ECSS-Q-70-07A
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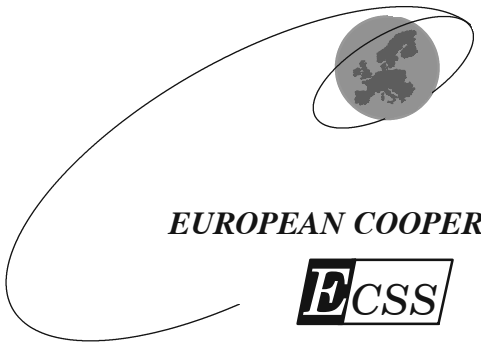

Space Product Assurance

Verification and approval of automatic machine wave soldering

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Foreword

This standard is one of the series of ECSS Standards intended to be applied together for the management, engineering and product assurance in space projects and applications. ECSS is a co-operative effort of the European Space Agency, National Space Agencies and European industry associations for the purpose of developing and maintaining common standards.

Requirements in this standard are defined in terms of what must be accomplished, rather than in terms of how to organise and perform the necessary work. This allows existing organisational structures and methods to be applied where they are effective, and for the structures and methods to evolve as necessary without rewriting the standards.

The formulation of this standard takes into account the existing ISO 9000 family of documents.

This standard has been prepared by editing ESA PSS-01-707, reviewed by the ECSS Technical Panel and approved by the ECSS Steering Board.

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Contents List

Introduction

Wave soldering is regarded as a critical process that will find limited application during the assembly of components on to printed-circuit boards (PCBs) intended for spacecraft. The preferred procedure is by manual soldering to the requirements of ECSS-Q-70-08. Generally the small number of identically designed circuits does not warrant the setting up of unique machine parameters for each individual layout.

When wave soldering is identified as a suitable alternative to manual soldering for use in the customer's projects, it will be essential to follow the steps outlined in this document before the final customer's approval is granted. The sequence of main events is shown in Figure 1. Each step shall be fully completed and the details recorded, so that a dossier is compiled for each manufacturer's assembly line. All dossiers will be kept updated by the final customer and serve as a reference for the final customer's Project Engineers.

NOTE A general qualification will not be granted for wave soldering. Wave soldering lines that have been previously verified (see also clause 5) may be also approved for use on named projects, but this shall depend entirely on the specific project requirements. Project process approval has to be requested, as for all materials and critical processes, by means of ECSS-Q-70.

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1

Scope

This specification defines the basic requirements for the verification and approval of automatic machine wave soldering for use in spacecraft hardware. The process requirements for wave soldering of double-sided and multilayer boards are also defined.

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2

Normative references

This ECSS Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these apply to this ECSS Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

ECSS-P-001	Glossary of terms
ECSS-Q-20	Space product assurance - Quality assurance
ECSS-Q-70	Space product assurance - Materials, mechanical parts and processes
ECSS-Q-70-08	Space product assurance - The manual soldering of high-reliability electrical connections (to be published)
ECSS-Q-70-10	Space product assurance - The qualification and procurement of two sided printed circuit boards (Gold plated or tin-lead finish) (to be published)
ECSS-Q-70-28	Space product assurance - The repair and modification of printed-circuit boards and solder joints for space use (to be published)

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3

Definitions and abbreviations

3.1 Definitions

The definitions given in ECSS-P-001 and ECSS-Q-70 are applicable. In addition, the definitions given below are specific to this document.

Ionisable contaminant

Process residues such as flux activators, fingerprints, etching and plating salts etc., that exist as ions and when dissolved, increase electrical conductivity.

Machine oil

Liquid compounds formulated for use as oil in wave-soldering equipment. They serve primarily to provide a barrier between the atmosphere and molten solder, thereby reducing the oxidation (drossing) of the solder. Certain oils also reduce the surface tension of molten solder, thereby enhancing the wetting characteristics of the solder.

Measling

A condition existing in the base laminate of a printed-circuit board in the form of discrete white spots or "crosses" below the surface of the base laminate, reflecting a separation of fibres in the glass cloth at the weave intersection.

Wave soldering

A process wherein printed-circuit boards are brought in contact with a gently overflowing wave of liquid solder which is circulated by a pump in an appropriately designed solder pot reservoir. The prime functions of the molten wave are to serve as a heat source and heat-transfer medium and to supply solder to the joint area.

Wave-soldering equipment

Systems that achieve wave soldering and which consist of stations for fluxing, preheating, and soldering by means of a conveyer. Cleaning is usually offered as an option. Normally, additional cleaning will be required in order to meet ESA cleanliness standards.

3.2 Abbreviations

The following abbreviations are defined and used within this standard.

Abbreviation	Meaning
PCB	Printed Circuit Board

PID	Process Identification Document

4

General

4.1 Design

Designers of printed-circuit boards shall be familiar with design parameters that are necessary for the wave-soldering process. Circuit tracks that are spaced close together should be oriented in line with the pass direction to avoid solder bridging. Large heat sink areas should be avoided; these will include ground planes and large leads closely connected to massive metal parts.

4.2 Rework

Space-quality requirements of solder joints (ECSS-Q-70-08) shall be met without more than 5 % rework on each wave soldered circuit.

NOTE Deficient wave-soldered connections are caused most frequently by the movement of component leads during solidification, the presence of solder alloy within stress relief bends and the entrapment of machine oils and solder fluxes within the solder fillet. Rework of any nature is costly. It involves not only the risk of irreparable lifted pads and measling, but also the possibility of heat damage to sensitive components.

A solder-joint-discrepancy log, such as that given in annex B, shall be maintained as an aid to process control, optimisation of parameters and repeatability.

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5

Request for verification of process

5.1 General

Verification tests shall be conducted to establish confidence in the reliability of all automatic machine soldering production lines.

Each application for verification shall contain a brief description of the facility, details of past experience and the name of the spacecraft project concerned; the application shall be signed by the person responsible for space-component-assembly processes and addressed to the relevant final customer's Materials and Processes engineer responsible for that project.

5.2 Documentation

The following documents shall also be forwarded with the application for evaluation:

a. company organigram related to wave-soldering production and control personnel (including names and functions of all key personnel involved);

b. list of materials such as solder, flux, solvents, PCBs and equipment (including types and names of supplier) used for wave soldering;

c. production flow chart, showing quality assurance inspection points;

d. list of process specifications, including reference numbers of relevant in-house documents. The general process requirements shall include those listed in annex A;

e. detailed report concerning optimisation of wave-soldering process parameters (i.e. preheat temperature, temperature of solder, conveyer speed, temperature – time profile, control of dross, cleaning procedure);

f. outline of company test capabilities (e.g. thermal cycling chambers, metallography, chemical analysis, failure analysis).

5.3 Samples

The application shall be accompanied by three samples of wave-solder assembled boards whose complexity is typical of that found in spacecraft and which meet space-quality workmanship standards. They shall have been cleaned, but not conformally coated. These items are hereinafter referred to as technology samples.

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6

Technology samples

6.1 Configuration

The technology samples shall consist of PCBs procured from a space-approved manufacturing line, which shall be assembled with components to a documented procedure as detailed in annex A. A listing of these procedures shall form part of the line's Process Identification Document (PID). Except for the actual machine soldering procedure, the full component assembly requirements of ECSS-Q-70-08 shall apply. The assembled board shall be free of flux residues and other contaminants.

6.2 Accompanying data

A description of the components, materials and processes utilised, together with the cleanliness test report, shall accompany the technology samples.

The cleanliness tests shall be made by the contractor using a method the same as, or equivalent to, requirements of ECSS-Q-70-08.

6.3 Examination

The technology samples shall be assessed by the final customer or by a recognised test house. Visual and metallographic inspections are required. After examination, the completed report shall be sent to the supplier.

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7

Line audit

Provided the technology samples are found acceptable, the final customer shall audit the wave-soldering and related facilities at a time when the equipment is in operation. The audit shall also include a further on-site review of the documentation listed in subclauses 5.2 and 6.2. Compliance with the process requirements of annex A shall be evaluated.

The final customer shall supply the manufacturer with a copy of the audit report.

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8

Verification

8.1 Planning, management and finance

After the successful completion of the line audit, the supplier shall furnish the final customer with an evaluation programme and flow chart for approval, The evaluation programme shall be performed by the supplier's quality laboratories under the supervision of a product assurance engineer, or by one or more independent test houses. Each test house shall require the final customer's approval prior to commencement of the programme. The entire evaluation programme shall be financed by the supplier and may be monitored by the final customer at various stages during testing.

8.2 Description of samples

The programme shall be designed to contain the following:

a. **Five PCBs from each production line** assembled according to the wave-soldering procedure of annex A. Each board shall have an identical layout (i.e. dimensions, number of layers, type of components).

b. The layout and component density (i.e. number of components per unit board area) shall be similar to that envisaged for spacecraft circuits.

c. The variety of component packages mounted on each board shall be restricted to those envisaged for spacecraft circuits. There shall be at least three of each type per board. Particular attention shall be given to heat-sensitive components. Only component types utilised during this programme shall be regarded as process approved.

NOTE Owing to the high cost of some components, the final customer may agree to the use of non-functional, or commercial-quality components but they shall be of the same lead material and finish (viz. solderability) as the hi-rel components required for flight.

d. Each component type shall be tabulated, together with details concerning:

- component lead material and finish;
- lead diameter-to-hole diameter ratio.

8.3 Initial tests

a. The following initial tests shall be performed on each of the five assembled PCBs:

- Visual inspection to ECSS-Q-70-08;
- Cleanliness test according to, or equivalent to, the method detailed in ECSS-Q-70-08;
- Warp (bow) and twist of circuit board (see ECSS-Q-70-10), limits are:-

Board thickness (mm)	l≤0,7	0,8-1,1	1,2-1,51	≥1,61
Warp and twist (%)	2,6	1,8	1,41	1,11

- Electrical continuity measurement for multilayer boards (not a requirement for double-sided PCBs); the circuit shall include at least 25 % of all holes with at least one internal connection per hole (see ECSS-Q-70-10).

b. One printed circuit board is to be kept for reference.

8.4 Environmental exposure

a. The four test samples shall be temperature cycled in air, 200 cycles from -55 °C (±5 °C) to +100 °C (±5 °C) at an average heating or cooling rate of 10 °C/min. The sample dwell time shall be 10 minutes ±5 minutes at each of the temperature extremes.

b. Assembled PCBs are not required to be vibration tested unless the assemblies deviate from the design requirements and workmanship standards prescribed in ECSS-Q-70-08.

8.5 Final tests

Following completion of exposure to 200 temperature cycles:

a. Each sample shall be visually inspected to ECSS-Q-70-08.

b. Multilayer boards shall be subjected to electrical continuity measurements which shall be monitored throughout a further 10 thermal cycles. Positive changes greater than 5 % shall be cause for failure.

c. At least two components, of each available type, shall be microsectioned so as to dissect their component leads. Components selected for microsectioning shall be those having, from visual inspection results, the worst solder fillet aspect. Evidence of propagating cracks in the solder joint vicinity shall be cause for failure, there shall be no defects in the board.

d. The leads of at least two components shall be cut and pull-tested at a constant strain rate; the results shall be compared with the values obtained for identical components on the reference board. Pull-testing shall be performed in a direction perpendicular (+5°) to the board surface. Fracture loads and positions shall be recorded. A 25 % reduction of mechanical strength after environmental testing shall be cause for failure.

8.6 Final report

The supplier shall prepare a final report containing a description of the samples (subclause 5.2), where possible a photograph of an assembled board, and the full results of all tests performed to subclauses 5.3 and 5.5.

9

Final customer approval

9.1 Notification

On successful completion of the verification programme and the submittal of the report to the final customer, the supplier shall receive a letter confirming that the verification programme has been approved.

9.2 Approval duration

When there are no changes to the Process Identification Document (PID) the period of validity is indefinite and takes effect from the date on which the successful verification programme ended.

9.3 Renewal of final customer approval

A new verification test programme shall be carried out whenever a change to the PID has been proposed.

9.4 Withdrawal of final customer approval

The final customer's approval of any wave-soldering line shall be withdrawn in any of the following cases:

a. the supplier experiences rework activities of more than 5 %;

b. any of the materials, permitted component types or manufacturing processes have been changed without prior authorisation (i.e. changes to the PID).

NOTE All modifications to the documents listed in subclauses 5.2 a through 5.2 c shall require final customer approval before implementation.

c. the final customer or his intermediate suppliers have experienced delays in delivery or manufacturing defects directly attributable to the wave-soldering process. Renewed approval may be granted following a review of the discrepancy(ies). A repeat, or partial repeat of the verification programme may be considered necessary.

9.5 Final customer approval

Requests for future project approval shall be made, as for all critical processes, through submission of the relevant project declared process list (DPL) (ECSS-Q-70).

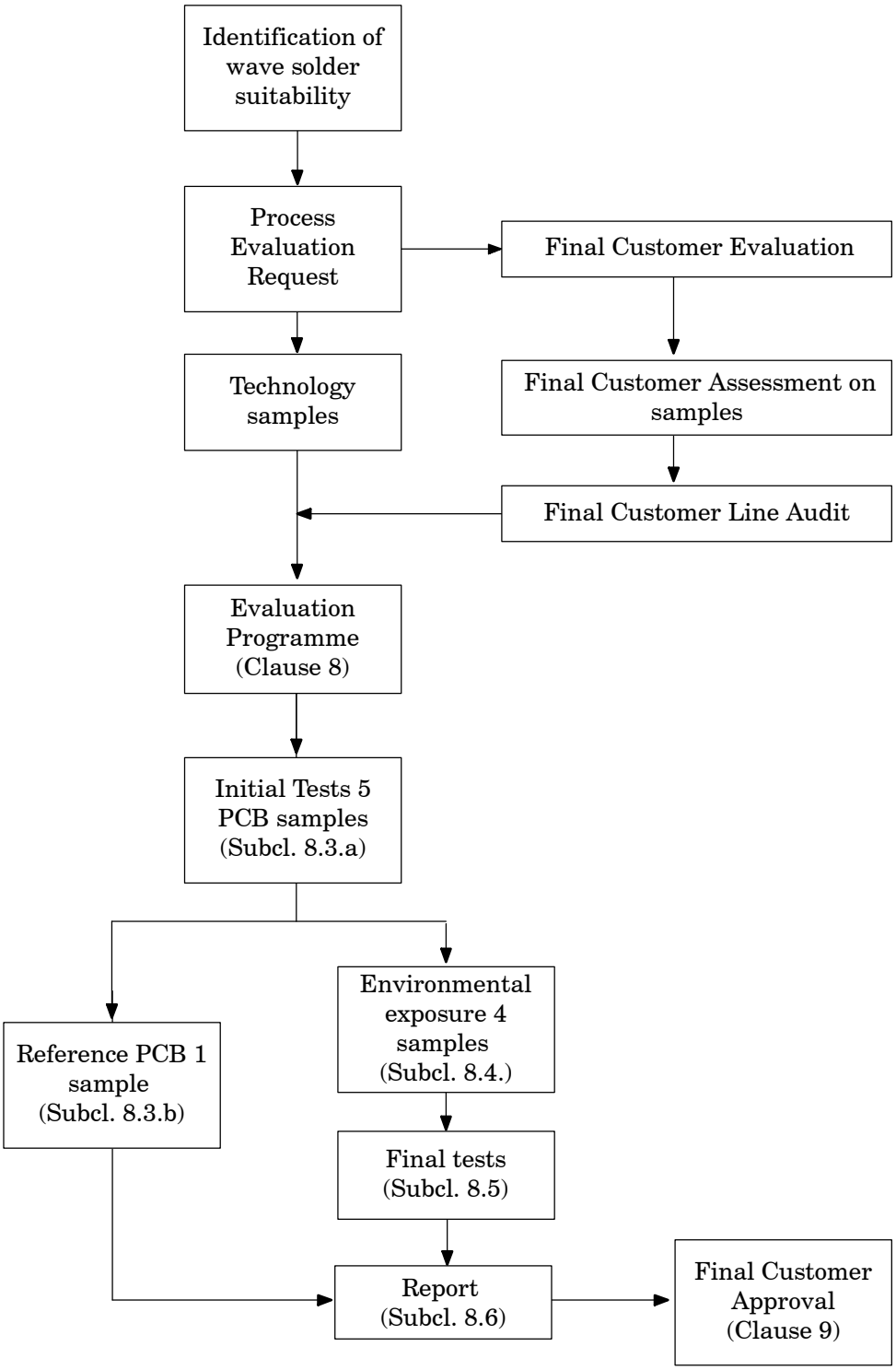

Figure 1: Sequence of main events for final customer evaluation and approval of wave soldering process

Annex A (normative)

Process requirements for wave soldering of printed-circuit boards

1. These requirements are applicable to all operations related to automatic machine soldering.
2. Except when otherwise specified and approved by the final customer, all materials and processes utilised in soldering and cleaning operations shall conform to ECSS-Q-70-08 and ECSS-Q-70-10.
3. Non-activated rosin fluxes are preferred, but mildly activated flux is permitted (See ECSS-Q-70-08 for approved flux products). All fluxes shall be adjusted frequently (e.g. specific gravity) to avoid variations from the optimum. When mildly activated fluxes are used, they should be changed frequently to ensure a constant and adequate level of activation.

   NOTE All fluxes, machine oils and ionisable contaminants on the assembly shall be removed within one hour of the wave-soldering operation.

4. The soldering area and machines shall be kept clean and orderly. Appropriate precautions shall be taken to avoid electrostatic-discharge problems as defined in ECSS-Q-70-08. Grounding of the conveyer is to be envisaged. Toxic or volatile vapours shall be exhausted. Lighting facilities and component lead preparations shall be as defined in ECSS-Q-70-08. Deviations shall require final customer approval before implementation.
5. Dross (oxides) shall be periodically removed from the solder bath to ensure that dross does not mix with the liquid solder. Automatic or manual methods are acceptable, provided that the dross does not come in contact with the PCB assembly during any portion of the soldering process. Dross removal materials shall not melt, dissolve or alloy with the liquid solder and flux.
6. Soldering equipment shall heat the PCB assemblies uniformly and have the capacity to maintain the temperature during repetitive solder operations with a maximum variation of +5 °C of the normal soldering temperature.

7. The supplier shall maintain operating procedures which describe the soldering process and its associated equipment. For the soldering machine, these procedures shall, as a minimum for given PCB assembly layouts, define the controlled fluxing unit, preheat temperature, solder temperature, rate of travel, cooling areas, frequency of temperature-verification measurements, frequency of solder bath analysis, masking and cleaning requirements. A listing of these processes together with their issue numbers and dates of issue shall form part of the PID.
8. The assembled board shall not become contaminated before being loaded on the carrier.
9. The preheat temperature shall be controlled to avoid damage to the PCB and the component package.
10. The conveyer speed shall not vary by more than ±5 %.
11. The solder temperature shall be controlled so that the solder in the wave making contact with the board is 235-275 °C (see 6).
12. The height of the solder wave shall be controlled to a constant pre-selected value across the width of the wave.
13. A machine-soldering logbook shall be maintained, showing the parameters required from requirements 9 - 12 in order to repeat previously successful runs. The logbook shall also be used to document results of solder-bath analyses and results of the, cleanliness test stipulated in requirement 14.
14. Cleanliness checks according to the requirements of ECSS-Q-70-08 shall be applied at established intervals, to pre-established resistivity limits. Intervals shall be based on the number and size of boards cleaned as well as time.
15. Inspection criteria detailed in ECSS-Q-70-08 are applicable to machine-soldered assemblies. Warp and twist of the board shall not exceed the limits specified by the detail drawing.
16. The rework of defective solder connections is permitted by hand soldering, provided this is not performed on more than 5 % of the solder connections. Any reworked boards shall be further cleaned and cleanliness tested and shall meet all the requirements of this Annex.
17. The leads of certain spacecraft components are designed for lap-soldering onto specially designed pads. They shall not be bent and subjected to wave soldering. Such components shall be manually assembled to the PCB in a subsequent operation and according to the requirements of ECSS-Q-70-08.

Annex B (informative)

Solder joint discrepancy log

Table B-1: Solder joint discrepancy log

Part identification
Assembly: __________ **PCB P/N:** __________

Wave soldering parameters
Preheat temp: ________ **Solder temp:** ________ **Conveyer Speed:** ________ **Wave height:** _________

Description					**Insufficient**						**Excess**					**Miscellaneous**			
MLB ❑ ❐ No. of thru holes: ______ No. of layers: ______ Ground plane estimated area: Topside: ______% Botside: ______%																			
Acceptable rework level: ___% total	Date	Inspector	Insptn. S/N	T: component side; B: bottom side	Lead poor wetting	Pad poor wetting	Large voids	Small bottomless voids	Insufficient solder flow-thru	Depressed solder	Bridging	Icicling	Accumulations	Excess solder (lead obscured)	Stress-relief bends filled	Raised component	Other solder discrepancies (specify)	Subtotals	% for rework
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ECSS Document Improvement Proposal

1. Document I.D.	2. Document Date	3. Document Title
ECSS-Q-70-07A	20 January 1998	Verification and approval of automatic machine wave soldering for spacecraft hardware

4. Recommended Improvement (identify clauses, subclauses and include modified text and/or graphic, attach pages as necessary)

5. Reason for Recommendation

6. Originator of recommendation

Name:	Organization:	
Address:	Phone: Fax: E-Mail:	**7. Date of Submission:**

8. Send to ECSS Secretariat

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Note: The originator of the submission should complete items 4, 5, 6 and 7.

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http://www.estec.esa.nl/ecss/improve/

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