



# CROSSRAIL

## 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 lifecycle, all contracts and all work by others (e.g. Network Rail) that form part of the programme. Therefore, CRL are accountable for the delivery of the integrated railway from Maidenhead and Heathrow in the west to Abbeywood 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 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.

The Crossrail programme broadly follows the following phasing:

- Phase 1 - Civils and Stations Architecture and MEP detailed design and systemwide reference design by the Framework Design Consultants (FDC);
- Phase 2 - Detailed systemwide and station mechanical and electrical design by the contractors;
- Phase 3 - Construction and installation;
- Phase 4 - Test and Commissioning.

The phase 1 design was produced under the direction of the Project Delivery Partner (PDP) and integration was assured by the PDP System Integration Management Plan (CRL1-PDP-O8-TPL-CRG03-00003).

The basis of the CRL Systems Integration approach is to produce an integrated design at phase 1 that meets the Sponsors' Requirements and then to ensure that this design is built and any changes to that design during subsequent phases are managed and their effect on integration captured.

This plan describes how Systems Integration will be managed by CRL through phases 2 to 4:

Figure 1 on the next page shows how this plan relates to the other Crossrail engineering plans.

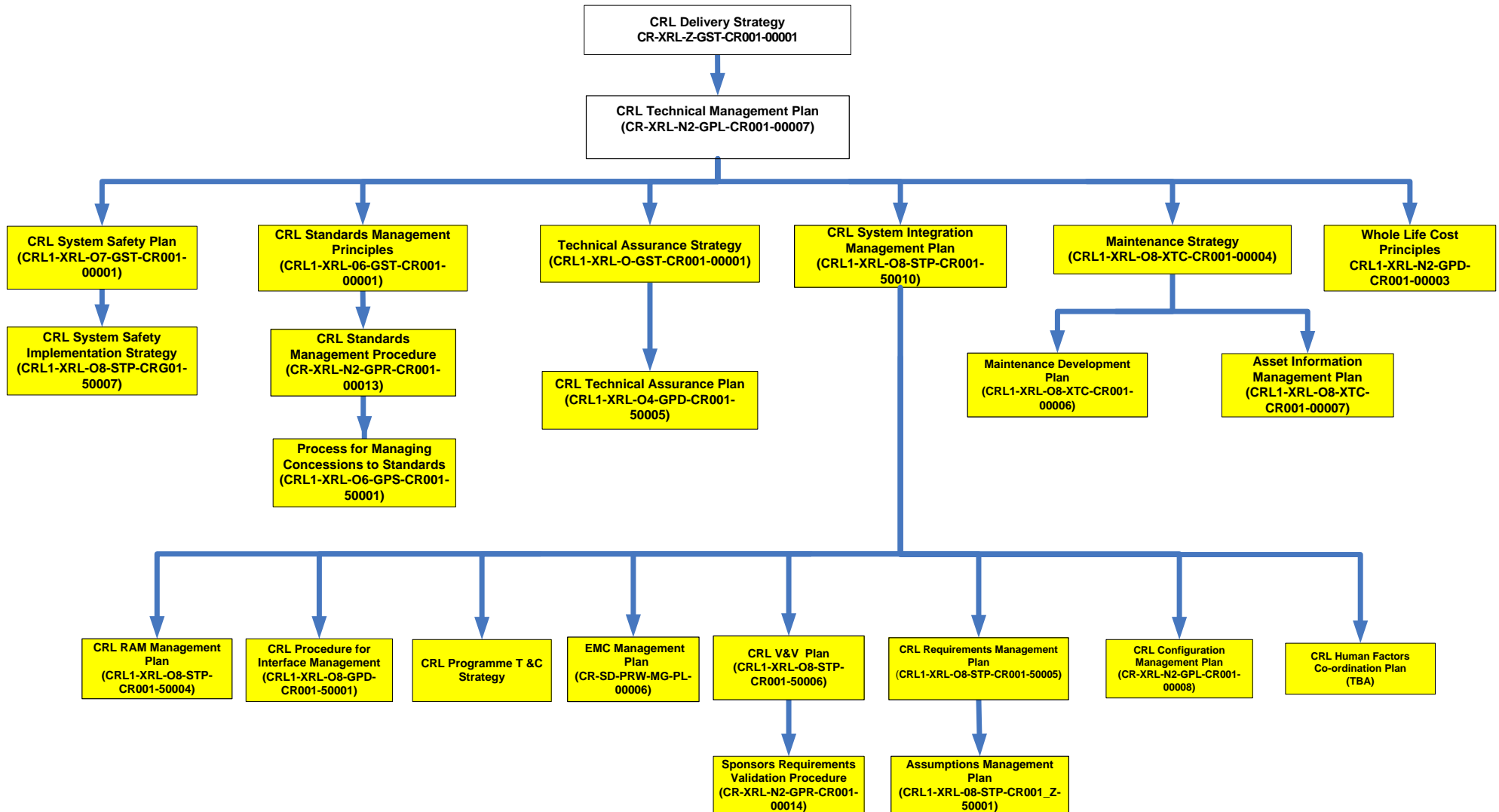


Figure 1

## 2 Abbreviations

Word	Explanation / Definition
CPFR	Crossrail Programme Functional Requirements
CRL	Crossrail Limited
CWG	Canary Wharf Group
CSW	Central Section Works
DOORS	Dynamic Object Oriented Requirements System – a software tool for managing requirements.
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
NNTR	Notified National Technical Rule
NR	Network Rail
ONFR	On Network Functional Requirements
RAM	Reliability, Availability, Maintainability
RfL	Rail for London
RIRP	Railway Integration Review Point
RSD	Rolling Stock and Depot
SI	Systems Integration
SIA	Systems Integration Authority
SIRP	Systems Integration Review Panel
T&C	Test and Commissioning
TSI	Technical Specification for Interoperability

## 3 System Integration Approach

### 3.1 General

The Crossrail Programme is delivered by various entities:

- The Central Section Works (CSW) 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 the Delivery Partners - Network Rail, London Underground, Canary Wharf Group and Berkley Homes;

CRL is the systems integrator for the programme ensuring that the elements delivered by these various parties integrate together to deliver the Sponsors' Requirements. In this role CRL:

- Apportions the Sponsors' Requirements between the various contractors and Delivery Partners;
- Allocates and manage scope between the various contractors and Delivery Partners;
- Manages the interfaces between the various contractors and Delivery Partners;
- Engineers functions delivered across multiple systems;
- Ensures commonality of design across delivery partners;
- Carries out Verification and Validation activities to demonstrate a safe, operable and maintainable railway, and that the Sponsors' Requirements are being delivered.

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

- Crossrail Programme Functional Requirements (CPFR)
- 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

These are further decomposed into the Rolling Stock and Depot Technical Specification (RSTS) and the various Central Section designs and specifications (see paragraph 5.3). These requirements are then delivered as follows:

- For the On-Network works, Network Rail deliver the requirements of the ONFR;
- For the rolling stock, 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;

- For the Central Section railway systems, the Systemwide FDCs have produced reference designs, including specifications, which meet the Employer's Requirements and have provided 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.

In summary, CRL will establish an integrated set of designs and requirements for delivery by the CSW contractors, the Delivery Partners and the RSD contractor. If these designs and requirements are delivered correctly and change is effectively managed, then the end result will deliver the Employer's and hence the Sponsors' Requirements.

Another key element is the Operations Concepts. These provide a single reference source describing how the railway will be operated. The specifications and designs are reviewed against the concepts by the System Integration Review Panel (SIRP) (see section 4.4).

The principal risks going forward are:

- Uncontrolled change leading to the loss of the integration achieved at reference design;
- Design development by the Systemwide contractors, NR and the RSD supplier, who must continue to maintain integration as the detailed design is developed.

In order to manage these risks, maintain the integrity of the requirements and resolve issues between delivery partners, CRL has established the Systems Integration Authority (SIA) and the supporting organisation described in section 4.

### 3.2 Process

The Systemwide team is responsible for putting in place processes to manage Systems Integration. The approach is different for the Central Section Works (CSW) executed directly by CRL's contractors and works carried out by Delivery Partners.

For the CSW the CRL Systemwide team is responsible for 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.

For works delivered by Delivery Partners, 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 some reviews of the design and attends the partner's own reviews.

### 3.3 Assurance

Assurance that integration is taking place is provided through the following:

- Application of the Technical Assurance Plan [7] and referenced documents.
- Review of specifications and assurance by the System Integration Review Panel (SIRP);
- Application of the system integration processes described in section 5 of this plan;
- For Civils works, Design Reviews and Gate Reviews in accordance with the Engineering Design Assurance Gates Procedure [14];
- Design Gate Reviews for Systemwide contracts, in accordance with the Systemwide Works Information;
- For works delivered by delivery partners, attendance at reviews carried out by the partner and some limited review of their design;

- The Test and Commissioning Process as specified in the Testing and Commissioning Strategy [10].

Evidence that the systems integration processes for CSW are being applied will be gathered by CRL through:

- review and acceptance of the design;
- review and acceptance of the designer's system integration plan (contained within the Design Management Plan);
- review and acceptance of the outputs of the processes (e.g. requirements capture, specifications, interface specifications, etc.);
- audit of the application of these plans and processes.



## 4 Management and Organisation

### 4.1 Role

The Systemwide Director is the Technical Authority for System Integration and has formed the System Integration Authority (SIA) to enable discharge of this responsibility.

The Systemwide Director ensures that the rail systems, rolling stock and infrastructure combined with operations and maintenance requirements deliver a safe operational railway that meets Sponsors' Requirements.

### 4.2 System Integration Authority

The SIA Panel is formed of representatives of the Systemwide Director, the Delivery Partners, the maintainers and the operators. It is chaired by the Systemwide Director.

The Panel's remit is to review Systems Integration issues which may take the form of Engineering, Operational/Maintenance or Programme/phasing integration issues. The SIA will assess their impact and make a decision as to the best way forward, thereafter monitoring progress to successful conclusion. In achieving this aim the SIA will mobilise teams from time to time to investigate particular issues and to derive a solution.

The SIA does not act as an assurance body, though it can support the needs of assurance.

The SIA will review change proposals, assessing its effect on the configuration. Any necessary change will be instructed into contract scope (including NR via the ONFR) in accordance with Project processes.

Change will be initiated and identified from a variety of sources including but not limited to:

- Changes in the Employer's Requirements
- Changes to Operational Concepts
- Changes identified in the System and Maintenance Integration Review Panels
- Design development
- Requests for Information
- Requests for Standards Concessions
- Constructability
- Response to Field Change Requests
- Changes notified through the Hazard Review Panel
- Changes from Notified or Designated bodies (Non Compliance with TSIs or NNTRs)
- Changes to the design at the interfaces between Civils, Stations, surface works and railway systems

For the majority of cases the changes will be initiated by the Systemwide teams. The teams will generate issues as a part of their day to day activities as they interface with the various stakeholders and delivery groups within the Crossrail programme. Each team has in place its own procedures and processes which allow progress to be monitored and integration issues identified. Those issues which are deemed to require escalation will be raised to the SIA.

If changes proposed by the SIA impact the programme baseline budget, programme or scope, then these changes will be initiated in accordance with the Crossrail Change Management Processes.

For more detail see [17].

### 4.3 Organisation

The Systemwide Director and the SIA are supported by four teams

- Requirements and Configuration
- Systemwide Delivery
- System Engineering and Integration
- Engineering Safety Management

**The Requirements and Configuration team** is responsible for developing the systems integration processes detailed in section 5 and assuring their implementation by review and audit. It also “owns” the Employer’s Requirements and the configuration of the design and manages change to either of these.

**The Systemwide Delivery team** provides day-to-day management of the systemwide contractors and is responsible for timely production of design and assurance deliverables. It is responsible for reviewing and accepting evidence that the designs meet the Reference Design in accordance with the Technical Assurance Plan [7].

**The Systems Engineering and Integration team** provides review of the specifications and safety justifications by the SIRP and of contractors’ deliverables by system engineers who own the “system level” and railway operations view. It manages the System Architecture, System Models, the Rail Control Centre, Human Factors and the relationships with the RSD delivery team, the Operators and the Infrastructure Managers.

**The Engineering Safety Management team** is responsible delivering assurance of the safety of the railway system through implementation of the System Safety Plan [11].

The SIA is also supported by Interface Working Groups to manage the relationship across the interfaces with NR and LU, as Delivery Partners, and the Rolling Stock Provider.

The Chief Engineer’s team also has an important role to play in ensuring integration with civil works is taking place through review and acceptance of design deliverables from contractors.

The processes applied by the teams are summarised in section 5 of this plan and a list of the detailed plans and processes is given in section 6.

### 4.4 Systems and Maintenance Integration Review Panels

The SIRP and MIRP provide a review of specifications (verification) and safety justifications (validation) against Operations Concepts and Maintenance Plans. It is made up of members of the Engineering Safety Management and System Engineering and Integration teams and will include the Designers and the Infrastructure Managers. It therefore maintains consistency between the methods of operation, maintenance and the railway as designed and built.

See [18] for more detail.

### 4.5 System Architecture

The System Engineering and Integration team will maintain the 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.

The system architecture will be updated and re-issued at each Railway Integration Review Points (see below).

#### 4.6 System Breakdown Structure

Crossrail will develop a System Breakdown Structure that will show, graphically, how all the individual elements of the railway relate to each other and will also identify the arguments that will need to be generated to demonstrate that an Integrated Railway is being delivered.

#### 4.7 System Modelling

The Systems Engineering and Integration team manages a set of system models that are used to demonstrate that the Employer's Requirement will be met as the design progresses, and to test the effect of proposed changes. See [20].

#### 4.8 Railway Integration Review Points

As a means of progressively assuring the integrated configuration of the complete Crossrail railway, Railway Integration Review points have been established at key points in the programme, these are:

Railway Integration Review Points have currently been drafted with timescales as follows:

Name	Timing	Headline Focus
RIRP 1	Q4 2012	Systemwide ITTs Issued and SIA processes in place
RIRP 2	Q2 2013	All Stations and Systemwide Contracts Awarded
RIRP 3	Q2 2014	60% System Design Reviews Complete
RIRP 4	Q2 2015	Begin Systemwide Installation
RIRP 5	Q4 2016	Stage 1 Readiness: Trains in Service on GE
RIRP 6	Q2 2017	Central Section Static Testing
RIRP 7	Q4 2017	Stage 2 Readiness: Trains in service on GW & COS Trial Running
RIRP 8	Q2 2018	Stage 3 Handover Readiness:, Passenger Service in Central Section
RIRP 9	Q1 2019	Stage 4 Readiness: Passenger Service extended to Great Eastern
RIRP 10	Q3 2019	Stage 5 Readiness:, Passenger Service extended to Great Western

At each Railway Integration Review Point the SIA, through its supporting teams, will carry out a review across all delivery partners and contractors to ensure continued alignment of scope and interfaces and that the sum of the various parts will deliver the Sponsors' Requirements. The review will assure that:

- The works will deliver the current Employer's Requirements baseline;
- The works take account of the current Operations Concepts baseline;
- The works have reached a defined standard of development;
- The interfaces between the various works are developed to defined standard;
- The assurance evidence has been produced and accepted to a defined standard.



The Railway Integration Review Points are not “stop/go” gates. The aim is to review the status of the programme and identify new integration risks, and agree any recovery actions.

The “defined standards” and the process are described in [16].

## 5 Systems Integration Processes

### 5.1 Key Processes

The key processes for System Integration are:

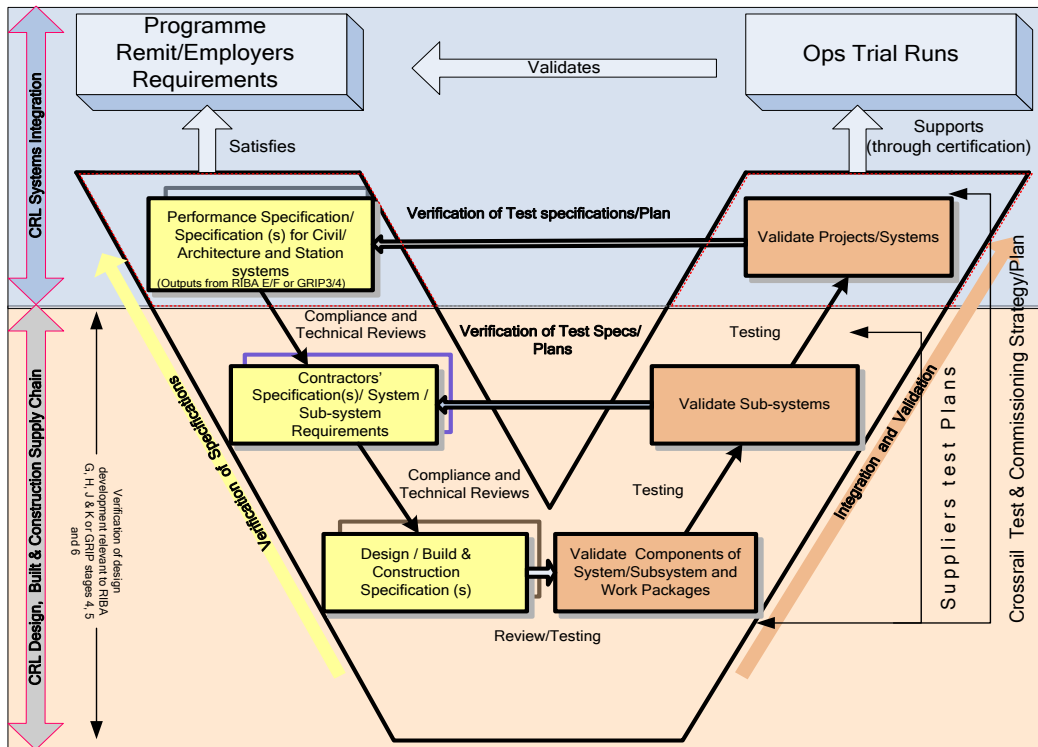
- Engineering Safety Management
- Requirements Management
- Verification and Validation
- Assumption Management
- Interface Management
- Configuration Management
- RAM Management
- Human Factors
- Electro-Magnetic Compatibility
- Test and Commissioning

This chapter shows how these processes fit with the “V Lifecycle” and 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 for the Civils Contracts and Volume 2B Parts 28, 29, 30 and 31 for the Systemwide Contracts.

### 5.2 The V Lifecycle

Figure 3 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.

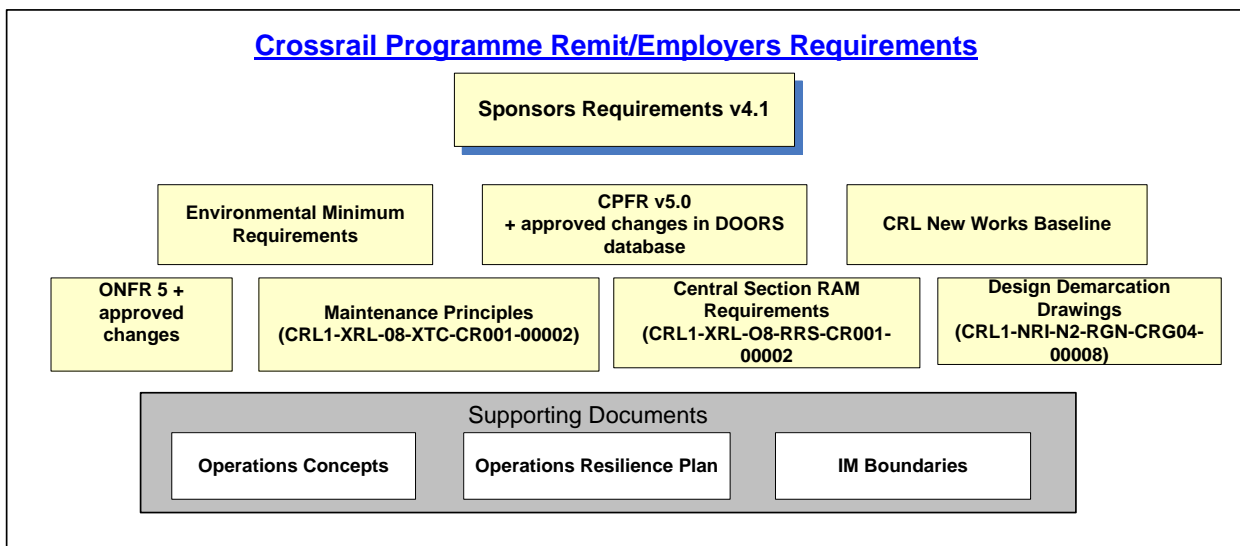


**Figure 3 The V Lifecycle**

### 5.3 Requirements Management

#### Crossrail Employers requirements

The Employers requirements which form the Crossrail Programme remit is depicted in the following figure.



Sponsors' Requirements 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) translate the Sponsors' Requirements into more detailed 'output-related' functional requirements.

Apart from these, other non-functional requirements exist in the Crossrail Act documents (e.g. Crossrail Assurance and Compliance Register), Crossrail Environment Minimum Requirements (part of Crossrail Act) and the CRL New Works Baseline.

Other documents defined within the Employers requirements are Central section RAM requirements, Maintenance Principles and Design demarcation drawings.

CRL has produced the Crossrail Operations Concept, which is a suite of documents. These documents describe the Crossrail normal and perturbed operations, the Rail systems and the procedures, together to realise an operational Crossrail.

Requirements were identified from the Employers Requirements and developed into reference designs and specifications by the FDCs.

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.

The source of requirements is stated by the designer in their Concept Design Submission (Civils works) or Design Statement (Systemwide Works) and checked and agreed by the CRL engineering teams.

The CRL Lead Requirements Engineer owns the Requirements Management Plan [9].

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.

CRL is responsible for updating and maintaining the Employers Requirements and ensuring they are consistent with the Sponsors' Requirements. CRL will update in a timely manner the Employer's Requirements to take account of any changed requirements approved by Change Control.

Section 5.3.1 and 5.3.2 provide further detail on responsibilities which are a summarised extract from the Requirements Management Plan

### 5.3.1 CRL (Crossrail Programme Managers and Systems Integrator)

CRL, as Crossrail Programme Manager is responsible for Management of the Crossrail Employers Requirements.

The relevant technical processes are designed and implemented to achieve Crossrail Systems Integration, Technical Assurance and Engineering Safety Management 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 the Employers requirements, and assessment of the necessary change proposals to ensure that they are satisfying the Sponsors and other Stakeholders' requirements;
- Implementation of agreed changes in a traceable and controlled manner through out the technical design and built so that not to import any substantial risk to cost, scope and schedule of the Programme;
- Maintenance of Requirements baseline for a consistent design configuration;

- Apportionment of the technical requirements to Projects and agreeing acceptance criteria for the apportioned requirements with the respective projects;
- Compilation of 'evidence of requirements implementation' throughout the relevant phases of the Crossrail Programme lifecycle, i.e. design, built, installation, testing and commissioning.
- Integration of the project requirements through a centralised Crossrail database to show compliance to the Sponsors' requirements, identify any design gaps with respect to Programme Requirements, and accept or reject any justification/ affirmation to the non-compliances.

### 5.3.2 Crossrail Designers / Contractors

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

- Producing and implementing a fit for the purpose 'Requirements Management Processes' in accordance with the Crossrail Management Plans including the Crossrail Engineering Requirements Management Plan and V & V Plan.
- Producing specifications as per the scope of delivery to satisfy the Programme Requirements or the Performance Specifications and Interface Requirements Specifications, and the approved changes provided by Crossrail as part of the ITT process (Information pack) or agreed through 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 to satisfy the Crossrail Performance Specifications supported by the relevant evidences.
- Closure of all the Design assumptions with traceability to requirements/issue and action.
- Where appropriate implementing specific processes to meet the requirements of other CRL Strategies and Plans with respect to Crossrail Engineering requirements.
- Producing compliance Matrix to show compliances to the Crossrail Environmental Minimum Requirements (EMR).

## 5.4 Verification and Validation

The Verification and Validation (V&V) process supports the assurance function in accordance with the Technical Assurance Plan [7].

The V life cycle presented in Figure 3 shows the Project life cycle. At all levels of the diagram, verification and validation takes place and these will be detailed more fully in the Verification and Validation Plan [9]

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 verification and validation of secondary requirements (see 5.3)

Section 5.4.1 and 5.4.2 provide further detail on responsibilities which are a summarised extract from the Verification and Validation Plan.

### 5.4.1 CRL (as Crossrail Programme Manager)

The CRL are responsible for Verification and Validation 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 i.e.
  - Management of verification of Performance Specifications against Crossrail Programme Remit/Employers requirements
  - Participating in the review meetings and supporting the coordination of V & V activities.
  - Review of the V & V reports and advice the Project Managers on acceptance of the V & V reports.
  - Compliance checking for Civil and Architectural Design
  - Configuration of DOORS modules for compliances and Verification activities throughout relevant phases of the Programme development
  - DOORS configuration for implementing V & V activities at Programme level
  - Facilitating the production of compliance matrix for Civil and Architectural disciplines
  - Verification of Compliance Matrix produced by Crossrail contractors
  - Verification of Design Assumptions
  - Review and Acceptance of V & V evidences
  - Acceptance of V & V reports produced by the Crossrail Contractors

#### 5.4.2 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;
- As appropriate, populating a traceability matrix with the compliance statements to satisfy Crossrail Specifications supported by satisfaction arguments;
- Verifying and closing all the design assumptions with traceability to requirements/issue;
- 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.

## 5.5 Assumption Management

Assumptions are managed in accordance with the Assumption Management Plan [3].

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 assumptions have been satisfactorily closed out as part of the Gateway Review process.

Assumptions related to Engineering Safety Management are managed separately by the Designers in accordance with the requirements of the System Safety Plan [11].

Section 5.5.1 and 5.5.2 provide further detail on responsibilities which are a summarised extract from the Technical Assumptions Management Plan

#### 5.5.1 CRL (as Crossrail Programme Manager)

Crossrail team will produce and implement a Assumptions Management Plan.

The Assumptions Management Plan will detail the processes to manage the technical assumptions such that it is possible to audit the entire process for traceability, closure and verification of technical assumptions throughout the programme life cycle.

Assumptions at Crossrail programme level will be managed through a centralised register where the status of an assumption can be monitored. This register will also provide traceability to an assumption from 'proposal' stage to 'closure' of that assumption. Custodian of this register will be Crossrail Requirements Management team.

Verification of 'closure' of the technical assumptions will be responsibility of the Crossrail Requirements Management team.

#### 5.5.2 Crossrail Designers and Contractors

Crossrail designers and contractors will be responsible for forwarding any technical assumption to CRL Requirements Management team where the related issue is not within the domain of their scope of work.

Assumptions related to the issues within the scope of the respective contract will be resolved and closed within that contract. For this purpose the

Crossrail designers and contractors will be responsible for identification, documentation and evaluation of the assumptions.

They will be responsible for producing and implementing a 'fit for the purpose' Assumptions Management process through an assumptions register so that the assumptions can be audited by Crossrail Teams at any stage of the Crossrail Programme lifecycle.

It will be the responsibility of the designers and contractors to coordinate the related activities, close the assumptions and verify that they are technically correct.

Verification of 'closure' of an assumption will be through Crossrail V & V processes. Designers and contractors will be required to provide the inputs to this process through their V & V reports.

## 5.6 Interface Management

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, designers, through interface working group meetings, document and agree the specification of that interface through an Interface Control Document (at reference design) or an Interface Requirement Specification (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 system, physical, informational 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.

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

Details of this process are contained in the CRL Procedure for Interface Management [8].

## 5.7 Configuration Management

Configuration control is distinct from change control. Configuration control captures all changes and ensures that all designers are aware and that the change is reflected in their design and across interfaces. These changes may or may not affect scope, cost and programme. Change Control is only concerned with those changes that affect scope, cost and programme.

Once a requirements baseline has been established the project will be placed under configuration control, to ensure that any changes are captured, the impact assessed and they are introduced in a controlled manner. From time-to-time the changes will be wrapped up and a new “Railway Baseline” declared. This will be carried out by CRL in accordance with the CRL Configuration Management Plan [4].

## 5.8 RAM Management

The Reliability, Availability and Maintainability (RAM) processes will provide confidence that the CSW railway will deliver the specified service in accordance with the CRL RAM Plan [5].

For systems that contribute to the operational targets set in CPFR, CRL have developed RAM targets for the CSW; 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 Principles [12] and life cycle costs in accordance with the CRL Whole Life Cost Principles [13].

## 5.9 Engineering Safety Management

Engineering Safety Management is applied in accordance with the Railway and Other Guided System Regulations and the Railway Interoperability Regulations through The System Safety Plan [11].

The process will ensure that all hazards are identified and controlled and will be evidenced through the production of engineering safety justifications by contractors and delivery partners. CRL will manage the integration of the safety justifications and, where necessary, produce additional justifications to demonstrate this integration.

## 5.10 Human Factors Management

Human factors issues and risks will be identified and managed in accordance with the Human Factors Co-ordination Plan [19]. Designers will ensure their designs take into account the relevant HF requirements and the System Integration Team will ensure that these requirements are applied consistently across the CSW and its interfaces.

The Control Centre and HF Managers will take responsibility for coordination across the designers and implementation of the plan.

### 5.11 Electro-Magnetic Compatibility

The Electromagnetic Compatibility (EMC) activity 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 CSW 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 Systemwide Delivery Team will be responsible for managing EMC issues in line with the EMC Management Plan [15].

### 5.12 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,
- Integration of each sub-system to work with its interfacing sub-systems, making use where appropriate of off-site test facilities;
- Testing of each sub-system and then the integrated system to demonstrate that they meet their requirements;
- Commissioning of each system to form the total railway, and
- Handover to the Infrastructure Managers and Operators for further trials.

CRL will be responsible for management of this process for the CSW, including bringing into service the interfaces with other transport undertakings, notably Network Rail. CRL will also be responsible for the management of the Testing and Commissioning activities between Plumstead Portal and Abbeywood to ensure that the activities being carried out by Network Rail and those being carried out by CRL are aligned.

This process is further described in the Testing and Commissioning Strategy [10] 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.

CRL will review and accept the contractor's test strategies and plans to ensure that integration risks are as far as possible managed at the factory acceptance test stage, before equipment is delivered to site.

CRL will review and accept the contractor's test procedures to satisfy itself that the tests will demonstrate compliance with the requirements, where this demonstration has not already been given through the design assurance process.

Railway Integration Review Points 6 and 8 provide control points to ensure a comprehensive review of the status of the Test and Commissioning Process.

## 6 References

Document	Reference
1. Sponsors' Requirements	
2. Crossrail Programme Function Requirements (CPFR)	CR-XRL-Z-GPR-CR001-00004
3. Assumption Management Plan	CRL1-XRL-O8-STP-CR001-Z-50001
4. Configuration Management Plan	CRL1-XRL-Z3-STP-CR001-50006
5. Systems Engineering RAM Plan	CRL1-XRL-O8-STP-CR001-50004
6. Verification & Validation Plan	CRL1-XRL-O8-STP-CR001-50006
7. Technical Assurance Plan	CRL1-XRL-O4-GPD-CR001-50005
8. Procedure for Interface Management	CRL1-XRL-O8-GPD-CR001-50001
9. Engineering Requirements Management Plan	CRL1-XRL-O8-STP-CR001-50005
10. Project Test and Commissioning Strategy	CRL1-PDP-O8-TSY-CR001-00001
11. Engineering Safety Management System Safety Plan	CRL1-XRL-O7-GST-CR001-00001
12. Crossrail Maintenance Principles	CRL1-XRL-O8-XTC-CR001-00002
13. Crossrail Whole Life Cost Principles	CRL1-XRL-N2-GPD-CR001-00003
14. Engineering Design Assurance Gates Procedure	CRL1-XRL-O4-GPD-CR001-50002
15. EMC Management Plan	CRL1-XRL-O8-STP-CRG03-50003
16. Railway Integration Review Point Process	CRL1-XRL-R-GPS-CR001-50001
17. System Integration Authority	CRL1-XRL-O8-GPD-CR001-50004
18. System Integration Review Panel Process	CRL1-XRL-O8-GUI-CR001-50001
19. Human Factors Co-ordination Plan	TBA
20. System Modelling Strategy	TBA