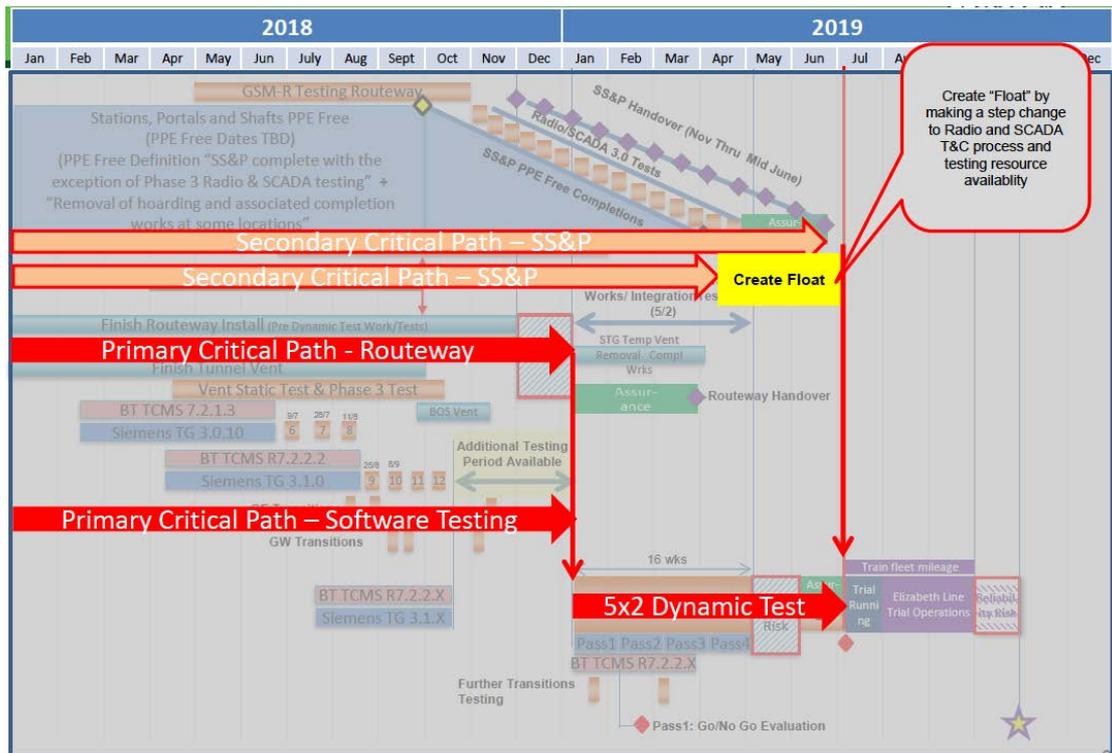
BT and Siemens Software Testing: as I have stated earlier in this report a clear and definitively substantiated plan for these works does not exist. I have little confidence that the BT and Siemens currently forecast that the software release and testing schedule will achieve the 30 September inclusive of full Melton testing. I doubt, based on slippages that have occurred, complexity and the need to fully complete Melton testing that even the later date of 21 October 2018 is at risk. My view is that by delaying the start of 5x2 Dynamic testing to 7 January 2019 an additional time window will be created that will provide the opportunity to achieve full Melton testing.

5x2 Dynamic Testing: I believe that the current four-pass, four-week DT testing plan does not provide adequate time risk provision and as such I recommend that a fifth four week pass risk provision be added. It should be noted that by completing the full testing regime at Melton prior to commencing 5x2 Dynamic Testing the four-pass plan will be de-risked to some extent.

Trial Running and Trial Operations: the durations for these activities appear appropriate however I would recommend that the suggested four- week risk allowance for Reliability risk be retained.

Primary and Secondary Critical Paths:

In effect there are two Primary Critical paths leading to the start of 5x2 Dynamic Testing (Routeway completion and Train Software testing at Melton). There is also a secondary path with a limited amount of float, the completion of SS&P. The level of float in this path could and should be increased to mitigate the risk that the completion of these works become critical to the opening of the railway.



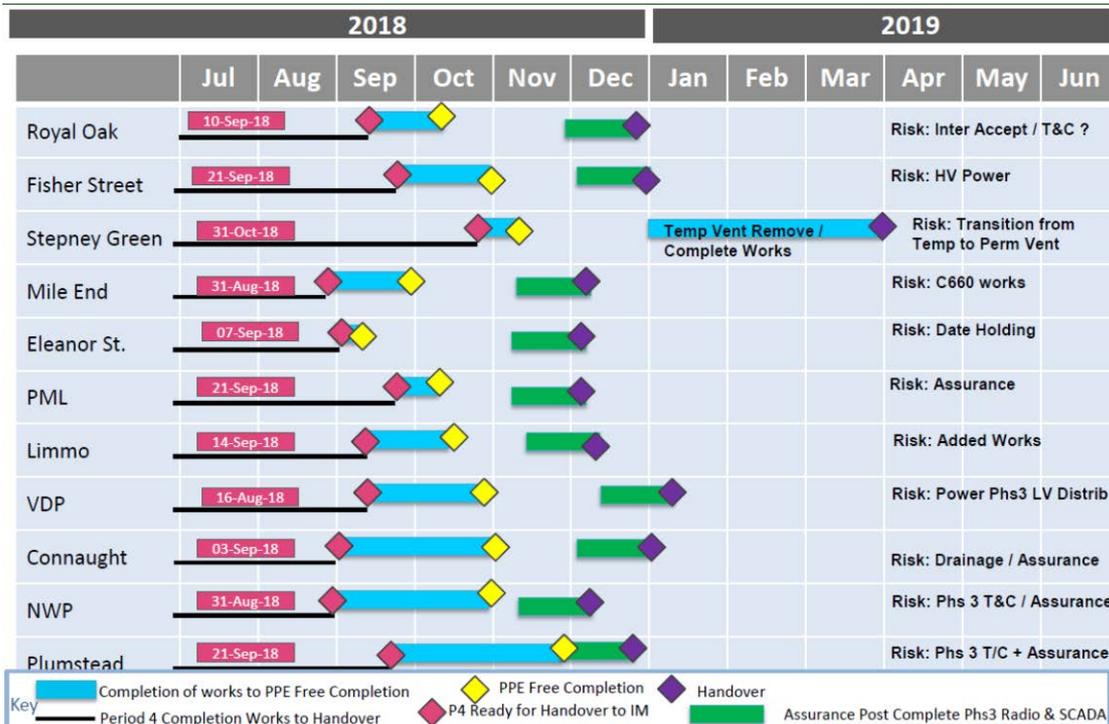
Forecast PPE Free Date for SS&P

For the purposes of this analysis the following definitions have been used for milestones

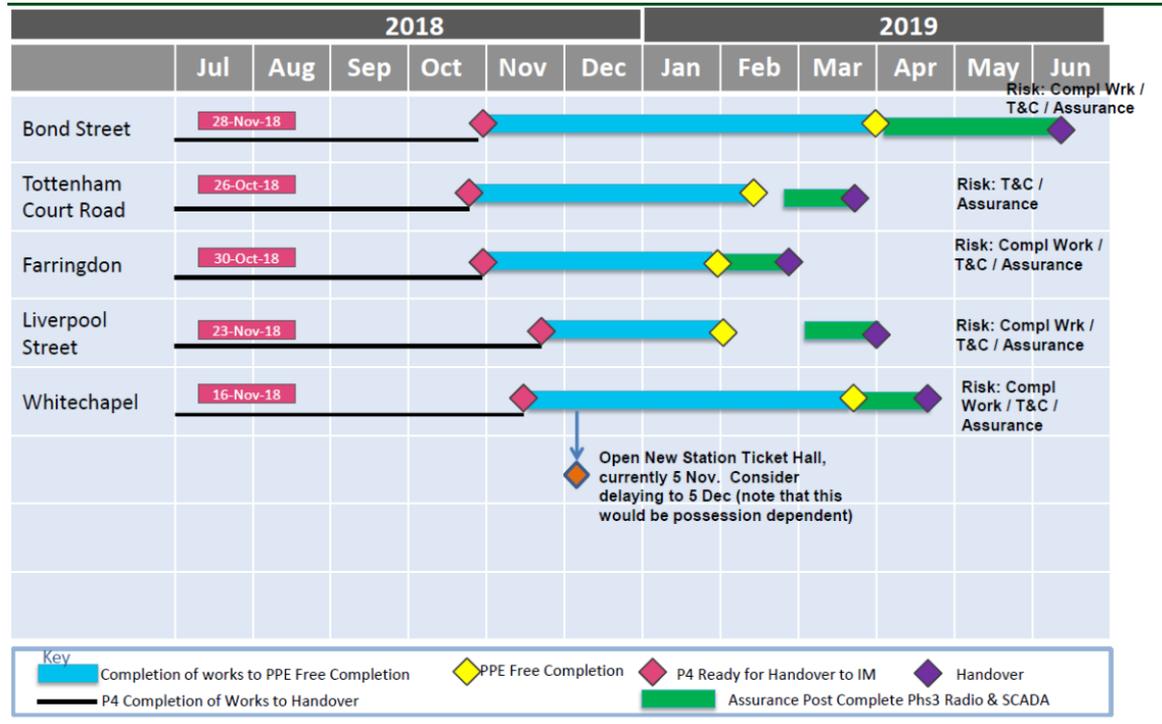
- ◆ P4 Ready For Handover: milestone dates as reflected in Period 4 update
- ◆ “PPE Free”- “SS&P complete and tested with the exception of C660 Phase 3 (including Radio, SCADA, CCTV, etc.) testing” and “Removal of some hoarding and associated completion works”
- ◆ Handover – 100% of all handover requirements are complete, including all as-builts and O&Ms at Code 1, all asset data. Full handover of all operational and maintenance accountability

Assessed Schedule of Completion Dates for SS&P

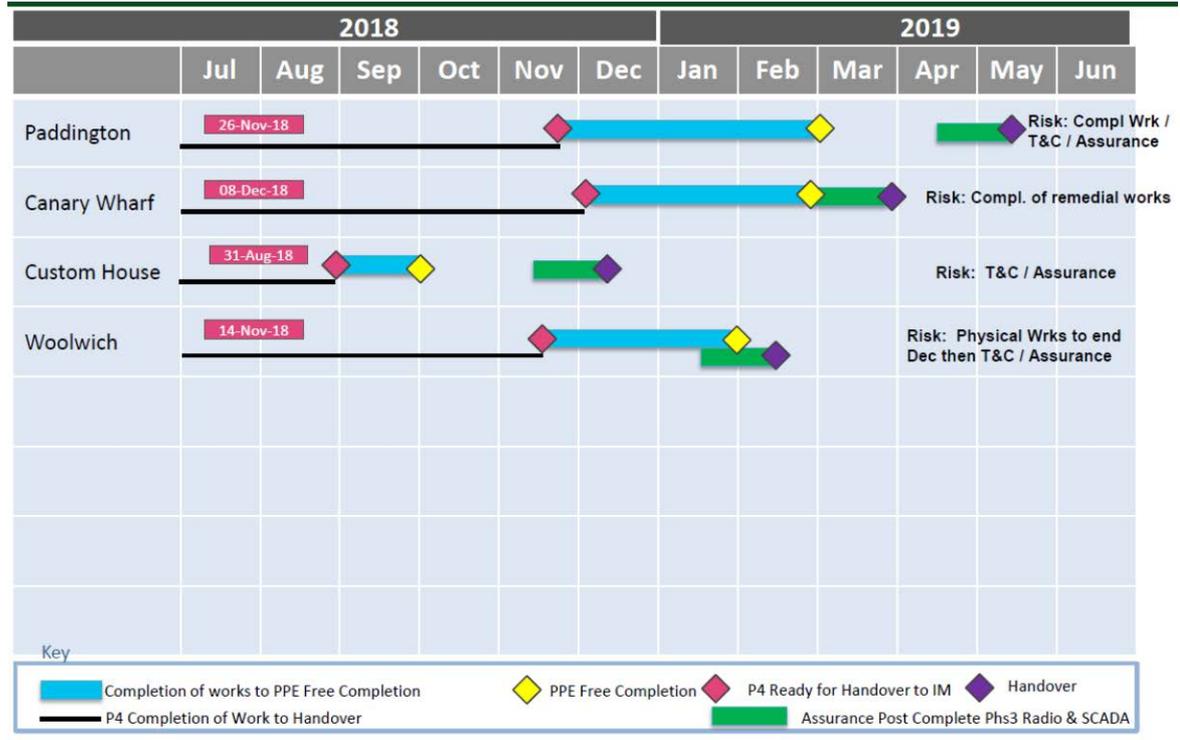
Portals and Shafts



RfL Stations



LuL Stations



6. Trial Running and Trial Operations

Durations and plans for tests to be conducted during Trial Running and Trial Operations have been developed. The durations that have been allowed in MOHS (9 weeks) for these two activities seem appropriate based on the scope of the plans that have been developed. The MOHS “Current View” included, as noted in section 3 of this report, suggests a need to include a four-week Reliability risk provision to be included immediately following the completion of Trial Operations. I believe that an allowance of this nature would be prudent.

Comparison of Trial Running and Trial Operations Durations:

	Trial Running	Trial Operations	Total Duration
Original Schedule	5 weeks	13 weeks	18 weeks
Current MOHS	3 weeks	9 weeks	12 weeks
Detailed Plans (RfL)	3 weeks	9 wks + 1 wk shadow running	13 weeks

Trial Running:

The original duration for Trial Running was 5 weeks. With the 5-week original schedule there had been a potential to shorten the duration and move some of the trials into the trial operations period. With the shorter duration it is unlikely that any further reduction in duration will be achieved.

Trial Operations:

The MOHS has a duration of 9 weeks for Trial Running. The detailed plans that have been developed by RfL are currently planned over a 9-week period plus one week for "Shadow Running" making a total of 10 weeks. A total of 110 trials plus one week of "Shadow Running" has been planned.

The plan of trials has been prepared supported by defined tests:

- Desktop Trials = 58 Trials
- Live Staff Trials = 41 Trials
- Live Volunteer Trials = 11 Trials (time sensitive trials utilising 1000 volunteers each trial)

Trials are planned over two shifts, one shift (night) available for works.

The 9-week MOHS duration, although one week shorter seems achievable and appropriate.

Service Reliability:

The MOHS “Current View” included in section 3 of this report suggests that there is a need to include a four week “Reliability” risk provision in the critical path, immediately following completion of Trial Operations. I believe that an allowance of this nature would be appropriate and prudent. I would also recommend that a bench marking analysis be carried out to substantiate the risk associated with establishing desired levels of reliability for a similar railway.

7. Response to Remit Questions

- **What confidence do you have that 21 October 2018 start of 5x2 Dynamic Testing can be achieved?**

The first critical path to the start of 5x2 Dynamic Testing relates to Routeway completion. I have a low confidence level that 21 October 2018 start of 5x2 Dynamic Testing can be achieved. Based on my assessment of installation rates and volumes of work left to complete and test an earliest completion date would appear to be the end of November, however it is my view that this date would not adequately allow for the risks relating to interface and disruption issues caused by competing interests.

In my view forecasts predicting achievement of the 21 October 2018 date are optimistic and have degraded the scope of work that will have been completed at that time, anticipating that the incomplete physical works and testing will be accomplished during the less efficient 5x2 Dynamic testing period.

Recognising that ultimately a balance between completion of physical work and testing scope and the start the 5x2 Dynamic Testing is required, I believe that the current plans lean too far to moving “completion” to the period of time that 5x2 Dynamic Testing is taking place.

The second equally critical path to start of 5x2 Dynamic Testing is the requirement to successfully and complete all of the Melton testing of BT and Siemens software to ensure that a ready to start 5x2 Dynamic Testing train is available. Based on the testing progress made to date and despite the confident 30 September 2018 completion prediction of Siemens and BT I am skeptical that 21 October will be achieved.

In establishing the balanced date to move to the 5x2 Dynamic Testing regime consideration of both routeway completion and readiness of a fully tested train be considered.

If the start of Dynamic Testing were to be delayed until the 7 January 2019 there would be a number of positive results:

- C610 and other Systemwide contractors, including C660 (GRM-R testing) would have additional time to complete and test their works to the greatest extent.
 - BT and Siemens software and testing will be provided with a similar additional period of time to ensure that the 29 Melton tests are completed prior to start of 5x2 Dynamic Testing. Completion of all Melton testing is expected to de-risk the four pass Dynamic Testing plan.
-
- **When do believe Stations Will Complete Phase 3 Testing.**

I have looked at this question from two aspects:

- When will all works be “complete” (PPE Free) except for Phase 3 Radio / SCADA testing and related assurance.
- When will all works be complete and assured.

The range of dates I have determined are shown in the table below and are noted in greater detail on the charts in section 5 of this report.

		Ready for H/O forecast at P4	Assessed Staged Completion	Assessed Handover (including C660)
Shafts and Portals	First	31 Aug 18	Early Sept 18	Early Dec 18
	Last	31 Oct 18	Mid Nov 18	Mid Jan 19
LUL Stations	First	26 Oct 18	End Nov 18	End Feb 19
	Last	23 Nov 18	End Mar 19	Mid June 19
RfL Stations	First	31 Aug 18	End Sept 18	End Dec 18
	Last	8 Dec 18	End Feb 19	Mid May 19

- **Are the durations for Trial Running and Trial Operations supported by a logical plan and defined scope of trials.**

Trial Running:

The 3-week duration for Trial Running is supported by a logical plan and defined trials that are to be undertaken. The original duration for this had been 5 weeks at which time there had been a potential to reduce the duration by carrying out some of the trials during the Trial Operations time period. The currently planned duration of 3 weeks appears appropriate but does not offer much opportunity for further time savings.

Trial Operations:

In overall terms the current duration in MOHS for this activity is 9 weeks versus the 10 weeks previously used in the MOHS (9 weeks plus one week for Shadow Running that is depicted in the detailed plans).

Reliability Risk Provision:

The current view of the MOHS contained in section 3 of this report included a four-week risk provision for Reliability risk that appears to be prudent and appropriate. I would recommend that a bench marking analysis be carried to further substantiate this risk allowance.

8. Other Observations

SCADA Testing:

- **Testing Resources:** unlike GSM-R radio, SCADA systems are widely used outside the rail industry (e.g. Oil & Gas, Power Generation). Crossrail should initiate a worldwide (Europe / USA / Asia) recruitment sweep to secure the resources and supervision required. The timing for this would be: Aug/Sept recruitment and mobilisation of the new resource, October / November the time frame when the new resources would be trained, December when deployment of resources could commence.
- **SCADA Completion and Testing Work Process:** a forensic review of the SCADA work process is required to identify pinch points and enable a step change in productivity: review to include quality of completed installations, production of I/O schedules and testing methodology.
- **GSMR Radio Completion and Testing Work Process:** there is a potential that, by pursuing step changes in the SCADA work processes and recruitment of testing resources, some benefits may also be realised in GSM-R radio production rates

Transition from Temp to Permanent Routeway Systems:

In general, I do not believe that the transition from temporary routeway systems to permanent systems has been planned in sufficient detail e.g.

- **Vent System:** an area of particular concern is the transition temp/perm and the impact of transition works at STG on 5x2 Dynamic Testing.
- **Tunnel Drainage:** when and how the transition from temporary to permanent pumps can be accomplished.
- **Fire Systems + Lighting Systems:** when and how will the transition be accomplished.

Areas where additional progress visibility (trackers) is required:

- BT & C620 Testing: risks, impacts of slippages, time required for fixes may not be fully recognised in forecasts
- C610 Terminations: I do not have a clear picture of C610 termination status, subsequently I have a concern in this area
- GSM-R routeway testing. Because of the critical nature of these works, re-start of GSM-R radio testing in SS&P being a critical dependency, greater visibility of progress in this area is required.
- Tier 1 contractor progress on IRN,s that support progress of C660 testing works, and that visibility of available work fronts for C660 exists.