ASSURANCE
ENGINEERING SAFETY MANAGEMENT

Engineering Safety Management
System Safety Plan

Document Number: CRL1-XRL-O7-GST-CR001-00001

Current Document History:

Revision:	Effective Date:	Author(s) ('Owner' in eB *)	Reviewed by: ('Checked by' in eB *)	Approved by:	Reason for Issue:
8.0	13-03-2020	M Scoble	H Zerkani	S Turner	This document has been reviewed and is fit for continued use

Previous Document History:

Revision	Prepared / Effective Date:	Author:	Reviewed by:	Approved by:	Reason for Issue
2.0	04-05-2011	K Watson	M Kilby	C Sexton	First issue after CAG acceptance
3.0	01-10- 2012	M Kilby	C Bloxsome	C. Sexton	Revised to take account of RIR 2011 and TfL as IM for Central Operating System
4.0	18-05-2016	G Sutherland / S James	C Wong	J Bates	Revised to take account of new CSM Regulations, contained in Directives EU 402/2013 and EC 2015/1136, updates to text.
5.0	14-07-2016	S James	C Wong	J Bates	Added Part 32 Contractors Engineering Safety Management Requirements (Stations, Shafts, and Portals MEP) as a reference
6.0	03-05-2017	S James	C Wong	J Bates	General update. Revised line diagram COS / Interfacing Partners. Addition of Railway Level Hazard Model (Ref 54). Addition of TSI procedure references. Chi Wong comments addressed.
7.0	23-05-2018	E Weli	H Zerkani	J Bates	Revised to address AsBo AR69 observations
8.0	13-03-2020	M Scoble	H Zerkani	S Turner	This document has been reviewed and is fit for continued use

Revision Changes:

Revision	Status / Description of Changes
6.0	General update. Revised line diagram COS / Interfacing Partners. Addition of Railway Level Hazard Model [Ref 54]. Addition of TSI procedure references. Chi Wong comments addressed.
7.0	Update of document to address the AsBo comments raised in Assessment Record AR69.
8.0	This document has been reviewed and is fit for continued use

Contents

1 Purpose Scope and Application

1.1 Purpose

1.1.1 This System Safety Plan (SSP) sets out the overall strategy and approach mandated by Crossrail Ltd (CRL) for the identification, control and management of system safety risks in the design, testing and potential future operation of the railway to as low as reasonably practicable, in compliance with legal requirements. This will enable the completed railway to be handed over and accepted by future Duty Holders to put into service in accordance with their Safety Authorisation/Safety Certification, and provide part of the evidence that the Joint Sponsors' requirements have been met.

1.1.2 It defines the CRL Engineering Safety Management (ESM) arrangements and the responsibilities for their delivery and covers the strategy for how CRL will deliver to RfL Infrastructure Limited (RfLI Ltd) "Authorisation to Place into Service (APIS)" from the ORR relating to the Central Operating Section (COS).

The Strategy for Crossrail End-to-End Safety Justification and Assurance has been issued as a separate document [Ref 35].

1.1.3 The SSP is a subsidiary document to the CRL Technical Management Plan [Ref 12] and supports the Technical Assurance Plan (TAP) [Ref 2] and the CRL System Integration Management Plan [Ref 9].

1.1.4 This version of the SSP only addresses the left hand side of the Safety lifecycle (and V-lifecycle) presented in Section 4.5. These include the Safety Lifecycle activities to be undertaken up to Design completion.

1.1.5 This document will have an addendum to address the right hand side of the V-lifecycle including installation, testing and commissioning, handover and operations.

1.2 Scope of the Crossrail Programme

1.2.1 CRL is accountable for the overall delivery, programme management, design, construction, testing, handover, trial running and completion of the Crossrail Programme.

1.2.2 CRL is responsible for delivering an integrated and assured Central Operating System Railway (including the sidings at Plumstead and Ilford) together with interface works with Network Rail and all other relevant works. The Central Operating System Railway includes the integration, testing and operation of the Crossrail Rolling Stock over the Central Operating Section (as defined in the Project Development Agreement (PDA)). The Rolling Stock and Depot Contractor will support CRL to assure the interfaces with the Central Operating System works and where applicable provide the assurance evidence from Network Rail (NR) on-line network works.

1.2.3 Overall Technical Authority for the Crossrail Central Operating System including end-to-end interfaces works lies with the CRL Chief Engineer.

1.2.4 CRL is also responsible for integrating all the assurance evidence of the end to end railway in order to demonstrate that all works delivered by both CRL and its Industry Partners are fully integrated and the performance will meet the Sponsors' requirements and support acceptance by the relevant Operators (as defined in ROGS).

1.2.5 This System Safety Plan specifically relates to the Central Operating Section (COS). The following diagram indicates the relationship between the COS and interfaces within the context of the overall Crossrail programme The COS is identified as the section contained within the dotted lines and is physically defined as the railway line between Paddington / Westbourne Park, Pudding Mill Lane Portal and Abbey Wood, together with the stations at Paddington, Bond Street, Tottenham Court Road, Farringdon, Liverpool Street, Whitechapel, Canary Wharf, Custom House, Woolwich and Abbey Wood. Interfaces exist with NRIL at the extremities and with LUL at the Platform Screen Doors at Bond Street, Tottenham Court Road, Farringdon, Liverpool Street and Whitechapel underground stations.

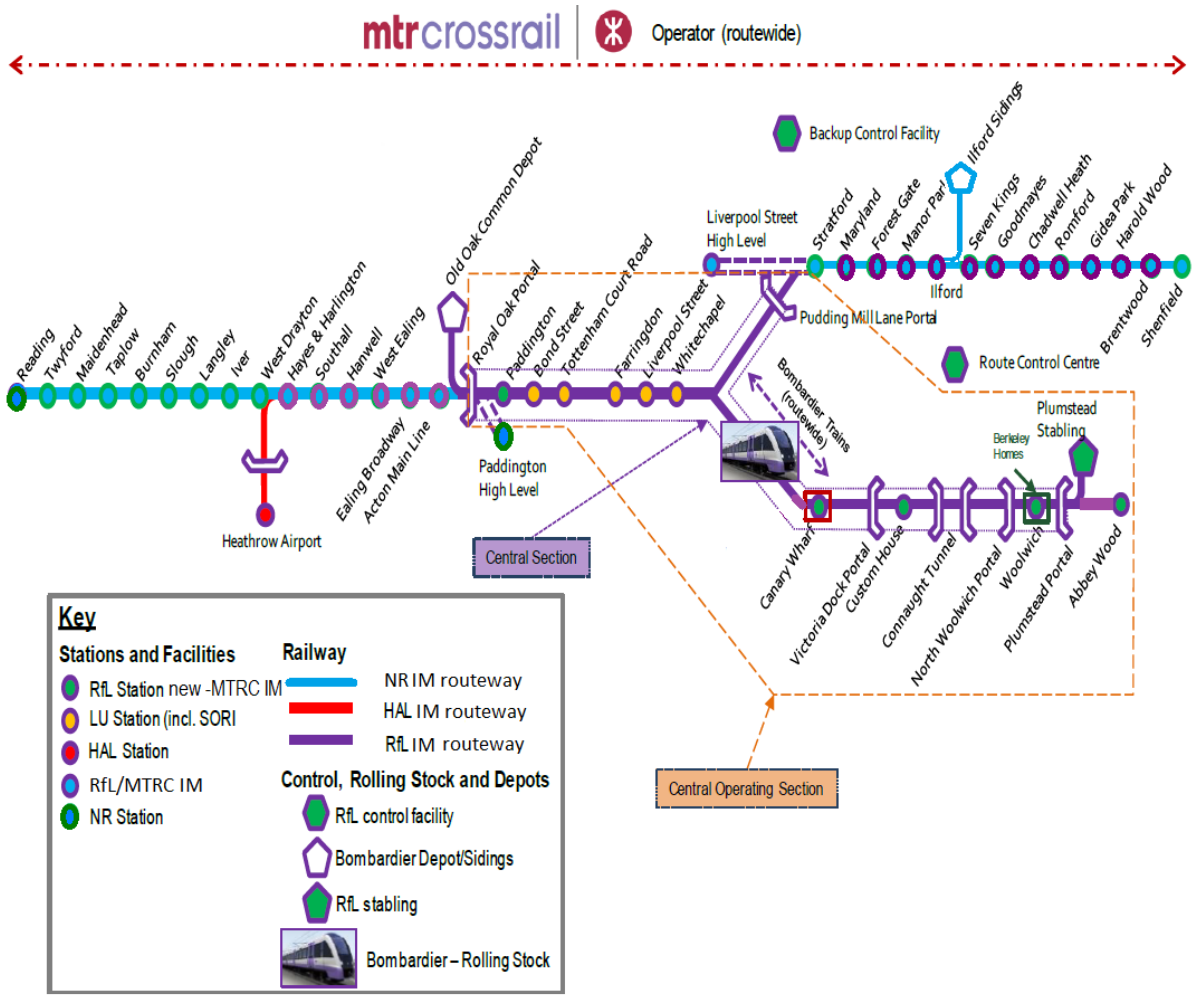

Figure 1: Crossrail Overview *(Source: Project Authorisation Strategy CRL1-XRL-O8-STP-CR001-50137).*

1.2.6 CRL are responsible for the integration of the Central Operating Section (COS) together with the interfaces with the Great Western Main Line at Royal Oak Portal / Westbourne Park and the Great Eastern Main Line at Pudding Mill Lane Junction as detailed in the previous diagram. The full scope of the COS is defined in the Project Development Agreement [Ref 58].

1.2.7 Network Rail have been contracted to provide the Earthworks, Track Slab, Track, Buffer Stop lighting, drainage, Overhead Line Electrification (OLE) structures and wiring, Under Track Crossings (UTX's) boundary fencing including demarcation between the AC and DC lines, cable troughing and walkways between Plumstead Portal and Abbey Wood, together with a Signalling Equipment Room and the station at Abbey Wood. Network Rail validate these elements through their internal own processes and present this evidence to CRL for incorporation within the overall assurance demonstration for the Central Operating Section. The following diagram represents inter-relationship between the NR and CRL process adopted for this section:

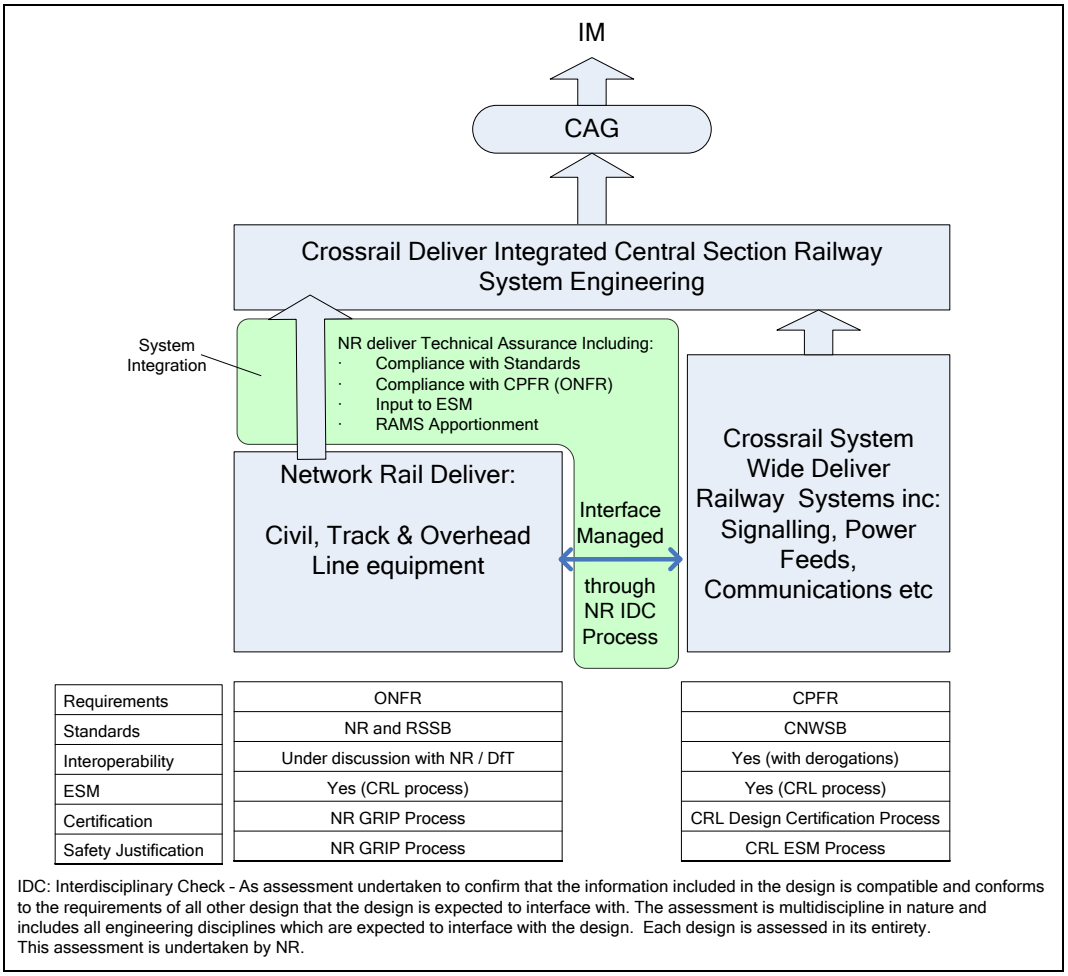

Figure 2: Crossrail Programme Delivery Responsibilities

1.2.8 The Crossrail Central Operating Section, together with stations up to a defined point, has been declared as an Interoperable Railway. A Strategy for Crossrail End-to-End Safety Justification and Assurance [Ref 35] has been created and contains within it the manner by which authorisation is to be achieved.

1.2.9 Technical compatibility and safe integration will be demonstrated through application of the following:

- 2008/57/EC (as consolidated by EU 2016/797) Railway (Interoperability) Regulations 2011 (& 2013 Amendments) - RIR (compliance with TSI's),
- EU/402/2013 as amended by EU/2015/1136 CSM for Risk Evaluation and Assessment, and
- 2004/49/EC Railway Safety Directive (ROGS) *(whilst strictly applicable only to the RU / IM for Putting into Use, evidence provided by CRL will promote this).

- Article 15 of Railway (Interoperability) Regulations 2011 requires a demonstration that the works:

  1. complies with TSI's and Notified National Technical Rules (NNTR's),
  2. is technically compatible with the system into which it will be integrated, and
  3. can be safely integrated.

- Progressive technical compatibility will be proven through the production of appropriate documentation as follows:

  Contractor driven:
  - Design Engineering Safety (DESJ) and Engineering Safety (ESJ) Justifications* (per Tier 1 Contract). Supported by FDC Contractors (where applicable).

  * Versions of the ESJ's will be provided to support partial / phased handover.

  CRL driven:
  - Interim Safety Justification (ISJ) per station, portal, shaft and depot.
  - Consolidated Interim Safety Justification (ISJ) for LUL Stations
  - Consolidated Interim Safety Justification (ISJ) for RfL Stations
  - Consolidated Interim Safety Justification (ISJ) for Shafts
  - Consolidated Interim Safety Justification (ISJ) for Portals
  - Interim Safety Justification (ISJ) for Tunnels, Cross Passages, Crossovers and LOR Civils.
  - Interim Safety Justification (ISJ) for combined "Systemwide" systems (inclusive of interfaces with NR)
  - Interim Safety Justification for the Central Operating Section (COS)
  - Safety Justification (SJ) per station, portal, shaft and depot**.
  - Consolidated Safety Justification (SJ) for Stations
  - Consolidated Safety Justification (SJ) for Tunnels, Shafts and Portals
  - Consolidated Safety Justification (SJ) for Sidings, Yards and Depots
  - Safety Justification (SJ) for combined "Systemwide" systems (inclusive of interfaces with NR)**.
  - Consolidated Central Operating Section (COS) Infrastructure Safety Justification for Zones 1-4.
  - CRL End-to-End Railway Infrastructure Safety Justification

  ** Versions of the Safety Justifications will be provided to support progressive energisation and dynamic testing per zone as detailed in the Technical Assurance Plan (ref 2).

- High Level Safety Hazards / Requirements and supporting strategies.

  The current listing of deliverables is in the "RABc Submissions – CRL & RFLI Programme". This is updated on a Period by Period basis.

1.2.10 These will collectively deliver evidence of:

- Compliance against applicable TSI's and NNTR's.
- Identification of interfaces and demonstration of successful integration between systems (both internally and externally e.g. interfaces with LUL and NRIL).
- Hazards identified through design, construction, integration, testing and commissioning (i.e. the phases of the "v" cycle) have been documented and appropriate mitigation applied, with due reference to the hazard model contained within the Railway Level Hazard Structure [Ref 54].
- Management of residual hazards to be transferred to others e.g. RfL IM and MTR-EL have been documented and appropriate mitigation validated e.g. by operational procedures.
- Safe integration will be demonstrated by application of the risk management process as set out in the CSM for Risk Evaluation and Assessment and the Railway Level Hazard Structure [Ref 54].

- The demonstrations of technical compatibility and safe integration will together provide one of the four pillars of technical assurance as detailed in the Technical Assurance Plan (TAP) [Ref 2].

1.2.11 A Strategy for Crossrail End-to-End Safety Justification and Assurance [Ref 35] has been created which defines the manner by which authorisation is to be achieved.

1.2.12 Ricardo Rail has been appointed by CRL to fulfil the role of NoBo and DeBo (technical compliance) under Railway (Interoperability) Regulations 2011 and Railway Safety Directive (ROGS), and the AsBo (safety assessment) under CSM for Risk Evaluation and Assessment.

1.3 Application

1.3.1 The SSP is mandatory as follows across:-

- CRL Technical and Delivery Directorates (this Revision),
- Designers and Contractors who undertake Design and Build contracts (Rev 3.0 being the version instructed in the Works Instruction and subsequent Project Managers' Instructions (PMI) being applicable).

1.3.2 It applies for the duration of the Crossrail Programme up to the point of Handover of the infrastructure to Duty Holders to put into service.

1.3.3 NR managed Crossrail related works undertaken on NR infrastructure are subject to the provisions of the Network Rail Crossrail Programme, System Safety Plan [Ref 13].

1.3.4 The scope of ESM described in this plan applies to all aspects of railway operations (day to day running including degraded, abnormal, emergency and maintenance activities) as well as technical matters. This includes the control of risks to As Low As Reasonably Practicable (ALARP) for passengers, workforce, maintainers, adjacent railways, neighbours, and members of the public.

1.3.5 This SSP does not address construction safety, which is covered by other CRL documentation (such as the CDM Risk Register), however hazards relating to the operations and / or maintenance phases will be captured in the PWHR at contract level for appropriate Risk Control Actions (RCA's) to be put into place.

1.4 Document Structure

1.4.1 This document comprises seven sections as outlined below:

Section 1	(This section) Describes the purpose and scope of this Plan and introduces the Crossrail Project approach to Engineering Safety Management (ESM).
Section 2	Abbreviations & Definitions.
Section 3	System Definition Summary - Central Operating Section (See separate document entitled "Engineering Safety Management System Definition" for full details) [Ref 86].
Section 4	Describes the System Safety Assurance Requirements for the CRL project
Section 5	Describes the ESM Activities for the Crossrail Project.
Section 6	Describes the ESM controls that will need to be undertaken by CRL as part of the safety assurance process.
Section 7	Describes the types of safety documents that will be produced and the role of CRL in respect of their review.
Section 8	Defines the high level document specifying system engineering activities applicable to the Crossrail project.

1.5 Plan Development and Revision

1.5.1 This SSP will be revised as necessary during the life time of the project so as to make sure that it remains relevant at all times. This revision is being issued to finalise and agree the handover safety deliverables to the respective Duty Holders and as a consequence of amendments to legislation.

1.5.2 Major or significant revisions of this SSP will be consulted with stakeholders. These stakeholders are as follows:

- IMs – RfL, LUL, Network Rail
- MTR-EL
- CRL

1.5.3 Tier 1 Contractors will be notified of significant changes as appropriate.

1.6 Communication of this Plan

1.6.1 This Plan shall be communicated to Crossrail Contractors using the Chief Engineer's Communication (CEC).

1.6.2 The CEC provides a means by which generic technical or engineering matters can be communicated to the Delivery teams in a controlled and consistent manner.

1.6.3 The intention of the CEC is to bring the matter under consideration to the attention of the delivery teams prior to the information being put into effect by the delivery teams. It will be a vehicle that will follow one of 3 differing work flows, which are:

- A clarification
- A change with no impact on the Works Information (WI) or
- A change to Works Information.

1.6.4 CECs will typically be used to inform the recipient (the Project Manager and Engineering Manager) that a design, or construction requirement dictated by design, may change or that a technical proposal is under consideration. This forewarns the Delivery teams of a potential issue so that the appropriate action may be taken on site. It remains at the discretion of the PM as to whether they decide to issue a Project Manager's Communication (PMC) or Early Warning Notice (EWN) to their Contractor.

1.6.5 The CEC Procedure [Ref 88] defines the process for undertaking the Chief Engineer's Communications

Abbreviations & Definitions

1.7 Abbreviations

Abbreviations	
AC	AC Electrified Line (i.e. with an alternating current overhead collection system)
ALARP	As Low as Reasonably Practicable (see definitions)
APIS	Authorisation to Place into Service
AsBo	Assessment Body (as defined in Common Safety Method on Risk Assessment)
ATO	Automatic Train Operation
BUCF	Back Up Railway Control Facility (located at Ilford)
CAG	Compliance Assurance Group
CBA	Cost Benefit Analysis
CDM	Construction (Design & Management) Regulations 2015
CIS	Customer Information System (s)
COP	Application of Codes of Practice (Common Safety Method on Risk Assessment)
COS	Central Operating Section (of Crossrail)
CPFR	Crossrail Programme Functional Requirements
CRL	Crossrail Limited
CSM	Common Safety Method
CSM-RA	Common Safety Method on Risk Assessment
CST	Common Safety Target (as defined in the ROGs)
CWG	Canary Wharf Group
DC	DC Electrified Line (i.e. with a direct current ground level collection system)
DeBo	Designated Body (as defined by the RIR)
DESJ	Design Engineering Safety Justification (Produced by a Contractor)
DfT	Department for Transport
DLR	Docklands Light Railway (part of TfL)
DRACAS	Data Reporting, Analysis & Corrective Action System
DSRM	Derived Safety Requirements Module (in PWHR)
E/E/PES	Electrical /Electronic /Programmable Electronic Systems
eB	Crossrail (CRL Ltd) Electronic Document Control System
EC	European Commission
ECHC	Element Completion Handover Certificate
ECHR	Element Completion and Handover Report
EMC	Electromagnetic Compatibility
ERA	European Rail Agency

Abbreviations	
ERE	Explicit Risk Estimation (Common Safety Method on Risk Assessment)
ESJ	Engineering Safety Justification (produced by a Contractor)
ESM	Engineering Safety Management (Commonly applied by the “Yellow Book”)
FDC	Framework Design Consultant
FDO	Final Design Overview
FWI	Fatality & Weighted Injuries
FMECA	Failure Modes Effects and Criticality Analysis
FRACAS	Failure Reporting, Analysis & Corrective Action System
GEML	Great Eastern Main Line
GRIP	Guidance for Railway Investment Projects (Network Rail)
GSM-R	Global System for Mobile Communications - Railway
GSN	Goal Structured Notation
GWML	Great Western Main Line
H&S	Health and Safety
HAZOP	Hazard & Operability Study
HLOS	High Level Output Specification
HMG	Her Majesty’s Government
HRP	Crossrail Project Hazard Review Panel
HS&E	Health, Safety and Environment
HSAWA	Health and Safety At Work Act 1974
IM	Infrastructure Manager as defined in ROGs
ISA	Independent Safety Assessor
ISJ	Interim Safety Justification (produced by CRL)
ISwA	Independent Software Assessor
LUL	London Underground Limited (part of TfL)
MIRP	Maintenance Integration Review Panel
MS	Member State
MTR-EL	MTR Elizabeth Line (Transport Undertaking and Concessionaire for the Crossrail service)
NKL	North Kent Line
NNTR	Notified National Technical Rule
NoBo	Notified Body (as defined by the RIR)
NR	Network Rail
NRV	National Reference Value
NSR	National Safety Rule
OHLE	Overhead Line Electrification System
ONW	On Network Works

Abbreviations	
ORR	Office of Rail and Road (previously Office of Rail Regulation)
PDA	Project Development Agreement
PMI	Project Manager's Instruction
PTI	Platform Train Interface
PWHR	Project Wide Hazard Register
QRA	Quantified Risk Assessment
RAB (C)	Crossrail (CRL Ltd sponsored) Rail Acceptance Board
RCA	Risk Control Action
RCC	Railway Control Centre (located at Romford)
RfL	Rail for London
RfL I	Rail for London Infrastructure Ltd (Crossrail IM)
RGS	Railway Group Standards
RIDDOR	Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013
RLHR	Railway Level Hazard Register
ROGS	Railway and Other Guided Transport Systems (Safety) Regulations 2006 as amended
RSSB	Rail Safety & Standards Board
RSSP	Railway Strategic Safety Plan
RIR	Railways Interoperability Regulations 2011
SCADA	Supervisory Control and Data Acquisition
SEJ	Strategic Engineering Justification
SFAIRP	So Far As Is Reasonably Practicable (see definitions)
SIF	Safety Issues File
SIL	Safety Integrity Level
SIRP	System Integration Review Panel
SJ	Safety Justification (produced by CRL)
SMS	Safety Management System
SOR	Station Operations Room
SRS	Similar Reference System (Common Safety Method on Risk Assessment)
SSP	System Safety Plan
SRM	Safety Risk Model
TAP	Technical Assurance Plan
TBA	To Be Advised
TfL	Transport for London
TSI	Technical Specification for Interoperability
TU	Transport Undertaking as defined under the ROGs

1.8 Definitions

Definitions	
Accident	An unintended event or series of events that results in harm.
ALARP /SFAIRP	The Health and Safety at Work Act 1974 (HSWA) places duties on employers in the UK to ensure that 'so far as is reasonably practicable' (SFAIRP) safety risks are reduced. When these duties are considered in relation to risk management the duty is sometimes described as a requirement to reduce risk to a level that is 'as low as is reasonably practicable' (ALARP). These terms therefore express the same concept in different context and should be considered to be synonymous. Note: 'ALARP' is taken to mean tolerable and ALARP.
Broadly Acceptable	A hazard where the risk is insignificant or negligible e.g. the hazard is unlikely to arise and there are no feasible control measures to control the risk or there is a credible failure mode, but the consequences are negligible.
Central Operating Section	That part of the Crossrail system bounded by the connections with the Great Western Main Line at Westbourne Park / Royal Oak Portal, the Great Eastern Main Line at Pudding Mill Lane Junction and the North Kent Line at Abbey Wood.
Central Operating System Works	The boundaries of the Central Operating System Works will not be at specific geographical locations, but will vary for each sub-system to best suit their interfaces with the existing infrastructure.
Collective Risk	The risk to a group of system users, expressed as fatalities and weighted injuries per unit time, usually per year, (FWI/yr) as a result of a hazard in a specified system.
Competent Authority	The Body under the RIR that has the responsibility to consider, and where appropriate, grant derogations against TSIs, or to obtain them from the European Commission as appropriate. Under the current RIR the Competent Authority is the DfT.
Compliance	A demonstration that a characteristic or property of a system, product or other change satisfies the stated requirements.
Consequence	The number of fatalities, major injuries, minor injuries, shock and trauma resulting from the occurrence of a hazardous event outcome. Consequences may range from benign to a multi-fatality accident.
Contractor	For the purposes of this document only, any organisation contracted to CRL which is required to, or carries out Design or Design and Build activity on behalf of the project. This definition is also specifically extended to include such contractors appointed by the Canary Wharf Group and Berkeley Homes Ltd to build Canary Wharf and Woolwich stations respectively.
Common Safety Methods	EU Commission Implementing Regulation (EU) 402/2013, together with amending Regulation EU 2015/1136 for a Common Method of applying safety methods across Member States
Crossrail	The railway system (to become the Elizabeth Line) that will permit movement of people between Shenfield, Abbey Wood, Heathrow Airport and Reading by construction of a new tunnelled section through the centre of London.
Crossrail Ltd	The company set up to build the new railway that will become known as the Elizabeth Line when it opens through central London in 2018.
Design Engineering Safety Justification	A formal presentation of evidence, arguments and assumptions provided at the completion of the design stage aimed at providing assurance that a system or product has met its safety requirements (including appropriate legislation and standards) and that the safety requirements are adequate.

Definitions	
	This is a sub-set of the Engineering Safety Justification evidence.
Designer	For the purposes of this document only, any organisation contracted to CRL which undertakes Design activity on behalf of the project. This definition is also specifically extended to include Designers appointed by the Canary Wharf Group and Berkeley Homes Ltd to design Canary Wharf and Woolwich stations respectively.
Duty Holder	A generic term which means in the context of Crossrail means either the Infrastructure Manager / Station Manager or Transport Undertaking as defined under ROGs / Railway Undertaking as defined under RIR.
E/E/PES	A system for control, protection or monitoring based on one or more electrical, electronic or programmable electronic devices, including all elements of the system such as power supplies, sensors and other input devices, data highways and other communication paths, and actuators and other output devices (BS EN 61508).
Engineering Safety Justification	A formal presentation of evidence, arguments and assumptions aimed at providing assurance that a system or product has met its safety requirements (including appropriate legislation and standards) and that the safety requirements are adequate.
Engineering Safety Management	The activities involved in making a system, product or other change safe and showing that it is safe. This involves considering the safety of the railway throughout the life of the change.
Essential Requirements	Interoperability Design requirements specified in TSIs for high speed and conventional interoperable railways (RIR).
Event	A significant happening that may originate in the system, product or other change or its domain.
Explicit Risk Estimation	One of the three risk acceptance principles set out in the CSM RA. It typically requires a more bespoke approach to risk assessment than the other risk acceptance principles, and can be qualitative or quantitative. When explicit risk estimation is applied the risk acceptance criterion that is generally used in GB is to ensure safety SFAIRP, as defined in general legislation.
Fatalities & Weighted Injuries	An overall measure of safety harm, taking account of injury and fatalities in the following way: One FWI = one fatality = 10 major injuries = 200 RIDDOR reportable minor Injuries or class 1 shock/traumas = 1,000 non-RIDDOR reportable minor injuries or class 2 shock/traumas.
Hazard	A hazard is a condition that could lead to an accident, loss or damage.
Individual Risk	The individual risk experienced by a person, is their probability of fatality per unit time, usually per year, from the operation of the railway. This is normally referred to different groups of individuals such as passengers' commuters, public, workforce.
Intolerable Risk	A risk which cannot be accepted and must be reduced.
Minimum Operating Requirements	A set of the minimum requirements that must be met for a station or for a particular function (such as ventilation, communications, power etc.) to be capable of safe operation. These requirements may also be specified by time of day and /or day of week.
Operator	Operator refers to a Duty Holder under the ROGS
Project Engineer	A generic term for the lead engineer for a particular sub system such as track, signalling, power systems, etc. within the CRL organisation with the overall responsibility for the management of the Designers and Contractors to deliver that subsystem, together with the associated Engineering Safety Justification.
Project Wide	The contract level hazard repository together with the evidence that all hazards have

Definitions	
Hazard Register	been suitably addressed through the various stages of the project through to commissioning. This, together with the RLHR will form the hazard record for the railway and will be handed over to the operator and maintainer
Railway Level Hazard Record	The repository of all high level railway based hazards, together with the evidence that these have been adequately mitigated. This, together with the PWHR will form the hazard record for the railway and will be handed over to the operator and maintainer.
Reference Design	A design that has been developed to justify that the Joint Sponsors' Requirements can be delivered. However this does not mean that the design shall be adopted by the Project.
Residual Risk	A hazard that has not been totally designed out and therefore requires other mitigation measures to be put into place to control the hazard.
RIDDOR	RIDDOR 2013 is a set of health and safety regulations that may require any major injuries, illnesses or accidents occurring in the workplace to be formally reported to the enforcing authority. It defines major and reportable minor injuries.
Risk	Combination of the likelihood of occurrence of harm and the severity of that harm.
Risk Analysis	A structure process which identifies both the likelihood and extent of adverse consequences arising from a given activity or facility.
Risk Assessment	A combination of risk analysis and risk evaluation.
Risk Evaluation	The appraisal of the significance of a given quantitative or qualitative measure of risk.
System Safety	The level of safety achieved via the application of Engineering Safety Management (ESM)
Safety	A statement of the relative acceptability of freedom from harm.
Safety Analysis	The application of systematic theoretical analysis to estimate the potential risk of an accident from a system or activity.
Safety Issues File	A list of hazards maintained by the CRL Technical Director that are intended to be transferred to a future Duty Holder.
Structural Sub System	One of the infrastructure, energy, control command and signalling, rolling stock sub systems constituting the structural areas of the rail system that are assessable against the respective TSI by a NoBo.
Transport undertaking	Any person (or organisation) who operates a vehicle in relation to any infrastructure but shall not include a person who operates a vehicle solely within an engineering possession. (Taken from ROGS definition)
Technical Specification for Interoperability	Defined in the RIR as being "technical specifications for interoperability adopted by the Commission, including any variations from time to time adopted, in accordance with the Directive or the Conventional Directive or the High Speed Directive and in force by which each subsystem or part subsystem is covered in order to meet the essential requirements and ensure the interoperability of the rail system".

2 System Definition Summary - Central Operating Section

2.1 Introduction

2.1.1 Requirement for a System Definition

The EU Regulation on the common safety method for risk evaluation and assessment (EU 402/2013) requires the provision of a System Definition. This is defined in Annex 1, Section 2.1.2 to the Regulation. This section of the SSP provides a summary only; the full details of the Central Operating Section System Definition are to be found in the Engineering Safety Management System Definition [Ref 86].

2.2 Purpose and Format

2.2.1 Purpose of System Definition

In accordance with the CSM Regulations (Annex 1, Section 2.1.2) and guidance further provided in GE/GN8641 (Guidance on System Definition), the Engineering Safety Management System Definition [Ref 86] is to address the following issues:

a) system objective, e.g. intended purpose;

b) system functions and elements, where relevant (including e.g. human, technical and operational elements);

c) system boundary including other interacting systems;

d) physical (i.e. interacting systems) and functional (i.e. functional input and output) interfaces;

e) system environment (e.g. energy and thermal flow, shocks, vibrations, electromagnetic interference, operational use);

f) existing safety measures and, after iterations, definition of the safety requirements identified by the risk assessment process;

g) assumptions which shall determine the limits of the risk assessment.

The Engineering Safety Management System Definition [Ref 86] is to be created in order to draw a boundary around the appropriate parts of the system and drive the high level hazard identification and risk management activity. It is to be developed to:

- Provide the basis for application of the CSM Assessment;
- Define the interfaces;
- Allow for a better understanding of the delivery of the safety requirement;
- Provide a record of the assumptions upon which the demonstration of safety is based;
- Provide a record of the safety requirements required.

2.2.2 System Boundaries – Overview

The Crossrail programme provides a new underground high frequency passenger train service connecting to and operating over the adjacent existing Overground Network Rail sections towards Reading, Heathrow Airport and Shenfield. An interchange is also made with the North Kent Line at Abbey Wood Station for passengers (the physical track connection is for non-passenger use only).

This Safety Plan specifically covers the Central Operating Section (COS) between the following locations:

West: Royal Oak Portal and Westbourne Park where a fully signalled and electrified end on connection is made with the Great Western main line towards Reading. Signalling will changeover between CBTC and ETCS / TPWS – AWS at this location.

North East: Pudding Mill Junction where a fully signalled and electrified end on connection is made with the Great Eastern main line towards Shenfield. Note that the Crossrail CBTC signalling is overlaid over the existing AWS / TPWS provision between Pudding Mill Lane Junction and the east of Stratford. Trains to / from the COS will make the changeover in the vicinity of Stratford Station and not at Pudding Mill Lane Junction.

South East: Abbey Wood Station where a passenger interchange is made with the existing North Kent Line services. A physical basic signalled but non electrified connection exists at the east of Abbey Wood Station to permit transfers of non passenger trains (mainly engineering and yellow plant) between NR and Crossrail. Note that the permanent way and OHLE between Plumstead Portal and Abbey Wood, together with Abbey Wood Station have been constructed by Network Rail on behalf of CRL.

2.2.3 System Elements, Functions and Operations Concepts

Crossrail is designed and constructed as a high capacity metro style heavy rail system.

The system function and elements comprise the following:

The provision, testing, commissioning and validation of the various component and integrated systems to enable the following:

- Capacity usage - systems, functionality and assets to permit under normal operation-
- An envisaged throughput of 24 trains per hour per direction (with capacity to expand to a maximum of 30 trains per hour) through the Central Operating Section. Each train is 240m long with a maximum capacity of 1500 passengers.
- Provision for a peak capacity handling of 36,000 passengers per hour in each direction.
- Capacity to grow from the 2028 volume with a 28% uplift (Canary Wharf having a lesser provision)
- Flexibility in service patterns, currently 24 tph through the COS, splitting 12 tph to Pudding Mill Lane / Shenfield and 12 tph to Abbey Wood in the east and 10 tph to the Great Western main line, with 14tph terminating at Paddington in the west.

Stations:

9 New stations, 8 underground and 1 above ground, as follows:-

- Paddington Low Level. Connections to the NR and LUL stations. Managed by the franchisee (MTR-EL)
- Bond Street. Integral with the LUL station and managed by LUL.
- Tottenham Court Road. Integral with the LUL station and managed by LUL.
- Farringdon. Integral with the LUL station and managed by LUL.
- Liverpool Street. Integral with the LUL station and managed by LUL.
- Whitechapel. Integral with the LUL station and managed by LUL.
- Canary Wharf. Standalone station. Managed by the franchisee (MTR-EL)
- Custom House. Above ground station adjacent to and connected to DLR station of same name. Managed by the franchisee (MTR-EL)
- Woolwich. Standalone station. Managed by the franchisee (MTR-EL)
- Abbey Wood. Above ground station. New station built by and owned by Network Rail. Station building and Crossrail platforms managed by the franchisee (MTR-EL)

Tunnels:

The provision of tunnels as follows:-

- 21 route kilometres of new twin bore running tunnels between Royal Oak Portal, Pudding Mill Lane and Victoria Dock Portal and between North Woolwich Portal and Plumstead Portal and

- Refurbishment of the pre-existing double track Connaught Tunnel,
- Together with the necessary rail, operational and safety features.

(Note: Connaught Tunnel is a modified legacy feature and does not have the same facilities as the new build tunnels, consequently, specific arrangements apply).

Central Operating Rail Systems:

The provision of all Central Operating Rail Systems as follows:-

- OHLE (conventional catenary and rigid bar collection systems) with associated traction power supplies,
- Non traction power supplies,
- Communications systems including radio, GSM-R and CIS together with propagation media (e.g. SCADA transmission network, Leaky Feeder),
- Permanent Way, Automatic Control and Signalling,
- All safety and emergency systems,
- Active tunnel ventilation system (smoke control and comfort), passenger evacuation systems, walkways and cross passages,
- A platform screen door passenger / train interface (PTI) at the sub surface stations,
- A Route Control Centre at Romford with a Back-Up Control Centre at Ilford.
- Evacuation, Intervention and Ventilation Shafts (some shafts performing more than one function),

Operations:

The outline of the Operational Concepts adopted are contained in the document “Operations Concept – CRL1-XRL-K2-GUI-CR001_Z-50007 and in particular the following chapters:

1 Line Operations

1b Great Eastern Interface

1c Great Western Interface

2 Route Control Centre (See Central Operating Rail Systems)

3 Sub Surface Stations

3a Station separation

4 Surface Stations (in so far as applicable to Custom House and Abbey Wood only)

5c Plumstead facility

6 Train Operations

6a Tunnels Detrainment

6b Tunnel Evacuation

6c Multiple Train Detrainment

6d Tunnel Incidents

8 Customer Information Systems

9 CCTV

10 Alarm Systems

12 Lifts and Escalators

14 Operational Resilience Plan (in so far as it applies to the COS)

The system definition is based upon the current versions of the Operations Concepts (September 2017). Any changes to the System Definition that are at variance to the current versions of the Operations Concepts will be referenced against the appropriate issued PMI.

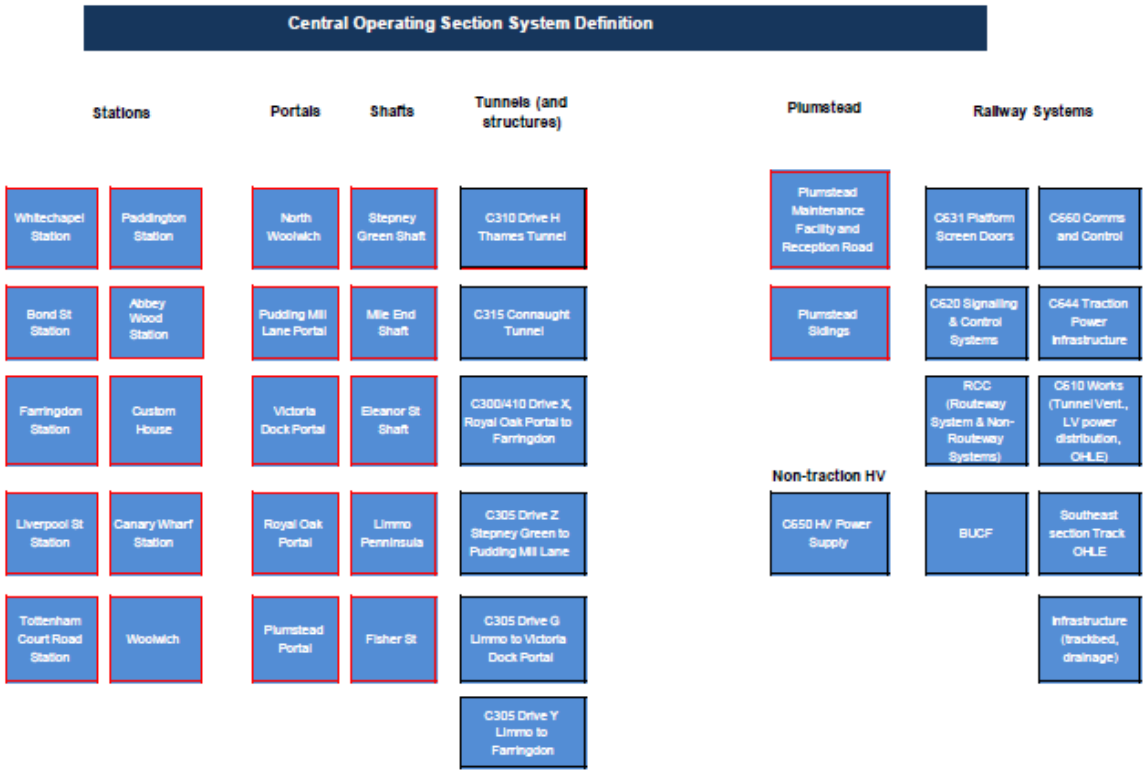

Figure 3: Block Diagram of the Central Operating Section System Definition *(Raw Data File "Crossrail Project Handover – Strategy and Plan CRL1-XRL-K1-STP-CR001-50001 Rev 4.0)*

A block diagram of the Central Operating Section may be found in the Crossrail Project Handover Strategy and Plan [Ref 47] and is a constituent of Appendix 5 Crossrail Handover Scope map (as extracted above).

Please also refer to the Systems Architecture Diagram entitled "Crossrail Systems Architecture L0/L1 Central Operating Systems Overview" [Ref 87] which provides a detailed overview of systems per location (including Systemwide applications). It is too large to reproduce here and should be accessed from eB.

The future operational / maintenance elements of the COS are being delivered by four organisations:

- Crossrail Train Operating Company (CTOC), MTRC – Operators of the train service and 5 railway stations
- London Underground (LU) – IM of 5 new sub-surface stations
- Rail for London (RfL) – COS IM for the track, non-LU stations, Railway Systems including the Crossrail Route Control Centre and the Back Up Control Facility (BUCF).
- Rolling stock provider, Bombardier Transport Services (BTS) – A specially created company that financed, designed, and is building and maintaining the Crossrail rolling stock and the maintenance depot.

3 System Safety Assurance Requirements

3.1 Requirements

3.1.1 The system safety assurance requirements covered in this plan shall be undertaken in conformity with the ESM activities shown in this Section.

3.2 CRL ESM Principles

3.2.1 The application of the System Safety Plan enables demonstration that the Infrastructure and Electrical & Mechanical systems will collectively provide the future Duty Holders with the required functionality to operate and maintain the railway safely and in accordance with legislation.

3.2.2 This is achieved through the production of Safety Justifications (SJs) supported by Engineering Safety Justifications (ESJ's) produced by the appointed contractors.

3.2.3 The overall coverage and logic of the various Safety Justifications (SJs) will be assessed by application of the Railway Level Hazard Structure [Ref 54]. A summary of the application of this process is to be found in Section 4 of this document.

3.2.4 Changes in legislation shall be periodically assessed for their impact on system safety and other System Safety Assurance Requirements. The TfL Group HS&E Policy has been used to inform the assurance arrangements for all the Crossrail works partners and will continue to be used to influence positively all stakeholder relationships.

3.2.5 The application of ESM and Construction (Design & Management) (CDM) will run in parallel, but only the ESM process will evaluate the safety of users (passengers, employees, contractors) during operation. During the construction phase, it is appropriate that hazard management is undertaken via the CDM process so that designers use a CDM risk register to close out or control risks to acceptable levels or transfer risks as detailed in section 5.3 of this SSP. Designers must use the Crossrail Engineering Safety Hazard Management Procedure [Ref 5] to transfer control of hazards through operating or maintenance procedures to the future Duty Holders.

3.2.6 CRL is responsible for the delivery of the overall integrated justification of the completed central operating section works, including interfaces with others. In order to do this the following responsibilities shall apply:

- The Delivery Director, Central Operating Section manages the delivery of the Engineering Safety Justification and Assurance for Civil works and D&B fit out by the Contractors to meet CRL, and Duty Holder's requirements.
- The CRL Project Systemwide Delivery Director enables the delivery of each Systemwide sub-system (such as track, signalling, etc.) and is responsible for making sure that the contractor(s) concerned provide the relevant Engineering Safety Justifications together with the relevant assurance evidence.
- RfL (through Bombardier) is responsible for the Rolling Stock and Depot at Old Oak Common, and is delivering Engineering Safety Justifications and Assurance in compliance with the CRL and MTR-EL's ESM processes (as described in this document).
- NR is delivering to CRL appropriate ESM and assurance evidence for the On Network Works together with the works between Plumstead and Abbey Wood provided on behalf of CRL. This is in the form of appropriate safety justification evidence for those works.
- CRL is accountable (and in the case of tunnel and station infrastructure works responsible) for the delivery of the safety assurance of the integrated systems for the central operating section.

3.2.7 The Contractor develops and manages their own safety management systems in accordance with their contract and to support this SSP. These are updated as required to accommodate notified changes to this SSP.

3.2.8 The RAP-1 and/or RAP-3 principles of the EC Regulation on Common Safety Method of Risk Assessment and Evaluation (CSM - RA) (Ref 22), shall be used for demonstrating that the project has achieved acceptable risk levels.

3.2.9 All reasonably foreseeable hazards are captured in the PWHR. The PWHR records where additional risk controls have been applied to reduce the risk to acceptable levels in accordance with the CSM-RA Regulations.

3.2.10 CRL requires that ALARP is demonstrated (over and above the CSM-RA requirement) in accordance with the LU Category 1 Standard, S1521 A8 - Safety Decision Making.

3.2.11 The System Integration Management Plan [Ref 9] describes the processes that shall be used to assure the various interfacing Duty Holders that the technical risks at the engineered interfaces will be ALARP.

3.2.12 The Crossrail Programme Functional Requirements (CPFR) [Ref 10] shall be met.

3.2.13 The CRL Project Safety Assurance Requirements shown in section 3.3 of this document shall be met.

3.2.14 The management of assumptions is addressed in the Engineering Safety Management System Definition [Ref 86]. A Railway level Assumptions Register will be developed to support the risk assessment(s) undertaken to present a safe, operational railway. Tier 1 Contractors will also keep a record and manage the Contract level assumptions through a Contract-level Assumptions Register.

3.3 Design Safety Assurance Requirements for the Crossrail project

3.3.1 Application of the Railways Interoperability Regulations 2011 [RIR], CRL has determined that the RIR shall be applied to:

- the railway sub-systems in the Central Operating System,
- Paddington, Canary Wharf, Custom House, and Woolwich Stations,
- the LUL stations Bond Street, Tottenham Court Road, Farringdon, Liverpool St and Whitechapel up to and including the Platform Screen Doors only. All other elements of the station design on the platform side of the Platform Screen Doors is excluded from the scope of the RIR at these stations;
- CRL Rolling Stock,
- and in so far as those Regulations apply, to the depots.

3.3.2 The processes applicable are contained within the Crossrail Process for Managing Interoperability Requirements [Ref 34] and Adoption of New Technical Specifications for Interoperability [Ref 53].

3.3.3 The Contractors for the Central Operating System works and the rolling stock and depot are therefore required to make sure that their designs are compliant to all the relevant Technical Specifications for Interoperability (TSIs) and associated Notified National Technical Rules (NNTRs) for Crossrail, with the exception of those parts of stations as detailed above.

3.3.4 Each TSI covers the interfaces with the other TSIs, together with all other aspects of interoperability specified in that TSI. For other parts of the railway being constructed, where the TSIs are silent, it will be necessary to apply other standards. For example the thickness of the tunnel walls or the interlocking processes used by a signalling system. For items not covered by TSIs the selection of relevant standards and the evidence of compliance will be subject to the requirements shown in this System Safety Plan.

3.3.5 CRL will apply for any necessary derogation from the Competent Authority (currently the DfT) for TSIs and propose any necessary NNTRs to cover the derogation. This will require supporting information to be provided from Designers. Details of the derogations obtained, together with any mitigation required will be published in the Standards Baseline. Designers shall take account of such information in their designs. Derogations have been obtained against part of the Infrastructure TSI, and the signalling element of the Control, Command and

Signalling TSI, as detailed in the CRL document Crossrail Process for Managing Interoperability Requirements [Ref 34].

3.3.6 During construction and testing activities the NoBo(s) and DeBo(s) appointed by CRL will review evidence supplied by the Design and Build Contractors to demonstrate compliance with the TSIs and NNTRs. By virtue of their appointment under the RIR Schedule 6 they have permanent right of access to offices and sites etc. to undertake audits and checks, site visits and to observe testing and commissioning activities.

3.3.7 With the exception of the LUL stations at Bond Street, Tottenham Court Road, Farringdon, Liverpool St and Whitechapel, Crossrail, once implemented, will be operated as part of the national railway network and therefore the safety risk levels associated with its design will contribute to the overall level of safety on the national network. Currently the following requirements influence the national and Crossrail safety levels;

- The legal requirements such as the Health & Safety at Work Act and associated legislation, Railways and Other Guided Transport Systems (Safety) Regulations 2006 [ROGS] as amended;
- National Reference Values (progressively replaced by Common Safety Targets when determined by the EC) as specified in the European Safety Directive (subsumed within the overall project safety processes);
- Adoption of good practice as shown in The Railway Strategic Safety Plan [Ref 17];
- Adoption of good practice as shown in the London Underground Safety Plan (current);
- High Level Output Specifications (HLOS) set by HMG for the national railway (not applicable to Crossrail).

3.3.8 The current HLOS are not relevant to Crossrail because they have been set by the DfT for the existing national railway managed by NR in which Crossrail does not exist. Therefore HLOS are not discussed further in this document. The other requirements are discussed further in relation to Crossrail in the paragraphs below. Each topic commences with CRL policy, followed by supporting information.

3.3.9 UK National Legislation

(i) CRL Policy

The FDC C100 series engineering packages of work predated CSM-RA and therefore applied existing CDM / RIBA and Yellow Book principles for risk assessment and evaluation. These packages included the majority of the tunnel, stations and shafts concrete works. Whilst essentially consistent with the CSM-RA requirements, the later (non C100 series) Design and Build Contractors undertook a review of the risk assessment and evaluation work previously undertaken, transferring those hazards not closed, as appropriate, into their respective sections of the PWHR, and by application of the later introduced CSM-RA principles demonstrated that appropriate mitigation was in place.

Certain of the civils elements of the construction undertaken by the C100 series contractors e.g. the shaft concrete structure and the tunnel linings were not subject to this review by the later Design and Build Contractors.

However, CRL has undertaken a separate activity for these elements to verify that the certified design requirements have been met through the constructed works by demonstration that the specified requirements have been met.

The document Tunnel, Cross Passages, Crossovers & Line of Route Civils Works Interim Safety Justification [Ref 68] outlines how the safety of the civils structures is being demonstrated such that it can form an input into the Interim Safety Justifications at the Final Design Overview (FDO) and provide an input to the Consolidated Tunnels, Shafts and Portals Safety Justification.

This activity is being carried out in accordance with the Verification and Validation Plan [Ref 16] and the "VAP Implementation and Progressive Assurance Procedure" [Ref 56]. Both the Verification Report and the resultant Verification Certification are lodged in eB.

The argument for how the risk assessment and evaluation of these elements have been demonstrated as being tolerable and ALARP is contained within the appropriate Strategic Engineering Justification (SEJ) as detailed within the Railway Level Hazard Structure [Ref 54].

If by applying the ALARP principle, those risks that are not at least tolerable cannot be achieved by design alone and require further mitigation (e.g. through an operational control), then this will be dealt with as detailed in the paragraphs below. No identified ‘Intolerable’ risks shall persist in the design, at the point of handover, or beyond.

CRL together with the Designers and Contractors is making sure that the completed railway can be operated by the Duty Holders in accordance with all relevant UK and European legislation, specifically Commission Regulation (EU) 402/2013, also known as “Common Safety Method for risk evaluation and assessment” (CSM) together with subsequent amendment (EU) 2015/1136. In particular, the risks to safety of the passengers, workforce (including contractors) and members of the public who may be affected by it shall be reduced to acceptable levels through design. In achieving this, account has been taken of the good practice shown in the RSSB Strategic Safety Plan [Ref 17] and the London Underground Safety Plan. Further information on this is shown in 4.3.10 below.

The following diagram illustrates how CSM Compliance is demonstrated for the whole of the Central Operating Section of Crossrail.

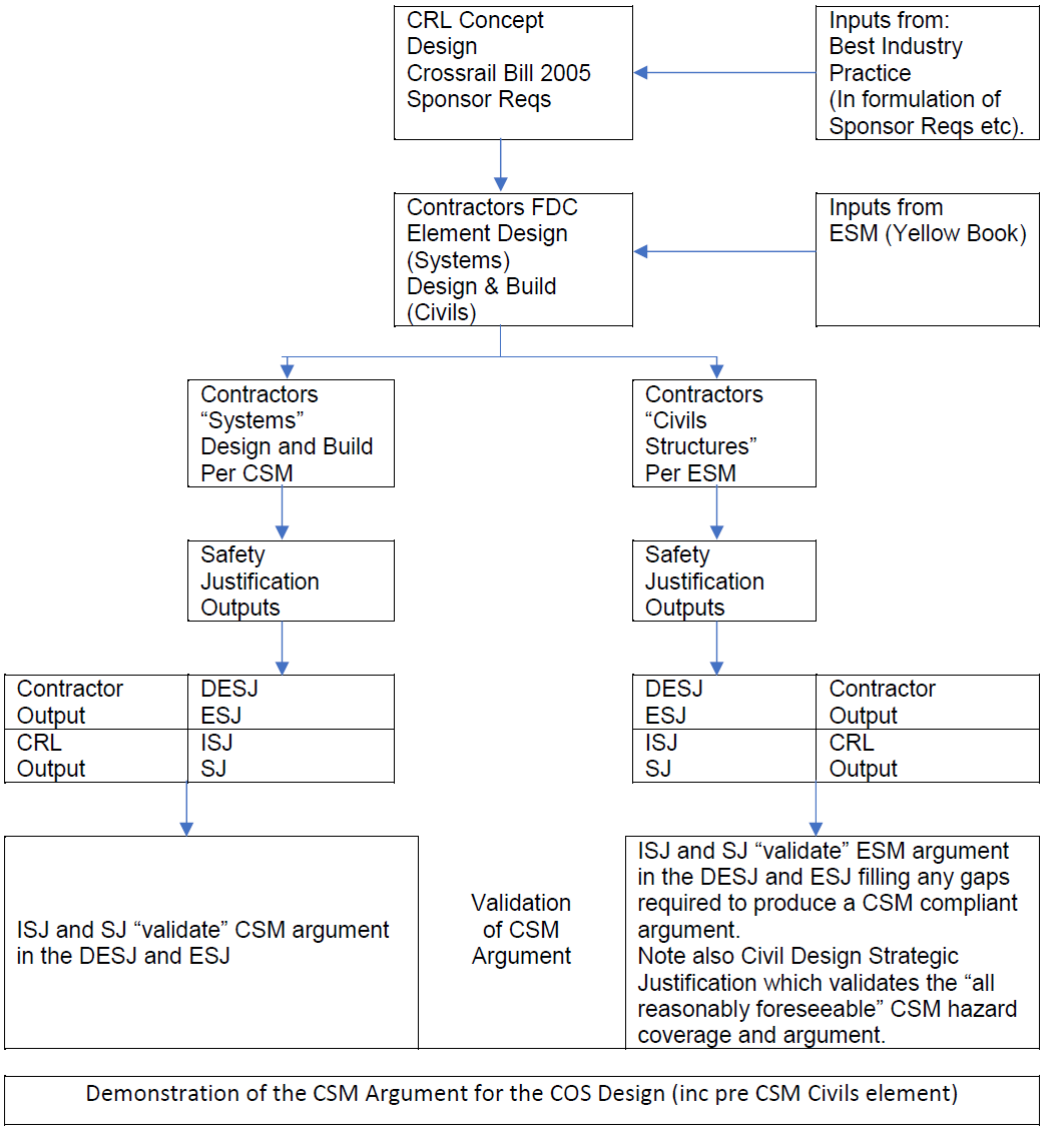

Figure 4: Systems Safety Management Activities for CSM Compliance

It is acknowledged that CSM-RA legislation (EU 352/2009) did not become law until 2010 with certain sections not being applicable until July 2012.

3.3.10 National Reference Values and Common Safety Targets

(i) CRL Policy

CRL together with Crossrail Designers and Suppliers, make sure that the obligations detailed or referenced in clause 4.3.7 above are met, and need take no further actions in respect of the delivery of NRVs and CSTs. Background information to support this policy is shown in clauses (ii) to (iv) below.

(ii) The European Safety Directive requires the European Rail Agency (ERA) to develop a set of Common Safety Targets (CSTs) for Member States. These are in effect risk targets for each topic defined by the CST. They are based on the assumption that, although the current levels of safety differ greatly in each Member State, that level of safety is acceptable in each. They seek to avoid compromising safety in countries, such as the UK, which have a higher standard of safety performance than others.

(iii) The EC has determined that an evolutionary process will be used to set CSTs and therefore have set National Reference Values (NRVs) for each MS which will precede the delivery of more meaningful CSTs. CSTs and NRVs are set at the Member State level for the whole railway system and do not apply to individual Duty Holders. They are therefore the

responsibility of the DfT to manage on behalf of the UK. The first and second set of CSTs were adopted by the EC by end of April 2012. However they currently apply only to the EU as a whole. Therefore NRVs still apply to each individual Member State. By the date that Crossrail will be in service operation, it is anticipated that CSTs will have replaced NRVs in their entirety.

(iv) The DfT have agreed for the National Railway System that the requirements of the CSTs / NRVs will be subsumed within the Health and Safety at Work and associated ALARP obligations. Therefore a Duty Holder's Safety Management System that complies with all relevant requirements shall assure the ORR that the Operator contributes to achieving the CSTs/ NRVs.

3.3.11 Checking of Safety of Design Requirements by use of CSM on Risk Assessment

(i) CRL Policy

- CRL through the activities of its Suppliers and Designers, takes account of good, practice shown by the initiatives detailed in the Railway Strategic Safety Plan (RSSP) 2009 to 2014 published by RSSB; and in respect of the LUL stations any relevant LUL current safety plan for stations. They shall make sure that the safety performance of their designs is at least as good as that shown in these Plans and wherever reasonably practicable, is improved upon.

- At the LUL stations, the platform side of the Platform Screen Doors the EC Regulation is not mandatory, however it is adopted by the CRL Project as best practice. CRL uses the Crossrail Engineering Safety Management Hazard Management Procedure [Ref 5] to check whether the hazard identification and associated risk assessments used by the Designer(s) have reduced the risks to tolerable and ALARP.

- For ONW it is the responsibility of NR to determine how CSM-RA is applied.

- Further background to support this policy is shown in clauses (ii) to (iv) below.

(ii) The demonstration that the process used to comply with the CSM Regulation has been applied on the Central Operating System and for the Crossrail rolling stock are reviewed by an Independent Assessor (the Assessment Body (AsBo), according to his Assessment Plan and in accordance with the Regulation. The outputs of the risk assessment shall be reviewed and endorsed by CRL. The results of the risk assessments shall be incorporated into the relevant Technical Files by the NoBo in a format agreed by CRL.

- In the case of On Network Works together with those works undertaken for CRL between Plumstead Portal and Abbey Wood, NR as the Project Entity is responsible for the determination of how CSM-RA is complied with.

(iii) The CSM Regulation has been implemented by the EU, through adoption of Directives EU 402/2013 as amended by EU 2015/1136.

These apply to:
- significant changes to structural sub systems and functional subsystems as defined by the RIR 2011, or as required by a TSI
- significant operational and organisational changes.

The ORR has issued guidance [Ref 33] on the Regulation and what is meant by "significant" in the context of the Regulation. So far as the CRL is concerned the construction of a new railway, comprising the structural sub systems within the Central Operating System that are the subject of TSIs, shall be deemed to be significant, and hence subject to application of CSM-RA. In order to comply with the EU directives on CSM-RA, the relevant IMs have

appointed their own AsBo to confirm compliance or otherwise, in accordance with the requirements of the Directive.

(iv) The CSM Regulation identifies three safety risk acceptance principles that demonstrate that such risks have been reduced to a suitable level by using one or more of the following principles:

- the application of codes of practice (COP) (considered "acceptable" without further mitigation being applied)
- comparison with similar reference systems (SRS) (considered "acceptable" without further mitigation being applied)
- an explicit risk estimation (ERE) (reduced to "ALARP").
- Application of the above risk acceptance principles is consistent with the need to demonstrate ALARP in accordance with the requirements of the Health and Safety at Work Act. The safety measures contained in suitable codes of practice and applied in similar reference systems are to be considered representative of good practice, whereas risk assessments are undertaken where there is an element novelty in the risk or that the risk may not have previously been encountered. The following key principles arising from implementation of the Directive shall be followed by CRL and its Contractor's in accordance with their requirements:

3.3.12 Risk Assessment Principles

- The three risk assessment principles contained in CSM-RA are discussed further as follows-
- Codes of Practice (COP)
- Similar Reference Systems (SRS) and
- Explicit Risk Estimation (ERE)

3.3.12.1 Codes of Practice (COP)

- The list of applicable standards can be found in the document Crossrail New Works Standards Baseline [Ref 24].
- The Contractor shall detail compliance with relevant standards where these are used as part of the safety justification. If COP is being claimed, then there shall be a justification supported by evidence for how and why that choice of standard or element thereof is applicable accompanied by evidence to demonstrate compliance. If a derogation is required against a particular standard (or part of a standard), then the reasons for this derogation, together with a risk assessment, should accompany the justification. The contractor's quality system can be used to provide or support this evidence. Note that it is not expected that standards need to be 'unpacked', I.e., no demonstration of clause-by-clause compliance is required, as most standards are considered to be either applicable in large sections or in the whole.
- Please see the ORR guidance [Ref 33] for application of Codes of Practice (COP).

3.3.13 Similar Reference System (SRS)

A reference system shall satisfy at least the following requirements (source ORR guidance 03/2015, [Ref 33]):

- it has been proven in use and has an acceptable safety level;
- it would qualify for approval in the Member State; and

- the system being assessed is used under similar functional, operational and environmental conditions and has similar interfaces as the reference system.

(Note that the ORR Guidance 03/2015 [Ref 33] states (in respect of the second bullet point above that) "it is accepted in the member state where the change is to be introduced")

3.3.14 For example, Designers may wish to use an existing modern LUL station fitted with Platform Screen Doors as a reference system, provided that it meets the criteria shown in the ORR guidance [Ref 33].

3.3.14.1 Explicit Risk Estimation (ERE).

- The UK ALARP risk acceptance criterion will be used in most cases where safety measures need to be derived using Explicit Risk Estimation. The supporting analysis is considered equivalent to what was done to meet the requirements of general safety legislation or previous best practice, contained within for example, 'Yellow Book 4.0', with the basic elements in the CSM RA risk management process – defining the system, identifying its hazards, and putting in place the controls needed to reduce the risk from them to an acceptable level. This process is already well established.

- Where a risk requires consideration under ERE, the assessment shall consider those facets of the identified hazard likely to lead to harm or loss, with a preference for quantified assessment for higher risk hazards, with a qualitative approach considered applicable for lower risk hazards. The degree of novelty or complexity shall be considered in the assessment with any uncertainties or partial knowledge explicitly identified within the assessment, where possible.

- Any combination of at least one of the above principles should be used to demonstrate adequate mitigation for each and every hazard that is not ranked "broadly acceptable" at the time of identification or prior to the effect of any mitigating factors or safeguards. Note that if the ERE approach is used, the ALARP principle must be adequately demonstrated.

- Note. Where a hazard relies on the presence or existence of a mitigating factor to control a hazard, and the initial risk is reduced to "Tolerable or ALARP" as a result of it, then that hazard mitigation shall be considered to possess safety requirements, which shall be subject to verification. Safety requirements are discussed in this Section.

3.3.15 As an example, in the case of the Central Operating System signalling system, the manufacturer would be required to demonstrate that the system would have SIL 4 functionality and thus meet the explicit risk acceptance criteria specified in the Regulation. For other structural sub systems the relevant TSIs shall be used as codes of practice supplemented as required by Notified National Safety Rules and Notified National Technical Rules relevant for the CRL Project.

3.3.16 The Contribution of Broadly Acceptable Risk to the Overall Risk:

The CSM-RA regulation Annex 1, clause 2.2.2 states that "To focus the risk assessment efforts upon the most important risks, the hazards shall be classified according to the estimated risk arising from them. Based on expert judgement, hazards associated with a broadly acceptable risk need not be analysed further but shall be registered in the hazard record. Their classification shall be justified in order to allow independent assessment by an assessment body."

Classification of hazards in this way allows the subsequent risk assessment work to focus upon the most important risks, by discounting those hazards which need no further consideration at an early stage.

The actual classification of a hazard is made on the basis of expert judgement through Hazard Workshops held in accordance with the Engineering Safety Hazard Management Procedure [Ref 5]. These Workshops have been held throughout the Crossrail Project and have been

convened with a competent panel of subject experts. The results of these Workshops are documented.

The CSM-RA regulation, Annex 1, clause 2.2.3 states that 'The expert judgement shall take into account that the contribution of all the broadly acceptable risks does not exceed a defined proportion of the overall risk.'

The Hazard Review Panel is the body of experts who have been designated by CRL to determine this.

3.3.17 For the Crossrail Rolling Stock and Depot the Designers shall take account of the requirements of the CRL policy.

3.3.18 CRL have developed a Safety Risk Model in order to determine overall risks in operating and maintaining the operational railway. It models the low frequency, high consequence events such as collisions between trains and derailments. The model provides a design baseline to which significant changes to the design basis or operating concept can be evaluated. It can be used as a tool to inform decisions on the proposed changes by assessing risk reduction associated with implementing different proposed control measures. The model results can be an input into CBA studies and used to demonstrate that the risk of railway operation has been reduced to ALARP.

3.3.19 Various System Definitions

- The parameters of the Contractor's System Definition (SD) (i.e. the scope of their contracts) is defined in the Contractor's 'Design Engineering Safety Justification (DESJ)' and kept current within successive revisions. This determines the boundary of the relevant contractor's scope of supply and influence and will assist with the assurance of comprehensiveness within that boundary.
- In parallel to the above, CRL have developed a set of System Descriptions which are used as a sense check at each FDO. These are used as a sense check to demonstrate that the sum of the parts will ultimately cover the whole. The "Final Design Overview (FDO) Process" document [Ref 61] describes this.
- The COS and overall railway SD's are being produced by CRL, and consolidate all elements of the SD's to support the COS and End-to-End Railway Infrastructure Safety Justifications.

4 Engineering Safety Management Activities

4.1 Responsibilities

4.1.1 Engineering Safety Management is the activity in making a system, product or other change safe and showing that it is safe. This involves consideration of the railway throughout the life of the change. CRL retains overall responsibility for the ESM Programme.

4.1.2 Ricardo Rail (formerly Lloyds Register Rail) were appointed by CRL to fulfil the following roles:

- NoBo and DeBo (technical compliance) under Railway (Interoperability) Regulations 2011 and Railway Safety Directive (ROGS), and the AsBo (safety assessment) under CSM for Risk Evaluation and Assessment.

4.1.3 The CRL's Project Engineers are responsible for managing and coordinating the individual contract work packages within their areas of responsibility, making sure that the Contractors concerned provide the relevant DESJs and ESJs together with the relevant assurance evidence in accordance with this Plan.

4.1.4 The safety of any system comes from a combination of the engineering, operations and maintenance arrangements and CRL is responsible for the delivery of a fully functioning railway that meets the Joint Sponsors' Sponsor Requirements (SRs). CRL is responsible for developing and integrating the design and the interfaces, so as to allow the railway to be operated and maintained to meet the Joint Sponsors' requirements.

4.1.5 The above requirements are being demonstrated by the delivery of Interim Safety Justifications (at completion of Design stage) and Safety Justifications (at completion of construction and prior to Trial Running).

4.2 Railway Level Hazard Structure

4.2.1 This section of the SSP provides a summary only; the full details of the Railway Level Hazard Structure shall be documented in the "Consolidated Railway Systems Interim Safety Justification for Central Operating Section" [Ref 89].

4.2.2 CRL shall produce a "top-down" Railway-Level Hazard Structure (RLHS) to show the contribution of each element of the railway to the hazard and the safety measure to mitigate that hazard to a broadly acceptable level.

4.2.3 The RLHS model will be utilised by CRL in assessing the overall coverage and logic of the many separate safety justifications (SJs) for each element of the railway. This will contribute to the overall integration of Crossrail across contractual boundaries and provide assurance that the combination and integration of each of the SJs add up to a safe overall system.

4.2.4 CRL shall also produce twelve Strategic Engineering Justifications (SEJs) which define the safety requirements to mitigate the railway level hazards in accordance with CSM Regulations.

4.2.5 The Strategic Engineering Justifications shall address:

1. Fire & Evacuation & Tunnel Ventilation
2. EMC
3. Earthing & Bonding
4. Tunnel Drainage and Flood Protection
5. Alarms & Security
6. Cyber Security
7. Lighting
8. Platform Train Interface
9. Civil Design
10. Maintenance
11. Station Crowding/sizing
12. Train Collision and Derailment

4.2.6 The ultimate goal is to demonstrate for the key hazards in the RLHS, the identified safety requirements in the SEJs have been satisfied by applying defined CSM risk acceptance principles evidenced at contract level. Where CSM is not applicable, the yellow book principles will be used.

4.2.7 This will be achieved by developing clear links from the railway level hazards to where the evidence is to be found, also providing a link to the source of the evidence. The source of evidence is generally found in PWHR but also in other documents not referenced in PWHR.

4.2.8 The comprehensive Railway-Level Hazard Structure is based on the RSSB Hazardous Event Descriptions and will be developed on the CRL PWHR Generic hazard list

4.2.9 The RLHS will be checked against LULs Network Risk Profile and contain input from the train accident risk model

4.2.10 The RLHS will be subject to review and agreement in a series of workshops with competent participants (including representation from the AsBo). The competence of the participants will be accepted by RAB(C) prior to the workshops, and the outputs in the form of the Railway Level Hazard Structure will be endorsed by RAB(C).

4.2.11 The RLHS will be a live document and will be updated during the project life cycle prior to handover to the Duty Holders.

4.2.12 In order to demonstrate the alignment of the safety evidence collected at Contract Level to the Railway Level Hazards, a document, “Alignment of Safety Evidence to Key Hazards Railway Level” document shall be created. This document will contain a matrix that links the railway level hazard to lower level hazards and associated safety requirements at element and contract level.

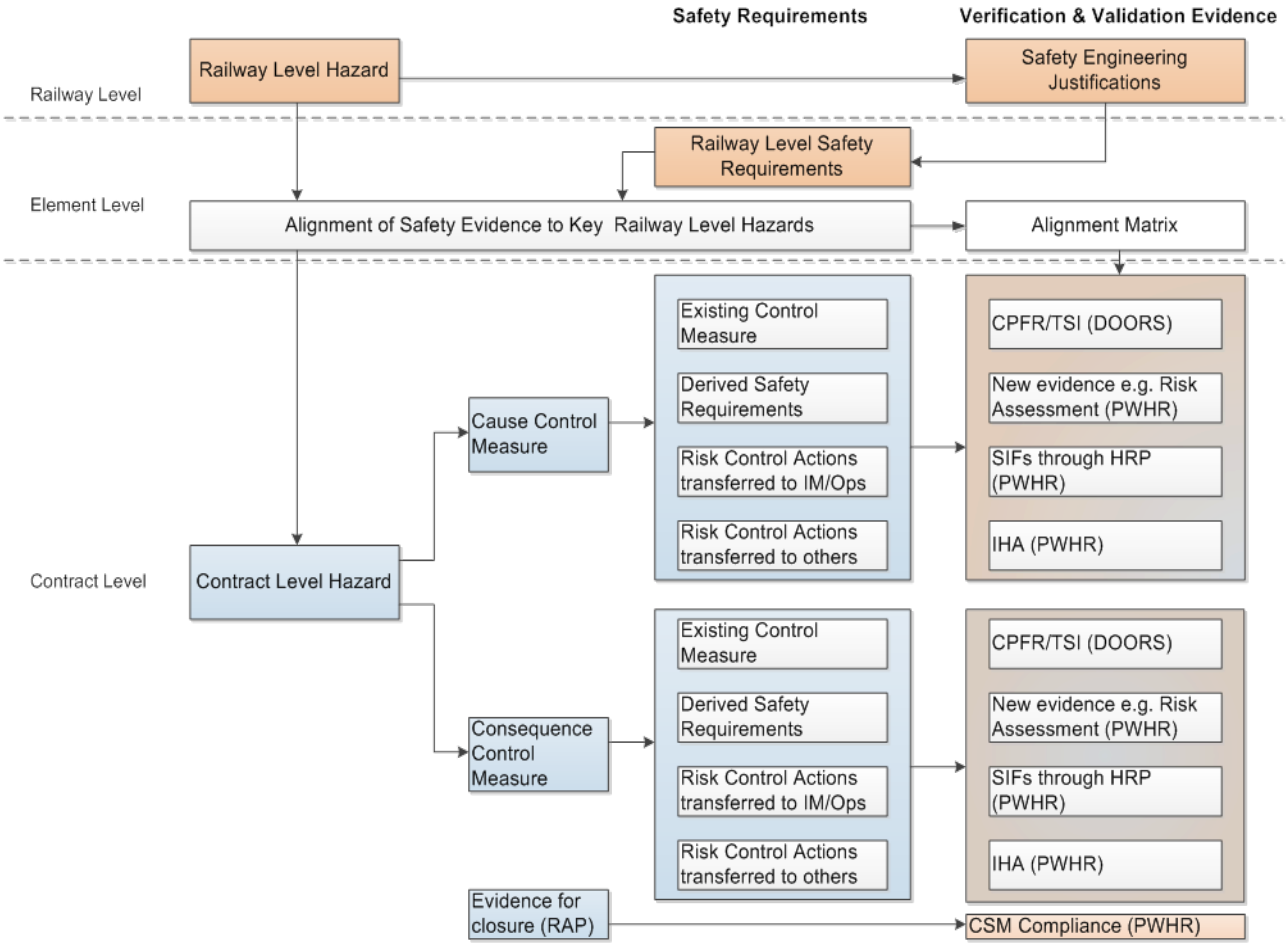

Figure 5: RLHS, Safety Requirements and V&V

 CRL RESTRICTED

4.2.13 Demonstration of safety at a strategic level will be demonstrated through the production of a series of Strategic Engineering Justifications which are supported by Engineering Safety Justifications. The listing of these can be found in CRL Railway Level Hazard Structure.

4.2.14 Safety requirements will be identified from TSI's (as prime requirement), risk assessments and technical strategy documentation. These safety requirements have been aligned to the assets and systems to which they apply.

4.2.15 Safety is proven per Strategic Engineering Justification by provision of evidence to demonstrate that the reference hazards have addressed the safety requirements, such that the hazards are either eliminated or mitigated as far as is reasonably practicable under CSM.

4.2.16 Figure 5 shows how the safety requirements from railway level to contract level associated with Railway Systems are managed.

4.2.17 The safety requirements from the CRL Railway Level Hazard Structure will be split into the requirements for each contract. The CRL Assurance ("Gates") process provides the confidence that the requirements have been captured in each contract in the Design Engineering Safety Justification and the Engineering Safety Justification.

4.2.18 The evidence supporting this is held per contract in The Crossrail Assurance Reporting Environment (CARE) [Ref 83] database. The data in CARE is grouped into eight evidence sets:- Design, Construction / Installation, Testing and Commissioning, Safety & Safety Justifications, Trail Running, Trial Operations, IM Products and CRL Products.

4.2.19 Figure 6 illustrates how a Railway Level hazard (and associated safety requirements) has been managed and linked to the contract level requirements. Note this is per contract.

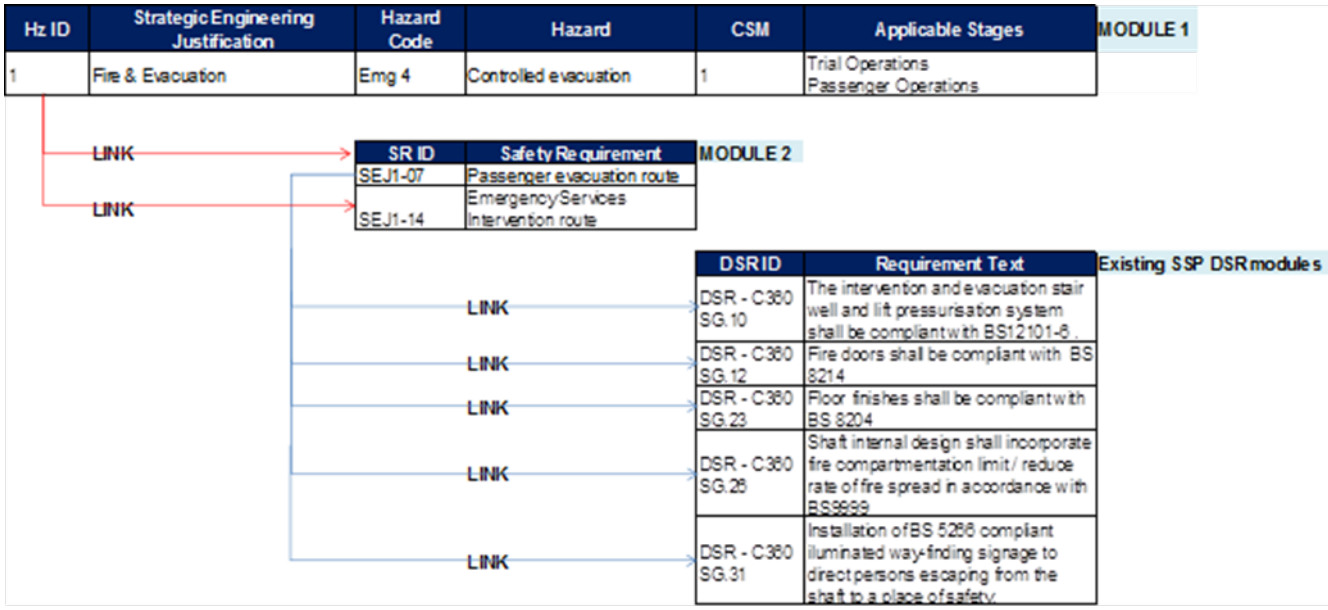

Figure 6: Illustration of RLHS and Alignment Matrix

4.2.20 Closure of the associated hazards per contract will be managed in the Project Wide Hazard Register [Ref 71] (PWHR) and associated documents e.g. Fire Safety Strategy for the contract (the hazards associated with fire being contained in the Fire Risk Assessment as per the Regulatory Reform (Fire Safety) Order requirements and TSI's, and not in the PWHR). The document "Alignment of Safety Evidence to Key Hazards Railway Level" will reference where the evidence is to be found, also providing a link to the source of the evidence.

4.2.21 The Interim Safety Justification (ISJ) [Ref 84] and Safety Justification (SJ) documents will reference the safety requirements together with confirmation of suitable closure. These build upon the main contract in question e.g. a particular shaft, together with the elements of other contracts that interact at that location e.g. traction power supply, to demonstrate that all hazards have been suitably mitigated. These demonstrate that the particular element of the system is technically safe.

4.2.22 In parallel to this, a series of System Integration Panels [Ref 69] (SIRPs) and Maintenance Integration Panels [Ref 70] (MIRPs) will carry out a sample check in “Normal”, “Abnormal”, “Degraded” and “Emergency” modes to validate that the elements are both operable and maintainable.

4.2.23 Thus the ISJ / SJ will demonstrate that the element is technically safe and the SIRPs / MIRPs demonstrate that the element is operable and maintainable.

4.2.24 The sum of these for every element will demonstrate that the system as a whole is safe and operable / maintainable. Evidence will be provided for each element such that the sum of each element will demonstrate that the Railway Level Hazard has been adequately mitigated throughout the complete system..

4.2.25 This evidence, together with the Project Wide Hazard Record will be documented within the End to End Safety Justification and Assurance Strategy [Ref 30].

4.2.26 This will ultimately permit the Infrastructure Manager to accept that the integration delivers a safe and operable railway in conjunction with the Infrastructure Manager’s Safety Management System.

4.3 CRL Organisation with respect to ESM

4.3.1 The CRL organisation will make sure that sufficient resources are made available to deliver the ESM related tasks required for successful project delivery. The CRL project safety organisation is shown in the Connect on Line>Company Information >Organisation Charts home page. It has been developed to take decisions required for the project, including safety related decisions. It shows the ESM responsibilities of the relevant CRL Directors and their relevant direct reports and will be kept up to date by CRL. See also 5.15 “Organisation for Managing Engineering Safety” which provides details of the ESM team resources.

4.3.2 It is not anticipated that external organisations will need the above detail, but further information regarding ESM responsibilities with the Crossrail Project can be obtained from the CRL Technical Director.

4.3.3 The CRL System Safety Team are responsible for assembling the information developing the various safety justifications. This information will be drawn from the various CRL technical disciplines. Further details of safety roles and responsibilities within CRL that are responsible for the various inputs to the Safety Justifications will be input into a later revision to this document.

4.3.4 CRL Project Team Safety Responsibilities

- All staff have responsibilities under the Health and Safety at Work Act for their own safety, the safety of their colleagues and the safety implications of their work. Staff are therefore responsible for performing their duties and roles in a safe manner and for making sure that safety is given priority in their work. In general, the safety duties of project personnel are defined in the Health & Safety Manual [Ref 7].

4.3.5 Sponsors

- Sponsors are responsible to the Secretary of State for specifying the objectives, the outputs to be delivered, securing funding for the project and making sure that CRL delivers the project to time, scope and budget in accordance with the Development Remit and the Business Case. The Sponsor is responsible for making sure that safety is given the necessary priority and resources by the Programme Deliverer to achieve a safe and successful outcome for the project. The Programme delivery role has been delegated to CRL by the Joint Sponsors DfT and TfL.

4.4 CRL Project Hazard Management Process

4.4.1 CRL has established a Crossrail Engineering Safety Hazard Management Procedure [Ref 5] for management of all hazards contained within the PWHR [Ref 71] to which all Contractors, and CRL’s Directorates shall conform. The hazard management process shall also satisfy the

hazard identification, risk analyses and evaluation requirements mandated in the EU Regulation on Common Safety Method on Risk Assessment & Evaluation [Ref 22].

4.4.2 The hazard management process is subject to assurance by CRL. In addition the Hazard Review Panel [Ref 51] detailed in Crossrail Engineering Safety Hazard Management Procedure [Ref 5] approves hazards that are proposed for mitigation by transfer to future Duty Holders.

4.4.3 Section 6.3 of this SSP provides further information on hazard management.

4.5 Safety Life Cycle

4.5.1 Strategy

- The project strategy takes cognisance of the NR programme process, known as Governance for Railway Investment Projects (GRIP) as described by the NR Policy Manual and Project Management [Ref 31] and the requirements of London Underground 1-538 standard “Assurance” [Ref 32[1]].
- The safety activities are carried out during the various stages of the project, and follow the requirements of the EC Regulation on CSM on Risk Assessment & Evaluation. The general guidance of BS EN 50126 [Ref 18], 50128 [Ref 19] and 50129 [Ref 20] may be used. It is a requirement of the project that a V lifecycle model is used for the development and application of appropriate safety activities at the correct part of the life cycle. A diagrammatic representation of this cycle as has been applied to Crossrail as a whole is indicated below. Not all stages are applicable to each contract. The breakdown of the various stages (Readiness Gates) for System Integration, Testing, Commissioning and Trial Running are contained within the document "Readiness Gates Procedure" [Ref 59] which overlays and complements the R1 to IM2 phases of the lifecycle as indicated in the following three diagrams.
- The V-lifecycle Stages is further used to develop the safety lifecycle activities and associated deliverables presented in subsequently in Section 4
- In accordance with CSM Regulations, these activities and deliverables are subject to assessments. A Crossrail Assessment Schedule (CAS) shall be developed and agreed between the Assessment Body (AsBo) and Crossrail.
- The AsBo NoBo programme will include listings and programme of CRL ESM artefacts to be assessed.
- The Crossrail Central Operating Section (Interim) Safety Justification will present a list of the ESM deliverables.
- A consolidated RAB-C List and associated RAB-C Submissions Programme (updated on a period by period basis) will track the progress of the CRL based deliverables, together with supporting deliverables from the respective contractors.
- These activities and deliverables are presented in subsequent sections of this document.

[1] RIBA Design Stages are used commonly amongst Tier 1 Contractors and others.

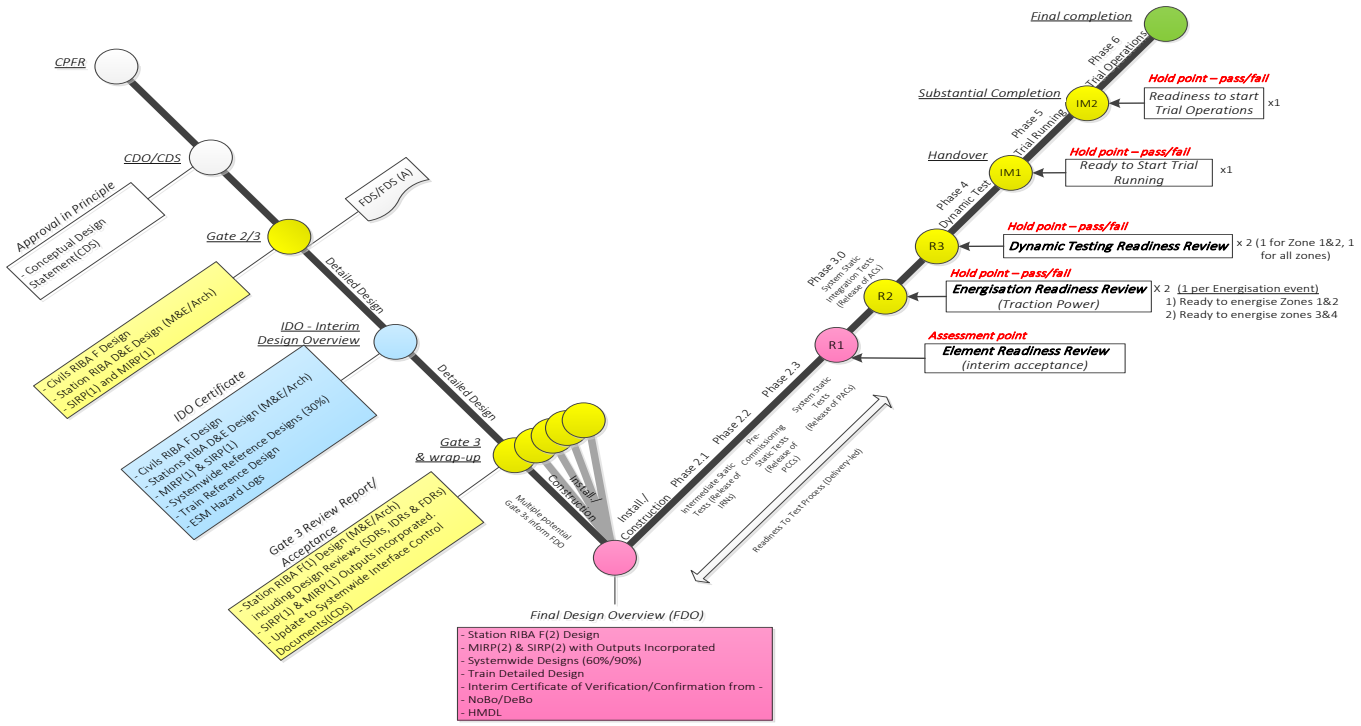

Figure 7: Overall Verification and Validation Life Cycle for the Crossrail Project

(Source document - Readiness Gates Procedure CRL1-XRL-O-GPD-CR001-50006)

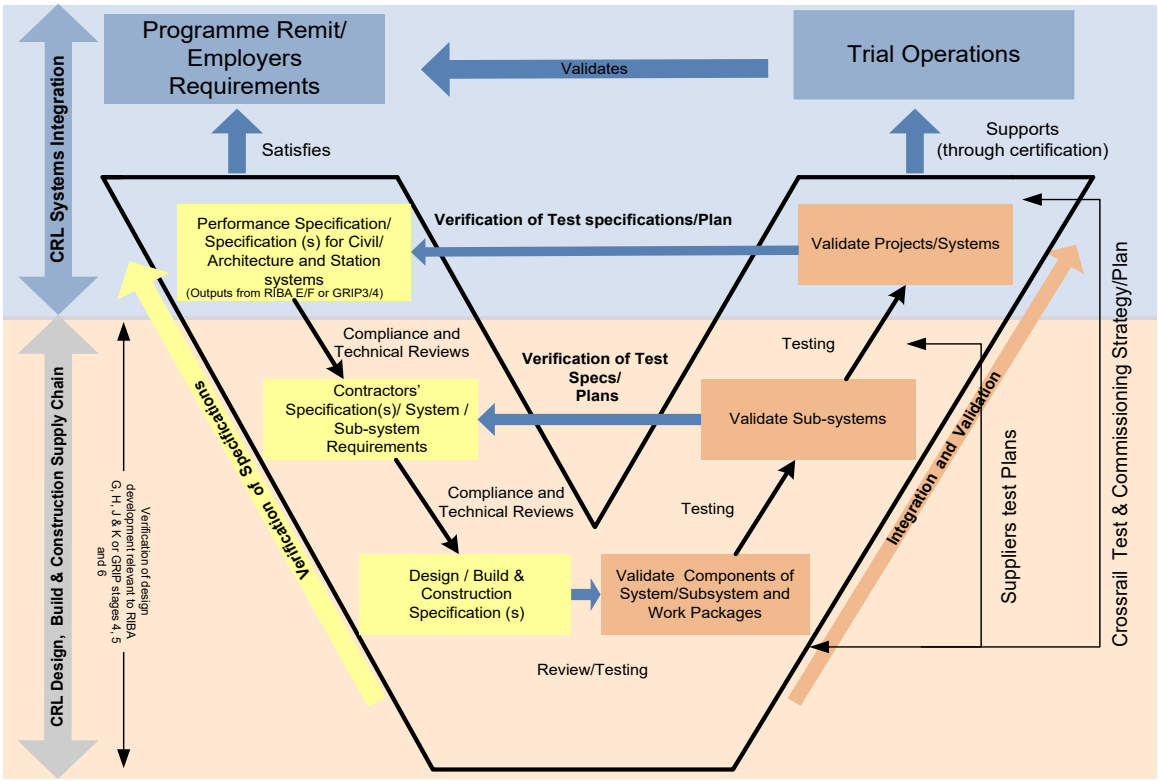

Figure 8: System Integration "V" Life Cycle (Testing and Commissioning validation)

(Source – System Integration Management Plan (CRL1-XRL-O8-STP-CR001-50010))

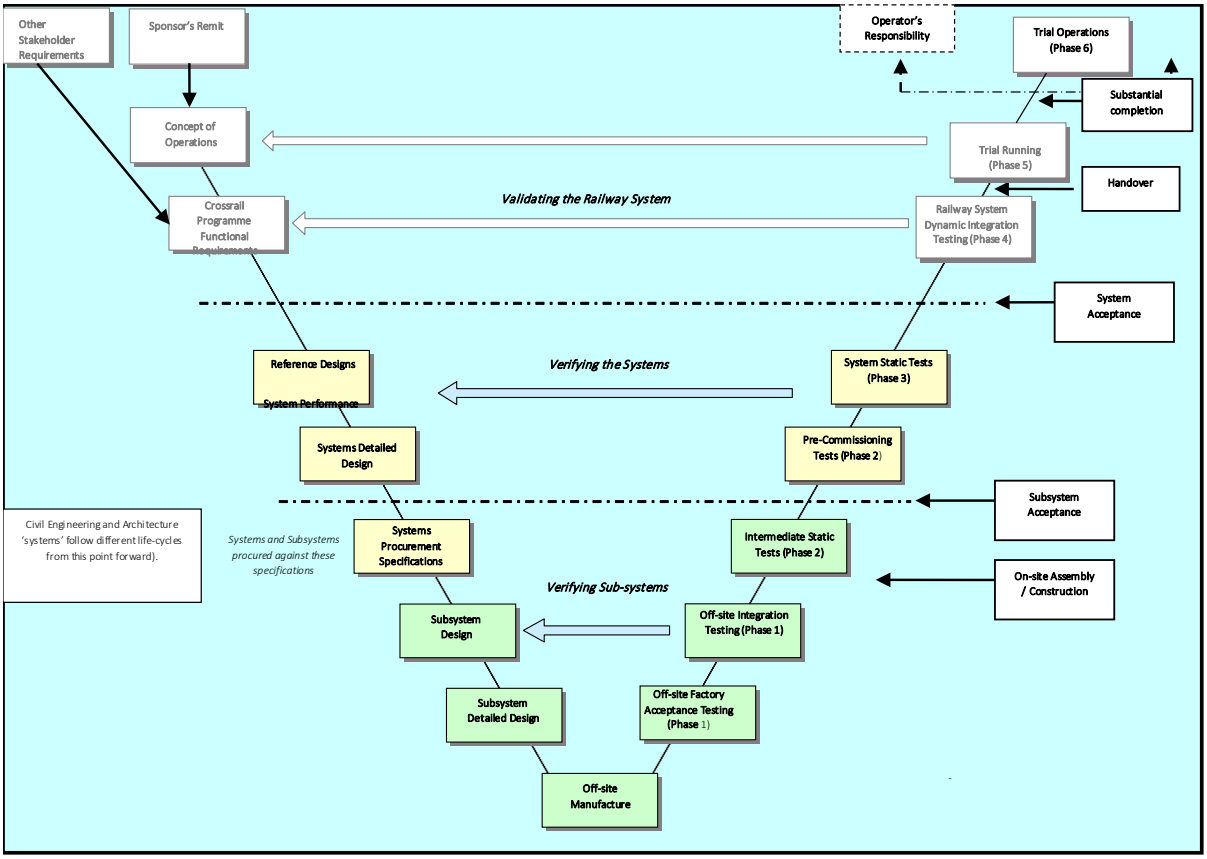

Figure 9: "V" Lifecycle, showing Testing and Commissioning Phases in detail. *Source – Testing and Commissioning Strategy (CRL1-XRL-O8-STP-CR001-50008)*

The following table gives an overview of the CSM based safety activities from Elemental Readiness Review (FDO) through to the handover of the Crossrail Project to the owner, operator and maintainer and should be read in conjunction with the above diagrams and the safety life cycle text that follows this section.

Phase	CRL Based Activity	Supporting Documents / Processes
FDO (Element Readiness Review)	ISJ	CRL will provide an ISJ to support the FDO stage for each contract. Various Product, System and Cross Acceptance Safety Cases will be provided by the various contractors in support of this e.g. PSC for Rigid Overhead Catenary, High Attenuation Sleeper Product Safety Case. The contract DESJ's (one per contract) support the creation of the ISJ and the FDO. The PWHR record is complete for the design phase
Post FDO (i.e. after Element Readiness Reviews have been completed)	Consolidated ISJ's	CRL will produce "consolidated" ISJs that draw various ISJs together e.g. for RfL Stations, drawing the individual ISJ's for each of the RfL stations together.

Phase	CRL Based Activity	Supporting Documents / Processes
		The PWHR record is complete for the design phase
Post FDO		Following FDO, contractors will work upon the creation of the respective ESJ's that will begin to compile the evidence necessary to elevate the design evidence to that of "as built". Evidence will be collected as the testing and commissioning phases progress. The PWHR is populated with appropriate evidence as this is obtained.
Energisation (Energisation is presently envisaged to occur in two distinct phases)	Safety Case	A "safety case" will be created to demonstrate the "safety" of the particular section of the COS that is to be energised. This is supported by ESJ's from the contractors that provide a "position" as to the completeness of the construction at the time of energisation. The CRL safety case draws upon this and provides the demonstration of safety for the activity. The PWHR evidence is obtained and the record is completed for this particular phase
Testing (Part of dynamic testing and trial running)	Safety Case	A "safety case" will be created to demonstrate the "safety" of the particular section of the COS and phase of testing that is to be undertaken. This is supported by ESJ's from the contractors that provide a "position" as to the completeness of the construction at the time of testing. The CRL safety case draws upon this and provides the demonstration of safety for the activity. The PWHR evidence is obtained and the record is completed for this particular phase
Commissioning (Part of dynamic testing and trial running)	Safety Case	A "safety case" will be created to demonstrate the "safety" of the particular section of the COS that is to be subject to commissioning. This is supported by ESJ's from the contractors that provide a "position" as to the completeness of the construction at the time of energisation. The CRL safety case draws upon this and provides the demonstration of safety for the activity. The PWHR evidence is obtained and the record is completed for this

Phase	CRL Based Activity	Supporting Documents / Processes
		particular phase
Post Trial Running / Handover (Trial Operations)	SJ	SJ's for the completed parts of the railway will be supported by appropriate ESJ's from the contractor. The PWHR record is now complete for handing over to the future operator and maintainer. (The PWHR record together with the Strategic Engineering Justifications provides a bottom up and top down demonstration that all reasonably foreseeable hazards have been identified and managed)
Substantial Completion	CESAC End to End Railway Infrastructure SJ	End to End Railway Infrastructure Safety Justification and Assurance Case (Overarching Document) End to End Railway Infrastructure Safety Justification. Both of these documents consider the safety of the whole of the Crossrail Railway Project i.e. from Abbey Wood and Shenfield through to Reading. Within these documents is embedded the safety justification for the Central Operating Section

4.5.2 Safety Life Cycle Activities

This Section will only present the Safety Lifecycle as it relates to Design. Post-design activities for Installation, Testing, Commissioning and Handover is introduced in this document however, will be comprehensively addressed in the updated System Safety Plan for phases post-Design.

(i) Design Development

The Contractor has developed a safety management process that meets the requirements of the Crossrail System Safety Plan (this document), and undertake (as appropriate to the contract in question);

- Creation of a suitable Safety Plan/Strategy document.
- Hazard identification workshops
- Focussed Quantified Risk Assessments may be undertaken if required, or as identified and commissioned by CRL.
- SIL assessments of the safety related functions of proposed E/E/PES.
- Development of a Safety Risk Profile assessment as necessary to demonstrate how design safety requirements will be satisfied.
- Maintenance of Hazard records in accordance with the Crossrail Hazard Management Procedure [Ref 5].
- Product Breakdown Structures for systems (PBS) [Ref 25]
- Progressive development of a Safety Assessment Report to summarise the safety risk assessment activities and present the ALARP justification for the design.
- Collection of safety evidence. The safety evidence may take the form of product, generic and application Engineering Safety Justifications from manufacturers and sub-system and system safety justifications from the Contractors, Conformity Certification, and qualitative/quantitative risk assessments. Where the RIR apply, the NoBo / DeBo will produce a Technical File to contain evidence as mandated by the TSI / NNTR concerned.

System safety requirements are specified in section 4.2 of this document.

Designers must recognise and contribute to the provision of assurance evidence presented in the form of an Operator's Assurance package that complies with the Concept of Operations (refer to 5.8 of this document) to enable Duty Holders to accept the handover of the completed railway.

(ii) Main Construction

The Crossrail System Safety Plan (this document) and the Contractors' System Safety Plans shall be revised as required to be relevant through the construction stage of the project. This will be undertaken as part of activities described in the updated System Safety Plan. Hazard records, safety evidence, and safety justifications shall be updated and collected as *necessary.*

(iii) System Integration Testing, Commissioning, and Trial Running

The safety planning and activities concerning this phase of the project are defined in Testing and Commissioning plans, and / or Safety Verification plans. The safety activities are designed to validate the safety requirements and the assumptions, dependencies and caveats in the project safety documentation and to provide the evidence needed for safety authorisation / acceptance.

Those activities necessary to demonstrate safety compliance have been agreed with the relevant Transport Undertakings and shall be detailed in the updated System Safety Plan. Precursors to the System Integration, Testing, Commissioning and Trial Running activities:

The Central Operating Section has been split into 4 zones for the purpose of Integration, Testing, Commissioning and Trial Running. These zones are as follows -

Zone 1 - Eastern section from Canary Wharf to Abbey Wood.

Zone 2 - From the NR connection at Pudding Mill Lane Junction to Canary Wharf via Stepney Green, including infrastructure to Whitechapel (excl).

Zone 3 - From the NR connection at Westbourne Park to Fisher Street Shaft (between Tottenham Court Road and Farringdon).

Zone 4 - From Fisher Street Shaft to Whitechapel (inc).

Activities will be undertaken in two stages, namely for Zones 1 & 2 combined, followed by all Zones 1 to 4 inclusive. The safety planning and activities related to this shall be defined in the following documents -

CRL Programme Testing and Commissioning Plan [Ref 46] are supported by the following;

- Crossrail Dynamic Testing "Yellow Paper" [Ref 62],
- Stations, Shafts and Portals - Integrated Test Plan "Purple Paper" [Ref 63],
- Crossrail Transition Testing "Green Paper" [Ref 64],
- Crossrail COS Energisation Strategic Plan "Orange Paper" [Ref 65] and
- Crossrail Trial Running Strategy [Ref 49].
- Crossrail Safety Strategy for Energisation and Dynamic Testing [Ref 66]

The precursors to the commencement of the various stages are described in the document "Readiness Gates Procedure" [Ref 59].

(iv) Testing and Commissioning Assurance

Project Testing and Commissioning Strategy [Ref 45] details the key processes and arrangements deployed for the testing and commissioning (T&C) of the Railway Systems and MEP works on Stations, Portals and Shafts.

The testing and commissioning phases will be applied appropriately to all works and associated interfaces in accordance with the Crossrail Programme Testing and Commissioning Plan [Ref 46].

CRL is responsible for management of this process for the Central Operating Section, including bringing into service the interfaces with other industry partners and operators.

Testing and commissioning certification is part of the assurance process and will be produced at each respective stages of testing. The certificates will be accompanied by test reports duly signed off by the Contractor(s) lead testers and further subjected to CEG and Systemwide team verification acceptance.

These include:

- Factory Acceptance Certificates (FAC) - at the end of phase 1 Factory Acceptance Tests;
- Installation Release Notices (IRN) – at the end of phase 2.1 Intermediate Static Tests;
- Pre-commissioning Certificates (PCC) – at the end of phase 2.2 Pre-commissioning Static Tests;
- Partial Acceptance Certificates (PAC) – at the end of phase 2.3 System Static Tests; and
- Acceptance Certificates (AC) – at the end of phase 3 Static Integration Tests (or during phase 4 Dynamic Testing if a system requires further phase 4 tests before being fully validated).

(v) Handover from Contractor to CRL

Crossrail's infrastructure has been broken into groups of assets for the purpose of Handover to the final owners. Each group of assets is called an 'Element'.

Elements are defined within Appendix 3 of the Handover Strategy and Plan [Ref 47]. An example of an Element is a station, including works completed by all CRL contractors within the station demise.

The final owner of each asset has been defined and agreed in the IM Boundaries Document [Ref 48].

Handover evidence will be collated and demonstrated through the Element Completion and Handover Certification process (ECHC). The IM Boundaries document [Ref 48] lists the asset boundaries / ownership on Crossrail and the interfaces with other locations and systems.

The ECHC process meets the requirements of a Completion Consent to Operate Report as defined in LU Standard 1538 [Ref 32]. It is the final report to be submitted to the party receiving Handover of an Element (the final owner, LU or RfL).

(vi) Safety Governance and Controls

In line with the phases identified within the Readiness Gates Procedure [Ref 59] process the following overall safety governance controls are being provided (not all are applicable to each phase):

Safety	• Design Wrap Up, Engineering Safety Management & FDO Tracker • RAB (C) [Ref 51] Submission Tracker • NoBo, DeBo and AsBo Progress Report • MTR-EL Staged Opening Dashboard	• Engineering Safety Management System Safety Plan (this document) • Crossrail End to End Safety Justification and Assurance Strategy [Ref 35] • Gates Readiness Procedure [Ref 59] • Final Design Overview (FDO) Process [Ref 61] • MTR-EL Safety Validation

		Panel for their SMS • RAB (C) [Ref 51] acting as the RfL SRP (in respect of the RfL I SMS)

(vii) Collection of Evidence through the Various Phases (To allow formal Closure of the PWHR and the Railway Level Hazard Records)

The PWHR has been designed to allow for evidence to be collected through the various phases of the Crossrail Project.

Prior to FDO being achieved, it was necessary for each contractor to have signed off all of the design related hazards relating to their design, or through the mechanism of the HRP or IHA processes to have an agreed transfer of the hazard or part mitigation thereof to either the end user (HRP) or to another contractor (IHA).

This in turn has had to be demonstrated at system level through the creation and acceptance of the Interim Safety Justification. (The programme for production of the Interim Safety Justifications plus submission to RAB(C) [Ref 51] as appropriate for endorsement is tracked on a period by period basis "RABc Submissions - CRL Programme").

The PWHR allows for evidence to now be collected through the testing and commissioning stages such that it can be demonstrated that the design intent has been met and each hazard within the PWHR can be formally closed out. This evidence will be provided in the suite of Safety Justification documents to be created for Stations, Tunnels, Shafts, Portals Systemwide Systems and Interfaces with the GWML, GEML and NKL.

In parallel to the above, evidence will be gathered to confirm the assumptions made within the Strategic Engineering Justifications by validation of the Railway Level Hazard Record.

(viii) Safety Assurance and Authorisation

Contractors will update their hazard records, safety evidence, and safety justifications in line with the outputs of the testing and commissioning phase to allow CRL to finalise the overall Safety Justifications in accordance with the System Safety Plan prior to Handover.

The completion of the Safety Justifications will support the IM's finalisation of their Safety Management System (SMS).

Completion of dynamic testing will allow the Technical Files to be updated and all relevant evidence submitted to the Office of Rail and Road (ORR) in order for CRL to obtain Authority to Place into Service (APIS).

Authority to Place into Service (APIS) is not required for Trial Running but is required prior to RfL submitting their application for Safety Authorisation.

The application will detail the SMS that RfL have developed to manage the hazards of RfL's operational and maintenance activities to ALARP.

(ix) Service

For 'placing into service', the safety analysis, compliance evidence, and the safety evidence and arguments that risks are ALARP will be collated by CRL into a series of Operator's Assurance Packages (see the Crossrail Technical Assurance Plan [Ref 2]), which will be submitted for acceptance to RAB(C) [Ref 51] on behalf of the future Infrastructure / Station Operators or to the relevant TU depending upon the agreement with the relevant Duty holder. This information will be made available to NR and / or LUL as required for their acceptance processes.

Subsequently, all project safety documentation will be retained by the Operators for maintenance and inspection during the lifetime operation of Crossrail.

(x) Decommissioning & Disposal

The disposal of products will be subject to legislation applicable at the time of the activity.

It is expected that the decommissioning and disposal of Crossrail infrastructure will be treated as a project in its own right. At that time, relevant safety documentation arising from former use (including appropriate H&S Files) shall be considered. Arrangements for complying with regulations and potential sources of hazards will be outlined in a decommissioning strategy to be provided by the contractors employed to carry out the activity.

4.6 Safety Analysis

4.6.1 CRL (as sponsor) and Contractors are required to use recognised safety analysis methodologies based on the processes described in the EC Regulation on Common Safety Methods on Risk Evaluation & Assessment [Ref 22]. Examples of recognised methodologies include those shown in the ORR Guidance to the EC Regulation, British Standards BS EN 50126 [Ref 18], BS EN50128 [Ref19], BS EN50129 [Ref 20] and BS EN 61508 [Ref 21], LU 1-526 [Ref 3] and in accordance with CRL Hazard Management Procedure [Ref 5], but this is not an exhaustive list.

4.6.2 The EC Regulation Common Safety Method on Risk Evaluation & Assessment [Ref 22] is a legal requirement and shall be complied with.

- RSSB has produced practitioner level guidance to assist the Industry with the application of Common Safety Methods (CSM) [Ref 6]. The guidance (current good practice) shall be followed unless a good reason for not doing so is agreed.

4.6.3 The scope of the Project Engineers and Contractor's engineering safety analysis shall be required to:

- Consider a comprehensive range of safety issues such as interfaces, operation, human factors, normal conditions, degraded conditions, emergency conditions, and credible fault conditions of the CRL systems and subsystems.
- Demonstrate that in all cases the system remains legally compliant with safety requirements.
- Demonstrate that the risk introduced by the Crossrail systems and subsystems is acceptable, i.e. that there are no intolerable risks and all other risks are reduced to tolerable and ALARP.
- Demonstrate that the requirements of this SSP have been met.
- Gain acceptance from the relevant organisations with respect to fulfilling their requirements for safety assurance.

4.6.4 CRL has the specific responsibility to check the interfaces of the Crossrail Central Operating Section systems which include signalling, telecoms, traction power are integrated with each other, and with the comparable systems with which they interface on other IMs' infrastructure such as NR.

4.6.5 The CRL Project Engineers and their Contractors shall also take account of the following issues in the safety analysis.

(i) Collective vs. Individual risk

For the Crossrail programme, priority shall be given, where a number of solutions exist, to collective risk reduction over individual risk in accordance with the Management of Health and Safety at Work Regulations 1999 (Reg. 4) [Ref 55], but subject to compliance with the CSM Regulation [Ref 22] as discussed above.

(ii) Hazard mitigation

The methods shall be addressed in the following order of precedence:

(a) **Eliminate the hazard** (e.g. by changing the design)

(b) **Design to minimise the risk.** If it is demonstrated that (a) is not possible, a design should be chosen to reduce the risk to an acceptable level (applicable only to issues under the control of the designer and can affect the frequency of the occurrence of the hazard only).

(c) **Incorporate safety devices**. If it is demonstrated that (b) is not possible, then devices shall be used to reduce the risk to an acceptable level. Human factors analysis shall be required to make sure that procedures, training etc. for using the devices are adequate

(d) **Isolate people from the risk.** If it is demonstrated that (c) is not possible, then a design should be chosen to isolate people from the risk to reduce it to an acceptable level. Human factors analysis shall be required to make sure that procedures, training etc. associated with the design are adequate

(e) **Provide warning devices.** If it is demonstrated that (d) is not possible, then warning devices shall be used to adequately warn personnel of the hazard. Human factors analysis shall be required to make sure that the warning devices will be correctly interpreted.

(f) **Develop procedures and training.** If it is demonstrated that (e) is not possible, then procedures and training shall be used to reduce the risk to an acceptable level. Human factors analysis shall be required to make sure that the procedures, training, are adequate.

(g) **Develop the use of PPE.** If it is demonstrated that (f) does not adequately reduce the risk, then personal protective equipment shall be considered in conjunction with procedures. Human factors analysis shall be required to make sure that the procedures, training and equipment are adequate.

(h) **Provide warning signs**. If it is demonstrated that (g) is not possible then warning signs shall be used to adequately warn the population at risk of the hazard. Human factors analysis shall be required to make sure that the warning signs are correctly interpreted.

4.6.6 Hazard Identification

- Hazard identification shall take a variety of forms depending upon the function under review. The System Definition will be used as the basis for the preparation of the briefing note. Designers may undertake structured brainstorming sessions as well as reference to existing hazard identification for railway operations. Where appropriate other techniques such as FMECA and the HAZOP process shall be employed. Hazards identified during informal sessions are also valid. All hazards and associated information e.g. causes, consequences, current safety measures etc., identified during these different types of processes shall be recorded. When a programmed hazard identification exercise has been undertaken, a draft report shall be produced and released to the participants and assurance representatives for comment within two weeks.

4.6.7 The initial hazard identification by the Contractors undertaking Reference Designs was forwarded by CRL to the Contractors taking forward development of the Design. In addition, these latter Contractors have also undertaken their own hazard identification based upon their own designs.

4.6.8 Contractors are responsible for identifying hazards, maintaining records of them and tracking progress of hazard close out. Where, following the hazard mitigation structure shown above, it is necessary to transfer that responsibility for close out to a Duty holder, then this shall be done in accordance with the Hazard Management Procedure [Ref 56].

4.6.9 CRL has made sure that Designers have used an appropriate method of quantitative or qualitative risk assessment, depending upon the where in the Life Cycle the project had reached and the nature of the risks under consideration to evaluate them and the effectiveness of the controls that are developed. As an example, changes to a SIL 4 system shall be the

subject of a rigorous quantitative risk assessment process to demonstrate that risks have been reduced to ALARP.

4.6.10 CRL's Directorates covering the Central Operating System and the rolling stock and depot are required to use the EC Regulation on CSM on Risk Assessment & Evaluation [Ref 22] to make sure that risks have been reduced to either an acceptable level or "Tolerable and ALARP".

- In line with CSM Regulations (Risk Acceptance Criteria), where it is necessary to undertake Explicit Risk Estimation (ERE), CRL makes sure that, where appropriate, Cost Benefit Analysis (CBA) has been carried out by Designers (based upon quantified analysis of collective risk) in support of demonstrating that risks have been reduced so far as is reasonably practicable (SFAIRP). The ORR's Internal Guidance on CBA in Support of Safety-related Investment Decisions [Ref 23] and RSSB's Taking Safe Decisions [Ref 8] may be used by Designers as guidance for the factors to consider when undertaking CBA. It is to be noted that a CBA cannot form the sole determinant of a SFAIRP decision. When undertaking CBA, the most up to date figure of the Value of Preventing a Statistical Fatality is to be used.
- The VPF values used for CRL CBA and ERE shall be derived from the LU Category 1 Standard LU-1521 – Safety Decision Making. This figure is in line with the rest of the Rail Industry and produced by the Rail Safety and Standards Board (RSSB). LU HSE shall review this value every two years, taking into account the published VPF figure from RSSB.

4.6.11 For the completed Crossrail Central Operating System, the CRL Safety Risk Model includes relevant Explicit Risk Estimates, as derived by the various Designers.

4.6.12 All First Tier contractors assumed full ownership, accountability and responsibility for designs provided by Functional Design Consultants (FDCs). This includes those hazards transferred to them under the Hazard Management Process. Contractors conducted appropriate due diligence of appropriate information so as to gain full familiarity with the inherited designs as a whole and the identified hazards associated with them.

4.6.13 A series of interface hazard analyses shall be undertaken by all contractors. Many of the identified hazards arising from the IHA will require co-ordination between contracts, where risk control actions are transferred between parties to mitigate risks.

4.7 Safety Evidence

4.7.1 The CRL's Directorate's are required to make sure that their Design and Build Contractors produced Design Engineering Safety Justifications or other means to demonstrate the safety of the design and that it can be constructed safely, operated and maintained safely in accordance with the relevant standards. An objective of the Design Engineering Safety Justification (DESJ) was to provide assurance that all hazards had been identified, associated hazard mitigating features were incorporated into the design and all safety requirements have been correctly specified. The Design and Build Contractors produce an Engineering Safety Justification (ESJ) once evidence is available on the as-built assets or systems, such that the associated safety risks have been demonstrated as being tolerable and controlled to ALARP [Ref 36] thus meeting the requirements of both CSM-RA and the HSAWA.

In the case of the civils infrastructure where a *Contractor* has been appointed to build a CRL engineer's design, the *Contractor* will produce the evidence that he has built the specified design. Both CRL and the relevant designers produce the Engineering Safety Justifications in accordance with the preceding paragraph.

The following, together with the diagram explain how this has been achieved in practice and how ultimately the requirements of CSM have been demonstrated:

Early concept design was undertaken by CRL. This utilised the Sponsor Requirements and defined key requirements in support of the Crossrail Bill of 2005 and subsequent Crossrail Act of 2008.

This was carried out pre CSM and hence the principles of the Engineering Yellow Book (ESM) were applied.

Concept designs were handed to the FDC Contractors to develop further in line with the Sponsor Requirements and the CPFR. The principles of the Yellow Book were applied to these contracts and hence the hazards were identified and populated in either a separate risk register or an early version of the PWHR, albeit to ESM principles.

The D&B contracts which followed on from the FDC Contractors and for Systemwide were required to apply CSM as this had become law at this stage (EU402/2013 & EU 2015/1136).

Where D&B contractors were supplied with the FDC design to finalise and build, they were required to review the hazards associated with output of the FDC contracts and incorporate these within their PWHR entries, applying the CSM-RA methodology to mitigate. The outputs from these are evidenced in the DESJ documents provided by each contractor.

CRL has, in its associated ISJ's undertaken a review to determine whether all reasonably foreseeable hazards have been managed through the CSM process. Where omissions have been identified, the ISJ provides the argument as to how such hazards have been adequately mitigated.

The exception is for the early civils construction works which were all carried out per CSM and hence CRL has created an ISJ that encompasses "Tunnels, Cross Passages, Crossovers and Line of Route Civils Works" to provide the complete argument to state how the CSM compliance demonstration has been achieved.

The Engineering Safety Justifications shall be integrated into the top level Strategic Engineering Justifications, which are expected to be as follows[2]:

- Systemwide Safety Justification (covers signalling, track, traction power, data transmission systems, communications including radio)
- Tunnels Safety Justification (also covers tunnel systems including ventilation systems)
- Rolling Stock Safety Justification
- Depot Systems Safety Justification
- Station Safety Justifications (one for LUL stations and one for RFL stations)
- Tunnel, Cross Passages, Crossovers & Line of Route Civils Works Safety Justification

The up to date list of Safety Justifications and Strategic Engineering Justifications that are being produced is maintained by the CRL Technical Directorate Each of the top level Strategic Engineering Justifications defined in this section and supporting Engineering Safety Justifications above are demonstrated as correctly interface with each other. This shall be done in accordance with the process described in section 4.8 below and this shall be checked in accordance with the Technical Assurance Plan (TAP) [Ref 2] by prior to submission, where this has been agreed, or to the relevant acceptance body. See document Alignment of Safety Evidence to Key Hazards Railway Level [Ref 85] and associated Strategic Engineering Justifications.

The plan for delivery of safety evidence is shown diagrammatically in Figure 1, "Plan for Delivery of Safety Evidence".

[2] Changes to these may be required as the Project progresses.

Fig 1. Plan for Delivery of Safety Evidence inc Railway Level Hazard Structure Assurance

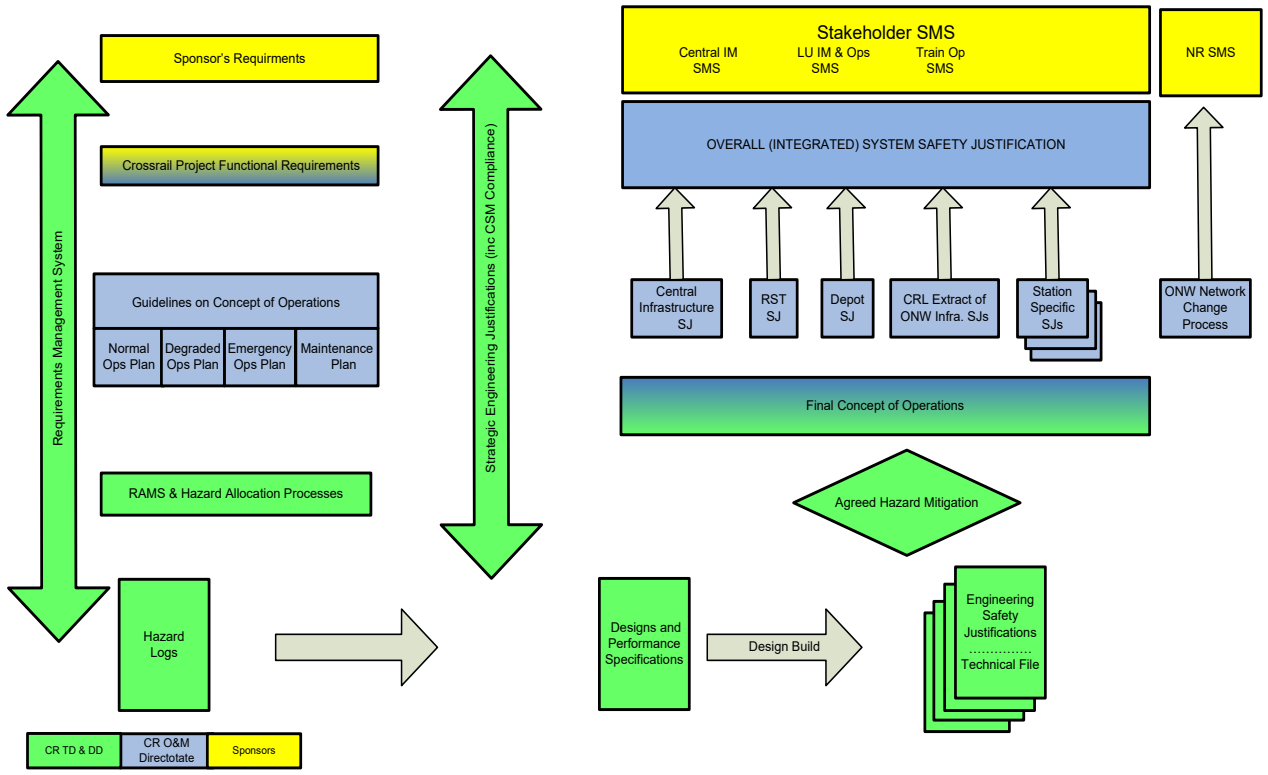

Figure 15: Plan for Delivery of Railway Level Hazard Structure

However in the case of the ONW and those works undertaken by NR on behalf of CRL between Plumstead and Abbey Wood, NR shall provide the appropriate safety justifications to CRL for those works that are required to enable Crossrail to operate, as per the Network Rail Crossrail Programme System Safety Plan [Ref 13]. This will be extracted by NR from the outputs of the application of their Project Management Process and Safety Management System. The evidence shall show that the works have been correctly designed and will properly integrate with the rest of the Crossrail top level justifications. This will be checked by CRL using the process described below.

4.7.2 A single integrated safety justification shall be produced for each of the stations. The project has carried out extensive modelling of passenger flows for normal, abnormal, degraded, emergency operations, and evacuation, for each station taking into account the LUL Station Planning Standards and Guidelines and the CPFR and this has led to design requirements for each station which have been agreed with the representative of each of the future station IMs. This has also been used as part of the development of the Operations Concept [Ref 11]. Once accepted the Safety Justification will be used to produce an Operator's Assurance package (refer to Technical Assurance Plan (TAP) [Ref 2] to enable the future Duty Holder to adopt the appropriate requirements into its Safety Management System.

4.7.3 The Engineering Safety Justifications shall provide evidence to support the contents of Operators' Assurance packages as specified in the Technical Assurance Plan [Ref 2]. The exact information to be provided is still to be defined, however, part of each Engineering Safety Justification and the Rolling Stock System Safety Justification will consist of the Technical File(s) prepared by the NoBo containing the evidence of compliance with the relevant TSIs and

NNTRs, together with the independent assessment report as mandated by the Common Safety Method for Risk Assessment Regulation, and other evidence as defined by the RIR.

4.7.4 Required Engineering Safety Justifications / other safety documentation covering assets or systems for which LUL is designated as the IM, shall satisfy the assurance requirements of LUL Assurance Standard S1538 [Ref 32].

4.7.5 The safety of any system comes from a combination of the engineering, operations and maintenance arrangements. CRL shall be responsible for the first and last of these factors by ensuring that the individual contract packages for which they are responsible are correctly designed and built with suitable maintenance instructions, and are properly integrated to enable the delivery of a complete railway.

4.7.6 CRL is responsible for developing the Concept of Operations with the support of relevant stake holders, to specify the operating assumptions which the design must take account of. Ultimately these will lead to a complete suite of operational documentation e.g. specific sections integrated within the GE/RT8000 Rule Book, Minimum Operating Requirements, the Engineering Access Statement and Planning Rules for Crossrail.

4.7.7 The objective is that the Engineering Safety Justifications integrate with each other such that the engineering, operational and maintenance functions will enable the railway to function correctly as per the Concept of Operations and meet the Joint Sponsors' and legal requirements. This evidence will be checked by CRL prior to submission to the appropriate acceptance body.

4.7.8 The AsBo NoBo programme and the Crossrail Central Operating Section (Interim) Safety Justification present a list of the documentation for assessment and safety deliverables.

4.8 Safety Justification (Integrated)

4.8.1 Crossrail comprises a complex interaction of systems, components, processes and people. The integrated safety justification for the railway will be contained in the End to End Safety Justification [Ref 35].

4.8.2 To achieve this, demonstration that the reasonably foreseeable hazards have been identified and adequately mitigated and managed will be carried out at two levels i.e. Strategic and Contract. Together, these will provide a demonstration that the railway is safe, reliable and is capable of being operated and maintained.

4.8.3 Strategic Level –

The process is described in the diagram below on a strategic basis.

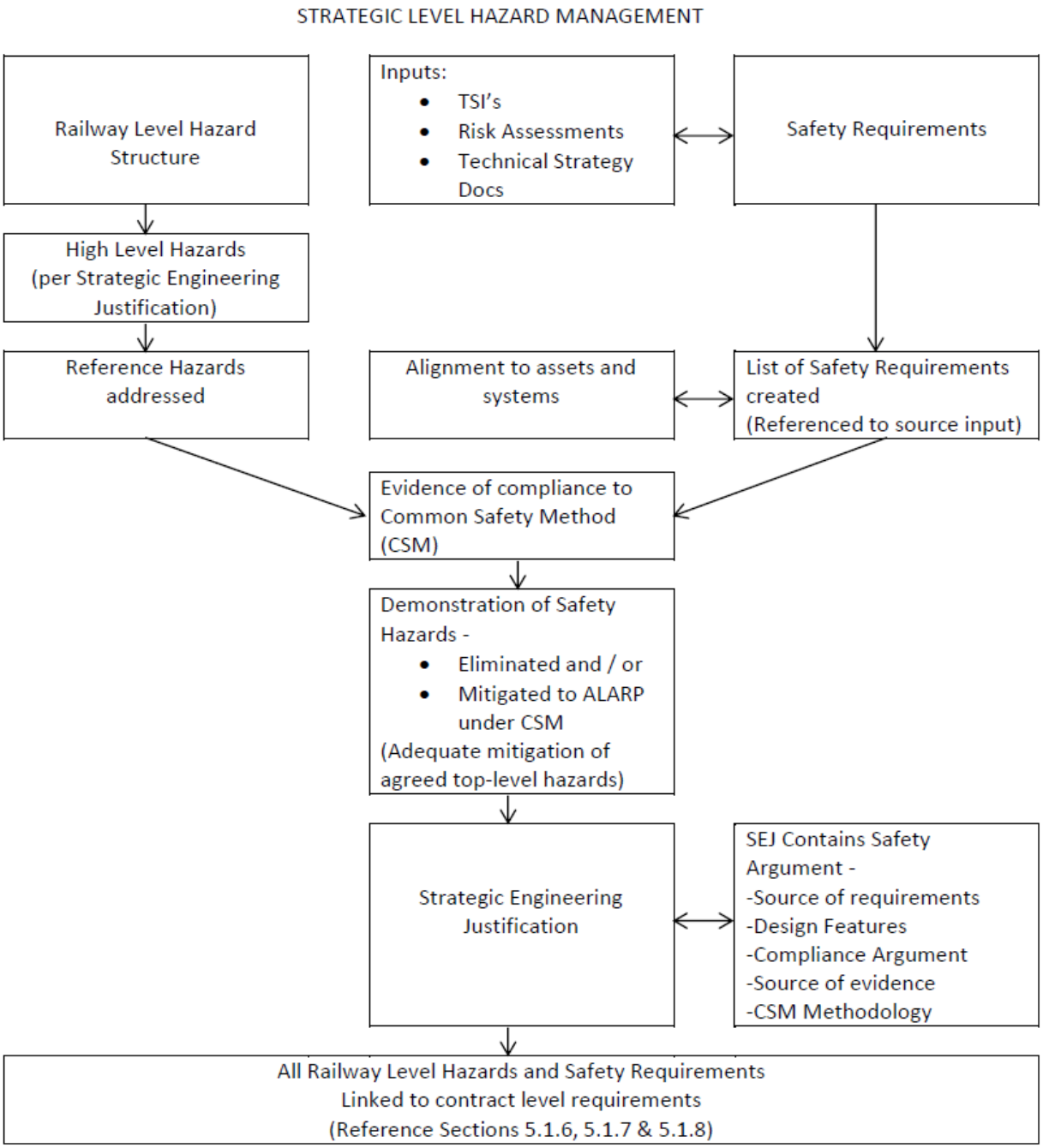

Figure 16: Strategic Level Hazard Management

4.8.4 Contract Level

The process is described in the diagram below on a per contract basis.

 CRL RESTRICTED

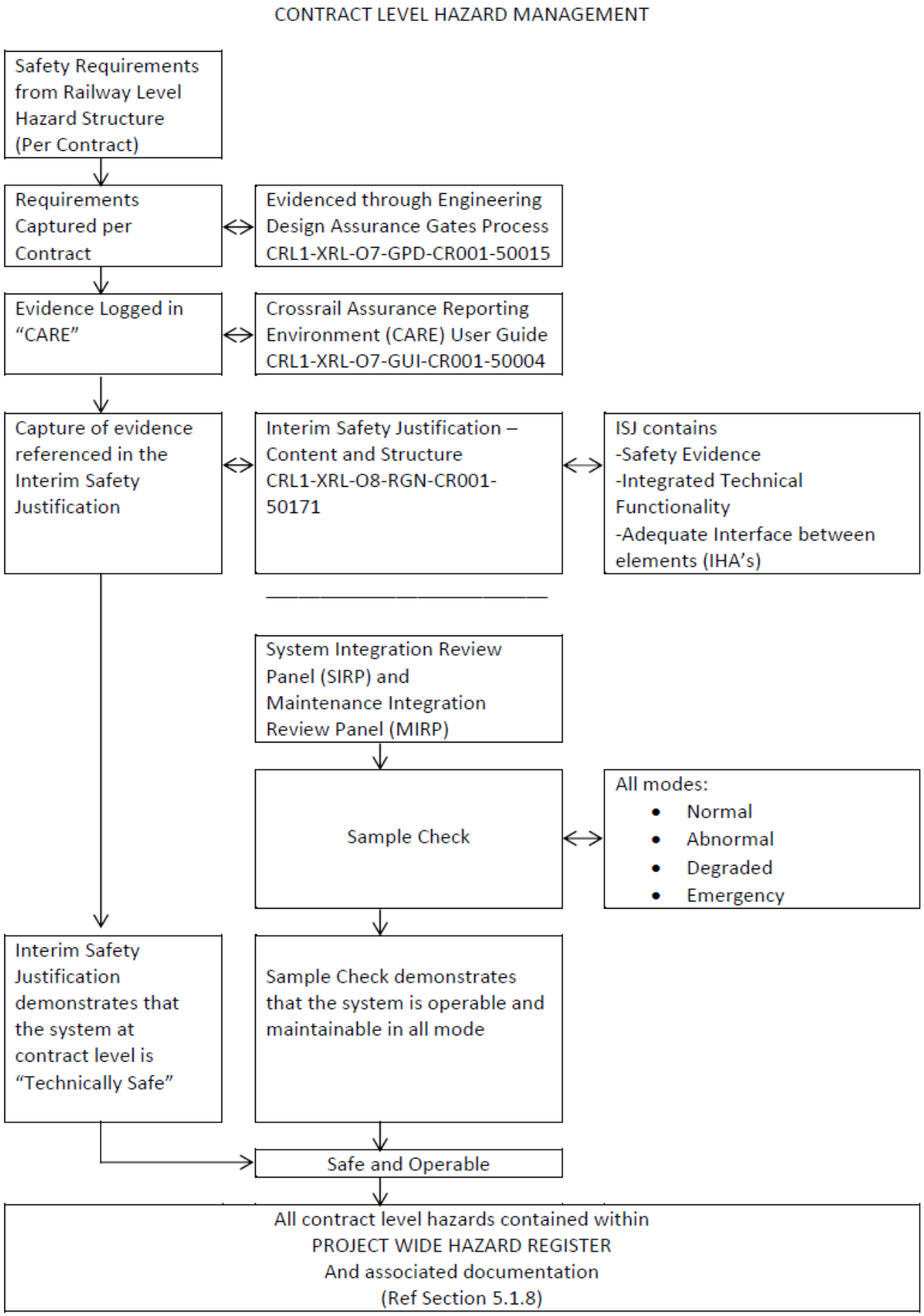

Figure 17: CONTRACT LEVEL HAZARD MANAGEMENT

Note that the diagram is a snapshot in time, indicating the position at the end of the FDO phase and creation of Interim Safety Justifications. This is equally valid for the creation of the Safety Justifications, together with evidence collected through the completion of construction, testing and commissioning.

4.8.5 End to End Safety Justification [Ref 35] will be prepared to enable the various receivers of assurance for Crossrail firstly; RAB(C) [Ref 51] and ultimately, the Office of Rail and Road (ORR) are in a position to make an informed decision on the “completeness of the system”. It will take account of the whole system, including Systemwide systems, stations, shafts and portals assets which cross contractual boundaries, therefore demonstrating that all interface issues are fully accounted for. This will therefore be an integrated case for the safety of Crossrail.

4.9 Integration of Safety Justification with Operations Concept

4.9.1 The method of integration of the Safety Justifications with the Operations Concept [Ref 11] follows the process below:

(i) As illustrated in Figure C below the method of checking the effective integration of the Safety Justifications against the Operations Concept [Ref 11] is as follows.

(ii) Step 1: A System Integration Review Panel (SIRP) using a “HAZOP type” approach led by CRL with each of the future Duty Holders, CRL Directorates, Project Engineers and the representatives of the Reference Designers, checked the current guidelines on Operations Concept Scenarios and RAM requirements against the Reference design assumptions made by the Designers. This either validated the Reference design or required technical or operational changes to be made to either the Reference design or to the Operations Concept as they existed at the time of the check. An analogous Maintenance Integration Review Panel (MIRP) checks that the design(s) are also maintainable within the scope of the Operations Concept.

(iii) Step 2: After the changes arising from step 1 were made, and documented in accordance with all the requirements specified in this SSP, Reference Designs are used by CRL to prepare the Procurement Performance Specifications and contract constraints (e.g. maximum size of an equipment room). By analogy these will also have been shown to have been successfully integrated to the Operations Concept. The Operations Concepts and the Performance Specifications are then base lined. Any subsequent changes to these documents must then be accepted by the change control process.

A review and re-issue of the Operations Concepts [Ref 11] was made in August 2016 to accommodate changes.

(iv) Provided no further changes are required as a result of applying Step 2, then the design and associated Procurement Performance Specification have been verified as fully compatible with the Operations Concept; is maintainable; and the designs at that point in time correctly integrate with each other and that the associated safety risks have been shown to be tolerable and ALARP. It therefore follows that the Safety Justifications also demonstrate that the safety risks are tolerable and ALARP, provided that any changes to the design or Operations Concept from which they are derived have been through the Change Control process. This will check that any change to one of the base lined parameter is understood and only permitted provided successful integration of the design and Operations Concept is still retained.

Figure C: INTEGRATION OF ISJ's AND SJ's WITH OPERATIONS CONCEPTS

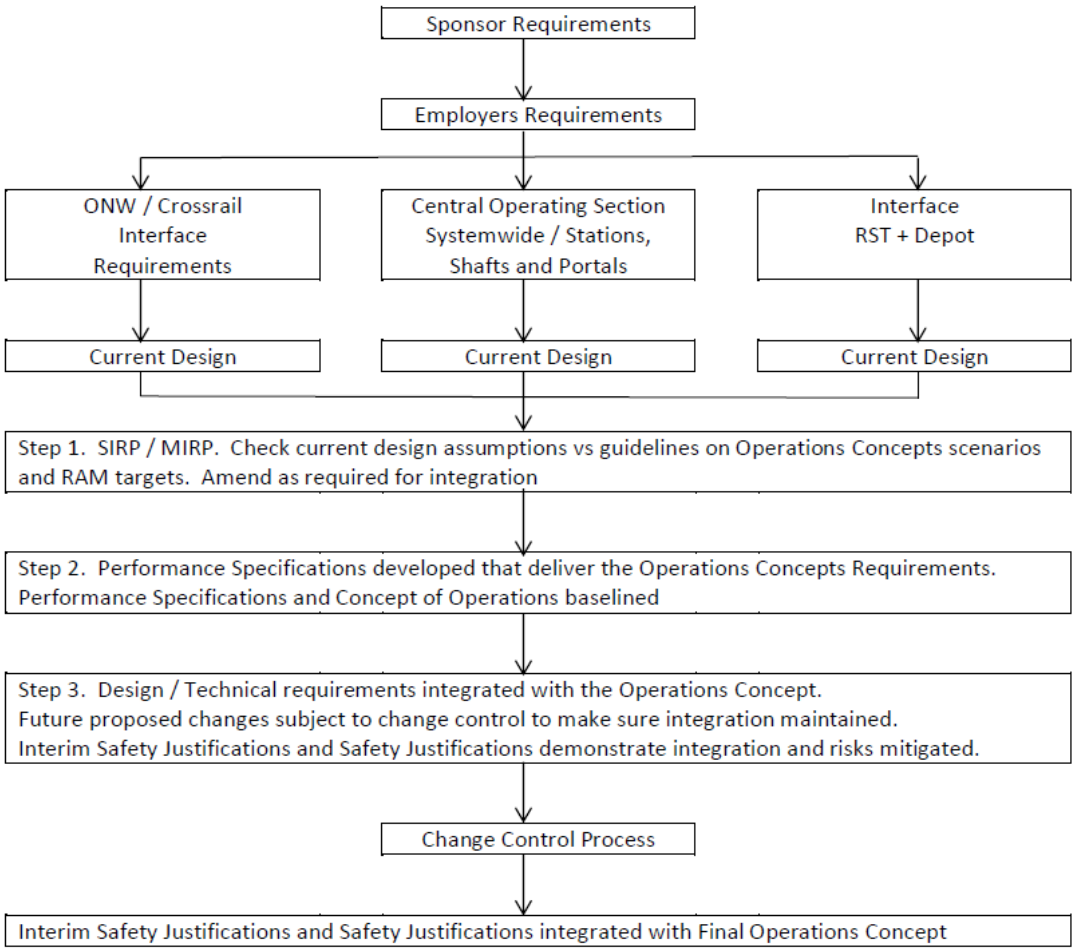

Figure 18: Integration of ISJs and SJs with Operating Concepts

4.10 System Integration Review Panel (SIRP)

The initial tranche of activity undertaken by the System Integration Review Panel (SIRP) was used as a mechanism to validate the alignment between baseline designs and operations concepts. These were the first SIRP and SIRP 1 tranches.

As the design process is basically complete with the creation of final designs, SIRP now looks at the validation of the alignment between the detailed design, the Safety Justifications and the Operational procedures, plans and rules. These are the SIRP2 tranches, as detailed in "Crossrail System Integration Panel (SIRP2) Terms of Reference and Management Procedure" [Ref 69]. CRL are the chair for these sessions.

As well as providing a validation of the design as being fit for purpose, the SIRP2 provides for the following functions (see above procedure for full details):

- Provision of formal operability impact assessment in support of the Crossrail Change Process
- Sponsor deployment, management and dissemination of integrated engineering and operations reviews, together with other assessments, reviews or studies that may be required.
- Assist with the management and coordination of the Railway Baseline Operations Concepts.
- Act as a sponsoring body for formalisation of change through the SIRP workshops.

SIRP 2 represents the evolution of the process of providing assurance of interoperability reflecting the nearly complete design and increasing preparedness of the operating organisations.

The methodology borrows from the system engineering discipline in the adoption of "use case" (i.e. instances of use) analysis. This approach has been successful on other projects such as Thameslink.

The "use cases" capture systematically all scenarios where the user interacts with the system and where those scenarios are characterised by novelty, complexity or particular risk. A prioritised rolling list of scenarios has been drawn up and this is subject to review by the SIRP2 Panel to make sure that the scenarios meet the above criteria. This approach is possible as the SIRP2 Panel comprises learned / experienced representatives from the respective disciplines including the operator.

4.11 Maintenance Integration Review Panel (MIRP)

These workshops were set up to consider the current Crossrail Maintenance principles, CPFR Requirements and the "as developed" design for the COS works. The details of the process are contained in "Maintenance Integration Review Panel (MIRP) Workshop Guidelines" [Ref 70]. The process is designed to:

- Provide confidence that the assets are maintainable in line with CPFR access arrangements,
- Confirm that interfaces between systems have been identified and designed and that they can be managed,
- Provide a mechanism whereby proposed design changes can be reviewed for maintainability and
- Identify outstanding issues.

The workshops are complementary to the detailed HAZID reviews carried out through the design process.

An initial set of workshops were held at concept design stage and these are being repeated (as MIRP 2) at the completion of detailed design.

The workshops are chaired by Crossrail and comprise learned / experienced representatives from the respective disciplines including the operator and maintainer.

4.12 Standards

4.12.1 Safety activities associated with the Crossrail project shall be in accordance with the safety requirements contained in the relevant TSIs, NNTRs, EC Regulation on CSM on Risk Assessment and Evaluation, together with those standards listed in the Standards Baseline.

4.12.2 The CRL Management Principles [Ref 72] specify the principles for the management of standards within the Project. The hierarchy of precedence, together with how they are to be delivered is specified in the Standards Management Procedure [Ref 26].

This states that “New Crossrail assets shall be designed and constructed in accordance with the agreed Standards Baseline. The Standards Baseline will be frozen at an agreed stage. Changes to standards after the baseline is frozen will be implemented by exception in accordance with this procedure. Where changes to standards in the standards baseline are adopted the design & construction teams will be briefed.”

The Conceptual Design Statement (CDS) for each design package, clearly states which issue of the Crossrail Standards Baseline the design shall comply. After the CDS has been approved, changes to standards for that package will only be made by formal instruction (via the individual contracts) if it meets one of the following standards criteria (see Standards Management Procedure [Ref 26] Section 1.7 (Document Development process)):

- It is required due to a change in legislation.

- It will result in a cost saving.
- It is required to provide for the safety of the railway.
- It has been instructed by the Sponsor.
- To remove a conflict between the Standards Baseline and interoperability.

The Crossrail Standards Baseline is frozen for individual design packages upon issue of the Design Completion Certificate (DCC), which will certify the appropriate issue of the Crossrail Standards Baseline (including the List of Applicable Standards), as well as any concessions granted.

4.12.3 As indicated above, it is acknowledged that there may require to be a concession to a standard required to deliver the COS works. The structured process for the requesting and acceptance of these is contained in the procedure “Process for managing concessions to standards” [Ref 80] and associated guidance note [Ref 81]. Requests for a concession that have a safety implication must be signed off by the Crossrail Head of Safety as being acceptable from a safety aspect. Additionally, where there is an implication for the future operator and / or maintainer, the concession must be supported by them.

The CRL Standards Manager (SM)

The CRL Standards Manager is responsible for managing the CRL standards management process and updating the standards Baseline as required.

The CRL Head of System Safety and Interoperability

The Head of System Safety and Interoperability is responsible for making sure that the CRL Standards Manager is provided with regular updates to make sure that the Standards Baseline remains compliant with the System Safety Plan.

4.12.4 It is anticipated that CRL and Contractors will draw up specific standards for adoption by the future Duty Holders, in addition to Operating and Maintenance Manuals. After internal review by the Project Engineers as appropriate these shall be submitted via CRL to the relevant Acceptance Body on behalf of the future Duty Holder depending upon the agreement with that Duty Holder.

4.12.5 Where applicable under the RIR, standards shall be proposed to the Competent Authority by CRL as Notified National Technical Rules applicable to Crossrail.

4.12.6 The Standards Management Procedure [Ref 26] defines the process for obtaining acceptance for derogations or non-compliance to the standards in the preceding paragraph.

4.12.7 Where a derogation from a TSI is required in accordance with Regulation 14 of RIR, after CRL Project endorsement, the application shall be submitted to the Competent Authority by the System Safety Manager for approval in accordance with the Interoperability Regulations.

4.12.8 Where derogation(s) are required against an NNTR this shall either be submitted to the appropriate standard's owner or a proposal for new NNTR for Crossrail sent to the Competent Authority as indicated above. However it should be noted that the Competent Authority will wish to make sure that only the minimum number of NNTRs are developed and submitted to the EU.

4.12.9 In certain circumstances a dispensation may be required against the provision of an NNTR, in accordance with the provisions of RIR, Regulation 46. In these cases the application shall be submitted to the Competent Authority. Where a dispensation from an NNTR is granted, a rule of strictly local nature may be created. This shall be recorded in the future Infrastructure Register.

4.13 Safety Assurance and Audit

4.13.1 The Technical Assurance Plan (TAP) [Ref 2] defines the responsibilities of CRL to deliver technical assurance.

4.13.2 As part of the quality process, CRL undertakes audits and surveillance in accordance with its quality management system in order to confirm compliance to the prescribed processes.

4.13.3 CRL undertakes regular audits and surveillance of the Designers' engineering safety management activities throughout the life cycle of the Project.

4.13.4 Where the CRL Directorate or associated Contractor, proposes the use of an Independent Safety Assessor (ISA) or an Independent Software Assessor (ISwA), for example where the use of software requiring a particular Safety Integrity Level that has not been previously justified, the proposer shall provide evidence of the competence of the ISA or ISwA. In particular CRL shall confirm (or otherwise) the acceptance of the competence of the individual(s) concerned and their remit prior to their appointment. For the ONW NR shall be responsible for determining their own arrangements in accordance with their SMS.

4.13.5 The appointment of an Independent Assessor (AsBo) under the EC Regulation on CSM on Risk Assessment and Evaluation shall meet the requirements specified in that Regulation.

4.13.6 It should be noted that in accordance with the RIR and CSM Regulations, the AsBo(s) / NoBo(s) / DeBo(s) have the right to undertake audits as defined by the relevant TSIs / NNTRs and CSM.

4.14 Product Approvals

4.14.1 Contractors are required to provide a Product Breakdown Structure (PBS) [Ref 25] to identify equipment with their scope of supply that may require Product Approval. A process has been published which describes how the PBS is completed. The PBS is thus a mechanism to make sure that CRL are aware of scope of items that are not supported by relevant documentary evidence which provides previous acceptance by a recognised railway authority. Contractors Engineering Safety Management Requirements (Systemwide) Works Information Volume 2B – Part 32 clarifies this [Ref 29]. Details of this process are contained within the document "Crossrail Process and Format of Product Breakdown Structure for Systems" [Ref 25].

4.14.2 New and novel equipment will need a formal product acceptance. Safety related equipment will need compliance with the CENCELE standards process (GPSC, GASC and ASSC) for acceptance by RAB(C) [Ref 51]. For non-safety related equipment can be acceptance by the CRL Discipline Lead for Crossrail Infrastructure use.

4.14.3 A Competent Person (i.e. an Independent Safety Assessor or ISA) may need to be appointed in order to make sure that safety requirements associated with the equipment can and will be met.

4.15 Safety Assessment

4.15.1 The CSM Regulations require the appointment by a Proposer (i.e. CRL) of a Safety Assessment Body (known colloquially as an "AsBo") to carry out independent assessment of:

- How the risk management process is being applied;
- The results obtained from the risk management process.

4.15.2 In carrying out the assessment, the AsBo must have a thorough understanding of the Project, based on access to information provided to it by CRL. According to Annex III of the CSM, the Assessment Report produced by the AsBo shall include a definition of its scope, the plan under which assessments were conducted, the results obtained, together with known limitations on the assessment.

4.15.3 Further guidance on the roles and responsibilities of the Independent Assessor is available from the Office of Rail and Road (ORR) [Ref 33].

4.16 Project Contractors' System Safety Management

4.16.1 The Project's Contractors have contractual obligations to produce and operate their own System Safety Plan that shall take into account the requirements of this CRL System Safety Plan. All Contractors' System Safety Plans have been subject to approval by CRL before any design or construction work commenced.

4.16.2 NR are be responsible for the approval of System Safety Plans covering ONW and the works provided on behalf of CRL between Plumstead and Abbey Wood and will support CRL in compiling the necessary safety justifications by providing safety evidence including the Infrastructure Safety Justification relating to the surface sections of the Crossrail route.

4.16.3 The procurement process adopted has made sure that Contractors have followed ESM practice that is appropriate to the services they are providing as part of the project.

4.16.4 The activities of the Contractor are planned and defined in their relevant safety plans, which are reviewed by the relevant key stakeholders as required (including RfL, CRL and AsBo, etc.) and the CRL Project Engineer as appropriate.

4.17 Configuration Management

4.17.1 The CRL Configuration Management Plan [27] describes the high level plans for the identification and control of programme items such as documents, specifications, models and data and how changes to these are managed.

4.18 Organisation for Managing Engineering Safety

4.18.1 The System Safety Team is located within the Integration arm of the Crossrail organisation. The full organisation may be found on Crossrail Connect.

Sufficient competent resources are made available to allow fulfilment of the following key functions:

- Setting the strategic safety direction to enable ultimate compliance against appropriate legislation to be demonstrated,
- Acceptance of the safety arguments from the various contractors, utilising such to create appropriate safety justifications to demonstrate the overall safety and operability of the Crossrail railway.
- Establishing and maintaining processes through the medium of the Crossrail Engineering Safety Management Reference Manual such that evidence is generated to support the Engineering Safety Justifications.
- Provision of strategic safety direction to the project to enable compliance against appropriate legislation to be demonstrated, in particular against the Railway Interoperability Regulations and Common Safety Method and that the appropriate evidence is gathered by the project to support same.
- Production and validation of assurance evidence and safety justifications at element level and for the end to end railway, including the integration of evidence provided by others.
- Making sure that all reasonably foreseeable engineering safety risks have been identified and are tolerable and ALARP with evidence provided and validated within the PWHR.
- Establishing processes across the project such that the works are compliant with the requirements of the Railway Interoperability Regulations and that the associated Technical Files are compiled and submitted to the Office of Rail and Road for authorisation.
- Facilitation of the Hazard Review Panel such that hazards and or risk control actions that cannot be completely implemented in design are accepted by and transferred to the operator and maintainer for incorporation within their safety management systems.
- Management of the NoBo, DeBo and AsBo activities such that their impartiality is not compromised whilst their outputs are provided in a timely manner.
- Compilation of safety evidence for the integrated railway.

4.18.2 Engineering Safety Team Organisation.

The Engineering Safety Team is led by a Head of System Safety Management and Interoperability who manages the following work streams:

- Strategy
- System Safety
- Interoperability

Please see the following diagram.

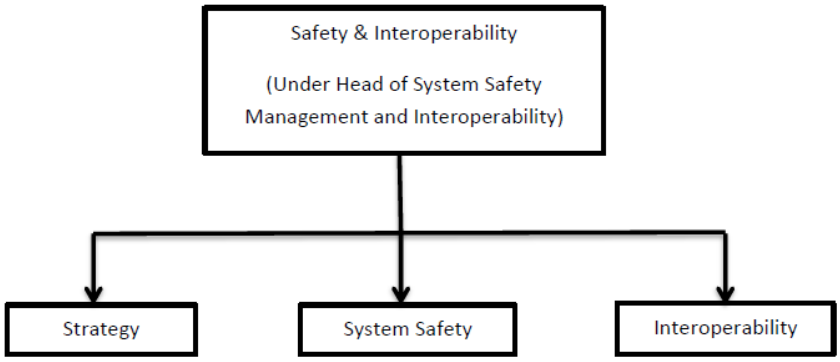

Figure 18: Engineering Safety Team Organisation

Engineering Safety Team Organisation (also see Crossrail Connect)

4.18.3 The Key Responsibilities of the Head of System Safety Management and Interoperability are as follows:

- Translation and delivery of key Company Directives within the Engineering Safety function
- Provision of Strategic Direction to the Engineering Safety Team
- Oversee management of the overall team.
- Make sure that the engineering safety competence of individuals within the team is maintained and that tasks are allocated according to competence and requirement.
- Maintain the overall safety deliverables programme such that outputs from the team are provided to achieve project timescales
- Liaise and progress issues from SIRP and MIRP
- Management of the RAB-C process, making sure that the papers for discussion are provided in a timely manner and outputs disseminated and actions carried out.
- Making sure that safety outputs are consistent with the requirements of applicable legislation, in particular HSAWA, RIR and CSM-RA.
- Provide direction and provide a logistical overview of the NoBo, AsBo and DeBo resources.

4.18.4 The three workstreams indicated above carry out the following key activities.

4.18.5 Strategy:

Key activities –

- Translation of the engineering safety management elements of key company objectives
- Provision of strategic safety direction to the project in respect of the above.
- Provision of documentation and processes to permit consistency of application across the department.

4.18.6 System Safety:

Key activities –

- Review of engineering safety management inputs from Contractors to ensure compliance with legislation and contract requirements
- Review and acceptance of contractor generated engineering safety justifications according to programme
- Creation of overall Safety Arguments and Justifications
- Making sure design and subsequent construction elements are demonstrated as safe, operable, maintainable and reliable
- Making sure that safety related CPFR requirements are met
- Practical management and delivery of the HRP process and its' outputs.
- Tracking population and progress of hazards within the PWHR and collection of evidence to permit timely closure.
- Ensure effective co-ordination and integration between the various contractors
- Provide engineering safety input to key testing and commissioning phases.

4.18.7 Interoperability:

Key activities –

- Manage the contract with the AsBo, NoBo and DeBo on a day to day basis.
- Manage the Register of Compliance with each contract against TSI requirements.
- Provide strategy and guidance to the project on key requirements to enable APIS to be obtained from the ORR
- Prepare EC Declaration of Verification for signature.
- Manage the assembly the Technical File to accompany the Declaration of Verification.

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5 Safety Controls

5.1 Documentation and Review

5.1.1 CRL, including RAB(C) [Ref 51] shall undertake the review and acceptance of documentation (such as Safety Justifications) produced both internally by the project and externally for the Central Operating System and its interfaces.

5.1.2 For each of the other Safety Justifications, the document(s) shall be accepted according to the process agreed by CRL with the relevant Duty Holder under the ROGS.

5.1.3 Documents shall be produced to the standards detailed in 5.9 above.

5.1.4 Documents due to be submitted to Duty Holders shall be subject to review and endorsement by appropriate personnel within the CRL Project prior to their submission.

5.1.5 RAB(C) [Ref 51] will be responsible for signing the “Declaration of Control of Risk”. This will be the CRL declaration that all hazards and associated risks are controlled to an acceptable level, as required by CSM – RA Article 16.

5.2 Railway Level Hazard Structure

5.2.1 The Railway Level Hazard Structure [Ref 54] will be utilised by CRL including RAB(C) [Ref 51] in assessing the overall coverage and logic of the various separate Safety Justifications (SJs) for each of the elements i.e. Systemwide systems, stations, shafts and portals. This will contribute to the overall integration of the Crossrail railway across the contractual boundaries and provide assurance that the combination and integration of each of the Safety Justifications (SJs) add up to a safe overall system.

5.2.2 Through demonstration of the hazard structure, the overall safety argument as to how CRL has mitigated the significant hazards will be supported. This will inform CRL including RAB(C) [Ref 51] as to how the requirements have been captured in appropriate documentation to deliver the intended mitigations. Interfaces

5.2.3 This will facilitate the approval of individual safety justifications for elements or systems as it will allow their combination to the overall safety case to be better understood. It will also enable the individual safety justifications to be simplified.

5.3 Hazard Management

5.3.1 The Hazard Management Procedure [Ref 5] specifies the process by which hazards shall be managed across the project.

5.3.2 The Safety Issues File (SIF) is a ‘live document’ maintained by the CRL Technical Directorate, which records details of hazards and risk control actions for the future Duty Holders identified during safety analyses of the Works design and which have been transferred to Duty Holders with the agreement of CRL.

5.3.3 The transfer documentation shall contain where available details of the appropriate control measures (manuals, procedures, training, etc.), in accordance with the Hazard Management procedure [Ref 5].

5.3.4 Hazard mitigation shall be as described in this System Safety Plan.

5.3.5 CRL makes sure that Hazard Records being populated by each of the Contractors for which they have responsibility are properly maintained through the lifecycle of the project, as part of their Engineering Safety Management (ESM) activities. Hazards that are transferred in accord with the Hazard Management Procedure shall be recorded in the Safety Issues File by CRL.

5.3.6 All hazards identified and recorded in the Safety Issues File will become project safety issues and tracked until closed out. Those hazards within the Safety Issues File that relate to design issues and referred back to the relevant Designers shall be tracked until CRL agree that they have been closed out.

5.3.7 The hazard management process used by NR for the ONW will be compatible with the CRL Hazard management procedure but the verification and validation process and hazard management tools used are different. Details are contained within the Network Rail Crossrail Programme, System Safety Plan. Any hazards required to be transferred to Duty Holders will be input by NR into the Crossrail PWHR. A form “Crossrail Hazard Transfer Agreement” formalises this.

5.4 Data Reporting, Analysis & Corrective Action System

5.4.1 The Project Engineer makes sure that an appropriate Data Reporting, Analysis & Corrective Action System (DRACAS) for failure reporting is utilised by their contractors to gather information on the types and causes of faults arising during the testing and commissioning process, and investigating all incidents from the point at which a version of the system approximating to the final operational version is available. This will make sure that action to correct faults will be taken in a managed manner. This system will also be used to initiate any changes to the systems that are required during system testing, trial running and commissioning.

5.5 Safety Requirements Management

5.5.1 The identification of Safety Requirements is mandated under the CSM Regulations. These are defined as the means of the safety characteristics (qualitative or quantitative) of a system and its operation (including operational rules and maintenance) necessary in order to meet legal or company safety targets. Safety measures are the set of actions, either reducing the rate of occurrence of a hazard or mitigating its consequences in order to achieve and / or maintain an acceptable level of risk. In the descriptions used in the management of the PWHR as described in the CRL Hazard Management Procedure, a Safety Measure is equivalent to a risk control action.

5.5.2 The overall Crossrail Project requirements (including safety requirements) are specified in the CPFR [Ref 10]. The Contractors are responsible for preparing the Safety Requirements Specifications although Contractors may identify additional safety requirements as part of the overall system requirements. The PWHR has the facility to record Derived Safety Requirements identified as part of the mitigation measures process [Ref 71]. The Derived Safety Requirements will be managed by the Contractors through to the completion of the works by use of the Derived Safety Requirements Module (DSRM) in the PWHR. The compliance status of the contract and derived safety requirements will be recorded within the Engineering Safety Justifications for the relevant systems. Should there be a non-compliance with a Safety Requirement, the non-compliance would need to be justified via risk assessment and recorded in the PWHR, DSRM and the Safety Requirements Specifications. These issues will be dealt with via the Hazard Review Panel [Ref 51].

5.5.3 Safety Measures are required to be traceable to hazards in the PWHR and there may be a many-to-one relationship between a particular hazard and the safety measures applied to make sure that the hazard risk remains tolerable and ALARP, meeting both the requirements of CSM-RA and the HSAWA.

5.5.4 Safety requirements are written to be the necessary, but not solely sufficient conditions that describe features which control or mitigate residual hazard risk to tolerable and ALARP (as per above). The safety requirements are derived from the Risk Control Actions (i.e. Safety Measures to be applied) and may require engineering input to fully, unambiguously and precisely describe their function. These derived requirements shall be capable of standalone understanding, without having to refer to supporting information or other documents and be feasible, quantifiable, verifiable and testable to demonstrate that the hazard risk in question can be readily understood so that it can be controlled throughout all future operational modes.

5.5.5 Safety Requirements need not be defined for actions to be transferred to the IM under the HRP Process. Engineering Safety Management Requirements including “Assumptions” are managed for all contracts under special purpose DOORS database modules designed for this purpose. Their management makes sure that a status can be conferred on any given identified requirement (including transfer to another contractor) at a given design stage, with satisfaction

of the requirement made only following the point at which the verification information becomes available. There are two sections to the DOORS database. The first is managed by the Crossrail Verification team. All Contract Performance Functional Requirements are contained within this database, with the identified safety requirements being a sub set. The second is managed as a discrete Derived Safety Requirements Module within the PWHR. This module is designed to capture those identified as a result of Risk Control Actions identified as mitigation within the PWHR.

5.5.6 Depending on the system, the Contractors may be required under the CSM Regulation to undertake a full qualitative and / or quantitative safety analysis in support of explicit risk estimation. In this case, the Contractors shall prepare a Safety Integrity Level (SIL) Requirements Report to recommend the system safety performance requirements against which the quantitative safety analysis will be evaluated. The identification of appropriate SILs is the responsibility of the Contractors, and shall be in accordance with the requirements of BS EN 50126 (Ref 18) and BS EN 61508 [Ref 21].

6 Safety Documentation

6.1.1 The Project Authorisation Strategy [Ref 82] contains the details of the authorisation process to bring the Central Operating Section of Crossrail into service. It also contains details of the documentation that is required to be submitted.

In addition, information will be handed over to the future owner, operator and maintainer to allow them to take over the railway.

The following is a summary of the information contained within the Strategy document:

6.1.2 Common Safety Method: EU/402/2013 as amended by EU/2015/1136

- Safety Assessment Report from the Assessment Body (AsBo)
- Evidence of the correct application of the Risk Assessment Process, together with output, to include the Project Wide Hazard Register indicating how all foreseeable hazards have been mitigated (in either design and / or operational / maintenance process).
- Submitted to the Safety Authority (ORR) as part of the “APIS”.

6.1.3 Interoperability and TSI Compliance: The Railways (Interoperability) Regulations 2011 and (EU 2016/797 (which consolidates 2008/57/EC as modified by 2014/106/EU))*.

- EC Declaration of Verification (by Crossrail) (Article 15)
- Certificate of Verification from the NoBo for each sub system (Annex IV, 2.3). This will include the Interim Statements of Verification provided to Crossrail throughout the design (Annex IV, 2.2).
- A Technical File to accompany the EC Declaration of Verification containing design evidence as per Annex IV, 2.4).
- (* Network Rail will compile and submit these in respect of their works on the South East spur).
- A similar process will apply for compliance with National Technical Rules, verified by a DeBo.
- Submitted to the Safety Authority (ORR) as part of the “APIS”.

6.1.4 Compatibility with Rolling Stock:

- For train compatibility with the infrastructure on the Central Operating Section, Crossrail will accept the proposed Interface Compatibility Assessment which Bombardier Transportation (on behalf of RfL) will submit to CRL prior to Dynamic Testing. This Interface Compatibility Assessment will detail the compatibility evidence obtained pre and during testing. This

output is an Interface Compatibility Agreement demonstrating compliance with the requirements of GE/RT 8270.

- Submitted to the Safety Authority (ORR) as part of the "APIS".

6.1.5 Handover Package (to permit the owner / operator / maintainer to manage the asset).

- The package provided will include "As built", Manuals, Plans, Procedures, Testing and Commissioning Certification (as per T&C Strategy) [Ref 45].

6.1.6 Applications to the ORR for authorisation of amendments to Safety Certificates (TUs) or Safety Authorisation (IMs) shall be made by the relevant Duty Holder, supported by CRL Project.

6.1.7 The AsBo NoBo programme and the Crossrail Central Operating Section (Interim) Safety Justification present a list of the documentation for assessment and safety deliverables.

7 Safety Engineering Activities

7.1 Engineering Design

7.1.1 All aspects of the engineering design of the CRL Project shall be undertaken in accordance with the Technical Management Plan [Ref 12], which specifies the systems engineering activities applicable to CRL.

7.1.2 CRL made sure that Contractors undertaking design and construction activities have produced System Safety Plans covering their ESM activities. These have been reviewed and accepted by CRL.

7.2 Verification and Validation

7.2.1 The Crossrail Verification and Validation Plan [Ref 16] specifies how all system components are to be verified and validated.

7.2.2 Section 4 details how the integration of the top level Safety Justifications with the Operations Concept is to be validated and verified.

8 Reference Documents

Ref:	Document Title	Document Number:
1.	Engineering Requirements Management Plan	CRL1-XRL-O8-STP-CR001-50005
2.	Technical Assurance Plan (TAP)	CRL1-XRL-O7-STP-CR001-50003
3.	The Assessment and Management of Health, Safety & Environmental Risk	LUL 1-526 Issue 3 June 2009
4.	Construction (Design and Management) Regulations 2015	
5.	Engineering Safety Management Hazard Management Procedure	CRL1-XRL-O8-GPD-CR001-50002
6.	Guidance Notes on application of Common Safety Methods (RSSB)	GE/GN 8640-5
7.	Health and Safety Manual	CR-XRL-Z7-GMN-CR001-00001
8.	RSSB, Taking Safe Decisions	GD-0001-SKP, 2009
9.	System Integration Management Plan	CRL1-XRL-O8-STP-CR001-50010
10.	CPFR baseline	CRL1-XRL-O8-RSP-CR001-50015

11.	Operations Concept(s)	CRL1-XRL-K2-GUI-CR001_Z-500xx series
12.	Technical Management Plan	CR-XRL-N2-GPL-CR001-00007
13.	Network Rail Crossrail Programme System Safety Plan	XWA1A-ESS-PLN-NCA-8908124
14.	Railways (Interoperability) Regulations 2011	
15.	Railways and Other Guided Transport Systems (Safety) 2006 as amended [ROGs]	
16.	Verification and Validation Plan	CRL1-XRL-O8-STP-CR001-50006
17.	Railway Strategic Safety Plan 2009 -2014 published by RSSB	(Note: current version of document is Railway Strategic Safety Plan 2014-2019)
18.	'Railway applications – The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS)'. Basic requirements and generic process	BS EN 50126 -1: 1999
19.	'Railway applications – Communication, signalling and processing systems – Software for railway control and protection systems	BS EN 50128: 2011
20.	'Railway applications – Communication, signalling and processing systems – Safety related electronic systems for signalling	BS EN 50129: 2003
21.	'Functional safety of electrical/electronic /programmable electronic safety-related systems – Part 1: General requirements	BS EN 61508-1: 2010
22.	Common Safety Method on Risk Evaluation & Assessment	EC Regulation EU 402/2013
23.	Internal guidance on cost benefit analysis (CBA) in support of safety-related investment decisions.	http://www.rail-reg.gov.uk/upload/pdf/risk-CBA_sdm_rev_guid.pdf
24.	Crossrail New Works Standards Baseline	CRL1-XRL-O6-RGN-CR001-00003
25.	Crossrail Process and Format for Product Breakdown Structures for Systems.	CRL1-XRL-O8-GPS-CR001-50002
26.	Standards Management Procedure	CRL1-XRL-O6-GPD-CR001-50001
27.	CRL Configuration Management Plan	CRL1-XRL-Z3-STP-CR001-50006
28.	CRL Competency Assessment - Guidelines	CR-XRL-O8-GUI-CR001-50001
29.	Volume 2B - General Requirements - Part 32 Contractor's Engineering Safety Management Requirements	CRL1-XRL-O8-XWI-CRG03-50002
30.	Network Rail Crossrail Programme, System Safety Plan	XWA1A-ESS-PLN-NCA-8908124
31.	Network Rail, Governance for Railway Investment Projects (GRIP), The Delivery Manual	DEL03
32.	London Underground, Category 1 Standard	S1538 Assurance

33.	ORR Guidance on the application of the Common Safety Method (CSM) on Risk Assessment and Evaluation, Issued by ORR March 2015 but subject to further revision. In such a case the most recent guidance should be used.	
34.	Crossrail Process for Managing Interoperability Requirements	CRL1-XRL-O8-GPS-CR001-50011
35.	Crossrail End-to-End Safety Justification And Assurance Case Strategy	CRL1-XRL-O8-STP-CR001-50030
36.	Crossrail Format and Process for Engineering Safety Justifications for Systems	CRL1-XRL-O8-GPS-CR001-50004
37.	Construction Management Plan	CRL1-XRL-N2-STP-CR001-50002
38.	Construction Quality Plan	CRL1-XRL-N2-STP-CRG03-50004
39.	Demonstration of Materials Compliance Procedure	CRL1-XRL-N2-GPD-CR001-50007
40.	Construction Certification for Structures and Civil Engineering Works Procedure	CRL1-XRL-O4-GPD-CR001-50006
41.	Monitoring and Surveillance Procedure	CRL1-XRL-Z-GPD-CR001-50001
42.	Snagging and Outstanding Works (Punchworks) Procedure	CRL1-XRL-O4-GPD-CR001-50010
43.	Completion of the Works (Project Manager's Duties)	CRL1-XRL-O4-GPD-CR001-50017
44.	Employer's Completion Process	CRL1-XRL-O4-GPD-CR001-50018
45.	Project Testing and Commissioning Strategy	CRL1-XRL-O8-STP-CR001-50008
46.	CRL Programme Testing and Commissioning Plan	CRL1-XRL-Z-STP-CR001-50017
47.	Handover Strategy and Plan	CRL1-XRL-K1-STP-CR001-50001
48.	IM Boundaries Document	CRL1-XRL-O8-XTC-CR001-00005
49.	Crossrail Trial Running Strategy	CRL1-XRL-R-STP-CR001-50001
50.	Crossrail Delivery Contracts Standard Engineering Safety Management Requirements Specification	CRL1-XRL-O8-GPD-CRG03-50001
51.	Rail Assurance Board (Crossrail) (RAB(C)) Terms of Reference	CRL1-RFL-O-GPD-CR001-50001
52.	Part 32 Contractors Engineering Safety Management Requirements (Stations, Shafts, and Portals MEP)	CRL1-XRL-O8-XWI-CRG03-50005
53.	Adoption of Technical Specifications for Interoperability	CRL1-XRL-O8-RGN-CR001-50031
54.	CRL Railway Level Hazard Structure (associated source visio file)	CRL1-XRL-O8-RGN-CR001-50156 CRL1-XRL-O8-XMO-CR001-50001
55.	The Management of Health and Safety at Work Regulations 1999	SI3242 1999

56.	VAP Implementation and Progressive Assurance Procedure	CRL1-XRL-O7-GPD-CR001-50021
57.	CRL Hazard Management Procedure	CRL1-XRL-O8-GPD-CR001-50002
58	Project Development Agreement	CR-XRL-Z8-AAG-CR001-50178
59	Readiness Gates Procedure	CRL1-XRL-O-GPD-CR001-50006
60	Engineering Design Assurance Gates Procedure	CRL1-XRL-O7-GPD-CR001-50015
61	Final Design Overview (FDO) Process	CRL1-XRL-O7-GPS-CR001-50009
62	Crossrail Dynamic Testing "Yellow Paper"	CRL1-XRL-R-STP-CR001-50008
63	Station Shafts and Portals Integrated Test Plan "Purple Paper"	CRL1-XRL-O8-STP-CR001-50024
64	Crossrail Transition Testing "Green Paper"	CRL1-XRL-O8-RSP-CR001-50047
65	Crossrail COS Energisation Strategic Plan "Orange Paper"	CRL1-XRL-R-STP-CR001-50011
66	Crossrail Safety Strategy for Energisation and Dynamic Testing	CRL1-XRL-O7-STP-CR001-50005
67	The Construction and Commissioning Rule Book	C610-ATC-R5-GPD-CRG03-50001
68	Tunnel, Cross Passages, Crossovers & Line of Route Civils Works Interim Safety Justification	CRL1-XRL-O8-STP-CR001-50111
69	Crossrail System Integration Panel (SIRP2) Terms of Reference and Management Procedure	CRL1-XRL-O8-GPS-CR001-50016
70	Maintenance Integration Review Panel (MIRP) Workshop Guidelines	CRL1-XRL-O8-GUI-CR001-50017
71	Project Wide Hazard Record Process	CRL1-XRL-O8-GPS-CR001-50013
72	CRL Management Principles	CRL-XRL-O6-GST-CR001-00001
73	RAM Requirements	CRL1-XRL-O8-RRS-CR001-00002
74	CRL Maintenance Strategy	CRL1-XRL-O8-XTC-CR001-00004
75	CRL Maintenance Development Plan	CRL1-XRL-O8-XTC-CR001-00006
76	CRL Maintenance Principles	CRL1-XRL-O8-XTC-CR001-00002
77	Configuration Management Plan	CR-XRL-N2-GPL-CR001-00008
78	CRL Asset Information Management Plan	CRL1-XRL-O8-XTC-CR001-00007
79	Engineering Management Plan	CR-XRL-N2-GPL-CR001-00007
80	Process for Managing Concessions to Standards	CRL1-XRL-O6-GPS-CR001-50001
81	CRL Guidance for Completing Concession Requests	CRL1-XRL-O6-CCN-CR001-50038
82	Project Authorisation Strategy	CRL1-XRL-O8-STP-CR001-50137
83	Crossrail Assurance Reporting Environment (CARE) User Guide	CRL1-XRL-O7-GUI-CR001-50004
84	Interim Safety Justification Content and Structure	CRL1-XRL-O8-RGN-CR001-50171`

85	Alignment of Safety Evidence to Key Hazards Railway Level	CRL1-XRL-O8-XMO-CR001-50002
86	Engineering Safety Management System Definition	CRL1-XRL-O8-RSP-CR001-50050
87	Crossrail Systems Architecture L0/L1 Central Operating Systems Overview	CRL1-XRL-O8-DWG-CR001-50002
88	Chief Engineer's Communication (CEC) Procedure	CRL1-XRL-O7-GPD-CR001-50010
89	Consolidated Railway Systems Interim Safety Justification for Central Operating Section	CRL1-XRL-O8-STP-CR001-50122

9 Standard Forms / Templates

Ref:	Document Title	Document Number:
A.	None	
B.		