WPENS-CPR(18) 20262

A. Muoz et al.

IFMIF-DONES Systems Engineering Approach

Preprint of Paper to be submitted for publication in Proceeding of
30th Symposium on Fusion Technology (SOFT)

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

IFMIF-DONES Systems Engineering Approach

A. Zsákai [a], A. Muñoz [b], A. Diez [c], R. Román [d], E. Marco [b], A. García [b], A. García [d], A. Ibarra [d]

[a] *Wigner Research Center, Budapest, Hungary*
[b] *Empresarios Agrupados, Madrid, Spain*
[c] *Visure Solutions, Madrid, Spain*
[d] *CIEMAT, Madrid, Spain*

In the framework of the EU fusion roadmap implementing activities, an accelerator-based Li(d,n) neutron source called DONES (Demo-Oriented early NEutron Source) is being designed as an essential irradiation facility for testing candidate materials for DEMO reactor and future fusion power plants. DONES facility is being developed within the EUROfusion workpackage WPENS, which main objective is to be ready for IFMIF-DONES construction as soon as 2020. Fourteen Research Units (RU) around Europe, as well as industry Third Parties, are involved working in different aspects of the DONES scope of works.

Taking into account the complexity of the facility and the geographical dispersion of the partners involved, it is of a paramount importance to properly develop the DONES Systems Engineering, creating and executing interdisciplinary processes to ensure that the DONES defined objectives are reached and that the facility fulfils the expected criteria.

This paper presents the Systems Engineering processes that are being developed for the DONES Project as an interdisciplinary approach to enable the realization of successful Structure, Systems and Components (SSCs). In order to reach this objective (defining, controlling and documenting the requirements and interfaces) a dedicated group has been set up. A matrix for the management (traceability) of the requirements is being developed and populated. Also, a specific tool is being used for the management of the project interfaces (physical, functional, etc.). These works are to be considered as part of the development phase, started as early as possible in the project and then used in further stages (design synthesis activities, SSC validation, subcontractors' control, etc.) following the Systems Engineering works.

Keywords: Fusion Roadmap, Neutron Source Accelerator, Systems Engineering, Requirements, Traceability, Interfaces.

1. Introduction

An irradiation environment in the future Fusion Power Plants (also in DEMO independently of its specific design) is characterized by the presence of 14 MeV fusion neutrons in the first wall area. Understanding the degradation of the materials and components' properties throughout the reactor operational life is a key issue to allow the design and subsequent facility licensing by the corresponding safety authorities.

A design called IFMIF has been in development since 1990, but recently it was agreed to first design DONES (Demo-Oriented Early NEutron Source), which is the first step towards IFMIF. The advantage of DONES is that it can yield specimens and experimental results which can be used for the design of DEMO and possibly ITER.

DONES plant is defined to provide an accelerator-based D-Li neutron source to produce high-energy neutrons at sufficient intensity and irradiation volume to simulate as closely as possible the first wall neutron spectrum of future nuclear fusion reactions.

The Plant will produce a 125 mA deuteron beam, that accelerated up to 40 MeV and shaped to have a nominal cross section in the range from 100 mm x 50 mm to 200 mm x 50 mm, impinges on a liquid lithium curtain 25 mm thick cross-flowing at about 15 m/s in front of it. The stripping reactions generate a large number of neutrons that interact with the materials samples located immediately behind the Lithium Target, on the Test Modules.

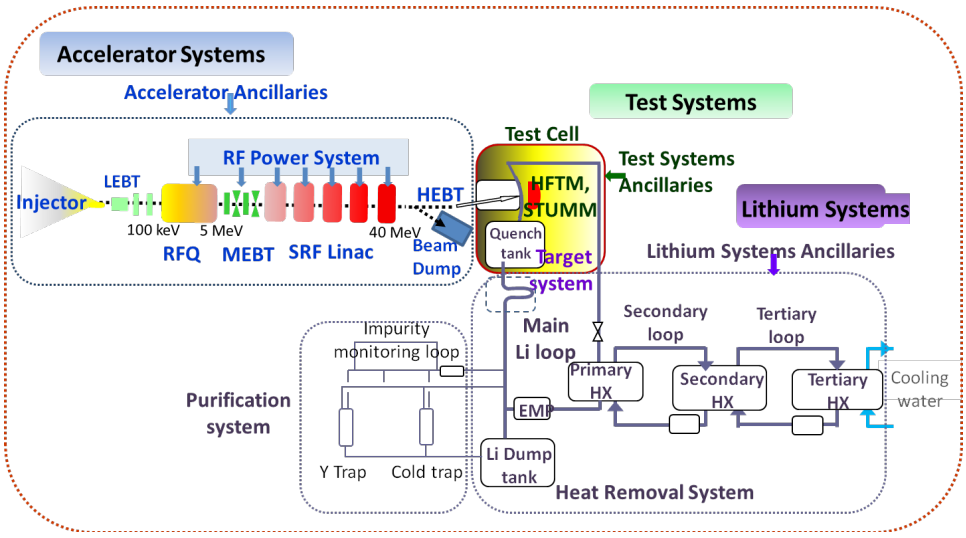

Fig. 1. Schematic of the DONES Plant

As fourteen Research Units (RU) around Europe, as well as industry Third Parties, are involved working in different aspects of the DONES scope, it is essential to have a solid Project Integration in order to let information and work flow smoothly between parties. As part of Project Integration a Systems Engineering Approach was implemented to have a common platform of the CAD works, Interface and Requirements management. For this purpose, a dedicated group (Requirements and Interface Management Group) has been set up.

2. Systems Engineering as part of Project Integration

The Systems Engineering Approach has as a main objective to set up and apply a useful set of interdisciplinary processes that help and allow all the disciplines working in DONES fulfil the Plant objectives. It is first based in the definition and development of a Plant Breakdown Structure (PBS) that allows to set the boundaries between the Main Systems of the DONES Plant and thus to set requirements for each unique System. Currently the PBS tree has 3 defined levels, first level as the main systems.

A schematic (Fig. 1) shows the basic layout of the Plant. Overall five (5) main PBS Systems are identified (Fig 2.) which consists of the following:

- Site, Building and Plant Systems (PS): includes the buildings and the systems providing power, cooling, ventilation, remote handling of components and services to the other systems.
- Test Systems (TS): systems in charge of the irradiation test module(s), the Test Cell and their support systems.
- Lithium Systems (LS): the systems related to the Lithium Target and Heat Removal Systems management.
- Accelerator Systems (AS): systems devoted to produce the high power beam.
- Central Instrumentation and Control Systems (CI&CS): systems in charge of performing the global control of the Plant.

PBS Number						PBS Item
1	2	3	4	5	6	
1						*Not used*
2						*Not used*
3						Site, Buildings and Plant Systems
4						Test Systems
5						Lithium Systems
6						Accelerator Systems
7						*Not used*
8						Central Instrumentation and Control Systems

Fig 2. Main PBS Systems

Based on the main objective of the Systems Engineering Approach the Requirements and Interface Management Group (R&I Group) was set up, in charge of the management and control of the Requirements, the management and control of Interfaces, and the systematic checking and integration in the 3D Model.

The management of the Requirements is first done considering the top level DONES documents as the main sources of the mandatory requirements. These documents are mainly the Top Level Plant Specifications [1], Plant Design Requirements [2], Safety, Standards and Guidelines. These documents contain the requirements to be fulfilled in the Plant design and lifecycle.

Based on these requirements, and the PBS tree, a set of System Requirements is defined and collected in a matrix (System Requirement Matrix), generated with the help of the System Engineer who has in-depth knowledge of each System. Alongside the System Requirements matrix (that has the role of the System Requirement Document (SRD)), the Detailed Design Documents (DDDs) are used for the detailing of each part of the Plant. These documents are set as the main documents to be used for the engineering design and construction of each system according to the objectives and the needs of the Plant.

The management of the Interfaces has as a main objective the precise definition and management of the boundaries and interfaces of each System. The first step consists in identifying the main boundaries of the systems with the help of a Systems Engineer who has in-depth knowledge of each. The Systems Boundary Document (less precise than the interfaces) describe

these correlations at PBS level 2 at a basic level, just to identify the connections. The next steps are to have a detailed description and bundling of interfaces at PBS level 2 and ultimately to have Interface Sheets for each connection with the detailed design.

In a later phase the CAD Configuration Models will also have significant impact on the detailing of the Requirements and Interfaces. For now, only regular checking of model clashes is done, but the integration of the CAD models activities into the R&I Group will be necessary for smooth information flow.

2.1 Requirements Management

The main goal of Requirements management is to ensure that the top level requirements are fulfilled by all the systems in the DONES Plant, and that all these systems are properly designed following the second level requirements. In order to fulfil this goal, a matrix for each PBS level 2 subsystem (the System Requirements matrixes) containing the requirements to be fulfilled by the subsystem is created, populated, controlled and monitored.

These requirements must be satisfied by the system design, mainly described in the Design Description Documents (DDDs). The correlations and leveling between documents can be seen on Fig 3.

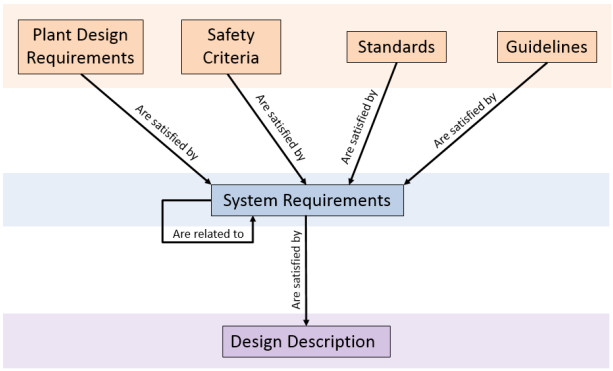

Fig 3. Correlations and leveling of documents

As it can be seen, the System Requirements matrices not only detail the requirements needed for the design, but also establish the upward and downward as well as horizontal traceability, which is essential to track the applicability of each system.

The procedure for these documents is detailed on Fig 4. Main steps consist of close collaboration of the Requirements and Interface Management Group (R&I Group) with the System Engineer who has in-depth knowledge of each System.

The procedure consists of three stages with many revision loops. First, definition of the requirements matrix by the R&I Group and the System Engineer. After the definition of the matrix, the revision can start which is done by the R&I Group for consistency checking, then by the Safety Team, and as a last step, a multidisciplinary checking starts by the other correlated systems. If every requirement is defined and written in a clear way, then the matrix can be approved and the Detailed Design must fulfill these approved requirements.

For now, a first revision and approval of most matrices is being done. Next steps will include the definition of a change management procedure to ensure that the requirements are up-to-date. Also, the definition of an assumption management procedure is to be done as some of the requirements are based on assumptions that will need frequent monitoring. There are other pending tasks such as allocation to lower levels of the PBS tree to define requirements for smaller parts. Integration of interface management process and requirements management process as Interfaces will also have requirements connected to them and these have to be assessed. And lastly, a definition of a method to deal with Remote Handling aspects as it is a transversal System of the Plant and therefore will affect almost every System.

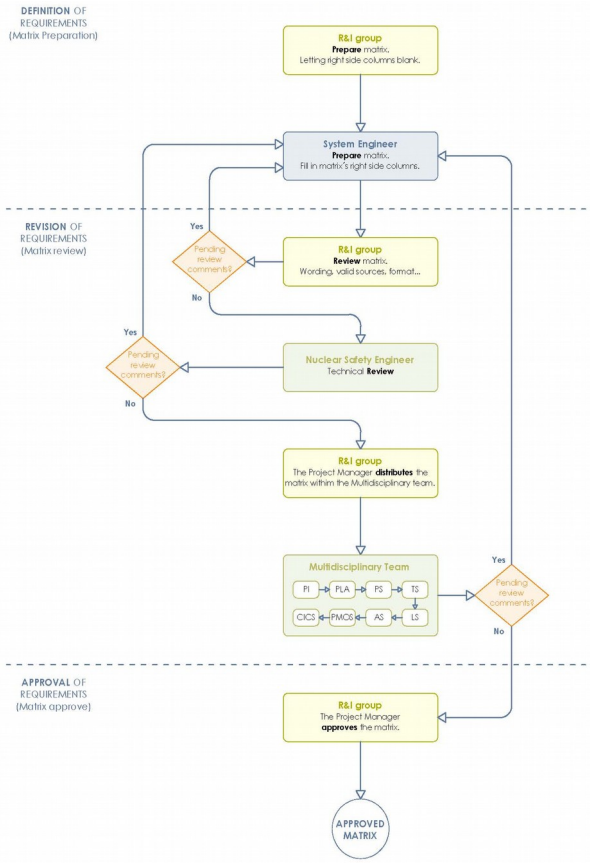

Fig 4. Requirements Identification Flow Chart

2.2 Interface Management

The main goal of the Interface is to achieve an integrated design of all the systems. In order to reach this integration, as many systems are correlated, it is basic to have the interfaces between them clearly identified and design them accordingly. These activities are fundamental at the early stages of the project in order to avoid delays and reducing the iterations in the design of the systems.

To reach this goal, it is very important to have a clear and common understanding of the details and needs in both sides of the interfaces (for instance, the equipment

or component at the interfacing point). As there are a significant number of different RUs working on the project, it is essential to have a common platform where the interfaces are identified and detailed.

In case of DONES this platform varies based on the amount of information we have on interfaces. As of now we are working with interfaces at PBS level 2.

The first identification of interfaces start with the description of boundaries. Boundaries focus on physical interfaces with minimal detail, the goal is to know every interfacing pair for later detailing. This document, called Systems Boundary Document, has been produced with the help of the RUs and uploaded to the Document Management Server of DONES.

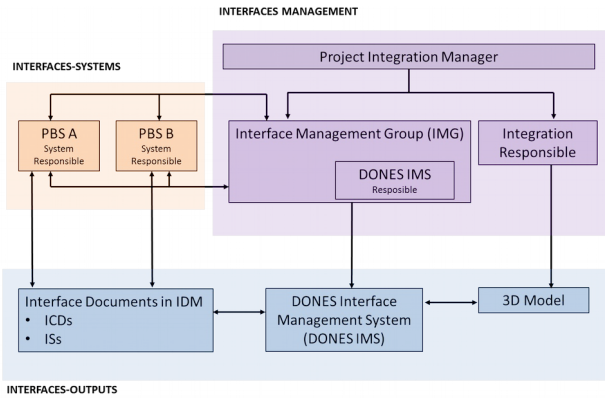

Fig 5. Interface management correlations

The second identification will involve the so called DONES Interface Management Server (DONES IMS) which will detail the interfacing elements, their basic function and will be able to manage the grouping of interfaces. At this stage the Interface Management Group and the System Responsible engineers will work in close contact to fill up this database consistently.

The third and last identification will consist of the interface detailed designs written in Interface Sheets (IS). At this point the Interface Management Group will only monitor the progress of detailing of interfaces in Interface Control Documents (ICDs) and ensure the consistency of ISs. These documents are also to be stored in the Document Management Server, ensuring that any update and change of the ISs are consistent alongside the update of ICDs.

2.3 CAD Configuration Models

The DONES CAD Configuration Models have a dedicated responsible person for every system level 2 (and level 3 in some cases). These responsible persons are working closely with each engineer system responsible in order to produce a 3D Model exactly reflecting what is being designed.

All the systems 3D models are then integrated in a unique DONES 3D Model by the 3D Project Integrator, checking the interfaces between the different structures and systems.

The R&I Group is to closely work with the 3D Model Integrator team in order to:

- Help in the definition of the systems interfaces.
- Check that the defined interfaces are well implemented in the model.
- Participate and review the interference report.
- Check that the requirements, in special those describing a physical issue, are well implemented in the model.

This work is to be consolidated when the R&I Group go in a further stage; for the moment only checking of some interfaces and physical requirements can be done.

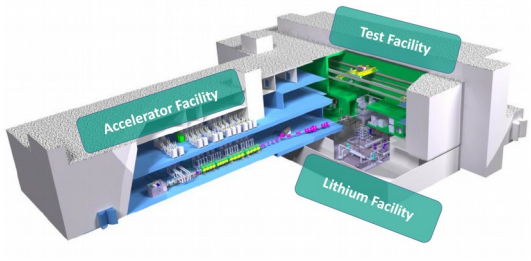

Fig. 6. CAD model Schematic

3. Conclusion and way forward

The introduced Project Integration and Systems Engineering Approach so far yielded good results. The RUs work was simplified and some redundancies in the Systems have already been cleared. With the establishment of the System Requirements Matrices and Interfaces Management System a common platform can be built and shared with each party. This provides a good basis for information flow and management in the future.

However, this common platform still needs frequent update which will be mainly managed by the R&I Group.

Next steps will be the introduction of CAD Configuration Models in the work of the R&I Group in the near future. The establishment of the DONES IMS system is already in work, but some details still need to be clarified.

Regarding the management of the Requirements, a change management procedure and an assumption management procedure need to be defined, issued and used by all the parties. A tool to be used by all the RUs to manage the requirements and their traceability is also envisaged; this will allow an easy access to all requirements and a total traceability of them.

Finally, it is an issue of paramount importance to integrate the requirements and interfaces in the CAD Configuration Models as part of the Integration works, as this interconnection will allow a successful development of the design.

Acknowledgments

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

References

[1] A. García, DONES Top Level Plant Specifications, EFDA_D_2MQ7YU, Unpublished result

[2] A. García, DONES Plant Design Requirements, EFDA_D_2MP6D6, Unpublished result