CubeSat PCB Survival Checklist

The intention is to introduce beginners to the topic of creating PCBs for space use.

Created by Andreas Chr. Dyhrberg, ufelectronics.eu

Version: 2025.09.25

Table of Contents

Introduction

This document is a **practical survival guide** for designing and building printed circuit boards (PCBs) intended for **CubeSats and other small spacecraft**.

It is **not** a replacement for the full ESA/ECSS or NASA workmanship standards. Those standards are much more detailed, cover a wider range of failure modes, and require specialized training, facilities, and inspection processes.

Instead, this guide captures the **most essential PCB design and assembly practices** that make the difference between a CubeSat that fails after a few orbits and one that works reliably for its planned mission. It’s aimed at **student teams, hobbyists, and new engineers** who want a concise, accessible checklist before diving into the official documentation.

How this differs from ESA/NASA standards

- **Simplified scope:** ESA/NASA standards include hundreds of requirements across design, manufacturing, inspection, and test. This guide focuses only on the most critical PCB-level practices.
- **Practical emphasis:** Instead of exhaustive clauses, this guide explains **why** each item matters in space and **what to do in practice**.
- **Accessibility:** ESA/NASA standards assume professional aerospace contractors. This guide assumes a **small team with limited resources**, working toward a reliable CubeSat.

Where to find the official standards

If you want to go deeper or need to comply with professional programs, start here:

- **ESA / ECSS standards (Europe)**
  - *ECSS-Q-ST-70-12C Rev.1*: Design rules for printed circuit boards.
  - *ECSS-Q-ST-70-60*: Qualification and procurement of PCBs.
  - Available at: https://ecss.nl/standards
- **NASA workmanship standards (USA)**
  - *NASA-STD-8739 series* (soldering, staking, conformal coating, cabling).
  - *NASA Workmanship Standards portal*: https://workmanship.nasa.gov
  - *NEPP (NASA Electronic Parts & Packaging)*: presentations, failure reports, lessons learned: https://nepp.nasa.gov

If your CubeSat is part of a funded or launch-provided program, you'll eventually be required to follow these standards. Use this survival checklist as an **entry point** and bridge toward them.

Part 1 – Quick Summary (tick-box style)

1. Materials

- Use high-Tg FR-4 or polyimide, low-outgassing (ASTM E595 compliant).
- Use space-qualified conformal coat & staking adhesives.
- Use ENIG/ENEPIG finish, not HASL for fine pitch.

2. Layout & Design

- Redundant vias for power & ground nets.
- Teardrops on pad-to-trace junctions.
- Solid ground/power planes; no splits under ICs.
- Decoupling caps close to each VCC pin.
- Maintain 0.5–1.0 mm creepage/clearance for >12 V nets.

3. Assembly & Soldering

- IPC-A-610 Class 3 solder joints.
- Stake/underfill large or heavy parts.
- Use space-rated crystals; short, symmetric traces.
- Provide JTAG/ISP header and test points.

4. Cleanliness

- Remove flux residues.
- Bake boards before coating & flight.
- Apply conformal coat (mask connectors).

5. Thermal & Mechanical

- Design for –40 to +85 °C.
- Account for ceramic vs FR-4 expansion mismatch.
- Use copper pours under hot ICs.

6. Protection & Reliability

- Enable watchdog (HW preferred).
- Use brown-out detection above min voltage.
- Add current limiter/fuse per domain.
- Protect external I/O with series resistors + TVS.

7. Testing

- Thermal cycle: –40/+85 °C.
- Vibration per CubeSat standard.
- Functional test hot & cold.
- Bake-out before integration.

Part 2 – Expanded Explanations

1. Materials

- **Why:** Low-quality FR-4 and adhesives release gases in vacuum. These gases condense on optics and solar panels, reducing performance.
- **What to do:** Choose **high-Tg FR-4 or polyimide laminates** rated for space. Ask vendors about **ASTM E595 compliance**. Use conformal coats and adhesives that are certified “low outgassing.” Avoid HASL; choose ENIG/ENEPIG for flat, reliable solder pads.

2. Layout & Design

- **Redundant vias:** Vias can crack under vibration and thermal stress. Doubling them increases reliability.
- **Teardrops:** Rounded copper at pad junctions prevents cracks at sharp corners.
- **Planes:** Continuous ground/power planes lower EMI, spread heat, and stabilize return paths.
- **Decoupling:** Place 100 nF capacitors close to VCC pins (<3 mm). This prevents voltage dips that can crash the MCU.
- **Clearance:** In vacuum, arcing can happen at lower voltages. Keep ≥0.5–1.0 mm clearance for nets above 12 V.

3. Assembly & Soldering

- **Workmanship:** Use IPC-A-610 Class 3 as baseline. It’s the aerospace-grade solder standard.
- **Staking:** Heavy parts (like connectors) shake loose under launch vibration if not epoxied. Use low-outgassing staking compounds.
- **Crystals:** Use space-rated crystals and place them with symmetric, short traces to avoid frequency drift and stress.
- **Access:** Always provide programming headers (JTAG/ISP) and test pads for debugging.

4. Cleanliness

- **Why:** Residues can absorb moisture and become conductive, causing short circuits in vacuum.
- **What to do:** Clean boards with IPA or professional cleaning processes after soldering. Bake them dry before coating. Apply conformal coating to protect against moisture and corona discharge. Mask connectors before coating.

5. Thermal & Mechanical

- **Cycles:** A CubeSat goes through ~16 hot/cold cycles per day in LEO. Materials expand/contract constantly.
- **Mismatch:** Ceramic chips expand less than FR-4. Wrong pad design causes solder cracks. Use recommended relief pad patterns.
- **Heat spreaders:** No air in space means only conduction/radiation. Use copper pours and planes under hot chips to spread heat.

6. Protection & Reliability

- **Watchdog:** Space radiation can flip bits and freeze CPUs. A watchdog timer ensures automatic reset.
- **Brown-out:** If voltage drops below safe limits, logic misbehaves. Brown-out detection resets cleanly.
- **Current limiting:** Latch-up events can short-chip power rails. Use resettable fuses or fast current-limit ICs.
- **I/O protection:** Add resistors and TVS diodes to connector pins to absorb ESD/EMI events.

7. Testing

- **Thermal cycling:** Expose boards to repeated –40 to +85 °C cycles to find weak solder joints.
- **Vibration:** Use a shaker table (CubeSat standard profiles) to simulate launch.
- **Functional hot/cold:** Test while the board is running at hot and cold extremes. Many faults only appear there.
- **Bake-out:** Heat the board under vacuum or nitrogen to drive out trapped volatiles before flight.