SMT QUALIFICATION: STANDARDS, APPROVALS AND SURVEILLANCE

Fernando Pérez Gracia [(1)], Brigitte Braux [(2)]

[(1)] *CRISA - Airbus Defence and Space, PTM C/Torres Quevedo 9, 28760 (Spain),*
Email: FernandoP.Gracia@astrium.eads.net
[(2)] *Airbus Defence and Space Elancourt, B. Jean Moulin 1, 78990 (France),*
Email: brigitte.braux@astrium.eads.net

ABSTRACT

Surface Mount Technology (**SMT**) **Qualification** is a bridge to cross for Electronic Equipment Suppliers in today's European space market.

It is essential for manufacturing reliable assemblies to demonstrate compatibility between materials and processes, to have skilled operators, a continuous training, maintenance of facilities and to define and apply tracking records for traceability.

Standards show the way for suppliers to demonstrate their performance and customer's **survey** and **approval** ensures the adequacy for mission requirements.

Airbus Defence and Space has created the role of Equipment Assembly Qualification Authority (EAQA) to face the challenge of controlling supplier's **qualification status**, in a living scenario as the one we face every day.

1. INTRODUCTION

The suppliers of electronic equipment afford EEE parts higher density assemblies as well as higher pressure to deliver equipment's into tighter schedules.

Prime Contractors afford a high volume of suppliers, and eventually they delegate assembly in different levels of subcontractors, with heterogeneous "living" qualification status.

ESA/ESTEC acted as a "big brother" during past century, creating the standard, and updating it in this century [1], and surveying qualification process for all the companies related to ESA projects.

Evolution of market, manufacturing facilities, PCB HDI, EEE supplies w/wo Pb finishes, provide so many parameters that keeping stability in manufacturing processes becomes a chimera.

SMT Qualification becomes a continuous challenge for the companies supplying electronic equipment's.

Ensure mature Qualification Status in the supply chain is a must for Satellite Prime Contractors, mainly when facing commercial and export markets, thus it is time to be autonomous in the surveillance of such status, to the application of the standards and tailor them for specific mission needs.

Airbus Defence and Space has created its own standard [8] to fix the frame of SMT Qualification Assembly with Electronic Equipment suppliers. This standard is based in [1] while some changes are introduced in order to reinforce robustness and stability.

In this context EAQA is the Approval Authority at Airbus Defence and Space customer side.

2. STANDARDS

Applicable standard for European suppliers is driven by Eurospace, the Space industry standardisation body, by means of dedicated ECSS Working Groups, supported by ESA/ESTEC and industry.

ECSS-Q-ST-70-38 [1] provides a set of rules and criteria to ease starting with SMT technologies verification:

- Minimum number of samples for Test Vehicles
- Definition of combined testing
  - Vibration Levels and Duration
  - Thermal cycling Profile and Number
- Success criterion for microsection.

Non-European suppliers, mainly US companies, are following IPC standards, rules and guidelines IPC-9701A and IPC-D-279 [2 & 3], among others, defining:

- Testing Conditions (TC)
- Number of Thermal Cycles (NTC)
- Success criteria are oriented to electrical monitoring and statistical analysis.
- But we miss:
  - Vibration conditions
  - Approval Authority

2.1. Which Qualification?

Perspective abroad is quite open, "*qualification is a process that assures **item** meet minimum mission requirements"* [4], recalling that "*It is NOT OK to just*

say Space Qualified or NASA Qualified"

We can find the concept of Packaging Qualification and Validation (PQV) [5], as a set of environmental tests to pass, defined for a Project Mission requirements, and also specific rules for CCGA validation from GSFC [6].

3. UNDERSTANDING REQUIREMENTS

Newcomers have a first task to digest and accept what qualification means and to plan the related activities in the frame of the project schedule.

Project natural optimism yields to underestimate the effort and resources to allocate, or what it can be worst, to neglect the criticity of this demonstration.

Only after a written credible Qualification Plan, also called "*Verification Programme*" in [1], we can see the right path to reach Qualification Status.

Shall we say that this becomes a task of non-negligible impact in cost (thinking in SME's)?

4. APPROVALS

The Approval Authority is the "*entity that reviews and accepts the verification programme, evaluating the test results and grants the final approval*" established by [1], and its responsibility is to *"approve the PID"*, fixing the Qualification Status of a supplier.

The missions of Authority are the Approval of:

- Verification programme established by the supplier.
- Temperature and time profiles for assembly identified by the supplier.
- Microsections.
- Audit report.
- Process Identification Document (PID)
- When a change appears in the materials used, component types or processing parameters, the supplier shall submit a delta-verification programme, which normally will yield to a PID update after the programme completion.

Approval Authority role has been played up to now by ESA/ESTEC, mainly because of working for ESA projects.

From now on, Airbus Defence and Space, when being Prime Contractor, as the Customer, EAQA will play the role of the Approval Authority.

5. GENERIC QUALIFICATION

We call generic qualification the one reached after fulfilling the combined testing given by ECSS [1] and when the microsections analysis shows all solder joints being compliant with the success criterion.

PID is a summary document giving a picture of supplier facilities, manufacturing flow, materials and processes used in assemblies and a summary table of packages verified.

PID is also linked to underlying proprietary information supporting the application for every project, such as footprint library and associated mounting techniques.

All these knowledge is the matter of the qualification, including constraints for PCB layout, fixation point's pattern, location of bulky and/or dissipative parts.

When Test Vehicles representative of the items above pass the combined testing of Technology Verification, as defined by [1] we call it familiarly Qualified.

Once know-how is consolidated in a company, after succeeding the generic qualification, validating materials selection and the process adequacy to the assembly techniques, the maintenance of this status is key, either verified periodically or completed incrementally.

The more generic is the qualification the wider is the scope for application.

6. SURVEILLANCE

EAQA has a target to build a relationship based in mutual trust with Electronic Equipment Suppliers oriented to Supplier instead of being oriented to Project.

This way will help to avoid dispersion in criteria applied between different projects, as well as avoiding repetitive complete reviews becoming incremental notices or updates.

Technology Readiness Level (TRL) reached is an asset of the suppliers, and in this sense periodical audits and an open communication will improve the control on the correct application, always remaining confidential between the approval authority and the supplier.

EAQA has also to play to respond to new trends, impacts and criticality, with a closer view on details.

7. ACCELERATION FACTORS

Acceleration factors, defined in Eq. (1), are used to compare effects of qualification testing (*L from Laboratory*) with respect to mission requirements (*F from Field*) in terms of number of cycles ($N_{L/F}$).

The use of AF is a very useful tool for several cases:

- Dimensioning mission allowances by Satellite Architect
  - If it is the case to define a specific PQV, because exceeding the threshold of generic qualification envelope.
- Defining a testing campaign tailored for a specific project needs
  - Mission constraints can be so comfortable that generic qualification may impose an excessive burden for the project, being the project sensible to relieve it.

Two criteria are available in the literature, which are well correlated to testing results, Norris-Landsberg given by [7] Eq. (2) $AF_{N\text{-}L}$ and Engelmaier (modified Coffin-Manson) derived from [3] Eq. (3) AF_E.

These criteria are rule of thumbs to apply in generic terms, as while they are independent from package geometry they reflect non-linearity effects of thermal cycling in solder joint fatigue, such as cycle duration (*f {frequency} or* t_D *{dwell time}),* temperature excursion (ΔT) and absolute temperature mean (T_{SJ}) and maximum ($T_{L/F}$).

$$AF = \frac{N_F}{N_L} \tag{1}$$

$$AF_{N-L} = \left(\frac{\Delta T_L}{\Delta T_F}\right)^{1,9} \cdot \left(\frac{f_F}{f_L}\right)^{1/3} \cdot e^{1414\left(\frac{1}{T_F} - \frac{1}{T_L}\right)} \tag{2}$$

$$AF_E = \frac{\Delta T_L^{\,m_L}}{\Delta T_F^{\,m_F}} \tag{3}$$

The main contributor to Eq.(2) is fraction of temperature differences.

Values for $m_{L/F}$ in Eq. 3, lies between 2 and 3 in front of analogous exponent 1,9 for Eq.(2).

$$m_{L/F} = \frac{-1}{0{,}442 - 6{\cdot}10^{-4}\cdot T_{SJ} + 1{,}74\cdot\ln\left(1 + \frac{360}{t_D}\right)} \tag{4}$$

AF_E. by Eq. (3) can be between 3 and 20 times higher than by $AF_{N\text{-}L}$ Eq. (2), for ΔT between 50ºC and 10 ºC.

Norris-Landsberg criteria is adopted by Airbus Defence and Space [9] as Mission Compatibility Assessment, for being conservative.

8. ECSS vs IPC

As a matter of informative comparison in Figs. 1, 2 and 3 they are shown different test definitions for thermal cycling and their effects for ECSS [1] and IPC [2] using Norris-Landsberg Eq. (2).

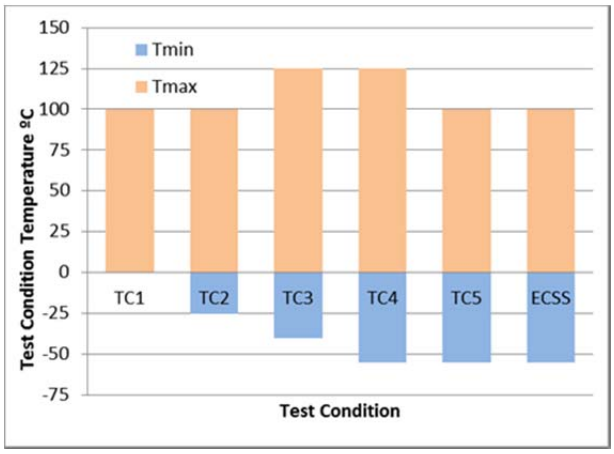

Figure 1. Test Conditions (TC)
IPC & ECSS

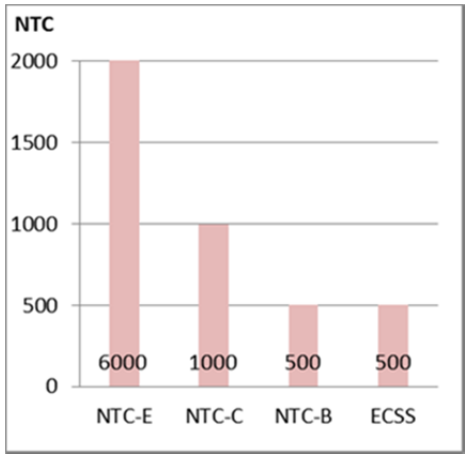

Figure 2. Number of Thermal Cycles (NTC)
IPC & ECSS

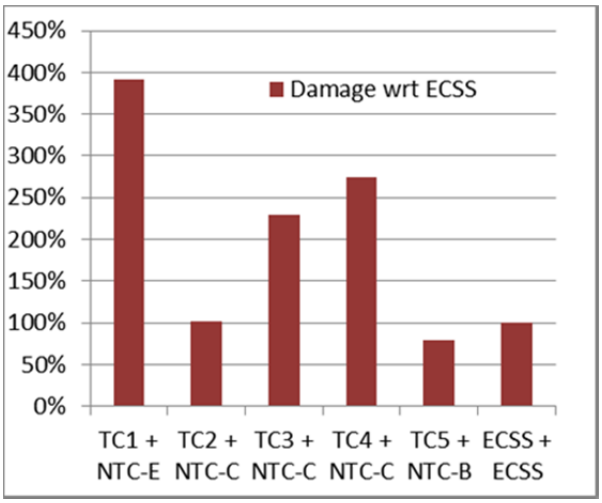

Figure 3. Damage Comparison: IPC wrt ECSS

The comparison between scenarios given by IPC and ECSS shows a coherent level of cumulated damage for two cases with very similar conditions (TC2-NTC-C) and (TC5-NTC-B), nevertheless ECSS it is clearly much less demanding than three other cases shown.

Following this observation it is extremely important to check, for suppliers abroad, which qualification level do they apply, by combining TC's and NTC's, to ensure at least to have a background similar enough to ECSS one.

9. PROJECT TAILOR

When competition is key for surviving in the market it is important to be proportional in the resources allocation to the project needs.

Specific conditions for technology qualification shall be negotiated and approved by the Approval Authority in a close communication between the Electronic Equipment supplier and the customer.

Two items, to get from different sources, need to be integrated for the finest evaluation:

- Mission Needs
- Equipment Operation Profiles

Not necessarily the two sources of temperature differences will be direct sum, a time history superposition will help to reduce excessive conservatism, and in the limit a coupled thermal simulation will account for filtering effects dues to heat capacity distributions along the Electronic Equipment housing and boards.

Once this is known the compatibility assessment of mission to technology validation testing can be done.

9.1. Mission Needs

It is quite difficult to get the right information to have a realistic environment, in which equipment will spend the complete lifetime.

It goes, as a minimum for the following steps:

- Ground Testing
  - Acceptance Conditions
    - Vibration
    - Thermal Cycling
- Launch and Commissioning
  - Temperature Excursions and Duration
- Orbit
  - Seasonal Events (Long Period)
  - Daily Operation (Short Period)

9.2. Equipment Operation

Electronic Equipment Operation shall be simulated by Thermal Analysis in order to identify hot spots and more sensitive packages locations, as to allow determining accurately the temperature excursions associated to orbit and operating conditions.

10. CONCLUSIONS

In Airbus Defence and Space we have introduced the role of EAQA to focus on Qualification issues, with all ingredients mentioned in this article, standards, suppliers facilities, and mission needs, to optimize the interactions between Customer and Suppliers with a minimum friction and avoiding overwhelming the slimmer budgets.

It is given an overview of what SMT technology qualification means, what are the standards and the way to apply them for reaching a sufficient TRL to deliver reliable Space Hardware.

EAQA Role is a closer actor to the Equipment Suppliers, from Airbus Defence and Space perspective, minimizing the gap for ESA projects, and taking over for Non-ESA projects.

11. REFERENCES

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12. ABOUT AUTHORS

Fernando Pérez Gracia is EAQA in Airbus Defence and Space, Expert in Electronic Equipment Packaging.

Brigitte Braux is Senior Expert in Electronics.