ARLISS2022 **report**

Submission date: November 21, 2022

• Examining instructor

Examining faculty member name	
email address	
Judging comments	Please see each comment. Regarding safety, there are some points that need to be reviewed regarding the timeout of the standby sequence, so please check them. Also, if a screw comes loose during a vibration test, please reconfirm its safety. Regarding the success or failure of the mission, within the scope of the explanation in this document, we have not been able to confirm that the navigation will function well. The test is still ongoing, but I hope it will improve.
Other words	

• Team information

CanSat team name	**University of Electro-Communications Takatama Laboratory** Team Hodr
CanSat team representative information	**Naoya Yatsu08028273076 ,** naoya990506@gmail.com
UNISEC organization name	University of Electro-Communications Takadama Laboratory
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Responsible teacher	**Takada Laboratory** keiki@inf.uec.ac.jp, Phone number
CanSat class	Open class

• Members

role	Name (grade, years of experience)
Leader and software team	Naoya Yatsu (M1, 2nd year of experience)
hard team	Yusuke Maekawa (M2, 3rd year of experience)
hard team	Hiroki Shiraishi (M2, 3rd year of experience)
hard team	Reo **Kambara (B4, 1st year experience)**
hard team	Kyosuke Maekawa (B2, 2nd year experience)

Software team	Keisuke Furuya (M2, 2nd year of experience)
Software team	Chota Kametani (M1, 1st year of experience)
Software team	Shunsuke Ueki (B4, 1st year of experience)
circuit group	Daiki Shintani (B4, 1st year experience)
circuit group	Akiya Hirano (B2, 2nd year of experience)

table of contents

Chapter 1 **Mission Statement**

1. 1Mission **Statement**

A mission statement is a clear statement of the mission's goals along with the background and rationale.

This mission proposes CanSat, which performs self-position estimation using a combination of wheel odometry and a calibration algorithm that compensates for its errors. Even in unknown environments where GPS* and geomagnetic information other than Earth cannot be used, the We will establish a method to realize navigation control to an arbitrary destination point using relative coordinates and relative

angles from the position. Wheel odometry is a self-position estimation method that estimates the vehicle's travel route and angle by calculating the amount of tire rotation using a motor encoder. Since the position can be easily estimated using only the amount of rotation of the tires, it can be applied even in unknown environments such as the moon. However, with wheel odometry alone, it is not possible to detect the angular deviation or spin of the vehicle body due to uneven ground, and the resulting errors accumulate and become large errors, which are critical to CanSat's (1) direction estimation

and (2) current coordinate estimation. The problem is that a discrepancy occurs. There are various methods to correct these errors, but most are desig Common methods include correcting the position by acquiring the current coordinates with GPS, and correcting the direction using a high-performance 9-axis sensor . However, these cannot be used on planets without poles or in environments

where satellites cannot be used. Therefore, this mission assumes an unknown planetary environment and uses wheel odometry by combining the skyline method, which is used as a landmark-based self-localization method using a camera, and distance estimation based on the LoRa radio field strength from a communication station. Correct the errors that occurred. The skyline method replaces CanSat's ÿ azimuth estimate by performing feature matching on the landscape image taken by CanSat and the image taken at the landing site and calculating how much the image has moved. In addition, by receiving the direction of the antenna from a communication station with directivity using a Yagi antenna, the error in current coordinate estimation is corrected using a filter based on the

direction of the antenna and the radio field strength of the received radio waves. By using this method, even in an unknown planetary environment, by installing a single communication station, it is possible to specify a location that has not been explored within the area where the communication station can communicate and search with CanSat. It is expected .

*Please note that in this book, GNSS that obtains coordinates is referred to as GPS.

1. 2 **mission sequence**

Figure 1.2.1 shows an overview of the mission sequence.

An overview of the mission sequence is shown below. The details **of the detailed controls within the sequence are described in the sequence flow and various algorithms in Section 4.4 below .**

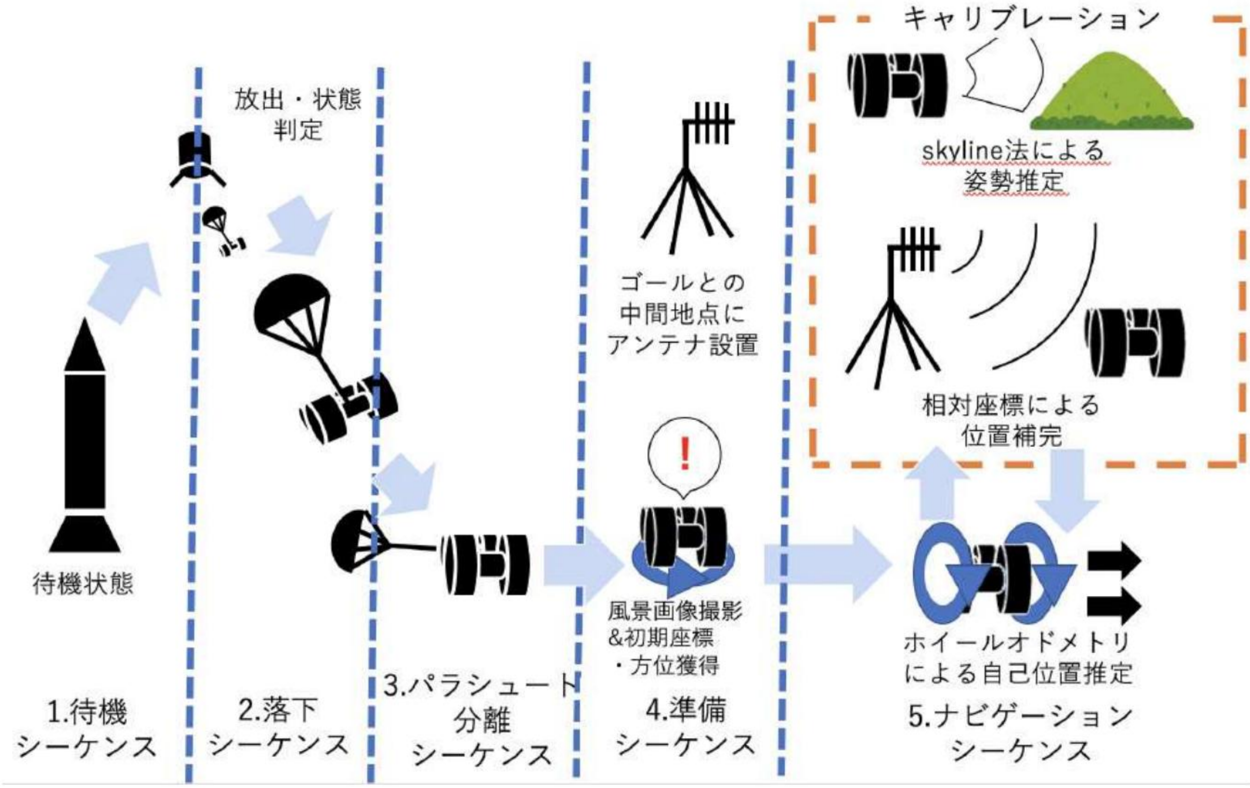

Figure 1.2.1 **Mission sequence overview diagram**

1. Load the carrier

containing the standby sequence CanSat onto a rocket and launch it. 2.

Falling sequence CanSat

is released from the rocket carrier in the air and descends with a parachute. 3. **Parachute separation**

sequence CanSat lands on the ground

and separates the parachute. 4. Preparation sequence Obtain

the current position and

direction of the drop point using GPS. *This mission is conducted on the premise that the initial coordinates and initial orientation can be specified by pinpoint landing. After that, images of the surrounding landscape will

be taken to be used in the calibration within the navigation sequence.In addition, assuming that a communication station

has been installed in advance, a communication station will be placed midway between the goal point and the CanSat drop point .

Install by hand.

5. Navigation sequence using wheel

odometry. * Perform navigation driving to the goal point (no GPS, no geomagnetism). After traveling a certain distance, the accumulated errors are calibrated using attitude estimation using the skyline method and position information based on relative coordinates from the communication station.

***Regarding the goal point:**

In this mission, due to the communication distance of the communication station, you will not go to the goal cone but to the virtual goal set up . The method for calculating the virtual goal to be set is as shown in Figure 1.2.2: ÿ set a point on the straight line connecting the CanSat's drop point and the goal cone, and ÿ set a point 1 km away from the CanSat as the virtual goal. **From then on, in this review report, the go**

Indicates the imagined goal point.

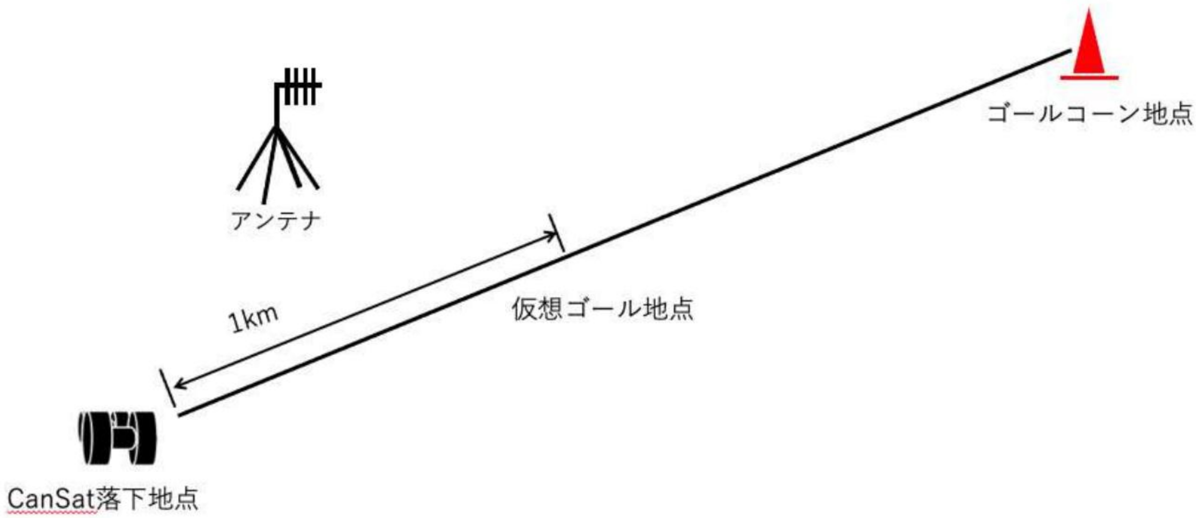

Figure 1.2.2 **Virtual goal setting location**

Chapter 2 **Success Criteria**

	Content	Evaluation method
Minimum Success	**After landing, the parachute is detached and the aircraft transitions to a state for preparations necessary for navigation.**	**can enter the preparation sequence**
Middle success	The following three points **necessary for navigation driving** can be achieved. 1. **To realize the skyline method** Obtain a 360° image of CanSat's surroundings . 2. **Establish communication with the communication station.** 3. **CanSat performs self-location, and based on the results CanSat can start traveling toward the goal point.**	**1. Photography in the preparation sequence can be completed. 2. Signals sent from communication stations can be observed using the rover program** . 3. **You can start navigation driving** .
Full success	1. **Odometry orientation errors can be corrected using the skyline method** 2. **Odometry coordinate errors can be corrected by radio wave strength.**	1. **CanSat's orientation can be corrected** if **the orientation estimated by the skyline method** is less than ±45 degrees on average compared to **the angle calculated by the 9-axis sensor** . 2. **In all trials, the robot was able to bring its own coordinates closer to the coordinates obtained by the GPS sensor using the** coordinates estimated from the radio field strength.

Extra success	**The vehicle will arrive near the goal point with an accuracy derived from a relative coordinate calculation test using radio field strength** (V18) **conducted in advance .**	**Whether it is possible to reach within a radius of 20 [m] near the goal by driving with navigation, which was** determined by a CanSat orientation estimation **test** using the skyline method and a relative coordinate calculation test using radio wave intensity.

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Chapter 3 **Setting requirements**

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

Request number	System requirements (ARLISS launch safety standards)
	The mass of the aircraft dropping S1 **meets the standards**
	S2 **volume meets carrier standards**
	Quasi-static loads during S3 **launch may impair functionality to meet safety standards. Tests have confirmed that there is no**
	Tests have confirmed that the vibration loads during S4 launch did not impair the functionality required to meet safety standards.
	Tests have confirmed that the impact load during separation of the S5 **rocket (when the parachute is deployed) does not impair functionality to meet safety standards.**
	S6Has **a deceleration mechanism to prevent it from falling at a dangerous speed near the ground, and its performance has been confirmed in tests. is made of**
	We have implemented countermeasures against S7 Lost, and their effectiveness has been confirmed through testing **(examples of countermeasures: location information transmission, beacons, fluorescent color paint, etc.)**
	It has been confirmed that it is possible to comply with the regulations for turning off the power of radio equipment at the time of S8 launch (devices **that are FCC certified and have a power output of 100mW or less do not need to be turned off. Also, when using a smartphone, it is FCC certified and requires a software or hardware switch . things that can be turned off)**
	We have confirmed that we are willing and able to adjust the S9 radio channel. **There is**
	End-to-end simulation of loading the S10 rocket, starting the mission, and recovering after launch **Tests have been conducted and there will be no major design changes in the future.**

3. 2 **mission request**

number	Mission requirements
	Tests have confirmed that the impact load upon landing on M1 **does not impair the functionality needed to accomplish the mission.**

Tests have confirmed that the M2 **CanSat can run on rough terrain.**
Tests have confirmed that it can run for the time required to accomplish the M3 mission.
Tests have confirmed that the M4 **CanSat can return to its normal running position when reversed and returned to its normal position.**
Communication between the M5 communication station and CanSat has been established, and CanSat has successfully received the information sent from the communication station. **Tests have confirmed that it is reliable.**
CanSat's travel route can be calculated using M6 **wheel odometry, and the travel route can be actually driven.** **We have confirmed through testing that it can be evaluated by comparing it with the travel route obtained using the method.**
CanSat's orientation can be estimated using the M7 skyline method, and the estimation results can be obtained from the geomagnetic sensor. **The error angle at which the vehicle can run has been confirmed through testing by comparing it with the actual angle.**
M8 **CanSat can estimate the relative position from the radio field strength received from the communication station, and the estimation result can be compared to the actual coordinates obtained by GPS. The error distance that can be traveled has been confirmed through testing.**
M9 **It has been confirmed that navigation driving can be performed by combining the contents of M5 to M8 above.**
After the M10 **mission, the specified control history report is ready to be submitted to the operator.**

Chapter 4 **System Specifications**

4.1 **Aircraft appearance**

Figures 4.1.1 and 4.1.2 show the overall image of CanSat taken from the front and rear, respectively. In addition, CanSat The diameter, height, and mass are shown in Table 4.1.1, and the measurements are shown in Figures 4.1.3, 4.1.4, and 4.1.5. In addition, the dimensions of the aircraft after the stabilizer and antenna are deployed are shown in the same table and in Figures 4.1.6 and 4.1.7. In this mission, it is required to be able to accurately determine the amount of tire **rotation** using a motor encoder. **Therefore, spikes are attached to the tires to prevent them from spinning. The servo motor attached to the center not only controls the attitude of the aircraft, but also serves as a stack escape mechanism and parachute separation mechanism.**

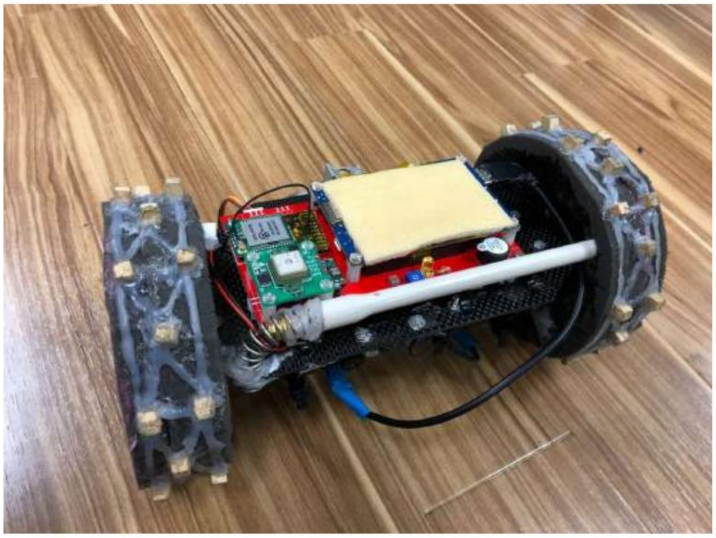

Figure 4.1.1 **Exterior of CanSat: Front**

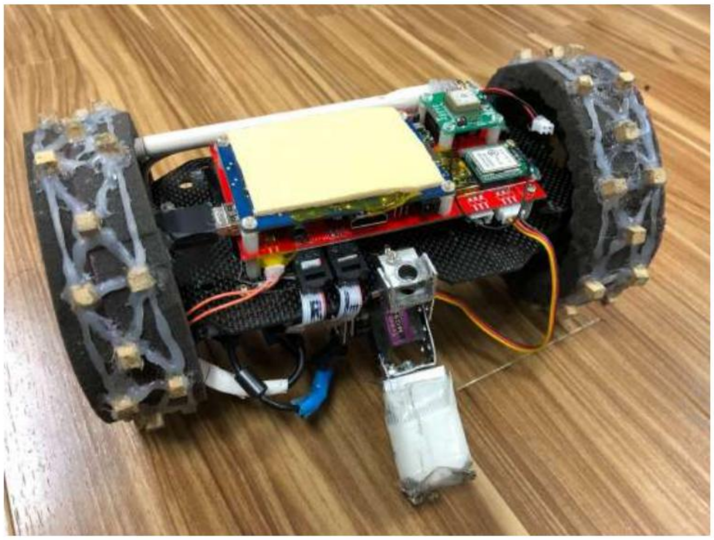

Figure 4.1.2 **CanSat appearance: rear**

Table 4.1.1 **CanSat diameter, height, and mass**

Diameter **before unfolding** [mm]		138
	Height [mm]	238
Total length **after deployment (antenna deployment) [mm]**		276
	Total length (stabilizer expanded) [mm]	180
	Mass [g]	956

Figure 4.1.3 **Airframe diameter**

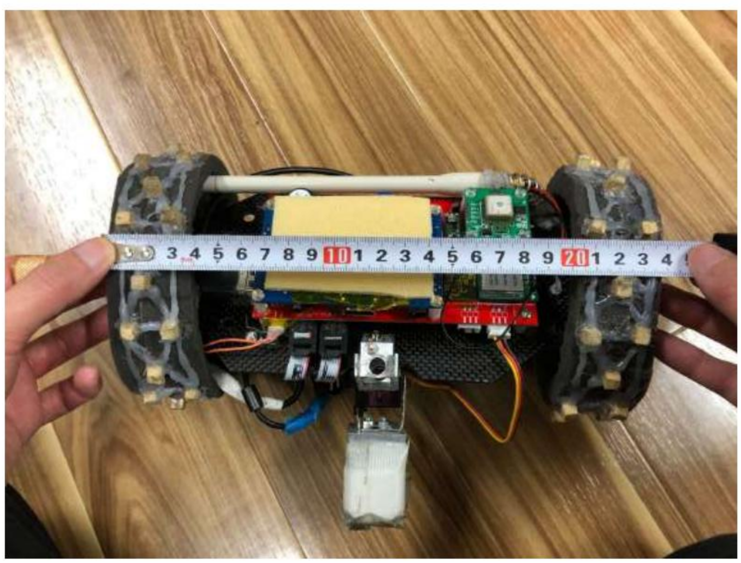

Figure 4.1.4 **Aircraft height (width)**

Figure 4.1.5 **Aircraft weight (956g shown)**

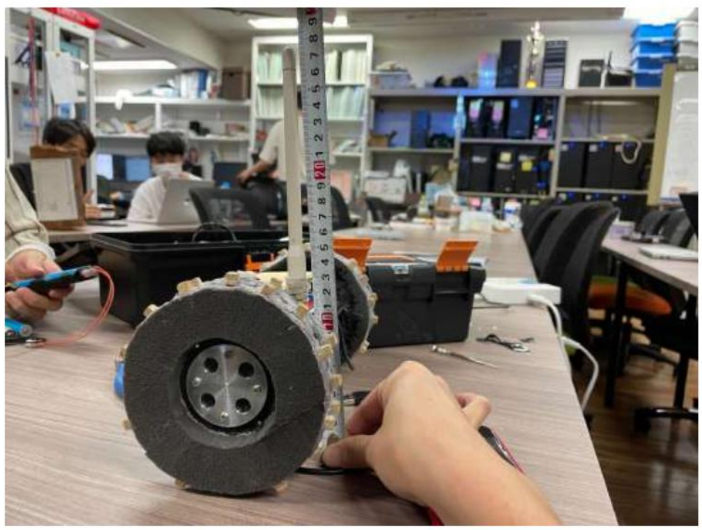

Figure 4.1.6 **Overall length of the aircraft after antenna deployment**

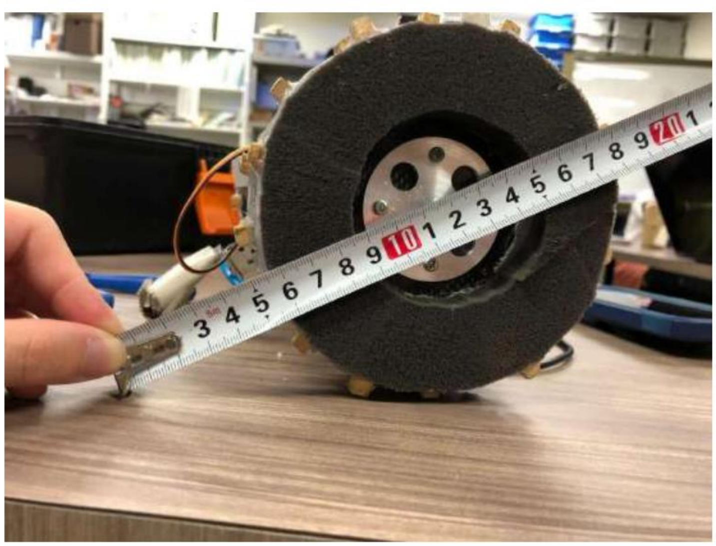

Figure 4.1.7 **Overall length of the aircraft after stabilizer deployment**

4.2 **Aircraft interior/mechanism**

Figures 4.2.1 and 4.2.2 show the upper and middle parts of the CanSat chassis (the carbon plate that forms the basis of the aircraft). **The circuit board, microcomputer, GPS sensor, antenna, and circuit power supply (lithium ion polymer battery) are installed here . The specific role of each element will be explained later.**

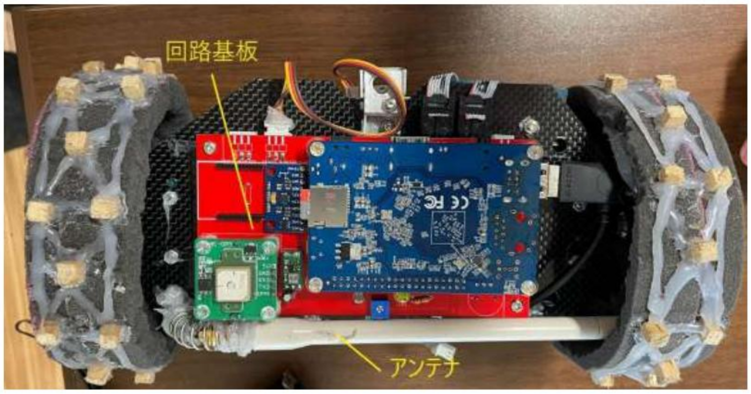

Figure 4.2.1 **Chassis top**

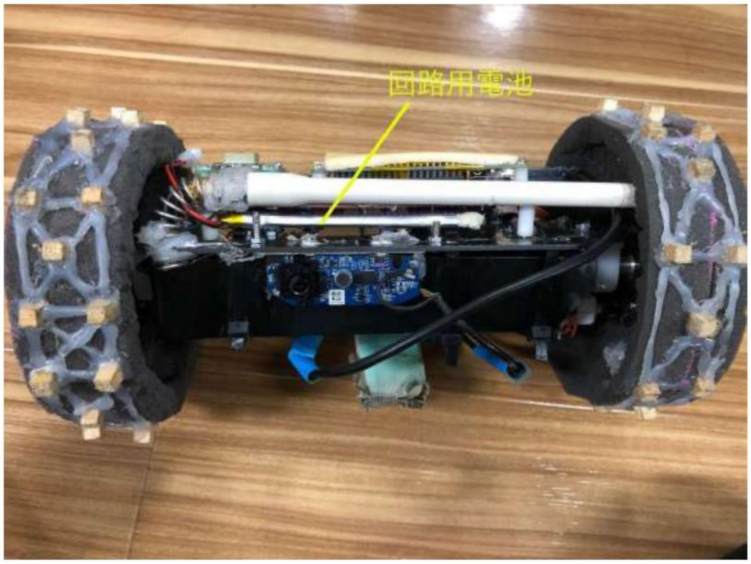

Figure 4.2.2 **Middle part of chassis**

Figure 4.2.3 shows the bottom of the CanSat chassis, which includes two motors, a camera, a power supply for the motors, an external device to speed up Orange Pi 's inference processing, a USB accelerator, a USB hub, and attitude control. A stabilizer servo motor is also installed to detach **the parachute . The motor on the right side of the image** is installed under the USB hub in a symmetrical position to the motor on the left side of the image.

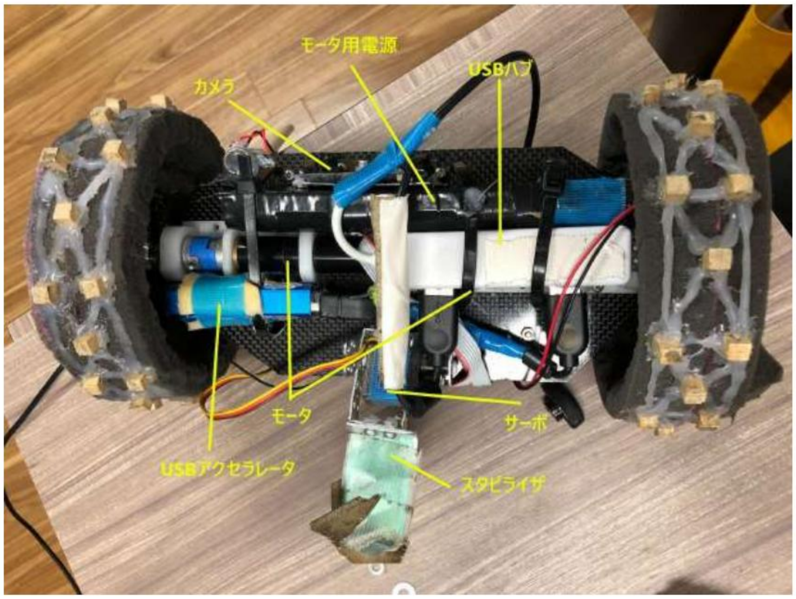

Figure 4.2.3 **Lower chassis**

The mechanism of Cansat is shown below. •Parachute release mechanism The parachute release mechanism, which is a deceleration mechanism, is shown in Figure 4.2.4. The parachute is detached using a servo motor attached to **the rear of** the CanSat .

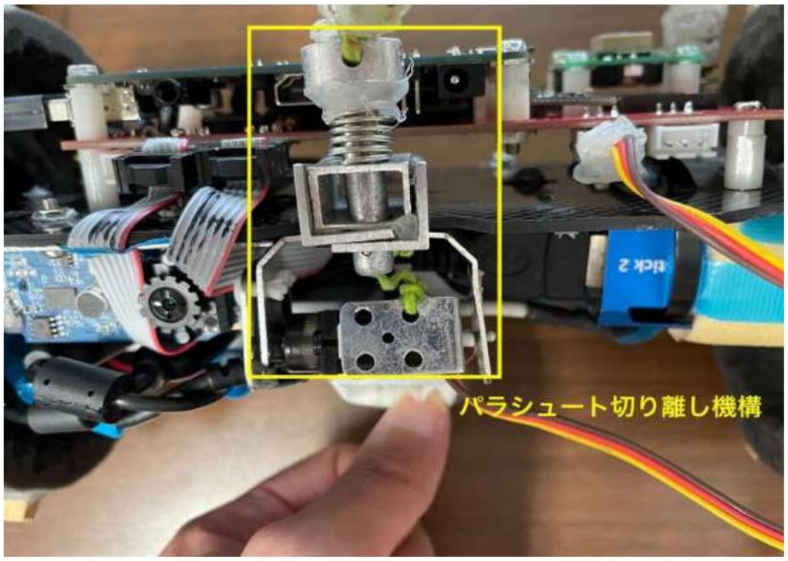

Figure 4.2.4 **Parachute release mechanism**

The operation of the parachute separation mechanism will be explained using a schematic diagram. This mechanism consists of a parachute pin, a spring, a rectangular parallelepiped aluminum part, and a nail (Figure 4.2.4). The parachute string is connected to a parachute pin , and the parachute pin is inserted into a hole made in a rectangular parallelepiped aluminum part. **The spring is also attached to the parachute pin. A repulsive force is generated on the parachute pin due to the contraction of the spring. Since the repulsive force is applied in the direction of pulling out of the rectangular parallelepiped aluminum part, a nail is inserted into the hole at the tip of the parachute pin to prevent it from coming off. The nail is attached to the stabilizer servo motor via a string.**

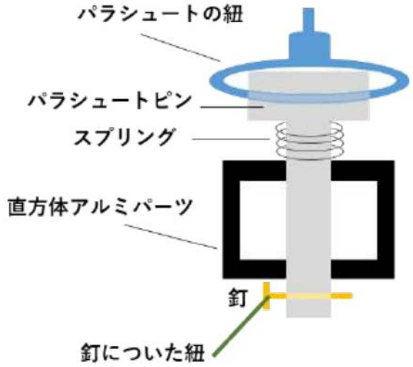

Figure 4.2.5 **Before parachute separation**

Figure 4.2.6 shows the situation when the parachute is detached. The stabilizer's servo motor operates and pulls the string attached to the nail, which pulls out the nail that was inserted into the parachute pin.

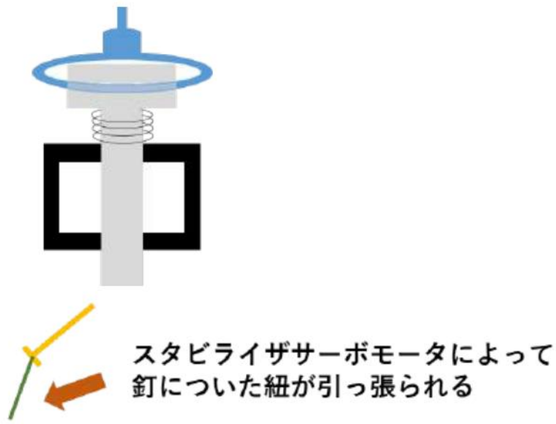

Figure 4.2.6 **When detaching the parachute**

Figure 4.2.7 shows the situation after the parachute is detached. When the nail stopper comes off, the repulsive force of the spring acts, and the parachute pin to which the parachute is attached comes off the rectangular parallelepiped aluminum part. At this time, the parachute pin is blown away from the CanSat by the repulsive force of the spring.

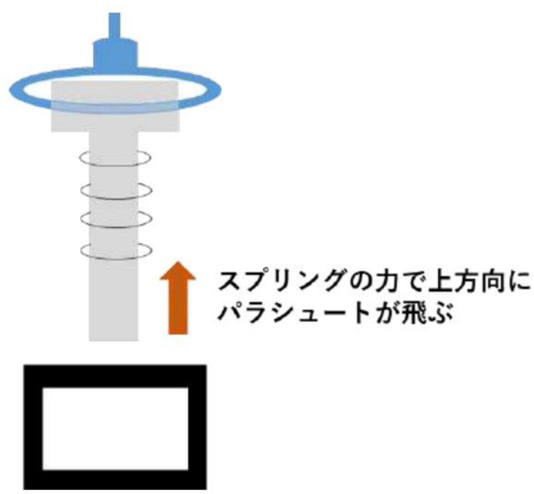

Figure 4.2.7 **After detaching the parachute**

•Antenna deployment mechanism

The antenna deployment mechanism is shown in Figure 4.2.8. The antenna is deployed using a spring attached to the chassis.

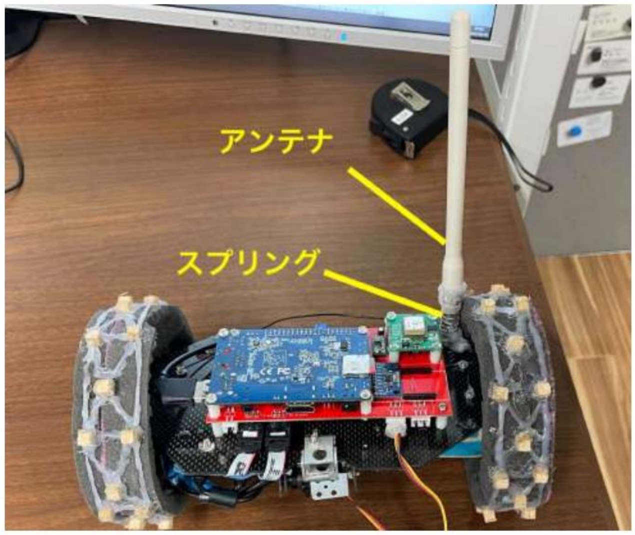

Figure 4.2.8 **Antenna deployment mechanism**

Bend the spring attached to the bottom of the antenna, hook the tip of the antenna inside the tire, and store it (Figure 4.2.9).

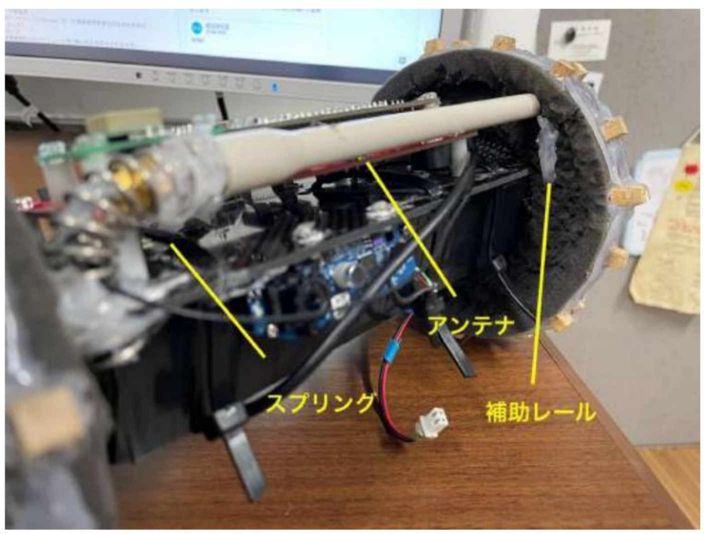

Figure 4.2.9 **Antenna storage**

The stowed antenna is deployed by the CanSat moving forward along the auxiliary rail inside the tire (Figure 4.2.10).

Figure 4.2.10 **Antenna deployment**

4.3 **Instruments installed**

4.3.1 System diagram (list of specifications for instruments mounted on the aircraft and communication station)

In each phase of the mission sequence, CanSat **uses input values obtained from the GPS sensor, 9-axis sensor (acceleration, gyro, geomagnetism), barometric pressure sensor, optical sensor, motor encoder, web camera, and LoRa communication module to determine the aircraft's status. It makes a judgment and takes action by controlling the motor, servo motor, LED, and buzzer. The communication station** uses the LoRa communication module to communicate **information obtained from the GPS sensor and 9-axis sensor while rotating the Yagi antenna .** In this mission, **a communication** station is used to calibrate the cumulative error of Cansat, which performs self-position estimation . **Figure 4.3.1 shows the appearance of the communication station. A microcontroller for antenna control** (using the same Orange Pi **PC2 as the CanSat itself) and a circuit board are mounted on the lower right side of this antenna. A motor is mounted in the center of the antenna, and the antenna rotates when power is applied to this motor. Figure 4.3.2 is a system diagram of CanSat. The arrow pointing from the sensor to Orange Pi** represents the input from the sensor, and **the arrow pointing from Onrage Pi to the sensor represents the control of each sensor. Red arrows represent power supply, and black arrows represent control and communication. Figure 4.3.3 is a system diagram of the communication station, and similarly to Figure 4.3.2, it shows how each sensor is controlled from Orange Pi. Table 4.3.1 shows the specifications of the onboard instruments used in this mission.**

In this mission, each sensor that acquires environmental information is used as follows. *1. Regarding obtaining initial coordinates using GPS, this mission assumes that a technology such as SLIM can be used to drop a bomb at a designated point, and that the initial coordinates of the drop point can be used . However, with ARLISS, it is difficult to specify the drop point because it is dropped by a rocket at a random location in the field. Therefore, in this mission, we will set up an antenna within the communication range of a communication station to obtain the initial GPS coordinates of the drop point. Due to the setting of the mission to install the communication station, the initial coordinates of the communication station will be obtained in the same way, and the location of the communication station will be known from the Cansat side.

***2. Regarding initial orientation acquisition using 9 axes, this mission assumes that CanSat's vehicle body at the initial location can be known remotely. Because ARLISS uses a rocket to drop the rover to random locations in the field,** remote control of the rover at the drop point requires establishing communication between the PC and CanSat several kilometers away, a function that deviates from the main focus of this mission. Since it will be necessary to implement a function to remotely control CanSat and photograph the surrounding landscape for 360 degrees , **only the initial orientation will be operated using 9 axes. However, this is only used to determine whether a 360° photo is being taken .**

CanSat

• GPS sensor • Initial
coordinate acquisition *1 ÿ
Obtain reference coordinates for relative self-position estimation

• Acquisition of coordinates
for evaluation ÿ Although not used for control, it is used to compare the coordinate position estimated in
this mission with the actual coordinate position and evaluate how much error has occurred.
• 9-axis sensor •
Initial orientation acquisition
*2 ÿ Obtain the reference orientation for relative orientation estimation

• Landing judgment
ÿ Uses the fact that the acceleration during the fall and after landing
is different • Stuck
judgment ÿ Uses the change in acceleration in the
direction of travel •
Rollover / reversal judgment ÿ Used to determine whether the CanSat has rolled over or
reversed from the gyro value
• Acquisition of orientation for evaluation ÿ Although not used for control, the orientation estimated in this mission is compared with the actu
Used to evaluate how much error has occurred.
• Atmospheric pressure
sensor • Landing
judgment ÿ Uses the fact that the atmospheric pressure changes greatly during a fall, and the change in atmospheric pressure decreases after landing.
• Optical sensor
• Carrier release judgment
ÿ Determine that it has been released from the carrier
•LoRa
• Lost
countermeasures • Distance estimation
using radio wave strength • Uses manufacturer's genuine external half-wave antenna

• Web camera •
Attitude control ÿ
Uses matching of horizon images (software) • Goal
detection ÿ Used to
take images to detect goal cones
• Motor encoder • Rotation
angle acquisition ÿ
Used for odometry • USB
accelerator • Goal detection ÿ
Used to speed up
calculation of deep learning model to detect goal cone

Communication station • GPS
sensor • *1. Coordinate
acquisition ÿ Obtain the coordinates of the transmitting station that communicates with CanSat
• 9-axis sensor •
*2.Geomagnetic acquisition

In addition, each module (output) is used as follows.
CanSat •
Electronic buzzer •
Determines the state in which CanSat is released from the carrier
• DC motor

• CanSat travel control ÿ **Forward** ÿ

Backward ÿ

Direction

change (right/left turn)

• Servo •

Parachute separation • Escape

from ruts •

Reverse return

Communication station • DC

motor • Antenna rotation •

LoRa + directional antenna

• Distance estimation using radio wave strength •

920[MHz]/250[mW] wireless station (LoRa)

ÿ **Operated as a registered station for land mobile**

stations ÿ **Persons other than radio operators as it falls under "simple operation" in Article 33 of the Radio Law Enforcement Regulations**

It is possible to operate even if

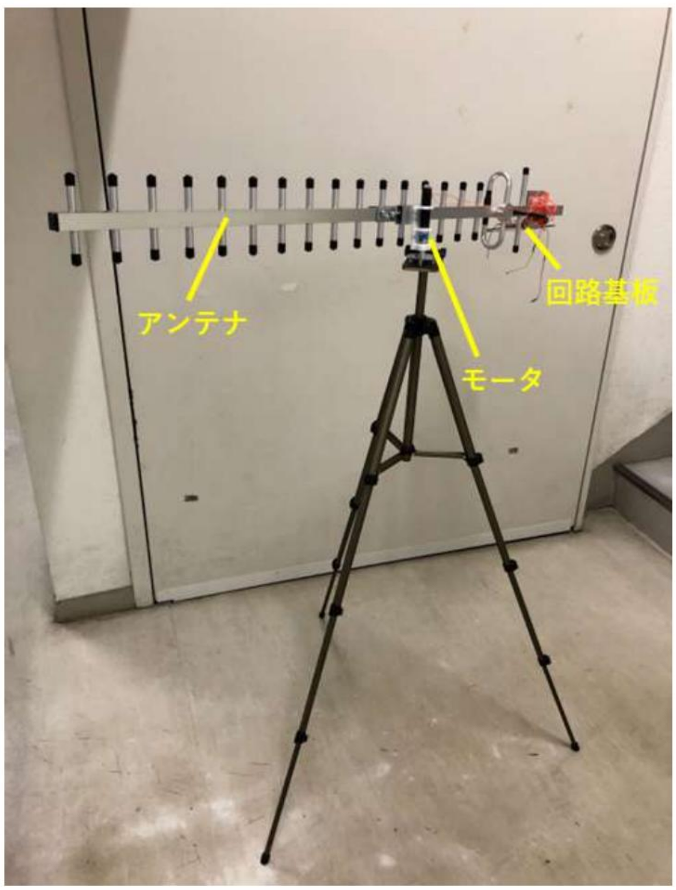

Figure 4.3.1 **Communication station There is a foundation at the base of the right side of the antenna in the image**

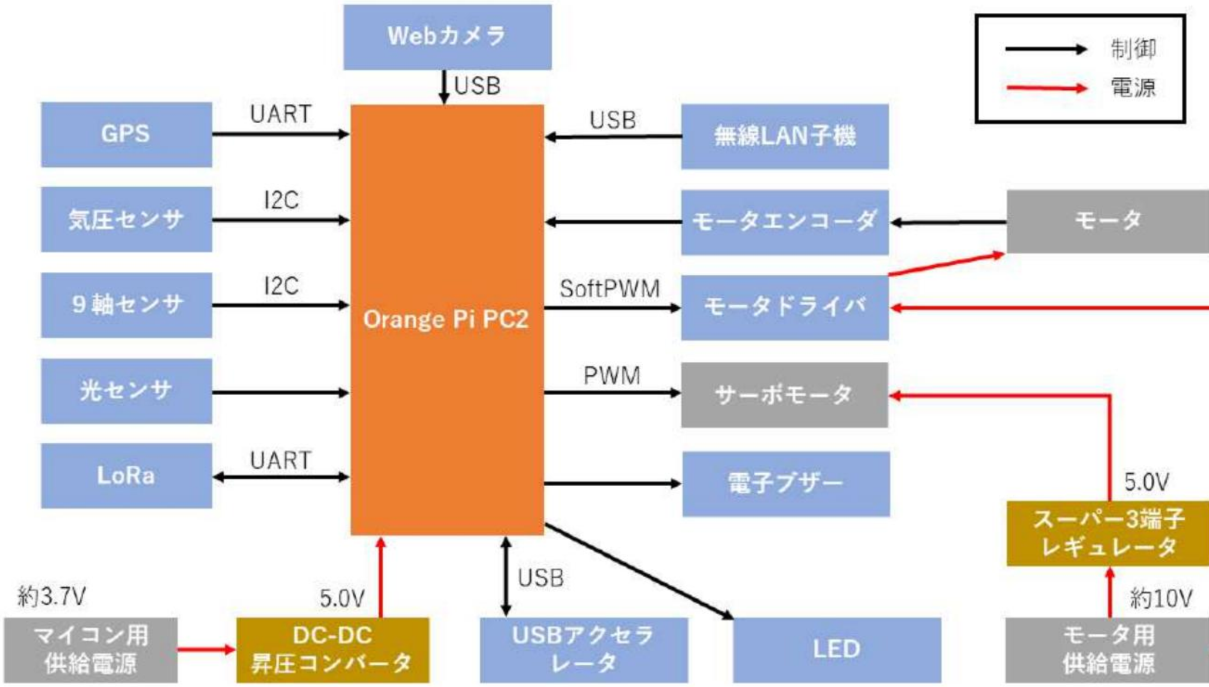

Figure 4.3.2 **CanSat system diagram**

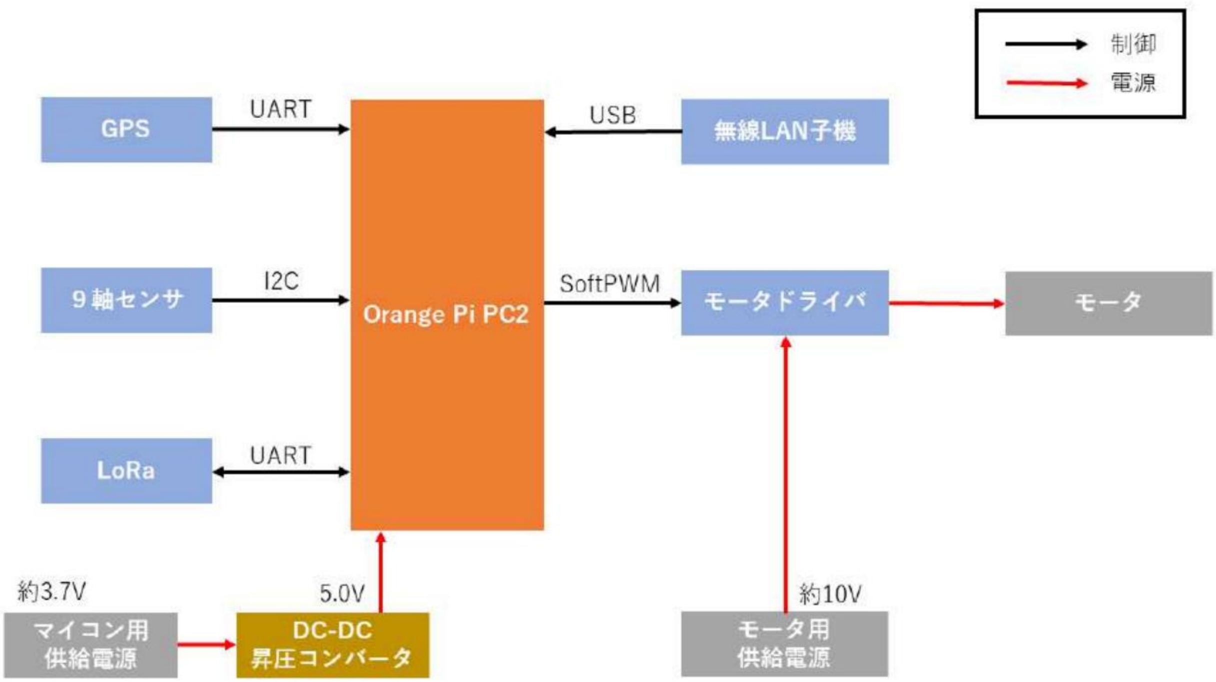

Figure 4.3.3 Communication station system diagram

Table 4.3.1 Mechanism specifications

Instrument name	Model number	Intended use	Source URL/reference information, etc.
Microcomputer	Orange Pi PC2 **input/output value calculation, and**		http://www.orangepi.org/html

		and record log data. record	/hardWare/computerAndMicr ocontrollers/details/Orange- Pi-PC-2.html
GPS module GYSFDMAXB	**Obtaining GPS coordinates**	http://akizukidenshi.com/cat	alog/g/gK-09991/
motor driver	DRV8835	**motor control**	http://akizukidenshi.com/cat alog/g/gK-09848/
motor	118699	**tire rotation**	https://www.maxongroup.co.j p/maxon/view/product/motor /dcmotor/re/re16/118699
motor encoder 201935		**Measuring tire rotation speed** fixed	https://www.maxongroup.co.j p/maxon/view/product/senso r/encoder/Magnetische-Enco der/ENCODERMR/ENCOD ER-MR-TYPM-32IMP-2-3KA NAL/201935
parachute servo bomota	MG90S	**detaching the parachute** death	https://akizukidenshi.com/cat alog/g/gM-13227/
Power supply for motor 12-2037		**Motor power supply**	https://www.energizer.com/b atteries/energizer-ultimate-lit hium-batteries
Power supply for microcomputer 5050100		**Microcomputer and sensor power supply to**	www.amazon.co.jp/dp/B09T 6F9V3K
DC-DC boost converter Ta	TPS61230	**Power supply for microcontroller** Increase the voltage to 5[V]	https://strawberry-linux.com/ catalog/items?code=16123
super three terminal rail regulator	**Supply voltage for** V7805-1000 motor	**The servo motor Step down to capacity voltage range do**	http://akizukidenshi.com/cat alog/g/gM-06350/
9 axis sensor	MPU9250	**acceleration, geomagnetism, Get gyro value**	https://www.amazon.co.jp/dp /B0154PM102/ref=cm_sw_e m_r_mt_dp_U_Mzp CbAD0 E5HF
atmospheric pressure sensor	BME280	**Landing judgment**	http://akizukidenshi.com/cat alog/g/gK-09421/
electronic buzzer	PB04-SE12HPR	**Is light detection in progress? Grasp of squid**	http://akizukidenshi.com/cat alog/g/gP-04497/
light sensor	**Emissions from** MI527/MI5527 carriers	judgement	http://akizukidenshi.com/cat alog/g/gI-00110/

LoRa communication module (CanSat)	RM-92A	**Distance estimation using radio field strength with communication stations, long-distance communication with ground stations as a measure against lost communication**	http://www.rflink.co.jp/index.html _
LoRa communication module (communication station)	RM-92C	**Distance estimation using radio wave strength**	http://www.rflink.co.jp/index.html _
Antenna for Lora	ANT-92XB	**Lora's communication reception**	https://www.greenhouse-stor e.jp/smp/item/451167711582 0.html
Web camera (front/rear)	C270n	**Goal cone detection, posture estimation using the horizon**	www.amazon.co.jp/dp/B07Q MKND9M
USB accelerator	INTEL-NCSM248 5DK	**Object detection calculation**	assistance https://www.switch-science.com/catalog/4104/

4.3.2 **Power supply used**

• **Dry battery (power supply for motor/servo motor) • Product name** ÿ

Energizer Ultimate Lithium AA Batteries • **Model number** ÿ 12-2037 • **Lithium ion polymer battery (power supply for microcontroller) • Product name** ÿ **Lithium ion polymer battery** 3.7[V]

4000[mAh] • **Model number** ÿ 5050100 • **Handling** ÿ **Store the battery in a special container to avoid damaging it.** ÿ **Do not store in places with high temperatures.** ÿ **Be sure to check that the battery is not swollen or disconnected before use.** ÿ **Use a battery with a protection circuit when charging, and keep an eye on it to avoid overcharging.** ÿ **When installing CanSat, install it in a space where it will not be directly exposed to external shocks.** ÿ **Also, make a protective sheet and attach it to the lithium ion polymer battery to prevent it from being hit by screws, etc. before installing it.**

4.4 **Sequence flow and various algorithms**

4.4.1 **Sequence flow**

The flowchart of the sequence is shown in Figure 4.4.1.

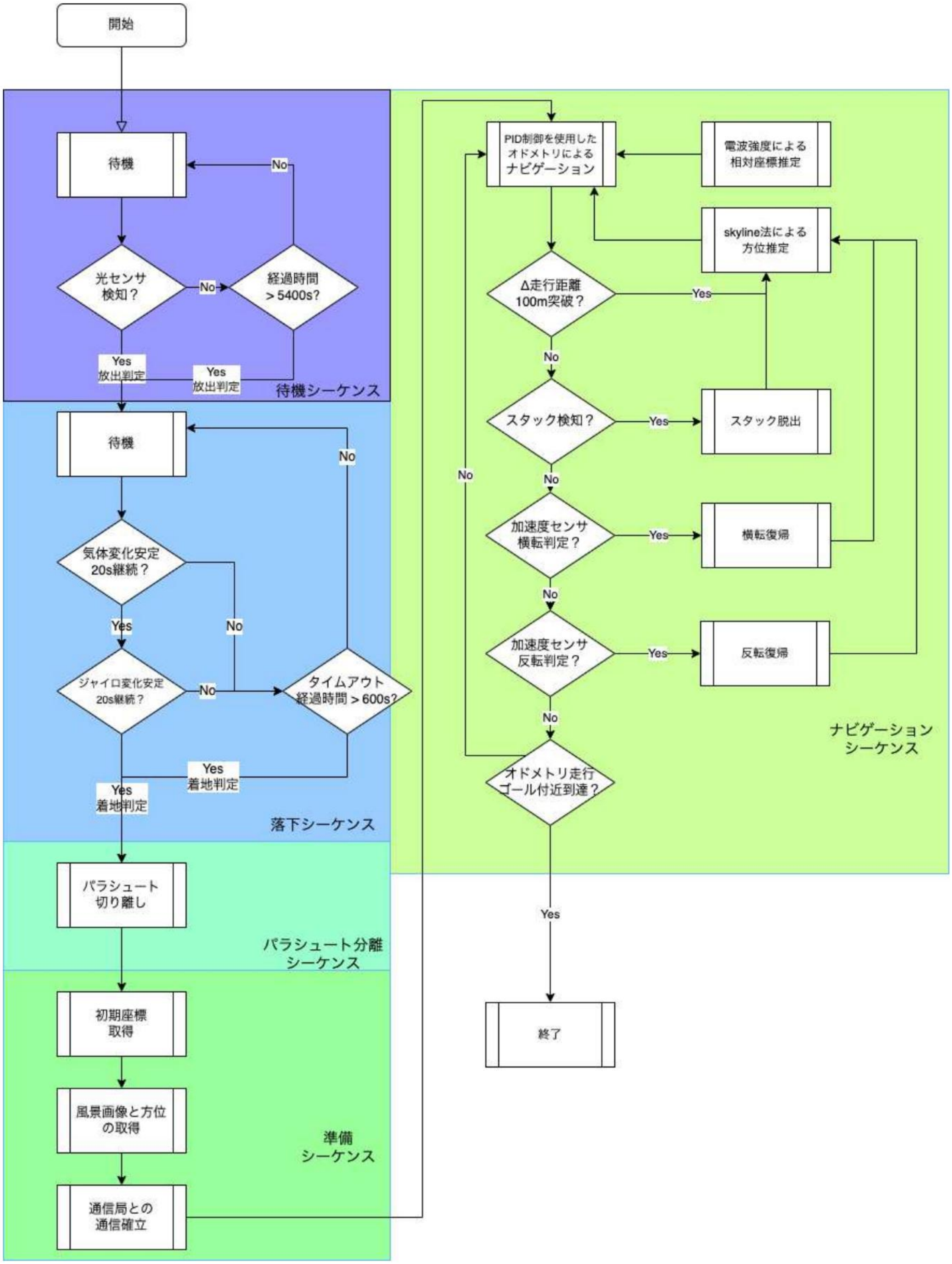

Figure 4.4.1 **Sequence flowchart**

The program used in this mission has the following five sequences. Details are shown below. Note that an appropriate timeout is set for each sequence, and even if the judgment conditions for sequence transition continue to fail due to unexpected accidents such as sensor failure, the sequence will transition to the next state.

1. **Standby sequence** 2. **Drop sequence** 3. **Parachute separation sequence** 4. **Preparation sequence**
5. **Navigation sequence**

1.Standby **sequence When**

the program starts, it moves to this sequence. During this state, CanSat assumes that it is waiting inside the carrier and determines whether it is being released from the carrier or not. The judgment is that if the optical sensor detects light for 10 seconds , the CanSat is released and the parachute is opened. After determining the release, the CanSat is determined to be released from the carrier and falling in the air, and the program moves to the next state, the falling sequence. Even if **the release is not determined ,** a timeout determination (*90 minutes after starting the standby state) **will result in a transition to the falling sequence. *Regarding timeout determination In the actual program, the rocket is installed on the rocket stand and then the program is started. Waiting for 90 minutes on a rocket platform is**

not possible unless something happens. If the weather is extremely bad, it is assumed that it will be difficult to launch the rocket, so we plan to move the rocket away from the rocket platform. Therefore, CanSat will not move within the carrier due to the activation of this timeout .

2. **Falling sequence In this**

sequence, we assume that the CanSat is released from the carrier and falling in the air, and determine whether it has landed on the ground or not. According to the following conditions, if the displacement of the values of the acceleration sensor and barometric pressure sensor is sufficiently small, it is determined that the object has landed.

• Condition 1: **The amount of change in the barometric pressure sensor value is below the threshold** • | **The amount of change in the barometric pressure sensor value** | < 6.0 [hPa] **continues for 10 seconds.**

• Condition 2: **The absolute value of the gyro sensor value is less than the threshold value**

• **Continue the following three conditions simultaneously for 10 seconds.** ÿ | **Gyro sensor x-axis value** | < 35.0 [deg/s] ÿ | **Gyro sensor y-axis value** | < 35.0 [deg/s] ÿ | **Gyro sensor z-axis value** | < 35.0 [deg/s]

After landing is determined, the process moves to the parachute detachment sequence. In addition, even if the landing judgment continues to fail, a timeout (10 minutes after the start of the falling state) will cause the parachute to release the sequence.

3. **Parachute separation sequence In this**

sequence, it is assumed that CanSat has landed, and the process of separating the parachute from CanSat is performed . The parachute is fixed to the stabilizer at the rear of the CanSat with pins, and is separated by the rotation of the motor and servo motor. If the detachment process is executed multiple times, it is assumed that the parachute detachment has been completed, and the system moves on to the next sequence.

4. **Preparation Sequence In**

this sequence, in order to run, (1) obtain initial coordinates, (2) obtain landscape images and direction, (3) confirm communication with the communication station. Performs the following processing.

(1) Initial coordinate

acquisition after parachute separation. Obtain the initial coordinates and orientation using the GPS sensor and geomagnetic sensor. This mission **assumes that a technology such as SLIM can be used to drop a bomb at a designated location, and that the initial coordinates of the drop point can be used . However, in ARLISS, it is difficult to specify the drop point because it is dropped by a rocket to a random location in the field, so this mission acquires the initial GPS coordinates of the drop point. The direction is also the same ,** and it is assumed that it is observable when it falls. **(2) Acquisition of**

landscape images and orientation

Generate an image set in which landscape images and orientations are linked to be used for orientation estimation using the skyline method described later. Landscape images are obtained by taking pictures of the surrounding area while circling the CanSat using cameras attached to the front and rear

of the CanSat. (3) Establishing

communication with the communication station At the same time, the communication station is manually brought and set up near the halfway point between the CanSat drop point and the virtual goal point. After installation, start the communication station program. Establish communication with CanSat.

5. **Navigation sequence This sequence**

uses wheel odometry navigation using PID control and wheel odometry navigation.

The CanSat can be navigated to near the goal through calibration that corrects the cumulative error caused by the collision. **Only wheel odometry**

is used for basic driving control. Wheel odometry is a technology that estimates the driving route and vehicle attitude based on the number of rotations of the CanSat's wheels, and the CanSat is navigated based on the values obtained through odometry . Stacking is determined by the amount of encoder pulse increase over

a certain period of time. If the number of pulse increases is small for a certain period of time, it is thought that the aircraft is stuck and the tires are unable to rotate properly and are spinning. In other words, when the increase in encoder pulses is clearly small, it can be determined that the encoder is stuck . In this mission, a stuck state is determined when the number of pulse increases within 20 seconds is less than 50,000. **Additionally, stack determination is performed once every two minutes. When it is estimated by odometry that the distance traveled has exceeded 100 [m] or that the vehicle is stuck, it is assumed that errors have accumulated and**

control by odometry has become difficult, and calibration is performed. Calibration involves (1) estimating relative coordinates by receiving radio waves from communication stations, and (2) estimating direction using the skyline method. **(1) Relative coordinate estimation by receiving radio waves from the communication station. In this process, the antenna orientation information sent from the communication station is used. Depending on the radio field strength, the signal to**

the communication station is

Estimate the relative coordinates of CanSat. Antenna angle information is sent from the communication station via LoRa. The communication station's **Yagi antenna** is directional, and even at the same distance, the radio field strength changes depending on the direction of CanSat as seen from the communication station's antenna.Also, due to the attenuation of electromagnetic waves, the radio field strength changes depending on the distance between the antenna and CanSat, even in the same direction. ÿÿ It travels for a certain period of time **and calculates relative coordinates from the received radio field strength and angle information of the communication station. When using these relative coordinates to correct wheel odometry, correction is performed using a Kalman filter. The Kalman filter calculates the reliability of the estimated value by wheel odometry and the reliability of the obtained relative coordinates using**

errors, and the higher the reliability, the

more these values are reflected. (2) Orientation estimation using the skyline method **In this process, a photograph of the landscape is taken with a camera, and the CanSat's orientation is estimated from that information.** By performing feature matching between the panoramic image created in **the preparation sequence** and the image taken during calibration processing, CanSat's orientation is estimated from the position of the matched feature in the image and replaced with the curren

4.4.2 **Various algorithms**

4.4.2.1 **Driving route/angle estimation algorithm using wheel odometry**

Wheel odometry is a method that estimates the current position by integrating the speed calculated from the amount of tire rotation. The formula for calculating wheel odometry is shown below. ÿ(t) is the direction CanSat is facing at time t, x(t), y(t) is the position of CanSat at time t (xy coordinates), v(t) is the moving speed of CanSat at time t, ÿ (t) **represents the angular velocity at time t. Using the fact that position is an integral of velocity, the change in CanSat's position can be calculated by definite integral** of the x component v * cos(ÿ) and the y component v * sin(ÿ) of the velocity over the elapsed time, **By adding this amount of change in position to the position at the previous time, the current position can be estimated.**

ÿ( ) = ÿ ÿ(ÿ) ÿ + ÿ($_0$)

$_0$

( ) = ÿ (ÿ) (ÿ(ÿ)) ÿ + ($_0$)

$_0$

( ) = ÿ (ÿ) (ÿ(ÿ)) ÿ + ($_0$)

$_0$

The angular velocity ÿ(t) and velocity v(t) **can be calculated using the following formula using the angular velocity ÿr of the right wheel and the angular velocity ÿl of the left wheel. R means the radius of the tire,**

and T means the distance between vehicles. ( ) = (ÿ ( ) + ÿ ( )) / 2

ÿ( ) = (ÿ ( ) ÿ ÿ ( )) /

In the actual system, the following approximate formula is used. CanSat also **estimates** its own position using the following approximate formula . **k represents time and ÿt represents the sampling period. In this mission, the sampling period is set to 0.01 .**

ÿ(+ 1) = ÿ( )ÿ + ÿ( ) (+ 1) = ( )
(ÿ( ))ÿ + ( ) (+ 1) = ( ) (ÿ( ))ÿ + ( )

4.4.2.2 **Relative coordinate estimation algorithm based on radio wave reception from communication station**

The communication station has directivity and transmits direction information once every 10 seconds while rotating. When **CanSat receives 60 pieces of azimuth information, it calculates the distance between the communication station and the rover using the azimuth information with the highest radio field strength and the value of that radio field strength, and calculates the relative coordinates from the communication station based on that distance. do.** When **radio waves are emitted uniformly in all directions from the antenna ,** the power density at a distance is determined by the surface area of a sphere with radius. **Therefore, the radio field strength can be expressed using the transmitted power and distance.**

$$= \frac{}{4ÿ \quad ^2}$$

If this is expressed using RSSI, which is a logarithmic value with the received power as a reference of 1 [mW], it is as follows. Become.

= 10 $_{Ten}$($\frac{2}{4ÿ}$)

= 10 $_{Ten}$($\frac{}{4ÿ}$) ÿ 10 $_{Ten}$(^{2})

In this case, if the distance from the communication station is 1_0 [m], it can be expressed as follows.

= ÿ10 0 Ten (2)

= 0 ÿ20 Ten ( )

From the above, the formula for calculating distance is as follows.

= 10 0

Here, is the damping constant.

4.4.2.3 **Orientation estimation algorithm using skyline method**

Landscape images prepared in advance (taken in the preparation sequence for this mission) and navigation By matching the landscape images taken during the sequence with features, you can determine which direction CanSat is facing at the travel point. Estimate whether the

1. **Create a matching image in advance by linking photos of the surrounding landscape with angle information at the time of shooting. Multiple sheets are generated until CanSat completes its rotation (see Figure 4.4.2).**

Figure 4.4.2: Matching image

2. **While driving, use the camera to take an image of the direction CanSat is facing (target image). shadow (see Figure 4.4.3). At this time, the camera should only be taken once to prevent image blurring. Do this after keeping CanSat stationary.**

Figure 4.4.3: Image taken while driving

3. **As shown in Figure 4.4.3, perform feature matching for each matching image and calculate the feature matching ratio using the following formula.**

$$\text{Feature matching rate} = \frac{\text{Number of feature}}{\text{matching Number of features of matching image}} \quad \text{(Formula 4.4.1)}$$

Using the angle with the highest feature matching ratio as the reference angle, we overlapped that image with the target image by feature matching, calculated the error pixel width (Figure 4.4.4), and multiplied the difference pixel count by 60/320 . The direction of CanSat is estimated by adding the angle at which the image was taken to the object (60 is the viewing angle of the camera being used and 320 **is the width of the image obtained by taking the image) . In addition, in**

this mission, in order to cope with changes in the scale of objects with features due to changes in the photographed location and changes in the field of view due to changes in the tilt of the vehicle body, AKAZE, which is robust against changes in scale, rotation, and translation, was used. Used for feature calculation.

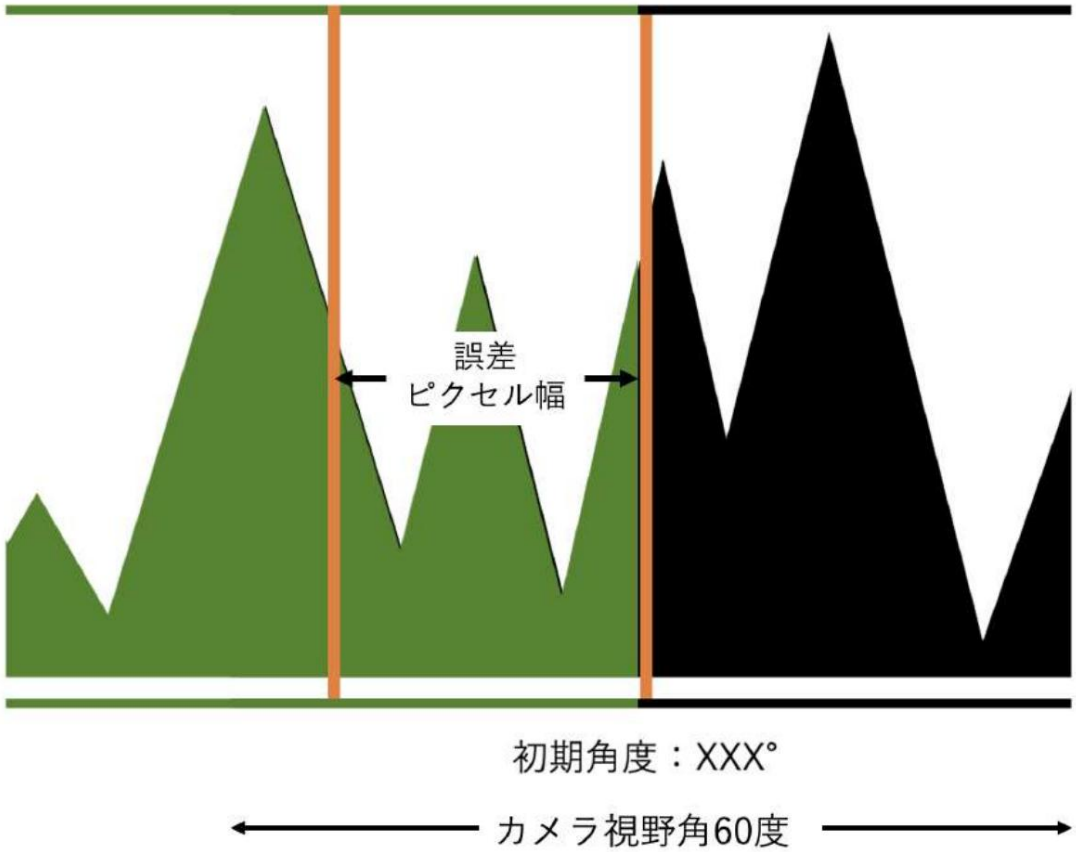

Figure 4.4.4: Obtain angle from image obtained by feature matching

4.4.2.4 **Correction algorithm using Kalman filter**

The Kalman filter uses the position estimated sequentially by wheel odometry and the radio wave strength of the communication station. Correct the estimated position based on the size of the error. The Kalman filter uses the following prediction speed. Adjust the estimate by repeating the steps and filtering steps.

1. **Prediction step**

The position of CanSat is determined **as follows using the amount of movement ÿ estimated by wheel odometry. It will be updated.** $\hat{}()$ **is the position of CanSat at** the time **.**

$$\hat{}( ) = \hat{}(ÿ 1) + ÿ$$

If the variance of the error in position estimation by wheel odometry is ÿ^2**, then the estimated position is**

The prior error covariance matrix is as follows. $( )$ (ÿ1) ÿ1 **is the posterior error at time is the covariance matrix.**

$$( ) = (ÿ 1) + ÿ^2$$

2. **Filtering step**

If **the variance of the error in** the position ( ) **estimated by the radio field strength of the communication station is ÿ, then the wheel** 2

The sum of the error in position estimation by odometry and the error in position estimation by the radio field strength of communication stations.
The error percentage of wheel odometry can be found as follows. Also, this The ratio of is called Kalman gain.

$$( ) = \frac{( )}{( )+ÿ^{2}}$$

Using Kalman gain, correct the estimated position as follows.

$$\hat{( )} = \hat{( )} + ( )(( ) ÿ \hat{( )})$$

The posterior error covariance matrix of the adjusted estimated position is as follows.

$$( ) = (ÿ ( )) \quad ( )$$

Chapter 5 **Test item settings**

number	**Verification item name**	**Corresponding self-examination items Request number(s)**	**Implementation date**
	ÿItems related to system requirementsÿ		
V1	**Mass test**	S1	6/25
V2	**Aircraft storage and release test**	S2	6/25
V3	**Quasi-static load test**	S3	7/3~7/5
V4	**Vibration test**	S4	7/29
V5	**Separation impact test**	S5	7/29
V6	**Opening impact test**	S5	7/3
V7	**drop test**	S6	6/23
V8	**Long distance communication test**	S7	7/10 ~ 7/14
V9	Communication device ON/OFF test	S8	6/25
V10	**Communication frequency change test**	S9	6/25
V11	End-to-end exam	S10	8/4 ~ 8/13
	ÿItems related to mission requirementsÿ		
V12	**Landing impact test**	M1	6/29

number	Verification item name	Corresponding self-examination items Request number(s)	Implementation date
V13	Tests related to running performance	M2	7/3 ~ 7/5
V14	Power durability test	M3	6/30 ~ 7/2
V15	Inversion/rollover/stuck return test	M4	7/1 ~ 7/4
V16	Communication establishment test	M5	7/1 ~ 7/4
V17	Route estimation test using odometry	M6	8/17~
V18	CanSat direction estimation test using skyline method experience	M7	8/2 ~ 8/4
V19	Relative coordinate calculation test using communication strength	M8	8/2 ~ 8/4
V20	navigation exam	M9	8/17~
V21	Self-location estimation evaluation report writing test	M10	8/4 ~ 8/5
V22	Control history report creation test	M10	8/4 ~ 8/5

Chapter 6 **Examination Contents**

v1. Mass test

- **Purpose**

  Ensure that the total mass of the CanSat and parachute stored in the carrier meets the regulations. confirm.
- **Test content**

  Measure the CanSat and parachute with a mass meter to confirm that the mass meets regulations. Ru.
- **Results**

  The total mass of the CanSat, parachute, and two hot bonds for adjusting the aircraft is stated in the regulations. We confirmed that it satisfies the requirement of 1050[g] or less.

  Experiment video: https://youtu.be/QlnYtzEcY4E

  Figure 6.1.1 shows the total mass. The mass was 956[g].

Figure 6.1.1 **Total weight of parachute, CanSat, and two hot bonds**

• **Discussion**

It was found that the total weight of CanSat, including the mass of the parachute, met the regulations.

v2. Aircraft storage and release test

• Purpose

The purpose is to confirm the following three points.

• Must meet the regulations for the base unit (inner diameter 146 [mm], height 240 [mm]) **• Must be able to be stored in the carrier and released smoothly** • The process to store the base unit is within 5 minutes be within

• **Test details**

CanSat is stored in a carrier that meets the regulations, and the carrier is gently shaken to confirm that the CanSat is being released . The storage procedure is as follows. (1) Fold the parachute (2) Gather the parachute strings so that they do not get tangled (3) Place the folded parachute on the side of the base unit (4) Store it in the carrier • Results Measurement results are shown in Table 6.2.1. From Figure 6.2.1 and Figure 6.2.2, the carrier used is regulated. **I was able to confirm that it was the same size as the version.**

Table 6.2.1 **Carrier size**

height	241 [mm]
width	147 [mm]

Figure 6.2.1 **Checking the carrier height**

Figure 6.2.2 **Checking the inner diameter of the carrier**

Table 6.2.1 **Results of carrier release experiment**

number of times	Experiment video	Storage time [m:s]	Release judgment
1	https://youtu.be/_yE3md4r-HM	0:48	was able to release
2	https://youtu.be/pEz2qU-dmCI	0:40	I was able to release it
3	https://youtu.be/nZ-jovHt5AM	0:36	I was able to release it

• **Consideration**

After storing CanSat in the carrier, it can be released by its own weight. In addition, the 5 minutes specified in the regulations It can be stored within

v3. Quasi-static load test

• **Purpose**

Due to the quasi-static load (hereinafter referred to as static load) during launch, CanSat's hardware and software Verify that there are no problems and that it is operating normally.

• **Test content**

CanSat, which is designed to be mounted on a rocket, can be placed in a bag connected to a string and rotated like a hammer thrower. Reproduce the static load caused by the ket. The static load is as stated in paragraph 5.2 of the Regulations.
Apply 10[G] to CanSat in the height direction of CanSat for 10 seconds. Then check that the hardware is not damaged.
Check that. In addition, each sequence operation from release judgment to parachute detachment operates normally. Check that there is no damage to the motor or servo motor. In addition, including this test, The sensor and motor outputs in subsequent impact system tests will be treated as normal if they meet the following criteria.

<Sensors>

•Atmospheric pressure sensor: Atmospheric pressure measured before the start of the experiment ±1 [hPa]•9-axis sensor: Regarding the norm of acceleration when the aircraft attitude is at rest, (sensor value measured before the experiment ± 5% allowable measurement error, and , The values of the x, y, and z axes change depending on the attitude of the aircraft.•Light sensor: It is determined that the light is hitting the sensor normally (the sensor value shows HIGH), and when the light sensor is covered with the hand, the light is hitting the sensor . Determine that there is no such thing (sensor value indicates LOW)

<Motors> •Servo motor: Can control the stabilizer in the vertical direction •Motor: Rotates to the extent that the aircraft can travel

The value of the 9-axis sensor confirmed before the experiment was approximately 0.70[G], so the 9-axis sensor is treated as normal between 0.65[G] and 0.75[G].

This test was conducted three times in total, and by acquiring time-series data of the magnitude of the acceleration applied to CanSat for each trial , we confirmed that a static load of 10 [G] was applied. In addition, the series of operations from the start of static load loading to confirmation of sequence operations is recorded on video.

• Results The

transition of acceleration obtained from the 9-axis sensor is shown in Figures 6.3.1 to 6.3.3. The horizontal axis shows time [s], and the vertical axis shows how many times the magnitude of acceleration (norm) is [G] compared to the gravitational acceleration of 9.8 [m/s 2]. From these graphs, it can be confirmed that a static load of approximately 10[G] is applied for more than 10 seconds by swinging CanSat.

First time

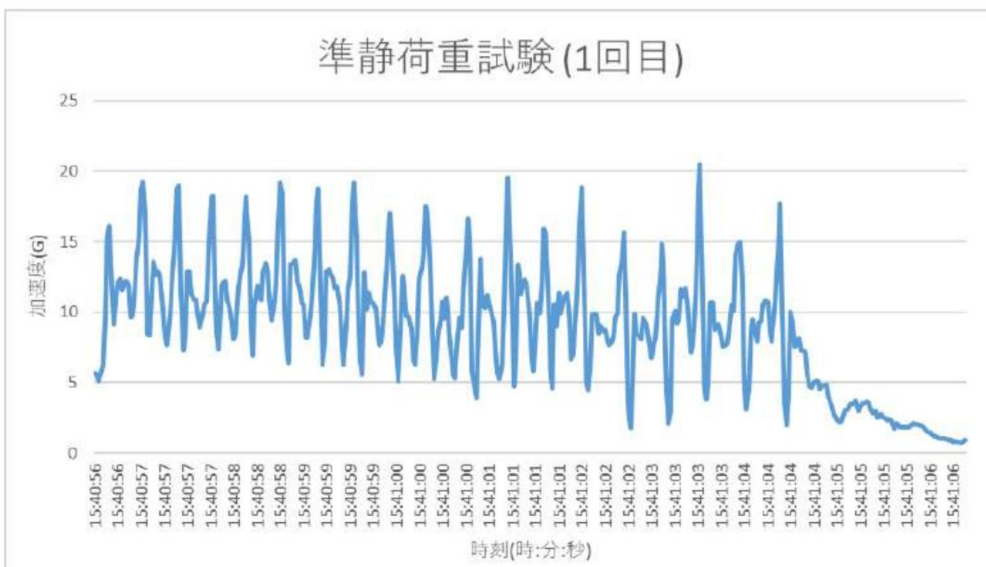

Figure 6.3.1 Acceleration graph for the first quasi-static load test

Second time

Figure 6.3.2 **Acceleration graph for the second quasi-static load test**

Third time

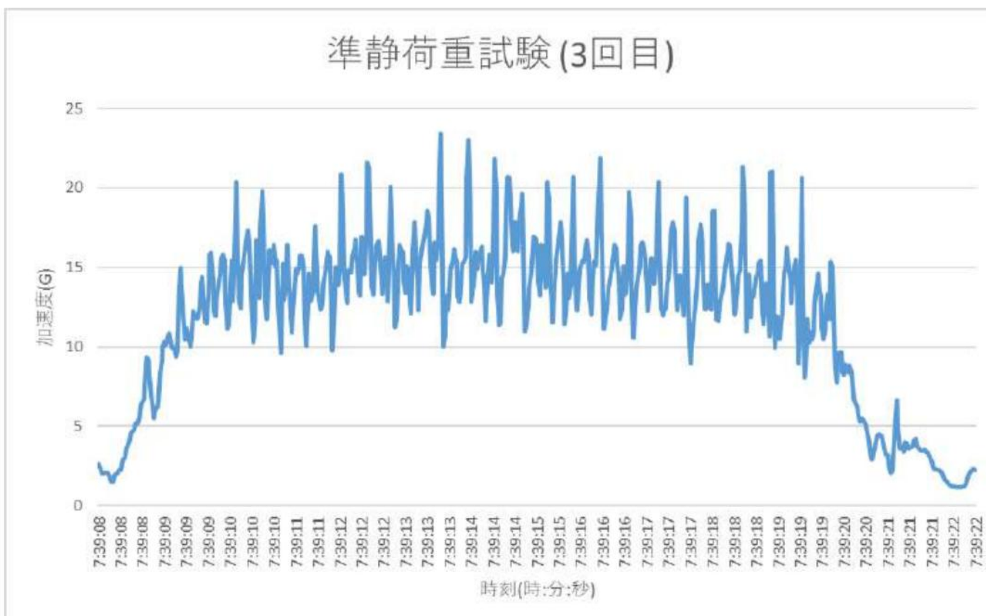

Figure 6.3.3 **Acceleration graph for the third quasi-static load test**

Table 6.3.1 shows the damage to the CanSat and the presence or absence of failure of each part after static loads were applied.

Table 6.3.1 **Static load test results**

trial times	CanSat external losses scratch	**Sensors**	**Motors**	YouTube link
First time	**no problem**	**normal**	**normal**	https://youtu.be/0Vb6RcYOYEw

Second time	no problem	normal	normal	https://youtu.be/06_k0Ed8C1I?lis t=PLJ_7eKAd4p nKYUDFwPLiK-SXNKAi_C70g
Third time	no problem	normal	normal	https://youtu.be/B0MiVJmrBxU

• **Discussion**

From the above results, it was confirmed that CanSat can withstand a static load of 10 [G] and operates normally without any problems in hardware or software caused by the shock during launch.

v4.Vibration test

• **Purpose :**

After applying a load equivalent to a rocket launch to CanSat using a vibration testing device, we will confirm that there is no damage to CanSat and that all sensors are operating correctly.

• **Test details**

CanSat is stored in a carrier, and a vibration testing device is used to apply random vibrations that occur when the rocket ascends . Type of Vibration According to item 1.4 of the ARLISS regulations, a sine wave vibration of 15[G] is required as **a regulation ,** so a random vibration of 15[G] that satisfies this requirement is added. **After the test, confirm that CanSat is working properly.** Also, when the aircraft was measured before the test, it was 1017[g]. (The video is shown below. https://youtu.be/VwCYzIHsm18

• **Results**

The following is a video of an experiment to determine whether CanSat operates normally after applying vibrations from the carrier storage using a vibration testing device . https://youtu.be/cG0bXUf85Uc

The times of each event in the video are shown below. 0:00 ~ **Carrier storage** 1:50 ~ **Preparation of vibration test equipment** 55:48 ~ **Random vibration start** ÿ 56:10 ~ **Random vibration start** ÿ 57:49 ~ **Random vibration start** ÿ 59:55 ~ **Shock vibration start** 62:30 ~ **Confirmation of program startup** 68:15 ~ **Carrier release**
68:42 ~ **Landing** 68:54 ~ **Parachute detachment (obtaining light, acceleration, gyro sensor values and barometric pressure sensor values)** 69:20 ~ **Acquisition of each sensor value, drive unit Confirmation** 72:15 ~ **CanSat confirmed that there is no damage**

Because it was difficult to continue applying large vibrations for a long period of time due to the equipment, the random vibration test was divided into three times: (1) 30 seconds, (2) 15 seconds, and (3) 15 seconds, for a total of 1 minute. Figure 6.4.1 shows the acceleration transition of the given random **vibration . The horizontal axis of the graph represents time [sec], and the vertical axis represents acceleration [G].** From **this** figure, it can be said that an impact of approximately 15[Grms]ÿ10[G] is applied to CanSat, which satisfies the **regulations .**

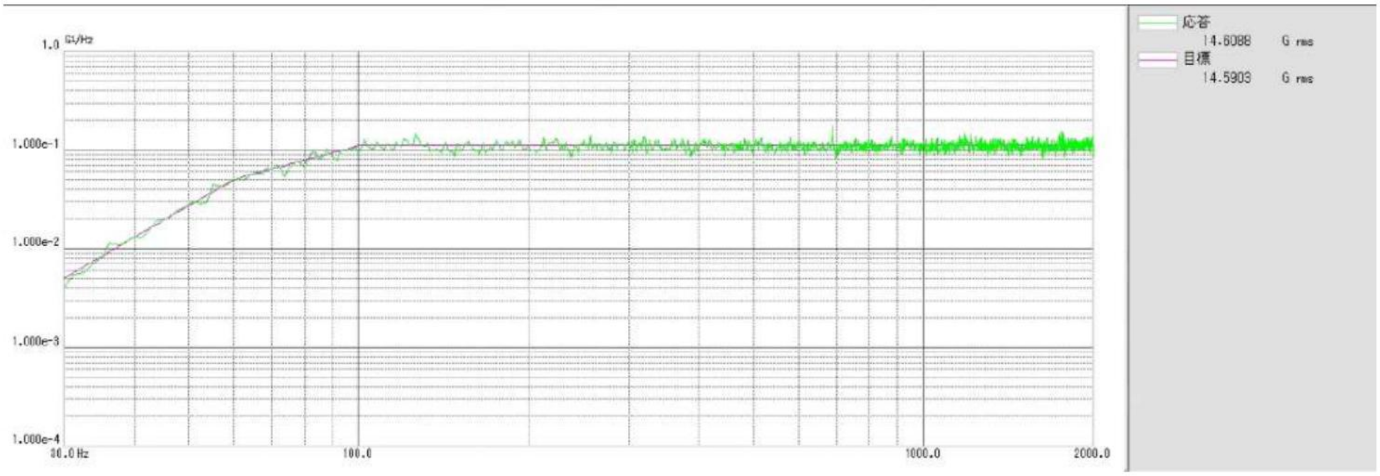

Figure 6.4.1 **Random vibration acceleration**

After applying random vibrations, we were able to obtain all sensor values (atmospheric pressure, acceleration, gyro, geomagnetism, light, and distance using GPS) correctly , and confirmed that the power system (motor and servo motor) was functioning without problems. ÿÿ

• **Discussion**

After applying a load equivalent to that during a rocket launch to CanSat using a vibration tester, we were able to confirm that there was no damage to CanSat and that each sensor was operating correctly. **However, it was discovered after the test that the screws were loose, so in the actual test, after tightening the screws, we fixed the nuts and screws with glue sticks to prevent them from loosening, thereby avoiding this problem.**

Regarding mass, when we measured the CanSat's weight again, it matched the mass test value. After that, we used it in the laboratory. When I replaced it with the dry cell battery (eneloop) I was using and measured it, it matched the vibration test value. In other words, the vibration test was conducted using a dry battery that was not intended to be used in the actual test, which caused the mass to differ from the mass test value. This is because the participants in the experiment overlooked this. Regarding this, we had conducted a vibration test with

a heavier mass than usual, but there were no problems with the aircraft's operation except for some screws coming loose (near the servo), so it can be said that the aircraft can withstand vibrations in real life.

v5. Separation impact test

• **Purpose**

After applying a shock equivalent to when a rocket separates to the CanSat using a vibration tester, **we confirm that there is no damage to the CanSat or its motors ,** and that all sensors are operating normally.

• **Test details** (V4) A

shock vibration of 40[G] is applied using the same vibration test equipment as in the vibration test. After the test, the sequence from exoskeleton escape to running will be performed to confirm that CanSat operates normally. The type of shock is **in accordance with item 1.4 of the ARLISS regulations, and shock vibration: [Target] 40[G] is applied (1[G]=9.8[m/s** 2]).

• **Results** The

experimental video for this test is the same as the (V4) vibration test. **The acceleration transition of shock vibration is shown in Figure 6.5.1 below. The horizontal axis of the graph represents time [sec], and the vertical axis [m/s** 2] **represents acceleration.**

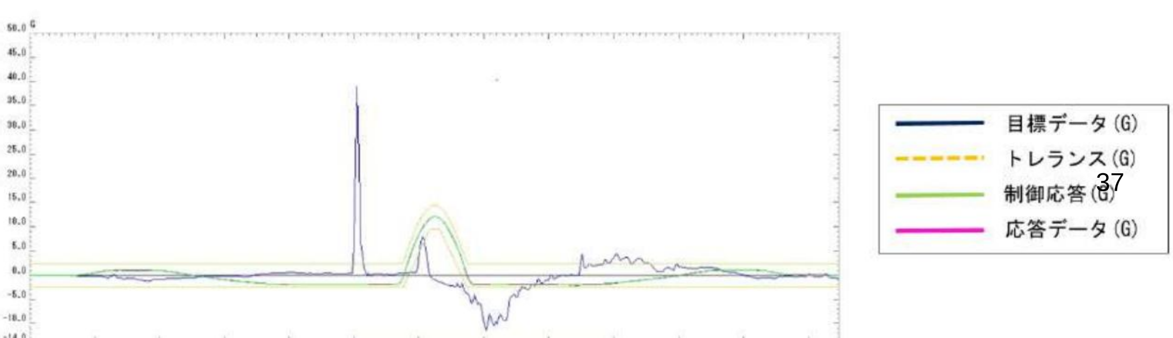

Figure 6.5.1 **Shock vibration acceleration**

After applying shock vibration, we confirmed whether CanSat operated normally. The results are the same as the (V4) vibration test, so they are omitted here.

• **Discussion**

After applying shock vibrations to CanSat equivalent to when a rocket separates using a vibration testing device, we were able to confirm that there was no damage to CanSat and that each sensor was operating correctly.

v6.Opening impact test

• **Purpose :**

To confirm that the joint between the CanSat body and the parachute can withstand the impact when the parachute is deployed.

• **Test details: Fix**

the CanSat, attach a parachute string, and let it fall freely. At this time, check the acceleration sensor log to see if it was able to withstand the impact (13 G) when the parachute was opened. After applying the impact, we carry out the sequence from parachute release to flight, check the operation of all sensors and power systems, and check for damage to the CanSat . The value of 13[G] **was set from the maximum acceleration observed at the time of opening from the past ARLISS logs . For each sensor, determine whether it is normal using the same criteria as (V3)**

quasi-static load test. Regarding **the nine-axis** sensor, the sensor value confirmed before the experiment was approximately 0.70[G], so it is treated as **normal** between 0.65[G] and 0.75[G].

• **Results As**

a result of conducting the experiment three times, there was no damage to the parachute joint or the CanSat itself in all cases. We **also confirmed that all sensors and power systems were operating normally.**

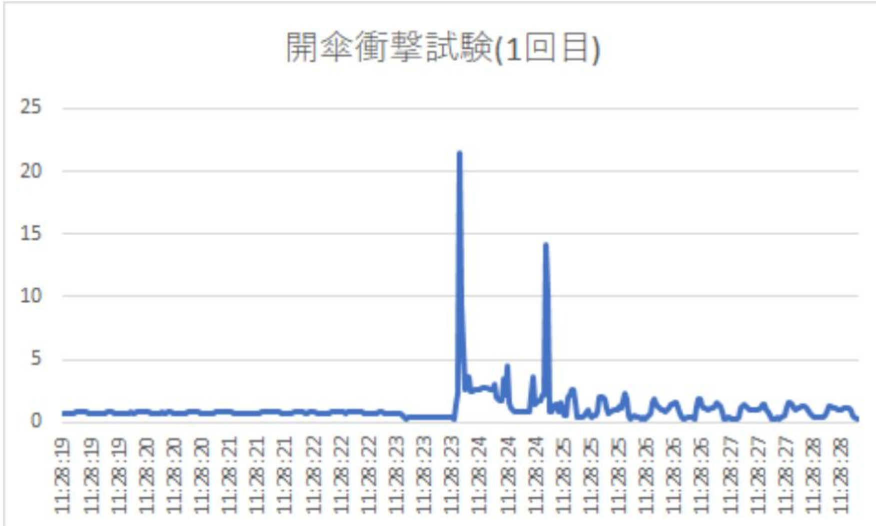

Figure 6.6.1 **Acceleration graph for the first opening impact test**

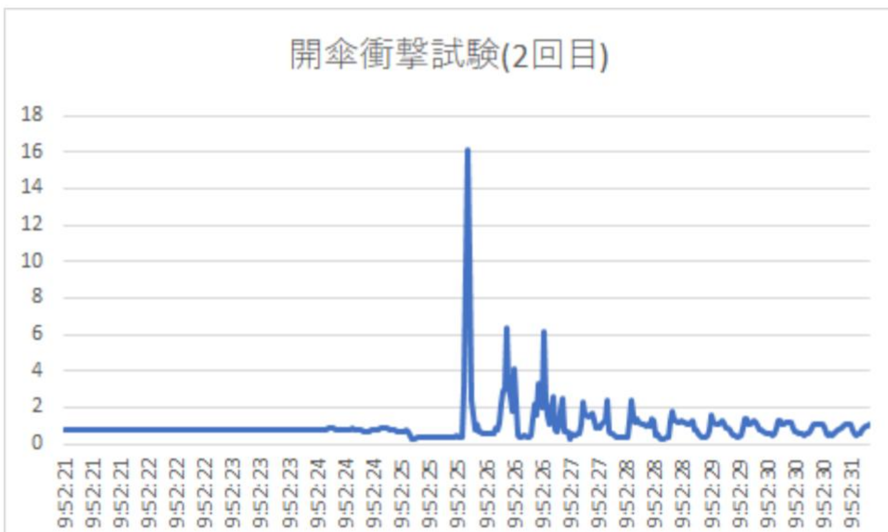

Figure 6.6.2 **Acceleration graph for the second opening impact test**

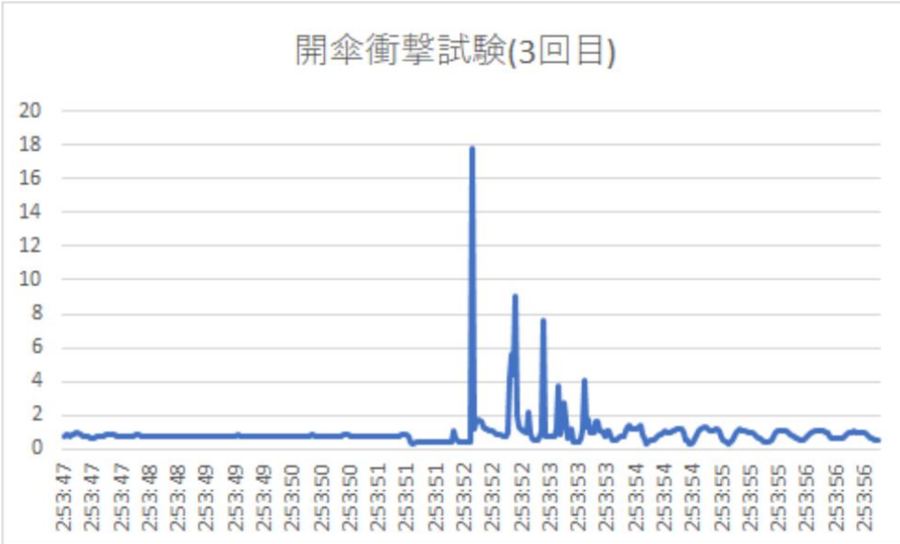

Figure 6.6.3 **Acceleration graph for the third opening impact test**

Table 6.6.1 **Opening impact test results**

Number of times	Experiment video	result
1st time	https://youtu.be/hdYXiIzHyxg **success**	
2nd time	https://youtu.be/owfPrjYMSuM **success**	
3rd time	https://youtu.be/bJZj0onxFgc **success**	

It was confirmed that CanSat and its parachute joints can withstand the impact of opening.

v7. Drop test

- **Purpose:**

To confirm whether the parachute, which is the deceleration mechanism, opens without problems and can decelerate when released from the carrier. Also, confirm that the minimum terminal speed is greater than or equal to the terminal speed 5 [m/s] stipulated in the regulations .

- **Test content** A

pseudo-simulator stored in a carrier from the 7th floor of West Building 6, University of Electro-Communications (approximately 25.2 m above the ground) **Release the CanSat and let it descend.** The pseudo-CanSat **was a mock-up shown in Figure 6.7.1, which has the same weight and size as the actual CanSat . The purpose of this test is to verify the performance of the parachute, so if the size and weight are the same, the purpose of the test will be met. The impact upon landing will be verified using the (V8) landing impact** test. **Verification of deceleration is performed by calculating the falling speed from the experimental video. This confirms that the speed during the fall is slower than the speed during**

free fall. As shown in Figure 6.7.2, the falling speed of the CanSat, which was released from the carrier with a parachute attached, was about 8.4 [m] from the ground (3rd floor of a building) as shown in Figure 6.7.2.) by measuring the time it **took** to land from the video. **The calculation is as follows.**

$$\ddot{y} = 8.4 [\ ]$$
$$= \frac{\ddot{y}}{} \ [\ /\ ]$$

Also, the speed during free fall can be calculated as 22.2 [m/s] from the following formula.

$$= 2\sqrt{\ddot{y}}$$

$$\ddot{y} = 25.2 [\ ], = 9.8 [\ / \ddot{y} = 22.2 [\ /\ ] \quad {}^{2}]$$

Figure 6.7.1 **Mockup used in the experiment**

Figure 6.7.2 **Height from the ground to the third floor**

• **Results**

The results of the drop test are shown in Table 6.7.1. Compared to the free fall speed of 23.1 [m/s], the average terminal velocity was 6.28 [m/s], which confirmed deceleration by the parachute. The minimum terminal speed was also 5.6 [m/s] , meeting the terminal speed specified by the regulations.

Table 6.7.1 **Drop test results**

number of times	Experiment video	result	Calculated terminal speed
1st	https://youtu.be/XP0Hc2 C7KyM	Successful opening	8.4 [m] / 1.2 [s] ÿ 7.0 [m/s] (video 21:9~23:1)
2nd time	https://youtu.be/8_ri1_x MMvQ	Successful opening	8.4 [m] / 1.5 [s] ÿ 5.6 [m/s] (video 23:7~25:2)
3rd time	https://youtu.be/T2SAC	Successful opening	8.4 [m] / 1.3 [s] ÿ 6.4 [m/s]

	AMupVA		(Video 6:6~7:9)
4th	https://youtu.be/Ugyxlm AmA3c	**Successful opening**	8.4 [m] / 1.3 [s] **ÿ** 6.4 [m/s] (video 7:4~8:7)
5th	https://youtu.be/Ax8B0Z eHHrY	**Successful opening**	8.4 [m] / 2.4 [s] **ÿ** 6.0 [m/s] (video 5:9~7:3)

• **Discussion**

The parachute, which is the deceleration mechanism, opened without any problems and decelerated, confirming that safety standards were met.

v8.Long distance communication test

• **Purpose**

In order to avoid losing the CanSat in the event that the drop point is lost when dropping the CanSat,
Confirm the distance from which headquarters can directly obtain CanSat's GPS data and the parachute's visibility distance.

• **Test/analysis content**

CanSat continues to periodically send GPS coordinates through the LoRa communication module. Note on it
Connect the LoRa communication module to your PC and confirm that you can receive GPS coordinates from CanSat. after that
, gradually move CanSat away from the PC and record the GPS coordinates of the point where communication was cut off. Then, calculate the maximum communication distance from the coordinates of these two points.

• **Results The**

communication distance with CanSat was approximately 2.52 [km]. The upper line in Figure 6.8.1 below shows the maximum distance over which CanSat could communicate.

Base station 35.642472ÿ139.523472
coordinates: Coordinates where communication was interrupted:
35.637738, 139.550878 **Communication distance:** 2.52 [km]

Figure 6.8.1 **Long-distance communication test (left: ground station, right: CanSat)**

• **Experiment video**

• https://youtu.be/G9D9NyjAdw0

- https://youtu.be/pLwEe4qO7ds

- **Conclusion**

The maximum communication distance using LoRa was about 2.5 km. With the above communication range, we judge that this CanSat is capable of long-distance communication that satisfies lost prevention measures. Every year, at ARLISS, we 1. look at CanSat through binoculars and head in its direction, and 2. near the drop point, we obtain GPS coordinates **from** LoRa mounted on CanSat and search around that location. **The p-parachute used this year is the same as the parachute used in 2018 ,** and **it can be confirmed from the 2018 MICHIBIKI review report that it has a visibility of at least 1 km. Considering that the ARLISS performance** uses binoculars (Vixen HR12*30) with a magnification of 8-12x, it is possible to see up to approximately 8km-12km away. **Even if you cannot see it with binoculars ,** the communication distance of LoRa in the sky is several tens of kilometers*. Even if the CanSat lands and is out of communication **range ,** as long as you can at least confirm its direction after the fall, **you can easily move within a 2.52 km radius where you can check the CanSat's GPS coordinates. Therefore, countermeasures against loss are sufficie**

* **Reference from** RFLink RM-92A/92C DATA SHEET p18

v9.Communication device ON/OFF test

- **Purpose:**

Confirm that Wi-Fi and LoRa power is turned off within the carrier so as not to adversely affect the rocket's communication equipment .

- **Test details** •

Wi-Fi

Turn on the Wi-Fi module connected to Orange Pi **installed in CanSat from your PC. Switch to Off. OrangePi is connected to the PC's hotspot via a Wi-Fi module . After the Wi-Fi communication status is turned off and disconnected, confirm that it is reconnected. First, change the Wi-Fi**

communication mode of the rover program. When you start the rover program and transition to the waiting sequence (Waiting), **confirm that the Wi-Fi communication status is switched off by no longer displaying the log on the terminal. Next, the CanSat is irradiated with light to make a release judgment, and the sequence shifts from Waiting. Then, the Wi-Fi communication status is switched to On ,** and **you can confirm that CanSat and the PC are communicating by checking that the sensor values and CanSat sequence status are displayed on the terminal.**

- LoRa

LoRa **can be put into sleep mode (radio wave output is 0) by controlling the GPIO pin of Prange Pi PC2 . Confirm that you can freely turn LoRa's sleep mode on and off by controlling the relevant GPIO pin .** First, enter a command in the

terminal to switch the LoRa communication status from On to Off.

Confirm **that the LoRa communication status is switched off by checking that LoRa on the ground station side can no longer receive the signal from CanSat .** Next, in the same way as Wi-Fi, LoRa on the ground station side **Confirm that the LoRa communication status switches to On by receiving the signal from CanSat .**

- **Result** •

Wi-Fi

A video of the experiment is shown below. During the Waiting sequence, I turned off the microcontroller's Wifi communication using the same procedure as in the actual production. I used the PC's mobile hotspot function to confirm whether it had actually been turned off . We also confirmed **that the Wifi communication function was automatically turned on after the Waiting sequence ended .**

https://youtu.be/do8bWBTCiOg

• The LoRa

experiment video is shown below. **In this situation, messages are being sent** from LoRa on the ground station side to LoRa on CanSat . After inputting **a command to put LoRa into sleep mode on the CanSat terminal ,** we confirmed that the ground station no longer received messages from the CanSat. https://youtu.be/OGfEANg3wy8

• **Consideration**

• Wi-Fi

You can switch the Wi-Fi communication status from On to Off without any problems, and then from Off to On after the sequence

transition . • LoRa

You can switch the LoRa communication status from On to Off without any problems, and then switch from Off to On after the sequence transition .

v10. **Communication frequency change test**

• **Purpose:**

To confirm that the communication frequency used can be changed if there is a possibility of interference between the communication frequency and other wireless communication.

• **Test content** Decide

on the initial communication frequency, and then use another communication frequency connected to CanSat's LoRa communication module and laptop. **Confirm that communication between LoRa communication modules (ground stations) is established. After that, start the setting mode of the LoRa module on the ground station side ,** change the communication frequency, and confirm that communication is no longer established. **Then, return the communication frequency on the ground station side to the original value and confirm that communication is re-established.**

• **Results The**

results of the LoRa frequency change test are shown in the video. We have **also compiled explanations for each of the Youtube videos of the exam .**

https://www.youtube.com/watch?v=fu6LeTxb3_8

• Explanation of YouTube videos of LoRa exams

0:00~ **Explanation of the**

test 0:45~ **Start communication software** 1:03~

Confirm sending and receiving messages ÿ Confirm

that communication is possible between channel numbers 54 (0x36)

1:21 ~ Change of frequency of LoRa on rover side **ÿ Change**

channel number from 54 (0x36) to 53 (0x35)

2:05~ **Confirm LoRa message transmission [after change] ÿ**

Confirm that communication is not possible

2:53 ~ Change the frequency of LoRa on the communication

station side **ÿ Change the channel number from 54 (0x36) to 53 (0x35)**

3:33 ~ **Check the frequency after change ÿ**

Confirm that communication is possible between channel numbers 53 (0x35)

• Consideration

We confirmed that the frequency can be changed using the LoRa communication module.

v11. End-to-end exam

• Purpose

Confirm that CanSat can perform the entire mission sequence as a continuous flow.

• Test content

CanSat meets the success criteria of this mission, and after releasing the carrier, landing judgment and parachute Confirm that you can disconnect and transition to navigation driving.

• Results

The experimental results are shown in the link below. The second video shows the running at the Noshiro Space Event.

• 1st time •

https://youtu.be/Er_3F1WoM4U (1st time) ÿ Carrier storage:

Success (0:00-1:06) ÿ Mass measurement:

Success (1:06-1:09) ÿ Ejection judgment:

Success (1:09-2:05) ÿ Landing judgment:

Success (2:05-2:27) ÿ Parachute detachment:

Success (2:27-2:48) ÿ Ready: Success (2:48-4:12) ÿ

Navigation: Failure (4:12-)

• Second time

• https://www.youtube.com/watch?v=-iozBmo0Cr8&list=PLJ_7eKAd4pnKY UDFwPLiK-SXNKAi_C70g ÿ Release

judgment: Success (1:17-1:21) ÿ Landing

judgment: Success (1:21-1:40) ÿ Parachute

separation: Success (1:40-1:55) ÿ Ready: Success (1:55)

~2:10) ÿ Navigation: Success (2:10~2:26)

Table 6.11.1 shows the achievement status of each success criterion. The success criteria are as follows.

(minimum success)

After landing, the parachute is detached and the state transitions to the state necessary for preparations for navigation.

(Middle Success)

Achieve the following three points. Achievement will be determined for each element. 1. Obtain a 360° image of the surroundings of CanSat to realize the skyline method. 2. **Establish communication with the communication station** 3. **Estimate its own position, and based on the results, CanSat moves toward the goal point. You can start.**

(Extra Success) 1. **Odometry orientation error can be corrected by skyline method**
2. **Odometry coordinate error can be corrected by radio wave intensity**

(Full Success)

Reach near the goal point with the accuracy derived from the relative coordinate calculation test using radio field strength conducted in advance (V18) .

Table 6.11.1 End-to-End test results (judgment of success criteria)

trial times	Success criteria classification			
	Minimum judgment	Middle judgment	Full judgment	Extra judgment
First time	•	1.• 2.• 3.×	1.× 2.×	×
Second time	•	1.• 2.• 3.•	1.× 2.×	•

• **Consideration**

After CanSat landed normally, it turned around while taking images of its surroundings, and then entered the navigation sequence after taking images, indicating that the preparation sequence itself operated normally and that minimum success was achieved. In the first attempt, the CanSat rover could not be controlled properly during the navigation sequence and repeatedly **turned** and moved on the spot , causing problems in parts related to motor control and camera. **If the motor is rotated, the servo is fixed, and the camera is photographed at the same time, processing delays may occur due to problems with the microcontroller's multi-thread processing ability. This kind of phenomenon has also been confirmed during other tests and verifications. In the video above, the minimum success was achieved, and the minimum safety of launch** was confirmed from this E2E, but in order to accomplish the mission, it is necessary to identify the cause of the runaway and modify the program. **be.** In the second time, we corrected that part and **succeeded in successfully navigating to the Noshiro Space Event ,** reaching a point 14m from the goal. **However, the venue of the Noshiro Space Event is very small, and if you can estimate it by odometry and face the goal to some extent, you will be able to enter within a 20m radius, which is full success.** Since it is necessary **to test E2E with a larger field and multiple calibrations by the day of launch ,** we plan to continue conducting experiments in the future.

v12. Landing impact test

• **Confirm**

that the CanSat is undamaged and can continue its mission even after the impact has been applied .

• **Test details In**

this test, the CanSat is subjected to a free fall from a height that reproduces the terminal velocity expected in the ARLISS production , thereby giving the CanSat a landing shock equivalent to that experienced in the local environment. The height ÿ of free fall is derived from the law of conservation of energy using the following formula, where the terminal velocity is v and the gravitational acceleration is g. However, g=9.81[m/s 2] .

$$ÿ = \frac{\;^2}{2}$$

If the expected terminal velocity v is 6.28 [m/s], which is the average value of the terminal velocity obtained in the (V7) drop test, the free fall height is 2.01 [m] from the following formula .

$$ÿ = \frac{(6.28)^2}{2\times 9.81} ÿ2.01[\ ]$$

Based on the above results, in this test, CanSat was dropped from a height of 2.1 [m] or more. Below is an image of the actual drop height. Drop it from the point where it is suspended from the string shown in Figure 6.12.1. In addition , Figure 6.12.2 shows a measuring tape being used next to the string in Figure 6.12.1, and it can be seen that the measuring tape is pointing at 2.1 [m].

Figure 6.12.1 **Measuring the drop position**

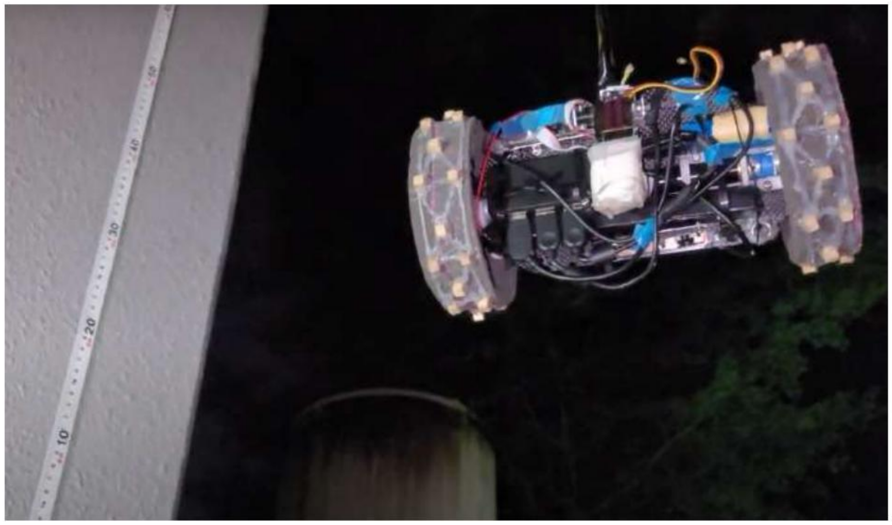

Figure 6.12.2 **Distance from the ground to the dropping position**

In addition, after the impact is applied, the sequence from parachute separation to travel is carried out, and all sensors and motion After checking the operation of the force system, check to see if there is any damage to the CanSat. **For each sensor, determine whether it is normal using the same criteria as (V3) quasi-static load test. Regarding the nine-axis sensor, the sensor value confirmed before the experiment was approximately 0.70[G], so it is treated as normal between 0.65[G] and 0.75[G].**

• Results The

results of the landing impact test are summarized in Table 6.12.1 below. After the fall, we checked the 9 axes, pressure sensor, light sensor , and GPS for the first time . From the second time onwards, in addition to the first time, LoRa communication and camera confirmation were also included in the sensor confirmation .

Table 6.12.1 Landing impact test results

Aircraft	**sensor**	**motor**	**Parachute separation**	Youtube link	**remarks**
The lithium ion battery for the microcomputer has protruded.	**normal**	**normal**	**normal**	https://youtu.be/mG yhwCw0Nko https://youtu.be/pqh 1T8883bk	**There are two videos because I stopped recording midway through.**
Normal	**Normal**	**Normal**	**Normal**	https://youtu.be/vPd 4-jP24tc	
Normal	**Normal**	**Normal**	**Normal**	https://youtu.be/LXfL MC6hCI4	**The patient landed with the parachute open, which may not satisfy the purpose of the test.**

					be

• **Consideration**

The above results confirmed that the aircraft, various sensors, and motors could withstand the impact upon landing. 1st time During the fall, the lithium-ion polymer battery for the microcontroller protruded from the aircraft, but this was due to the battery being fixed. This is thought to be because it was loose. After the second time, we will install a partition to prevent the battery from coming out of the aircraft. did.

v13.Tests **related to running performance**

• **Purpose**

Confirm whether CanSat has sufficient running performance to travel through the envisaged environment.

• **Test content**

Run CanSat under several environments and confirm that it can run without stopping midway.

• **Results**

The experimental results are shown in Table 6.13.1. In addition, images of each location are cut out from the video and shown in Figure 6.13.1 ~ Described in 6.13.4.

Table 6.13.1 **Driving performance test test video**

place	Experiment video	result
gravel	https://youtu.be/QWYhB0IPAJw	Can be covered
small step	https://youtu.be/DESN1oLyyHM	Can be covered
low grassland	https://youtu.be/HgySw9E9cSw	Can be covered
high grassland	https://youtu.be/xn__qKbK7BI	Can be covered

The diagrams **below show the details of each experiment.**

Figure 6.13.1 **Test on gravel**

Figure 6.13.2 **Testing on a small step (the image is dark) However, there is a level difference of about 5 cm)**

 Figure 6.13.2 **Test on low grassland**	 Figure 6.13.2 **Test in high grassland**

• **Consideration**

It was confirmed that CanSat has the ability to run in various environments.

v14.Power **durability test**

• **Purpose**

Confirm that the CanSat has enough batteries to complete the mission.

• **Test content**

Run CanSat on sandy ground until it becomes unable to run. The power supply installed in CanSat includes the microcontroller. Power supply to sensors (battery for microcomputer) and power supply to drive system (battery for motor) Use two batteries, fully charged before the test.

• **Results**

The test video is shown in Table 6.14.1, and the voltage of various batteries before the test starts and after the test is finished is shown in Table 6.14.2. Open Two hours and 23 minutes after the start, Orange Pie's power went out and it became unable to run. From the above results, The CanSat can run for 2 hours and 23 minutes on sandy soil.

Table 6.14.1 **Power durability test video**

CanSat running time	**Exam video**
Voltage measurement of motor/servo motor power supply (dry battery)	https://youtu.be/fOMJ1DkmCXs
Voltage measurement of circuit power supply (lithium ion battery) **Start running~**	https://youtu.be/4yRuf04vcbs
~30 minutes	https://youtu.be/szl0AkZSE4I
~1 hour	https://youtu.be/TjguQo137_s
~1 hour 30 minutes	https://youtu.be/1aKW4FTUZsQ
~2 hours	https://youtu.be/nzLOhKsXZVg
~2 hours 23 minutes **Voltage measurement of circuit power supply (lithium ion battery)**	https://youtu.be/ZTLEwc_F46k
Voltage measurement of motor/servo motor power supply (dry battery)	https://youtu.be/_FyJ6MowBRQ

Table 6.14.2 **Power durability test results**

	Power supply for circuit (lithium ion battery)	**Power supply for motor and servo motor (dry battery)**
Before the start of the exam	3.98[V]	10.53[V]
At the end of the exam	3.042[V]	9.25[V]

• **Discussion**

From the above results, it was found that it is possible to run for 2 hours and 23 minutes on sandy soil. ARLISS is equipped with a failsafe of 90 minutes + 10 minutes for wait and fall until the start of the mission (up to navigation), which is 100 minutes . **In other words, the "minimum" time that can be spent on a mission is 143 minutes - 100 minutes, which is approximately 40 minutes. In addition, preliminary experiments have shown that the maximum communication range of the communication station** is about 1 km, so the mission **is planned to be carried out within 1 km from the drop point. For the above reasons, if a vehicle can travel 1 kilometer within 40 minutes,** it can be considered that it has enough power to succeed in its mission. **The motor used this time is a motor that rotates 2.7 times per second. The radius of the tire is 23cm . Considering the resistance, the number of rotations per second should be 1000m** ÷ (40×60) ÷ (0.23×2×3.14) = **0.28 times /s . Videos of CanSat running during E2E tests and other tests confirm that the CanSat is producing higher rotational speeds, so it can be said that there is no problem with electric power.**

v15. **Inversion/overturn/stuck return test**

• **Purpose**

Confirm that CanSat can return to a drivable position if it flips or rolls over while running.

• **Test details •**

Reverse return

Execute the inversion return sequence program from the inverted state of the CanSat to return it to a position where it can run.

• **Rollover recovery**

After the CanSat is rolled over, the rollover recovery sequence program is executed to return it to a position where it can run.

• **Stack return**

When CanSat is not stuck, it runs normally, and when CanSat is stacked, it detects the stack and escapes from the stack.

• **Results The**

results of the inversion recovery test are shown in Table 6.15.1, and the results of the rollover recovery test are shown in Tables 6.15.2 and 6.15.3, respectively. show. The results of the stack recovery test are shown in Table 6.15.4.

Table 6.15.1 **Reversal return test results**

Number of times (location)	**Experiment video**	**result**
1st time (artificial grass)	https://youtu.be/mJPiC9bTSow **success**	
2nd time (artificial grass)	https://youtu.be/K2__TXZupWw **success**	
3rd time (sand)	https://youtu.be/fZ2pCySToWQ **success**	

4th time (sand)	https://youtu.be/R94J_qxwm7k **success**	
5th time (sand)	https://youtu.be/dTnfoC5vpsU **success**	

Table 6.15.2 **Rollover recovery test results (right tire)**

Number of times (location)	Experiment video	result
1st time (artificial grass)	https://youtu.be/v2IxxhaEODg **success**	
2nd time (artificial grass)	https://youtu.be/Ept9c8cKEk8 **success**	
3rd time (artificial grass)	https://youtu.be/tWjiwf1kHKU **success**	
4th time (sand)	https://youtu.be/_TA8mgdoPs0 **success**	
5th time (sand)	https://youtu.be/toRdMSea10I **success**	
6th time (sand)	https://youtu.be/IjiUAgPfhRo **success**	

Table 6.15.3 **Rollover recovery test results (left tire)**

Number of times (location)	Experiment video	result
1st time (artificial grass)	https://youtu.be/N731p9zK10s **success**	
2nd time (artificial grass)	https://youtu.be/r8KLCRdcBns **success**	
3rd time (artificial grass)	https://youtu.be/BjWM0IYG2Jg **success**	
4th time (sand)	https://youtu.be/eH1rCp89BYw **success**	
5th time (sand)	https://youtu.be/VWQxE9i134E **success**	
6th time (sand)	https://youtu.be/CZBpD5pPBAs **success**	

Table 6.15.4 **Stuck detection test results**

Number of times (location)	Experiment video	result
First time	https://youtu.be/UhdEidqUlUI **success**	
Second time	https://youtu.be/RUIWHw4B2Nw **success**	
Third time	https://youtu.be/7j79Zhi2gv8 **success**	

• **Consideration**

It is confirmed that the CanSat can return to a running position if it flips, rolls over, or gets stuck while running. I recognized it.

v16. **Communication establishment test**

- Check that
  the target base station's LoRa can communicate with CanSat's LoRa.

- **Test details** We
  confirmed whether we could transmit from LoRa on the base station side and receive from LoRa on the CanSat side.

- **Results**
  The experimental video is shown in
  the link below. https://youtu.be/zWCrzz4PUQ4

  The video confirmed that CanSat's LoRa was able to receive information sent from the base station.

- **The**
  discussion video shows that it is possible to perform LoRa communication correctly.

v17.Route **estimation test using odometry**

- **Purpose:**
  Verify whether the driving route can be estimated by wheel odometry.

- **Test details**
  Navigate to a set GPS coordinate using only route estimation using wheel odometry, and investigate how much error is produced by route estimation using only wheel odometry.

- **Result**
  Figure 7.17.1 shows the driving route based on odometry. The horizontal axis of the figure is the x coordinate in relative coordinates, and the vertical axis is the y coordinate in relative coordinates, each unit being m. The solid blue line is the route obtained by self-position estimation, the blue arrow is the direction obtained by self-position estimation, the orange dotted line is the route obtained by GPS, and the red arrow is the direction obtained by the 9-axis sensor. be. Also, the origin is the starting point and the star is the goal point.

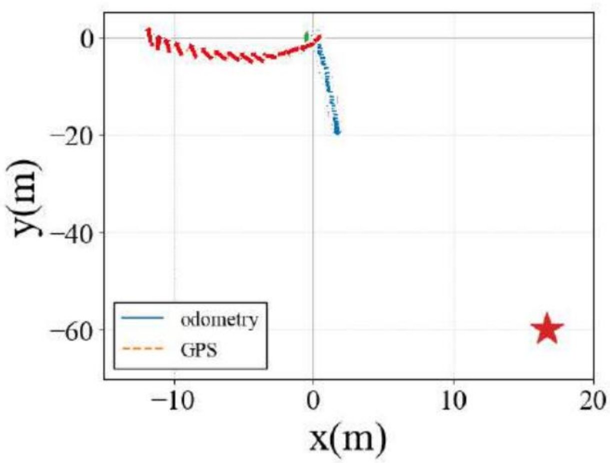

Figure 7.17.1 **Route estimation by odometry**

- **Consideration**

As you can see from the figure, the estimated heading by odometry has an error of about 90 degrees compared to the actual heading. I was born. Also, since the error in azimuth reaches about 90 degrees at about 5 to 10 m, it is difficult to calibrate. **It is considered that the appropriate running distance is 5 to 10 meters.**

v18. CanSat direction estimation test using skyline method

• **Purpose**

Check whether CanSat's own orientation can be estimated using the skyline method.

• **Test content**

First, CanSat is rotated and a matching image is taken by linking surrounding images and angle information. after that, The CanSat orientation is estimated by changing the CanSat orientation in various directions and applying the skyline method.

In addition, in order to simulate the production environment, **we obtained a 360° image of the blackrock desert from Google Earth and By dividing the image, we reproduce the landscape image that will be obtained in real life. Other images of blackrock obtained in the same way By applying the skyline method, we simulate the skyline in the desert.**

• **Results**

The results of the first test are shown in Table 6.18.1.

Table 6.18.1 **skyline verification test results**

number of times	Estimated angle	9-axis angle (actual angle)	absolute angle error
1st time	305.4°	203.1°	102.3°
2nd time	Matching failure		
3rd time	303.5°	213.9°	89.6°
4th time	299.7°	253.7°	46.0°
5th time	297.6°	275.5°	22.1°

Table 6.18.2 shows the results of the second test assuming a desert environment.

Table 6.18.2 **Skyline verification test results (desert environment)**

number of times	Estimated angle	actual angle	absolute angular error
1st time	60°	100°	40°
2nd time	90°	60°	30°
3rd time	45°	60°	15°

In addition, the target image and matching image used for estimation in the second test are shown in Table 6.18.3.

Table 6.18.3 **Target images and matching images used in desert environment reproduction**

Number of images	(log indicates target image and matching image. (From the left, the images are the original image, the preprocessed image, and the matching image used for estimation)

<table>
<tr><td>First time</td><td>
</td></tr>
<tr><td>Second time</td><td>
</td></tr>
<tr><td>Third time</td><td>
</td></tr>
</table>

- **Video**

1st time	https://youtu.be/1mOoOyO8zXc

- **Consideration**

It can be seen that the estimation error occurs between 20° and 100°. The angle of the 9 axes used is about 2.30° at most.
Due to the degree of error, the error during shooting + error during comparison may be approximately 40° to 60°.
So it should be allowed. For matching failures, when the inference result is calculated, it is
It is necessary to move to and then perform angle detection using skyline again.

Based on feedback from the review report, we also verified skyline in a desert environment. blackrock's image is amaa
Although we were not able to conduct many trials due to the lack of a
We found that it is possible to extract characteristic points and perform matching.

Regarding the estimation accuracy, as shown in Table 6.18.1, there are cases where the estimation error becomes large. Examination report
Even after the estimation error is generated, the estimation error should be reduced, or images that are expected to have too much estimation error (images with few features
Verify processing such as not using images) for calibration to improve the accuracy of orientation calibration.
We plan to increase it.

v19. Relative coordinate calculation test based on communication strength

• **Purpose**

According to the algorithm shown in 4.4.2.2, CanSat
Confirm that the relative coordinates of can be calculated.

• **Test content**

Place CanSat at a certain distance from the communication station and compare the relative coordinates obtained at that point with the actual coordinates.
Evaluate. We also conduct tests from various distances and compare the results. Communication with CanSat at the experiment starting position
The distance of the station is 30[m], this position is used as the reference, and the distance from this point is 30[m], 60[m], and 90[m].
We confirmed the relative coordinate results.

• **Results**

Video: https://youtu.be/tcBh15J5FEo

The calculation results of relative distance are shown in Table 6.19.1

Table 6.19.1 **Relative coordinate verification test results**

number of times	Relative distance 30m	Relative distance 60m	Relative distance 90m
1st time	72.9m	61.0m	74.1m
2nd time	66.6m	50.9m	84.6m
3rd time	55.5m	84.6m	81.5m
average	65.0m	65.5m	80.1m

• **Consideration**

The calculation results show that there is an error of about 10[m] to 40[m]. Is it the propagation characteristics of LoRa used this time?
It can be seen that it becomes stable when the distance is about 60 [m] or more. Considering this, the calculated relative distance is reasonable.
This is a reasonable result. The error for distances over 60[m] is 25~26[m], and the propagation characteristics of LoRa are
Considering that it becomes stable when the distance is about 60 [m] or more, we believe that it is possible to move closer to the goal.
It will be done. By installing a communication station outside the field at least 90 [m] away from the goal cone, the error can be reduced to less than 20 [m].
It was determined that this could be controlled within the limits.

v20.Navigation **exam**

- **Purpose:**

Verify whether it is possible to approach the goal by driving with navigation, using wheel odometry, relative coordinates based on communication strength, and direction estimation using the skyline method.

- **Test content**

Setting a certain GPS coordinate and navigating driving including calibration that proposes to that point I do. Then, test how far the driving result is from the set GPS point.

- **Results**

This test will be conducted after submitting the final review report.

- **Consideration**

v21.Self **-location estimation evaluation report writing test**

- **Purpose :**

Check the transition of the self-position that CanSat actually traveled during this mission and the transition of the self-position estimated by various algorithms, and create a report to check the degree of error.

- **Test content**

An E2E test was conducted, and the actual driving route and self-position estimation were obtained from the logs obtained. Compare driving routes and create a report to evaluate self-position estimation results.

- **Results In**

this test, we used the logs obtained from the drop at the Noshiro Space Event held on August 13, 2022. The self-location estimation evaluation report created from the log is shown in Figure 7.21.1. The horizontal axis of the figure is the x coordinate in relative coordinates, and the vertical axis is the y coordinate in relative coordinates. The unit of each is m. The solid blue line is the route obtained by self-position estimation, the blue arrow is the direction obtained by self-position estimation, the orange dotted line is the route obtained by GPS, and the red arrow is the direction obtained by the 9-axis sensor. be. Also, the square is the starting point and the star is the goal point.

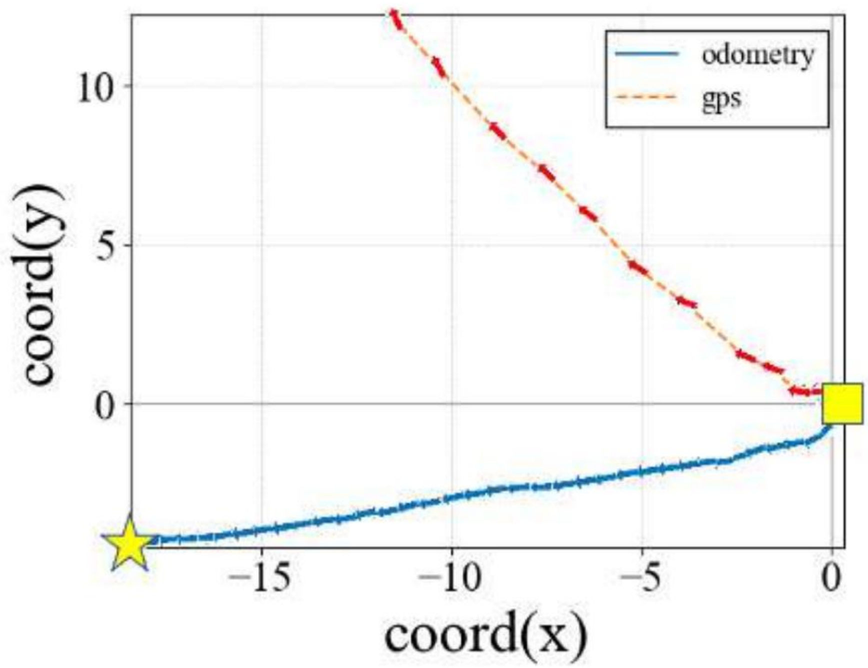

Figure 7.21.1 **Self-location estimation evaluation report**

•

Consideration It is possible to graph the route of self-position estimation on the spot from the log, and how much error occurs.
I found out that it is possible to evaluate whether the

v22.Control **history report creation test**

• **Purpose**

After the mission, create a control history report from the log data obtained in order to submit the specified control history report.

• **Test content**

A control history report for submission is actually created from the log data related to the control history obtained in the end-to-end test. Regarding the route map that includes the travel trajectory and control direction at each point, estimated values and actual measured values are available for this mission, so they will be described in the self-position estimation evaluation report.

• **Results**

The control history of CanSat is shown below. A sentence starting with **> means an input command, and no commands have been input after wait at the beginning of the control history. Explanations are in red.**

CanSat control history
[1m[07:00:19] [36mSequence: [32m'testing' [0m [5C[F

```
> wait (CanSat is in standby state)

= start waiting
Waiting Mode :light, 1
[1m[07:01:31] [36mSequence: [32m'waiting' (Executes release judgment process using light sensor)

[0mTime: 07:01:32
Light count: 0/10 (LOW)

Time: 07:01:33
Light count: 0/10 (LOW)

Time: 07:01:34
Light count: 0/10 (LOW)

Time: 07:01:35
Light count: 0/10 (LOW)

Time: 07:01:36
Light count: 0/10 (LOW)

Time: 07:01:37
Light count: 0/10 (LOW)

Time: 07:01:38
Light count: 0/10 (LOW)

Time: 07:01:39
Light count: 0/10 (LOW)

Time: 07:01:40
Light count: 0/10 (LOW)

Time: 07:01:41
Light count: 0/10 (LOW)

Time: 07:01:42
Light count: 0/10 (LOW)

Time: 07:01:43
Light count: 0/10 (LOW)

Time: 07:01:44
Light count: 0/10 (HIGH)

Time: 07:01:45
Light count: 2/10 (HIGH)
```

Time: 07:01:46
Light count: 3/10 (HIGH)

Time: 07:01:47
Light count: 4/10 (HIGH)

Time: 07:01:48
Light count: 5/10 (HIGH)

Time: 07:01:49
Light count: 6/10 (HIGH)

Time: 07:01:50
Light count: 7/10 (HIGH)

Time: 07:01:51
Light count: 8/10 (HIGH)

Time: 07:01:52
Light count: 9/10 (HIGH)

[1m[07:01:53] [36mSequence: [32m'falling' (Transition to falling state as release judgment was successful for 10 consecutive seconds)

[0m
(Hereafter, the process of determining landing using the gyro sensor is executed) (As you can see in the video, the landing determination using the gyro sensor keeps failing because the CanSat is shaken on purpose to simulate a fall.)

[0mstoi
Time: 07:01:54
Pressure count: 1/10 (1004.97 hPa)
Gyro count: 0/10
GPS position: 35.6403167, 139.5448950

[0mstoi
Time: 07:01:55
Pressure count: 2/10 (1005.009 hPa)
Gyro count: 0/10
GPS position: 35.6403167, 139.5448950

[0mstoi

```
Time: 07:01:56
Pressure count: 3/10 (1005.138 hPa)
Gyro count: 0/10
GPS position: 35.6403167, 139.5448950

[0mstoi
Time: 07:01:57
Pressure count: 4/10 (1004.916 hPa)
Gyro count: 0/10
GPS position: 35.6403167, 139.5448950

[0mstoi
Time: 07:01:58
Pressure count: 5/10 (1005.004 hPa)
Gyro count: 0/10
GPS position: 35.6403167, 139.5448950

[0mstoi
Time: 07:01:59
Pressure count: 6/10 (1005.004 hPa)
Gyro count: 0/10
GPS position: 35.6403167, 139.5448950

[0mstoi
Time: 07:02:00
Pressure count: 7/10 (1005.044 hPa)
Gyro count: 0/10
GPS position: 35.6403167, 139.5448950

[0mstoi
Time: 07:02:01
Pressure count: 8/10 (1005.044 hPa)
Gyro count: 0/10
GPS position: 35.6403167, 139.5448950

[0mstoi
```

Time: 07:02:03
Pressure count: 9/10 (1005.018 hPa)
Gyro count: 0/10
GPS position: 35.6403167, 139.5448950

[0mstoi
Time: 07:02:04
Pressure count: 10/10 (1005.014 hPa)
Gyro count: 0/10
GPS position: 35.6403167, 139.5448950

[0mstoi
Time: 07:02:05
Pressure count: 11/10 (1005.006 hPa)
Gyro count: 0/10
GPS position: 35.6403167, 139.5448950

[0mstoi
Time: 07:02:06
Pressure count: 12/10 (1004.978 hPa)
Gyro count: 0/10
GPS position: 35.6403167, 139.5448950

[0mstoi
Time: 07:02:07
Pressure count: 13/10 (1004.984 hPa)
Gyro count: 0/10
GPS position: 35.6406067, 139.5447833

[0mstoi
Time: 07:02:08
Pressure count: 14/10 (1005.037 hPa)
Gyro count: 0/10
GPS position: 35.6406183, 139.5447817

(Since CanSat was stationary at this point, the gyro sensor's landing judgment was successful from then on.)

continue)

[0 mstoi
Time: 0 7:0 2:0
9 P ressurecount: 1 5 / 1 0 (1 0 0 5.0 4 1 h P a)
G yrocount: 1 / 1 0
GPS position: 3 5.6 4 0 6 4 3 3 , 1 3 9.5 4 4 7 7 5 0

[0 mstoi
Time: 0 7:0 2:1
0 P ressurecount: 1 6/ 1 0 (1 0 0 4.9 8 2 h P a)
G yrocount: 2 / 1 0
GPS position: 3 5.6 4 0 6 3 8 3 , 1 3 9.5 4 4 8 0 8 3

[0 mstoi
Time: 0 7:0 2:1
1 P ressurecount: 1 7/ 1 0 (1 0 0 4.9 8 5 h P a)
G yrocount: 3 / 1 0
GPS position: 3 5.6 4 0 6 3 3 3 , 1 3 9.5 4 4 8 3 5 0

[0 mstoi
Time: 0 7:0 2:1
2 P ressurecount: 1 8/ 1 0 (1 0 0 5.0 1 8 h P a)
G yrocount: 4/ 1 0
GPS position: 3 5.6 4 0 6 3 6 7 , 1 3 9.5 4 4 8 3 8 3

[0 mstoi
Time: 0 7:0 2:1 3
P ressurecount: 1 9 / 1 0 (1 0 0 5.0 6 2 h P a)
G yrocount: 5 / 1 0
GPS position: 3 5.6 4 0 6 3 0 0 , 1 3 9.5 4 4 8 4 6 7

[0 mstoi
Time: 0 7:0 2:1
4 P ressurecount: 2 0 / 1 0 (1 0 0 5.0 3 1 h P a)
G yrocount: 6/ 1 0
GPS position: 3 5.6 4 0 6 0 8 3 , 1 3 9.5 4 4 8 6 1 7

[0mstoi
Time: 07:02:15
Pressure count: 21/10 (1004.991 hPa)
Gyro count: 7/10 GPS
position: 35.6406050, 139.5448717

[0mstoi
Time: 07:02:16
Pressure count: 22/10 (1005.019 hPa)
Gyro count: 8/10 GPS
position: 35.6405900, 139.5448983

[0mstoi
Time: 07:02:17
Pressure count: 23/10 (1005.076 hPa)
Gyro count: 9/10 GPS
position: 35.6405700, 139.5449317

[0mstoi
Falling completed! (by gyro and pressure)
[1m[07:02:18] [36mSequence: [32m'para_separating'(The gyro sensor's landing judgment was also successful for 10 consecutive seconds , so it transitioned to the separating state)

[0m

[0mstoi
Para separating... (1/10)

[0mstoi

[0mstoi
Para separating... (2/10)

[0mstoi
Para separating... (3/10)

```
[0mstoi

[0mstoi
Para separating... (4/10)

[0mstoi
Para separating... (5/10)

[0mstoi

[0mstoi
Para separating... (6/10)

[0mstoi
Para separating... (7/10)

[0mstoi
Para separating... (8/10)

[0mstoi

[0mstoi
Para separating... (9/10)

[0mstoi
Para separating... (10/10)
Para separating finished!
[1m[07:02:33] [36mSequence: [32m'para_separating' >
'waking' [0mWaking
finished! [1m[07:02:39] [36mSequence:
[32m'para_separating' [0mThis rover is
used
as PARENT rover! town [1m[07:02:39]
[36mSequence: [32m'ready' [0mreceived
data in carryber rover
Success! lora cmd push: 1
Success! lora cmd push:
2
```

```
[1m[07:02:39] [36mSequence: [32m'ready' > 'magnet_calibrating' (CanSat is calibrating the geomagnetic
 field )

[0mMagnetCalibrating: Turning right...
MagnetCalibrating: Turning left...
MagnetCalibrating: Turning stopped! min:
(-16.95, 53.4, -41.85) max:
(31.5, 103.95, -11.7)
Command:
nineaxis minmax -16.95 53.4 -41.85 31.5 103.95 -11.7
--------------------
filtered min: (-10.5, 56.4, -36.6)
filtered max: (26.4, 98.85, -15.15)
Command:
nineaxis minmax -10.5 56.4 -36.6 26.4 98.85 -15.15
MagnetCalibrating has been finished!
[1m[07:02:51] [36mSequence: [ 32m'ready' (CanSat is preparing for geomagnetic navigation, here Now,
we are acquiring the surrounding landscape image to use for skyline) [0mangle info : [0,
0, 0, 1, ] append img angle
info : [0, 0, 0,
1, ] append img angle
info : [1, 0, 0,
1, ] append img angle
info : [1, 0, 0,
1, ] append img angle
info : [1, 0, 0,
1, ] append img angle
info : [1, 0, 0,
1 , ] append img angle
info : [1, 0, 0,
1, ] append img angle
info : [1, 1, 0,
1, ] append img angle
info : [1, 1, 0,
1, ] append img angle
info : [1, 1, 1,
1, ] append img angle
info : [1, 1, 1,
1, ] append img angle
info : [1, 1, 1,
1, ] finish making
panorama write path : ./ log/
20220805_0702_panorama_0.png write path : ./log/
20220805_0702_panorama_1.png write path : ./log/
20220805_0702_panorama_2.png write path : ./log/
20220805_0702_panorama_3.png write path : ./log/
20220805_0702_panorama_4.png
```

```
write path : ./log/20220805_0702_panorama_5.png
write path : ./log/20220805_0702_panorama_6.png
write path : ./log/20220805_0702_panorama_7.png
write path : ./log/20220805_0702_panorama_8.png
write path : ./log/20220805_0702_panorama_9.png
write path : ./log/20220805_0702_panorama_10.png
write path : ./log/20220805_0702_panorama_11.png
finish aroundcapture, next skylne
popRecievedData()
This rover is used as PARENT rover!
[1m[07:03:34] [36mSequence: [32m'navigating'(CanSat starts navigating)

[0m

[0mstoi
Time: 07:03:35
target coord:(35.64060650,139.54393000)
target xy coord:(-26.88408787, 89.26174746)
Target Azimuth: 286.766
Current Azimuth(odometry): (0.008, 0.000)
Current Azimuth(nine axis): 321.826
Goal Distance: 93.225 m

[0mstoi
Time: 07:03:36
target coord:(35.64060650,139.54393000)
target xy coord:(-26.88408787, 89.26174746)
Target Azimuth: 286.864
Current Azimuth(odometry): (0.140, 0.113)
Current Azimuth(nine axis): 157.629
Goal Distance: 93.154 m

(snip)

[2K[0Gt
[1C[2K[0Gte
[2C

[0mstoi
Time: 07:04:20
```

```
target coord:(35.64060650,139.54393000)
target xy coord:(-26.88408787, 89.26174746)
Target Azimuth: 286.741
Current Azimuth(odometry): (-0.037, 0.006)
Current Azimuth(nine axis): 104.319
Goal Distance: 93.206 m

[2K[0Gtes
[3C[2K[0Gtest
[4C

[0mstoi
Time: 07:04:21
target coord:(35.64060650,139.54393000)
target xy coord:(-26.88408787, 89.26174746)
Target Azimuth: 286.851
Current Azimuth(odometry): (0.120, 0.109)
Current Azimuth(nine axis): 150.584
Goal Distance: 93.153 m
```

• **Consideration**

The logs obtained from the E2E test are used. Even if the mission itself fails, all logs are orange pie
This test confirmed that the control history can be created instantly.

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

• **Attach the URL of the Gantt chart spreadsheet below. This Gantt chart is**
also used as the Gantt chart for the Noshiro Space Event to be held in Noshiro, Akita in August. hodr_GanttChart.xlsx • **The**

milestones leading up to the
actual production are shown below.
• **Entire team (8/8 ARLISS main examination**
submitted) ÿ **Regular MTG:**
Every Thursday ÿ
Outline decision: 5/1 ÿ
BBM creation: 5/21 • **For**
technical verification ÿ EM creation: 6/1~6/23
• **To secure PM creation period & safety review verification**
ÿ **Communication establishment**
test: 6/25 ÿ PM creation:
6/26~7/10 • **About 3 weeks before submission of safety**
book examination documents ÿ **End-To-**
End test: 7/10~8/8 ÿ **FM creation ((including**
spare parts): 7/20~8/1 ÿ **Preparation of main**
examination documents : 8/1 ~ 8/17 • **Hardware**

ÿ **BBM aircraft creation: 5/10** ~ 5/21 ÿ
EM aircraft creation: 6/10 ~ 6/22 ÿ
Parachute drop test: 6/23 ÿ PM
aircraft creation: 6/26 ~ 7/10 **• The**
following Approximately 1 week to
create parts •
Chassis •
Tires • Motor holder
• Parachute mechanism
• Stabilizer • Axle
ÿ
Parachute drop test: 6/23 ÿ Mass
test: 6/25 ÿ **Aircraft**
storage/release test: 6/25 ÿ **Landing**
impact test :6/29 ÿ **Opening**
impact test: 7/3 ÿ Static
load test: 7/3~7/5 ÿ **Test on**
running performance: 7/3~7/5 ÿ **Vibration**
test: 7/29 ÿ **Isolation**
impact test: 7/29 • Circuit ÿ
Circuit
diagram design: 5/5~5/15 ÿ
Creation of BBM circuit: 5/20
ÿ **Final decision on required sensors:**
5/29 ÿ **Circuit order:**
6/1 • Design print board Order
later ÿ **Sensor**
implementation: 6/20 • Start as
soon as print board arrives ÿ **Print board**
debugging: 6/20~6/23 ÿ **Communication**
station side circuit creation
7/1 ~ 7/10 ÿ Circuit mass production:
7/15 ~ 8/10 ÿ
Power durability test: 7/15~7/21 **• Software** ÿ **Route**
calculation using wheel odometry:
5/20 ~ 6/4 ÿ **LoRa control implementation: 6/8**
~ 6/21 ÿ **Attitude estimation using skyline method: 7/1** ~
7/4 ÿ **Implementation of relative**
coordinate calculation based on
communication strength: 6/8 ~
6/21 ÿ **Implementation of sequence: 6/30~7/5** ÿ
Implementation of precision goal detection: 7/1~7/3 ÿ
Communication establishment test: 7/1 ~ 7/4 ÿ **Reversal/**
overturn recovery test 7/4 ~ 7/10 ÿ **Driving route**
calculation test using wheel
odometry: 7/15 ~ 8/4 ÿ CanSat direction
estimation test using skyline method: 7 /15 ~ 8/4 ÿ **Relative**
coordinate calculation test based on communication strength: 7/15 ~ 8/4 ÿ **Goal detection test; 7/15** ~ 8/4 ÿ **Control history r**

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

•If you do not want to participate in the comeback competition, please delete M3 and M4.

1.Safety standards review

要求番号	自己審査項目	自己審査結果	責任教員コメント（特筆すべき事項があれば）
	ARLISS2022安全基準		
	The mass of the aircraft dropping S1 **meets the standards**	ÿÿ	
	S2 **volume meets carrier standards**	ÿÿ	
	Tests have confirmed that the quasi-static loads during S3 **launch did not impair the functionality required to meet safety standards.**	ÿÿ	
	Tests have confirmed that the vibration loads during S4 launch did not impair the functionality required to meet safety standards.	ÿÿ	
	Tests have confirmed that the impact load when the S5 **rocket separates (when the parachute is deployed) does not impair its functionality to meet safety standards.**	ÿÿ	
	S6It **has a deceleration mechanism to prevent it from falling at dangerous speeds near the ground, and its performance has been confirmed through tests.**	ÿÿ	
	We have implemented countermeasures against S7 Lost, and their effectiveness has been confirmed through testing. (Examples **of measures: location information transmission, beacons, fluorescent color paint, etc.)**	ÿÿ	
	It has been confirmed that it is possible to comply with the regulations for turning off the power of radio equipment at the time of S8 launch (devices with FCC certification and 100mW or less are **No need to turn it off. Also, if you use a smartphone,** FCC certified and **can be turned off with a software or hardware switch)**	ÿÿ	
	I have confirmed that I am willing and able to adjust the S9 radio channel.	ÿÿ	
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.	ÿÿ	

1.Responsible teacher's impressions

Towards navigation without GPS, this year we are working on a rover that calibrates both its own position based on the radio field strength from installed antennas and its orientation based on matching landscape images. The experiment has almost been completed, and preparations are now in place to accomplish the mission.
The number of end-to-end tests is small, and the accuracy of position and orientation correction is insufficient, so I think it is necessary to take measures to address this issue. We will continue to provide guidance regarding this area, so we appreciate your consideration.

Chapter 9 **Competition Results Report** 9.1 **Purpose In order to**

verify the effectiveness of the developed CanSat, it was loaded onto a rocket and launched, and then the carrier release judgment and goal test were carried out. I participated in this project to verify whether it is possible to autonomously control the sequence of process determination and mission accomplishment.

9.2 **Results**

Table 9.2.1 Degree of achievement of success criteria

	minimum success	middle success	full success	extra success
First time	×	×	×	×

• **Acquired data** Figure 9.2.1 **shows the log of acceleration calculated from the values obtained from the 9-axis sensor from ascent by the rocket to after landing . The vertical axis represents acceleration (m/s^2), and the horizontal axis represents date and time. Also, the blue, orange, and gray lines indicate the acceleration in the x, y, and z axes, respectively .**

Figure 9.2.1: Change in acceleration

CanSat was found damaged. The state of Cansat at the landing point is shown in Figures 9.2.2 and 9.2.3.

Figure 9.2.2: Appearance of the aircraft after landing

Figure 9.2.3: Tire removed from the aircraft

9.3 **Discussion**

While the CanSat was falling, the parachute accidentally detached, resulting in a free fall. The cause of the free fall was that multiple control histories were being output, so one program that was activated multiple times moved to the running sequence , and the Waking sequence was repeatedly executed in response to the values of the 9 axes in the air. **It's possible .**

CanSat control history 1
[1m[17:47:11] [36mSequence: [32m'testing' [0mcontinue sequence is :waiting Waiting Mode :light [1m[17:47:11] [36mSequence: [32m'waiting' [0mTime: 17:47:12

CanSat control history 2

```
[1m[17:47:10] [36mSequence:
[32m'testing' [0mcontinue
sequence is :falling [1m[17:47:10]
[36mSequence: [32m'falling' [0mTime: 17:47:11
```

Chapter 10 **Summary**

10. 1 **Points of improvement/ effort [Points of improvement]**

- **Hardware • In order to rotate the transmitting station antenna horizontally, we connected it to the antenna fixing base by considering the center of gravity of the antenna.**
- **In order to deploy the receiving station antenna smoothly, there is an antenna deployment device inside the tire. I installed the guide.**

• Circuit •

By separating the positions of the motor and Raspberry Pi power supply, we created a structure that prevents human errors caused by incorrect pointing. • By sharing Cansat and communication station infrastructure, it can be used as a backup in case either one breaks dow It can be used immediately.

• Software •

Because orangepi has a limit in PWM control, we devised a way to prevent multiple startups at once. Ta.

[Points I struggled with] •

Hardware • I had a hard time fixing the transmitting station antenna to the antenna stand. • Make sure that the battery box, USB accelerator, USB hub, and each connection cable do not interfere. **I had a hard time arranging it.**

• Circuit • I didn't know the specifications of the orange pi **pc2, so some parts didn't work as usual, so I It was necessary to check that each pin moved properly.**

• Software •

The orange pi **pc2 was quite difficult to use. It was completely useless as a CANSAT microcontroller because it could not output the set pulse waves, ran out of control due to heat, and could not withstand heavy processing.**

10. 2 **Issues •**

Hardware • The aircraft design and parts placement should have been carefully determined in advance. •

Circuit •

Since we were having problems with the circuit until just before the actual production, it took away time from debugging the software. Oops.

• While we were able to proceed with the **software implementation smoothly, we were unable to proceed with the experiments that were to be conducted after implementation in a planned manner, resulting in schedule delays. • It was almost impossible to verify the accuracy of the algorithm. Most of the time during the development period I ended up debugging something unrelated to the application.**

10. 3 **Conclusion**

This team proposed CanSat, which performs self-position estimation without relying on GPS or geomagnetic information. We aimed to enable exploration in unknown planetary environments by establishing a method for realizing navigation control to an arbitrary destination point using relative coordinates and relative angles from the initial position . Unfortunately, we were not able to accomplish our mission, but through this participation, **we were able to understand the issues with the developed Cansat . The issues will be shared with the entire team and will be utilized in future Cansat development.**