ESCC Qualification of Space components – Schemes and New Opportunities

F. Martinez

ESA, 2200 AG Noordwijk, The Netherlands

fernando.martinez.martin@esa.int

Abstract

The European Space Components Coordination (ESCC) system offers opportunities for the recognition of established performance, product maturity and independent Space qualification of advanced microelectronics products aimed at high reliability in their operation as part of critical equipment on-board long-life Space systems. This has been achieved for decades with older microcircuit products and, after some recent developments, is enabled now as well for the latest devices.

I. ESCC AS AN EXAMPLE OF SUPPLIER-USER COOPERATION

ESCC is established with the objective of harmonising the efforts concerning the various aspects of EEE space components by ESA, European national public space organisations, the component manufacturers and the user industries. The goal is to improve the availability of strategic EEE space components with the required performance and at affordable costs for institutional and commercial space programmes. ESCC aims at achieving this goal by harmonising the resources and development efforts for space components in the ESA Member States and by providing a single and unified system for the standardisation, product specification, evaluation, qualification and procurement of European EEE space components and for the certification of components and component manufacturers. ESCC is end-product oriented, so it must be noted that the ESCC system does not provide a standard methodology for technology development activities which start at very low Technology Readiness Levels (TRL 3 or below). Similarly, the ESCC system does not address systematically the actual design flow of EEE components, nor does it prescribe the specifics of their actual implementation (assembly processes, bias circuits) in the context of a particular mission or application. However, some of these application-related topics (like mission-specific Radiation Hardness Assurance, or soldering of components on a PCB, of Surface Mount assembly techniques and associated requirements) are addressed in Working Groups which function under the "umbrella" of coordination and cooperation provided by the ESCC system. This ensures, for instance, that components are only qualified in package types which are compatible with existing and approved board level assembly processes All public outputs of ESCC are posted online at https://escies.org

As mentioned, the ESCC system is based on the technical collaboration among its partners (manufacturers, users, space agencies). This cooperation is effective in addressing technology harmonization and the development of standards. Such standards support the evaluation, procurement and qualification of components and technologies. The actual implementation of these standards in the context of qualification activities is primarily the responsibility of manufacturers, with the help and support of National Space Agencies (NSAs) and ESA as certifying authority.

The various activities which happen in the scope ESCC can therefore be grouped in two main categories: Harmonisation tasks and Executive tasks. When ESCC delivers technology road-maps, annual qualification plans, technical reports or assessments, draft specifications, test methods, proposals or endorsement of technical development activities, we talk about Harmonisation work. When ESCC results in published specifications, certifications of qualification, actions related to Quality Assurance, we talk about Executive work. Of course most activities are interrelated with each other and there are obvious overlaps.

The main actor in Europe in space components Harmonisation is the ESCC Component Technology Board (CTB). The CTB coordinates the work of technology-specific Working Groups (WG). One of them, the CTB Silicon WG has mixed-signal and advanced CMOS components in their scope of activities. The CTB Silicon WG advices ESA and other European national space agencies on activities (and priorities) which should be supported and funded for such components, in terms of technology development, technology characterisation, space evaluation and ESCC Qualification. The ESCC Harmonisation Task includes maintaining strategic plans areas. These are considered proprietary to the ESCC membership. The development activities are harmonised by the ESCC members within the CTB to maximise the use of funds and to prevent duplication of effort. As regards participating in the ESCC Harmonisation Task, this implies joining one or more of the standing and ad-hoc working groups. A willing European organisation (or company) may well be accepted to contribute and would be expected to appoint members of staff to represent the organisation in one or more of the working groups. A contribution of this nature will in general be welcomed but will have to be agreed with the ESCC preeminent body, the Space Components Steering Board (SCSB). This is in part to maintain the appropriate balance, as required by the ESCC Charter, between the different interest groups.

The ESCC Executive task is carried out by various National Space Agencies and ESA. The publicly visible outputs of this shared task are the ESCC specifications, the ESCC Qualified

Parts List (QPL), the ESCC Qualified Manufacturers List (QML) and the European Preferred Parts List (EPPL). The ESCC Executive is also responsible for ensuring the implementation (by manufacturers) of ESCC requirements on Quality Assurance.

A better understanding of the ESCC system can be achieved by checking the information published at the mentioned website (https://escies.org), through the reading of ESCC 20000, by sending specific questions or requests to secretariat@escies.org or by attending an ESCC training session, such as those organised periodically by ESA at its ESTEC establishment periodically, which are free of charge.

II. ESCC SPECIFICATIONS – THE SKELETON OF THE SYSTEM

ESA can only provide certification of ESCC Qualification when the pertinent requirements have been verified. Such requirements are defined in a number of specifications. The ESCC system is supported by some 600+ published specifications.

For example, in the case of integrated circuits, the ESCC requirements can be found in various specifications, which can be grouped as follows:

A. Basic specifications

Table 1: Basic Specifications (methodology)

Subject	ESCC Number
Component Qualification	20100
Component Evaluation	22600 + 2269000
Capability Approval Qualification	24300 + 2439000
Technology Flow Qualification	25400 + 2549000

Table 2: Basic Specifications (test methods)

Subject	ESCC Number
Internal Visual inspection	20400 + 2049000
External Visual inspection	20500 + 2059000
SEM inspection	21400
Total Dose Steady-state irradiation	22900
EDS Sensitivity Test Method	23800
Resistance to solvants	24800

Table 3: Basic Specifications (system and Quality Assurance)

Subject	ESCC Number
Preservation, packaging, dispatch	20600
Terms, definitions, symbols, units	21300
Marking	21700
Leads materials and finishes	23500
Quality System requirements	24600
Non-conformance management	22800

B. Generic specification

ESCC 9000, Monolithic and Multichip Microcircuits, wire-bonded, hermetically sealed AND flip-chip monolithic microcircuits, solder ball bonded, hermetically and non-hermetically sealed.

C. Detail specification

This will be a device-specific procurement specification, issued by ESA upon a review of a manufacturer-provided initial draft. In principle, such review will include the ESCC Executive only.

Probably, the best starting point to become familiar with the ESCC qualification concept is the generic specification ESCC 9000. This specification will set the basic rules for Flight microcircuits screening, periodic testing and qualification (initial qualification and maintenance) and is most relevant for manufacturers and users. Incidentally, it may be noted that some space system projects may be ready to accept the use of unqualified components on the basis of their capability to conform to ESCC 9000 requirements for production control and screening.

The ESCC qualification concept is based on a two-step approach consisting of an evaluation and a qualification test phase. Evaluation test requirements are defined in ESCC 2269000 and the evaluation of the manufacturer itself, which is carried out in the form of an audit by the ESCC Executive (ESA and/or national agencies) is defined in ESCC 2029000.

Finally, customers will need to refer to a procurement specification in their Purchase Orders for Devices. The ESCC Detail specification serves that purpose. The ESCC Executive readily supports manufacturers and users in the preparation and publication of ESCC Detail specifications. The process can be started by a manufacturer at any time, using the spacecomponents.org website. The ESCC Detail specification, as a supplement to ESCC 9000, will define the product in its basic constituents and absolute limits (package drawing, pin-out, power dissipation, Operating temperatures…) as well as the acceptance limits for electrical testing of the microcircuits and the bias conditions for endurance and radiation evaluation testing. It must be highlighted that the ESCC Detail specification does not replace the product data sheet and associated application notes in what refers to typical performances, application-specific instructions or recommended bias circuits or load conditions.

The rest of the specifications mentioned earlier in this paragraph contain more detailed requirements and ESCC Quality Assurance system provisions which the manufacturer needs to understand and implement in his own processes. The adoption of such requirements is rarely problematic and can normally and gradually be achieved, with the support of the ESCC Executive, in the early phases of Evaluation. It may be noted in this respect that the use of alternative test methods or manufacturer's own procedures may well be agreed at that stage or early evaluation. In such cases, for ESCC Qualified components, the agreed deviations are described publicly in a manufacturer-specific agreed deviations annex to the ESCC Detail specification. When a component is not qualified, even if available in accordance with an ESCC Detail specification, no agencies' monitoring nor supervision of compliance to

ESCC requirements can be assumed and customers may need to decide on their own on the best strategy for verification of such requirements (if the manufacturer's self-certification is not enough) in the context of their own supplier's evaluation or rating.

III. ESCC QUALIFICATION SCHEMES

The ESCC system supports the procurement and qualification of EEE Components suitable for use in most space systems. However, additional evaluation or tests during procurement may be required for use in projects with exceptional application conditions (e.g. extended temperature range or Radiation Hardness Assurance).

Various schemes of qualification co-exist in the ESCC system, and all have been used over the years to achieve qualification of microelectronics products and manufacturer's technology flows and capability domains. The ESCC Secretariat has recently published a very detailed brochure which provides details and insight into the various schemes of ESCC Qualification. This brochure is available for download at the ESCIES website.

In addition, it may be noted that several standardization initiatives have been developing and running, since some years ago, to build an alternative certification scheme in order to address non-integrated supply chains. This was reported already at AMICSA in 2012. The new scheme is called Process Capability Approval (PCA) and is described in ESCC 25600 specification. The first implementation of this scheme has been achieved with hermetic hybrid products. Further developments in this context may address assembly and test houses and, possibly, other services related to the production of space components.

All three schemes of Qualification share a basic underlying structure which includes an evaluation stage (product and manufacturer) and a qualification testing stage, all accompanied by the production of a certain amount of documentation aimed at establishing a verified baseline of product configuration and performance which would then be exercised in procurement during the validity of the qualification. Even when overlapping these two stages is not necessarily forbidden in the system, it rarely happened as it was usually understood that proceeding to Qualification testing without the product knowledge and other assurances obtained in the Evaluation stage might actually lead to a failed exercise, or the Qualification results might still be impaired at the last minute by unexpected evaluation outputs requiring a resolution or a change to the product. A typical example of this could be a product which does not perform as expected when evaluated in a radiation facility in a Total Dose test. It may be noted however that, in an effort to expedite and simplify the access to Qualification, the ESCC system has decided to start in 2016 an exercise aimed at merging, in a single test stage, the previously established two stages. This optional "fast track" to full Qualification is to be developed for microcircuits, among some other families of components. It is understood that a unified flow may reduce time and cost by eliminating any possible repetition of tests (hence less test samples would be used up in the total exercise) and creating additional opportunities for concurrent test implementations.

Another interesting area of recent development in the ESCC system is the already-started re-writing of specifications in order to enable the ESCC Qualification of integrated circuits in DIE form. This additional possibility, perhaps in combination with the expected PCA of Assembly and Test Houses, might enable the "concatenation" of certifications in fragmented microcircuits' supply chains involving various suppliers. In this respect, even when there are no explicit ESCC documents that define requirements/restrictions in the area of IP ownership and/or subcontracting, a legal entity that has no design, production (incl. test) tool of any kind could only achieve an ESCC qualification if they could verifiably demonstrate to have full control and effective authority over their supply chain just as if they were an almost self - sufficient designer/producer (materials, utilities, etc. excluded) with beginning to end (comprehensive) product competence. In practice, this would require nearly perfect management and technical competence, and a lot of "interfaces verifications" by the ESCC Executive. As the primary added value of a qualification is a manufacturer's credible commitment to the customer that he is effectively capable of resolving product issues (within the specification) of almost any kind and implement the necessary corrective actions within a reasonably limited time, the more fragmented a supply chain is, the more difficult this demonstration will become. So far, only moderately-fragmented microcircuit manufacturers have really achieved ESCC qualification. Typical examples include fabless manufacturers or manufacturers with an established partnership with external assembly house for packaging operations.

Finally, it should be noted that significant efforts have transformed already the ESCC 9000 specification during the last two years. These reforms have reshaped the specification so that its present (issue 8 of February 2016) scope for procurement and qualification includes MONOLITHIC AND MULTICHIP MICROCIRCUITS, WIRE-BONDED, HERMETICALLY SEALED AND FLIP-CHIP MONOLITHIC MICROCIRCUITS, SOLDER BALL BONDED, HERMETICALLY AND NON-HERMETICALLY SEALED. So the specification is not any more addressing simpler constructions with a single monolithic chip wire-bonded in a hermetic enclosure as it now also includes useful requirements for the screening and qualification of much more advanced and complex devices.

IV. BENEFITS OF QUALIFICATION

What would a manufacturer obtain in return for his efforts in pursuing ESCC Qualification? ESCC qualified components come with added value as potential users will see advantages such as simplified procurement effort, robust components - ESCC qualified components hold an impressive record of faultless operation in thousands of space systems and, if any faults do appear, national space agencies and ESA commit their resources to address and fix the problems together with the manufacturer and any affected customers, high product

maturity and low rate of obsolescence, a simplified parts approval process – for projects complying with ECSS-Q-ST-60C ESCC qualified products are, in the majority of cases, pre-approved, solid performance - very high repeatability between manufacturing lots and across manufacturers (multiple sources may be qualified to a common standard), proven supply chains - periodic testing and audit are inherent to the system. In addition, qualified manufacturers operate an open-books policy with the qualifying agencies and ESA, so their cooperation in any problems' resolution is guaranteed. In terms of Quality Assurance, ESCC qualification implies third-party independent monitoring of the manufacturer's operations, performed by impartial space agencies and ESA and the ESCC Executive approves the full industrial configuration of qualified components. In summary, a valid ESA certificate is perceived by most space system customers as a strong endorsement of performance and quality, which in fact supports the customers' high level of trust and offers them a reduced cost of ownership - as quality problems are very infrequent with ESCC components. ESCC qualified components are acceptable for use in all ESA satellite missions and meet as well the requirements of most commercial and scientific space missions.

V. SUMMARY AND ADDITIONAL CONSIDERATIONS

The ESCC system continues to adapt itself to a changing industrial landscape and to enable the qualification of advanced technologies and components. The activities performed under the ESCC represent a successful example of systematic partnership and cooperation among European private and public entities with interests in the field of EEE components for Space applications.

Even for cases where Qualification is not suitable or possible, the ESCC system provides the relevant specifications which may enable procurement, inspections and various other Quality Assurance actions aimed at producing and testing Space grade components. To provide recognition of intermediate achievements on the way to full space qualification the European Preferred Parts List (EPPL) offers the possibility to list components which have successfully completed an ESCC evaluation programme.

REFERENCES AND ACKNOWLEDGEMENTS

General information and the procedures and documentation that describe the ESCC system are publicly available for download at the ESCC website, https:spacecomponents.org

All specifications mentioned in this paper are publicly available for download at the European Space Components Information Exchange System website, https://escies.org

The author thanks A. Pesce and R. de Marino, at ESA ESTEC, for their review, suggestions and inputs resulting in this communication.