ARLISS2022 Tournament Report

Submission date: November 21, 2022

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CanSat class	Open class

• Table of Contents

Chapter 1 Mission Statement ....4 1. Members ....4 2. Background 4
Chapter 2 Success Criteria .. ..5 Chapter 3 Setting requirements ....6 1. System requirements (requirements for safety and regulation) ... .6 2. Mission sequence ....7 3. Mission Requirements ....8 Chapter 4 System specifications ....12 1. Interior and exterior appearance of the aircraft ....12 2. Mechanism of the aircraft ....14 3. Control system .... .18 Chapter 5 Test item settings ....20 Chapter 6 Contents of the exam ....21 V1. Mass test ....21 V2. Storing and discharging the aircraft test 21
V3. Quasi-static load test 23
V4. Vibration test ....24 V5. Separation impact test 26
V6. Drop test ....28 V7. GPS Data downlink test... ....29 V8. Communication device ON/OFF test................................ 30
V9. Radio frequency change test ....31 V10. End-to -End exam ....32 V11. Surface confirmation test ....32 V12. Long Run test ....33 V13. Data storage test ....34 V14. Parachute separation test ... .35 V15. Driving test ....36 V16. Stuck avoidance test ....37 V17. 0m goal test ....38 V18. Control history report creation test ....40 Chapter 7 WBS and Gantt chart (work management) ....41 Chapter 8 Summary of self-safety review results by the responsible teacher ....42 1. Safety standards review ....42 2. Responsible faculty member's impressions 43
Chapter 10 Tournament Results Report 44
1. Purpose 44

2. Results ....44 3.
Discussion .. ..47 Chapter 11
Summary ....49 1. Points of improvement
and effort ....49 2.
Issues ....50 3. Future
prospects 50

Chapter 1 Mission Statement

Reach the target point using a spherical rover.

1. Table 1 shows

the team members and their roles.

Table **1** Member table

Name	role
East	PM
Tsubasa	Electrical equipment team leader
Shun Katsube	Structure team leader
Kentaro Shirai Haruki Sashida	Electrical equipment team, structure team

2. Background

Strong feelings such as ``I want to try CanSat'' and ``I want to participate in ARLISS'' came together, and this A team was formed. However, all the members are in their second year of master's program and are busy with research and job hunting. Considering this, difficult missions are unrealistic. Therefore, we already have the know-how*1 and We focused on the ``spherical rover,'' which has begun to be considered for space exploration.*2 spherical rover The advantages of this are that the separation mechanism (parachute) is less likely to get tangled and the tires are less likely to get stuck in ruts. These advantages are greater than conventional models. The main cause of mission failure for two-wheeled rovers can be avoided. Also, this time, the previous members The causes of mission failure when participating were ``damage to the motor shaft'' and ``lost due to loss of wireless communication.'' We aim to complete the mission by taking sufficient measures.

Furthermore, since we already have the know-how and have a 3D printer in our laboratory, we are able to determine the general specifications and requirements. We were able to quickly decide on the requirements and to start building the aircraft right away, so we were able to work as an adjuster. We decided to incorporate file development*3 into CanSat development. The number of teams that your organization has participated in in the past is at most 4 While we were building a similar number of aircraft, we built at least seven aircraft and conducted more tests. The plan is to do so. It is believed that by repeating many tests and failures, the mission will be closer to success. It is growing.

*1 At ARLISS in 2018, members Katsube and Sashida developed a spherical rover and entered it in the Comeback Competition category.

*2 Transformable lunar robot jointly developed by Takara Tomy, JAXA, and others is active in space exploration: https://asset.watch.impress.co.jp/img/hbw/docs/1395/513/001_l.jpg

*3 Agile development: https://hnavi.co.jp/knowledge/blog/agile_software_development/

Chapter 2 Success Criteria

Table 2 shows the success criteria.

Table 2 Success Criteria

level	item	Method of verification
minimum success	The spherical rover starts moving.	Check from the log that both of the following conditions are met. •The spherical rover is in driving mode.•The position coordinates of the spherical rover change over time.
full success	The spherical rover reaches the goal.	Check CanSat's GNSS goal*3 from the log.
advanced success	Achieve the 0m goal with a spherical rover.	Both of the following are satisfied. - Visually confirm that the CanSat body is in contact with the goal cone. •Confirm from the log that CanSat has reached the 0m goal*4.

*3 GNSS Goal: A state in which CanSat's positioning results detect tha~~t it has arrived~~ within a circle with a radius of "GNSS error 2" [m] from the destination .

*40m Goal: A state in which CanSat has reached the goal using a camera. detected and stopped.

Chapter 3 Setting Requirements 1.

System Requirements (Requirements for Safety and Regulation) Table 3

shows the system requirements.

Table 3 System requirements

Request number	System requirement item	specification
S1	The mass of the aircraft to be dropped must meet the standards.	•The mass is 1050[g] or less.
S2	volume must meet carrier standards.	- Fits into a cylinder with a diameter of 146 [mm] and a height of 240 [mm] or less.
S3	The quasi-static load at the time of launch satisfies the safety This has been confirmed through testing. Tests have confirmed functionality required to meet safety standards. Safety	standards.The quasi-static load of 10[G] satisfies the safety standards. ÿÿ that the vibration loads during launch do not impair the
S4	due to the shock load at the time of rocket separation •The function to satisfy the safety standards is impaired by the shock load of 40 [G] at the time of rocket separation.	•The design is such that random vibrations of 30 to 2000 [Hz] and 15 [Grms] do not impair functionality to meet safety standards.
S5	What has been confirmed in the test. This is the total. In order to it is equipped with a parachute deceleration mechanism that achi has been verified through tests. What has been done.	prevent the parachute from falling at dangerous speeds near the ground, eves a terminal speed of approximately 3 to 5 [m/s], and its performance
S6		―――
S7	Countermeasures against lost data have been implemented, and their effecti distances that are effective for lost countermeasures (example of countermea device, information transmission, beacon, fluorescent light, etc.) color paint	veness has been confirmed through wireless tests that allow communication even at sures: equipped with a positioning - Equipped with a GPS receiver. •It has a structure that does not block GPS and radio waves. etc).
S8	It has been confirmed that regulations for turning off radio equipment during launch can be complied with (FCC-certified devices with a power output of 100 mW or less must not be turne can be confirmed to do so.) (If you use a smartphone, it must be and can be turned off with a software or hardware switch).	d off. - No radio waves are emitted during launch, and the equipment FCC certified
S9	The applicant must be willing to adjust the wireless channel and be able to confirm that the adjustment can actually be made.	•[Luck] Willingness to adjust wireless channel.•The design allows the frequency channel of the radio to be changed.

Request number	System requirement item	specification
S10	The mission begins by loading the rocket, We have been able to conduct an end-to-end test that simulates the process from launch to recovery, and we are planning to make significant changes in the future. There are no changes to the total.	•[Luck] Starting the mission from loading the rocket The plan is to conduct an end-to-end test that simulates the initial stage, post-launch, and recovery. •[Luck] Starting the mission from loading the rocket After an end-to-end test simulating the process from start to recovery after launch, major design changes related to safety were made. do not.
S11	In the entire sequence, the operator was injured. There is nothing.	- Designed without sharp edges. •[Ground] Designed without sharp edges. •[Luck] Always put safety first.
S12	After carrier release, CanSat is placed inside the carrier. No parts left behind.	•CanSat is designed so that it does not separate within the carrier. Ru.

[Luck]: Operator

[Ground]: Ground station

2. Mission sequence

The mission sequence is divided into ÿ to ÿ in Table 4. This is shown in Figure 1. Also, the following missions The input requirements and related specifications are described for each sequence.

Table 4 Mission sequence

sequence	Content
ÿ Preparation	From assembly to carrier storage
ÿ Launch	From carrier storage to release determination
ÿ Descent	From release judgment to landing judgment
ÿ Preparation for driving	From landing judgment to start of driving
ÿ Running	From start of trip to GNSS goal
ÿ 0m goal	From GNSS goal to 0m goal
ÿ Analysis	From CanSat collection to data analysis

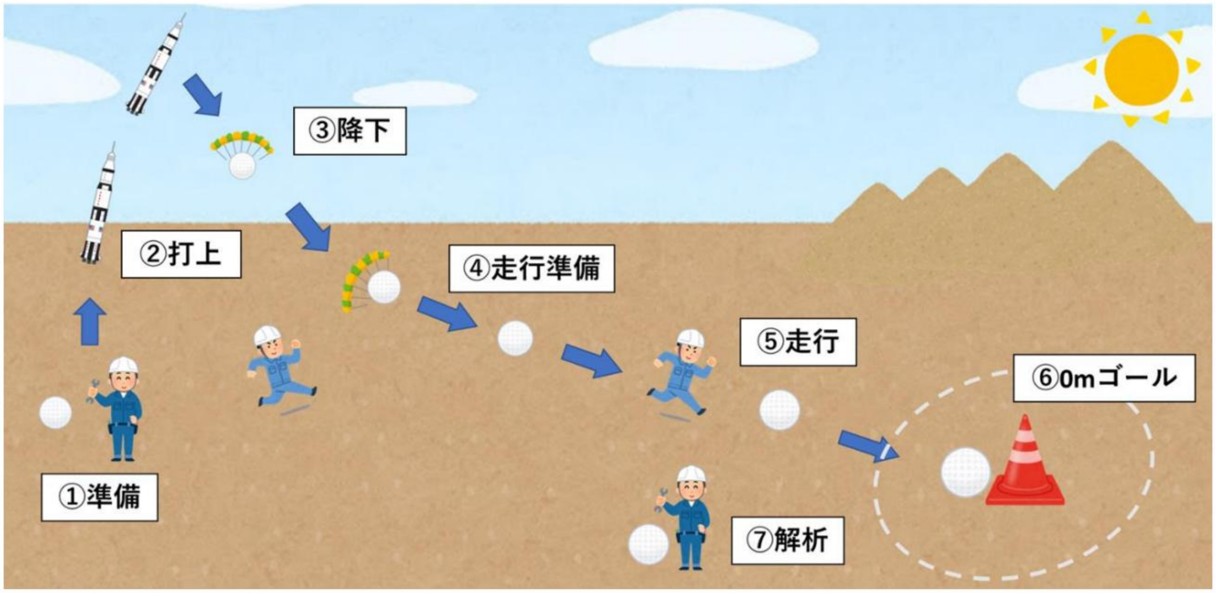


Figure **1** Mission sequence diagram

3. Mission Requirements Mission

requirements are shown in Table 5.

Table 5 Mission requirements

Seake ance	Number	Request details	specification
whole	M1	CanSat analyzes the entire sequence Provides power for successful completion What you can do.	- Up to 4 hours of operation (1 hour standby + 3 hours mission) It is equipped with a battery that can supply power for Ru.
	M2	Human intervention during the mission Implem~~ent inde~~pendent autonomous control without Be able to confirm that.	•After being stored in the carrier, it becomes independent without human intervention. It is designed to implement control. •[Luck] We have a plan to conduct a test to confirm the above specifications. be.
	M3	CanSat stores HK data What you can do.	•Sampling necessary for verification of success criteria Storage device capable of storing HK data acquired at rates is installed.
ÿ Preparation	M4	CanSat assembly delayed It can be completed without any problems.	- Designed to complete assembly within 2 hours.
	M5	Can power up CanSat thing.	- Power switch is installed within easy reach. •Equipped with an LED to confirm that the power is turned on It has been done.
	M6	CanSat can be stored in a carrier What you can do.	•Satisfies S2.

sequence	Number	Request details	specification
ÿ Launch	M7	CanSat must not interfere with rocket communications.	•Do not emit radio waves during sequence ÿ.
	M8	CanSat must be able to determine release.	•The design uses a ~~light sensor, barometr~~ic pressure sensor, and timer to determine release.
	M9	CanSat was able to carry out the mission 30 to 2000 [Hz]. to accomplish the mission *5 will not be	with the loads applied during launch: quasi-static load of 10 [G] and random vibration of The design is such that even if 15 [Grms] is added, the minimum functions required compromised. Ikoto.
ÿDescent	M10	The operator must be able to obtain and track CanSat's position coordinates.	•It is designed to obtain its own position coordinates from GPS. - Equipped with a radio to transmit location information to the ground station.•[Ground] Prepare a portable ground station with the ability to receive location information from CanSat.•Equipped with a parachute that has a terminal velocity
	M11	CanSat should not lose the minimum functionality necessary to carry out its mission due to landing impact.	of 3 to 5 [m/s].•It is designed so that the minimum functions necessary to accomplish the mission will not be impaired even if it receives a landing impact at a terminal velocity of 3 to 5 [m/s] .
	M12	The CanSat is designed to maintain the accomplish the mission, even if it is subjected Do not impair its functions.	minimum load required to accomplish the mission and not impair the functions necessary to to the opening impact that occurs during deceleration.
	M13	CanSat must be able to determine landing.	•It is designed to use an acceleration sensor, barometric pressure sensor, and timer to determine landing.
ÿ Preparation for driving	M14	CanSat can separate the airframe and deceleration mechanism.	•It is designed to connect the parachute and the aircraft with a thread. -Equipped with nichrome wire that burns out the wire. - The design allows the program to be
	M15	CanSat must be able to obtain the goal position coordinates.	rewritten in order to input the goal coordinates before sequence ÿ.

*5 Minimum functions required to complete the mission: Can run, can know the relative position of the goal and CanSat

sequence	Number	Request details	specification
ÿRunning	M16	CanSat must not become unable to run due to obstacles such as deceleration mechanisms or ruts.	- Equipped with deceleration mechanism escape mode. -Equipped with a rut escape mode.
	M17	CanSat must be able to obtain the direction of the goal.	•It is designed to obtain its own position coordinates from GPS.•The design allows calculation of the relative azimuth between the own position coordinates and the goal cone position coordinates.
	M18	CanSat can move in any direction.	•Equipped with a high torque motor of 0.05[Nm] or more. - Designed to move the center of gravity using a servo motor.•It is designed to obtain its
	M19	The operator must be able to obtain and track CanSat's position coordinates.	own position coordinates from GPS. - Equipped with a radio to transmit location information to the ground station.•[Ground] Prepare a portable ground station with the ability to receive location information from CanSat.
	M20	CanSat's position coordinates are within a radius of GNSS fr~~om the destination~~. designed to be able to detect when a player the circle. and.	•It is designed to obtain its own position coordinates from GPS. It is has reached within a circle of 2" [m] by comparing the distance with the radius of
ÿ0m goal	M21	CanSat must not become unable to run due to obstacles such as deceleration mechanisms or ruts.	- Equipped with deceleration mechanism escape mode. -Equipped with a rut escape mode.
	M22	CanSat must be able to obtain the direction of the goal.	- Designed to recognize goal cones using a camera.•It is designed to be able to calculate the relative azimuth between its own position and the position of the goal cone.
	M23	CanSat can move in any direction.	•Equipped with a high torque motor of 0.05[Nm] or more. - Designed to move the center of gravity using a servo motor.•It is designed to obtain its
	M24	The operator must be able to obtain and track CanSat's position coordinates.	own position coordinates from GPS. - Equipped with a radio to transmit location information to the ground station. •[Ground] Prepare a portable ground station with the ability to receive location information from CanSat.
	M25	CanSat should be able to detect that it has reached the 0m goal and stop its operation.	•It is designed to use a camera to detect when a goal has been reached.•It is designed to stop operating after detecting the 0m goal.

sequence	Number	Request details	specification
	M26	The design allows the operator to migrate data to the ground station. Collect logs for rear verification - The design is such that saved HK data is not deleted or overwritten. What you can do.	
ÿAnalysis	M27	mission, the specified control 3. CanSat's 5. Control end time and position where CanSat Something. (If the control stops due to some and position at that time) 6. Straight line distance between control end	- The design allows the operator to report to the operator regarding the following items. 1. Control mechanism and algorithm 2. A clear visualization of the relationship between CanSat's position trajectory and control commands After the position trajectory is the result of active autonomous control. 4. Control start time and position stopped autonomously kind of trouble, the control end time distance between control start position coordinates and goal coordinates 7. Straight line position coordinates and goal coordinates 8. Control start position and control end position straight line distance of

[Luck]: Operator

[Earth]: Ground station

Chapter 4 System specifications

1. Inside and outside appearance of the aircraft

Figures 2 and 3 show CAD drawings of the CanSat aircraft, and Figure 4 shows an overhead view of the CanSat aircraft. Tip of single shaft motor A set collar is attached to the end, and the set collar and spherical shell are fixed with screws. on the opposite side of the motor The shaft stabilizer is not fixed to the spherical shell, but is in contact with the spherical shell using a bush. Figure 2 or Figure 3 The components other than the spherical shell described in are fixed to an aluminum plate.

Examples of spherical shells include ``one made with filament such as PLA or TPU using a 3D printer'' and ``Ornament balls'' and ``hamster balls'' were cited. Select a spherical shell from among them When setting the mass of the aircraft to 900[g], the aircraft launches itself from a height of approximately 1.3[m] where the terminal velocity is 5[m/s]. An experiment was carried out in which it was dropped. As a result of considering the degree of damage and cost, we decided to use a HAMS with an outer diameter of ÿ=140[mm]. Tarball was adopted.

As for the structure, the aircraft has been manufactured to the level of an EM aircraft, but the parachute has not yet been manufactured. The plan is to have it manufactured by the drop test on July 16th. Therefore, the specifications of only the aircraft at this stage are displayed as an error! Reference source not found. It is shown in In the future, it will be possible to attach it to the tip of a parachute or servo horn. Although it is planned that mass such as weights will be added, it is thought that the regulations will not be exceeded.

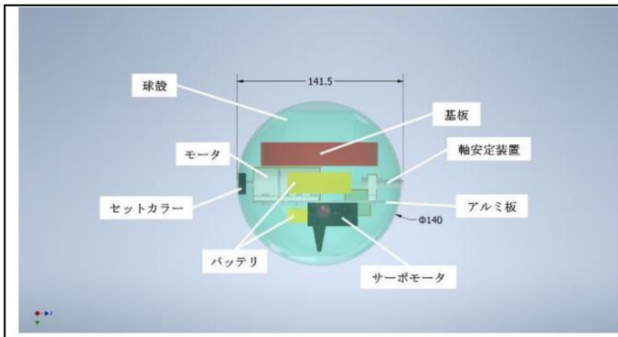


Figure **2** Front view of the aircraft

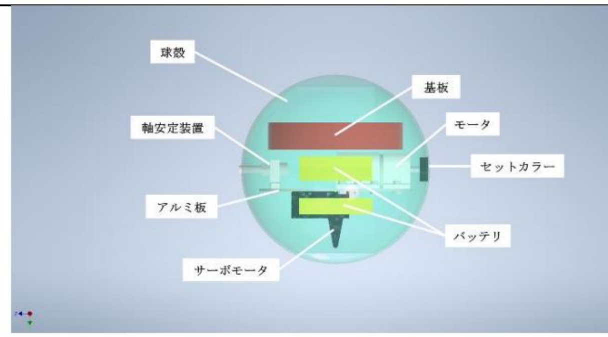


Figure **3** Aircraft rear view

Figure 4 Overhead view of the aircraft

Table 6 Specifications of **CanSat** aircraft only

Diameter [mm]	141.5
Height [mm]	140
Mass [g]	561.1

The spherical shell has two advantages: ``the hemispheres can be combined with each other from the perspective of assembly flexibility'' and ``the ability to run from the perspective of running performance.''

The hemispheres could be fixed together using bolts, taking into account two points: 1) to prevent the deformation of the spherical shell during the process;

We adopted the following. In addition, in order to provide landing impact resistance, the ham has flexibility to the extent that it does not affect running performance.

A star ball (outer diameter: 140[mm]) was used. Take the shaft and bush into this hamster ball.

By attaching it, the maximum diameter is 141.5mm. Furthermore, damage caused by stress concentration can be prevented.

To prevent this, tape is pasted on the gaps and mounting boundaries.

Figures 2 and 3 show the front exterior and interior views of the CanSat, and Figures 4 and 5 show the rear exterior of the CanSat.

and an interior view. Furthermore, Figure 6 shows an overhead view of the aircraft.

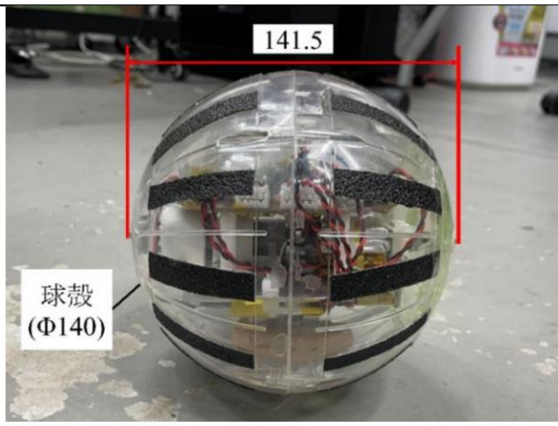


Figure **2** Front view of the aircraft (exterior)

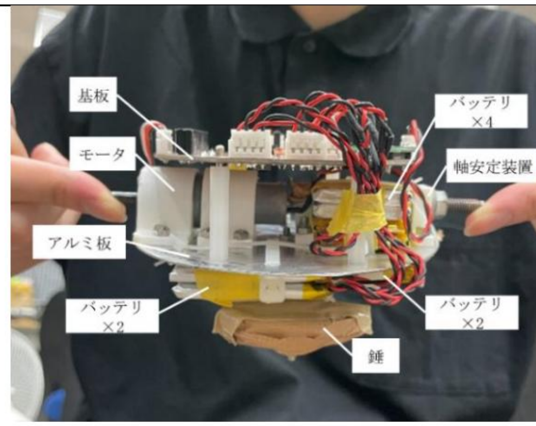


Figure **3** Front view of the aircraft (interior view)

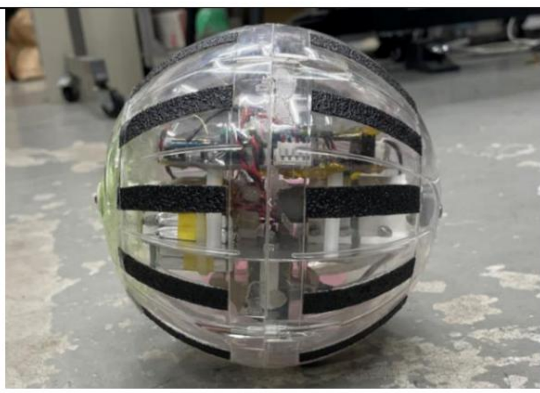


Figure **4** Rear view of the aircraft (exterior)

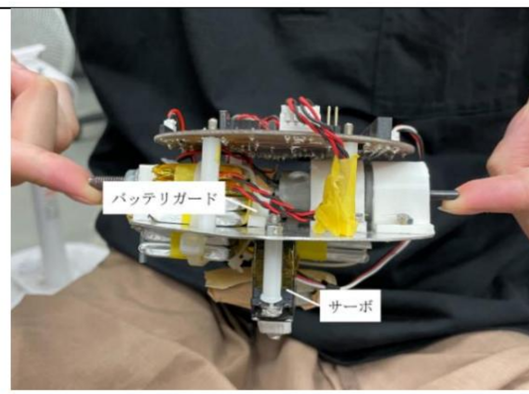


Figure **5** Rear view of the aircraft (interior view)


Figure **6** Overhead view of the aircraft

Attach the set collar to the spherical shell and fix the motor shaft to the set collar (Figure 7). Axis of rotation
The shaft stabilizing device (Fig. 3) installed to stabilize the vehicle improves running performance and stabilizes the shaft during running or falling.
In order to prevent the spherical shell from coming off, a bushing is used to keep it in contact with the spherical shell without being fixed to it (Figure 8). difference
Furthermore, in order to prevent the Li-Po battery from being damaged due to the rotation of the motor shaft located at the center inside the structure,
Therefore, install a battery guard. In addition, components other than the spherical shell of the aircraft are fixed to aluminum plates.
It is set. All bolted parts of the fuselage, connections between bushes and spherical shells, and connectors on the board.
Potting is applied to provide shock and vibration resistance.

Table 6 shows the specifications of the CanSat aircraft only.

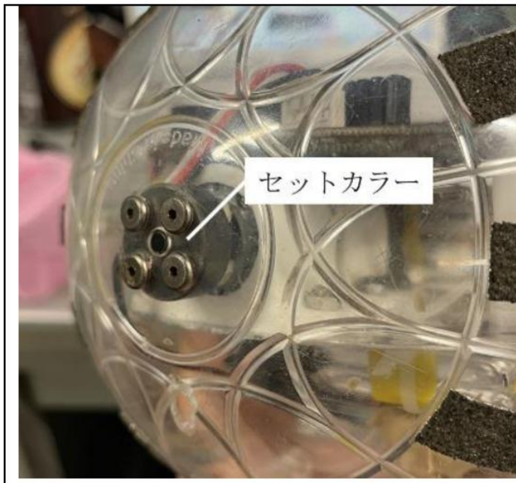


Figure **7** Shaft mounting part

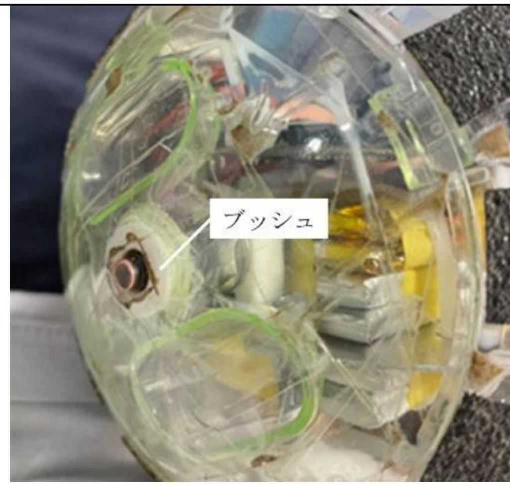


Figure **8** Bush mounting part

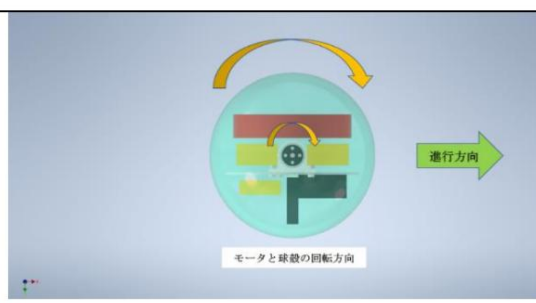
Table 6 Specifications of **CanSat** aircraft only

Diameter [mm] 140 (max. 141.5)	
Height [mm]	140
Mass [g]	658.2

2. Airframe mechanism ÿ

Travel The tip

~~of the single-axis motor and the spherical shell are fixed, but the shaft stabilizer in the opposite direction is fixed to the spherical shell. Therefore, even when the motor is driven, the spherical shell only rotates, and the aluminum plate inside does not rotate and is almost completely covered with water. Stay calm. This mechanism uses the rotation of the spherical shell to propel the aircraft. Figure 5 shows the forward running field. A simple mechanism for this is shown.~~



~~Figure **5** Mechanism of forward running~~

Figure 9 shows the forward running mechanism. The motor shaft is fixed to the spherical shell with a set collar, and the driving force is transmitted to the spherical shell through the set collar. Since the moment of inertia inside the fuselage is larger than the moment of inertia of the spherical shell, it is difficult for the interior of the fuselage to rotate. Therefore, only the spherical shell is rotated by the driving force of the motor, and the CanSat aircraft moves forward. The interior of the aircraft moves forward while remaining almost horizontal.

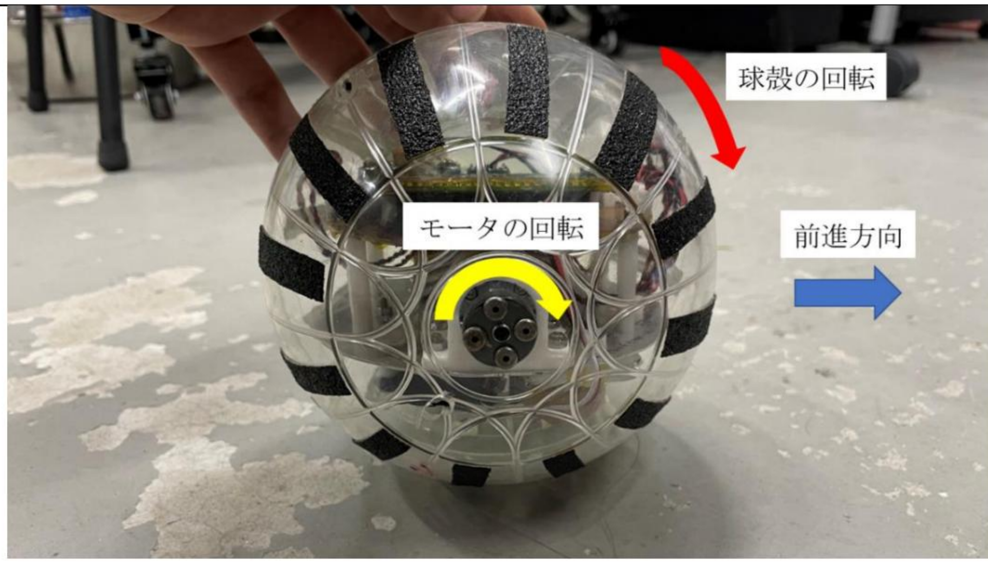
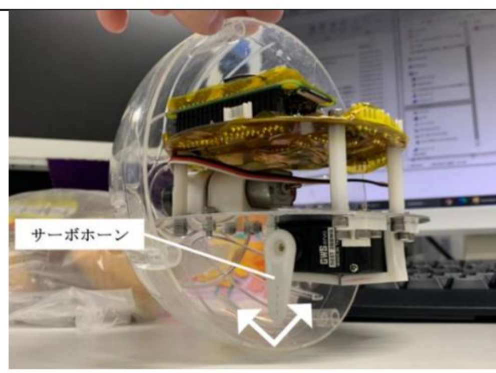


Figure **9** Mechanism of forward running

ÿ Direction change By

~~attaching a weight to the tip of the servo horn in Figure 6 and rotating the servo motor, the weight of the aircraft can be changed~~ ~~Move the heart position. This mechanism causes the aircraft to tilt in the direction in which the center of gravity moves, changing the direction in which the aircraft is traveling. Additionally, the angle of direction change can be controlled by the rotation angle of the servo motor.~~



~~Figure 6 Direction change mechanism~~

A weight close to the optimal shape that does not interfere with the spherical shell and Li-Po battery was attached to the tip of the servo horn (Figure 10). By rotating the servo motor left and right, the center of gravity of the aircraft is moved. As a result, the aircraft tilts in the direction in which the servo motor rotates, changing the direction of travel of the aircraft. Additionally, the angle at which the direction is changed can be controlled by the magnitude of the rotation angle of the servo motor. By using high-density, low-cost SUS304 as the material for the weight, ideal direction changes are possible.

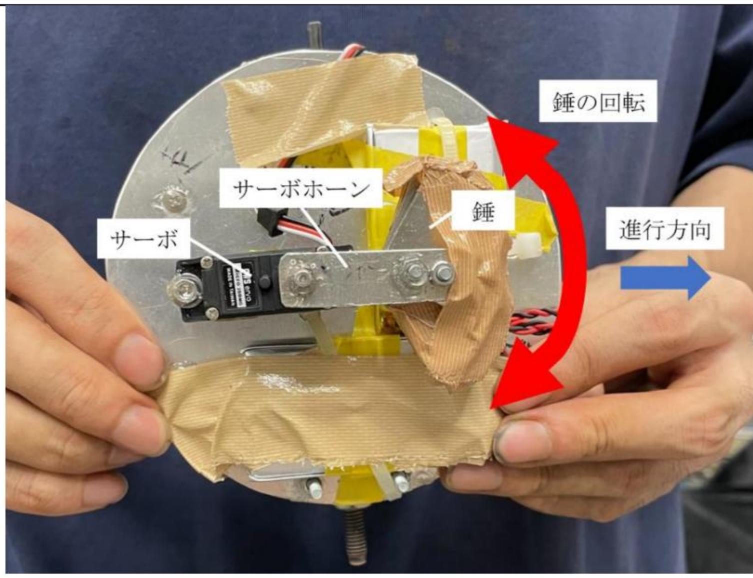


Figure **10** Direction change mechanism (lower surface inside the aircraft)

ÿ Parachute mechanism

The parachute mechanism consists of a parachute, a parachute connection board, a parachute cutting board, It consists of four CanSat furoshiki. Figure 11 shows a schematic diagram of the parachute mechanism. The parachute is connected to the parachute connection plate. A parachute cutting board is mounted on the parachute connection plate, and it cuts the wire connecting the parachute connection plate and the CanSat furoshiki. Figure 12 shows the actual photo. The nichrome wire mounted on the parachute connection board is used to cut the wire (see Chapter 4, 3. Control System and V14_Parachute Separation Test). Also, since the CanSat aircraft is spherical, it is not possible to connect a parachute directly to it. Therefore, we connected it to the parachute by wrapping it in the CanSat furoshiki shown in Figure 13.

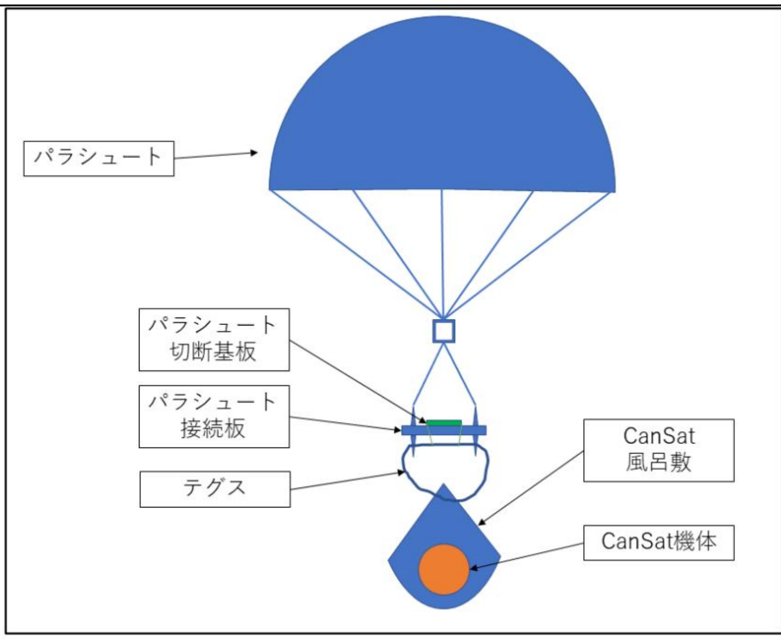


Figure **11** Schematic diagram of parachute mechanism

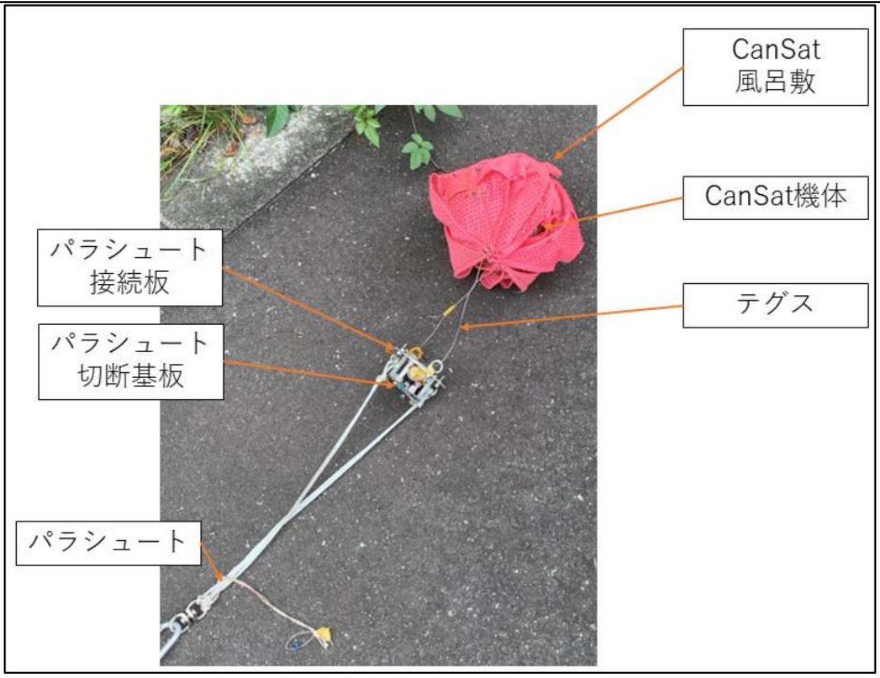


Figure **12** Photo around the parachute connection board

Figure **13 Photo of CanSat** Furoshiki

3. Control system

ÿ System block diagram

Figure 14 shows the system block diagram of CanSat (aircraft). Since the mission includes image processing using a camera , we adopted RaspberryPi ZeroWH for OBC. The power source uses 8 cells of lithium polymer secondary batteries with a capacity of 1000 mAh . Take care to ensure safety by controlling the voltage of each battery and carrying it in a fireproof bag. The radio device used is ES920LR, a specified low-power radio device in the 920 [MHz] band. According to the catalog specifications, the line-of-sight distance for communication is 10 [km], which is considered to be sufficient to accomplish the mission. In addition, by setting the Sleep pin of the ES920 to LOW, the power to the RF section is cut off, making it impossible ~~to transmit o~~r receive (waves are stopped).

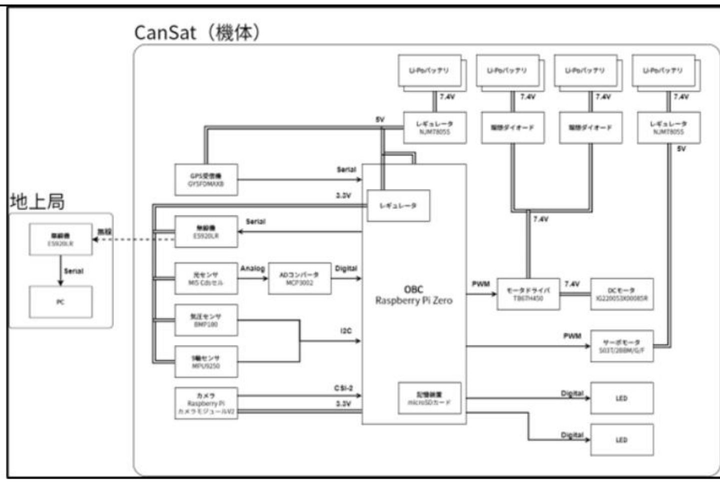


Figure **14** CanSat (aircraft) system block diagram

Figure 15 shows the system block diagram of the parachute separation mechanism circuit. The parachute and CanSat are connected with fishing hooks (nylon) with a diameter of 1 mm, and after landing, the CanSat (aircraft) and parachute are separated by burning off the hooks with nichrome wire. This mechanism has been demonstrated by the Tokyo Metropolitan University team (TMU_MAG.) at ARLISS2018.

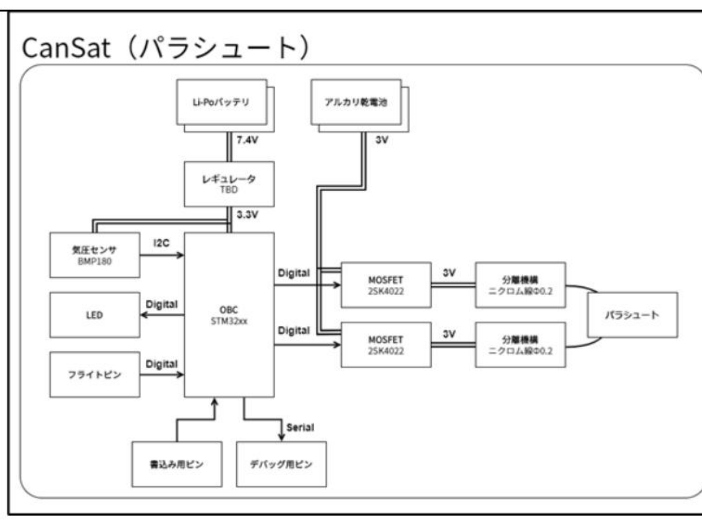


Figure **15** CanSat (parachute) system block diagram ÿ Figure 16 shows the

phase transition diagram of the control flow program. Each phase operates as shown in Table 7.

Run the program. The program ~~is still in production, and it has been repeatedly brushed up through driving tests, etc.~~ ~~I do. In addit~~ion, the transition between each phase is determined according to Table ~~8. Threshold used to determine phase transition~~ ~~The optimum value will be determined through various future tests.~~

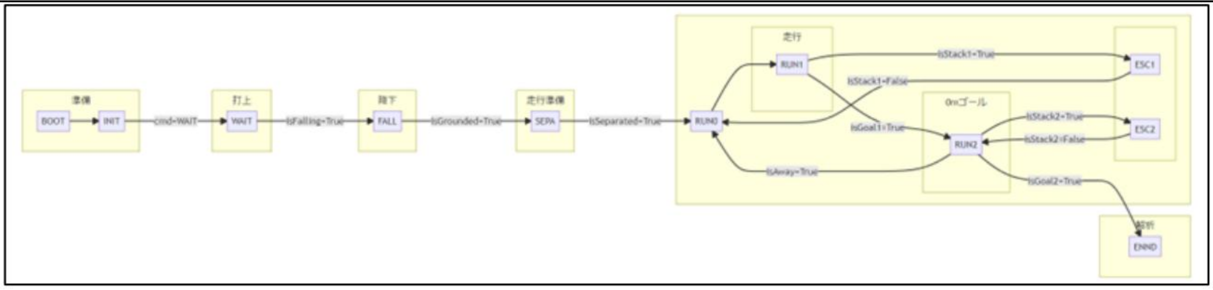


Figure **16** Phase transition diagram

Table **7** Phase definition

Phase name	Contents
BOOT	Performs initialization processing for each
INIT	program. Check the operation of each sensor.
WAIT	From carrier storage to release determination, the radio wave transmission is carried out in accordance with regulations. Stop.
Fall	From release determination to landing determination, the current altitude and position are transmitted via radio.
SEPA	After determining the landing, perform actions to separate the parachute.
RUN0	After performing the parachute separation operation, the motor output is gradually increased.
RUN1	Obtain your own position coordinates from GPS and calculate the distance and azimuth from the goal. Total Based on the calculation results, operate the servo motor for direction change and run toward the goal. Go.
ESC1	If the motor is stuck, repeat the operation and stop of the motor randomly to prevent the stuck state. Get out of the situation.
RUN2	It detects the goal cone through image processing and runs.
ESC2	If you get stuck while starting the camera, take action.
ENND	Perform program termination processing and protect log files.

Table **8** Phase transition determination

Method name	Data used to determine phase transition
isFalling	The brightness is determined by a light sensor, the altitude is determined by a temperature/pressure sensor, and the emission is determined by a timer. Execute the exit judgment.
isGrounded	Landing is determined using the altitude from temperature and pressure sensors and a timer.
Use the isSeparated	timer to determine whether the parachute is separated.
isStack1	The stack is determined using the moving speed determined by GPS.
isGoal1	Goals are determined using position coordinates determined by GPS.
isStack2 Undetermined	~~Stack~~ determination is performed by image processing using a RaspberryPi camera.
isGoal2	The 0m goal is determined by image processing using the RaspberryPi camera.
isAway	The location coordinates from GPS are used to determine whether the goal is too far away.

Chapter 5 Test item settings

Table 9 shows the test items and the corresponding self-examination item request numbers and implementation test dates .

Table **9** Test table

Number	Verification item name	Request number(s) of corresponding self-examination item(s)	Scheduled implementation date
	ÿItems related to system requirementsÿ		
V1	Mass test	S1	7/21
V2	airframe stowage/release test	S2, M4, M5, M6, M8	7/21
V3	quasi-static load test	S3, M9	7/22
V4	vibration test	S4, M9	7/22
V5	separation (parachute deployment) impact test	S5, M12	7/22
V6	drop test	S6, M11, M13	~~7/16~~ÿ8/6
V7	GPS data downlink test	S7, M10, M19, M24	6/30
V8	communication device ON/OFF test	S8, M7	7/12
V9	Radio Frequency Change Test	S9	7/12
V10	End-to-end exam	S10, M2	~~7/22~~ÿ8/2
V11	Surface confirmation test	S11	7/21
	ÿItems related to mission requirementsÿ		
V12	long run test	M1	7/14
V13	data storage test	M3, M26	~~7/22~~ÿ8/2
V14	Parachute separation test	M14	7/14
V15	driving test	M15, M17, M18, M20	~~7/16~~ÿ8/2
V16	Stuck Avoidance Test	M16, M21	~~7/28~~ÿ8/2
V17	0m goal test	M22, M23, M25	~~7/28~~ÿ8/6
V18	Control history report creation test	M27	~~7/28~~ÿ8/2

Chapter 6 Contents of Implementation Test V1.

Purpose of Mass

Test	Confirm that the mass of CanSat meets the regulations.
Test Contents	Measure the mass of all modules of the FM machine, including the parachute, using a scale.
result	~~Since the test has not yet been conducted, it will be filled in once the test is conducted.~~ Figure 17 shows the mass of the carrier. The carrier in Figure 17 also includes a parachute. Figure 18 shows the total mass when all CanSats are included. From Figure 17 and Figure 18, the rocket The mass of all the CanSat modules stored in the was measured to be 969.27[g]. 1442.34 ÿ 473.07 = 969.27 [g]  Figure **17** Mass of carrier Before  Figure **18 Total mass of CanSat** and carrier
Consideration	storing the rocket, potting work will be done with adhesive to reinforce the parts. However, even taking that into consideration, the mass merge is sufficient to allow the regulation of 1050[g]. I confirmed that the power was removed.

V2. Aircraft stowage/release test

the purpose	Check the following five points. ÿ Assembling can be completed within 2 hours. ÿ Be able to turn on power to CanSat. ÿ The dimensions of CanSat must meet the regulations. ÿ CanSat stored in a carrier falls from the carrier due to its own weight. ÿ Be able to determine release using a light sensor, atmospheric pressure sensor, and timer.
contents of the test	1. Assemble CanSat. 2. Turn on power to CanSat. 3. Measure the dimensions of the aircraft. Then store it in the carrier. 4. By lifting the carrier containing CanSat and then flipping the carrier, The CanSat is dropped from the carrier by its own weight. 5. Check from the data whether the release judgment is being performed.

<table>
<tr>
<td>result</td>
<td>
~~Since the test has not yet been conducted, it will be filled in once the test is conducted.~~
It took about 25 minutes to assemble the CanSat and turn on the power to the CanSat. This process is shown in the video at the URL below. Figures
19 to 21 show the results of measuring the dimensions of CanSat, including the parachute. From measurements, the dimensions of CanSat were found to be width: 145[mm] and height: 228[mm].
After lifting the carrier containing the CanSat, flip the carrier over.
CanSat was dropped from the carrier by its own weight. We also confirmed that the release judgment was made based on the data. This process is shown in the video at the URL below.


Figure 19 CanSat width

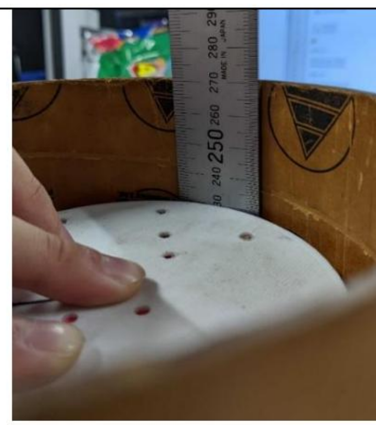

Figure 20 CanSat height (ÿ)


Figure 21 CanSat height (ÿ)
ÿ Video URL (assembly): https://youtu.be/uNmrMCYXnRk ÿVideo URL (released): https://youtu.be/Ykl04iZO6s8 ÿ Assembly Before storing the rocket, we
</td>
</tr>
<tr>
<td>Consideration</td>
<td>
plan to perform
potting work with adhesive to reinforce the parts, but even with that work in mind, it is difficult to power the CanSat. We confirmed that it could be loaded and that assembly could be completed within two hours. ÿ Storage/ discharge
We confirmed that the CanSat can be stored and released because its dimensions meet regulations and it falls from the carrier under its own weight. We also confirmed that CanSat can make release decisions using optical sensors, air pressure sensors, and timers.
</td>
</tr>
</table>

V3. Quasi-static load test

the purpose	Confirm that the quasi-static load during launch does not impair CanSat's ``functions to meet safety standards'' and ``minimum functions necessary to accomplish the mission.''
contents of the test	1. Apply sine wave excitation of 20[Hz], 10[G], 20[s] to CanSat. 2. Check the following seven points. Functions to satisfy safety standards ÿ Equipped with a parachute that has a terminal velocity of about 3 to 5 [m/s]. ÿ Equipped with a radio device that can communicate over long distances, which is effective as a countermeasure against lost data. ÿ Must be equipped with a GPS receiver. ÿ Do not block GPS and radio wave~~s. ÿ No ra~~dio waves are emitted during launch, and this can be confirmed. Minimum functions required to accomplish the mission ÿ Ability to drive. ÿ Know the relative position of the goal and CanSat. 3. Figure 22 shows the test equipment used.

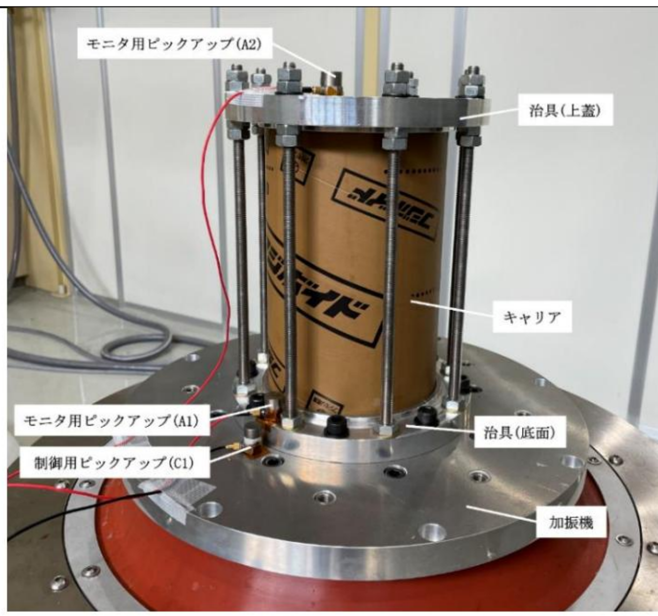


Figure **22** Test equipment

Machine Translated by Google

result

~~Since the test has not yet been conducted, it will be filled in once the test is conducted.~~

A quasi-normal loading test was performed in which sinusoidal vibration was applied for 20[s] to achieve the target response acceleration of 10[G].

Figure 23 shows the results of the experiment. From Figure 23, it can be seen that A1 and A2 have values close to the target values.

After running through tests V3 to V5, CanSat was operated for a few seconds. With sine wave excitation

Videos of each operation of CanSat are shown at the URL below.

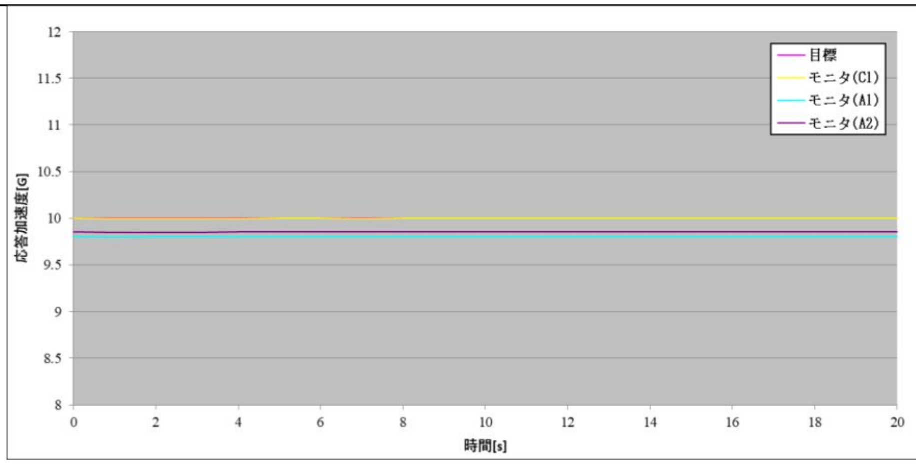


Figure **23** Quasi-static load test results

ÿ Video URL (sine wave excitation): https://youtu.be/cdhPFQPfZfk ÿ Video URL (CanSat operation): https://

youtu.be/qjfASn6UNPE Values close to the target values were confirmed for A1 and A2. Therefore, this test was

Consideration

performed using a quasi-static load during launch.

It is thought that the weight can be reproduced.

By considering the subsequent movement of CanSat, the quasi-static load at the time of launch can be

We confirmed that CanSat does not impair its ``functions to meet safety standards'' and ``minimum functions necessary to accomplish its mission.''

V4. Vibration test

the purpose	Confirm that CanSat's ``functions to meet safety standards'' and ``minimum functions necessary to accomplish the mission'' will not be impaired due to vibration loads during launch. 1. Apply random excitation of 30 to 2000[Hz], 15[Grms], 60[s] to CanSat. 2. Check
contents of the test	the following seven points. Functions to satisfy safety standards ÿ Equipped with a parachute that has a terminal velocity of about 3 to 5 [m/s]. ÿ Equipped with a radio device that can communicate over long distances, which is effective as a countermeasure against lost data. ÿ Must be equipped with a GPS receiver. ÿ Do not block GPS and radio waves. ÿ No radio waves are emitted during launch, and this can be confirmed. Minimum functions required to accomplish the mission ÿ Ability to drive. ÿ Know the relative position of the goal and CanSat. 3. The same test equipment as V3 (Figure 22) was used.

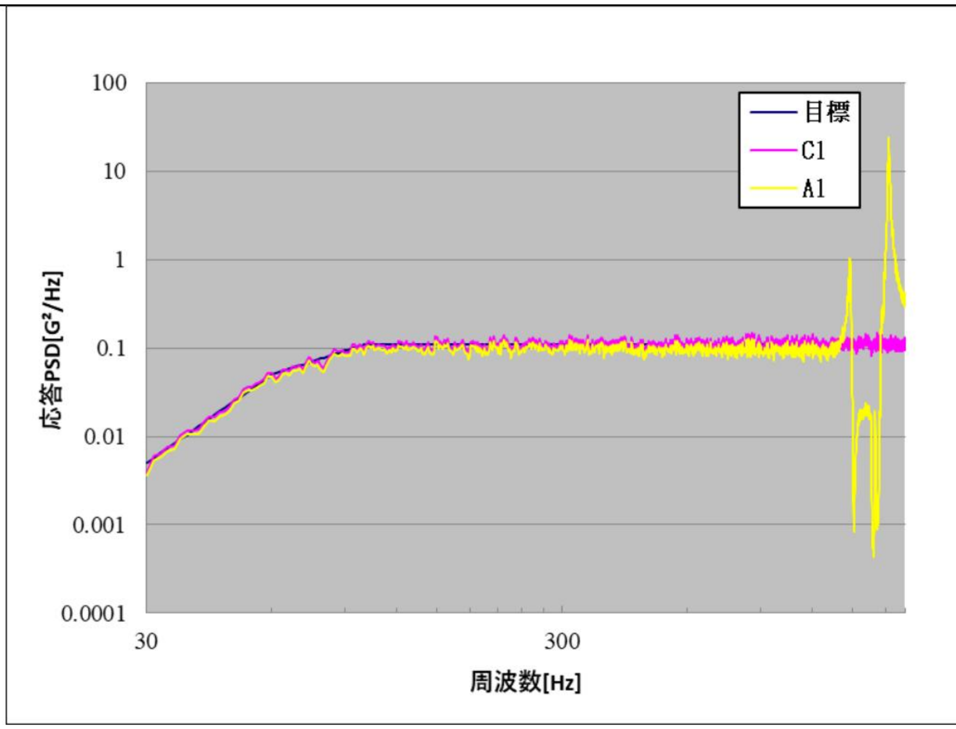
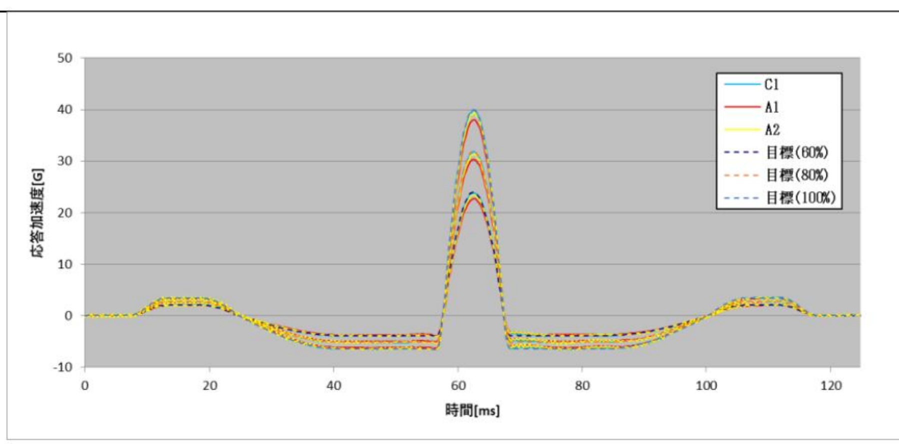
<table>
<tr>
<td>result</td>
<td>
~~Since the test has not yet been conducted, it will be filled in once the~~
test is conducted. The target waveform data is 15 [Grms], and the excitation frequency is set to 30~30 to obtain the target waveform. Figure 24 shows the results of a vibration test in which random excitation was performed at 2000[Hz] and 60[s]. From Figure 24, we confirmed that C1 (control pickup) had a response PSD close to the target value, and A1 (monitor pickup) had a response PSD that deviated from the target value in the frequency band of 1200 [Hz] or higher. ÿÿ
After running through tests V3 to V5, CanSat was operated for a few seconds. Random excitation and Videos of each operation of CanSat are shown at the URL below.


Figure **24** Vibration test results
ÿ Video URL (random excitation): https://youtu.be/uVFZVTkxgNI ÿ Video URL (CanSat operation): https://youtu.be/qjfASn6UNPE
</td>
</tr>
<tr>
<td>Consideration</td>
<td>
In C1, we confirmed a response PSD close to the target value, but in A1, we confirmed a response PSD that deviated from the target value in the frequency band of 1200 [Hz] or higher, indicating that there was resonance in the jig during this test. It turns out that Therefore, during this test, CanSat was exposed to a vibration environment even more severe than that simulated during launch, and it is considered that the environment was sufficient to fulfill its purpose.
By considering the subsequent movement of CanSat, the vibration load at the time of launch can We confirmed that CanSat does not impair its ``functions to meet safety standards'' and ``minimum functions necessary to accomplish its mission.''
</td>
</tr>
</table>

V5. Separation impact test

the purpose	Confirm that CanSat's ``functions to meet safety standards'' and ``minimum functions necessary to accomplish the mission'' are not impaired by separated impact loads. Also, confirm that the parachute mechanism does not lose its ``function to meet safety standards'' due to the impact load of the parachute opening. 1. Apply 60%, 80%, and 100% vibrations to CanSat with a maximum
contents of the test	of 40[G] sine wave half-shock excitation. Ru. 2. Check the following seven points. Functions to satisfy safety standards ÿ Equipped with a ~~parachute~~ that has a terminal velocity of about 3 to 5 [m/s]. ÿ Equipped with a radio device that can communicate over long distances, which is effective as a countermeasure against lost data. ÿ Must be equipped with a GPS receiver. ÿ Do not block GPS and radio waves. ÿ No radio waves are emitted during launch, and this can be confirmed. Minimum functions required to accomplish the mission ÿ Ability to drive. ÿ Know the relative position of the goal and CanSat. 3. The same test equipment as V3 (Figure 22) was used. 4. When the parachute is deployed, we assume that the rocket speed at the time of CanSat release is 100 [km/h], and that the parachute opens 5 seconds after release and the approximately 1 [kg] CanSat decelerates to 10 [m/s]. do. From the impulse equation ÿ ÿ = ÿ ÿ, the load generated at this time is approximately 3.6[N]. Therefore, we used something weighing approximately 4 kg to check the durability of the parachute, carabiner, leg, etc. (parachute opening impact test). Since the test has not yet been conducted, it will be filled in once the test is conducted.
result	Figure 25 shows the results of a separate shock test in which sinusoidal half-shock excitation was performed with target accelerations of 40 [G] at 100%, 32 [G] at 80%, and 24 [G] at 60%. From Figure 25, A1 (monitor pickup) has a response acceleration that is below the target value, while C1 (control pickup) and With A2 (monitor pickup), you can check the response acceleration close to the target value. After running through tests V3 to V5, CanSat was operated for a few seconds. Videos of sine wave shock excitation and CanSat operation are shown at the URL below.  Figure **25** Separation impact test results Figure 26 shows the parachute opening impact test. Connect two PET bottles containing 2 [L] of water to the legs of the parachute mechanism, hold the parachute cloth part, and lift the PET bottles.

<table>
<tr><td></td><td>I lifted the le. As a result, no abnormalities were found in the parachute, carabiner, or leg. Furthermore, the following URL shows how two 2L plastic bottles connected to the leg were dropped from a lifted position, and a shock was applied to the entire parachute, carabiner, leg, etc. At this time, no abnormalities were found in the parachute, carabiner, or tail.

Figure 26 Parachute opening impact test

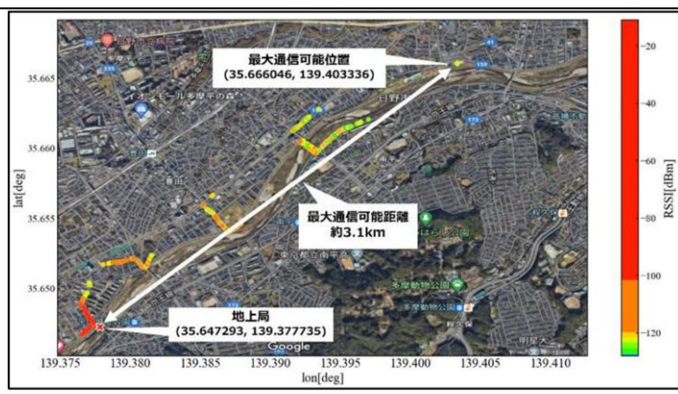
ÿ Video URL (sine wave shock excitation): https://youtu.be/M-3BGZdR5uQ ÿ Video URL (CanSat operation): https://youtu.be/qjfASn6UNPE ÿ Video URL (parachute opening impact test) :
https://youtube.com/shorts/XUmAy_0jUgo</td></tr>
<tr><td>Consideration</td><td>In A1, we confirmed a response acceleration that was lower than the target value, but in C1 and A2, we confirmed response accelerations that were close to the target value, so it is thought that this test was able to reproduce the rocket's separation impact load. By considering CanSat's subsequent operation, we confirmed that CanSat's ``functions to meet safety standards'' and ``minimum functions necessary to accomplish the mission'' were not impaired by the separate impact load during launch. ÿÿ
As a result of reproducing the hypothetical impact that would occur when a parachute is deployed using a plastic bottle filled with approximately 4 kg of water, no abnormalities were found in the parachute, carabiner, or tail. We confirmed that the parachute mechanism has sufficient durability against impact loads, and that the parachute mechanism does not lose its ``function to meet safety standards'' under the assumed impact of parachute deployment.</td></tr>
</table>

V6. Drop test

the purpose	Check the following three things. ÿ During ~~CanSat 's descent, the deceler~~ation mechanism is activated after carrier release, and the terminal speed of CanSat is reduced to 3 . It should be ab~~out ~5~~[m/s]. ~~ÿ The landing impact at a terminal velocity of 5 [m/s] should not impair the minimum functions necessary to accomplish the mission .~~ ~~During the period from carrier rel~~ease to landing determination, CanSat must not lose its ``functions to satisfy safety standards'' and ``minimum functions necessary to accomplish the mission.'' ÿ Be a~~ble to determine landing u~~sing an acceleration sensor, barometric pressure sensor, and timer. 1. CanSat stored in
contents of the test	a carrier is released from the roof of Building 5 of Tokyo Metropolitan University's Hino Campus (about 10m high) and lowered. 2. Film this and find the terminal velocity of CanSat from the video. 3. Check the following 76 items. Functions to satisfy safety standards ÿ Equipped with a parachute that has a terminal velocity of about 3 to 5 [m/s]. ÿ Equipped with a radio device that can communicate over long distances, wh~~ich is e~~ffective as a countermeasure against lost data. ÿ Must be equipped with a GPS receiver. ÿ Do not block GPS and radio waves. ÿ No radio waves are emitted during launch, and this can be confirmed. Minimum functions required to accomplish the mission ÿ Ability to drive. ÿ Know the relative position of the goal and CanSat. 3. Check from ~~the data whether the landing judgment is successful. Since the test has not yet been~~ conducted, it will be filled in once the test is conducted.
result	The first drop test is shown in the video at the URL below. The CanSat was released from the carrier under its own weight, and the parachute opened during the descent. However, the aircraft landed before the parachute had sufficiently decelerated. The second drop test is shown in the video at the URL below. The second time I took it out of the carrier. It was dropped in this condition. The opening of the parachute decelerated sufficiently, and the terminal velocity was approximately 3.3 [m/s]. After that, CanSat made a landing judgment and operated CanSat for several seconds. The ground station reception log and CanSat operation log during the drop test are shown at the following URL. ÿ Video URL (1st time): https://youtu.be/BUY-S79J12A ÿ Video URL (2nd time_drop test): https://youtu.be/LN7m0aCvtmw ÿ Video URL (2nd time_terminal velocity): https://youtu.be/wp0foHcNPLY ÿ Ground station reception log URL: https://drive.google.com/file/d/1tQdhBtY_zXeJvOlKE-- uLISRQUmbKGB-/view?usp=sharing ÿ CanSat operation log URL: https://drive.google.com/file/d/176fyBJkDYOvnd2dK4zpZURVsePEmAJ4C/view? usp=sharing

Consideration	In the first drop test, after being released from the carrier, it was confirmed that the deceleration mechanism operated (the parachute opened) during the descent. However, the deceleration mechanism (parachute) of CanSat was not sufficient. This is thought to be due to insufficient time, or altitude, to sufficiently decelerate. In the second drop test, the CanSat was lowered without being stored in the carrier in order to confirm that the parachute opened and the CanSat was properly decelerated to the target speed and that there were no problems with the CanSat's operation. The deceleration mechanism started operating during the descent, and the deceleration mechanism reduced the terminal speed to approximately 3.3 [m/s]. [m/s]. By combining these results with the results of the first drop test, it is believed that it was confirmed that ``the deceleration mechanism operates after the carrier is released, and the terminal velocity of CanSat becomes 3 to 5 [m/s]." ÿÿ Also, based on the results of the second drop test,  We confirmed that ``landing could be determined using an air pressure sensor and a timer." Furthermore, taking into account that CanSat has started operating normally after landing, we have developed a system that allows CanSat to meet the safety standards and the minimum functions required to accomplish its mission from carrier release to landing determination. It was confirmed that the

V7. GPS data downlink test

the purpose	We will confirm that the communication equipment installed on CanSat is useful for lost countermeasures and that it can be received by the ground station. Also, obtain the maximum communication distance. Using
contents of the test	the ES920LR radio, we performed the following two tasks on a riverbed in Asakawa, Hachioji City, Tokyo. 1. Move CanSat, which continues to wirelessly transmit position coordinates, away from the ground station. 2. The ground station records the received data while checking it on the terminal software to obtain the maximum communication distance. The test results are shown in Figure 27 .
result	The maximum distance from which the ground station could obtain CanSat's position coordinates was 3.1 [km].  Figure **27 GPS** data downlink test results The maximum
Consideration	communication distance of the radio ES920LR used in this test is approximately 10 [km] with a line of sight, but this time the result was 3.1 [km]. This is thought to be due to the influence of obstacles such as trains and houses passing between CanSat and the ground station, and the small height difference between CanSat and the ground station. Since there are very few obstacles that impede communication in the Black Rock Desert, where ARLISS is held, it is thought that the possible communication distance will further increase. Furthermore, during the actual launch, after visually confirming the CanSat that has been released, we will immediately track the CanSat using a vehicle, etc., in an effort to keep the distance between the CanSat and the ground station within 3.1 [km].

V8. Communication device ON/

OFF Test purpose: Confirm that no radio waves are emitted

contents of the test

during launch. Use the RaspberryPi Zero W computer to enable the sleep function of the ES920LR radio to prevent CanSat from emitting radio waves. 1. CanSat continues

~~to send the string to the ground station, and the string is checked on the ground station side. 2.~~

~~After continuing to transmit for a while, enable the sleep function of the radio and write the string at the ground~~ station.

~~Check that it has been interrupted.~~

1. Send the string "test" from CanSat 10 times and confirm that it is being received by the ground station.
confirm.
2. Transition the radio installed in CanSat to sleep mode. 3. Transmit the string "test" from CanSat 10 times and make sure that it is not received by the ground station.
Check. 4. Exit the sleep mode of the radio installed in CanSat. 5. Send the string "test" from CanSat 10 times and confirm that it is being received by the ground station.
confirm. Since

result

~~the test has not yet been conducted, it will be filled in once~~

the test is conducted. Figure 28 Figure 28 shows the transmission history on the CanSat (RaspberryPi Zero W) side, and Figure 29 shows the reception history on the ground station side. We confirmed that the ground station did not receive anything from the time CanSat transitioned to sleep mode until it ended (from ``sleep'' to ``wakeup'' in Figure 29).

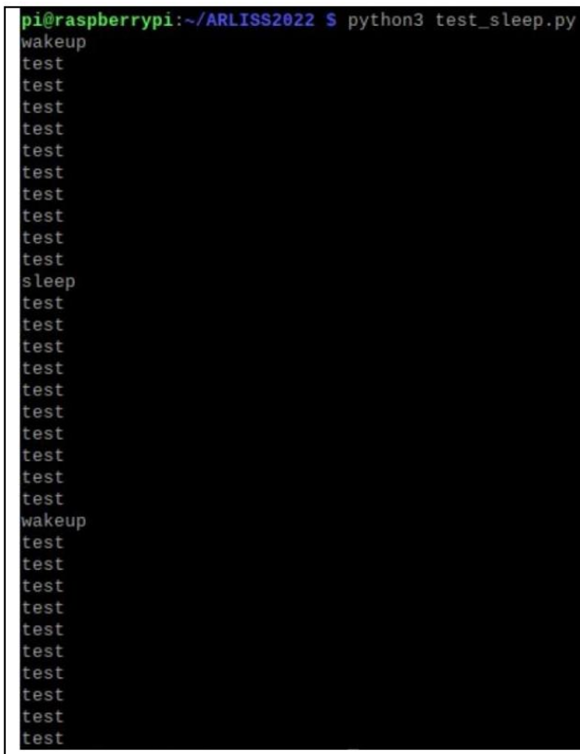


Figure **28 CanSat** transmission history

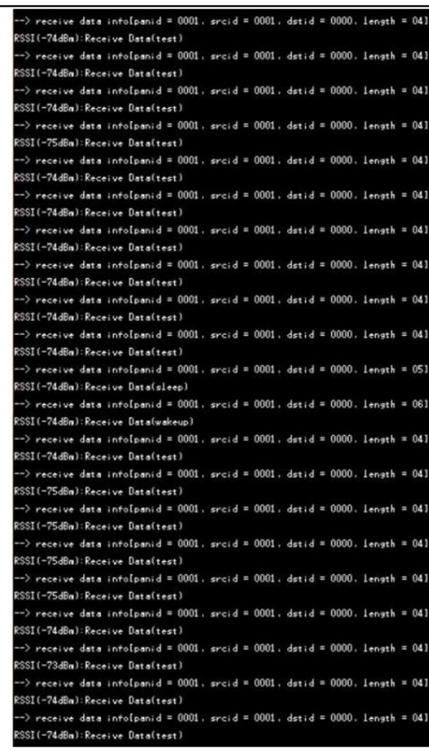


Figure **29** Ground station reception history

Discussion We confirmed that CanSat has a function that prevents it from emitting radio waves during launch.

V9. Confirm that it is possible to change

the purpose

the frequency of the radio equipment installed on CanSat so that it can respond even just before the radio frequency change test launch. The radio

contents of the test

ES920LR performs wireless communication with a bandwidth of 125kHz and a spreading factor of 7 by combining the radio channel number settings (frequency settings, 1ch to 15ch) and the transmitting/receiving node network address settings (0x0000 to 0xFFFE). Table 10 shows the correspondence between channel numbers and frequencies. 1. Using TeraTerm, check the channel number

and node number of CanSat and ES920LR mounted on the ground station.

~~Change the network address. 2. Ch~~aracter strings

can be transmitted from CanSat to the ground station using the ES920LR after changing the frequency.

Check.

Table **10** Correspondence between channel number and center frequency [MHz]

1ch: 920.6	2ch: 920.8	3ch: 921.0	4ch: 921.2	5ch: 921.4
6ch: 921.6	7ch: 921.8	8ch: 922.0	9ch: 922.2	10ch: 922.4
11ch: 922.6	12ch: 922.8	13ch: 923.0	14ch: 923.2	15ch: 923.4

result

~~Since the test has not yet been conducted, it will be filled in~~

once the test is conducted. Figure 30 shows the communication test results for channel number 1 and Figure 31 shows the communication test results for channel number 2. It can be seen that the ground station is able to receive the string sent from CanSat on both channels.

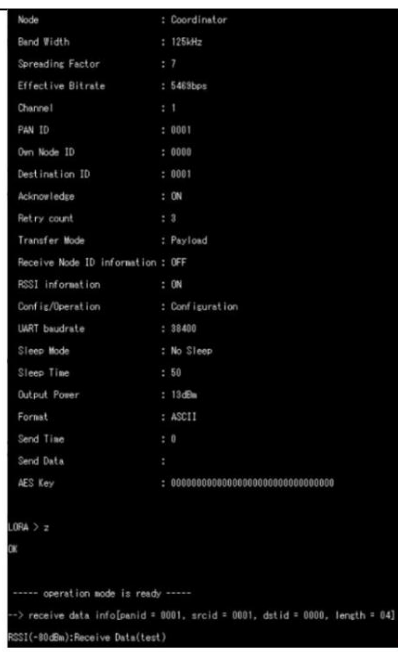


Figure **30** Radio frequency change test results (channel 1) We

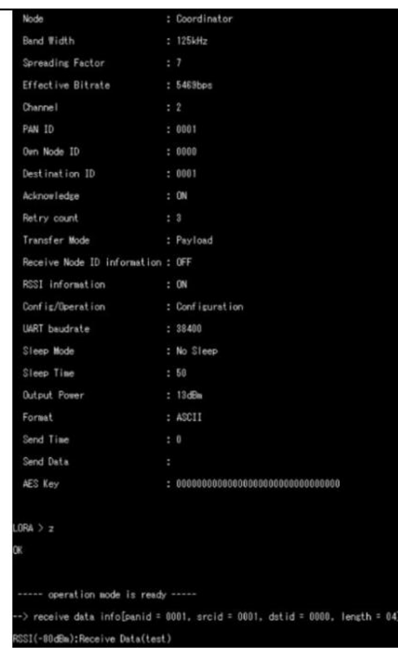


Figure **31** Radio frequency change test results (channel 2)

Consideration

confirmed that CanSat and the ground station can communicate even when the radio frequency is changed, and that we can respond to requests to change the radio frequency.

V10. End-to-End Test Check

the purpose	the following two things. ÿ CanSat's mode transition is performed in a series of operations. ÿ CanSat can autonomously drive towards the goal without human intervention. What you can do.
contents of the test	Perform sequences ÿ to ÿ in order. However, the actual launch environment (rocket and geographical environment) etc.), it is difficult to completely reproduce it, so we declare the following. ÿ The strength of CanSat against the loads applied in sequences ÿ and ÿ is based on the test results of V3, V4, V5, and V6. Sequences ÿ and ÿ should be reproduced in this test, as they have been proven to be sufficient in experiments. stomach. ~~ÿ Sequence ÿ will run for 10 seconds.~~
result	~~Since the test has not yet been conducted, it will be filled in once the test is conducted.~~ The phases autonomously transitioned and executed sequences ÿ to ÿ in order. In sequence ÿ, CanSat stopped after detecting a failure. The video URL at that time is shown below. ÿ Video URL: https://youtu.be/BNbUvRDzNo8
Consideration	In the video, the flight pin is reconnected after being removed. this is, This is to conserve battery capacity in anticipation of conducting multiple tests, and the parachute I did this without changing the position or orientation. CanSat autonomy by reconnecting flight pins There is no intervention in control, and there is no problem even if reconnection is not performed. Based on these facts, we confirmed the following two things from the test results. ÿ CanSat mode transitions can be performed in a series of operations. ÿ CanSat can autonomously drive toward the goal without human intervention thing.

V11. Surface confirmation

test purpose	To confirm that CanSat does not have sharp edges.
Test details	Confirm by sight and touch that the CanSat does not have sharp edges.
result	~~Since the test has not yet been conducted, it will be filled in once the test is conducted.~~ Check the surface of the CanSat both visually and by touch as shown in Figure 32 to confirm that the CanSat is We confirmed that there were no sharp edges.  Figure **32** Check the surface of **CanSat** by touch
Consideration	When touching the CanSat with your hands, the operator may feel uncomfortable because the CanSat does not have sharp edges. We confirmed that there were no injuries and that we could safely participate in ARLISS.

V12. Long run test

eye target

Verify that it can provide power for up to 4 hours of operation (1 hour standby + 3 hours mission).
Ru.

trial experience Inside capacity

1. Operate for 1 hour in a mode assuming standby in the carrier.
2. Measure the battery voltage and check the operating status.
3. Operate for 3 hours in a mode that assumes driving.

Mode assuming driving: Motor operates at maximum output, servo drive every second, and commands GPS information acquisition.
vinegar.

4. Measure the battery voltage and check the operating status.

Conclusion Fruit

~~Since the test has not yet been conducted, it will be filled in once the test is conducted.~~

The results of the test conducted on August 20th are shown in Table 11 and the log is available at the URL below, and the video of the test is available at the URL below.

It is shown in All batteries installed in the CanSat aircraft are Li-Po batteries (3.7[V], 1000[mAh]).
be. Standby mode 1 hour 15 minutes from 11:15 to 12:30, running mode 3 o'clock from 12:30 to 15:59
We confirmed that it worked without problems in 29 minutes.

~~Table **11** Long run test voltage measurement results~~

~~measurement time~~	~~logic ÿ[V]~~	~~logic ÿ[V]~~	~~The servo ÿ[V]~~	~~The servo ÿ[V]~~	~~motor ÿ[V]~~	~~motor ÿ[V]~~	~~motor ÿ[V]~~	~~motor ÿ[V]~~
~~13:00 4.18~~	~~14:00~~	~~4.19~~ 4.06 4.08 ~~4.16~~ 3.97 4.05 4.04 4.16			~~4.19~~		~~4.08~~	~~4.23~~
~~3.96~~					~~4.19~~		~~4.08~~	~~4.24~~
~~17:00 3.64~~		~~3.63~~	~~3.79~~	~~3.79~~	~~4.03~~	~~4.02~~	~~3.99~~	~~4.07~~

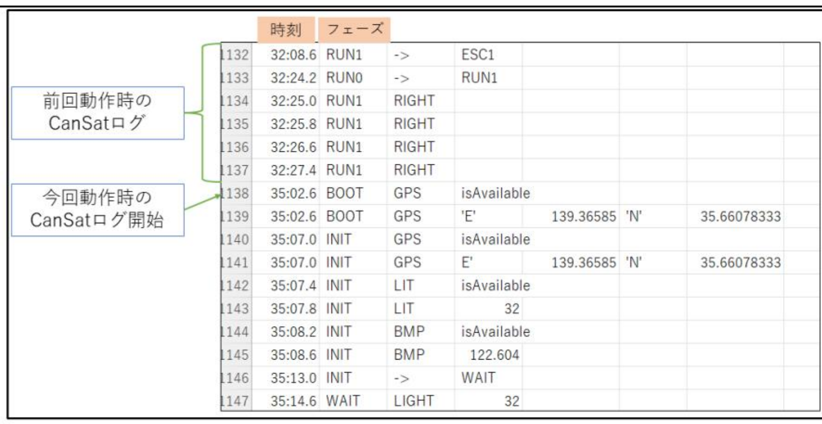
Table **11** Long run test history

11:15	Power on
12:30	Start running
12:40	Stop running
12:42	Resuming running
12:57	Maximum motor rotation speed
14:14	Stop running
14:19	Resuming running
14:26	Stop running
14:29	Resuming running
14:48	Stop running
15:07	Resuming running
15:15	Stop running
15:18	Resuming running
15:59	End of run
16:15	Battery dead

	ÿ Operation log URL: https://drive.google.com/file/d/15uaSQTus_Ibv0PTYOHK3Gh9mOJPy6naC/view?usp=sha ring ÿ Video URL: https://youtu.be/4tWwlNUGu6A We confirmed that
Consideration	the Li-Po battery installed in CanSat can supply power for up to 4 hours of operation (1 hour of standby + 3 hours of mission).

V13. Data storage test Check the

the purpose	following three things. ÿ CanSat must be equipped with a storage device that can store HK data acquired at the sampling rate required for verification of success criteria. ÿ Data can be transferred to the ground station. ÿ Saved HK data must not be deleted or overwritten. 1. A MicroSD card is installed on the main system for recording experimental data. 2. Operate CanSat and
contents of the test	record the following data on the MicroSD card. 3. Check that the data was recorded and has not been overwritten. ÿ Time when the following data was acquired ÿ CanSat position coordinates ÿ CanSat phase As this has not been conducted yet, it will be filled in once the test is completed. Figures 33 and 34 show some of the logs saved on the MicroSD card when operating CanSat and some of the logs received by the
result	~~ground station. It was confirmed that the CanSat operation~~ log was saved without being overwritten by the log from the previous operation. It was also confirmed that the same data log was saved at the ground station.



	時刻	フェーズ					
1132	32:08.6	RUN1	->	ESC1			
1133	32:24.2	RUN0	->	RUN1			
1134	32:25.0	RUN1	RIGHT				
1135	32:25.8	RUN1	RIGHT				
1136	32:26.6	RUN1	RIGHT				
1137	32:27.4	RUN1	RIGHT				
1138	35:02.6	BOOT	GPS	isAvailable			
1139	35:02.6	BOOT	GPS	'E'	139.36585	'N'	35.66078333
1140	35:07.0	INIT	GPS	isAvailable			
1141	35:07.0	INIT	GPS	E'	139.36585	'N'	35.66078333
1142	35:07.4	INIT	LIT	isAvailable			
1143	35:07.8	INIT	LIT	32			
1144	35:08.2	INIT	BMP	isAvailable			
1145	35:08.6	INIT	BMP	122.604			
1146	35:13.0	INIT	->	WAIT			
1147	35:14.6	WAIT	LIGHT	32			

Figure **33 Operation log (CanSat)**

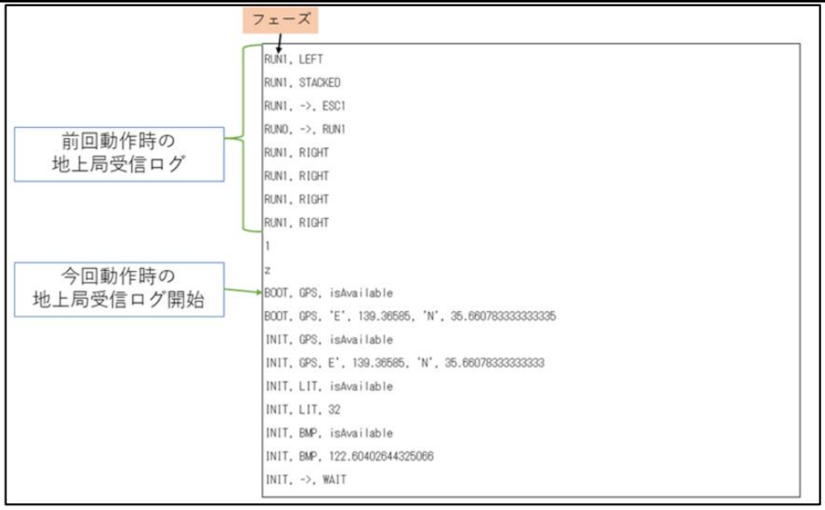


Figure **34** Operation log (ground station)

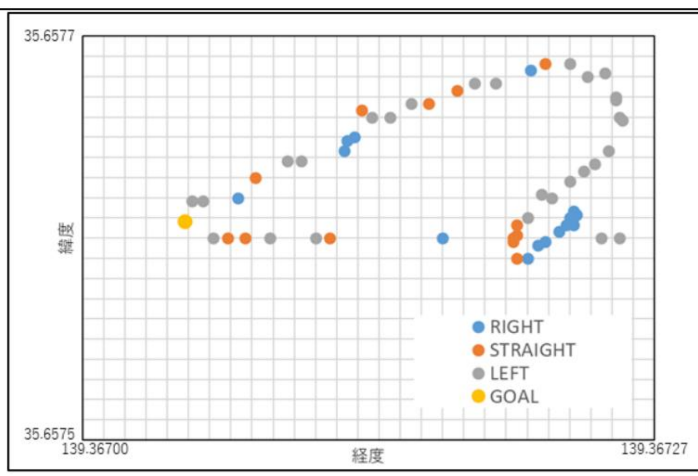
ÿ Operation log URL (CanSat): https://drive.google.com/file/d/1ahXjIc3FO-1L-pDO0z4sAmeINTJeJT8f/view?usp=sharing ÿ Operation log URL (ground station): https://drive.google.com/file/d/1Hdzta2_QcBeyjlvxGyJRf0cLnOf46i3j/view? usp=sharing

Consideration	ÿ The results showed that the operation log could be saved in the MicroSD card, indicating that ``CanSat is equipped with a storage device that can save the HK data acquired at the sampling rate required for verification of the success criteria." It was confirmed. ÿ The results show that ``data can be transferred to the ground station" and ``saved HK data can be deleted." It was confirmed that the data was not deleted or overwritten.

V14. Parachute separation test purpose: Confirm

that the wire connecting the parachute and the aircraft can be burned out with nichrome wire. Perform the parachute separation phase while	
contents of the test	applying strong wind from an electric fan to the parachute separation mechanism, and confirm that the nichrome wire breaks the wire. Also, take pictures of the situation. Since the test has not yet been conducted, it will be filled in once the test is conducted. The
result	~~parachute separation phase was performed while applying~~ strong wind from an electric fan to the parachute separation mechanism, and the nichrome wire broke the legs. The situation at that time is shown in the video at the following URL. Video URL: https://youtu.be/ugHcYM3DNK4 Discussion It was
confirmed that the wire connecting the parachute and the aircraft could be burned out by nichrome wire.	

V15. Driving test Check

the purpose	the followin~~g~~ 76 items. ÿ CanSat writes a program to input the goal coordinates before sequence ÿ. To be able to be replaced. ÿ CanSat can obtain its own position coordinates from GPS. ÿ CanSat can calculate the relative azimuth between its own position coordinates and the goal cone position coordinates. What you can do. ÿ CanSat must be equipped with a high torque motor of 0.05[Nm] or more. ÿ CanSat can move its center of gravity using a servo motor. ÿ CanSat can obtain its own position coordinates ~~from GPS. ÿ CanSat calculates the straight line distance and radius of the circle between~~ its own position coordinates and the goal cone position coordinates. Ability to compare and detect arrival.
contents of the test	1. CanSat is driven under autonomous control from a distance of several tens of meters from a preset goal point. Let. 2. Visually confirm that CanSat has reached the goal point. 3. Confirm CanSat's GNSS goals from the data. GNSS goal: A state in which it is detected that the CanSat positioning result has arrived within a circle with a radius of "GNSS error 2" [m] from ~~the destination. T~~his has not yet been conducted, so it will be filled in once the test is conducted.
result	CanSat was operated under autonomous control from a point approximately 16 [m] away from the preset goal coordinates (east longitude, north latitude) = (139.3670483, 35.6576083) . According to the log, the coordinates of the position where CanSat determined the goal were (East longitude, North latitude) = (139.3670517, 35.6576183), and the difference from the preset goal coordinates was 1.2 [m]. A plot of the coordinate history is shown in Figure 35 . "RIGHT" "LEFT" "STRAIGHT" in Figure 35 This is the control value for the direction in which CanSat should move, calculated from its own position coordinates/traveling azimuth and the goal position coordinates. The video of the test and the log of the autonomous running are shown at the following URLs.  Figure 35 Position coordinate history while **CanSat** is running ÿ Video URL: https://youtu.be/MN-jLfGxD2M ÿ Log URL: https:// drive.google.com/file/d/1g- A_wHyqKedhV4zANyON2SGiSg2OyEBh/view?usp=sharing

Consideration	ÿ Since you have set the goal coordinates in advance, CanSat will sequence the goal coordinates. It was confirmed that the program could be rewritten to input information prior to the first instance. ÿFrom Figure 35 , we can see that CanSat is repeatedly running toward the goal and changing direction. I understand. Therefore, ``CanSat must be able to obtain its own location coordinates from GPS." and "CanSat calculates the relative azimuth between its own position coordinates and the goal cone position coordinates. "CanSat is equipped with a high torque motor of 0.05[Nm] or more." We confirmed that CanSat can move its center of gravity using a servo motor. ÿ CanSat judged the goal at a point 1.2 [m] from the goal. Compare the straight line distance between your own position coordinates and the position coordinates of the goal cone and the radius of the circle to reach the goal. We confirmed that it can be detected.

V16. Stuck avoidance test

the purpose	Confirm that CanSat is equipped with deceleration mechanism escape mode and rut escape mode.
contents of the test	If CanSat does not move from a circle with a radius of 2 [m] for 10 seconds, CanSat automatically activates the deceleration mechanism escape mode. Verify visually and by watching the video that the vehicle has transitioned to mode and rut escape mode.
result	~~Since the test has not yet been conducted, it will be filled in once the test is conducted.~~ A CanSat can be held down by hand for 5 seconds to autonomously enter deceleration mechanism escape mode/rut escape mode. It has transitioned. After that, it started running normally, but it got caught on an obstacle on the ground and started running again. The vehicle automatically transitioned to deceleration mechanism escape mode/rut escape mode. Perform stack avoidance movement 3 times. After that, the vehicle resumed driving normally. The video at that time is shown at the URL below. Video URL: https://youtu.be/ViXoonBXX3o
Consideration	The test results show that CanSat is equipped with deceleration mechanism escape mode/rut escape mode, and It was confirmed that the system operates after detecting a stuck state, and returns to normal driving after the operation is completed. Ta.

V17. 0m goal test

the purpose	Check the following 73 items. ÿ CanSat can recognize the goal cone using a camera. ÿ CanSat can calculate the relative azimuth between its own position and the goal cone position. and. ~~ÿ CanSat must be equipped with a high torque motor of 0.05[Nm] or more. ÿ CanSat can move~~ ~~its center of gravity using a servo motor. ÿ CanSat can obtain its own~~ ~~position coordinates from GPS. ÿ CanSat can detect when a goal has been~~ reached using a camera. ÿ CanSat should be able to stop operation after detecting ~~the 0m goal.~~
contents of the test	~~Perform the following steps five times to confirm that CanSat has the ability to achieve the 0m goal. 1. Place~~ ~~CanSat 2m~~ ~~from the goal cone. 2. Execute CanSat's 0m goal phase. 3. Check~~ ~~if CanSat reaches the 0m goal.~~ ~~Confirm the following items~~ using ~~the camera and Raspberry Pi ZeroWH installed~~ in CanSat. 1. Use a camera to determine the position of the goal cone and determine whether to go straight, turn right, or turn left. can be done. 2. A camera can be used to judge the proximity to the goal cone and determine the goal. Ru.

result

~~Since the test has not yet been conducted, it will be filled in once the test is~~

conducted. Figures 36 to 39 show the judgment results. From the left: the image obtained from the camera, the image for which red color was judged, and the judgment result. We confirmed that it was possible to determine whether to go straight, turn right, or turn left, and determine the goal. Here, the goal is determined when the number of pixels considered red satisfies 80% of the number of pixels on the entire screen.

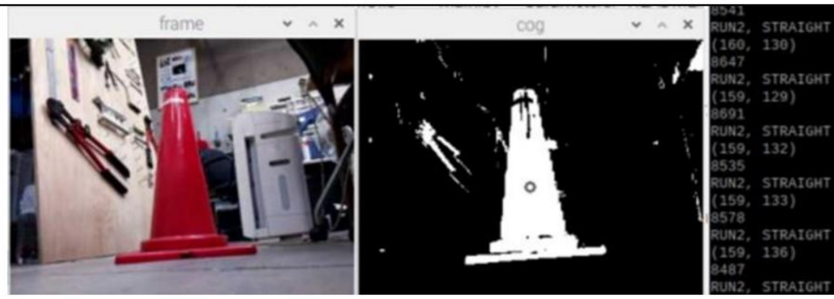


Figure **36** Straight running judgment result

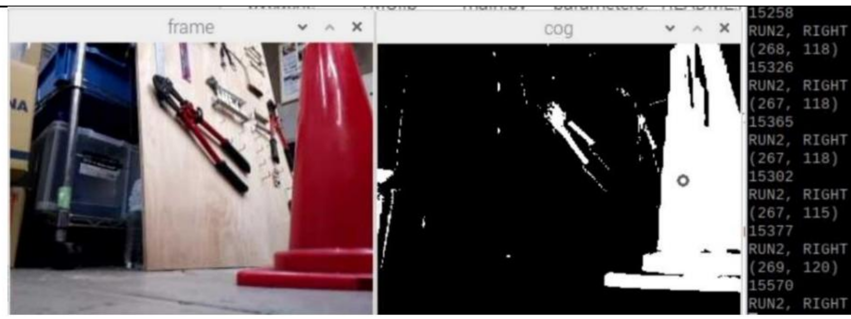


Figure **37** Right turn determination result

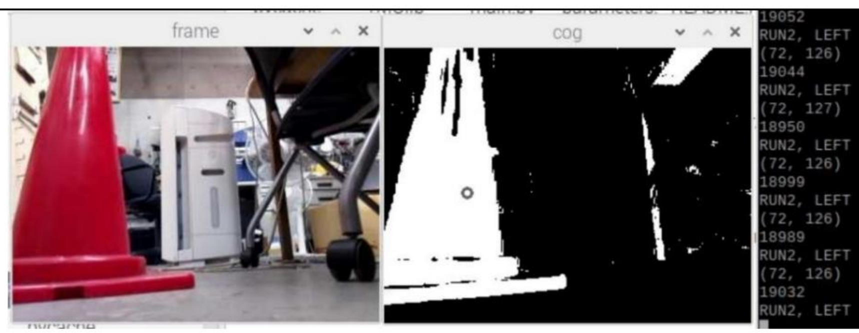


Figure **38** Left turn determination result

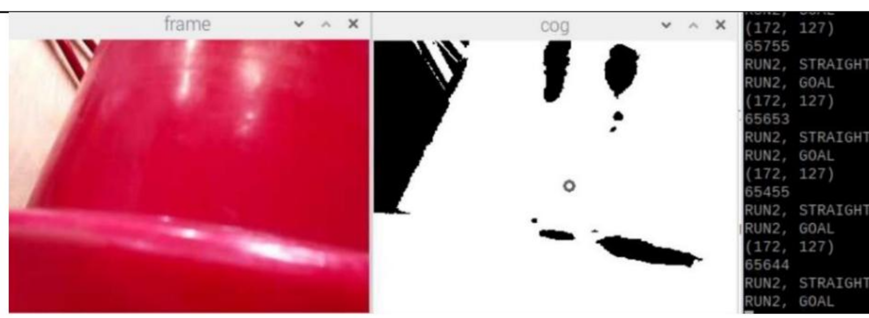


Figure **39** Goal judgment results

Consideration

We confirmed that CanSat can recognize the goal cone using a camera and determine the direction of movement and goal based on the positional relationship between CanSat and the goal cone.

V18. Control history report creation test

Purpose: Confirm that it is possible to save the specified control history and submit and analyze the control history.

contents of the test

1. Run CanSat from near the preset goal. 2. CanSat's state quantities

(time, latitude, longitude, speed, heading, distance to ~~goal, azimuth to goal, pitch angle) and control variables (motor output value, servo motor input) until reaching the goal. pulse value)~~ to SD. 3. Extract and analyze the SD. ~~Since the test has not yet been conducted~~, it will be filled in

once the test is conducted. Sequences ÿ

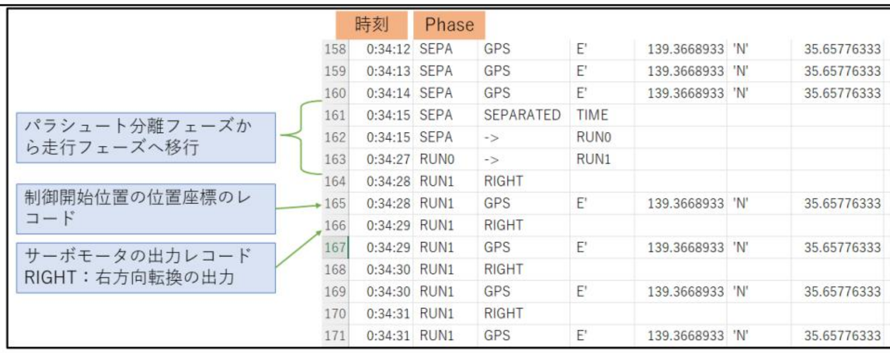
result

~~and ÿ were executed and logs were obtained.~~ Figure 40

shows the starting part of the log . The transition from the parachute separation mode to the running phase and the position coordinates at the start of control have been acquired and saved. After starting to drive, it can be confirmed that the vehicle is being controlled to move to the right. Figure 41 shows the goal determination part of the log .

GNSS goal determination and location at that time

The location coordinates are acquired and saved. Also, all logs are stored at the URL below.



	時刻	Phase					
158	0:34:12	SEPA	GPS	E'	139.3668933	'N'	35.65776333
159	0:34:13	SEPA	GPS	E'	139.3668933	'N'	35.65776333
160	0:34:14	SEPA	GPS	E'	139.3668933	'N'	35.65776333
161	0:34:15	SEPA	SEPARATED	TIME			
162	0:34:15	SEPA	->	RUN0			
163	0:34:27	RUN0	->	RUN1			
164	0:34:28	RUN1	RIGHT				
165	0:34:28	RUN1	GPS	E'	139.3668933	'N'	35.65776333
166	0:34:29	RUN1	RIGHT				
167	0:34:29	RUN1	GPS	E'	139.3668933	'N'	35.65776333
168	0:34:30	RUN1	RIGHT				
169	0:34:30	RUN1	GPS	E'	139.3668933	'N'	35.65776333
170	0:34:31	RUN1	RIGHT				
171	0:34:31	RUN1	GPS	E'	139.3668933	'N'	35.65776333

Figure **40** Driving log (at start)

	時刻	Phase					
830	0:43:40	RUN1	RIGHT				
831	0:43:40	RUN1	GPS	E'	139.36733	'N'	35.65752667
832	0:43:41	RUN1	RIGHT				
833	0:43:41	RUN1	GPS	E'	139.367335	'N'	35.65751833
834	0:43:42	RUN1	RIGHT				
835	0:43:42	RUN1	GPS	E'	139.367335	'N'	35.6575
836	0:43:43	RUN1	RIGHT				
837	0:43:43	RUN1	GPS	E'	139.367335	'N'	35.6575
838	0:43:44	RUN1	RIGHT				
839	0:43:44	RUN1	GPS	E'	139.3673317	'N'	35.65750167
840	0:43:45	RUN1	RIGHT				
841	0:43:46	RUN1	GPS	E'	139.367325	'N'	35.65750167
842	0:43:46	RUN1	GOAL1				
843							

Figure **41** Running log (at the goal)

ÿ Log URL:
https://drive.google.com/file/d/1PHES3Snm4okoVmI26VenZfYJhJzksk-e/view?usp=sharing

Consideration

We confirmed that CanSat's state variables (phase and various sensor output values) and control variables (servo motor output mode) were recorded from the start of travel to the end of travel. It is thought that these data can be used to submit a specified control history report.

Chapter 7 WBS and Gantt chart (work management)

The URL of the spreadsheet containing the WBS and Gantt chart is shown below. The WBS and Gantt chart are updated from time to time, and the latest version is shown on a sheet named ``WBS and Gantt chart_latest version.'' Additionally, images of the WBS and Gantt chart are attached to the final page.

WBS and Gantt chart URL: https://docs.google.com/spreadsheets/d/1lC5rctA9XKpOyk7iIYsNJVng0H6e9EUI/edit?usp=sharing &ouid=117101125820105959988&rtpof=true&sd=true

Even at this stage, development has been delayed by about two to three weeks due to problems that could not have been predicted at the initial stage, such as a ``3D printer failure'' and ``changes in the vibration testing site and schedule.'' Since we had originally secured a margin of about 2 to 3 weeks, we managed to submit the screening documents in time. There are only about two months left until the actual production, so I would like to do my best to develop CanSat by increasing the frequency of my activities so that development does not fall behind.

At the end of July, when final adjustments were being made for the second screening, one of the members became infected with the new coronavirus. However, by working together among the members, we were able to complete the FM device and the examination report within the deadline. In the future, we would like to improve the mission success rate as much as possible in preparation for the actual ARLISS mission in September. To this end, we will continue to conduct repeated tests and discussions with all members, without separating them into structure teams or electrical equipment teams, to improve the accuracy of CanSat as a whole.

Chapter 8 Summary of self-safety review results by responsible instructor 1.

Safety standards review

request number	Self-examination items	Self-examination results	Comments from the responsible teacher (if there are any noteworthy items)
	ARLISS2022 Safety Standards		
S1	Make sure that the mass of the aircraft to be dropped meets the standards. and.	ÿ	
S2	volume must meet carrier standards.	ÿ	
S3	Tests have confirmed that the quasi-static loads during launch do not impair the functionality required to meet safety standards.	ÿ	
S4	It has been confirmed through testing that the functions required to meet safety standards are not impaired by vibration loads during launch.	ÿ	
S5	It has been confirmed through testing that the functionality required to meet safety standards is not impaired by the shock load during rocket separation (when the parachute is deployed).	ÿ	
S6	It must have a deceleration mechanism to prevent it from falling at dangerous speeds near the ground, and its performance has been confirmed through testing.	ÿ	
S7	Countermeasures against loss have been implemented, and their effectiveness has been confirmed through testing. (Examples of measures: location information transmission, beacons, fluorescent color -paint, etc.)	ÿ	
S8	It has been confirmed that the regulations for turning off the power of radio equipment at the time of launch can be observed (devices that are FCC certified and have a power output of less than 100 [mW] do not need to be turned off. Also, if a smartphone is used, it must be FCC certified and powered off). (can be turned off with a software or hardware switch).	ÿ	

S9	The applicant must be willing to adjust the wireless channel and have confirmed that the adjustment can actually be made.	ÿ	
S10	We have been able to conduct end-to-end tests simulating the loading of the rocket, the start of the mission, and recovery after launch, and there will be no major design changes in the future.	ÿ	
	If you wish to participate in the Comeback Competition, please be sure to meet the following requirements:		
M2	It must be confirmed that autonomous control is performed without human intervention during the mission.	ÿ	
M27	After the mission, be able to submit the specified control history report to the management and judges and explain the logs and acquired data.	ÿ	

2. Impressions of the responsible teacher

This team's CanSat is positioned as a solution to the problems that emerged locally with the spherical rover produced by TMU-MAG., which participated in ARLISS in 2018. Two of the four members of this team are "TMU-MAG.", so they not only have experience with CanSat, but are also skilled with the spherical rover itself. In this way, we were able to iterate on both system engineering and project management, both in terms of systems and people, while also passing on the technology to the two first-time participants. Each stage of development and various tests are progressing smoothly, and I have high expectations for the team and CanSat as the responsible faculty members.

Chapter 10 Tournament Results Report

1. Purpose

We aim to improve team project management and system engineering through CanSat production. We built CanSat and participated in ARLISS with the aim of "learning about ARLING." Also, team members Two members of the team participated in ARLISS four years ago with a spherical rover, but they completed the mission without actually moving. Since he failed, he is also seeking revenge. Furthermore, through the mission, it will replace the two-wheeled rover. We will verify the usefulness of the ``spherical rover'' as a new shape.

2.Results

Table 12 shows the results of the competition . We performed two launches and failed to achieve minimum success on all launches. Ta. The details of the first and second times are described below.

Table **12** Summary of tournament results

	Minimum Success	Full Success	Advanced Success
1st (9/12) 2nd	×	×	×
(9/15)	×	×	×

ÿ 1st time

The first launch took place on September 12th, the first day of the tournament, at around 2:00 pm. Since it was afternoon, on the ground A strong wind was blowing, and I expected an even stronger wind to blow above. CanSat after launch? I was unable to receive position information from the aircraft and lost sight of the descending CanSat, which I was following visually. Therefore, it was not possible to determine the landing point. After that, I continued searching for CanSat, but CanSat could not be discovered within days. The next day, we started searching for CanSat in the morning. CanSat was discovered around 15:00 based on information provided by other organizations. The landing point is the launch point Near the extension of the drop point of the rocket's nose, both the fuselage and parachute were undamaged. The two parts were separated (Fig. 42, Fig. 43). However, there are signs of CanSats running around the area. Since there were no marks, it was not possible to achieve minimum success on this launch. Ma Table 13 shows the CanSat operation results for each sequence .

Figure **42** Discovery point ÿ

Figure **43** Discovery point ÿ

Table **13** Results for each sequence in the first launch

Sequence Classification	Results ÿ	Preparation	Failure details
(from assembly to carrier storage) ÿ Launch	Aircraft ÿ	-	
	Para ÿ	-	
(from carrier storage to release judgment) ÿ Descent	Aircraft ÿ	After launch, communication with the ground station was lost.	
	Para ÿ	-	
(from release judgment to landing judgment)	Communication between the aircraft and the ground station was lost.		
	Para ÿ	-	
ÿ Travel preparation (from landing judgment to	Communication between the aircraft and the ground station was lost.		
	Para ÿ		
start of driving) ÿ Running (from start of driving)	Communication between the aircraft and the ground station was lost.		
GNSS goal) ÿ0m goal (From GNSS goal to 0m goal) ÿ Analysis	Communication between the aircraft and the ground station was lost.		
(from CanSat collection (up to data analysis)	Communication between the aircraft and the ground station was lost.		

The HK data from the first CanSat is stored at the URL below. ÿ

HK data URL:

https://drive.google.com/drive/folders/1s3twUeFwfAxicO6Y2AzFaPZIRRborHv_?usp=sh aring

ÿ Second time

The second launch took place at around 9:00 on September 15th, the last day of the tournament. Since it was mid-morning, the wind on the ground was weak. Several minutes after launch, we successfully received location information from CanSat, got into a car, and tracked it using GPS. During the pursuit, communication from CanSat was interrupted, so we headed to the location indicated by the last location information received and discovered the aircraft wrapped in furoshiki. The aircraft was in a state where it could not travel (Figure 44, Figure 45, Figure 46). Also, place a parachute on the nose of the rocket at a distance from the aircraft. I found a CanSat parachute entangled with a cane (Figure 47).

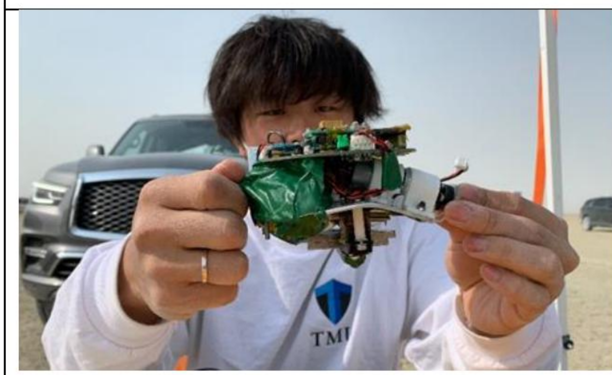
 Figure **44 CanSat** at landing point	 Figure **45 CanSat** appearance after landing
 Figure **46** Internal structure of **CanSat** after landing	 Figure **47** Tangled parachute

Table **14** Results for each sequence in the second launch

Sequence classification	result		detail
ÿPreparation (from assembly to carrier storage)	Aircraft ÿ		
	Para ÿ		
ÿLaunch (from carrier storage to release judgment)	Aircraft ÿ		
	Para ÿ		
ÿDescent (from release judgment to landing judgment)	Aircraft ÿ		
	Para ×		The parachute mechanism separated from the aircraft in the sky and did not function.
ÿTravel preparation (from landing judgment to start of movement)	Aircraft ×		The aircraft was damaged by the impact of the fall and was unable to travel.
	Para ×		The parachute mechanism separated from the aircraft in the sky and did not function.
ÿRunning (from start of travel to GNSS goal)	Aircraft ×		Aircraft cannot travel due to damage.
ÿ0m goal (From GNSS goal to 0m goal)	Aircraft ×		Aircraft cannot travel due to damage.
ÿ Analysis (from CanSat collection (up to data analysis)	Aircraft ×		No data because it is not running.

Store the second HK data at the URL below.

ÿ HK data URL:

https://drive.google.com/drive/folders/1s3twUeFwfAxicO6Y2AzFaPZIRRborHv_?us p=sharing

3. Discussion

ÿ 1st Drop

We determined that the reason we could not receive position information from CanSat during the 1st drop was that the program stopped operating after the carrier was stored. In the ground test, the CanSat program was commanded to start through an SSH connection using Tera Term, but a problem was confirmed in which the program stopped operating as soon as the connection between CanSat and Tera Term was interrupted. As a countermeasure, a command was executed to continue the job even after logging out from the remote server, and a double check was performed even after the carrier was retracted for the first time, but the command was not executed correctly.

CanSat's discovery locations are shown in Figure 48 , and the search history is shown in Figure 49 . CanSat was discovered approximately 6 km along the straight line connecting the launch point and the landing point of the rocket's nose. Furthermore, the search history revealed that the aircraft had passed near CanSat's landing site. There was a strong wind blowing at the time of launch, and it was unclear which direction the CanSat was being blown in, but based on these results, it is thought that no matter how strong the wind, CanSat will land on an extension of the rocket's nose.

Figure **48 CanSat** discovery point

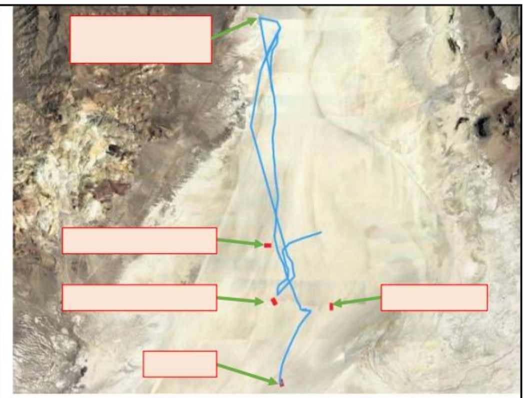


Figure **49** Search history

ÿ Second time

As a countermeasure for the second deployment, start the program using VNC instead of Tera Term. It was decided that

FTA was performed for the event of free fall. The results are shown in Table 15 . as a cause of failure. He listed three possibilities. However, the only data that could be obtained during the flight was atmospheric pressure. Although it is certain that the vehicle fell down, the cause of the failure has not yet been determined.

Table **15 FTA** for free fall

Event	Primary cause	secondary factor		Flight data results
freedom falling	cutting of tegus	parachute board abnormality of	ÿ	First flight with successful parachute separation The malfunction occurred because it was the exact same board/program as Although the possibility is low, it cannot be ruled out.
		abnormal load application of	ÿ	Rocket parachute and CanSat parachute Because the parts were entangled, centrifugal force etc. were not expected. It is possible that a heavy load was applied to the shaft.
	Unraveling of Tegusu	The knot of the tegus loose	ÿ	Specify the tape to tie the strings by hand. Since I haven't been there, the strings may come loose easily. It is possible that
	Furoshiki gap escape from	Tegusu tied long	×	The length of the prongs is determined in advance, and long prongs are was not used, so the design was such that no gaps were created. there were.
		Torn wrapping cloth	×	The wrapping cloth was not torn.
	parachute string cutting of	abnormal load application of	×	The parachute string was not torn.
	parachute string unraveling	parachute loosely tied	×	The parachute string had not come undone.

Chapter 11 Summary

1. Points of innovation and effort ÿ Structure

team (aircraft) ÿ The spherical

shell is lightweight, has high impact resistance and flexibility (flexibility to the extent that it does not impair running performance), and does not come off when falling or during travel. We selected a resin material that allows the boundaries to be fastened with bolts.

ÿ It was divided into three main modules (spherical shells 1 and 2 and the inside of the structure), and preparations were made so that they could be assembled within minutes during the actual production.

ÿ Adjustment of the center of gravity was extremely sensitive, but we conducted development to maintain reproducibility.

Ta.

ÿ The weight for direction change should be brought close to the optimal shape, and should not interfere with other components.

First, we were able to realize a change of direction that satisfied the running

performance. ÿ Structure team (parachute) ÿ

When sewing the parachute cloth overlappingly, the thread was passed through at least two times so that it could withstand the impact of opening the parachute. Furthermore, the ends of the cloth, which are subject to large impacts, are folded back to make the cloth thicker, thereby increasing its strength.

ÿThe parachute did not break even after receiving the impact of opening the parachute. ÿ The strong string used when

pitching tents for camping etc. is used to connect the parachute and the aircraft.

Used for tying thread.

ÿThe thread connecting the parachute and the aircraft did not break during CanSat's descent. ÿ When threading the thread

connecting the parachute and the aircraft, we sewed a thick denim fabric onto the parachute and made a hole with a metal eyelet to pass the thread through so that it could withstand the impact of opening the parachute. ÿÿ

ÿThe parachute did not break even after receiving the impact of opening the parachute. ÿ Electrical equipment team

(aircraft) ÿ Parameters to be

changed on the day of launch were written in separate files to prevent unexpected changes to the main program.

ÿ Electrical equipment team (parachute)

ÿ Two Tegus fusing systems using nichrome wire were installed. ÿ l The volume and weight were

reduced by using LiPo with a large discharge capacity as the battery for the nichrome wire. ÿ l It is now possible to automatically enter flight mode even if a reset occurs during flight.

2. Issues ÿ Structure

team (aircraft) ÿ During the

development period, development proceeded through repeated production and experimentation without much consideration of the budget, resulting in excessive production costs and work time. Therefore, we should have determined the accuracy through numerical analysis and then conducted manufacturing and experiments to reduce manufacturing costs and work time. ÿ

When turning on the power, it was necessary to remove the spherical shell, which resulted in power loss due to the assembly time of about 5 to 10 minutes after turning on the power, so it is best to turn on the power after assembly is complete. It would have been better if they had developed something that would allow them to do so.

ÿ Structure team (parachute)

ÿ One of the reasons why the nose of the rocket and our CanSat's parachute got entangled and fell during the second launch is thought to be that the parachute string was too long. ÿ One of the reasons why the CanSat aircraft fell

free during the second launch was that the threads used to connect the parachute mechanism and the CanSat aircraft came undone or became tangled due to centrifugal force. It is thought that it may have been torn off.

ÿ Despite the large load being applied to the leg, it was a single point.

ÿEfforts should have been made to eliminate single points as much as possible, such as by using double wires. ÿ The tegus was

tied by a human on the day.

ÿ Reduce as much as possible things that are influenced by people's conditions on the day (such as people tying strings). If it is absolutely necessary, set standards. ÿ Electrical equipment team (aircraft) ÿ Despite

double checking during

the first drop, a malfunction occurred.

Ta. This is because they only checked that the procedure had completed execution, but did not check whether the procedure worked normally. It is also a problem that could have been prevented if sufficient ground tests had been conducted. ÿIn the future, we

will not only execute procedures, but also implement operational procedures and implementations that will allow us to confirm that the procedures are working correctly.

ÿ Electrical equipment team (parachute)

ÿTroubleshooting is impossible because logs are not saved.

3. Future outlook ÿ In order

for all teams to participate in the tournament safely, we must not act selfishly, thinking only of ourselves.

Instead of acting in a similar manner, act with consideration for the management and surrounding teams.

ÿ Since development almost never goes as planned, the schedule should be set with a margin of at least one week before and after. Let's set it up.

ÿ We recommend launching first thing in the morning. The wind is calmer in the morning than in the afternoon, especially early in the morning. There is often almost no wind, and the direction of CanSat's descent is easy to predict.

ÿ CanSat should actively receive reviews from experts. The successes and failures of our predecessors Let's learn more.