B2SPACE

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

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

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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

* Mode A1: Ascent mode 1
* Mode A2: Ascent mode 2
* Mode F1: Float mode 1
* Mode F2: Float mode 2
* Mode F3: Float mode 3

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **MODE** | **HTL power dissipation (W)** | **Cubesat** | **End mode criterion** | **Safety criterion (turn OFF HTL)** | **Safety criterion (turn ON HTL)\*\*\*** |
| **A1** | 0.8\*\*\*\* | ON | *p*≤ *p* (10 km) **AND** *tmission*≥ 30 min | *Tplate*≥ 65°C  **OR**  |*Tplate*–*Tair*| ≥ 60 °C | *Tplate*≤ 55 °C  **AND**  |*Tplate*–*Tair*| ≤ 50 °C |
| **A2** | 0.6\*\*\*\* | ON | *p*≤ *p* (18 km)  **OR** *tmission*≥ 80 min |
| **F1** | *P*A2\* | ON | *t*F1 ≥ 120 min |
| **F2** | *P*F1/2\*\* | ON | *t*F2 ≥ 120 min |
| **F3** | 0 | ON | Until end of mission | N/A | N/A |

\*Variable: At least the last power dissipation of Mode A2 or lower.

\*\*Variable: At least ½ the last power dissipation of Mode F1 or lower.

\*\*\*After meeting the Safety criterion (turn OFF HTL).

\*\*\*\*New power update from Jonathan Martín Palomo (18/06/2021)

Functional Test - pressure:

* + Ambient temperature
  + Start the cubesat operating sequence. Vary the TVAC pressure in order to change between consecutive modes, meeting the end mode criterion of pressure.

Functional Test - time:

* + Ambient temperature
  + Start the cubesat operating sequence. Wait the specified time (reduce the time specified to 5-10 min each mode) to change between consecutive modes.

# TEST PARAMETERS

## Test requirements

## Test tolerances

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

Pressure tolerances for Functional Test - pressure are +/- 3 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 resists a short period between 50ºC and 60ºC

**CRITICAL TEMPERATURE SENSORS:**

* PT1000 of the aluminum plate (PT\_5) and of the heater (PT\_6).
* Internal temperature sensors of the electronics (Raspberry, pressure sensors, IMU).
* TC4 (battery tray).

## 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 cubesat operatin sequence (A1, A2, F1, F2, F3) in both functional test (pressure and time).

# 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. |  | 18/06/2021  9:30 |  | Ok |
| 05 | * Fix the external temperature sensors (thermocouples) in the appropriate location over the cubesat. * Take photos of TC fixing. |  |  |  | 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. |  |  |  | Ok |
| 15 | * Take photos of the assembly. |  |  | LPP | OK |
| 20 | * Connect all the thermocouple wires to the TVAC I/F. * Check the thermocouple signals. | All signals at ambient temperature. |  | MSG  FAA | OK |
| 25 | * Start to record the thermocouples signal. * Thermal vacuum chamber operation procedure. * Disconnect the turbo pump |  |  | MSG | OK |
| 30 | * Check the battery voltage | Voltage > 18 V |  | FAA | V\_BAT = 24.12  11:00 LAUNCH FLIGHT SOFTWARE  11:45 STOP FLIGHT SOFTWARE |
| 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. |  | 12:59 | FAA | 12:50 CONNECT CUBESAT AGAIN  SEE FUNCTIONAL TEST #1  END 13:06 |
| 40 | * Stop Functional Test #1 * Continue recording the signals, etc. |  | 13:06 | FAA | OK |
| 45 | * Start recording the data for **Functional Test - pressure** * Start Functional Test – pressure * Mode A1 * Check pressure, temperature and etc. signals of the cubesat. | Ambient temperature and pressure |  | FAA  LPP |  |
| **Step #** | **Description** | **Expected Result** | **Date/Time** | **Sign** | **Comments** |
| **TVAC commissioning phase & Functional Tests** | | | | | |
| 50 | * Close the chamber * Start vacuum pump and wait until the required pressure level is reached for the **Functional Test - pressure** * Check the variation of pressure rate of change. It shall be similar to the variation in the ascent profile. | ***p*> 265mbar (10 km)**  **time ≈ XX h** | 13:25 | AGP  FAA  MSF  LPP | 13:32 V\_BAT = 23,4 V  13:46 P = 265 MBAR  13:54 Switch off heater at T>65ºC  13:54 Switch on heater at T>55ºC  13:54 Switch to A2 mode |
| 55 | * Vary the TVAC pressure to meet the end mode A1 criterion (automatic change to A2) (meeting the time criterion is also required) * Check pressure, temperature and etc. signals of the cubesat. * **Check every half hour the battery voltage** | *p*≤ 265mbar (10 km) **AND** *tmission*≥ 30 min  P(W) = 0.8 W  Voltage > 18 V | 13:54 |  | 13:55 V\_bat = 23.3 V |
| 60 | * Vary the TVAC pressure to meet the end mode A2 criterion (automatic change to F1) * Check pressure, temperature and etc. signals of the cubesat. * **Check every half hour the battery voltage** | *p*≤ 84 mbar (18 km) **OR** *tmission*≥ 80 min  P(W) = 0.6 W  Voltage > 18 V | 13:54 |  | 13:54 Fire alarm belled  14:16 Heater switch off T>65ºC  14:17 Heater switch on T<55ºC  14:19 Switch to F1 because p<84mbar |
| 65 | * Wait for mode F1 to end (automatic change to F2) * Check pressure, temperature and etc. signals of the cubesat. * **Check every half hour the battery voltage** | *t*F1 ≥ 15 min  P(W) = 0.6 W  Voltage > 18 V | 14:19 |  | 14:21 p≈55mbar (20km)  14:24 Heater switches off because T>65ºC  14:26 Heater switches on T<55ºC and power lowers to 0.5W  14:33 Switch to F2 |
| 70 | * Wait for mode F2 to end (automatic change to F3) * Check pressure, temperature and etc. signals of the cubesat. * **Check every half hour the battery voltage** | *t*F2 ≥ 15 min  P F2 (W) = PF1 /2  Voltage > 18 V | 14:34 |  | Starts with 0.25W (0.5 W of F1 divided by 2)  14:42 p≈52 mbar (30km)  14:49 Switch to F3 |
| 75 | * Wait for mode F3 to end * Check pressure, temperature and etc. signals of the cubesat. * **Check every half hour the battery voltage** | *t*F3 ≥ 15 min  P F3 (W) = 0  Voltage > 18 V | 14:49 |  | Starts with 0W  15:04 End F3 |
| 80 | * End of **Functional Test – pressure** * **Check the battery voltage** | Voltage > 18 V | 15:04 |  | V\_bat = 23,02 V  P = 20mbar |
| 81 | * Continue in vacuum * Set manually F1 * Open valves to increase the pressure until 541 mbar (5km) * Check it switches to F3 mode | Voltage > 18 V | 17:44 | FAA  MSG | 17:15 Cubesat turns on  17:20 V\_bat = 22,8V  17:44 mode F1  P(W) = 0.1W  17:46 switches to F3 when P>541 mbar (5km) |
| 82 | * Lower the pressure until p>84mbar (18km) and p<541mbar(5km) * Set A2 mode * Open the valves to increase pressure until 541mbar * Check it switches to F3 mode |  | 17:46 | FAA  MSG | 17:47 mode A2 at 500mbar  17:47 switch to F3 automatically |
|  | * Open valves to increase pressure until ambient | P=940mbar | 17:48 | MSG | 17:50 P = P\_amb |
| **Step #** | **Description** | **Expected Result** | **Date/Time** | **Sign** | **Comments** |
| 85 | * Start recording the data for **Functional Test - time** * Start Functional Test – time * Mode A1 * Check pressure, temperature and etc. signals of the cubesat. | Ambient temperature and pressure | 17:48 |  | 17:55 V\_bat = 22,6 V  17:56 Start goes wrong  17:57 starts goes right - mode A1 |
| 90 | * Start vacuum pump and wait until the required pressure level is reached for the **Functional Test – time** * Check the variation of pressure rate of change. It shall be similar to the variation in the ascent profile. | ***P<541mbar***  ***p*> 265mbar (10 km)**  **time ≈ XX h** | 17:57 |  | 17:50 p\_amb  18:24 p=500mbar |
| 95 | * Meet only the time criteria * Vary the TVAC pressure to meet the end mode A1 criterion (automatic change to A2) (meeting the time criterion is also required) * Check pressure, temperature and etc. signals of the cubesat. * **Check every half hour the battery voltage** | *P<541mbar*  *(p*≤ 265mbar (10 km) **AND** *tmission*≥ 30 min)  *OR (tmission*≥40 min)  Voltage > 18 V | 17:57 |  | 18:24 p=500mbar  18:24 v\_bat=22.3V  18:37 End. Switches to A2 |
| 100 | * Wait for mode A2 to end (automatic change to F1) WHITOUT meeting the pressure criterion. * Check pressure, temperature and etc. signals of the cubesat.   **Check every half hour the battery voltage** | *p*≤ 84 mbar (18 km) **OR** *tmission*≥ 80 min  Voltage > 18 V | 18:37 |  | 18:49 P=180mbar  19:00 V\_bat=22.05V  19:17 Switches to F1 |
| 105 | * Wait for mode F1 t end (automatic change to F2) * Check pressure, temperature and etc. signals of the cubesat.   **Check every half hour the battery voltage** | *t*F1 ≥ 5 min  Voltage > 18 V | 19:17 |  | 19:22 Ends. Switches to F2 |
| 110 | * Wait for mode F2 to end (automatic change to F3) * Check pressure, temperature and etc. signals of the cubesat.   **Check every half hour the battery voltage** | *t*F2 ≥ 5 min  Voltage > 18 V | 19:22 |  | 19:22 V\_bat = 21,09V  19:27 Swithces to F3 |
|  | * Wait for mode F3 to end * Check pressure, temperature and etc. signals of the cubesat.   **Check every half hour the battery voltage** | *t*F3 ≥ 5 min  Voltage > 18 V | 19:27 |  | 19:32 Ends of F3. It stays forever in F3 |
| 120 | * End of **Functional Test – pressure**   **Check the battery voltage** | Voltage > 18 V | 19:32 |  | 19:32 END |
| **Step #** | **Description** | **Expected Result** | **Date/Time** | **Sign** | **Comments** |
| **Inspection** | | | | | |
| 125 | Check that all temperatures are above 10 ºC.  Go to ambient pressure  Open the thermal vacuum chamber | T\_amb  P\_amb |  | MSG | 13:34 P\_amb |
| 130 | Visual inspection (take photos). |  |  | LPP | OK |
| 135 | **Check the battery voltage** | Voltage > 18 V |  |  | 19:36 V\_bat = 21.9V |
| 130 | * 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. |  | 19:46 |  | 19:58 V\_bat = 21.88V  19:58 ENDS |
| 135 | Dissasembly the cubesat from the chamber and wiring connections. |  |  |  |  |
| 140 | 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** |  |  |  |