

INTEGRATION

System Integration Management Plan

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1. Purpose

The Project Development Agreement gives CRL the role of systems Integrator for the Crossrail Programme. Systems Integration is applicable to all stages of the project lifecycle, all contracts and all work by others (e.g. Network Rail) that form part of the programme.

CRL are therefore accountable for the delivery of the integrated railway from Reading and Heathrow in the west to Abbey Wood and Shenfield in the east. This includes the integration of works carried out by others, i.e. Network Rail, Canary Wharf Group and Berkley Homes, with the Central Section Works.

Integration activities start in requirements and design and will continue all the way through construction and into testing and commissioning. At the programme level within Crossrail it can be defined as the task of detailing and apportioning the Sponsors' Requirements [1] into components or sub-systems that can be designed and built, and then bringing together these components into a system and ensuring that they deliver a safe, operable and working railway that meets the Sponsors' Requirements.

This plan describes how Systems Integration will be managed by CRL through the final phases of the project:

- Detailed systems design, including the design of Rolling Stock and the completion of station mechanical and electrical design by the D+B Contractors.
- Construction and installation, where any changes or further developments to that design are managed and their effect on integration captured.
- Test and Commissioning.

2. Scope

Figure 1 shows how this plan relates to the other Crossrail engineering strategies and plans.

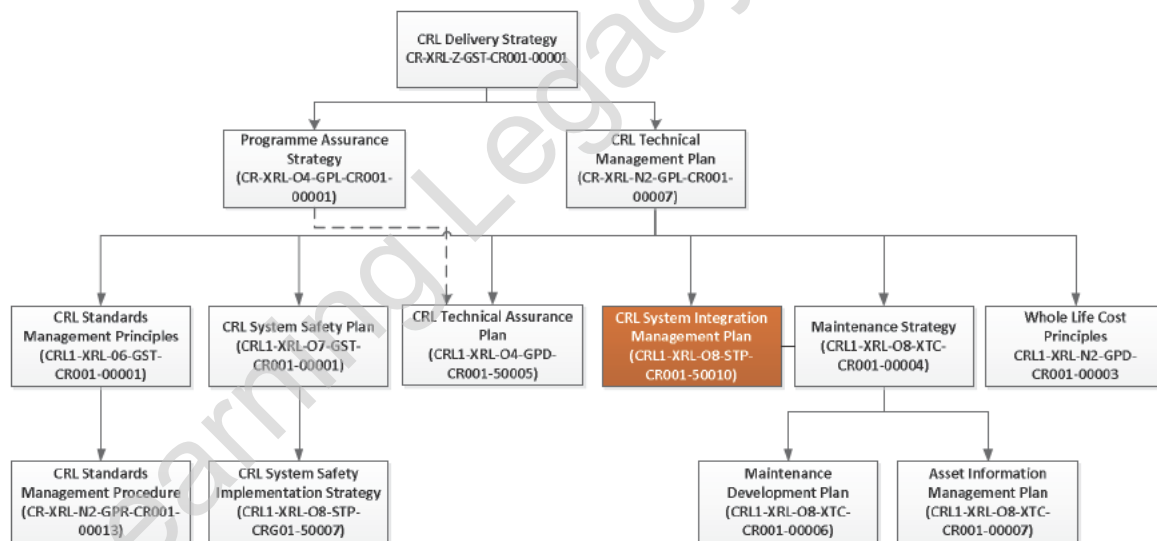


Figure 1

3. Abbreviations

Word	Explanation / Definition
COS	Central Operating Section
CPFR	Crossrail Programme Functional Requirements
CRL	Crossrail Limited
CWG	Canary Wharf Group
DCS	Delivery Control Schedule
DOORS	Dynamic Object Oriented Requirements System – a software tool for managing requirements.
EOP	Earliest Opening Programme
EMC	Electromagnetic Compatibility
FDC	Framework Design Consultant
LU (L)	London Underground (Limited)
ICD	Interface Control Document
IRS	Interface Requirements Specification
ITT	Invitation to Tender
M&E	Mechanical and Electrical
MIRP	Maintenance Integration Review Panel
NNTR	Notified National Technical Rule
NR	Network Rail
ONFR	On Network Functional Requirements
RAM	Reliability, Availability, Maintainability
RfL	Rail for London
RIA	Railway Integration Authority
RIRP	Railway Integration Review Point
RSD	Rolling Stock and Depot
SI	Systems Integration
SIRP	Systems Integration Review Panel
T&C	Test and Commissioning
TSI	Technical Specification for Interoperability

4. System Integration Approach

4.1. General

The Crossrail Programme is delivered by various entities:

- The Central Operating Section (COS) works are executed by Contractors employed by CRL;
- The Rolling Stock and Depot (RSD) Contractor, managed by Rail for London (RfL);

Other works are delivered by various Delivery Partners including Network Rail, London Underground, Canary Wharf Group and Berkley Homes;

The integration approach applies across the whole of the Crossrail Route, shown in Figure 2:

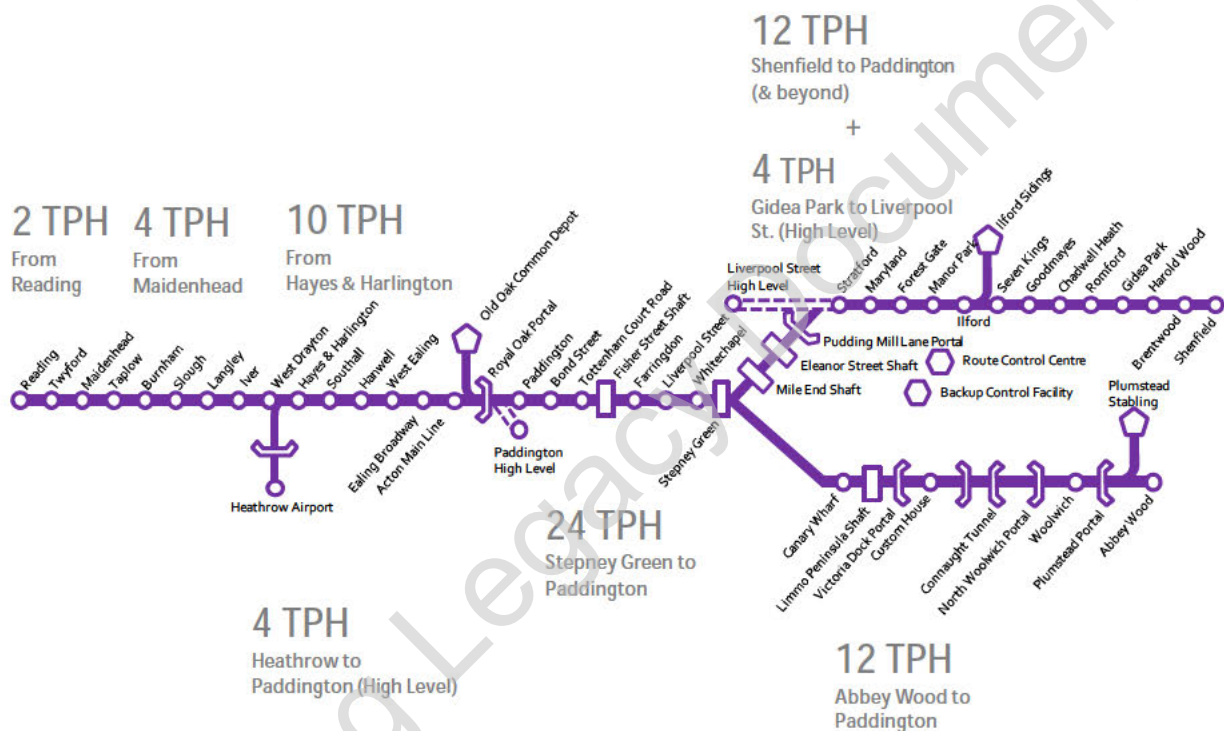


Figure 2

4.2. Requirements Management and Responsibilities

The Sponsors' Requirements have been further detailed and expressed through the Employer's Requirements:

- Crossrail Programme Functional Requirements (CPFR) [2]
- On Network Functional Requirements (ONFR)
- Maintenance Principles
- Central Area RAM Requirements
- The Undertakings and Assurances Register;
- The Environmental Minimum Requirements;
- The Crossrail New Works Standards Baseline

The Employers Requirements are further broken down into the Rolling Stock and Depot Technical Specification (RSTS) and the various Central Section designs and specifications (see paragraph 6.3). These requirements are then delivered as follows:

For the On-Network works, Network Rail will apply their own processes to demonstrate delivery of the requirements of the ONFR;

For the rolling stock and Old Oak Common Depot, the rolling stock and depot (RSD) Contractor will apply their own processes to demonstrate delivery of the requirements of the RSTS;

For the Central Section civil works and the station architectural components and mechanical and electrical (M&E) works the Framework Design Consultants (FDC) have produced co-ordinated designs that meet the Employer's Requirements; these designs will be constructed by the Contractors, who will also complete the design of the station M&E equipment and any outstanding areas of civils design

For the Central Section railway systems, the Systemwide FDCs have produced reference designs, including specifications, which meet the Employer's Requirements and have identified the appropriate space proofing within the civils design. The Contractors are responsible for completing the design and delivering integrated solutions that meet the requirements of the reference designs, including across the interfaces with other Contractors.

The finalisation of designs in line with the requirements along with effective change management will deliver the Employer's and hence the Sponsors' Requirements.

4.3. Process

CRL is responsible for putting in place processes to manage Systems Integration across the Crossrail route. The approach is different for the COS works executed directly by CRL's Contractors and those works carried out by Delivery Partners and the Rolling Stock and Depot Contractor:

- For the COS, CRL is responsible for managing and co-ordinating the relevant processes to ensure that the works delivered by the Contractors meet the requirements of the reference designs and that the Contractors are discharging their obligations to integrate their own designs and interface with each other and the relevant Delivery Partners and the Rolling Stock Contractor.
- For works delivered by Delivery Partners and the Rolling Stock Contractor, they apply their standard processes to deliver an integrated solution that meets the requirements apportioned to them by CRL

CRL satisfies itself that they have appropriate processes in place to manage the interfaces, carries out selected reviews of the design and attends the partner's own reviews. The level of review and depth of attention applied by CRL is based on the level of risk, novelty and complexity as judged by CRL.

4.4. Assurance

Assurance that integration is taking place is provided through the application of the processes described in this plan and through the application of the Technical Assurance Plan [6] and referenced documents.

5. CRL Systems Integration Management and Organisation

5.1. Crossrail Systems Integration Responsibility

The Crossrail Technical Director is accountable for demonstrating and assuring an integrated railway.

Responsibility for system integration activities across Crossrail has been apportioned across various parties and teams both within the Crossrail Client organisation, the Contractors, Delivery Partners and Infrastructure Managers.

All system integration activities collectively ensure that the rail systems, rolling stock and infrastructure combined with operations and maintenance requirements deliver a safe operational, maintainable railway that meets Sponsors' Requirements.

The distribution of responsibility across the various teams is illustrated below in Figure 3.

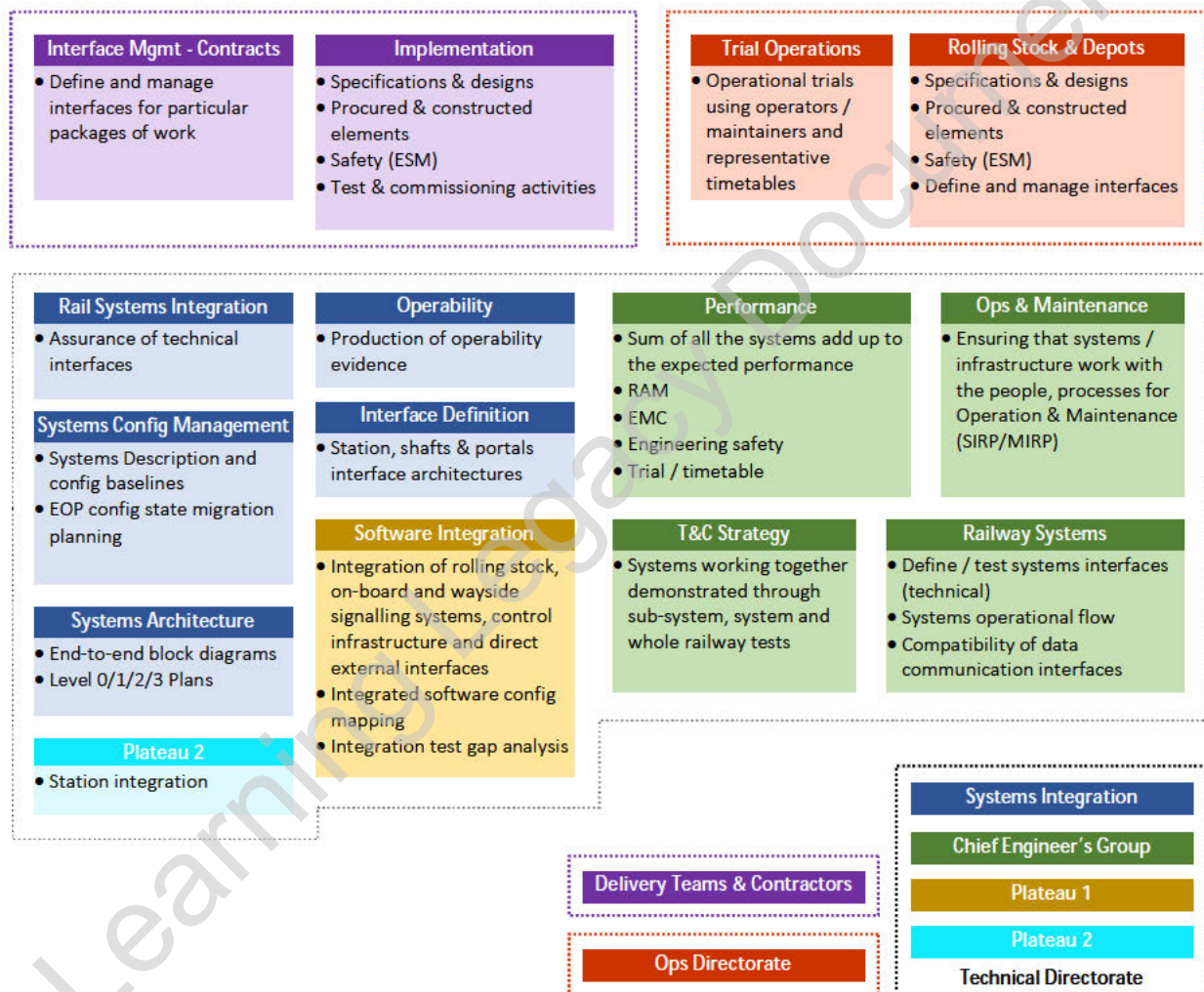


Figure 3 Systems Integration

5.2. Overarching Crossrail Responsibilities:

CRL is the systems integrator for the programme ensuring that the components delivered by these various parties integrate together to deliver a railway system in line with the Sponsors' Requirements. In this role CRL:

- Apportions the Sponsors' Requirements between the various Contractors and Delivery Partners;
- Allocates and manages scope between the various Contractors and Delivery Partners;

- Defines, monitors and coordinates interfaces between COS Contractors;
- Manages and coordinates the interfaces between the Contractors and Delivery Partners;
- Co-ordinates engineering functions that are delivered across multiple systems;
- Where necessary, ensures commonality of design across delivery partners;
- Carries out Verification and Validation activities to demonstrate a safe, operable and maintainable railway, and evidences that the Sponsors' Requirements are being delivered;
- Collates and (where necessary) adds to the assurance evidence from Contractors and Delivery Partners to produce integrated assurance evidence for the entire railway.

5.3. Systems Integration Team:

The Systems Integration Team is responsible for the overall approach to managing Railway Integration, and the following parts of systems integration:

- Management of all Crossrail Employers and Sponsor Requirements, including ownership of the Sponsor Requirements, CPFR and ONFR.
- Dissemination of requirements to the COS Contractors and Delivery Partners
- Interface management process [7].
- Definition of overall railway configuration for the Earliest Opening Programme (EOP)

5.4. Plateau 1 Team:

The Plateau Team drives collaboration and integration between Crossrail, Bombardier and Siemens in working efficiently together to identify, remove or mitigate risks to delivery of fully integrated, functional and assured signalling systems that achieve a safe and reliable railway, in line with the Delivery Control Schedule (DCS). The scope includes Rolling Stock, on-board signalling systems, related signalling and control infrastructure, and relevant direct external interfaces. All other non-direct signalling related subsystems and their integration are outside the scope of the Plateau Team.

5.5. Plateau 2 Team:

The Plateau 2 Team is takes with ensuring stations are fully integrated & functional, including:

- Station Operation Rooms (SOR)
- Route Control Centre (RCC) interfaces
- Implementation of Operability and Maintainability elements
- Assurance

The team principle is to drive greater collaboration to achieve programme and technical integration between Crossrail, Siemens, LU, RfL, and station Tier 1, 2 and 3 contractors in working efficiently together.

5.6. Delivery Teams:

The Delivery teams provide day-to-day management of the Contractors and are responsible for timely production of design and assurance deliverables including evidence that Contractors interfaces are satisfactorily met.

5.7. Chief Engineers Group:

The Chief Engineer's team assures the Contractors' Works through review and acceptance of design deliverables from Contractors [13]. The systems Heads of Discipline are responsible for reviewing and accepting evidence that the systems designs are in accordance with the Technical Assurance Plan [6].

5.8. Trials, Test & Commissioning Team:

The TT&C team is responsible for setting the testing and commissioning strategy for both the line-wide systems and the station systems. It is also responsible for setting the strategy and defining the trials to demonstrate performance and operational capability of the rail systems.

It also coordinates and reports on the routeway integration testing and station integration scenario testing through Dynamic Testing and Trial Running. These tests aim to prove end-to-end integrated performance and alignment of designs with operational and maintenance concepts.

The governance and function of the TT&C team is defined in [20].

5.9. Operations Directorate:

The Operations Directorate manage the back end of the systems integration process through the execution of Trial Operations which finally proves the end to end railway meets the sponsors requirements. They also manage the Rolling Stock and Depot contract and so provide day-to-day management of Bombardier and are responsible for timely production of design and assurance deliverables including evidence that interfaces are satisfactorily managed.

The processes applied by the teams are summarised in section 6 of this plan and a list of the detailed plans and processes is given in section 6.13.

5.10. Railway Integration Authority

The Railway Integration Authority was demobilised in 2017. Any ongoing issues were transferred to the newly reformatted Programme Delivery Board (PDB).

Due to the dispersed responsibility for integration, CRL established the Railway Integration Authority (RIA) and the supporting organisation to manage the principal risks regarding system integration.

For more detail on how the RIA was organised, see the RIA terms of reference [16].

5.11. System Integration '4 Pillar approach'

Core responsibility for design has been procured through the Contractors, who are individually responsible for demonstrating that their individual design elements meet the allocated requirements and specifications as contracted by Crossrail.

To generate evidence that the collective designs are sufficiently integrated to produce a cohesive railway system, Crossrail organises integration activities and assessments around the "4 pillars" of:

- Are the designs collectively operable?
- Are the designs collectively safe?
- Are the designs collectively maintainable?
- Do the designs collectively meet the Crossrail performance requirements?

These assessments are executed through the forums described below in sections 5.5 to 5.8 and shown in Figure 4.

Where the assessments either fail or evidence is found that configuration control has not been sustained, CRL will determine the best approach to rectify the root cause of the issue, either through instruction to Contractor to re-design or to request a change the approach to Operation/maintenance through the Infrastructure manager or train operator.

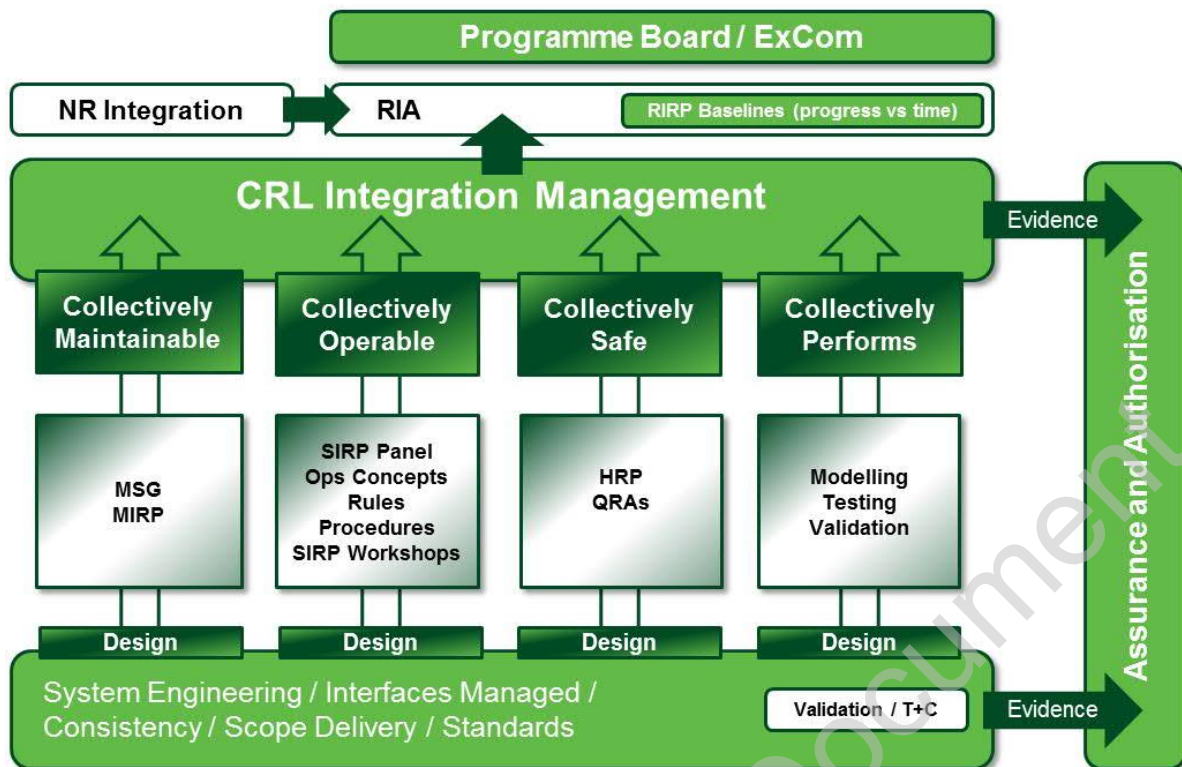


Figure 4

5.12. Integrated Programme Design Review

The purpose of the Integrated Programme Design Review (IPDR) is to:

1. Maintain an updated Programme Migration Strategy including;
 - a. Defined set of stages with clear scope;
 - b. Structured timeline plan for delivery;
 - c. Clear understanding of functionality
2. Align proposed Programme staging with revisions to the Delivery Control Schedule (DCS)

IPDR will review proposed staged delivery of programme technical elements from an Operational, Programme and Technical Integration perspective to inform updates to the programme Migration Strategy. This will make sure that all baseline configurations are updated as proposed staged handover of functionality are endorsed and built into the DCS.

The membership will ensure that the right stakeholders are involved with the decision making to allow for a coordinated transition of functionality to the Infrastructure Managers (IMs).

5.13. System Integration Review Panel

The System Integration Review Panel (SIRP) is now demobilised.

The SIRP provided risk-focussed workshop-based reviews of the designs and specifications (verification) against the Operations Concepts. SIRP also checked the alignment of the Safety Justifications with the Operational Concepts and the configuration of the completed railway.

Issues that could not be resolved were escalated to the PDB.

5.14. Maintenance Integration Review Panel

The Maintenance Integration Review Panel (MIRP) workshops are now demobilised.

MIRP provided risk-focussed reviews of the designs and specifications against the collected designers' Maintenance Plans and the Infrastructure Manager's maintenance delivery plans. The workshops were co-ordinated by the Maintenance Steering Group (MSG)

Issues that could not be resolved were escalated to the PDB.

5.15. Performance and System Modelling management

CRL collectively manages a number of system models and simulation tools. The responsibility for the deployment of these tools lies with both CRL and the relevant Contractors.

Crossrail co-ordinates the deployment and configuration of the suite of models through the Crossrail Performance Steering Group. The various models are used to demonstrate the following;

- Design Verification: that the Employer's Requirements for the end-to-end railway capacity, reliability and performance will be met by the proposed designs, including those for Network Rail, the COS and other delivery partners.
- Design Validation: that the above Employer's Requirements have been met by the as built designs.
- Design Change: to test the effect of proposed changes on the overall performance of the railway.

Crossrail approach to modelling is further described in the Crossrail V+V plan [5].

5.16. Engineering Safety Management

Engineering Safety Management (ESM) is applied in accordance with the Railway and Other Guided System Regulations and the Railway Interoperability Regulations through The System Safety Plan [10]. The Engineering Safety Management team is responsible for co-ordinating and delivering assurance of the safety of the railway system through implementation of this plan.

The ESM process will ensure that all hazards are identified and controlled and will be evidenced through the production of Engineering Safety Justifications (ESJs) by Contractors and delivery partners. The integrated safety assurance that an Element is safe is undertaken by CRL by the production of Safety Justifications (SJs) which combine the ESJs and any other assurance evidence required to demonstrate the top level safety evidence.

CRL will manage the co-ordination and transfer of Hazards between Contractors and also manage the integration of the safety justifications. Where necessary CRL will also produce additional justifications to demonstrate this integration. [10].

5.17. Interface Working Groups

Interface Working Groups have now been demobilised.

The primary purpose of the Interface Working Groups (IWGs) was to provide a common platform for the resolution of engineering issues at the key interfaces between new and existing Infrastructure, ensuring that impacts of design by other parties were considered and captured.

Each group ensured that interface documents were developed and agreed between CRL, the Contractors and the relevant IMs. There are eight IWGs as follows:

- NR/CRL interfaces GE
- NR CRL interfaces SE
- NR CRL interfaces GW
- Telecoms and Information Systems
- Rolling Stock and Depots
- Regulation and Traffic Management (Line-wide)
- Signalling Operating Rules and Principles
- RCC/BUFC

Each IWG was charged with maintaining the configuration of their relevant interface documents and to manage change as appropriate. Crossrail, Rail for London, LUL and Network Rail engineers and operators were represented as required. Contractors were only represented on an as-required basis.

The seven groups each reported into, and were co-ordinated by, the Interface Steering Group (ISG). Issues that could not be resolved at the IWG were escalated directly to the RIA.

This process has since culminated in Interface Control Documents (ICDs), Interface Requirement Specifications (IRs), and Detailed Interface Requirements (DIRs), and are now managed through local interface forums between the interfacing parties.

5.18. Railway Integration Review Points

Railway Integration Review Points (RIRP) and the associated RIRP process have been demobilised.

These were established in order to provide a means of measuring the progress of integration activities and that configuration of the complete Crossrail railway is being maintained.

The RIRP process for RIRP1-7 were administered through the Railway Integration Authority (Section 5.10).

The method for documenting and agreeing “defined standards” and the RIRP process are described in [15].

Learning Legacy Document

6. Systems Integration Processes

6.1. Key Processes

The key processes for System Integration are:

- Requirements Management
- Verification and Validation
- Assumption Management
- Interface Management
- Configuration Management
- System Architecture
- RAM Management
- Human Factors
- Electro-Magnetic Compatibility
- Test and Commissioning

This chapter gives details on how each process is to be implemented.

These processes are implemented into the Tier 1 Contracts through the Works Information Volume 2B Part 7 and 28, 30 and 31 for the Civils Design and Build Contracts and Volume 2B Parts 28, 29, 30 and 31 for the Systemwide Contracts.

The V Lifecycle

Figure 6 shows the “V lifecycle” in System Integration terms and shows how the various processes are applied during the lifecycle. The left-hand side of the V is the “design phase” and the right-hand side is the “implementation phase”. This cycle is repeated for each individual package and for the complete railway system.

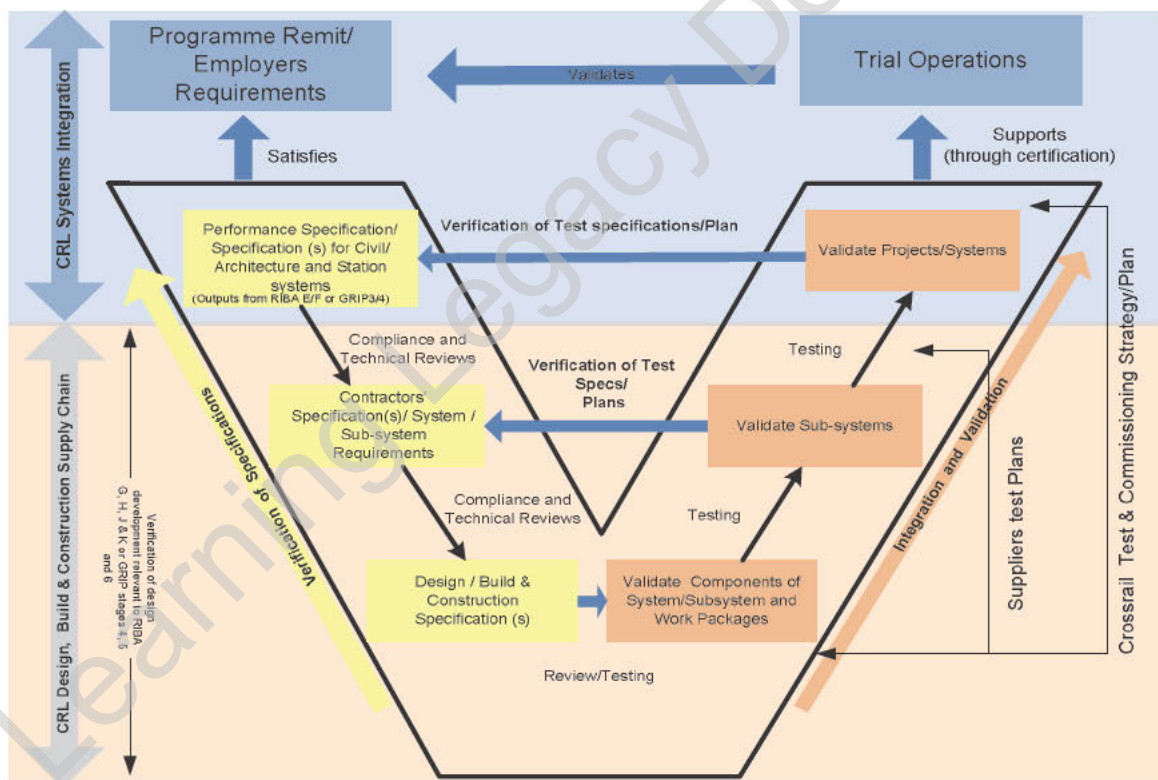


Figure 5

Requirements Management

Requirements Management process is defined in the Requirements Management Plan [8].

Crossrail Employers requirements

The Employers requirements which form the Crossrail Programme remit are depicted in Figure 6.

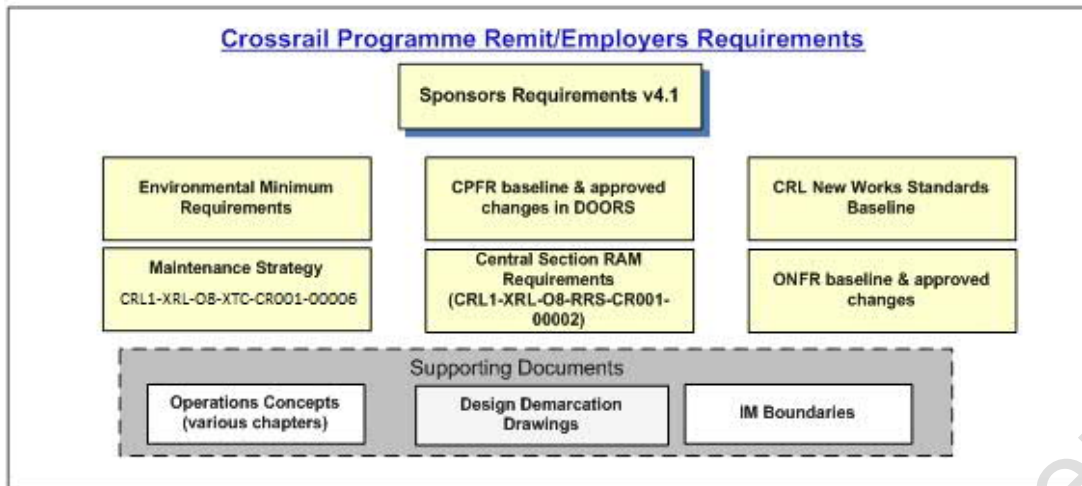


Figure 6

The key documents that define requirements are:

- Sponsors' Requirements, which contains the high-level objectives of the Programme along with the operational and service requirements for the railway.
- Crossrail Programme Functional Requirements (CPFR) and On Network Functional Requirements (ONFR) which translate the Sponsors' Requirements into more detailed 'output-related' functional requirements.
- Crossrail Environment Minimum Requirements (part of Crossrail Act)
- The Crossrail New Works Baseline which define the standards we follow
- Central section RAM requirements, Maintenance Principles and Design demarcation drawings.

Other supporting documents exist which supplement the formal requirements such as the Crossrail Operations Concepts and the IM Boundaries definition.

Secondary requirements that flow from Operations Concepts are captured in package-specific specifications and the design. Those emanating from interfaces are captured through the interface management process and recorded in the Interface Control Documents. At the Verification and Validation phases, these secondary requirements are addressed along with those flowing from the Employers Requirements.

CRL will certify that the requirements have been met through review of evidence produced by the Requirements Management process and through review of the design itself by CRL engineers.

Roles and Responsibilities

Section 6.3.1 and 6.3.2 provide further detail on responsibilities which are a summarised extract from the Requirements Management Plan

CRL (Crossrail Programme Managers and Systems Integrator)

CRL is responsible for Management of the Crossrail Employers Requirements.

The specific activities at the Programme level will be focused on:

- Elicitation of Employers requirements to meet the operational and service objectives of the Crossrail Programme;
- Analysis of any changes that affect the Employers requirements and implementation of agreed changes in a traceable and controlled manner
- Maintenance of a Requirements Baseline for a consistent design configuration;
- Apportionment of the technical requirements to projects and agreeing acceptance criteria
- Compilation of compliance evidence

- Management of requirements through a centralised Crossrail database

Crossrail Designers / Contractors

Based on a scope of work, Contractors for design, build and construction will be responsible for:

- Producing and implementing a 'Requirements Management Process' in accordance with the Crossrail Engineering Requirements Management Plan and V & V Plan.
- Producing specifications to satisfy the Programme Requirements or the Performance Specifications and Interface Requirements Specifications, and the approved changes provided by Crossrail through the change control process.
- Agreeing with Crossrail Requirements Management and Systems Integration Team, a 'Requirements Test and Acceptance' criteria for each of the functional requirements in the Performance Specifications.
- Producing a traceability matrix with the compliance statements and evidence
- Closure of all the Design assumptions with traceability to requirements/issue and action.
- Producing a compliance matrix to show compliances to the Crossrail Environmental Minimum Requirements (EMR).

6.4. Verification and Validation

The Verification and Validation (V&V) process supports the assurance function in accordance with the Technical Assurance Plan [6].

The V life cycle presented in Figure 6 shows the project life cycle. At all levels of the diagram, V&V takes place and these are more fully in the V&V Plan [5]

The designers are responsible for producing verification evidence during the design development phase and for developing the validation methodology to be applied during the implementation phase. CRL review and accept this evidence as part of the assurance process. This includes V&V of secondary requirements (see 6.3)

Section 6.4.1 and 6.4.2 provide further detail on responsibilities which are a summarised extract from the Verification and Validation Plan.

CRL (as Crossrail Programme Manager): CRL are responsible for V&V of the Crossrail Programme Requirements. The following activities will be undertaken

- Development and implementation of Crossrail Programme V&V Plan;
- Management of the Programme Requirements compliance and verification processes;
- Compilation of the validation evidences from requirements testing activities during the system integration and testing phases of the Crossrail Programme.
- Management of assurance evidences in form of V & V reports, this will be through implementation of various processes/activities

Crossrail Designers and Contractors:

Crossrail Contractors will provide evidence that the design and build elements of their contract comply with the Crossrail Programme Requirements/ Performance Specifications and the applicable standards.

Based on the Works Information (provided by Crossrail as part of the ITT Process), Contractors are responsible for:

- Producing lower level V & V plans/processes to comply with the Crossrail V & V Plan and processes;
- Ensuring independence of verification activities for safety related /critical systems;
- As far as practicable, making sure that the systems specifications are verifiable in accordance with the review and completeness criteria provided in the Crossrail Engineering Requirements Management Plan;
- Depending in the nature of specification, a compliance matrix to show compliances to the Crossrail Environmental Minimum Requirements (EMR);
- Closing all the observations raised during verification process and production of a comprehensive V & V report for approval of the Crossrail Programme.
- In an appropriate phase of systems integration, use the requirements 'acceptance criteria' to demonstrate that the requirements have been successfully tested or implemented.

CRL in its role as systems integration will define and perform the necessary tests, over and above those performed by the Contractors, to provide evidence of end-to-end system integration testing.

6.5. Assumption Management

Designers only raise assumptions if they are unable to close out issues through liaison with other designers or, failing this, through a Request for Information to CRL.

It is the responsibility of the designers to record, manage and close-out the assumptions they make during the design process. CRL will seek evidence that all assumptions have been satisfactorily closed out as part of the design acceptance process.

Assumptions related to Engineering Safety Management are managed separately by the Designers in accordance with the requirements of the System Safety Plan [10].

6.6. Interface Management

Interfaces are managed in accordance with the Procedure for Interface Management [7]

The main functions of interface management are to manage, identify, plan, coordinate, track, and facilitate the informational and material interfaces.

Once an interface has been established, the Framework Design Consultants or Design and Build Contractors, through interface working group meetings, document and agree the specification of that interface through an Interface Control Document (ICD) at reference design or an Interface Requirement Specification (IRS) at detailed design. The requirement is that each ICD or IRS uniquely identifies the interface attributes in sufficient detail to be acceptable to the interfacing parties. These interfaces may be systemic, physical, informational, programme or construction.

If designers cannot reach agreement on an interface, CRL will be notified through a Request for Information and will arbitrate and adjust contracts as necessary.

The specific requirements for interface verification during the implementation phase including functional acceptance criteria and test procedures, will be developed by the designer, consistent with the testing requirements identified during design to enable correct testing across interfaces and final integration of the systems.

The interfaces can be categorized into the following four types;

- System Interfaces
- Physical Interfaces
- Information Interfaces
- Design-for-Construction Interfaces

All interfaces and links to the relevant ICD or IRS are held within the database managed by CRL.

6.7. Configuration Management

As described above in section 6.5, any design, scope or programme changes made by a designer or Contractor that impacts an agreed interface control document shall be both communicated to and agreed by the relevant interfacing designers and Contractors.

It is not, however, always evident that a design change made and agreed by a pair of Contractors will have a resulting impact on a third-party designer/Contractor. It is the role of CRL to maintain a vigilant, rigorous checking regime whereby CRL engineers are made aware of the change that may impact their assets or location.

The required processes will be carried out by Designers/Contractors and CRL in accordance with the CRL Configuration Management Plan [3].

As described in sections 5.5 and 5.6, the SIRP and MIRP processes describe how configuration is maintained between designs and the base-lined operational concepts (and emerging rules and processes) and asset / maintenance regimes respectively.

6.8. System Architecture

CRL shall maintain the overarching (Level 0/1) system architecture, which is a diagrammatic representation of the railway, showing the various systems and their interfaces. It provides a means for visualising and controlling the configuration of the railway. CRL shall also develop and maintain a series Level 2/3 architectures for the individual elements for each station, shaft and portal.

The CRL System Architecture will be updated and re-issued as part of the evidence submitted at Final Design Overview points.

6.9. RAM Management

The Reliability, Availability and Maintainability (RAM) processes will provide evidence that the COS railway will deliver the specified service in accordance with the CRL RAM Plan [4].

For systems that contribute to the operational targets set in CPFR, CRL have developed RAM targets for the COS; these will form the performance basis for eliciting and developing RAM targets to the Design Consultants and Contractors.

The designers will demonstrate achievement of these RAM requirements through Failure Modes Effects and Criticality Analysis (FMECA) and other techniques. The results will be assessed by the RAM Manager against the RAM targets and the criticality matrices contained in the CRL RAM Plan.

For all other systems the designers and suppliers will apply standard RAM analysis techniques to calculate the performance of their products. CRL will judge the acceptability or otherwise of these against baselines derived from the railway and metro industry.

Maintainability will also be assessed in accordance with the CRL Maintenance Development Plan [11] and life cycle costs in accordance with the CRL Whole Life Cost Principles [12].

6.10. Human Factors Management

Human factors issues and risks will be identified and managed in accordance with the relevant Human Factors standards contained in the Crossrail Standards Baseline and the Human Factors Management Plan [18]. Designers will ensure their designs take into account the relevant HF requirements and CRL will co-ordinate and ensure that these requirements are applied consistently across the COS and its interfaces.

The Human Factors Integration Plan also identifies and prescribes responsibility for critical areas where additional Human Factors co-ordination needs to take place. These are predominantly locations where:

- There are areas of complex Human-Machine interaction, e.g. Rolling Stock Driving Cab
- The user, in the course of normal, degraded and emergency conditions will interface with assets delivered by multiple Contractors, e.g. Station Control Rooms, Route Control Centre

For each of these areas a Human Factors Engineering Plan shall be produced that describes design management responsibilities and the processes to be used to identify and resolve risk and issues as relevant.

All other areas of Human Factors shall follow the interface regimes as per other design and engineering functions and the ergonomics standards as contained in the standards baseline.

6.11. Electro-Magnetic Compatibility

The project Electromagnetic Compatibility (EMC) management activities will ensure that the electrical and electronic apparatus that generates Electromagnetic Interference (EMI) does not cause other equipment to malfunction, resulting in unsafe or unreliable operation and in turn is not affected by other systems that generate EMI. It will also ensure that the relevant European and British legislation is adhered to and that applicable standards are also identified and applied.

The EMC activity will identify and consider EMC sources, those impacted, media and hazards that impact the COS to ensure that compatibility is achieved within the railway and wider environment, and that all EMC hazards are mitigated (to ALARP) or eliminated.

The CRL EMC Engineer within the Systems Delivery Team will be responsible for managing EMC issues in line with the EMC Management Plan [14].

6.12. Trials, Testing and Commissioning Management

The process by which the various elements that make up the Crossrail transport system are progressively integrated together, and demonstrated to deliver the Stakeholders' requirements, is known as Integration, Testing and Commissioning. It is part of the Verification and Validation process and comprises:

- Factory acceptance of each sub-system before delivery to site, or off-site test facility (Phase 1)
- Integration of each sub-system to work with its interfacing sub-systems, making use where appropriate of off-site test facilities (Phase 2)
- Testing of each sub-system and then the integrated system to demonstrate that they meet their requirements (Phase 3)
- Dynamic Testing and Commissioning of each system to form the total railway (Phase 4)
- Trials of the railway to demonstrate performance and operational capability (Phase 5)
- Handover to the Infrastructure Managers and Operators for further trials (Phase 6)

CRL will be responsible for management of this process (up to the end of Phase 5) for the COS works, including bringing into service of the COS stations and the interfaces with other transport undertakings, notably Network Rail.

This process is further described in the Testing and Commissioning Strategy [9] which will be developed into detailed plans during the implementation phase.

This is implemented into the contracts through the Works Information Volume 2B Part 28. Contractors are responsible for demonstrating that systems within their scope meet the requirements and work together with interfacing systems.

The Trials, Test and Commissioning management arrangements covering both the TT&C team and the key responsibilities of other interfacing parts of the organisation and stakeholder community are set out in the TT&C Management Plan [20]. This plan defines:

- The TT&C principles and objectives;
- Production of strategies and plans for trials, testing and commissioning of the routeway and stations;
- KPIs and progress reporting;
- Management, planning and coordination of TT&C activities spanning station integration testing, dynamic testing, routeway integration testing and trial running;
- Interfaces with key parts of the CRL organisation, including CEG, Assurance team and Plateau 1&2 teams;
- Coordination of works by other delivery partners including Network Rail and the Rolling Stock and Depot provider;
- Engagement with key stakeholders including RFLI, MTREL, LU, and Network Rail; and
- TT&C organisation and governance arrangements.

6.13. Final Design Overviews (FDO)

In accordance with the CRL Technical Assurance Plan, CRL will produce and submit a Final Design Overview (FDO) report and certificate for acceptance by RfL and LU for each component.

A component may comprise a station, shaft, portal or system. See the reference Final Design Overview Process [19].

CRL will demonstrate the following, in order to deliver an integrated design:

Safety

CRL will demonstrate that the component is safe in compliance with S1538 clause 3.17.1 e). The CRL Engineering Safety Management process and activities will form an integral part of the FDO process. Assurance will be evidenced through the production of a RAB C accepted Interim Safety Justification (ISJ); following LU and/or RfL/MTR acceptance of risk control actions at Hazard Review Panel's (HRP) - for the integrated component.

Maintainability

System Integration Management Plan
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CRL will demonstrate that the component is maintainable in compliance with S1538 clause 3.17.1 p) through the production of a CRL Holistic Maintenance Plan (accepted by LU/RfL) for that component that is jointly produced with LU/RfL and refers to the LU/RfL Maintenance readiness plan. Closure of all issues identified through the MIRP process will be included within the Holistic Maintenance Plan.

Operability

CRL will demonstrate that the component is operable in compliance with S1538 clause 3.17.1 k) and in accordance with the (LU/RfL/MTR produced) Operational Concept and/or evolved use cases for that component and closure of all issues identified through the SIRP process. The demonstration of operability through the output of the SIRP process will be captured in Statement of Operability Assessments covering each COS station, routeway assets and Plumstead sidings.

Performance

CRL will demonstrate that the component meets the Sponsors/requirements performance.

The purpose of the FDO process is to achieve Compliance by obtaining acceptance of the Design by the Infrastructure Managers.

Learning Legacy Document

7. References

Ref:	Document Title	Document Number:
1.	Sponsors Requirements	CR-XRL-O6-GPD-CR001-50002
2.	Crossrail Programme Function Requirements (CPFR)	CRL1-XRL-O8-RSP-CR001-50015
3.	CRL Configuration Management Plan	CRL1-XRL-Z3-STP-CR001-50006
4.	RAM Plan (Reliability, Availability and Maintainability)	CRL1-XRL-O8-STP-CR001-50004
5.	Verification & Validation Plan	CRL1-XRL-O8-STP-CR001-50006
6.	Technical Assurance Plan (TAP)	CRL1-XRL-O7-STP-CR001-50003
7.	Procedure for Interface Management	CRL1-XRL-O8-GPD-CR001-50001
8.	Engineering Requirements Management Plan	CRL1-XRL-O8-STP-CR001-50005
9.	Project Testing and Commissioning Strategy	CRL1-XRL-O8-STP-CR001-50008
10.	Engineering Safety Management System Safety Plan	CRL1-XRL-O7-GST-CR001-00001
11.	Crossrail Maintenance Development Plan	CRL1-XRL-O8-XTC-CR001-00006
12.	Whole Life Cost Principles	CRL1-XRL-N2-GPD-CR001-00003
13.	Engineering Design Assurance Gates Procedure	CRL1-XRL-O7-GPD-CR001-50015
14.	EMC Management Plan	CRL1-XRL-O8-STP-CRG03-50003
15.	Railway Integration Review Point Process	CRL1-XRL-R-GPS-CR001-50001
16.	Railway Integration Authority	CRL1-XRL-O8-GPD-CR001-50004
17.	Crossrail Systems Integration Review Panel (SIRP) Terms of Reference & Management Procedure	CRL1-XRL-O8-GPS-CR001-50016
18.	Human Factors Management Plan	CRL1-XRL-O8-STP-CR001-50020
19.	Final Design Overview Process	CRL1-XRL-O7-GPS-CR001-50009
20.	Trials, Testing & Commissioning Management Plan	CRL1-XRL-Z-STP-CR001-50017