System Integration Test Program

Revision 1 – July 2022

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Document Revisions

Revision	Date	Description of changes
0	June 2018	Initial Issue. Approved LCR-03973-00, Dated 6/26/18.
1	June 2022	Various formatting and spelling corrections Section 3.1: Added paragraph regarding SITS identification of unique design/safety issues to be addressed as part of the project Section 4.1: Added paragraphs and table identifying tests which may not be defined in contract documents and how to define them Section 4.1.2: Section Added Approved CR-00388-00; Dated July 8, 2022

Executive Summary

Sound Transit plans, builds, and operates regional transit systems and services to improve mobility for Central Puget Sound. Over the next 25 years, Sound Transit is expanding the regional light rail system from 22 miles to 116 miles along with new services and routes to the Sounder Commuter Rail and Bus Rapid Transit.

Successful start-up of these projects requires that all activities necessary for initiation of revenue operations be well managed from design and construction to testing and certification across multiple contracts and system boundaries.

System Integration Testing is a key phase of a project to validate that all elements of the project function properly together as an integrated system. Systems Integration Testing verifies the system against design requirements, safety requirements and federal and state regulation as well as providing a validation of the system as a whole.

This System Integration Test Program identifies the processes and procedures, which shall be 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. Safety during testing and of the ultimate operations of the system for both the users and maintainers are of paramount importance and is a focus throughout this document.

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Acronym List

DCM	Design Criteria Manual
DECM	Design Engineering and Construction Management
EAG	Executive Activation Group
EIC	Employee in Charge
KCM	King County Metro
LCC	Link Control Center
LRV	Light Rail Vehicle
OMF	Operations and Maintenance Facility
PPE	Personal Protective Equipment
PMP	Project Management Plan
PSO	Portfolio Service Office
QMSP	Quality Management Safety Plan
RAC	Rail Activation Committee
RAM	Rail Activation Manager
RE	Resident Engineer
ROW	Right-of-Way
SIT	System Integration Testing
SITM	System Integration Test Manager
SITPP	System Integration Test Project Plan
SITS	System Integration Testing Subcommittee
SOP	Standard Operating Procedures
SQA	Safety & Quality Assurance
SSCP	Safety & Security Certification Plan
SSMP	Safety & Security Management Plan
ST	Sound Transit
TPSS	Traction Power Sub Station

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1.0 Introduction

Sound Transit plans, builds and operates regional transit systems and services to improve mobility for Central Puget Sound. Over the next 25 years, Sound Transit is expanding the Seattle region light rail system from 22 miles to 116 miles in length to serve over 600,000 riders per day. In addition, Sound Transit is adding capacity and new stations to the Sounder Commuter Rail Service and adding Bus Rapid Transit routes. The Future service map is illustrated in Figure 1.

Successful start-up of these projects requires that all activities necessary for initiation of revenue operations be well managed from design and construction to testing and certification across multiple contracts and system boundaries.

Safety during testing and the operation of the system for both users and maintainers are of paramount importance and shall be a focus of all requirements listed throughout this document.

1.1 Purpose of the System Integration Test Program

System Integration Testing (SIT) is a key phase of a project to validate system function, operation and performance. SIT verifies the system against design requirements, safety requirements and federal and state regulations as well as providing a validation of the system as a whole.

The purpose of this System Integration Test Program is to provide a framework of processes to govern the verification of the project system. This includes test identification, planning, execution, reporting and issue management.

The SIT Program identifies the roles and responsibilities of Sound Transit, the Construction Contractor(s) and System Operators to successfully complete SIT for a project.

Each major project will be required to have its own Systems Integration Test Project Plan (SITPP). The project specific plan will serve to identify individual roles and responsibilities across organizations. Each SITPP will be agreed by DECM, Operations, SQA and the Rail Activation Manager. It will also reference the specific test procedures and other project specific requirements.

Figure 2 illustrates the document hierarchy of the System Integration Test Program (this document) and the project specific System Integration Testing Project Plans.

Figure 1 - Sound Transit Future Service Map May 2018

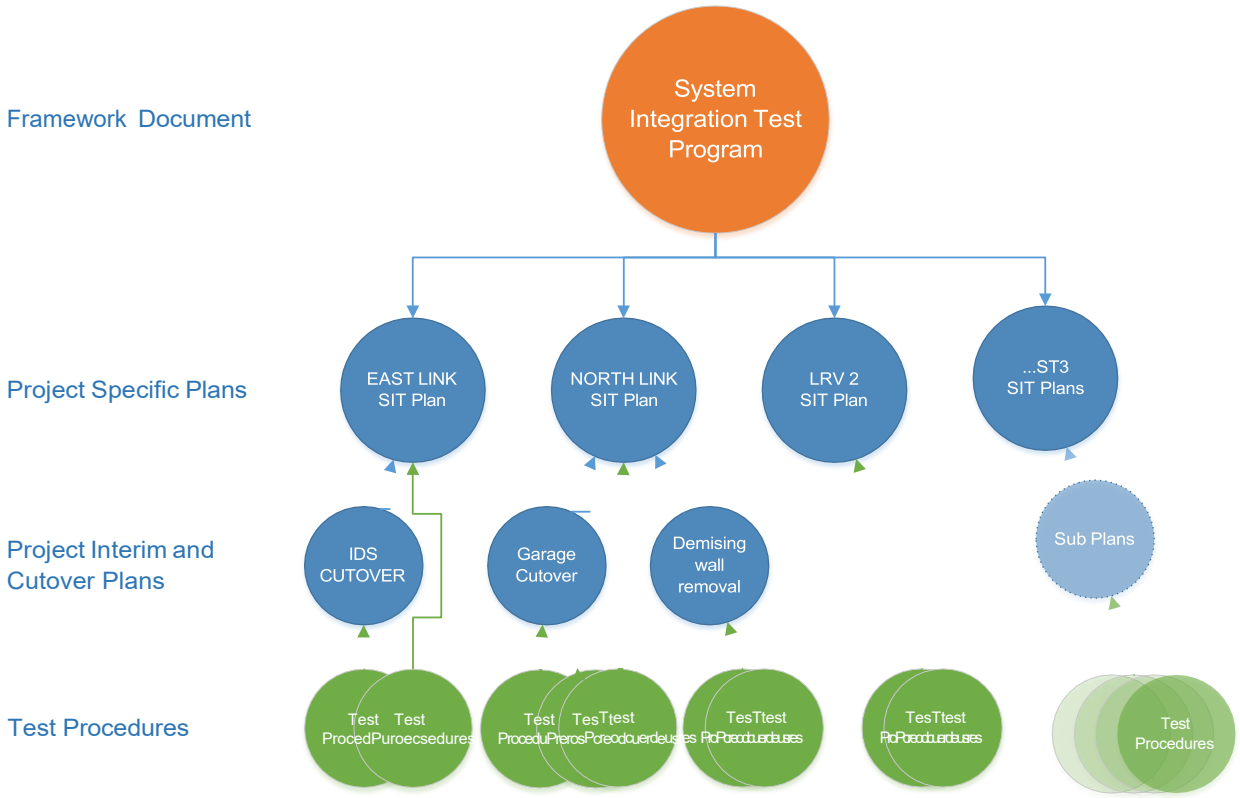

Figure 2 - Relationship of System Integration Test Program and Plans for Link Light Rail projects

1.2 Objectives

The objective of this document is to provide a framework for achieving SIT objectives by:

- Identifying the test program organization and defining roles and responsibilities of the participants
- Including the SIT sub-committee and TIGER team
- Defining the process for test identification
- Defining the process for managing test plan activities
- Including managing test scheduling, resourcing and daily test activities
- Defining the process for the recording, reporting, resolution and escalation of test issues
- Defining the administrative requirements of the plan

- Including accurate and auditable test planning and reporting documentation

- Describing the communication plan for the test team and the rest of the organization

- Describing the interaction with other Sound Transit processes such as Safety Certification and Rail Activation

- Providing a framework for a consistent and efficient approach across projects

- Outlining the process for sub-projects, interim openings and cutover plans

1.3 Reference Documents

The SIT program draws on other key agency and project documents, which define system characteristics, operation, safety and security requirements and testing. Many of these documents will be used at a project level to develop each project specific SIT plan.

1. Project Management Plans (PMP)
2. Project Rail Activation Plan
3. Master Project Schedules
4. Rail Fleet Management Plan, Revision 9
5. Bus Fleet Management Plan, Revision 7
6. Safety and Security Management Plan (SSMP)
7. Agency Safety and Security Certification Plan (SSCP)
8. Agency System Safety Program Plan (SSPP)
9. Quality Management System Plan (QMSP)
10. Transition to Operations Procedure – OPS PRO 17
11. Project specific Transition to Operations plans
12. General Commissioning Plan
13. Emergency Drills
14. Pre-Revenue Operations and Start-Up Plan
15. Track Access Procedure, (E.g. Link SOP 6.15)
16. Lockout/Tagout Procedure, (E.g. Link SMP 27.5
17. Standard Operating Procedures
18. Construction Manual
19. Test Plans developed by contractors
20. Contract specifications for the procurement, installation or construction
21. Interface Coordination and Integration Plan
22. Design Criteria Manual (DCM)

2.0 Test Program Structure

The main objective of System Integration Testing is to verify the project provides a safe service and is ready for revenue operations. This is achieved through the management of agency-run-tests, oversight of contractor-managed tests and ensuring all verification tests are successfully completed as planned.

2.1 Facility and System Commissioning

The Systems Engineering 'V' diagram illustrated in Figure 3 is an accepted industry standard for illustrating systems engineering through a product lifecycle from requirements through to user acceptance. In this context, this diagram represents the hierarchy of verification and validation through a project from detailed component verification through to user acceptance and performance validation. Overlaid on the 'V' are the four levels of commissioning.

The hierarchy of verification and validation testing is defined by the Sound Transit General Commissioning Plan and illustrated in Figure 4. Systems Integration Tests are performed following Level 1 and 2 commissioning tests and are known as Level 3 tests.

2.2 System Integration Testing

In the context of this document and the validation of a new project, System Integration Testing (SIT) is to ensure that all elements of the project function properly together as an integrated system.

System integration tests typically follow facility and system commissioning and acceptance testing; performance is the responsibility of Sound Transit to define. Whereas acceptance tests are required to be performed by a contractor on the facility, equipment or system delivered under a specific construction contract, SIT typically involves the facilities, equipment and/or systems delivered by two or more contracts or tying new systems into existing systems in revenue service.

This testing is complex and requires careful planning, coordination, communication and management between all stakeholders. The objective of Systems Integration Testing is to ensure:

- Pre-requisites for SIT are completed such that all elements of each sub-system are successfully tested in isolation

- All system elements function effectively together

- All project elements are interfaced effectively and comply with the established Safety and Security requirements

Level 4 is Pre-Revenue operations and Emergency Drills which are covered in separate agency and project documents.

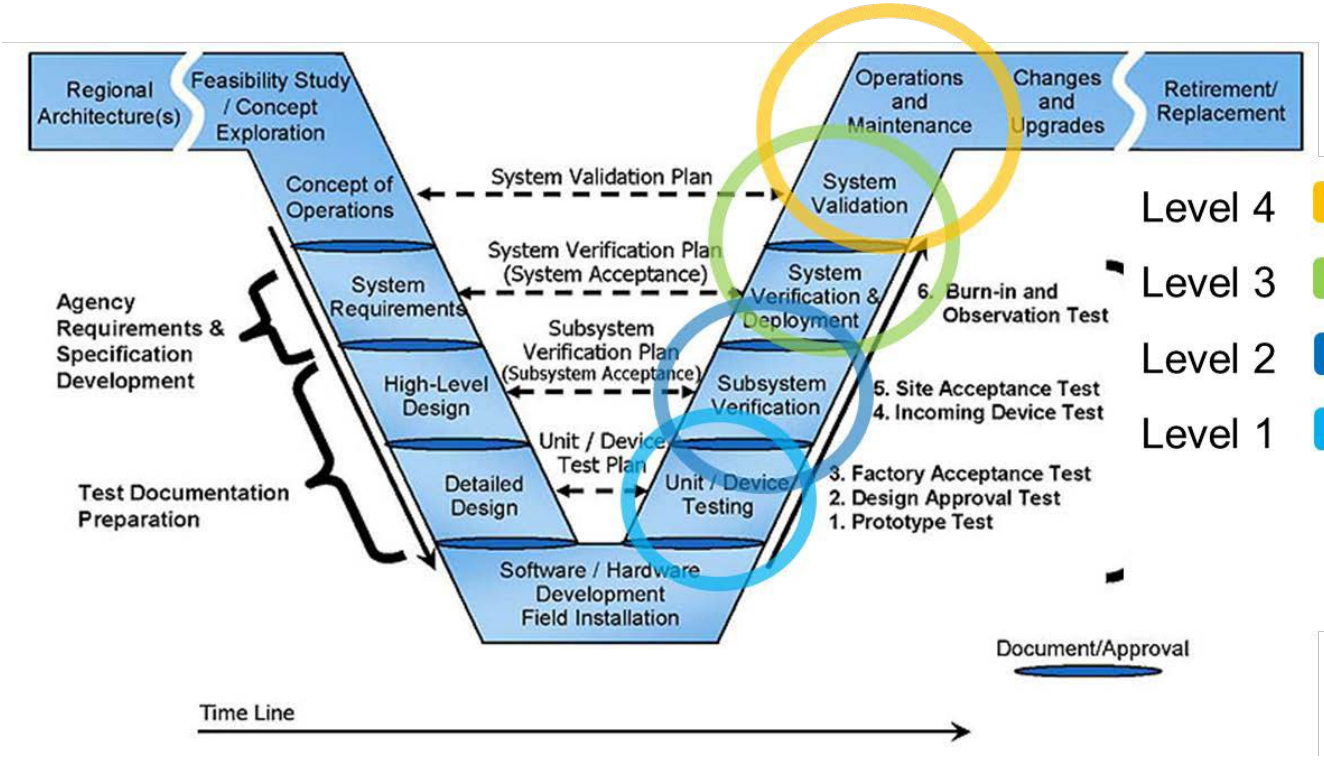

Figure 3 - Systems Verification and Validation process. Source US Department of Transportation.

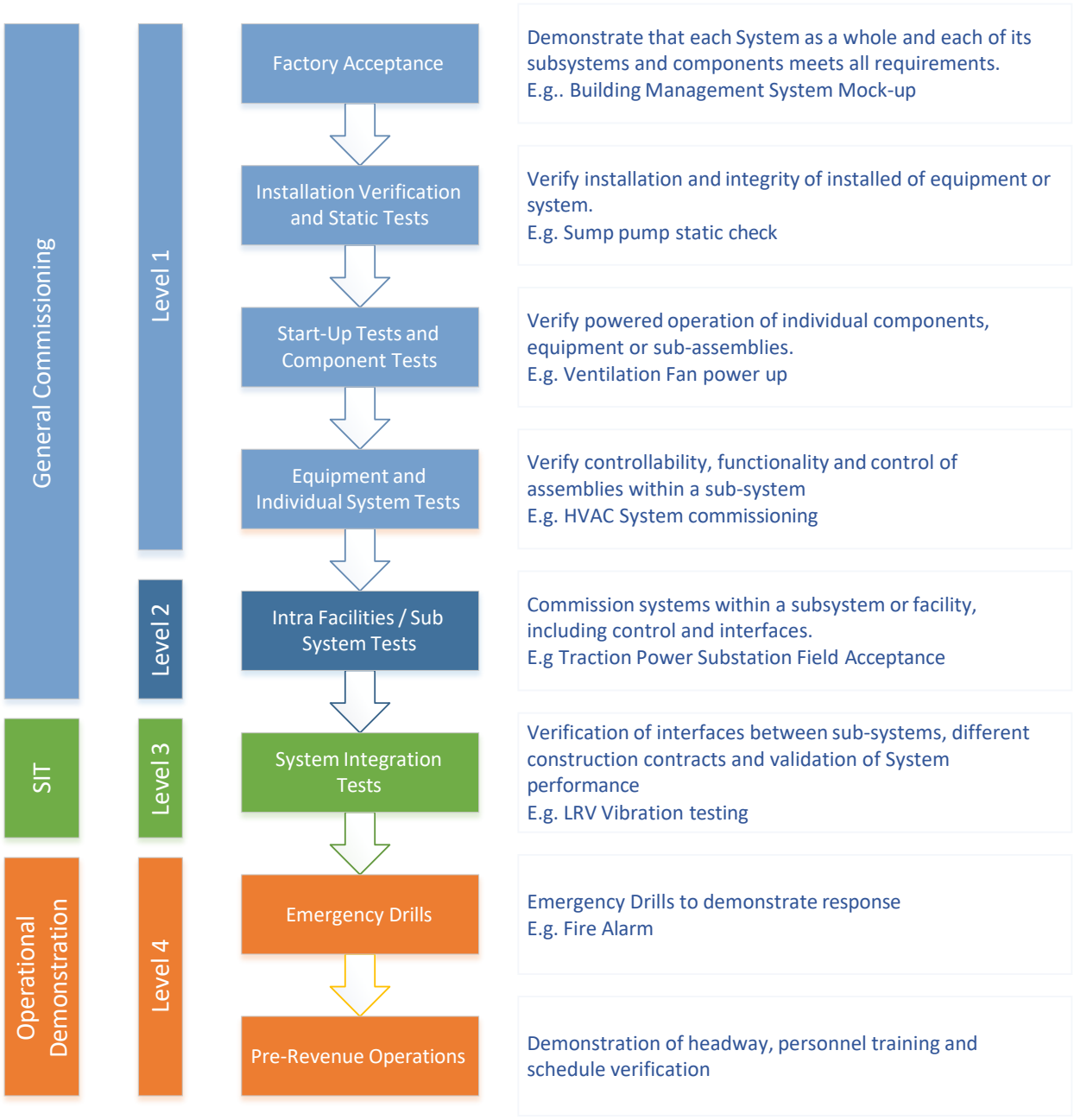

Figure 4 - Hierarchy of Testing and Commissioning for a Sound Transit Project

2.3 System Integration Testing Project Plans (SITPP)

The purpose of the SIT program is to outline the framework for planning; managing, executing and reporting SIT for a project. Each project from a Link light rail extension to a Sounder signal upgrade will differ in size and scope.

Each major project shall have a Systems Integration Testing Project Plan (SITPP) following the process and framework laid out in this document. The Systems Test Manager is responsible for developing each SITPP with assistance from the Project Director, SIT Co-Coordinator, Resident Engineer, Construction Manager, Contractor and Test Directors. The relevant Project Director shall approve the SITPP.

The SITPP will contain details on:

- Program organization including roles and responsibilities
- Project specific test requirements
- Project SIT schedule
- Required SIT procedures – ST owned and Contractor owned. Procedures will be referenced and not contained in the SITPP.
- Issue reporting, tracking and management
- SIT Sharepoint database

2.4 Sub-projects, Cut-over, facility openings

Interim project milestones such as project cutovers, single-tracking and early opening of facilities are to be detailed in the SITPP. Testing and reporting may be in advance of the SITPP depending on the project schedule. This testing shall be tracked and stored in the SIT Sharepoint database for review and audit later in each project. Typically a cutover plan will be detailed in the contractor's work plan and will delineate the changing of ownership of the right of way for a staged opening of a project. The contractor's work plan shall include the SIT, interim safety certification requirements and be reviewed by the SITS.

The process is outlined as follows:

1. Identify SIT requirement for sub-project, cutover or early opening

2. Engage stakeholders and prepare an interim SITPP to detail the cutover/opening/sub-project plan, safety certification items and reporting requirements.

3. Organize SIT subcommittee and co-ordination meetings as appropriate including all relevant stakeholders

4. Update cutover interim SITPP based on test reporting

5. Update safety certification documentation with appropriate test certificates and SIT completion certificate.

6. Incorporate interim SITPP into project SITPP as appropriate.

Tracking of test issues shall follow the process laid out in section 4.7. Test issues shall be reported, tracked and managed through the project with stakeholder engagement. Importantly, this includes any agreements which impact design and/or operations.

2.5 Safety Certification

Safety and Security certification projects are detailed in the Safety and Security Certification Plan. The SSCP describes how all safety and security requirements in design criteria and specifications are verified and how the safety content of the plans, procedures and training materials are systematically reviewed

While safety and security certification and SIT are managed separately, they complement and reinforce each other and must be coordinated. When all SIT is completed, the project will be certified under the requirements of the SSCP.

Outside agencies such as Police, Fire and Emergency Responders may also participate in the SIT planning and certification, especially in the area of emergency response drills which are covered in project-specific Emergency Drill Plans.

The SIT Master Test Matrix included within the SITPP will identify test procedures and reports as certifiable under the SSCP. The test program provides the final verification that systems function safely and securely. As the test program proceeds, the SITS must assure that safety- related tests are successfully completed. The SQA member of the

SIT sub-committee will review and certify these along with any arising issues against their intended purpose.

2.6 Contractual Requirements and Relationships

Projects are often designed and built through multiple contracting methods and with multiple contractors. The importance of the SIT program is to ensure proper verification across systems and contractual boundaries.

The Systems Test Manager shall work with the Construction Managers and CDMs in the development of the contract requirements to ensure the commissioning and SIT are appropriately specified within the contract deliverables.

Resident Engineers, reporting to the Construction Manager are responsible for administering construction contracts. This includes commissioning and SIT as included in each respective project contract.

For contractor owned SIT, the contractor is responsible for planning the testing, writing the test procedures, securing test resources and ensuring test reports and issues are transmitted to ST in a timely manner as stipulated in the contract and / or SITPP.

Each SITPP will detail roles and responsibilities between ST and the Contractor(s) for each test. ST managed tests may still require contractor support for test conduct and issue resolution. Scope for Contractor support should be included in contract requirements.

3.0 Test Program Organization

3.1 System Integration Testing Subcommittee (SITS)

For each project, Sound Transit will establish a System Integration Test Subcommittee (SITS) responsible for oversight and/or management of all integrated testing. The SITS approves and provides oversight of the Systems Integration Testing Project Plan (SITPP) execution.

For major capital projects, the SITS operates as a subcommittee of the Rail Activation Committee (RAC), which is charged with overseeing the Start Up/Rail Activation phase of the project. The RAC is responsible for implementation of the Rail Activation Plan (RAP) and the timely completion of all activities required prior to the commencement of Revenue Service. The SITS is responsible for managing and overseeing the execution of a large subset of the Rail Activation Plan, under the guidance of the project specific SITPP.

The mission of the subcommittee is to develop, and approve the project specific SITPP and detailed test procedures and then monitor and/or execute the System Integration Tests to ensure the safe, secure, successful start-up of the project.

One of the first orders of the subcommittee will be to review the scope of the project, including all unique aspects (e.g. noise & vibration considerations, floating bridge, etc.) and all approved and in-process deviations, as presented by the Design Managers. With this information, the subcommittee will determine the scope of testing required, which is then documented in the Master Test Matrix. Through the system testing phase, if a new Request for Deviation is proposed by the Engineer of Record, the Design Manager will brief the committee with a recommendation for any potential impact to testing. The subcommittee may require additional testing based on information provided.

The SITS is chaired by the System Test Manager and is comprised of Sound Transit Design Engineering and Construction Management (DECM), Sound Transit Operations, Sound Transit Systems Assurance and the Contractor(s)/Consultant Construction Management Team(s). The SITPP will identify the SITS structure and members for the project. To best meet project specific requirements, it may be necessary to modify and/or delegate roles and responsibilities.

Nine to twelve months prior to commencing System Integration Testing, the SITS will meet on a monthly basis to begin test planning and organization. More frequent meetings are expected when System Integration Testing begins.

The responsibility of the subcommittee is:

- Management and approval of SITPP
- Oversight, management and approval of Sound Transit and Contractor test

procedures

- □ Test planning including forecasting and coordination of personnel, equipment, vehicles, facilities, track access, contractors, systems safety specialists and outside agencies

- □ Long term scheduling

- □ Review, tracking and approval of on-test issues
- □ Monitor and track the status of the test program
- □ Communication to wider organization of test planning, test completion status, test results and test issues
- □ Review of Systems Integrated Testing related safety certification items
- □ Escalation of issues to RAC or equivalent as appropriate
- □ Review and approval of test results

Figure 5 illustrates the SITS structure, with representation from DECM, Operations, Contractor, Consultant, SQA and the Operator. Each project SITPP will define the subcommittee organization assigning responsibility and authority to individuals from each stakeholder organization.

The role of the SITS will complement the track access procedure, which co-ordinates and authorizes permits for access and work in the right of way, vehicles and any other parts of the railroad currently in operation and/or under the control of the operator.

For early openings, cutovers and sub-projects, the project stakeholders will form a committee on an ad-hoc basis as required and deemed necessary by the System Test Manager.

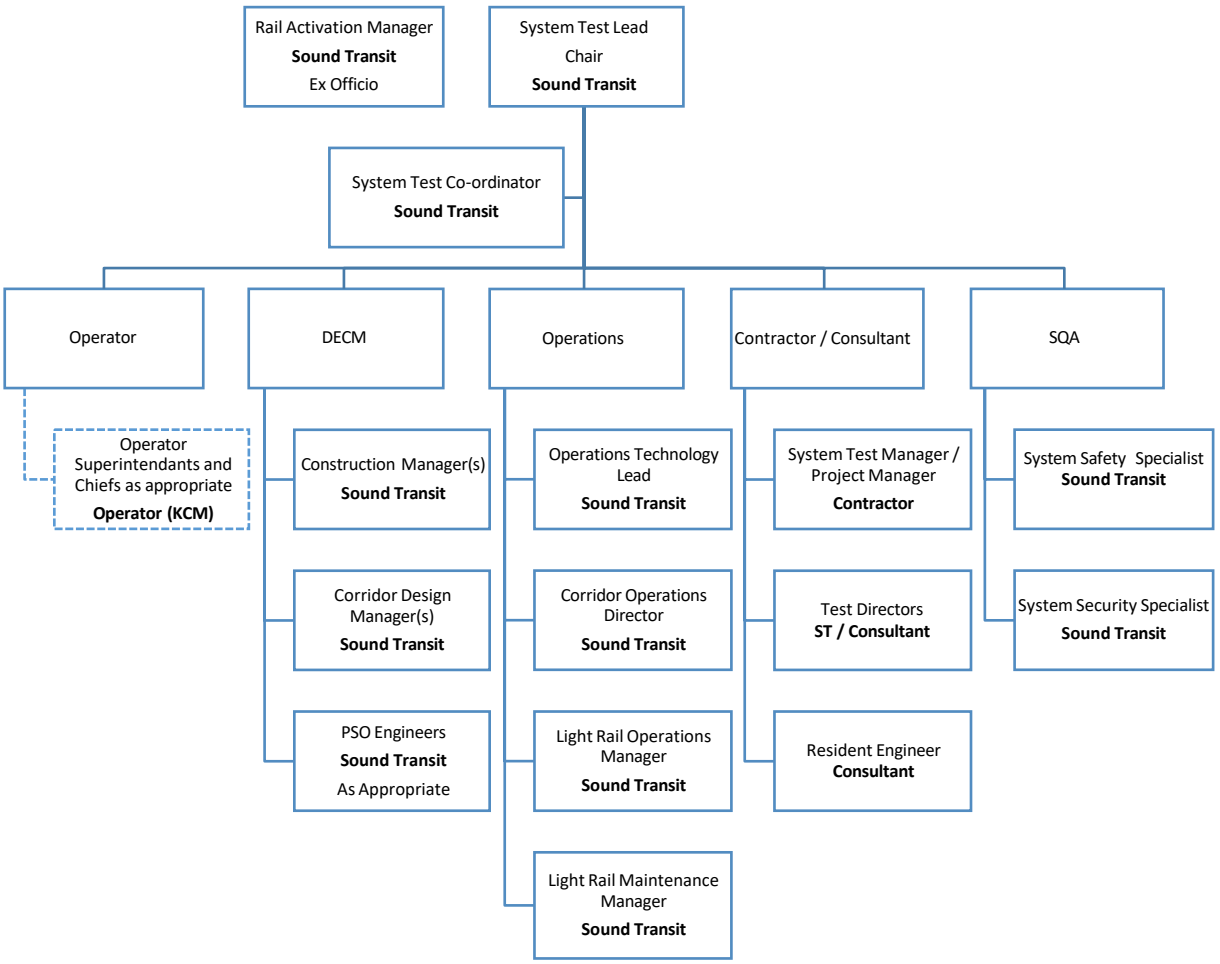

Figure 5 - System Integration Testing Subcommittee (SITS) example

3.2 Tiger Team

For larger capital projects with significant test activity, successfully meeting test program milestones will rely on the agility of the test team and their ability to make efficient engineering and program decisions, which will influence daily and weekly test activities.

The Tiger team will comprise of a subset of the subcommittee with the ability to meet on a regular basis during the test planning and execution phases. It is anticipated this team will meet daily once SIT is in progress. The project SITPP will define the members of the Tiger Team and meeting frequency for each project.

Dependent on the size and scope of the project, the Tiger Team may evolve to a different size and members may be delegates of those listed below. The importance is that the team remains agile, with all members' active participants. All with the expertise, knowledge and most importantly the authority within the organization to make timely and accurate decisions based on the latest information such as last night's test results, recent on-test issues and unexpected external influences on the test schedule.

Often, testing of a project will be split into individual sections as construction on a project is finished in stages. The Tiger Team shall oversee and/or manage the short term planning and decision making to ensure there is an efficient and safe plan for sequential testing such as between stations, facilities and the existing right of way.

The Tiger team is accountable for and has the authority for the following:

- Daily status update and co-ordination with the on-site test team including daily handovers
- Daily decisions and direction of the SIT program / schedule
- Initial approval / rejection / routing of test results and test issues prior to SITS review
- Bringing issues to system experts / specialists as they arise for prompt disposition
- Organization of last minute resource (personnel, vehicles, facilities) to meet unforeseen changes to the day or week ahead plan
- Witnessing or ensuring tests are witnessed as defined in SITPP
- Communication to wider organization about test progress, plan changes, initial test results /issues (as appropriate)

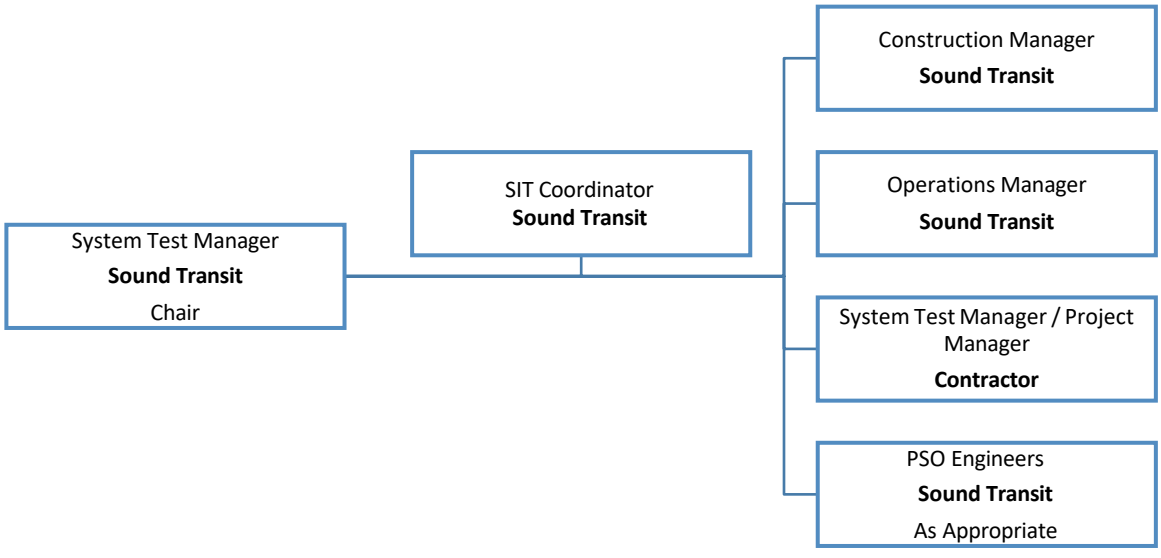

Figure 6 - Tiger Team

3.3 Communication

Good communication and collaboration are key to engaging and updating the different stakeholders and project leadership throughout each organization. Each SITPP will define as appropriate a frequency and accountability for producing the following communication:

- Long range schedule through the SIT phase of the project
- Monthly SITS meeting minutes including agenda and action items
- 3 week look ahead of SIT activities.
- Daily report out produced by the Tiger team in a summary email to the SITS and other organization stakeholders
- Test Handover produced by Test Directors following a day / night / shift of test activity to summarize the testing, initial results and issues.

3.4 Roles & Responsibilities

Table 1 summarizes the roles and responsibilities for the SITS. Each SITPP will detail the project specific subcommittee structure and the individual members. It is anticipated the SITS organization will differ between projects due to the differing nature of the contracting method and the organizational structure support. It is the responsibility of the Systems Test Manager supported by the Rail Activation Manager to ensure the subcommittee comprises the right stakeholders.

For clarity, the Tiger team discussed in section 3.2 are highlighted in orange.

Title	Organization	Committee Responsibilities
Systems Test Lead	Sound Transit	• Chairs the SIT Subcommittee. • Chairs the Tiger Team. • Develops SITPP. • Oversight and management of SIT process with support of SITS. • Ensures efficient and accurate test planning, scheduling, execution and reporting processes are in place.
Project Director	Sound Transit	• Approves the SITPP • Ensures project requirements, budget and schedule account for SIT
Rail Activation Manager	Sound Transit	• Chairs the rail activation committee and manages new project start up.

Title	Organization	Committee Responsibilities
		• Reports to Project Transition Director and manages all rail activation activities. • Verifies operational readiness in coordination with Operations
System Test Coordinator	Sound Transit	• Administers test documentation and test matrix for Sound Transit. • Works with System Test Manager and Test Director to ensure timely and accurate submission and recording of test documentation. • Develops SITS meeting minutes and tracks action items.
Construction Manager	Sound Transit	• Oversees and administers construction activity including contractor SIT responsibilities. • Verify construction work is complete prior to commencing testing. • Provide committee with construction and contractor testing updates. • Manage the punch list and test issues list. • Provides documentation for project safety certification elements. • Witness testing as required.
Design Managers	Sound Transit	• Manage the development of the test plan and procedure requirements within the contract or project requirements.
PSO Engineers	Sound Transit	• Subject matter expert support for test documentation creation, review, approval and test issue support. • Support the development of the test plan and procedures as appropriate. • Review and approval of SIT procedures and reports • Witness SIT as required.
Operations Technology Lead	Sound Transit	• Manage interface with network interfaces and existing right of way. • Coordinate support from Operations Technology • Manage interface and coordination with IT and Information Security
Corridor Operations Director	Sound Transit	• Manage interface between Operations and SITS including long range resource forecasting and reporting. • Liaise and coordinate on technical and logistical issues. • Manages with Transition to Ops. • Authority to approve test exceptions and work-arounds
Maintenance Manager (E.g. Light Rail Maintenance Manager/Sounder Maintenance of Way Superintendent)	Sound Transit	• Support SIT with test document review, approval and coordinating test resourcing. • Engagement of operations department and acceptance of testing prior to hand over to operations. • Integrates with Transition to Ops. • Authority to approve test exceptions and work-arounds
Operations Manager. (E.g Light Rail Operations Manager / Sounder Operations Superintendent)	Sound Transit	• Support SIT with test document review, approval and coordinating test resourcing. • Manage the relationship and communication to operator for resources and work authorization.

Title	Organization	Committee Responsibilities
		• Authority to approve test exceptions and work-arounds.
System Safety Specialist	Sound Transit	• Manage the relationship between SIT and Safety certification. • Reviews procedures and reports data to ensure consistent with certification expectations.
System Security Specialist	Sound Transit	• Manage relationship between SIT and security certification. • Reviews procedures and reports data to ensure consistent with cert expectations.
Test Directors	Sound Transit /Contractor	• Safe testing execution. • Plan, Manage and report on-site test. • Ensures quality hand overs and is responsible for accurate test documentation. • Leads pre and posttest briefs.
System Test Manager / Project Manager	Contractor	• Contractor interface – manage test schedule, procedures, reports, issues and contractor resource
Resident Engineer	Consultant	• Manage interface, review and approval of contractor plans, procedures, report and other documentation. • Manages the construction management inspections / witnessing of contractor-performed work and testing. • Completes safety certification documentation in accordance with SSMP.

Table 1 - Subcommittee roles and responsibilities summary

4.0 Test Procedure Administration

Effective test program management is required to ensure thorough and efficient verification of project, federal and safety requirements.

The steps in the testing process are:

1. Identify test requirements
2. Prepare, review and approve test procedures
3. Verify prerequisites are met
4. Schedule, perform and document tests
5. Test Briefings
6. Review and evaluate test data
7. Test Reporting
8. Management of Test Issues
9. SITS Acceptance
10. Certification

These steps are further defined in the following sections.

Figure 7 outlines the timeline for implementing the SIT processes which is complementary with completing the work in time for commencing revenue operation. Each SITPP will outline the project specific timelines for each step in the process.

Activity / Phase	Start Construction	50% Construction	90% Construction	SIT	Pre-Revenue Operations	Revenue Service
SITPP	Develop	Finalize			Update	
Schedule for SIT Activities		Develop	Finalize		Update	
Test Procedures		Develop	Finalize		Update	
Testing						

Figure 7 - SIT timeline taken from FTA Guidance OP54

4.1 Identify Test Requirements

System Integration Tests shall be identified early in the project based on project scope, previous project best practice, verification of new designs, output of hazard analysis and input from each engineering discipline. Lessons learned from previous projects shall be reviewed and incorporated as appropriate. Each SITPP shall contain the SIT Master Test Matrix with all system integration tests identified. An example SIT Master Test Matrix is in Appendix 1.

Each project construction contract will specify the ownership of each testing level between Sound Transit and the Contractor(s).

PSO subject matter experts review, comment and approve on SIT procedures to verify that the tests will adequately demonstrate that systems and equipment function as specified. The Systems Test Manager distributes the SITPP to the SITS for review and comment. Following resolution of comments, the SITPP is baselined and managed as a controlled document through the subcommittee. Subsequent requests to perform additional tests that are not included on the SIT Master Test Matrix shall be approved by the Systems Test Manager, using a Test Request Form as shown in Appendix B. Following approval, the test is added to the SIT Master Test Matrix .

Many system integrated tests are defined within the contract documents in their specific system technical specification, but several are not. Particular care must be given to those that are not to ensure adequate care in determining the appropriate scope and criteria. This should be evaluated by the appropriate subject matter expert(s) and Design Managers. Several tests which may fall under this category are as follows:

Test ID	Test Description	SME(S)
101	Radio Communications Device	PSO Comms & SCADA
102	Cart Clearance	PSO Track
103	LRV Car Mover Clearance	PSO Track
201	LRV Dead Tow Clearance & ADA	PSO Track
202	Track Switch / LRV Interface	PSO Track & Signals
203	Bumping Post / LRV Interface	PSO Track
204	Ride Quality	PSO Vibrations
305a	Rail / Earth / Isolation / Detection	PSO Track
405	Signal Aspect Sighting	PSO Signals
407	Wayside Sign / Marker Visibility	PSO Signals
501a	EFN Test (Emerg Fire Network)	PSO Comms & SCADA
501b	TCN Test (Train Control Network)	PSO Comms & SCADA
502 / 503	SCADA EVS Airflow & Sequence	PSO FLS & MEP
506	PA/VMS/VES & ERM Verification	PSO FLS & MEP

While all of these tests are conducted during the System Integration Testing phase of a project, and primarily under the scope of the Systems Contractor, several items verified are installed under the civil contracts. Examples of these are clearance to concrete and conduits relative to track, placement of insulated joints, platform gap to train (ADA), and sight lines blocked by walls, etc… All of these tests need to ensure collaboration between the Civil and Systems teams to ensure criteria is agreed and appropriate remedies are provided if any changes are required.

4.1.1 SIT Master Test Matrix

The System Test Coordinator with the support of the System Test Manager and the contractor is responsible for developing and maintaining a SIT Master Test Matrix. The matrix format shall be defined in the each SITPP and maintained as a live document on the Sound Transit SharePoint site.

At a minimum, the SIT Master Test Matrix should specify; test number, objective, description, project, prerequisites, and the ability to track and status the planning and reporting documentation

This matrix shall contain the detail required for managing and tracking test planning, status, reporting and completion.

The matrix shall contain all required testing identified in Test Plans for systems elements in all Categories. Because many tests may have to be performed multiple times at different locations (e.g. clearance tests, aspect tests), the matrix shall allow for tracking the location of each test, as well as for tracking test procedures, test reports and other aspects of each individual test. The Test Director with oversight from the System Test Manager is responsible for ensuring that any given test has been performed a sufficient number of times to cover all locations on the project (as appropriate). The System Test Coordinator shall also use the matrix to ensure that all test procedures are completed and approved and test data sheets have been created well in advance of scheduled testing, as well as ensuring timely completion of test reports.

4.1.2 Verify prerequisites are met

Civil and system prerequisites as applicable for each test shall be identified as the scope of each SIT is determined. The corresponding subject matter expert (as referenced in Section 4.1) provides insight as to what milestones must be achieved for the test to be performed safely and produce a meaningful result. In the case of SIT 102 - Cart Clearance, the test may physically be performed once all track work is verified as fully installed from the civil scope. However, if all wayside equipment is not installed from the systems scope, then the test results are not final and the test must be repeated after wayside equipment installation.

These prerequisites shall be entered into the Test Matrix for each test and verified in writing by delivery of Certificates of Conformance which are issued by the civil and systems Resident Engineers. Certificates of Conformance shall be issued to the SIT Lead Engineer, Corridor Operations Director, and Systems Safety Manager or their designees.

4.1.3 Test numbering

SIT are based on a master test numbering system. A test procedure is written and then applied to the extension, facility or system element as applicable. This is the test number. This ensures that the core elements of a particular test are applied across the entire system and any future extensions. Separate data sheets are then

generated and used for each line segment, facility or system element as required. The SITPP will define the project specific numbering system if there is a project specific deviation from the following.

Test series numbering system:

100 Radio, Car Mover Clearance, Car Mover Interface

200 ROW Clearance, LRV Interface

300 Traction Power, OCS, Traction Power Substations

400 Signals, Signal Interface, Train Tracking, Train Control

500 Communications and SCADA

600 Vibration, EMI, Floating Slab, Wheel Flat Detector

700 Project specific testing

4.2 Prepare, review and approve test procedures

After SITPP approval, the test procedures are prepared and submitted. Each test procedure includes information on the test objective, success/failure criteria, resources, equipment and instrumentation to be used, test setup, test methodology, test data evaluation procedures, sequence of hold points, test duration, test pre-requisites and the type of report or data required. Test procedures shall be complete with required data sheets specific for each test.

Technical requirements include the actual technical step-by-step procedure, fallback plans (if the test is on an active system) and criteria for stopping the test if a particular parameter is exceeded (‘knock-it-off’).

The project construction contract outlines the test owners who are responsible for preparation of the specific test procedures. It is likely that the ownership of test procedures will be split between Sound Transit and the construction contractor. In this instance it is desirable to compile the separate test procedures in a stand alone document to be stored on the SIT Sharepoint site. It is not required to rewrite contractor test procedures into Sound Transit format.

Systems Integration Test procedures shall be approved by the SITS with signatures from the System Test Manager, Resident Engineer (as applicable), PSO Subject Matter Expert (as appropriate) and the Corridor Operations Director.

Due to the volume of change anticipated through a testing program, it is anticipated the test procedures document will be updated more regularly than the SITPP and therefore shall be a referenced document in the SITPP.

4.3 Schedule, perform and document tests

Resources, including facilities, vehicles and support personnel are arranged through the subcommittee, with the responsibility for resource split between the Systems Test Manager, Test Director, Operations Managers, Corridor Operations Director and the Contractor. The specific resource responsibilities should be project specific and outlined in the project specific SITPP.

The System Test Manager with support from the Contractor and Test Director shall ensure:

- □ The test can be performed safely at the scheduled time and location;
- □ Test pre-requisites are appropriate and complete;
- □ Contractual tests that can, or should be, run concurrently or in sequence do not conflict with the schedule of system integration tests and system readiness drills;
- □ All appropriate personnel are notified in a timely manner of the system integration tests.
- □ Public notification and traffic control is arranged for when necessary.

The Operator is responsible for train movement and control of facilities and equipment while the test is performed. In the case of Link Light Rail, this is King County Metro. Operations personnel shall follow established rules and standard operating procedures at all times. As each test step is successfully completed, observations and measured test data shall be recorded on the test data sheets.

Each SIT shall be conducted by a Test Director who is responsible for safely executing the test. The role of the Test Director will be established in the SITPP, but it is anticipated this role can be fulfilled by either the Contractor, experienced Sound Transit Staff or the Consultant. The Test Director is responsible for the complete and accurate documentation of each system integration test including securing all necessary witness signatures.

As each step in the test is completed, the Test Director records the results on the test results data sheets. The Test Director shall be responsible for all of the documentation associated with each test. Approved test procedures and the associated test results data sheets shall be available at the conclusion of each test for review and determination that the test was successfully completed and that all discrepancies are noted. At the end of the test, the Test Director shall ask each responsible witness to sign the witness sign-in sheet.

4.4 Test Briefings

Before each test commences and after the conclusion of a test day, the Test Director is responsible for conducting a pre and post-test briefing with all test participants.

The pre-brief should cover the site and test specific safety items and then step through the test procedure for the day to ensure all test participants are familiar with the process and their role. This also serves as a last opportunity to ask any pre-test co-ordination questions and ensure all of the last minute details are worked out prior to commencing the test, potentially saving valuable test time and budget.

Following the end of the test day, the Test Director shall conduct a post-test brief. This brief recaps the test with all participants, ensures all issues are captured and all test documentation is complete. The briefing covers the next day plan and handover items for the rest of the SITS and/or Tiger Team as appropriate. All test documentation is to be made available to the test director at this time where photocopies can be taken and stored.

Any safety incidents that occur during a test shall be reported through ST approved procedures and to the SIT.

4.5 Review and Evaluate Test Data

Upon completion of a test, a brief recap shall be discussed in the post-brief, which will then be communicated to the SITS and/or Tiger Team as appropriate to decide whether to proceed, hold or adjust the plan accordingly based on the initial results.

Contractor test results shall be submitted to Sound Transit through the Resident Engineer for review in a timely manner. The System Test Manager and Sound Transit subject matter experts and/or consultant will review the results to determine if each test was successful.

Evaluation of test data may reveal equipment, facilities or software that does not meet design requirements. In this case, a test issue shall be logged and the process in section 4.7 should be followed.

4.6 Test Reporting

After each test is successfully completed, the contractor or other entity responsible for conducting the test must produce a test report. The test report references the specific procedure and provides a narrative describing the test activity and generally describing the test results. Signed and dated test data sheets are attached with specific results and pass/fail criteria. Test Issues shall be noted in the test report against the specific test number and exported to the test issue log. If no discrepancies are found, this should be noted. Each report shall be submitted for approval as they are completed. SIT report approval is required by the following positions or delegates as defined by the SITPP: System Test Manager, Corridor Operations Director, Subject Matter Expert, Resident Engineer, and Test Director approval.

4.7 Management of Test Issues

During testing it is likely that unexpected issues will arise. It is important that these are recorded, tracked and managed proactively as to not delay the project start-up nor create undue operational burden through temporary or permanent workarounds.

If the correction of a test issue requires a design change, this should be documented and subjected to Sound Transit's construction management change process, led by the Construction Manager.

4.7.1 Issue Tracking

Issues which occur during System Integration Testing must be formally captured in the Sound Transit System Integration Issue Tracking matrix and easily traceable back to the test failure and test report. The construction management team with the support of the SIT Coordinator is responsible for managing this database to ensure issues are closed, escalated or dispositioned prior to system start-up.

Any test which may continue without immediately correcting an issue will be flagged to ensure the issue is closed before test results are accepted.

4.7.2 Workaround Process

Any abnormalities or restrictions which may affect subsequent tests or operations must have a test issue raised and be included in the Test Report which will be reviewed by the Subject Matter Expert, System Test Manager, the Corridor Operations Director, and Operations Manager.

If a workaround, either permanent or temporary is required to complete the test, approval is required from the SITS.

If the work-around is deemed to have a significant risk, operational impact or cost associated with it, the RAM shall be informed with the option to take this workaround for further disposition in the Rail Activation Committee. All workarounds shall be reviewed by the SITS for impacts to safety certification. When impacts to safety certification requirements are determined they shall be tracked via the SSCP.

If the work around is rejected, the condition shall be corrected and the system retested by the test owner. All workarounds shall be documented in the final test report.

4.7.3 Repeat Tests

A repeat test will be required if either:

1. The systems being tested do not meet the success criteria set out in the test procedure, or

2. Work has been performed on an already tested system

In the event of a test failure, a test issue is raised.

It is possible that anomalies discovered during testing can be corrected on the spot and can be retested after correction. To successfully complete the test, it may be necessary to modify safety briefings, the test set-up, test procedures, or the equipment itself.

Given either (1) or (2), the System Test Manager with the support of the Tiger Team and/or SITS decides whether a system integration test shall be repeated and what modifications are required for successful test completion.

4.7.4 SITS Acceptance

The System Test Manager makes the final determination of test acceptance and/or workarounds and recommends approval to the SITS.

The subcommittee may review unsuccessful tests of any type to determine the cause of the failure. The test, or portions of the test, shall be repeated after the approved corrective action(s) have been completed, unless otherwise authorized by the System Test Manager.

4.7.5 Certification

A signed System Integration Test Certificate as shown in Appendix C is completed following verification by the Safety and Security Certification Subcommittee.

5.0 Management and Control

Establishing and strictly adhering to a system of management and control of all on-site activities, including construction/installation work and testing, is critical to the success of all transit projects. Only when an approved and in-place management and control system of this type exists will the work be able to proceed safely, on schedule, and with a minimum of conflicts between Sound Transit and all other parties. Key to the success of the System Integrated Test Program is keeping Sound Transit senior management staff informed of the current progress of the Systems Integration Test Project Plan and providing them with an early warning of any potential issues that may negatively impact project completion.

Among the goals of the System Integrated Test Program is to create a historical record of the testing and commissioning of the system. Test documentation should be self-explanatory, with sufficient detail to allow a given test to be repeated or audited in the future. Test data sheets and reports shall be traceable back to the test procedures, including resolution of all discrepancies.

5.1 Program Controls

Adequate methods of control of the SIT Program are essential to achieve the objectives described throughout this document. Implementation of the many tests required by contract specifications and by the SITPP necessitates documentation and control procedures that are described below.

Tracking and recording of test documentation shall be detailed in the SITPP. Test reports shall be compiled by subsystem and electronic and hardcopy versions will be provided to the end user upon turnover of the system to Operations.

5.2 Rail Activation Plan

For major capital projects, the Rail Activation Plan is an overall management tool for the start up process of the project. It is based on a management strategy for the optimum use of personnel and identifies all of the program requirements essential for system revenue service.

5.3 Systems Integration Testing Project Plan (SITPP)

This System Integration Testing Program provides a framework for future Systems Integration Test Project Plans. Each SITPP shall outline the phase of testing in which individual systems/subsystems are tested as part of an integrated whole, and the processes by which that integrated system is tested. Integrated testing is a key part of the certification process as it ensures that all of the project elements operate/function as intended, are effectively interfaced, and comply with established safety and security performance requirements.

5.4 Rules and procedures

Execution of certain final acceptance and system integration tests requires implementation of rules and procedures to govern safe operations. These arise from the complexity of interfaces among contractors systems and facilities, and the potential hazards associated with high voltage and moving equipment, amidst pedestrian and vehicular traffic. Specific reference procedures shall be outlined in the SITPP and as applicable within the specific test procedures. For light rail, these include the Central Link Light Rail Rulebook, Standard Maintenance Procedures (SMP) and Standard Operating Procedures (SOP), which outline the manner in which to safely perform work while on the system. These documents shall be used to control test and operations during the start-up testing period.

The rules and procedures shall control the activities of all personnel on the extension, including contractors, consultants, and all on-site staff. These rules and procedures will then be in effect during the test program, and revised if necessary.

5.5 On-test safety

The Test Director is directly responsible for the safety and conduct of test personnel during testing. The Test Director shall conduct a pre-test briefing covering safety items, knock-it off calls and any specific hazards.

5.6 Track / Site Access

All persons must have authorized access to the ROW prior to performing work within the construction limits. Authorized access is necessary in order to avoid conflict or delays with construction operations, and in order to maintain safe movement of equipment and personnel through work areas. For light rail projects, the Track Access process during construction and testing is managed as described in the Link Track Access Procedure.

As projects often involve cut-overs between construction and the active operating project / railroad – the SITPP shall define the general cutover sequence including the track access responsibility for each phase of the cutover. The test procedures shall identify the specifics for safely executing the testing.

5.7 Test Notification

Prior to commencing testing, a Test Bulletin is sent to all parties to inform them of the upcoming testing. The Test Director shall be responsible for the production and distribution of the Test Bulletins. The Test Bulletin is distributed to all parties affected by the test, including members of the SITS, to provide proper advance notification. The Test Bulletin provides all logistical information and provides notification for witnessing opportunities. Some test activities may be complex enough to require

staging plans and careful coordination with construction activities, all of which should be described in the Test Bulletin, if applicable. The SIT Coordinator should ensure that Test Bulletins are transmitted as appropriate, and are tracked in the SIT Master Test Matrix.

A template for the Test Bulletin is in Appendix D.

5.8 Reporting

The SITPP shall define the reporting structure through each project. For major capital projects, the Systems Test Manager will report to the Rail Activation Manager on test result status during the System Integration Test phase.

The master test matrix shall be utilized to track the test program. The System Test Coordinator shall keep the list current and will indicate the scheduled and actual date of a particular test, as well as the disposition of the tests. Progress reports will be prepared by the System Test Manager concerning the status of the test program, to enable a timely review of all test-related issues and resolution of any problems. The reports shall include the following information:

- □ Tests completed in the report period;
- □ Tests expected to be completed during the next month;
- □ Retesting for recorded open item abnormalities and exceptions;
- □ Test program progress with percentage completion

The final test report will be prepared within 5 working days after completion of the last SIT. The RAM will conditionally approve and forward the completed and signed test result documents to SQA. It will describe the overall status of testing including the SITs completed without exceptions and those with exceptions and proposed workarounds. The final report will include the following information:

- □ Summary of all testing completed including achievements and issues;
- □ Description of the current status of the test program, including a summary of any remaining test requirements and operational restrictions;
- □ List of open issues and recommended actions for their resolution;
- □ Recommendation to certify SIT (with exceptions noted, if any) or conditionally certify SIT pending transmittal of approved contractor test submittals.

The final test report will be revised and resubmitted if necessary to support final systems safety certification after SSCRS review

5.9 Lessons Learned

Following the completion of the SIT period, lessons learned shall be captured and reviewed to share improvements with other projects. The output of this session will be made available on the SIT SharePoint site in a list forward with recommendations for new projects. As part of the SITPP planning and development process, lessons learned shall be reviewed and incorporated as necessary.

If a significant process change is required, recommendations will be captured in a future update of this document.

APPENDIX A – Example SIT Master Test Matrix

Example SIT Master Test Matrix for Light Rail Northgate Extension

Test Overview								Test Planning - approved dates				Test Dates		Reports			
Test Number	Description	System	Segment	Objective	Responsible	Pre-requisites	Safety Cert Items	Test Summary	Test Procedure	Test Bulletin	Permits	Start	Finish	Draft Submitted	Final Report	Link to Test Documents	Comments
101.1	Radio Communications Device	Radio	University of Washington Station to U District Station	Verify personnel are able to communicate by radio on the extension	Systems Contractor	Radio installed	199, 201	1-Apr-19	1-Jun-19	15-Aug-19	15-Aug-19	31-Aug-19	2-Sep-19	1-Oct-19	31-Oct-19	https://sharepoint.soundtransit.org/sites/llr/SE/Sy...	Accepted with workarounds. Example here:
101.2	Radio Communications Device	Radio	U district Station to Northgate station	Verify personnel are able to communicate by radio on the extension	Systems Contractor	Radio installed	199, 201	1-Apr-19	1-Jun-19	15-Aug-19							
102	Cart Clearance	Track/Wayside		Verify that there is adequate clearance between the Car mover and equipment and facilities along the Segment	Sound Transit	Wayside structures and track complete											
103	LRV Car Mover Clearance	Track/Wayside			Systems Contractor												
201	LRV Dead Tow Clearance	Track/Wayside			Systems Contractor												
202	Track Switch / LRV Interface	Track/Wayside			Systems Contractor												
203	Bumping Post / LRV Interface	Track/Wayside			Civil Contractor												
204	Ride Quality	Track/Wayside			Sound Transit												
301	Live Wire OCS (Including Camera)	Track / Traction Power			Systems Contractor												
302	OCS Air Gap / Overlap / Section Insulator	Traction Power			Systems Contractor												
303	TPSS Emergency Trip	Traction Power			Systems Contractor												
304	Overcurrent Relay / Pull-Away	Traction Power			Systems Contractor												
305	Rail / Earth / Isolation / Detection	Track / Traction Power			Systems Contractor												
401	Track Circuit Shunting	Signal			Systems Contractor												
402	TWC	Signal			Systems Contractor												
403	Control Line / In Cab Signaling	Signal			Systems Contractor												
404	Train Tracking	Signal			Systems Contractor												
405	Signal Aspect Sighting	Signal			Systems Contractor												
406	Control Line Braking Distance	LRV / Signal			Systems Contractor												
407	Wayside Sign / Marker				Systems Contractor												
408	Traffic Signal Interface				Systems Contractor												
501	EFN Test (Emerg Fire				Systems Contractor												
502	SCADA EVS Test				Sound Transit												
503	EVS Sequence Testing				Sound Transit												
504	SCADA TCS Test				Systems Contractor												
505	SCADA BMS Test				Systems Contractor												
506	PA/VMS/VES & ERM Verification				Sound Transit												
601	Vibration Monitoring System				Sound Transit												
602	Wheel Flat Detector				Sound Transit												
603	Prototype Vibration Mitigation				Sound Transit												
604	Magnetic Field Certification				Sound Transit												
605	Vibration Certification				Sound Transit												

APPENDIX B – SIT Test Request

System Integration Test Request

Requestor : _____ **Date :** _____

Company : _____ **Cell Ph #** _____

Email : _____ **Wk Ph #** _____

Line Segment : **Fax #**

Test Requested :			
Purpose :			
Requirements (Including Facilities & Resource)			
Acceptance Criteria :			
Recommendation: (circle one)	Approved	Approved as Noted	Disapproved
Comments :			

System Test Manager: **Date :**

APPENDIX C – Safety and Security Certificate

Example Safety and Security Certification Certificate

SOUNDTRANSIT Link

Agency Safety and Security Certification for:

[Project Name]

Systems Integration Testing Certificate of Conformance

Completion of this Certificate verifies that the Integration Tests listed below comply with all applicable requirements for Safety, Security, Fire/Life, and Systems Assurance for Link Light Rail [Project]. Exceptions are listed below (if applicable)

The following Systems Integration Tests were completed and verified to confirm that the systems and sub-systems function properly and have been adequately documented. Verified tests are:

Test #	Test Title	Test #	Test Title

Exceptions Noted:

_____ Date
Project Director, Project

_____ Date
Director of Public Safety

_____ Date
Director, Systems Engineering & Integration

_____ Date
Director of Construction & System Safety

_____ Date
Rail Activation Manager

_____ Date
Executive Director of Design Engineering & Construction Management (DECM)

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APPENDIX D – Test Bulletin

Test Bulletin Template and Example

SOUNDTRANSIT

System Integration Test Bulletin

Date: 18 June 2018

Project: East Link Light Rail

Test: Signal Aspect Sighting – I90 bridge (405.3)

Test Director: John Michaels (Contractor)

Distribution: Required participants & SIT sub-committee members

Test Date, Time	07 July 2018	08:30	
Required Participants	John Michaels	Test Director (Contractor)	Contractor
	Andrew Sandwich	Signals (DECM), Witness	Sound Transit
	Danny Hart	System Test Manager	Sound Transit
	Harry Kane	Light Rail Super Intendant	Sound Transit
	Tracey Andrews	Resident Engineer	Consultant
	Gareth Southgate	Construction Management	Consultant
	Euan Stevens	Vehicle Chief	KCM
	George Foreman	Signals Chief	KCM

Logistical information

Pre-Test Brief. 08:30 07-Jul-18. Judkins Park Station meet at East Entrance.
Test duration: 3 hours.
Post-Test Brief: Judkins Park Station.
PPE required for all test participants

Staging plans:

None required.

Special Test Equipment

Train loading AW1.

Contacts:

Test Director: John Michaels
Construction Manager: Lewis Hamilton +1 206 567 8998
Site Foreman: Dawn French +1 506 898 7899

Test Bulletin 1 6/18/2018