B2SPACE

**PROCEDIMIENTO DE ENSAYO DE BALANCE TÉRMICO A BAJA PRESIÓN DEL HEAT TRANSFER LAB (B2SPACE)**

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| Preparado por | *prepared by* |  |
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**LISTA DE CAMBIOS**

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| **Razones del cambio** | **Edición** | **Revisión** | **Fecha** |
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# INTRODUCTION

## Purpose

## Scope

# GLOSARY AND DEFINITIONS

## Acronyms and abbreviations

# APPLICABLE AND REFERENCE DOCUMENTS

## Applicable documents

## Normative documents

## Reference documents

# TEST OVERVIEW

## Test objectives

## Test Facility

## Environmental conditions

## Test documentation

## Participants

## Safety

## Equipment under test

# TEST SET UP

## Thermal interface

* Conductive interface: The cubesat is simply supported over the base plate through rubber supports without bolts.
* Radiative interface: Base plate and Shroud are the radiative interface.

## Temperature sensors

Temperature sensors of the thermal vacuum chamber are thermocouples, and their locations are listed in Table 1.

Table 1 – Temperature sensors locations and number on the elements of the cubesat.

|  |  |  |
| --- | --- | --- |
| **TC #** | **Sensor location** | **Element** |
| 1 | Base plate below the cubesat | BP |
| 2 | Base plate at a corner | BP |
| 3 | Shroud surface | SHR |
| 4 | External surface of lower tray of the cubesat (Z-) (Battery tray) | Cubesat |
| 5 | External surface of upper tray of the cubesat (Z+) | Cubesat |
| 6 | External surface of lateral panel of the cubesat (X+), half upper area | Cubesat |
| 7 | External surface of lateral panel of the cubesat (X+), half lower area | Cubesat |
| 8 | External surface of lateral panel of the cubesat (Y+), half upper area | Cubesat |
| 9 | External surface of lateral panel of the cubesat (Y+), half lower area | Cubesat |
| 10 | External surface of lateral panel of the cubesat (X-), half upper area | Cubesat |
| 11 | External surface of lateral panel of the cubesat (X-), half lower area | Cubesat |
| 12 | External surface of lateral panel of the cubesat (Y-), half upper area | Cubesat |
| 13 | External surface of lateral panel of the cubesat (Y-), half lower area | Cubesat |
| 14 | Air horizontally separated from the cubesat (5 cm from the cubesat) | Air |
| 15 | Air between the lower tray and the base plate | Air |

.

### Temperature Reference Point (TRP)

* **TBT HOC test:** Internal temperature sensors of the electronics (Raspberrry, pressure sensors, IMU).
* **TBT COC test:** TC\_4 (battery tray).

## Heat Transfer Lab functional and testing modes. Power consumption

|  |  |  |
| --- | --- | --- |
|  | **Power Consuption (W)** | |
| **Element** | **COC** | **HOC** |
| Plate Heater | 0.5 | 0.1 |
| Battery Heater | 0.5 | 0.5 |
| Raspberry Pi 3B+ | 1.8 | |
| GPS | 0.0858 | |
| Pressure Sensor 1 | 0.000005 | |
| Pressure Sensor 1 | 0.000005 | |
| IMU | 0.01518 | |
| Battery | 0.4 | |

Functional Test #1:

* + Ambient temperature
  + Ambient pressure
  + Check Fernando’s procedure.

TBT HOC Test:

* + TBP = 31 °C
  + TSHR = 42 °C
  + p = 13.81 mbar (30 km).
  + Heater power:

TBT COC Test:

* + TBP = -10 °C
  + TSHR = -3 °C
  + p = 84.08 mbar (18 km).
  + Heater power:

Functional Test #2:

* + Ambient temperature
  + Ambient pressure
  + Check Fernando’s procedure.

# TEST PARAMETERS

## Test requirements

## Test tolerances

Temperature tolerances for temperature set point of Shroud and Base Plate are +/- 3 ºC.

Pressure tolerances for TBT HOC Test (14 mbar) are +/- 3 mbar.

Pressure tolerances for TBT COC Test (84 mbar) are +/- 6 mbar.

## Abortion criteria

If any of the thermocouples or temperature sensors (electronic temperature sensors, TC74 and PT1000 sensors) exceed the temperature limits shown in Table 2 the test shall be stopped or the thermal and pressure scenario shall be modified.

Table 2 – Temperature limits of the cubesat parts.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Element** | **Minimum Operating Temperature** | **Maximum Operating Temperature** | **Reference** | **Temperature sensors**  **ID** |
| **Raspberry**  **Presssure sensors**  **IMU** | 0 | +65 | [ref raspberry](https://www.raspberrypi.org/documentation/hardware/raspberrypi/frequency-management.md) | Electronics internal temperature sensors |
| **Battery** | +5 | +40\* | Pindado meeting April 28th | TC\_4 |
| **Heated plate** | ‒15 | +70 | Defined by TASEC team | PT\_5  PT\_6 |
| **Structure** | ‒15 | +70 | Defined by TASEC team | TC\_5 to TC\_13  TC74\_1 to TC\_5 |
| **Air** | ‒15 | +70 | Defined by TASEC team | TC\_14  TC\_15  PT\_1 to PT\_4 |

\*The battery resist a short period between 50ºC and 60ºC

**CRITICAL TEMPERATURE SENSORS:**

* **TBT HOC test:** PT1000 of the aluminum plate (PT\_5) and of the heater (PT\_6).
* **TBT COC test:** Internal temperature sensors of the electronics (Raspberry, pressure sensors, IMU).

## Test success criteria

The test will be successful if any part of the cubesat is not damaged and the temperature limits are not exceeded. The TBT test must accomplish the stabilization criteria:

* ΔT<1 °C/h
* dwell time = 2 h

# STEP-BY-STEP TEST PROCEDURE

Stabilization criteria

Table 3 – Step by step TBT procedure.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Step #** | **Description** | **Expected Result** | **Date/Time** | **Sign** | **Comments** |
| **PREPARATION** | | | | | |
| 00 | * Preparation of the equipment under test: * Remove bolts from upper tray and fix it with kapton tape. * Clean all the parts intended to be inside of the thermal vacuum chamber. * Assembly the four aluminum lateral panels and the corresponding TC74 temperature sensors. * Tighten the anemometer connector in the lower tray. * Fix the wiring from converter to mosfet. |  | 03/06/20219:30-11:15 | FAA  MSG  LPP | In the final Assembly it must have glue between the TC74 and the lateral panels.  It is necessary to drill a hole for the upper TC74. During this test it has been fix with kapton tape. |
| 05 | * Fix the external temperature sensors (thermocouples) in the appropriate location over the cubesat. * Take photos of TC fixing. |  | 03/06/2021  11:15-11:45 | FAA  MSG | Ok |
| 10 | * Cover base plate area below the anemometer connector with kapton avoiding electrical short-circuit. * Fix the Ethernet connection from the inside chamber interface of the chamber to the cubesat. * Fix the power wiring from the inside chamber interface to the battery terminals of the cubesat. Identify the wiring!! * Assembly the new wiring for external battery charge. * Fix the ground connections (if needed). * Take photos of the connections. |  | 03/06/2021  11:45  12:10 | FAA  MSG | V\_bat=24.44V (11:50h) |
| 15 | * Take photos of the assembly. |  | 03/06/2021  12:10 | LPP | ok |
| 20 | * Connect all the thermocouple wires to the TVAC I/F. * Check the thermocouple signals. | All signals at ambient temperature. | 03/06/2021  12:10 | MSG | Maximum difference of 0,5ºC between the hottest and the coldest TC |
| 25 | * Start to record the thermocouples signal. * Thermal vacuum chamber operation procedure. * Disconnect the turbo pump |  | 03/06/2021  12:25 | MSG | Ok |
| 30 | * Check the battery voltage | Voltage > 18 V | 03/06/2021  12:25 | FAA | V\_bat = 24,44V |
| 35 | * Start recording the data for **Functional Test #1** * Perform Functional Test #1 * Fernando procedure * Check pressure, temperature and etc. signals of the cubesat. * Turn ON the plate heater and check the temperature variation. |  | 03/06/2021  12:57 | FAA | V\_bat = 24.3V (12:58) |
| 40 | * Stop Functional Test #1 * Continue recording the signals, etc. |  | 03/06/2021  13:20 | FAA | ok |
| **Step #** | **Description** | **Expected Result** | **Date/Time** | **Sign** | **Comments** |
| **TVAC commissioning phase** | | | | | |
| 45 | * Close the chamber * Start vacuum pump and wait until the required pressure level is reached for the **TBT HOC test**. * Check the variation of pressure rate of change. It shall be similar to the variation in the ascent profile. | **p ≈ 13.81 mbar**  **(30 km)**  **time ≈ 1 h** | 03/06/2021  13:22  13:55 | FAA  MSG  LPP | V\_bat=24,01V (13:44)  There is a difference of 15mbar between the pressure meassured by the Raspberry and by the TVAC sensor.  During the test the TVAC sensor will be used as reference. |
| **Step #** | **Description** | **Expected Result** | **Date/Time** | **Sign** | **Comments** |
| **TBT** | | | | | |
| 55 | * Warm up the chamber to HOT conditions for the TBT HOC test. | **TBP = 31 °C**  **TSHR = 42 °C**  **time ≈ 10 min** | 03/06/2021  13:55 | MSG | The electronics is at 47ºC at 14h |
| 60 | * Perform the **TBT HOC test** * **Check every half hour the battery voltage** | Voltage > 18 V | 03/06/2021  13:55 | FAA  LPP | P\_heater =0.2W (14:00h) Changed because it is really close to its temperature limit.  V\_bat = 23,8V (14:14h)  V\_bat = 23.6V (14:42h)  15:03 -> P\_heater = 0.1W  TC04 (battery tray) is at 39ºC (15:00)  Temperature of electronics is at 58ºC (15:10)  V\_bat = 23.57V (15:30)  V\_bat = 23,17V (16:15)  V\_bat = 23,01V (16:48)  16:50 GUI gst hunged  V\_bat = 22,9V (17:14)  V\_bat = 22,7V (17:44) |
| 65 | * Meet the stabilization criteria in all temperature sensors (thermocouples, PT1000 and TC74). * Stop TBT HOC test. * Turn off the cubesat | ΔT<1 °C/h  dwell time = 2 h  **Maximum time allowed 4 h.** | 03/06/2021  18:04 | LPP FAA MSG | V\_bat= 22,67V (18:04) |
| 66 | * Cool down the chamber to ambient conditions. * ~~Go to ambient pressure.~~ | Ambient temperature ~~and pressure~~ | 03/06/2021  18:04 | LPP FAA MSG | TVAC is cool down to 10ºC (BP and SHR) during the night. |
| 67 | CHARGE the battery after the TBT HOC test and before the TBT COC test. |  | 04/06/2021  9:24 | MSG  FAA | Charging from 9:24 to 10:51  V\_bat = 24,45V (10:51) |
| 68 | * Start vacuum pump and wait until the required pressure level is reached for the **TBT COC test**. | **p ≈ 84.09 mbar (18 km)** | 04/06/2021  10:01 | MSG | The vent valve is open until 83mbar is reached.  There is a difference of 24mbar between the raspberry and the TVAC sensor.  TVAC pressure sensor is used as reference. |
| 70 | * Cool down the chamber to COC conditions for the **TBT COC test**. | **TBP = -10 °C**  **TSHR = -3 °C**  **time ≈ 3 h** | 04/06/2021  11:01 | MSG  FAA | A 1ºC/10min slope is set  V\_bat = 24.3V (11:03)  V\_bat = 24.2V (11:13)  V\_bat = 23.9V (11:53)  V\_bat = 23.8V (12:19)  V\_bat = 23.7V (12:35)  V\_bat = 23.6V (12:51)  Stop the cool down at -2ºC and maintain at that temperature.  Check TC\_04 is over 5ºC.  The pressure has dropped to 70mbar  V\_bat = 23.5V (13:08)  Set the SHR and BP at -1ºC. (13:35)  V\_bat = 23.3V (13:50)  TC04 has stabilize at 5ºC (15:10) |
| 75 | * Perform the **TBT COC test** * **Check every half hour the battery voltage** | Voltage > 18 V | 04/06/2021  15:12 | MSG  FAA | V\_bat = 23V (15:12)  Switch on the heater at 0.5W (15:13)  V\_bat = 22.7V (15:43)  V\_bat = 22.6V (15:59)  V\_bat = 22.3V (16:37)  V\_bat = 22.2V (16:50)  V\_bat = 22V (17:17)  V\_bat = 22V (17:26) end of COC |
| 80 | * Meet the stabilization criteria in all temperature sensors (thermocouples, PT1000 and TC74). * Stop TBT COC test. | ΔT<1 °C/h  dwell time = 2 h  **Maximum time allowed 6 h.** | 04/06/2021  17:24 | MSG  FAA | 2h after switching on the heater the stabilization criteria are met. |
| 85 | * Warm up the chamber to ambient conditions. * Go to ambient pressure. | Ambient temperature and pressure | 04/06/2021  17:24 | MSG | A 1ºC/min slope is set to warm up  At 17:54 al temperature sensors are above 10ºC |
| 90 | **End of the TBT** |  |  |  |  |
| **Step #** | **Description** | **Expected Result** | **Date/Time** | **Sign** | **Comments** |
| **Inspection** | | | | | |
| 95 | Check that all temperatures are above 10 ºC.  Open the thermal vacuum chamber |  | 04/06/2021  17:54 | MSG  FAA | Vent valve is open at 17:54  Ambient pressure is reached at 17:57 |
| 100 | Visual inspection (take photos). |  | 04/06/2021  17:58 | LPP | Ok |
| 105 | **Check the battery voltage** | Voltage > 18 V | 04/06/2021  17:59 | FAA | V\_bat = 21,9V (17:59) |
| 110 | * Start recording the data for **Functional Test #2** * Perform Functional Test #2 * Fernando procedure * Check pressure, temperature and etc. signals of the cubesat. * Turn ON the plate heater and check the temperature variation. * Stop Functional Test #2 * Turn off the cubesat * Stop recording the thermocouple signals. |  | 04/06/2021  18:06 | FAA | V\_bat = 21,9V (18:12)  Baterry connector is unplug at 18:12 |
|  | Dissasembly the cubesat from the chamber and wiring connections. |  | 8/6/2021  10:15 | MSG | ok |
| 115 | Check the items if needed. |  |  |  |  |

# GSE

The list of GSE items to be used during the test is indicated in Table 4.

Table 4 – List of materials, tools and items needed for the test.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **#** | **Item** | **Manufacturer** | **Serial Number** | **Calibration Status** | **Stored in** |
| **1** | Kapton tape |  |  |  |  |
| **2** | Aluminun tape |  |  |  |  |
| **3** |  |  |  |  |  |
| **4** |  |  |  |  |  |
| **5** |  |  |  |  |  |
| **6** |  |  |  |  |  |
| **7** |  |  |  |  |  |
| **8** |  |  |  |  |  |
| **9** |  |  |  |  |  |
| **10** |  |  |  |  |  |

# SPECIAL REMARKS

## Anomalies

Anomalies written down in Table 5 will be reported in the final approved as-run test procedure as part of the test documentation.

Table 5 – List of anomalies.

|  |  |  |
| --- | --- | --- |
| **#** | **Anomaly** | **Comments** |
| **1** |  |  |
| **2** |  |  |
| **3** |  |  |
| **4** |  |  |
| **5** |  |  |
| **6** |  |  |
| **7** |  |  |
| **8** |  |  |
| **9** |  |  |
| **10** |  |  |

## Test deviations

Test deviations written down in Table 6 will be reported in the final approved as-run test procedure as part of the test documentation.

Table 6 – List of test deviations.

|  |  |  |  |
| --- | --- | --- | --- |
| **#** | **Time** | **Test Deviation** | **Comments** |
| **1** |  |  |  |
| **2** |  |  |  |
| **3** |  |  |  |
| **4** |  |  |  |
| **5** |  |  |  |
| **6** |  |  |  |
| **7** |  |  |  |
| **8** |  |  |  |
| **9** |  |  |  |
| **10** |  |  |  |