California High-Speed Train Project

Request for Proposal
for Design-Build Services

RFP No.: HSR 11-16
Reliability, Availability, and Maintainability (RAM)
Program Plan
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Appendix A RAMPP Requirements For CP01 Initial Construction Package Procurement
Appendix B Example Contractor RAM Program Plan
Abstract

The California High-Speed Train Project (CHSTP) has established and is executing a Reliability, Availability, and Maintainability (RAM) Program that provides for the following:

- Ensures RAM performance of California High-Speed Train (CHST) equipment and facilities
- Guides and coordinates the RAM design, analysis, test, documentation, and certification activities between CHST project management, systems, and sections through all project phases
- Complies with applicable regulatory requirements, including RAM requirements in 49CFR 200-299 and EN 50126-1 for all CHST systems, structures, and sections
- Implements the CHSTP Reliability, Availability, Maintainability, and Safety (RAMS) Program Policy stated in TM 300.05

Project Management Team (PMT) RAM work includes:

- RAM Program Plan
- RAM Requirements
- RAM Metrics
- RAM Design Criteria
- RAM analysis and design review
- RAM requirements for contractor and equipment supplier bid specifications
- Monitoring and evaluation of contractors and suppliers by project engineers and managers
- System integration RAM

Contractor and Supplier RAM work includes:

- Contractor and equipment supplier RAM Plans
- Contractor and equipment supplier RAM design analyses for Final Engineering 100% designs
- System integration RAM
- Monitoring and evaluation by project engineers and manager.

This RAM Program Plan (RAMPP) implements the CHST RAM Program which will:

- Fulfill the RAM Program requirements listed above
- Conform with EN 50126-1
- Satisfy RAM requirements from the CHST TM 300.05 RAMS Policy, System Requirements, Technical Memoranda, Safety and Security Management Plan (SSMP), Design Criteria, and other CHSTP sources
- Establish RAM design guidelines and criteria
- Define scope, organization, responsibilities, tasks, deliverables, milestones, RAM requirements, RAM testing, analysis, feedback, reporting, etc. for the RAM Program
1 Introduction

The California High-Speed Train Project (CHSTP) has established a Reliability, Availability, and Maintainability (RAM) Program to ensure adequate system and service availability for the California High-Speed Train (CHST) project. The CHSTP developed this RAM Program Plan (RAMPP) for all CHST systems, structures, and sections, to comply with the CHSTP RAMS Program Policy in TM 300.05, RAM-related CHST System Requirements (SRs), and applicable regulatory requirements, including RAM requirements in 49CFR 200-299. This RAMPP guides and coordinates RAM design, analysis, test, documentation, and certification activities between all participants in all CHST project stages and phases.

The RAMPP provides RAM guidance and requirements for all CHSTP sections, structures, system and equipment suppliers, including CHSTP and its contractors, and for all work including Design, Construction, Procurement, and System Integration.

The CHSTP has adopted International Electrotechnical Commission (IEC) and European Committee for Electrotechnical Standardization (CENELEC) RAMS standards, particularly European Norm (EN) 50126-1, as the basis for CHSTP RAM specifications and programs. These IEC and ENs govern RAM development and certification for worldwide rail projects large and small, including most recently developed high-speed rail systems.

Per the RAMS Program Policy, the RAM work will be closely coordinated with the Safety work governed by the Safety and Security Management Plan.

This RAMPP covers all project phases, and emphasizes activities in the present preliminary engineering and initial construction project phases. It outlines the activities in the later construction buildout, systems procurement, integration, operating and maintenance phases. Later RAMPP versions will provide more detail as the project advances to further construction, procurement, and integration phases.

As Design/Build contracts are awarded, each contractor will prepare a Contractor RAM Program Plans (CRMP) for its covered scope, and all such CRMP documents will be referenced in and integrated with later versions of this RAMPP.

1.1 RAM Program Organization

CHSTP has organized a RAMS management team. The RAM and Safety teams have established working groups to drive and coordinate the RAM and Safety activities. The RAM and Safety teams consist of the engineering, operations, systems assurance, safety, and systems integration personnel working on the Project in their specific disciplines. The RAM team is managed by the RAM Manager and the Safety team is managed by the Safety Manager.

1.2 RAM Program Objective

The RAM Program objective is to assure adequate availability of all elements of the complete CHSTP and to minimize service disruption caused by system failures, so the CHSTP provides adequate, scheduled, dependable scheduled rail service for passengers.
The RAMPP establishes system-wide RAM requirements and actions. The RAMPP governs RAM tasks and deliverables by all CHSTP Section Contractors and System Suppliers.

To meet the RAM Program objective, this RAMPP specifies the following:
- Activities and deliverables for the CHSTP and its Project Management Team (PMT), System Suppliers, construction contractors, and subcontractors
- RAM design requirements to be included in the Functional and Performance Specifications for each affected system or piece of equipment
- RAM analyses and tests to demonstrate compliance with CHSTP RAM requirements.
- RAM design guidelines, criteria, and methods

### 1.3 RAM Program Scope

The CHSTP RAM program scope includes all CHSTP design, implementation, operation, and maintenance aspects which can affect the dependability of passenger service. The RAM project scope includes Infrastructure, Systems, Rolling Stock, Train Storage and Maintenance Facilities, and Operations and Maintenance.

The CHSTP RAM program scope includes the PMT work, the work of each Project section, and the scope of each contractor and equipment supplier.

RAM program results will be tracked, verified and validated (V&V) by the CHSTP Verification and Validation Management Plan (VVMP) described in TM 700.01.

### 1.4 RAM Program Activities

CHSTP RAM Program activities during design include:
- Create and maintain the RAMPP and execute the RAM program
- Perform the RAMPP design activities and create the required deliverables
- Track and report on RAM task completion status and RAM issues

CHSTP Contractors and System Suppliers must:
- Develop Contractor RAM Program Plans (CRMP) for their scopes of supply, perform the planned activities, and create the required deliverables
- Fulfill the RAM requirements per the Functional and Performance Specifications
- Track and report on RAM task completion status and RAM issues
1.5 Reference Information

Table 1-1 identifies CHST project documents and standards for the CHSTP RAM Program.

**Table 1-1: CHSTP RAM Program – Reference Project Documents and Standards**

<table>
<thead>
<tr>
<th>ID</th>
<th>Issued By</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>TM 300.05</td>
<td>CHSTP</td>
<td>CHSTP Reliability, Availability, Maintainability, and Safety (RAMS) Program Policy</td>
</tr>
<tr>
<td>TM 700.1</td>
<td>CHSTP</td>
<td>CHSTP Verification and Validation Management Plan</td>
</tr>
<tr>
<td></td>
<td>CHSTP</td>
<td>CHSTP Business Plan</td>
</tr>
<tr>
<td>EN 50126-1:1999</td>
<td>CENELEC</td>
<td>Railway applications - The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS) - Part 1: Basic requirements and generic process</td>
</tr>
<tr>
<td>EN 50126-2:2007</td>
<td>CENELEC</td>
<td>Railway applications - The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS) - Part 2: Guide to the application of EN 50126-1 for safety</td>
</tr>
<tr>
<td>EN 50126-3:2008</td>
<td>CENELEC</td>
<td>Railway applications - The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS) - Part 3: Guide to the application of EN 50126-1 for rolling stock RAM</td>
</tr>
<tr>
<td>EN 50128:2011</td>
<td>CENELEC</td>
<td>Railway applications — Communication, signaling and processing systems — Software for railway control and protection systems</td>
</tr>
<tr>
<td>IEC 60812</td>
<td>IEC</td>
<td>Analysis techniques for system reliability – Procedures for failure mode and effects analysis</td>
</tr>
<tr>
<td>IEC 60863</td>
<td>IEC</td>
<td>Presentation of reliability, maintainability, and availability predictions</td>
</tr>
<tr>
<td>IEC 61025</td>
<td>IEC</td>
<td>Fault Tree Analysis</td>
</tr>
<tr>
<td>IEC 61078</td>
<td>IEC</td>
<td>Analysis techniques for dependability – Reliability block diagram method</td>
</tr>
<tr>
<td>IEC 61165</td>
<td>IEC</td>
<td>Application of Markov Techniques</td>
</tr>
<tr>
<td>--</td>
<td>RiAC</td>
<td>Reliability Toolkit: Commercial Practices Edition</td>
</tr>
<tr>
<td>NPRD-2011</td>
<td>RiAC</td>
<td>Nonelectronic Parts Reliability Data</td>
</tr>
</tbody>
</table>
## 1.6 Acronyms and Abbreviations

Table 1-2 lists acronyms and abbreviations in the RAMPP.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGREE</td>
<td>Advisory Group on Reliability of Electronic Equipment</td>
</tr>
<tr>
<td>AKA</td>
<td>Also Known As</td>
</tr>
<tr>
<td>ALARP</td>
<td>As Low As Reasonably Practicable</td>
</tr>
<tr>
<td>ATC</td>
<td>Automatic Train Control</td>
</tr>
<tr>
<td>ATS</td>
<td>Automatic Train Supervision</td>
</tr>
<tr>
<td>Authority</td>
<td>California High-Speed Rail Authority</td>
</tr>
<tr>
<td>BET</td>
<td>Basic Events Table</td>
</tr>
<tr>
<td>CCTV</td>
<td>Closed circuit television</td>
</tr>
<tr>
<td>CDRL</td>
<td>Contract Deliverable Requirement List</td>
</tr>
<tr>
<td>CENELEC</td>
<td>European Committee for Electrotechnical Standardization</td>
</tr>
<tr>
<td>CFR</td>
<td>Code of Federal Regulations</td>
</tr>
<tr>
<td>CHST</td>
<td>California High-Speed Train</td>
</tr>
<tr>
<td>CHSTP</td>
<td>California High-Speed Train Project</td>
</tr>
<tr>
<td>CMA</td>
<td>Corrective Maintenance Analysis</td>
</tr>
<tr>
<td>COTS</td>
<td>Commercial off-the-shelf</td>
</tr>
<tr>
<td>CP01</td>
<td>Initial Construction Package</td>
</tr>
<tr>
<td>CRMP</td>
<td>Contractor RAM Program Plan</td>
</tr>
<tr>
<td>DBM</td>
<td>Design Basis Manual</td>
</tr>
<tr>
<td>EMU</td>
<td>Electric multiple unit</td>
</tr>
<tr>
<td>EN</td>
<td>Euro Norm</td>
</tr>
<tr>
<td>FMECA</td>
<td>Failure Modes and Effects Criticality Analysis</td>
</tr>
<tr>
<td>FRACAS</td>
<td>Failure Reporting, Analysis and Corrective Action System</td>
</tr>
<tr>
<td>FRA</td>
<td>Federal Railroad Administration</td>
</tr>
<tr>
<td>FRB</td>
<td>Failure Review Board</td>
</tr>
<tr>
<td>FTA</td>
<td>Fault Tree Analysis</td>
</tr>
<tr>
<td>GAMAB</td>
<td>Global Au Moins Aussi Bon (globally at least as good)</td>
</tr>
<tr>
<td>HPMR</td>
<td>Historical Product Maintainability Report</td>
</tr>
<tr>
<td>HVAC</td>
<td>Heating, ventilation, and air conditioning</td>
</tr>
<tr>
<td>IOS</td>
<td>Initial Operation Section</td>
</tr>
<tr>
<td>KPI</td>
<td>Key Performance Indicator</td>
</tr>
<tr>
<td>LRU</td>
<td>Line Replaceable Unit</td>
</tr>
<tr>
<td>MD</td>
<td>Maintainability Demonstration</td>
</tr>
<tr>
<td>MDBF</td>
<td>Mean Distance Between Failure</td>
</tr>
<tr>
<td>MDBSF</td>
<td>Mean Distance Between Service Failure</td>
</tr>
<tr>
<td>MDTP</td>
<td>Maintainability Demonstration Test Plan</td>
</tr>
<tr>
<td>MEP</td>
<td>Mechanical, Electrical, and Plumbing</td>
</tr>
<tr>
<td>MIS</td>
<td>Management Information System</td>
</tr>
<tr>
<td>mph</td>
<td>miles per hour</td>
</tr>
<tr>
<td>MRTT</td>
<td>Mean Repair Travel Time</td>
</tr>
<tr>
<td>MTBF</td>
<td>Mean Time Between Failure</td>
</tr>
<tr>
<td>MTBFF</td>
<td>Mean Time Between Functional Failure</td>
</tr>
<tr>
<td>MTBSF</td>
<td>Mean Time Between Service Failure</td>
</tr>
<tr>
<td>MTBSI</td>
<td>Mean Time Between Service Interruption</td>
</tr>
</tbody>
</table>
1.7 RAM Definitions

The following definitions apply to the RAMPP.

**Availability** is the ability of the System to be in a state to perform a required function under specified conditions over a specified time interval assuming that the required external resources are provided.

**Corrective Maintenance** is the non-scheduled maintenance carried out after failure recognition, whose purpose is to restore the System so it can perform its required function.

**Down Time** is a time interval during which the System is in a down state, e.g., is not able to perform its required function. Down time consists of administrative and logistics delay time and time to restore the System.

**An Immobilizing Failure** is a failure which affects a CHSTP element and fulfills any of the following:
- It causes or could cause more than one train to be delayed longer than a Threshold Delay Time.
• It causes more than one train to run in a more restrictive operating mode than would have otherwise been the case in its absence.

**Maintenance** is the combination of all technical and administrative actions, including supervision actions, intended to retain the System in, or restore it to, a state in which it is able to perform the required function.

**Mean Time To Restore (MTTR)** is the average of the System Down Time that includes time to troubleshoot and fault isolate a failure, remove and replace/repair faulty items, and perform functional check out to verify restoration to operational status, and excludes administrative and logistics delay.

A **Minor Failure** is a failure which affects a CHSTP element and is neither an Immobilizing Failure nor the Service Failure.

**Preventive Maintenance** is the scheduled maintenance carried out at pre-determined intervals or according to prescribed criteria whose purpose is to minimize disruption of revenue service.

The **RAM Program** is a documented set of scheduled activities, resources and events serving to implement the organizational structure, responsibilities, procedures, activities, capabilities and resources that together ensure that the CHSTP will achieve its RAM requirements.

A **Service Failure** is a failure which affects a CHSTP element and fulfills any of the following:

• It causes or could cause one train to be delayed longer than the threshold delay time.
• It causes one train to run in a more restrictive operating mode than would have otherwise been the case in its absence.

The **System Lifecycle** consists of all activities which occur from first System planning phase, through the development, implementation, operation and maintenance until the final decommissioning and disposing of the System.

The **Threshold Delay Time** is a maximum delay time in which a train is not considered delayed.

**Up Time** is a time interval during which the System is in an up state, e.g., fully performs its required function.

## 2 RAM Program Requirements

CHSTP document TM 300.05, Technical Memorandum, CHSTP Reliability, Availability, Maintainability, and Safety (RAMS) Program Policy, establishes the project level RAM requirements.

The Federal Railroad Administration (FRA) regulates the safety of U.S. railroads through the Code of Federal Regulations (CFR). 49 CFR 236 for signaling systems, microprocessor based systems and Positive Train Control, and 49 CFR 229 for Locomotive Safety Standards require both qualitative and quantitative safety and RAM analysis and assessments to be conducted, therefore the CHSTP RAM Program must develop failure rates for use in the safety and RAM analyses and assessments.
RAM requirements identified in the System Requirements task are incorporated in the TM 300.05 RAMS Policy.

3 RAM Assurance Concept

3.1 RAM Assurance Overview

TM 300.05, CHSTP Reliability, Availability, Maintainability, and Safety (RAMS) Program Policy, established that the CHSTP will establish and achieve RAM goals, objectives, key performance indicators (KPIs), and RAM targets by implementing a RAM program per EN 50126-1, Railway applications - The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS) - Part 1: Basic requirements and generic process. EN 50126-1 is an internationally proven basis for RAM assurance in high-speed train projects.

CHSTP established this system-wide RAMPP to implement the RAM Program for all CHSTP sections and systems. This RAMPP complies with EN 50126-1.

CHSTP RAM assurance will be achieved by PMT actions, described in section 5 of this RAMPP, and by Section Contractors and System Suppliers actions, described in section 6.

PMT RAM work includes:
- Establish a system-wide RAM Program
- Define system RAM requirements
- Establish RAM metrics
- Assess RAM characteristics of system designs
- Define RAM requirements for bid specifications
- Coordinate RAM with other parties/outside owners
- Monitor and evaluate RAM work by Section Contractors and System Suppliers
- System Integration RAM.

RAM work by Section Contractors and System Suppliers includes:
- Establish Section and System RAM Programs
- Allocate RAM
- Perform RAM analyses in all engineering phases
- Perform RAM tests
- Provide Failure Reporting and Corrective Action System (FRACAS)
- Integrate RAM with system safety, O&M, manuals, V&V, and other
- Apply Reliability Centered Maintenance (RCM) design

3.2 CHSTP RAM Approach

The CHSTP is a complete high-speed railway consisting of Infrastructure with major Structures, Systems, Rolling Stock, Train Storage and Maintenance Facilities, and Operations and Maintenance activities. The CHSTP RAMS policy is to implement a structured RAMS program based on EN 50126-1 to achieve RAMS goals by applying consistent standards and values in the Project specification, design, construction, installation, acceptance, operation, and modification/extension.
RAM requirements, objectives, and activities of all CHSTP disciplines and contractors must be coordinated so that the RAM performance levels set for each discipline and contractor are both realistic and stringent enough to achieve the overall high-speed rail service targets.

The formal RAM program described in EN 50126-1 applies to the following disciplines:
- Infrastructure
- Systems
- Rolling Stock
- Train Storage and Maintenance Facilities
- Operations and Maintenance

The CHSTP will apply EN 50126-1 processes for Infrastructure. Infrastructure elements will comply with stringent federal, state and local codes for construction and RAM program requirements to ensure fitness for purpose and required safety and availability. In addition, the CHSTP has developed Infrastructure design criteria and specific requirements to ensure that maintainability needs are compatible with CHSTP operating constraints, including accessibility for inspection, preventative maintenance, and other activities.

The RAM program will establish quantified and measurable Key Performance Indicators (KPIs) and RAM targets for the complete CHSTP. The CHSTP RAM team will establish RAM targets for the project as a whole and develop a RAM model. Compatible targets will be allocated to each discipline. Each discipline will use these targets to distribute RAM allocations to subsystems within the discipline. These RAM allocations will be included in the performance specification and procurement documents.

For each procurement, construction, and operating phase, the CHSTP will establish a compatible set of RAM targets. The first set will apply to the civil infrastructure components constructed in the first construction package, CP01, and the final compatible set will apply to the full phased CHSTP build-out.

At each construction and operating phase, the CHSTP VVMP will track completion of all RAM activities.

The CHSTP will use a Reliability Centered Maintenance (RCM) approach, described in section 6.10.

### 3.3 EN 50126-1 Compliance

Table 3-1, adapted from EN 50126-1, shows the required RAM and safety tasks for each project phase. Authority/PMT areas of responsibility are indicated in **BOLD**.

Figure 3-1 is a V diagram which represents RAMS activities throughout the project lifecycle, including commissioning, operations and maintenance.
Table 3-1: EN 50126-1 Lifecycle Phases and CHSTP Phases and RAM Tasks

<table>
<thead>
<tr>
<th>LIFECYCLE PHASE</th>
<th>CHSTP PHASE</th>
<th>RESPONSIBLE ENTITY</th>
<th>PHASE RELATED RAM TASKS</th>
<th>PHASE RELATED SAFETY TASKS</th>
<th>COMPLETION STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Design And Implementation</td>
<td>PROCUREMENT OF DESIGN/BUILDER FINAL DESIGN</td>
<td>Authority / PMT</td>
<td></td>
<td></td>
<td>In Progress</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D/B CONTRACTOR</td>
<td></td>
<td></td>
<td>In Progress</td>
</tr>
<tr>
<td>LIFECYCLE PHASE</td>
<td>CHSTP PHASE</td>
<td>RESPONSIBLE ENTITY</td>
<td>PHASE RELATED RAM TASKS</td>
<td>PHASE RELATED SAFETY TASKS</td>
<td>COMPLETION STATUS</td>
</tr>
<tr>
<td>----------------</td>
<td>-------------</td>
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<td>-------------------------</td>
<td>----------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>10. System Acceptance</td>
<td>SUBSTANTIAL COMPLETION, SAFETY CERTIFICATION</td>
<td>D/B CONTRACTOR, Authority/PMT, FRA</td>
<td>Assess RAM Demonstration. RAM V&amp;V Reports.</td>
<td>Safety V&amp;V Reports. Authority self-certifies compliance w/FRA Safety regulations Prepare System Safety Program Plan</td>
<td>Not started</td>
</tr>
<tr>
<td>13. Modification and Retrofit</td>
<td>MODIFICATION AND RETROFIT</td>
<td>Authority, O&amp;M CONTRACTOR</td>
<td>Consider RAM Implications for Modification and Retrofit.</td>
<td>Consider Safety Implications for Modification and Retrofit.</td>
<td>Not started</td>
</tr>
</tbody>
</table>
4 CHST Project Description

4.1 Project Overview

The planned CHST System encompasses approximately 800 route miles and will provide intercity travel in California between the major metropolitan centers of Sacramento, the San Francisco Bay Area, the Central Valley, Los Angeles, the Inland Empire, Orange County, and San Diego. The CHST System will be a state-of-the-art, electrically powered, high-speed, steel-wheel-on-steel-rail technology, including state-of-the-art safety, signaling, and train-control systems.

The CHST System route will be constructed at-grade, in open trench, in tunnels, or on elevated guideway, depending on the terrain and physical constraints encountered. Extensive portions of the CHST System may lie within, or adjacent to, existing rail or highway rights-of-way to reduce potential environmental impacts and minimize land acquisition costs.

The alignment will be designed for a maximum design speed of 250 mph, where feasible and practicable. The CHST System will interface with commercial airports, mass transit, and the highway network. As the CHST System and sections are developed, updated, and refined, ridership data will be used to confirm desired system capacity, service levels and frequency of service, and operating plans.

The CHSTP authorizing legislation calls for:

- Maximum nonstop service travel times:
  - San Francisco-Los Angeles Union Station: two hours, 40 minutes
  - San Francisco-San Jose: 30 minutes
  - San Jose-Los Angeles: two hours, 10 minutes
  - San Diego-Los Angeles: one hour, 20 minutes
  - Inland Empire-Los Angeles: 30 minutes
  - Sacramento-Los Angeles: two hours, 20 minutes

- Operating headway (time between successive trains) will be five minutes or less.

- Trains can pass by intermediate stations at mainline operating speed.

- The total number of CHSTP stations is 24 or less, with no station between Gilroy and Merced.

- Passengers can travel from any station on a corridor to any other station on that corridor without changing trains.

4.2 CHSTP RAM Program Schedule

The CHSTP RAM schedule is coordinated with the implementation steps defined by the CHSTP Business Plan:

1. Early Investments/statewide benefits
   - The first construction segment (Contract packages – CP01 through CP04 and track and systems contract packages)
• Northern California Unified Service (The first construction segment of the IOS will be put into use immediately upon completion for improved service on the San Joaquin intercity line)
• Improve service in the “bookends” -- Caltrain in the San Francisco peninsula area and Metrolink in the Los Angeles Metro area
• Electrify the Caltrain corridor

2. Initial High-Speed Rail Operations over the Initial Operating Segment (IOS) from Merced to San Fernando
3. The Bay to Basin System
4. The Phase 1 System – San Francisco to Los Angeles
5. The Phase 2 System – extensions to San Diego and Sacramento.

Step 1 – Early Investments / Statewide Benefits includes initial civil construction packages CP01, CP02, CP03, and CP04, and procurement of track and systems

The first construction of dedicated high-speed infrastructure for the Initial Construction Segment (ICS) begins in the Central Valley. Amtrak may operate on the new high-speed ICS tracks, but without impacting the design or integrity of the CHSTP infrastructure. Improved passenger rail service over the CHSTP track would begin upon completion of the first IOS segment by connecting the San Joaquin service, ACE, Sacramento Regional Transit, the Capitol Corridor (and potentially Caltrain). Through a new, strategic approach, there is also the opportunity for new or improved travel between Bakersfield and Sacramento, Oakland, San Jose, and San Francisco. This expanded Northern California Unified Service could begin operation as early as 2018.

Step 1 CHSTP RAM activities include:
• Develop the CHSTP RAMS Policy and RAMPP
• Establish system-wide KPIs and compatible RAM Targets
• Allocate system-wide KPIs and RAM Targets to initial construction packages
• Incorporate RAM design requirements in the CHSTP Design Criteria
• Coordinate RAM with other parties and establish RAM requirements for shared Systems and Infrastructure on shared corridors
• Establish RAM requirements for bid specifications
• Monitor and evaluate RAM work performed by Section Contractors and System Suppliers
• Perform system integration RAM activities.

Step 2 - Initial High-Speed Rail Operations, operating into the Los Angeles Basin

The service will be blended with regional/local systems. The IOS is achieved through expansion of the first construction segment into an electrified operating high-speed rail line from Merced to Palmdale and the San Fernando Valley, accessing the populous Los Angeles Basin. Following on the work discussed above, the next priority in implementing the IOS will be closing the rail gap between Northern and Southern California by crossing the Tehachapi Mountains with new, dedicated high-speed rail infrastructure. Prior to completion of the IOS to the San Fernando Valley, this link will tie the north to the south at Palmdale, where Metrolink commuter rail service can then provide service and connections throughout Southern California. Currently, the IOS is defined as extending from Merced to the San Fernando Valley, and high-speed revenue service would only start once the full IOS is built and operable. Should ridership and revenue forecasts and financial projections demonstrate that revenue service compliant with Proposition 1A could begin earlier, with a shorter IOS, appropriate reviews would occur to consider and implement earlier service, if appropriate.

Step 2 CHSTP RAM activities include:
• Track RAM performance of Step 1 Systems and Infrastructure. As necessary, perform reliability improvement work and modify specifications to incorporate lessons learned.
• Allocate system-wide KPIs and RAM Targets to the new construction and system packages.
• Coordinate RAM with other parties and establish RAM requirements for shared Systems and Infrastructure on shared corridors.
• Establish RAM requirements for bid specifications.
• Monitor and evaluate RAM work performed by Section Contractors and System Suppliers.
• Perform system integration RAM activities.

**Step 3 - The Bay to Basin System**

The dedicated high-speed rail infrastructure of the IOS will be expanded north and west to San Jose, providing HSR service between the state’s major population centers in the north and south and providing the platform for the transition to statewide blended operations. At this stage, passengers will be able to take a one-seat ride between greater Los Angeles (San Fernando Station) and the San Francisco Transbay Transit Center using blended infrastructure in the north between San Francisco and San Jose (assuming electrification of the Caltrain corridor by 2020 as proposed by Caltrain), using dedicated high-speed rail infrastructure between San Jose and the San Fernando Station, and in the south, connecting via Metrolink between the San Fernando Valley Station and Los Angeles’ Union Station and on to other points throughout Southern California.

Step 3 CHSTP RAM activities include:
• Track RAM performance of Step 2 Systems and Infrastructure. As necessary, perform reliability improvement work and modify specifications to incorporate lessons learned.
• Allocate system-wide KPIs and RAM Targets to the added construction and system packages.
• Coordinate RAM with other parties and establish RAM requirements for shared Systems and Infrastructure for shared corridors.
• Establish RAM requirements for bid specifications.
• Monitor and evaluate RAM work performed by Section Contractors and System Suppliers.
• Perform system integration RAM activities.

**Step 4 - The Phase 1 System**

For the blended approach, the dedicated high-speed rail infrastructure of the Bay to Basin system will be extended from the San Fernando Valley to Los Angeles Union Station, linking to a significantly upgraded passenger rail corridor developed to maximize service between Los Angeles and Anaheim while also addressing community concerns about new infrastructure impacts in a congested urban corridor that includes a number of established communities that abut the existing right-of-way. Under a Full Build scenario, dedicated high-speed rail infrastructure would be extended from San Jose to San Francisco’s Transbay Transit Center and from Los Angeles to Anaheim.

Step 4 CHSTP RAM activities include:
• Track RAM performance of Step 3 Systems and Infrastructure. As necessary, perform reliability improvement work and modify specifications to incorporate lessons learned.
• Allocate system-wide KPIs and RAM Targets to the added construction and system packages.
• Coordinate RAM with other parties and establish RAM requirements for shared Systems and Infrastructure for shared corridors.
• Establish RAM requirements for bid specifications.
• Monitor and evaluate RAM work performed by Section Contractors and System Suppliers.
• Perform system integration RAM activities.
Step 5 - The Phase 2 System

Phase 2 will extend the high-speed rail system to Sacramento and San Diego, representing completion of the 800-mile statewide system. Travelers will be able to travel among all of the state’s major population centers on high-speed rail. Phase 2 areas will see improvements in rail service well in advance of the expansion of the high-speed rail system through the combination of early investments and blended operations, as described in this Revised Plan.

Step 5 CHSTP RAM activities include:
- Track RAM performance of Step 4 Systems and Infrastructure. As necessary, perform reliability improvement work and modify specifications to incorporate lessons learned.
- Allocate system-wide KPIs and RAM Targets to the added construction and system packages.
- Coordinate RAM with other parties and establish RAM requirements for shared Systems and Infrastructure for shared corridors.
- Establish RAM requirements for bid specifications.
- Monitor and evaluate RAM work performed by Section Contractors and System Suppliers.
- Perform system integration RAM activities.

4.3 Project Organization for RAM

The CHSTP has established a RAMS team. RAM activities are under the responsibility of the RAM Manager. Safety is the responsibility of the Safety Manager. Both Managers work in close cooperation and hold coordination meetings on a regular basis. Safety tasks are conducted by safety specialists under the direction of the Safety Manager. RAM engineering is conducted by the various discipline engineers under the coordination and direction of the Project RAM manager.

Figure 4-1 shows the CHSTP RAMS management organization. The RAM and Safety teams have established a series of working groups to drive and coordinate the RAM and Safety activities. The RAM and Safety teams consist of the engineering, operations, systems assurance, safety, and systems integration personnel already working on the Project in their specific disciplines, managed jointly by the RAM Manager and the Safety Manager.

CHSTP RAM program management is performed by establishing an appropriate RAM organization and by conducting, coordinating, and monitoring RAM related activities.

4.4 RAM Program Responsibilities

California High-Speed Rail Authority: The Authority is responsible for the following:
- Approve and implement the CHSTP RAMS Policy
- Approve the CHSTP RAMPP
- Make agreements with third parties in shared corridors
- Monitor RAM progress in each project phase

PMT RAM Team Roles: The main roles of the PMT RAM Team are as follows:
- Develop the CHSTP RAMS Policy and RAMPP
- Define the overall KPIs and RAM targets for the project and allocate RAM requirements to the various disciplines
- Distribute the RAM allocations among the discipline subsystems
Incorporate RAM design requirements in the CHSTP Design Criteria
Coordinate RAM with other parties and establish RAM requirements for shared Systems and Infrastructure on shared corridors
Establish RAM requirements for bid specifications
Perform RAM design assessments.
Provide RAM documentation demonstrating how the RAM requirements have been appropriately distributed and specified how the various contractors will demonstrate that they have been met
Perform system integration RAM activities.

PMT RAM Manager Responsibilities: The Project RAM Manager is responsible for the following:
- Manage the RAM engineering processes
- Lead the project RAM related activities
- Work closely with the Project Safety Manager to ensure that RAM and safety activities are closely integrated
- Work closely with the Engineering and Discipline managers to ensure RAM activities are being given the correct priority and are being properly conducted
- Manage the relationships and work closely with other parties to ensure RAM performance on shared Infrastructure and Systems
- Plan for sufficient resources are brought to bear on the project to complete the RAM activities within schedule
- Issue and distribute project RAM Documentation
- Be the point of contact on all RAM matters of the project
- Monitor progress and report on the status of RAM activities

Figure 4-1: Project RAMS Organization
Section Contractors and System Suppliers: Section Contractors and System Suppliers are responsible for the following:

- Develop and implement a RAM Program in accordance with this RAMPP
- Control RAM work by subcontractors and subsystem suppliers
- Comply with RAM design standards, including the CHSTP Design Criteria
- Perform RAM design analyses
- Perform RAM V&V activities

5 Project Management Team RAM Program Activities and Deliverables

5.1 PMT RAM Program Tasks and Deliverables Overview

Project Management Team (PMT) RAM work includes the following:

- RAM Program Plan
- RAM Metrics
- RAM Design Criteria
- RAM analysis and design review of Preliminary Engineering designs
- RAM requirements for contractor and equipment supplier bid specifications
- Monitoring and evaluation of contractors and suppliers by project engineers and managers
- Coordinate RAM with other parties
- System integration RAM

5.2 RAM Program Plan

This RAMPP is a PMT RAM Program deliverable. This RAMPP provides the CHSTP RAM Program objectives, scope, requirements, organization, activities, methodologies, and deliverables.

The RAMPP implements the CHST RAM Program which will:

- Fulfill the RAM Program requirements listed above;
- Conform with EN 50126-1;
- Satisfy RAM requirements from the CSHT TM 300.05 RAMS Policy, System Requirements, Technical Memoranda, SSMP, Design Criteria, and other CHSTP requirement sources;
- Establish RAM design guidelines and criteria;
- Define scope, organization, responsibilities, tasks, deliverables, milestones, RAM requirements, RAM testing, analysis, feedback, reporting, etc., for the RAM Program.

Each Section Contractor and System Supplier must review the CHSTP RAMPP and implement the RAM actions and requirements.

5.3 RAM Metrics

The RAM Program will use metrics to plan, achieve, and document the CHSTP RAM performance. These metrics are:

- Key Performance Indicators (KPIs)
- RAM Targets.
The PMT will create the KPIs, which are high level RAM metrics, in a CHSTP RAM Metrics document. The basis for the CHSTP RAM Metrics document is RAMPP section 3.

The PMT will allocate RAM targets for each applicable contract, system, structure, and Operations and Maintenance program. The allocated RAM targets will be incorporated into the applicable procurement documents.

At each construction, procurement, and operating phase, the CHSTP will establish compatible sets of RAM targets, beginning with the civil infrastructure components constructed in the first construction package, CP01, and culminating with the full phased CHST System build-out.

The interim RAM targets will be compatible with the highly available RAM targets for the complete CHST System.

At each construction and operating phase, the CHSTP VVMP will track completion of all RAM activities.

KPIs and RAM Targets will cover events that disrupt scheduled train operations and events that impact customers such as failure of passenger information displays, elevators, and escalators.

Typical Service Critical KPIs:
- Missed station stops and missed trips
- On-time performance (delayed departure and/or arrival) for differing levels of service interruption.

Typical Rolling Stock RAM targets:
- Fleet availability
- Mean Distance Between Failure (MDBF) for differing levels of service interruption
- Mean Time To Repair (MTTR)
- MDBF for train subsystems.

Typical Infrastructure and Systems RAM Targets:
- Mean Time Between Failure (MTBF) for major, minor, and immobilizing failures
- MTTR for major and MTTR for minor service failures
- Availability of critical systems such as emergency communications and tunnel ventilation.

Typical Station RAM Targets:
- Elevator and escalator availability
- Passenger Information System availability
- Other station systems.

5.4 Design Criteria RAM

The PMT will develop system-wide RAM design requirements for the Design Criteria, covering all equipment, structures, and facilities. The RAM design requirements will be consistent with and implement the RAM-related requirements specified in:
- RAMS Policy, TM 300.05
- Euronorm and other standards cited by the RAMS Policy
- CHSTP System Requirements
- FRA regulations
The Design Criteria will include provisions necessary to achieve the CHSTP KPIs and RAM targets.

Design Criteria RAM topics will include:
- Reliability Centered Maintenance
- RAM Design, general
- RAM Design, specific per system/subsystem
- Fault Tolerance
- Accessibility
- Parts Stress Derating
- Environmental Stress Screening
- Software Reliability
- Fault Detection and Annunciation
- Infrastructure dependability

The Design Criteria will also include topics related to RAM for structures and facilities, such as:
- Accessibility
- Seismic design standards
- Flood level
- Maintainability features to prolong equipment life
- Fire Protection
- Availability
- Identification and mitigation of influences on infrastructure availability
- Repairable / replaceable during 5-hour non-revenue period
- Equipment redundancy, such as for pumps
- Design life of civil works, structures, roads, expansion joints, bearings, etc.
- Inspection and replacement plan
- Watertightness
- Drainage

5.5 RAM Design Assessment

5.5.1 CHSTP RAM Design Assessment

The PMT will perform a RAM Analysis (RA) for each CHSTP project phase. The RA will include:
- RAM metric allocation
- RAM Fault Tree Analysis (FTA)
- RAM Critical Items List

The RA results will guide RAM-related requirements and activities in the design and procurement of systems and infrastructure.

The RA will:
- Document failures and conditions which have the maximum impact
- Identify design, operating, and maintenance solutions to control the impact
- Establish RAM and fault tolerance design and procurement requirements to be tracked by the V&V process to ensure the solutions are implemented

The PMT will perform a review of the RAM Design. Design review objectives are:
- Provide feedback on the system and facility design drawings and Performance Specifications
• Identify changes needed to incorporate RAM and fault tolerance requirements
• Evaluate design-specific mitigations against RAM impacts on service and passenger provisions

At each phase, the PMT will develop a RAM Report, combining results of the RAM Analysis and the RAM Design Review for Systems and Section designs.

The preliminary engineering RA will recognize that the initial construction packages are for infrastructure only and not for systems. Therefore, the preliminary engineering RA will clearly indicate the specific provisions that must be assigned to and achieved by infrastructure contractors so that the infrastructure RAM impacts conform to the overall CHSTP KPIs.

5.6 RAM Requirements for Systems and Equipment Bid Specifications

The PMT is establishing RAM requirements and design provisions for inclusion in the Performance Specifications and Design Criteria for all systems, rolling stock, and equipment.

The system, rolling stock, and equipment RAM requirements for each affected supplier and contractor are to:
• Develop, deliver, and follow a RAM Plan
• Use and document appropriate RAM Design Criteria and methods in its equipment and construction
• Perform required RAM metric allocation, analysis, and reporting
• Perform required RAM analysis of equipment designs

The PMT will establish RAM requirements for Infrastructure and Systems shared with other parties on shared corridors. These can include bridges and guideway, and traction electrification, ATC, communications, OCS, and dispatch.

Refer to the CHSTP Design Criteria for additional System Bid RAM requirements.

5.7 RAM Requirements for Construction Bid Specifications

The PMT is establishing RAM requirements and design provisions for inclusion in the Performance Specifications and Design Criteria for all structures, facilities, and construction procurements.

The Performance Specification RAM Requirements will include requirements for each affected supplier and contractor to:
• Develop, deliver, and follow an RAM Plan
• Use and document appropriate RAM Design Criteria and methods in its equipment and construction
• Perform required RAM metric allocation, analysis, and reporting
• Perform required RAM analysis of equipment designs

Construction RAM requirements will cover:
• Design life and durability issues including:
  o Acid attack
  o Chlorides and sulfates
5.8 Coordination with Outside Owners

The PMT will perform RAM coordination with utilities and infrastructure having potential to impact or disrupt CHSTP operation. This will include coordination with outside owners of gas pipelines, bridges, utilities, adjacent railroads, local public works departments, etc.

The PMT will establish RAM requirements for Infrastructure and Systems shared with other parties on shared corridors. These can include structures such as bridges and guideway, and Systems such as traction electrification, ATC, communications, OCS, and dispatch.

As part of the RAM Analysis, PMT will perform a RAM risk assessment to identify necessary coordination activities.

5.9 Monitoring and Evaluation

The PMT will monitor and evaluate the RAM status, deliverables, and results of the contractors and suppliers during each construction, installation, integration, test, and operating phase.

The PMT will track and report on system availability in the operating phase, using the V&V process.

5.10 System Integration RAM

The PMT will develop a System-wide System Integration RAM Qualification Test Plan.

Equipment suppliers will support the System-wide System Integration RAM Qualification Test per the Bid Specification requirements. The RAM Qualification Tests will be tracked for completion under the CHST Verification and Validation program.

The Performance Specifications will require the supplier of each item subject to a RAM qualification test requirement to:

- Submit a test procedure for review and Statement of No Objection (SONO)
- Perform the test per the test procedure and the applicable CHSTP Bid Specification requirement
- Submit a test report for approval.
6 Section Contractors and System Suppliers RAM Program Activities and Deliverables

6.1 Section Contractors and System Suppliers RAM Program Overview

Table 6-1 is an overview of the RAM Program tasks and deliverables. It shows the responsibilities of the PMT, Section Contractors, and System Suppliers.

Section Contractor civil works with RAM responsibilities include:
- Bridges
- Viaducts
- Trenches
- Tunnels
- Roadbed
- Facilities

CHSTP systems with RAM responsibilities are:
- Core systems of Communications, Automatic Train Control, Traction Power, and Overhead Contact systems
- Mechanical, electrical and plumbing systems, including ventilation, fire alarms and fire suppression systems
- External utilities, such as power and communications
- Rolling stock
- Track components
- Hazard detection systems
- Operations and Maintenance

Each CHSTP Section Contractor and System Supplier must ensure that its suppliers and contractors perform all needed work to fulfill the RAMPP requirements, and that the results are recorded using the V&V process.
Table 6-1: Section Contractors and System Suppliers RAM Program Tasks and Deliverables

<table>
<thead>
<tr>
<th>No.</th>
<th>Tasks and Deliverables</th>
<th>PMT Scope</th>
<th>Contractor Scope</th>
<th>System Supplier Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CHSTP RAMPP</td>
<td>Prepare RAMPP and distribute to Section Contractors and System Suppliers</td>
<td>Review RAMPP and perform RAM work per RAMPP</td>
<td>Review RAMPP and perform RAM work per plan</td>
</tr>
<tr>
<td>2</td>
<td>Contractor and Supplier RAMPP</td>
<td>Approve supplier’s CRMPs</td>
<td>Develop and submit CRMP to PMT</td>
<td>Develop and submit CRMP to PMT</td>
</tr>
<tr>
<td>3</td>
<td>RAM Allocations</td>
<td>Approve RAM allocations</td>
<td>Develop RAM allocations. Distribute to equipment suppliers and infrastructure builders</td>
<td>Develop RAM allocations. Distribute to subsystem suppliers</td>
</tr>
<tr>
<td>4</td>
<td>Preliminary Reliability Analysis (PRA)</td>
<td>Approve PRA</td>
<td>Develop and submit PRA to CHSTP. Applies to all equipment.</td>
<td>Develop and submit PRA to CHSTP</td>
</tr>
<tr>
<td>5</td>
<td>Historical Product Maintainability Report (HPMR)</td>
<td>Approve HPMR</td>
<td>Provide HPMR to CHSTP. Applies to all equipment.</td>
<td>Provide HPMR to CHSTP</td>
</tr>
<tr>
<td>6</td>
<td>Reliability Prediction Report (RPR)</td>
<td>Approve RPR</td>
<td>Conduct Reliability Predictions and provide report to CHSTP. Provide periodic updates. Applies to all equipment.</td>
<td>Conduct Reliability Predictions and provide report to CHSTP. Provide periodic updates.</td>
</tr>
<tr>
<td>7</td>
<td>Reliability Failure Modes and Effects Analysis (FMEA)</td>
<td>Approve R-FMEA</td>
<td>Submit R-FMEA to CHSTP and provide periodic updates. Applies to all equipment.</td>
<td>Submit R-FMEA to CHSTP and provide periodic updates</td>
</tr>
<tr>
<td>8</td>
<td>Reliability Fault Tree Analyses (FTA)</td>
<td>Approve R-FTA</td>
<td>Submit R-FTA to CHSTP and provide periodic updates. Applies to all equipment.</td>
<td>Submit R-FTA to CHSTP and provide periodic updates</td>
</tr>
<tr>
<td>9</td>
<td>RCM Decision Tool Report</td>
<td>Approve RCM Reports</td>
<td>Submit RCM Report to CHSTP and provide periodic updates. Applies to all equipment.</td>
<td>Submit RCM Report to CHSTP and provide periodic updates</td>
</tr>
<tr>
<td>10</td>
<td>Corrective Maintenance Analysis (CMA)</td>
<td>Approve CMA</td>
<td>Submit CMA to CHSTP and provide periodic updates. Applies to all equipment and infrastructure.</td>
<td>Submit CMA to CHSTP and provide periodic updates</td>
</tr>
<tr>
<td>11</td>
<td>Preventive Maintenance Analysis (PMA)</td>
<td>Approve PMA</td>
<td>Submit PMA to CHSTP and provide periodic updates. Applies to all equipment and infrastructure.</td>
<td>Submit PMA to CHSTP and provide periodic updates</td>
</tr>
<tr>
<td>No.</td>
<td>Tasks and Deliverables</td>
<td>PMT Scope</td>
<td>Contractor Scope</td>
<td>System Supplier Scope</td>
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</tr>
<tr>
<td>13</td>
<td>Reliability Demonstration Test (RDT) Plan (RDTP) and Procedures</td>
<td>Approve RDTP prior to RDT</td>
<td>Submit RDTP to CHSTP. Applies to all equipment.</td>
<td>Submit RDTP to CHSTP</td>
</tr>
<tr>
<td>14</td>
<td>Reliability Demonstration Test</td>
<td>Accept test results</td>
<td>Conduct RDT per approved RCHSTP and Procedures. Correct any identified system defects. Applies to all equipment.</td>
<td>Conduct RDT per approved RCHSTP and Procedures. Correct any identified system defects.</td>
</tr>
<tr>
<td>15</td>
<td>Monthly Failure Report</td>
<td>Approve Monthly Failure Report format. Review Monthly Failure Reports.</td>
<td>Submit monthly failure reports to CHSTP. Applies to all equipment.</td>
<td>Submit monthly failure reports to CHSTP</td>
</tr>
<tr>
<td>17</td>
<td>Maintainability Demonstration (MD)</td>
<td>Select preventive and corrective maintenance tasks for MD. Approve supplier’s MDTP.</td>
<td>Submit MDTP. Perform MD as required by CHSTP. Applies to all equipment and infrastructure.</td>
<td>Submit MDTP. Perform MD as required by CHSTP.</td>
</tr>
<tr>
<td>18</td>
<td>Failure Reporting and Corrective Action System (FRACAS)</td>
<td>Approve FRACAS prior to RDT</td>
<td>Submit FRACAS to CHSTP. Applies to all equipment.</td>
<td>Submit FRACAS to CHSTP</td>
</tr>
</tbody>
</table>

Each CRMP must establish a comprehensive RAM analysis approach covering the contractor or supplier’s scope, such as diagrammed in Figure 6-1.
To assure that availability and reliability are addressed early in the design of each system, each CRMP must require the following during design:

- Analysis of service failure modes for the covered system
- Reliability Analysis for Lowest Level Replaceable Units (LLRUs) to provide LRU failure rates for the Reliability FMEA
- A Preliminary Service Failure Analysis to provide input to the Service Interruption Fault Tree Analysis and Reliability FMEA tasks, including service failure modes, causes, and potential mitigations

In the Detailed and Final Design phases, each CRMP will require a combined top-down and bottom-up approach for RAM analysis. The Reliability FTA is a top-down analysis that determines the basic events that can cause or contribute to service interruption or delay. The Reliability FMEA is a bottom-up analysis of all failure modes per LRU or component that determines effects of failures, failure annunciations, mitigations, and restoration time. The Reliability FMEA provides detailed information about equipment failure bottom events in the Reliability FTA.

Reliability FTA basic events provide required information for the Preventive Maintenance Analysis (PMA), including for equipment failures, conditions and states, and O&M errors that necessitate preventive maintenance tasks. The Reliability FMEA provides required information for the Corrective Maintenance Analysis (CMA), including LRU failure rates and time to repair.

The PMA and CMA will identify and provide information about maintenance tasks for the O&M manuals. The System Safety FTA and FMECA will provide information about safety-critical maintenance tasks; however, this is not within the RAM Program scope.

Section Contractors and System Suppliers will maintain traceability between the O&M Manuals and the PMA and CMA.

Section Contractors and System Suppliers will coordinate the RAM Program with other program tasks, such as System Safety, Security, Software Quality Assurance, Verification and Validation, User Education, O&M manuals, etc.
Table 6-2 shows the Section Contractor and System Supplier RAM approach for compliance with EN 50126-1.

### Table 6-2: CHSTP Section Contractor and System Supplier RAM Approach

<table>
<thead>
<tr>
<th>Contractor and Supplier RAM</th>
<th>Phase</th>
<th>EN 50126-1</th>
</tr>
</thead>
</table>
| RAM Program Plan (RAMPP)    | Concept | 1. Concept | Concept documentation  
|                             |        |            | RAM management structure |
|                             |        | 2. System Definition | RAM policy |
|                             |        | 3. Risk Analysis | |
| Supplier Reliability, Availability, and Maintainability Program Plans (RAMPP) | Requirements | 4. System Requirements | Detailed RAM requirements |
| RAM Allocations              |        |            | Detailed RAM Program |
| Preliminary Reliability Analysis (PRA) |        |            | |
| Historical Product Maintainability Report (HPMR) |        |            | |
| Reliability Analysis Report (RAR) |        |            | |
| Reliability Prediction Report (RPR) |        |            | |
| Reliability Failure Modes and Effects Analysis (R-FMEA) | Design | 6. Design and Implementation | Detailed RAM plans for future lifecycle phases |
| Reliability Fault Tree Analyses (R-FTA) |        |            | O&M Procedures |
| Corrective Maintenance Analysis (CMA) |        |            | |
| Preventative Maintenance Analysis (PMA) |        |            | |
| Reliability Demonstration Test Plan (RDTP) | Implementation | 7. Manufacture | Subsystem and component RAM documentation |
| Reliability Demonstration Test Procedures (RDT Procedures) |        |            | O&M procedures |
| Updated RPR |        |            | Training material |
| Updated R-FMEA |        |            | |
| Updated R-FTA |        |            | |
| Updated CMA |        |            | |
| Updated PMA |        |            | |
| Reliability Demonstration Test (RDT) | Test | 9. System validation | RAM Validation |
| Monthly Failure Report |        |            | |
| RDT Report |        |            | |
| Maintainability Demonstration (MD) |        |            | |
| Failure Reporting and Corrective Action System (FRACAS) |        |            | |

**Operation and Maintenance**

| Availability Tracking and Reporting | 11. Performance Monitoring | |
|-------------------------------------|---------------------------| |
|                                     | 12. Operation and Maintenance | |
|                                     | 13. Modification and Retrofit | |
|                                     | 14. Decommissioning and Disposal | |
6.2 Section Contractor and System Supplier RAM Program Plan

Each CHSTP Section Contractor and System Supplier must provide a Contractor RAM Program Plan (CRMP) for PMT SONO.

The CRMP must be consistent with:
- This RAMPP and EN 50126-1, Railway applications - The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS) - Part 1: Basic requirements and generic process, for the overall RAM program and for availability
- MIL-STD-785B, Reliability Program for Systems and Equipment, Development and Production, for reliability tasks
- MIL-STD-470B, Maintainability Program Requirements (For Systems and Equipment), for maintainability tasks

The CRMP must:
- Define RAM Program scope, tasks, techniques, deliverables, and milestones
- Provide a RAM Program schedule, which identifies specific tasks, with start and completion dates, and explains how these tasks are coordinated and integrated with major program milestones for design, manufacturing, and testing
- Provide the organization of personnel responsible for performing the RAM Program
- Identify RAM allocations
- State methodology to predict compliance with the RAM requirements
- Provide demonstration testing plans for verification of compliance with RAM requirements
- Describe monitoring and control of subcontractors and suppliers
- Define interfaces to and coordination with other system assurance activities such as system safety, design, procurement, and quality assurance

CHSTP Section Contractors and System Suppliers will perform the RAM work. The RAM work will include:
- Develop a detailed RAMPP
- Coordinate RAM and System Safety work
- Pass all RAM requirements down to subsystems (and/or to their suppliers)
- Design equipment per RAM requirements in contract specifications, DBM, and RAMPP
- Develop detailed RAM allocations for subsystems, assemblies, and equipment
- Perform RAM analyses for the Preliminary Design phase
- Perform RAM analyses for the Detailed and Final Design phases
- Integrate RAM design and analysis results into test planning, maintenance planning, maintenance manuals, and operating manuals
- Perform a Maintainability Demonstration
- Perform a Reliability Demonstration
- Provide a Failure Reporting and Corrective Action System (FRACAS)
- Provide all necessary reports and documentation for tracking by the V&V process

CHSTP will perform RAM design reviews and will approve all Section Contractor and System Supplier RAM work.

6.3 RAM Allocation

Each CHSTP Section Contractor and System Supplier must provide RAM allocations for equipment down to the subsystem level or lower. The CHSTP Section Contractor and System Supplier must submit
the RAM allocations for CHSTP approval. CHSTP will use the RAM allocations to assess compliance of the RAM analyses for subsystem equipment.

Subsystem RAM allocations:
- Must be consistent with contract, technical specification, and RAMPP requirements
- May be based on:
  - Historical information
  - Experience with similar equipment
  - Techniques such as Feasibility of Objective or Advisory Group on Reliability of Electronic Equipment (AGREE) Allocation Method
- Must include:
  - MTBF or MDBF, as appropriate
  - MTTR
  - MTBSF or MDBSF, as appropriate
  - MTTRS
- Must assign responsibility to equipment suppliers

Each CHSTP Section Contractor and System Supplier must provide the PMT with a RAM Allocation Report, demonstrating that the system will achieve required reliability and maintainability, for SONO review. The report will describe the basis for the RAM allocations.

6.4 Preliminary Reliability Analysis

Each CHSTP Section Contractor and System Supplier must provide a Preliminary Reliability Analysis (PRA) for CHSTP approval.

The PRA provides an initial and broad assessment of all known service failure and service interruption modes for top-level events such as minor, major, and immobilizing service interruptions. The Section and System Bid Specifications may identify specific top-level events for the PRA.

The PRA lists a preliminary statement of possible corrective actions by which the supplier will eliminate or control service failures to the levels acceptable to CHSTP.

The purpose of the PRA is to ensure that the potential service failure modes, causes, and mitigations are well understood by all parties as the design, integration, fabrication, testing, and acceptance activities move forward.

Each Section Contractor and System Supplier will use the PRA to identify and select service failures for in-depth assessment in the Fault Tree Analysis (FTA). Each Section Contractor and System Supplier will use the FTA rather than the PRA as the basis for service failure resolution tracking and maintenance task development.

Each CHSTP Section Contractor and System Supplier will provide a PRA consistent with the example in Figures 6-2, as appropriate to the contractor’s or supplier’s scope. The PRA will cover reliability failures for each mode identified in the example tables. Reliability failures may be at the system, subsystem, assembly, or LLRU level. Each CHSTP Section Contractor and System Supplier will provide a Preliminary RAM Analysis Report which summarizes the PRA results, highlight any service reliability issues, and describe next steps.
Figure 6-2: Preliminary RAM Analysis -- Minor Service Interruption Failures

<table>
<thead>
<tr>
<th>Mode</th>
<th>Cause</th>
<th>Mitigation</th>
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<tbody>
<tr>
<td></td>
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<td>Design</td>
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<td>O&amp;M Procedures</td>
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<td>Equipment Failures</td>
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<td>Software Errors</td>
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<td>Design Errors</td>
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<td>Operation Errors</td>
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<td>Maintenance Errors</td>
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</table>

Minor Service Failure requires less than 1.0 hr Time to Restore Service (TTRS).

6.5 Historical Product Maintainability Report

Each CHSTP Section Contractor and System Supplier must provide a Historical Product Maintainability Report (HPMR) for CHSTP approval. The HPMR will present RAM information based on previous applications of the equipment.

In general, the HPMR will designate each subsystem; indicate the subsystem supplier; identify previous equipment applications; demonstrate that the equipment meets the RAM allocations; describe the configuration of the subsystem, identifying any differences between the CHSTP design and previous applications; indicate the source, date, and reference contact for the historical product RAM information; and provide user certifications from the cited equipment applications.

The Section Contractors and System Suppliers will present historical maintainability information for the CHSTP equipment, including corrective maintenance summaries, MTTR, preventive maintenance task descriptions, and task time per interval information from previous equipment applications. In addition, the report will furnish details regarding any maintainability, accessibility, or interchangeability improvements or degradations related to design changes for the CHSTP. The Section Contractors and System Suppliers will provide historical scheduled preventive maintenance information consistent with the example in Figure 6-3.

Figure 6-3: Historical Preventive Maintenance Task List

<table>
<thead>
<tr>
<th>System / Subsystem / LLRU</th>
<th>Preventive Task Title</th>
<th>Task Time Per Location (Man-Hrs)</th>
<th>Task Interval (month)</th>
<th>Special Tools</th>
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Each CHSTP Section Contractor and System Supplier will provide a summary of corrective maintenance tasks performed on a given subsystem for each cited previous application of the equipment. The Section Contractors and System Suppliers will provide historical scheduled preventive maintenance information consistent with the example shown in Figure 6-4. In the summary, the Section Contractor and System Supplier will provide information including a description of the failing item, the failure mode, corrective action taken, time taken for repair, and any special tools required to facilitate the repair.

**Figure 6-4: Historical Corrective Maintenance Summary**

<table>
<thead>
<tr>
<th>System / Subsystem / LLRU</th>
<th>Failed Item</th>
<th>Failure Description</th>
<th>Corrective Action</th>
<th>Time To Repair</th>
<th>Special Tools</th>
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### 6.6 Reliability Prediction

Each CHSTP Section Contractor and System Supplier will provide a first iteration of the Reliability Prediction Report (RPR) for CHSTP's approval. Each Section Contractor and System Supplier will submit periodic RPR updates until the task is concluded. Section Contractors and System Suppliers will conduct the Reliability Prediction in accordance with IEC 60863, Presentation of reliability, maintainability, and availability predictions, and IEC 61078, Analysis techniques for dependability – Reliability block diagram method.

Each Section Contractor and System Supplier will conduct Reliability Predictions at the appropriate level of detail to ensure adequate reliability and fulfillment of the CHSTP specifications and RAMPP requirements. This may entail conducting an analysis at the subsystem, assembly, lowest level replaceable unit (LLRU), block, element, or component level, and may require combining differing analyses from different levels for a single subsystem. The System Supplier Analyst will establish the appropriate level of detail, and the System Supplier Reliability Manager will review each analysis to confirm that the detail level is appropriate.

To the extent possible, each Section Contractor and System Supplier will base Reliability Predictions on existing performance records, reliability test data, warranty and operating data, and reliability prediction analyses from previous similar projects. For equipment with incomplete or inconclusive operating, failure, and/or reliability demonstration data, the equipment supplier will develop a reliability prediction using other information sources, such as:

- MIL-HDBK-217F Notice 2
- Nonelectronic Parts Reliability Data (NPRD)
- Manufacturer test data

Each Section Contractor and System Supplier will review the prediction information, develop details about the equipment application history and service-proven design, evaluate the subsystem reliability predictions versus the subsystem reliability allocations, and prepare a RPR.
For service-proven equipment with suitable existing reliability data, the RPR will:

- Designate the subsystem equipment
- Indicate the subsystem equipment supplier
- Identify previous applications of same or similar equipment
- Describe the configuration of the subsystem equipment, identifying any differences in configuration, component or device quality, function, operating environment, stress, or other factor affecting reliability between the CHSTP design and previous applications
- Adjust the reliability prediction to accommodate the differences between the previous and CHSTP application, using MIL-HDBK-217F or similar factors to account for increased or reduced stress, component quality, etc.
- Furnish details regarding MDBF or MTBF improvements or degradations related to design changes for the CHSTP
- Indicate the sources, dates, and reference contact for the historical product information
- Demonstrate that the CHSTP equipment meets the allocated failure rate

For non-service proven equipment and/or for equipment requiring further detailed analysis, the equipment supplier will use all applicable sources of information and prediction methodology for prediction of CHSTP equipment failure rates. These include:

1. MIL-HDBK-217F Notice 2, Reliability Prediction of Electronic Equipment
2. MIL-STD-756B, Reliability Modeling and Prediction
   - Method 2001, Similar Item Method
   - Method 2002, Similar Circuit Method
   - Method 2004, Parts Count Method
3. Other well-established industrial reliability prediction databases.

For MIL-HDBK-217 predictions, the equipment suppliers will generally use factors for reliability prediction which are most applicable to the CHSTP subsystem in use under specified conditions. For example, bogie truck-mounted equipment may be rated for ground-mobile application, while car body mounted electronics may be rated for ground-fixed application. Quality, stress, construction, learning, and other factors will be applied as appropriate to the specific circuit or subsystem.

The reliability predictions will be subject to confirmation during the Reliability Demonstration Test, described below.

Each Section Contractor and System Supplier will use RPR data to establish failure rates in the Reliability FMEA.

Each Section Contractor and System Supplier will provide a summary report on Reliability Allocations and Predictions for the monthly progress meetings. The monthly report will present allocated MDBF (or MTBF) budgets, predicted MDBF (or MTBF) for each subsystem, overall predicted MDBF (or MTBF) for the system, and issues. The System Suppliers will provide the monthly reports until the Reliability Prediction task is completed.
6.7 Reliability FMEA

Each CHSTP Section Contractor and System Supplier will perform a Reliability Failure Modes and Effects Analysis (R-FMEA) in accordance with IEC 60812, Analysis techniques for system reliability – Procedures for failure mode and effects analysis, for CHSTP approval in the Detailed Design phase. Each Section Contractor and System Supplier will submit periodic R-FMEA updates until the task is concluded.

Each Section Contractor and System Supplier will perform the R-FMEAs at the lowest level replaceable unit (LLRU) level. R-FMEAs will be consistent with the example shown in Figure 6-5.

The R-FMEA:
- Provides the lowest-level analysis of failures and failure effects on the system and its subsystems and equipment.
- Identifies weaknesses in system hardware and software design and analyze failure modes and effects, particularly for when these details are not established by historical records of equipment operation.
- Uses inductive logic in a “bottom up” system analysis. This approach begins at the lowest level of the equipment under analysis and traces consequences up to the system level to determine the end effects on system performance.

**Figure 6-5: Detailed RAM Analysis -- Reliability FMEA**

<table>
<thead>
<tr>
<th>No.</th>
<th>LRU ID</th>
<th>LRU Name</th>
<th>Function</th>
<th>Failure Mode</th>
<th>Failure Rate</th>
<th>Reliability Failure Effects</th>
<th>Detection</th>
<th>Mitigation</th>
<th>Time to Repair</th>
<th>Maint. Ratio</th>
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The R-FMEA systematically analyzes each potential equipment failure mode of each LLRU, and for each failure mode, determines the modal failure rate, failure effects, means of failure detection, failure management strategies, time to repair, and maintenance ratio. (The Maintenance Ratio is the product of the Failure Rate times the Time to Repair, and is used in calculation of Mean Time to Repair).

The R-FMEA will use Failure Rates developed in the Reliability Prediction task. As necessary to distribute a failure rate among multiple failure modes, the System Supplier will use the Reliability Analysis Center (RiAC) failure mode apportionment guidelines (or similar) and/or engineering judgment.

Each System Supplier will update and review the FMEA on a periodic basis, including in conjunction with the Final Design Review, to ensure that necessary design modifications are made and that these do not introduce new service-affecting failure modes.

The R-FMEA provides:
- Identification of single failure points critical to proper system performance
- A basis for selecting the location and coverage of performance monitoring and fault sensing devices and other built-in automatic test equipment
6.8 Reliability Fault Tree Analyses

Each CHSTP Section Contractor and System Supplier will perform a Reliability Fault Tree Analysis (R-FTA) or equivalent analysis for their scope of supply. The Section Contractor and System Supplier will submit periodic R-FTA Report updates until the task is concluded. System R-FTA Reports will include fault trees and Basic Event Tables.

Each CHSTP Section Contractor and System Supplier will perform a R-FTA for each level of service interruption specified in the applicable Section or System Bid Specification.

Each CHSTP Section Contractor and System Supplier will perform the R-FTA per IEC 61025, Fault Tree Analysis. Alternately, Section Contractors and System Suppliers may perform Markov Analyses where appropriate per IEC 61165, Application of Markov Techniques.

The R-FTA is a structured, top-down deductive analysis which identifies basic faults, events, and conditions that can lead to service failures and interruptions. The top-down approach of the R-FTA uses a logic diagram to document the events and conditions leading to a service failure or interruption. It traces the causes of a service failure or interruption to the conditions and failure or combination of failures that might lead to it.

For each top-level service failure or service interruption listed in the PRA, the R-FTA shows the logical relationship between the service failure or interruption and basic events which must occur for the service failure or interruption to occur. The top-level item in the R-FTA is the service failure or interruption. The fault tree depicts the logical interrelationships of all of the lowest level events and intermediate conditions and events that lead to the service failure or interruption which is the top event of the fault tree.

Using each PRA service failure or interruption as a top-level event in a fault tree ensures that the R-FTA and following analyses investigate all significant causes, conditions, and mitigations related to the PRA service failure or interruption.

The Section Contractors and System Suppliers must develop quantitative fault trees or equivalent analysis. Basic Event failure rates must be consistent with the R-FMEA.

Steps to develop a R-FTA are:

1. **Draft R-FTA:** Starting with the PRA, develop a fault tree for each top-level event in the PRA. Develop a Basic Events Table (BET) for each Fault Tree.
2. **Submit FTA and Basic Events Table:** Provide the draft R-FTA for review and comment by CHSTP.
3. **Update R-FTA and Basic Events Table:** Based on comments from CHSTP and additional RAM analysis, provide the final, fully detailed R-FTA.

### 6.9 Reliability Centered Maintenance

Each CHSTP Section Contractor and System Supplier will utilize a Reliability-Centered Maintenance (RCM) approach to determine preventive maintenance (PM) intervals and activities. RCM is effective to:

- Minimize downtime
- Maximize reliability and availability
- Minimize Life Cycle Cost (LCC)

Maintenance requirements balance system availability, reliability, and life cycle costs. With RCM, PM tasks are based on results from:

- Reliability analyses
- Maintainability analyses
- FMECA

RCM tasks must be integrated with other project tasks, such as:

- FMECA
- LCC
- Special Tools List
- Maintainability Analyses
- Reliability Analyses
- Safety Analyses
- User Education
- Equipment Design
- Design Reviews

Each CHSTP Section Contractor and System Supplier will establish RCM program per EN 60300-3-11:2009 Dependability management – Part 3-11: Application guide – Reliability centered maintenance.

For more information about RCM, refer to:


### 6.10 Corrective Maintenance Analysis

Each CHSTP Section Contractor and System Supplier will provide a Corrective Maintenance Analysis (CMA) for CHSTP approval in the Detailed Design phase. Each Section Contractor and System Supplier will submit periodic CMA Report updates until the task is concluded.
The CMA consists of a tabular summary of subsystem and subsystem element MTTRs. The goal of the CMA is to ensure that the equipment supplied by all subsystem suppliers meets the MTTR requirements established in this RAMPP. Figure 6-8 shows a sample CMA table.

The CMA will include each LLRU. Failure rates will be per the R-FMEA. Each supplier will maintain traceability between the CMA and the Maintenance Manuals.

The Maintenance Ratio depicts the number of staff-hours of corrective maintenance per mile or hour of system operation. The Maintenance Ratio will be used in the Maintainability Prediction worksheets to linearize the MTTR quantity so that the Maintenance Ratio can be linearly summed up to the system level from the subsystem / subsystem element / LLRU level.

CMA Reports will provide the MTTR Summary tables, describe compliance with the RAM requirements and allocations, identify issues, and describe next steps.

**Figure 6-8: Detailed RAM Analysis - MTTR Summary**

<table>
<thead>
<tr>
<th>No.</th>
<th>LLRU ID</th>
<th>LLRU Name</th>
<th>Failure Rate</th>
<th>Corrective Maintenance Task</th>
<th>Maintenance Ratio</th>
<th>Time to Repair</th>
</tr>
</thead>
<tbody>
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</table>

Overall Failure Rate

Overall MTTR

Maintenance Ratio = Failure Rate * MTTR (man-hours)

MTTR = [Sum of all Maintenance Ratios] / Overall Failure Rate

The final CMA Report will demonstrate compliance with the RAM requirements established in this RAMPP.

**6.11 Preventive Maintenance Analysis**

Each CHSTP Section Contractor and System Supplier will provide a Preventive Maintenance Analysis (PMA) for CHSTP approval in the Detailed Design phase. Each Section Contractor and System Supplier will submit periodic PMA Report updates until the task is concluded.

The PMA consists of a tabular summary of subsystem and subsystem element preventive maintenance tasks. The goal of the PMA is to ensure that all preventive maintenance tasks are justified by the R-FTA and R-FMEA, and that task intervals are appropriate. Figure 6-9 shows a sample PMA table.

The PMA will address all hardware failure Basic Events from the R-FTA. Suppliers will maintain traceability between the PMA and the Maintenance Manuals, to show that the Maintenance Manuals include all tasks required by the PMA.
**Figure 6-9: Detailed RAM Analysis – Preventive Maintenance Summary**

<table>
<thead>
<tr>
<th>System / Subsystem / LLRU</th>
<th>Preventive Task Title</th>
<th>Task Time Per Location (Man-Hours)</th>
<th>Task Interval (months)</th>
<th>Task Justification</th>
<th>Special Tools</th>
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PMA Reports will provide Preventive Maintenance Summary tables, identify issues, and describe next steps. PMA Reports will also provide a summary table, organizing preventive maintenance tasks per interval, and summarizing preventive maintenance task time per interval.

CHSTP Section Contractors and System Suppliers will employ a RCM approach for determining preventive maintenance tasks. Refer to Section 6.9 for guidance on employing RCM.

### 6.12 Software Dependability Assurance

Each software supplier for CHSTP Section Contractors and System Suppliers will assure software dependability by establishing and implementing a Software Quality Assurance Program (SQAP).

The SQAP will:
- Identify, monitor and control all technical and managerial activities necessary to ensure that the software achieves the required quality
- Ensure that an audit trail is established which enables verification and validation that the SQAP activities were effectively completed.

Each software supplier will provide evidence that the SQAP activities were carried out, by submitting the documents in Table 6-9 for CHSTP approval. Each document must comply with either the Euronorm or IEEE standard in the table.

The software supplier may use existing software documentation that complies with the relevant standard. If the software documentation varies from the standard, the software supplier shall provide engineering justification for the variation.
Table 6-9: CHST Software Quality Assurance Plan Requirements

<table>
<thead>
<tr>
<th>Documentation</th>
<th>European Standard</th>
<th>IEEE Standard</th>
</tr>
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<tbody>
<tr>
<td>Software Project Management Plan</td>
<td>EN 50128 section 5</td>
<td>IEEE Std 1058-1998</td>
</tr>
<tr>
<td>Software Quality Assurance Plan</td>
<td>EN 50128 section 6.5</td>
<td>IEEE Std 730-2002</td>
</tr>
<tr>
<td>Software Configuration Management Plan</td>
<td>EN 50128 section 6.5, 6.6</td>
<td>IEEE Std 828-1998</td>
</tr>
<tr>
<td>Software Verification and Validation Plan</td>
<td>EN 50128 section 6.2, 6.3</td>
<td>IEEE Std 1012-1998</td>
</tr>
<tr>
<td>Software Verification and Validation Plan Specification</td>
<td>EN 50128 section 7.2</td>
<td>IEEE Std 830-1998</td>
</tr>
<tr>
<td>Software Design Description</td>
<td>EN 50128 section 7.3, 7.4</td>
<td>IEEE Std 1016-2009</td>
</tr>
<tr>
<td>Software Verification and Validation Report</td>
<td>EN 50128 section 6.2, 6.3</td>
<td>IEEE Std 1012-1998</td>
</tr>
<tr>
<td>Traceability</td>
<td>EN 50128 section 5.3.2.7, D.58</td>
<td>IEEE Std 1012-1998</td>
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</table>

6.13 Reliability Demonstration

In coordination with the PMT’s System-wide System Integration RAM Qualification Test Plan, each CHSTP Section Contractor and System Supplier will perform a Reliability Demonstration Test (RDT) to verify that the system meets the required reliability performance requirements when:

- Scheduled maintenance is performed in accordance with approved Maintenance Plan and Maintenance Manuals, and
- Systems are operated within the environmental limits described in the Design Basis Manual.

RDT task steps are:
1. Develop and submit the RDT plan and procedures.
2. Perform the test according to the approved plan and procedures.
3. Provide monthly failure reports during the test.
4. Provide a final test report.

The RDT will start after CHSTP’s acceptance of the section or system and continue for 24 months. All system equipment shall be included in the demonstration. If at the end of the 24 month test period the equipment has not met the reliability requirements, the System Supplier will implement design changes or modifications, as needed, to meet the reliability requirements. The test duration will be extended to ensure that the changes made result in achieving the requirements.

Each CHSTP Section Contractor and System Supplier will submit a Reliability Demonstration Test Plan (RDTP) before the Final Design Review. The RDTP will be consistent with MIL-HDBK-781. The plan will address the following to illustrate compliance with the reliability requirements:

- Plan schedule
- RDT procedures and forms for recording and submitting data
- Success-failure criteria for measuring reliability values for individual equipment items and subsystems
- Failure analysis of reported failures to identify the cause and need for corrective action
- Establish a Failure Review Board (FRB) to meet with CHSTP, as required, to determine the need and depth of failure analyses
- Change control procedures for implementing design changes
- Format and location of test records, test logs, and data records
Each CHSTP Section Contractor and System Supplier will identify a qualified reliability engineer who will oversee the Reliability Demonstration and associated activities.

CHSTP must approve the RDT plan and procedures before the RDT commences.

The RDT Procedures will include all information necessary to ensure the successful, accurate and safe performance of the RDT. The RDT Procedures will include, as required:

- Safety Precautions
- Identification of the reliability performance parameters that are verified by the test
- Scope of test (what is being tested and how many)
- Test equipment required (by model number)
- Personnel required
- Any special conditions required, including condition of the equipment under test
- Reference drawings or documents
- Clearly understood step-by-step instructions for performing the test, and test equipment set-up
- Clear pass/fail criteria, including applicable tolerances
- Data sheets to record test results, including confirmation of test equipment certification
- Raw data correlation procedures

RDT Procedures will address the following:

- Each equipment failure reported during the RDT will be classified as relevant or non-relevant failures by the Failure Review Board (FRB). The assessment will include all failures, whether occurring in or out of revenue service.

- The System Supplier will propose an organization for the FRB, consisting of representatives from the System Supplier, CHSTP operations, and CHSTP’s consultant, as appropriate. The FRB will direct subsystem supplier representatives to meet with the FRB, as required to classify failures which require specialized experience or skills.

- The procedure will describe the details of the burn-in period preceding the RDT. All equipment failures during the burn-in will be reported and recorded, but not counted in establishing reliability performance values.

- A proposed procedure for corrective action will be developed and included. The procedure will include proposed changes and appropriate supporting data. The procedure will identify a specific method for verifying the effectiveness of change(s). Credit may not be taken for time from previous failed tests, and the specified performance and other required characteristics of the equipment will not be changed to achieve reliability requirements unless approved.

- Preventive maintenance procedures specified for the equipment during the RDT will be performed by CHSTP in accordance with applicable Contract Terms and Conditions.

- System suppliers will maintain records which contain all the information necessary to calculate reliability performance for the system and major subsystems, and to verify satisfactory reliability requirements. System suppliers will provide failure records to CHSTP in hard copy and in an approved electronic format.

- System suppliers will use a Failure Reporting, Analysis and Corrective Action System (FRACAS) to track and report on system failures. The FRACAS will consist of a set of data management
tools for capturing and reporting on equipment incident data, and a set of procedures which use the data management tools. The FRACAS procedures:

- Implement key project functions of reliability demonstration and warranty administration
- Route failure information from the operating authority to System Suppliers
- Assess compliance of delivered equipment with requirements
- Provide field and operating information to equipment and project design and analysis tasks
- Assess the effectiveness of modifications to equipment in the field.

- Where system failures indicate the possibility of a non-compliant design, the FRACAS process will consist of the following activities:
  - Communication of failure information from the operating authority to System Suppliers
  - Assessment of the failure conditions, impacts, and possible causes by the System Supplier Quality Assurance and Engineering departments, and by equipment suppliers
  - Where appropriate, failure analysis by the equipment supplier
  - Corrective action by the equipment supplier
  - Once corrective action has been completed through field or factory action, verification by the System Supplier that the implemented solution is adequate and acceptable.

A chargeable failure in the RDT is defined as any relevant failure that requires repair or replacement of any subsystem or vehicle component. Chargeable failures also include intermittent failures, unverified failures, and software failures.

Non-chargeable failures in the RDT are:

- Consumable items, except for those which are not achieving their specified life
- A failure occurrence in equipment of another subsystem, due to the primary failure
- A failure of CHSTP to perform recommended preventive maintenance actions
- Vandalism or physical mistreatment at a human interface
- Failures due to an accident

The time, place, or type of service in which the system was being operated at the time of a failure will not be of any consequence. The data collection will be made throughout the Reliability Demonstration Period and continue until the test results are accepted by CHSTP.

Each CHSTP System Supplier will monitor failure mode rates during the RDT to identify system defects. System suppliers will repair, adjust, redesign or replace all affected items in the system, in the event that any single failure mode develops in any 12 month period which reaches:

- 5% of the population of an item, or
- 10% of a system

Each CHSTP Section Contractor and System Supplier will provide Monthly Failure Reports during the RDT. Each Section Contractor and System Supplier will submit the format and structure of the report to CHSTP for review and approval at least three months before system commissioning begins. Each Section Contractor and System Supplier will submit Monthly Failure Reports to CHSTP documenting the current and cumulative failure totals for the system equipment, comparing the totals to the reliability requirements.
Each CHSTP Section Contractor and System Supplier will provide a Reliability Demonstration Test Report at the conclusion of the Reliability Demonstration Test, showing that the system meets the reliability requirements.

The following general test requirements apply to the RDT:

- No test shall be considered complete until a formal test report has been received and approved by CHSTP.
- Written reports of all tests performed on the systems and their components shall be submitted within thirty (30) calendar days of test performance to CHSTP for acceptance.
- All reports shall clearly identify the equipment being tested, the date(s) of test, any conditions that may have affected results, and pass/fail status. The test record sheet shall be signed by the personnel performing and witnessing the test. All measured data shall be recorded in numeric form on the reports (not just checked off as acceptable). For the RDT, this means that the applicable support data for the RDT must be included with the RDT Report.

### 6.14 Maintainability Demonstration

In coordination with the PMT’s System-wide System Integration RAM Qualification Test Plan, each CHSTP Section Contractor and System Supplier will conduct a Maintainability Demonstration (MD) to establish the accuracy of task time estimates for the preventive and corrective maintenance tasks described in the applicable Maintenance Plan, Maintenance Procedures, and/or Maintenance Manuals. Each Section Contractor and System Supplier will perform the MD concurrent with the CHSTP personnel training program. Each Section Contractor and System Supplier will demonstrate selected servicing, preventive maintenance, troubleshooting, change out of components, corrective maintenance, and use of special tools where special emphasis, instruction, or proficiency is needed. CHSTP will notify System Suppliers which preventive and corrective maintenance tasks have been selected for the MD.

Each CHSTP Section Contractor and System Supplier will provide a Maintainability Demonstration Test Plan (MDTP) before the Final Design Review. The MDTP will be consistent with MIL-STD-471.

MDT task steps are:
1. Develop and submit the MDTP.
2. Perform the test according to the approved plan and procedures.
3. Provide a final test report.

The PMT must provide SONO review of the MDTP and procedures before the demonstration.

### 6.15 Failure Reporting and Corrective Action System

Each CHSTP Section Contractor and System Supplier will provide a Failure Reporting and Corrective Action System (FRACAS) that supports requirements of the RDT and Warranty Program. Each Section Contractor and System Supplier will submit the FRACAS for CHSTP approval before the Final Design Review. The FRACAS will be consistent with RiAC’s Reliability Toolkit: Commercial Practices Edition.

CHSTP must approve the FRACAS before commencement of the Reliability Demonstration Test.
Appendix A

RAMPP Requirements For CP01 Initial Construction Package Procurement

Per RAMPP section 5.7, the PMT is establishing RAM requirements and design provisions for inclusion in the Design Criteria for all structures, facilities, and construction procurements.

The RAM Requirements include requirements for each affected supplier and contractor to:
- Develop, deliver, and follow an RAM Plan
- Use and document appropriate RAM Design Criteria and methods in its equipment and construction
- Perform required RAM metric allocation, analysis, and reporting
- Perform required RAM analysis of equipment designs.

Construction RAM requirements will cover:
- Design life and durability issues including:
  - Acid attack
  - Chlorides and sulfates
  - Alkali
  - Carbonation
  - Watertightness
  - Wetting and drying
  - High ambient temperature
  - Stray current
  - Cast-in items and fixtures
  - Coatings
  - Water / cement ratio
  - Gas and water permeability
  - Corrosion protection
  - Fiber reinforced concrete
  - Contaminated ground.
- Maintainability and Availability requirements

The Section Contractor shall perform RAM Program tasks per this RAMPP. The Section Contractor shall provide:

1. Contractor RAM Program Plan (CRMP) per section 6.2. Include statements covering the RAM Allocation Report per section 6.3, demonstrating that the infrastructure will achieve required availability and maintainability. Describe the basis for the RAM allocations.
2. Historical Product Maintainability Report (HPMR) per section 6.5. The HPMR will present RAM information based on previous applications of the infrastructure design.
3. Reliability-Centered Maintenance (RCM) per section 6.9 to determine preventive maintenance (PM) intervals and activities for all equipment and infrastructure.
4. Corrective Maintenance Analysis (CMA) per section 6.10.
5. Preventive Maintenance Analysis (PMA) per section 6.11.
6. Maintainability Demonstration (MD) per section 6.14 to establish the accuracy of task time estimates for the preventive and corrective maintenance tasks described in the Maintenance Plan.
Appendix B

California High-Speed Train Project

Construction Package 01

Example RAM Program Plan
For Typical Avenue Bridge

Prepared by:  Contractor RAM Manager  Date
Checked by:  Contractor Design Manager  Date
Approved by:  Contractor  Date
Released by:  Project Construction Manager  Date
Reviewed by:  Project Management Oversight  Date
Reviewed by:  PMT RAM Manager  Date

<table>
<thead>
<tr>
<th>Revision</th>
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<tbody>
<tr>
<td>0</td>
<td></td>
<td>Initial Release, R0</td>
</tr>
</tbody>
</table>

Note: Signatures apply for the latest technical memorandum revision as noted above.

Prepared by
Example Bridge Contractor Corporation
Executive Summary

The California High-Speed Train Project (CHSTP) is executing a Reliability, Availability, and Maintainability (RAM) Program that ensures the RAM performance of California High-Speed Train (CHST) equipment and facilities. The CHSTP RAM Program Plan (RAMPP) specifies the CHSTP RAM program requirements, activities, and deliverables for all CHSTP participants in design and construction.

Example Bridge Contractor Corporation (EXBC) is the design build contractor for the Typical Avenue Bridge (TAB) subcontract of Construction Package 01 (CP01). This document is the EXBC Contractor RAM Program Plan (CRMP) for the TAB.

EXBC work includes:
- This EXBC TAB CRMP
- Application of CHSTP Design Criteria and methods
- EXBC RAM design analyses
- System integration RAM.

This EXBC TAB CRMP defines the TAB scope portions of the CHST RAM Program. This EXBC TAB CRMP define the scope, organization, responsibilities, tasks, deliverables, milestones, RAM requirements, RAM testing, analysis, feedback, and reporting for the TAB RAM Program.

In addition to the EXBC TAB CRMP, the EXBC RAM deliverables are:

1. RAM Allocation Report (RALR)
2. Historical Product Maintainability Report (HPMR)
3. Reliability-Centered Maintenance (RCM) task to determine preventive maintenance (PM) intervals and activities
4. Corrective Maintenance Analysis (CMA)
5. Preventive Maintenance Analysis (PMA)
6. Maintainability Demonstration (MD) to establish the accuracy of task time estimates for the preventive and corrective maintenance tasks described in the Maintenance Plan.
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1 Introduction

The California High-Speed Train Project (CHSTP) has established a Reliability, Availability, and Maintainability (RAM) Program to ensure adequate system and service availability for the California High-Speed Train (CHST) project. CHSTP developed a system-wide RAM Program Plan (RAMPP) for all CHST systems, structures, and sections, to comply with the CHSTP RAMS Program Policy in TM 300.05, RAM-related CHST System Requirements (SRs), and applicable regulatory requirements, including RAM requirements in 49 CFR 200-299. The CHSTP RAMPP guides and coordinates RAM design, analysis, test, documentation, and certification activities between all participants in the CHSTP Planning Stage and Implementation Stage.

Example Bridge Contractor Corporation1 (EXBC) is the design build contractor for the Typical Avenue Bridge (TAB) subcontract of Construction Package 01 (CP01). This document is the EXBC Contractor RAM Program Plan (CRMP) for the TAB. The EXBC TAB CRMP complies with the requirements of the CHSTP RAMPP.

EXBC’s TAB CRMP defines the TAB scope portions of the CHST RAM Program. It also defines the scope, organization, responsibilities, tasks, deliverables, milestones, RAM requirements, RAM testing, analysis, feedback, and reporting for the TAB RAM Program.

1.1 RAM Program Organization

Figure 1-1 shows the EXBC RAM program organization. See section 4 for additional information.

Figure 1-1: EXBC RAM Program Organization

1 A fictional corporation name.
1.2 RAM Program Objective

The EXBC TAB RAM Program objective is to assure adequate availability of the TAB and to prevent service disruption caused by TAB maintenance or failures, so the TAB does not in any way prevent the CHSTP from providing adequate, scheduled, dependable scheduled rail service for passengers.

To meet the RAM Program objective, this TAB CRMP specifies:

- EXBC RAM activities and deliverables
- RAM design requirements
- RAM analyses and tests to demonstrate compliance with CHSTP RAM requirements.

1.3 RAM Program Scope

The EXBC RAM program scope includes all TAB design, implementation, operation, and maintenance aspects which can affect the dependability of CHSTP passenger service.

RAM activities will be tracked, verified and validated (V&V) by the CHSTP VVMP described in TM 700.01.

1.4 RAM Program Activities

EXBC:

- Developed this TAB Contractor RAM Program Plans (CRMP) for the TAB scope of supply
- Is performing the CRMP activities and will create the required deliverables
- Will fulfill the RAM requirements per the Functional and Performance Specifications
- Will track and report on RAM task completion status and RAM issues

1.5 Reference Information

Table 1-1 identifies CHST project documents and standards for the CHSTP RAM Program.

Table 1-1: CHSTP RAM Program – Reference Project Documents and Standards

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<tr>
<th>ID</th>
<th>Issued By</th>
<th>Title</th>
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<tr>
<td>TM 300.05</td>
<td>CHSTP</td>
<td>CHSTP Reliability, Availability, Maintainability, and Safety (RAMS) Program Policy</td>
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<tr>
<td>TM 300.01</td>
<td>CHSTP</td>
<td>CHSTP Verification and Validation (V&amp;V) Program Plan</td>
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<td>CHSTP</td>
<td>CHSTP Business Plan</td>
</tr>
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<td>EN 50126-1:1999</td>
<td>CENELEC</td>
<td>Railway applications - The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS) - Part 1: Basic requirements and generic process</td>
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### 1.6 Acronyms and Abbreviations

Table 1-2 lists acronyms and abbreviations used in the RAMPP.

#### Table 1-2: Acronyms and Abbreviations

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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</thead>
<tbody>
<tr>
<td>ATC</td>
<td>Automatic Train Control</td>
</tr>
<tr>
<td>Authority</td>
<td>California High Speed Rail Authority</td>
</tr>
<tr>
<td>CDRL</td>
<td>Contract Deliverable Requirement List</td>
</tr>
<tr>
<td>CENELEC</td>
<td>European Committee for Electrotechnical Standardization</td>
</tr>
<tr>
<td>CFR</td>
<td>Code of Federal Regulations</td>
</tr>
<tr>
<td>CHST</td>
<td>California High Speed Train</td>
</tr>
<tr>
<td>CHSTP</td>
<td>California High Speed Train Project</td>
</tr>
<tr>
<td>CMA</td>
<td>Corrective Maintenance Analysis</td>
</tr>
</tbody>
</table>
### 1.7 RAM Definitions

The following definitions apply to the RAMPP.

**Availability** is the ability of the System to be in a state to perform a required function under specified conditions over a specified time interval assuming that the required external resources are provided.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP01</td>
<td>Initial Construction Package</td>
</tr>
<tr>
<td>CRMP</td>
<td>Contractor RAM Program Plan</td>
</tr>
<tr>
<td>DBM</td>
<td>Design Basis Manual</td>
</tr>
<tr>
<td>EMU</td>
<td>Electric multiple unit</td>
</tr>
<tr>
<td>EN</td>
<td>Euro Norm</td>
</tr>
<tr>
<td>EXBC</td>
<td>Example Bridge Contractor Corporation</td>
</tr>
<tr>
<td>FRA</td>
<td>Federal Railroad Administration</td>
</tr>
<tr>
<td>FRB</td>
<td>Failure Review Board</td>
</tr>
<tr>
<td>HPMR</td>
<td>Historical Product Maintainability Report</td>
</tr>
<tr>
<td>IOS</td>
<td>Initial Operation Section</td>
</tr>
<tr>
<td>KPI</td>
<td>Key Performance Indicator</td>
</tr>
<tr>
<td>LLRU</td>
<td>Lowest Level Replaceable Unit</td>
</tr>
<tr>
<td>LRU</td>
<td>Line Replaceable Unit</td>
</tr>
<tr>
<td>MD</td>
<td>Maintainability Demonstration</td>
</tr>
<tr>
<td>MDTP</td>
<td>Maintainability Demonstration Test Plan</td>
</tr>
<tr>
<td>MEP</td>
<td>Mechanical, Electrical, and Plumbing</td>
</tr>
<tr>
<td>mph</td>
<td>miles per hour</td>
</tr>
<tr>
<td>MRTT</td>
<td>Mean Repair Travel Time</td>
</tr>
<tr>
<td>MTTR</td>
<td>Mean Time To Repair</td>
</tr>
<tr>
<td>MTTRS</td>
<td>Mean Time To Restore Service</td>
</tr>
<tr>
<td>NTP</td>
<td>Notice to Proceed</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>Operations and Maintenance</td>
</tr>
<tr>
<td>OCS</td>
<td>Overhead Contact System</td>
</tr>
<tr>
<td>PE4P</td>
<td>Preliminary Engineering For Procurement</td>
</tr>
<tr>
<td>PM</td>
<td>Preventative Maintenance</td>
</tr>
<tr>
<td>PMA</td>
<td>Preventive Maintenance Analysis</td>
</tr>
<tr>
<td>RAM</td>
<td>Reliability, Availability, and Maintainability</td>
</tr>
<tr>
<td>RAMPP</td>
<td>Reliability, Availability, and Maintainability Program Plan</td>
</tr>
<tr>
<td>RAMS</td>
<td>Reliability, Availability, Maintainability, and Safety</td>
</tr>
<tr>
<td>RALR</td>
<td>Reliability Allocation Report</td>
</tr>
<tr>
<td>RCM</td>
<td>Reliability Centered Maintenance</td>
</tr>
<tr>
<td>RiAC</td>
<td>Reliability Analysis Center</td>
</tr>
<tr>
<td>TAB</td>
<td>Typical Avenue Bridge</td>
</tr>
<tr>
<td>TPS</td>
<td>Traction Power System</td>
</tr>
<tr>
<td>V&amp;V</td>
<td>Verification and Validation</td>
</tr>
<tr>
<td>VVMP</td>
<td>Verification and Validation Management Plan</td>
</tr>
</tbody>
</table>
Corrective Maintenance is the non-scheduled maintenance carried out after failure recognition, whose purpose is to restore the System so it can perform its required function.

Down Time is a time interval during which the System is in a down state, e.g. is not able to perform its required function. Down time consists of administrative and logistics delay time and time to restore the System.

An Immobilizing Failure is a failure which affects a CHSTP element and fulfills any of the following:
- It causes or could cause more than one train to be delayed longer than a Threshold Delay Time;
- It causes more than one train to run in a more restrictive operating mode than would have otherwise been the case in its absence.

Maintenance is the combination of all technical and administrative actions, including supervision actions, intended to retain the System in, or restore it to, a state in which it is able to perform the required function.

Mean Time To Restore (MTTR) is the average of the System Down Time that includes time to troubleshoot and fault isolate a failure, remove and replace/repair faulty items, and perform functional check out to verify restoration to operational status, and excludes administrative and logistics delay.

A Minor Failure is a failure which affects a CHSTP element and is neither an Immobilizing Failure nor the Service Failure.

Preventive Maintenance is the scheduled maintenance carried out at pre-determined intervals or according to prescribed criteria whose purpose is to minimize disruption of revenue service.

The RAM Program is a documented set of scheduled activities, resources and events serving to implement the organizational structure, responsibilities, procedures, activities, capabilities and resources that together ensure that the CHSTP will achieve its RAM requirements.

A Service Failure is a failure which affects a CHSTP element and fulfills any of the following:
- It causes or could cause one train to be delayed longer than the threshold delay time;
- It causes one train to run in a more restrictive operating mode than would have otherwise been the case in its absence.

The System Lifecycle consists of all activities which occur from first System planning phase, through the development, implementation, operation and maintenance until the final decommissioning and disposing of the System.

The Threshold Delay Time is a maximum delay time in which a train is not considered delayed.

Up Time is a time interval during which the System is in an up state, e.g., fully performs its required function.
2 RAM Program Requirements

2.1 CHSTP RAM Program Requirements

CHSTP document TM 300.05, Technical Memorandum, CHSTP Reliability, Availability, Maintainability, and Safety (RAMS) Program Policy, establishes the project level RAM requirements.

The Federal Railroad Administration (FRA) regulates the safety of U.S. railroads through the Code of Federal Regulations (CFR). 49 CFR 236 for signaling systems, microprocessor based systems and Positive Train Control, and 49 CFR 229 for Locomotive Safety Standards require both qualitative and quantitative safety and RAM analysis and assessments to be conducted, therefore the CHSTP RAM Program must develop failure rates for use in the safety and RAM analyses and assessments.

RAM requirements identified in the System Requirements task are incorporated in the TM 300.05 RAMS Policy.

2.2 Typical Avenue Bridge RAM Program Requirements

2.2.1 Special Provisions

CP01 RFP No. HSR 11-16, Book 2, Part A, Special Provisions (SP), section 14 provides RAM requirements for CP01, including for the TAB.

SP 14.3 states that “the availability of the Work during the operating hours of the railroad for the duration of its design life shall be 100%. The Contractor shall identify the influences on the availability of the Work and shall demonstrate that these influences have been mitigated.”

SP 14.4 states that “The Contractor shall provide the Work to minimize preventive and corrective maintenance requirements. The Contractor shall ensure that all required maintenance can be completed within the five (5) hour maintenance window of non-revenue time.

Components which have a shorter design/service life than the whole subsystem, this includes bridge bearings and expansion joints, shall be replaceable or maintainable within the five (5) hour maintenance window of non-revenue time. The contractor shall conduct all the necessary analysis and submit the report to identify if there is any other similar element which is part of the Work.

The contractor shall assure and demonstrate these requirements as per the Contractor’s Maintainability Program Plan, and Contractor’s Maintainability Demonstration Plan and Procedures and demonstrate verification through the Contractor’s Maintainability Demonstration Report as outlined in the RAMPP.”

Therefore, for the design life of the TAB, all TAB maintenance activities which require CHST track access or which have the potential to interfere with CHST operations must be structured, provisioned, and demonstrated to be performed in a maintenance window of five hours duration.
2.2.2 Scope of Work

CP01 RFP No. HSR 11-16, Book 2, Part C: Scope of Work (SOW) section 5.17, Maintainability states: “The following additional maintainability requirements shall be ensured in the design and construction:

- Accessibility – This includes inspection points, hatches, doors, swing out racks, quick release covers and similar features aimed at providing rapid access to equipment and structural elements which requires routine maintenance inspection, cleaning or replacement (such as gratings and filters), without the need for special tools or equipment. Contractor shall ensure ease of access for inspections and for the replacement of components that can be relatively easily replaced.

Other accessibility issues will include physical access into confined spaces, access that does not require dismantling of components and structures, access that minimizes a need for the isolation of the OCS wherever possible, and the maximizing of access and repair activities that require less than five hours to include the set-up of equipment, including scaffolding and lifting platforms in order to conduct inspections and repair replaceable elements, and necessary final inspections and tests that will allow the return of the works to operational status.

Components which have a shorter design/service life than the whole subsystem, this includes bridge bearings and expansion joints, shall be replaceable or maintainable within the five hour maintenance window of non-revenue time. Contractor shall conduct all the necessary analysis to identify if there is another similar element which is part of the structure. Contractor shall assure and demonstrate these requirements as per the Maintainability Demonstration Plan and Procedures and demonstrate verification through the Maintainability Demonstration Report.

Special attention shall be given to avoiding the need to access the underside of bridges and viaducts directly above the tracks given the proximity of the future high voltage OCS, including feeder and static wires and the supporting poles, portals, and headspans. Inspection access shall avoid to the maximum extent possible the need for special equipment, the isolation of OCS, and the occupation of the tracks themselves.

Access shall not require the removal and/or deconstruction of any part of the works in order to inspect bearings, expansion joints and other sensitive elements of the structures that require inspection as part of the regular preventive maintenance program.

Necessity for isolation of the OCS and/or tracks for passenger and work train operations to perform maintenance activities shall be minimized.

Visible fault indicators shall be provided to assist in the physical monitoring or repair of structural elements and equipment.

Handling provisions shall be facilitated - this may include provisions such as lifting lugs for removal/replacement of heavy items or assemblies, fork-lift compatibility and lifting limitations for manual handling.

- Adjustment and Alignment – Provisions shall be made to allow for adjustment or alignment of equipment such that it can be done with no isolation or occupation of the future operating tracks.”
2.2.3 RAM Targets

The allocated RAM budgets for the TAB are:

- MTBF: No failure or condition of the TAB can occur which can affect passenger service or make the TAB unavailable.

- Maintainability TAB maintenance requiring track access or potentially interfering with CHST operations shall require no more than \{insert appropriate number here\} consecutive five-hour maintenance windows and no more than \{insert appropriate number here\} five-hour maintenance windows per calendar year, averaged over all the maintenance tasks performed in the TAB design life.

3 RAM Assurance Concept

3.1 CHSTP RAM Assurance Overview

CHSTP document TM 300.05, Technical Memorandum, CHSTP Reliability, Availability, Maintainability, and Safety (RAMS) Program Policy, established that the CHSTP will establish and achieve RAM goals, objectives, key performance indicators (KPIs), and RAM targets by implementing a RAM program per EN 50126-1, Railway applications - The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS) - Part 1: Basic requirements and generic process. EN 50126-1 is an internationally proven basis for RAM assurance in high speed train projects.

CHSTP established a system-wide RAMPP to implement the RAM Program for all CHSTP sections and systems. This system-wide RAMPP complies with EN 50126-1.

RAM work by Section Contractors including the CP01 Contractor includes:

- Establish Section RAM Programs
- Allocate RAM
- Perform RAM analyses in all engineering phases
- Perform RAM tests
- Provide Failure Reporting and Corrective Action System (FRACAS)
- Integrate RAM with system safety, O&M, manuals, V&V, and other
- Apply Reliability Centered Maintenance (RCM) design.

The CHSTP applied EN 50126-1 processes for Infrastructure. Infrastructure elements must comply with federal, state and local codes for construction and RAM program requirements to ensure fitness for purpose and required safety and availability. In addition, Infrastructure design criteria and specific requirements ensure that maintainability needs are compatible with CHSTP operating constraints, including accessibility for inspection, preventative maintenance, and other activities.

The CHSTP system-wide RAM program established quantified and measurable Key Performance Indicators (KPIs) and RAM targets for the complete CHSTP. The CHSTP RAM team established RAM targets for the project as a whole and developed a RAM model. Compatible targets are allocated to each contract, system, and discipline. Each party uses these targets to distribute RAM allocations to structures.
and subsystems within the party. These RAM allocations are included in the performance specification and procurement documents.

For each procurement, construction, and operating phase, the CHSTP is establishing a compatible set of RAM targets. The first set applies to the civil infrastructure components constructed in this first construction package, CP01. The final compatible set will apply to the full phased CHSTP buildout.

At each construction and operating phase, the CHSTP VVMP will track completion of all RAM activities.

The CHSTP will use a Reliability Centered Maintenance (RCM) approach.

### 3.2 TAB RAM Approach

The TAB RAM approach is as follows:

1) Design the TAB to achieve the RAM allocations:

- **MTBF:** No failure or condition of the TAB can occur which can affect passenger service or make the TAB unavailable.

- **Maintainability** TAB maintenance requiring track access or potentially interfering with CHST operations shall require no more than \{insert appropriate number here\} consecutive five-hour maintenance windows and no more than \{insert appropriate number here\} five-hour maintenance windows per calendar year, averaged over all the maintenance tasks performed in the TAB design life.

2) TAB design provisions will conform to CHSTP Design Criteria requirements, including for:

- Design life and durability issues including:
  - Acid attack
  - Chlorides and sulfates
  - Alkali
  - Carbonation
  - Watertightness
  - Wetting and drying
  - High ambient temperature
  - Stray current
  - Cast-in items and fixtures
  - Coating reinforcement
  - Water / cement ratio
  - Gas and water permeability
  - Corrosion protection
  - Fiber reinforced concrete
  - Contaminated ground.

- Maintainability and Availability requirements.
3) Perform analyses per this TAB CRMP.

1. **RAM Allocation Report** (RALR) per CRMP section 5. The RALR shows the total allocation of failures and maintenance resources to the TAB, and allocates RAM budgets to TAB elements, suppliers, and subcontractors.

2. **Historical Product Maintainability Report** (HPMR) per CRMP section 5.5. The HPMR will present RAM information based on similar previous bridge applications.

3. **Reliability-Centered Maintenance** (RCM) per CRMP section 5.9 to determine preventive maintenance (PM) intervals and activities for all equipment and infrastructure.

4. **Corrective Maintenance Analysis** (CMA) per section 6.10.

5. **Preventive Maintenance Analysis** (PMA) per section 6.11.

6. **Maintainability Demonstration** (MD) per section 6.14 to establish the accuracy of task time estimates for the preventive and corrective maintenance tasks described in the Maintenance Plan.

4) Provide analysis results and reports to the CHSTP PMT for review, analysis, acceptance, and for V&V tracking.

4 **CHST Project Description**

4.1 **Project Overview**

The full CHST System will span approximately 800 route miles and will provide intercity travel in California between the major metropolitan centers of Sacramento, the San Francisco Bay Area, the Central Valley, Los Angeles, the Inland Empire, Orange County, and San Diego. The CHST System will be a state-of-the-art, electrically powered, high-speed, steel-wheel-on-steel-rail technology, including state-of-the-art safety, signaling, and train-control systems.

The CHST System will operate primarily on dedicated track. The CHST System route will be constructed at-grade, in open trench, in tunnels, or on elevated guideway, depending on the terrain and physical constraints encountered. Extensive portions of the CHST System may lie within, or adjacent to, existing rail or highway rights-of-way to reduce potential environmental impacts and minimize land acquisition costs.

CHST trains will run at up to 220 mph on a fully grade-separated alignment, with a trip time objective from San Francisco to Los Angeles of two hours and forty minutes. The alignment will be designed for a maximum design speed of 250 mph, where feasible and practicable. The CHST System will interface with commercial airports, mass transit, and the highway network. As the CHST System and sections are developed, updated, and refined, ridership data will be used to confirm desired system capacity, service levels and frequency of service, and operating plans. The CHSTP authorizing legislation calls for San Francisco-Los Angeles Union Station in two hours 40 minutes.
4.2 Typical Avenue Bridge Overview

The Typical Avenue Bridge Overview comprises the following: {insert narrative that provides details as to location, scope, and other pertinent details.}

4.3 CHSTP RAM Program Schedule

The CHSTP RAM schedule is coordinated with the implementation steps defined by the CHSTP Business Plan:

1. Early Investments/statewide benefits
   - The first construction segment (Contract packages - CP01 through CP4 and track and systems contract packages)
   - Northern California Unified Service (The first construction segment of the IOS will be put into use immediately upon completion for improved service on the San Joaquin intercity line)
   - Improve service in the “bookends;” Caltrain in the San Francisco peninsula area and Metrolink in the Los Angeles Metro area
   - Electrify the Caltrain corridor
2. Initial High-Speed Rail Operations
3. The Bay to Basin System
4. The Phase 1 System – San Francisco to Los Angeles
5. The Phase 2 System – extensions to San Diego and Sacramento.

The Step 1 – Early Investments / Statewide Benefits step includes initial civil construction packages CP01, CP2, CP3, and CP4, and procurement of track and systems.

The first construction of dedicated high-speed infrastructure for the IOS begins in the Central Valley. Amtrak may operate on the new high-speed tracks, but without impacting the design or integrity of the CHSTP infrastructure. Improved passenger rail service over the CHSTP track would begin upon completion of the first IOS segment by connecting the San Joaquin service, ACE, Sacramento Regional Transit, the Capitol Corridor (and potentially Caltrain). Through a new, strategic approach, there is also the opportunity for new or improved travel between Bakersfield and Sacramento, Oakland, San Jose, and San Francisco. This expanded Northern California Unified Service could begin operation as early as 2018.

Step 1 CHSTP RAM activities include:

- PMT develops the CHSTP RAMS Policy and RAMPP
- PMT establishes system-wide KPIs and compatible RAM Targets
- PMT allocates system-wide KPIs and RAM Targets to initial construction packages
- PMT incorporates RAM design requirements in the CHSTP Design Criteria
- PMT and Section Designers coordinate RAM with other parties and establish RAM requirements for shared Systems and Infrastructure on shared corridors
- PMT establishes RAM requirements for bid specifications
- PMT monitors and evaluates RAM work performed by Section Contractors and System Suppliers
- PMT performs system integration RAM activities
• Each contractor performs specific RAM activities required in the RAM project scope for that contract

See the CHSTP RAMPP for other project steps.

4.4 CHSTP RAM Project Organization

4.4.1 CHSTP RAMS Team

The CHSTP has established a RAMS team. RAM activities are under the responsibility of the RAM Manager. Safety is the responsibility of the Safety Manager. Both Managers work in close cooperation and hold coordination meetings on a regular basis. Safety tasks are conducted by safety specialists under the direction of the Safety Manager. RAM engineering is conducted by the various discipline engineers under the coordination and direction of the Project RAM manager.

Figure 4-1 shows the CHSTP RAMS management organization. The RAM and Safety teams have established a series of working groups to drive and coordinate the RAM and Safety activities. The RAM and Safety teams consist of the engineering, operations, systems assurance, safety, and systems integration personnel already working on the Project in their specific disciplines, managed jointly by the RAM Manager and the Safety Manager.

CHSTP RAM program management is performed by establishing an appropriate RAM organization and by conducting, coordinating and monitoring RAM related activities.

4.4.2 CHSTP RAM Program Responsibilities

PMT RAM Team Roles. The main roles of the PMT RAM Team are the following:

• Define the overall KPIs and RAM targets for the project and allocate RAM requirements to the various disciplines
• Distribute the RAM allocations among the discipline subsystems
• Guide and coordinate the Engineering Team to ensure that RAM requirements are properly accounted for and that these requirements are conveyed into the Design Criteria and the functional and performance specifications
• Provide RAM documentation demonstrating how the RAM requirements have been appropriately distributed and specified how the various contractors will demonstrate that they have been met
PMT RAM Manager Responsibilities. The Project RAM Manager is responsible for the following:

- Manage the RAM engineering processes
- Lead the project RAM related activities
- Work closely with the Project Safety Manager to ensure that RAM and safety activities are closely integrated
- Work closely with the Engineering and Discipline managers to ensure RAM activities are being given the correct priority and are being properly conducted
- Manage the relationships and work closely with other parties to ensure RAM performance on shared Infrastructure and Systems
- Ensure sufficient resources are brought to bear on the project to complete the RAM activities within schedule
- Issue and distribute project RAM Documentation
- Be the point of contact on all RAM matters of the project
- Monitor progress and report on the status of RAM activities

California High-Speed Rail Authority. The Authority is responsible for the following:

- Approve and implement the CHSTP RAMS Policy
- Approve the CHSTP RAMPP
- Make agreements with third parties in shared corridors
- Monitor RAM progress in each project phase
4.4.3 Section Contractors

Section Contractors are responsible for the following:
- Develop and implement a RAM Program in accordance with this RAMPP
- Control RAM work by subcontractors and subsystem suppliers
- Comply with RAM design standards, including the CHSTP Design Criteria
- Perform RAM design analyses
- Perform RAM V&V activities

4.5 Typical Avenue Bridge RAM Program Organization

Figure 4-1 shows the EXBC RAM program organization.

(In this section, insert text to describe organizational relationships, organization of prime and sub contractors. Also introduce key roles and key personnel.)

Figure 4-1: EXBC RAM Program Organization
5 Example Bridge Contractor Corporation RAM Program Activities and Deliverables

5.1 Third Avenue Bridge RAM Program Overview

Table 5-1 is an overview of the TAB RAM Program tasks and deliverables. It shows the responsibilities of the CHSTP, CP01 Contractor, and EXBC.

EXBC and its subcontractors and suppliers must perform all needed work to fulfill the CRMP requirements.

Table 5-1: Section Contractors and EXBC RAM Program Tasks and Deliverables

<table>
<thead>
<tr>
<th>No.</th>
<th>Tasks and Deliverables</th>
<th>CHSTP Scope</th>
<th>CP01 Contractor Scope</th>
<th>EXBC Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CHSTP RAMPP</td>
<td>Prepare RAMPP and distribute to Section Contractors and System Suppliers.</td>
<td>Review RAMPP and perform RAM work per RAMPP.</td>
<td>Review RAMPP and perform RAM work per plan.</td>
</tr>
<tr>
<td>2</td>
<td>Contractor and Supplier RAMPP</td>
<td>Approve supplier CRMPs.</td>
<td>Develop CP01 Contractor CRMP and submit to PMT.</td>
<td>Develop and submit TAB CRMP to PMT.</td>
</tr>
<tr>
<td>4</td>
<td>Preliminary Reliability Analysis (PRA)</td>
<td>Approve PRA.</td>
<td>Develop and submit PRA to CHSTP. Applies to all equipment.</td>
<td>Not applicable</td>
</tr>
<tr>
<td>5</td>
<td>Historical Product Maintainability Report (HPMR)</td>
<td>Approve HPMR.</td>
<td>Provide HPMR to CHSTP. Applies to all equipment.</td>
<td>Provide HPMR to CHSTP.</td>
</tr>
<tr>
<td>6</td>
<td>Reliability Prediction Report (RPR)</td>
<td>Approve RPR.</td>
<td>Conduct Reliability Predictions and provide report to CHSTP. Provide periodic updates.</td>
<td>Not applicable</td>
</tr>
<tr>
<td>7</td>
<td>Reliability Failure Modes and Effects Analysis (FMEA)</td>
<td>Approve R-FMEA.</td>
<td>Submit R-FMEA to CHSTP and provide periodic updates. Applies to all equipment.</td>
<td>Not applicable</td>
</tr>
<tr>
<td>8</td>
<td>Reliability Fault Tree Analyses (FTA)</td>
<td>Approve R-FTA.</td>
<td>Submit R-FTA to CHSTP and provide periodic updates. Applies to all equipment.</td>
<td>Not applicable</td>
</tr>
<tr>
<td>No.</td>
<td>Tasks and Deliverables</td>
<td>CHSTP Scope</td>
<td>CP01 Contractor Scope</td>
<td>EXBC Scope</td>
</tr>
<tr>
<td>-----</td>
<td>------------------------</td>
<td>-------------</td>
<td>-----------------------</td>
<td>------------</td>
</tr>
<tr>
<td>9</td>
<td>RCM Decision Tool Report</td>
<td>Approve RCM Reports.</td>
<td>Submit RCM Report to CHSTP and provide periodic updates. Applies to all equipment.</td>
<td>Not applicable</td>
</tr>
<tr>
<td>10</td>
<td>Corrective Maintenance Analysis (CMA)</td>
<td>Approve CMA.</td>
<td>Submit CMA to CHSTP and provide periodic updates. Applies to all equipment and infrastructure.</td>
<td>Submit CMA to CHSTP and provide periodic updates.</td>
</tr>
<tr>
<td>11</td>
<td>Preventive Maintenance Analysis (PMA)</td>
<td>Approve PMA.</td>
<td>Submit PMA to CHSTP and provide periodic updates. Applies to all equipment and infrastructure.</td>
<td>Submit PMA to CHSTP and provide periodic updates.</td>
</tr>
<tr>
<td>12</td>
<td>Software Dependability Assurance</td>
<td>Approve Software Quality Program plans and documentation.</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>13</td>
<td>Reliability Demonstration Test (RDT) Plan (RDTP) and Procedures</td>
<td>Approve RDTP prior to RDT.</td>
<td>Submit RDTP to CHSTP. Applies to all equipment.</td>
<td>Not applicable</td>
</tr>
<tr>
<td>14</td>
<td>Reliability Demonstration Test</td>
<td>Accept test results.</td>
<td>Conduct RDT per approved RCHSTP and Procedures. Correct any identified system defects. Applies to all equipment.</td>
<td>Not applicable</td>
</tr>
<tr>
<td>15</td>
<td>Monthly Failure Report</td>
<td>Approve Monthly Failure Report format. Review Monthly Failure Reports.</td>
<td>Submit monthly failure reports to CHSTP. Applies to all equipment.</td>
<td>Not applicable</td>
</tr>
<tr>
<td>17</td>
<td>Maintainability Demonstration (MD)</td>
<td>Select preventive and corrective maintenance tasks for MD. Approve supplier’s MDTP.</td>
<td>Submit MDTP. Perform MD as required by CHSTP. Applies to all equipment and infrastructure.</td>
<td>Submit MDTP. Perform MD as required by CHSTP.</td>
</tr>
<tr>
<td>18</td>
<td>Failure Reporting and Corrective Action System (FRACAS)</td>
<td>Approve FRACAS prior to RDT.</td>
<td>Submit FRACAS to CHSTP. Applies to all equipment.</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>
The EXBC TAB CRMP establishes a comprehensive RAM analysis approach covering the EXBC scope. The EXBC RAM program includes all applicable elements of the RAM work shown in Figure 5-1, RAM Analysis Flow Diagram, from the CHSTP RAMPP.

**Figure 5-1: RAM Analysis Flow Diagram**

![RAM Analysis Flow Diagram](image)

The applicable EXBC elements are the PMA and CMA.

The TAB RAM allocations do not allow any failures during the bridge design life, and the TAB design and design analysis will document that the possibility of any failure is precluded. Accordingly, failure impact analysis is not part of the TAB RAM program.

The PMA and CMA will identify and provide information about maintenance tasks for the O&M manuals. EXBC will maintain traceability between the O&M Manuals and the PMA and CMA.

EXBC will coordinate the RAM Program with System Safety, Security, Verification and Validation, User Education, and O&M manuals.

### 5.2 TAB Contractor RAM Program Plan

This document is the required TAB Contractor RAM Program Plan (CRMP). It is submitted for CHSTP approval.

This TAB CRMP is consistent with:

- The CHSTP RAMPP and EN 50126-1, Railway applications - The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS) - Part 1: Basic requirements and generic process, for the overall RAM program and for availability
- MIL-STD-785B, Reliability Program for Systems and Equipment, Development and Production, for reliability tasks
- MIL-STD-470B, Maintainability Program Requirements (For Systems and Equipment), for maintainability tasks.

The TAB CRMP:
- Defines the TAB RAM Program scope, tasks, techniques, deliverables, and milestones
- Provide a RAM Program schedule, which identifies specific tasks, with start and completion dates, and explains how these tasks are coordinated and integrated with major program milestones for design, manufacturing, and testing
- Provide the organization of personnel responsible for performing the RAM Program
- Identify RAM allocations
- State methodology to predict compliance with the RAM requirements
- Provide demonstration testing plans for verification of compliance with RAM requirements
- Describe monitoring and control of subcontractors and suppliers
- Define interfaces to and coordination with other system assurance activities such as system safety, design, procurement, and quality assurance

EXBC is performing the RAM work. The RAM work will include:
- Develop a detailed RAMPP
- Coordinate RAM and System Safety work
- Pass all RAM requirements down to subsuppliers
- Design structures per RAM requirements in contract specifications, DBM, and RAMPP
- Develop detailed RAM allocations for subsystems, assemblies, and equipment
- Perform RAM analyses for the Preliminary Design phase
- Perform RAM analyses for the Detailed and Final Design phases
- Integrate RAM design and analysis results into test planning, maintenance planning, maintenance manuals, and operating manuals
- Perform a Maintainability Demonstration
- Provide all necessary reports and documentation

CHSTP will perform RAM design reviews and will approve all Section Contractor and System Supplier RAM work.

5.3 RAM Allocation

EXBC will provide RAM allocations for all TAB elements, including those provided by suppliers or subcontractors.

The TAB RAM allocations are:

- MTBF: No failure or condition of the TAB can occur which can affect passenger service or make the TAB unavailable.

- Maintainability TAB maintenance requiring track access or potentially interfering with CHST operations shall require no more than [insert appropriate number here] consecutive five-hour maintenance windows and no more than [insert appropriate number here] five-hour maintenance windows per calendar year, averaged over all the maintenance tasks performed in the TAB design life.
Accordingly, suballocation of RAM targets consists of allocating maintenance window intervals for preventative maintenance, over the design life of the TAB.

EXBC will provide a RAM Allocation Report (RALR), demonstrating that the TAB will achieve the required reliability and maintainability. The RALR will describe the basis for the RAM allocations.

5.4 Historical Product Maintainability Report

EXBC will provide a Historical Product Maintainability Report (HPMR) for CHSTP approval. The HPMR will present RAM information based on previous similar bridge applications.

The TAB HPMR will designate each bridge scope element; indicate the supplier or subcontractor if appropriate; identify previous applications; demonstrate that the equipment meets the RAM allocations; describe the element configuration, identifying any differences between the TAB design and previous applications; indicate the source, date, and reference contact for the historical product RAM information; and provide user certifications from the cited equipment applications.

The TAB HPMR will present historical maintainability information for the TAB bridge configuration, including corrective maintenance summaries if any, MTTR, preventive maintenance task descriptions, and task time per interval information from previous equipment applications. In addition, the report will furnish details regarding any maintainability, accessibility, or interchangeability improvements or degradations related to design changes for the CHST project.

The TAB HPMR will provide historical scheduled preventive maintenance information consistent with the Figure 5-2 example.

**Figure 5-2: Historical Preventive Maintenance Task List**

<table>
<thead>
<tr>
<th>System / Subsystem / LLRU</th>
<th>Preventive Task Title</th>
<th>Task Time Per Location (Man-Hrs)</th>
<th>Task Interval (month)</th>
<th>Special Tools</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

The TAB HPMR will provide a summary of corrective maintenance tasks performed on bridge elements for each cited previous application of the equipment. The TAB HPMR will provide historical scheduled preventive maintenance information consistent with the 5-3 example. In the summary, the TAB HPMR will provide information including a description of the failing item, the failure mode, corrective action taken, time taken for repair, and any special tools required to facilitate the repair.

**Figure 5-3: Historical Corrective Maintenance Summary**

<table>
<thead>
<tr>
<th>System / Subsystem / LLRU</th>
<th>Failed Item</th>
<th>Failure Description</th>
<th>Corrective Action</th>
<th>Time To Repair</th>
<th>Special Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>
5.5 Corrective Maintenance Analysis

EXBC will provide a Corrective Maintenance Analysis (CMA) for CHSTP approval in the Detailed Design Phase. EXBC will submit periodic CMA Report updates until the task is concluded.

The CMA consists of a tabular summary of TAB element MTTRs. The goal of the CMA is to ensure that the TAB elements meet the allocated MTTR requirements. Figure 5-4 is an example of a CMA table.

The CMA will include each element or LLRU. Failure rates will be per the HPMR. EXBC will maintain traceability between the CMA and the Maintenance Manuals.

The Maintenance Ratio depicts the number of staff-hours of corrective maintenance per calendar hour. The Maintenance Ratio will be used in the Maintainability Prediction worksheets to linearize the MTTR quantity so that the Maintenance Ratio can be linearly summed up to the system level for all elements.

CMA Reports will provide the MTTR Summary tables, describe compliance with the RAM requirements and allocations, identify issues, and describe next steps.

**Figure 5-4: Detailed RAM Analysis - MTTR Summary**

<table>
<thead>
<tr>
<th>No.</th>
<th>LLRU ID</th>
<th>LLRU Name</th>
<th>Failure Rate</th>
<th>Corrective Maintenance Task</th>
<th>Maintenance Ratio</th>
<th>Time to Repair</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

**Overall Failure Rate**

<table>
<thead>
<tr>
<th>Overall MTTR</th>
</tr>
</thead>
</table>

Maintenance Ratio = Failure Rate * MTTR (man-hours)

MTTR = [Sum of all Maintenance Ratios] / Overall Failure Rate

The final CMA Report will demonstrate compliance with the RAM requirements established in this TAB CRMP.

5.6 Preventive Maintenance Analysis

EXBC will provide a Preventive Maintenance Analysis (PMA) for CHSTP approval in the Detailed Design phase. EXBC will submit periodic PMA Report updates until the task is concluded.

The PMA consists of a tabular summary of element preventive maintenance tasks. The goal of the PMA is to ensure that all preventive maintenance tasks are included and that task intervals are appropriate. Figure 5-5 is an example of a PMA table.

EXBC will maintain traceability between the PMA and the Maintenance Manuals.
Figure 5-5: Detailed RAM Analysis – Preventive Maintenance Summary

<table>
<thead>
<tr>
<th>System / Subsystem / LLRU</th>
<th>Preventive Task Title</th>
<th>Task Time Per Location (Man-Hours)</th>
<th>Task Interval (months)</th>
<th>Task Justification</th>
<th>Special Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

PMA Reports will provide Preventive Maintenance Summary tables, identify issues, and describe next steps. PMA Reports will also provide a summary table that organizes preventive maintenance tasks per interval, and summarizes preventive maintenance task time per interval.

EXBC will employ a RCM approach for determining preventive maintenance tasks. Refer to Section 5.5 for the RCM approach.

5.7 Maintainability Demonstration

EXBC will conduct a Maintainability Demonstration (MD) to establish the accuracy of task time estimates for the preventive and corrective maintenance tasks described in the applicable Maintenance Plan, Maintenance Procedures, and/or Maintenance Manuals. EXBC will perform the MD concurrent with the CHSTP personnel training program. EXBC will demonstrate selected servicing, preventive maintenance, troubleshooting, change out of components, corrective maintenance, and use of special tools where special emphasis, instruction, or proficiency is needed. CHSTP will notify EXBC which preventive and corrective maintenance tasks have been selected for the MD.

EXBC will provide a Maintainability Demonstration Test Plan (MDTP) before the Final Design Review. The MDTP will be consistent with MIL-STD-471.

CHSTP must approve the MDTP and procedures before the MD starts.