E-ELT Requirements Management

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ABSTRACT

The E-ELT has completed its design phase and is now entering construction. ESO is acting as prime contractor and usually procures subsystems, including their design, from industry. This, in turn, leads to a large number of requirements, whose validity, consistency and conformity with user needs requires extensive management.

Therefore E-ELT Systems Engineering has chosen to follow a systematic approach, based on a reasoned requirement architecture that follows the product breakdown structure of the observatory. The challenge ahead is the controlled flow-down of science user needs into engineering requirements, requirement specifications and system design documents.

This paper shows how the E-ELT project manages this. The project has adopted IBM DOORS™ as a supporting requirements management tool. This paper deals with emerging problems and pictures potential solutions. It shows trade-offs made to reach a proper balance between the effort put in this activity and potential overheads, and the benefit for the project.

Key Words: E-ELT, Requirements Management, Product Breakdown Structure, Flow-down, Derive, Trace, Link, DOORS

1. INTRODUCTION

The E-ELT Programme has implemented a Requirement Management process that supports specifying, identifying and tracing requirements in a controlled manner.

Individual requirements have attributes, most of which usually do not end up in requirement specification documents, but which carry meaningful information that the project needs to record: the rationale that justifies a requirement, a certain decision or value that is of interest and use for the project, the verification method of each requirement or even the comments that result from reviewing the requirements in a team. Such attributes may be pertinent to the requirement itself at the time it is produced (e.g. a verification method), to the understanding of the underlying line of thought (e.g. a rationale), and may allow it to be evolved, if needed, in a safer manner (changes).

Identifying requirements is also crucial if it comes to managing changes. This is where Requirements Management interfaces and overlaps with the Configuration Management process. The methods of requirement identification that were implemented at the E-ELT will be shown and explained.

Tracing requirements is usually used to support their system-level verification, showing that subsystem design complies with higher-level requirements. Traceability is also needed to support change processes and perform impact analysis of deviations.

Implementing all of the above tasks usually requires quite some effort on the part of the authors, to organize the information and communicate it to the team members. Without appropriate tools and methods, information may get lost, difficult to access, or become inconsistent.

Using a centralized database and following a structured approach based on the product tree, we managed to mitigate such difficulties and to allow a transparent working process.

We decided not to make the tool an exclusive domain for Systems Engineering only, but to involve the document owners and authors directly in populating the database as stakeholders of their requirements.

The real-life work on Requirements Management makes it necessary to use a set of tools, which need to be efficiently adjusted to the intended use. The E-ELT tool-chain is presented at the end of this paper, illustrating a practical implementation.

2. PRODUCT BREAKDOWN STRUCTURE

During the design phase the Product Breakdown Structure (PBS) of the E-ELT went through several iterations in order to follow the evolution of the design and of the procurement strategy (the responsibility for low-level breakdowns being devolved on suppliers). Entering the construction phase, consolidation has taken place and it is anticipated that future iterations, if any, will be minor.

The high level product breakdown structure is shown in Figure 1. The actual breakdown is much more extended than as shown; it has been cut to provide an overview.

Procurement of products may happen on any level of the product tree. The E-ELT Programme manages the requirements of all products down to the contracted items. This excludes the sub-products of the contracted item; they will be specified by the contractor and are part of their Requirements Management.

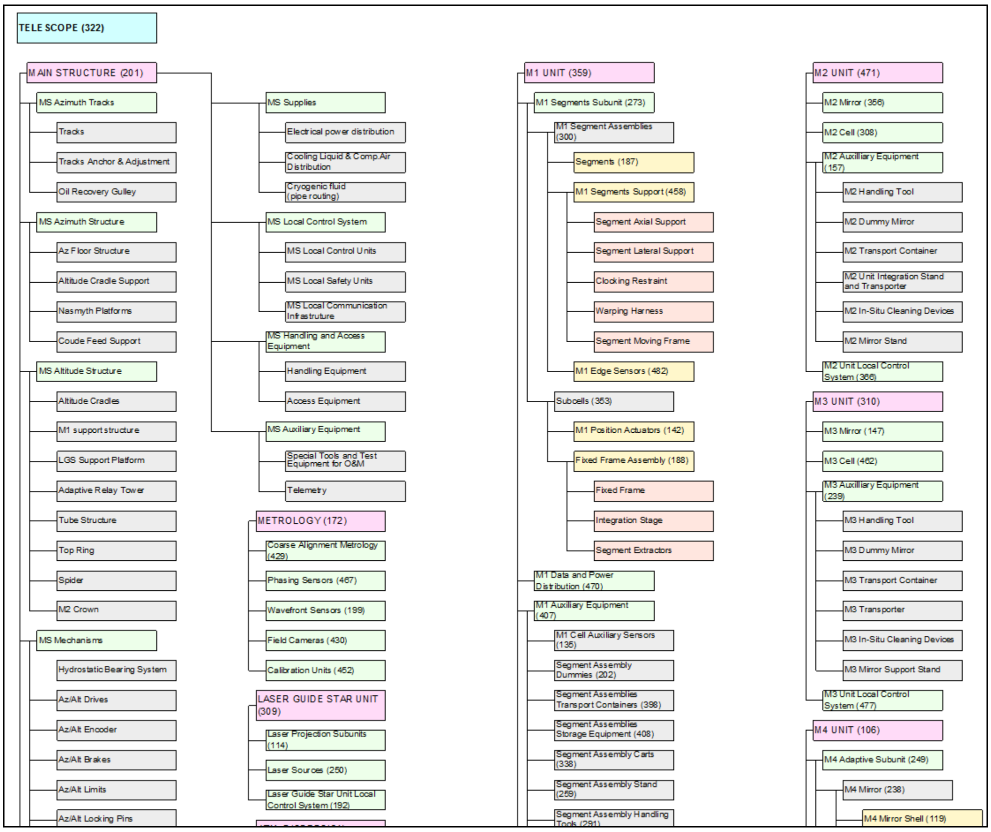


Figure 1. Product Breakdown Structure of the E-ELT (partial) - the colors indicate the different levels of the product tree (i.e. System, Sub-System, Unit, Sub-Unit, etc.)

Together with the PBS we manage the product definition, product codes (for unique identification in configuration management) and product acronyms (for quick identification and tagging) of each product. Managing the PBS of a system of that size needs some effort that pays off against losses and risks that result from inconsistent product definitions and contradicting assumptions. Usually this causes rework, time delay and, potentially, further errors.

3. REQUIREMENTS TRACEABILITY

The data (requirements and, to some extent, design data) and their relationships are managed in a DOORS database using modules (i.e. a structured collection of objects) and links representing relationships between individual objects in different modules. Links are structured to follow a hierarchical path.

The links are implemented in collaborative sessions. Usually the Requirements Manager prepares the links of a document and passes the ownership to the owner of the document. The owner in return continues the linking effort together with the Systems Engineer and Requirements Manager by stepping through the document requirement by requirement. If a requirement is derived or copied from another requirement they create a link and check consistency. In the case of an inconsistency they note a comment in the database and communicate the problem to the owner of the other specification and/or to the Interface Manager in order to mutually resolve it.

The E-ELT Requirements Management system contains requirement documents (requirement specifications and Interface Control Documents (ICD)), design documents (e.g. optical design, wavefront control design, technical budgets, etc.) and other supporting documents that record design constrains (e.g. environmental conditions, design standards, etc.).

The database contains design documents only at system level and ICDs mainly at unit level and below. The ICDs are used to control both the requirements and the design of an interface within a single module. So far this concept has satisfied our needs, thus there are no dedicated Interface Requirement Documents for the E-ELT.

Figure 2 shows the relationships (in terms of requirements management) between the various documents, i.e. the arrows represent derive-, satisfy- and copy-links[1]. The links help analyzing and identifying impacts of change requests.

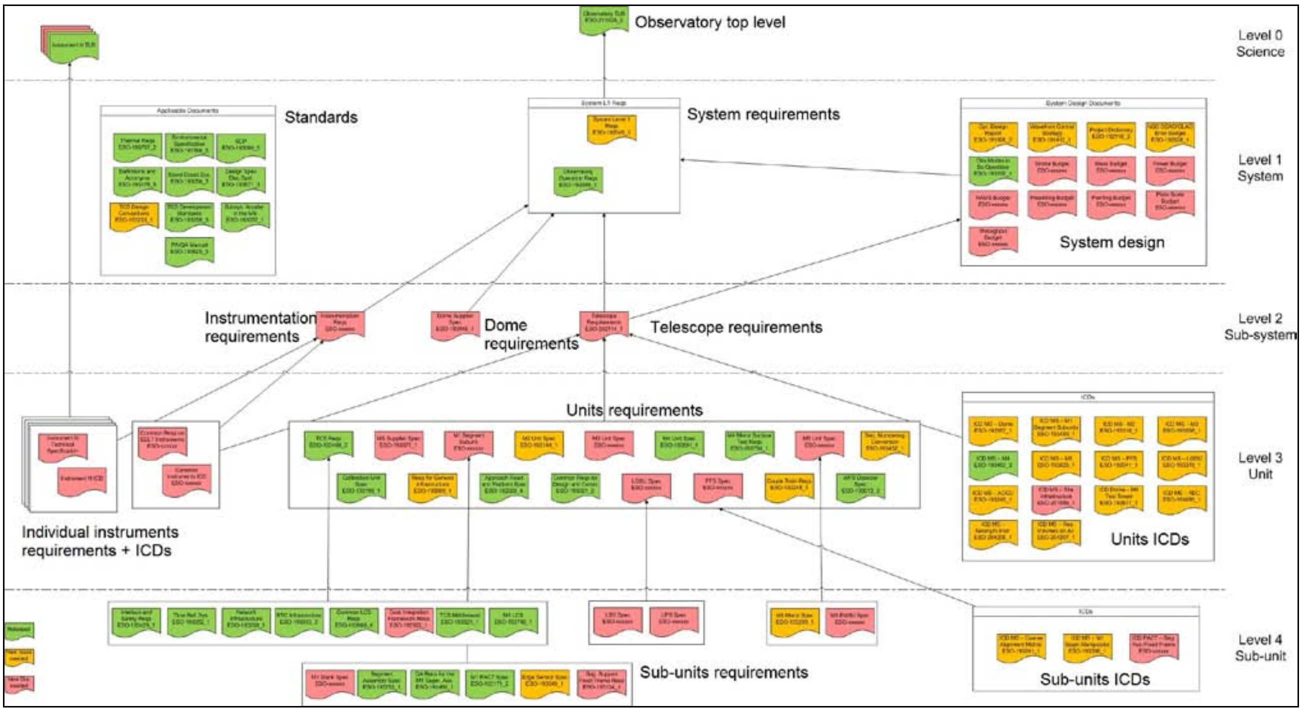


Figure 2. Documentation Structure - the Module Tree shows all requirement documents and their relation to each other

The documentation follows a tree-like hierarchical structure, with the science user needs at the top. The Top Level Requirements (TLRs) are the stakeholder requirements by the scientific community on the whole system, including but not limited to the telescope and the individual instruments.

Those TLRs are derived into a system level (Level 1) specification that describes the system baseline requirements in engineering terms. This system level specification is to translate science needs into engineering requirements, constrain the architecture and drive the design of the whole system.

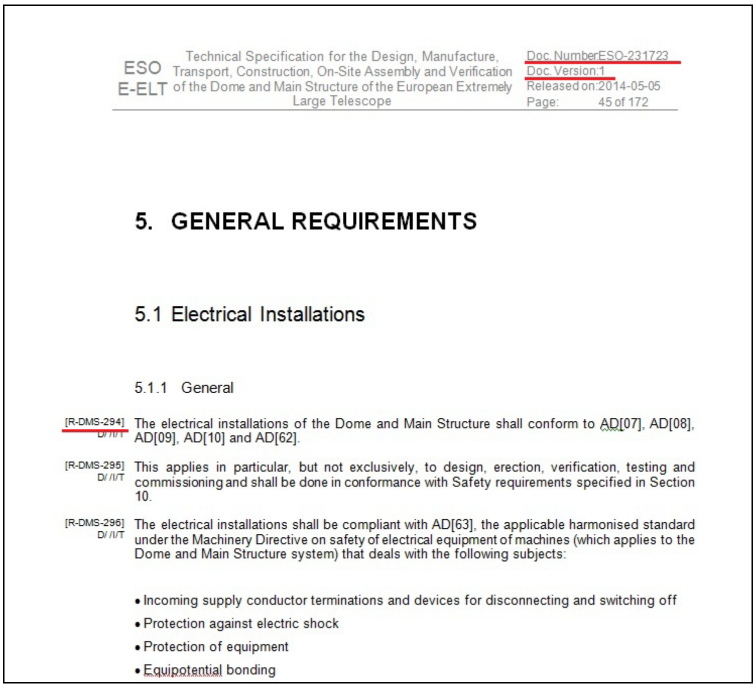
The system level specification is the input to the system design documents. The latter record a baseline design satisfying the requirements and allocating budgets, which in turn are flowed down into requirements or design constrains on sub-systems.

The unit level (or below) is usually where most of the E-ELT products are procured from vendors. That is why it is important to control the interfaces between those products in order to assure that two contractors of interfacing products work with clear common assumptions.

4. REQUIREMENT IDENTIFICATION

During the life of a requirement it underlies potential, multiple changes. Thus a sound identification system is key to managing the evolution and references of the different versions of a requirement.

Using unique numbering allows proper identification of requirements over the whole lifecycle of the system. On the other hand it must be practical and useful in the daily life of the authors of a specification to allow quick and easy reference to a requirement of a known specification.



ESO E-ELT | Technical Specification for the Design, Manufacture, Transport, Construction, On-Site Assembly and Verification of the Dome and Main Structure of the European Extremely Large Telescope | Doc. Number:ESO-231723 Doc. Version:1 Released on:2014-05-05 Page: 45 of 172

5. GENERAL REQUIREMENTS

5.1 Electrical Installations

5.1.1 General

[R-DMS-294] D/ /I/T The electrical installations of the Dome and Main Structure shall conform to AD[07], AD[08], AD[09], AD[10] and AD[62].

[R-DMS-295] D/ /I/T This applies in particular, but not exclusively, to design, erection, verification, testing and commissioning and shall be done in conformance with Safety requirements specified in Section 10.

[R-DMS-296] D/ /I/T The electrical installations shall be compliant with AD[63], the applicable harmonised standard under the Machinery Directive on safety of electrical equipment of machines (which applies to the Dome and Main Structure system) that deals with the following subjects:

- Incoming supply conductor terminations and devices for disconnecting and switching off
- Protection against electric shock
- Protection of equipment
- Equipotential bonding

Figure 3. E-ELT Specification – requirements are identified by a unique number (within the document) and the document number and document version of the respective specification. The requirement tag allows quick (but not unique) identification of requirements

Therefore the E-ELT programme has decided to use two self-standing identification methods. Both have their pros and cons and serve distinct purposes:

- the requirement tag
- the unique identifier

The requirement tag consists of a prefix including the acronym of the specified product (as documented in the PBS) and the requirement number. This allows referring quickly to a requirement of the current version of a specification. The drawback is that it does not include the clear document number and document version, i.e. the working context (document number and version) must be clear for the user. This method is the one mainly applied during the daily work, since it is quick and easy to use. The tag would take a form such as

[R-DMS-294] ,

where "R" indicates a requirement, "DMS "is a nomenclature-based acronym (Dome & Main Structure) and "294" is a unique number generated by the requirements management tool. Within a specified module, this number is generated only once i.e. there can be no duplicate of it over the lifetime of the module.

The unique identifier consists of document number, document version and requirement number. This allows to uniquely referring a requirement over the complete programme lifecycles to a specific document baseline version that is usually related to a specific product and/or contract. This works, even if there are multiple specifications for one product existing (e.g. of different contracts, project phases or previous versions) or where formal, unambiguous reference is strictly required (e.g. to look up the history of a document). The drawback is that the non-speaking document numbers make it more difficult for the users to understand which product or specification the requirement belongs to. This method is rarely used and only if exact identification is needed. The unique identifier would take the form

ESO-231723 V1 #294 .

5. RM PROCEDURE AND TOOL-CHAIN

Since E-ELT authors/owners are direct stakeholders in the requirement database, it is essential to provide them with convenient input/output interfaces. The proportion of users electing to provide their input directly in the database has steadily increased, but from the start, the project decided to offer the option of a more familiar interface (Word). This is subject to a major reservation, though: once the data are in the database, they can only be evolved there as there is no practical way to re-import data from standard text processors without losing the attributes and links that can only be implemented in the database.

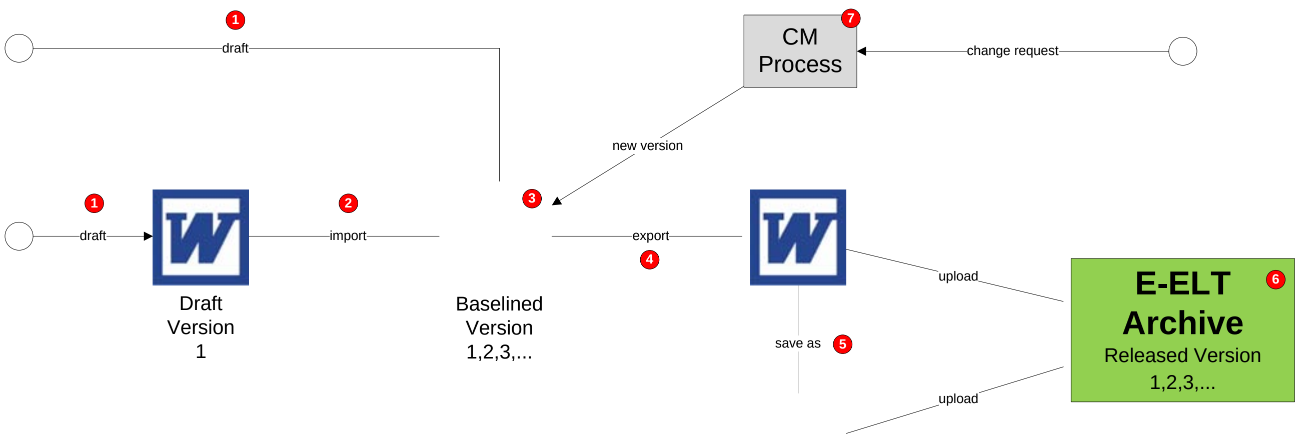


Figure 4. Tool-Chain of the E-ELT Requirements Management Process

The E-ELT procedure for generating requirement documents is as follows (see also Figure 4):

1) At the discretion of the author(s), a draft Version 1 of a document may be written in MS Word™ or directly in IBM DOORS™.

2) If written in Word, the draft document is imported into the DOORS database.

3) From there on, the module (document) is managed in DOORS. This includes updates, corrections, setting attributes (e.g. requirement rationale), linking and baselining the requirements. The DOORS database is structured along the PBS. It contains more information than what is visible in the final paper copy of a document, e.g. rationales, comments and links at individual requirement level, as well as module attributes (see Figures 5 and 6).

4) A finalized version is exported from DOORS to Word,

5) … and from here saved as PDF.

6) These two files are uploaded to the E-ELT Archive. The web-based tool contains a folder structure that is based on the PBS (see Figure 5).

7) A change to a released document triggers a new version of the corresponding module in the DOORS database. This is usually handled by the configuration management process. The versions of DOORS modules and released documents are correlated.

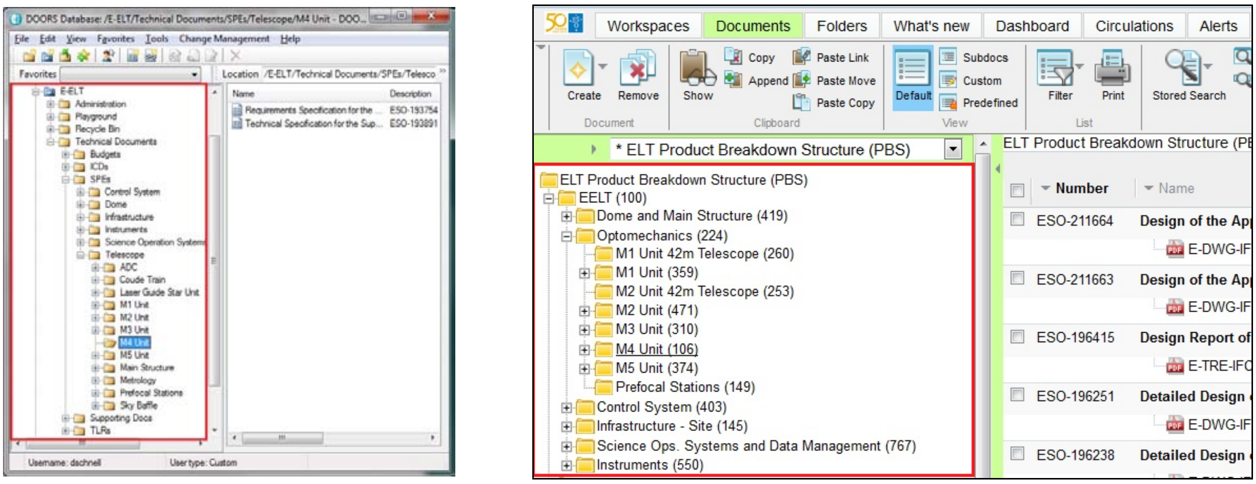


Figure 5. E-ELT DOORS (left) and E-ELT Archive (right) – structured along the Product Breakdown Structure

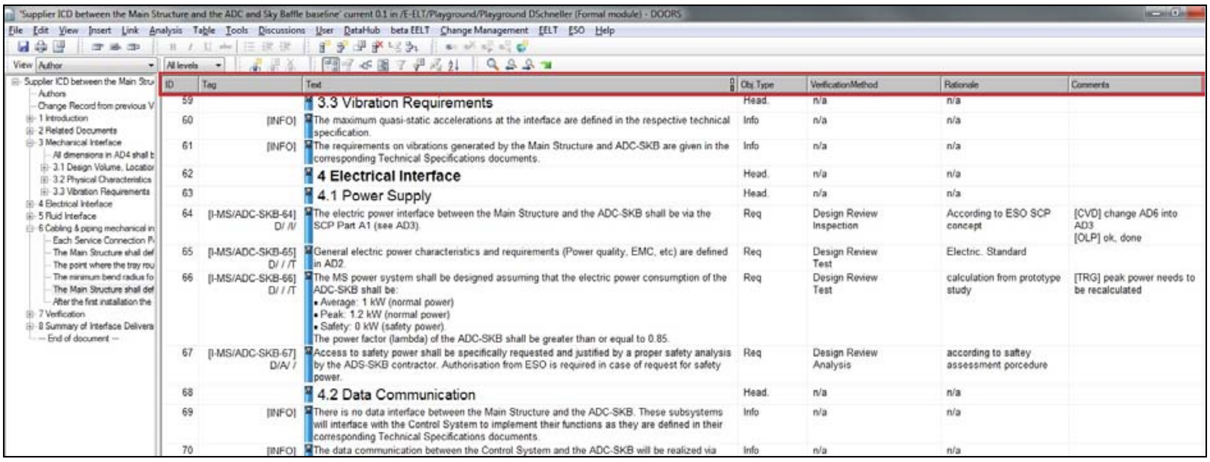


Figure 6. E-ELT DOORS Module – contains (beyond others) the ID, Tag, Requirement Text, Links, Object Type, Verification Method, Rationale and Comments of a requirement.

6. SUPPORTING TOOLS

We have developed additional tools that help managing the requirement database. The need for them arose during the implementation and execution of our processes. Some have proven useful others not, we share a few lessons-learned below.

DXL Scripts with various different functionalities allow the database administrator to e.g. set the access rights, views, attributes of multiple modules at a time, to avoid cumbersome and error-prone manual work.

A Database Analysis enables to quantify the state and development of the project requirements. The data shows the number of modules, requirements, headings or other objects and links within the complete database and to/from each individual module. This allows monitoring the evolution of the requirements set over the project lifetime, and detecting anomalies.

The DOORS Support Pages are a web-based tool that shows graphically the linking between all current modules in the database. In combination with the document structure, described above, this helps comparing the target with the as-is state of the database.

The Nightly Export is a tool that was requested by project members who, for one or another reason, have irregular access to internet and thus cannot access the database server online. We developed an automatic export tool that creates a read-only file of all current module versions every night. The user can download PDF files for later offline work. In practice usage has been low as most concerned users eventually preferred to generate exports themselves, on an ad-hoc basis.

7. CONCLUSION

The E-ELT Programme has decided to set a Requirements Management framework structured around the PBS. Experience shows that the underlying discipline and overheads are broadly accepted as it mitigates the occurrence and the effect of inconsistencies, confusion, misunderstandings and incorrect information being propagated.

The transparent use of a centralized tool, which is used as the unique repository of all valid requirements, fosters teamwork, communication and the owner’s ownership of and responsibility for a requirement document. This also facilitates managing interfaces between products and documents.

Last but not least, we feel that this framework, while representing a significant evolution in relation of past working habits, has been broadly accepted by the project team; we feel that this is due, in significant part at least, to team members recognizing long-term benefits and eventually becoming advocates of the system.

REFERENCES

[1] Friedenthal, S., Moore, A. and Steiner, R., „A Practical Guide to SysML“, The MK/OMG Press, 322-339,(2012)