A EUROPEAN APPROACH TO QML

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Abstract

A concept for a **QUALIFIED MANUFACTURER LISTING (QML)** approach in the European ESA/SCC system has been established. The existing ESA/SCC specifications have been adapted and new basic specifications drafted. The system is currently being validated at 2 European microcircuit manufacturers.

INTRODUCTION

The US-MIL system for certification and qualification of electronic components for use in military and space applications has been completely restructured over the last decade.

The reason for this activity was the drastically decreased volume of military components in the late 80's or early 90's, the associated diminishing supplier base for such components and the pending obsolescence for many part types used in military equipment and systems.

To cope with this challenging situation and to secure the future availability of suitable EEE-components for military and space applications, the US DoD and associated/affiliated authorities have reacted with a change to the well established procurement system and it's underlying philosophy by introducing a so-called "Qualified Manufacturer Listing" - QML - among other modifications carried out in several iterations. These activities finally resulted in the generation of a new certification and qualification concept which is based on SPC methodologies and total quality management (TQM) and which permits the certification of design, fabrication, assembly and packaging. The objective was to have a single process flow on which both commercial and military devices are indistinguishable and only at qualification testing will the differences be evident.

This acquisition reform culminated in 1994 in the publication of the Dr. William Perry - US Secretary of Defence - memorandum, which directed all military organisations to turn away from the standard "cookbook type" procurement specifications and convert them to so-called "Performance Specifications".

The implementation of the QML system in the US necessitated that a concept for the QML system be set up and that the specifications and standards be re-written to include that new concept. The US MIL-specifications have been successively revised so that both the QPL (Qualified Parts List) and the QML approach are covered.

Although the qualification of individual components is still possible, the majority of the manufacturers of electronic components for military and space applications have switched over to the Qualified Manufacturer Listing (QML) approach to the qualification of components. That approach has been shown to be more cost effective and is more in line with procedures used for the qualification of commercial electronic components.

The European space industry of course was affected accordingly by this acquisition reform which gave rise to serious concerns about the future availability of space components at affordable cost. As these European companies tried to retain their market shares in the space business, they began to give serious thought to alternative suitable sources and specification systems for qualified space components at competitive prices.

Initiated by the EUROSPACE organisation the "Space Components Ad Hoc Committee - SCAHC" was founded at the end of 1994 and analysed the current parts procurement practices (in Europe) with a view to reducing components' cost without jeopardising components' reliability. These activities were carried out in close co-operation with ESA/ESTEC and with various Working Groups - WG - assigned for different subjects. Eventually, the results of each WG's analysis were published in Final Reports in May 1995 with recommendations covering how to improve the current ESA/SCC specification system.

The SCAHC WG1 was responsible for "Technical Issues And Product Assurance Aspects". One of the formulated tasks dealt with the "Assessment of MIL QML with ESA/SCC" as follows:

"EVALUATE QUALITY ASSURANCE CONCEPTS TO REDUCE LEAD TIME AND COST FOR QUALIFICATION UTILISING ELEMENTS OF A LINE QUALIFICATION CONCEPT (QML)"

The existing European ESA/SCC system for the qualification of space parts is based on the QPL approach and was later extended to include an element of the QML approach with the introduction of "capability approval". The results of a study initiated by ESA and carried out by Tesat-Spacecom and Astrium under a German DLR contract have indicated that modification of the ESA/SCC system to include the QML approach would be advantageous. In addition to the technical advantages of the QML approach, it

would improve compatibility to the US system and increase the attractiveness of ESA/SCC qualification.

The recommendation of the European study was that a QML approach should be introduced into the ESA/SCC system, and this could be achieved most efficiently by extending the existing ESA/SCC capability approval system to all active EEE components and increasing the flexibility of the system. This approach was later modified to make the European system as similar as possible to the US MIL QML system while still making maximum use of existing and proven qualification requirements, methods and documentation in the ESA/SCC system.

DEVELOPMENT OF A EUROPEAN SYSTEM

A programme for the development of a European QML system was started in 1996. That programme reviewed the US QML system, proposed a concept for the European system, and discussed the proposed concept with the European space industry and space agencies. An implementation plan for the agreed concept was set up and the concept has been to a large extent already worked into the ESA/SCC documentation. The reworked documentation includes:

- 3 new specifications
- 7 major modifications to specifications
- 69 minor modifications to specifications

The 3 new specifications are basic specifications that describe the QML system itself and its application to ICs and MMICs (Note: the latter specification is still under modification by a separate, dedicated Sub-Working Group of the SCSB Implementation Team).

The reworked QML specifications are currently under validation and have not yet been released for general use.

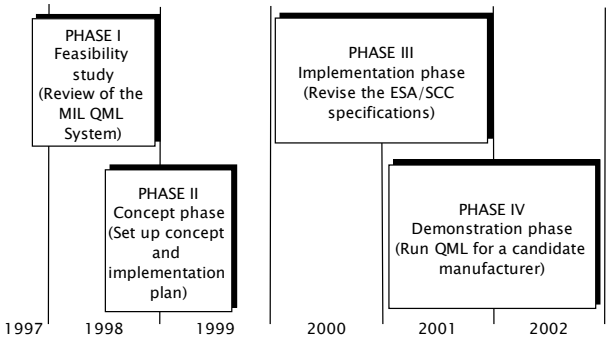


Figure 1: Phases of the programme to develop and implement a European QML approach

THE ESA/SCC QML CONCEPT

This new concept covers all aspects of the ESA/SCC qualification of technology flows used to produce EEE parts for space applications. In this qualification approach a manufacturer's defined technology flow is evaluated, certified and qualified, after which it can be added to the ESA/SCC Qualified Manufacturers' Listing (QML).

Any component made within the boundaries of the qualified flow, and meeting the requirements of the procurement specifications, can then be included on the QML as qualified.

Although having similarities to the existing ESA/SCC Capability Approval approach, the new concept emphasises not only the manufacturing processes to be employed but also a complete quality management programme designed to ensure component quality.

Differences from Capability Approval are made more apparent by considering some Key Items of the QML concept:

- Co-operative relationship between manufacturer and Qualifying Authority (Q.A.)
- Transfer of responsibility to the manufacturer's Technical Review Board (TRB) once QML certification / qualification has been granted
- Enhanced flexibility for manufacturers, because the concept describes a non-mandatory test baseline which can be modified by manufacturers on condition that component quality and reliability is not degraded.

In addition, and in common with the US QML system, the new concept allows QPL listed manufacturers to select "transitional" QML qualification. This involves less effort to obtain full QML approval but must be completed within a reasonable period of time (2 years are proposed). Manufacturers who do not want to apply for QML can also maintain their QPL products until the component type or the technology becomes obsolete.

The major differences between ESA/SCC QML and MIL QML are:

- The ESA/SCC system is a uniform system
- The ESA/SCC QML concept is applicable to all EEE parts including passive parts (while hybrids are so far not yet covered in the ESA/SCC specification system).
- The ESA/SCC QML concept maintains a dedicated and clearly visible Evaluation step
- QML and transitional QML parts shall be listed separately from QPL parts

MAIN ELEMENTS OF THE ESA/SCC QML SYSTEM

The following elements are the essential features of the system, some of which are then explained in more detail in the following text sections:

- Establishment of a Technical Review Board (TRB) at the manufacturer.
- Setting up of a Quality Management (QM) plan
- Provision of a description of the technology flow for the technology to be qualified
- Evaluation of the technology by means of a test programme
- Performance of a qualification programme
- Establishment of a system for self-audit at the manufacturer
- Pre-validation or pre-audit by the manufacturer shall be carried out
- An audit shall be performed by the Qualifying Authority (Q.A).
- Certification of the technology: Certification is the recognition of evidence that the manufacturing line is capable of producing components compliant with the requirements
- Qualification of the technology: Qualification is the actual demonstration of the capability of the certified manufacturing line by producing components with the required quality and reliability
- Component Listing on the European QML
- Maintenance & retention of qualification until there are changes in test results, materials, processes or facility locations that the TRB or QA believes to invalidate the certification, qualification or listing.

THE QUALIFICATION PROCEDURE

The formal qualification procedure consists essentially of five main phases:-

1. Definition of Technology Flow and Quality Management Plan
2. Evaluation of Technology Flow
   - Establishing Evaluation Test Programme to cover areas where there are insufficient existing data.
   - Carrying out Evaluation Test Programme to demonstrate process capability.
   - Establishing Qualification Programme to cover areas where there are insufficient existing data.
   - Review of defined Technology Flow, Evaluation Test Programme Results, and proposed Qualification Programme.
3. Certification of Technology Flow
   - Full on-site Audit of Manufacturer to validate management and technology.
   - Granting of QML Certification.
4. Qualification of Technology Flow
   - Carrying out Qualification Test Programme.
   - Granting of QML Qualification.
5. Listing of Qualified Component Types

This qualification approval procedure is also shown diagrammatically in Chart I. The Chart shows the overall procedure in more detail than given here and also shows the respective responsibilities of the Manufacturer and Qualifying Authority. Although the chart shows all steps in the qualification flow as being performed sequentially, the Manufacturer and Qualifying Authority can agree to perform parts of the flow in parallel in order to reduce the overall qualification time scale. All steps must still be performed however and there is a risk that the results of any steps performed out of sequence might later be invalidated by other results.

It must be noted that the qualification of a technology flow, rather than just an individual component type, results in an increased importance for evaluation and related activities, and a relatively lower importance for the qualification testing of completed components.
In most of the qualification approval procedure activities the Manufacturer's Technical Review Board (TRB) plays an essential role. The creation of a suitable TRB at an early stage in the procedure is therefore a fundamental requirement for the Manufacturer. Details of the required organisational structure, duties and responsibilities of a TRB are given in the following section below.
Note: A Manufacturer who already has ESA/SCC QPL listed components, or who has an ESA/SCC approved capability domain, can use the existing qualification data to apply for transitional certification. This gives the Manufacturer the possibility of transferring existing qualified components from the QPL to the QML and is covered later in the text.

THE TRB RESPONSIBILITY AND AUTHORITY

The Technical Review Board has the following responsibilities and duties as described in the QM Plan and comprises responsible persons from all areas of the QM programme, i.e. management, design engineering, processing, manufacturing, testing, quality assurance etc. … .

The Technical Review Board

- Assumes responsibility with decision making competence in all technical and quality aspects of

any technology flow proposed for qualification, i.e. for managing the QML programme.

- Defines the boundaries and details of any proposed technology flow and collects or generates data to support its suitability for qualification.
- Must define an appropriate qualification programme to verify the quality of the proposed technology
- Must perform a self-audit to identify and correct any deficiencies in its planned application for QML qualification
- Must document all decisions and report to the Qualifying Authority

THE QUALITY MANAGEMENT (QM) PLAN

The QM Plan plays the key role in the new concept for QML certification and qualification.
For each technology flow proposed for qualification a dedicated Quality Management (QM) Programme shall be developed and implemented by the Manufacturer, and this shall be documented in a QM Plan. The TRB shall be responsible for developing, approving and maintaining the QM Plan.

The plan shall be included in a comprehensive pre-validation data package submitted to the Qualifying Authority for approval as part of the technology flow evaluation.

The QM Plan, as a minimum, shall address and provide details of the following items, many of which are self-explaining:

- Index of Certified Baseline documents
  This shall list all specification, plan or procedure titles, together with their document and issue numbers, which make up the Manufacturer's technology flow certification programme. It shall form the baseline to which the Manufacturer will be certified after a satisfactory Qualifying Authority audit.
- Conversion of Customer requirements
  This shall define a system for converting all external requirements for new QML listed component types into in-house requirements
- Quality Improvement programme
- Calibration programme
- Training and Certification programme
- Cleanliness and Atmospheric Control programme
- Third Party control programme
  This shall document the Manufacturer's procedures for ensuring that all activities within the technology flow which are performed by third parties are controlled to the same levels as the Manufacturer's own activities.
- Failure analysis programme
- Statistical Process Control (SPC) programme
- Corrective Action programme
- Change Control programme
- Parametric Monitors, Technology Characterisation Vehicles (TCV) and Standard Evaluation Circuit (SEC) Assessment programme
  This shall establish the details of what parametric monitors, technology characterisation vehicles or standard evaluation components are to be used for test purposes. It shall also establish the test frequency and methods of test, and criteria for evaluating the test results. The Manufacturer's assessment of possible reliability risks associated with his technology flow and components manufactured using it, which he has then used as a basis for formulating his test programme, shall also be addressed. Finally the correlation between test structures and actual product shall be addressed.
- Evaluation test programme
  This shall establish the testing which the Manufacturer proposes to perform on the specified technology flow to verify its quality and suitability for space class components. The initial proposal might require later modification as a result of the analysis of any existing data intended to support the suitability of the technology for qualification. The requirements given in ESA/SCC Basic Specification No. 22600 can be used as a baseline guide for generating a suitable test programme.
- Qualification programme
  This shall establish the testing which the Manufacturer proposes to perform on actual components manufactured using the specified technology flow in order to verify his ability to produce space quality components. The initial proposal might require later modification on the basis of the results of the evaluation or Manufacturer's audit. It shall also clearly identify any testing proposed for components manufactured using the specified technology flow which could be considered as screening, and which should therefore be performed on all components manufactured using that flow even after qualification.
  The requirements given in ESA/SCC Basic Specification No. 20100 and in the applicable Generic Specification can be used as a baseline guide for generating a suitable test programme.
- Validity of Qualification
  This shall define the period for which qualification remains valid together with requirements for extension or renewal of qualification. It shall also include details of any periodic testing which is considered necessary. The requirements given in

the applicable Generic Specification can be used as a baseline for this.

TECHNOLOGY FLOW AND BOUNDARIES

Technology Flow Description

The Manufacturer shall prepare a Technology Flow Description to describe, in a comprehensive manner, the scope and extent of the technology flow for which certification and qualification is sought. It shall cover design processes, fabrication processes, assembly processes, the package and in-process testing and control, and it shall also specify the plant or plants where the processes are to be carried out. The description shall clearly delineate all necessary boundaries, such that there can be no uncertainties regarding the extent of what is to be certified and qualified and deciding whether specific component types will be covered.
The document shall be included in a detailed pre-validation data package submitted to the Qualifying Authority for approval as part of the technology flow evaluation, and shall contain commercially insensitive information suitable for publication in the ESA/SCC Qualified Manufacturer Listing (QML).
More detailed information on what must be addressed in the technology flow description is given in the appropriate ESA/SCC 25400 series ancillary specification covering the relevant technology.

Process Identification Document

A PID for the technology flow to be approved shall be prepared by the manufacturer to the satisfaction of the Qualifying Authority. In terms of content, lay-out and configuration control the PID shall fulfil all requirements of ESA/SCC Basic Specification No. 22700 for a technology flow qualification document. It shall be updated, as necessary, during the course of the qualification exercise such that at the completion of qualification it accurately identifies all the processes used in the qualified technology flow.
In preparing the PID the Manufacturer may use extensive references to any in-house documentation describing his processes as long as the relevant issues are clearly identified and subject to an acceptable control system

Test Structures

Any special test structures shall be fully documented in the PID. They shall be manufactured and tested in accordance with the technology flow proposed for qualification.

Package Selection

The Manufacturer shall establish and implement systematic package design or selection reviews to ascertain compatibility of internal functional elements and packages with respect to thermal, electrical and mechanical performance and manufacturing, testing and reliability requirements.

EVALUATION OF THE TECHNOLOGY FLOW

The evaluation of a technology flow shall verify that the chosen technology and quality procedures are suitable for the manufacture of high reliability components for space applications. The evaluation programme shall also help to determine whether realistic and appropriate boundaries have been set for the technology flow and shall give a high level of confidence in a positive result to the subsequent Manufacturer audit and qualification test programme. The evaluation of a technology flow shall include but not be limited to:

- The review of existing data and/or test results from components and/or test structures manufactured using the technology flow.
- The establishment of an evaluation test programme.
- Acceptance of the evaluation test programme by the Qualifying Authority.
- The evaluation testing of the technology flow using suitable components or test structures.
- The establishment of a qualification test programme based on the evaluation of the technology flow.
- Self-validation of Manufacturer's data, documentation and facilities through TRB audit.
- Preparation of comprehensive pre-validation data/documentation package and submission to the Qualifying Authority for review and acceptance.
- Review of the pre-validation data/documentation package by the Qualifying Authority, identification and completion of any corrective actions, and acceptance by the Qualifying Authority.

CERTIFICATION OF TECHNOLOGY FLOW

Certification of the technology flow means that the Qualifying Authority has recognised that there is acceptable evidence that the Manufacturer's defined technology flow, in conjunction with the TRB and the QM plan, is capable of producing high quality circuits compliant with the requirements of this specification. The evidence studied and evaluated by the Qualifying Authority shall include, but not necessarily be limited to, the following.

- The evaluation data and documentation supplied by the Manufacturer in the pre-validation package.
- The results of an on-site audit of the Manufacturer designed to validate, as a minimum, the following areas of the Manufacturer's facility: management, TRB, quality assurance, design, manufacturing, assembly and package, environmental/mechanical test and electrical test.

Granting of Certification

If the results of the Qualifying Authority review of the pre-validation package are that it meets all of the requirements for evaluation data and documentation, and the results of the on-site audit are fully acceptable, and there are no outstanding corrective actions resulting from the review or audit which are still to be implemented, then the Qualifying Authority shall grant the Manufacturer certification of the technology flow proposed for qualification.

QUALIFICATION OF TECHNOLOGY FLOW

Qualification Test Plan

Once the technology flow is certified the qualification test plan shall be updated in accordance with any changes agreed between the Manufacturer and Qualifying Authority during the evaluation or certification phases. It shall then be resubmitted to the Qualifying Authority for approval, together with a proposed schedule for performing all the activities described in the plan.

Qualification Test Vehicles

The Manufacturer shall normally produce, using the certified technology flow, a minimum of two types of demonstration vehicle, as documented in the qualification test plan submitted during the certification process. The demonstration vehicles shall be such as to be representative of the total range of actual devices which can be produced by the technology flow and which the Manufacturer wishes to qualify and supply for space use. For some technology flows which are used for non-standard components a single type of demonstration vehicle might be appropriate and sufficient. Any proposal to use a single type of demonstration vehicle must be clearly identified and justified by the Manufacturer in his Qualification Test Plan and approved by the Qualifying Authority.

Each demonstration vehicle should operate and perform in compliance with the appropriate generic and detail specifications and, if applicable, should be manufactured in a package type which is suitable for space use and which will not induce additional failures. Before qualification testing the components should be subjected to any screening which has been identified as necessary to ensure the required performance of components manufactured using the defined technology flow.

Qualification Test Performance

The technology flow qualification testing shall be performed in accordance with the requirements of the approved test plan. The Qualifying Authority shall have the right to witness the testing and to review the test data. The testing may be performed at the Manufacturer's premises or at any mutually agreed facility approved by the Qualifying Authority.

Qualification Test Report

On completion of the technology flow qualification testing programme, the Manufacturer shall collect all relevant data and documentation in the form of a technology flow qualification test report. This report shall be sent to the Qualifying Authority for review.

Disposition of Qualification Test Lot and Data

The components of the qualification test lot shall be kept together and shall be clearly identified as being the qualification test lot. The final disposition of the test components, and the disposition of all data and documentation generated, shall be as agreed between the Manufacturer and the Qualifying Authority.

Granting of Qualification

The Qualifying Authority shall perform a detailed review of the technology flow qualification test report. If this is found to meet all of the requirements defined in the Manufacturer's approved Qualification Test Plan, and if there are no outstanding corrective actions to be implemented resulting from the certification or qualification, the Qualifying Authority shall grant the Manufacturer qualification of the technology flow and shall apply for ESA approval and listing on the appropriate QML.

LISTING ON THE ESA/SCC QML

When a technology flow is initially qualified it shall, with ESA approval, be listed on the ESA/SCC QML, together with the demonstration vehicles used to perform qualification testing if these are standard component types intended for further production.

The Manufacture can submit requests to the Qualifying Authority that other component types be added, with ESA approval, to the QML. When requesting the addition of a new component type to the QML the Manufacturer must supply a certificate of compliance which, as a minimum, certifies the following.

- The component type is manufactured entirely within the boundaries of the certified and qualified technology flow using only certified and qualified processes.
- The component type uses a package type which was covered by the original certification and qualification, or which is otherwise qualified for space use.
- The component type is capable of meeting all the functional and test requirements given in the applicable generic and detail specifications.

If no suitable detail specification exists the Manufacturer shall also supply a draft new detail specification in ESA/SCC format.

The Qualifying Authority shall have the right to request the Manufacturer to supply additional detailed supporting information if required.

TRANSITIONAL CERTIFICATION

A manufacturer with ESA/SCC QPL listed components, or with an approved capability domain, can apply to the Qualifying Authority for Transitional Certification of the technology flow used for the qualified components or used within the approved capability domain. If this is granted by the Qualifying Authority, and approved by ESA, the technology flow and any qualified components are listed on the QML for a transitional period during which the Manufacturer can perform the actions necessary to gain full qualification.

The advantage to a Manufacturer of having transitional certification is that during the transition period he can supply components as QML listed and also has the benefits of technology flow qualification available to him, unless these are specifically excluded by this document or by the Qualifying Authority.
For a Manufacturer to be granted transitional certification the following requirements must be met:

- The technology flow for which qualification is sought must have been used for manufacturing the components which are already listed on the QPL, or it has been described and used for obtaining capability approval.
- The evaluation test requirements for technology flow qualification must be covered in full or in part by testing already performed on QPL listed components or capability approval test structures.
- The Manufacturer must have performed a self validation to identify deficiencies in the requirements already met for component qualification or capability approval when compared with those given in this document for technology flow qualification.
- The Manufacturer must submit a plan for achieving full technology flow qualification. This plan must be based on the deficiencies identified during the self validation. The requirements for a Technical Review Board and a Quality Management Plan rather than just a Quality System, for example, are unlikely to be covered by any existing component qualification or capability approval.
- The Manufacturer must be prepared to submit to an initial on-site audit by the Qualifying Authority if this is considered necessary.
- The Manufacturer must make a clear commitment to becoming fully technology flow qualified within a stated period of time.

If the above requirements are met, and any on-site audit which is performed is satisfactory, the Qualifying Authority can certify the technology flow and grant transitional certification. The Manufacturer can then apply for any components which were previously listed on the ESA/SCC QPL to be transitioned to the ESA/SCC QML.

For components manufactured under transitional technology flow certification the Manufacturer must initially continue to comply with all relevant requirements of the ESA/SCC Basic Specifications and other specifications under which the components were originally qualified. As the planned activities for achieving full technology flow qualification are satisfactorily completed, and Manufacturer moves towards full qualification, the Qualifying Authority can allow relaxation of these requirements as part of the transition process.

If a Manufacturer wishes to make any changes to components or processes covered by transitional certification, these changes must be approved by the Qualifying Authority and by ESA in accordance with the requirements applicable for the original qualification.

It should be noted that regardless of whether a manufacturer initially applies for transitional or full technology flow certification, he is expected and encouraged to use the available data from any existing qualification or approval in support of his application.

FURTHER REQUIREMENTS ADDRESSED BY THE SYSTEM

The ESA/SCC basic specification No. 25400 has addressed further requirements not detailed herein. It defines the procedures for granting Technology Flow Qualification including validity, extension, loss or suspension of Qualification and also gives details about the QCI requirements and finally makes reference to any ancillary basic specifications in the ESA/SCC 254XXX series, which will be listed in the ESA/SCC REF/001 List of Documents and Specifications under Configuration Control

CONCLUSIONS

A QML concept for implementation in the European ESA/SCC system has been developed. Existing specifications that needed to be modified to cover the QML approach have been revised and three new specifications have been drafted. The specifications are currently under validation. The system includes many of the aspects of the US QML system but maintains evaluation as a clearly visible step and is also applicable to passive components. After general implementation, the system will offer manufacturers the possibility to qualify components via QML or to make use of the existing QPL or capability approval approaches. QPL qualified manufacturers can make use of a transitional certification as a simplified means for switching from QPL to QML.

CHART I(A) – TECHNOLOGY FLOW CERTIFICATION AND QUALIFICATION FLOW (PREPARATORY ACTIONS AND EVALUATION PHASE)

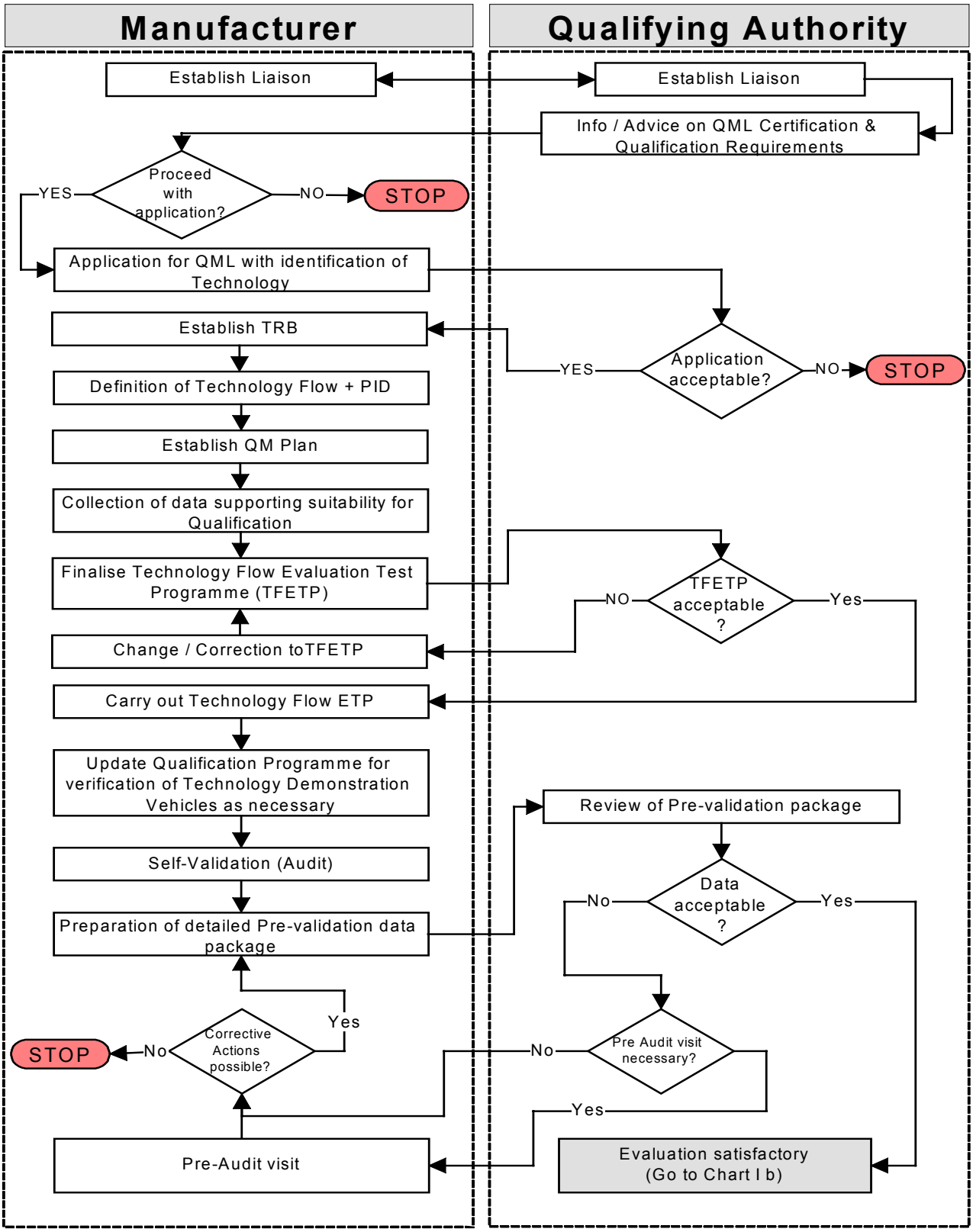
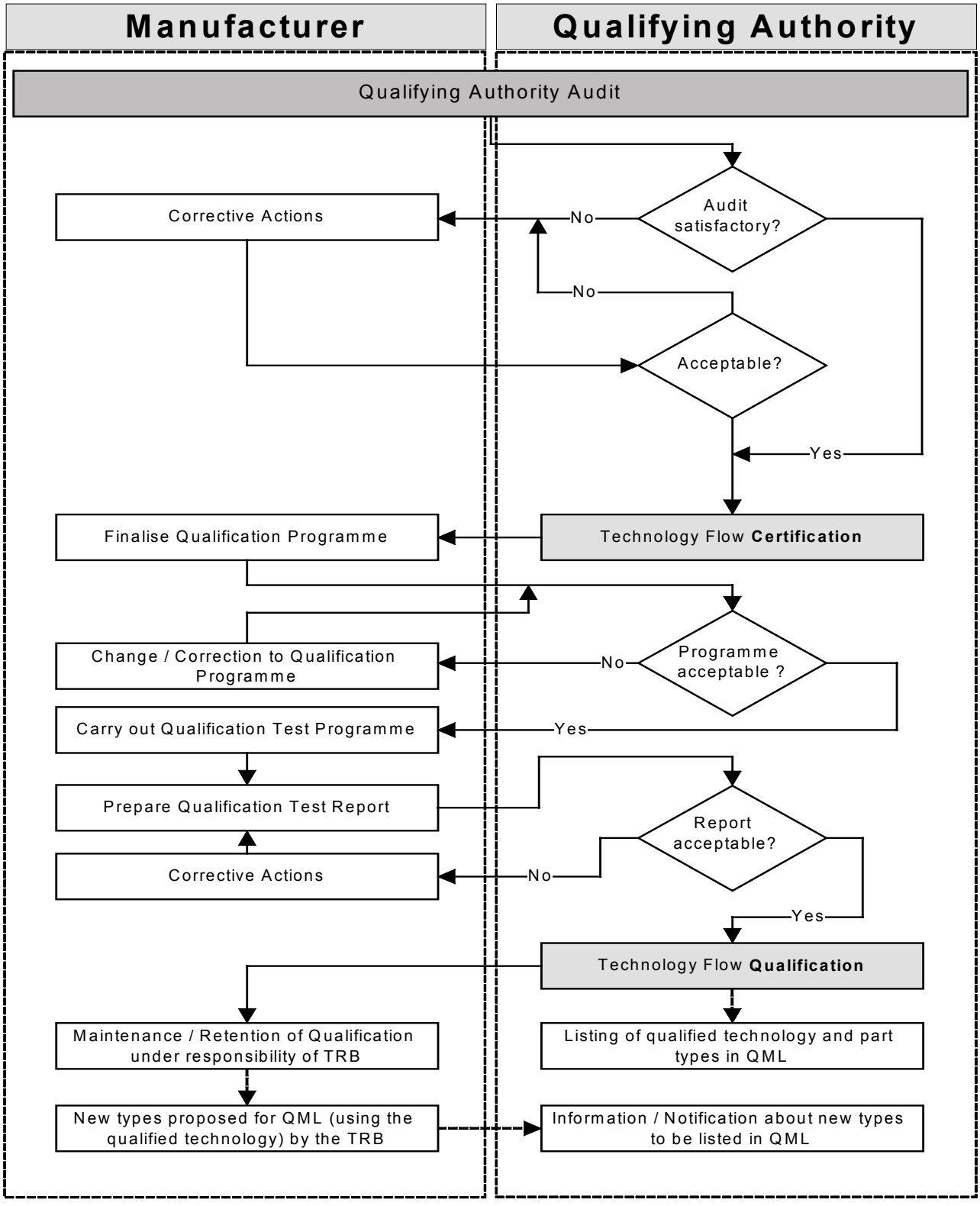


CHART I(B) – TECHNOLOGY FLOW CERTIFICATION AND QUALIFICATION FLOW (CERTIFICATION AND QUALIFICATION PHASES)



Abbreviations, Acronyms & Definitions

DoD	Department of Defence (USA)
EEE	Electrical, Electronic & Electromechanical
ESA	European Space Agency
IC	Integrated Circuit (= microcircuit)
MMIC	Monolithic Microwave Integrated Circuit
PID	Process Identification Document
PM	Process Monitor
Q.A.	Qualifying Authority
QM	Quality Management
QML	Qualified Manufacturer Listing
QPL	Qualified Parts List
SCC(G)	Space Components Co-ordination (Group)
SEC	Standard Evaluation Circuit
SPC	Statistical Process Control
TCV	Technology Characterisation Vehicle
TQM	Total Quality Management
TRB	Technology Review Board

Reference Documents

- ESA/SCC Basic Specification No. 25400, Issue 1, QML Draft (March 2000) : "Requirements for the Technology Flow Qualification of Electronic Components for Space Application"
- "Feasibility Study for the Introduction of QML Concepts into the ESA/SCC System" Phase 1 Final Report under DLR contract FKZ 50 PS 9601
- "QML Study Phase II: Development of the ESA/SCC QML Concept to Maximise Compatibility with the MIL QML System" Phase 2 Final Report under DLR contract FKZ 50 PS 9801
- "Qualified Manufacturer Listing (QML) – Phase 3: Adaptation of the ESA/SCC Specifications" Phase 3 Final Report under DLR contract FKZ 50 PS 9902 1

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