Objective: O-5, T-2, S-1 and S-2

ECSS-E-TM-10-25 evolution and the state of COMET

Short paper for MBSE 2022 Conference

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1. Introduction

ECSS-E-TM-10-25A is a technical memorandum ™ published under the E-10 System Engineering. It defines both a language and an exchange protocol to facilitate collaborative Model Based System Engineering (MBSE) in the context of Concurrent Design.

The topic of this paper is to report on the evolution of ECSS-E-TM-10-25A ecosystem driven by various ESA R&D projects and unexpected use cases in both the space domain and non-space domain

2. Evolution of ECSS-E-TM-10-25 and the COMET master model

ECSS-E-TM-10-25 provides 3 annexes on the bases of which software implementations can be developed:

- Annex A: a formal model defined in UIML.
- Annex B: a population of so-called reference data that contains definitions of categories, parameter types and units, etc.
- Annex C: a definition of a REST API and file-based storage.

The current version of E-TM-10-25 is version 2.4.1 released in 2013-2014, approved by the Concurrent Design User Board (CDUB) made up of ESA, national agencies, and industrial partners. The TM has been in use almost 10 years. During this time the data-model has proven to be very useful to support early phase design, e.g. Phase 0, A and B1. Between 2014 and the current date numerous updates to the TM have been proposed as either internal R&D of stakeholders such as RHEA or as the outcome of ESA funded R&D activities. Currently these have not yet been formally adopted in a new version, and exist as tool specific extensions of Annex A and Annex C. The RHEA implementation of E-TM-10-25, called COMET™, has a set of 3 extensions, of which 2 are currently supported in production, the third extension will be supported in 2022-Q2-Q3. The COMET master model is 100% backwards compatible with E-TM-10-25 Annex A, version 1.0 is equal to version 2.4.1 of Annex A. Versions 1.1, 1.2 and 1.3 provide so-called pure extensions of Annex A and Annex C, guaranteeing backwards compatibility as well as 100% compliance to Annex A and Annex C.

The extensions contain valuable concepts such as:

- **PA/QA: concepts such as RIDs, RFx etc to support a Model-Based review process**
- **Diagramming: concepts to create diagrams that are the basic modelling environment of many MBSE tools such as Capella and SysML tools**
- **New ParameterTypes such as SampledFunctionParameterType that supports time series data.**

These extensions have been defined in RHEA internal funded development to support customer requests as well ESA (co-)funded activities such as “Digital Engineering Hub Pathfinder” and “Generative Concurrent Design”. Other R&D activities may have led to other improvements the community is not aware of because they may not have been made publicly available.

COMET Community Edition is an open-source implementation, available in the public domain via GitHub. The extensions are therefore also in the public domain and in use by the current COMET user base (this includes the ESA CDF). The COMET master model documentation is available at https://sdk-reference.cdp4.org/

Even though E-TM-10-25 is (not yet) a formal standard it has found its way into numerous Concurrent Design Facilities in Europe and beyond, applied to both Space and non-Space early design activities. A case can be made that it is time to let the TM graduate to a proper standard. A next step would be to make Annex A (the

formal UML model) available in the public domain. Both steps will guarantee more formal governance and further evolution of the standard into new improved versions taking lessons learned into account.

3. Interoperability

E-TM-10-25A Annex A and C make sure interoperability can be achieved at the tool level (OCDT, COMET, COSM), but not necessarily at the level of data. To assure interoperability at the data level, the so-called reference data (Annex B) needs to be synchronized between partners that want to collaborate. Definitions of Categories, Parameter Types and units need to be shared in order too remain interoperable.

A public resource where versioned reference data is made available for use, review and update would be of great benefit to the community. A GitHub based solution is presented in Figure 1. It contains components to maintain a public reference data library (that can be hosted by ESA, or any other organisation that acts as reference data librarian), to maintain this reference data using a public vetting/review mechanism, and a means for organisations to synchronise their reference data with the public reference data library

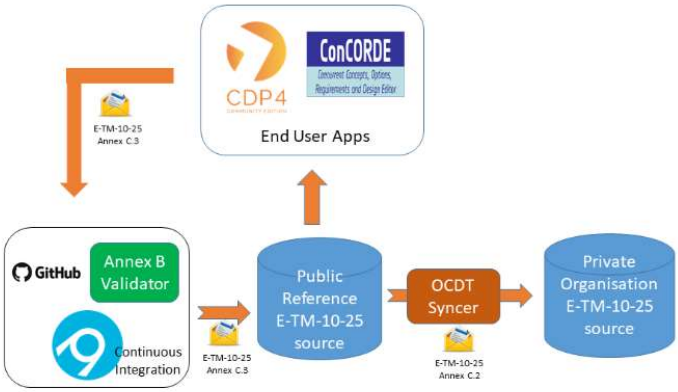

Figure 1: Annex B - Public resource – Public Governance

The diagram shows the following components:

- Private Organisation E-TM-10-25 Source: This represents an E-TM-10-25 based server installed locally. This is a server that is used by an organisation in a typical CDF production environment to conduct Concurrent Design studies with. This server contains not only Models, but also organisation specific reference data. E-TM-10-25 Annex C.2 is typically used as communication protocol. Applications such as the OCDT ConCORDE, the COMET-IME, COSM and different Domain Specific Tools are used to model, perform analysis and to exchange information.
- Public Reference E-TM-10-25 Source: Currently there is no mechanism through which standardised and configuration controlled reference data libraries are shared with the users of E-TM-10-25. A generic reference data library is distributed with the COMET. This may cause different instances of the “same” Generic Reference Data Libraries to evolve on their own and diverge from each other. When the reference data libraries go out of sync, there is a risk of incompatibility of engineering data (at instance level) between different E-TM-10-25 sources. The purpose of this component is to function as a centralized (semi) publicly available read-only E-TM-10-25 Annex C.2 source through which “tagged” versions of the reference data can be distributed to all users so that the different site-specific E-TM-10-25 sources remain synchronized at reference data level and remain compatible to the maximum extent. This Public Reference E-TM-10-25 Source will be populated by a continuous integration setup using a combination of GitHub, special purpose libraries for validation and verification of reference data instance, and Continuous Integration platform such as AppVeyor. This will facilitate an automated deployment of updated verified and validated reference data to the Public Reference E-TM-10-25 Source. RHEA proposes to host this instance on a public cloud.

- Annex B Validator: The Annex B validator is (headless) tool that can execute validation rules on an E-TM-10-25 model, where the focus is on the correctness and validity of reference data.. The Annex B Validator makes use of the CDP4Rules library to execute checking rules on a E-TM-10-25 data set and generates a report on the validity. The list or rules is publicly available and is based on rules specified in E-TM-10-25 Annex A as well as experience using E-TM-10-25 in production.
- Syncer: The Syncer tool is a command line tool distributed that is used to synchronize data between any 2 instances of E-TM-10-25 Annex C.2 sources. It can be used to synchronize local site-specific E-TM-10-25 sources with the centralized (semi) publicly available read-only E-TM-10-25 Annex C.2 source. The purpose of the synchronisation is to update an organisation E-TM-10-25 source with the Public Reference E-TM-10-25 Source.
- COMET-IME / ConCORDE / COSM: COMET, OCDT or COSM end-user tools are used to edit the content of the Reference Data Libraries contained in an E-TM-10-25 Annex C.2 Source. An export of this data towards Annex C.3 can be made using either the COMET-IME or the COMET Web Services.
- GitHub repository: A publicly available git repository where an unzipped Annex C.3 archive is kept under configuration control. Updates to this repository in the form of Pull Requests trigger the Annex B Validator to execute. When no errors/failures are reported and the required quality is reached an expert Reference Data Librarian can “peer review” the proposed changes using a text based (JSON) diffing tool. The updates can be inspected based on an Annex C.3 archive of this data using the COMET-IME.

The proposed approach to maintain the reference data libraries, have configuration control and distribution is inspired by modern software development practices (e.g. automated builds, unit testing and quality checking). The following steps show how one could absorb reference data updates and distribute these to the community in a controlled manner:

1. Use COMET-IME or ConCORDE to create updates to a reference data on a Site Instance E-TM-10-25 source (COMET Web Services or OCDT WSP).
2. Export the Reference Data Library to an Annex C.3 file (using COMET).
3. Clone the Git repository, create a feature branch and unzip the archive (see step 2) to the repository replacing the current files.
4. Push the branch to origin (on GitHub) and create a Pull Request.
5. The AppVeyor CI system starts a build which includes loading the data into the COMET-SDK, verifying the cardinality of all properties and executing the Annex-B-Validator.
6. In case the results of the build are successful a Reference Data Librarian (an E-TM-10-25/QUDV expert) can inspect the diff using GitHub code review/diffing capability. The data can also be loaded using COMET -IME and inspected using the existing GUI based tools.
7. When the librarian finds the updates acceptable these are merged into the master branch of the git repository.
8. When a set of updates has been accumulated which warrant a new release a tag is created.
9. Tags trigger the public “Public RDL Seed Instance E-TM-10-25 Source” to reseed, the updated data set is now available using Annex C.2.
10. An organisation can synchronize the public reference data to their local instance of the E-TM-10-25 source using the OCDT Syncer tool, importing the updates to their server.

This approach can be implemented using building blocks that exist today. A more user-friendly approach can be envisioned developing dedicated tools that provide GUI’s to inspect the diff in a model-based fashion as opposed to inspecting raw JSON. But this would take a significant amount of effort which does not fit within the scope of the current project. A prototype Annex-B-Validator component exists today and a Continuous Integration setup is a work in progress at RHEA.

It must be noted that this approach is not only relevant for ECSS-E-TM-10-25, but also for the developments around the Space System Ontology (SSO). Work is ongoing to define the SSO, focussing on concepts and much less on the population. A reference population to have semantic interoperability at the data level will be required there as well.

4. Use of ECSS-E-TM-10-25 and COMET in and outside the space domain

Even though ECSS-E-TM-10-25A originates from the space domain, it is by no means specific to space systems engineering. It is a general-purpose language to support highly collaborative MBSE for complex systems during the early phases. Currently it is being used in both the space and non-space domain as well as beyond phase B1. The following sections provide a non-exhaustive listing of perhaps unexpected use-cases:

LOTUS: The Low Observable Tactical Unmanned Air System (LOTUS) project is a €9.7 million initiative to create a Europe-wide, cyber-resilient unmanned aircraft with a stealth design. Funded by the European Commission (EC) through the European Defence Industrial Development Programme (EDIDP. RHEA is part of the LOTUS consortium that is developing this next generation of tactical remotely piloted aircraft systems (RPAS). The 4-year project covers the design, production of prototypes and testing. RHEA is leading the cybersecurity-related activities and supporting the system engineering phases for both the avionics and ground station design by applying our concurrent design expertise based on ECSS-E-TM-10-25 and COMET, combining both to ensure 'security by design' from the start of the project. Using this combined approach, RHEA provided an overview of the security risks with a high level of detail that had significant advantages compared with a regular cybersecurity assessment:

- High level of completeness
- Awareness of security risks by all stakeholders
- Full traceability, with clear links between airworthiness requirements, design components and cybersecurity risks modelled in COMET
- Identification of trade-offs, with the ability to identify the impact of design changes on security measures, and vice versa modelled in COMET

PLATO Mission Parameter Database: The PLATO mission is well beyond phase B1. The PLATO team at ESAC has selected COMET to implement the so-called Mission Parameter Database. This is a "database" that contains an expression of what it means to be the PLATO mission. The various building blocks are defined and parametrized in COMET/ECSS-E-TM-10-25. Various stakeholders of the PLATO mission have access to the parameters / properties that define the mission to drive their simulations. As such, ECSS-E-TM-10-25 is used as the single source of truth in phase C/D of PLATO.

5. References

[1] ECSS E-TM-10-25A, "Space engineering – Engineering design model data exchange (CDF)", ECSS Secretariat, made available 20 October 2010.
[2] COMET-IME https://www.rheagroup.com/cdp;
[3] Collaborative System Manager; http://blue-group.it/collaborative-system-manager/
[4] OCDT Community Portal, https://ocdt.esa.int
[5] CDP4 – An industrial Open Source ECSS-E-TM-10-25A Implementation, Gerené, S; Bieze M; Fijneman, M; Vorobiev, A; Phou, N; SECESA 2018

[6] Next Generation Concurrent Design and Engineering, Gerené, S; Matthyssen A; Bieze M; Vorobiev A; Ozkoidi, P; Phou N; Nair R, Gonzalex M.; SECESA October 2016
[7] Open Concurrent Design Tool – ESA Community Open Source Ready to Go!, de Koning, H.P; Gerené, S; Ferreira, I; Pickering, A.; Beyer, F; Vennekens, J; SECESA October 2014
[8] Model Based For System Engineering Advisory Group - Terms of Reference, MB4SE-ToR, Issue 2, Revision 1; 06/09/2019
[9] CDP4-SDK-Community-Edition, https://github.com/RHEAGROUP/CDP4-SDK-Community-Edition
[10] ECSS-E-TM-10-25-Annex-B-Validator https://github.com/RHEAGROUP/ECSS-E-TM-10-25-Annex-B-Validator
[11] ECSS-E-TM-10-25-Annex-B https://github.com/RHEAGROUP/ECSS-E-TM-10-25-Annex-B