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Methods for Testing and Specification (MTS); Planning for validation and testing in the standards-making process

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Foreword

This ETSI Guide (EG) has been produced by ETSI Technical Committee Methods for Testing and Specification (MTS).

1 Scope

The purpose of the present document is to provide sufficient information and guidelines to enable the following when planning the development of an ETSI Standard (ES), Technical Specification (TS) or European Standard (EN):

- the identification of an appropriate method of validation of the standard;
- the identification of an appropriate type of test specification for products based on the standard.

In both cases, various criteria such as time-to-market and the level of confidence in the technology, are considered when determining what is appropriate for the standard in question.

In addition, the present document gives guidance on the cost, effort and schedule requirements to implement the selected approach.

The present document does not elaborate methods for validation and testing where guidelines and methodologies already exist in other documents. Instead, it provides references to these documents and any other information sources. ETR 184 [6], ETR 304 [9] and TCR-TR 006 [10] contain useful additional background material.

The guidelines set out in the present document are, necessarily, based on the prevailing policies, methods and techniques for validating standards and specifying test suites.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.
- A non-specific reference to an ETS shall also be taken to refer to later versions published as an EN with the same number.

[1] EG 201 015 (V1.2): "Methods for Testing and Specification (MTS); Specification of protocols and services; Validation methodology for standards using SDL; Handbook ".

[2] EG 201 383 (V1.1): "Methods for Testing and Specification (MTS); Use of SDL in ETSI deliverables; Guidelines for facilitating validation and the development of conformance tests".

[3] Void.

[4] ETS 300 406 (1995): "Methods for Testing and Specification (MTS); Protocol and profile conformance testing specifications; Standardization methodology ".

[5] ETR 141 (1995): "Methods for Testing and Specification (MTS); Protocol and profile conformance testing specifications The Tree and Tabular Combined Notation (TTCN) style guide".

[6] ETR 184 (1995): "Methods for Testing and Specification (MTS); Overview of validation techniques for European Telecommunication Standards (ETSs) containing SDL".

[7] ETR 266 (1995): "Methods for Testing and Specification (MTS); Test Purposes style guide".

[8] ETR 298 (1996): "Methods for Testing and Specification (MTS); Specification of protocols and services; Handbook for SDL, ASN.1 and MSC development".

[9] ETR 304 (1996): "Methods for Testing and Specification (MTS); The future in ETSI of quality of standards-making, validation and testing".

[10] TCR-TR 006 (1996): "Methods for Testing and Specification (MTS); ETSI and certification in telecommunications; Overview of outstanding issues and some recommendations".

[11] SR 001 262: "ETSI drafting rules".

[12] ISO 9646-1 (1992): "Information technology - Open Systems Interconnection-Conformance testing methodology and framework - General concepts".

[13] ISO 9646-3 (1998): "Information technology - Open Systems Interconnection-Conformance testing methodology and framework - Part 3: The Tree and Tabular Combined Notation (TTCN)".

[14] ITU-T Recommendation Z.100 (1993): "CCITT Specification and description language (SDL)".

[15] ITU-T Recommendation Z.105 (1994): "SDL combined with ASN.1 (SDL/ASN.1)".

[16] ITU-T Recommendation Z.120 (1993): "Messages sequence charts".

[17] ITU-T Recommendations X.680 (1994): "Information technology - Open Systems Interconnection - Abstract Syntax Notation One (ASN.1): Specification of basic notation".

[18] C Don, M Zoric et al (ETSI, 1996): "Making better standards; Practical ways to greater efficiency and success" (ISBN 2-7437-0916-2).

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

base standard: standard which expresses conformance requirements for a product, service or standard.

conformance testing: process of establishing the extent to which an Implementation Under Test (IUT) satisfies both static and dynamic conformance requirements, consistent with the capabilities stated in the implementation conformance statement (ISO 9646-1 [12], subclauses 3.4.10 and 3.5.6).

coverage (testing): proportion, usually expressed as a percentage, of the requirements described in a standard that are explicitly identified or defined in the associated test suite.

coverage (validation): proportion, usually expressed as a percentage, of a formal specification that is exercised as part of the validation process.

end-to-end testing: testing of a network as it is seen from the user's terminal equipments i.e. taking the user-network interfaces as Points of Control and Observation (PCO).

formal validation: use of automatic tools to validate the structure and integrity of a set of standardized requirements expressed in a formal specification language.

implementation conformance statement: document supplied by the manufacturer of a product that defines which standards are claimed to be implemented and which implementation options in the standards are supported.

node-to-node testing: testing of a network as it is seen from other network components, i.e. taking the external network-network interfaces as PCOs.

semantics: meaning of a specification that relates it to the real system it describes.

syntax: form of a specification and the rules specifying the use of the elements of the specification language.

test purpose: prose description of a well-defined objective of testing, focusing on a single conformance requirement or a set of related conformance requirements as specified in the base specification.

validation: process, with associated methods, procedures and tools, by which an evaluation is made that a standard can be fully implemented, conforms to rules for standards, satisfies the purpose expressed in the record of requirements on which the standard is based and that an implementation that conforms to the standard has the functionality expressed in the record of requirements on which the standard is based.

validation model: detailed version of a specification, possibly including parts of its environment, that is used to perform formal validation.

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

ASN.1	Abstract Syntax Notation No.1
CATG	Computer Aided Test Generation
ES	ETSI Standard
EG	ETSI Guide
EN	European Norm
ICS	Implementation Conformance Statement
IUT	Implementation Under Test
IXIT	Implementation eXtra Information for Testing
MSC	Message Sequence Chart
PE	Public Enquiry
PCO	Point of Control and Observation
PICS	Protocol Implementation Conformance Statement
PIXIT	Protocol Implementation eXtra Information for Testing
SDL	Specification and Description Language
TB	Technical Body
TR	Technical Report
TS	Technical Specification
TTCN	Tree and Tabular Combined Notation

4 Introduction

When a new Work Item is raised for an ETSI standard (ES or EN), it is easy to forget that effort over and above that needed to develop the standard itself may be necessary to assure the quality of the document and to ensure that appropriate test specifications, including conformance tests, are available by the time the standard has been implemented as commercial products. This additional effort is rewarded by the better standards produced by ETSI and the overall improved quality of ETSI deliverables.

To assist in the planning of these activities, the present document contains the following information:

- a description of the position of validation and test specification within the standards making process (clause 5);
- an identification of relevant validation and test methods for a range of different types of standards (clause 6);
- a description of available validation and test specification methods with references to other, more specific documents (clause 7);
- a guide to planning and providing resources for the validation and test specification processes (clause 8).

In addition, a number of example scenarios are developed in clause 9 to show how appropriate decisions on validation and test specification methods can be made and the likely supplementary costs involved in typical standards development projects.

5 Overview of the standardization process

5.1 Specification of base standards

Base standards produced by ETSI fall into a number of generic types. They are used to specify services and protocols, transmission characteristics, electrical properties and other physical attributes as well as methodologies and common definitions of terms.

In order to be able to validate the contents of a base standard, it is important that the same process should be followed in the development of all standards of a similar type. General guidelines exist for the basic presentation style of ETSI standards and for the use of the English language (SR 001 262 [11]) and the "Making better standards" book [18] published by ETSI provides useful background into the standards-writing process and the methods that are available for rapporteurs to follow. Guidelines for the development of standards containing Specification and Description Language (SDL) specifications can be found in EG 201 383 [2], DEG/MTS-00050 (see bibliography) and ETR 298 [8]. However, specific methodologies and guidelines do not exist for other types of base standards. Consequently, the processes followed in the development of such standards are dependent primarily on past practice rather than formalized methods.

All base standards can benefit from some form of planned validation and test specifications should be developed for any standard that can be implemented as a product or service. Validation and testing of standards leads to a higher quality standard. Also, the earlier that problems are corrected in the development cycle of the standard, the cheaper it is to fix them, thus avoiding more costly errors at a later stage, e.g. during implementation.

5.2 Validation of base standards

EG 201 015 [1] defines validation as follows:

- "The process, with associated methods, procedures and tools, by which an evaluation is made that a standard can be fully implemented, conforms to rules for standards, satisfies the purpose expressed in the record of requirements on which the standard is based and that an implementation that conforms to the standard has the functionality expressed in the record of requirements on which the standard is based".

This is a very broad definition which covers validation approaches from structured visual inspection of the text up to field trials of telecommunications products.

One of the most frequently used techniques for early validation of a standard is a detailed review of its contents performed by experts. This is a particularly useful method for validating standards which specify, for example, definitions of terms, methodologies, transmission characteristics, electrical properties and other physical attributes as there are few automatic tools available for this purpose. ETR 184 [6] and EG 201 015 [1] have identified formal validation as an important means of further improving the quality of protocol and service standards.

5.2.1 Formal validation

Formal validation of a standard which uses SDL to specify behaviour (a service or protocol standard) includes the checking of both the syntactic and semantic correctness of the specification and establishing that the known requirements of the specified system are clearly and unambiguously expressed within the standard.

The main validation techniques implemented in automatic tools are:

- interactive simulation;
- "exhaustive " state space exploration;
- random state space exploration.

All these techniques depend on the specification being executable by computer. It is, therefore, essential that the SDL specifications included in standards should comply with the rules of syntax and semantics described for the language in ITU-T Recommendation Z.100 [14]. Before such a specification can be formally validated it will also be necessary to specify:

- which implementation options have been selected;
- those parts of the system that are out of the scope of the present document but which are necessary to complete the specification such that it is executable.

5.3 Specification of tests for base standards

The purpose of standardizing telecommunication systems, services, protocols and interfaces is to enable the inter-working of similar or associated products made by different manufacturers. Testing the conformance of a product to a standard is considered to be essential in ensuring that the product is able to inter-operate with other products that implement the same standard or a complementary one. ETS 300 406 [4] describes a methodology which should be followed when producing conformance test specifications for protocol and profile standards.

A conformance test consists of two parts (ISO 9646-1 [12]):

- the static conformance review:

    checking whether the choices between the implementation options that the manufacturer claims to have implemented is a combination permitted by the standard.

- the dynamic conformance test:

    execution of test cases to determine whether the product has implemented the standard correctly.

The purpose of a conformance test suite is to check whether a product conforms to the standard. Each test case within a test suite is related to one or more conformance requirement of the standard.

In order to facilitate the process of test suite development, an ETSI standard should be able to identify:

- the conformance requirements in the standard (test purposes);
- the interfaces of the product type that can be accessed for test execution (points of control and observation, PCOs);
- how the requirements can be tested using the available interfaces in a product that claims to implement the standard.

The specification of test suites for protocol and service standards can be expressed accurately and concisely using a formal language such as the Tree and Tabular Combined Notation (TTCN). Test suites using such notations can be implemented directly into test equipment having the appropriate language support.

Although producing a conformance testing suite as described above is quite a rigorous process, the above methodology ETS 300 406 [4] may be used to produce other types of tests such as basic inter-connection tests or interoperability tests. These tests may also be produced in TTCN.

Sometimes it is considered sufficient to produce only the test purposes and to identify the PCOs. This may provide clear guidelines for users of the base specification who wish to develop a test suite.

There are no formal languages available for the specification of test suites for the evaluation of transmission characteristics, electrical properties and other physical attributes of a product. As a result, test suites for this type of standard rely on skills and experience of the responsible rapporteur and those who review the draft standard.

6 Selecting an appropriate approach to validation and test specification

6.1 Factors effecting choice of methods

There is no simple rule for establishing which are the best methods of validating a particular standard or for specifying conformance tests or other tests for it. Each standard or set of standards has to be treated individually. In many instances, the choice will be based on the skills and experience of those involved in the development of the standard and the methods previously used by the responsible Technical Body. When making these decisions, the following factors should be taken into consideration:

- Approval procedure for the standard:

  If the standard is to be published as an EN requiring a Public Enquiry (PE), errors detected during PE can significantly delay publication. Formal validation (use of formal validation techniques) can greatly reduce this risk. On the other hand, a standard can be published as a TS with only the approval of the responsible TB. This approach can be used to gain early feedback from implementers and users prior to publication of the standard as an EN.

- Type of the products and service concerned:

  The type of product that is intended to be implemented from a standard should be a major consideration when selecting appropriate methods for validating the standard and producing test specifications from it. As an example, low-end consumer products may not require the rigorous conformance test specifications that are considered necessary for public network equipment but the commercial impact of inadequate validation may be significant.

- Notation used:

  If the base specification is written in a formal language, then it is easier to proceed with a formal validation and it may also be possible to generate the test specification automatically. Such a formal approach ensures a much greater confidence in the correctness of the base specification but is much more difficult if the standard has been written in natural language. The base specification may be written in one or more of the following:

  - ASN.1, specifying the format of the messages;
  - SDL specifying the behaviour in structured terms:
    - incomplete SDL (for descriptive purposes);
    - complete SDL;
  - MSCs specifying the flow of information;
  - text specifying the standardized behaviour in unstructured prose.

- Size and complexity of the specification:

  A simple specification may require little more than an independent review to validate that it meets its requirements. The more complex a specification is the more formal the validation should be. This is because the possibility of errors being introduced into the base standard is so much higher.

6.2 Determining validation and testing policies

The extent of validation depends on the technical nature of the deliverable. This subclause identifies possible validation and testing policies with respect to the type of deliverable to be produced.

Regardless of the type of deliverable, four criteria should be taken into account when planning for validation and/or testing:

- Interest expressed by technical body members:

  Some validation methods, e.g. early implementation, require significant voluntary work to be performed.

- Need for interoperability:

  When it is essential that products from different vendors can inter-operate, validation guarantees a certain level of completeness of the deliverable. This may sometimes be achieved through the definition of profiles. Otherwise, there is a risk that incompatible implementation options are chosen. Examples of interoperability testing are the end to end testing and node to node testing used in complex networks. If a standard is complex, the standard writers may choose not to produce the profiles but to allow the marketplace to agree on de facto profiles. These profiles may be added to the official standard at a later stage.

- Maturity of the technology developed:

  New technologies may not have established methods of validation and testing. Efforts to define these methods should be carefully considered at an early stage in development of the new technology. The experience of other groups working on similar issues should be considered.

- Pressure of the market:

  This may have an impact on the time that is devoted to the validation phase. In order to capitalize on market opportunities it may be acceptable to perform less validation than would otherwise be desirable. Conversely, market pressure for a highly stable and error free specification may make it necessary to carry out more validation than might normally be expected. In the second case, the benefits of validating the specification are recognized as important and resources are allocated to the task.

6.2.1 Standards specifying physical characteristics

These deliverables contain specifications with formal characteristics but do not specify behaviour, e.g. transmission characteristics. Physical layer specifications usually belong to this type. They are often presented as collections of tables and diagrams. Such specifications are difficult to model and validate using automatic tools.

6.2.1.1 Possible validation

- Walk through/inspection.
- Prototyping.
- Early implementation.

6.2.1.2 Possible testing

Test specifications can be expressed using tables, diagrams and free text procedures.

6.2.2 Protocol and service standards

EG 201 383 [2] recommends the use of formal description techniques to avoid ambiguity when specifying protocols and services. Validation of such specifications can then rely on modelling techniques. Testing may be specified using a language such as TTCN.

6.2.2.1 Possible validation

- Static analysis:

  Syntax and semantics checking. Static analyses do not require the model to be executed.

- Dynamic analysis:

  When the specification of the protocol is in plain text, or when the SDL/MSC/ASN.1 used in the specification is not directly executable (incomplete or informal) then a specific validation model may be written in order to use dynamic analysis. Further validation of the model can be achieved by simulation using an automatic tool.

- Walk through/inspection.

- Test suite development:

  The development of test suites, in addition to having their own value, may be used to validate the base standard. However, when formal notations are used in the base standard, it is recommended to proceed with the validation before developing test specifications.

- Early implementation.

6.2.2.2 Possible testing

- Test purposes only:

  This possibility can be envisaged to reduce the time to issue test specifications. However, this solution does not provide the same guarantees of conformance and interoperability as a complete TTCN test suite although it does offer some level of validation of the standard. Similarly, by identifying the PCOs, test tool developers are helped in tool production.

- TTCN test suite:

  The test suite may cover complete conformance testing or a subset of testing such as interoperability testing, basic interconnection testing, etc.

6.2.3 Test specifications, ICS, IXIT

Validation of a test specification will concentrate on its own properties and on its consistency with the base specification.

6.2.3.1 Possible validation

- Walk through/inspection.

- Early implementation:

  May be tested iteratively against an early implementation of the base standard.

- Static analysis: syntax and semantic checking, compilation (multiple compilers to be used). There is no static analysis available for ICS/IXIT documents in particular for cross checking of references.

6.2.3.2 Possible testing

Testing is not relevant to this type of deliverable.

6.2.4 Standards that do not require testing

Some standards, such as Stage 1 (overall service descriptions) and Stage 2 standards for supplementary services, are written primarily as descriptive text but with some formal content to illustrate the requirements. The purpose of these standards is to provide input to a more detailed standard such as a supplementary service Stage 3 (protocol specification) and there is no requirement to specify tests.

6.2.4.1 Possible validation

- Walk through/inspection.
- Static analysis.

6.2.4.2 Possible testing

Testing is not relevant to this type of standard.

6.2.5 Specifications with no formal content

The validation of a standard which has no formal content such as a glossary of terms, an ETSI Guide (EG) or a Technical Report (TR), can only concentrate on the format, style and completeness of the deliverable.

6.2.5.1 Possible validation

- Walk through/inspection.

6.2.5.2 Possible testing

Testing is not relevant to this type of deliverable.

7 Available methods

This clause provides further information and explanations about the types of validation methods and testing methods proposed in clause 6 of the present document and provides guidelines on how to choose the methods.

When identifying the most suitable methods, several factors have to be considered. The choice of validation method will have a major impact on the quality of the base standard produced. The choice of validation method and testing method will also have an impact on the resources that will be necessary and on the commitment that will be necessary from the technical body/working group responsible for the base standard.

The purpose of validation is to identify problems in the base specification so that corrections and other improvements can be incorporated into it. This implies that there should be an agreed method of reporting problems discovered during validation.

7.1 Available validation methods

7.1.1 Walk through/inspection

"Walk through" is a method of reviewing a specification which, if used correctly, can identify many of the inaccuracies and inconsistencies present in the specification. It is particularly effective when used to validate the following:

- text and other informally defined specifications;
- formal models which are not complex (as a guideline, up to 5 pages of formal description can easily be validated using the walk through method but more than 10 pages would be better validated using an automated tool);
- sets of related standards where correlation and consistency between documents is essential.

The Walk Through method, which is also referred to as "design review", uses a group of independent experts to review a specification in detail on a line-by-line (or symbol-by-symbol) basis. These experts may have an interest in the document under review (as members of the responsible STC, for example) but should not have taken any direct role in its development. One of these expert reviewers, not the author of the specification to be reviewed, is appointed to chair the walk through session when it takes place.

NOTE: In cases where the official rapporteur of a standard is not the author, this person is the ideal choice to chair the walk through.

Other experts with specific skills may also be invited to take part. Their collective expertise could cover such aspects as the formal language used to describe behaviour, the notation used to define data structures and the base technology implied in the document to be reviewed. Members of the Protocol Specification Methodology (PSM) group within the ETSI Secretariat can provide the necessary expertise in formal specification languages and notations.

The specification which is to be reviewed is distributed to the reviewers prior to the walk through session itself with sufficient time allowed for each of them to read and prepare comments on it. Within ETSI's infrastructure of voluntary committees and working groups, this period is likely to be a few weeks rather than a few days or hours. At this time, the reviewers are made aware of their individual responsibilities in reviewing the specification, particularly those who have been invited to take part for their expertise in a specific subject area.

At the start of a walk through session, the author of the specification makes a presentation of the material to be reviewed and then answers questions and comments from the reviewing experts. Authors are expected to defend their work while remaining open to alternative suggestions. In most cases, it is not possible to solve many of the problems identified during the session but a consensus should be reached on which areas of the specification require modification. Once the specification has been reviewed at the abstract level and assuming that there are no major errors in the design, it can be very useful to work through the specification using realistic and concrete parameter values in order to determine whether the specified algorithms and equations combine to give the expected results.

When the walk through is complete, the authors incorporate the agreed corrections into the document and investigate those parts of the specification that were identified as requiring further study.

7.1.2 Test suite development

The development of test suites, as described in subclause 7.2, involves a systematic and thorough review of a base standard. This may be a valuable extension to a walk-through. Test suite development may be used as a validation method when the base specification has not been produced in a formal language and so the effort to develop a validation model would be too great.

7.1.3 Prototyping/Early implementation

When the subject matter of a standard concerns physical characteristics rather than behaviour, it is difficult to produce an abstract model which can be used for simulation purposes. In such cases, the only validation method which can be considered as an alternative to walk through is prototyping.

Prototyping involves the implementation of a design specification in a small number of representative, rather than commercial, pieces of equipment for the purpose of demonstrating the feasibility of a concept or the correctness of the specification. The fabrication of prototype models usually requires highly skilled technicians working in a laboratory environment. As a result, the cost of prototypes can be high and, in some cases, prohibitive. These costs normally make it impossible for ETSI to fund such implementations of its standards for validation purposes. It is, therefore, a method that can only be used if a member organization (or group of organizations) is willing to undertake the work on ETSI's behalf.

The use of a prototype model to validate a standard or set of standards, involves the following steps:

- a clear agreement is reached on which parts of the standard are to be modelled in the prototype;
- a full schedule of tests to be performed and the expected results is prepared and agreed before prototype testing begins;
- prototype models are built using parts and methods that ensure that the models are completed as quickly and as accurately as possible within the constraints of the available resources;
- testing is performed according to the agreed schedule;
- a clear report is produced giving details of:

    - problems found in the specification during manufacture and system testing;
    - the actual results of testing;
    - the impact of the results on the standard.
- the results are reviewed by the responsible TB and actions assigned to ensure that any necessary changes to the standard are completed.

This is likely to be an iterative process where the modifications to the standard as a result of the testing are incorporated into the prototype model(s) and re-tested.

When planning to use prototyping as a means of validating a standard, the following aspects should be taken into consideration:

- prototypes can be used to model partial specifications as well as complete specifications;
- existing commercial products can be used as platforms for testing prototype functions;
- it is essential that the organization(s) carrying out the building and testing of prototype models share the results of the project with the other members of the responsible TB.

7.1.4 Use of automatic tools

7.1.4.1 Formal validation of protocols

EG 201 015 [1] describes a validation methodology for standards using SDL which is summarized here.

This methodology requires a validation model to be developed. A protocol standard normally uses a mixture of techniques for describing the functions of the protocol. These may include informal prose as well as formal notations such as SDL, MSC and ASN.1 which are defined in ITU-T Recommendations Z.100 [14], Z.105 [15], Z.120 [16] and X.680 [17].

A validation model is a detailed SDL specification of the protocol which is both complete and executable. A protocol specification is likely to contain implementation options and it is necessary that a particular set of these is selected before the model can be made executable.

Using the appropriate tool support, the following activities can be performed:

- static analysis: detection of syntax and semantic errors, completeness of the model, cross-reference checking, cross-reading of the specification;
- state space analysis: identification of particular situations such as deadlocks and the identification of non-reachable states.

Checking with more than one tool is desirable for static analysis, because:

- it ensures that features that are specific to one tool and not specified in the relevant standard (ITU-T Recommendations Z.100 [14] and Z.105 [15]) are not used;
- it ensures better error detection (checkers of different tool are complementary).

Subclauses 7.1.4.1.1 and 7.1.4.1.2 provide a brief summary of the SDL development and validation methods recommended in EG 201 015 [1], EG 201 383 [2] and DEG/MTS-00050 (see bibliography).

7.1.4.1.1 Writing an SDL model for validation

The following tasks have to be performed to obtain the SDL model:

- identify validation-level signals and data types:
    - the standard may use complex message structures. Only those parts of the message that have an impact on the behaviour of the SDL model should be considered. Unnecessary information and complexity slows down the validation process;

    - SDL signal names and the level of detail shown should be chosen so that signal exchanges make the behaviour of the model easier understand. Signal parameters should be simple. This improves the readability of Message Sequence Charts and allows the validation tool to perform a better exploration of the possible data values;

    - SDL signals coming from the environment should be used to provide input values to the system. A set of possible signal parameters can be defined so the validation tool will try all possible values;

- write ASN.1 or SDL data types corresponding to signal parameters;

- write the system structure showing signal exchanges between functional entities of the model (represented as SDL processes);

- define the behaviour of the SDL model:

    - actions can be represented as informal text if their result has no impact on the behaviour. Otherwise variables on which the behaviour of the system depends should be set in a way that allows automatic exploration of possible values. The actual way to do this depends on the validation tool (informal decisions, unspecified operators or signals from the environment);

    - decisions whose question cannot be formalized should have an informal question (between single quotes).

When the SDL model associated with a standard was not designed as a validation model, it usually needs some rewriting in order to be used by a validation tool. The steps are similar to used in writing the SDL model from scratch, except that some of it may already be available. However, an existing SDL model will usually have to be adapted for validation. Some parts of the standard (such as signal parameters) may also be only described in the text, not in the SDL model.

7.1.4.1.2 Performing the validation

The validation phase itself involves:

- determining validation input data;

- running various kinds of validation:

    - automatic state space exploration to detect errors (deadlocks, unreachable elements etc.);

    - random exploration if the model is too large for exhaustive exploration;

    - manual exploration of most common paths (which can also be done as part of the simulation phase);

- generating MSC diagrams (or checking the SDL model against MSC diagrams which are part of the standard);

- reporting results of the validation exercise.

7.1.4.2 Simulating the SDL specification

Simulation allows the exploration of critical execution paths in a more detailed way than automatic validation. Simulation does not have to cover all aspects of the system.

SDL tools usually simulate a system, and provide a user interface for control. However, different tools provide different capabilities and these should be taken into account when preparing the model for simulation.

A simulation is performed in three steps:

- select a simulation scenario (signals to be sent to the system, with their parameters);

- start the simulator user interface, and provide the system with the appropriate stimuli (e.g. signals from the environment);

- check the MSC trace from the simulation against the expected behaviour of the system.

Since the system may not be fully specified, the user may be prompted to determine which branch to take after an informal decision (or a decision using ANY) or which value an undefined operator should return.

7.2 Available testing methods

7.2.1 Introduction

When choosing a test method, several factors should be taken into account, the language used to produce the base specification (formal, informal), the amount of testing required (regulatory, full conformance, basic interconnection, test purpose production only) and the resources available (time, financial, people). All of these factors influence the choice of the methods described below.

The reason for producing the test specification should be clearly understood and agreed. The writers of the test suite can then concentrate on the areas identified as important, for example, basic interconnection, interoperability or, full conformance. Usually, the test specification will be used to check that the base standard has been implemented correctly. It provides a recognized quality check for implementations.

A test case covers at least one aspect of the base standard. When deciding on the number of test cases to be produced, the degree of coverage should be selected. Complete coverage can be costly because of the effort required to achieve it, often a compromise is reached where the technical body responsible for the base standard agrees on an acceptable level of coverage. One possible solution is to produce test purposes which provide full coverage and then to produce complete test cases for only a subset of these, either formally or informally.

If the base specification has been written in SDL then it may be possible to generate the test purposes and the TTCN for the test cases automatically. The Validation Manual [1] provides some guidance on the use of CATG techniques to produce TTCN automatically from SDL. The automatically generated TTCN usually requires some additional human intervention to complete it.

7.2.2 Tables, diagrams and free text procedures

Tables, diagrams and free text procedures can be used to define the testing requirements for some types of standards. This method is most applicable when the base specification has been written using informal language and where the base specification specifies physical characteristics such as radio transmission properties. Base standards of this type are often written in this way so the tests produced should relate to the tables and diagrams in the base specification. Because the description of the tests is informal, using mainly diagrams and free text, it is important that sufficient text is included to avoid ambiguity and provide sufficient detail to define the tests clearly. Ensuring that this text is unambiguous and complete is not trivial and usually requires several iterations.

7.2.3 Test purposes only

Test purposes are normally the first step in producing a test suite. They are relatively cheap to produce and can usually be written quite fast. It is easy for the number of test purposes to grow very rapidly, therefore the technique of combining test purposes has been developed. This allows several purposes of the base standard to be covered by the one test case. Such combinations will be produced very carefully so that each individual test purpose can still be identified. The guidelines set out in ETR 266 [7] should be followed when writing test purposes.

Producing only test purposes will not allow a product to be tested according to a base standard, but it gives an idea of the amount of testing to be done in each area of the standard. Normally when only test purposes are produced, it is expected that the complete test specification will be produced at a later date, perhaps when more resources become available. Also, when defining the test purposes, the PCOs can also be identified. This will help tool manufacturers to produce test tools for the standard.

7.2.4 TTCN test suite

TTCN is a formal language used to define test suites and is itself defined in ISO9646 part 3 [13]. There are many editors which perform automatic syntax checking on the TTCN and compilers exist to generate executable code from the TTCN.

TTCN is most suitable for specifying the testing of protocols although it has been used for some tests of the layer 1 of the OSI reference model. Test purposes are usually written first. The test cases are collected together into a tree-like structure, called the test suite structure which should group the test cases into related areas of the base standard and provide an overview of the coverage achieved by the test suite. It should also show the areas where testing is concentrated. The TTCN Style Guide, ETR 141 [5], provides useful guidance to the presentation and layout of TTCN.

7.2.5 Interoperability testing

Interoperability is outside the scope of this document but is discussed briefly for completeness. It is a difficult term to define but in general refers to two or more entities or systems communicating together successfully. There are many levels of interoperability, end-to-end, node-to-node in a network or even between the layers of a protocol.

Conformance testing alone is not sufficient to guarantee interworking capability. However, successful interworking of two or more entities is more likely to be achieved if they conform to the same profile(s) than if not (ISO 9646-1 [12]).

Before interoperability testing can begin, the two parties should agree on what they are testing and perform a static analysis of their systems, including the profiles implemented and any options selected. A completed ICS document for each system can be used to perform this comparison. It is also important that each party has a degree of confidence in the other party’s product and this can be achieved through conformance testing of each product in advance.

A set of criteria should be defined which may be used to decide if the two systems inter-operate correctly. These criteria could be presented as test purposes with clearly defined PASS/FAIL verdicts.

In general, interoperability testing does not have a well-defined methodology and it is up to the two parties to agree their working methods and how problems will be resolved.

8 Planning and resources

With so many methods to choose from, it is important to spend some time at the start of a standards development program, deciding what approach to take and planning the time and resources that will be necessary. Resources will be allocated to the validation and testing activities in order to achieve a high quality standard.

As was indicated in clause 6, there is no simple guideline or formula to assist in the choice of validation methods to use and the types of tests to be specified. These are evaluated on a case-by-case basis and may depend on a wide range of factors. The available options are summarized in Figure 1 while the examples in clause 9 describe the decisions that might be made in a number of typical standards projects.

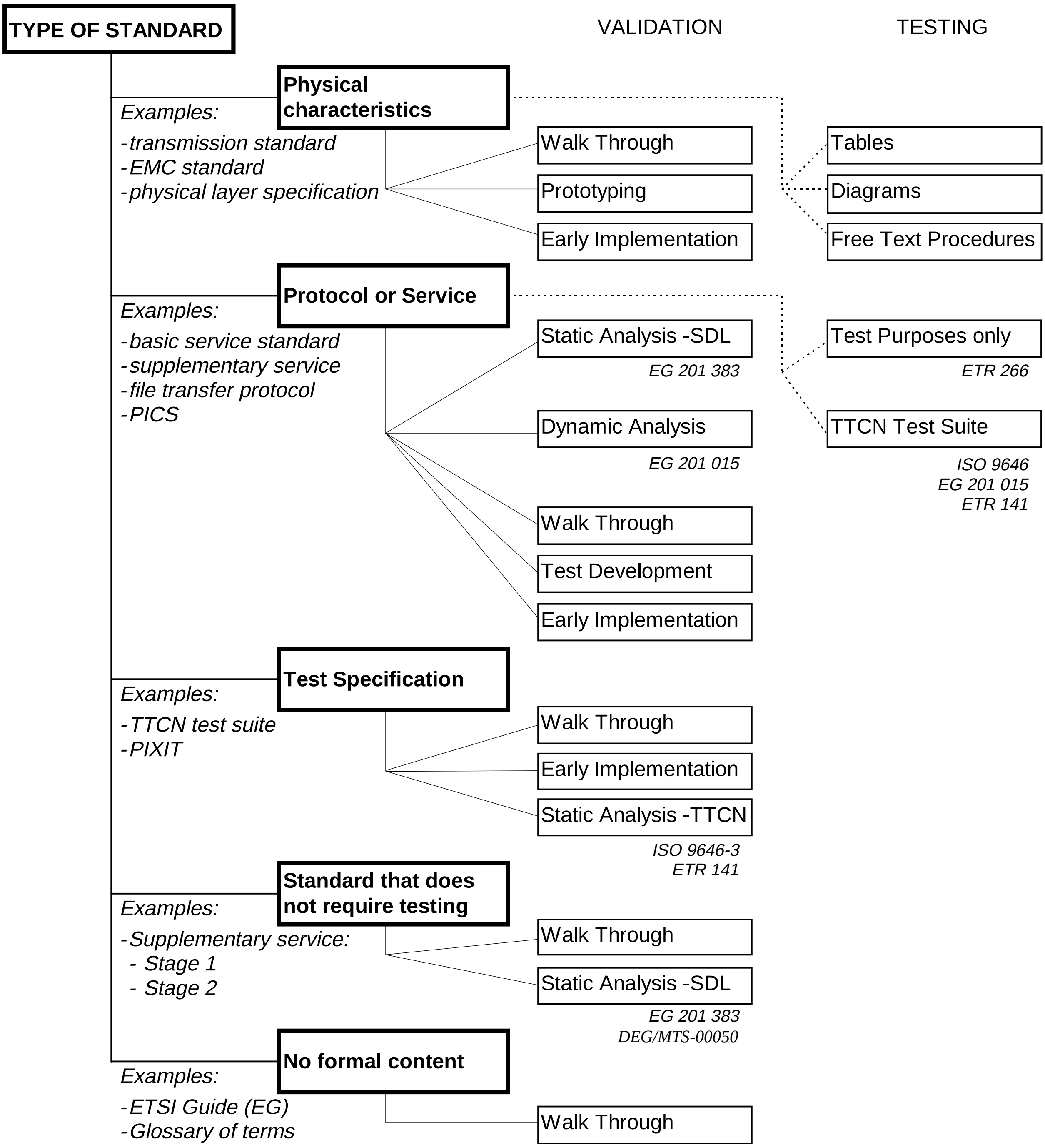


Figure 1: "Road-Map" of possible validation and test specification methods

8.1 Estimating resource requirements

Although it is very difficult to provide a set of simple rules for estimating the additional effort that will be required for each of the validation and test development methods, it is possible to give some guidance on the likely impact of these activities on the standards-writing process.

8.1.1 Planning for validation

8.1.1.1 Walk through

The amount of additional time spent in using the walk-through technique to validate a standard will depend on the following:

- the length of the standard;
- the complexity of its contents;
    - a short standard may, for example, contain very complex concepts and a long standard may describe only simple and straightforward concepts.
- the maturity of the technology being standardized;
    - a mature technology is likely to be more familiar to the reviewers and will, thus, be easier to read and understand in order to provide critical comment.
- the skills available among the reviewers.

As a result, it is only possible to give rough guidelines on the amount of additional effort that a TB would need to provide in order to validate a standard by this method. The length and complexity of the draft standard to be reviewed can be taken into account by grouping drafts according to the amount of effort required by the authors to develop them, e.g.:

- up to 3 months of effort;
- between 3 and 9 months of effort;
- more than 9 months of effort.

The effort required for each walk-through should include the time for reviewers to read and provide comments on the draft as well as the time for the review itself. It can then be estimated using to the formulae shown in where:

- a = no of authors;
- r = no of reviewers;
- w = effort expended on walk-through.

Table 1: Effort estimation formulae for walk-through

Effort required for draft	Effort required for walk-through (days)
< 3 months	w = 0,5a + 1r
3 - 9 months	w = 1a + 2r
> 9 months	w = 1,5a + 4r

EXAMPLE: A standard was written by two authors who spent 5 months of effort in developing it. A walk-through was held half-way through the project and another on completion. A panel comprising one chairperson and four additional experts was selected to review the standard. The effort required to review the first draft (with only 2½ months used) would be approximately:

$$(0,5 \times 2) + (1 \times 5) = 6 \text{ days}$$

The effort required for the final review (after 5 months of development) would be approximately:

$$(1 \times 2) + (2 \times 5) = 12 \text{ days}$$

The total effort for validating this standard by walk-through would thus be approximately 18 days.

8.1.1.2 Prototyping/early implementation

Prototyping is an activity normally performed outside of normal ETSI resources. The major cost is usually borne by member companies who undertake to produce prototype models and who may not be willing to reveal the amount of resources needed for this activity. When planning to validate through prototyping, the TB needs to have a commitment from at least one member to share the results of the prototyping activity with the other members of the TB. This member will normally be an expert in the area or in related areas and will have a good idea of the time and effort required to build and test the prototype.

To gain the most benefit out of a prototyping project when used to validate a standard, it is necessary to schedule regular reviews of progress and results in order to allow early feedback on any modifications that may be necessary in the base standard. Such reviews are likely to take between 0,5 and 1 day each, although this will depend on the complexity of the product and the number of errors reported.

8.1.2 Planning for validation

8.1.2.1 SDL validation

The amount of time spent in validating a standard using SDL is highly dependent on the quality of the SDL description of the standard.

SDL-related factors that can help in reducing validation time are:

- SDL model is syntactically and semantically correct;
- SDL model is produced using an SDL tool;
- SDL model has an appropriate level of detail;
- SDL model is suitable for validation.

SDL-related factors that may increase validation time are:

- No SDL model;
- SDL model is incomplete or inaccurate with regard to the textual description of the standard;
- SDL model is not syntactically or semantically correct;
- SDL model is written using a non-SDL tool (such as a word processor);
- SDL model is over-specified (more like an implementation than a standard).

There are other factors which are also likely to have an impact on the time that will be spent and these include:

- standard length and complexity;
- technology maturity;
- the skill level of people performing the validation.

These mainly affect the work that has to be done to obtain an SDL model suitable for validation. Validation itself does not require an in-depth knowledge of the standard to be validated.

8.1.2.1.1 Effort estimation

The effort required for validation is defined as follows:

- if the SDL validation model is part of the standard, then it is the extra work needed in order to produce a model that is sufficiently formal to be validated, plus validation time;
- if the standard already exists, then it is the effort needed to write the SDL validation model (or to adapt an existing model), plus validation time.

Validation effort estimation formulae are shown in Table 2, where:

- **sdl-pages** is the number of pages of SDL diagrams to be converted to SDL which is suitable for validation (counting about 15 to 25 symbols per page);
- **text-pages** is the number of pages in the textual description of the standard;
- **w** is the effort expended on SDL validation.

Table 2: Effort estimation formulae for SDL validation

Case	Nature of SDL in standard	Effort required for SDL validation (days)
1	electronic version, designed for validation	w = 0,5 × sdl-pages
2	no electronic version, needs small updates for validation	w = 1 × sdl-pages
3	incomplete, incorrect, untrustworthy	w ≥ 1,5 × sdl-pages
4	no SDL	w = 3 × text-pages

In case 3 it is likely that a substantial amount of work will be needed to obtain a validation model. In some cases, writing a new validation model from scratch may be preferable. This formula presupposes that each page of text yields between one and two pages of SDL, each page of SDL being written and validated in two days.

These effort estimates apply to validation by a single person, who has a reasonable knowledge of SDL and the validation tool, but is not familiar with the standard to be validated (validation performed separately, usually cases 2 and 3), or conversely, by a person who knows the standard but is not familiar with SDL tools and SDL validation (validation performed by the project team, cases 1 and 4).

EXAMPLE: An existing standard contains a 40-page SDL model, which is correct, but expresses signal names and parameters informally. The SDL model was written using a generic drawing tool.

Rewriting the model for validation using an SDL tool and validating it should take in average 40 days (1 × 40).

8.1.2.2 MSC validation

Standards usually contain a description of signalling flows using Message Sequence Charts. SDL validation tools can check that an SDL model behaves as described in an MSC diagram. This mainly verifies that the SDL model and the MSC diagrams are consistent.

There are two approaches to MSC validation:

- visually checking the MSCs in the standard against those produced by simulation;
- automatically checking MSCs as part of validation.

The first approach is faster if the MSC diagrams in the standard are not suitable for automatic validation. The second approach provides a more reliable validation since the MSC diagrams are produced independently of the SDL model and verified formally instead of visually.

MSC diagrams to be included in the standard can be generated from the SDL model, which saves the time that would have been necessary to write them. Such MSC diagrams cannot be used for validation of the SDL model from which they were generated, but may be useful for regression tests if the SDL model is modified.

The amount of time spent in MSC validation is shown in Table 3, where **msc-pages** is the number of pages of MSC diagrams to be validated and **w** is the effort expended on MSC validation.

Table 3: Effort estimation formulae for MSC validation

Case	MSC checking strategy	Effort required for MSC validation (days)
1	Generate MSC, visual inspection	w = 0,2 × msc-pages
2	Need to enter existing MSC in SDL tool	w = 0,5 × msc-pages

8.1.2.3 Simulation

Performing an extensive simulation of the standard as part of the validation process makes it possible to find erroneous behaviour paths that would otherwise not be discovered until testing. Since the testing phase is separate from the validation phase, and possibly carried out by a different team, simulation is cost-effective.

Simulation is usually performed on the SDL specification that is used for validation (or on a very similar one), so the simulation cost is mainly in determining the simulation scenarios, running them, and checking the result.

If MSC diagrams have been written for the specification, part of the simulation may be done in terms of MSC validation (8.1.2.2), so the effort that was put into MSC validation does not have to be put into simulation.

The amount of time that will be spent in exploring the main expected behaviour paths of the system depends on the following factors:

- number of signals that may be received by the system;
- whether these signals should be tested separately, sequentially, or in combination;
- number of informal decisions (or decisions using ANY) and undefined operators, which will result in user interactions during the simulation;
- expected behaviour coverage.

NOTE: Informal decisions or decisions using ANY yield an important number of possible combinations. If a decision has three possible answers, the simulation will have to be run three times to test all branches. The resulting number of branches depends on how the decisions are combined (if they add or multiply or contain loops which are the worst case).

In order to avoid user interaction during the simulation, informal or ANY decisions may be replaced with a test on a value that is returned by a procedure. If all such procedures are easily accessible, the value to be returned by the procedures - and consequently the answer branches that will be chosen - can be modified easily or even automatically generated if the SDL tool allows it.

Simulation effort estimation formulae are shown in Table 4, where:

- **sdl-pages** is the number of pages of SDL diagrams (counting about 15 to 25 symbols per page);
- **runs** is the expected number of simulations that will have to be run. They correspond to the various combinations of input signals, informal decision answers (or use of ANY) and undefined procedures;
- **w** is the effort expended on simulation.

Table 4: Effort estimation formulae for simulation

Case	Complexity of SDL (from validation phase)	Effort required for simulation (days)
1	Few input signals and informal decisions, or limited coverage	w = 0,2 × sdl-pages
2	Need to simulate a large number of similar paths due to informal decisions	w = 0,05 × runs + 0,1 × sdl-pages

The formula in case 1 considers that both the number of tests to be performed and the time to check the results are proportional to the size of the specification.

In case 2, the simulator has to be run repeatedly to take into account small variations in the system behaviour, for instance, to try different rejection causes. The simulation cost therefore depends on:

- the size of the specification as regards the number of main behaviours and the time to check the conformance of a behaviour (0,1 × sdl-pages);
- the number of times the simulator has to be run (about 15 minutes per run). The duration of a run does not include the analysis of the results since several runs may relate to the same main behaviour.

If there is a large number of input signals or informal decisions, obtaining a good behaviour coverage using simulation may not be possible. The main behaviour paths should be tested manually, then others can be checked automatically using validation techniques.

8.1.3 Planning for testing

8.1.3.1 Test purposes only

Test purposes can be produced relatively quickly because they often do not enter into the details of the standard but remain at a high level. It is estimated that test purposes for a standard can be produced in about 10% of the time taken to write the standard.

As usual, this depends on the level of knowledge of the people writing the test purposes and whether test purposes have already been produced for other standards for this technology. If such test purposes exist then there is probably an accepted way of producing them from the new standard, e.g. exploration of the state space, analysis of the messages exchanged and functional tests.

8.1.3.2 Tables, diagrams and free-text procedures and TTCN test suites

These two types of testing are treated together because the planning required for both of them is very similar.

There are several factors which have to be taken into account for the planning, but in general the resources needed for testing will be at least twice those required to produce the base specification.

Factors which may either increase or decrease this requirement are:

- the quality of the base standard:

  If the base standard is well written, then the testing requirements will be easier to identify, conversely, if the standard is poorly written, then extra time will be spent analysing the standard and related standards to clearly define the testing requirements.

- the expertise of the people generating the testing specifications:

  This can depend on whether it is a new technical area or whether there has been a lot of testing done in the area already. For example, if a base technology has already been tested then tests for supplementary services may re-use some of the test steps or PDU definitions used to test the base standard. However, if this is the first time that testing specifications are to be generated in a particular technical area, then the TB may be looking for new ways to express the testing requirements;

- the amount of testing that is required:

  This depends on whether the testing required is for full conformance testing, interoperability testing or basic interconnection testing. This will effect the number of test cases to be produced and this has a directly proportional effect on the resources necessary for testing.

As methods and tools for automatically generating test suites improve, the resources necessary may be reduced.

9 Example scenarios

Table 5 to Table 8 show some realistic examples of the use of the road-map (Figure 1). Taking four typical standards-writing scenarios, they work through the decisions that are likely to be faced by TBs when planning for validation and the development of test suites.

Table 5: Example sequence - a standard to specify physical characteristics

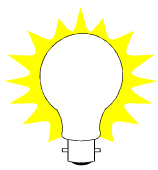
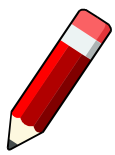
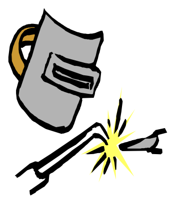
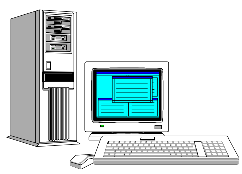
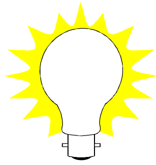
The need for a new standard is identified and the technical body agrees to produce it. The standard has the following characteristics: - it specifies mostly physical properties; - some members of the group involved in writing the standard are willing to implement prototypes; - the standard will mainly be presented as tables and diagrams with supporting text.	
1st draft of standard will be produced. This draft will initially be validated using walk-through.	
Validation through implementation/prototyping Some members of the team will take the draft standard and try to implement it. Any problems and proposed solutions will be fed back to the standard writers for input to the next draft.	
Iterative improvements to the standard using prototyping and further walk-through.	
Final version of the standard to be accepted by the technical body. ETSI has produced a standard of high quality.	

Table 6: Example sequence - a complex protocol standard using formal notation

The need for a new standard is identified and the technical body agrees to produce it.

The standard has the following characteristics

- it includes large and complex protocols;
- the cost of prototyping is high;
- market pressure for an error-free standard is high;
- the standard will be produced using a formal notation.

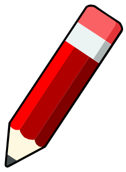


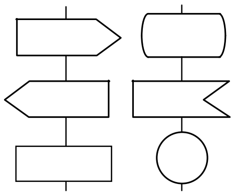
A validation group will be established.

This group will work in parallel with the standard writers and develop a validation model. They may also be part of the standard writing group.

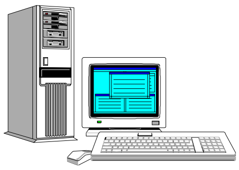
1st drafts of standard and validation model are produced.

Walk-through will be performed regularly.





Iterative improvements to the standard using the validation model and to the validation model using the standard.



A TTCN test suite will be produced automatically from the validation model and completed manually.

Specification errors in the standard or validation model may be discovered. Both the standard and the validation model will be improved.

Behaviour	L	Cref	V	C
L1 ! SETUP(0)		SETUP1		
L1 ? ALERT				
L1 ? CALL_PROC			(P)	
L2 ! ERR_MSG(88)				

The ETSI Help Desk and PSM group will assist with any problems encountered using validation languages or tools.

Final versions of the new standard and validation model to be accepted by the technical body.

ETSI has produced a standard of high quality.

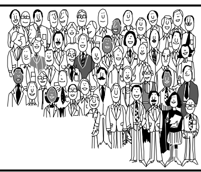
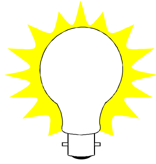


Table 7: Example sequence - a complex protocol standard using informal notation

The need for a new standard is identified and the technical body agrees to produce it.

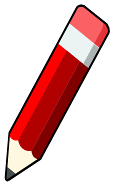
The standard has the following characteristics:

- it includes large and complex protocols;
- the cost of prototyping is high;
- the standard is to be defined using an informal notation;
- there are insufficient resources for formal validation;
- there is a need to produce complete conformance tests;
- market pressure for an error-free standard is high.



Standard will be produced.

Preliminary validation will be performed by walk-through.



A test suite will be produced in TTCN.

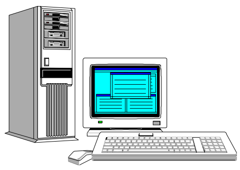
Specification errors may be discovered in the standard.

Behaviour	L	Cref	V	C

L1 ! SETUP(0)
  L1 ? ALERT
  L1 ? CALL_PROC
    L2 ! ERR_MSG(88)
		SETUP1	
			
			(P)	

Iterative improvements to the standard using the test suite. Also improvements to the test suite.

Further walk-through of both standard and test suite will be performed.

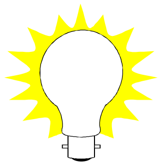
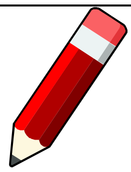
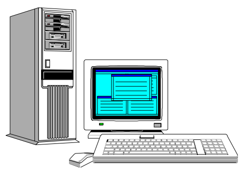
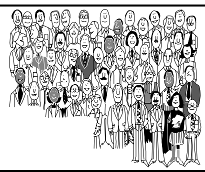


The ETSI Help Desk and PSM group will help with any problems encountered using TTCN language or tools.

Final versions of the new standard and test suite to be accepted by the technical body.

ETSI has produced a standard of high quality.

Table 8: Example sequence - an ETSI Guide (EG)

The need for a new EG is identified and the technical body agrees to produce it. The EG has no formal content.	
1st draft will be produced.	
Draft will be validated by a walk-through.	
Iterative improvements to the EG following successive walk-through. There will be no testing phase.	
Final version of the new EG to be accepted by the technical body. ETSI has produced a standard of high quality.	

10 Further help available

The Protocol Specification Methodology (PSM) group within the ETSI Secretariat is able to provide assistance in the planning and application of validation and test development programmes. This group offers specific expertise in the use of formal languages, validation techniques and the specification of test suites. They can provide a value input to improve the quality of standards development.

The PSM group can be contacted on:

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Email: pex@etsi.fr

Bibliography

The following material, though not specifically referenced in the body of the present document (or not publicly available), gives supporting information.

- DEG/MTS-00050: "Methods for Testing and Specification (MTS); Use of SDL in European telecommunication standards; Guidelines for the use of formal SDL for descriptive purposes".

History

Document history		
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