ITARUS – ATC TRIAL SITE

ITARUS - ATC
RAM PLAN

DOCUMENT ISSUE

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1. INTRODUCTION

1.1 Identification and purpose of the document

This document is the RAM Plan, that defines how the RAM activities foreseen by the ASTS RAM team for the "ITARUS ATC Trial Site" project will be carried out. This document is in accordance with CENELEC standard [S1] and with the contractual agreement with NIIAS [A2].

The purpose of this document is to describe the RAM (Reliability, Availability and Maintainability) activities that will be performed for the Signalling system offered by ASTS during project lifecycle. It also defines organization and the responsibilities related to the implementation of the RAM programme. This document is related to RAM, Safety aspects are covered in [A6] and [A7] documents. The RAM programme addresses:

- The Reliability & Availability programme
- Indications for Maintainability programme
- Preliminary indications for the Reliability demonstration programme. These indications will be completed in the RAM Demonstration Plan, if foreseen.

This RAM Plan is the first issue; it will be submitted to the Customer for acceptance, and updated according to the project phases, if necessary.

1.2 Definition and Acronyms

1.2.1 Definitions

Availability	The ability of a product to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval assuming that the required external resources are provided.
Customer	JSC NIIAS
Failure	An event which causes loss of function or performance within any part of the Signaling and Traffic Control System and requires a maintenance intervention to restore full functionality and performance.
Maintainability	The probability that a given active maintenance action, for an item under given conditions of use can be carried out within a stated time interval when the maintenance is performed under stated conditions and using stated procedures and resources.
Maintenance	The combination of all technical and administrative actions, including supervision actions, intended to retain a product in, or restore it to, a state in which it can perform a required function.
Project	ITARUS ATC Trial Site

Reliability — The probability that an item can perform a required function under given conditions for a given time interval (t_1, t_2).

System Life Cycle — The activities occurring during a period of time that starts when a system is conceived and ends at decommissioning when the system is no longer available for use.

1.2.2 Acronyms

Acronym	Definition
AIRBS	Ansaldo Interface Radio Based System
ART	Alarms, Recordings and Telecommand
ASTS	Ansaldo STS
CC	Communication Computer
ERTMS	European Railways Traffic Management System
ETCS	European Train Control System
IXL	Interlocking
CENELEC	Comité Européen de Normalisation Electrotechnique (European Committee for Electrotechnical Standards)
CIL	Critical Items List
CTC	Central Traffic Control
D&M	Diagnostic and Maintenance
FMEA	Failure Mode and Effects Analysis
FMECA	Failure Mode Effects and Criticality Analysis
FR	Failure Rate
FRACAS	Failure Reporting and Corrective Action System
FTA	Fault Tree Analysis
LRU	Lowest Replaceable Unit
MDT	Mean Down Time
MTBF	Mean Time Between Failures
MTBSAF	Mean Time Between Service-Affecting Failures
MTTR	Mean Time To Repair
NIIAS	Russian Research and Design Institute for Information Technology, Signalling and Telecommunications on Railway Transport
NS	Safety Nucleous
QL	Display Panel
RAM	Reliability Availability Maintainability

Acronym	Definition
RAMS	Reliability Availability Maintainability Safety
RBD	Reliability Block Diagram
RBC	Radio Block Center
RCIL	Reliability Critical Items List
RZD	Russian Railways JSC
SIL	Safety Integrity Level
TO	Operator Terminal
T&C	Testing and Commissioning
UPS	Uninterruptible Power Supply
VBG	Virtual Balise Group
λ	Failure rate
μ	Repair rate

Table 1 – Acronyms

1.3 Applicable Documents and Standards

1.3.1 Applicable Documents

This document refers to the documents listed hereafter. It will be updated only when the alteration of a reference document will compromise its validity.

Ref.	Identification	Authors	Title
[A1]	Contract n. 1640-156/09	ASTS and JSC NIIAS	Itarus ATC Trial Site Contract - Main
[A2]	Contract n. 1640-156/09	ASTS and JSC NIIAS	Itarus ATC Trial Site Contract - Annex 14. RAMS Documentation Plan
[A3]	S00A.B80001.S07.00EN	ASTS	RBC System Specifications (SS)
[A4]	S00A.B80001.S04.02RU	ASTS	AIRBS Product Requirement Specification
[A5]	S00AB80001S0700RU	ASTS	Trial Site Architecture
[A6]	B81A.000003.426.01E	ASTS	Safety and V&V Plan for Generic product
[A7]	S00AB80001P1500EN	ASTS	Safety and V&V Plan for RBC Generic and Specific Application
[A8]	S00AB8000172100E	ASTS	Engineering Management Plan

Table 2 - Applicable Documents

1.3.2 Applicable Standards

In case of references to dated Applicable Standards, their subsequent alterations or revisions apply to this document only when explicitly cited. For undated references, the latest issue of the publication is applicable.

Ref.	Identification	Authors	Title
[S1]	EN 50126 2000-03	CENELEC	Railway Applications: the Specification and Demonstration of Dependability - Reliability, Availability, Maintainability and Safety (RAMS)
[S2]	IEC 60812	IEC	Analysis techniques for system reliability – Procedure for failure mode and effects analysis
[S3]	US MIL HDBK 217	Department of Defense of USA	Reliability Prediction for electronic Systems
[S4]	RDF93	CNET	Hardware Components Reliability Database, June 1993 updated 02/95

Table 3 - Applicable Standards

1.4 Document Structure

This document is organized in the following sections:

- **Chapter 1** describes the purpose of the document. It also provides the explanation of acronyms used inside the document and mentions the applicable and reference documents.
- **Chapter 2** provides a general description of the signalling system provided by ASTS.
- **Chapter 3** defines RAM responsibilities and interfaces.
- **Chapter 4** provides a schematic description of RAM activities to be performed during the project lifecycle.
- **Chapter 5** is the core part of the document; it describes RAM analysis that will be performed throughout the project lifecycle.
- **Chapter 6** lists RAM deliverable documents to be prepared and submitted to the Customer for acceptance throughout project phases.

2. GENERAL DESCRIPTION OF THE SIGNALLING SYSTEM

The Signaling system proposed for Itarus ATC Trial Site is a radio signalling system suitable for controlling train distancing along properly equipped lines.

2.1 Main architecture of the Itarus ATC Trial Site

The Itarus ATC Trial Site system consists of a top-down structure that branches off from a central control and supervision post until it reaches the field units.

The line units are centralized into interlocking units (IXL) where the wayside safety logic (station logic) is resident.

The radio-signalling or radio train distancing safety logic is, instead, resident in the RBC (Radio Block Centre) situated at the Control Centre and connected to the IXLs, from which it receives information about the line status.

Figure 1 illustrates the system's main block diagram, pointing out the main signalling, automation and telecommunication subsystems, and specifies ASTS responsibilities.

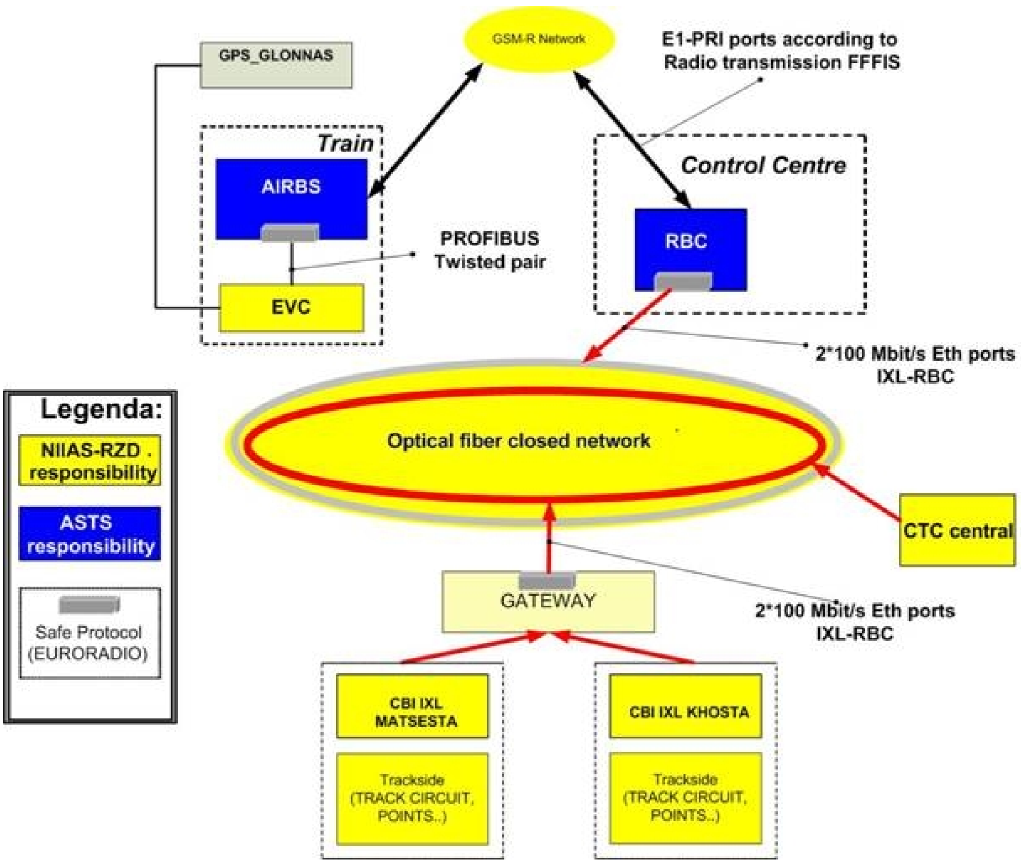


Figure 1 – Architecture of the ERTMS L2 System for ITARUS project

It can be stated that the main task of the Itarus ATC Trial Site is to manage train distancing in a safely manner. In addition, the traditional light signals cannot be used for distancing on high-speed lines since they would follow one another too quickly for the driver to be able to see them.

Therefore, the traditional signals have been eliminated: the distancing information are made available on board in such a way that the on-board systems will automatically calculate both the speed and the braking curves, thus relieving the tasks entrusted to the engine driver and helping the latter to better drive the train.

2.2 Main System Components

The ASTS installations in the Control Center in Khosta Station, as agreed with the Customer in [A1] and defined in [A5], are composed by the following:

- 1 Radio Block Centre (RBC) Safety Nucleous cabinets;
- 1 RBC ART cabinet in redundant configuration (ART1/2 servers);
- 2 AC/DC Power Suppliers (SECAP) with 2 Fuse Rack Distribution (FURD Primary/Slave), used for the feeding lines to the RBC users;
- 1 RBC Operator Interface (Display Panel and Operational Terminal);
- 1 RBC D&M Desk;
- 1 DRD system (Desk Rack Distribution) fed by the FURD and used to distribute power supply between TO/QL and D&M monitors;

The ASTS installation on-board is composed by the following component:

- 2 AIRBS modules, to be installed on the two onboard systems for trial runs.

2.2.1 Main subsystems' functionalities

The main functions of the subsystems are described below:

- **RBC Safety Nucleous**: managing main safety logic for radio signalling, distancing and TSR (Temporary Speed Restriction) management;
- **ART 1/2**: collecting information from the Safety Nucleous to be Displayed on Operational terminal, and collecting of diagnostic information to be sent to Monitoring System;
- **RBC Operator Interface** consists of:
  - Operator Terminal and Display Panel (TO/QL) PC and monitors
  - Mouse and keyboard

  The Operator Interface enables to carry out selections by mouse in both the macro area dedicated to the Operator Terminal and to the Display Panel.
- **Diagnostic&Maintenance Desk (D&M)**:

  The D&M desk will provide to the maintenance operator the tools:
  - to detect timely any faults, anomalies and degraded conditions;
  - to localize them;
  - to diagnostic the type of fault;
  - to perform the repairing.

  The D&M desk is connected to the signalling network, i.e. directly connected to ART1 and ART2 and Safety Nucleous (TMR) so that it can provide real-time all the diagnostic information.

- **AIRBS module:**

  The main functions of AIRBS module, to be part of the on-board subsystem, are:

  - To implement the euroradio protocol
  - To interface with the KLUB-U
  - To interface with Mobile Terminal(supplied by NIIAS)

  The AIRBS module is able to manage several keys and use them in order to encode and decode the messages provided by RBC and KLUB-U according to Subset-037.

Further details on subsystems' architecture and functionalities are given in [A3] and [A4] documents. A more complete description of RBC will be provided in the RBC RAM Prediction Report, that will be produced and submitted to the Customer after the acceptance of this RAM Plan.

3. RAM INTERFACES AND RESPONSIBILITIES

The main ASTS's internal interfaces and responsibilities related to the RAMS activities are:

- The Project Manager: is responsible for the success of the Project and for the performance of the supplied equipment, including its RAMS performance.
- The Project Engineer: is responsible to manage all technical aspects of the Project, including RAM activities.
- The RAMS Referent/Manager: is responsible for defining the RAMS requirements (when required and in line with the contractual requirements), assessing the RAMS performances of the proposed equipment, and providing evidence of its compliance with the RAMS requirements.
- The RAM Engineers: are responsible for performing RAM analysis.

Customer – RAM Interface

The person in charge of the interface related to RAM activities with the Customer can be the Project Engineer (PE) or the RAMS referent/manager. This professional will interface with the RAMS referent/manager, or RAM Engineers regarding technical RAM aspects.

Ansaldo STS can provide all the necessary support to NIIAS in order to interface with RZD (End-User) concerning RAM issues.

Subcontractors – RAM Interface

In case RAM analysis or equipment design is subcontracted by Ansaldo STS, the RAMS referent/manger remains responsible for the final design of equipment or RAM study provided by sub-contractors.

Any partners, suppliers and external sub-contractors involved in the RAM studies have to know and understand the requirements they have been allocated by Ansaldo STS's RAMS referent/manager. They are requested to show their misunderstanding with regards to any RAM requirements.

RAM requirements are provided to sub-contractors through purchase specification.

Safety – RAM Interface

Any conflicts between RAM and Safety are dealt by specific RAMS studies that are managed by the Ansaldo STS's RAMS referent/manager.

The RAM engineers involved in the Project are required to inform as soon as possible the RAMS referent/manager in case any conflicts between RAM activities and Safety activities are identified. Safety related issues are covered in [A6] and [A7] documents.

Maintenance – RAM Interface

Through the Testing & Commissioning process, the data from any test failure is fed back into the RAM considerations to enable previous decisions to be revised in order to verify that the RAM targets can be achieved. The applicable failures considered within this are described hereafter.

An applicable failure is a failure which is attributable to technical factors and that results in a restriction of the operation of the functional item due to one of the following reasons:

- a failure of a component which occurs during the operation within the design-related or environment-specific load limits;
- a failure of the component which is caused by an operating error or by improper maintenance (human error), when the failure to carry out maintenance or operating work is due to incorrect technical documentation of the manufacturer.

Any other failure not previously described will not be considered. This includes:

- failures due to an operation not complying with the specifications;
- a failure of a component which has been caused by the failure of another unit, however such failure will be assessed to determine whether it can be designed out or if it has an effect on the time it takes to return the equipment to full operations;
- failures due to human error (except for the previously described cases);
- failures caused by operating errors (except for the previously described cases);
- failures due to accidents or a situation not corresponding to the normal operating condition (e.g. force majeure, natural phenomenon, vandalism…).

More details about ASTS organization regarding Itarus project are provided in document [A8].

4. SCHEMATIC DESCRIPTION OF RAM ACTIVITIES TROUGHOUT SYSTEM LIFECYCLE

This document and the activities described herein are fully compliant with recommendations provided by CENELEC standard EN-50126 ([S1]).

Figure 2 shows the typical system lifecycle for a railway application, as specified in [S1]; for each identified phase, the main RAM related tasks, to be executed during the project, are listed. These tasks are described and explained in the following chapters.

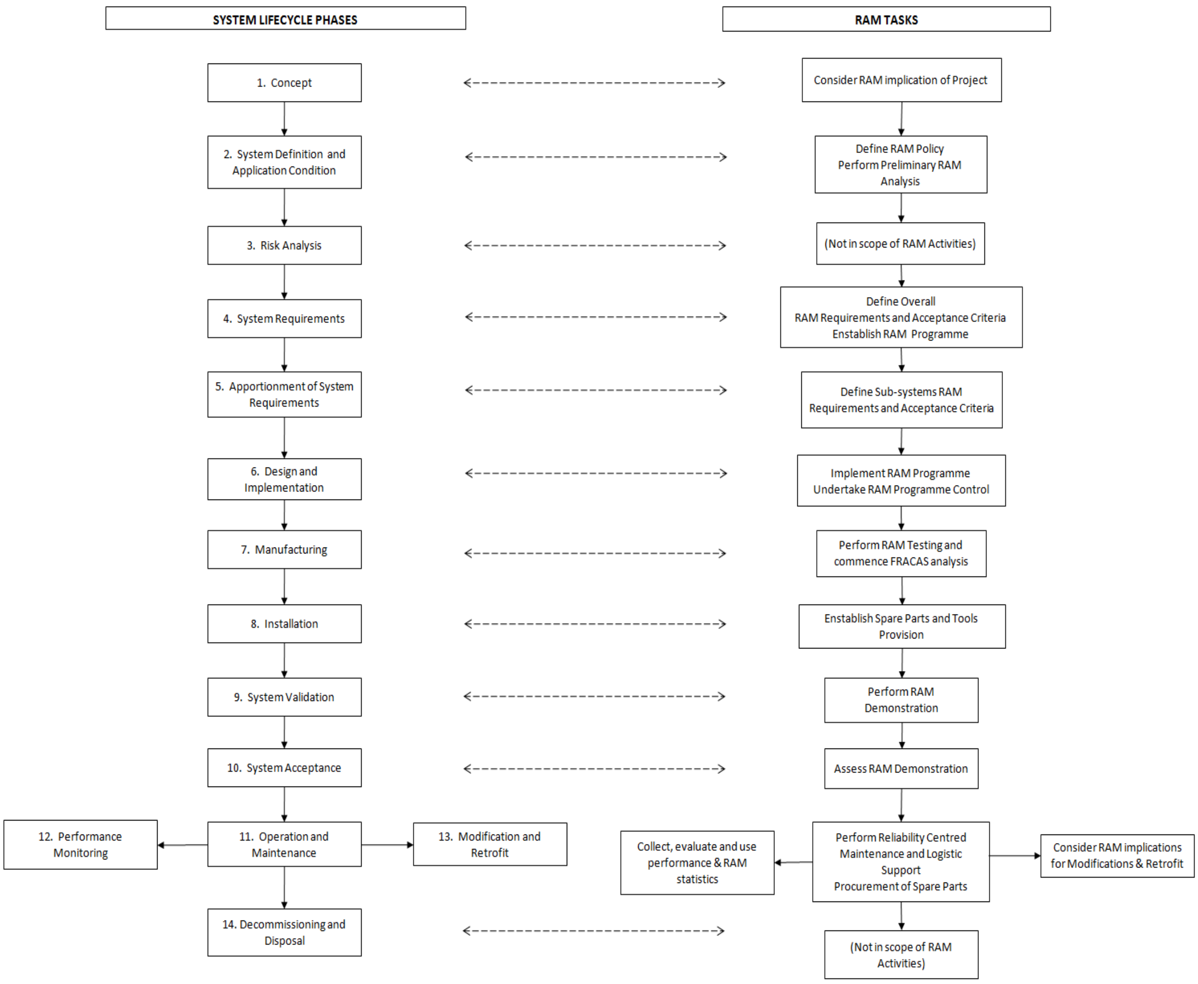


Figure 2 - EN 50126 system lifecycle and RAM related tasks

5. RAM ANALYSIS AND MODELS

In the project's technical and contractual documentation there are not any specific quantitative RAM requirements to respect. Anyway, ASTS will develop the RAM analysis following the [S1] standard to demonstrate that Signalling equipments offered for the project are adequately reliable and maintainable.

The following sections provide a description of the usual RAM tasks that will be carried out by Ansaldo STS throughout the project in order to verify the RAM performance of the proposed Signalling system.

5.1 RAM Approach

RAM analysis will be carried out applying the following general process:

- The design teams carry out the Design. The proposed equipments are designed using reliability and maintainability techniques widely used in Railway application;
- The designers take the RAM requirements into account (if provided), in particular when defining the architecture and the hardware design. The designers define the maintenance tasks.
- The RAM Engineers within the RAMS Department prepare a RAM Plan (the present document) which describes all the RAM analyses to be performed.
- Qualitative analyses are carried out early in the design process, so as to verify that the proposed design choices enable the RAM requirements to be met (if provided). More detailed RAM analyses are conducted later on, and included in the RAM Prediction Reports, in order to more formally evaluate the RAM performances of the supplied equipment.
- RAM demonstration programme is carried out by the RAM Engineers. This demonstration relies on the processing of failure data obtained during Defects Liability Period (if foreseen, DLP have to be agreed with the Customer).

5.2 RAM Assumptions

The following assumptions are taken into account throughout the functional RAM evaluation:

- Components' failure rate is constant, as usually considered for electronic components.
- Calculations are valid throughout the useful life of the equipment.
- For calculations, failures are assumed to be independent (all dependent failures are avoided by design).
- Systematic failures will not be taken into account in RAM calculations and RAM demonstration. In fact, a systematic failure is not a "fault" in the sense of the term, i.e. a stochastic and unforeseeable event, but it is the permanent existence of an incorrect function in the system, which only manifests itself under certain conditions. In general this kind of faults is caused by human error in the design, specifications, implementation, utilization or maintenance of the system.

  To minimize the risk of this type of failure, it's only possible to assure a stringent design process and to introduce control and supervision procedures as well as inspections and system tests and in the right selection of commercial equipment.

  Therefore, as it is not possible to quantify the impact of systematic failures on RAM figures, only random errors are taken into account in the reliability calculations.
- Preventive maintenance does not impact the operation of the equipment, and then does not impact RAM calculations. Preventive Maintenance will be carried out in such a way to not create impact to

the Service (traffic), also ASTS equipments for this Project are designed do not need particular preventive maintenance activities.

5.3 Tools

The following tools are usually used for RAM purposes:

- Excel/CAD: A RAM model will be built up based on the detailed RBD and FMECA using Excel spreadsheet. RBD can be depicted using CAD. The reliability and availability is calculated according to the description provided in this RAM Plan;
- Word: Tool used for producing RAM plans and reports;
- TELSTRESS and MILSTRESS: software tool used for quantitative RAM analysis for new items developed by ASTS;
- Isograph tools for Fault Tree Analysis (FTA).

The following databases can be used for failure rates estimation of the electronic equipments produced by ASTS: MIL-HDBK-217 ([S3]) or RDF93 ([S4]).

5.4 Detailed Description of RAM Activities (to be carried out in the RAM Prediction Report)

The following RAM activities are foreseen for Itarus project.

5.4.1 LRU

The RBC will be represented as a hierarchical structure, indicating disaggregation levels until the LRU level. The LRU level is intended to be the level at which the first level of maintenance is performed. Such a structure could be updated during the project phases development, if necessary.

5.4.2 MTBF and MTTR List

The MTBF figures, can be obtained from field data when available, otherwise from reliability predictions. MTBF figures will take into account environmental conditions where RBC is supposed to work.

The MTTR values come from Ansaldo STS experience from other previous projects already in operation. These values have been calculated following the procedure described in section 5.4.8, taking into account all the times needed to implement corrective maintenance, except for logistic times.

The MDT values can be obtained by MTTR value, adding logistic delays, such as time spent to inform maintenance personnel about the failure, time the maintainer takes to find the correct spare part, if available in the warehouse, and time spent to reach the maintenance site.

An MTBF/MTTR list will be provided for each LRU and will be used as an input to the remaining RAM tasks.

5.4.3 RAM Failure Modes, Effects and Criticality Analysis (RAM FMECA)

The purpose of this task is to analyze systematically the consequences of possible hardware failures of each Line Replaceable Unit (LRU) in a table format, so as to identify the types of failures that can cause service disruptions, and describe the corresponding automatic and/or human failure management actions required. The FMECA analysis allows to:

- Prepare the Availability calculations as well as the Service Reliability calculations (which need to take into account the impact of possible failures);
- Define the reliability-critical items (to be recorded in a Reliability Critical Items List: RCIL, which will be submitted to the Customer)
- Identify the Means to Restore each failed LRU
- Identify the failure category (severity) of each piece of equipment

Results of FMECA can be registered in the format shown in the following table.

FMECA Analysis for RBC									**Rev:**		**Date:**	
									Filled by:			
ID	**Sub-system**	**Equip.**	**LRU**	**Function**	**Failure Mode**	**Effects**			**Diagnosis**	**Compensation Means**	**Severity**	**Remarks**
						Local	**Sub-system**	**Service**				

Table 4 – Example of FMECA sheet

The meaning of each column of this FMECA sheet is:

- *Id*: Identification of the scenario number,
- *Sub-system*: Identification of the sub-system target,
- *Equip.*: Identification of the equipment where the failure is located,
- *LRU*: Identification of the Line Replaceable Unit
- *Function*: Identification of the assigned function,
- *Cause and Failure mode*: Cause and Failure mode leading to the undesired event,
- *Effects*: effects induced by the failure divided into:
  - Local: effect induced by LRU failure on the uplevel assembly;
  - Sub-system: effect induced in the sub-system (RBC);
  - Service: effect induced in the train movement under the RBC area;
- *Diagnosis*: identification of how the failure is detected;
- *Compensation Means*: actions implemented to re-establish normal operative conditions;
- *Severity*: identification of failure severity level. ASTS proposes the following three categories:
  - Immobilizing Failure: a failure which causes the system to be unable to safely control two or more trains (severity level III);
  - Service Failure: a failure which causes the system to be unable to safely control at most one train (severity level II);
  - Minor Failure: A failure which results in excessive unscheduled maintenance and cannot be classified in the above defined failure conditions (severity level I);

- *Remarks*: any applicable note.

5.4.4 Inherent Reliability Analysis

Inherent Reliability analysis is linked to equipment failures that lead to a maintenance intervention but do not necessarily lead to the degradation of the function or of the provided service, i.e. “minor” failures, according to failure severity description provided above. It is an arithmetical sum of the failure rate of all components making up the equipment; therefore it decreases as the number of component increases.

The inherent Mean Time Between Failures (MTBF) will be calculated by:

- Multiplying, for each item type, the number of items by the item failure rate;
- Then, adding the resulting figures, to obtain the overall failure rate;
- The inherent MTBF is equal to the inverse of the overall failure rate.

Since all failures are counted, the inherent reliability calculation does not include any qualitative criteria that mitigate the effects of the consequences of these failures on the mission.

Inherent Reliability is guaranteed by:

- The choice of components (proven in use, temperature rate...), and the proper choice of suppliers.
- Taking into account the final operating conditions during the design.
- Observance of the state-of-the-art, in particular by a reduced load rate.
- Manufacturing Quality (observance of ISO standards). For boards manufactured by Ansaldo STS, the experience has shown that the product line is well controlled. Many boards manufactured with the actual product line are in service and few defects have been observed. For the boards purchased, the experience of the manufacturer will be considered.
- When feedback data are available, reliability is assessed with operational data.

5.4.5 Service Reliability Analysis

Service Reliability analysis is linked to the equipment failures that lead to the degradation of the function or of the provided service, i.e. “Immobilizing” or “Service” failures, according to failure severity description provided above. MTBSAF (Mean Time Between Service-Affecting Failures) can be calculated taken into account the real reliability configuration of equipments that are necessary for the achievement of the functions linked to the passenger transportation service.

Service reliability analysis can be carried out using RBD technique, as shown in Figure 3. This method links the behavior of equipment components (represented by a block or combination of blocks) to the behavior of the entire equipment.

For MTBSAF calculations, techniques like Fault Tree Analysis (FTA) can also be applied. This analysis allows to determine the various combinations of events which can lead to a hazardous event. The results appear in a graphical tree structure, as shown in Figure 4.

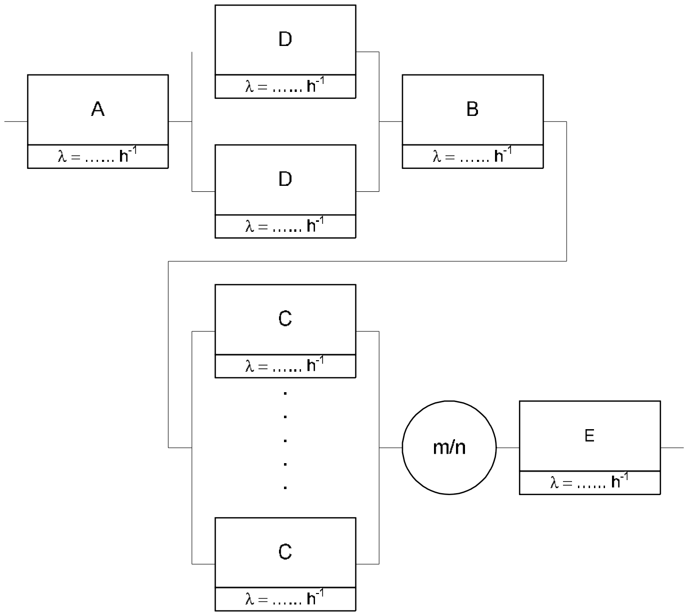


Figure 3 – Example of Reliability Block Diagrams

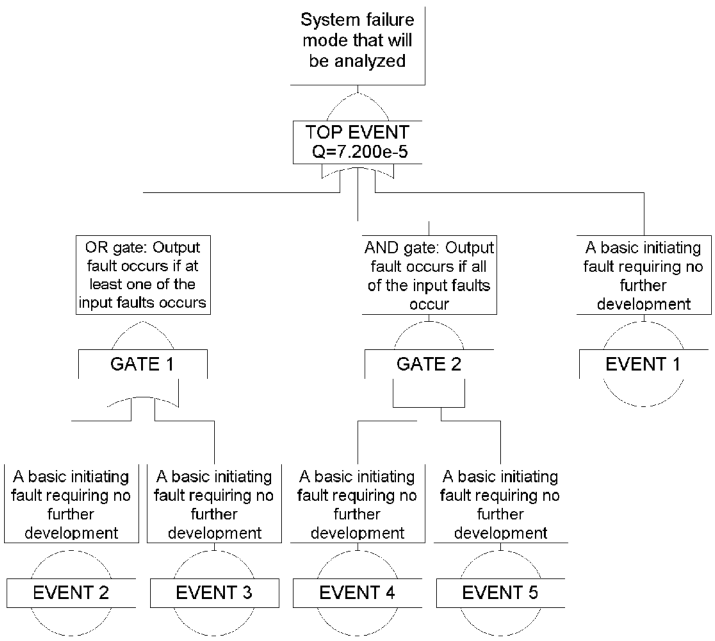


Figure 4 – Example of Fault Tree Analysis

5.4.6 Software Reliability Analysis

No RAM analysis is performed for software. Anyway, software reliability estimation is managed at Ansaldo STS via a stringent process such as verification during the design phase, robust and complete factory and on-site tests, quality controls, corrective actions. The Software design quality process set up will limit failures due to software errors.

Software errors occurring during design phase are managed through a quality cycle and any software errors which occur during the test phase and during operation will be assessed and corrected if their effects and their occurrences are against the RAM objectives.

5.4.7 Availability Analysis

The availability figures will be calculated from the LRU's MTBF/MTBSAF and MTTR/MDT, using adequate mathematical models, widely used in literature:

Single component:

$$\lambda \quad (1)$$

$$A_i = \frac{MTBF}{MTTR + MTBF} \quad (2)$$

Serial architecture:

$$\Lambda s = \sum_{i=1}^{n} \lambda i \quad (3)$$

$$A = \prod A_i \quad (4)$$

Parallel architecture:

$$\Lambda p = \frac{2 \times \lambda^2}{\mu} \quad (5)$$

$$A = 1 - \prod (1 - A_i) \quad (6)$$

Architecture 2 out of 3:

$$\Lambda_{2/3} = \frac{6 \times \lambda^2}{5 \times \lambda + \mu} \quad (7)$$

$$A = 3A_i^{\,2} - 2A_i^{\,3} \quad (8)$$

Where:

- A_i is the technical availability of the component
- μ is the repair rate of the component (inverse of MTTR)
- λ is the failure rate of the component (inverse of MTBF/MTBSAF)

According to formula (2), at least two types of availability can be defined:

1. Inherent Availability: is the availability related to non-critical (MTBF) failures, taking into account only the time spent to perform the repair/substitution (MTTR).

$$A_i = \frac{MTBF}{MTBF + MTTR}$$

2. Operational Availability: is the availability related to non-critical (MTBF) or service (MTBSAF) failures, taking into account the time needed to perform maintenance intervention, it may include logistic delays (MDT).

$$A_i = \frac{MTBF(MTBSF)}{MTBF(MTBSF) + MTTR(MDT)}$$

Availability is guaranteed by:

- High inherent reliability of components.
- Redundancy of critical equipment to ensure that a single fault will not result in the loss of the main mission.
- Gradual degradation which allows the mitigation of the impact on the operation when a failure occurs and when the redundancy is not a feasible or reasonable solution.
- Testability and maintainability

5.4.8 Maintainability Analysis

This analysis examinates the events that can affect the achievement of the system maintainability performance. It is realized through the preventive maintenance and corrective maintenance analysis activities.

The purposes of this analysis are:

- evaluate the MTTR relative to the active maintenance time only;
- draw up the preventive and corrective maintenance sheets;
- define the types and amounts of the stock materials;
- provide the data required to draw up the maintenance operator training manuals;
- identify the specialization level and the required number of maintenance operators and the tools outfit

Maintenance operations can be sub-divided in:

- **Preventive:** The maintenance carried out at pre-determined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item,
- **Corrective:** The maintenance carried out after fault recognition and intended to put again the failed system into a state in which it can perform its required functions. For ITARUS project, NIIAS and RZD maintenance personnel will be responsible during the warranty period for on-site interventions, in order to replace ASTS out of order devices with spare parts.

Such activities will be organized and programmed at different levels with all involved areas because in some cases, maintenance activities could cause temporally the out of service of items necessary for the achievement of the service. Signalling system proposed by ASTS guarantees that main equipments have an architecture that allow maintenance activities to be performed without interruption of service.

Maintainability is guaranteed by:

- Detectability. The ability of the diagnostic monitoring used by the maintenance teams to isolate the origin of a failure, affects significantly the total intervention time: fault isolation time + troubleshooting time + inspection time before returning to service.
- Accessibility. Most non line-side equipment will be sited in equipment rooms outside the restricted zone close to the tracks. The arrangement of equipment inside the rooms will permit easy access to items.
- Modularity. As far as possible the equipments are being built from modular components that are field replaceable.
- Swappable boards. Many of the equipments consist of boards that fit into standard racks and back planes. These are particularly easy to maintain.

5.4.8.1 Preventive Maintenance Analysis

The scope of preventive maintenance is to examine all actions that prevent item's failure to occur, anticipating any repairing or substitution.

Systems provided by Ansaldo STS need only periodic preventive maintenance in order to control the state of equipments. Any preventive maintenance activity is foreseen during Railway Service, so any operational impact is expected; in case some preventive action will be foreseen, such activity will be carried out following procedures and at time so that it doesn't have an operational impact.

Preventive maintenance analysis can be performed by filling in preventive maintenance sheets with the following data.

PREVENTIVE MAINTENANCE SHEET						Rev.:	Date:		Filled by:		
Step	Action	Frequency (months)	Tools	Consumables		Personnel		Duration (hours)	Total Quantity	Total man-hours	Remarks
				Identification	Quantity	Skill	Quantity				

Table 5 – Preventive maintenance sheet

- *Step:* action's progressive number;
- *Action:* recommended action to be implemented;
- *Frequency:* foreseen frequency for preventive maintenance action;
- *Tools:* description of main instrumentation and tools needed to implement the recommended action;
- *Consumables:* material and quantity, needed to implement the required action;
- *Personnel:* indications about personnel in terms of skill level and quantity;

- *Duration:* time spent to implement the required action;
- *Total Quantity:* total number of items that require the maintenance action;
- *Total Man-hours:* man-hours per year required for the relative maintenance action;
- *Remarks:* any remarks taken when the analysis is performed.

5.4.8.2 Corrective Maintenance Analysis

The scope of corrective maintenance is to examine procedures and actions aimed to restore the functionalities of the equipment, identifying the LRU to be substituted. The corrective maintenance is performed whenever an error occurs. It focuses not only on immediate failure, but also on possible errors that caused the system failure.

Mean Time To Repair (MTTR) can be calculated based on steps needed to implement the corrective maintenance (access, localization, isolation, etc.), the sum-up of these times indicates the intrinsic MTTR (not taking into account logistic times).

MTTR for the sub-systems (NS, ART, CC etc.) can be calculated from LRU's MTTR (MTTRi), based on the following formula:

$$\lambda_b = \sum_{i=1}^{N} \lambda_i$$

$$MTTR_{SUB-SYSTEM} = \sum_{i=1}^{N} \frac{\lambda_i}{\lambda_b} * MTTR_i$$

Corrective maintenance analysis can be performed by filling in corrective maintenance sheets with the following data.

CORRECTIVE MAINTENANCE SHEET					Rev.:	Date:	Filled by:			
					Personnel					
Symbol	Failure mode	Detection means	Procedure	Tools	Skill	Quantity	Total Quantity	Duration (hours)	Total man-hours	Remarks

Table 6 – Corrective maintenance sheet

- *Symbol*: module symbol;
- *Failure mode*: brief description of failure modes;
- *Diagnosis*: brief description of failure diagnosis;
- *Procedure:* brief description of actions to be implemented:
  - Access: remove panels, covers, etc.;
  - Localization: physical identification of failed item;
  - Isolation: removal of danger voltage;
  - Disassembly: removal of failed item;
  - Substitution: substitution with a working item;

- Realign: trimmer reset, calibration, etc.;
- Test: phase needed to evaluate the good outcome of the performed activity;

- *Tools*: description of main instrumentation and tools needed to implement the recommended action;
- *Personnel*: indications about personnel in terms of skill level and quantity;
- *Duration*: time spent to implement the required action;
- *Total Quantity:* total number of items that require the maintenance action;
- *Total Man-hours:* man-hours per year required for the relative maintenance action;
- *Remarks:* any applicable note.

5.5 RAM Demonstration

The intention of RAM demonstration is to demonstrate the reliability/availability performance of the proposed system during a period to be agreed with Customer.

According to [A1], field data used by RAM activities are provided in the forms of Failure Registers, compiled by RZD maintenance personnel during their on-site intervention every time a defective ASTS equipment is replaced with a spare part. These registers will indicate at the least the time, date, typology of ASTS out-of-order device, identification number of the ASTS out-of-order device, characteristics of the failure (for example failure mode (software, hardware, environment…), if the failure is safety-critical, causes and effect on the equipment and trains operation), name, surname and signature of the maintenance person who compiles the register, possible notes.

According to [A1], RZD maintenance personnel shall send NIIAS a copy of the abovementioned failure register within one (1) working day from the moment when failure occurs. Then NIIAS will send to Ansaldo STS RAM team a copy of the original register in Russian and an English version of the same register within three (3) working days from the moment when failure occurs. Ansaldo STS RAM team will confirm its own responsibility for failures and will provide indications about tasks and tools needed to carried out maintenance activities for RBC; as indicated in § 5.4.8, these maintenance activities will be carried out by NIIAS and RZD personnel.

In case any failure occurs in the RBC, ASTS will provide support to analyze such failure.

If required by the Customer, a RAM Demonstration Plan will be produced after the acceptance of this RAM Plan. The RAM Demonstration plan will show organization, responsibilities, targets to be met by the demonstration, and demonstration activities programme.

During the operation, the RAM activities usually consist in tracking RAM indicators based on the field observations. Following assumptions can be used for operational RAM calculations.

- Failures are distributed according to constant failure rate law. This assumption is reasonable for electronic components.
- Failed components are replaced as soon as they failed.

If during the demonstration period one of the RAM parameters declared by ASTS is not met, ASTS will send to Russia a specialist, in order to prepare together with NIIAS a Failure Report for RZD, where all the data regarding failure detection and removal and an expected reasonable date to comply with declared RAM values will be specified. Both ASTS and NIIAS will sign the Failure Report.

In order to provide to NIIAS all technical support to analyze failure causes, ASTS is supposed:

- to receive periodically detailed failure reports
- to receive periodically *logs* registered in the ART and D&M sub-systems.

During such period, all failures and service interruptions shall be stored in a database, which shall include all information necessary to:

- Understand the causes of the failure, and allow any necessary improvement of the failure recovery process;
- Enable responsibilities to be assigned;

Reviews of all open failure reports, failure analysis and corrective actions will be followed-up in order to assure that effective corrective actions are taken in a timely manner.

A RAM Demonstration Report, if foreseen, will be produced on completion of the RAM demonstration period, to demonstrate that operational RAM performance is coherent with predicted RAM figures.

ASTS will agree with NIIAS any other aspect related to RAM monitoring and demonstration.

5.6 Spare Parts Calculation

A list of recommended spare parts for initial supply can be delivered to the customer providing quantity of spare parts, MTBF, and price for the Warranty period of five (5) years.

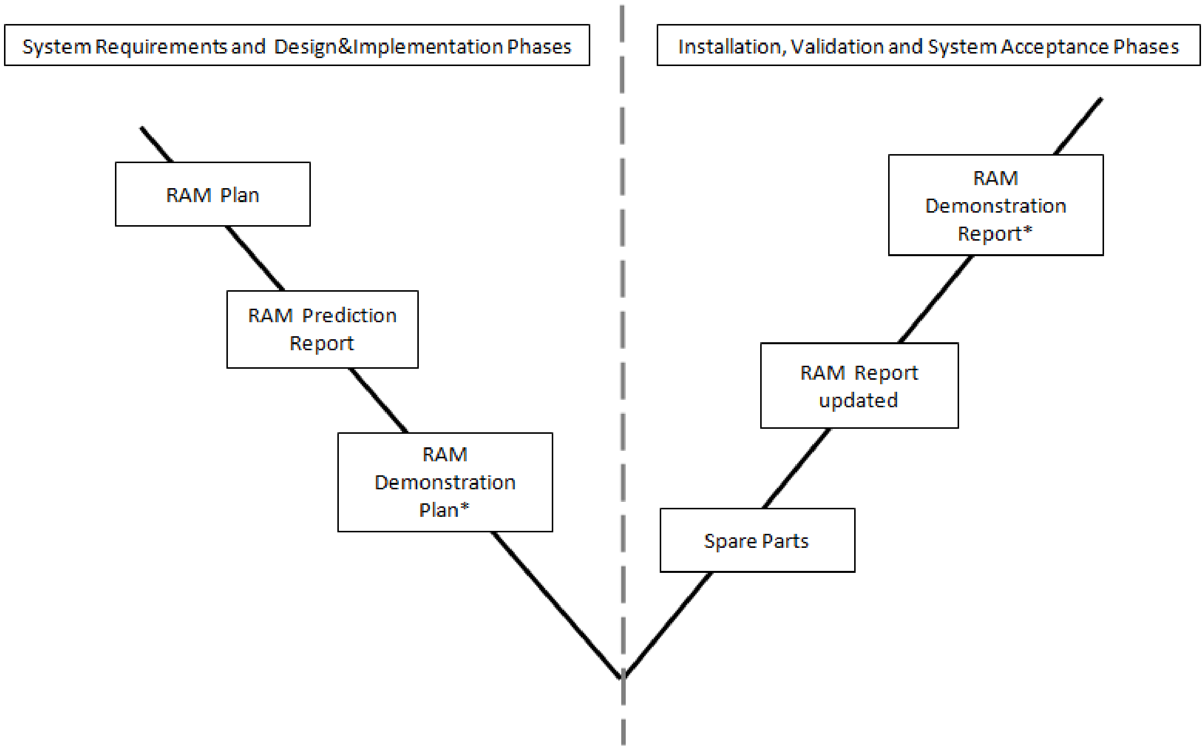
For each LRU of the supplied equipments, the parameters needed to implement the spare parts calculation are:

- Installed quantity of LRU
- MTBF or failure rate of LRU
- Restocking time (Turn Around Time, TAT)
- Probability of Non Stocking Disruption (PNSD)

More details about Spare Parts calculation, if required, will be given in the RAM Prediction Report, to be prepared during the project design phase, or in a separate document, as stated in §6.

6. RAM DELIVERABLES AND PROGRAMME

The following figure shows RAM analyses to be performed through the Project Life Cycle of the supplied Signalling System.



* RAM demonstration activities and equipments under contractual RAM demonstration shall be defined with the Customer.

Figure 5 – RAM activities throughout Project Lifecycle

The RAM activities and their associated schedule information are listed in the table below. Their deliveries are subject to contractual arrangements. They will be included in the overall planning of the Project.

RAM Deliverables	Note
RAM Plan	The current document
RBC RAM Prediction Report	After equipment, component and hardware design has been selected, a dedicated RAM Prediction Report for the RBC subsystem (including Operator Interface, D&M desk and Power Supply) will be produced. This report will include predictive reliability analysis (inherent and service), availability analysis (inherent and operational), FMECA, maintainability analysis. The RAM Prediction reports can be updated during Testing and Commissioning, if necessary.

RAM Deliverables	Note
Spare Parts	Spare parts list can be included in an update of the RAM Prediction Report or a dedicated document can be issued, if requested.
RAM Demonstration Reports	If foreseen, the RAM demonstration reports can be issued periodically and at the end of demonstration period, to be agreed with the Customer.

Table 7 – RAM Deliverables

RAM deliverables will be submitted to the Customer for acceptance.

6.1 RAM Reviews

In agreement with the Customer, RAM reviews will be undertaken at each essential stage of the project. RAM discussions will be included in each of these reviews. As a minimum, the following can be presented to the client:

- RAM related documentation deliveries, indicating the relevant revisions;
- Status of current activities;
- Notification of problems affecting RAM and their corrective actions;
- Updated planning and list of deliverables; and
- A list of action items (planned and completed).