

**Maintainability Program Plan for:**

**LFEV – SP17 – Y5**

**Version: 0.1**

**Approval date:02/22/2017**



|  |  |  |
| --- | --- | --- |
| **DOCUMENT CONTROL PANEL** | | |
| File Name: | Maintainability Program Plan Template | |
| File Location: | VSCADA Git repo | |
| Version Number: | 1 | |
| **Name** | | **Date** |
| Created By: | Martin Townley | 02/10/2017 |
|  |  |
| Reviewed By: |  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
| Modified By: |  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
| Approved By: |  |  |

Table of Contents

1 Overview 1

1.1 Scope 1

1.2 Purpose 1

1.3 Reference Documents 1

2 General Requirements 1

*1.1 Software Installation on Hardware*

*1.2 Errors, exceptions and logs*

*1.3 Backup and Restoring*

*1.4 Deployment on new Hardware*

*1.5 Log file trimming*

*1.6 System API*

*1.7 System Configuration Maintainability*

*1.8 System Configuration Checking*

*1.9 Tool Chain, Design Suite*

*1.10 Third Party Software*

*1.11 Requirements of GPR007*3 Reliability and Maintainability Program Organization and Control 6

3.1 Program Organization 6

3.1.1 Organizational Structure 6

3.1.2 Responsibilities 6

3.2 Management and Controls 7

3.2.1 Management Tasks 7

3.2.1.1 Reliability and Maintainability Program 7

3.2.1.2 Technical Reviews 7

3.2.1.3 Documented Actions 7

3.2.1.4 Schedules and Milestones 7

3.2.2 Reliability and Maintainability Program Integration 8

3.2.3 Problem Resolution and Lessons Learned 8

3.2.4 Subcontractor/Vendor Program 8

3.2.4.1 Selection and Surveillance 8

3.2.4.2 Subcontractor/Vendor Program Controls 8

4 Detailed Requirements 9

4.1 Reliability and Maintainability Design Analysis 9

4.1.1 Reliability Analytical Tasks 9

4.1.1.1 Reliability Modeling, Allocations and Predictions 9

4.1.1.2 Derating 9

4.1.1.3 Failure Modes, Effects and Criticality Analysis 9

4.1.1.3.1 Lowest Replaceable Unit Definition 9

4.1.1.3.2 Reliability Critical Items 9

4.1.1.3.3 Life-Limited Items 10

4.1.1.4 Analysis of the Operating and Environmental Conditions 10

4.1.1.5 Technical Reviews 10

4.1.1.6 Impact of Software on Reliability 10

4.1.1.7 Human Impact on Reliability 10

4.1.2 Maintainability Analysis Tasks 10

4.1.2.1 Maintainability Modeling, Allocations, and Predictions 10

4.1.2.2 Maintainability Analysis 10

4.1.3 Human Impact on Maintainability 11

4.2 Reliability and Maintainability Program Controls 11

4.2.1 Reliability Engineering Design Criteria 11

4.2.2 Reliability Trade-Off Studies 11

4.2.3 Parts Control Program 12

4.2.3.1 End-of-Life Process Control 12

4.2.3.2 Engineering Change Proposal Process 12

4.2.4 Maintainability Program Control Tasks 12

4.2.4.1 Maintainability Design Criteria 12

4.2.4.2 Maintainability Design Analysis 12

4.2.4.3 Maintainability Trade-Offs 13

4.2.4.4 Maintenance Concept and Maintenance Plan 13

4.2.4.5 Maintainability Requirements in Subcontractor Specifications 13

4.2.4.6 Technical Reviews 13

4.3 Reliability and Maintainability Evaluation 14

4.3.1 Reliability Evaluation Tasks 14

4.3.1.1 Reliability and Maintainability Working Group 14

4.3.1.2 Failure Reporting 14

4.3.2 Reliability Testing 14

4.3.3 Maintainability Testing 14

5 Program Status/Technical Reporting 15

6 User Definitions 15

List of Tables

Table 1: Title 15

List of Figures

Figure 1: Title 15

**List of Acronyms and Abbreviations**

FMECA Failure Modes, Effects, and Criticality Analysis

FRACAS Failure Reporting and Corrective Action System

ILS Integrated Logistics Support

LRU Lowest Replaceable Unit

MACMT Mean Active Corrective Maintenance Time

MTTR……...…………………………………………………………………Mean Time to Repair

QA Quality Assurance

R&M Reliability and Maintainability

RMPP Reliability and Maintainability Program Plan

RMWG Reliability and Maintainability Working Group

# Overview

## Scope

This Reliability and Maintainability (R&M) Program Plan (RMPP) describes the necessary tasks, responsibilities, and controls that should be implemented in the Lafayette Formula Electric Vehicle Project.

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

## Purpose

The purpose of the RMPP is to:

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

## Reference Documents

Statement of Work

Florida DOT R&M Program Planning

# 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:

1. How will the software be installed on new hardware? What happens if the hardware goes obsolete?
2. How are errors and exceptions handled? How are logs viewed? How are exceptions configured and modified as requirements change?
3. How is backup performed? What is the restore procedure?
4. How is a fresh system deployed and validated on new hardware?
5. Are system logs and data files automatically trimmed? On do they grow and require manual trimming or offloading? If so, how is this accomplished?
6. What is the design of the system API and how will this design support ongoing reliable operation, maintenance and expansion?
7. How is system configuration maintained? Will the system auto detect hardware configuration changes or will configuration maintenance be required? If the latter, what is the consequence of misconfiguration? How will the software function when only some of the system hardware is available? Are demo or simulation stubs available for major hardware?
8. How is system configuration checked? Are tools provided for generating valid configurations?
9. What tool chain will be used? Is the tool suite up-to-date and actively supported? Is the tool suite mature enough to have stable functionality? How is the tool chain installed in a new development system.
10. What third party software will be incorporated into the system? How will this be maintained, upgraded, or patched during the life of the system.
11. How are requirements in GPR007 met?
    1. All software source code must be maintained under configuration control. Release snapshots must be archived on the project website.
    2. The system must start from cold power-up and boot to full operational status without requiring user interaction beyond enabling power and safety procedures
    3. Any PC software must be packaged for installation with a SETUP.EXE, RPM, “make install” or equivalent installer allowing it to be installed easily on any compatible computer.
    4. Configuration parameters, calibration factors, preferences, and options shall not be hardcoded within the software source code. It shall be possible to alter these various factors without recompiling software or physically disassembling hardware. Altered configuration parameters must be persistent through power cycling and reboots. The system must have a function to initialize itself with sane (factory default) configuration content if requested.
    5. All data and configuration files must be in a generally supported format (e.g. XML) or the format required by a mature and well supported application (e.g. MySQL database files, Berkeley db, etc… ).  Files shall be accessible either through removable media or network file transfer or both.

## Software Installation on Hardware

Please consult the general requirements section and elaborate

## Errors, exceptions and logs

Please consult the general requirements section and elaborate

## Backup and Restoring

Please consult the general requirements section and elaborate

## Deployment on new Hardware

Please consult the general requirements section and elaborate

## Log file trimming

Please consult the general requirements section and elaborate

## System API

Please consult the general requirements section and elaborate

## System Configuration Maintainability

Please consult the general requirements section and elaborate

## System Configuration Checking

Please consult the general requirements section and elaborate

## Tool Chain, Design Suite

Please consult the general requirements section and elaborate

## Third Party Software

Please consult the general requirements section and elaborate

## Requirements of GPR007

Please consult the general requirements section and elaborate

# Reliability and Maintainability Program Organization and Control

## Program Organization

### Organizational Structure

Describe the R&M organization and its participation as part of the LFEV systems project team.

### 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
* 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

## Management and Controls

Management will consult with VSCADA teams to discuss maintainability requirements, as described in section 2.

### Management Tasks

#### 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.

#### Technical Reviews

- PDR: Feb 8th

- CDR: Mar 9th

- Conference Paper, presentation and video due: Apr 9th

#### 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.

#### Schedules and Milestones

Please consult the semester schedule in the LFEV-sp17 Google Drive. Major milestones include:

- PDR: Feb 8th

- Maintainability Plan Due: Feb 22nd

- FH Forms due: Feb 24th

- CDR, HPD: Mar 9th

### 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 system engineering procedures 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, systems engineering, design engineering, mechanical engineering, software engineering, and ILS engineering. How they interact should be described.

### 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.

# Detailed Requirements

## 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.

### Reliability Analytical Tasks

#### Reliability Modeling, Allocations and Predictions

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

#### 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.

#### 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.

##### 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.

##### 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

##### Life-Limited Items

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

### Maintainability Analysis Tasks

#### Maintainability Modeling, Allocations, and Predictions

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

#### Maintainability Analysis

The maintainability analysis process encompasses task integration of maintainability design influence, maintainability trade-off studies, and impacts of human factors engineering 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

## Reliability and Maintainability Program Controls

### 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.

### 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.

### Parts Control Program

The details of the parts control program should be described.

#### Engineering Change Proposal Process

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

### Maintainability Program Control Tasks

#### 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

#### 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

#### 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.

#### Maintenance Concept and Maintenance Plan

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

#### 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.

#### Technical Reviews

- PDR: Feb 8th

- CDR: Mar 9th

- Conference Paper, presentation and video due: Apr 9th

## Reliability and Maintainability Evaluation

### Reliability Evaluation Tasks

#### 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.

#### Failure Reporting

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

### 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 reliability qualification testing 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.

### 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 in-service maintainability demonstration is conducted on the system during installation.

# 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

Table 1: Title

Figure 1: Title

# User Definitions

| DOCUMENT REVISION HISTORY | | | |
| --- | --- | --- | --- |
| Version Number | **Approved Date** | **Description of Change(s)** | **Created/**  **Modified By** |
| 1 | 2/10/17 | Document Created | Marty Townley |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |