Testing Cyber-Physical Systems under Uncertainty: Systematic, Extensible, and Configurable Model-based and Search-based Testing Methodologies

D6.2: Report on Selection of Standardization Bodies

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Executive Summary

This deliverable (D.6.2) describes the work (Task 6.1) for selecting relevant standardization bodies and standards, and summarizing the standardization activities of the U-Test consortium in 2015. The deliverable serves as a reference for developing the U-Test frameworks and provides an overview of the standards that are relevant to the U-Test projects, which can be: used as references when developing the U-Test frameworks, considered as potential candidates where the U-Test outcomes can be promoted, and the targets where the U-Test consortium can potentially contribute within the scope of the U-Test project.

1   Introduction

The standardization effort of U-Test is defined as Task 6.1 of WP6. The overall objective of Task 6.1 and thus this deliverable (D6.2) is to *(1)* involve the U-Test consortium in the European and worldwide standardization initiatives, *(2)* assess the impact of the U-Test results towards relevant standardization activities of selected standardization bodies, *(3)* evaluate the impact of U-Test results on the standardization effort of UML Testing Profile (UTP) 2, and *(4)* introduce U-Test results to standardization bodies. To achieve these objectives, we plan to first identify relevant standardization bodies such as European Telecommunications Standards Institute (ETSI)[1] and Object Management Group (OMG)[2]. Then, we plan to promote U-Test results to work groups of relevant standardization efforts of the selected standardization bodies. This deliverable particularly focuses on selecting relevant standardization bodies.

SRL leads the task, coordinates with FF and EGM on various standardization effort and harmonize standardization activities of the consortium. In this deliverable, we first provide an overview of relevant standards and standardization bodies. Second, we summarize the key standardization activities of the consortium in 2015. Third, we summarize the procedure of selecting standardization bodies. Finally, we present a list of the selected standardization bodies. The selected standardization bodies will be used as the target of the U-Test standardization activities in the remaining duration of the U-Test project. The abbreviation reference of this deliverable is provided in Table 1.

This deliverable does not depend on the other deliverables of the project and it does not have any major impact on other deliverables and WPs.

The rest of the deliverable is organized as follows. In Section 2, we provide an overview of selecting relevant standardization bodies and standards. In Section 3, we present the procedure that was followed to select relevant standardization bodies and standards. In Section 0, we provide the list of selected standardization bodies and standards. In Section 5, we provide a summary of the standardization activities of the consortium, before concluding in Section 6.

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[1] ESTI, http://www.etsi.org/

[2] OMG, http://www.omg.org/

Table 1 Description of Abbreviations

Abbreviation	Description
ETSI	European Telecommunications Standards Institute
ICT	Information and Communications Technology
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
ITU	International Telecommunication Union
JCGM	Joint Committee for Guides in Metrology
MBE	Model-Based Engineering
MBT	Model-Based Testing
NIST	The National Institute of Standards and Technology
OASIS	Advancing Open Standards for the Information Society
OMG	Object Management Group
OMA	Open Mobile Alliance
OSI	Open Systems Interconnection
UMF	Uncertainty Modelling Framework
UTF	Uncertainty Testing Framework
RTF	Revision Task Force
RFP	Request For Proposal
SACM	Structured Assurance Case Metamodel
TDL	Test Description Language

2   Context

Standardization bodies are commonly classified, according to their geographical designation, into three types: international, regional and national standardization bodies [1]. International standardization bodies develop international standards. There are four most well-known and well-established international standardization bodies: the International Organization for Standardization[3] (ISO), the International Electrotechnical Commission[4] (IEC), the International Telecommunication Union[5] (ITU), and the IEEE Standards Association[6]. Under these three standardization bodies, a large number of standards have been defined. For the regional level standardization bodies, we only consider EU standards, among which the European Telecommunications Standards Institute (ETSI) produces a lot of standards in ICT. We do not include any national standardization body into the consideration, as standards produced by national level standardization bodies inherently have limited application scopes, in comparison to international and EU standards.

In the rest of the section, we define the four selection criteria (C1-C4) and justify their relevance to the U-Test project.

The U-Test project aims to define methodologies to test Cyber-Physical Systems (CPSs) under uncertainty. One important mean to achieve this objective is that the project relies on Model-Based Engineering (MBE) technologies. Therefore, the first criterion of selecting relevant standardization bodies is to include standards in MBE field such as the Object Management Group (OMG) (C1). As the project aims to devise testing methodologies, the second selection criterion is to include standardization bodies and standards that are relevant to the testing field (C2). For example, one of the highly relevant standard is the OMG's UML Testing Profile (UTP) 2 [2]. The third selection criterion is to select standardization bodies and standards that are relevant to software-intensive systems, particularly CPSs (C3). Since U-Test proposes general purpose modelling and testing frameworks, we exclude domain-specific standards from the selection (C4).

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[3] ISO, http://www.iso.org/iso/home.html

[4] IEC, http://www.iec.ch/

[5] ITU, https://www.itu.int/en/Pages/default.aspx

[6] IEEE, http://standards.ieee.org/

3   Procedure

We follow two sequential steps to select a set of standardization bodies and standards: collecting and classifying relevant standards by going through major standardization bodies, and identifying standards that the U-Test outcomes can contribute to.

3.1   Collecting and Classifying Relevant Standards

Based on the selection criteria C1-C4 (Section 2), we started from screening through the standards of the standardization bodies: ISO, IEEE, IEC, JCGM, OMG, ETSI and OASIS from two perspectives: modelling uncertainty and CPS, and testing uncertainty and CPS, which correspond to the three outcomes of the U-Test project: Uncertainty Modelling Framework (UMF), Uncertainty Testing Framework (UTF) and Uncertainty Taxonomy (U-Taxonomy). As the results of the first step, we pre-selected a set of standardization bodies and standards as shown in first column of Table 2. In the second column of Table 2, we indicate whether a standard is for modelling, testing, Model-based Testing (MBT), or others. In the fourth column of Table 2, we indicate whether a specific standard explicitly define or describe *Uncertainty* (including *Probability*) and *Uncertainty Measurement*. The fifth column of Table 2 indicates which role a specific standard plays in the U-Test project: being a reference ('R'), being a target that the U-Test outcomes can potentially contribute to ('C'), and being a potential dissemination target ('D'). In the last two columns of Table 2, we indicate which standard is supported currently by FF and EGM's tool suites.

As one can see from Table 2, in terms of modelling, OMG defines standards on system and software modelling: UML [3], SysML [4], MARTE [5], OCL [6] and MOF [7]. ISO/IEC defines UML [8], OCL [9] and KDM [10] modelling notations, which are also defined and maintained by OMG. In addition ISO/IEC also defines RM-ODP [11] for enabling conceptual modelling of complex systems such as CPSs.

In terms of testing and MBT, OMG defines UTP. ETSI also defines standards on model-based testing: ETSI TR 102 840 V1.2.1 [5], ETSI ES 202 951 V1.1.1 (2011-07) [12] and ETSI EG 201 015 V2.1.1 (2012-02) [13] as shown in Table 2. ISO/IEC/IEEE 29119 [14] is a widely recognized standard on testing. In addition, ISO/IEC joined the effort to define the ISO/IEC 9646 series [15] for supporting conformance testing of OSI. As shown in Table 2, a number of standards have been also defined in IEEE from the aspects of system and software verification and validation [16], test documentation [17], unit testing [18] and classification of Software Anomalies [19].

In Table 2, we also include standards (from ISO, IEC and/or IEEE under Other) that are relevant to various aspects of system and software engineering, including vocabulary, architecture description, development lifecycle, risk management and assessment, and quality assurance.

Particularly, we collected standards that are relevant to *Uncertainty* and *Uncertainty Measurement*, as indicated in the column "Uncertainty" of the table. ISO 61508 [20], OMG SysML [4] and MARTE [5] define concept *Probability*, which is one type of uncertainty measures. OMG SACM defines Evidence, Confidence and Confidence Level, which are all relevant to uncertainty and several concepts defined in U-Taxonomy. ISO/IEC and JCGM defined few standards on *Uncertainty Measurement*. The concept of Uncertainty and few relevant concepts are explicitly defined in ISO 31000.

Regarding tool support, Fokus!MBT currently supports all the OMG standards listed in Table 2. The Fokus!MBT tool also conform to several ISO/IEC/IEEE/ETSI standards listed in Table 2. CertifyIt currently conforms to UML and two ETSI standards, as listed in the table.

Table 2 A Pre-selected List of Standardization Bodies and Standards

Body	Modeling/Testing/MBT/Other	Standard	Uncertainty	Potential Role	Tool Support	
					FF	EGM
OMG	Modeling	Unified Modeling Language (UML) [3]	No	R, D	Fokus!MBT	CertifyIt
		UML Profile for MARTE: Modeling and Analysis of Real-Time and Embedded Systems [5]	**Yes (Probability)**	**R, C, D**	Fokus!MBT	No
		Systems Modeling Language (SysML) [4]	**Yes (Probability)**	**R, C, D**	Fokus!MBT	No
		Object Constraint Language (OCL) [6]	No	R, C, D	Fokus!MBT	No
		MetaObject Facility (MOF) [7]	No	R	Fokus!MBT	
		Structured Assurance Case Metamodel (SACM) [21]	**Yes (Evidence, Confidence, Confidence Level)**	R, C	No	No
	MBT	UML Testing Profile (UTP) [2]	No	R, C, D	Fokus!MBT	No
ISO, IEC and IEEE	Modeling	ISO/IEC 10746 series – Reference model of Open Distributed Processing (RM-ODP) [11]	No	R	No	No
		ISO/IEC 19505 series – OMG UML 2.4.1 [8]	No	R, D	Fokus!MBT	No
		ISO/IEC 19507:2012 – OMG OCL 2.3.1 [9]	No	R, D	Fokus!MBT	No
		ISO/IEC 19506:2012 – OMG Architecture-Driven Modernization (ADM) — Knowledge Discovery Meta-Model (KDM) [10]	No	R, D	No	No
	Testing	ISO/IEC/IEEE 29119 series – Software Testing Standard [14]	No	R, C, D	Fokus!MBT	No
		ISO/IEC 9646 series – Open Systems Interconnection (OSI) - Conformance testing methodology and framework [15]	No	R	Fokus!MBT	No
		IEEE 1012-2012 – System and Software Verification and Validation [16]	No	R	Fokus!MBT	No
		IEEE 829-2008 – Software and System Test Documentation [17]	No	R	Fokus!MBT	No
		IEEE SA - 1008-1987 – IEEE Standard for Software Unit Testing [18]	No	R	No	No
		IEEE 1044-2009 – Classification for Software Anomalies [19]	No	R	No	No
	Other	ISO/IEC/IEEE 24765:2010 – Systems and software Engineering – Vocabulary [22]	No	R	No	No
		ISO/IEC/IEEE 42010:2011 – Systems and software Engineering - Architecture description [23]	No	R	No	No
		ISO/IEC/IEEE 15288:2015 – Systems and software engineering- System life cycle processes [24]	No	R	No	No
		ISO/IEC 16085:2006 – Systems and software Engineering - Life cycle processes - Risk management [25]	No	R	No	No
		ISO/IEC 25010:2011 – Systems and software Quality Requirements and Evaluation (SQuaRE) — System and software quality models [26]	No	R	Fokus!MBT	No
		ISO/IEC 15026 series – Systems and software assurance [27]	No	R	No	No
		ISO/IEC 12207:2008 – Systems and software engineering - Software life cycle processes [28]	No	R	No	No
		ISO/IEC Guide 98 series – Uncertainty of Measurement [29]	**Yes**	**R**	No	No

Body	Modeling/Testing/MBT/Other	Standard	Uncertainty	Potential Role	Tool Support	
					FF	EGM
		ISO/IEC 10165-7:1996 – Open Systems Interconnection (OSI) - Structure of management information: General relationship model [30]	No	R	No	No
		IEC Guide 115:2007 – Application of uncertainty of measurement to conformity assessment activities in the electrotechnical sector [31]	**Yes**	**R**	No	No
		IEC 61508:2010 – Functional safety of electrical/electronic/programmable electronic safety-related systems [20]	**Yes (Probability)**	**R**	No	No
		IEC 31010:2009 – Risk Assessment Techniques [32]	No	R	No	No
		IEEE 730-2014 – Software Quality Assurance Processes [33]	No	R	No	No
		IEEE 1061-1998 – Software Quality Metrics Methodology [34]	No	R	No	No
		IEEE P2413 – Standard for an Architectural Framework for the Internet of Things (IoT) [35]	No	R	No	No
		ISO 9000 series – Quality Management [36]	No	R	Fokus!MBT partially	No
		ISO 31000 – Risk Management [37]	**Yes (Risk, Uncertainty, Effect, Likelihood)**	R	No	No
		ISO 3534-1:2006 – General statistical terms and terms used in probability [38]	**Yes**	**R**	No	No
		ISO 21748:2010 – Guidance for the use of repeatability, reproducibility and trueness estimates in measurement uncertainty estimation [39]	**Yes**	**R**	No	No
		ISO/TR 13587:2012 – Three statistical approaches for the assessment and interpretation of measurement uncertainty [40]	**Yes**	**R**	No	No
		ISO/TS 17503:2015 – Guidance on evaluation of uncertainty using two-factor crossed designs [41]	**Yes**	**R**	No	No
		ISO 9241 series – Ergonomics of human-system interaction [42]	No	R	No	No
JCGM	Other	JCGM 200:2012 – International vocabulary of metrology- Basic and general concepts and associated terms (VIM) [43]	**Yes**	**R**	No	No
ETSI	Testing	ETSI TR 102 422 V1.1.1 (2005-04) – IMS Network Integration Testing Infrastructure Testing Methodology [44]	No	R, D	No	No
		ETSI EG 203 130 V1.1.1 (2013-04) – Methodology for standardized test specification development [45]	No	R, D	No	No
		ETSI TR 101 583 V1.1.1 (2015-03) – Security Testing; Basic Terminology [46]	No	R	No	No
		ETSI ES 201 873 series on TTCN-3 [47]	No	R, D	Fokus!MBT	No
		ETSI ES 203 119 series on Test Description Language (TDL) [48]	No	R, D	Fokus!MBT (Partially)	No
	Testing, MBT	ETSI TR 102 840 V1.2.1 (2011-02) – Methods for Testing and Specifications (MTS); Model-based testing in standardization [49]	No	R, D, C	Fokus!MBT	CertifyIt
		ETSI ES 202 951 V1.1.1 (2011-07) – Methods for Testing and Specification (MTS); Model-Based Testing (MBT); Requirements for Modeling Notations [12]	No	R, D, C	Fokus!MBT	CertifyIt

Body	Modeling/Testing/MBT/Other	Standard	Uncertainty	Potential Role	Tool Support	
					FF	**EGM**
		ETSI EG 201 015 V2.1.1 (2012-02) – Methods for Testing and Specification (MTS); Standards engineering process; A Handbook of validation methods [13]	No	R, D, C	No	No
OASIS	Other	Open Services for Lifecycle Collaboration (OSLC) [50]	No	R	ModelBus	No

3.2   Identifying Standards that U-Test Can Potentially Contribute to

Results of the second step are shown in the fifth column of Table 2 (Potential Role). From the table, we can see that the U-Test project refers to all standards listed in the table. Based on the analysis of the table, the U-Test project can potentially play a role by contributing to *eight* OMG/ISO/IEC/IEEE/ETSI standards. In the rest of the period of the project, we will investigate further on these aspects.

More specifically, one can see from the table that, four OMG standards (i.e., UTP [2], MARTE [5], SysML [4] and OCL [6]) can be the potential candidates that the U-Test outcomes can contribute. We chose these standards because they are highly relevant to the U-Test project and because these four standards are currently under revisions, which makes the U-Test contribution nearly straightforward. MARTE has an RTF (Revision Task Forces) working on MARTE 1.2. The UTP2 work group (in which SRL and FF are the two key contributors) is making efforts on the revision of the initial submission of UTP2. The System Modelling Assessment and Roadmap Working Group[7] (SysML-Roadmap) in OMG is currently defining the SysML v2 RFP (Revision for Proposals). In addition, a work group is actively working on the OCL 2.5 RTF (Request For Proposal). SRL is involved in the work group tasks of SysML v2 RFP, OCL 2.5 RTF and MARTE 1.2 RTF.

The work group of the ISO/IEC/IEEE 29119 series − Software Testing Standard [14] is currently working on the last two parts of the standards Part 4 and Part 5, the latter one being about test techniques. They have showed the intention of including MBT as part of it. Therefore, this standard is also classified as a potential target where the U-Test outcomes can contribute.

ETSI accommodates the Methods for Testing and Specification (MTS) working group, which is responsible for the identification and definition of advanced specification and testing methods. ETSI MTS developed and published the TTCN3 testing language (i.e., TDL) and also authored two standards for MBT. TDL is a language for specifying test descriptions and presenting test execution results. FOKUS and EGM are members of the ETSI MTS working group. ETSI is also a founding member of OneM2M[8] standardization initiative. OneM2M is developing a major open standard for IoT platforms. OneM2M working parties include a testing working group, in which EGM is active. In addition, ETSI founded the SmartM2M working group to discuss EU relevant activities in the field of Machine-to-Machine (M2M). To sum-up, ETSI as a European body is a highly relevant standisation body for the U-Test project outcomes, at the level of the MTS Working Group, at the level of SmartM2M and OneM2M standardization activities.

4   Results

As summarized in Table 3, the U-Test consortium refers to a number of standards when defining the U-Test outcomes. In addition, the U-Test consortium disseminates the U-Test outcomes in different standardization bodies. In Table 3, we particularly present the selected standardization bodies and standards that U-Test can potentially contribute to. As one can see from the table, the selected six standards are either under revisions or to be completed, which provide the U-Test project opportunities to contribute to the selected standards. The U-Test consortium has started some activities related to these standards. Please refer to Section 5 for further details.

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[7] SysML-Roadmap, http://www.omgwiki.org/OMGSysML/doku.php?id=sysml-roadmap:sysml_assessment_and_roadmap_working_group

[8] OneM2M, www.onem2m.org

Table 3 Selected Standardization Bodies and Standards that U-Test can Potentially Contribute

Standard	Current Status	On-going Activity	U-Test Outcome
OMG MARTE [5]	v1.1 released in 2011	v1.2 RTF	U-Taxonomy, UMF
OMG SysML [4]	v1.4 released in 2015	v2 RFP	U-Taxonomy, UMF
OMG OCL [9]	v2.4 released in 2014	v2.5 RTF	UMF
OMG UTP [2]	Revised submission submitted in May 2016	FTF	UTF
ISO/IEC/IEEE 29119 [14]	Part 1: Concepts and Definitions in 2013 Part 2: Test Processes and Test Documentation in 2013	Part 4 (Test Techniques) Part 5 (Keyword-Driven Testing)	UTF
ETSI EG 201 015 V2.1.1 [13]	v2.1.1 released in 2012	Part 6.2 (Model-based validation methods)	UTF

So far, we have been discussing the possibilities of contributing to existing standards. There is also an opportunity to initiate the definition of a new standard. The U-Test consortium has started to look for such opportunities in OMG, ISO and ETSI. The rationale behind is that U-Taxonomy is generic in the sense that it can be combined with other standards, e.g., UML, MARTE, SysML, and SACM to fulfil certain modelling requirements. From this perspective, it makes sense to think from this perspective.

5   Key Standardization Activities in 2015

In this section, we report the standardization activities we conducted in 2015. Table 4 summarizes the key activities of the U-Test consortium in the context of the U-Test project in 2015. SRL, EGM and FF are the partners who actively contribute to/involve in/use (by referencing) various standards from various standardization bodies in 2015. Both SRL and FF are two key contributors to UTP 2, which is a highly relevant standard for the UMF and UTF of U-Test. EGM and FF are additionally participating in the definitions of several ETSI standards. SRL is participating in the definition of SysML 2 roadmap. UML and MARTE are applied during the process of defining UMF. In addition, several standards (e.g., ISO/IEC/IEEE 29119) are referenced when defining U-Test outcomes. It is worth highlighting that SRL started to make effort on proposing a new standard, to which the U-Taxonomy of the U-Test outcomes can contribute by giving a presentation about U-Taxonomy to the Analysis & Design TF meeting of OMG in December of 2015.

Table 4 Standardization Activities of the U-Test Consortium in 2015

Partner	Standardization Body	Standard	Standardization Activity	Relevance
SRL	OMG	UTP [2]	Key contributor of the standard definition	High
		SysML-Roadmap [51]	Disseminating U-Test results	High
		Proposal a new standard for U-Taxonomy	Promoting the standardization of U-Taxonomy	Very High
		UML MARTE [5]	Referencing to the standard Applied the standard	High
		UML [3]	Referencing to the standard Applied the standard	High
		SysML [4]	Referencing to the standard	High
	ETSI	ETSI ES 202 951 [12]	Referencing to the standard	High
	ISO/IEC/IEEE	ISO/IEC/IEEE 29119 [14]	Referencing to the standard	High
EGM	ETSI	Standards on testing methods for MBT working group	Participating in the definition of the standard	Medium
	Others	Open Mobile Alliance (FIWARE) [52]	Participating in the definition of the standard	Medium
FF	OMG	UTP 2	Key contributor of the standard definition	High
		Participating in the UML 2.6 RTF	Applied the standard	High
	ETSI	TTCN-3 [47] (ETSI STF 491)	Participating in the definition of the standard	Medium
		TDL [48]	Participating in the definition of the standard	Medium

6 Conclusion

The U-Test project highly relies on standards from various standardization bodies. One of the objectives of the U-Test project is to develop its solutions based on standards and potentially contribute to existing or new standards. The U-Test consortium keeps this objective in mind and selects standardization bodies and standards that are relevant to the U-Test project. The results of the standardization activities of 2015 mainly focus on the selection of standardization bodies and standards. In 2016 and 2017, we will focus more on the application of the selected standards, promoting the U-Test outcomes to the selected standardization bodies, pursuing opportunities to contribute to highly relevant and exiting standards, and pursuing opportunities to propose new standards.

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[49]   ETSI, "ETSI TR 102 840 Methods for Testing and Specifications (MTS); Model-based testing in standardisation (v1.2.1)," 2011.

[50]   OASIS, "Open Services for Lifecycle Collaboration Core Specifications Version 3.0," 2013.

[51]   OMG, "System Modeling Assessment and Roadmap Working Group."

[52]   OMA, "FI-WARE NGSI-9 Open RESTful API Specification."