Appendix W

Reliability and Maintainability Program Plan Template

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1. Overview

1.1 Scope

This Reliability and Maintainability (R&M) Program Plan (RMPP) describes the necessary tasks, responsibilities, and controls that should be implemented in an FDOT Project. (*Note: If a project is very hardware-intensive and/or complex, the RMPP may be split into a separate documents.*)

The primary function of the R&M effort is to document the procedures; ensure both high operational readiness and availability; and minimize life-cycle cost. The RMPP should address the aspects of the design and engineering in relation to:

- Management
- Schedule
- Analytical tasks
- Control tasks
- Evaluation tasks
- Design

1.2 Purpose

The purpose of the RMPP is to:

- Define the R&M tasks to be accomplished
- Define the R&M organization, its engineering program interfaces, and support organizations
- Define the R&M management and control processes
- Identify, describe, and schedule the deliverable documentation
- Describe maintainability qualification testing (MQT)
- Describe reliability qualification testing (RQT)
- Identify reporting requirements necessary for logistic support analysis
- Describe the maintenance data collection and reporting system

1.3 Reference Documents

List applicable documents that are used on the project.

2. General Requirements

The vehicle for commitment to effective R&M engineering is the R&M program plan developed for the project. The RMPP should emphasize early participation commencing with requirements definition and system development, followed by a comprehensive test, corrective action, and demonstration program to identify and correct deficiencies as required. The RMPP should be implemented at the onset of a development and subcontractor/vendor selection process.

The R&M program should cover the following major elements:

- Reliability analysis and predictions
- Maintainability analysis and predictions
- Failure modes, effects, and criticality analysis (FMECA)
- Failure reporting and corrective action system (FRACAS)
- Part and materials reliability assurance
- Critical items analysis
- Monitor/Control of subcontractors and suppliers
- Environmental effects analysis
- Reliability development, testing, and qualification
- Provide an interrelationship between reliability and FRACAS results
- Ensure reliability performance levels are maintained
- Reliability provisions for spares
- Development and demonstration of product maintainability and testability

2.1 Reliability and Maintainability Program Goal

The goal of the R&M program is to minimize reliability and maintainability risks by working with system design groups through the concurrent engineering process and project management in the early design stage of the project development activities. System R&M requirements should be established and integrated into system design/modification requirements. The R&M engineering involvement in the project should be described. Reliability and maintainability risks should be identified, and the methods of control by the R&M analyses, prediction tools, and data collection and corrective action system should be described in the following sections.

2.2 Reliability Program

2.2.1 Reliability Analysis and Predictions

Reliability modeling, allocation, and prediction activity that is to be performed for the project should be discussed in this section. The approach to determine the reliability, tools, and methodologies to be used; the mathematical models; reliability predictions; and the FMECA should all be described.

2.2.2 Reliability Tasks

Basic reliability tasks that are to be conducted for the project should be included in this section. Typical reliability tasks include:

- Integration of reliability in design
- Reliability program plan
- Monitor/Control of Subcontractors and suppliers
- Design reviews
- Analysis of the operating and environmental conditions
- Reliability design criteria
- Reliability trade-off studies
- Parts and materials reliability
- Reliability modeling
- Reliability allocations
- Reliability predictions
- Failure modes, effects, and criticality analysis
- Impact of software on reliability
- Human impact on reliability
- Derating
- Reliability critical items
- Life-limited items
- Reliability and integrated logistics support (ILS)
- Data reporting, analysis, and corrective action system
- Reliability qualification test
- Environmental stress screening (ESS)

Equipment will be evaluated throughout the design process, and detailed reliability assessments will be presented during periodic internal, formal technical, and design reviews. The schedule for these activities should be provided in this section.

2.2.3 Spares Reliability Provisions

Spares will be of the same configuration as the baseline equipment developed for the project, therefore ensuring spares reliability. The quality assurance (QA) program will implement procedures for ensuring that spare quality requirements quality are satisfied. The manufacturing and workmanship standards and operating procedures that will be developed and/or used should be described, and their requisite government standards, specifications, and handbooks referenced.

2.3 Maintainability Program

2.3.1 Maintainability Analysis and Predictions

Describe analytical studies for the project that will be conducted to assure compliance with the specific maintainability requirements and to ensure system performance. Describe in this section what maintainability data will be collected and evaluated for accuracy. Also discuss the maintainability predictions that will be performed. The maintainability elements of the system will be assessed, evaluated, and presented during periodic internal reviews and formal design reviews per contractual requirements. The schedule for these activities should be included here.

2.3.2 Maintainability Tasks

Maintainability engineers will perform various maintainability tasks applicable to the project. Typical maintainability tasks include:

- Maintainability program plan
- Monitor/Control of subcontractors and suppliers
- Design reviews
- Analysis of the operating and environmental conditions
- Maintainability design criteria
- Maintainability modeling
- Maintainability allocations
- Maintainability predictions
- Failure modes, effects, and criticality analysis
- Impact of software on maintainability
- Human impact on maintainability
- Maintainability and ILS
- Maintainability qualification testing
- In-service maintainability demonstration (ISMD)

2.3.3 Maintainability Performance

An effective maintainability concept requires special emphasis on features such as built-in testing (BIT), and fault isolation acknowledging the criticality of these features to the effectiveness of system testability and maintainability. Built-in testing goals should be established that provide the attainment of the highest fault coverage detection possible and isolation to the minimum number of lowest replaceable units (LRUs).

Typical measures of maintainability performance are mean active corrective maintenance time (MACMT) and maximum mean repair time (MMax). These, and any others required, should be specified in this section.

2.4 Failure Reporting, Analysis and Collective Action System

The project should implement a closed-loop FRACAS that provides for the collection, processing, analysis, and reporting of failure data for failures occurring during testing. The FRACAS should be described in this section.

2.5 Testing

2.5.1 Reliability Testing

This section should describe test activities related to reliability, failure data collection, trend analysis required, subcontractors requirements, and reporting requirements.

2.5.2 Maintainability Testing

This section should describe test activities related to maintainability, such as MQT, failure data collection, trend analysis required, subcontractor requirements, and reporting requirements.

2.6 Quantitative Reliability and Maintainability Requirements

The quantitative R&M requirements for the project should be discussed in the following sections.

2.6.1 System Reliability

Describe the system for the purpose of reliability. Provide a block diagram. Provide the reliability requirements for the system and the allocation of the requirements to the subsystems. Typical measures would be mean time between failures (MTBFs), system reliability, availability, etc.

2.6.2 System Maintainability

Describe the system for the purpose of maintainability. Provide a block diagram. Provide the maintainability requirements for the system and the allocation of the requirements to the subsystems. Typical measures would be mean time to repair (MTTR), system reliability, MACMT, availability, etc.

2.6.3 Maintainability Goals

The maintainability goals, in conjunction with the maintainability requirements, formulate the key ingredients that establish design objectives and the basis for the maintainability concept design criteria. The project maintainability goals should be included in this section. Typical maintainability goals are:

- Reducing system support requirements by minimizing the logistics delay time with quick repair turnaround time, supply delivery time, and selection of equipment that does not require extensive technical logistics data
- Exceeding MACMT requirements to ensure high operational availability
- Utilizing to the full extent vendors' depot repair facilities and support resources to minimize special tool requirements and for cost-effectiveness
- Optimize the fault monitoring (FM) and fault localization (FL) capabilities to support the maintainability requirements
- Removing and replacing procedures that can be performed by the operator/maintainer in the field

3. Reliability and Maintainability Program Organization and Control

3.1 Program Organization

3.1.1 Organizational Structure

Describe the R&M organization and its participation as part of the FDOT ITS project team.

3.1.2 Responsibilities

The mission of R&M engineering is to ensure that delivered hardware achieves the highest practical R&M standards and meets all specified requirements.

To achieve this end, R&M engineers are an integral part of the planning, design, and development of systems beginning with program inception and continuing through deployment in the field. Their specific responsibilities and authority should be described in this section. Typical responsibilities include:

- Preparing and updating the R&M program plan
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- Allocating R&M requirements to the products
- Implementing and managing the R&M program plan
- Actively participating in the on-going product design efforts of the project
- Performing quantitative and qualitative analyses
- Assessing impacts of resultant product designs on system-level goals and reassigning allocations when needed
- Attending program reviews and technical reviews, and reviewing the evolving engineering design to assure compliance with the R&M requirements
- Performing and documenting R&M and supportability analyses, and trade-offs to determine alternatives
- Collecting and analyzing failure data during tests

- Overseeing failure analysis coordination, remedial action, and corrective action activities
- Assisting in equipment selection and subcontractor/vendor specifications development
- Planning, coordinating, conducting, and reporting R&M testing
- Obtaining data on maintenance frequency from the reliability activity, and providing feedback for effective resolution of any associated problems
- Coordinating the human factors and safety aspects of maintenance with appropriate engineering activity

3.2 Management and Controls

This section should describe R&M program management, and the controls imposed on or by it.

3.2.1 Management Tasks

3.2.1.1 Reliability and Maintainability Program

The lead R&M engineer who will oversee R&M on a project should be identified. The lead R&M engineer will provide for any necessary program focus, direction, and status monitoring for the R&M program elements.

3.2.1.2 Technical Reviews

Participation in technical reviews provides the R&M Engineers with a vehicle to ensure that the specifications for quantitative and qualitative requirements are met. The project reviews planned should be listed and scheduled in this section.

3.2.1.3 Documented Actions

Any technical problems that are identified by the project's R&M analyses will be reviewed for their impact on specific program requirements. How these actions are documented and dealt with should be addressed here.

3.2.1.4 Schedules and Milestones

Detailed schedules should be included in this section.

3.2.2 Reliability and Maintainability Program Integration

One of the objectives of this R&M program is to integrate reliability, maintainability, logistics, and other engineering specialties with the SEP and with each other. The approach to this integration process should be provided in this section. Reliability engineering will support, as required, the pertinent reliability aspects of human engineering, safety engineering, quality, configuration management (CM), systems engineering, design engineering, mechanical engineering, software engineering, and ILS engineering. How they interact should be described.

3.2.3 Problem Resolution and Lessons Learned

The use of a lessons learned database to identify and resolve R&M problems on past projects should be described. Primary emphasis will be placed on parts control, part derating, FMECA, QA, equipment compatibility, and impacts on life-cycle cost. The collection of lessons learned data for the current project should also be described.

3.2.4 Subcontractor / Vendor Program

3.2.4.1 Selection and Surveillance

This section should include the acquisition strategy of the project and should clearly define the R&M requirements that will be provided to each subcontractor/vendor.

3.2.4.2 Subcontractor / Vendor Program Controls

Subcontractors/Vendors are contacted frequently to ensure continued understanding of the R&M requirements. These requirements are included in procurement specifications imposed on vendors to ensure continued procurements of reliable units, subassemblies, components, and materials. Typical vendor controls that will be specified include:

- Control processes
- Materials
- Packaging
- Screening
- Lot testing
- Repair and failure rate requirements

4. Detailed Requirements

4.1 Reliability and Maintainability Design Analysis

Reliability and maintainability engineering influences the design and modifications to maintain an optimum balance between reliability, maintainability, and cost effectiveness. Details on the application of parts control; supplier control; design qualification; and development testing and production should be included in this section.

4.1.1 Reliability Analytical Tasks

4.1.1.1 Reliability Modeling, Allocations, and Predictions

Reliability modeling, allocation, and prediction activities should be delineated in detail is this section.

4.1.1.2 Derating

The project's reliability analysis needed to ensure that components are operated at stress levels less severe than their maximum specified rating should be described.

4.1.1.3 Failure Modes, Effects and Criticality Analysis

The details of the FMECA should be included in this section. The primary purposes of the FMECA performed for a project are to:

- Identify and eliminate any single points of failure.
- Validate the modeling used in the reliability predictions.
- Identify the criticality of each failure and its related interaction among units/subsystems so that improvements can be made to reduce the severity of failure.

4.1.1.3.1 Lowest Replaceable Unit Definition

An LRU is an essential support item, which may be removed and replaced at operator or first line maintenance levels to restore the end item to an operationally ready condition. The LRUs should be defined in this section.

4.1.1.3.2 Reliability Critical Items

All reliability critical items that represent elements of risk in meeting the requirements of the project specifications should be identified. The selection of the critical items will be based on one or more of the following criteria:

- High system usage
- Technical risks for new concept, advanced technology, unusual application, and noncompliant areas
- High failure rate
- High replacement cost
- Limited life
- Single point failure

4.1.1.3.3 Life-Limited Items

Life-limited items form a subset of the critical items list. Any life-limited items identified should be included.

4.1.1.4 Analysis of the Operating and Environmental Conditions

Environmental effects analyses may be performed to ensure that any aspect of the design that may prevent the achievement of the specified reliability criteria is addressed and resolved. The required analyses and/or testing should be described here.

4.1.1.5 Technical Reviews

Technical reviews that require R&M participation should be listed and scheduled here.

4.1.1.6 Impact of Software on Reliability

Any software reliability requirements and required analyses should be discussed in detail in this section.

4.1.1.7 Human Impact on Reliability

Any human reliability requirements and required analyses should be discussed in detail in this section.

4.1.2 Maintainability Analysis Tasks

4.1.2.1 Maintainability Modeling, Allocations, and Predictions

Maintainability modeling requirements and methodology should be described in this section. Special emphasis should be placed on maintainability predictions.

4.1.2.2 Maintainability Analysis

The maintainability analysis process encompasses task integration of maintainability design influence, maintainability trade-off studies, and impacts of human factors engineering (HFE) in maintainability. These tasks should be conducted throughout the development and production phases, and their details should be discussed here.

The analysis process may include:

- Evaluating and revising maintenance and support concepts
- Reviewing all equipment designs to ensure implementation of the maintainability design requirements
- Reviewing diagnostic capability and assisting in the selection process to support maintainability requirements
- Preparing and updating maintainability predictions
- Reviewing and analyzing the design, and recommending changes as required
- Identifying, reporting, and resolving maintainability issues at technical review meetings
- Performing maintainability trade-off studies with the engineering design team

4.1.3 Human Impact on Maintainability

The man machine interface (MMI) is of primary concern during the development phase. The maintainability engineer's involvement in the efforts to create a user-friendly interface should be discussed in detail in this section.

4.2 Reliability and Maintainability Program Controls

4.2.1 Reliability Engineering Design Criteria

Reliability engineers will establish and maintain detailed reliability design criteria and detailed design guidelines for system development. This section should highlight these criteria. Typical criteria include:

- Limit the use of technology with unproven reliability
- Eliminate critical single-point failure modes
- Reduce stresses applied to individual parts and components
- Reduce effects on design performance from parameter variation (e.g., aging, drift, tolerance buildup, etc.)

The criteria are usually refined and updated as the design progresses.

4.2.2 Reliability Trade-off Studies

A structured approach to carrying out reliability trade-off studies should be implemented during the design phase. The design trade-off studies and reliability studies that are anticipated to be performed to optimize the system design should be listed here.

4.2.3 Parts Control Program

The details of the parts control program should be described.

4.2.3.1 End-of-Life Process Control

The end-of-life process should be described in detail. Life-limited items should be identified and monitored, and the maintenance of these items carefully planned to maximize the useful life of the items.

4.2.3.2 Engineering Change Proposal Process

The engineering change proposal (ECP) process should be described with special emphasis on R&M participation.

4.2.4 Maintainability Program Control Tasks

4.2.4.1 Maintainability Design Criteria

Maintainability engineering will be influence the design by providing design criteria and guidelines. These criteria should be included here. Typical design criteria includes:

- Accessibility/Work space
- Interchangeability
- Fault detection and isolation techniques and capabilities
- Special tools and support equipment
- Maintainer skill and requirements
- Testability and test points
- Training requirements
- Transportability and handling
- Supportability requirements
- Compatibility of equipment

4.2.4.2 Maintainability Design Analysis

Maintainability design analysis will be conducted throughout the project to ensure that maintainability requirements are being achieved. The primary intent of the maintainability design analysis is to translate maintenance concepts, requirements, and constraints into detailed quantitative and qualitative maintainability requirements. These analyses will be performed concurrently with the development effort so that identification of potential problems can be made early enough to permit trade-off studies that will provide inherent maintainability of the system. The maintainability design analysis on the project should be discussed in this section. Typical maintainability design analysis includes the following steps:

- Evaluating and revising maintenance and support concepts
- Developing the maintainability model
- Allocating maintainability requirement
- Performing maintainability task time analysis to determine element task times used in the maintainability predictions
- Preparing and updating maintainability predictions
- Reviewing and analyzing design developments, and recommending changes
- Identifying reporting, and resolving maintainability issues at unit design meetings
- Performing maintainability trade-off studies with other engineering disciplines
- Participating in design reviews

4.2.4.3 Maintainability Trade-offs

Maintainability design trade-offs are initiated to resolve maintainability deficiencies and supportability issues, as well as concerns in other disciplines. The effect of alternate approaches on the maintainability or supportability of the system is analyzed and reported in the technical meetings or reviews. Anticipated trade-off studies should be listed and described in this section.

4.2.4.4 Maintenance Concept and Maintenance Plan

The maintenance concept should be developed early in the program and detailed in this section.

4.2.4.5 Maintainability Requirements in Subcontractor Specifications

Maintainability engineering will impose maintainability requirements on the subcontractors and review all subcontractors' design to ensure that the requirements are being met. This section should describe the requirements and the process that will be used to control the subcontractors.

4.2.4.6 Technical Reviews

The technical reviews that involve maintainability engineering should be listed and scheduled here.

4.3 Reliability and Maintainability Evaluation

4.3.1 Reliability Evaluation Tasks

4.3.1.1 Reliability and Maintainability Working Group

A reliability and maintainability working group (RMWG) will be established to review failure trends; to evaluate failure causes; and to recommend failure analysis and corrective actions when necessary to achieve the specified reliability. This section should define the RMWG membership and authority. Typically, the RMWG will include representatives from hardware design, systems engineering, software design, components engineering, QA personnel, R&M engineering, safety, and the customer.

4.3.1.2 Failure Reporting

The failure data collection process (i.e., FRACAS) should be described in detail.

4.3.2 Reliability Testing

Required reliability testing should be listed and scheduled in this section. Several types of typical reliability tests include:

- **Reliability Qualification Tests –** A system RQT may be conducted on the system to demonstrate compliance with the contractual reliability requirements.
- **In-Service Reliability Demonstration –** A system ISRD is conducted on the system during installation.
- **Environmental Stress Screening –** Environmental stress screening is conducted on components to prove they can survive the environments to which they will be exposed.

4.3.3 Maintainability Testing

This section should describe any maintainability testing that is planned. Several types of typical reliability tests are:

- **Maintainability Qualification Test –** As a final evaluation of the maintainability design, a system-level maintainability demonstration is conducted to remove and replace components using actual maintenance personnel.
- **In-Service Maintainability Demonstration –** A system ISMD is conducted on the system during installation.

5. Program Status / Technical Reporting

Reporting requirements should be described in this section. Typical reporting may include:

- Documentation for R&M management, design, analysis, testing, and monitoring
- Reliability and maintainability program plan
- Reliability qualification test plan
- Reliability qualification test report
- Maintainability qualification plan
- Maintainability qualification test report
- Status reports
- Technical reviews
- Technical meetings

6. Acronyms and Notes

This section contains any general information that aids in understanding this document. This section will contain an alphabetical listing of all acronyms and abbreviations, along with their meanings as used in this document, and a list of any terms and definitions needed to understand this document.

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