DOI: 10.13009/EUCASS2023-364
Aerospace Europe Conference 2023 – 10TH EUCASS – 9TH CEAS

How to use the AI tools for the Space Systems delivery

Jamel METMATI
Telespazio France
26th Champollion avenue, Toulouse
djamel.metmati@telespazio.com

Abstract

The Space of Things around Earth and the Moon is growing very rapidly for scientific, commercial, defence or test purposes, the need to take measures to improve the quality and the speed of the Space systems delivery. This paper provide an analysis of the main identified challenges to be addressed by the Artificial Intelligence techniques to improve the tempo of Space systems delivery. Then, the volume of technical documents including the standards and the operational requirement is discussed, taking into account the need to merge data to accelerate the qualification process for the launch. At last, the methodology to use the Artificial Intelligence tools shall provide the capacity to improve the operational cycle to ensure the launch, to detect the errors and the parameters to be change to complete the validity of the system. The Intelligence Artificial through the tools available on the market provide new operational capacity to improve the management of the requirements to be applied to validate the functions and to configure the components of the Space system. Above all, with the commercial Space ports in Cornwall or in Esrange, the processing for the delivery shall change to ensure the time to market for the Space of Things on orbit around Earth and potentially to support the activities to the Moon. The Space sector requires significant financial funds and times to develop a system. Moreover, its development need to produce a large volume of documents. Within these documents, the recommandations, the requirements, the references give the elements to provide the Space of Things. Indeed, the life cycle include several steps : satellite mission analysis, preliminary design of satellite modules, manufacturing, assembly of module, qualification testing, acceptance testing with accreditation and cyber-security requirements. The baseline to be applied to follow these steps is based on the traçability of technical documents and the coherence of the requirements. And some sources come from others references linked with the international standards updated with the new rules. These digital documents are also stored following some requirements in the database. Their structure shall be aligned with the coherence of the system expected. In this context, the Artificial Intelligence tools should improve the writing of the documents in each steps to provide the Space system through the IAS algorithm based on the structured inputs linked with the space sector.

1. Introduction

1.1 The technology

The regulations and the technologies provide the capacity to deliver of Space assets with the functionalities faster than before. The process is not yet fully industrialized become it needs education, training, infrastructure, agencies, compagnies in the same tempo. The Space ecosystem requires the networks science to produce the nominal systems and the sub-systems for Space. The specificity of Space system is the volume of documents within the requirements to be applied in the design and to find the technical solution from the design. The technical baseline allows to build and to follow the system to implement new functionalities and to follow the compliance linked with the frameworks of the international regulations.
The Space engineering process is based on the international regulations. All technologies and methodologies must follow the requirements of industrial framework. In order to ensure the safety and the security in Space operations, the quality, the safety and the security requirements gather the main domain of any system and sub-system for the ground and the Space segment.

DOI: 10.13009/EUCASS2023-364

The IA tools shall be reliable with the requirements of the RAMs and operational security. The first use case has been used in Space for the diagnostis and the software. By now, the techniques are implemented in the ground segment to maintain the performance of the systems. Therefore, the documentation which describes the systems and the sub-systems shall be linked with the IA process in which it exists the AI requirements. The main international standards encompass the ISO documentation, the ECSS, the CCDS, the Space shield for cyber-security [1].
Then, all the documentations which describe the Space system use the tools to built system according to the requirements choosen. Moreover, the systems change with the new component in the design and the new functionalities. To reach this purpose, the follow up requires others tools to built faster the document in the same framework in the engineering process in which the Artificial Intelligence comes up in Space activities.

The features for AI and Space have been described and the regulations can already be applied for the Space data. The amount of data is enough to use it in the context of the high performance computation to produce a result from the Doors use case with the natural language in the technical requirements for the systems and the sub-systems [2]. The Doors from the European Cooperation for Space Standardization shall be matched with GPT to look for the inputs and the outputs of design change and the compliancy. The Doors database is composed of modules pre-defined or modules can be created after a validation. The numbers of modules are linked with an item : Space Engineering, Space Project Management, Space Sustainability. Each Folder contains a list of sub-folders that themselves includes one formal Module and one link module. Each formal Module contains the content of a published ECSS standard. The link Module handles the cross-references within the formal Module.

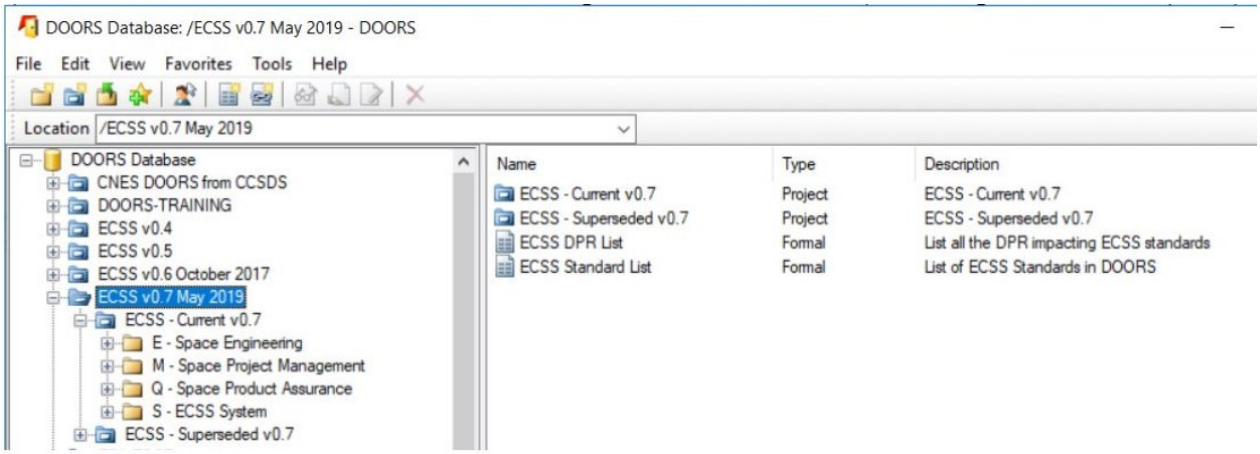

Figure 1

The limit and the issue of the work through the Doors module needs to use the links, to fulfill the headings and to manage the notes. Indeed, the standards with interleaved notes in one or more requirements didn't have the notes split from the normative text to a separate attribute. In this case, the notes can only be moved on a next revision of the Standard if the problem is corrected. An interleaved note is when there is normative text before and after the note, in which case, if the note is split from the rest of the requirement, it may not be possible to know to which content it was referencing.
Then, even if a DOORS script (DXL) created all the links in the Standards automatically, it needs to be created. For exmaple, a NOTE is inside the requirement field and the NOTE has a reference to a Requirement / Table / Figure. When a link was created by the script, only after moving these NOTEs to the correct field the links can be corrected as they are created automatically. Moreover, the Tables / Figures might have an IE PUID without being called by normative text. A work for the requirements of a system rely on the knowledge gathered by previous studies. As the documents can be incomplete, the technical information flow is constrained by who can access and share them among other documents design engineers.

The AI can answer complex queries with reliable and relevant information to help and to produce the documents [3]. This means from Doors database with an API to a search engine with a cluster or not, the natural language framework procudes the responses to the question about a system or subsystem. The concept already exists through Daphne which is an intelligent assistant for designing Earth observation satellite systems including feedback and answers to specific queries [4]. The paper focus on the first preparation steps to describe the system : mission acknowledge, the constraints, the requirements necessary, the initial inputs and the trade off.

DOI: 10.13009/EUCASS2023-364

1.2 The Doors architecture

As DOORS is a requirements management tool designed to capture, link, trace, analyze and manage a range of information to ensure a project's compliance to specified requirements and standards. Systems engineers require requirements management in order to provide solutions. The structure of the organizing requirements shall be manageable to register them and to check the duplicate information. The requirement is the step to apply the technologies for the systems. The purpose is to manage the requirements for the product for the ground segment and the Space segment. The preparation need times to built the documents to describe a model. Most of the cases, the organizations use the consultants to provide the draft of documents. The database are often available from some documents with different versions. To find something, the manual search is used by the function "find" in the Word or PDF document due to the specific digital environment. As mentioned, others database are available, mainly Doors, it requires training to manipulate the modules, the links and the structure of the documents. This methodology is incomplete to provide the complex combination of subjects and objects.

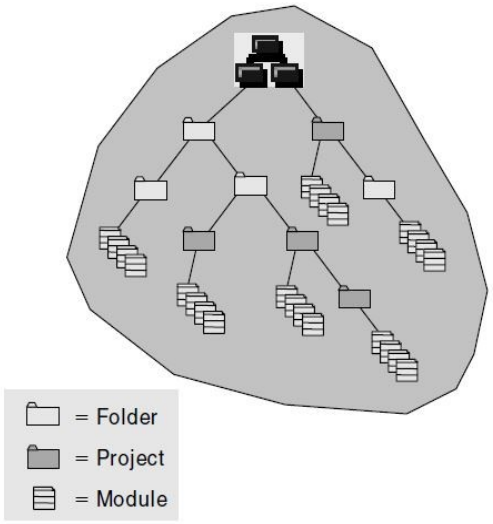

Figure 2

The work of an AI Space systems engineer requires to organize well the structure of the database to ensure the module is compliance with the system and the sub-system incoming. To do that, the AI framework shall describe the requirements to be follow to understand the structure and the semantic of the database as the digital environment as well [5]. Moreover, the AI Space systems engineer shall be able to request line code to question the database to display a result. For example, it will be the sentence " write a code able to display the requirements linked with the interfaces between the system and the subsystem of the spacecraft". The gain of times will provide a product faster than the classic methodology.

2. The Space Ecosystem by AI

2.1 The datasets

The engineering tools via AI needs datas and the advantage of Doors is to provide a structure (figure 2). The requirements and related information can be stored in a central database in DOORS. The database can be accessed in a variety of ways and exists throughout the lifetime of the application. The information in a DOORS database is stored in modules. Modules can be organized within the database by using folders and projects. A project is a special

DOI: 10.13009/EUCASS2023-364

kind of folder that contains all the data for a particular project. DOORS *folders* are used to organize data and are just like folders in a computer file store. Folders may contain other folders, projects or modules. Folders are given a name and description and the ability for users to see or manipulate the data in a folder may be constrained using access controls. DOORS *projects* are used by a team of people to manage a collection of data relating to that team's work effort. The project should contain all of the data related to the requirements, design, development, test, production and maintenance for an application. The project provides the capability to manage users and their access to the data in the project, to back up the data and to distribute portions of the data to other DOORS databases. DOORS *modules* are containers for data sets. At last, IBM Rational DOORS offers APIs to integrate with other IT applications. These integrations allow for example to connect to a database, to exchange data, or to synchronize files between several computer programs via an extension, a plugin, or an application programming interface.

2.2 The DOORS_GPT

The documentation assistant means to produce faster the document for costumer on a topic requested to get a baseline to get a new document. The use case is the reach the objective of compliancy from system thanks to the documentation existing. It describes the matrix of compliance and the follow-up from the Space Shield framework. The SPACE-SHIELD (Space Attacks and Countermeasures Engineering Shield) is a knowledge-base framework for Space Systems. The Matrix concerns the Space Segment, the Ground Segment, the Space link communication. The purpose is to find if the requirement is compliance with threats, tactics, the mitigation proposed for a system in Space. The use case is the waste of propellant with the saturation and the exhaustion of Spacecraft.
The AI Space engineer identify the risks for the system for a new satellite. So, it needs to check this point rapidly to provide the inputs to produce the satellite. The framework precise that the risk is linked with that "an attacker can maliciously consume satellite propellant resources to achieve the goal of reducing satellite life". In this case, the satellite must have a life expectancy over 10 years. The Doors GPT architecture to be used to be faster shall follow the requirements following : the database shall use available the Doors on the target system. Then, the need to import requirements from the system and the sub-system shall be concerned by the using API .
If the classic tools can be MATLAB and Simulink. By now, the AI tools should be asssociated by MatGPT to improve the computation. The cluster making the search engine could compute the response to the request in the documents. In this example, you will import all of the requirements from the " FuelSys Requirements Specification module". The Doors documentation provide the procedure to import the requirement via the API by the code on below (figure 3), and a filter can be applied with the attribute, the condition, the value. With this, the module displays the requirements that match the filter. The requirements Toolbox in which the engineer can find the import does not store the filters used for a future use. It means the memory of research is known only by the engineer doing the requests on below :

```
# OpenExample('slrequirements/ImportRequirementsFromIBMRationalDOORSByUsingTheAPIExample')"
# Use slreq.import to import the module.
# Enter the name of the requirement set file.
# Specify that the requirements are referenced requirements and should use Rich Text Formatting.
# Name the requirement set fuelSysReqSpec.
# Enter the module ID. The function returns the number of imported referenced requirements, the requirement set file
path, and the requirement set object.
#[refCount1,reqSetFilePath1,myReqSet1] = slreq.import("linktype_rmi_doors", …
#AsReference=true,RichText=true,ReqSet="fuelSysReqSpec",DocID="000001c1")
```

In the figure 3, there is an "Export function" can be used inside the Doors system. The export can be done with xls format on the hundred lines on the specific topic of fuel system to provide the compliancy of the waste of propellant. Through the MatGPT as MATLAB app used on a workstation, the process allows to guarantee the integrity of the database. The process can be faster in adding a search engine via a cluster following the volume of data expected. And by The MatGPT you can load a list of prompts for specific use cases and engage in conversations with the data exported on the workstation. The AI Space engineer can use a notebook like Jupyter AI to improve the analysis [6]. Inside the notebook, the engineer can write directly a request in semantic language to display the result of the compliance. It could be "write a code by python to display the requirement linked with the security of waste of propellant"

DOI: 10.13009/EUCASS2023-364

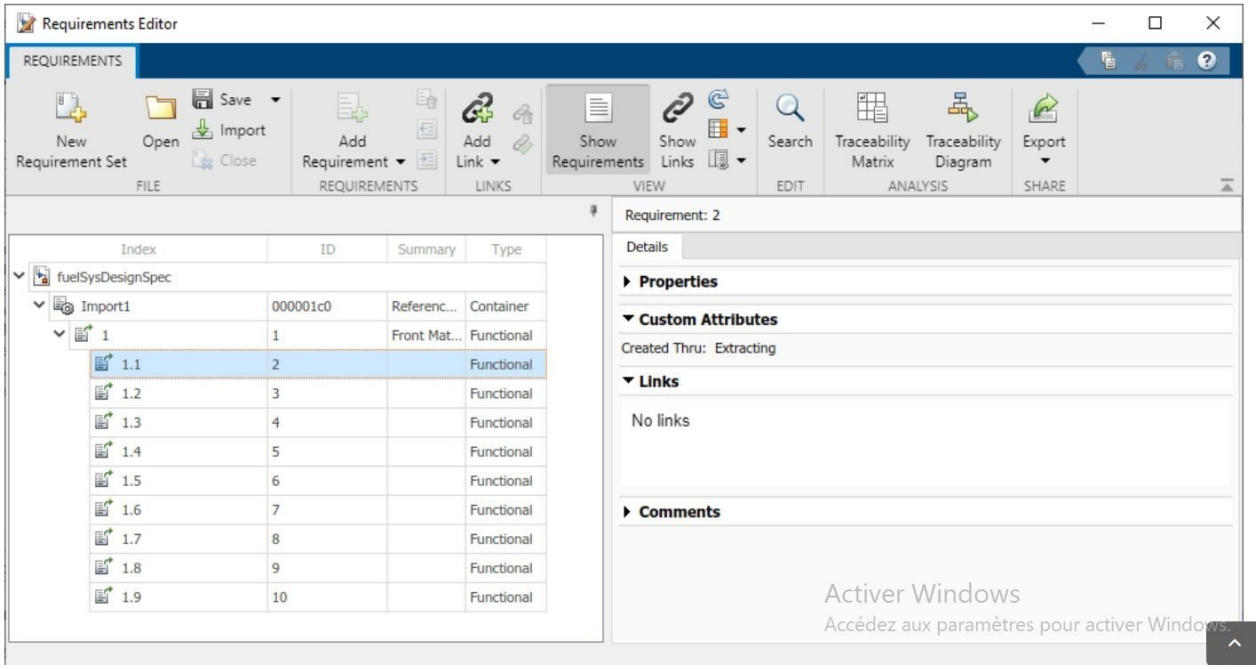

Figure 3

The pre-requisites to apply the methodology are the MATLAB R2021 or later version with an OpenAI API Key from the platform : https://platform.openai.com/account/api-keys. With the MATLAB, it needs an environment variable with your OpenAI API key providing by the software architecture including Doors, Export function with search engine or not to a workstation, the notebook with AI components.

setenv(“OPENAI_API_KEY”, “your key here”)

The specific of Space sector provides an advantage because all the systems and subsystem are documented in the database with formal procedure to be exploited. The Artificial Intelligence Space algorithm gathers the methodology to apply the work of AI for an engineer in this sector in the same principle as ESA Cloud [7]. The algorithm details the database from the Doors in which there are requirements and the API to be applied to export data in a AI methodology. This methods includes the tools, the architecture, the technology to be used through the Space regulations.

DOI: 10.13009/EUCASS2023-364

References

[1] EU SHIELD project, (Securing against intruders and other threats through an NFV-enabled environment) https://www.shield-h2020.eu/

[2] IBM-Rational-Doors-Release-9.6-DXL-Reference:Manual:https://www.ibm.com/docs/en/SSYQBZ_9.6.0/com.ibm.doors.requirements.doc/topics/dxl_reference_manual.pdf

[3] Digital Twin and Artificial Intelligence Enabling Innovative Spacecraft Design, Development, and Flight, IAC-22,D1,3,6,x69088, 3.19 Sep 2022, Dr. Christine Edwards, Lockheed Martin (Space Systems Company)

[4] Myers et al., " An intelligent personal assistant for task and time management", AI Magazine, Vol. 20, No. 2, 2007, pp. 47

[5] D3.js, "D3.js – Data-Drive Documents" [Online] Available: https://d3js.org/
About - Space CODEV Platform (space-codev.org)

[6] GitHub - jupyterlab/jupyter-ai: A generative AI extension for JupyterLab

[7] https://www.esa.int/ESA_Multimedia/Keywords/Description/cloud_computing/(result_type)/videos