

Kyushu Institute of Technology
Department of Applied Science for Integrated System Engineering



BIRDS-X Project

Vibration Test Report

B: 2024/03/21

Revision History

Date	Version Number	Writer	Annotation
2024/03/16	A	Tasuku Matsui	Initial Release
2024/03/21	B	Jorge Casir	Added results/revision

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1. Purpose

This document summarizes the results of the Vibration Test for BIRDS-X which will be deployed from JEM Small Satellites Orbital Deployer-R (J-SSOD-R).

2. Applicable Document

- | | |
|-------------------------|---|
| (1) JX-ESPC-101132-E | JEM Payload Accommodation Handbook-Vol.8-
Small Satellite Deployment Interface Control Document |
| (2) JMX-2011303
JAXA | Structure Verification and Fracture Control Plan for
Selected Small Satellite Released from J-SSOD |
| (3) 15_BIRDS-X-FCE-02 | Structure Fracture Control Evaluation Form for
Small Satellite deployed from J-SSOD |
| (4) 16_BIRDS-X-SAR-02 | BIRDS-X Flight Safety Assessment Report
for phase III |

3. Test method

The verification points are as follows,

- (1) No breakage in main structure
- (2) Main structure needs to satisfy specified natural frequency
- (3) Natural frequency before and after tests need to remain unchanged
- (4) No improper antenna deployment, and no malfunction to CubeSat
- (5) No breakage in glass material
- (6) No loosening in all fasteners

3.1. Test Objectives

Table 3.1-1 Test Articles

	Article name	Number	Manufacturer
1	DRAGONFLY	1	HMD
2	3U Pod	1	HMD
3	1U Dummy	1	HMD

3.2. Acceleration measurement point

The acceleration measurement points are shown in Figures 3.2-1 to 3.2-3 and Table 3.2-1. “Ch.○” are acceleration measurement points for data acquisition. “Control point ○ (CP○)” are acceleration measurement points for average value control for the vibration machine.

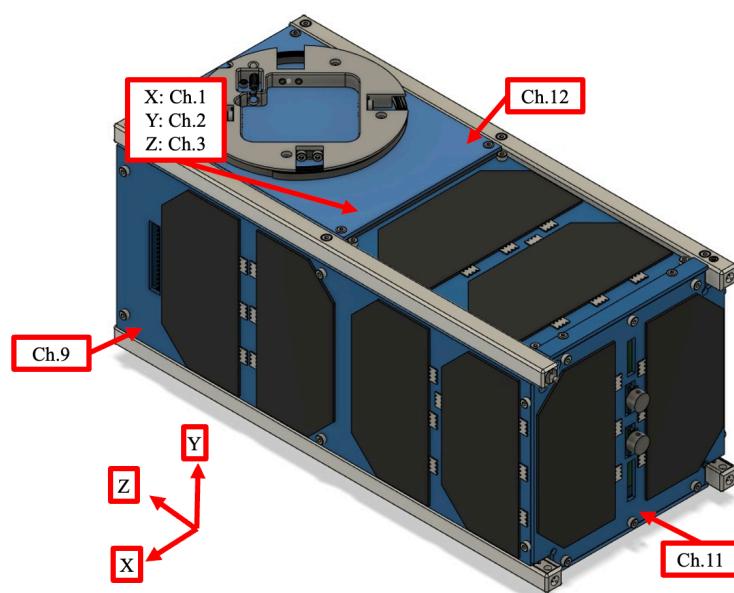
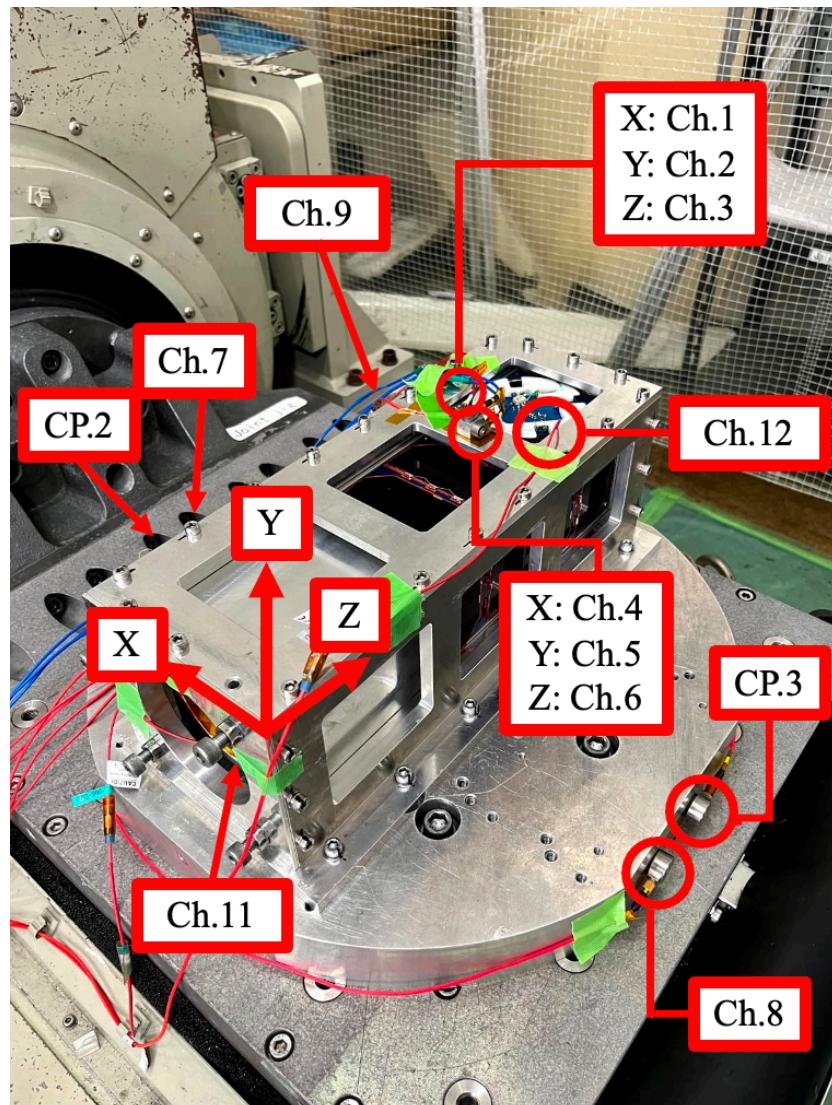


Figure 3.2-1 Acceleration measurement point (X-axis) in DRAGONFLY test.

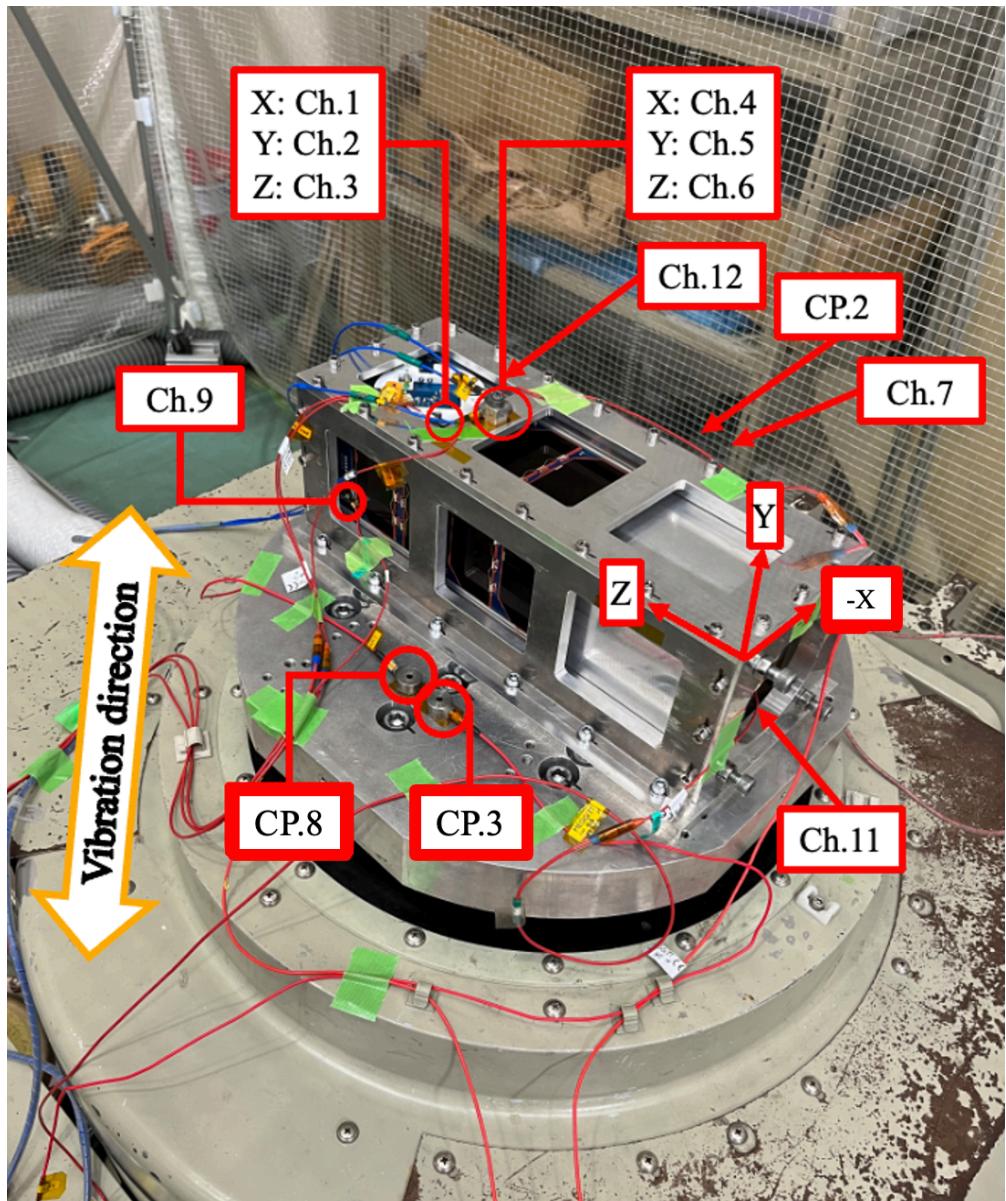


Figure 3.2-2 Acceleration measurement point (Y-axis) in DRAGONFLY test.

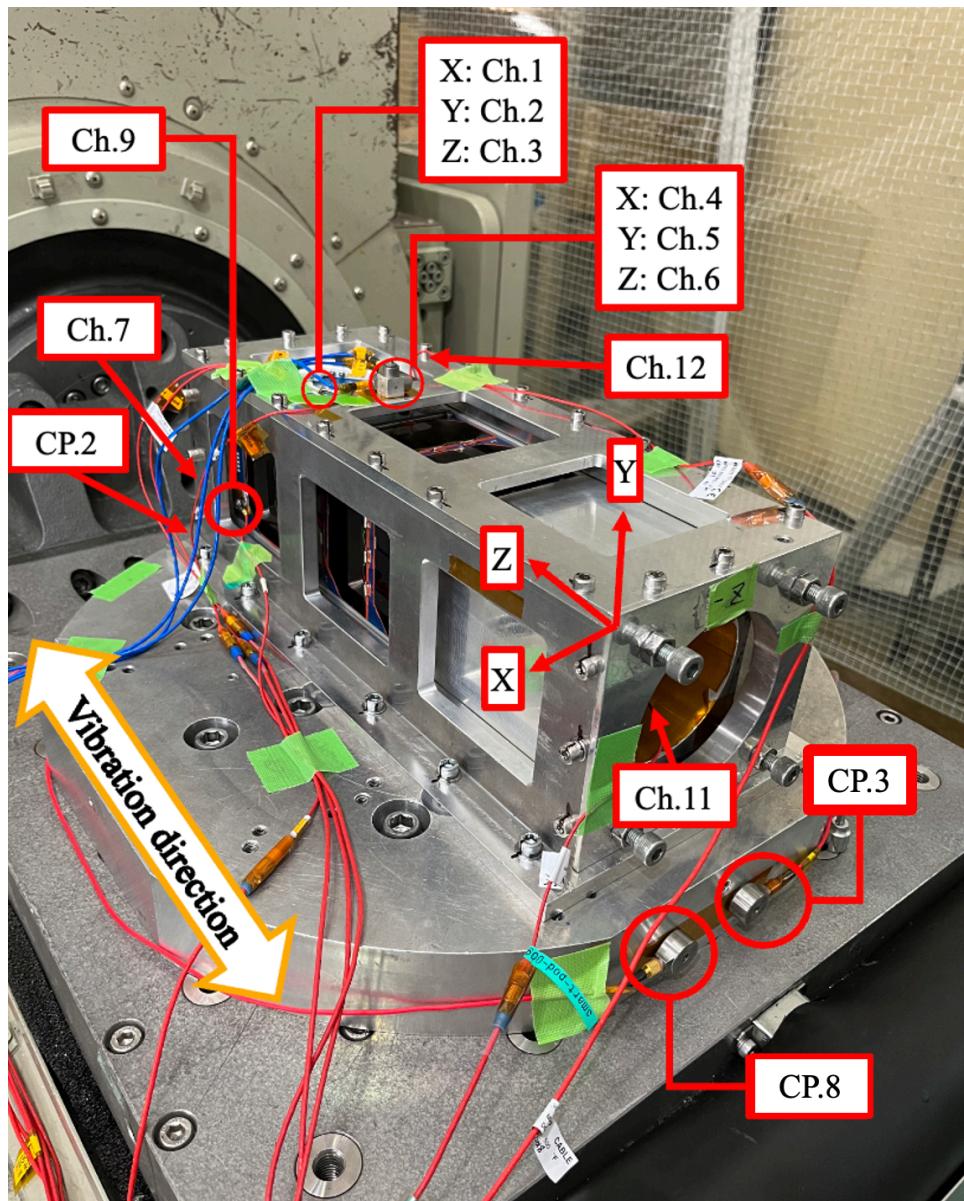


Figure 3.2-3 Acceleration measurement point (Z-axis) in DRAGONFLY test.

Table 3.2-1 Acceleration measurement point

a) DRAGONFLY test

Measurement point	Measurement axis	Acceleration sensor	CH	Note
Control Sensor	1-axis	EM15	CP2	
	1-axis	EM13	CP3	
Jig	1-axis	EM16	Ch.7	
	1-axis	EM17	Ch.8	
DRAGONFLY	X	en04	Ch.1	
		smart-pod-010	Ch.9	
	Y	en05	Ch.2	
		smart-pod-007	Ch.12	
	Z	en06	Ch.3	
		smart-pod-009	Ch.11	
Pod	X	tt02	Ch.4	
	Y	tt01	Ch.5	
	Z	tt03	Ch.6	

3.3. Test Contents

Following vibration tests were performed along X, Z and Y axes, respectively.

- (1) Low level white noise vibration (Modal survey)
- (2) Random vibration

3.4. Vibration Test Level

- (1) Low level white noise vibration (Modal Survey)

Modal survey test parameters are described in Table 3.4-1

Table 3.4-1 Modal survey vibration environment

	Frequency [Hz]	Acceleration [Grms]	Time [sec]
Each axis	20~2000	0.5	60

(2) Random Vibration

The random vibration test level is shown in Table 3.4-2, the level is the envelope of the environments for HTV-X, Dragon and Cygnus (reference: JX-ESPC-101132-E). This test level was defined by Structure Fracture Control Evaluation Form.

Table 3.4-2 Random vibration test level
(Envelope of the environments for HTV-X, Dragon and Cygnus)

Freq. [Hz]	PSD [G ² /Hz]
20	0.025
30	0.025
40	0.015
41.3	0.015
50	0.02
120	0.031

230	0.031
858.3	0.0055
1200	0.0055
2000	0.0025
Overall	4.28Grms
Duration	60 sec/axis
Direction	axes each

3.5. Test Tolerance

<Random Vibration Test>

- (a) Overall [Grms] : $\pm 1.5\text{dB}$
- (b) PSD [G^2/Hz] : $+3.0\text{dB} / -1.0\text{dB}$
- (c) Frequency [Hz]: larger one of $\pm 2\%$ or 1 [Hz]
- (d) Duration [sec]: $+10\% / -0\%$

3.6. Test Sequence

Table 3.6-1 shows the test sequence.

Table 3.6-1 Test Sequence

	Test Contents	Test ID
Before vibration test	Visual inspection of satellite	
X-axis test	Satellite setup	
	Modal survey	1-modal
	Random vibration test	2-random
	Modal survey	3-modal
	Axis change	
Z-axis test	Modal survey	4-modal
	Random vibration test	5-random
	Modal survey	6-modal
	Axis change	
Y-axis test	Modal survey	7-modal
	Random vibration test	8-random
	Modal survey	9-modal
	Visual inspection of satellite	
After vibration test	Function test of satellite	

4. Test Results

Date: 2024/03/15

Location: Center for Nanosatellite Testing (CeNT)

Laboratory of Lean Satellite Enterprises and In-Orbit Experiments

Kyushu Institute of Technology

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

4.1. Visual inspection

The visual inspection for the satellite was conducted before and after the test. No breakage was found in the satellites after the test. No deformation and damage were seen on the deployment switches. Also, no breakage in the solar cell cover glass. No loosening was found in all fasteners. There was also no inadvertent antenna deployment during and after the vibration. After the vibration test, the knot of the wire restraining the antenna was not loosened, and the wire was not damaged or stretched. No malfunction occurred to CubeSat, either. No scratches or cracks of any significance were found on the structural components, panels, and glass parts. Test results show in Table 4.1-1 and Figure 4.1-1 to Figure 4.1-18.

Table 4.1-1 Inspection Result

	Part Name	Quantity	Inspection Result
1	DRAGONFLY		
1-1	External panel	6	Pass
1-2	Solar panel cover glass	16	Pass
1-3	Torque mark	92	Pass
1-4	Antenna mechanism	2	Pass

a) DRAGONFLY

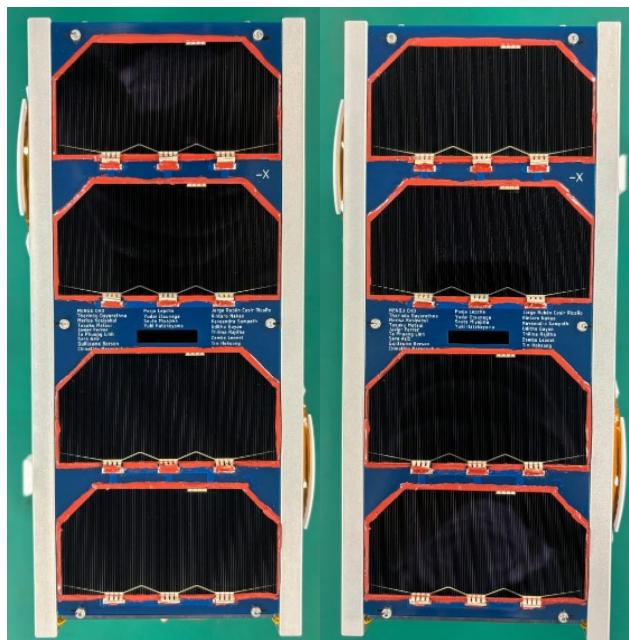


Figure 4.1-1 Photo on the +X surface (Left: before test Right: after test)

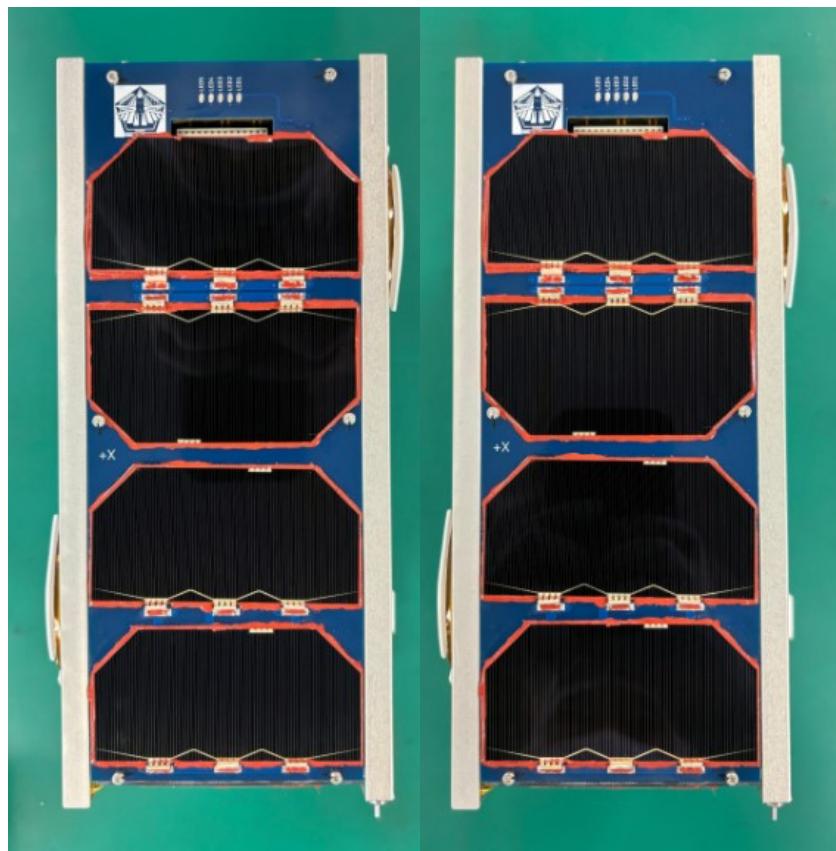


Figure 4.1-2 Photo on the -X surface (Left: before test Right: after test)

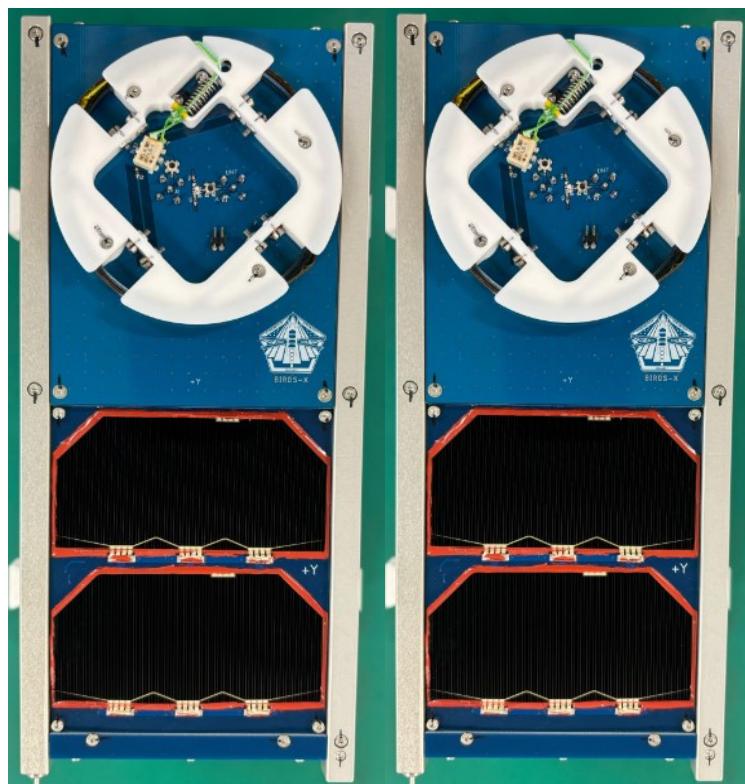


Figure 4.1-3 Photo on the +Y surface (Left: before test Right: after test)

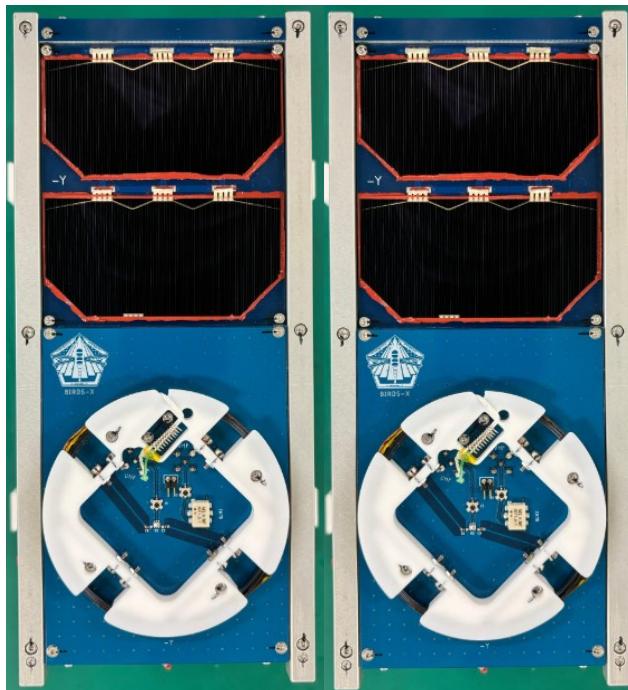


Figure 4.1-4 Photo on the -Y surface (Left: before test Right: after test)

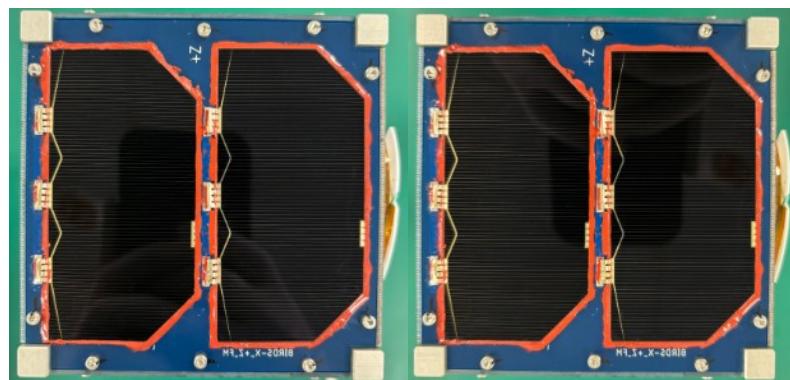


Figure 4.1-5 Photo on the +Z surface (Left: before test Right: after test)

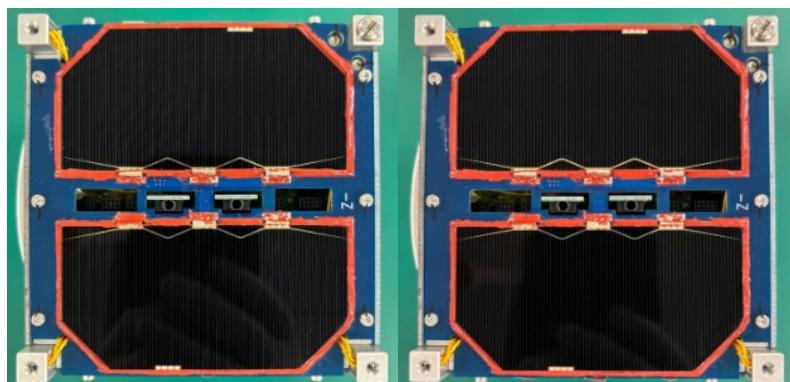


Figure 4.1-6 Photo on the -Z surface (Left: before test Right: after test)

4.2.Random Vibration Test

4.2.1. X-axis vibration

The required acceptance level of vibration was met by the vibration machine. Test results show in Figure 4.2.1-1 to Figure 4.2.1-2.

In the modal survey before and after the random vibration, the resonant frequency was 284 Hz and 283 Hz, respectively. There is no significant change in the minimum natural frequency before and after the random vibration. It is 30Hz or higher and meets the requirements.

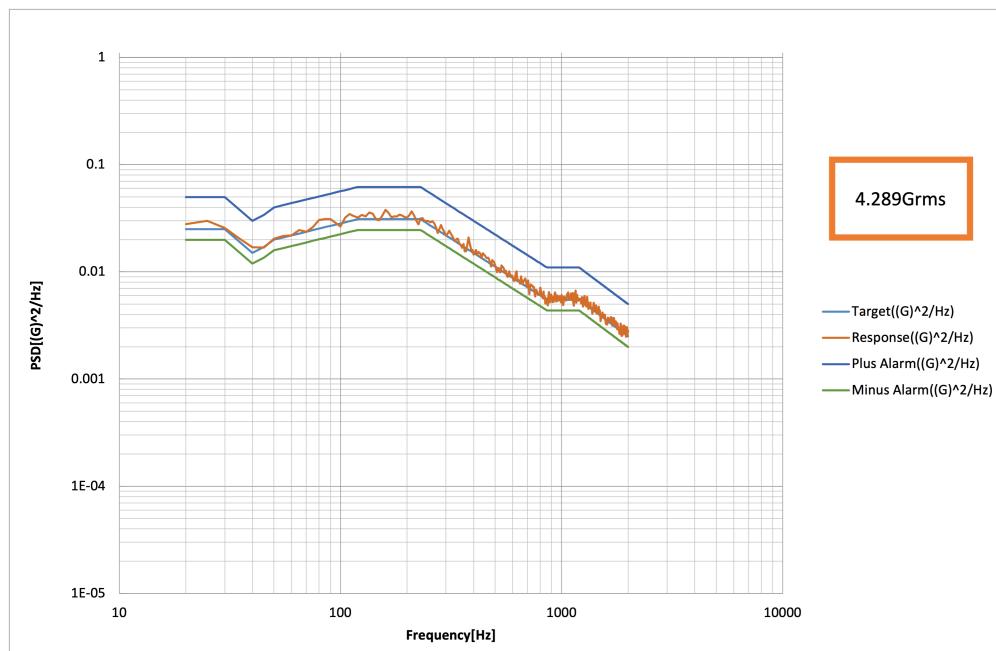
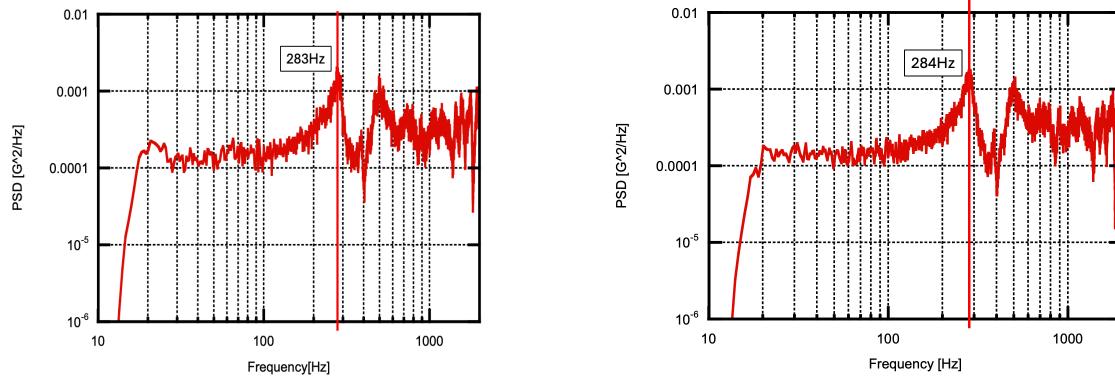


Figure 4.2.1-1 X-axis random vibration at Control Sensor



**Figure 4.2.1-2 Modal Survey before Vibrating X-axis at Mesurement Point (Ch.1)
(Left: before, Right: after)**

4.2.2. Z-axis vibration

The required acceptance level of vibration was met by the vibration machine. Test results show in Figure 4.2.2-1 to Figure 4.2.2-2.

In the modal survey before and after the random vibration, the resonant frequency was 314 Hz and 315 Hz, respectively. There is no significant change in the minimum natural frequency before and after the random vibration. It is 30Hz or higher and meets the requirements.

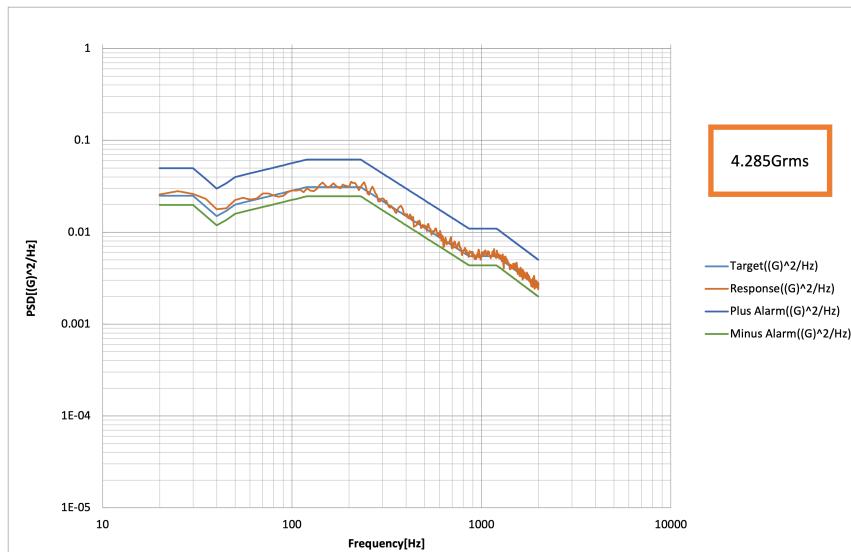
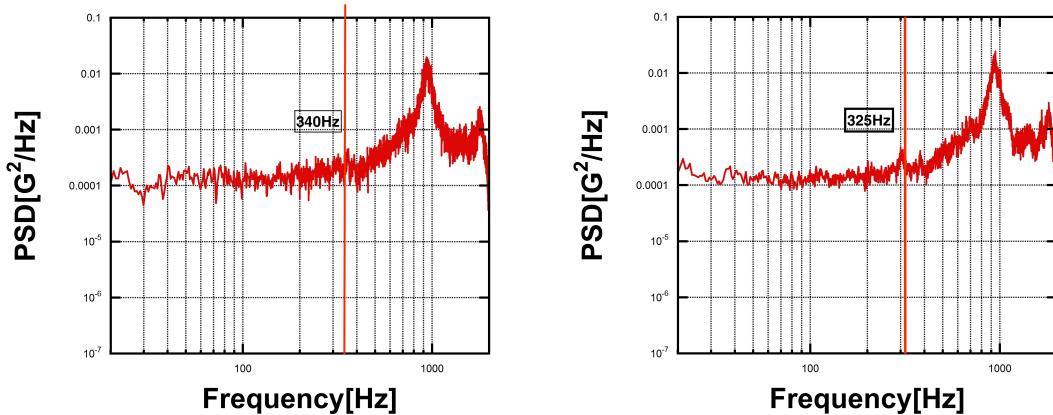


Figure 4.2.2-1 Z-axis random vibration at Control Sensor



**Figure 4.2.2-2 Modal Survey before Vibrating Z-axis at Mesurement Point (Ch.3)
(Left: before, Right: after)**

4.2.3. Y-axis vibration

The required acceptance level of vibration was met by the vibration machine. Test results show in Figure 4.2.3-1 to Figure 4.2.3-2. In the modal survey before and after the random vibration, the resonant frequency was 320 Hz and 321 Hz, respectively. There is no significant change in the minimum natural frequency before and after the random vibration. It is 30Hz or higher and meets the requirements.

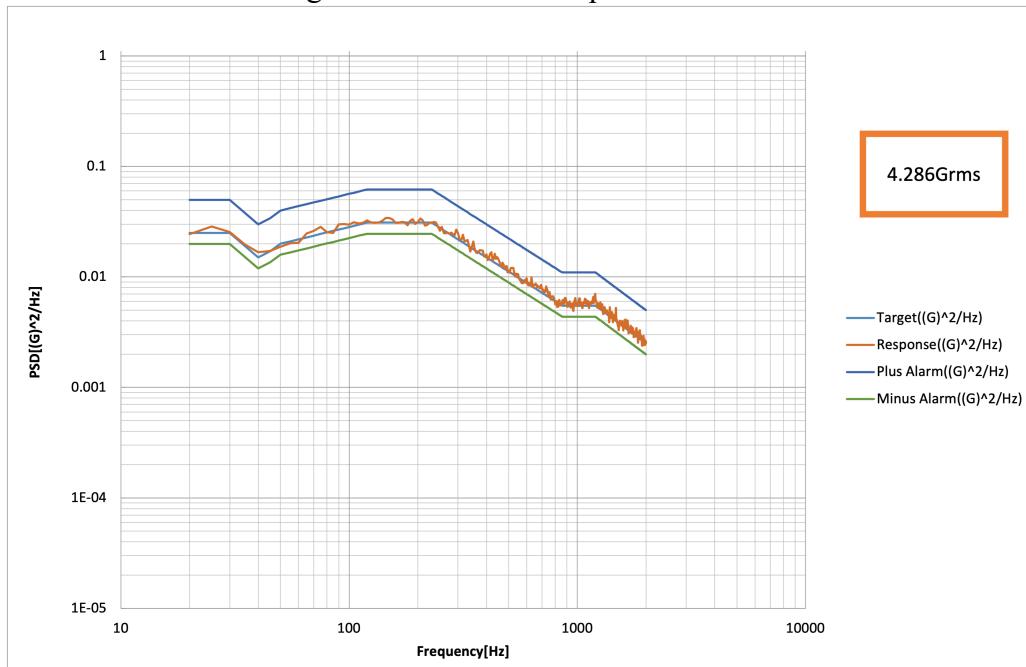


Figure 4.2.3-1 Y-axis random vibration at Control Sensor

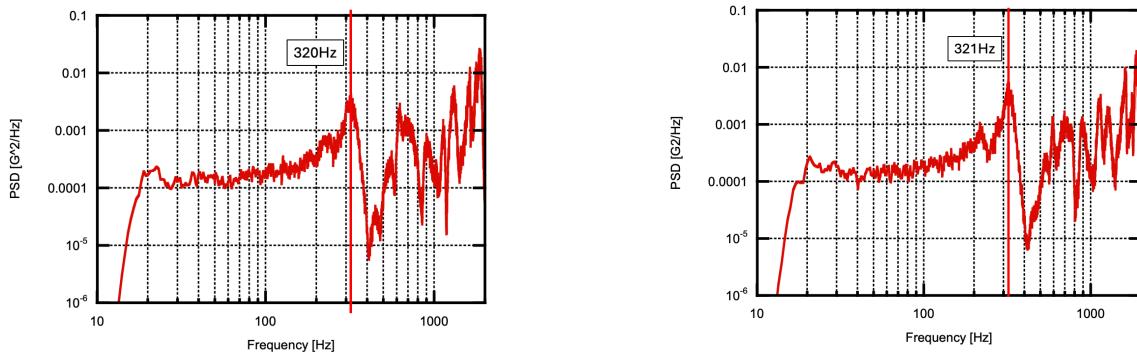


Figure 4.2.3-2 Modal Survey before Vibrating Y-axis at Mesurement Point (Ch.12)
(Left: before, Right: after)

4.3.Function Test

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

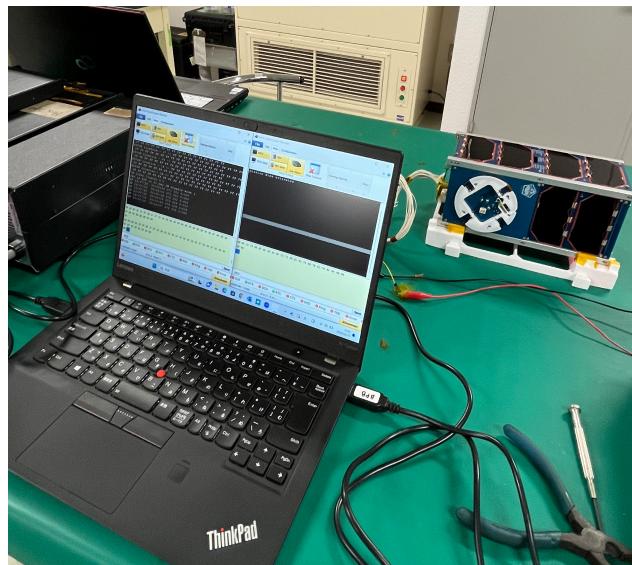


Figure 4.3-1 DRAGONFLY: When DepSW1 was released, SepSW3 got closed, and the battery supplied power to the load.

5. Conclusion

No distortion or damage was found on the BIRDS-X flight model. No loosening was found in the fasteners which constitute a main structure. Moreover, no breakage, scratching, or cracking of the external panels, the solar cell cover glass, or structural components were found based on visual inspection after the vibration.

The minimum natural frequency of each axis is 30Hz or higher, which meets the requirements. The measured satellite's minimum natural frequency did not change significantly before and after the random vibration test.

There was no inadvertent antenna deployment during and after the vibration. The knot of the wire restraining the antenna was not loosened, and the wire was not damaged or stretched.

No malfunction occurred to CubeSat, either.

In conclusion, the results of the vibration test show that the DRAGONFLY flight model has successfully passed all requirements and is ready to launch.

No	Verification Items	Results
1	DRAGONFLY	
1-1	No breakage in main structure	Pass
1-2	Main structure needs to satisfy specified natural frequency	Pass
1-3	Natural frequency before and after tests need to remain unchanged	Pass
1-4	No improper antenna deployment, and no malfunction to CubeSat	Pass
1-5	No breakage in glass material such as solar cell cover	Pass
1-6	No loosening in all fasteners as stated in the structural analysis report and is listed below: #1-1 to #1-10, #2-1 to #2-6,#3-1 to #3-6,#4-1-#4-6,#5-1-#5-6, ,#6-1-#6-12,#7-1-#7-4,#8-1-#8-2, #9-1-#9-6, #10-1-#10-12, #11-1-#11-4, #12-1-#12-2, #13-1-#13-13, #14-1-#14-3 The screws are represented in fig 5.5.3-1 to 5.5.3-9	Pass

Satellite	Natural Frequency (Hz)		
	a. Pre-Modal	b. Analysis	a/b
DRAGONFLY	X	283	258.4
	Y	320	273.8
	Z	340	293.1