B2SPACE

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

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5.1   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.

5.2   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

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5.2.1   Temperature Reference Point (TRP)

- **TBT HOC test:** Internal temperature sensors of the electronics (Raspberrry, pressure sensors, IMU).

- **TBT COC test:** TC_4 (battery tray).

5.3 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	

5.3.1 Functional Test #1:
- o Ambient temperature
- o Ambient pressure
- o Check Fernando's procedure.

5.3.2 TBT HOC Test:
- o T_{BP} = 31 °C
- o T_{SHR} = 42 °C
- o p = 13.81 mbar (30 km).
- o Heater power:

5.3.3 TBT COC Test:
- o T_{BP} = -10 °C
- o T_{SHR} = -3 °C
- o p = 84.08 mbar (18 km).
- o Heater power:

5.3.4 Functional Test #2:
- o Ambient temperature
- o Ambient pressure
- o Check Fernando's procedure.

6 TEST PARAMETERS

6.1   Test requirements

6.2   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.

6.3   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	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).

6.4   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:
- $\Delta T < 1$ °C/h
- dwell time = 2 h

7 STEP-BY-STEP TEST PROCEDURE

7.1 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!!		03/06/2021 11:45 12:10	FAA MSG	V_bat=24.44V (11:50h)

	• Assembly the new wiring for external battery charge. • Fix the ground connections (if needed). • Take photos of the connections.				
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)

Step #	Description	Expected Result	Date/Time	Sign	Comments
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.	T_{BP} = 31 °C T_{SHR} = 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			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)
			03/06/2021 13:55	FAA LPP	
65	• Meet the stabilization criteria in all temperature sensors (thermocouples, PT1000 and TC74). • Stop TBT HOC test. • Turn off the cubesat	$\Delta T < 1$ °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**.	$p \approx 84.09$ 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.	$T_{BP} = -10$ °C $T_{SHR} = -3$ °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)

Step #	Description	Expected Result	Date/Time	Sign	Comments
					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.	$\Delta T<1$ °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.				

8   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					

9   SPECIAL REMARKS

9.1   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		

9.2 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			