General Testing and Commissioning Plan

REV 1

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PREFACE

This General Testing and Commissioning Plan provides the technical and project management requirements fundamental to verifying the functional performance of DECM projects. In addition, it covers best practices and lessons learned that will help ensure that each project meets the operations, facilities, and maintenance requirements identified in the contract documents. This plan is designed to be a comprehensive and practical guide to the requirements and processes that direct and guide DECM and Consultant activities.

This plan places emphasis on the roles and responsibilities of Sound Transit staff, the design consultants or Design-Builders, and the Contractor and construction management team throughout each project's delivery and includes significant discussion geared towards supporting consistent planning, detailed test and commissioning procedure development, effective issue resolution, clear results reporting, and strong communication practices, as follows:

(1) Responsibility, Accountability, and Authority – Section 4.0 addresses the requirements and expectations of all individuals involved in the testing and commissioning process. Roles and responsibilities with respect to good planning and communication practices are emphasized, as well as the need for practices that result in clear, concise, accurate, and well-coordinated procedures and test forms.

(2) Approach – Section 5.0 addresses the implementation of this plan and its applicability to all construction contracts for DECM projects. Each Contractor or Design-Builder is required to submit a Testing and Commissioning Plan. The plan will assign roles, tailor plan requirements to suit the scope of the project, establish schedules, and define activities and deliverables. The plan requires DECM Civil/Systems Integration approval.

(3) Procedure – Section 6.0 provides the technical requirements of the plan. This section presents a disciplined procedure for ensuring and documenting that, as the construction progresses, the proper planning is conducted, procedures and test forms are developed, and inter-discipline communication is being performed.

(4) The Testing and Commissioning Database – Section 7.0 addresses the T/C Database. This database is a SharePoint-based tool that shall be used by DECM Staff, Operations, Facilities, and Transition to Operation staff, as well as each Contractor or Design-Builder to collect, manage, collate, report, and archive testing and commissioning information. The database includes reporting tools that shall be used to indicate up-to-date status of active and resolved issues for each Contract or Project.

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1.0 PURPOSE

The purpose of testing and commissioning is to ensure a facilities' civil and Systems infrastructure performs as intended and minimize the potential for operational problems. Poorly performing facilities inherently have high costs. Benefits of testing and commissioning include a smoother construction process (from improved communication, fewer change orders, and avoided litigation), reduced operation and maintenance costs, lower energy costs (through improved energy efficiency) and improved customer satisfaction (through better facility functionality).

The purpose of this plan is to provide a structured testing and commissioning process for Design, Engineering, and Construction Management (DECM), as well as Operations, Facilities, and Transition to Operations staff. The structure is a building block approach, where the process adds each verified item to a verified base, which then supports the integrated testing of further items or systems.

This plan provides the technical coordination and project management requirements fundamental to the inter- and intra-contract verification of equipment and systems for DECM projects. This plan is used in conjunction with the Washington State and local codes related to testing and commissioning, for example, Labor and Industries requirements. It is also a comprehensive and practical guide to the testing and commissioning requirements and the hierarchy of tests. Finally, it directs and guides test conduct and verification-related activities for projects prior to entering revenue service.

This plan explains the roles and responsibilities of DECM, consultants, Sound Transit Operations, and Sound Transit Contractors. The testing and commission plan includes methods and roadmaps that ensure consistent planning for testing and commissioning activities, provides an understanding of the testing sequence and hierarchy, explains how to compile documentation for complete system verification, and provides informal opportunities for training Sound Transit personnel in addition to formal contractual obligations.

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2.0 SCOPE

The purpose of this plan is to provide a formal, systematic, and documented process to ensure that design elements prepared by the design consultants or a Design-Builder and constructed by the Contractor meet their function and physical requirements. The testing and commissioning process comprises the integrated application of a set of engineering techniques and procedures to check, inspect, and test every operational component of the project, from individual functions, such as devices and equipment, up to complex amalgamations such as subsystems and systems.

DECM organizations and design consultants/Design-Builders shall follow this plan during all phases of project design. This plan is applicable to the following DECM projects as part of the design phase:

- Link Light Rail.
- Tacoma Link.
- Sounder Commuter Rail.
- Sound Transit Express Bus Service facilities.
- Bus Rapid Transit.
- Parking facilities for the projects listed above.
- Maintenance facilities for the projects listed above.
- Engineering Service requests and On-Call Support tasks on a case-by-case basis. Selected testing and commissioning requirements may be included in Statements of Work or Contract documents in order to ensure a satisfactory level of verification commensurate with the scope of the work.

The General Testing and Commissioning Plan scope shall include, but not be limited to the following activities:

- Contractual requirements for testing and commissioning.
- Responsibilities for the development of testing requirements within the contract specifications.
- Requirements that tests appear as part of a logical hierarchy for each technical division.
- Requirements for testing and commissioning schedule development, and integration with the overall project schedule.
- Verification that elements of each contract are integrated and perform as expected.
- Regression testing as required when upgrade, replacement, and improvement activities are conducted on systems.
- Criteria for a certification process for the turnover of a project to Operations

3.0 DEFINITIONS

Authority Having Jurisdiction (AHJ)	The governmental agency or sub-agency that regulates the construction process and enforces construction codes and regulations.
Building Management System (BMS)	A computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power, fire, and security systems.
Commissioning Authority (CA)	The individual performing qualified oversight of the development, planning, and evaluation of testing and commissioning work on behalf of Sound Transit. The requirements and responsibilities for the Commissioning Authority are dependent upon the project contract. The Commissioning Authority is a specialty consultant to Sound Transit (ST) or an ST team member.
Concept of Operation	A Concept of Operation describes the characteristics of a proposed system from the viewpoint of an individual who will use that system. In addition, it is used to communicate the quantitative and qualitative system characteristics to all stakeholders. The Concept of Operations shall be used as a guide when developing test procedures.
Design Consultant (Engineer of Record)	Shall refer to the design consultants or a Design-Builder responsible for developing the final design for a DECM project.
Inter-Facility System Interface Test	Tests of systems that require interaction with numerous facilities and/or remote monitoring and control by the Link Central Control (LCC) or, in the case of parking facilities, the Security Operations Center (SOC). Tests are performed to ensure that system-wide contract elements function properly. These tests include traction electrification, wayside equipment, train control, fire detection responses, emergency ventilation, communications systems, and building management systems. Considered Level 3 testing.
Intra-Facility System Interface Test	Tests of the controllability, functionality, and coordination of multiple systems provided within a facility. Tests to demonstrate that systems elements perform satisfactorily when connected to interfacing systems elements or subsystems. An example may include the control of HVAC through the BMS or Fire Alarm Control Panel. Considered Level 2 testing.

Pre-Revenue Operations	Tests conducted to simulate revenue service operations during normal and abnormal conditions, e.g. emergencies, and to verify proper training of operations staff. Considered Level 4 testing.
Resident Engineer (RE)	ST's delegated representative responsible for the administration of a specific construction contract, and serves as the primary point of contact for the construction Contractor.
System	An assembly of multiple components and/or items of equipment, including connecting hardware and wiring.
Systems Integration Test Program	The System Integration Test Program identifies the processes and procedures which are used to ensure a safe, efficient and successful integrated test program. This program document serves as the framework for the project specific System Integration Test Plans containing the project specific details, test plans, individual roles, and responsibilities.
System Test Manager	The individual performing qualified oversight and control of the System Integration Test Program for each Project.
Test	A test is a qualitative or quantitative activity using a procedure that determines one or more characteristics of a given product according to a specified procedure. The resulting written account of a test is the Test Report.
Test Demonstration	Contractor's performance of selected tests to demonstrate to ST's witness the acceptable performance of these tests.
Testing and Commissioning Specification	The 01 91 13 General Systems Testing and Commissioning Requirements specification is provided by Sound Transit and provides the administrative requirements for testing and commissioning. The nn 08 00 technical specifications are prepared by the Design Consultant or the Design-Builder, and provide the testing requirements for equipment and systems provided under the contract.

Test Report	A written and signed document approved by a qualified testing party that contains sufficient data and information to verify the actual functionality and performance of components, equipment and systems and the actual results of all required tests. Testing and commissioning test reports may be used by other ST staff to provide objective evidence of compliance with LEED requirements or objectives.
Test Types:	
Component Test	Test of the controllability, functionality, and calibration of individual instrumentation and control devices. This includes input and output hardware, relays and signal converters, and standalone instruments that directly indicate the condition of a variable. Considered Level 1 testing.
Factory Acceptance Test (FAT)	Test that evaluates the product during and after the assembly process by verifying that it is built and operating in accordance with design specifications. As the name suggests, this testing is performed at the factory. Considered Level 1 testing.
Equipment Test	Test of the controllability, functionality and capacity of individual assemblies or items of equipment, including items identified in equipment schedules. Considered Level 1 testing.
Installation Verification Test	Procedures to confirm material and equipment installation is in accordance with contract provisions and manufacture's requirements. Also includes verification of successful factory testing prior to delivery of devices to ST. Considered Level 1 testing.
Start-Up Test	A test to verify procedures to bring equipment or systems from a state of complete installation to powered operation. Considered Level 1 testing.
Static Test	A test of the integrity of installed piping, ductwork, or wiring. Considered Level 1 testing.
System Test	A test of the controllability, functionality and coordination of individual systems. A system's Concept of Operations shall serve as the foundation for identifying and developing all necessary System Tests. Considered Level 1 testing.
System Integration Test	A System Integration Test is a key activity of a project to validate that selected elements of the project function properly together as an integrated system.

Testing and Commissioning	The process for verifying and documenting that the system performs according to requirements set forth in contract specifications. From a terminology standpoint, tests may be conducted during a Commissioning program or a Systems Testing program. Commissioning Tests are generally associated with building systems, while Systems Tests are generally associated with Train Control, Traction Electrification, and Communications (See Table 2).
Testing and Commissioning Activity	Any one of the following activities: Development of contract test requirements, installation verification, static tests, start-up, component tests, equipment tests, system tests, intra-facility system interface tests, and inter-facility system-wide interface tests.
Testing and Commissioning Activity Procedure	Detailed, systematic instructions for performing commissioning activities that also includes the means and methods. The Contractor or Design-Builder develops testing and commissioning activity procedures.
Testing and Commissioning Report	The final report summarizing the testing and commissioning activities for the Contract.
Testing and Commissioning Manager	Contractor or Design-Builder representative responsible for the planning, coordination, and execution of the Contractor's or Design-Builder's testing and commissioning activities.
Testing and Commissioning Issue	Mechanism used to document a test outcome or anomaly that is considered an unsettled matter. All commissioning issues shall be resolved prior to Substantial Completion.
Testing and Commissioning Database (T/C DB)	The T/C DB is the repository for testing and commissioning information. The T/C DB will track test forms and procedures that have been generated, the relationships between the responsible engineering disciplines, status test conduct, and record test results. Filtered views/reports will be available from the database information. The reports will address critical test issues that may require immediate resolution and test issues that have been resolved during the identified reporting period. Access to the T/C DB is via a dedicated DECM SharePoint site. Refer to Section 7.0 for T/C DB details.
Testing and Commissioning Plan	Written plan of how the Contractor will accomplish the commissioning work. The plan describes how the Contractor will assign commissioning responsibilities, accountability, and

	authority. The plan also identifies the tools and materials required and includes a commissioning schedule.
Testing and Commissioning Witness	The CA, ST's Project Manager (PM), or the RE's designated witness, authorized to authenticate reported test data and to sign completed commissioning test data forms.

4.0 ROLES AND RESPONSIBILITIES

Table 1, Responsibility Matrix, identifies the roles and responsibilities for each participant in the testing and commissioning process.

Table 1 –Responsibility Matrix

Position/Organization	Responsibility
ST DECM Civil/Systems Integration Manager	• Coordinate and maintain continuous interaction with the DECM Corridor Design Managers, DECM design and construction management staff, design consultant project managers and discipline leads, specialty design consultants, and ST operations and maintenance personnel for testing and commissioning coordination and planning. • Review Designer Statements of Work and Design-Builder Project Requirements for completeness and adequacy. • Responsible for the overall testing and commissioning activity. • Supervises and continually evaluates the testing and commissioning process and makes modifications as required. • Approve, or delegate approval for testing and commissioning products and deliverables. • Oversee development of training courses in the testing and commissioning processes.
Testing and Commissioning Manager	• Shall be identified as a “Critical Team Member” or “Key Personnel” by the Design Consultant or Design-Builder and be an experienced mechanical or electrical engineer. • Specific duties and responsibilities shall be in accordance with Specification 01 91 13. • Define testing boundaries. • Responsible for the Testing and Commissioning Plan. • Responsible for the overall development and coordination of the Testing and Commissioning schedules. Coordinate with the Project Schedule. Develop look-ahead schedules. • For Design-Build, oversee the development of testing and commissioning specifications (nn 08 00 specifications). • Coordinate with Design-Build design managers, design discipline leads, task leads, subcontractors, vendors, and suppliers in developing testing procedures and forms. • Responsible for the Testing and Commissioning database. • Conduct regular coordination meetings. Maintain status of activity and provide minutes and reports. • Monitor and manage the Testing and Commissioning progress, evaluate the process, and make adjustments as necessary. • Complete and document results for Testing and Commissioning Levels 1-3. • Ensure support for Level 3 and Level 4 activities lead by others. • Track Testing and Commissioning Issues. • As opportunities permit, allow for informal training and familiarization opportunities for Sound Transit Operations, Facilities, and Transition to Operations staff.
System Test Manager	• Chairs the SIT Subcommittee. • Chairs the System Integration Tiger Team. • Develops the System Integration Test Program Plan. • Provides oversight and management of system integration processes. • Ensures efficient and accurate test planning, scheduling, execution, and reporting processes are in place.
Systems Integration Test Manager	• Shall be identified as a “Critical Team Member” or “Key Personnel” by the Consultant and be an experienced mechanical or electrical engineer. • Specific duties and responsibilities shall be in accordance with Specification 01 91 13. • Define testing boundaries. • Responsible for managing all Systems Integrated Testing that involves Systems elements such as Communications, Supervisory Control and Data Acquisition (SCADA), Signaling, Traction Electrification, and Passenger Vehicles.

Position/Organization	Responsibility
	• Responsible for the overall System Integrated Test effort, including coordinating access to test locations, arranging support personnel from other Contractor functional areas and from areas not under the Contractor's authority, coordinating test efforts with other functional area construction and test activity, and providing overall monitoring of the System Integrated Test Performance. • The System Integration Test Manager shall: o Manage the development of the Systems Integration Testing procedures. o Report to the Testing and Commissioning Manager and provide support with the timely scheduling and execution of all System Integrated Tests as identified in the Testing and Commissioning Plan. o Plan, schedule and execute each System Integration Test. o Ensure that all pre-requisite tests have been performed prior to the performance of each Systems Integration Test.
Commissioning Authority (ST DECM Consultant)	• The Commissioning Authority is a specialty consultant to Sound Transit, responsible for overseeing the Testing and Commissioning process on behalf of Sound Transit. • The duties of the Commissioning Authority include, but are not limited to, the following: o Review and recommend Acceptance of the Contractor's Testing and Commissioning Manager candidate qualifications. o Review and recommend acceptance of the Contractor's Testing and Commissioning forms and procedures. o Observe and issue site activity reports on the quality of work in progress pertaining to material, equipment, and systems included in the scope of the Testing and Commissioning work. Track issues for acceptable resolution. o Participate in Testing and Commissioning meetings. o Witness, verify, and recommend Acceptance of satisfactory completion of Commissioning activities. Sound Transit may appoint other staff or consultants to witness some Testing and Commissioning activities in lieu of the Commissioning Authority. o Track documentation and resolution of Testing and Commissioning issues. Facilitate and lead Consultant, Design-Builder, and Contractor efforts to resolve testing issues. o When Testing and Commissioning work has been completed, recommend approval of the Final Commissioning Report to Sound Transit. o The Commissioning Authority is expected to communicate as follows: ▪ The Commissioning Authority shall formally communicate with the Contractor or Design-Builder via accepted Contract requirements. It is expected, however, that the Commissioning Authority shall communicate and coordinate informally directly with the Contractor and the Testing and Commissioning Manager. As Sound Transit's Commissioning consultant, it is expected that the Commissioning Authority shall communicate directly with the Resident Engineer and consultants, as may be appropriate. ▪ The Commissioning Authority shall keep Sound Transit, Resident Engineer, and Contractor advised regarding the status of Commissioning work, progress, problems that may develop, and solutions to problems, performance, and schedules.
ST DECM Corridor Design Managers (CDM)	• Ensure testing and commissioning provisions and requirements are incorporated into Consultant Statements of Work, design-build project requirements, standard specifications, guidance drawings, and prescriptive drawings and specifications. • Monitor DECM staff and design consultants to ensure that testing and commissioning is accomplished in accordance with this plan and is consistent with Project budgets and schedules.
ST DECM Systems Integration Team (Manager and Leads)	• Support project CDMs during the design phase and the project Construction Managers during construction phase. • Responsible for oversite of the Testing and Commissioning process. • Responsible for oversight of the Testing and Commissioning Database. • Assist in defining testing boundaries. • Maintain the General Testing and Commissioning Plan. • Review submittals and Requests For Information as needed in order to gain familiarity with devices, equipment, and systems to be tested. • Monitor the progress of the design and review design documentation to identify testing issues and coordinate with designers and Link staff for resolution of these issues. Ensure test requirements are well defined, well understood, and well planned for. • Oversee the testing and witness tests as required.

Position/Organization	Responsibility
	• Provide technical and administrative support as required to ensure the success of the Testing and Commissioning program. • Ensure that design changes are evaluated for test impacts.
ST DECM Engineering Staff	• Provide subject matter expertise as necessary to support testing goals, objectives, requirements, and planning. • Support the development of the Testing and Commissioning Plan products, and assist in incorporating testing requirements into designs. • Support the review of testing issues, identify those requiring resolution, and support resolution with the Civil/Systems Integration Manager. • Support the monitoring of existing ST infrastructure for testing impacts. • Witness tests as required.
System Test Engineer	• Serve as the lead engineer responsible for performance of the system testing and integrated tests for Communications, Supervisory Control and Data Acquisition (SCADA), Fare Collection, Signaling, and Traction Electrification. • Provide support to the System Integration Test Manager and the Testing and Commissioning Manager as required. • Lead the development of the Systems test procedures and test reports. • Be responsible for the execution of System testing. • Support the Testing and Commissioning Manager and the Systems Integrated Test Manager in development of the Testing and Commissioning Program Plan and Testing and Commissioning Master Schedule.
Design Consultant or Design-Builder Design Leads, and Engineering Staff	• Support the development of testing and commissioning plans and products. • Monitor testing and commissioning progress and ensure test forms allow verification of technical requirements. • Support the development, review, analysis, and disposition of test issues. • Ensure that design changes are evaluated for testing and commissioning impacts and communicate design changes to all affected organizations.
Contractor or Design-Builder	• Ensure that all tests are planned and executed in a manner such that no adverse impacts on Sound Transit assets or operations and those of adjacent Contractors result. • Perform testing and commissioning in a safe and effective manner. • Be responsible for the progressive levels of testing and final acceptance into operational service of all new or modified equipment installed under the contract. • Be responsible for testing the equipment installed under the contract, as well as equipment installed under an adjacent contract that has been modified by this contract, in order to demonstrate that all equipment will operate as specified and can be monitored or controlled remotely by Sound Transit's Link Control Center, back-up Link Control Center, or Security Control Center. • Be responsible for coordinating and providing all procedures, equipment, instruments, and personnel required to complete the required testing and commissioning other than equipment, instruments, and personnel provided by Sound Transit or their designee.
ST DECM Construction Management	• Ensure the construction management scope and budget includes the Commissioning Authority and supporting staff necessary to provide the oversight required by this plan.
Sound Transit Operations/Facilities Managers and Staff	• Support the development of Testing and Commissioning Plan products (such as forms and procedures) and assist in incorporating testing requirements into designs. • Witness testing and commissioning as needed to become familiar with devices, equipment, and systems. This witnessing of tests shall be in addition to any Division 01 specification regarding Training or O&M Manuals. • Monitor existing ST infrastructure for testing impacts. • Provide support for Level 3 and Level 4 as required to ensure Sound Transit resource obligations are met.

5.0 APPROACH

5.1. PRE-DESIGN, DESIGN AND PRE-CONSTRUCTION

Testing and commissioning activity shall begin early in each DECM contract. Activity during pre-design allows development of Project Requirements and inclusion of prescriptive drawings and specifications for testing and commissioning. Activity during design allows the Commissioning Authority to work with the final designer, the Systems Integration Team (SIT), and ST Operations to ensure the contract testing and commissioning requirements are clear, concise, and accurate. Planning for integration of testing and commissioning into the design development process helps to ensure compliance with criteria, codes, standards, and guidance/prescriptive drawings. Early understanding and compliance will avoid problems and additional work later during and following construction. It is imperative that contract documents clearly identify testing and commissioning requirements and expectations. This will ensure that the Contractors properly estimate and plan testing and commissioning efforts.

Specification 01 91 13, General Systems Testing and Commissioning Requirements, is a comprehensive specification that defines the administrative requirements of testing and commissioning.

The technical specifications are prepared by the Design Consultant or the Design-Builder and shall provide the functional performance and physical requirements for equipment and systems provided under the contract.

The nn 08 00 technical specifications are prepared by the Design Consultant or the Design-Builder, and shall provide the testing requirements for equipment and systems provided under the contract.

See Figure 1 for responsibilities and the general timeline for pre-design, design, and pre-construction activity.

5.2. PLANNING DURING EARLY CONSTRUCTION

Sound Transit assigns a Commissioning Authority. This assignment occurs prior to the selection of the Testing and Commissioning Manager.

The Contractor assigns a Testing and Commissioning Manager and develops the Testing and Commissioning plan. This plan shall be coordinated, accepted, and released as early as possible in the construction phase.

The Contractor and the Testing and Commissioning Manager utilize the construction project schedules to develop a Testing and Commissioning schedule. Based on requirements in the technical and commissioning or testing specifications, the Testing and Commissioning Manager reviews submittals, operation and maintenance data, and Requests for Information and monitors contract changes in order to develop detailed tests for each system and piece of equipment involved in the test program. Using the commissioning tests, contract drawings, and contract specifications, the CA and ST review and endorse the Contractor's Testing and Commissioning plan and Testing and Commissioning schedule. The Testing and Commissioning schedule shall be an integral part of, and integrated with, the master construction schedule.

The Testing and Commissioning Database is populated with all tests and is used to track progress of test activities. The Testing and Commissioning Manager shall populate, maintain, and utilize the information stored in the Testing and Commissioning Database with oversight from the CA and ST.

Each contract must manage the integral process of timing test activities and the mutual support of these activities with interfacing contracts where necessary.

5.3. ACTIVITY DURING INSTALLATION AND TESTING

The Testing and Commissioning Manager coordinates all testing and ensures that all test reports and checklists are completed and all deficiencies resolved.

The Commissioning Authority makes site visits to observe construction, notes details that might affect equipment and system performance or operation, and coordinates with the various Contractors, through the RE, to witness the tests and demonstrations. The Commissioning Authority also documents all observed commissioning issues, and ensures the information is entered by the Testing and Commissioning Manager into the Testing and Commissioning Database.

The Commissioning Authority also verifies corrective measures and ensures the presence of completed operation and maintenance manuals. Various Contractors typically carry out the actual performance testing. The Commissioning Authority oversees this process and actively participates.

Certain tests may be selected by the RE to fulfill the requirements of the Specification Conformance Checklists as required by the Agency Safety and Security Certification Plan. These tests are considered safety critical or help verify safety related elements and will be used to validate and obtain the Safety Certification for the contract. The Sound Transit System Safety & Assurance Specialist, who may also elect to observe certain safety critical tests, may review test procedures, test results, and safety related testing.

As part of the Testing and Commissioning plan process, the Commissioning Authority and ST staff will extend invitations to Operations personnel to witness tests for the purposes of training. Training for Operations staff generally occurs in parallel with intra-facility system testing and/or before building occupancy. To provide an opportunity for hands-on learning, instructors may carry out training prior to or during the testing. Furthermore, the Commissioning Authority is involved in supporting the coordination of training for Operations staff.

5.4. COMPLETION OF TESTING AND COMMISSIONING

After completion of testing, including the Systems Integration Testing, the Contractor or Design-Builder finishes the Testing and Commissioning Report , including all supporting documentation, and submits it to ST as a contract submittal. All commissioning issue reports shall be resolved prior to substantial completion.

5.5. POST ACCEPTANCE

During pre-revenue operations, ST Operations staff ensure the facility and Light Rail Vehicle-related systems function properly, allow maintainers and vehicle operators to train and gain experience with the

systems and practice adapting to changing occupancy or use. The CA may be involved in reviewing performance, and recommending improvements. The Contractor or Design-Builder shall be required to conduct any incomplete seasonal performance tests and add results to the commissioning report.

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Figure 1 – Testing and Commissioning Phases and Overview

NTP | EARLY FD PHASE | LATE FD PHASE | IFC | SUBSTANTIAL COMPLETION (End of L3) | ACCEPTANCE AND REVENUE SERVICE START

Responsibility	Pre-Design and Design – Testing and Cx Preparation	Early Construction – Testing and Cx Planning	Construction – Testing & Commissioning Execution
ST DECM and Operations	• ST 01 91 13 - Testing and Commissioning Requirements • Project Requirements available (For D-B) • Commissioning and Testing DB provided • Attend status/coordination meetings	• ST 01 91 13 - Testing and Commissioning Requirements • Commissioning and Testing DB provided • Attend status/coordination meetings • Review procedures and forms	• Commissioning and Testing Database used for status and progress • Attend status/coordination meetings

Design Builder or Contractor	• Design Manager (For D-B)
	  • Develop technical performance requirements
	  • Develop xx 08 00 testing specifications
	  • Hold status/coordination meetings
		• Test and Commissioning Manager
		  • Testing and Commissioning Plan
		  • Testing procedures and forms
		  • Testing and Commissioning Schedule
		  • Populate and maintain Testing and Commissioning DB
		  • Hold status/coordination meetings
		• Systems Integration Test Manager
		  • Systems Integration Test Procedures
		• System Test Engineer
		  • Lead engineer for developing system tests
			• Testing and Commissioning Manager
			  • Commissioning and Testing Database used for status and progress
			  • Implement changes and incorporate into design interfaces and testing and commissioning requirements
			  • Facilitate status/coordination meetings
			• Systems Integration Test Manager
			  • Develop Systems Integration Test Procedures
			  • Manage systems integration testing
			• System Test Engineer
			  • Performance of system tests

Design Consultant	• Design Manager
	  • Develop technical performance requirements
	  • Develop xx 08 00 testing specifications
	  • Hold status/coordination meetings
		• Consulted as needed	• Consulted as needed

Design Build Project Manager (DBPM) or Construction Management Consultant (CMC)	• Commissioning Authority
	  • Oversee Testing and Cx planning
	  • Oversee development of xx 08 00 specifications
	  • Attend status/coordination meetings
		• Commissioning Authority
		  • Approve submittals
		  • Attend status/coordination meetings
		  • Provide oversight of testing and commissioning
			• Commissioning Authority
			  • Approve submittals
			  • Attend status/coordination meetings
			  • Provide oversight of testing and commissioning

Responsibility	Level 1 Testing & Commissioning	Level 2 Testing & Commissioning	Level 3 Testing & Commissioning	Level 4 Pre-Revenue Service
ST DECM and Facilities	• Consulted as needed/witness tests as needed	• Consulted as needed/witness tests as needed	• Consulted as needed/witness tests as needed • Systems Integration Test Plan (SITP) • Rail Activation Committee • Rail Activation Manager	• Consulted as needed/witness tests as needed • Rail Activation Committee • Rail Activation Manager
ST Operations	• Consulted as needed/witness tests as needed	• Consulted as needed/witness tests as needed	• Operators/maintainers as needed	• Operators/Maintainers as needed
Design-Builder (Testing and Commissioning Manager/Systems Integration Test Manager/Systems Test Lead)	• Factory testing • Installation verification • Static testing • Start-up tests • Component tests • Equipment and system tests • Test reports/status/progress meetings	• Intra-station testing • Multiple system testing • Test reports/status/progress meetings	• Inter-station testing • Systems integration procedures and testing • Coordinate support from ST Operations • Test reports/status/progress • Safety Certification • Cut-over planning and execution	• Monitor System performance • On site support • Troubleshoot/Repair • AHJ training/briefings
DBPM (Commissioning Authority)	• Witness testing • Approve test results	• Witness testing • Approve test results	• Witness Testing • Approve test results • Recommendation for Substantial Completion	• Witness Pre-revenue • Recommendation for Acceptance

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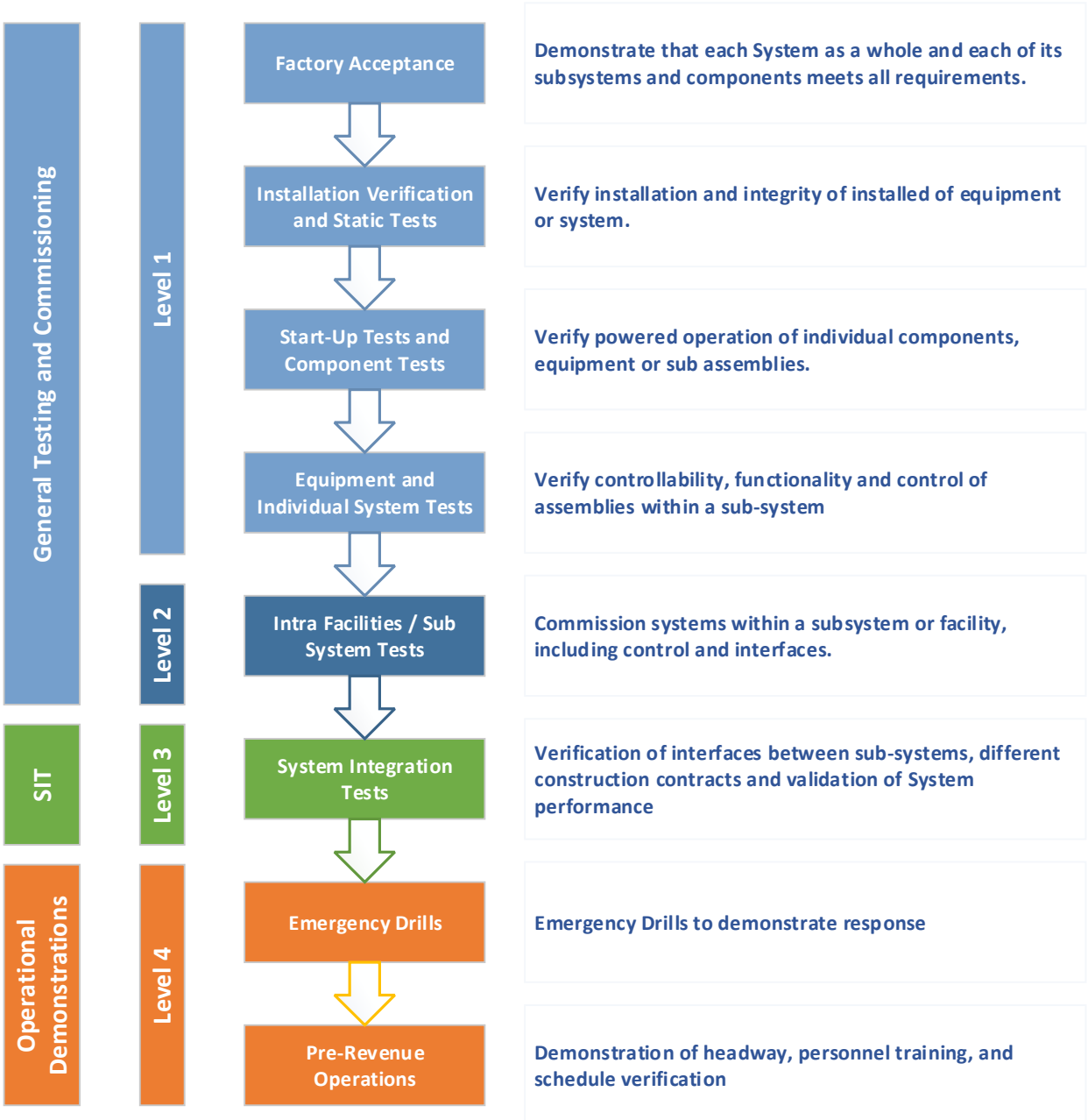
6.0 PROCEDURE

Each contract conducts testing using a bottom-up approach. This approach details individual base elements that link together forming larger subsystems that link, sometimes in many levels, into a complete top-level system. This strategy resembles a seed model, whereby the beginnings are small, but eventually grow in complexity and completeness. See Figure 2 for Testing and Commissioning Levels.

Figure 2 – Testing and Commissioning Levels



Depending on the scope of the project, ST shall determine if testing and commissioning level definitions are necessary. For example, an all-inclusive small-scale Design-Build or small works project with limited or no contract interfaces may elect not to use the testing and commissioning level approach. However, all parties involved with testing and commissioning shall adhere to the attributes and requirements for activities defined herein.

The purpose of developing levels of commissioning is to:

- Define the testing and commissioning development responsibilities for contract documents where numerous consultants and a Commissioning Authority are working on a single project.
- Support the development of testing and commissioning planning for multiple interfacing contracts.
- Identify the order of equipment and systems testing.

Table 2 is a list of testing and commissioning categories. Each category has testing and commissioning tests, which are assigned levels. This table is not intended to be a complete list or to apply to all projects.

Table 2: List of Testing and Commissioning Categories

Testing and Commissioning Categories				
Intrusion Detection	Access Control	Building Management Systems	Crew & Break Rooms	Security Rooms & Facilities
Vertical Transportation	Lighting and Lighting Controls	Fire Detection and Suppression	Roofing Systems	Exterior Improvements
Electrical	Water Penetration Barriers *	Fire Alarm Control	Irrigation	Personal Safety Equipment
HVAC	Uninterruptible Power Supply	Emergency Ventilation	Building Envelope	Thermal Performance
Utilities	Air & Vapor Barriers	Condensation Controls	Acoustical Treatments	Openings and Doors
Plumbing	CCTV	Emergency Telephones	Train Control	Overhead Contact System
Vibration Monitoring	Radio Systems	EMI Monitoring	SCADA/ Networks	Variable Messaging/ Passenger Information
Traction Power	Public Address	Emergency Communications	Track Systems	Traffic Control Systems

* Includes wall systems, glazing, entrances, soffits, and projections.

6.1. LEVEL 1 TESTING AND COMMISSIONING

Activities:

Level 1 testing and commissioning activities include factory acceptance testing, installation verification, static tests, start-up tests, component tests, equipment tests, and system tests.

Testing and Commissioning Attributes:

1. Documentation (test procedures, test forms, and test reports) and oversight to ensure the functional and physical performance requirements of the component, subsystem, or system meets contract specification requirements and is in accordance with approved submittals.
2. Factory Acceptance Testing at a manufacturer, supplier, or vendor site to demonstrate that the design, assembly, and programming of the test article meets the contract.
3. Installation verification of equipment and devices with respect to physical condition upon delivery, and compliance with installation plans and instructions.
4. Installation verification of equipment and devices to ensure performance in accordance with contract drawings, shop drawings, work plans, approved submittals, and approved changes.
5. Completion of static testing requirements. Examples of static testing include, but are not limited to, hydrostatic tests of piping, integrity (air and fluid leakage) tests, continuity testing of electrical wiring, and insulation testing (megohmmeter testing) of wiring.
6. Verification that devices are controllable, calibrated, and responsive. Includes start-up tests, component tests, equipment tests of individual assemblies, and system tests of individual systems. Examples of these tests include manufacturer's start-up requirements, current draw, water flow, and airflow.
7. Cable pulling results.

6.2. LEVEL 2 INTRA-FACILITY SYSTEM TESTING

Activities:

Level 2 testing and commissioning activities include system testing within a specific facility, such as a station or a portion of a tunnel. Activities to verify the controllability, functionality, and coordination of multiple systems within a facility.

Testing and Commissioning Attributes:

1. Verification of the system's ability to act in concert, while performing specified functions.
2. Examples include Heating, Ventilation, and Air Conditioning (HVAC) system balancing, fire alarm system testing at the Fire Alarm Control Panel (FACP), BMS controls and

alarms, sump pump operation at indicated sump levels, Uninterruptable Power Supply (UPS) functions, elevator/escalator remote commands from BMS or FACP, public address acoustics, security system and Emergency Ventilation System (EVS) operation.

3. Proof-of-design testing, such as HVAC and EVS testing of ability to control conditions under a full range of operating loads and to start within the specified times, UPS capacity relative to actual loads, and sump pump pressure and flow tests.

6.3. LEVEL 3 SYSTEM INTEGRATION TESTING

Activities:

Level 3 testing and commissioning activities include system testing between facilities, or between portions of infrastructure with any head-end or central control servers and systems.

Testing and Commissioning Attributes:

1. Remote monitoring and control testing.
2. Requires communication/connectivity between facilities and the control system to accomplish the testing.
3. Examples include EVS final mode testing, remote control and monitoring of the facility equipment such as fire alarm, HVAC, pumps, and traction power functionality.
4. Execution of the series of integration tests that are part of the System Integration Testing Program.

6.4. LEVEL 4 PRE-REVENUE OPERATIONS AND OPERATOR TRAINING

Activities:

Level 4 testing and commissioning activities consist of pre-revenue operations.

Testing and Commissioning Attributes:

1. Includes operator training.
2. Includes Contractor support for emergency drills.
3. Includes verification of training and instruction for ST Facilities and ST Operations.
4. Re-testing performed by ST and supported by the Contractors of issues and anomalies encountered during pre-revenue operations.

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7.0 TESTING AND COMMISSIONING DATABASE

The Testing and Commissioning Database is an Owner-furnished SharePoint-based site used to collect, manage, collate, and report on testing and commissioning information, progress, and status. There are four primary work areas within the database:

1. Testing and commissioning activity procedures and data forms.
2. The matrix of testing and commissioning activities.
3. Testing and commissioning reports.
4. An issues log.

The database will track planned tests, test form development, test conduct, and test results. It will also provide visibility of the relationships between affected engineering and construction disciplines, illuminating issues that are critical to the planning and test execution process. Reports detailing status shall be developed from database information and made available to DECM and Consultant staff. Reports addressing issues requiring immediate resolution are also generated. The database may be accessed via SharePoint.

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8.0 REFERENCES

1. City of Seattle Department of Planning and Development, Commissioning for Nonresidential Mechanical and Lighting Systems (www.ci.seattle.wa.us/dclu/Publications/cam/ cam419.pdf)
2. U.S. General Services Administration, The Building Commissioning Guide (www.gsa.gov/Portal/gsa/ep/channelView.do?pageTypeId=8195&channelPage=%2Fep%2Fchannel%2FgsaOverview.jsp&channelId=-15374)
3. Building Commissioning Association (http://www.bcxa.org/)
4. Washington State Department of General Administration, Building Commissioning (www.ga.wa.gov/Eas/bcx/index.html)
5. Sound Transit System Integration Test Program