ATENA+ — EGS-CC-compatible automation system for AIT/AIV and operations based on OTX

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ABSTRACT

The ATENA project (Adjusting open Test Exchange staNdard to the spAce domain) delivered the first version of a tool for a comprehensive treatment of the equipment testing processes (presented inter alia at SESP 2017). A distinctive feature of the tool was the fact that it was based on the OTX – Open Test sequence eXchange standard (ISO 13209) which was adjusted within the project to the requirements and peculiarities of the space domain, in particular taking into account the Space System Model (defined within ECSS-E-ST-70-31C) and the ECSS-E-ST-70-32C standard related to test and operations procedure language.

The present ATENA+ project is aimed at upgrading the original system (consisting of the ATENA IDE (OTX Editor), ATENA OTX Engine, and SUT (System Under Test) Driver), with the upgrade directed mainly towards further integration of the system with the space specific solutions. This will be achieved first of all by providing compatibility with the European Ground Systems Common Core (EGS-CC), but also by implementing the additional SUT Drivers to support SCOS2000 (Satellite Control and Operation System 2000), MiB and OMG XTCE. A strong emphasis will be put on enhancing usability of the tool by equipping it with further, relevant functionalities and on making it more user-friendly.

INTRODUCTION

The diversity and complexity of the activities carried out by ESA and the organisations collaborating with the agency make it necessary to develop and implement well-designed and uniform solutions, in order to avoid any major inconsistencies in data exchange between the involved entities as well as unnecessary increases in cost and error susceptibility in the AIT/AIV (Assembly, Integration & Test or Verification) phases of building space systems. This problem was recognized and addressed in the ATENA project (Adjusting open Test Exchange staNdard to the spAce domain), which delivered a functional version of a tool for a comprehensive treatment of the equipment testing processes (presented e.g., at SESP 2017 [10]), assessed to be TRL-4 which indicates that it is a prototype . A distinctive feature of the tool was the fact that it was based on the OTX – Open Test sequence eXchange standard (ISO 13209) [1]-[3], which was adjusted within the project to the requirements and peculiarities of the space domain. In particular, the adjustment took into account the Space System Model (SSM) [4] as well as the standard related to test and operations procedure language introduced in [5].

An important part of the work in the ATENA project was devoted to elaborating SSM-oriented extensions to match the requirements of OTX, which was achieved by exploiting a model consisting of two SSM levels. These levels are SSM Declaration (general specification of the SSM objects, e.g. activities' names and identifiers) and SSM Implementation (a set of values and technical description of the interfaces/communication channels, e.g., specific XTCE – XML Telemetric & Command Exchange – data, or, in the case of ATENA proof of concept, the description of REST interfaces for the Arduino-based robot). In order to enable building, exchanging, executing, and maintaining SSM-based test sequences, a development of space-oriented OTX runtime environment was also necessary. The approach to the design and implementation of the space domain OTX Extensions followed the extension mechanism rules defined in OTX Core [2] and already used to apply existing OTX Extensions of the standard in the automotive industry. In a result, a common language for exchanging ESA diagnostic test sequences was delivered.

The figure below presents the mechanism which the ATENA System uses to perform an integration between ECSS-E-70 and OTX.

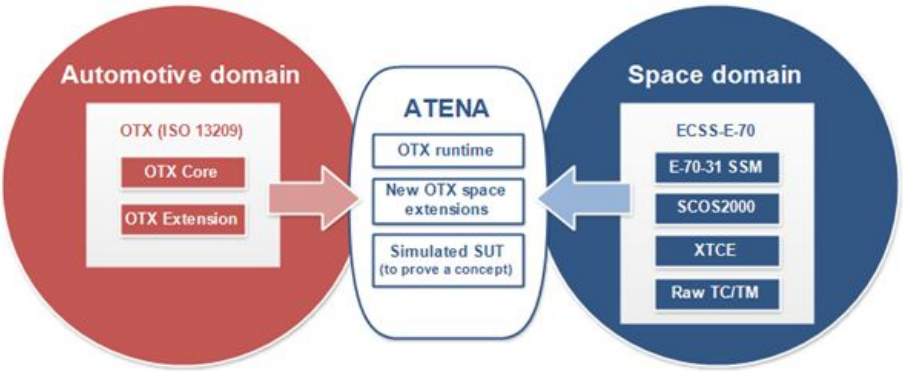

Fig. 1 ATENA - General Concept

The OTX runtime and library of relevant existing OTX Extension combined with new space-specific OTX Extensions (as the main part of the ATENA system) constitute an integration point for both OTX and SSM. In the ATENA project, an Arduino-based robot was used as a SUT to play the role of a real system (e.g.

spacecraft, ground station) communicated via dedicated channel equivalent to TM/TC interfaces to give a proof of the proposed concept.

The components of the original ATENA system are presented in Fig. 2.

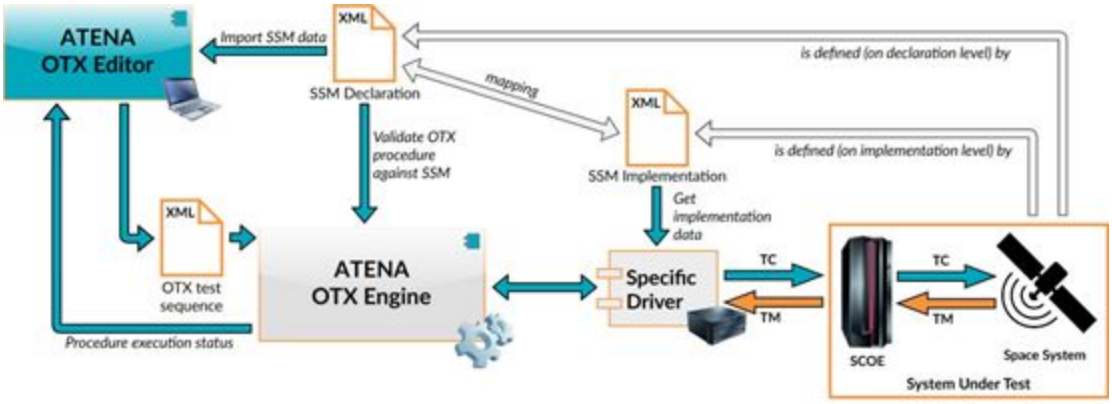

Fig. 2 Products of the ATENA system

Three main components of the system are OTX Editor for creating OTX procedures, OTX Engine for running OTX procedures and SUT Driver for assuring communication with SUT. Each of these components takes part in the process of building and executing OTX test sequences, with dependencies and data flows between them as presented on Fig. 2.

Even though the ATENA project fulfilled its aims completely, and the ATENA system developed within its course proved to be a fully independent and operational toolkit, it also faced various limitations. On the one hand, a necessity to extend existing functionalities by new features was realized. It also turned out that the UI should have been improved. In addition, a necessity to integrate the system with the European Ground Systems Common Core (EGS-CC) [6] emerged. These observations, originating mostly from the recommendations expressed by the users of the original ATENA system, kindled the idea to develop ATENA+, which will be built upon its direct predecessor.

OBJECTIVE AND MOTIVATION

In order to improve the ATENA system and meet the ESA expectations regarding its further development, new features and functionalities will be implemented. The ideas for the upgrades originated mainly from feedbacks provided by its potential and actual users. The system was already presented on three different conferences, including SpaceOps 2018 [9], SESP 2017 [10], and ESAW 2017 [11]. Moreover, ATENA has been tested by the Space Research Centre (SRC) of the Polish Academy of Sciences, which is responsible for creating tools used for conducting space missions (e.g., MUPUS - *Multi purpose sensors for subsurface science,* which was used in the Rosetta mission). The feedback obtained during the conferences and from the SRC evaluators can be summarized in the following points:

- to make ATENA more user-friendly,
- to improve the usability of the system,
- to integrate ATENA with ESA Common Core architecture and services,
- to provide capabilities to support testing equipment which is managed by the SCOS2000,

- to implement capabilities necessary to support testing of SCOE modules.

TWO STANDARDS INVOLVED IN ATENA

What sets ATENA apart from other test automation systems is the fact that it is based on two open standards: OTX and SSM, that specify the capabilities of a SUT and test sequence performed on it. It means that the work carried out within the ATENA system may be reused in other software packages (compliant with either OTX or SSM).

The OTX standard was initially introduced in the automotive industry in order to standardise the specification and execution of the test sequences but afterwards proved to be applicable in other domains as well. One of its major advantages is the fact that it provides a mature XML Schema data model. Furthermore, it enables procedure exchangeability since the data model is standardized and very strict, the OTX files conforming to the standard are guaranteed to be compatible with any OTX-compliant authoring system. Moreover, it offers a possibility to provide a user with more than one view, since it can be easily translated into a pseudo-language or displayed in a graphical way. Additionally, OTX compared to Java and other languages coincides in terms of their complexity but overcomes its competitors in terms of intelligibility and easy-to-use nature. What is also of crucial importance is that OTX not only makes it possible to use a unified method of data exchange but also provides effective validation mechanisms in terms of test sequences, syntax and semantics.

The other standard involved in the ATENA, i.e., SSM, illustrates a functional decomposition of space systems in a form of a tree structure which describes a space system. The objects definable using the SSM are:

- System Elements (SE) that are results of a functional decomposition of a space system defined in [4] and [5],
- Activities (A) that provide monitoring and control functions. They are associated with SE referring to procedures, telecommands and any function provided by the EMCS (Electrical Monitoring and Control System) implemented within the EGSE (Electrical Ground Support Equipment) or any other mission control system,
- Reporting Data (RD) associated with SE that comprises parameters,
- Events (E) associated with SE and RD representing occurrences of a set of conditions that can arise.

ATENA+ FUNCTIONALITIES

Figure 3 illustrates the main process executed within the ATENA+ system. The diagram is divided into two parts, one of which represents Procedure Upload and the other one Procedure Execution. They connect via the ATENA+ Procedure Repository which is placed in the centre of the figure. The previously developed version of ATENA system (described in [1]-[3]) was focused mainly on the execution of OTX procedures. During that work only prototype version of the ATENA IDE was provided, whose main aim was to enable preparation of OTX files and tracking of their execution. Within the current work on ATENA+ IDE it is planned to refine the user interface of the original IDE and improve it. Within that refinement, the procedure creation interface will be simplified and re-developed according to the UX guidelines. Furthermore, the IDE will also provide additional functionalities depicted on Fig. 3.

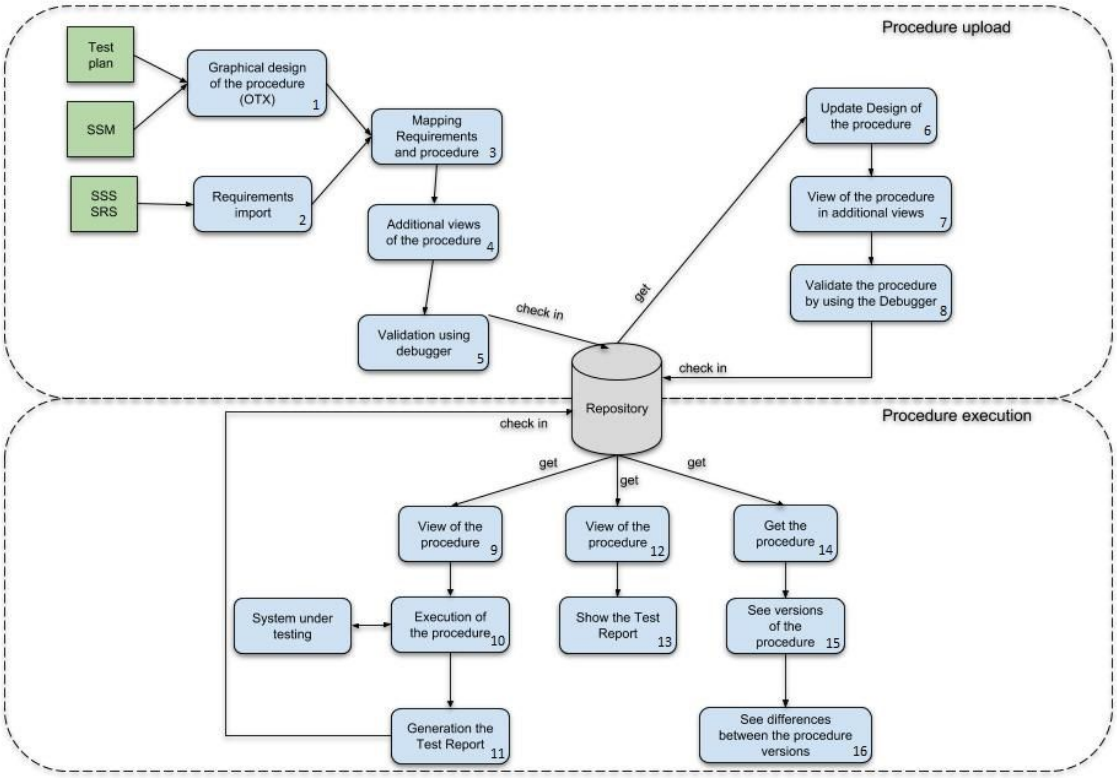

Fig. 3 Functionalities of ATENA+ OTX Editor

The usability of ATENA+ will be enhanced by making use of OTX standard more in-line with the needs of an end-user. This will be achieved by improvement and refinement of the graphical procedure creation interface (Fig. 3, box 1). Graphical symbols to represent high-level elements of the procedure will be created. This will enable abstracting from the OTX elements and hiding technical details, i.e., a condition will be represented by just one box instead of a dozen of different OTX elements. Furthermore, additional procedure views will be provided, e.g., an activity diagram and state diagram (as defined in UML) to enable an insight into the structure and workflow of procedures. A view of a procedure in a language similar to Java code will be also made available. The extension of procedure debugging possibilities will include an option of selecting a list of variables to be tracked as well as setting breakpoints (both conditional and non-conditional).

The ATENA+ Procedure Repository based on a code management system (e.g., GIT, SVN, etc.) enabling modifications of procedures management introduced by different users will be created. This approach will allow to maintain consistent test procedures, to control introduced modifications, to restore their earlier versions, and to resolve conflicts related to simultaneous modifications.

Creation of a simplified version of the ATENA+ IDE (i.e., ATENA+ Viewer), containing merely read-only views, is also planned (Fig. 3, boxes 12, 13). The system will provide an ability to link requirements with created procedures and their elements. For this purpose, the option of importing files with requirements in selected formats (CSV or DOORS) will be added (Fig.3, box 2). The link between requirements and parts

of OTX file will be shown in the ATENA+ IDE as a table (requirement vs. OTX element) or a property of ATENA+ diagram elements.

In addition, a format for storing requirements in the ATENA+ Procedure Repository together with the procedures will be developed, which will enable a synchronization of the created content between different instances of the ATENA+ IDE. After a procedure execution, the ATENA+ IDE will generate as-run reports containing common information (Fig. 3, box 11), such as procedure name, author, date, time, logs, etc. and full execution log. In addition, it will be possible to select detailed data of the collected information, a list of input variables, telemetry generated by SUT, etc. These reports could be optionally stored in the ATENA+ Procedure Repository as files for viewing by other interested parties. ATENA+ IDE will also allow work audits to be performed. During a procedure creation, logs containing information about every task performed by a user will be created.

The following points describe respective processes to be executed within the ATENA+ system:

The process of transferring requirements, model of the system and test plans into an OTX compliant code
While a user is creating a graphical design of a procedure, the requirements are being imported from the SSS (Space System Specification) and SRS (System Requirements Specification). Then the requirements are mapped onto the procedure. The process makes it possible for the procedure to be viewed in additional perspectives resulting in better intelligibility of the procedure. Validation performed by the Debugger is the last phase of the procedure. It is then stored in the Repository. (Fig. 3, boxes 1-5)

The process of executing a procedure
A procedure is shown in the viewer so that a user can check if it meets their expectations. The next step is an execution of the procedure. In this process the SUT Driver translates and realizes the procedure using an external device. (Fig. 3, boxes 9-11)

The process of auditing
The first step is downloading a procedure from the Repository. The downloaded file contains all the crucial information, e.g., its authors or its previous versions. All the information is accessible to a user. (Fig. 3, boxes 14-16)

The process of updating ATENA procedures
After downloading it from the repository, the procedure can be edited by a user. Then a user can view it in various perspectives and verify its correctness. The procedure is afterwards stored in the Repository. (Fig. 3, boxes 6-8)

Viewing the procedure
The view-only mode can be used if a user doesn't have permission to edit procedures. In this situation a simple view is provided along with all the Test Reports generated for this procedure. (Fig. 3, boxes 12, 13)

ATENA+ ARCHITECTURE

Figure 4 presents the overview of ATENA+ architecture and vision for its Envisaged Fully-Fledged development. The original version of the ATENA system consists of ATENA IDE (OTX Editor), ATENA OTX Engine, and one SUT Driver for demo kit, as mentioned in the introduction to the article. The new elements that have been introduced to the system are ATENA+ Repository, prototype of EGS-CC SUT Driver and ATENA+ Viewer. Furthermore, the functionalities of the ATENA IDE have been extended,

thus it has evolved into ATENA+ IDE (these new functionalities have been described in the previous section). A module responsible for a complete integration with the ESA Common Core will be implemented within an Envisaged Fully-Fledged development. However, this work is intended to be carried out at further stages of the project, and within the first stage only an initial prototype will be developed. The aim of this would be to prove that ATENA+ system could invoke activities on EGS-CC and collect reporting data from it.

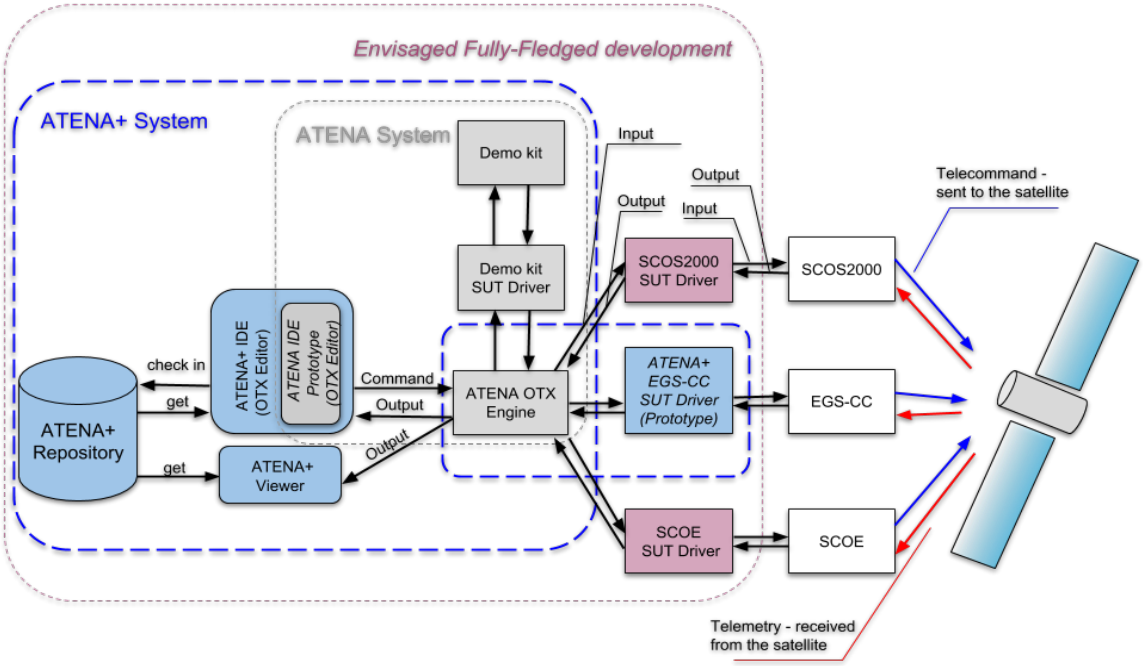

Fig. 4 ATENA+ System Architecture

The ATENA+ Repository will be responsible for managing modifications of procedures. A code from the Repository can be pulled to the ATENA+ IDE and ATENA+ Viewer. The ATENA+ Viewer will be a light version of the editor, allowing to just load procedures from the Repository and to receive data from the ATENA OTX Engine. The ATENA+ IDE will enjoy extended functionalities comparing to the ATENA+ Viewer, in particular it will be able to push a code into the Repository and send commands to the Engine. The integration of the system with the ESA Common Core will be realized by connection with the ATENA OTX Engine. The SUT Driver performs communication and translation between the Engine and tested device. It has to be stressed that a dedicated SUT Driver has to be provided for each system to which the ATENA OTX Engine is to be connected (e.g. SCOS2000, EGS-CC, SCOE, etc.).

FURTHER EXTENSIONS

ATENA system has been designed with the extensibility approach in mind. This means that extensions to the OTX standard could be also applied in ATENA+ system. However, this will require providing an additional set of functionalities for ATENA OTX Engine and ATENA+ IDE. In case of the Engine it might be realized as additional module extending core capabilities of OTX standard. For the ATENA+ IDE it might be a set of new objects which could be used during the process of defining the procedures. Such an

approach makes the system open and ready for future improvements. It could be for instance application of the whole solution to a domain different than space-related one. Due to flexibility of the standard and its implementation every case in which complex systems providing APIs are present could be covered.

CONCLUSION

The outcomes of the ATENA+ project are assumed to make a significant addition to the previously developed ATENA system. The main extensions are connected with its further development in order to reach higher software maturity level (i.e. TRL 6). These extensions will provide additional functionalities for ATENA+ IDE, make it more user-friendly and intuitive for the users without knowledge about OTX standard structure. It will lead to faster adaptation of ATENA+ System by users with expertise in space equipment test domain. Furthermore, ATENA+ will be initially integrated with EGS-CC and will provide the capability to execute tests on it. Such approach will assure that ATENA+ could be used in future as a part of EGS-CC compliant test framework.

It is also worth emphasizing that the OTX approach will be still the cornerstone of ATENA+ and its advantages will be still valid. The OTX approach clarifies the requirements imposed by vendors regarding the testing procedures in the space domain which leads to simpler specification of system requirements. A unified data model smoothens and simplifies the data exchange between different entities.The combination of theses advantages creates common understanding between the collaborating stakeholders, leading to an overall improvement in cooperation amongst them.

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