RAM METHODOLOGY AND ACTIVITIES FOR IFMIF ENGINEERING DESIGN*

J. M. Arroyo#, A. Ibarra, J. Mollá, CIEMAT, Madrid, Spain
J. Abal, E. Bargalló, J. Dies, C. Tapia, Fusion Energy Engineering Laboratory, UPC, Barcelona, Spain

Abstract
IFMIF (International Fusion Materials Irradiation Facility) will be an accelerator-based neutron source to test fusion candidate materials. The Engineering Validation and Engineering Design Activities (EVEDA) of IFMIF are aimed to deliver the complete engineering design file of this major facility.

Achieving a high level of availability and reliability is a key point for IFMIF mission. A goal of 70% of operational availability has been established. In order to fulfil the availability requirements, RAM (Reliability, Availability and Maintainability) has to be considered during the engineering design phase. This paper summarizes the methodology developed and the proposed process aimed at including RAM in the design of IFMIF, as well as the activities performed in this framework.

Overall RAM specifications have been defined for IFMIF project. RAM methodology dealing with RAM design guidelines, reliability database and RAM modelization has been developed. As a first step for the iterative process of RAM analysis of IFMIF design, a fault tree model based on a new reliability database has been performed with Risk Spectrum®. The result is a first assessment of the availability and first allocation of RAM requirements.

INTRODUCTION

IFMIF is one of the three main projects signed by Euratom and Japan in the Broader Approach agreement for future demonstration of fusion power reactors. The aim of IFMIF project is to test samples of candidate materials for fusion energy reactors.

To generate the needed intense flux of neutrons, there are planned two deuteron accelerators working in parallel and continuously (Accelerator Facility). Each one delivers 125 mA of D^+ at 40 MeV in a continuous wave (CW) mode of 175 MHz. The deuteron flux will collide with a liquid lithium target (Target Facility) and the interaction will produce a neutron flux irradiating the samples of the Test facility.

IFMIF EVEDA phase is aimed at providing the Engineering Design of IFMIF and at validating the key technologies of IFMIF through several prototypes (low energy part of the accelerator, lithium facility, and high flux modules).

The main objective of RAM activities in EVEDA phase is to integrate RAM into the engineering design of IFMIF with the final objective of validating IFMIF adequacy as an irradiation facility.

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#josemanuel.arroyo@ciemat.es

The importance of these activities is highlighted by two facts:

- Each of the three main IFMIF facilities has very important technological challenges to be accomplished, and therefore, reliability, availability and maintainability challenges.
- IFMIF should be considered an industrial irradiation facility as is designed for producing a big amount of displacements per atom (dpa) in a determinate period in order to be useful in the fusion framework (ITER and DEMO).

AVAILABILITY GOALS

The operational availability requirement for IFMIF is 70% which together with its specifications regarding damage rate in iron (25-45 dpa/fpy in high flux area) is directly linked to the main mission of IFMIF. This requirement is established for normal operation.

The availability budget was shared between the facilities inherent availability requirements assuming the following overall maintenance plan:

- One weekly beam-off 8-hour period for maintenance operations in the accelerator facility, and
- Month period for maintenance in the lithium target facility and test modules replacement following 11 months of continuous operation.

The inherent requirements for the different facilities are in the next table. These requirements were established in CDA (ref [1]), and confirmed in CDR, (ref. [3]).

Table 1: IFMIF Inherent Availability Goals

IFMIF Facilities	Inherent availability
Tests Facility	97.5 %
Target Facility	95.0%
Accelerator Facility	88.0%
Conventional Facilities	99.5%
Central Control System and Common Instrumentation	99.5%
TOTAL	**80%**

RAM METHODOLOGY DEVELOPMENT

As very strong availability goals have been established for IFMIF, RAM has a key role in the design, and it is essential to develop proper tools and methodologies that allow a good integration with the design. This section summarize different RAM tools developed in order to be able to analyse the design at the different stages, from RAM point of view, so integrating RAM into the engineering design in that way.

RAM Design Guidelines

In order to include RAM considerations in the design since the beginning, technical guidelines for the designers were developed. These guidelines include:

- General concepts and ways of improving RAM, standards that can be adopted and good practise to be followed by designers.
- Specific recommendations from operation experience of similar facilities
- Checklist for designers application

Specific recommendations have been collected for the different part of the accelerator: Injector, RFQ, RF system, RF cavities, Beam Transmission Lines, Vacuum System, Control System, and for the conventional part: Electrical Power, Water Cooling, HVAC (ref [4]).

Reliability Database

High technology systems as IFMIF ones have difficulties to apply probabilistic analysis as they usually contain elements for which no or few historical statistics exists. A reliability database has been created for IFMIF (ref [5]) based on exploration of accelerator component reliability database and other databases.

The facilities (no matter their state of operability) explored, from which reliability data has been found, have been the following: LANSCE (former LAMPF), SNS, SLAC, FERMILAB, ISIS, MEGAPIE, XADS, PETRA-III- DESY's source, TRIUMF, GANIL- CEA's ECRIS, J-PARC – KEK, JET, ASDEX-U, TORE SUPRA, DIII-D, TSTA LANL and TPL- JAERI. Other databases as power supply, electronic or fusion database were explored.

On the other hand, a data capture methodology has been defined for IFMIF in order to collect RAM valuable data from the different prototypes of the EVEDA phase. A failure report has been created to be filled in the operation of such experiments (ref. [7]).

Integrated Logistic Database

Two main parameters take part in RAM analysis:

- MTBF: Mean Time Between Failure, a basic measure of reliability
- MTTR: Mean Time to Repair, a basic measure of maintainability.

First one can be deduced from operational experience of similar components in similar conditions (reliability database). But the second one is often estimated through engineering judgement. MTTR may include time to diagnose the failure, time to have access to the failed component, time to have spare and tools available, etc. (logistic time). The consideration of these logistic times may have a very strong impact in the availability result according to experience in similar projects. And, of course, it is completely linked to the particular design.

Therefore, it is very important to develop an appropriate tool in order systematically gather subsystem and component information (logistic and maintenance characteristics: scheduled and unscheduled maintenance tasks, cooling time if needed, logistic needs, etc.). This will be essential to improve the model and to perform Integrated Logistic Support tradeoffs.

RAM Models

In order to be able to assess the availability of the different facilities and systems, and to allocate the RAM requirements among the different systems and subsystems, a methodology has been adopted consisting in the following:

- Plant Breakdown Structure (PBS) in order to define systems and subsystems limits and interfaces.
- Functional analysis (FA) in order to identify the main functions of the system, and its dependencies.
- Success criteria definition, in order to establish the conditions in which the system is considered available.
- Failure Mode and Effect Analysis (FMEA) in order to identify in a systematic way the component possible failures modes and their effect from availability point of view.
- Fault tree (FT) models for the different facilities in order to have the logical architecture and dependencies of different systems and subsystems.

The software chosen for RAM analysis is Risk Spectrum®. Using it, systems may be analyzed through:

- Availability calculations: break down and time evolution.
- Parametric analysis: Importance and sensitivity relationship. Critical parameters highlight
- Time dependency analysis. Failures intensities and frequency calculations
- Uncertainty analysis: confidence interval calculations

Through this methodology, weak points from the RAM point of view are identified and first design recommendations can be given.

RAM Requirement Allocation

One of the first steps in order to integrate RAM into design is to establish RAM requirements for the subsystem in coherence with the availability goal for the facilities. This means a top-down allocation of the availability requirement among the different subsystems.

The methodology used in IFMIF for this purpose is the following: based on the RAM models (Fault Tree), the facility availability goals are allocated among subsystem, therefore proportionally to availability data collected (MTBF and MTTR), to reach the facility goal.

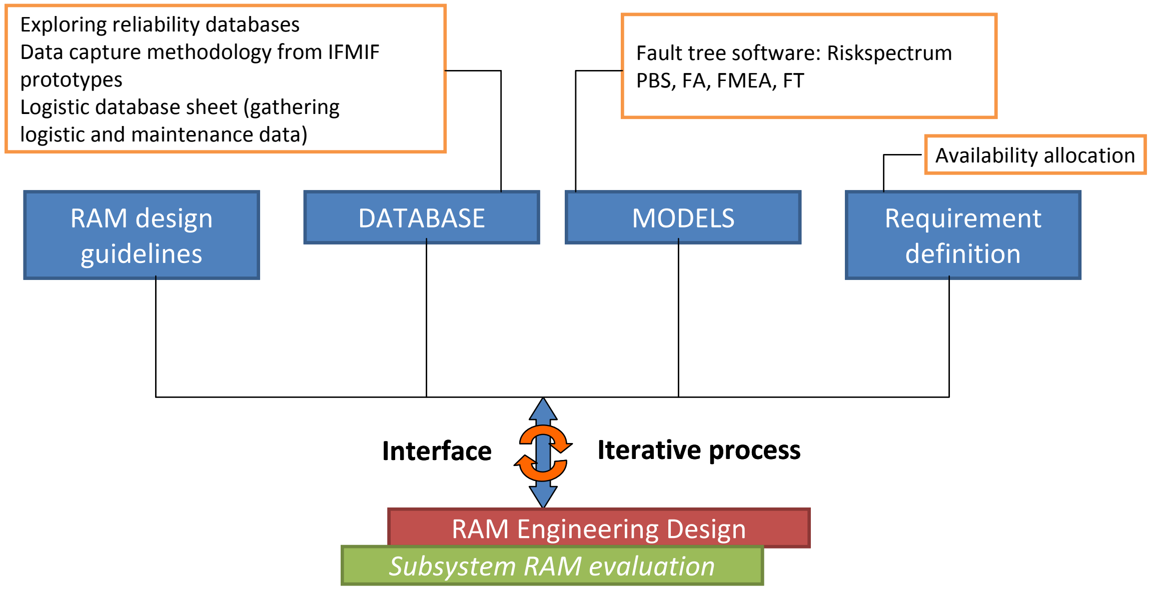

Figure 1: RAM approach for IFMIF engineering design

This way the availability requirements for the designers are established.

This makes up the first step of an iterative process for RAM engineering. Then, a second further step will have to be taken in order to allocate availability requirement between reliability and maintainability. This will be done through detailed model of subsystem.

RAM IN THE ENGINEERING DESIGN PHASE

Figure 1 summarizes the RAM approach for IFMIF. The top part represents the developed RAM methodology itself, explained in the previous section. This methodology constitutes the tools that allow developing the iterative process between RAM analysis and design. Therefore, with this methodology the RAM engineering can be tackled.

This process has been defined for IFMIF (ref. [8]) specifying the different levels of activities and the different roles in the RAM analysis, design, redesign and reallocation of RAM requirements.

CONCLUSIONS AND FUTURE WORK

Availability is one of the main and strong requirements of IFMIF plant as it is directly linked to its main mission: deliver fusion material database in time for fusion reactors development.

Therefore, IFMIF has to be considered and designed as an industrial facility for dpa production in determined conditions.

A methodology in order to be able to tackle with this issue in the engineering design of IFMIF has been developed.

The main challenges now are:

- Continue integrating RAM into design and assess feasibility of design for these strong availability requirements.
- Develop a RAM analysis flexible enough in order to take into account variability in availability requirement for IFMIF linked to its mission according to fusion program.

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