ARLISS 2022 **report**

Submission date: November 21, 2022

• **Team information**

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CanSat class	Open class

• **Members**

role	**Name (grade)**
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Electrical equipment (mission system)	**Sorasen** Hamashita (B3)
Electrical equipment (sensor/power system)	**Kotaro** Hori (B3)
Electrical equipment (C&DH system)	**Taku** Yamamoto (B3)

• **CanSat production purpose/reason for participation in the competition**

To learn system engineering and project management through CanSat production. Every year, we The group Saharakan participated in ARLISS during their second year as undergraduates, but last year they lost due to the impact of the new coronavirus. Due to this, the competition was not held, so I decided to participate this year.

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Chapter 1 **Mission Statement**

Reach the goal after demonstrating the obstacle avoidance system using a slave device

In recent planetary satellite exploration, in order to perform detailed observations, not only observations from orbiters but also celestial bodies have been The method used has been to land a rover-type probe on the surface and survey the surface while moving. Obstacles such as uneven surfaces and rocks act as obstacles when a rover-type probe performs an exploration. In order to avoid these obstacles, **NASA's Mars** exploration rovers **Perseverance and Curiosity have adopted a method of taking photos of the surface, transmitting them to Earth, and determining the route after human analysis. Interplanetary communication and analysis require time. Another problem is that the images are taken using a rover-mounted camera, which means that only a portion of the earth's surface can be seen.**

Various methods have been tested for obstacle avoidance missions in CanSat, such as ACTS and ARLISS . Methods include a method of deploying a structure equipped with a camera from a CanSat into the sky to take pictures, a method of using two rovers to take pictures of the ground surface, and a method of mounting a camera on the body of a rover-type CanSat to take pictures of the ground surface. **there were. Most of these conventional methods take images from a camera mounted on CanSat, so the shooting altitude is only a few tens of centimeters at most , and only** convex obstacles that are partially present at a short distance are captured. **could not. Therefore, in this mission, we will demonstrate obstacle avoidance using a rover-type master unit and a drone-type slave unit. By using a drone-type handset, it is possible to photograph a wide range of uneven obstacles called ruts from several meters above the ground, and the captured images are processed by the computer installed in the rover-type main unit. We believe that this will make up for the shortcomings of conventional methods. At the site, the slave unit is separated from the rover-type parent unit, takes off based on commands from the parent unit, and photographs the ground surface from the air. Images are then sent from the child device to the parent device, analyzed on the CanSat-equipped computer, and the route to the goal is determined. After that, the parent machine runs toward the goal. The sequence is performed in an environment without human intervention. The following is the mission sequence (Figure** 1.1).

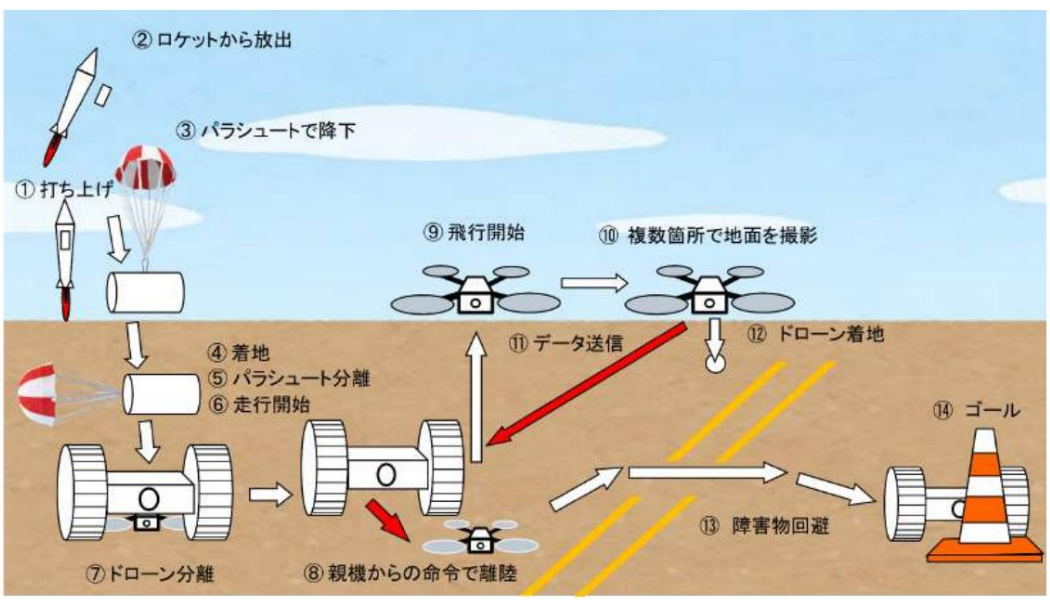


Figure 1.1 **Mission sequence**

Chapter 2 **Success Criteria**

The success criteria for this mission are as follows.

minimum success	1. **The handset used for obstacle avoidance was able to start up and worked.** 2. **I was able to confirm the presence of obstacles.**
middle success	**Not set**
full success	**Based on information from the child device, the parent device appropriately judges the course and determines the goal.**
advanced success	**0m goal**

Obstacles in this mission are defined as "ruts" (plants etc. are not defined as obstacles). On the day of launch, even if the mission lands on an area with no tracks, this mission is a demonstration of the obstacle avoidance system, and obstacles are not necessarily required, so if the presence or absence of obstacles can be determined, minimum success can be achieved and appropriate course decisions can be made. Full success was achieved if the goal could be determined using the GNSS sensor. Furthermore, after achieving full success, we performed terminal guidance using image analysis, and if we were able to achieve the 0m goal, we considered advanced success to be achieved. The evaluation of Advanced Success will be based on the distance meas

Chapter 3 **Setting requirements**

3.1 **System requirements (requirements for ensuring safety and regulation)**

Request number	System requirements (ARLISS launch safety standards)
The mass of S1 CanSat must be less than 1050g	
S2 **CanSat size must be less than 146mm in diameter and 240mm in height**	
Quasi-static load (10G) during S3 **launch impairs functionality to meet safety standards** **Tests have confirmed that this is not the case.**	
Vibration load during S4 launch (15G **or equivalent random vibration with** sine wave 30~2000Hz) **Therefore, it has been confirmed through testing that the functionality required to meet safety standards is not impaired.**	
Tests have confirmed **that the impact load (40G) during** S5 rocket separation (when the parachute is deployed) **does not impair functionality to meet** safety standards.	
S6It **has a deceleration mechanism to prevent it from falling at dangerous speeds near the ground, and its performance has been confirmed through tests. I am able to recognize**	
S7 **Components installed on CanSat need to function even after landing impact**	
It is necessary to devise ways to reduce power consumption while waiting for S8 launch.	
It has been confirmed that it is possible to comply with the regulations for turning off the power of radio equipment at the time of S9 launch (devices that are FCC **certified** and have a power output of 100 mW or less do not need to be turned off. Also, when using a smartphone, **FCC certified and can be turned off with a software or hardware switch)**	
Measures against S10 **lost have been implemented, and their effectiveness has been confirmed through testing.**	
S11 **It is necessary that the deceleration mechanism does not become entangled when landing.**	
S12 **CanSat needs to separate the deceleration mechanism after landing**	
S13It **is necessary to acquire location information and extract the information necessary to guide you to the goal.**	
To prevent S14 **loss, it is necessary to be able to receive data from CanSat at multiple ground stations.**	
Need to guide S15 CanSat to the goal	
A separation mechanism is required to separate the S16 slave unit.	
Separation control is required to separate S17 slave units	

S18 **handset needs to observe obstacles from the air**
S19Observation **equipment that can detect obstacles is required.**
It is necessary to recognize obstacles using software based on data from the S20 observation device.
It is necessary to be able to understand the positional relationship between S21 **CanSat and obstacles.**
S22 **Communication is required to share obstacle information**
It is necessary for the S23 **base unit to guide the user to avoid obstacles.**
A motor is required to rotate the tires used to move to the S24 goal point.
S25 **CanSat needs to detect stuck**
Even if S26 **CanSat gets stuck, it is necessary to return to the original running state.**
S27 **CanSat needs to determine the goal and stop running**
S28 CanSat **must be able to provide power for proper operation**
If the S29 **main unit loses power due to vibration or shock, it is necessary to be able to continue the mission even if it returns again.**
It has been confirmed that autonomous control without human intervention will be implemented during the S30 mission.
S31 CanSat, which has been designed to satisfy S1-S31 , has been able to conduct end-to-end tests that simulate **the** loading of the rocket, the start of the mission, and recovery after launch. **No major design changes**
Must be willing and able to adjust the S32 radio channel.

3. 2 **mission request**

number	Mission requirements
M1	**A device is required to separate the handset for** obstacle detection.
M2	**Control is required to separate the handset for** obstacle detection
M3	Observation is required for the **slave unit and base unit to detect obstacles.**
M4	Control is required for **handset to detect obstacles**
M5	Guidance is required for the **base unit to avoid obstacles.**
M6	**It is necessary for the** slave device and the parent device to work together.
M7	**CanSat needs to obtain location coordinates**
M8	**CanSat must be able to complete its mission even after landing impact**
M9	**Guidance is required from the** drop point to the goal.
M10	**We need to provide the** CanSat with enough power to complete its mission.
M11	**CanSat needs to escape when stuck**
M12	**It is necessary to be able to check the log after completing the** mission.
M13	The **child unit needs to detect the parent unit and obstacles from a high place.**
M14	The base unit needs to move on the ground to avoid **obstacles**
M15	**It has been confirmed that autonomous control without human intervention will be implemented during the** mission.
M16	After the **mission, the specified control history report was submitted to the management and examiners and logged/obtained. Data can be explained**

Chapter 4 **System Specifications**

4.1 **Exterior of main unit**

Since this mission is to avoid obstacles and reach the goal using a child device (drone), the structure has two wheels. It is a rover-type CanSat with a small drone mounted in the center of the CanSat. The appearance of the aircraft is shown below. show.

Figure 4.1 **Front view of the aircraft**

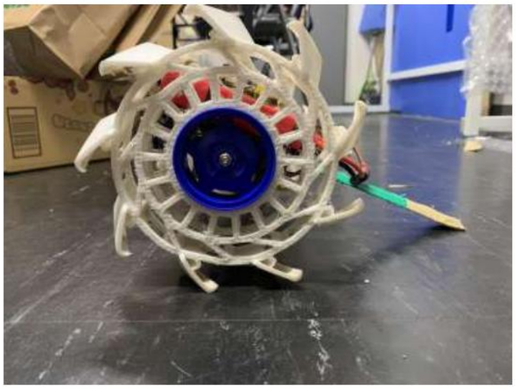


Figure 4.2 **Side view of the fuselage**

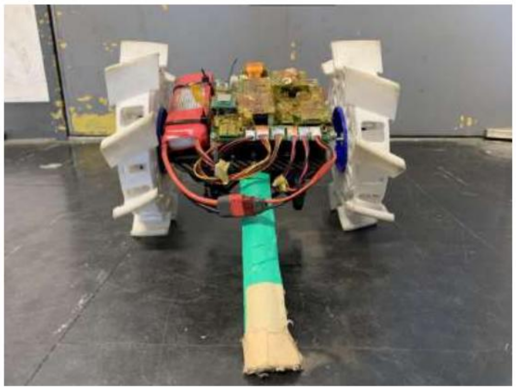


Figure 4.3 **Underside of the fuselage**

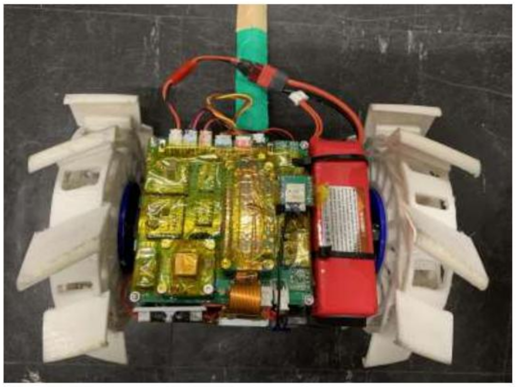


Figure 4.4 **Top view of the fuselage**

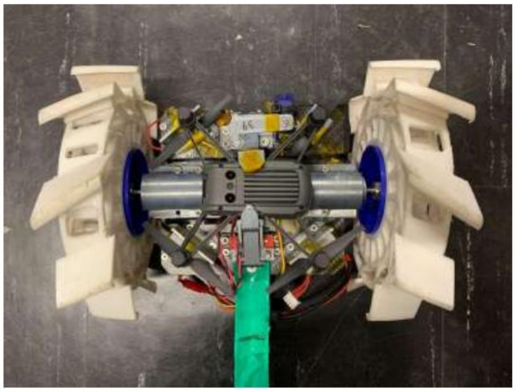


Figure 4.5 **Underside of the aircraft (when no handset is installed)**

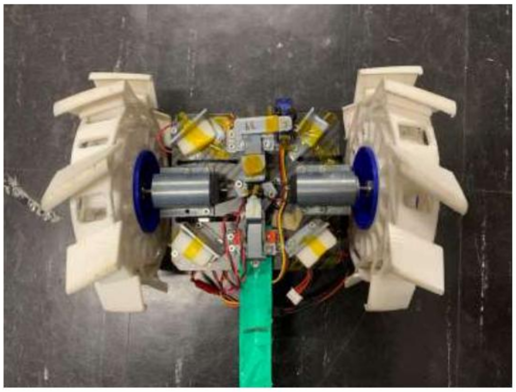


Figure 4.6 **Underside of the fuselage (when equipped with child unit)**

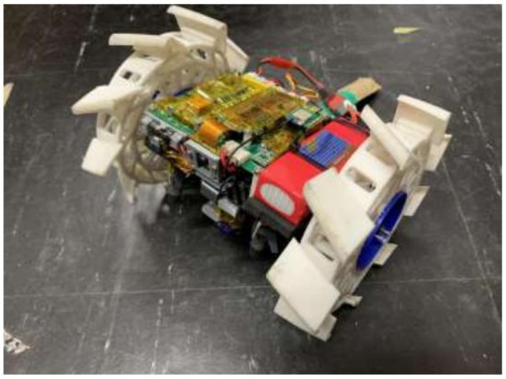


Figure 4.7 CanSat bird view map

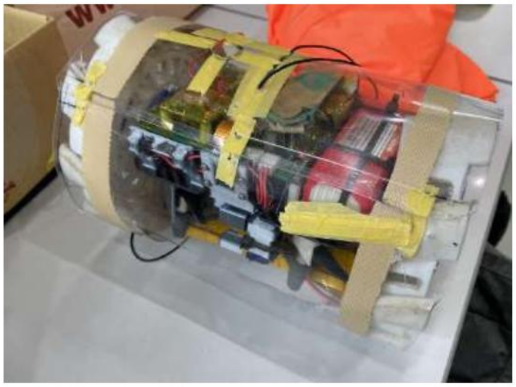


Figure 4.8 **Bird's eye view (with inner carrier stored)**

The tires were integrally molded using a 3D printer. The material is highly flexible TPU, and the aircraft can be stored in a parapet when stored.

By pressing the diameter with the inner carrier that connects the chute, the diameter can be kept below 146mm, and when the inner carrier is expanded, the diameter will be 186mm.

Become. In terms of structure, a two-layer structure was adopted to protect the handset. A gap is created between the first and second layers, and the second layer on the outside is used when landing. The first layer on the inside has a structure that minimizes deformation in order to protect the handset. Furthermore, there is a screw-like structure on the surface that contacts the ground. By mounting the grip diagonally on the handle, it has a structure that makes it easy to escape when stuck.

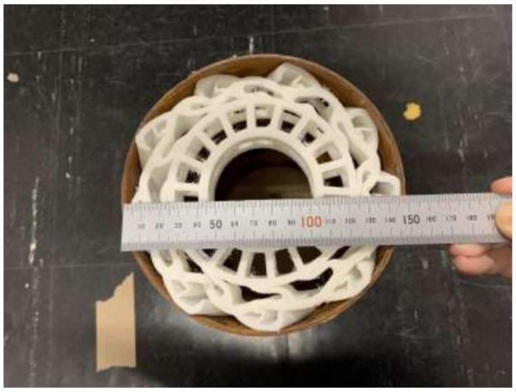


Figure 4.9 **Tire side (when stored)**

Figure 4.10 **Tire side (when unfolded)**

Table 4.1 Aircraft dimensions and weight when deployed (excluding parachute)

Diameter [mm]	**186**
Height [mm]	**220**
Mass [g] **(including drone)**	**1047**

4.2 Exterior of handset

The slave device used for this mission is the commercially available Tello drone developed by Rize Tech with technical cooperation from DJI and Intel.
be. There is a power button on the side of Tello (Figure 4.11), a camera mounted on the front of the aircraft (Figure 4.12), and sensors on the bottom of the aircraft.
(Figure 4.13).

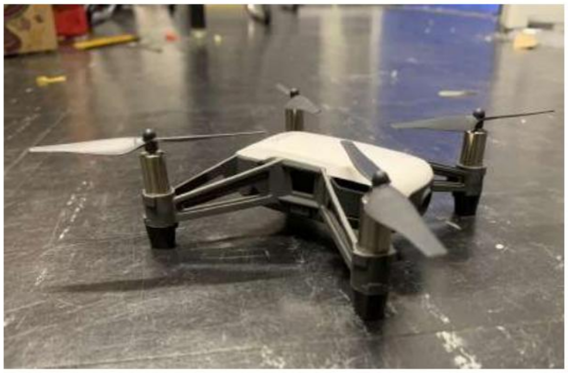


Figure 4.11 Side view of the fuselage

Figure 4.12 Front of the aircraft

Figure 4.13 Underside of the fuselage

Figure 4.14 Appearance of slave unit (left) and base unit (right)

Table 4.3 below shows an overview of the slave units. Since the weight of the aircraft is 80[g], it can be used in the United States without registration.
It is Noh. Since the maximum flight time is 13 [min], we plan to take several photos.

Table 4.3 Overview of slave units

Aircraft weight [g]	80
Size [mm]	150×150×41
camera	5MP photo shooting possible
Maximum speed [m/s]	8
Maximum flight time [min]	13
Maximum flight distance [m]	100

4.3 **Aircraft interior/mechanism •**

Nichrome wire separation

mechanism When separating the inner carrier from the aircraft after landing, the nylon thread is fused with a nichrome wire. Figure **4.15 shows the nichrome wire separation mechanism . The parts produced with a 3D printer are fixed to the CFRP board of the aircraft, and nichrome wire (thick yellow wire) is hooked onto the claws to secure them. Form the nichrome wire into a spiral shape. Then thread the nylon thread (thick blue line) through the nichrome wire (Figure** 4.15 left).

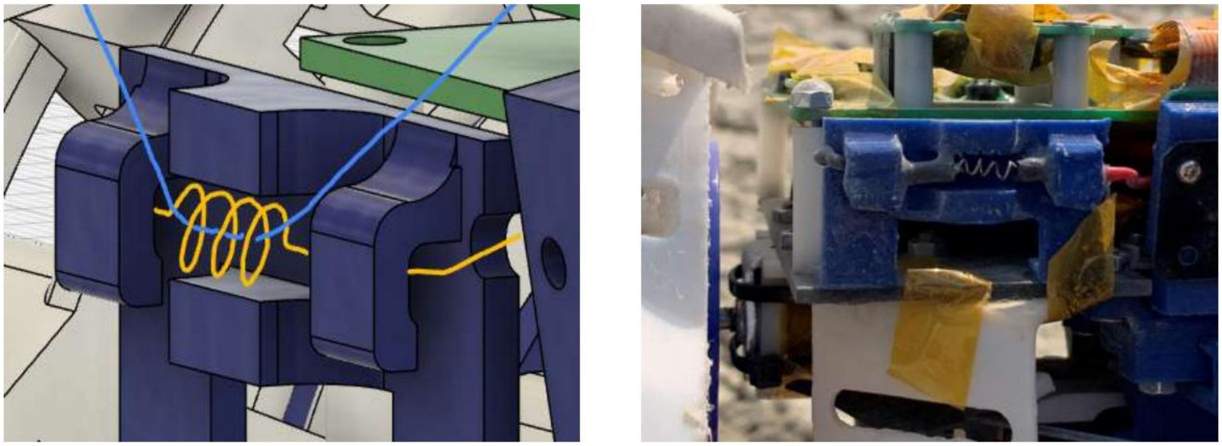


Figure 4.15 **Nichrome wire separation mechanism**

• **Drone power-on mechanism This**

is the mechanism attached to the side of the drone that turns on the power of the drone. The situation is shown in Figure 4.16. The 3D printed part fixed to the servo motor rotates in the direction of the yellow arrow around the yellow circle, and presses the power button on the side of the drone.

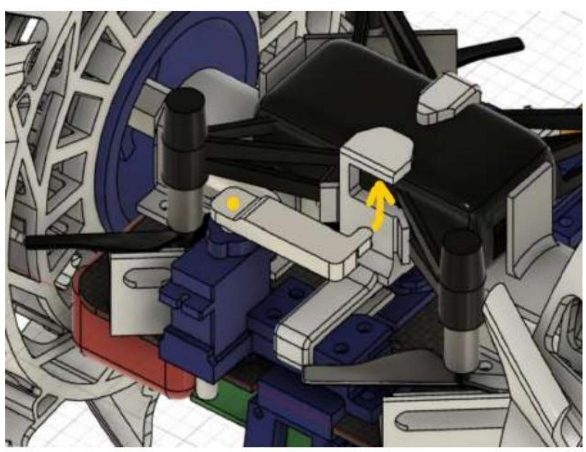


Figure 4.16 **Drone power-on mechanism**

• **A video showing how the prototype works. YouTube video**

URL: https://youtu.be/MC071pbsLA4

• **Drone separation mechanism**

• **This is a mechanism that separates the drone from the CanSat body.** Figure 4.17 **shows the situation when the drone is installed, and Figures** 4.18 to 20 show the situation when the drone is not installed. **A servo motor is attached to the center, and its rotation is converted into horizontal force to open the arm like a crane game arm (Figure 4.20) . This causes the drone to fall to the ground under its own weight.**

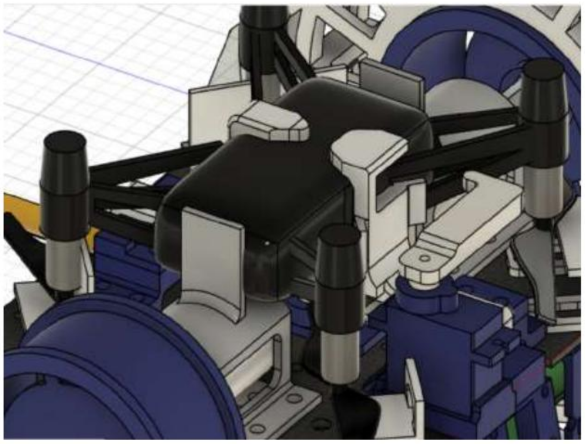


Figure 4.17 Drone separation mechanism (when equipped with a drone)

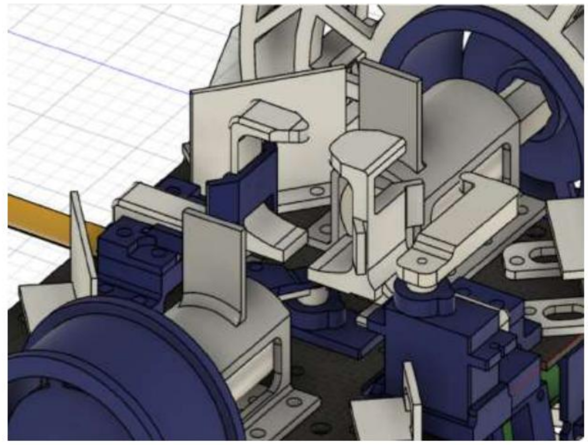


Figure 4.18 **Drone separation mechanism (after drone separation)**

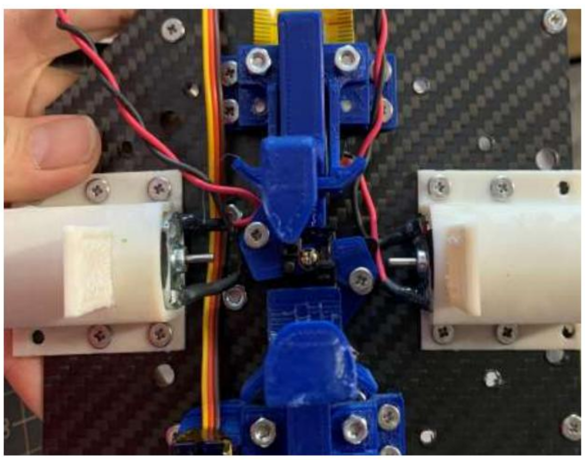


Figure 4.19 **Drone separation mechanism (from top)**

Figure 4.20 **Drone separation mechanism (rotating part)**

• **A video showing how the prototype works. YouTube video URL:** https://youtu.be/xKcMKSkoQ-o

• **This video shows the series of operations of the drone power-on mechanism and drone separation mechanism. YouTube video URL:** https://youtu.be/M5CnhrKa370

4.4 **Electrical equipment**

Figure 4.19 below shows the system block diagram.

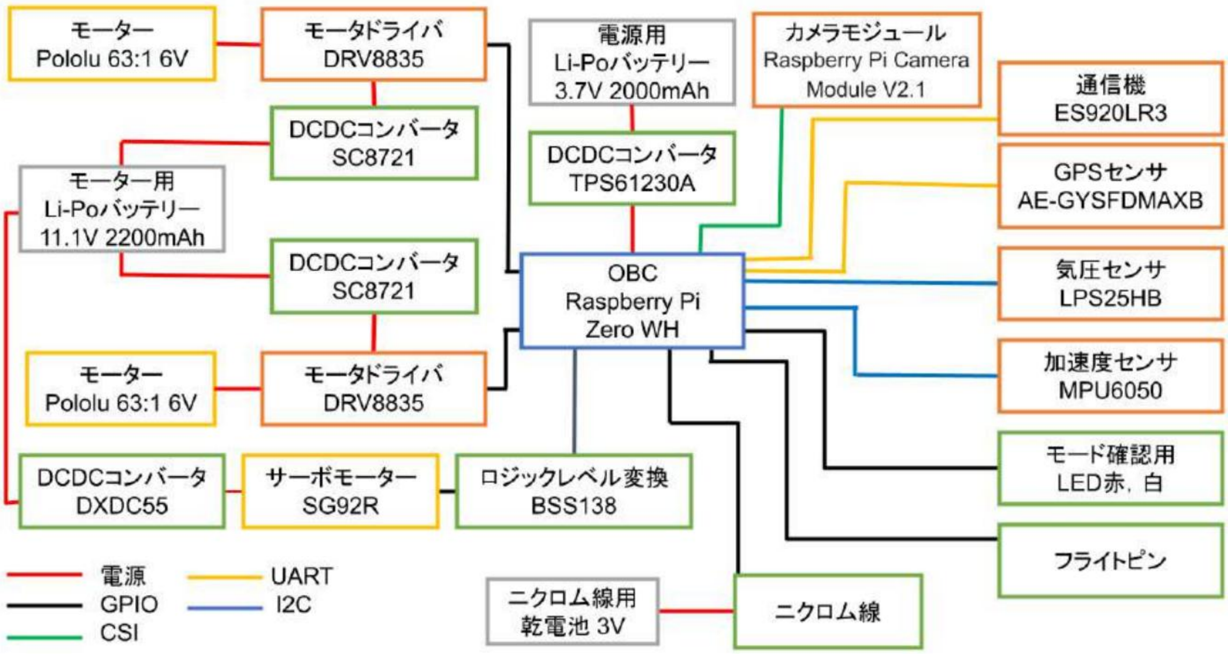


Figure 4.19 **System block diagram**

To participate in the runback category, a GPS sensor will be used to guide the participants to the goal. This is mainly **used** to guide the user to the goal . **The atmospheric pressure sensor is used to determine release from the rocket and landing. The acceleration sensor is used as a criterion for determining whether the drone is stuck while driving or when separating the drone. It is also used to measure vibrations and static loads inside the rocket. The installed motor driver** DRV8835 can control two motors with one, but when using two motors at the same time, the current **is limited to 1.5A, so two identical motor drivers are installed. did. The camera module is used to avoid a parachute after landing and to determine the goal using image recognition.**

Power is supplied to each sensor from Raspberry Pi Zero WH. **Power is supplied to** Raspberry Pi Zero WH **by using a 3.7V2000mAh Li-Po battery that is boosted to 5V using a DCDC converter. Power is supplied to the motor by using a 11.1V 2200mAh Li-Po battery that is stepped down to 6V using a DCDC converter.** Power is supplied to the servo motor for the power **on /discharge mechanism of the slave** unit by using an 11.1V Li-Po battery that is stepped down to 5V through a DCDC converter. **A printed circuit board is used for**

the board. All GNDs are common and solid, but there are two for the motor driver and servo motor.

Because the Li-Po battery of the device collides with the other, one point of grounding was used.

Table 4.4 below shows the equipment installed.

Table 4.4 **Installed equipment**

No	name	Purpose	URL
1	Raspberry Pi Zero	**main computer**	https://raspberry-pi.ksyic.com/main/index/pdp.id/409/pdp.open/409
2	Raspberry Pi Camera Module V2.1	**The camera module**	https://akizukidenshi.com/catalog/g/gM-10518/
3	Pololu 63:1 6V	**dc motor**	https://www.switch-science.com/catalog/7073/
Four	AE-GYSFDMAXB	**GPS sensor**	https://akizukidenshi.com/catalog/g/gK-09991/
Five	DRV-8835	**motor driver**	https://akizukidenshi.com/catalog/g/gK-09848/
6	LPS25HB	**atmospheric pressure sensor**	https://akizukidenshi.com/catalog/g/gK-13460/
7	SC8721	**DCDC converter (motor)**	https://strawberry-linux.com/catalog/items?code=18721
8	TPS61230A	**DCDC converter (microcontroller)**	https://strawberry-linux.com/catalog/items?code=16123
9	MPU6050	**Acceleration sensor**	https://www.amazon.co.jp/VKLSVAN-MPU-6050
Ten	**battery box**	**Nichrome wire circuit**	https://www.marutsu.co.jp/pc/i/14736/
11	BSS138	**logic level conversion**	https://akizukidenshi.com/catalog/g/gK-13837/
12	SG92R	**Servomotor**	https://akizukidenshi.com/catalog/g/gM-08914/
13	LXDC55	**DCDC converter (servo)**	https://akizukidenshi.com/catalog/g/gK-09981/
14	CR2	**Lithium battery (nichrome wire)**	https://www.yodobashi.com/product/100000001002740685/
15	KIOXIA 32GB	microSD (for **Raspberry Pi)**	https://akizukidenshi.com/catalog/g/gS-15844/
16	ES920LR3	**wireless module**	https://tokyodevices.com/items/296
17	11.1V 2200mAh	**Li-Po (motor)**	https://www.kkhobby.com/SHOP/BT117.html
18	3.7V 2000mAh	**Li-Po (microcontroller)**	https://www.marutsu.co.jp/pc/i/836419/
19	PRI-A-003	**camera cable**	https://www.marutsu.co.jp/pc/i/40266795/
20	**electrolytic capacitor**	**capacitor**	https://akizukidenshi.com/catalog/g/gP-03122/
twenty one	OSW4YK3Z72A	3mm LED	https://akizukidenshi.com/catalog/g/gI-11631
twenty two	**switch**	**switch**	https://akizukidenshi.com/catalog/g/gP-15707/
twenty three	2228GG-RD	**flight pin**	https://akizukidenshi.com/catalog/g/gP-03888/
twenty four	**Nichrome wire** 0.5mm	**nichrome wire**	https://www.amazon.co.jp/gp/product/B07KP32MQL/ref=ppx_yo_dt_b_asin_title_o04_s00?ie=UTF8&psc=1

The final components are also shown in the link below.

Overall accounting sheet_for examination report

The circuit diagram is shown in Figure 4.20 below .

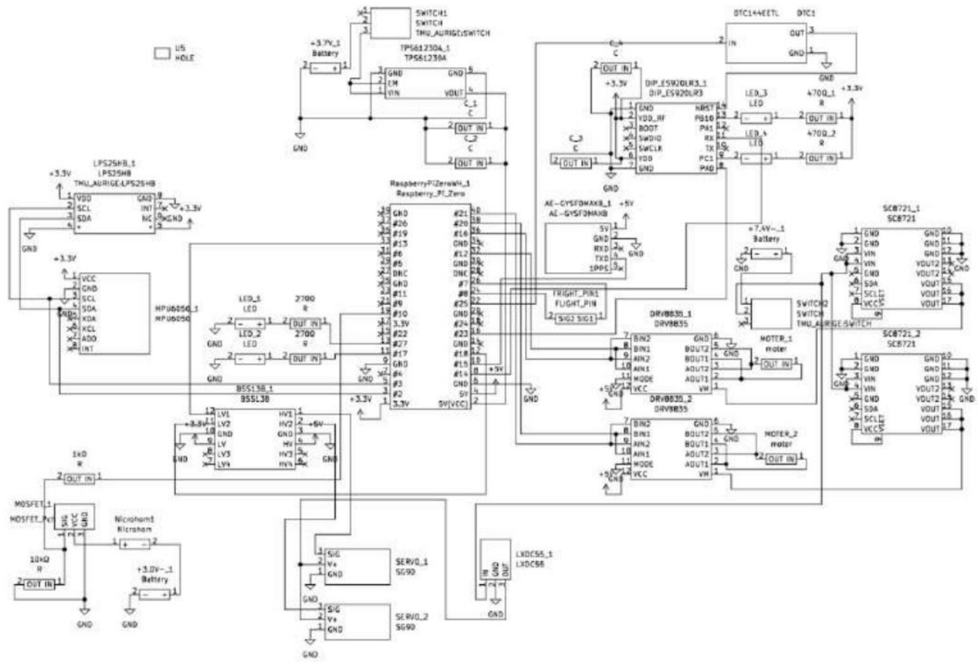


Figure 4.20 **Circuit diagram**

Figure 4.21 below shows the circuit layout.

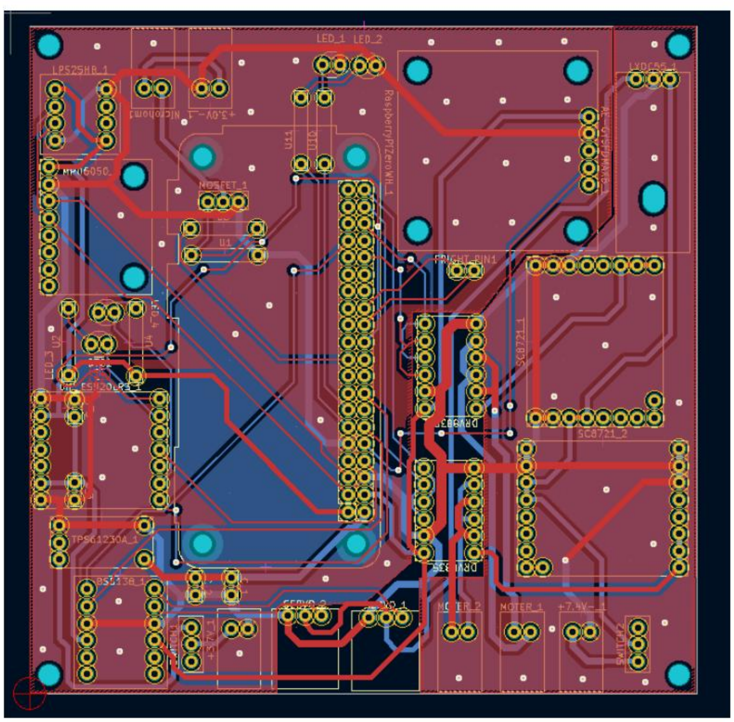


Figure 4.21 **Circuit layout**

Figure 4.22 below shows a board with components mounted on it.

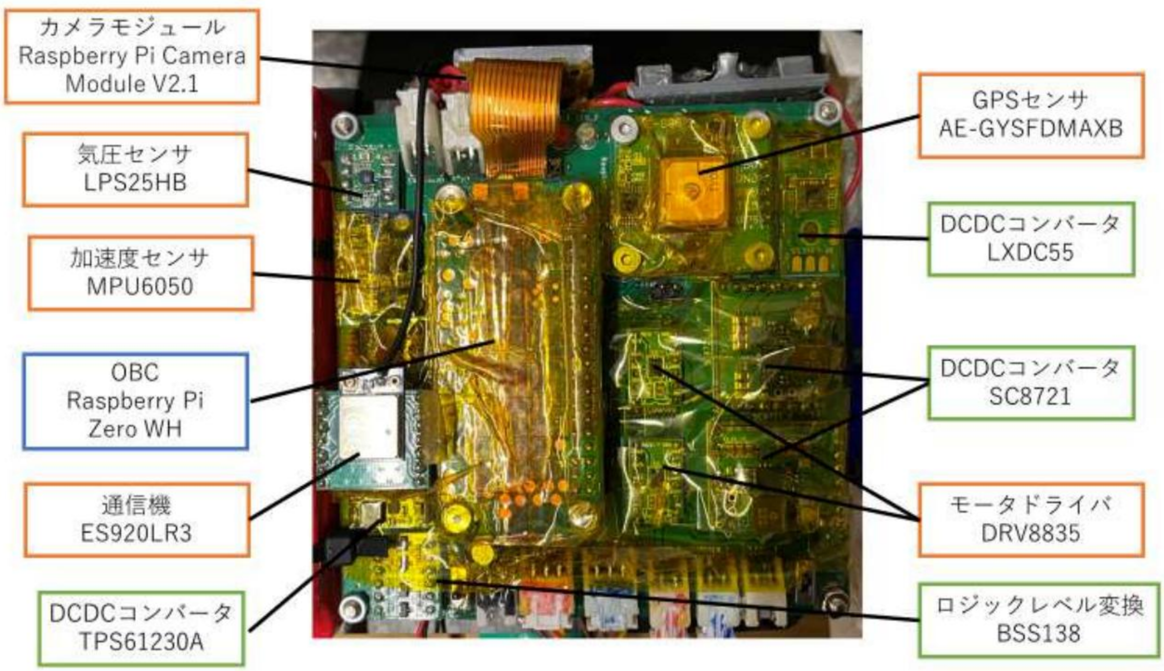


Figure 4.22 **Board with components mounted**

4.5 **algorithm**

Figure 4.23 shows a flowchart of the current system and shows the series of steps. Start the timer after turning on the power to the aircraft. After launch, the flight pin is checked repeatedly and it is determined that the flight pin has come out, and if the atmospheric pressure is below a certain value, a release is determined. Once it is confirmed that there are no fluctuations in atmospheric pressure or acceleration, a landing judgment is made and the carrier and parachute are separated. After evading the parachute, the handset is separated. The slave unit is powered on before separation, and after separation, it flies according to instructions from the OBC installed in the parent unit and detects ruts. The master unit determines the course based on images from the slave unit , and after avoiding obstacles, uses GPS to guide the user to the goal again. A goal is determined **when** the player enters a circle within 4m of the goal. **After determining the GPS goal, a 0m g**

Figure 4.24 shows the flowchart of the slave unit and the rut detection algorithm. Track detection is performed during image processing in the figure . **Convert the acquired image to grayscale and perform binarization processing. By performing binarization processing, it is possible to detect ruts, depressions, and bulges on the ground. The threshold value is obtained on site. To control CanSat, specify the distance to move and the angle from the direction CanSat is currently facing. Since only one image is acquired this time and it is not possible to accurately determine the distance to the object, the image area is divided into five strips and guidance is performed in the direction with the fewest obstacles . At this time, we confirmed that significant data could be acquired up to about 200m from the image ,** so we instructed it to proceed to 500m, which is a sufficient distance.

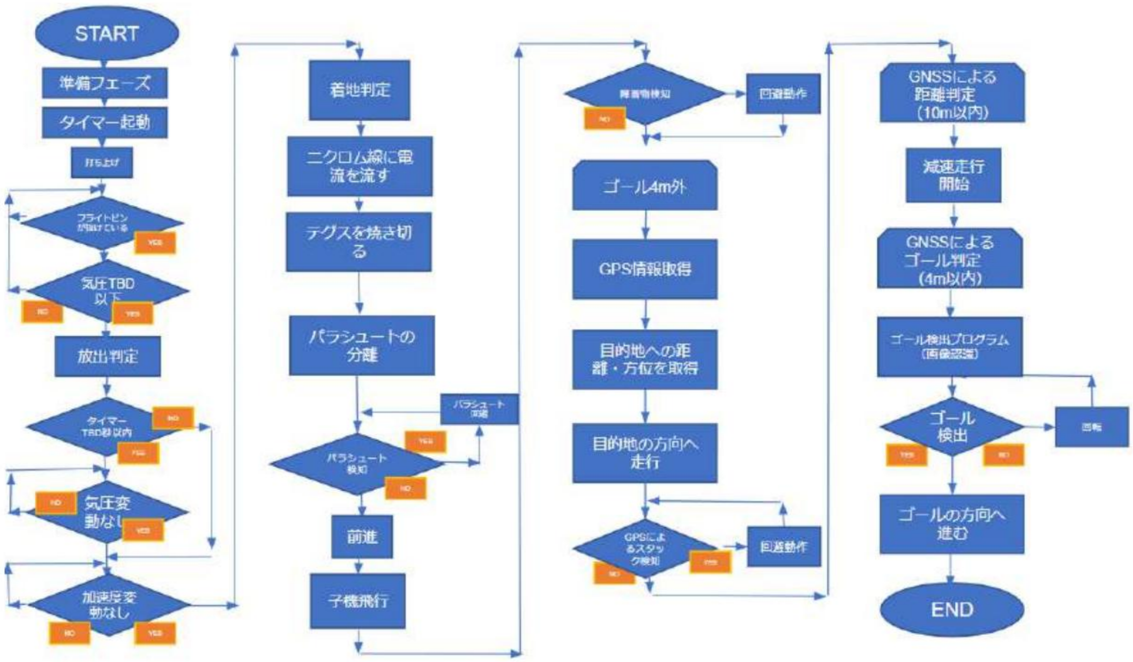


Figure 4.23 **Flowchart**

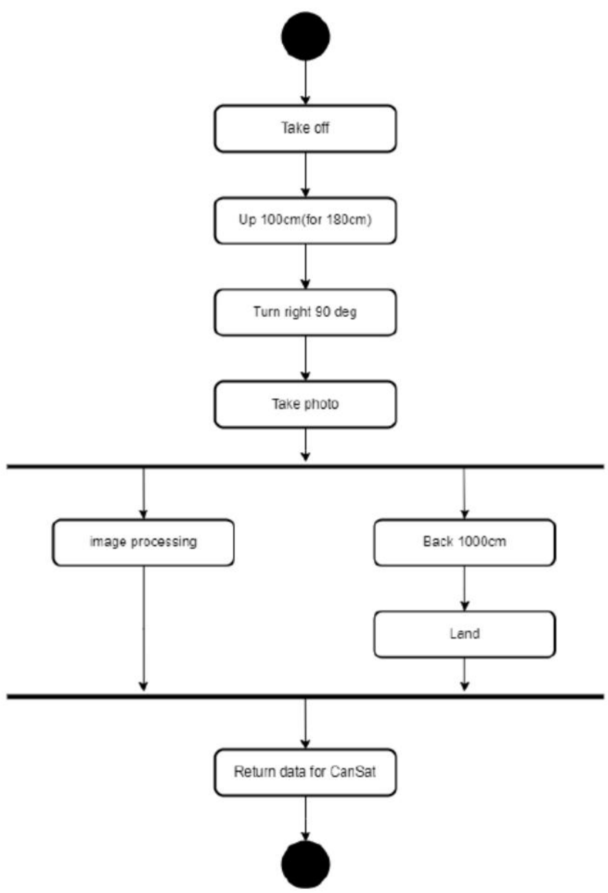


Figure 4.24 Child aircraft flight flowchart

Chapter 5 **Test item settings**

number	Verification item name	Corresponding request number(s)	Implementation date
V1	**Mass test**	S1	7/17
V2	**Aircraft storage and release test**	S2	7/17
V3	**Landing impact test**	S7,M8	8/5
V4	**Communication frequency change test**	S32	8/7
V5	Communication power ON/OFF test	S9	8/6
V6	**Parachute drop test**	S6, S7,S11	8/8
V7	**Parachute separation test**	S12	8/10
V8	**Handset separation test**	S16, S17, M1, M2	8/7
V9	**Driving performance confirmation test**	S24, S25, S26, M11	8/7, 8/8
V10	**GNSS data downlink test**	S13, S14, M7	8/7
V11	**long run test**	S8, S28, M10	7/21
V12	**Quasi-static load test**	S3, S29	7/22
V13	**Vibration test**	S4, S29	7/22
V14	**Separation impact test**	S5	7/22
V15	**Long distance communication test**	S10	7/9
V16	**Slave aircraft flight test**	S18, M3, M4	6/24
V17	**communication and image analysis test between handset and main unit**	S19, S20, S21, S22, M13	9/5
V18	**Parent unit guidance test**	S23, M5, M6, M14	9/11
V19	**GNSS guidance test (goal detection test)**	S15, S27, M9	8/10
V20	**Control report creation test**	M12, M16	8/10
V21	End to End exam	S30, S31, M15	9/7,8

Chapter 6 **Examination Contents**

v1. **Mass test**

• **Requirements**

• [S1] The mass of CanSat must be 1050g or less • **Purpose** • Confirm that the entire weight of CanSat, including the reduction mechanism, is 1050g **or less ,** which is the OpenClass regulation . • **Test details**

• Measure the total weight of the CanSat, including the deceleration mechanism, and confirm that it is less than 1050g. • Results • The test is shown in Figure 6.1.1. The value displayed on the mass meter is the value after zero point correction with the carrier and polycarbonate plate placed on it, and indicates the mass of the CanSat itself. The mass meter displayed 1027[g], which confirmed that it was below the regulations.

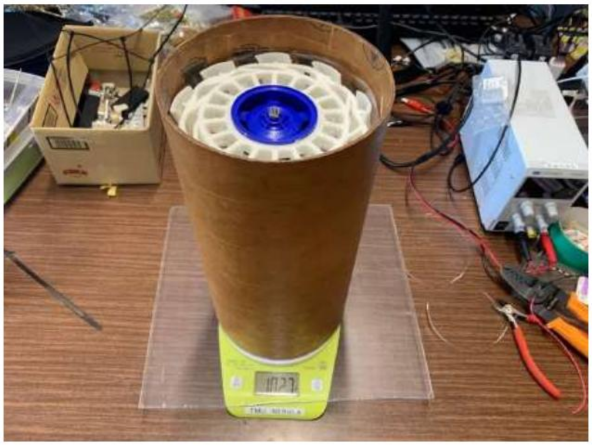


Figure 6.1.1 **Mass test**

•

Considerations : We have confirmed that this machine satisfies system requirement S1. • Since there is a margin of about 20g, it is considered that even if an unexpected situation occurs, it can be handled. Ru.

v2. **Aircraft storage and release test**

• **Requirements**

• [S2] The size of the CanSat must be 146 mm or less in diameter and 240 mm or less in height. •Purpose • **The** volume **of the CanSat main body and deceleration mechanism including the parachute must meet OpenClass regulations.** Make sure that the diameter is 146mm x height 240mm or less.

• **Test content**

• **Make sure that the CanSat can be stored in a carrier that has the same height and width as stipulated by the regulations ,** and measure the diameter and height using a ruler to confirm that they are below the regulations.

• **If it is confirmed that the CanSat falls from the carrier under its own weight, the width will be below the regulations and it will be released smoothly from the rocket, so we will also confirm in this test that the CanSat will fall under its own weight .**

• **Results •**

As shown in Figure 6.2.2, it was confirmed that the height was less than 240mm. Also, see Figure 6.2.3 and the movement during release. From the image, we were able to confirm that the width was 146 mm or less.

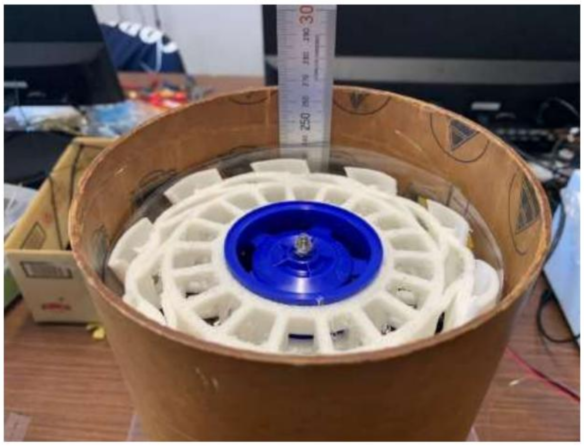


Figure 6.2.2 **CanSat height measurement**

Figure 6.2.3 **CanSat width measurement**

• The scene of the release was posted on YouTube.

YouTube video link: https://youtu.be/U8K_oNCaLZs

•

Considerations : We have confirmed that this machine satisfies system requirement S2. • Depending on the tightness of the inner carrier, it may not be released, so it is necessary to create an assembly procedure manual and set it quantitatively.

v3. **Landing impact test**

• **Requirements •**

[S7] Components installed on CanSat must function even if it receives landing impact **• [M8] CanSat must be able to complete the mission even if it receives landing impact • Objective • CanSat lands Confirm that it can withstand the impact of time. • After landing, confirm that the structure and electrical equipment are functioning properly.**

• **Test content**

• **Since CanSat is equipped with a handset separation mechanism and a handset release mechanism,** there is a possibility **of damage if the terminal speed is too high ,** so the terminal speed was set at a relatively slow 4.0m/s. Here, the gravitational acceleration is 9. **If we set** $8 /^{2}$, then from the relationship between potential energy and kinetic energy,

$$ÿ = \frac{1}{2} \quad ^{2}$$

, and by transforming the formula, we get

$$ÿ = \frac{2}{2}$$

Therefore, in order to simulate landing on the ground with a terminal velocity of 4.0 m/s, we can see from the above equation that it is sufficient to let the CanSat fall freely from 0.82 m above the ground. Therefore, the CanSat is allowed to fall freely from a height of 0.82m .

• Check whether the motor shaft and structure can withstand the impact of landing. • After that, confirm that there is no damage to both hardware and software that would interfere with the mission.

• **Results :**

Landing impact tests were conducted three times. In all three tests, there was no damage to the motor shaft, structure, or electrical equipment. • The details of the test are shown below. i. **1st video link:** https://youtu.be/hmfGB-BATY0 ii. **Second video link:** https://youtu.be/AVgj6XZKmh8 iii. **Third video link:** https://youtu.be/Gnbk1AI7MMc

• **Considerations :** It was confirmed that this aircraft satisfies system requirement S7 and mission requirement M8.

v4. Communication frequency change test

• **Requirements** •

[S32] Must be willing and able to adjust radio channels • Purpose • To ensure that the frequency of the radio installed in CanSat can be changed to prevent interference with other teams.

I agree. •

Test content

• The communication device installed in CanSat is ES920LR3 manufactured by EASEL. As shown in Figure 6.4.1, when performing LoRa modulation, the number of channels is 38 if the bandwidth is 125kHz or less, and 19 if the bandwidth is 250kHz.There are 12 teams participating in this tournament. Since we are a team , we can confirm that we have a sufficient number of channels. Therefore, if it is possible to change to multiple channels, it is possible to show that there is an intention to change the frequency. • Send data from the communication device on the CanSat side that was paired in advance to the communication device assumed to be the ground station. Next, change the channel of the rover's communication device, confirm that the ground station cannot receive data, and then return to the original channel to confirm that the frequency can be changed. Also, check the command history when setting these channels.

4.2.2. LoRa 変調

① 帯域幅・チャンネル

ARIB STD-T108の規定により920.6～928.0MHzの帯域を使用します。

帯域幅	チャンネル数	備考
125kHz以下	38ch	920.6MHzから200kHz間隔
250kHz	19ch	920.7MHzから400kHz間隔

Figure 6.4.1 Number of channels of communication device ES920LR3

(Quoted from EASEL's **specified power-saving wireless module** ES920LR3 **data sheet** Version 1.05, **p11** https://easel5.com/documents/files/ES920LR3%E3%83%87%E3%83%BC%E3%82%BF%E3%82%B7%E3%83%BC%E3%83%88_ 1.05.pdf **(Citation date:** July 6, 2022))

• Results •

CanSat-equipped communication device ES920LR3 and ground station communication device ES920LR3 were set to channel 1 in advance. We confirmed that simulated data was sent from the communication device mounted on CanSat and received by the ground station . Next, we changed the frequency channel of only the communication device on the CanSat side to 3, and confirmed that data could not be transmitted from the CanSat side and received by the ground station in that state. After that, we set the frequency channel back to 1 and confirmed that communication was possible. **• Figure 6.4.1 below is the communication log after restoring the frequency channel, but from CanSat It can be confirmed that communication to the ground station has been resumed.**

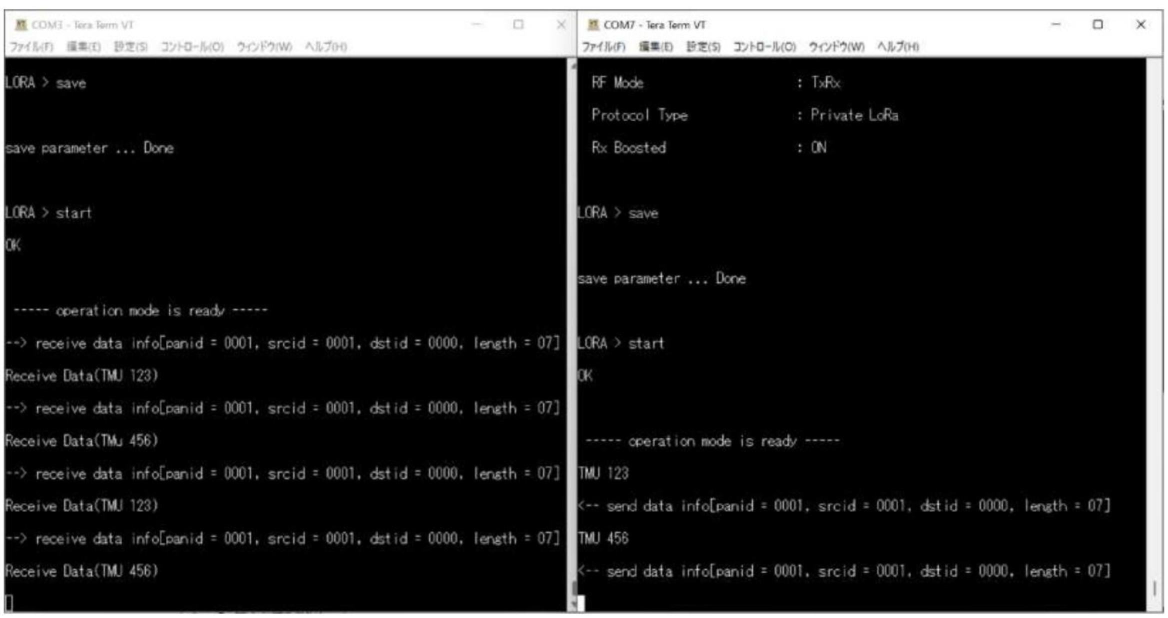


Figure 6.4.1 **CanSat side monitor (left) and ground station monitor (right)**

• The test was posted on YouTube. **YouTube video link:**

https://youtu.be/XOGU7HW-8ck

•

Considerations • It was confirmed that the aircraft satisfies system requirement S32.

v5. Communication power ON/OFF test

- **Requirements**
  - **[S9] It has been confirmed that the regulations for turning off the power of radio equipment at the time of launch can be complied with .**
    FCC certified and can be turned off with a software or hardware switch)
- **Purpose**
  - **Inside the rocket, the power of the communication device installed in CanSat must be OFF, and it is necessary to turn on the communication device after release is determined, so check their functions. •**

Test content

- The communication device installed on CanSat is ES920LR3. Do not transmit power to this communication device.
  It has a sleep function, and by waking up an interrupt from an external microcontroller, the power of the communication device can be turned off. It can be turned from OFF to ON.
- Connect the GPIO pin of **the Raspberry Pi installed in CanSat** to the ES920LR3, and **confirm that the sleep function is canceled by setting the GPIO pin that was set to HIGH on the** Raspberry Pi side to LOW. **When sleep is released, the Raspberry** Pi **is set in advance to send data to the communication device, and the communication device that receives the data sends the data to the ground station and connects to the ground station. Check that you can receive it on your PC.**

- **Result •**

By connecting the OBC installed in CanSat and the sleep pin of the communication device on the board, and **setting the pin of Raspberry Pi Zero, which is the onboard computer, to HIGH, the sleep function that stops the RF section of the communication device is activated . , it was confirmed that no radio waves were emitted.** We confirmed that by setting the pin on **the onboard computer** to LOW, the sleep function is canceled, the RF section of the communication device **is powered on, and communication is possible. In the log shown in Figure 6.5.1 below , it is ssleep_mode_off, and although data before that cannot be received,** sleep_mode_off, which can only be received when sleep mode is canceled, can be received, so communication has **started . It could be confirmed.**

```
ssleep_mode_off
TMU_AURIGA
11
22
33
TMU_AURIGA
11
22
33
TMU_AURIGA
11
22
33
TMU_AURIGA
11
22
33
```

Figure 6.5.1 **Ground station log received by Tera Term**

- The test was posted on YouTube. **YouTube video link:** https://youtu.be/7oycXid3Sr8

•

Considerations • It was confirmed that the communication device satisfies system requirement S9.

v6. **Parachute descent test**

• **Requirements •**

[S6] It has a deceleration mechanism to prevent it from falling at a dangerous speed near the ground, and its performance can be confirmed by testing.
ing
• [S7] Components installed on CanSat must function even if it receives a landing impact. • [S11]
The deceleration mechanism must not become entangled upon landing.

• **Purpose**

• Confirm that the parachute deploys normally after being released from the carrier. •
Check that the terminal velocity of the parachute is 3 to 5 [m/s] from the fluctuation of the atmospheric pressure sensor. • Confirm that the CanSat aircraft can withstand the impact of landing. • After landing, confirm that the deceleration mechanism including the parachute does not cover the CanSat.

• **Test details :**

The parachute is folded and stored in a carrier, then allowed to fall freely from the carrier and opened. • When landing, confirm that CanSat is not damaged and that both the software and hardware are in a condition that allows the mission to be accomplished.
I agree.

• **Results •**

The test was conducted four times, and the parachute opened normally in all cases. Also, the parachute did not cover the aircraft. Figure 6.6.1 shows a graph of the altitude above sea level and time obtained. The average terminal velocity of these four tests was 3.78 m/s.

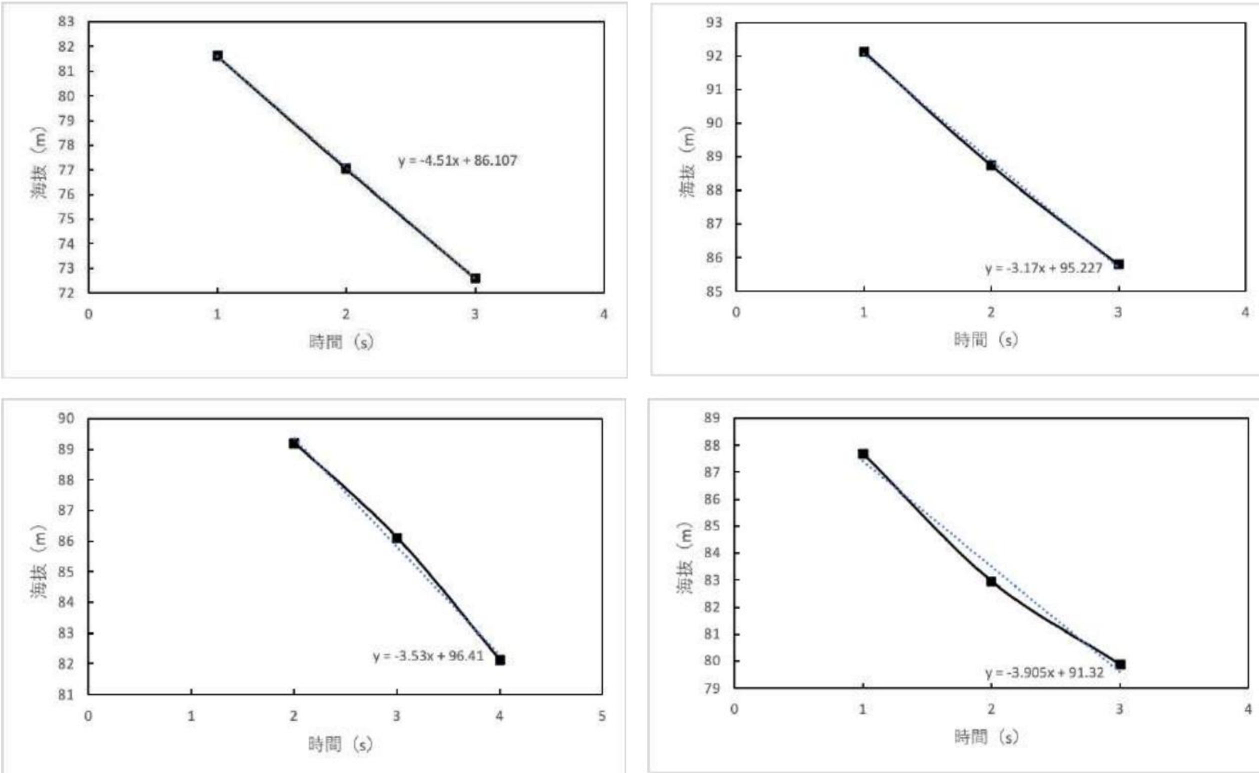


Figure 6.6.1 **Parachute altitude above sea level and time during descent**

•

Considerations • This machine satisfies system requirements S6, S7, and S11.

• We confirmed that the parachute has a terminal velocity of 3 to 5 [m/s] and can sufficiently decelerate.

v7.Parachute **separation test**

• Requirement •

[S12] The separation mechanism needs to be separated after CanSat lands.

• Purpose •

After CanSat lands, confirm that the inner carrier, which connects the aircraft and parachute using nichrome wire, is separated. • Use the camera

mounted on the aircraft and Raspberry Pi Zero to photograph the direction in which CanSat is moving, determine the presence or absence of a parachute from the photographed images, and confirm that parachute avoidance behavior is performed appropriately.

• Test content

• Drop the CanSat with a parachute and determine the landing. After that, we use a nichrome wire to burn out the tentacles, deploy the inner carrier, and use image analysis to determine the presence or absence of a parachute. Confirm that parachute avoidance action will be taken if the parachute is in the CanSat's direction of travel.

.

• **Results** •

The following is a video of the test. In all three drops, CanSat deployed its inner carrier after landing, **used image recognition to determine the presence or absence of a parachute, and separated from the inner carrier by running. A subsequent check of the onboard equipment confirmed that there was no damage to the electrical equipment or structure, and that the mission could be carried out.**

• The test was posted on YouTube.

YouTube video link (1st time): https://youtu.be/aLRA661HZMQ **YouTube video link (second time):** https://youtu.be/27PO-Gfx3WU **YouTube video link (3rd time):** https://youtu.be/fBQAjbb611g

•

Considerations : We have confirmed that this machine satisfies system requirement S12.

v8.Slave **unit separation test**

• **Requirements** •

[S16] A separation mechanism is required to separate the handset. • [S17] Separation control is required to separate the handset. • [M1] **Separation of the handset for obstacle detection.** • [M2] Control **is required to separate the handset for detecting obstacles.**

• **Purpose** •

This mission requires separation from CanSat in order to use a slave unit. Also, **since it is necessary to turn on the power externally, make sure that these steps are performed in sequence.**

• **Test content**

• With the handset (drone) mounted on CanSat, turn on the power to the handset using the power-on mechanism, and confirm that the handset can be dropped to the ground using the handset separation mechanism. • The slave aircraft landed on the ground without becoming entangled with the CanSat's body, and the parent aircraft took evacuation action. • When a child unit (drone) is powered on, the LED repeatedly flashes green and red, and then turns orange, so you can tell whether the power has been turned on or not from the flashing LED. The video shows the situation. YouTube video link: https://youtu.be/6OTw0gEIIMM

• **Result** •

Conducted 5 times. All five times, we turned on the power to the handset using the power-on mechanism, and confirmed that it was possible to drop the handset to the ground using the handset separation mechanism. It was also confirmed that the parent unit took evacuation actions after that.

.

• YouTube video link (1st time): https://youtu.be/VseCZAcfEb4 **• YouTube video link (second time):** https://youtu.be/UhSPfFobPeM **• YouTube video link (3rd time):** https://youtu.be/KHlvUhlWNUc **• YouTube video link (4th time):** https://youtu.be/UwBAPn0Po_8 **• YouTube video link (5th time):** https://youtu.be/ClaHIP-kNzs

•

Considerations : It was confirmed that this aircraft satisfies system requirements S16 and S17, and mission requirements M1 and M2.

v9. **Driving performance confirmation test**

• **Requirements •**

[S24] A motor is required to rotate the tires used to move to the goal point. • [S25] It is necessary for CanSat to detect when it gets stuck. • [S26] Even if CanSat gets stuck, it will resume its original run. It is necessary to return to • [M11] It is necessary to escape when CanSat is stuck • Purpose • Assuming that CanSat becomes stuck, confirm that it is possible to escape from detection.

• **Test content**

• The depth of the rut should be larger than the radius of 90 mm, which is the size when the CanSat's tires are deployed. • The width **of the rut should be at least the length (90 mm radius) in the CanSat's direction of travel. • Results • A test was conducted by creating a simulated track in the sandbox as shown in Figure** 6.9.1. **A mountain with a height of about 30 mm was created next to a hole with a depth of about 130 mm . The height difference between the bottom of the hole and the top of the mountain is approximately 160 mm.**

Figure 6.9.1 **Created simulated rut**

• Video ÿ and Video ÿ show how the vehicle entered the simulated rut at an approach angle of 30° and an approach angle of 45°. In **both cases , the CanSat used its tires to plow through the sand and escape from the simulated rut.**

i.Video **ÿ** (approach angle 30°): https://youtu.be/wM4XCXbJvAM ii.Video **ÿ** (approach angle 45°): https://youtu.be/I7slJx4N6IM **• Next, CanSat was placed at the bottom of the hole shown in Figure 6.9.1, and video ÿ shows how it started moving toward the mountain from there . CanSat was unable to break through the mountain. Video ÿ shows a similar test conducted in a hole shallower than the simulated rut shown in Figure 6.9.1 . CanSat was able to escape from the hole.** i.Video **ÿ (from the bottom of the simulated rut hole):** https://youtu.be/yPNxICw4uJ8 ii.Video **ÿ (from the bottom of a hole shallower than the simulated rut):** https://youtu.be/k5vNEj2sacQ **• Next, assuming driving on a rough road, video ÿ shows driving on a slope with an inclination of approximately 30°.**

Video ÿ shows how the vehicle was driven through a sandbox with undulations. In both cases, CanSat **was able to run without stopping .** i.Video **ÿ** (Slope): https://youtu.be/3fQozxvK8as ii.Video **ÿ (Sandbox):** https://youtu.be/svWIKQN76gU

• **Consideration**

- CanSat is thought to be able to overcome most obstacles, but in rare cases it was unable to overcome a drop of more than 160mm, so improvements to the tires or software algorithms should be made in preparation for such cases. is necessary.

- **The aircraft was confirmed to meet system requirements S24, S25, S26 and mission requirement M11.**

v10. **GNSS data downlink test**

• Requirements •

[S13] It is necessary to acquire position information and extract the information necessary for guidance to the goal •

[S14] It is necessary to be able to receive data from CanSat at multiple ground stations as a countermeasure against lost •

[M **7ÿ CanSat needs to obtain position coordinates • Purpose • CanSat**

transmits

its own position as a way to track CanSat after it is released from the rocket

Check what you can do. • Test

content

- Using the GPS sensor installed in CanSat, Raspberry Pi Zero, and communication device ES920LR3 **, Process the data acquired by the GNSS sensor with the Raspberry Pi, transmit it to the ground station connected to the PC using a radio, and confirm that it can be received by the ground station.**
- **The transmitted data should include location information (longitude, latitude) and time on the CanSat side, and the receiving side should Confirm that you can receive data using TeraTerm.**

• Results

Figure 6.10.1 shows the ground station monitor, and the ground station was able to receive the data sent from CanSat . In addition, when this data was displayed on Google Maps, the trajectory of CanSat could be **displayed ,** and since there was no significant difference from the trajectory actually traveled , **it can be assumed that the downlink of the GNSS data was successfully performed.**

Figure 6.10.1 Transmission data from CanSat received at ground station

Figure 6.10.2 **Travel trajectory plotted on Google Map**

•

Considerations • It was confirmed that system requirements S13 and S14 and mission requirement M7 were met.

v11.Long **run test**

• **Requirements •**

[S8] It is necessary to conserve power during launch standby • [S28] **It is necessary to be able to supply power for** CanSat to operate normally **• [M10] Provide CanSat with enough power to complete its mission need to supply**

• **Purpose •**

According to the ARLISS2022 regulations, the maximum launch waiting time is 60 minutes . In addition, since the created CanSat travels at a speed of 5 km/h, the maximum travel distance is assumed to be 7 km, so a travel time of 90 minutes is required. Therefore, we will take a margin in the running time and confirm that it can run for 120 minutes . • Confirm that there is no significant damage to the tires that would impede driving during the expected operating time.

• **Test content**

• After leaving CanSat powered on for 60 minutes, it can run for 120 minutes in a park. Make sure that.

• **Results •**

A video of the test is shown in the link below. The video shows the exam taking place at Shofaze Park near the university. First, to simulate the rocket loading time, CanSat was left powered on for 60 minutes. Next, the vehicle was run in a circular motion for 120 minutes, simulating actual driving. Occasionally, it would collide with surrounding fences, so in those cases I had to hold the tail to correct the trajectory.

However, I was able to run for 120 minutes without the battery running out midway. The voltage of **the Li-Po battery for the motor** was 12.53V before the test and 11.42V after the test. In addition, the voltage of the Li-Po battery for Raspberry Pi was 4.03V before the test and 3.91V after the test.

• **There was no significant damage to the tires of this aircraft that would impede driving during the expected operating time. won. •**

The following is the state of the test.

YouTube video link: https://youtu.be/aTSndJNtMNI

•

Considerations : It is believed that the battery installed in this aircraft can supply enough power **for** normal operation for 60 minutes of standby time and 120 minutes of driving time . **This is because the rated voltage of the Li-Po battery for the motor is 11.1V, and the rated voltage of the Li-Po battery for the Raspberry Pi is 3.7V, and the voltage after the test exceeds these.**

• **This aircraft satisfies system requirements S8, S28, and mission requirements M10.**

v12. **Quasi-static load test**

• **Requirements •**

[S3] Tests have confirmed that the functions required to meet safety standards are not impaired by the quasi-static load (10G) during launch. • [S29] The base unit does not vibrate **or If**

the power goes out due to an impact, etc., it is necessary to be able to continue the mission even if the power is restored. Ru

• **Purpose :**

To confirm that CanSat does not cause mechanical or electrical damage or abnormalities due to quasi-static loads during launch .

• **Test content**

• **A quasi-static load that simulates the mechanical environment during a rocket launch is applied using a vibration tester located at the Japan Advanced Reliability Evaluation Testing Center (IMV) in Iruma City, Saitama**

Prefecture . • The test conditions for the quasi-cumulative load test are sine wave according to ARLISS2022 regulations. The vibration was 10[G], 20[Hz], and the excitation time was 20[sec].

• **Turn on the power to CanSat and store it in the carrier of the shaker in the same way as in the actual production. Loads are applied based on quasi-static loads, vibration loads, and impact loads. After that, we took out the CanSat and confirmed that there was no structural damage and that the electrical equipment was working.**

• **The test equipment is shown below.**

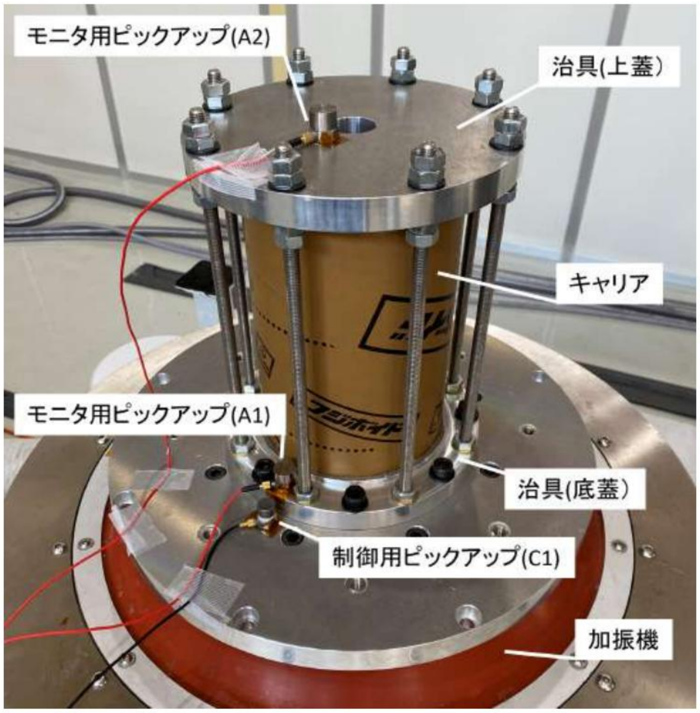


Figure 6.12.1 **Test equipment**

• Results •

Sine wave excitation was performed for 20[s] to achieve the response acceleration of 10[G] required by the regulations . The results of the quasi-static load test are shown in Figure 6.12.2 below. From Figure 6.12.2, a value close to the target value of 10[G] could be obtained for 20[s] with pickups A1 and A2. **There was no damage to the onboard equipment even after it was removed from the carrier** after the test .

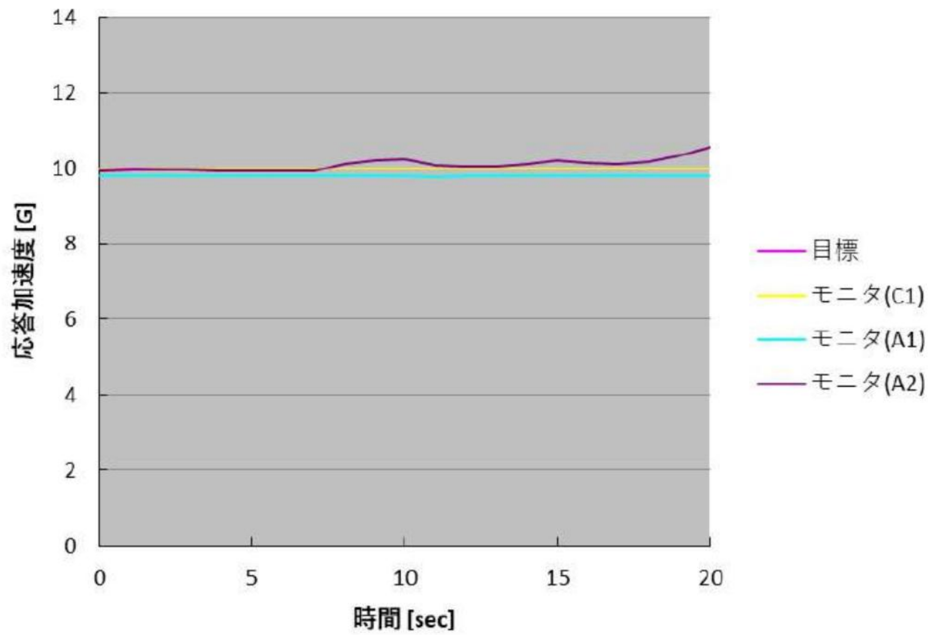


Figure 6.12.2 **Quasi-static load test results**

- **The test video is shown in the link below. YouTube video link:** https://youtu.be/sQDGjjtSeHc?t=1299

- **Considerations : We were able to obtain values close to the target values with pickups A1 and A2, and it is thought that we were able to reproduce the environment without a rocket during launch.**
- **We were able to confirm that there was no structural damage and that the electrical equipment was operational. Therefore, the aircraft** satisfies system requirements S3 and S29.

v13.Vibration **test**

- **Requirements •**

[S4] **Tests have confirmed that the functionality required to meet safety standards is not impaired by the vibration load during launch (15G or equivalent random vibration** with a sine wave of 30 to 2000Hz).

- **[S29] If the main unit loses power due to vibration or shock, it is necessary to continue the mission even if it returns again. Ru**

- **Purpose :**

To confirm that CanSat does not cause mechanical or electrical damage or abnormalities due to quasi-static loads during launch . • **Test content**

- **Using a vibration testing machine located at the Japan Advanced Reliability Evaluation Testing Center (IMV) in Iruma City, Saitama Prefecture A vibration load is applied that simulates the mechanical environment during a rocket launch. •**

The test conditions for the vibration load test are random according to ARLISS2022 regulations.

The excitation was 15Gms, 50~2000Hz, 60[s]. • **Turn on the power to CanSat and store it in the carrier of the shaker in the same way as in the actual production. Since it is conducted simultaneously with a quasi-static load test, loads are applied based on quasi-static load, vibration load, and impact load. after that, Take out the CanSat and check that there is no structural damage and that the electrical equipment works.**

• The test equipment is the same as Figure 6.12.1.

• Results •

The target waveform data was set to 15[Grms], and random excitation was performed at an excitation frequency of 30 to 2000[Hz] and 60[s] to obtain the target waveform. Figure 6.13.1 below shows the vibration test results.

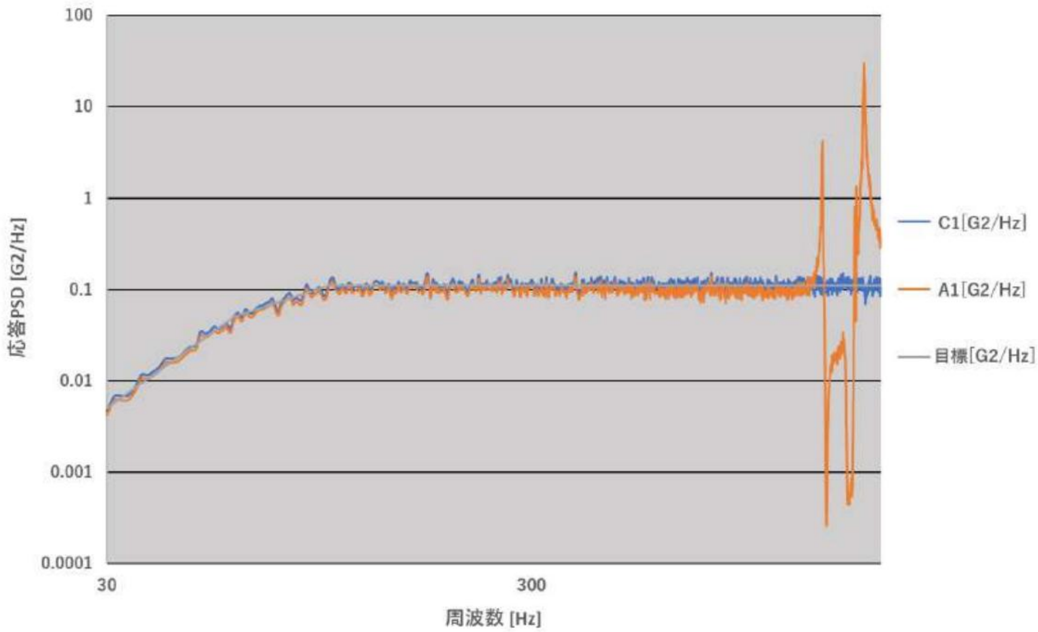


Figure 6.13.1 **Vibration test results**

• From Figure 6.13.1, the response PSD of the control pickup was confirmed to be close to the target value. Pickup monitor A1 had a response PSD that was far from the target value after 1200 [Hz].

• The test video is shown in the link below.

YouTube video link: https://youtu.be/sQDGjjtSeHc?t=1650 **• After testing V12 to V14, CanSat was taken out of the carrier and put into operation. The operation is shown below.**

Posted on YouTube. **YouTube video link:** https://youtu.be/sQDGjjtSeHc?t=2543

•

Consideration • We confirmed that C1 had a response PSD close to the target value, but A1 had **a value that deviated from the target value from around 1200 [Hz], suggesting that there was resonance with the jig. Therefore, such an environment is harsher than the actual launch environment, and CanSat is considered to fully satisfy system requirements S4 and S29 .**

v14. **Separation impact test**

• Requirements •

[S5] Satisfies safety standards by impact load (40G) when the rocket separates (when the parachute is deployed)

It has been confirmed through testing that the functions necessary to

• **Purpose :**

To confirm that CanSat does not cause mechanical or electrical damage or abnormalities due to quasi-static loads during launch .

• **Test content**

• **A vibration tester at the Japan Advanced Reliability Evaluation Testing Center (IMV) in Iruma City, Saitama Prefecture is used to apply a separate shock load that simulates the mechanical environment during rocket launch.** • The test conditions for the quasi-component load test are as per the ARLISS2022 regulations, with a maximum of 40[G] in sine wave half-shock excitation, and continuous excitation in three stages of 60%, 80%, and 100%. **Let .**

• **Turn on the power to CanSat and store it in the carrier of the shaker in the same way as in the actual production. Since the quasi-static load and vibration load are applied simultaneously, the quasi-static load and vibration load are applied in that order. After that, we took out the CanSat and confirmed that there was no structural damage and that the electrical equipment was working. • The test equipment is the same as Figure 6.12.1.**

• **Results •**

Target acceleration was set to 40G (100%), 32G (80%), **24G (60%), and sine wave half-shock excitation was performed.** The situation is shown in Figure 6.14.1.

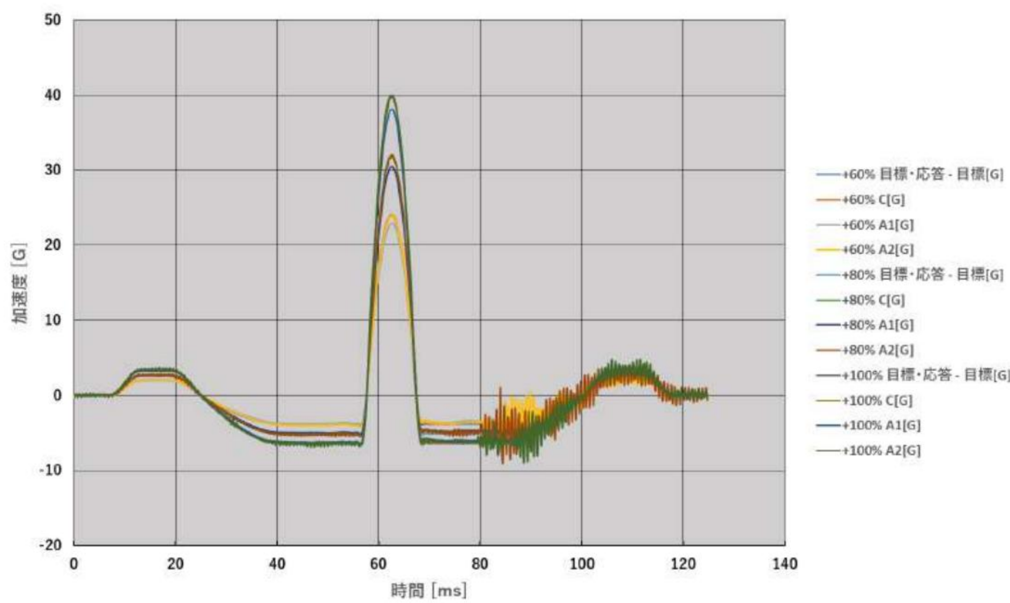


Figure 6.14.1 **Separation impact test results (upward direction)**

• From Figure 6.14.1, in the three types of excitation, A1 did not reach the target value, but C and A2 confirmed **response accelerations close to the target value.**

• **In the same way, we also performed separate shock excitation in the downward direction. Figure 6.14.2 shows how sinusoidal half-shock excitation was performed with target accelerations of -40G (100%),** -32G (80%), and -24G (60%) .

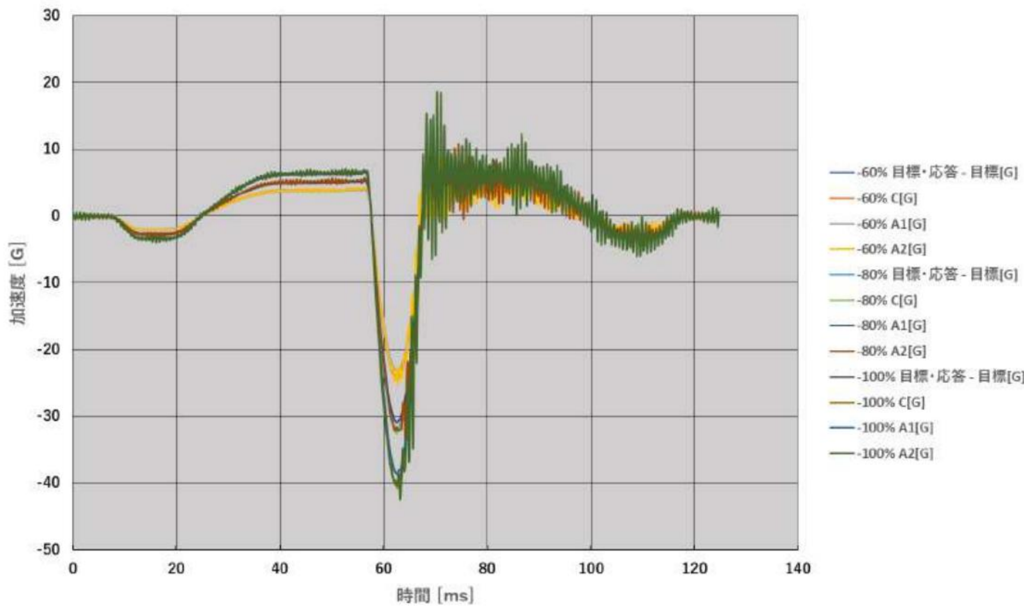


Figure 6.14.3 **Separation impact test results (downward)**

- **From Figure 6.14.3, A1 did not reach the target value in the three types of excitation, but response acceleration close to the target value was confirmed in C and A2.**

- **The test video is shown in the link below.**

YouTube video link: https://youtu.be/sQDGjjtSeHc?t=1852 • **After testing V12 to V14, CanSat was taken out of the carrier and put into operation. The operation is shown below.**

Posted on YouTube. **YouTube video link:** https://youtu.be/sQDGjjtSeHc?t=2543

- **Considerations : With pickup A1, we did not detect a response acceleration that reproduced the target value, but with pickup C and A2, we were able to confirm response acceleration that was close to the target value. It is thought that we were able to reproduce the separation impact. Therefore, the aircraft satisfies system requirement** S5.

v15.Long **distance communication test**

- **Requirements** •

[S10] Countermeasures against loss have been implemented, and their effectiveness has been confirmed through testing. • Purpose • After being released from the rocket, CanSat will be able to transmit position information from an altitude of 3 to 4 km. Confirm that long-distance communication is possible because it is **required . We also confirmed that it is effective as a countermeasure against loss. • Test details • A wire antenna is used for the ES920LR3 antenna installed on CanSat. On the ground station side Attach an external antenna to the ES920LR3.** According to the data sheet shown in **Figure 6.15.1 below , communication with a line of sight of 5 km is possible using an external antenna and a wire antenna .** Therefore, first of all, confirm that communication is possible at a line-of-sight distance of 5 km. • **The test will be conducted along the Tama River with good visibility. First, CanSat and the ground station are separated by 2.5 km.**

Confirm that communication is possible in the state (Figure 6.15.2). Next, the CanSat side **moved to the area around the ruins of Takiyama Shiromaru (170m above sea level), and the ground station side moved to Hitachi Bridge over the Tama River, confirming that communication over a distance of 7.4km was possible. (Figure** 6.15.3)

アンテナタイプ	通信距離の目安	
	LoRa変調使用時	FSK変調使用時
外付けアンテナ — 外付けアンテナ	見通し10km	見通し1200m
外付けアンテナ — ワイヤーアンテナ	見通し5km	見通し400m
ワイヤーアンテナ — ワイヤーアンテナ	見通し2km	見通し200m

Figure 6.15.1 Communication distance of ES920LR3

(Quoted from EASEL's **specified power-saving wireless module** ES920LR3 **data sheet** Version 1.05, **p9** https://easel5.com/documents/files/ES920LR3%E3%83%87%E3%83%BC%E3%82%BF%E3 %82%B7% E3%83%BC%E3%83%88_1. 05.pdf **(Citation date:** July 6, 2022))

Figure 6.15.2 Positional relationship between CanSat and ground station in long-distance communication test (2.5km)

Figure 6.15.3 Positional relationship between CanSat and ground station during long-distance communication test (7.4km)

• Result •

2.5km communication was successful. Figure 6.15.4 below shows the ground station log. along with RSSI value

Simulated data was continuously received from the CanSat side.

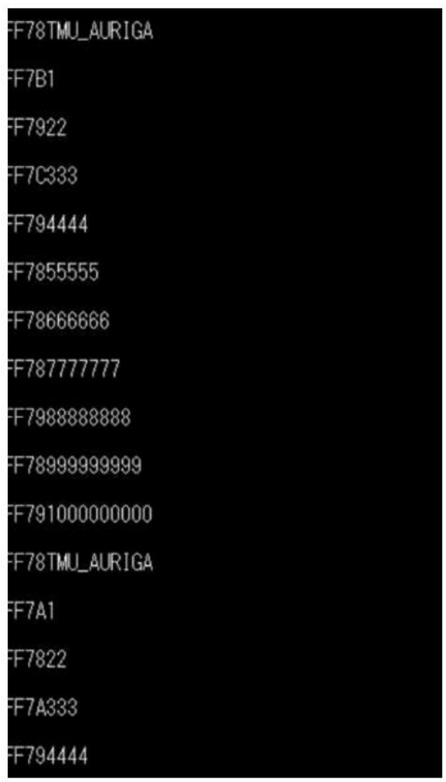


Figure 6.15.4 **Communication log for 2.5km (ground station side)**

• We attempted to communicate from a distance of 7.4km, but the ground station could not receive the signal.

•

Considerations : The maximum communication distance of the ES920LR3 radio used in this test is 10 [km] in line of sight, but in this test, the maximum communication distance was 2.5 km. Although this is an open area along the Tama River, there are several bridges between the main unit and the slave unit, and there are residential areas and factories in the surrounding area, so it is thought that the area was affected by these . ÿÿ Since ARLISS is held in the Black Rock Desert with good visibility, the communication range is expected to be longer than 2.5 km, but the countermeasure is to drive in the direction of the rocket's progress after the CanSat scheduled release time. , we want to secure communication distance.

v16.Slave aircraft flight test

• Requirements •

[S18] It is necessary for the child unit to observe obstacles from the air. • [M3] It is necessary for the child unit and parent unit to observe obstacles in order to detect them. • [M4] The child unit is in trouble. Control to detect objects is required • Purpose •

Confirm whether the preset flight phase can be executed by commands from the base unit. • Check that the slave aircraft can fly up, down, left and right, and forward and backward.

• Test details • After the slave unit is separated from the base unit, it receives a command from CanSat, takes off, and sets it in advance. Confirm that you can fly to multiple locations. • The flight area is assumed to have an altitude of 5m and an action range of 20m x 20m. • The child device (drone) used for the flight is a drone weighing less than 100g, but the area around our university where the test is scheduled is a densely populated area. Therefore, we applied to our university and conducted a test above the lawn on the campus.

• Result •

The drone was able to fly along the pre-planned route. The YouTube link below shows a video of horizontal flight movement. YouTube video link (horizontal movement): https://youtu.be/284w8KnGS-8 • It was also confirmed that the aircraft changed its course at 5m above the ground. Watch the video on the YouTube link below.

show.

YouTube video link (change of course): https://youtu.be/2-mi4Uqln90

•

Considerations • We confirmed that the flight phase set in advance can be executed by commands from the base aircraft. • We confirmed that the slave aircraft can fly up, down, left and right, and forward and backward.

v17.Communication /image analysis test between handset and master unit

• Requirements •

[S19] Observation equipment that can detect obstacles is required • [S20] Obstacles need to be recognized on software based on data from observation equipment • [S21] CanSat and obstacles • [S22] Communication is required to share obstacle information • [M13] The child unit needs to be able to detect obstacles with the parent unit from a high place • Purpose • Check whether you can understand the status of the slave unit. • Make sure that the child unit can shoot and send ground images in the air, and that the base unit can receive them on the ground. Furthermore, we will analyze the multiple images sent to us and see if we can determine the course.

• **Test details • Send**

a command from Raspberry Pi Zero, **which is CanSat's OBC ,** and make the slave unit take off. **Shooting begins after takeoff, the captured images are transferred to the base unit, and image analysis is performed using OpenCV.**

-

• **Result • We**

were able to control the slave unit using commands from CanSat. • I was able to transfer images taken by the slave unit to the base unit. • Confirmed that image processing will be performed. However, since we were not in an environment where we could reproduce the ruts, we used an arbitrary threshold value.

Figure 6.17.1 **Image obtained in this test**

•

Considerations : The slave unit can be controlled by CanSat commands. •

CanSat can use images acquired by slave devices for image analysis. • It is necessary to adjust the threshold value on site.

v18. **Master unit guidance test**

• **Requirements •**

[S23] It is necessary for the base unit to guide the user to avoid obstacles • [M5] It is necessary for the base unit to guide the user to avoid obstacles • [M6] Collaboration between the slave unit and the base unit • [M14] The base unit **needs to move on the ground to avoid obstacles • Purpose • Confirm that the series of sequences has been implemented.**

• Detect obstacles based on images from the handset and check whether the appropriate route is selected. • Make sure that the base unit can travel on the determined route.

• **Test details •**

Confirm that the following sequence has been implemented.

i. **Turn on the power to the slave unit and disconnect it. After that, the child device takes off based on a command from the parent device, takes pictures of the ground, and transmits the images to the parent device.** ii.The **base unit analyzes the sent images and detects obstacles.** The course is determined based on **the positional relationship between obstacles and CanSat .** iii. **The base unit travels along the determined route.**

• **Results** •

Test contents i and ii obtained the same results as the actual test v17. • **CanSat was able to change direction and travel a certain distance based on the obtained route information.**

•

Considerations • CanSat detects obstacles based on images obtained from slave devices and finds routes with fewer obstacles. It can be washed and driven.

v19. **GNSS guidance test (goal detection test)**

• Requirements •

[S15] CanSat needs to be guided to the goal • [S27] CanSat needs to determine the goal and stop running • [M9] **It is necessary to guide from the point of fall to the goal • Purpose • We demonstrated that CanSat can be guided to its destination using GNSS sensors from the drop point to the target point. confirm. •**

Test details •

Landing is determined using a barometric pressure sensor, and GNSS guidance is started after parachute avoidance action. ÿÿ Then, confirm that CanSat's direction of travel and control amount are appropriate.

• After CanSat reaches the vicinity of the target point, it acquires the coordinates of its current location from the GNSS sensor multiple times and stops traveling after confirming that it is within a 4m radius from the goal.

• Result •

Successful GNSS guidance 7 times in a row. Please note that the 8th test was not conducted. The code was able to detect arrival within a 4m radius from the target point each time, and the motor was able to stop normally. • A video showing the test is shown in the link below. First time: https://youtu.be/E1Nm4tqRtS0 **Second time:** https://youtu.be/Gw84_PHAvjM **Third time:** https://youtu.be/0Yn_QRw9VaM **4th time:** https://youtu.be/c8p4-paJQnQ **5th episode:** https://youtu.be/JZSpuLvrAJ8 **6th time:** https://youtu.be/TcN_yao9YpE **7th episode:** https://youtu.be/W8g9hubopfo **Please note that the 8th test was not conducted.**

•

Considerations : In consecutive GNSS guidance tests, CanSat reached within a 4m radius of the goal cone seven times in a row , confirming that CanSat can be guided from the point of fall to the goal.

• It was also confirmed that CanSat detected that the goal was within 4m and stopped guidance. • This aircraft satisfies system requirements S15, S27, and mission requirements M9.

v20.Control **report writing test**

• Requirements •

[M12] It is necessary to be able to check the log after the mission ends •

[M16] After the mission, submit the specified control history report to the operation and examiner and log/obtain It is possible to explain the data obtained.

• Purpose •

From the data saved as a csv file in the SD card after the CanSat mission ends. Create a table showing the control history.

• This mission requires submitting control history to the tournament management in order to participate in the runback category.

In order

to • Test details •

CanSat is driven to the destination and the control history is saved at that time. Power on after goal detection

Remove the SD card and tabulate the CanSat's position coordinates, time , control amount, and azimuth that were saved as a

csv file , and confirm that it can be guided properly.

• Results •

The implementation results are shown below. Figure 6.20.1 is the display on Google Maps, Figure 6.20.2 is the control history,

Figure 6.20.3 is the original data. The following driving data is the second control report of the GNSS guidance test .

Figure 6.20.1 **Enlarged view of travel trajectory**

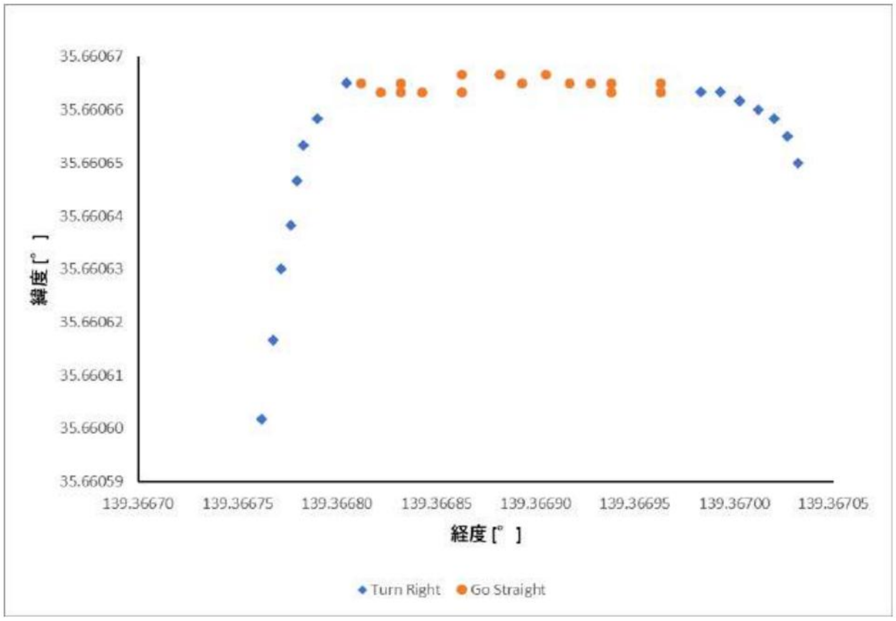


Figure 6.20.2 **Driving log**

gnss_time	status	lon	lat	direction	speed
124051	R	139.366762	35.6606017	21.77	4.7226
124052	R	139.366768	35.6606167	18.97	4.92632
124053	R	139.366772	35.66063	21.85	4.57444
124054	R	139.366777	35.6606383	26.79	4.00032
124055	R	139.36678	35.6606467	33.81	3.53732
124056	R	139.366783	35.6606533	38.9	3.1484
124057	R	139.36679	35.6606583	53.33	3.0558
124057	R	139.36679	35.6606583	53.33	3.0558
124059	R	139.366805	35.660665	69.62	2.75948
124100	S	139.366812	35.660665	81.48	2.42612
124101	S	139.366822	35.660665	87.79	2.6854
124102	S	139.366832	35.6606633	95.26	2.90764
124102	S	139.366832	35.6606633	95.26	2.90764
124103	S	139.366843	35.660665	92.95	2.9632
124105	S	139.366863	35.6606633	96.79	2.8706
124105	S	139.366863	35.6606633	96.79	2.8706
124107	S	139.366882	35.6606667	91.38	2.9632
124107	S	139.366882	35.6606667	91.38	2.9632
124108	S	139.366893	35.6606667	94.33	3.09284
124109	S	139.366905	35.660665	95.51	3.25952
124110	S	139.366917	35.6606667	94.89	3.37064
124111	S	139.366928	35.660665	96.32	3.31508
124112	S	139.366938	35.660665	95.99	3.38916
124112	S	139.366938	35.660665	95.99	3.38916
124114	S	139.366963	35.6606633	96.45	3.5188
124114	S	139.366963	35.6606633	96.45	3.5188
124115	S	139.366973	35.660665	92.5	3.38916
124116	R	139.366983	35.6606633	93.51	3.25952
124117	R	139.366993	35.6606633	95.75	3.1484
124118	R	139.367003	35.6606617	98.82	3.16692
124118	R	139.367003	35.6606617	98.82	3.16692
124119	R	139.367012	35.66066	102.46	3.12988
124120	R	139.36702	35.6606583	104.08	2.94468
124121	R	139.367027	35.660655	109.55	2.778
124122	R	139.367032	35.66065	116.59	2.51872

Figure 6.20.3 **Driving log (saved csv file)**

- **The movement of the aircraft in the second GNSS guidance test and the trajectory in the control log matched. This results in We confirmed that CanSat is capable of acquiring control logs and that it is also possible to extract logs.**

- **Also, the control log contains instructions issued by CanSat, making it possible to check the control status. This confirmed that it was possible to explain the status of CanSat, including aerial photographs.**

•

Considerations : It was confirmed that the aircraft satisfies mission requirements M12 and M16.

v21. End to End **exam**

• **Requirements** •

[S30] It has been confirmed that autonomous control is carried out without human intervention during the mission. • [S31] CanSat, whose design has confirmed the fulfillment of S1-S31, starts the mission from loading the rocket. , we have been able to conduct an end-to-end test simulating the period from launch to recovery, and there **will be no major design changes related to safety** in the future

- **[M15] We have decided to implement autonomous control without human intervention during the mission. It has been confirmed**

• **Purpose** •

In the end-to-end test, we will perform the same steps as the actual test, from dropping the CanSat to deploying the parachute, executing the mission, and retrieving data, and confirm that each sequence is successful.

• **Test details** •

The End to End **test will be conducted according to the following steps.**

i. **Power on CanSat and check the values from various sensors.** ii. **Execute the program and store it in the carrier.** iii. **Release from the carrier and decelerate using a parachute.** iv.After landing, the air pressure sensor is used to determine the landing, and the inner carrier surrounding the CanSat is sealed with nichrome. It unfolds in a line and CanSat starts moving.
v. CanSat separates the drone, takes off and flies according to commands from CanSat. vi.The **main unit determines the route based on the images from the drone and travels. ÿÿ** vii.After **reaching within 4m radius of the goal, determine the goal and end the program. Ru.**
viii. **Check whether the driving data is saved on the SD card.**

• **Result** •

The v17 **communication/image transfer test between the handset and the master unit and the v18 master unit guidance test were not completed, and the End** to End **test was not completed, but the other series of steps were able to be carried out. ÿÿ** We confirmed that one of **the minimum successes** was achieved. **The video below shows the process from launch to minimum success. Figure 6.21.1 below is a log showing that the landing was determined after the flight pin came out and the nichrome wire fusing mechanism was implemented.** YouTube video link : https://youtu.be/lHB7B0-U_uM

1778	4	PIN_OUT...	1003.57					
1779	5	PIN_OUT...	1003.57					
1780	6	PIN_OUT...	1003.57					
1781	7	PIN_OUT...	1003.57					
1782	8	PIN_OUT...	1003.57					
1783	9	PIN_OUT...	1003.52					
1784	10	PIN_OUT...	1003.52					
1785	11	PIN_OUT...	1003.52					
1786	12	land...	1003.53					
1787	13	nk_before...	1003.53					
1788	14	nk_after...	1003.53					
1789	15	devide...	1003.53					
1790	161845	sensor_check	1003.54	139.367	35.6606	-0.01416	-0.32031	1.0463
1791	161845	Nichrome_code_end...///	1003.54	139.367	35.6606			

Figure 6.21.1 **Log of parachute separation after landing determination**

• **We have also confirmed that it has a runback function. The running trajectory is shown below. Although there was some delay in control, we were able to reach a radius of 4m from the goal.**

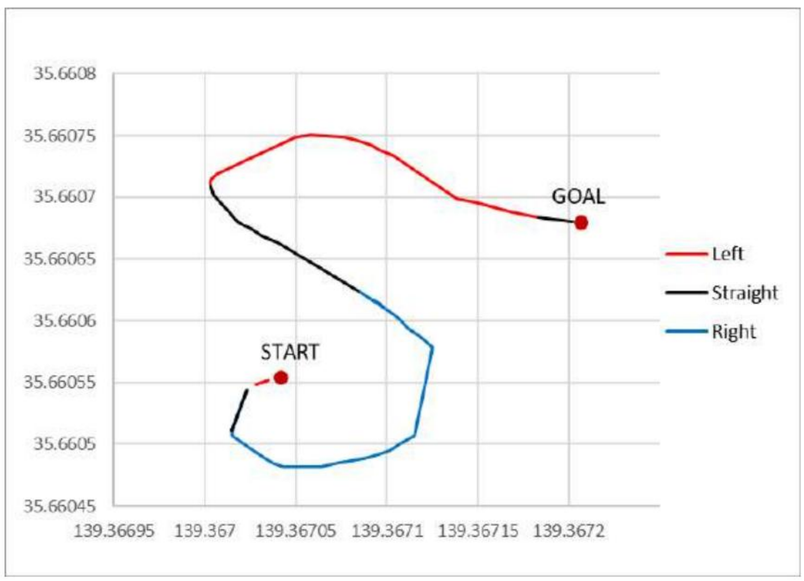


Figure 6.21.1 **Log of parachute separation after landing determination**

•

Consideration • Although we were unable to complete the End to End test because we were unable to complete the v17 **communication/image transfer test between the handset and the main unit and the v18** master unit guidance test, we achieved one of the minimum successes. We were able to confirm that **this is possible** and that it has a runback function. **Therefore, we believe that it is necessary to complete the above two studies, which our organization has not been able to conduct,** as soon as possible.

Chapter 7 **Gantt chart (process control)**

The Gantt chart for this project is shown below. Due to problems with the aircraft and delays in the development of the handset, this schedule shows that 4.
There was a delay of about a week. https://docs.google.com/spreadsheets/d/1SbGfBGynjaOKEjgf0DnNm0jjYI_Hs_NL/edit#gid=74640862

Chapter 8 **Summary of self-safety examination results by the responsible teacher**

1.Safety standards review

要求番号	自己審査項目	自己審査結果	責任教員コメント（特筆すべき事項があれば）
	ARLISS2022安全基準		
	The mass of the aircraft dropping S1 **meets the standards**	☑	
	S2 **volume meets carrier standards**	☑	
	Tests have confirmed that the quasi-static loads during S3 **launch do not impair functionality to meet safety standards.**	☑	
	Tests have confirmed that the vibration loads during S4 **launch did not impair the functionality required to meet safety standards.**	☑	
	Tests have confirmed that the impact load during separation of the S5 **rocket (when the parachute is deployed) does not impair the functionality required to meet safety standards.**	☑	
	S6It **has a deceleration mechanism to prevent it from falling at dangerous speeds near the ground, and its performance has been confirmed through tests.**	☑	
	Measures are being taken to prevent S7 Lost, and their effectiveness has been tested. (Examples **of countermeasures: location information transmission, beacons, fluorescent color paint, etc.)**	☑	
	It has been confirmed that it is possible to comply with the regulations for turning off the power of radio equipment at the time of S8 launch **(devices** that are FCC certified and have a power output of 100mW or less do not need to be turned off. Also, **when using a smartphone, it is necessary to turn off the power of radio equipment that is FCC certified and**	☑	

	(Can be turned off with software or hardware switch)		
There is	a willingness to adjust the S9 **radio channel, and we have confirmed that adjustment can actually be made.**	☑	
We have	**been able to conduct** an end-to-end test that simulates **loading the** S10 rocket, starting the mission, and recovering it after launch, and there will be no major design changes in the future.	☑	**I have tried this, but it has not been successful.**
	If you wish to participate in the Comeback Competition, please be sure to meet the following requirements:		
Achieves	**autonomous control without human intervention during** M3 missions **We have confirmed that this will be carried out.**	☑	
After the	M4 **mission, it will be possible to submit the specified control history report to the management and examiners and explain the logs and acquired data.**	☑	

Responsible teacher's impressions

This team is made up of members of Saharakan, an official club on the Hino Campus of our university, and our laboratory provides technical guidance as a reviewer at each stage of the review. These members participated in ACTS last year, and the CanSat project has come full circle. Therefore, this year's **The project for ARLISS is progressing autonomously. However, because we are having difficulty securing opportunities for tests such as vibration tests, which cannot be conducted within our university or require approval within our university, we have conducted functional confirmation tests in several categories while overlapping them. Although I was able to do it, I had difficulty with all stages of the E2E test. As the responsible faculty member, I am receiving reports from time to time, and I believe that I am able to judge that he is fully capable of flying ARLISS at this point.**

Chapter 9 **Tournament Results Report**

ÿ Purpose

ÿ **Achieve the goal after demonstrating the obstacle avoidance system using a slave device**

ÿ Results

ÿ **First launch results (Launch date and time: September 13, 2022** 9:40 (PST))

Table 9.1 **Results of the first drop test**

item	result	How to judge results
parachute opening	ÿ	Visual inspection, value returned by the barometric pressure sensor
Release judgment	ÿ	Check the logs saved on the base unit
Landing judgment	ÿ	Check the logs saved on the base unit
Internal career development	ÿ	Visually check the logs saved on the base unit
Power on the slave unit	ÿ	Visual inspection*1, check the logs saved on the base unit
Handset holding/separation	ÿ	Visual inspection*2, check the logs saved on the main unit
child aircraft flight	ÿ	Visually check the log from the slave unit
Handset obstacle detection	ÿ	Check the logs saved on the base unit
GNSS guidance	×	Check the logs saved on the main unit
Goal judgment	×	Check the logs saved on the main unit
Positioning information downlink	ÿ	Check the ground station log

- *1 **Confirmed before operation of the handset power-on mechanism**
- *2 **Confirmed before operation of slave unit separation mechanism**

- **Shows the logs acquired by CanSat.**

  https://drive.google.com/file/d/1IDb5HWHTb_Tp-LEG7Ny79SEmh_qzNke7/view?usp=
  sharing

- **CanSat's acquisition logs confirmed that landing could be determined using the barometric pressure sensor.**

4556	91905	land...	882.068604	-119.1046683

Figure 9.1 **Log landing determination part**

- **A video was taken during the CanSat descent. This allows you to record the descent, landing, etc.**

  came. I uploaded the video to Youtube. The link is shown below.

  https://youtu.be/HE0Y73xCdps

- **After landing, CanSat took pictures using a camera mounted on the front of the aircraft (Figures 9.2 to 9.4). 1st shoot**

  In this case, the parachute was recognized, so an evasive action was taken, and after the second image capture and image discrimination, the image was successfully detected.

  Avoided the parachute.

Figure 9.2 **Photographed image used for the first judgment**

Figure 9.3 **Output image used for the first judgment**

Figure 9.4 **Captured image used for second judgment**

Figure 9.5 **Output image used for second judgment**

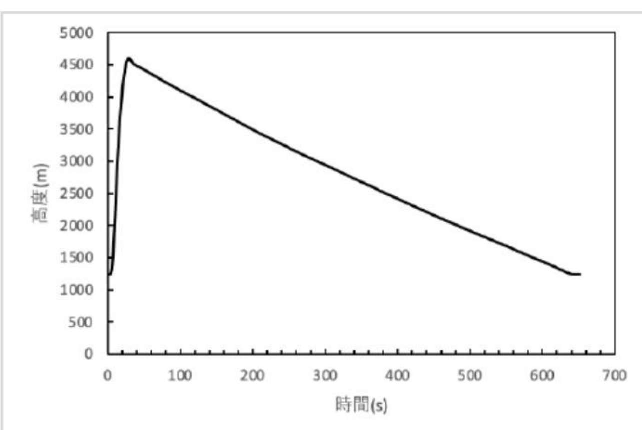


Figure 9.6 **Altitude change after launch**

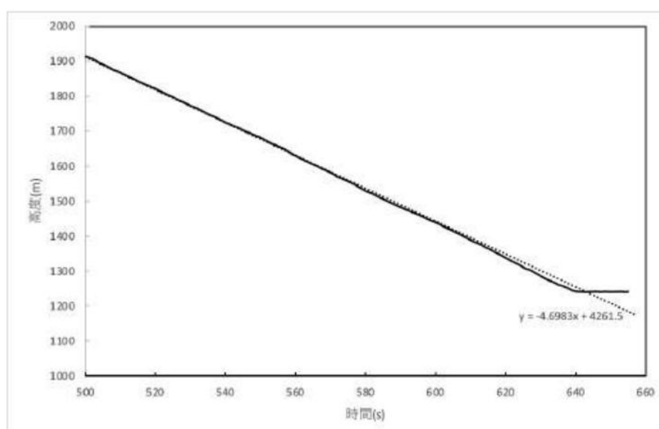


Figure 9.7 CanSat terminal velocity

• **CanSat also acquired atmospheric pressure data and determined changes in altitude from launch to landing. The graph is shown below. It can be seen that after ascending to an altitude of 4500m, it gradually descended while being decelerated by the parachute.**

• **The terminal velocity of CanSat can be derived by restricting the altitude change after launch to near the ground and performing linear approximation. put out**

• **When discovered, the child unit was powered on and separated from the parent unit (Figure 9.8). Afterwards, we confirmed the operating sounds of the handset power-on mechanism** and handset separation mechanism. **The slave aircraft flew (Figure 9.9) and performed a sequence to determine the presence or absence of obstacles . After that, the main unit attempted to start GNSS guidance, but the left tire did not work, and the aircraft continued to run counterclockwise around the left tire. Although it got caught in the cloth of the parachute on the way (Figure 9.10), it escaped and continued traveling, stopping about 7 minutes after it was discovered. After that, I waited for about 20 minutes, but the train did not resume running , so I retired (Figure 9.11).**

Figure 9.8 CanSat at discovery

Figure 9.9 CanSat during child flight flight

Figure 9.10 **Parachute entrainment**

Figure 9.11 CanSat at retirement

• **Figure 9.5 shows the damage to the aircraft. The left tire motor bracket was bent toward the center of the aircraft (Figure 9.12 ÿ), and the motor had shifted toward the center of the aircraft and protruded (Figure 9.12 ÿ). As a result, the surface of the left tire facing the aircraft came into contact with the aircraft. No damage to other parts could be confirmed.**

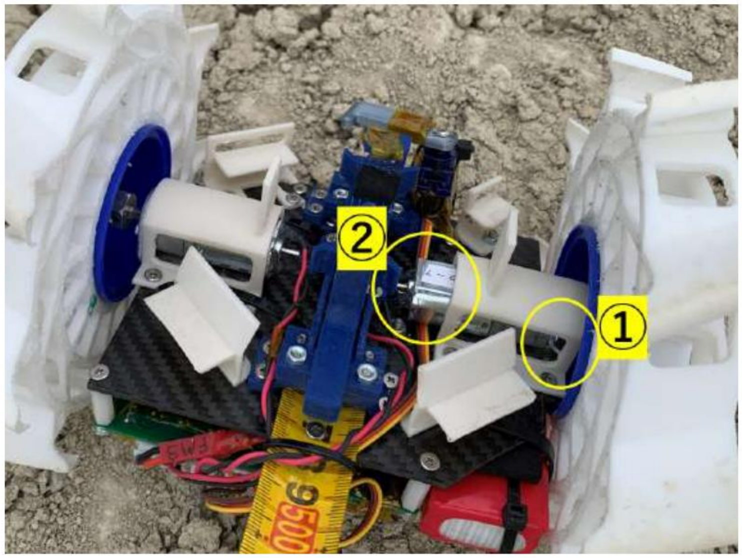


Figure 9.12 **Damage situation of the aircraft**

• **The slave aircraft flew as shown in Figure 9.9. The flight sequence log is shown in Figure 9.13. Synopsis from log You can see that the set sequence has been executed.**

Figure 9.13 **Flight sequence record**

• **Next, the analysis results are shown. The obtained image is shown in Figure 9.14. The image after binarization** is shown in Figure 9.15. This instructed CanSat to rotate 22.5[deg] to the left and proceed 572.5[m].

Figure 9.14 **Acquired image**

Figure 9.15 **Image after binarization**

• There were few ruts at the landing point that could interfere with CanSat's operation. However, when comparing the acquired image and the image after binarization, we can see that the faintly remaining ruts have been colored, and we have been able to detect soft spots on the ground. The large white area at the top is empty and is excluded from the analysis.

ÿ **Second launch results (Launch date and time: September 14, 2022** 15:34 (PST))

Table 9.2 **Results of second drop test**

item	result	How to judge results
parachute opening	ÿ	**Visual inspection, value returned by the barometric pressure sensor**
Release judgment	ÿ	**Check the logs saved on the base unit**
Landing judgment	ÿ	**Check the logs saved on the base unit**
Internal career development	×	**Visually check the logs saved on the base unit**
Power on the slave unit	×	**Visually check the logs saved on the base unit**
Handset holding/separation	×	**Visually check the logs saved on the base unit**
child aircraft flight	×	**Visually check the log from the slave device**
Handset obstacle detection	×	**Check the logs saved on the main unit**
GNSS guidance	×	**Check the logs saved on the main unit**
Goal judgment	×	**Check the logs saved on the main unit**
Positioning information downlink	×	**Check the ground station log**

• **CanSat's acquisition logs confirmed that landing could be determined using the barometric pressure sensor.**

1663194889	land...	883.38623	-119.1048283	40.87405167

Figure 9.16 **Landing judgment part of log**

• **The parachute was deployed, but the rocket disintegrated in the air and landed before reaching terminal velocity (Figure 9.17)**

ÿÿ After landing, the motor was running, but the inner carrier was not deployed, and no further missions or driving were possible.

I decided that I could not continue and retired. When the CanSat fell, it was exposed to rocket smoke, as shown in Figure 9.18.

The entire inner carrier had turned white.

Figure 9.17 Rocket (front) and CanSat (back)

Figure 9.18 **CanSat turned white by plume**

• Figures 9.19 and 9.20 show the damage to the aircraft. As with the first drop, the left tire motor bracket was

It bent toward the center of the fuselage (Figure 9.19), and the motor protruded toward the center of the fuselage (Figure 9.20). 1st throw In response to the results below, the left motor was secured with a cable tie to prevent it from moving, but the cable tie tore. Ta.

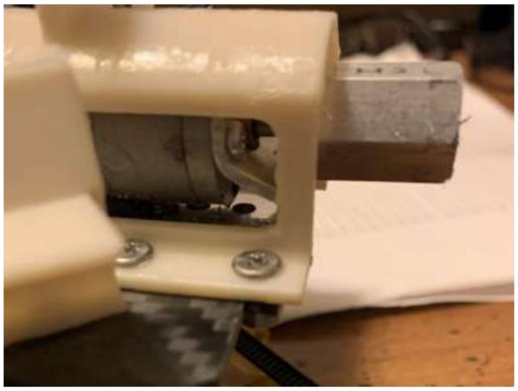


Figure 9.19 **Deformed motor bracket Figure** 9.20 **Motor damage caused by cutting cable ties**

ÿ **Third launch result (Launch date and time: September 15, 2022** 8:43 (PST))

Table 9.3 **Results of the third drop test**

item	result	How to judge results
parachute opening	×	Visually, the value returned by the barometric pressure sensor
Release judgment	ÿ	Check the logs saved on the base unit
Landing judgment	ÿ	Check the logs saved on the base unit
Internal career development	×	Visually check the logs saved on the base unit
Power on the slave unit	×	Visually check the logs saved on the base unit
Handset holding/separation	×	Visual inspection*1, check the logs saved on the main unit
child aircraft flight	×	Visually check the log from the slave device
Handset obstacle detection	×	Check the logs saved on the main unit
GNSS guidance	ÿ	Check the logs saved on the base unit
Goal judgment	×	Check the logs saved on the main unit
Positioning information downlink	ÿ	Check the ground station log

*1 **It is thought that the device was separated before the handset separation mechanism operated (see discussion)**

- **Shows the logs acquired by CanSat.**

  https://drive.google.com/file/d/1f2oXgUcGcs3EG7zS0Dvqi-lLsvIog3i3/view?usp=sharin
  g

- **CanSat's acquisition logs confirmed that landing could be determined using the barometric pressure sensor.**

1663256747	land...	885.309082	-119.1239183	40.87878667

Figure 9.21 **Landing judgment part of log**

- **A video was taken during the CanSat descent.** This video **allowed us to record the descent and landing . It was also confirmed that the CanSat had separated from the parachute and was falling freely . I uploaded the video to Youtube. The link is shown below.** https://youtu.be/Xuon-ci3Ex4

- CanSat photographed the front of the aircraft after landing. Confirm that there is no parachute in front of the CanSat, then **We have moved to the phase of**

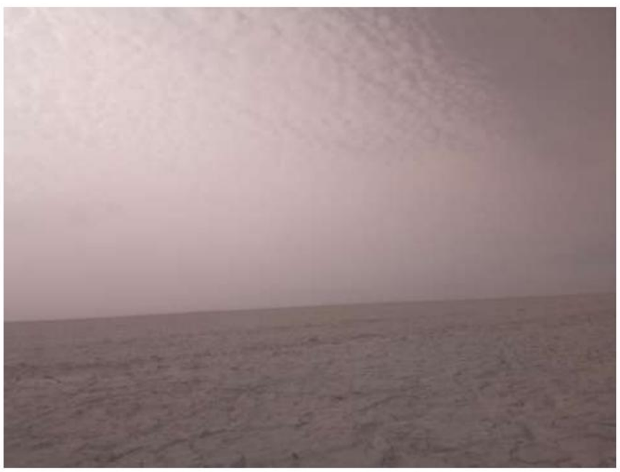
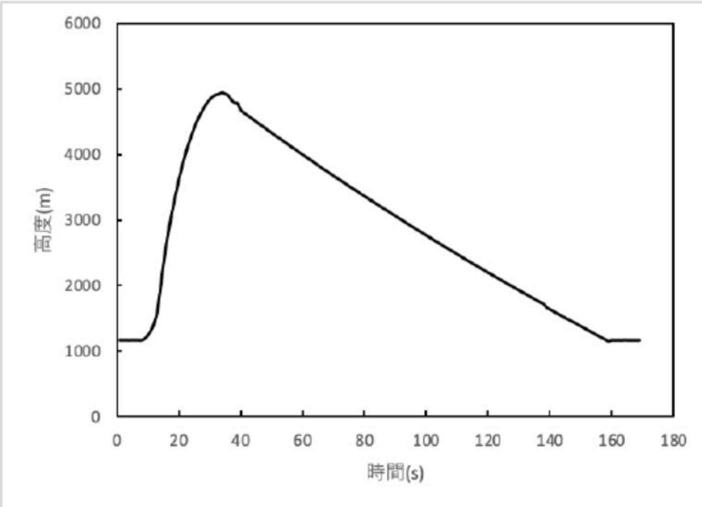


Figure 9.22 Photographed image of the front of CanSat upon landing

Figure 9.23 **Output result after analysis**

- **CanSat also acquired atmospheric pressure data and determined changes in altitude from launch to landing. The graph is shown below. The CanSat fell to the ground from the highest altitude in a very short time, and it is thought that it fell freely after being released from the rocket .**



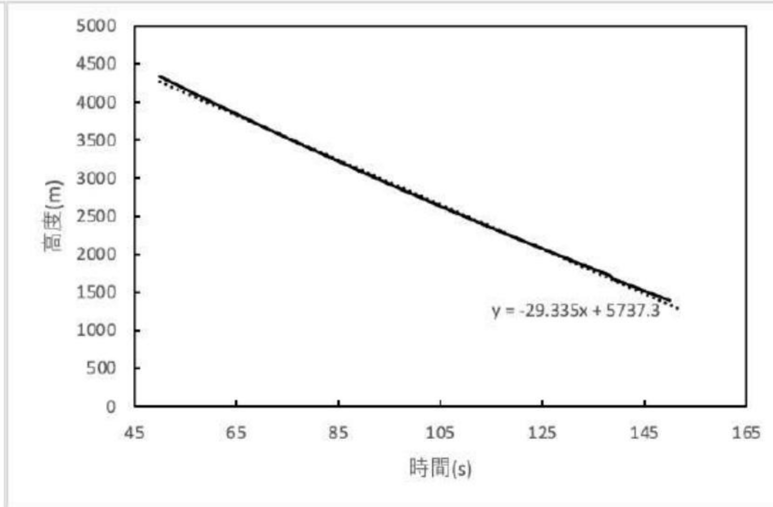


Figure 9.24 **Altitude change after launch**

Figure 9.25 CanSat terminal velocity

- The terminal velocity of CanSat was derived by trimming the time in the above figure to 50 to 150. The terminal velocity near the ground **was 29.33 m/s. This supports the idea that CanSat was in free fall.**

- **During the third launch, CanSat fell freely, but after landing, it traveled about 200m to the target coordinates . The CanSat's left wheel was distorted and it was unable to travel in a straight line, but the logs confirmed that the CanSat correctly traveled to the target coordinates while correcting its travel route according to the GNSS guidance.**

Figure 9.26 **Relationship between CanSat running direction and target coordinates**

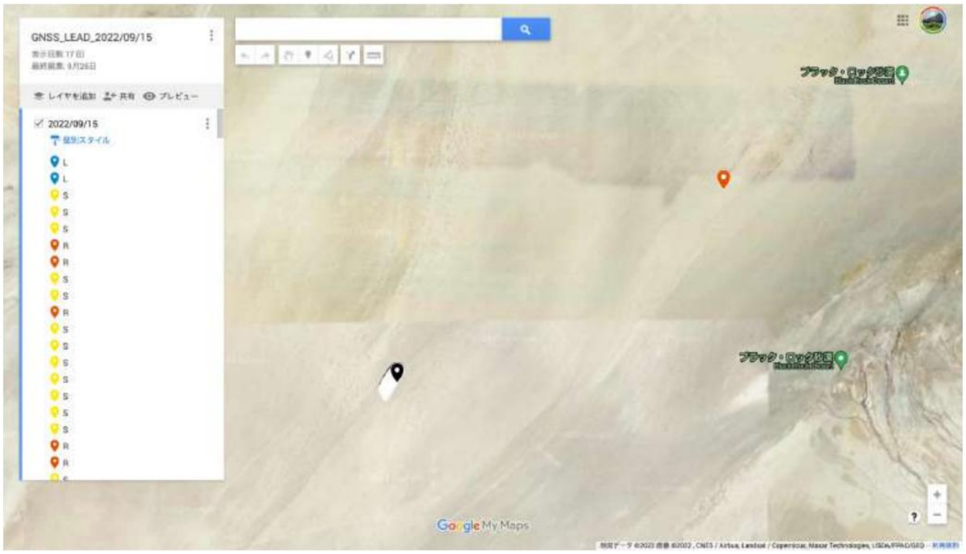


Figure 9.27 CanSat travel route

• **After the CanSat was ejected from the rocket, the inner carrier was damaged (Figure 9.28) and the CanSat fell freely. At the landing point, the parent unit separated from the slave unit and ran, overturned in the ruts like a soft sandbox and executed a high-speed rotation (stuck escape** mechanism) (Figure 9.29). **After that, it ran again and got stuck again (Figure 9.30). The handset was discovered at the CanSat landing** site, with the blade broken and the motor detached, as shown in Figure 9.31. **The power to the handset was not turned on.**

Figure 9.28 **Parachute and part of the inner carrier**

Figure 9.29 **Main unit overturning and rotating at high speed**

Figure 9.30 **Master unit when retired**

Figure 9.31 **Child unit when discovered**

• **Figure 9.32 shows the damage to the aircraft. The motor holder made with a 3D printer was damaged (Fig. 9.32ÿ), the motor was separated from the aircraft. The plate of the motor holder for the right motor that supports the slave unit was broken (Figure 9.32 ÿ). The nichrome wire fixing plate (Figure 9.32ÿ) and blade fixing plate (Figure 9.32ÿ) were also damaged. The damaged parts of these two were found near the handset (Figure 9.31).** • **There was a crack in the arm used to hold the handset (Figure 9.33).** • Figure 9.34 shows how the motor bracket of the left motor is deformed. **The amount of deformation of the motor bracket was less than** after the first and second drop tests . • **Escaped from the stuck state twice after the aircraft was discovered, but was unable to escape from the stuck state again.**

I decided that it was possible and retired.

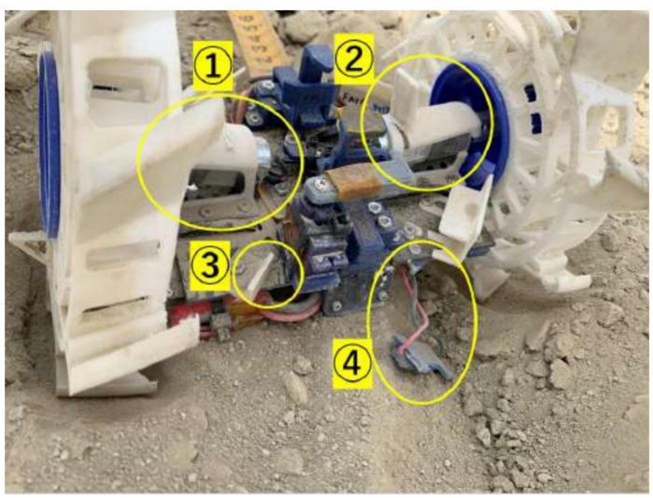


Figure 9.32 **Destruction status of base unit**

Figure 9.33 Crack in the arm used to hold the handset

Figure 9.34 Left motor

ÿ Discussion

ÿ **The degree of achievement of the success criteria was evaluated as follows through the three test runs.**

•

success criteria		Level of achievement
Minimum	1. The handset used for obstacle avoidance can be started and is working. 2. I was able to confirm the presence of obstacles.	ÿ
full	Based on the information from the child device, the parent device appropriately judges the course and determines the goal.	×
advanced	0m goal	×

- **The following are possible reasons for not achieving full success.**
  - **The aircraft was damaged and could not run stably after landing. ÿ**
    Structural members around the motor were damaged due to vibration and landing impact, causing the aircraft to travel in a meandering manner. For this reason, it seems necessary to allocate more weight to motor-related parts within the limited weight at the time of design to create a more robust design.
  - **The aircraft fell freely and excessive impact was applied to the aircraft. ÿ The third launch was carried out because the second launch failed, but the CanSat structure was damaged during the second launch. , the CanSat used for the third launch was assembled from spare parts. As a result, we were unable to strictly control the weight, and the weight exceeded the limit during the regulation check, so we decided to cut out a portion of the inner carrier. This cutting was done using scissors, and the cut out areas did not have even edges, but had many notches. Therefore, it is thought that the inner carrier disintegrated in the air during the fall, causing the free fall. It was necessary to conduct a preliminary separation impact test and drop test with the inner carrier cut off. It was also necessary to measure the weight before checking the regulations and carefully carry out weight reduction work.**
  - **The obstacle avoidance system was inadequate.**

ÿ Given the difficulty of the mission, members had less time to devote to development. When considering the mission, it was necessary to give priority consideration to time and environmental constraints.

• Below, we will discuss the events that occurred for each drop test.

ÿ **1st time** •

Regarding the fact that the handset was powered on before the handset power-on mechanism operated, the cause was that the power-on arm touched the ground when landing and rotated due to the reaction force, causing the handset to turn on. This is probably because the power button was pressed. The reason for this decision was that during the preparation period, there was an incident in which someone touched the power-on arm with their hand and the force caused the arm to rotate and press the power button.

Regarding the fact that the handset separated from the base unit before the handset separation mechanism operated, the cause was that the arm that was holding the handset touched the ground when it landed and bent, causing the handset to drop . it is conceivable that. The reason for this decision was that a similar case occurred during a drop impact test during the preparation period. The servo motor that is driven during separation is not supplied with electricity in the software before the mechanism operates, so it is unlikely that the servo motor malfunctioned and the separation arm opened. • **Regarding the fact that the left tire did not work, the cause was that the motor of the left tire was ejected towards the inside of the aircraft, as stated in the results. It is thought that this caused the tires to also move towards the inside of the aircraft, making contact with the aircraft and becoming unable to rotate. The reason why the left tire motor flew out is thought to be because the left tire was placed downwards when the rocket was stowed and was affected by the impact of the rocket's separation.**

ÿ **Second time**

• **The inner carrier did not deploy after landing, which is thought to be due to insufficient heating of the nichrome wire. After recovering the aircraft, we performed an operation test on the nichrome wire, but found that no voltage was flowing through the nichrome wire and it could not be heated. Heating the nichrome wire is powered by a lithium battery. Although it is controlled by MOSFET, in the operation test after recovery, the power supply from the lithium battery was 0V at the timing when the heating signal was sent . Since it was operating normally in the pre-flight operation test, it is thought that there are no problems with the wiring or programming. When we performed a continuity check, we could not confirm continuity in the conductor from the lithium battery box. Therefore, it is thought that the cause was poor contact of the conductor from the lithium battery box.**

ÿ **Third time** •

Regarding the fact that CanSat was able to run even after a free fall, the first reason is thought to be that measures were taken to reduce the amount of deformation of the motor bracket, which allowed the tires to rotate even after receiving an impact. Since the motor bracket was deformed in the first and second drop tests (Figure 9.35), **the direction of the motor relative to the motor bracket was rotated 90 degrees and fixed in the third drop test (Figure 9.36). Due to this measure, the amount of deformation of the motor bracket due to impact was small, and therefore the amount of movement of the motor protruding toward the inside of the aircraft was also small. Therefore, it is thought that the phenomenon where the tires got caught on the aircraft and stopped rotating did not occur. The second reason is thought to be that the tires absorbed the landing impact.** Because **the inner carrier disintegrated in the air ,** the large, flexible TPU tires were deployed when the aircraft landed.

Figure 9.35 **Motor bracket after first drop Figure** 9.36 **Motor bracket after third drop**

- **The reason why the CanSat was able to move even after it rolled over and rotated at high speeds is thought to be because the parts were firmly fixed to the body of the aircraft because adhesive was applied to each part and to the screw holes.**
- One of the reasons why the main unit got stuck is **that the motor holder was damaged by the landing impact after CanSat's free fall. This caused the motor to separate from the aircraft, making stable running impossible.**

- **Regarding the fact that the handset could not be powered on, it is thought that the cause was that the handset separated from the base unit when it landed. As stated in the results, there was a crack in the arm used to hold the handset, making it possible to remove the handset from the base unit without turning the servo motor and operating the handset separation mechanism. This crack is thought to have been created upon landing due to the impact of free fall. Therefore, the slave unit jumped out from the parent unit, and it is thought that the slave unit was already separated when the slave unit's power-on mechar**

Chapter 10 **Summary**

ÿ **Points of innovation and effort (all aspects of hardware, software, and management)** ÿ Hardware ÿ **We spent the most time**

designing and manufacturing the drone power-on mechanism and drone separation mechanism. By **introducing a 3D printer, we were able to easily produce prototypes and repeatedly make detailed adjustments.** ÿ We made and reflowed a DIP board for EASEL's latest model, ES920LR3, and were able to **use it** on site without any problems . ÿ **Separating the parachute is the first hurdle in CanSat, and in the previous competition that our organization participated in, the parachute** string got tangled around the CanSat, and it was not possible to separate **the parachute. Made it difficult for CanSat to fall in the direction of travel. Additionally, a bowline knot was used to tie the parachute string.** ÿ **At domestic competitions, the importance of radio equipment is low because CanSat can be seen visually, but at ARLISS, after launch**

Because CanSat cannot be seen visually, the radio equipment is much more important than in domestic competitions. Therefore, we conducted numerous tests to ensure reliable operation and installed multiple ground stations.

ÿ **When taking photos of desert sand using a Raspberry Pi camera, the images are overexposed, so it is no longer necessary to use sunglasses. Because this occurred frequently, sunglasses were installed as standard equipment on the aircraft.** ÿ **The base of the Raspberry Pi camera cable is easily cut, so I wrapped it in Kapton tape.** ÿ **The XH connector is horizontal rather than vertical, making the cable shorter and less likely to get caught.**

ÿ **In order to reduce the amount of thinking and work that must be done on the day of the event, we have colored switches and connectors so that they can be turned ON and OFF. We made it easy to check before starting up, followed the procedure manual, and carried out preparations in a calm manner.**

ÿ **Software** ÿ

Regarding the GNSS guidance algorithm, we were able to spend more time on this mission by referring to the program we created last year. Therefore, we were able to create a countermeasure program based on last year's failures.

ÿ **I tried to implement it according to the specifications. Although there were major limitations in terms of purchased items and hardware, the objective was achieved.** ÿ **Management**

ÿ **It was a busy period for my studies as my activities were often restricted due to the effects of the new coronavirus, but I was able to complete the aircraft in time for the competition.** ÿ **We investigated failures in past tournaments and incorporated countermeasures for failures into the specifications.** ÿ **Since launches may fail on the day, it is a good idea to bring three FMs.** ÿ **We purchased goods early because we predicted a weak yen, a shortage of semiconductors, and a rise in metal prices.**

ÿ **Issues • The fixation of the tire motor was not strong enough to withstand shock, and the operation of the slave unit power-on mechanism and slave unit separation mechanism was not reliable. • A solid GND alone was not sufficient to remove noise caused by the motor. Current when the motor starts was large, and is thought to have had an effect on GNSS sensors. • One program has become too long. It was necessary to separate the files by importing them separately.**

• It took a lot of time to handle the GNSS acquired data. • Only one image could be used and depth information could not be obtained. • It was a highly difficult mission, and it was difficult to manage the test schedule for the aircraft. • It is possible that we were unable to assume an environment closer to the actual site when measuring the terminal velocity of the parachute. • End-to-end **success rate was low.**

- The carrier for regulation checks owned by the department had been used for many years, so its diameter was slightly larger.
  Listen, I got caught up in the tournament regulations.
- I forgot one cable in Japan, and there was a system that didn't work yesterday, so I had to
  It is necessary to manage and check to ensure that nothing has happened.

ÿ Future prospects

Our organization plans to continue activities aimed at participating in ARLISS. In future CanSat production, we will take into account what we learned from this experience, and will create a simple aircraft design that allows not only the person who designed it but also others to assemble the aircraft, thorough noise countermeasures on the hardware side, and improvements to the code on the software side. While aiming to create an aircraft that is easy to modify and check, we aim to develop an aircraft that is novel by using mapping technology such as LiDAR and 3D printers.