



# EPS 2.0 Qualification Test Plan

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*EPS 2.0 Qualification Test Plan*

*SpaceLab, Universidade Federal de Santa Catarina, Florianópolis - Brazil*



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*February, 2024*

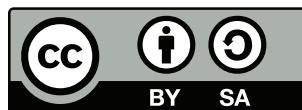
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# CHAPTER 1

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## Introduction

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This document presents a test plan for the qualification of the design of the EPS 2.0 module, developed for the FloripaSat-2 service platform, according to the requirements defined for the GOLDS-UFSC satellite.

The development of this document follow the guidelines and recommendations outlined in the EPS Test Plan Guidelines [1] document, which is based on the ECSS-E-ST-10-03 [2] standard for testing.

The test plan was prepared considering SpaceLab's laboratory and equipment as the test facility, and tests were selected based on that premise. For this reason, environmental tests were not included.

Multiple EPS designs are being developed at SpaceLab and there is an interest in performing performance comparisons between the different modules. With that in mind, this test plan will also include tests aimed at fulfilling the purpose of providing data for future performance comparisons.

### 1.1 Objectives

The objectives of this test plan are:

- The qualification of the design of the EPS 2.0 module, ensuring that the design of the module is capable of performing in accordance with its specifications.
- To generate data regarding the performance of this module for later comparison with different designs developed at SpaceLab.



# CHAPTER 2

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## Hardware Models

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For the execution of this test plan, dedicated qualification models of the EPS 2.0 were manufactured. Figure 2.1 and Figure 2.2 show the models as they were delivered to SpaceLab.

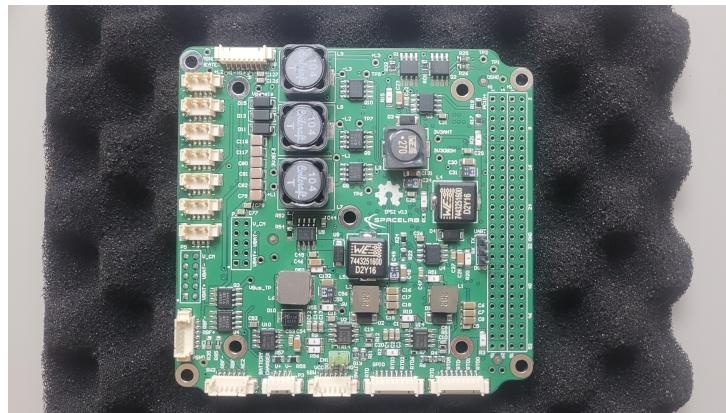


Figure 2.1: EPS 2.0 v0.3 top view.



Figure 2.2: EPS 2.0 v0.3 bottom view.

The models were manufactured with the version v0.3 of the hardware design, found in the EPS 2.0 GitHub repository [3]. The manufacturer used was PCBWay, and the models were delivered in February, 2024.



# CHAPTER 3

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## Requirements to Verify

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This test plan is intended to verify the requirements from the GOLDS-UFSC mission, associated the EPS 2.0 module. Those requirements are listed in Table 3.1. Along with its primary purpose, this test plan also aims to generate data for future performance comparison of the different EPS modules designed at SpaceLab, for this purpose an additional requirement was created (identified as REQ-PERF in Table 3.1) to represent this objective.

ID	Requirement
REQ-1	The power system must be able to harvest solar energy.
REQ-2	The power system must be able to store energy for use when GOLDS-UFSC is eclipsed.
REQ-3	The power system must supply energy to all other modules.
REQ-PERF	Generate data for future performance comparisons.

Table 3.1: Requirements to be verified.

An important note, since the mission requirement are few and broad, and considering that the EPS 2.0 module is developed for a multi-mission platform, some of it's functionalities do not have requirement directly related to it in this mission. So, in order to not leave any functionality untested, not all tests in the programme will have an specific associated requirement.



# CHAPTER 4

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## Test Programme

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The test programme will follow the test matrix presented in Table 4.1, based on the baseline matrix provided in the EPS Test Plan Guidelines [1].

Test Block	Test Activity
Inspection	Manufacturing Inspection
	Electrical Inspection
	Mechanical Inspection
	Integration Inspection
Functional	Harvesting System
	Output Regulators
	Output Control
	Communication Buses
	Sensor Readings
Performance	Battery Management
	Protection Circuits
	Module Power Consumption
	Harvesting System Efficiency
Mission	Output Regulators Efficiency
	Overall/System Efficiency
	System Initialization
Mission	Basic Execution Flow
	Payload Activation Schedule

Table 4.1: Test matrix

The baseline test matrix is organized in four test blocks: inspection, functional, performance and mission tests. In the next sections, a description of each block's objective and a list of the test activities and individual tests associated, will be presented.

Test specifications, procedures and reports will be identified through each test's ID in the respective documents.

### 4.1 Inspection

The Inspection test block has the objective of verifying the integrity of the manufacturing process and conformance of the physical model with the design files, ensuring there are

no workmanship defects or flaws in the model.

Table 4.2 lists the test activities and individual tests associated with this block, and explanation of each activity is presented below.

Activity	Test	ID
Manufacturing Inspection	Packaging quality and integrity assessment	INS-MAN-1
	Manufacturing standards assessment	INS-MAN-2
Mechanical Inspection	Board dimensions measurements	INS-MEC-1
	Board mass measurements	INS-MEC-2
	Mounting holes size and positioning	INS-MEC-3
Electrical Inspection	Components assessments	INS-ELE-1
	Solder quality and integrity assessment	INS-ELE-2
	Power bus continuity test	INS-ELE-3
	First power up procedure	INS-ELE-4
Integration Inspection	Connector pinout assessment	INS-INT-1
	Connector positioning assessment	INS-INT-2

Table 4.2: Inspection tests.

- Manufacturing Inspection:
  - has the purpose of verifying the integrity of the manufacturing and transportation processes;
  - consists of visual inspection of the packaging conditions and conformance to the fabrication standards requirements;
- Electrical Inspection:
  - has the purpose of verifying the electrical integrity of the module;
  - consists of verifying conformance with the electrical schematics, checking solder quality and integrity, checking for absence of short circuits and performing first power up of the module;
- Mechanical Inspection:
  - has the purpose of verifying the physical properties of the board in relation to the design files;
  - consists of measurements of board dimensions, mass, size and position of mounting holes;
- Integration Inspection:
  - has the purpose of verifying that the module can be physically integrated with the satellite;
  - consists of checking the connectors pinout and positioning in relation to the design files.

## 4.2 Functional

The Functional test block has the objective of verifying that the module is capable of executing all of its required functions according to its designed specifications.

Table 4.3 lists the test activities and individual tests associated with this block, and explanation of each activity is presented below.

Activity	Test	ID
Harvesting System	Boost converters test	FUN-HSYS-1
	MPPT algorithm test	FUN-HSYS-2
Output Regulators	EPS/TTC regulator test	FUN-OREG-1
	OBDH regulator test	FUN-OREG-2
	Antenna regulator test	FUN-OREG-3
	Radio 0 regulator test	FUN-OREG-4
	Radio 1 regulator test	FUN-OREG-5
	Payloads regulator test	FUN-OREG-6
Output Control	Output regulators enable pins test	FUN-OCON-1
Communication Buses	Internal module peripherals comm test	FUN-COMM-1
	OBDH communication test	FUN-COMM-2
	TT&C communication test	FUN-COMM-3
Sensor Readings	Voltage sensors readings test	FUN-SENS-1
	Current sensors readings test	FUN-SENS-2
	Temperature sensors readings test	FUN-SENS-3
Battery Management	Battery monitor IC configuration test	FUN-BATM-1
	Battery monitor IC data readings test	FUN-BATM-2
	Battery heater hardware test	FUN-BATM-3
	Battery heater control algorithm test	FUN-BATM-4
Protection Circuits	Battery monitor IC protection functions test	FUN-PROT-1

Table 4.3: Functional tests.

- Harvesting System:
  - has the purpose of verifying the correct operation and functioning of the module's harvesting system
  - consists of testing the three boost converter channels as well as the MPPT perturb and observe algorithm;
- Output Channel Regulators:
  - has the purpose of verifying the correct operation and functioning of the output channels regulators;
  - the test consist of applying incremental loads to the six output voltage regulators, according to the expected limits during mission operation;
- Output Channels Control:

- has the purpose of verifying the correct operation and functioning of the output channels control system;
  - consists of testing the operation of the controllable channels regulator's enable pins;
- Communication Buses:
    - has the purpose of verifying the correct operation and functioning of the communication buses and integrity of information;
    - consists of verifying the communication buses' configuration and protocols and verifying the integrity of the messages, for internal module peripherals communication buses as well as communication with OBDH and TT&C modules.
- Sensor Readings:
    - has the purpose of verifying the correct operation and functioning of the sensors and the correctness of the readings;
    - consists of testing and comparison of the module's voltage, current and temperature sensors readings against external measurement instruments;
- Battery Management:
    - has the purpose of verifying the correct operation end functioning of the battery management system;
    - consists of testing the DS2777G+ battery monitoring IC, verifying the correct configuration and data readings, as well as testing of the battery heater resistors and its control algorithms;
- Protection Circuits:
    - has the purpose of verifying the correct operation and functioning of the modules protection circuits;
    - consists of testing the protection functions of the DS2777G+ battery monitoring IC.

## 4.3 Performance

The Performance test block has the objective of verifying and evaluating the performance aspects of the module in relation to its requirements. The main focus of this block is on evaluating the efficiency of the multiple conversion stages present in the module, as well as of the module as a hole.

Table 4.4 lists the test activities and individual tests associated with this block, and explanation of each activity is presented below.

- Power Consumption:
  - has the purpose of evaluating the power consumption of the EPS 2.0 in isolation, in normal operating conditions, with no loads connected;

Activity	Test	ID
Power Consumption	Isolated EPS power consumption measurement	PERF-MCON-1
Harvesting System Eff.	MPPT boost regulators efficiency measurement	PERF-HARV-1
Output Regulators Eff.	EPS/TTC regulator efficiency	PERF-OREG-1
	OBDH regulator efficiency measurement	PERF-OREG-2
	Antenna regulator efficiency measurement	PERF-OREG-3
	Radio 0 regulator efficiency measurement	PERF-OREG-4
	Radio 1 regulator efficiency measurement	PERF-OREG-5
	Payloads regulator efficiency measurement	PERF-OREG-6
System Efficiency	Overall system efficiency measurement	PERF-SYS-1

Table 4.4: Performance tests.

- the test consist of measuring the power consumption of the module when powered through a bench power supply and no loads connected;
- Harvesting System Efficiency:
  - has the purpose of evaluating the efficiency of the harvesting system;
  - the test consist of simulating different operating points of the solar panels at the input of the boost converters and measuring output power;
- Output Regulators Efficiency:
  - has the purpose of evaluating the efficiency of the converters of the six output channels;
  - the tests consists of applying incremental loads to the regulator's output and measuring input and output power consumptions;
- System Efficiency:
  - has the purpose of evaluating the efficiency of the system as a hole, considering all conversion stages;
  - an analysis of the previous performance tests results may be used to evaluate system efficiency;

## 4.4 Mission

The Mission test block has the objective of verifying the correct operation of the module in relation to the mission concept of operations.

Table 4.5 lists the test activities and individual tests associated with this block, and explanation of each activity is presented below.

- System Initialization:
  - has the purpose of evaluating the correct operation of the module during initialization;

Activity	Test	ID
System Initialization	Execute system initialization procedure	MISS-INIT-1
Normal Execution Flow	Execute normal execution flow	MISS-FLOW-1
Payload Activation	Simulate payload activation schedule	MISS-PYLD-1

Table 4.5: Mission tests.

- Normal Execution Flow:
  - has the purpose of evaluating the correct operation of the module during the normal execution flow defined in the documentation;
- Payload Activation:
  - has the purpose of evaluating the behavior of the module considering the payload activation schedule;

## 4.5 Requirements Mapping

The Table 4.6 relates the tests with the associated requirements. As stated before, not all tests have an direct associated requirement, and only the ones that have are listed.

Test ID	Associated Requirement
FUN-HSYS-1	REQ-1
FUN-HSYS-2	REQ-1
FUN-OREG-1	REQ-3
FUN-OREG-2	REQ-3
FUN-OREG-3	REQ-3
FUN-OREG-4	REQ-3
FUN-OREG-5	REQ-3
FUN-OREG-6	REQ-3
FUN-OCON-1	REQ-3
FUN-COMM-1	REQ-3
FUN-COMM-2	REQ-3
FUN-COMM-3	REQ-3
FUN-SENS-1	REQ-1
FUN-SENS-2	REQ-1
FUN-BATM-1	REQ-2
FUN-BATM-2	REQ-2
FUN-BATM-3	REQ-2
FUN-BATM-4	REQ-2
PERF-MCON-1	REQ-PERF
PERF-HARV-1	REQ-PERF
PERF-OREG-1	REQ-PERF
PERF-OREG-2	REQ-PERF
PERF-OREG-3	REQ-PERF
PERF-OREG-4	REQ-PERF
PERF-OREG-5	REQ-PERF
PERF-OREG-6	REQ-PERF
PERF-SYS-1	REQ-PERF

Table 4.6: Requirements mapping.



# CHAPTER 5

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## Test Facilities

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The test facility selected for the execution of this test plan is the SpaceLab's laboratory, located at Universidade Federal de Santa Catarina's campus in Florianópolis, and the tests were selected considering its infrastructure and available equipment.

Below is a list of equipment available at SpaceLab's laboratory:

- SpaceLab FlatSat Platform;
- Desk Power Supplies;
- Computers;
- SpaceLAb Interstage Interface Panel boards;
- Logic Analyzer;
- MSP-FET Flash Emulation Tools;
- USB-UART converters;
- General purpose measurement instruments:
  - Oscilloscope;
  - Digital multimeters;
  - Pachymeter;
- Protoboards;
- Electronic components;



# CHAPTER 6

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## Documentation

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The documentation for this testing process will follow and adapted version of the documentation structure defined in the ECSS-E-ST-10-02 [4] and ECSS-E-ST-10-03 [2], as recommended in the EPS Test Plan Guidelines.

Three documents are to be generated based on this test plan, and later annexed to this document, resulting in a single instance at the end of the testing process. These documents are: Test Specifications document, Test Procedures document and Test Reports document.

The Test Specification document describes the detailed specifications and requirements for the tests. It contains, for each test a description of the purpose of the test, test approach, model to be used, the requirements being verified, required equipment, instrumentation and uncertainties, test conditions and tolerances, pass/fail criteria and related documentation.

The Test Procedures document describes the detailed procedures for execution the tests. It contains for each test, reference to corresponding TSPE document, description of the item under test configuration, and detailed step-by-step instructions for the test execution.

The Test Reports document contains the reports for each test. Each report describes the execution of the test, the test results, data analysis and assessments, as well as considerations and conclusions regarding the requirements being verified.

At the end of the testing process, when combining and annexing these documents, it may be of interest to group each test's specification section with the respective procedures and report, for easier reading.



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- [1] Ramon de Araujo Borba. *EPS Test Plan Guidelines*. SpaceLab, February 2024.
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