Quality Assurance Plan
SatNOGS COMMS

Libre Space Foundation

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1. Introduction

1.1 Purpose and Scope

This QA plan focus mainly on the hardware components and their assembly on the PCB of the SatNOGS COMMS transceiver. Regarding the software components, throughout the entire development all the affected software packages integrate QA techniques using automated tests and coverage reports. The QA sessions of the assembled PCB, is performed by the designers of the board, using semi-automated testing procedures, ensuring the end to end functionality and interoperability based on in house test-bed platform [1].

On par, a non-conformance control system ensures that possible deviations from the initial requirements are identified early and possible mitigation strategies are explored.

1.2 Acronyms

BOM Bill of Materials

COTS Commercial off the Self

CSV Comma-separated values

DCL Declared Component List

DML Declared Material List

DMPL Declared mechanical parts list

DPL Declared process list

DUT Device Under Test

ECC Error-correcting code

EDA Electronic Design Automation

EEE electrical, electronic, electromechanical

EOL End of Life

ESD Electrostatic Discharge

IC Integrated Circuit

IPA Isopropyl Alcohol

LSF Libre Space Foundation

NC Non Conformance

NCR Non Conformance Report

NRB Non Conformance Board

PCB Printed Circuit Board

QA Quallity Assurance

RFD Request for Deviation

RFW Request for Waiver

SEU Single-event upset

TMR Triple Mode Redundancy

UV Ultra Violet

2. Quality Assurance Plan

2.1 Procurement

The selection of procurement sources for EEE is based on the ECSS-Q-ST-60C clause 5.2.2, except from clause 5.2.2.3 which refers to in radiation hardness. The SatNOGS COMMS transceiver targets the Cubesat market. In this spectrum, radiation hardened components are not necessary and in most cases are prohibitive in terms of cost for the limited budget of such missions. In addition, the procurement strategies ensure that the components selected do not reach their EOL and will be available for long time. The procurement of the PCBs is full-filled by sources conforming with the IPC-A-610E Class 2 directives.

For all the components from external suppliers, a detailed BOM document is tracking the components and the source suppliers, while at the same time it records for possible defects or deviation from nominal specification values.

2.2 Manufacturing, assembly and integration

Manufacturing of the PCBs and EEE components is performed by external suppliers that conform with the IPC-A-610 Class 3 specification. In order to ensure the product quality, hardware components storage and handling follows the ECSS-Q-ST-20C, clause 5.2.7.

The assembly and the integration takes place in the LSF facilities. The process starts with the unpacking of the externally supplied components. To minimize cross-contamination, before unpacking the components their packaging is cleared using dry air. Large components, like PCBs and heatsinks are wiped and cleaned with IPA and deionized water pre-wetted low particle wipers. Then they are stored in sealed antistatic ESD-safe bags until their final usage. Supplied EEE components are considered to be contaminant-free in their ESD-safe packaging.

Assembly of the SatNOGS COMMS board is performed in a controlled environment at a dedicated for this purpose area, taking measures to minimize contamination and ESD. Before any assembly, the soldering mask stencil, the stencil printer, the pick-and-place and similar tooling is also cleaned with dry air and wipers to remove any kind of debris. After the EEE components placement, the PCB process continues with the soldering in the reflow oven. With the reflow process completed, the assembled PCB undergoes extensive cleaning with dry air, IPA and wipers to remove any left over contaminants. Then it is placed inside an ISO 7 cleanbox available at LSF premises. From this point

and until the final delivery, the SatNOGS COMMS board does not exit the cleanbox, until the final packaging.

After the assembly the integration process follows. This process includes the conformal coating of the PCB and visual inspection using UV light to ensure proper application of the coating. The integration process finalizes with the placement of the heatsink blocks.

2.3 Testing

Testing and performance measurements are full-filled by LSF at its own facilities. The hardware equipment used for testing (spectrum analyzers, DC supplies, vector analyzers) is ensured to have a valid calibration certificate.

Each DUT, is subjected to predefined and automated test according the the test plan. The complete verification and test plan can be found in the **Verification and Test Plan** document. Each testing stage produces reports that include the observed performance values and their deviation from the nominal and expected performance. If all measurements are within the acceptance margins, a final report is produced, including the date and the personnel conducted the tests, among with other informative details, like equipment used, etc.

In case the DUT fails to conform with the tests, it is discarded. No fixing or disassembly attempts are permitted at this stage. This event is triggering an internal investigation for tracing the defected parts or deviations from the manufacturing procedure.

2.4 Acceptance and delivery

Before any delivery, a final review of the testing results is performed by the QA personnel. Each delivered item is accompanied by the report of the testing campaign, the date of manufacturing, the serial number of the board and the name of the engineer conducted and approved the tests.

Prior shipping a proper packaging ensures the minimum possible risk of damage. The SatNOGS COMMS board is enclosed in a heat sealed ESD safe bag. At this point the board can exit the cleanbox and is stored in a dedicated place of the laboratory.

Prior delivery, the board is firmly placed inside single-wall corrugated chipboard using Polyethylene Foam A-A-59136, Class 1, Grade A, Type 1. Proper labeling is applied to the packaging, with ESD sensitive and fragile markings.

2.5 Declared Components List

All the component of SatNOGS COMMS Transceiver neither designed nor manufactured with reference to military or space standards. The EEE shall be COTS which not included in parts and material restriction as defined in ECSS-Q-ST-60C [2], clause 5.2.2.2. Also all the EEE shall be recommended for new designs or could be active from component manufacturer. For all the EEE should be provided compliance with tailored standards for In-Orbit Demonstration Cubesat missions and flight heritage [3]. It mentions that radiation testing is not applicable according to tailored standards for In-Orbit Demonstration Cubesat

missions. For that reason in DCL, does not include all proposed field as is defined in the ECSS-Q-ST-60C [2] Annex B. The fields of list are:

- Footprint: Contains the footprint type, for example SMD 0603.
- Mfr Name: Contains the name of manufacturer.
- Mfr Part Number: Contains the part number of manufacturer.
- Description: Describe the type of part, for example Capacitor, 2.2uF-16V-X5R-10%
- Mfr Name-–1: The first alternative manufacturer.
- Mfr Part Number-–1: The first alternative manufacturer part number.
- Mfr Name—2: The second alternative manufacturer.
- Mfr Part Number-–2: The second alternative manufacturer part number.

The DCL will be generated from EDA software, KiCad [4] and will be available in CSV format.

2.6 Declared Materials List

All the components shall be selected according to ECSS-Q-ST-70–12C [5]. More specific the PCB material shall be follow the ECSS-Q-ST-70–12C [5], clause 12. For all the components should be provided compliance with tailored standards for In-Orbit Demonstration Cubesat missions and flight heritage. In order to improve the thermal management of the system, possibly a heatsink could be used. The material selection shall be follow the ECSS-Q-ST-70–12C [5], clause 10. Additional materials which would be arise like from the design of heatsink bonding in to PCB shall be added in the DML. The DML shall be populated according to ECSS-Q-ST-70C [6], Annex A. The fields of list are:

- Commercial identification or standardized designation.
- Chemical nature and product type.
- Use and location.

According to ECSS-Q-ST-70C [6] Rev.1 Annex A, the DMPL is part of DML as a separate group with the corresponding numbers.

2.7 Declared Process List

DPL is populated according ECSS-Q-ST-70C [6] Annex C. As described in section Manufacturing, assembly and integration of Quality Assurance Plan the assembly of PCB (soldering, cleaning, etc) will be done by external supplier. This is a process that will be included in the DPL. The machining and coating of heatsink parts will be included in DPL. Integration processes, like the assembly of assembled PCB with heatsink parts will be included in this list.

2.8 Failure Modes and Effects Analysis

The complete FMEA can be found in **Failure Modes and Effects Analysis** chapter of the **System Design Document**.

3. Non-conformance Management Plan

3.1 Process and objectives

Throughout the development of the SatNOGS COMMS system a non - conformance control system ensures that any kind of NC are quickly identified and the affected stakeholders are informed. The routines of the control system are presented in Figure 3.1. This control system is derived from ECSS-Q-ST-10–09C [7] and adapted to the workflow of LSF.

3.2 Non-conformance detection

A NC can be detected at any phase of the development,testing or QA phase. When NC item is detected, an internal NCR is created. The NCR has the form of a Gitlab issue at the issue board of the organizational repository of the SatNOGS COMMS system (`https://gitlab.com/librespacefoundation/satnogs-comms/satnogs-comms-org/-/boards`). The NCR, lists all the NC requirements and is immediately assigned to an engineer, responsible to introduce this NC to the internal NRB.

A NC detection, triggers an engineering meeting. The purpose of this meeting is to analyze the root cause of the NC, identify the affected items and discuss possible solutions or workarounds that could mitigate the NC.

3.3 Non-conformance review board

3.3.1 Internal NRB

The internal NRB investigates the root causes of the NC and lists all the affected components of the project. It is also responsible to block all the affected ongoing tasks, utilizing the corresponding feature of the Gitlab issue tracker, until the close-out of the NCR. Then, the internal NRB classifies the NC, as minor or major. In case the NC is minor, an RFD is compiled and the Agency is informed. If the RFD is accepted, the process continues with the necessary corrective and preventive actions.

On the event of a major NC or a rejected RFD, a NRB meeting with the agency is arranged for further discussion.

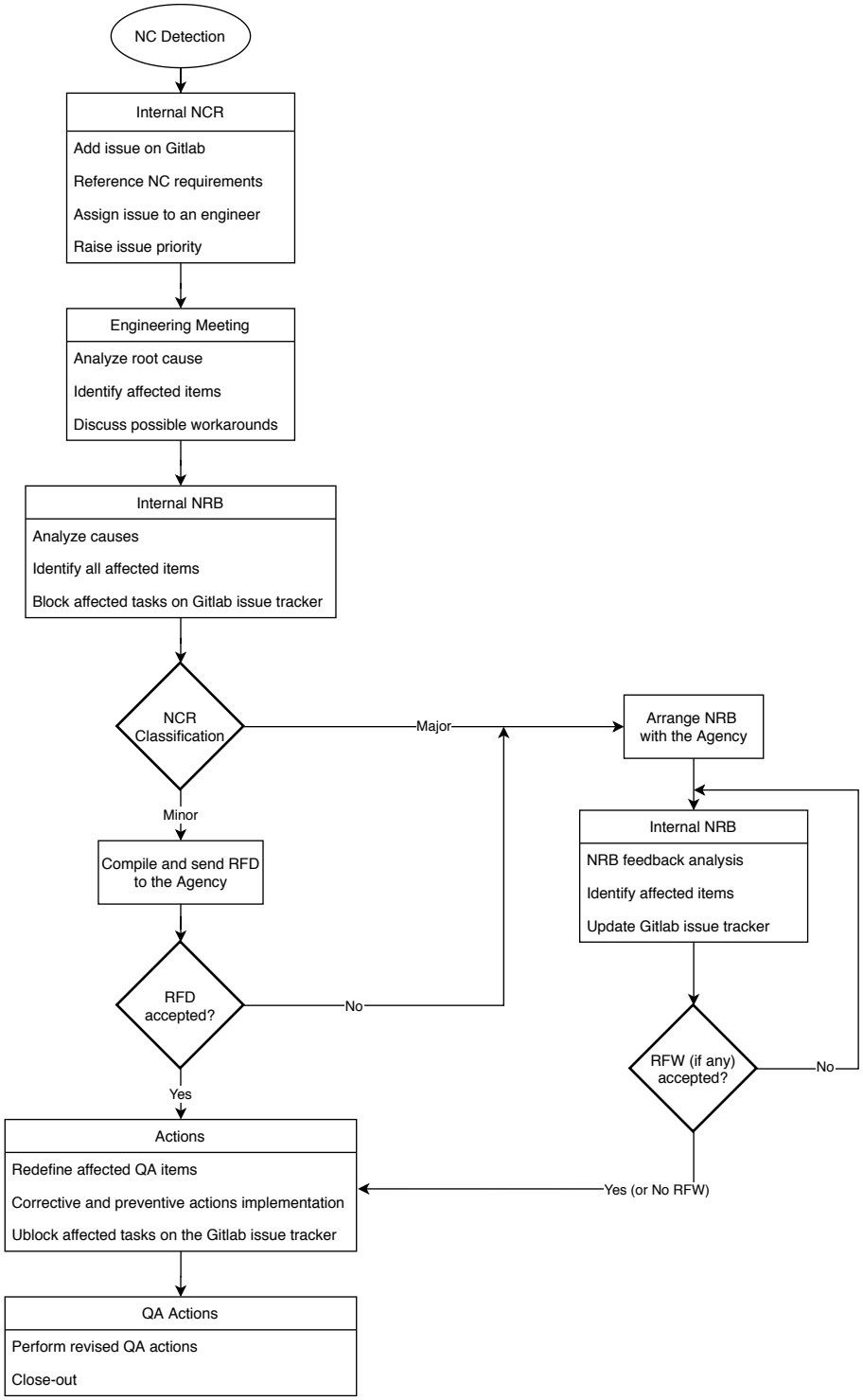

Figure 3.1: Non-conformance processing flow chart

In addition, the internal NRB may review feedback originating from the Agency NRB and evaluate the need of a RFW.

3.3.2 Agency NRB

The Agency NRB follows the same process with the internal one and feedback on the affected NC is requested (if possible).

3.4 Actions

After the NRB and possible feedback from the Agency, the affected QA items are redefined accordingly. Engineers implement all the necessary corrective and preventive actions and upon close-out all the affected blocked tasks at the Gitlab issue tracker are unblocked. Possible QA actions that failed due to the NC, are revised and re-triggered.

4. Safety-Hazard Requirements

4.1 Generic Hazards

Hazard matrix of SatNOGS COMMS transceiver		
Generic Hazards		
Thermodynamic and fluidic	Pressure	—
	Temperature	✓
	Heat transfer	✓
	Fluid Jet	—
	Thermal properties of materials	—
Electrical and electromagnetic	Voltage	✓
	Static electricity	✓
	Electric current	✓
	Magnetic field	—
	Ionization	—
	Sparks	—
Radiation	Light	—
	Radioactivity	—
	Open fire	✓
Chemical	Toxicity	—
	Corrosiveness	—
	Flammability	—
	Explosiveness	—
	Asphyxiant	—
	Irritant	—
Mechanical	Physical impact or mechanical energy	—
	Mechanical properties of material	—
	Vibration	✓
Noise	Frequency and intensity	—
Biological	Human waste	—
	Micro-organism	—
	Carcinogenic	—
Psychological		—
Physical	Confined space	—
Environment — space	Zero gravity	—
	Vacuum	—
	Atmospheric composition	—
	Contaminants, pollutants	—
	Temperature	✓
	Radiation	✓
	South Atlantic anomaly	✓
Environment — Earth	Environmental extremes	—
	Natural disasters	—
	Lightning	—
✓ = applicable — = not applicable		

SatNOGS COMMS transceiver hazard manifestation list	
Mission phase	**Manifestation list**
Ground operation	Handling and integration of the SatNOGS COMMS transceiver in an ESD-safe environment
In-orbit operation	Vibration forces during launch or deployment inside the limits specified by [8]
	Power supply voltage exceeding the maximum rating of 14V and unregulated current can cause fire
	High energy particles can cause system reboots or permanent damage
	Temperature exceeding the operational limits can cause reboots or permanent damage

The hazard scenario and consequence severity terminology and allocation is conforming with definitions as per ECSS-Q-30-02A [9].

Hazard scenario list for ground operations phase				
Hazard Manifestation	**Cause-Events-Consequence**	**Consequence Severity**	**Observable Symptoms**	**Mitigation**
Static electricity	Assembly and integration in without ESD protection-ESD event-failed EEE	Critical 2	Loss of communication, abnormal operation	Handling in ESD-safe environment

Hazard scenario list for in-orbit phase				
Hazard Manifestation	**Cause-Events-Consequence**	**Consequence Severity**	**Observable Symptoms**	**Mitigation**
Vibration environment	Launch vehicle vibrations-failed EEE-loss of the transceiver	Critical 2S	Loss of communication, abnormal operation	Vibration tests, soldering of EEE following IPC-A-610 Class 3 specification
Voltage and electric current	Power supply above 14V, unregulated current — short circuit can cause fire - loss of spacecraft	Critical 2S	None	Transceiver power supply must be off until deployment, hardware overvoltage supervisor
Radiation environment	SEU from high energy particles-memory corruption-loss of spacecraft	Critical 2	Loss of communication, abnormal operation, system reboots, watchdog reboots	Use ECC capable memories, use software techniques for ECC and/or TMR, periodic update of ICs registers

Bibliography

[1] Libre Space Foundation. Software Defined Radio Testbed, 2020.

[2] ECSS. ECSS-Q-ST-60C, 2013.

[3] ESA. Tailored ECSS Engineering Standards for In-Orbit Demonstration CubeSat Projects, 2016.

[4] KiCad.

[5] ECSS. ECSS-Q-ST-70-12C, 2014.

[6] ECSS. ECSS-Q-ST-70C, 2014.

[7] ECSS. Space product assurance, Nonconformance control system, ECSS-Q-ST-10-09C, 2018.

[8] ECSS. ECSS-E-ST-10-03C, 2012.

[9] ECSS. ECSS-Q-30-02A, 2001.