Verification & Validation Plan

BBS Consortium		
	Date	**Agreed**
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BBS Deputy Project Director	15.8.12	

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Document History

Rev.	Issue Date	Description of Change	Author
A	2010/02/16	First Issue	M. Hecht
B	2012/07/27	tie review comments incorporated, Aligned with Settlement Agreement	S. Moffatt

Revision	Summary of Changes	
	Reference	**Description**
A	All chapters	First issue
B	1.1	Reference to ISO updated to ISO 9000:2005
B	1.5	References updated
B	2	Tie comments incorporated
B	3	Tie comments incorporated. Section for Integrated design added
B	4	Tie comments incorporated, Aligned with Testing and Commissioning Plan, V&V method Document Review added.
B	Attachment I	New ETN V&V model

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1 GENERAL

1.1 PURPOSE & SCOPE

The Verification and Validation Plan details processes, procedures, tools, schedules, documentation Requirements and required test and validation results format for the Edinburgh Tram Network. This Plan will be used to confirm that BBS will comply with the Employer's Requirements during all BBS connected phases of the V Lifecycle..

Following the Settlement Agreement, executed on 15 September 2011, CAF is no longer part of the Consortium. However, pursuant to the express provisions of the Tram Supply Agreement, the Tram Maintenance Agreement and the Tram Interface Agreement, and in order to ensure discharge of system integration (including Tram Supplier Integration) obligations this Plan is applicable for CAF, in particular in relation to the interfaces with BBS. Accordingly, whilst not expressly referred throughout, this Plan seeks to satisfy the Requirements for system/tram supplier integration in the Tram Supply Agreement, Tram Maintenance Agreement and the Tram Interface Agreement

The Verification and Validation (V&V) Plan includes verification and validation procedures which define the detailed procedures to be used by BBS and CAF to confirm compliance with the Requirements. The verification and validation processes applicable to each of the Requirements are set out in the Requirements Matrix.

The verification and validation lifecycle model described below forms the basis for the overall Verification and Validation Plan. The model is based on European standard EN 50126 – 1999 Railway applications – The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS).

BBS and CAF recognise that, as a process leading to completion of the Requirements Matrix the verification and validation will be required to confirm compliance with the Requirements. The Verification and Validation Plan shall be updated as required throughout the different project phases consistent with the needs of the ETN Project.

The terms used in this Verification and Validation Plan are as defined in the ISO 9000:2005 Quality Management Systems - Fundamentals and vocabulary and EN 50126: 1999 Railway Applications, the specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS). In the event of any inconsistencies between any terms in above mentioned standards and the Infraco Contract /RD3/, the terms defined in the Infraco Contract shall prevail.

- Section 2 of this Plan, provides an overview of the verification and validation process, while
- Section 3 provides a description of the verification and validation lifecycle.
- Section 4 identifies and describes the various methods used for verification and validation.

This document only defines the process of Verification & Validation. Responsibilities for Verification and Validation are defined in the Requirement Management Plan [RD5]

1.2 THE DOCUMENT & IT'S ENVIRONMENT

This Plan is part of the Requirements Management Plan as defined in [RD5].

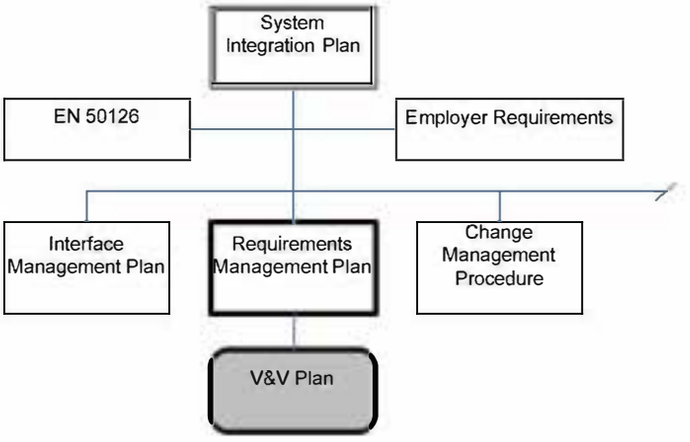

Figure 1-1: The document and its Environment

1.3 OBJECTIVES

The objectives of this Verification and Validation Plan are:

- To ensure that all project Requirements are met in a demonstrable manner with traceable evidence of achievement;
- To provide a structured methodology for verification and validation of requirement achievement throughout the project lifecycle.

The following table provides the definitions and objectives of the verification and validation in general.

	Verification	Validation
Definition (EN50126)	Confirmation by examination and provision of objective evidence that the specified requirements have been fulfilled. ("Build the product right")	Confirmation by examination and provision of objective evidence that the particular requirements for a specific intended use have been fulfilled. ("Build the right product")
Objective (EN50126)	The objective of verification is to demonstrate that, for the specific inputs, the deliverables of each phase meet in all respects the requirements of that phase.	The objective of validation is to demonstrate that the System under consideration, at any Phase of its development and after its installation, meets its requirements in all respects.
Remarks	Verification demonstrates whether the Output of a phase conforms to the input of a phase as opposed to showing that the Output is actually correct. Verification will not detect errors resulting from incorrect input specification and these errors may propagate without detection through later stages in the development cycle.	It is not enough to only depend on verification, so validation is necessary (1) to check for problems with the specification and (2) to check the validity of models used and (3) to demonstrate that the System is functional and operational

Table 1: Definition and Objectives of Verification and Validation

This Plan also covers the following Employer's Requirement's /RD2/ or parts of it:

Requirement	
3.6.2 Design Approach	This plan describes phases not covered by the SDS V&V plan /RD14/
37.4.2 System Integrator	Description of Verification and Validation management
23 Testing and Commissioning	Providing cross reference to Requirements

	regarding testing and commissioning.

1.4 RESPONSIBILITIES AND CHANGES

The responsibility of this document lies with the Requirement Manager as described in the RM Plan [RD5].

1.5 APPLICABLE AND REFERENCE DOCUMENTS

1.5.1 Reference Documents

Where a specific revision is mentioned this document is dependent on the referred document and needs to be checked after updates of the referred document.

	Title	Rev.	Issue Date
RD1	BBS Specific Procedure – Document Control BSC/25.1.201/PSP/002	latest	
RD2	Employer's Requirements (Schedule Part 2) PRO-INFRACO-1399	Version 5	14/09/2011
RD3	InfraCo Contract LONDON\THV\21368667.13 And Settlement Agreement		15/09/2011
RD5	Requirements Management Plan, ETN(BSC$MC&ADB#050401	C	2012/07/20
RD6	Change- and Claim Management, ETN(SPM$Q&ADB#050704	latest	
RD7	BBS Over-arch Safety Management Plan, BSC/25.1.201/SMP/001	latest	
RD8	BBS ETN Detailed Design Assurance Plan, ETN(BSC$TE&ADB#050058	latest	
RD9	BBS Design Management Plan, BSC/25.1.201/DMP/001	latest	
RD10	Design Assurance Statement (DAS) & Interdisciplinary Design Check (IDC) BSC/25.1.201/PSP/003	latest	
RD11	PSP for ITP Planning, Execution and Packaging BSC/25.1.201/011	latest	
RD12	System Integration Plan ETN(BSC$TE&ADB#053638	B	
RD13	BBS Quality Management Plan BSC/25.1.201/QMP/008	latest	
RD14	SDS Verification and Validation Plan ULE90130-SW-SW-PPN-00005	8	
RD15	BBS Testing and Commissioning Plan Airport to	latest	

	York Place (Initial Phase 1a) ETN(SPM$Q&ADB#054674		

Table 2: Reference Documents

1.6 GLOSSARY OF TERMS

The following tables contain the definitions of those terms, abbreviations and acronyms that are used in this document. These tables are supplied only for the ease of reading the document.

1.6.1 Definitions

Term	Definition
BBS	Consortium of Bilfinger Berger and Siemens
CONJECT/BIW	Document Management System used within BBS
CAF	CONSTRUCCIONES Y AUXILIAR DE FERROCARRILES
Verification	Confirmation, through the provision of objective evidence, that specified Requirements have been fulfilled
Validation	Confirmation, through the provision of objective evidence, that the Requirements for a specific intended use or application have been fulfilled
Objective evidence	Data supporting the existence or verity of something

Table 3: Terms and Definitions List

1.6.2 Abbreviations and Acronyms

Abbreviations / Acronym	Definition
ER	Employer's Requirements (Schedule Part 2 of Infraco contract)
RM	Requirement Management
V&V	Verification and Validation
CfS	Case for Safety
DAS	Design Assurance Statement
IDC	Interdisciplinary Design Check
ITP	Inspection and Test Plan
IFC	Issued for Construction
AFC	Agreed for Construction

Table 4: Abbreviations and Acronyms List

2 VERIFICATION AND VALIDATION PROCESS OVERVIEW

2.1 VERIFICATION AND VALIDATION LIFECYCLE MODEL

The verification and validation lifecycle model, “V-Model”, provides a sequence of phases, each containing tasks covering the total life of the ETN Project, from initial concept through to System Acceptance. The “V-Model” provides a structure for planning, managing, controlling and monitoring all aspects of the ETN Project, in order to demonstrate compliance with the Requirements during design, construction, installation, integration, testing, commissioning and maintenance.

Attachment 1 illustrates the “V-Model” for the ETN Project. This illustration shows how the development of the System has been structured to follow the “V-Model” from Apportionment of Requirements (Phase 5) until System Acceptance (Phase 10). For each of the phases, a series of activities will be performed to develop, design, install, test and integrate the System. The results from each phase will be in the form of objective evidence of verification and validation. This will include such documents as test records, inspection records, test reports, results of analysis’, etc., as outlined in Section 3 of this document Phases 1 to 4 will be not covered by the BBS V&V plan because these phases are addressed under the SDS V&V Process. Any misalignment between the ER, ref [RD2] and the SDS Requirements have been captured as part of the 'misalignment process' and managed under the BBS Change and Design Management Processes /RD9/..

To manage the verification and validation documentation resulting from each phase, BIW will be used, in accordance with internal quality management system procedures for configuration management and document control /RD1/, to collect the evidence of verification and validation. This verification and validation related documents within BIW will be used to incrementally progress the Requirements Matrix.

The ETN System will be assembled, constructed, installed, tested and validated at each stage of the lifecycle as the ETN Project development progresses up the right-hand side of the “V” model if applicable.

The BBS Requirement Manager will co-ordinate the overall verification and validation processes for the ETN Project and maintain the verification and validation Requirements Matrix specifically organised to collect the evidence of verification and validation.

3 VERIFICATION AND VALIDATION LIFECYCLE

3.1 INTRODUCTION

Verification and validation for the ETN Project will be applied to each System level.
The main objectives are:

- To ensure that the individually designed, manufactured, installed, commissioned, maintained Sub-systems are brought together and integrated into a coordinated system which satisfies and performs in accordance with the contract;
- To ensure that the System and ETN Activities satisfy the Requirements.

3.2 APPORTIONMENT OF REQUIREMENTS (PHASE 5)

Apportionment of the Requirements will be achieved by taking the Requirements and identifying for each Sub-system those Requirements which are applicable to each Sub-system. The results of this activity will be documented in a suitable requirements management tool. For more information regarding requirements management refer to the Requirements Management Plan /RD5/

3.3 DESIGN AND IMPLEMENTATION (PHASE 6)

The Design and Implementation Phase activities will be divided into 4 stages: Sub-system Design, Equipment Design, Installation Design and Integrated Design. Each is generally described below.

3.3.1 Sub-system Design (Phase 6.1)

The objective of Sub-system design is to develop the Sub-system specifications and produce the outline design for the Sub-system as listed in the plans. The Sub-system design is internally reviewed to evaluate the ability of the results of design and development to meet the apportioned Requirements, identify any problems and propose necessary actions.

The review processes for the Sub-systems are described in their own internal procedures and the Quality Plans. (BBS and underlying plans)

Typical tasks and documentation prepared during this stage include:

- Project identification;
- Technical description of Sub-systems;
- Records of Review;
- Updated Hazard Log;
- Design packages;
- Interface Control Forms (ICF);

- Design Assurance Statement (Sub-systems);
- Case for Safety (Sub-systems).

3.3.2 Equipment Design (Phase 6.2)

The objective of this phase is to carry out the equipment design in accordance with the Sub-system design and verify that the Requirements apportioned to the equipment, including any apportioned Requirements, are verified through design review. Typical tasks and documentation prepared in this phase are:

- Design of Sub-systems Elements according to:
  - Sub-system and Sub-system design Requirements (apportioned to the elements);
  - Update of Interface Requirements.
- Records of Review;
- Updated Hazard Log;
- Updated Design packages;
- Updated Design Assurance Statement (Sub-systems);
- Updated Case for Safety (Sub-systems);
- Equipment Test Plan/ Schedule of Work Tests.

3.3.3 Installation Design (Phase 6.3)

The objective of this phase is to define the installation Requirements of the Sub-systems and elements. Design reviews in this phase will verify the adequacy of the installation design. Typical tasks and documentation for this phase include:

- Installation Drawings per cluster
- Records of Review;
- Updated Hazard Log;
- Updated Design packages;
- Updated Design Assurance Statement (Sub-systems);
- Updated Case for Safety (Sub-systems);
- Inspection and Test Plan (ITP);
- Installation Plan.

3.3.4 Integrated Design (Phase 6.4)

The objective of this phase is verification and validation of the integrated design as described in the Design Management Plan /RD9/ and DAS/IDC Procedure /RD10/. More detailed information regarding system integration can be found in the System Integration Plan /RD12/

Typical tasks and documentation for the integrated design include:

- Records of Review;
- Updated Hazard Log;
- Design Assurance Statement;
- IDC Certificates;
- Case for Safety;
- IFC/AFC drawings;
- Testing and Commissioning Plan.

3.4 MANUFACTURING/ FABRICATION (PHASE 7)

The objective of this phase is to produce and deliver the equipment and materials for the ETN Project within the manufacturing processes in accordance with the design and production Requirements. References to Requirements and specifications and relevant test procedures are listed in the ITP's.

3.4.1 Factory Tests (Phase 7.1)

The objective of this phase is to verify each assembled Sub-system, or part of Sub-system (e.g. the Sub-system hardware and software) against its respective design specification.

For verification and validation of ITP packages refer to the procedure for ITP Planning, execution and packaging /RD11/

Typical verification documents are:

- FAT procedures;
- Specifications;
- Checksheets;
- Inspection and Test plans.

This phase is validated by successful completion of the test documented with:

- FAT reports;
- Certificates;
- Signed checksheets;
- Initialled ITP activities;
- Signed-off ITP packages (FAT-phase).

3.4.2 Delivery (Phase 7.2)

The objective of this phase is to confirm/verify the conformance of delivered items after transport. After delivery of the items in the warehouse, storage or on site an inspection takes place. Arrival of the goods in good order can be validated by signed ITP's, signed delivery sheets etc.

Specific for CAF is the Delivery Acceptance Test and test report.

3.5 CONSTRUCTION/INSTALLATION (PHASE 8)

The objective of this phase is to construct, assemble and install the total combination of Sub-systems and elements.

3.5.1 Installation Tests (Phase 8.1)

The objective of this phase is to carry out appropriate Sub-system installation tests and Sub-system commissioning. Typical tasks and documentation for this phase include:

- Commissioning
- On Site Tests/Site Acceptance Tests;
- Test Reports and Certificates;
- Site Acceptance Test Reports;
- Initialled ITP activities.

3.5.2 Sub-system Validation (Phase 8.2)

The objective of this phase is to review all previous Sub-system test results in order to validate the Sub-systems conformance to the Sub-system design Requirements. At this phase, Sub-systems integration will be completed.

For verification and validation of ITP packages refer to the procedure for ITP Planning, execution and packaging /RD11/. At this point the packages should be complete.

More detailed information regarding system integration can be found in the System Integration Plan /RD12/

Typical tasks and documentation for this phase include:

- System Tests;
- Sub-system Integration;
- Dynamic Test Drives (Test Train);
- Test Reports;
- Test Records;
- Inspection Records;

- Certifications;
- Initialled ITP activities;
- Signed-off ITP packages;
- Maintenance and Operation Manual;
- As-built drawings;
- Updated Case for Safety (Sub-system);
- Updated Design Assurance Statement (Sub-system);
- Updated hazard log.

3.6 SYSTEM VALIDATION (PHASE 9)

The objective of this phase is to verify & validate the System against the Requirements.

Typical tasks and documentation for this phase include:

- System Integration Tests;
- Commissioning Tests; (SCT);
- Dynamic Test Drives (Test Train);
- Integration Test Reports;
- Test Records;
- Inspection Records;
- Certifications;
- Work site completion certificates;
- Maintenance and Operation Manual;
- As-built drawings;
- Updated Case for Safety;
- Updated Design Assurance Statement;
- Updated Hazard Log.

Refer to Section 4 below for a description of the verification methods applied to this phase.

The Testing and Commissioning Plan /RD15/ contains a detailed overview of all system integration relevant tests and their interdependencies.

Successful completed tests provide the validation for this phase.

3.7 SYSTEM ACCEPTANCE - (PHASE 10)

The purpose of the System Acceptance Phase shall be to assess all system verification and validation tasks, specifically the RAM verification and validation and the Case for Safety have been delivered in accordance with the System Assurance Plan, (see [RD8RD7]).

This phase includes the verification and validation of system performance Requirements and readiness of Operator and Maintainer to enter Passenger Service.

During this phase the ETN System shall be formally accepted for entry into service, if appropriate.

The Hazard Log shall be reviewed and updated to record any residual hazards identified during system validation or acceptance and to ensure that the risks from any such hazards are effectively managed.

Typical tasks and documentation for this phase include:

- Hazard Log;
- Acceptance System handover Case for Safety and test results by ICP and PSCC;
- List of residual risks;
- Test reports;
- Performance reports and Analysis;
- Audit reports;
- Training reports;
- Where appropriate letter of approval or 'Letter of No Objection to Proceed' from HMRI or relevant approval body to enter into the next phase;
- Consents to achieve full passenger service.

The Testing and Commissioning Plan /RD15/ contains information and references to relevant test procedures for this phase.

4 VERIFICATION AND VALIDATION METHODS

The principle methods by which verification and validation will be achieved throughout the ETN Project are listed below. These methods are indicated on the Requirements Matrix under the column entitled "V&V by" with a code that is indicated along with each method.

- Design Reviews (DR);
- Analysis, Study, Assessment, Calculation, Evaluation of Similar Solution (SACE);
- Modelling/Simulations (MOS) to indicate the specific simulation to be used;
- External Certification (XC);
- Factory Acceptance Test (FAT) for Siemens and Bilfinger only;
- Site Acceptance Test (SAT) for Siemens and Bilfinger only;
- Sub-System Integration Test (SIT-BBS) for Siemens and Bilfinger only;
- System Commissioning Test (SCT-BBS) for Siemens and Bilfinger only;
- Factory Acceptance Tests (FAT) for CAF only;
- Delivery Acceptance Test (DAT) for CAF only;
- Site Commissioning Test (SCT-CAF) for CAF only;
- System Integration Test (SIT-CAF) for CAF only;
- System Acceptance Tests (SATS);
- Cases For Safety (CFS);
- Safety and Health Plan (SHP);
- Process Audit (PA);
- Document Review (DoR).

.The next table shows by which test types the verification and validation methods are covered in the Testing and Commissioning Plan /RD15/.

ER	Verification and Validation method	T&C plan by test type
23.4	Factory Acceptance Test (FAT)	FAT
23.5	Site Acceptance Test (SAT) a) Construction/installation activities have been completed correctly by demonstrating that the design specification and functionality of the Employer's Requirements have been achieved; b) The Sub-systems, in isolation and before passengers are carried, function and behave at site as designed and tested	 ICT SAT

ER	Verification and Validation method	T&C plan by test type
	in the FATs; c) The infrastructure Sub-systems and the Trams will then be integrated with each other insofar as is possible to prove that they collectively function and behave at Site as designed and tested in the FATs; and d) The Initial Phase 1a functions and behaves at Site as designed and tested in the FATs. This is defined as system commissioning tests and involves the integration of the infrastructure Sub-systems and the Trams.	SIT SIT
23.6	Sub-System Integration Test (SIT-BBS) shall be undertaken in respect of each section. • Each sub-system, module or component of the system functions in isolation as designed and does not deviate from FAT results. • All Sub-systems for the relevant section of Initial Phase 1a are demonstrated to collectively perform in accordance with the operations and performance criteria specified in the Employer's Requirements	SAT SIT
23.7	System Commissioning Test (SCT-BBS) shall be undertaken in relation to each section. • Each sub-system, module or component of the system functions collectively as designed and do not deviate from FAT results. • All Sub-systems for the relevant section of Initial Phase 1a are demonstrated to collectively perform in accordance with the operations and performance criteria specified in the Employer's Requirements for a representative number of consecutive passes of a Tram in each direction over the relevant section of Initial Phase 1a. • The integration testing shall include demonstrating that the Control Room systems and Control Centre equipment connected to a representative sample of the substation SCADA and other equipment required for Tramstops can be effectively exercised under a robust simulation of trams progressing around Initial Phase 1a.	SIT SIT SIT
23.13	System Acceptance Tests (SATS) Post Commissioning Test – Test T1 shall demonstrate and prove that Section B, C or D of Initial Phase 1a in sequence is able to perform in an acceptably safe manner and deliver the required run times. This is the gateway test to driver training.	T1

ER	Verification and Validation method	T&C plan by test type
23.14	System Acceptance Tests (SATS) Performance Test 1 – Test T2 shall demonstrate and prove that Initial Phase 1a (or sections thereof other than Section A and Section B) is able to perform satisfactorily in order to progress into the three-month Shadow Running period. This is the gateway test to Shadow Running.	T2
23.15	System Acceptance Tests (SATS) Pre-Operation Test – Test T3 shall test the capability of Initial Phase 1a to deliver the Operational Timetable, and subsequently to test a proxy of the Enhanced Timetable and includes infrastructure, Trams, and operational systems.	T3
23.16	System Acceptance Tests (SATS) Network Performance Test – Test T4 shall be carried out over a 28 day period in Passenger Service to establish that Initial Phase 1a can reliably operate the Operational Timetable in normal- and outage operation.	T4
23.17	System Acceptance Tests (SATS) Network Reliability Test – Test T5 shall demonstrate the reliability of certain Sub-systems in Passenger Service.	T5
23.19	Factory Acceptance Tests (FAT)	FAT
23.20	Tram Delivery Acceptance Tests (DAT) shall be carried out by the Tram Supplier upon delivery of each Tram and shall establish that the Tram has not been damaged or affected in any way by the delivery process.	DAT
23.20.1	Site Commissioning Test (SCT-CAF) shall comprise both Static and Dynamic Type -and Routine Tests.	SCT
23.21	System Integration Test (SIT-CAF) consists of Tests carried out by the Infraco supported by the Tram Supplier and the Operator to prove that Initial Phase 1a as a whole can function as intended.	SIT

Table 5 Cross reference ER, V&V Method and Test type

The way in which each of these methods will be applied is described below

4.1 DESIGN REVIEW (DR)

The ETN System Requirements have been apportioned by the Client and are represented in the Requirements.

BBS will review and apportion the Requirements into applicable Sub-systems as described under Section 3.2, apportionment of Requirements (Phase 5).

BBS will do systematic reviews of Requirements apportionment; design and development will be performed in accordance with planned arrangement/procedures to:

- Confirm the apportionment and decomposition of the Requirements;
- Evaluate the ability of the design to meet the Requirements;
- Evaluate the ability of the design to be built and maintained;
- To identify any problems and propose necessary actions;
- Ensure consideration of interfaces;
- Establish design freeze point for configuration management.

Participants in these reviews will include specialists of the functions concerned with the design being reviewed. For example, when looking at maintenance aspects of the design, maintenance specialists and RAMS specialists will be included in the review, along with any other cognizant functions to insure maintenance and/ or safety specific concerns are addressed and resolutions incorporated.

The review will ensure all input Requirements, including interfaces have been incorporated into the design. Once this has been completed, the design is considered “Frozen” for configuration management purposes. (please compare the BBS Design Management Plan [RD9])

Upon freeze of design, control of changes will be in accordance with internal change control [RD6], configuration management and document control procedures. Any changes to a frozen design will follow the internal change control procedure [RD6] which includes the reassessment of the design review for the previous stage. Design changes will be identified and records maintained.

Outputs from design and design reviews will be documented in a form which enables verification against design input in accordance with the Project Management Plan.

Design output provides documents such as:

- Technical documents related to product development or system configuration, including those characteristics that are critical to the safe and proper functioning of the product, in accordance with the Requirements;
- Technical documents for purchasing or procurement of materials, production, inspection and testing, installation, commissioning, maintenance and disposal;
- Descriptive documents for Operator control and servicing and - where necessary - evidence of the safe, reliable and proper functioning of the product for customers and authorities.

Design verification will be performed in accordance with planned arrangements to ensure that the design has met the design input Requirements, code/regulatory Requirements and any/all supporting Requirements.

Records of the results of the design reviews, design verifications and design validation and any necessary actions will be maintained in accordance with the Project Management Plan. Open actions will be tracked to ensure resolution and incorporation into the designs prior to IDC and design certification..

4.2 ANALYSIS (SACE)

Calculations, analysis, research, studies, assessments, and evaluations of similar solutions will be performed in accordance with established internal quality management system procedures/instructions. The procedures require the following activities to be performed as part of the process:

- Identify the sources of material/information to be used;
- Identify the processes/methods to be used for analysis and calculations;
- Identify the process to be followed and individuals to be used to review. In all cases, the reviewer is not the individual performing the calculations, analysis, research or evaluation. Third party reviewers can be used, when required.

Analysis techniques, such as Fault Tree Analysis, Failure Mode, Effects and Criticality Analysis, Hardware Reliability Analysis and/ or Common-Mode Failure Analysis, may be applied, as appropriate. Records from these analyses will be maintained in the project documentation system, in accordance with the Configuration Management and Document Control Plan. Individual Lots will detail the types of analysis used in the respective Case for Safety. (FTA, etc.)

4.3 MODELLING/ SIMULATIONS (MOS)

BBS can conduct simulations to demonstrate the ability of the design to comply with the Requirements.

Assumptions taken for the simulations will be documented together with the study results including the scope of the simulations.

All simulations will be controlled by quality management and configuration management procedures to assure their correctness and accuracy. If the function and accuracy of a simulation is inconsistent with the expected output, a complete check/ verification of the simulation will be made. This may include independent reviews/ audits/ tests for accuracy, as necessary. Built into the process of assurance of the simulations, will be a feedback loop to design.

When a new simulation is determined to be needed through the design and design review process, a design development process is followed, starting with a clear definition of the Requirements, to design a new simulation or upgraded an existing simulation. As the simulation progresses in the design, a series of design reviews are performed, at intervals consistent with the complexity and criticality of the simulation. These reviews will be performed in accordance with standard internal quality management system/design control /RD13/ and

assurance procedures /RD10/. The design will be reviewed for adequacy by reviewers other then the individuals actually responsible for the design. Tests will be performed to prove the adequacy of the design. This process will be followed for all newly designed simulations before the simulation is allowed to be implemented/used. Records will be established and maintained to provide objective evidence of conformity to Requirements.

When it is determined to purchase a simulation from outside the company, quality management procurement procedures and processes will be followed to assure suppliers can provide a resultant product in accordance with specified Requirements. /RD13/

The process for utilisation of third party verification in respect to safety is documented in the relevant Case for Safety

4.4 EXTERNAL CERTIFICATION (XC)

BBS shall utilize where appropriate, third party certification for verification and validation.

4.5 TESTING

4.5.1 General

Testing will be carried out in a structured and well-documented manner, generally in reverse order from the design process (i.e., bottom up). A Testing and Commissioning Plan /RD15/, and Programme are established and will be updated by BBS, commencing during the design process. It will detail and confirm the tests and procedures necessary to confirm that the System and ETN Activities are compliant with the Requirements, including:

- Testing and Commissioning Plans, including description of tests, methods, and anticipated results;
- Testing and commissioning organisation, including the description of responsibilities;
- Communication, documentation, and reporting of testing and commissioning issues;
- Testing and commissioning procedural Requirements, including pass-fail criteria for the tests;
- Testing and commissioning schedule in conjunction with the ETN programme.

Identify Test Requirements and Prepare Test Plan

Test plans and procedures typically contain the following:

- Objective;
- Description;
- Sub-systems involved (tests only);
- Pre-requisites;
- Resource Requirements (personnel, facilities, equipment);
- Time required to complete;

- Accept/reject criteria.

As elements of the Sub-system become operational, certain start-up tests will be performed to verify operational readiness.

All inspection/testing will be performed under the responsibility of the quality assurance function as part of the overall quality management system. If during the course of inspection/ testing a failure is determined/found, internal non-conformance procedures will be applied to segregate the non-conformance until it has been properly dispositioned and re-tested to compliance after non-conformance is removed. Inspection/ test records are created and maintained from each inspection/test and serve as documented evidence of compliance, as outlined in the Project Management Plan

4.5.2 Factory Acceptance Test (FAT) for Siemens and Bilfinger only ER23.4

Overview

Factory Acceptance Tests consist of a series of progressive activities all of which are undertaken at the sub-system manufacturer's premises.

Initial testing at the component manufacturer's premises of components to be used as part of a sub-system shall be undertaken to verify that the components behave as predicted in the design and satisfies the Employer's Requirements for that component.

Initial testing undertaken at the manufacturer's premises shall be undertaken to verify that the sub-system or component behaves as predicted in the design and meets the Requirements of the design specification and provides correct functionality.

Once Sub-systems or components have been successfully tested they shall be incrementally integrated and tested to verify that the Sub-systems behave as predicted in the design and meet the Requirements of the design specification and provide correct functionality.

Part of the FATs are first article inspections or type tests. These shall be undertaken on the first production item. This inspection shall verify that the Quality and functionality of the product is acceptable and that the manufacturers' quality control processes and procedures have been implemented.

The test specification(s) shall be produced by Infraco and shall be submitted to CEC for review at least ten business days prior to the date of the component, sub-system and FAT tests identified above and any additional tests required by Infraco.

Pass Criteria

FAT testing shall demonstrate that the individual Sub-systems or components and equipment fully meet the Requirements and are suitable for the subsequent release from the factory environment, delivery to site and installation.

FATs demonstrate the integration of the modules and Sub-systems under factory conditions and their reliable operation under cyclical testing.

As far as applicable the FAT will demonstrate that the sub-system or components has been successfully exercised through simulation, including a demonstration on how the alarm handling manages the worst case alarm flood..

4.5.3 Site Acceptance Test (SAT) for Siemens and Bilfinger only ER 23.5

Overview

The objective of site tests is to demonstrate that:

- Construction/installation activities have been completed correctly by demonstrating that the design specification and functionality of the Employer's Requirements have been achieved; Referred to as ICT in Testing and Commissioning Plan /RD15/. Verification and Validation of Inspection and Test Plans is described in the BBS Quality Management Plan /RD13/
- The Sub-systems, in isolation and before passengers are carried, function and behave at site as designed and tested in the FAT
- The infrastructure Sub-systems and the tram will then be integrated with each other insofar as is possible to prove that they collectively function and behave at Site as designed and tested in the FAT. and
- The ETN functions and behaves at Site as designed and tested in the FAT. This is defined as system commissioning tests and involves the integration of the infrastructure Sub-systems and the tram.

The Independent Competent Person as defined under the ROGS Regulations, other regulatory bodies and the PSCC shall need to be satisfied that the ETN is safe to operate before commencement of system commissioning activities. In order to verify this it shall be necessary for the Infraco to address the issues raised by the Independent Competent Person, PSCC, HMRI (or the appropriate approval regime in force) and Approval Bodies. This may necessitate defining specific tests or incorporating additional T1-T2 Test details into the suite of verification commissioning tests. Often the areas of interest to these bodies do not become clear until the majority of issues on the risk register and hazard log have been closed out.

4.5.4 Sub-system Integration Tests (SIT-BBS) for Siemens and Bilfinger only ER 23.6

Overview

Sub-system Integration Tests cover items 23.5.1 of these Employer's Requirements. They shall be undertaken on Sections.

The Infraco shall submit the suite of SIT testing specifications no later than two months prior to the commencement of the tests.

Pass Criteria

The tests are passed when:

- Each sub-system, module or component of the system functions in isolation as designed and does not deviate from FAT results.
- All Sub-systems for the given section of tramway are demonstrated to collectively perform in accordance with the operations and performance, and all of the Employer's Requirements.

4.5.5 System Commissioning and Integration Tests (SCT) for Siemens and Bilfinger only ER 23.7

Overview

System Commissioning and Integration Tests shall be undertaken on Sections.

Such activities include the running of tram(s) over section(s) of the Edinburgh Tram Network for which Sub-system Integration Tests have been successfully completed. This will verify that the System behaves as predicted and as demonstrated as far as was practical in previous tests.

Infraco shall liaise with both Turner & Townsend / CEC and the Operator to ensure that sufficient competent operational personnel are available to conduct the required activities, including tram drivers and Control Room staff. The Testing and Commissioning Plan /RD15/ documents the processes which will be put in place, in liaison with the Operator and Maintainers, covering responsibilities for systems, testing activities, provision of competent operating staff and safety of tram manoeuvres and traction power switching prior to handover.

Pass Criteria

The tests are passed when:

- Each sub-system, module or component of the system functions collectively as designed and do not deviate from FAT results. Referred to as SIT in Testing and Commissioning Plan /RD15/.
- All Sub-systems for the given section of tramway are demonstrated to collectively perform in accordance with the operations and performance, and all of the Employer's Requirements for a representative number of consecutive passes of a tram in each direction over the given section of the network. Referred to as SIT in Testing and Commissioning Plan /RD15/.
- The integration testing shall include demonstrating that the Control Room systems and Control Centre equipment connected to a representative sample of the substation SCADA and other equipment required for Tramstops can be effectively exercised under a robust simulation of trams progressing around the ETN. Referred to as SIT in Testing and Commissioning Plan /RD15/.

4.5.6 Factory Acceptance Tests (FAT) for CAF only ER 23.19

Factory Acceptance Tests– This group of tests shall be undertaken at the Tram Supplier's Factory and upon successful completion the Tram Supplier will be issued with a Factory Acceptance Type Test Certificate and Factory Acceptance Routine Test Certificate for each tram by the Tram Inspector. The Factory Acceptance Tests shall be conducted in accordance with the Tram Manufacturing Delivery Programme and the CAF Test Plan. The FAT will be broken down into Factory Acceptance Type Tests and a series of Factory Acceptance Routine Tests and will comprise both static inspections and dynamic tests. The Factory Acceptance Type Tests shall be undertaken on a single Tram. This shall be the first Tram unless agreed otherwise in writing by the Tram Inspector.

4.5.7 Delivery Acceptance Tests (DAT) for CAF only ER 23.20

These tests shall be carried out by the Tram Supplier upon the delivery of each Tram. They shall establish that the Tram has not been damaged or affected in any way by the delivery process and that it remains in the condition in which it was inspected prior to dispatch from the Tram Supplier's factory. On satisfactory completion of the DAT the Tram Inspector will issue a Certificate of Tram Delivery.SAT

4.5.8 Site Commissioning Tests (SCT-CAF) for CAF only ER 23.20.1

The Site Commissioning Type Tests shall be undertaken on the Tram(s) as appropriate, when they are delivered to the Depot and following the completion of the DAT. Upon successful completion the Tram Supplier will be issued with a Tram (Site) Commissioning Type Test Certificate by the Tram Inspector. The tests shall comprises Static and Dynamic tests and will include, but not be limited to, the tests referred to in the tables on the following page.

4.5.9 System Integration Tests (SIT-CAF) for CAF only ER 23.21

The System Integration Tests consist of tests carried out to prove that the ETN as a whole can function as intended. All infrastructure, operation and control systems shall be exercised during these tests. The Tram Supplier will provide reasonable input to the development of the SAT specifications as well as participation in, and support to, the tests whenever reasonable technical support is needed in reference to the Trams. Referred to as SIT in Testing and Commissioning Plan /RD15/.

The System Integration Tests will involve carrying out gauging runs over all parts of the ETN in order to establish that the Trams (when operating individually or in conjunction with other Trams) accord with the Tram cross Section and the agreed detailed interface arrangements in terms of the alignment geometry, clearances, loads, pantograph dynamics, wheel rail interface, traction power system, communications and route setting equipment, compliance with operational procedures and Tram performance values. In particular it shall be demonstrated that there is sufficient clearance between passing Trams on the Network and between Trams and other Network equipment and installations to ensure that the Trams can be operated safely and without damage to themselves and to the other parts of the System.

4.5.10 System Acceptance Test (SATS);

Once a Section of the ETN is physically completed and the System Integration Tests are satisfactorily completed then the formal acceptance process requires the Infraco to carry out and pass the following:

T1 - Post Commissioning Test ER 23.13
The test shall demonstrate and prove that each Section of the ETN in sequence is able to perform in an acceptably safe manner and deliver the required run times. T1 will immediately follow the successful commissioning of the nominated section (excluding Section A) and is a Requirement for progressing into Driver Training.

T2 - Performance Test 1 ER 23.14
This test shall be undertaken after Section C has passed the T1 test. The test shall demonstrate that Initial Phase 1a (or sections thereof other than A and B) can be operated to the Operational Timetable in an acceptably safe manner, that the completed Operator training programme has achieved an adequate competency to proceed to shadow running and shall demonstrate the mobilisation and competency of the maintenance teams provided by the

Infraco and the Tram Maintainer. The undertaking of Test T2 shall essentially be an operational function led by Infraco in conjunction with the Operator.

T3 - Pre-operations Test ER 23.15
The test shall be conducted during the shadow running phase of Initial Phase 1a and forms part of the Requirements for the final System Acceptance. The undertaking of Test T3 shall essentially be an operational function led by Infraco in conjunction with the Operator.

The test shall demonstrate that the system can operate to a sustained level of performance as specified in the Operating Timetable, such that the Operator can safely and reliably commence Passenger Services, the Infrastructure and Tram Maintainers can commence the Planned Maintenance, and Initial Phase 1a passes the ride quality criteria as specified in the Employer Requirements.

T4 - Network Performance Test ER 23.16
The test shall be conducted during Passenger Service and forms part of the Requirements for the final System Acceptance. The test is the operation of the whole of Initial Phase 1a to the Operational Timetable and shall measure the Punctuality Service Element over 28 day consecutive period. The test shall be completed within twelve months after the Service Commencement Date...

T5 - Network Reliability Test ER 23.17
This test shall be conducted during the Passenger Service and forms part of the Requirements for the final System Acceptance. The test is a set of sub-system reliability tests each measured over 28 day period. The tests may start on the same date as test T4 and shall be completed within twelve months after the Service Commencement Date.

More details regarding the System Acceptance Tests can be found in the Testing and Commissioning Plan /RD15/.

4.5.11 Cases For Safety (CFS)

The acceptance by the client of the Case for Safety will constitute verification that the relevant Requirements have been achieved as defined in the Design Assurance Plan. (see [RD8])

The Case for Safety will provide the justification that the overall tram system, Sub-systems and products supplied by BBS as part of the ETN project are acceptably safe.

The Design Assurance Plan /RD8/ gives a detailed description of the case for safety strategy and used verification and validation methods.

4.5.12 Safety and Health Plan(s) (SHP)

The Over-arch Safety Management Plan. [RD7] covers all contract Health and Safety activities. For information regarding verification and validation of the Health and Safety Requirements refer to this Plan.

4.5.13 Process Audit (PA)

BBS will develop and implement an Internal Process Audit Schedule, as part of the quality management system and in accordance with the ISO-9000 series of standards. The Internal Process Audits will examine objective evidence to confirm compliance with the Requirements

including but not limited to the ETN activities. Where a Process audit is agreed as a Verification and Validation method the frequency and time of the audit will be agreed with the client. The related audit reports will form part of the evidence.

When the client decides internal audits are not sufficient for close-out of specific Requirements additional audits can be performed by the Client in accordance with Clause 104 of the Infraco Contract.

The audits will be performed, in accordance with internal procedures, by qualified auditors, at planned intervals, to determine whether the ETN processes and plans conform to the Requirements and are effectively implemented and maintained.

Audits will take into consideration the status and importance of the processes, areas to be audited, and current as well as the results of previous audits. Selection of auditors and conduct of audits shall ensure objectivity and impartiality of the audit process. Auditors shall not audit their own work.

Internal Process Audit findings will be documented in accordance with the Configuration Management and Document Control Plan. An audit report will be issued by the audit team to the auditees after each audit. The audit report will include audit findings and conclusions. Any nonconformity will be actioned and managed, to resolution, in accordance with the Quality Plan.

The management responsible for the area being audited shall ensure that actions are taken without undue delay to eliminate detected nonconformities and their causes. Follow-up activities shall include the verification of the actions taken and the reporting of verification result.

Submission of internal audit reports is decided by BBS Project Management. However if specific audit reports are used for close-out evidence of Requirements, submission of the reports is highly recommended.

4.5.14 Document Review (DoR)

Verification and validation of the design is described in the Design Management Plan /RD9/ and DAS/IDC procedure /RD10/.

All project documents are subject to an internal review. The choice of reviewers is dependant on the document contents but must include a designated person to check the technical aspects of the customer Requirements. For BBS level plans the Consortium Quality Manager must be included as reviewer. After incorporation of review comments the document is formally released by the responsible engineer and project directors.

Documents are submitted to the Client under cover letter with a request for review. The documents will be reviewed according to Schedule part 14 (Review procedure). This excludes all design submissions.

Final validation of the documents is provided by the RoR received from the Client.

5 ATTACHMENTS

5.1 ATTACHMENT 1: "V" MODEL

ATTACHMENT I