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| A logo of a dragonfly  Description automatically generated |

**BIRDS-X Project**

**Thermal Vacuum Test Report**

Kyushu Institute of Technology

Laboratory of Lean Satellite Enterprises and In-Orbit Experiments (LaSEINE)





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# Introduction

This document summarizes the result of the Thermal Vacuum Test for BIRDS-X DRAGONFLY satellites, DRAGONFLY, which will be deployed from JEM Small Satellites Orbital Deployer (J-SSOD-R).

# Applicable Document

(1) JX-ESPC-101132-E JEM Payload Accommodation Handbook-Vol. 8-

Small Satellite Deployment Interface Control Document

(2) ISBN 1-884989-11-X Spacecraft Thermal Control Handbook

(3) BIRDS-X RAS BIRDS-X Project Requirement Allocation Sheet

Table 2.1 Requirements from RAS to be satisfied by the test

|  |  |
| --- | --- |
| **Requirement Number** | **Requirement Description** |
| **N/A** | All the DRAGONFLY components/parts' temperature ranges shall be within the operating temperature ranges. |
| **DR 1** | The allowable internal temperature range shall be from -15ºC to 55ºC. |
| **DR 2** | The allowable external temperature range shall be from -40ºC to +80ºC. |
| **DR 3** | Temperature of the battery shall be monitored. |
| **DR 4** | Internal boards shall provide temperature data. |
| **DR 5** | The battery shall be kept within temperature range (0ºC to 40ºC). |

# Test method

The verification points are as follows,

1. Withstand the defined temperature conditions.
2. The satellite can operate under extremely high temperature conditions.
3. The satellite can operate under extremely low temperature conditions.
4. No breakage in glass material

# Test Objectives

DRAGONFLY is the objective of this thermal vacuum test. The flight model 3D model is shown in Figure 3.1-1. The actual flight model is shown in Figure 3.1-2.

|  |
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| A blue and black computer tower  Description automatically generated  Figure 3.1-1 DRAGONFLY flight model 3D model |

|  |
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| Figure 3.1-2 DRAGONFLY flight model |







# Temperature measurement point

The positions of thermocouples are summarized in Table 3.2.1.

Table 3.2.1 Positions of Thermocouples (K type)

|  |  |  |
| --- | --- | --- |
|  | **Position** | **Measurement Point** |
| **1** | Battery | On a battery cell |
| **2** | +X panel | Surface |
| **3** | -X panel | Surface |
| **4** | +Y panel | Surface |
| **5** | -Y panel | Surface |
| **6** | +Z panel | Surface |
| **7** | -Z panel | Surface |

Figure 3.2-1 to Figure 3.2-7 show the position of thermocouples attached to the satellite:

|  |  |
| --- | --- |
| A battery in a box  Description automatically generated  Figure 3.2-1 Battery cell | A machine with wires on a table  Description automatically generated  Figure 3.2-2 +X panel |
| A close up of a device  Description automatically generated  Figure 3.2-3 -X panel | A close up of a device  Description automatically generated  Figure 3.2-4 +Y panel |
| A machine with wires and wires  Description automatically generated  Figure 3.2-5 -Y panel | A blue rectangular device with black squares  Description automatically generated with medium confidence  Figure 3.2-6 +Z panel |
| A close up of a machine  Description automatically generated  Figure 3.2-7 -Z panel |  |

# Test Flow, Level, and Conditions

The chamber pressure should be kept below 1x10-3 Pa during all conditions of the thermal vacuum test. In this pressure range, heat exchange by molecular flow is negligible. Table 3.3.1 summarizes the originally planned and targeted temperature range and number of cycles of the test. In the experiment, a target of -20ºC and +60ºC were taken as control temperatures.

Table 3.3.1 Temperature range and number of cycles

|  |  |
| --- | --- |
|  | Target Temperature |
| Worst cold | -20ºC |
| Worst hot | +60ºC |
| Number of cycles | 1 |

* The test is conducted for one cycle (1 cold and 1 hot), as shown in Figure 3.3-1.
* Soaking time would be two hours, with functional testing at the extremely cold and hot temperatures of each cycle.
* There are 7 temperature measurement points, including 6 on the external panel.
* The monitoring/control temperature is one of the panels.
* The worst cold condition for the external panel is -20°C.
* The worst hot condition for the external panel is +60°C.

|  |
| --- |
| A diagram of a temperature profile  Description automatically generated  Figure 3.3-1 Thermal cycle profile as planned |

Figure 3.3-2 to Figure 3.3-5 are the test configuration.

|  |
| --- |
| A machine with wires and tubes  Description automatically generated  Figure 3.3-2 Small thermal vacuum chamber at CeNT |
| A diagram of a machine  Description automatically generated  Figure 3.3-3 Overall test set up |

|  |
| --- |
| Figure 3.3-4 Connection from COM-UHF transceiver board to GS equipment |
| A machine with wires and wires  Description automatically generated  Figure 3.3-5 Placement of the satellite inside the small thermal vacuum chamber |

# Heater Position

The thermal control of this test is performed by the heater jig installed in the chamber. DRAGONFLY is inserted inside the heater jig. Figure 3.4-1 shows the placement of the satellite inside the heater jig.

Table 3.4.1 Heater jig position, resistance, and power

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Heater Number | Position | Resistance (Ω) | Maximum Power (W) | Power Supply Number |
| H1 | +X | 7.1 | 100 | 6 |
| H2 | -X | 7.1 | 100 | 5 |
| H3 | +Y | 7.2 | 100 | 3 |
| H4 | -Y | 7.2 | 100 | 4 |
| H5 | +Z | 13.6 | 50 | 2 |
| H6 | -Z | 15.1 | 50 | 1 |

|  |
| --- |
| A machine with wires and wires  Description automatically generated  Figure 3.4-1 Heater position aligns with the satellite axis |

# Actual Test Flow

The actual test flow, estimated from the measured temperature profile, is summarized in Table 3.5-1.

Table 3.5-1 Actual test flow executed (estimated from measured temperature profile)

|  |  |  |  |
| --- | --- | --- | --- |
| Phase | | Duration  (Hours) | Time  (Hour) |
| Chamber closing, start of vacuuming | | - | 0  (= reference time) |
| Vacuuming, room temperature | | 12 | 12 |
| FT | | 2 | 14 |
| Cold Ramp 1 | Start | 3 | 17 |
| Cold Ramp 1 | Stop |
| FT |  | 2.5 | 19.5 |
| Hot Ramp 1 | Start | 1 | 20.5 |
| Hot Ramp 1 | Stop |
| FT | | 1.5 | 22 |
| Room temperature control | | 0.5 | 22.5 |
| FT trials in vacuum at room temperature | | 2 | 24.5 |
| De-vacuuming and recovery | | 1 | 25.5 |
| FT trials in atmospheric room condition | | 2 | 27.5 |

# Test Results

Date ：2024/2/20-2024/2/22

Location ：Center for Nanosatellite Testing

Laboratory of Spacecraft Environment Interaction Engineering

Kyushu Institute of Technology

* 1. Sensui, Tobata, Kitakyushu, 804-8550 Fukuoka, Japan

# Detailed Test Procedure

The detailed test procedures are shown in Table 4.1.1 with tasks that need to be done before, during, and after the test; the person in charge of each task should check the task once it is finished.

|  |
| --- |
| Verification |
| Preparation and checking the satellite and chamber |
| Make vacuum and conduct the thermal test and functional test |
| Stop the test, clean up and check the satellite |

Table 4.1.1 Detailed test procedure

|  |  |  |
| --- | --- | --- |
| **No.** | **Procedure** | **Check** |
| 0 | Verify all satellite functionalities and operation (preliminary, in clean room – SVBL 3F) | ✔ |
| 1 | Prepare and check thermocouples | ✔ |
| 2 | Prepare and check heaters | ✔ |
| 3 | Check chamber's heater connections | ✔ |
| 4 | Check chamber's thermocouple connections | ✔ |
| 5 | Check chamber's D-Sub and RF port connections | ✔ |
| 6 | Disassemble structure and center box | ✔ |
| 7 | Attach thermocouples and heaters to satellites | ✔ |
| 8 | Take photos and note the heaters and TCs’ positions and number | ✔ |
| 9 | Reassemble satellite and check thermocouples and heaters connection | ✔ |
| 10 | Check satellite functionalities | ✔ |
| 11 | Move satellite to the chamber | ✔ |
| 12 | Install the satellite in the chamber | ✔ |
| 13 | Check again all heaters and TCs’ response on the PC | ✔ |
| 14 | Check satellite functionalities | ✔ |
| 15 | Close the chamber | ✔ |
| 16 | Make vacuum | ✔ |
| 17 | Start cold ramp 1 | ✔ |
| 18 | Start cold soak 1 | ✔ |
| 19 | Satellite functional test | ✔ |
| 20 | Start hot ramp 1 | ✔ |
| 21 | Start hot soak 1 | ✔ |
| 22 | Satellite functional test | ✔ |
| 23 | Start ramp down to room temperature | ✔ |
| 24 | Satellite functional test at room temperature | ✔ |
| 25 | De-vacuuming | ✔ |
| 26 | Open chamber, move satellite to clean room | ✔ |
| 27 | Satellite functional testing | ✔ |
| 28 | Disassemble satellite | ✔ |
| 29 | Remove TCs and heaters | ✔ |

# Temperature data from measurement point

Temperature profile data are shown in Figure 4.2-1. The functional testing was conducted in each soak. The pressure in the chamber is less than 1×10-3 [Pa] during the entire testing period Figure 4.2-2.

|  |
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| Figure 4.2-1 Temperature plots of six external panels and battery throughout the thermal vacuum test |
| Figure 4.2-2 Pressure profile during the thermal vacuum test |

# Visual inspection

The visual inspection of the satellite is conducted after the test. No breakage is found in the satellite after the test. Also, there is no breakage in the solar cell cover glass. Test results are shown in Figure 4.3-1 to Figure 4.3-6

|  |  |
| --- | --- |
| A close up of a device  Description automatically generated  Figure 4.3-1 +X panel | A rectangular object with many panels  Description automatically generated with medium confidence  Figure 4.3-2 -X panel |
| A back of a machine  Description automatically generated  Figure 4.3-3 +Y panel | A close up of a machine  Description automatically generated  Figure 4.3-4 -Y panel |
| A hand holding a small square device  Description automatically generated  Figure 4.3-5 +Z panel | A close up of a device  Description automatically generated  Figure 4.3-6 -Z panel |

# Function Test

There is no failure or abnormal status on the voltage of the battery and health data of the OBC (On-Board Computer) after the environment test. The satellite has no damage from the environment test.

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| A computer on a table  Description automatically generated  Figure 4.4-1 Functional test configuration |

# Conclusion

CubeSat was performed to thermal vacuum tests at temperatures ranging from -20°C to 60°C and functional tests at worst-cold and worst-hot temperatures.

No malfunction occurred during and after the thermal vacuum test. Based on visual inspection after the thermal vacuum, no solar cell cover-glass breakage was found, either. No malfunction occurred to the CubeSat in the functional test after the thermal vacuum test.

The test temperature envelopes the required environmental temperature (-15°C to 60°C). Therefore, the CubeSat can withstand the required environmental temperatures.