Using XTCE in the SVOM Chinese ground segment– Roadmap and current status

Feifei Liu[1] and Maohai Huang[2]
National Astronomical Observatories, Chinese Academy of Sciences, Beijing, 100012, China

Tai Hu[3]
National Space Science Center, Chinese Academy of Sciences, Beijing, 100190, China

Bo Li[4]
GSegment Space Technologies, Inc. Beijing, 100040, China

Wei Bian[5] and Ju Su[6]
National Space Science Center, Chinese Academy of Sciences, Beijing, 100190, China

The Space-based multi-band astronomical Variable Object Monitor (SVOM) is a space mission for Gamma-Ray Burst (GRB) studies, developed in cooperation between China and France. The SVOM mission faces the challenge of the TM/TC data exchange between the spacecraft manufacturer, instrument manufacturers and ground components throughout the mission lifecycle. The XML Telemetric&Command Exchange (XTCE) standard is proposed a solution to this problem. This paper describes the road map and the current status of using XTCE in the SVOM Chinese ground segment. We identified the application scope and methods and the tools needed in the context of current SVOM ground segment architecture. An XTCE-based prototype of TM data ingester has been developed for demonstration and verification purpose, using the Herschel Common Science System (HCSS) as a backend platform.

I. Introduction

Dedicated to GRBs study, the SVOM (Space-based multi-band astronomical Variable Object Monitor) mission is a small satellite built with joint efforts from France and China. The main scientific objectives of the mission include providing fast and reliable GRB positions, measuring the broadband spectral shape and temporal properties of the detected GRBs.[1] The mission has started its detailed design phase and is currently scheduled to launch in 2015.

The SVOM mission is characterized by the collaborative observation of its space instruments and the ground observation system and by the cooperation of France and China in building both the space and the ground segment. Each country will contribute 2 of the 4 space instruments and half of the whole ground segment.

With its international cooperation background and highly distributed collaborative entities, the SVOM Chinese ground segment (CGS) faces the challenge of TM/TC data exchange between the spacecraft and instrument manufacturers and ground components throughout the mission cycle. The XML Telemetric&Command Exchange (XTCE) is proposed as a solution to this problem.

By providing a unique TM/TC definition format and an information model defined as an XML schema, the XTCE standard provides convenient TM/TC information exchanging among ground systems and eliminates the need of format conversion between TM/TC data description file formats used by those systems.[2]

This paper describes the current status and road map of using XTCE in the SVOM Chinese ground segment.

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[1]Engineer, NAOC, 20A Datun Road, Chaoyang, Beijing, China. liuff@nao.cas.cn.
[2]Professor, NAOC, 20A Datun Road, Chaoyang, Beijing, China. mhuang@nao.cas.cn.
[3]Professor, NSSC, NO.1 Nanertiao, Zhongguancun, Haidian, Beijing, China. hutai@nssc.ac.cn.
[4]Engineer, GST, CRD YinZuo, Wanda Plaza, ShijingShan District, Beijing, China. libo@GSegment.com.
[5]Engineer, NSSC, NO.1 Nanertiao, Zhongguancun, Haidian, Beijing, China. bianwei@nssc.ac.cn.
[6]Engineer, NSSC, NO.1 Nanertiao, Zhongguancun, Haidian, Beijing, China. suju@nssc.ac.cn.

The requirements on XTCE application posed by the current SVOM CGS architecture are described in detail in session II. In order to demonstrate the application methods and identify the technical difficulties, a preliminary study on the XTCE application in the scope of SVOM Chinese science center was carried out. In session III we present the tailoring practices on the XTCE standard and the development of an XTCE-based TM data ingester prototype for the SVOM CSC with the HCSS (Herschel Common Science System) as a backend platform. With the experiences obtained from the feasibility study, the proposed methods and XTCE tools needed in the context of current SVOM GS architecture are presented in session IV. Section V is a conclusion and future work.

II. SVOM CGS Requirements on XTCE Application

The whole SVOM ground segment is divided into two separated while collaborative parts, the French ground segment (FGS) and the Chinese ground segment. Figure 1 shows the current SVOM ground segment architecture.

The CGS provides the only Mission Center (MC), the Chinese Science Center (CSC) and the Chines ground observation System (C-GOS) that includes a C-GFT (Chinese Ground Follow-up Telescope) and two arrays of GWAC (Ground Wide Angle Camera). [4] The main tasks of the MC are traditional ones including mission operation, payload heath monitoring and raw data processing, managing and distributing. The CSC will be responsible for the science operation and data processing, archiving and distributing of Chinese instruments (both space and ground). The C-GOS will provide a ground complementary observation on targets detected by the space instruments.

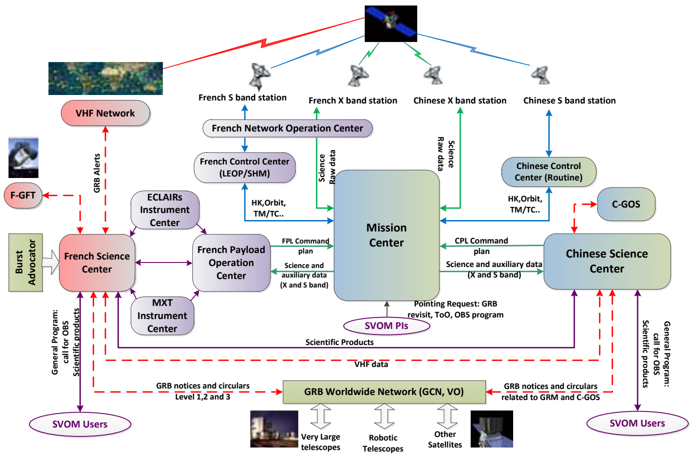

Figure1. SVOM ground segment architecture.[3]

The MC and CSC are heavily involved with TM/TC processing operations which will be implemented with components functioning by referring to TM/TC definition information. The XTCE standard is proposed to be applied in developing those components to meet the following requirements:

1) Providing a unique format for TM/TC description files used by TM/TC definition dependent components of the MC and CSC.
2) Separating the application from the TM/TC data definition so that the SVOM MC and CSC can be built from early mission phase and are adaptable to possible frequent TM/TC definition changes during the development and ground testing phases.
3) Building an XTCE-compatible Chinese payload database that enables the SVOM CGS to interoperate with the SVOM FGS that will be built with XTCE-compatible systems.
4) Providing an information model for common TM/TC processing components of the MC to realize reusability. The SVOM MC is planned to be built with a set of common components that will support the operation of other 5 science exploration satellites.

III. Feasibility Study on XTCE Application in the SVOM CSC

In order to identify the technical difficulties, a feasibility study on the XTCE application in the CSC was carried out. One of the key tasks of the CSC is to analyze data collected by the SVOM Chinese space and ground instruments. Those data are of various formats and need be imported to a local database of the CSC before further analysis. The XTCE was applied in implementing a TM ingester that can cope with all those different data formats without changing the application code.

The feasibility study included two aspects, the study on the XTCE schema and the study on the application of XTCE. An experiment on tailoring the XTCE schema was carried out by eliminating the duplicated elements definition methods. Then we tried to convert the interface control documents (ICD) of a historical space mission to XTCE format file to verify the compatibility between the new XTCE standard and the traditional instrument TM/TC definition. Secondly, an XTCE-compatible TM ingester for the CSC prototype was implemented to verify and demonstrate the XTCE-based TM processing.

A. XTCE standard tailoring practice

By defining an XML schema, the XTCE standard defines where the TM/TC information should go in an XML file. However, it is not as simple to convert instrument ICDs to corresponding XTCE files, especially when constrained by the requirements that the XTCE files should be processed automatically by a set of applications.

The difficulties mainly come from the flexibility of the XTCE standard. While it reduces the complexity of expressing TM/TC data information in XTCE files, this flexibility makes it almost impossible to develop tools to extract information automatically from an XTCE file that are compatible with the complete version of the standard. A typical example is the choice in describing the containers, by inheriting from a base container or by combining several containers. Those two definition choices lead to completely different algorithms in determining the position of each entry in a container. Another example is the definition of the position of an entry in a container. One can use a position reference to the start of the container, to the end of the container, to the previous entry or to the next entry. With those choices, it is very hard to develop an application to automatically compute the organization of a whole TM packet according to the XTCE files solely.

To solve the above problem, we tried to constrain the scope of choices and tailor the XTCE standard (schema V1.1). The basic principle was to identify those elements with multiple definition choices and keep only one way of description. Also in order to simplify the data types, only two kinds of parameter type (integer and float) were kept.

With the tailored XTCE schema, we tried to convert the interface data definition document of a historical mission into its corresponding XTCE file. About 600 TM parameters, 200 kinds of TC packet, 20 kinds of TM packets, 4 kinds of frames and related auxiliary definition information (calibrator, alarm, etc.) were expected to present in the output XTCE file. The results and findings are as follows.

1) All information in the original document was preserved except the definition of TM transfer frame. The mission defines a fixed length CCSDS TM frame type containing CCSDS TM packets of variable length. We found it difficult to present this information with the current XTCE schema.
2) We encountered the similar questions on the XTCE standard such as whether alarm limit and calibration properties of parameter types or individual parameters, also mentioned by Simon Maslin in their paper [5]. During the conversion, we got no parameters that were of the same calibration, alarm, encoding and length and thus could share a same parameterType but many parameters that had different calibration characteristics or alarm limits while the same encoding and length features. With the current XTCE definition, those parameters had to be assigned a different Parametertype each, which intuitively makes the separation of parameterType and parameter unnecessary.
3) We found that an editor dedicated to XTCE standard would be extremely useful to prepare the XTCE files. During the conversion practice, the XMLspy was used as an editor preparing the XTCE files, which although provides convenient XML editing and XML file-schema validation, could not eliminate the need of manually checking the name references among containers, parameters and parameterTypes. Automatic validation on reference checking and XTCE file generation will reduce the workload and improve reliability of the final XTCE files.

B. XTCE-compatible TM ingester prototype implementation

1. Design and development

In order to demonstrate the XTCE application in the CSC and identify the key technical risks, an XTCE-compatible TM ingester prototype was implemented, mimicking the process of SVOM level0c data importing and raw data product generating, storing and displaying. As shown in Fig. 2, the TM ingester consists of 4 modules:

1) A TM file parser that extracts TM packets and parameter values from the input TM data files according to the corresponding XTCE format TM/TC description files and generates raw product objects.
2) An XTCE file parser that validates the XTCE files and provides application interfaces for other modules (i.e. the TM file parser) to obtain TM definition information. The parser will validate the input XTCE files first. The validation includes XTCE schema violation check, duplicated element names check and non-existing name references check. The

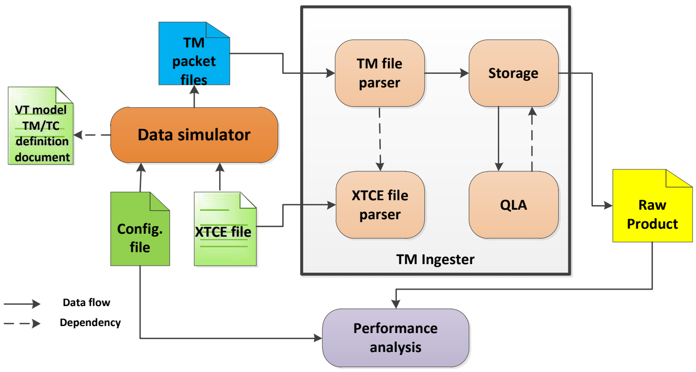

Figure 2. Basic architecture and data flow of the TM ingester.

XTCE file parser will stop and print the error information (element/attribute name, causes and location) if errors are found.

3) A storage module that stores the extracted TM packets, parameter values and raw data products. It also provides query and retrieval of previously stored TM packets, TM parameter values and the generated raw data products.
4) A QLA (Quick Look Analysis) module that is used to examine the imported TM data in on-line and play-back mode.

The prototype was implemented in Java. The XTCE file parser is based on JAXB (Java Architecture for XML Binding) with each XTCE element casted to a Java class.

The prototype was also a practice on the adoption of the HCSS, a key system providing common supports for Herschel instrument and science operations from ILT phase to post mission phase [6]. The team responsible for the development of the SVOM CSC has been involved in the development of Herschel scientific ground segment since 2005 and contributed several key components. It is planned to re-use in the SVOM CSC the infrastructural frameworks and modules of HCSS. The TM file parser splits binary TM data files into java objects representing the TM packets and parameters which are modified from the java package abstracting the Herschel TM packet definition. The QLA module of the TM ingester was adapted from the one in the HCSS. The output raw data products can be saved as FITS files so that they can be loaded into the HIPE (Herschel Interactive Processing Environment) for further analysis with Python scripts.

2. Function and performance verification of the TM ingester

The function verification of the TM ingester focused on its abilities in XTCE file parsing and validating and adaptability to changes of TM definition, that is, changes of input XTCE files. To fulfill those tasks, three kinds of XTCE files were prepared.

The first two kinds were XTCE files of two instrument models that defined TM packets of different structures and contained no errors. Those description files, together with their data counterparts, were used to test the adaptability of the TM ingester to changes on the TM definition.

The third kind was XTCE files that contained schema violation, duplicated XTCE element names and non-exist name reference errors inserted on purpose. They were used to test the XTCE validation function of the XTCE parser. Figure 3 shows the structure of an example XTCE file. All XTCE files used during the functional test were generated by modifying this template.

A simulator based on simplified models of Visible Telescope, one of the SVOM space instruments, was implemented to generate simulated TM data files as input data for the TM ingester verification. The TM data files contained simulated science and HK CCSDS TM packets that were mimics of the real TM data files distributed to the CSC by the MC. The HK parameter values were of fixed patterns and the science parameter values were extracted from several pre-defined astronomical images so that the output raw products could be compared with the original input values.

Test results show that the TM ingester worked with all its main requirements fulfilled. It will extract TM packet and parameters from data files if all the input files are correct and will log the error messages if the XTCE file fed contains any of the 3 kinds of errors mentioned above. Different XTCE files can be fed without changing the application code, which demonstrates the adaptability obtained by XTCE standard application. The successful adoption of HCSS modules in the TM ingester encourages further investigation on the re-usability of the HCSS. Figure 4 presents the GUIs of the XTCE file parser, TM data file parser and data query and retrieval.

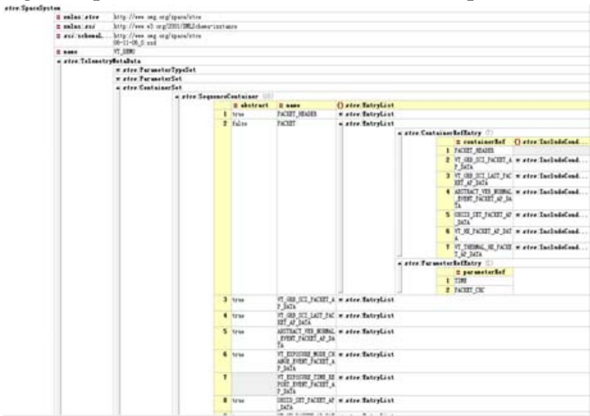

Figure 3. XTCE file example.

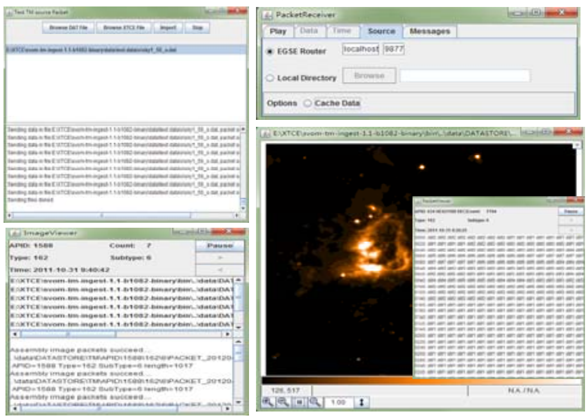

Figure 4. TM ingester GUIs.

IV. Proposal for Future Roadmap

The implementation of XTCE-based TM ingester prototype is a simplified demonstration of using XTCE in the scope of SVOM CSC. Although the expected adaptability was verified, further experiments are still needed before the standard can be fully applied. The proposed improvements mainly lie in the following two ways:

1) During the previous study, only TM data processing was considered. Feasibility studies on the TC processing are needed in order to evaluate applying XTCE standard in implementing related components of the SVOM MC.
2) The previous study focused on using the XTCE as the TM/TC description format while did not investigate the full potential of using XTCE as an information model to implement automatic TM/TC processing abilities including, for example, the parameter calibrating, alarming, algorithm-based TM data analyzing. In the next phase when the TM/TC processing requirements become more specific as the mission proceeds, applying XTCE in those fields will be fully evaluated.

Although the components involving with TM/TC definition have different functional and performance requirements, tools needed to generate and process the XTCE files for those components to refer to TM/TC definition can be identical. With the experiences obtained from the TM ingester implementation, a set of common XTCE tools is proposed to be developed.

1) An XTCE file editor dedicated to XTCE file preparation. Our previous study suggests that an XTCE file editor providing XTCE element-based GUI editing windows and automatic syntactic and semantic validation of XTCE files will greatly reduce the workload needed to convert interface documents to correct XTCE files. The editor will also provide supporting functions for system engineering purpose such as the conversion from XTCE files back to interface documents so that ICD version control could be easier.
2) An XTCE file parser that extracts instrument TM/ TC definition from the XTCE files.
3) A Spacecraft database that manages the TM/TC information extracted from XTCE files and provides a unique interface for the ground segment components to obtain the TM/TC definition services.
4) An XTCE based payload data simulator that generates simulated data for the SVOM MC and CSC prototype.

Figure 5 presents application of those XTCE tools in implementing CGS components in different mission phases. With those XTCE tools separating the TM/TC definition from the CGS components, changes on the TM/TC definition will not affect the implementation of related functional components, therefore making it possible for the SVOM MC and CSC developed from the very early mission phase and to evolve as the mission proceeds.

The implementation of those XTCE tools considers not only the requirements of the SVOM mission but also their re-usability. An XTCE file editor prototype is now under development, supporting the XTCE file editing, validating, project management and version control. It will be used as a system kernel with new functions added as the mission proceeds. The XTCE file parser and the payload data simulator can be adopted from the corresponding modules developed for the TM ingester prototype. The non-XTCE parts of the spacecraft database and the data simulator are dependent on the requirements raised by components of the SVOM CGS and thus will be developed in a later phase when functional requirements become more specific and their preliminary architecture designs are finished.

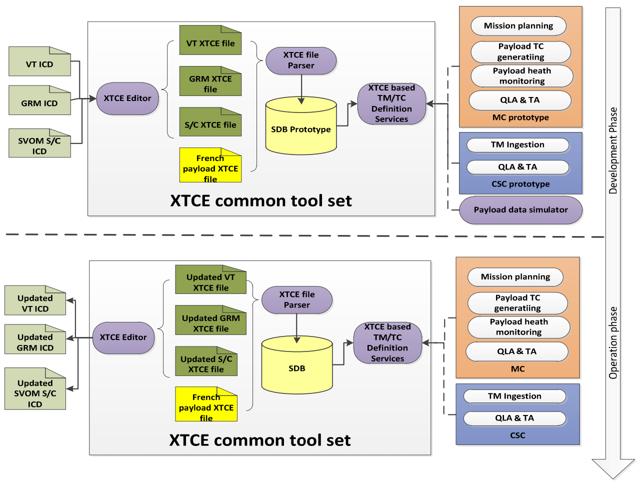

Figure 5. XTCE tools in the SVOM CGS.

V. Conclusion

Aiming at providing unique TM/TC data exchange format among various ground systems and breaking the coupling between TM/TC data description file and the applications using them, the XTCE standard is in the trend of replacing the traditional TM/TC description methods.

Our practices on the XTCE feasibility study in SVOM CSC suggest that the main difficulties of applying XTCE in space missions come from the understanding of XTCE itself and the tailing of this very flexible standard to fit the mission requirements while keeping the tailored XTCE schema as generic as possible. Further investigation on the full potential of the XTCE standard used not only as the TM/TC description format but as an information model enabling automatic TC generation and TM parameter calibration, out of limit alarming and analyzing will be carried out, benefiting the development of the SVOM CGS as well as the evolution of the XTCE standard itself.

With the modules developed for the TM ingester prototype as system kernels, a set of XTCE tools that handling all aspects of XTCE-related processing will be developed aiming at supporting not only the SVOM mission but missions in the future.

Appendix A
Acronym List

C-GOS	Chinese Ground Observation System
C-GFT	Chinese Ground Follow-up Telescope
CGS	Chinese Ground Segment
FGS	French Ground Segment
GRB	Gamma-Ray Burst
GWAC	Ground Wide Angle Camera
HCSS	Herschel Common Science System
ICD	Interface Control Document
QLA	Quick Look Analysis
SVOM	Space-based multi-band astronomical Variable Object Monitor
XTCE	XML Telemetric&Command Exchange

References

[1]Schanne, S., Paul, J., Wei, J., Zhang, S. ,Basa, S., Atteia, J. L., et al., "The future Gamma-Ray Burst Mission SVOM," ArXiv e-prints arXiv:1005.5008, 2010, URL: http://arxiv.org/abs/1005.5008v2.

[2]CCSDS Secretariat, "XML TELEMETRIC AND COMMAND EXCHANGE (XTCE) NFORMATIONAL REPORT," CCSDS 660.0-G-1, 2006.

[3]Fabienne, S. and Chen, W., "SVOM System inputs for Programming Loop," CNES and SEMC, SV-SY-NT-145-CNES, 2011.

[4]Huang, M., Li, X., Li, A., Cai, H., "Chinese SVOM Ground Segment Functional Specification," CAS, SV-GS-SP-002-CAS, 2008.

[5]Braun, A., Wasser, Y., Schmidhuber, M., Hofmann, H., Wickler, M., "XTCE at GSOC - First Experiences Adopting a New Standard," *SpaceOps 2010 Proceedings,* AIAA-2010-2015, Huntsville, USA, 2010.

[6]Peter, R., "Designing for Software Reuse - the Herschel Common Science System," ERCIM News online edition [online journal], Number 65, URL: http://www.ercim.eu/publication/Ercim_News/enw65/EN65.pdf [cited April 2006].