ARLISS2022 **Tournament Report**

Submission date: November 21, 2022

• **Team information**

CanSat team name	**University of Electro-Communications Takatama Laboratory** Dolphins
CanSat team representative information	**Keisuke Toita** kawawa792526@gmail.com, 070-6962-3654
UNISEC organization name	**University of Electro-Communications Takadama Laboratory**
UNISEC organization student representative	**Tomoya Kuga** t_kuga@cas.lab.uec.ac.jp, 090-1268-2024
Responsible teacher	Keiki **Takada** keiki@inf.uec.ac.jp, 042-443-5808
CanSat class	Open class

• Members

役割	名前(学年, 経験年数)
リーダー 兼 回路班*	Keisuke Toita (M1, 2nd year of experience)
ソフト班*	Naoya Matsuda (M2, 3rd year of experience)
ソフト班	Ryuki Ishizawa (B4, 1st year experience)
ソフト班	Amika Hara (B2, 2nd year of experience)
ソフト班	Ken Horikoshi (B2, 2nd year of experience)
ソフト班	Yoshi Nakamori (M1, 2nd year of experience)
回路班	Tomoya Kuga (M1, 1st year of experience)
ハード班*	Shun Kato (M2, 2nd year of experience)
ハード班	Rinnori Sakagami (B4, 1st year of experience)
ハード班	Chika Tomizawa (B1, 1st year of experience)

• CanSat production purpose/reason for participation in the competition

Our organization aims to improve cooperation through team development and acquire the technical skills necessary for development.

, and CanSat development and participation in competitions for the purpose of improving CanSat technology in laboratories.

We are implementing additional measures.

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Chapter 1 **Mission Statement**

The mission statement is shown below. (Due to the nature of the mission, "CanSat" is referred to as "master machine" and "slave machine"). It is written as)

The contents of the mission are explained below.

Proposal of a method for a parent device to safely explore large unexplored areas using a group of child devices

Currently, planetary exploration, especially exploration of the earth's surface, is basically carried out by a single aircraft. However, exploration with a single aircraft is inefficient, and there are problems such as mission failures due to overlooking safer routes. From this perspective, we **(1) collected data*2 to evaluate the route and the safety of each point while exploring the area *1 specified by the base unit using multiple slave units, and (2) collected data*2 to evaluate the safety of the route and each point.** By **repeating the two phases of deriving a safe search route*3 from this data** and actually driving along that route, the master unit can safely explore a wide unexplored area using a group of slave units. **The aim is to realize a method to do this. To achieve this objective, we established mutual communication technology between multiple aircraft and technology for deriving the best route*4 from safety evaluation data collected by searching each child machine, and we hope that it will work effectively** in ARLISS. **Demonstrate.**

***1 The designated area (hereinafter referred to as designated area) is the area that the parent unit requests the slave unit to search, which is generated from the direction the base unit wishes to search and the distance within which the base unit and slave units can communicate. (For details, see the algorithm in Chapter 4, Section 4) *2 Calculated from the acceleration of the slave unit and GNNS coordinates. (For details, see the algorithm in Chapter 4, Section 4) *3 A safe search route is a route that avoids obstacles that could cause the aircraft to hit, flip, or roll over, and that can be traveled with relatively little vibration. (For details, see the algorithm in Chapter 4, Section 4.) *4 The best route here is one that is calculated from the safety evaluation data collected by searching each child device, and is one that is difficult for the parent device to roll over, flip over, or get stuck, and that This is a r**

Figure 1 shows an overview of the mission flow. Only the base unit is dropped, and each operation is performed as a sequence: waiting, dropping after release, separating the parachute, and navigation including search. When the mission was first conceived, it was planned to drop both a master unit and a slave unit, but in order to efficiently and sufficiently explore the designated area, a large number of slave units would be required, so In order to respond flexibly to this situation, we judged that it would be appropriate to drop the child unit at a different time from the parent unit, so we decided to drop only the parent unit this time. As a result, we decided to install the slave units around the base unit after it lands. After that, 1) the handsets gather under the base unit from the navigation , 2) each slave unit searches the area/route specified by the base unit, and 3) **the safety evaluation collected by the slave unit while driving is performed. Transfer the data for the comeback mission to the base unit, derive the best route on the base unit, 4) drive the derived** route, and 5) repeat these steps to aim for the goal for the comeback mission as a temporary search target. **The specific operation of the sequence is as follows.**

I. **[Standby sequence]: The base unit is stored in the carrier and remains in standby mode until it is released into the sky. After being released from the carrier, the base unit uses an optical sensor to determine release. After release, the parachute opens.**

II. **[Falling sequence]: Uses 9-axis sensor and barometric pressure sensor to determine whether the main unit is descending or has landed Start judgment.**

III. **[Parachute separation sequence]: After landing is determined, the base unit starts the action of separating the parachute. The parachute is separated by moving the servo motor multiple times (see** Chapter 3 for the parachute separation mechanism).

IV. **[Navigation Sequence]: Obtain the GNSS point information of a preset goal point and find the best route that is estimated to allow the base unit to travel safely toward that** point using the following steps.

1. **Place the child device near the parent device*5.**

2. **Wait until communication is established between the slave unit and the base unit.** 3.The **child devices gather under the parent device. (This is the initial placement guidance for the slave unit. For the specific placement relationship,** refer to the algorithm in section 4.4.) 4. **Search the rectangular area in front of the base unit specified in the direction in which the base unit wants to move using multiple slave units. The system collects safety evaluation data such as coordinates while driving, acceleration norms, and stuck judgment history . (This is a slave unit search command.)** 5. **The slave unit sends the collected safety evaluation data to the base unit, and the base unit derives the best route . (The best route is derived.)** 6. **Drive the base unit along the derived best route. (Moving the master unit and slave unit)** 7. **Repeat steps 3 to 6 of the above steps until you reach the goal.**

***5 Regarding the installation of the slave aircraft, when the landing site of the base aircraft is discovered after the base aircraft has landed, it is manually installed around 15 [m] away from the base aircraft.**

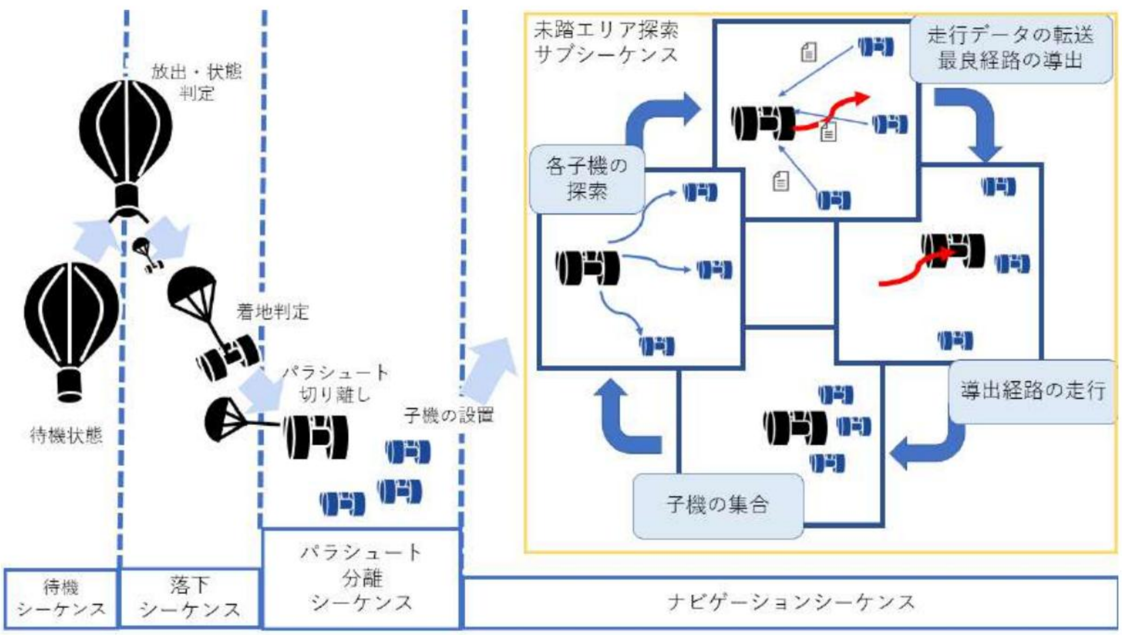

Figure 1 **Overview of mission flow**

Chapter 2 **Success Criteria**

minimum success	**After the parent aircraft lands, two-way communication is established with each slave unit, and each slave unit begins traveling to search for the best route.**
full success	**Full success will be achieved by achieving the following four items in order.** 1. **After each slave machine travels in the designated area from the master machine, it transfers the travel data *6 to the master machine.**

	2. The master unit calculates the best route in the specified area based on the travel data received from the slave unit. 3. The master unit completes the derived best route. 4. The slave units gather under the master unit.
advanced success	The base machine runs along the route derived from the full success flow (=100 [m]) x (=5) set*7. When doing so, make sure to avoid locations where the handset has determined that it is difficult or impossible to travel.

*6 Acceleration sensor z-axis value (uphill/uphill determination), GNSS sensor and gyroscope (stack/inversion determination) *7 : The distance between the aircraft is such that communication is possible, the number of child units provided is sufficient for searching, and each child Determined by taking into consideration the distance at which members following the aircraft can communicate with each other to confirm the status of the aircraft.: Set according to the results of the power durability test.

In addition, the evaluation method for all success criteria will be set as follows.

minimum success	Confirm in the log that command strings for establishing communication and starting running have been sent and received between the base unit and each slave unit. Visually confirm that the base unit and each slave unit have successfully received the character string and that each slave unit has started running.
full success	1. Confirm in the log that all slave units that have traveled the specified section are transmitting travel data to the base unit. 2. Log that the parent unit calculates the best route from the travel data of the slave units Check with . 3. Always drive while keeping a distance of 10 [m] or less*8 from the route derived by the base unit. Make sure that 4. Confirm that all the mobile devices that can run are gathered within 10 [m]*8 of the set coordinates of the child devices specified by the parent device .
advanced success	•The distance traveled from the point where the base unit landed is 500 (=100x5) [m] or more.•Log of the point where the slave unit had difficulty traveling and the route that the base unit took to avoid that point, and then continue driving. A log that shows what was not done

*8 Considering the error of GNSS sensor

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 . What you can do to turn it off)**
	We have confirmed that we are willing and able to adjust the S9 radio channel. **There is**
	CanSat, which has been designed to meet S10 S1-9 , has been able to conduct end-to-end tests that simulate the **loading of the rocket, the start of the mission, and recovery** after launch. **There are no major design changes.**

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. It has been confirmed**
	Tests have confirmed the running performance of the M2 base unit and slave units on rough ground.

Tests have confirmed that it can run for the time required to accomplish the M3 mission.
Tests have confirmed that the M4 parent unit and slave unit can return to normal running posture when flipped or rolled over.
Tests have confirmed that communication can be established between each M5 slave unit and the base unit.
It has been confirmed that when the M6 parent unit and slave units are running at the same time, they drive in a way that avoids a collision when there is a possibility of a collision, such as when their routes overlap.
Tests have confirmed that the M7 slave aircraft can evaluate and record its own route.
After each M8 slave machine travels multiple routes and reflects the travel data on the base machine, the base machine derives the best route. It has been confirmed through testing that it is possible to
Tests have confirmed that after the M9 base unit has traveled the best route, the slave units can gather near the base unit to search for the next route.
Tests have confirmed that the parachute can be separated after M10 lands.
If the communication from the M11 handset is lost or if it is unable to travel, the remaining mobile aircraft that can run are recognized and the mission can be continued according to the number of them. Tests have confirmed that it can be stopped to prevent the above operations from occurring.
Tests have confirmed that the M12 base unit and slave unit can each travel on a designated route.
It has been confirmed that autonomous control without human intervention will be implemented during the M13 mission.
After the M14 mission, the specified control history report was submitted to the management and examiners and logged/obtained. Data can be explained

Chapter 4 **System Specifications**

4.1 **Aircraft appearance**

In this mission, we will use a ``master'' and ``slave'' units, each with a different role, in order to conduct a demonstration experiment aimed at realizing safe wide-area exploration of the main aircraft. Both aircraft were designed with the following points in mind.

- **Main unit: Since this is an important unit that plays the backbone of exploration, it is necessary to improve the running performance of the unit so that it can run stably. Therefore, by increasing the width of the aircraft as much as possible and adjusting the center of gravity of the aircraft, we will reduce the risk of rollover and reversal as much as possible.**
- **Slave device: Serves as a sub device for the parent device to safely proceed with exploration. Since it is necessary to acquire data for the parent unit's route search, reducing the weight allows it to sensitively sense ups and downs, and making it smaller** † allows for nimble movement even with low torque.

†: Due to the miniaturization of the aircraft, there is an increased risk that the aircraft will be unable to travel in areas that were previously possible. However, in this mission, it is possible to evaluate the environment based on the aircraft that has become unable to travel, and to continue the mission by separating the aircraft that has become unable to travel. We have therefore given due consideration to the risks associated with downsizing the aircraft, and the measures we have taken to address these risks are one of the best parts of this mission.

4.1.1. Base unit

Figure 4.1.1.1 shows an image taken of the front of the base unit. Encircled by a solid green line below the circuit board A lithium polymer battery is installed in the part to power Orange Pi. **In addition, dry batteries for the drive wheels and servo motor are installed in the area surrounded by the red solid line at the bottom of the fuselage** (details are described in 4.2.1 (Aircraft interior/mechanism - **Main unit)).** Figure 4.1.1.2 shows an image **from the top of the main unit ,** Figure 4.1.1.3 shows an image from the right side of the main unit, and Figure 4.1.1.4 shows an overhead view. **The sensor module mounted on the circuit board in the center of the upper part of the aircraft in** Figure 4.1.1.2 **will be described in detail later in the system diagram in Chapter 4, Section 3, Item 1. In addition, the stabilizer surrounded by the solid red line in Figure 4.1.1.5 prevents the aircraft from flipping by touching the ground and maintains the balance of the aircraft. This stabilizer** can be controlled by a servo motor, and by folding it under the fuselage as shown in Figure 4.1.1.6, it can be stored in a carrier while meeting **regulations . In addition, a cylindrical sponge with a radius of 10 [mm] coated with chloroprene cloth is attached to the tip to reduce the impact directly applied to the stabilizer (details of the stabilizer are described in 4.2.1) .). Furthermore, in order to improve running performance, a piece of wood (5** [mm] x 5 [mm] x 5 **[mm]) is attached to the tire using hot bond. Furthermore, even after completing a three-hour power durability test under the scorching sun, no melting of the hot bond was confirmed.**

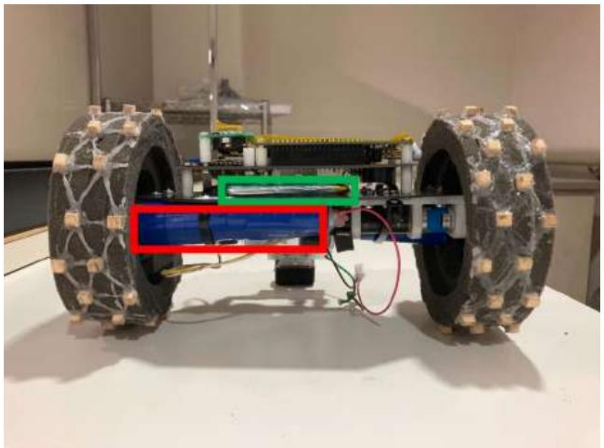

Figure 4.1.1.1 **Base unit (front)**

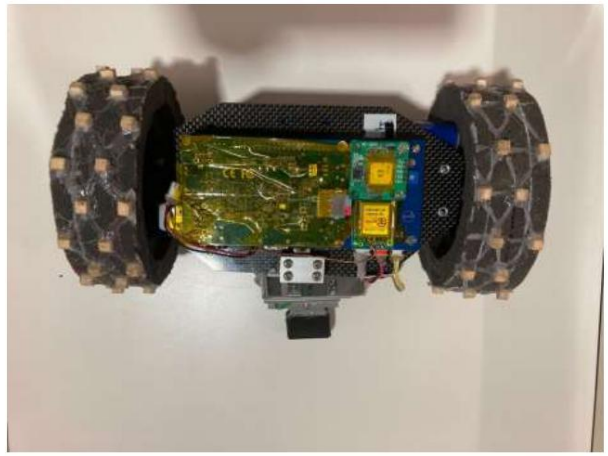

Figure 4.1.1.2 **Base unit (top)**

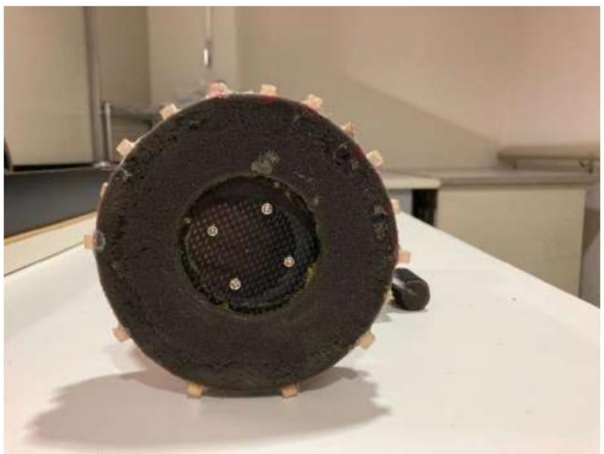

Figure 4.1.1.3 **Base unit (right side)**

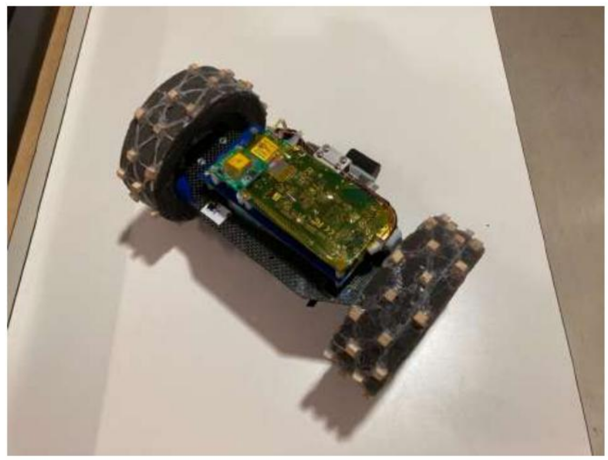

Figure 4.1.1.4 **Base unit (overhead view)**

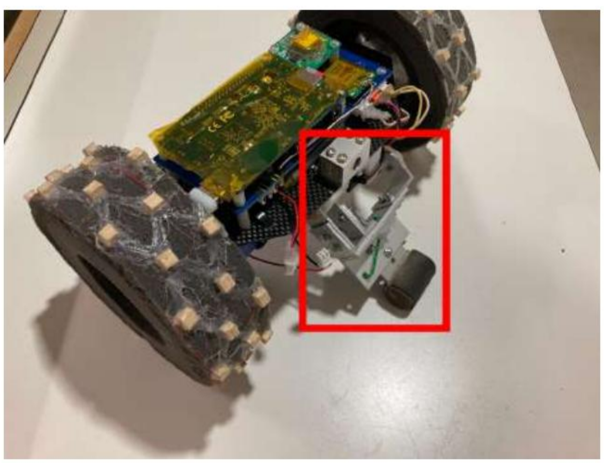

Figure 4.1.1.5 **Base unit (stabilizer deployed)**

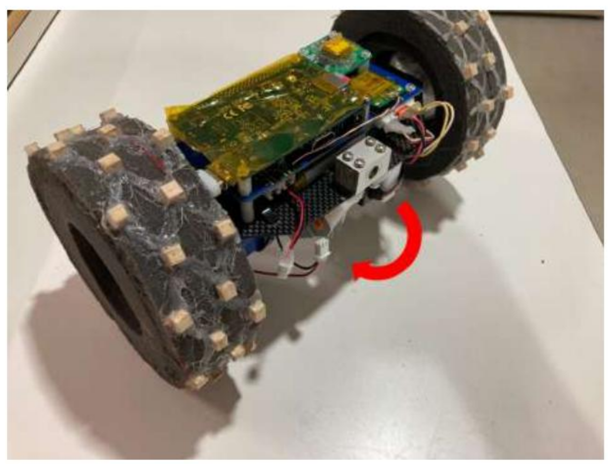

Figure 4.1.1.6 **Base unit (stabilizer storage)**

Figure 4.1.1.7 shows an image of applying a tape measure to the front of the main unit to measure the width of the main unit.

Figure 4.1.1.8 shows an image of the main unit with a measuring tape applied to the side of the main unit to measure the height of the main unit.

The figure below shows an image of a tape measure placed on the side of the main unit parallel to the ground to measure the total length of the unit.

4.1.1.9, Figure 4.1.1.10 shows an image of the mass of the base unit. Table 4.1.1 also shows the base unit support.
I will summarize the size and mass. What actually meets the regulations is 7
Please refer to the results of the mass test and storage/release test in Chapter 1.

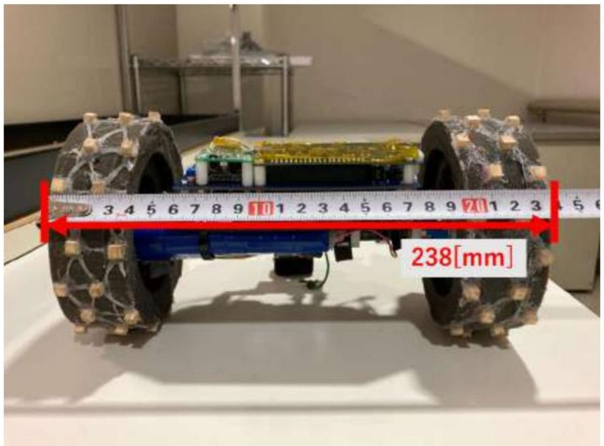

Figure 4.1.1.7 **Base unit body width measurement**

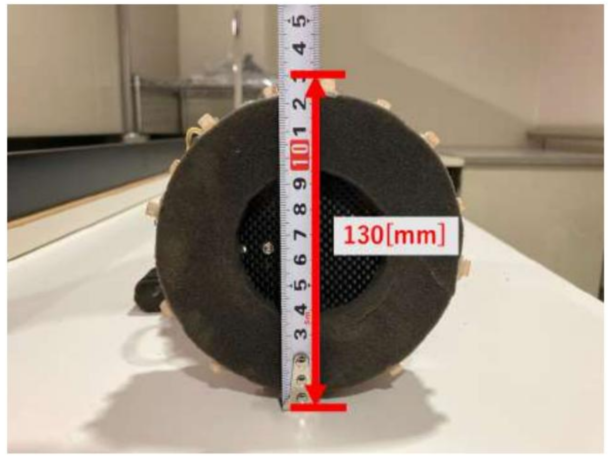

Figure 4.1.1.8 **Base unit height measurement**

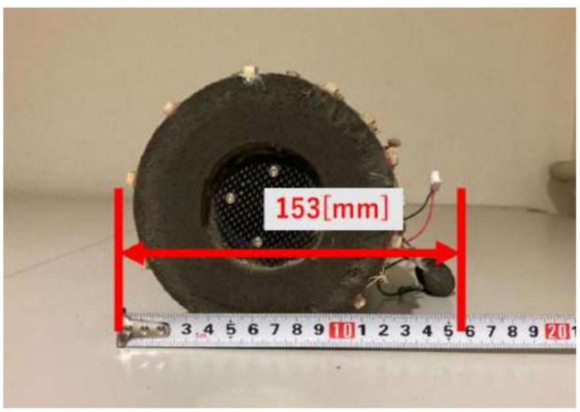

Figure 4.1.1.9 **Total length measurement of main unit**

Figure 4.1.1.10 **Mass measurement of base unit only**

Table 4.1.1 **Base unit size**

Aircraft width [mm]	238
Height [mm]	130
Total length [mm]	153
Mass [g]	783

4.1.2.An

image taken from the front **of the handset** is shown in Figure 4.1.2.1. Two sets of **two AAA batteries for the front wheel drive motor are installed horizontally in the red circle in the center of the bottom of the fuselage .).** Figure **4.1.2.2 shows an image from the top of the handset ,** and Figure 4.1.2.3 shows an image from the right side of the handset. **The sensors and modules mounted on the circuit board in the center of the upper part of the aircraft in Figure 4.1.2.2 will be described in detail later in the system diagram in Chapter 4, Section 3, Section 2.** Additionally, in the area surrounded by the green dashed line in the figure , **a lithium polymer battery is installed under the circuit board** to start the Rasberry Pi Zero. **Furthermore, a stabilizer is fixed to the lower part of the fuselage, which plays the same role as the main unit. The front wheel in Figure 4.1.2.3 uses eight pieces of bamboo (2** [mm] x 5 [mm] x 35 **[mm]) for the spokes to reduce weight, and a piece of wood (same as the parent machine) is hot-bonded. Adhesion improves traversal performance (the axle part will be explained in detail in the internal view of the slave unit). Finally,** an overhead view is shown in Figure 4.1.2.4.

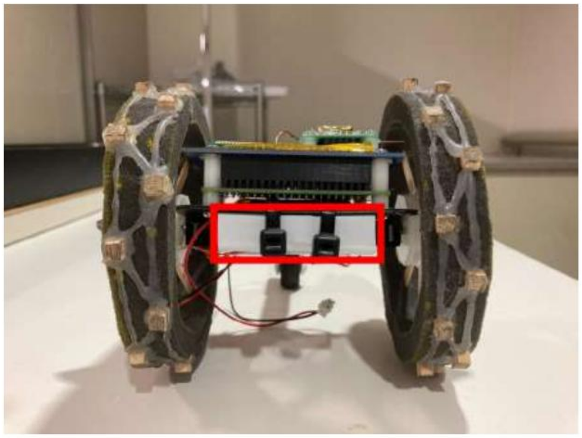

Figure 4.1.2.1 **Handset (front)**

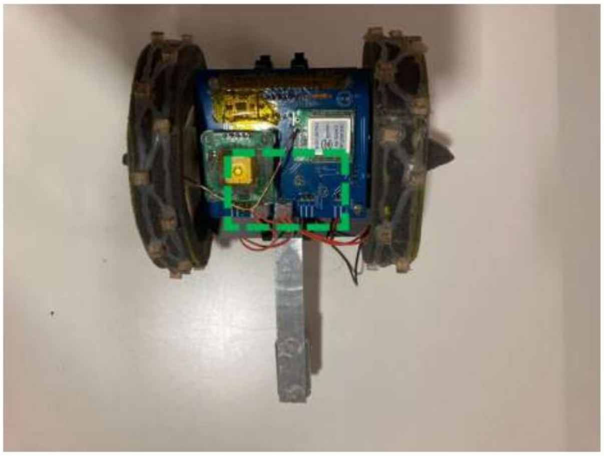

Figure 4.1.2.2 **Handset (top)**

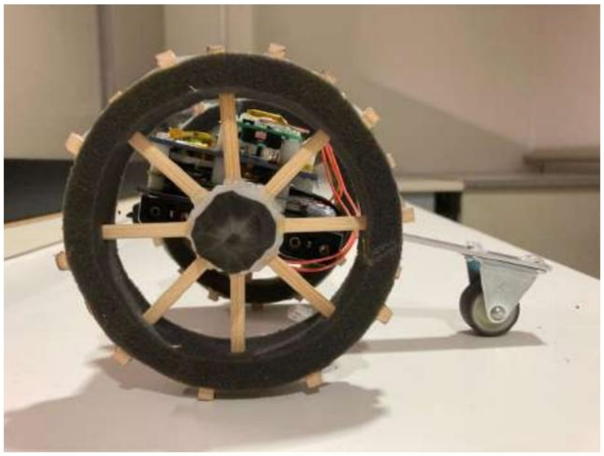

Figure 4.1.2.3 **Handset (right side)**

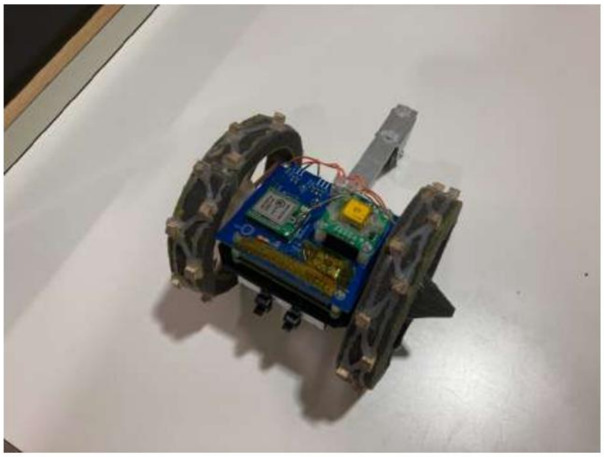

Figure 4.1.2.4 **Handset (overhead view)**

Figure 4.1.2.5 shows an image of the tape measure placed on the top of the handset to measure the width of the handset, and

Figure 4.1.2.6 shows an image of the tape measure applied to the side of the handset to measure the height of the handset. , total length of slave unit

Figure 4.1.2.7 is an image of the tape measure including the stabilizer to measure the quality of the handset. An image of the amount measured is shown in Figure 4.1.2.8. **Table 4.1.2 also shows the size and mass of the handset. Summarize.**

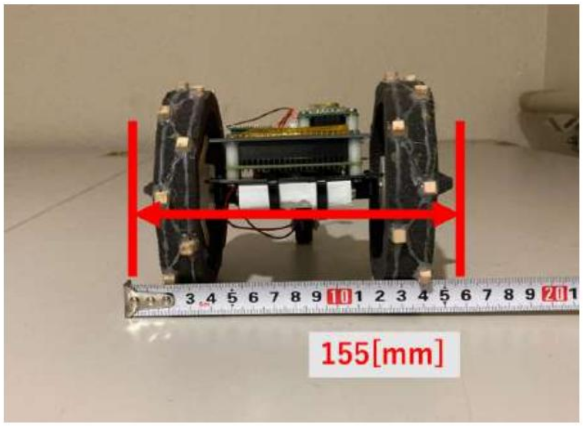

Figure 4.1.2.5 **Measuring the body width of slave unit**

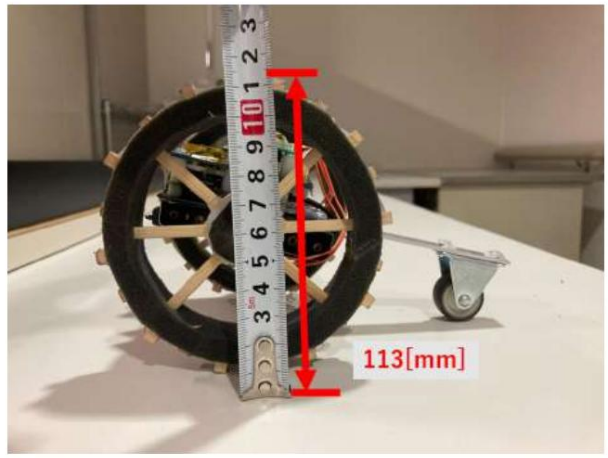

Figure 4.1.2.6 **Height measurement of slave unit**

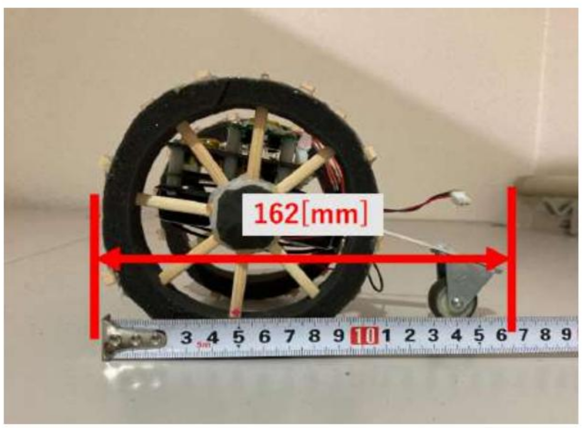

Figure 4.1.2.7 **Total length measurement of slave unit**

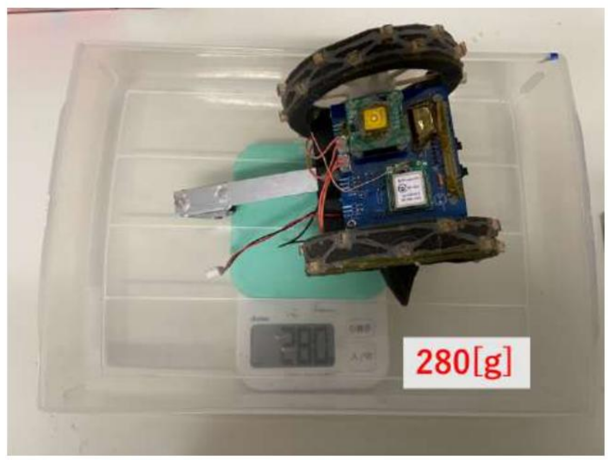

Figure 4.1.2.8 **Mass measurement of slave unit**

Table 4.1.2 **Handset size**

Aircraft width [mm]	155
Height [mm]	113
Total length [mm]	162
Mass [g]	280

4.2 Aircraft interior/mechanism

4.2.1 Base unit

• **Motor power supply** Figure 4.2.1.1 shows an image taken from the back of the base unit. Six AA batteries (four on the front in the direction of travel, two on the rear) for the drive wheels and servo motor are installed in the area surrounded by the solid red line . By arranging them separately at the front and rear of the aircraft as shown in the figure, rather than placing all six at the front of the aircraft, the center of gravity of the aircraft is adjusted so that it is not too far forward in the direction of movement of the aircraft.

• **Stabilizer**

Figures 4.2.1.2 and 4.2.1.3 show images of the base unit's stabilizer. The stabilizer is L-shaped and It is formed by combining metal plates and flat plates as shown in Figure 4.2.1.4. A servo motor to control the stabilizer is installed near the center of Figure 4.2.1.3, surrounded by red. In addition, in order to smoothly attach the parachute pin, the polyacetal stabilizers that secure the stabilizer to the fuselage were placed apart from each other (Figure 4.2.1.4). This makes it easy to attach the nails for fixing the parachute pins to the holes visible between the polyacetals.

Finally, the L-shaped part of the stabilizer comes into contact with the tire drive motor when folded. In the event of a landing impact, etc., these things collide, leading to damage to the motor. Therefore, we soften the impact by attaching a sponge to the area where the metal L-shape and the motor come into contact, as shown in the area surrounded by the solid green line in Figure 4.2.1.6.

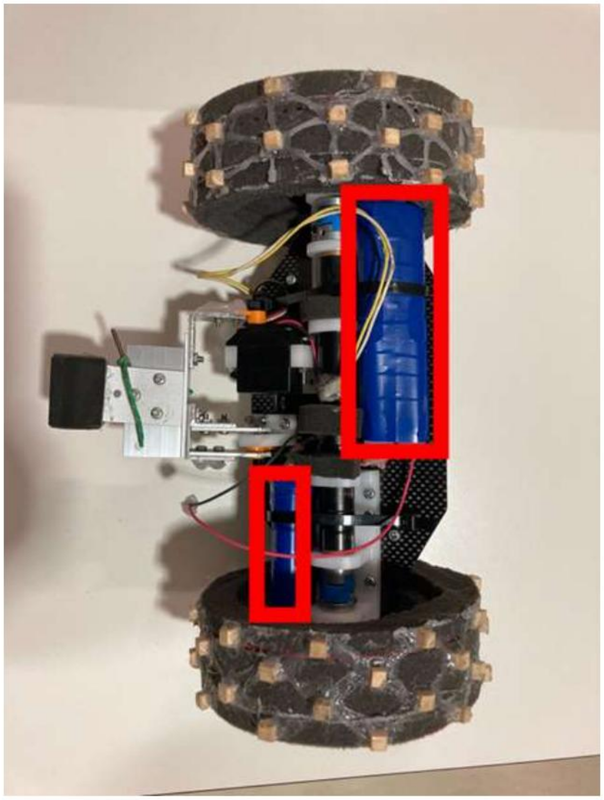

Figure 4.2.1.1 **Base unit (back side)**

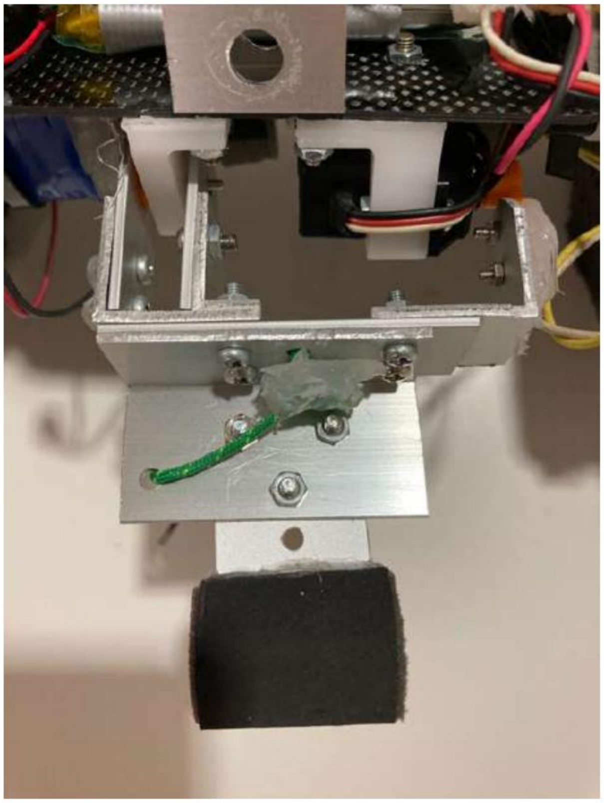

Figure 4.2.1.2 **Base unit stabilizer (top side)**

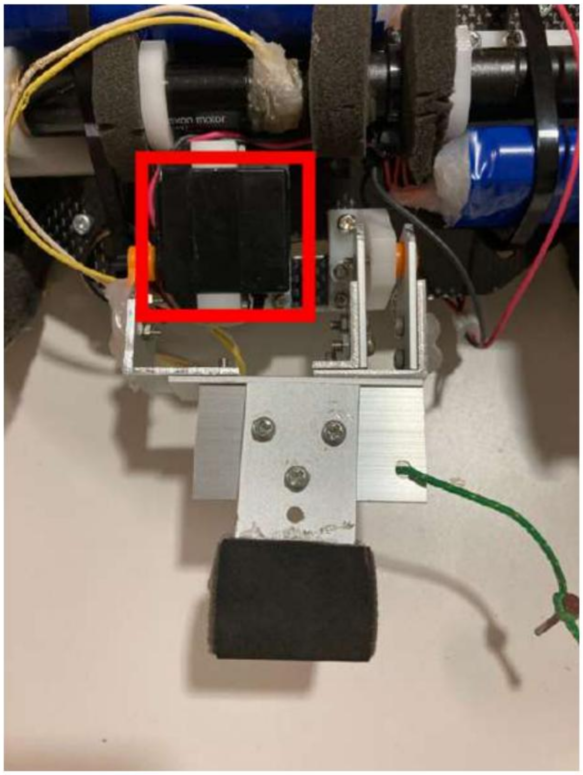

Figure 4.2.1.3 **Base unit stabilizer (bottom side)**

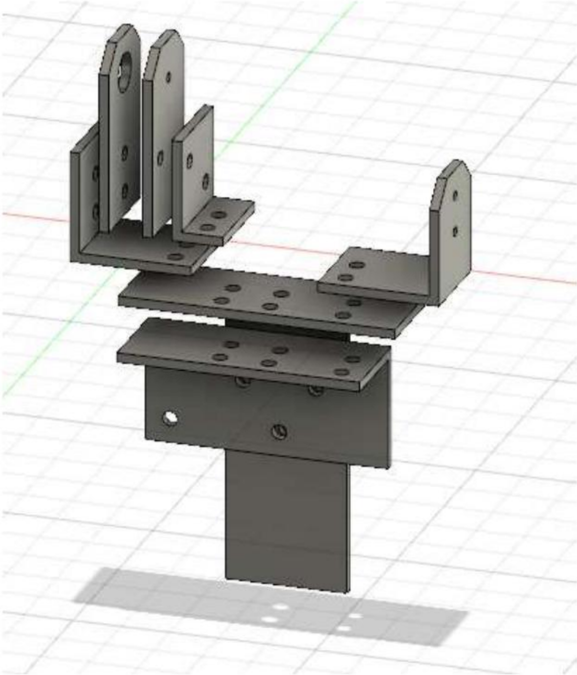

Figure 4.2.1.4 **Base unit stabilizer (design diagram)**

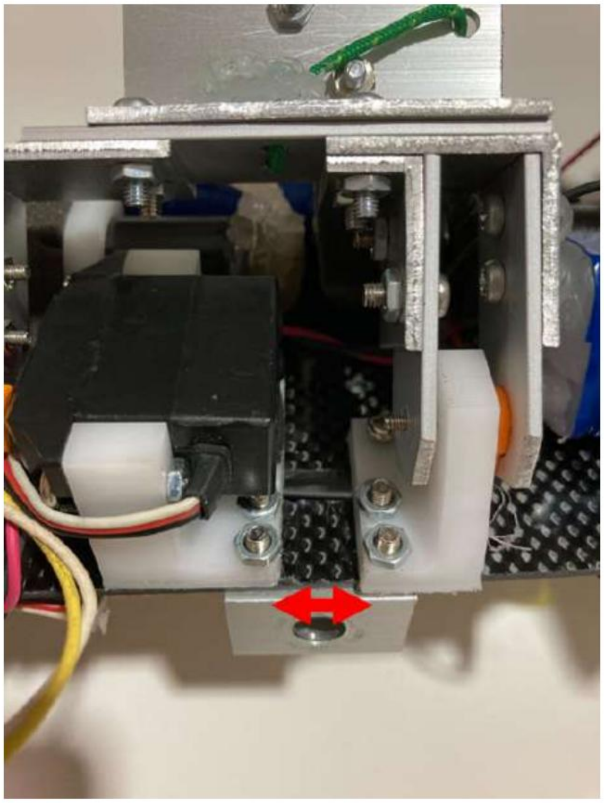

Figure 4.2.1.5 **Polyacetal placed apart**

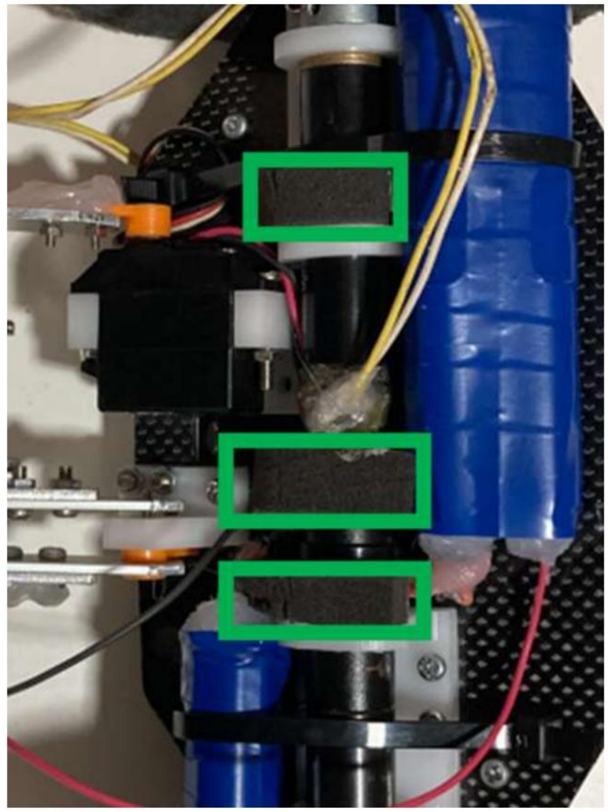

Figure 4.2.1.6 **Shock mitigation sponge**

• **Parachute separation**

mechanism Figures 4.2.1.7 and 4.2.1.8 are images of the parachute separation mechanism of the parent unit. Figure 4.2.1.7 shows the parachute connected to the base unit, and Figure 4.2.1.8 shows the parachute disconnected . The parachute is connected to the end of the orange string in Figure 4.2.1.7.

Figure 3.2.1.7 **Balachute separation mechanism (installed)**

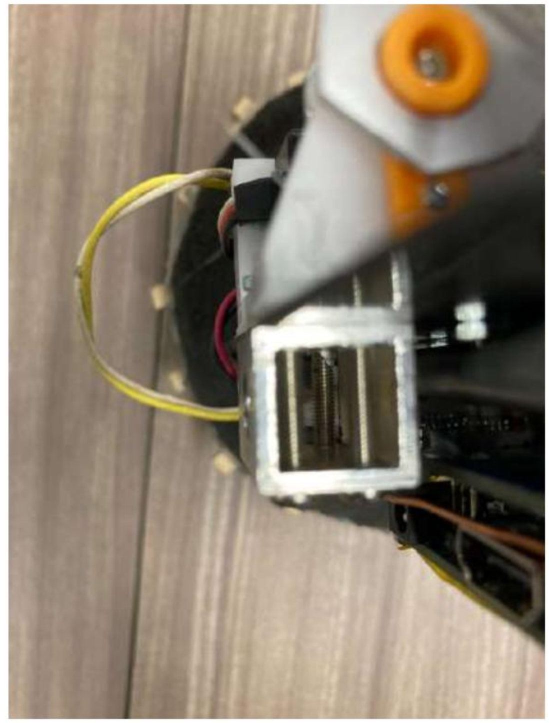

Figure 4.2.1.8 **Parachute separation mechanism (not installed)**

Figure 4.2.1.9 **Pin to connect parachute**

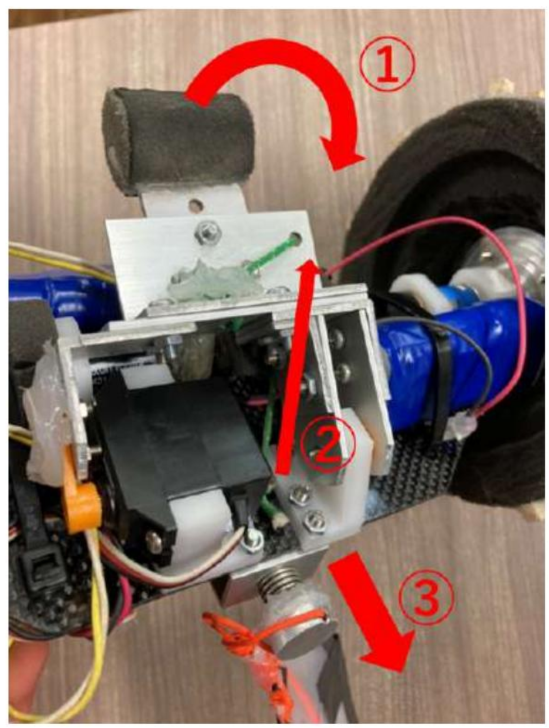

Figure 4.2.1.10 **Flow of parachute separation**

As shown in Figure 4.2.1.9, the pin that connects the parachute and the base unit has a hole near its tip , **and by inserting a nail into the hole, the pin and the base unit are connected (Figure 4.2.1.7). Maintained . Figure 3.2.1.10 shows the flow of parachute separation. ÿFixed to the bottom of the main unit**

When the servo motor is driven, the stabilizer opens in the direction of the arrow in the figure. ÿ The nail comes off when the green string is pulled by the movement of the stabilizer. ÿThe pin of the parachute is separated from the base unit. A spring is installed on the pin to facilitate smooth separation, and when the nail comes off, this spring stretches and the pin is separated from the parent machine with

force. In addition, based on my experience, this setting drives the servo motor up and down for 3 seconds and move It is known that the pin can be separated by repeating the operation once or twice. In the flow chart, the above operation is repeated 10 times to increase the probability that the pin will come out . The number 10 is based on the idea in mechanical engineering that in order to increase the certainty of an uncertain operation, the number of trials for which the operation is expected to be successful is multiplied by the safety factor S. It was set **as the value multiplied by the safety factor S = 6 for the repeated operation of metal parts such as .**

Here, we confirm by numerical calculation that the parachute pin is released by the elastic force of the spring. The conditions under which the parachute pin is released by the elastic force of the spring are expressed by the following equation . Here, k is the spring constant and E is the longitudinal elastic modulus. The material of the pin used this time is spring steel, and according to JIS B 2704, **=** 206×10^3 [N/mm] .

$$k < E$$

From here, we will confirm that the spring adopted this time satisfies this condition. First, the spring constant k of the spring actually used for the parachute pin can be found based on the following relational expression . In reality, it is thought that the energy of friction has a large effect. However, we have successfully repeatedly separated the springs smoothly through experiments, and the selection of springs is considered appropriate, so we will omit the discussion of frictional energy this time. The left side shows the elastic energy of the spring constant, and the right side shows the difference

$$\frac{1}{2}kx^2 = mg\{h - (l - x)\}$$

Here, is the natural length of the spring [mm], ÿ is the length of the pin, and is the displacement of the spring from the tip of the spring when installed [mm]. Figures 4.2.1.11 and 4.2.1.12 **show** these dimensions on actual images .

From actual measurements, ÿ = 30 [mm], = 18 [mm], = 13 **[mm], and the mass of the pin** = 8 [g] . **Note that gravitational acceleration** = 9.8 **[m/s^2]. Substituting these values into the above equation, we get**

= 23.2×10^3 **[N/mm]. Therefore** $3 <= 206 \times 10$ [N/mm], and the maximum

It was confirmed that the parachute pin satisfied the condition **described above for being released by the elastic force of the spring .**

Additionally, the torque applied to the nail when separating the parachute is 53 [N] (ÿ 5.4 [kgf]) generated by the servo motor (see the servo motor data sheet). **Furthermore, when referring to SUS304, the material** of the nail, from the JIS standard , **it is shown that the nail strength ÿ is 205 [N/mm^2]. Here, when the nail is pulled by the rotation of the servo motor, the area where the force is applied is half of the contact area of the string connecting the servo motor and the nail to the nail (the part directly opposite to the direction in which the force is applied), so Considering that the trunk diameter 2** is 1.25 **[mm] and the width of the string** is 2 [mm], it can be calculated using the following formula.

$$S = \frac{2\pi rw}{2} = 3.14 \times 0.625 \times 2 = 3.925[mm^2]$$

From the above, the force **ÿ expected to be applied to the nail surface when separating the parachute is**

$$\sigma' = S\sigma = 3.925 \times 205 = 804.6[\mathrm{N}]$$

becomes. Therefore, the nails used can withstand the torque applied during parachute separation without deformation, and are appropriate for use in the parachute separation mechanism.

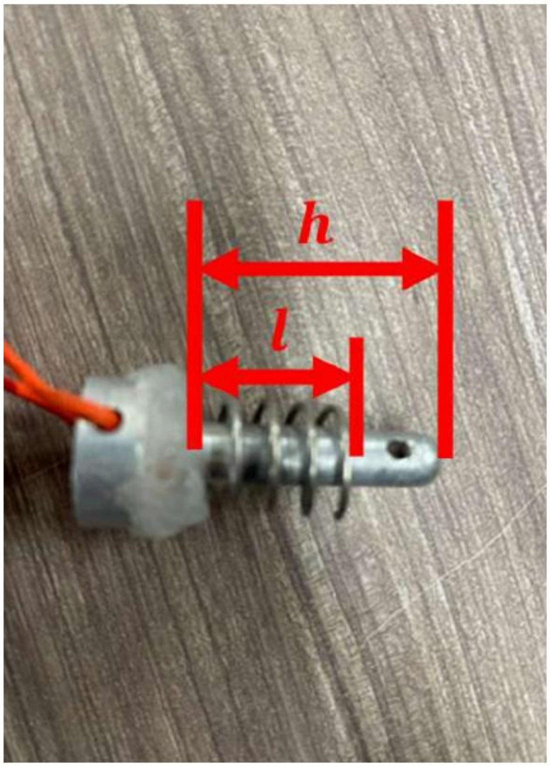

Figure 4.2.1.11 **Spring and pin dimensions**

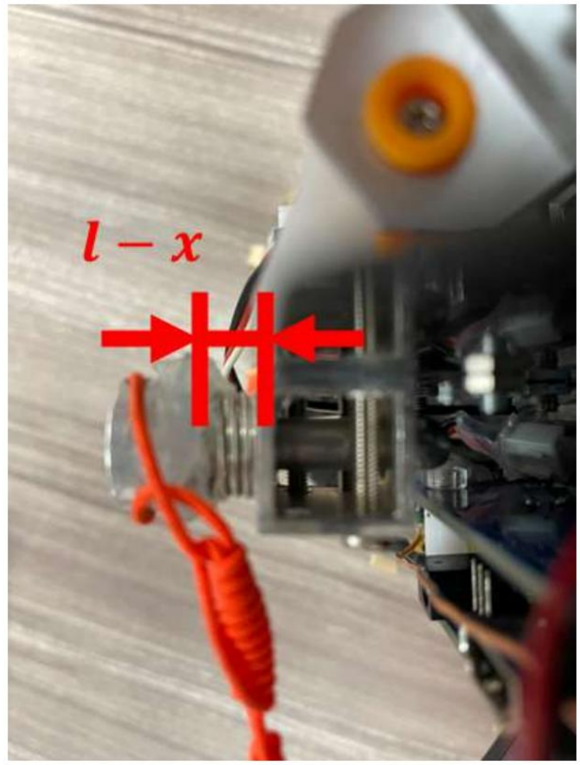

Figure 4.2.1.12 **Dimensions of spring and pin when retracted**

4.2.2 Slave

Unit • Figure 4.2.2.1

shows the back of **the motor power slave** unit. Two sets of two AAA batteries for the front wheel drive motor are installed **in the area circled in red in the image .**

Experiments have shown that the motor's output performance is not sufficient and the rotational speed is low. I was able to confirm that this is true. This is a problem related to running and return performance and can be a factor in reducing search performance. Therefore, in

order to ensure sufficient voltage, the number of batteries stored in the battery box at the rear of the aircraft was changed

from two to

three, as shown in Figure 4.2.2.4 . • Axle part The axle is directly connected to the motor by sandwiching the coupling (part) shown in the figure between two types of parts (material: polyacetal, manufactured by 3D cutting) as shown in Figure 4.2.2.2. ing. Additionally, there are grooves on the side of the axle for inserting spokes. There is also a hole at the top of the figure for operating the set screw to

secure the motor. •

Stabilizer The stabilizer is shown in Figure 4.2.2.3. An aluminum plate (15 [mm] x 120 [mm] x 2 **[mm]) was used for the stabilizer . A wheel is attached to the tip to suppress vibration. These wheels also play the role of shifting the center of gravity backwards as a countermeasure to the problem of reversal and return, which is a concern since servo motors are not used.**

Experiments have shown that the rear wheel attached to the tip of the stabilizer can only rotate in one direction.

It was confirmed that noise was added to the data obtained when the aircraft made a sudden rotation. This is a factor that reduces the accuracy of the data used by the base unit to derive the best route, and is thought to have a bearing on the success or failure of the mission. Therefore, **we changed the rear wheels to ones that can rotate 360 degrees, as shown in Figure 4.2.2.5 . On the day of the test, the type of rear wheels to be used will be decided based on the results of the field tests.**

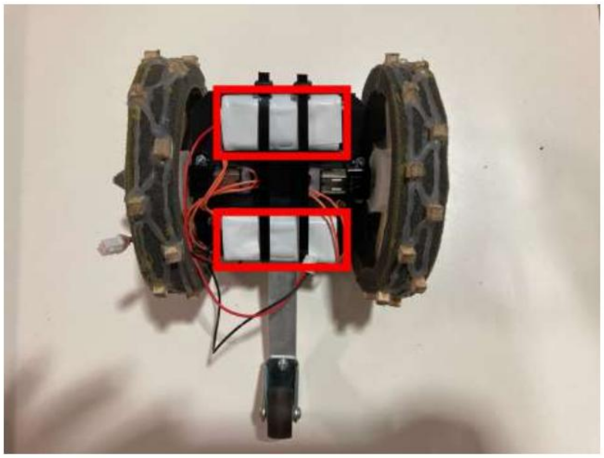

Figure 4.2.2.1 **Back side of handset (before change)**

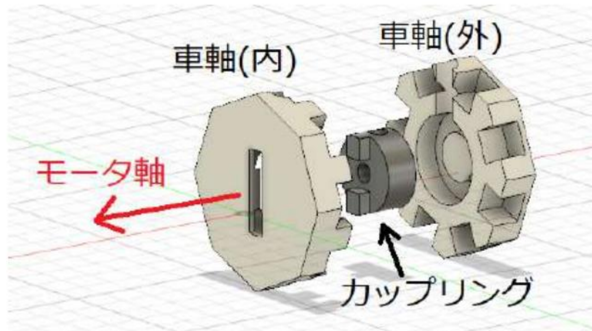

Figure 4.2.2.2 **Axle**

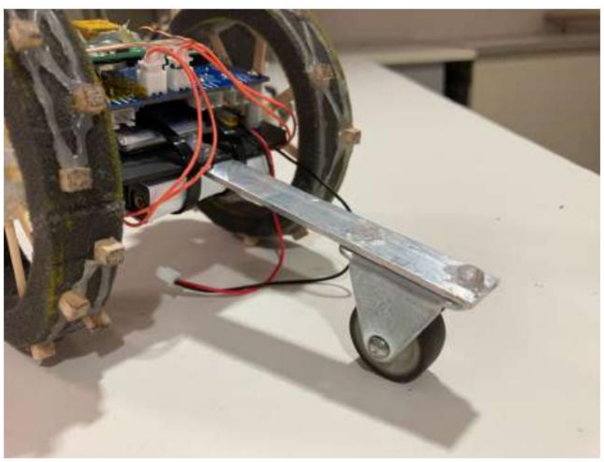

Figure 4.2.2.3 **Handset stabilizer**

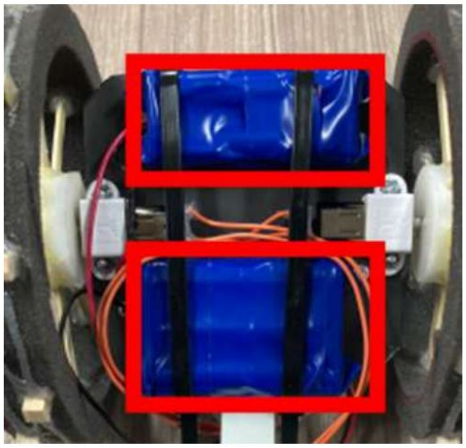

Figure 4.2.2.4 **Back side of handset (after change)**

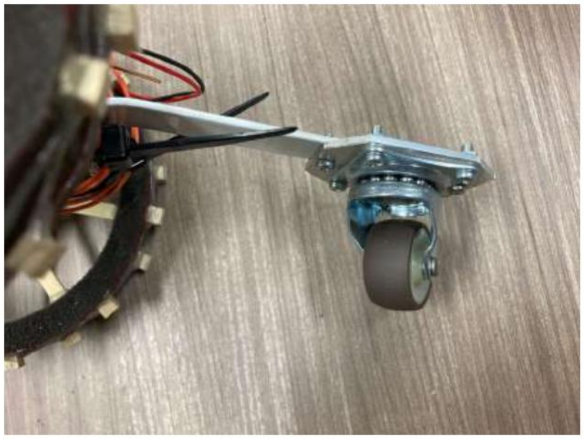

Figure 4.2.2.5 **Handset stabilizer (casters with ball bearings)**

※なお，子機は上記変更を施した場合，32[g]増加し，総重量は280[g]から312[g]となる.

4.3 **System diagram**

4.3.1 Base unit

Figure 4.3.1 shows the configuration of the system that controls the base unit. The main unit is equipped with a 9-axis sensor (acceleration, gyro, geomagnetism), barometric pressure sensor, optical sensor, and GNSS sensor, and uses the information obtained from these sensors to control the operation of the motor and servo motor. **In addition, communication between aircraft is performed through the LoRa module. Send the location information of the base unit to the ground station as appropriate.** The names and purposes of **each sensor and module used** are summarized in Table 4.3.1, and the details are shown below.

In addition, in this mission, each sensor (input) that acquires environmental information is used as follows . (How to use specific values is described in Section 4.4 Mission Sequence and Algorithm.)

• GNSS sensor

• Self-location estimation

ÿ **Updating self-position coordinates using the acquired GNSS coordinates •**

Navigation processing ÿ Determine

the direction of travel from the difference between the goal coordinates*9 and the GNSS coordinates acquired each time

Adjustment • Stack judgment

ÿ **If the difference between the GNSS coordinates obtained each time is within a certain amount, it is considered to be stuck.**

judgement

• 9-axis sensor •

Landing

determination ÿ **Utilizes the difference in acceleration during falling and**

after landing • Navigation

processing ÿ **Adjustment of traveling direction using**

geomagnetism • Rollover/reversal determination

ÿ Understand the status of the base unit from the direction of gravity •

Attitude control ÿ

Control the posture during running from the direction of gravity •

Atmospheric pressure

sensor • Landing

judgment ÿ The atmospheric pressure changes significantly during the falling sequence, and after landing, the atmospheric pressure changes. Take advantage of being small

• Optical sensor •

Carrier release judgment ÿ Determines

that it has been released from the rocket carrier

• LoRa • Mutual

communication between aircraft •

Countermeasures against lost during

drop ÿ The self-position coordinates acquired by the GNSS sensor are periodically transmitted and received by the base station LoRa after visually tracking to the range where it can communicate with the base unit.

*9 "Goal coordinates" refers to the goal for the comeback mission, which is a temporary search target.

Refers to GNSS coordinates (described later in Chapter 4.4).

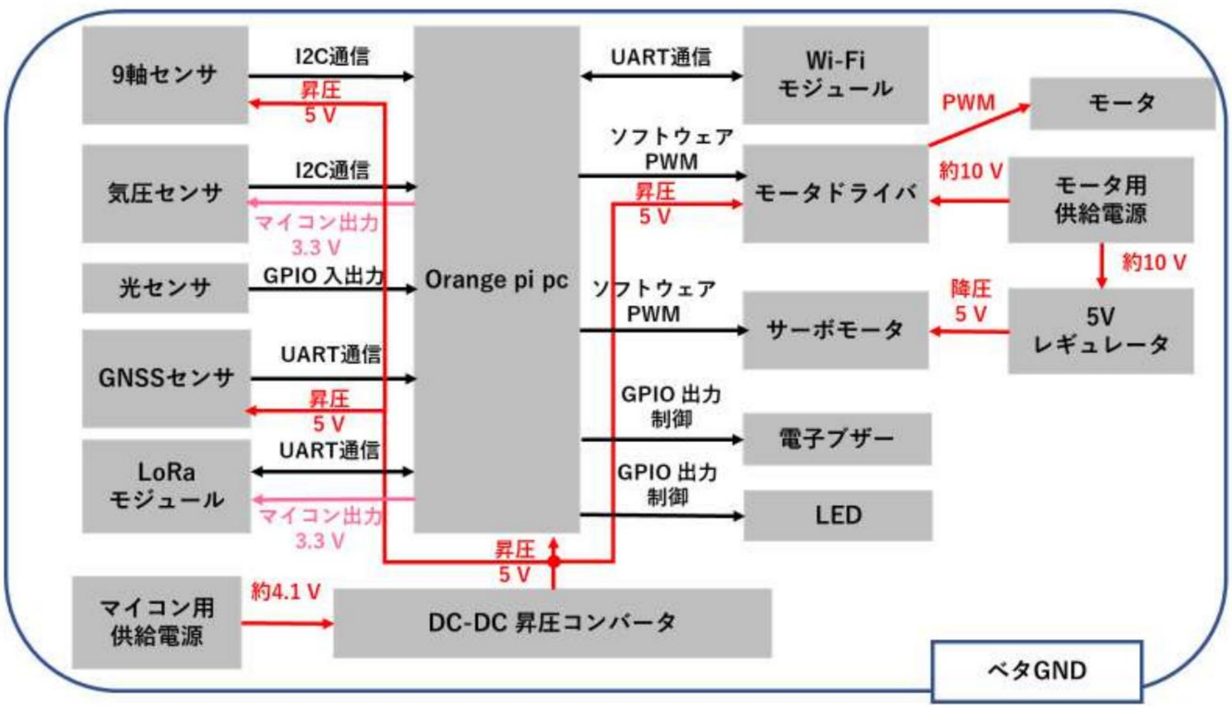

Figure 4.3.1 **System diagram of base unit**

Table 4.3.1 **Use of instruments mounted on main unit**

classification	Name/model number	Intended use	Source URL/reference information, etc.
Microcomputer	orange pi pc	Calculation of input/ output values, log data	https://ja.aliexpr ess.com/item/ 10

		record of	0 5 0 0 1 6 8 9 1 5 2 6 3 5.ht ml
GNSS sensor	AE-GYSFDM AXB	**Obtain direction/ distance to goal point, stack determination** (GPS (USA), Compatible with QZSS (Japan))	https:// a kiz u kid ens hi.com / cat alo g / g / g K - 0 9 9 9 1 /
motor driver	D RV 8 8 3 5	**Motor output control**	http:// a kiz u kid ens hi.com / cat alo g / g / g K - 0 9 8 4 8 /
motor	DC motor REEBCLL 3.2 WSL 2 WE	**tire rotation**	https:// ww wm axongrou pc oj p / maxon / vie w / product / motor/ dcmotor/ re / re 1 6 / 1 1 8 6 9 9
Servomotor	GWS MIR MG FAS03T/2BBM G/J	**Release the parachute and control the main unit so that it is in a horizontal position.**	http:// a kiz u kid ens hi.com / cat alo g / g / g M - 0 1 9 0 8 /
Power supply for motor	E ner giz er L 9 1 Ultimate Lit hiu m AA B atte rie s	**Power supply** to **drive system** (servo, **motor)**	https:// ww al mart.com/ ip/Ene rgizer-Ultimate-Lithium-AA-Batt eries-12-Pack-D ouble-A-Batterie s/139060065
Power supply for microcomputer	DTP 6 0 5 0 6 8 (PHR)	**Power supply to microcontrollers and sensors**	https:// ww wm aruts uc oj p / pc /i/ 8 3 6 4 1 9 /
DC to DC **Boost Converter**	TPS 6 3 0 7 0	**The supply voltage for the microcomputer is** 5 **Boost to** [V]	https:// strawberry -lin u xc om / catalog/items? code =16370
Super 3 terminal 5V **regulator**	V 7 8 0 5 - 1 0 0 0	**Reduce the supply voltage for the motor to the permissible voltage range of the servo motor.**	http:// a kiz u kid ens hi.com / cat alo g / g / g M - 0 6 3 5 0 /

9 axis sensor	AE-BMX055	**Acquisition of values** for acceleration (rollover, **reversal determination), geomagnetism** (control **history for orientation estimation), and gyro (landing determination)**	https://akizukidenshi.com/catalo g/g/gK-13010/
atmospheric pressure sensor	AE-BME280	**Landing judgment**	http:// akizukiden shi.com/catalog/g/gK-09421/
electronic buzzer	PB04-SE12H PR	**Understanding whether light is being detected**	http:// akizukiden shi.com/catalog/g/gP-04497/
light sensor	MI527/MI552 7	**Determination of release from carrier**	http:// akizukiden shi.com/catalog/g/gI-00110/
LED	OSTA5131A-R/PG/B	**Understand the sequence being executed**	http:// akizukiden shi.com/catalog/g/gI-02476/
LoRa communication **module**	RM92-AN	**Inter-machine communication, long-distance communication with the ground station as a measure against loss, sending own position coordinates to the ground station (downring)**	https://www.gre en-house.co.jp/products/rm-92a n /
Wifi **wireless** LAN **handset**	TL-WN725N	**Expand** Wifi on Orange Pi PC	https://www.tp-li nk.com/jp/home -networking/ada pter/tl-wn725n/

4.3.2 Slave device

Figure 4.3.2 shows the configuration of the system that controls the slave units. The slave unit is equipped with a 9-axis sensor (acceleration, gyro, and geomagnetic field) and a GNSS sensor, and the motor operation is controlled from the information obtained from these sensors. It is also equipped with a LoRa module, and communication between aircraft is performed through this module. As a measure against loss, the location information of the handset is sent to the ground station as appropriate through the LoRa module. The names and purposes of each sensor and module used are summarized in Table 4.3.2, and the details are shown below.

In addition, in this mission, each sensor (input) that acquires environmental information will be used as follows.

ÿÿ (How to use specific values is described in Section 4.4 Mission Sequence and Algorithm.)

• GNSS sensor

ÿ **Self-position estimation**

• Update self-position coordinates using the acquired GNSS coordinates ÿ

Navigation processing • Adjust

the traveling direction from the difference between the target coordinates and the GNSS coordinates acquired each time

ÿ **Stack judgment**

• If the difference between the GNSS coordinates obtained each time is within a certain range, it is determined that the state is stuck.

fixed

• 9-axis sensor ÿ

Navigation processing •

Adjustment of traveling direction using earth's

magnetism ÿ **Rollover/**

reversal detection • Grasping the attitude of the handset

from the direction

of gravity ÿ **Attitude control • Controlling the attitude when traveling from the direction of gravity**

• LoRa ÿ **Used**

for mutual communication between aircraft

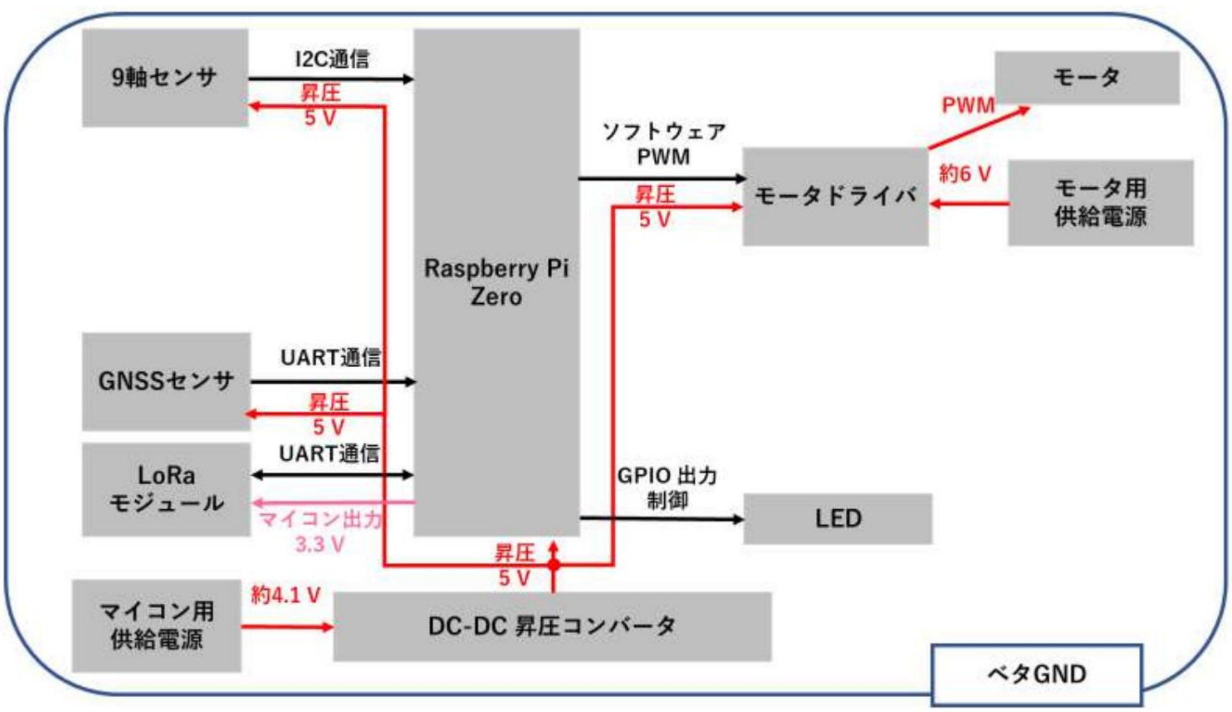

Figure 4.3.2 **System diagram of slave unit**

Table 4.3.2 **Use of instruments mounted on slave unit**

classification	Name/model number	Intended use	Source URL/reference information, etc.
Microcomputer	Raspberry Pi Zero W.H.	**Calculation of input/output values, recording of log data**	https://www.switch-science.com/catalog/3646/
GNSS sensor	AE-GYSFDMAXB	**Acquisition of direction and distance to target point, stack determination** (Compatible **with** GPS (USA), QZSS (Japan))	https://akizukidenshi.com/catalog/g/gK-09991/
motor driver	DRV8835	**Motor output control**	http://akizukidenshi.co m/catalog/g/gK-09848/
motor	Pololu 210:1 Micro Metal Gearmotor HP 6V	**tire rotation**	https: //store.shopping.yahoo.co.jp/suzakulab/pololu-996.html
Coupling	ASJ12-3-3	**axle parts**	https://jp.misumi-ec.com/vona2/detail/221006 230444 /
Motor power supply	eneloop pro BK-4HCD/4SA **AAA rechargeable battery**	Power supply to **drive system (servo, motor)**	https://www.amazon.co. jp/dp/B07FQPFBHM?ref_=cm_sw_r_cp_ud_dp_H23A3AZQWRBQVFMHD9M4&th=1
Power **supply for microcontroller**	DTP603048 (PHR)	**Power supply to microcontroller and sensors**	https://www.marutsu.co.jp/pc/i/836350/
DC-DC boost converter	TPS63070	Boosting **the supply voltage for the microcontroller** to 5 **[V]**	https://strawberry-linux. com/catalog/items?cod e=16370
9 axis sensor	AE-BMX055	Acquisition of values for **acceleration (for determining rollover and reversal),** geomagnetism (for **control history of orientation estimation), and gyro (for** determining landing)	https://akizukidenshi.com/catalog/g/gK-13010/
LED	OSTA5131A-R/PG/B	**running sequence grasp of**	http://akizukidenshi.com/catalog/g/gI-02476/
LoRa communication **module**	RM92-AN	**Long-distance communication with the ground station as a countermeasure against lost data, sending self-position coordinates to the ground station (downring)**	https://www.green-house e.co.jp/products/rm-92a n/

4.3.3 Power supply

used • **Main unit**

power supply • **Dry batteries (power supply for motors**

and servo motors) ÿ **Product name:** Energizer Ultimate Lithium AA

Batteries ÿ **Model number:**

12-2037 ÿ

Notes • 6 batteries in series (approx.

9~10 [V]) **• Since the required voltage for the servo motor is 5V, a super** three-terminal

regulator is used to step down the voltage.

• Lithium ion polymer battery (power supply for circuit) ÿ

Product name: Lithium ion polymer battery 3.7 [V] 2000 [mAh] ÿ **Model number:**

TP605068 (PHR) ÿ **Notes • Because**

the voltage

required for Orange Pi PC is 5 [V] , **a step-up DC-DC converter module is used to**

boost the voltage.

• Power supply for

slave unit • **Dry battery (power**

supply for motor) ÿ **Product name: ENELOOP** PRO **AAA nickel-metal hydride battery**

ÿ **Model number:** BK-4HCD/4SA ÿ

Notes • 5

batteries in series (approx. 6~7 [V])

• Lithium ion polymer battery (power supply for circuit) ÿ

Product name: Lithium ion polymer battery 3.7 [V] 860 [mAh] ÿ **Model number:**

DTP603048 (PHR) ÿ **Note • Since the**

voltage

required for Raspberry Pi is 5 [V], **Boost the voltage using a step-up DC-DC**

converter module .

• Safety measures :

Lithium-ion polymer batteries are basically used as the circuit power supply. To prevent this battery

from catching fire, store it in a lipo battery safety bag when not in use. Also , **when storing it,**

always store it in a position where it will not be subject to impact from

other items.

Place it in

4.4 **Algorithm The**

flowchart of the algorithm is shown in Figure 4.4.1 (the details below correspond to the numbers in the flowchart). In particular, the unexplored area search subsequence in the figure is the most important for this mission, and corresponds to the procedure for deriving the best route for the master unit from the safety evaluation data collected by searching each slave unit. To put this method

simply, based on the location information, acceleration information, and azimuth when the handset is traveling, it is possible to detect areas where the dispersion of acceleration increases significantly on rough ground or where there is a possibility of the aircraft getting stuck.

Generates a terrain evaluation (safety evaluation data) that focuses on the fact that the dispersion is greatly reduced on the surface. The base unit captures the location information of the data not as a point but as a circle corresponding to the error of the GNSS sensor, which interprets the data in a fuzzy manner and efficiently creates a wide-area map, while simultaneously allowing multiple slave units to search for the base unit. The aim is to discover points. This can be said to be an attempt to efficiently investigate and generate a hazard map for exploration, including the points to be searched, without the main unit

moving (without incurring the risks associated with moving without prior information). Figure 4.4.2 compares common mapping methods that can be u
It is something. The important aspects of this method are the small amount of information, efficient information collection, and low cost. LiDAR SLAM and satellite photography require the exchange of large-sized data such as 3D map data and images, but acceleration can be compressed by using methods such as dispersion. In addition, LiDAR requires observation while the spacecraft is running at low speed or stopped for high-precision scanning, which not only takes time but also makes it impossible to evaluate the topography of the spacecraft's driving performance . Satellite photographs lack the resolution to evaluate the safety of the terrain, and there are other problems such as the inability to evaluate permanent shadows. Regarding accuracy, LiDAR It is true that SLAM has the potential to estimate a position with relatively high accuracy, but unless there is a guarantee that the position will pass through the same coordinates, it is important to consider how large the circle for the error mentioned above should be (how fuzzy it is). This is an extension of the discussion on whether aircraft performance or 3D maps should be used for safety evaluation, and the trade-off must be considered from the perspective of efficiency and cost. We selected this method from the viewpoints of terrain evaluation and search efficiency for aircraft performance, and cost reduction.

4.4.1 Flowchart of the entire program

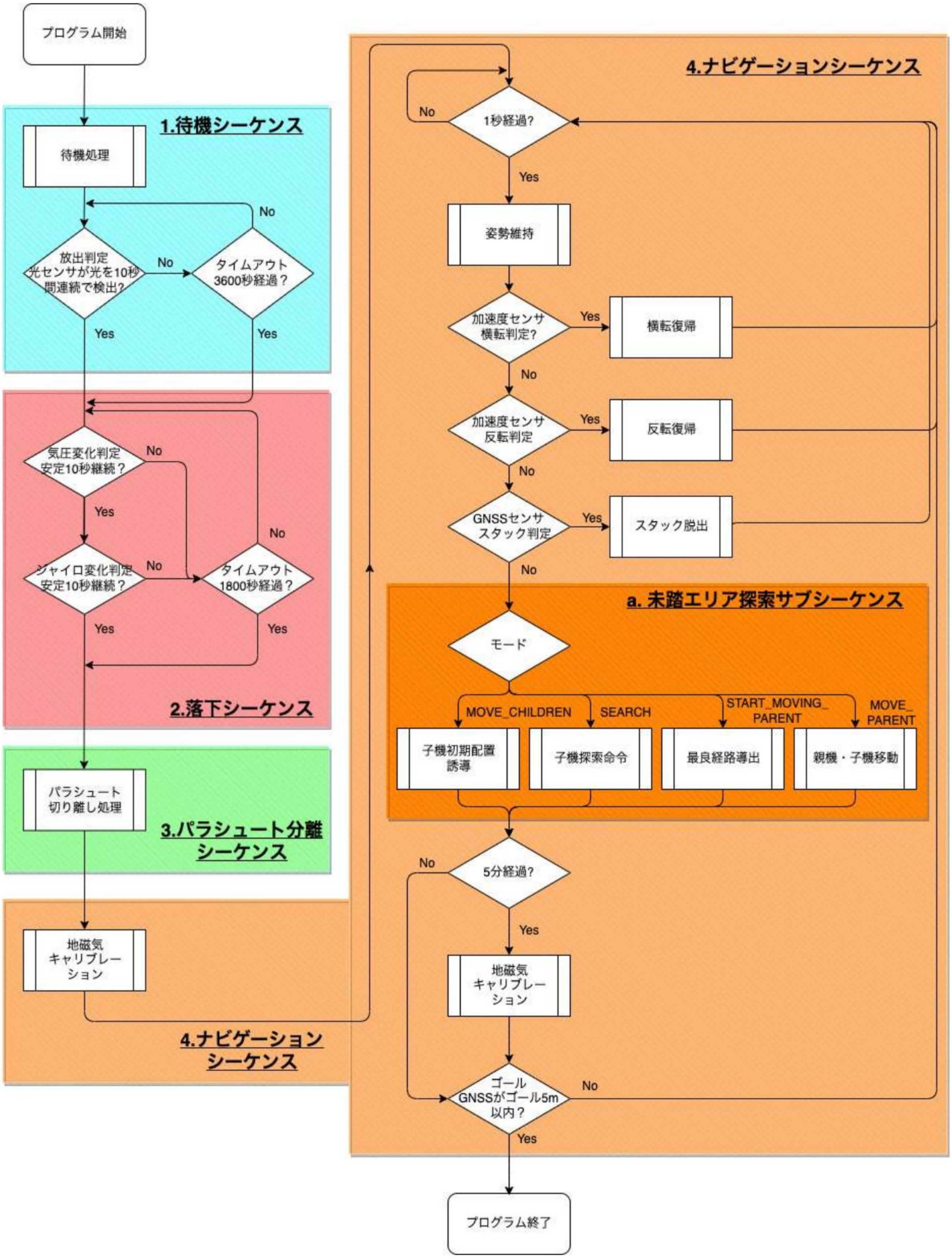
プログラム開始
1.待機シーケンス
待機処理
放出判定
光センサが光を10秒間連続で検出?
No
Yes
タイムアウト
3600秒経過?
2.落下シーケンス
気圧変化判定
安定10秒継続?
ジャイロ変化判定
安定10秒継続?
タイムアウト
1800秒経過?
3.パラシュート分離シーケンス
パラシュート
切り離し処理
4.ナビゲーションシーケンス
地磁気
キャリブレーション
1秒経過?
姿勢維持
加速度センサ
横転判定?
横転復帰
加速度センサ
反転判定
反転復帰
GNSSセンサ
スタック判定
スタック脱出
a. 未踏エリア探索サブシーケンス
モード
MOVE_CHILDREN
SEARCH
START_MOVING_PARENT
MOVE_PARENT
子機初期配置誘導
子機探索命令
最良経路導出
親機・子機移動
5分経過?
ゴール
GNSSがゴール5m以内?
プログラム終了

Figure 4.4.1 **Algorithm flowchart**

	主要素	位置精度	情報量	惑星探査 (屋外)利用
ファジーな地形評価 (本手法)	• GNSS • 加速度	約5m (GNSSセンサの精度)	少ない	○
LIDAR SLAM	• GNSS • LIDAR • SLAM	約数十cm (屋内)	非常に多い	×
衛星写真	• GNSS • 衛星写真	約50cm以下 (地上分解能)	多い	○

Figure 4.4.2 **Method comparison matrix table**

1. **Standby sequence Since**

the base unit must be on standby from loading the carrier to releasing the base unit, it is placed in a standby state from the start of the program. If the light sensor , **whose detection threshold has been adjusted in advance by adjusting the variable resistor,** continues to detect light for 10 seconds , **it is determined that the base unit has been released and moves to the next flow. In case light is not detected due to an abnormality in the optical sensor, if the following conditions are met at the same time, it is determined that the base unit has been ejected and the process moves to the next flow.**

• Condition A: **Acceleration sensor value is below the threshold**

• **L2 norm value of acceleration sensor** < 0.8 [deg/s]

• Condition B: **Observe an acceleration sensor value of 5.0 [G] within 3 seconds after satisfying condition A.**

***Unit G is gravitational acceleration** (ÿ 9.81 [m/s^2])

2. **Falling sequence To**

determine that the base unit has landed, wait until all of the following conditions are met simultaneously for a certain period of time.

• Condition 1: **The amount of change in the barometric pressure sensor value is less than the threshold value**

• | **Amount of change in barometric pressure sensor value** | < 6.0 [hPa] **for 10 seconds.**

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

• **The following three conditions continue for 10 seconds**

at the same time. 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] **If the condition is met, it is determined that the flow has landed and the process moves to the next flow.**

3. **Parachute separation sequence**

Drive the servo motor to separate the parachute joint. Specifically, the servo motor is driven up and down for 3 seconds to move the main unit forward. Repeat this 10 times. After finishing, move on to the next flow.

4.Navigation **sequence**

Specify the direction in which the main unit should move and a rectangular (width 50 [m] **do) do. Then, it travels on the best route estimated to be safe in the area in front of the main unit using the unexplored area search subsequence. After driving, the system determines the direction to proceed and the specified area, and repeats the unexplored area search subsequence. In addition, immediately after starting this sequence and every 5 minutes, the geomagnetic field is calibrated by moving the aircraft in a figure 8 pattern and acquiring geomagnetic data in each direction. Furthermore, while driving, rollover, reversal, and stuck detection are performed based on values obtained from the acceleration sensor and GNSS sensor. The specific judgment conditions for each are as follows.**

- **Rollover**

  detection: x-axis (left/right direction) acceleration norm > 0.65 [G] **Measured every 1 second**

- **Reversal judgment:**

  Z-axis (board vertical direction) acceleration sensor value < 0.8 [G] **Measured every 1 second**

- **Stack judgment:**

  Average of the past 5 recordings < 1.0 [m] **with GNSS recording every 5 seconds**

If a rollover or reversal is detected, the mission is temporarily interrupted and a return operation is performed using the tires and servo motor.

a. Unexplored area search subsequence •

Summary

In order to safely explore unexplored areas using the launched rover, which serves as the main unit, multiple slave units collect safety evaluation data and use that data to generate the best route. Run. The specific flow is shown below, and an image diagram is shown in Figure 4.4.3. 1. **In order for the parent device to**

place the child devices around the parent device and perpendicular to the direction in which the parent device wants to proceed (goal direction), the parent device calculates the GNSS coordinates and places the child devices in each child. The data is sent

to the machine, and the slave machine runs. 2. **The base unit generates search coordinate points for the slave unit from within a specific range that is an unexplored area set in the direction of the goal, sends the coordinate points to the slave unit to search, and collects safety evaluation data. collect.**

3. **Based on the collected safety evaluation data, the base unit searches for the best route that is considered to be safe and runs the base unit along that route. The handset is**

Send your coordinates to the base unit, have the base unit derive the best route from that point, and send it back to the slave unit. The slave unit then travels along that route to the next initial position. 4. Repeat steps 1.

to 3. **until the parent device reaches the goal.**

Note that during the execution of this subsequence, the child device becomes too far away from the parent device and becomes unable to communicate (after **120 seconds of being unable to receive any data, the connection confirmation command is issued).** If **a message is sent and there is no response for 120 seconds ,** it is determined that communication is not possible), or if the slave unit rolls over or flips over, it becomes impossible to continue the mission. **If this occurs, cancel the pairing between the parent device and the child device and stop the program on the child device.**

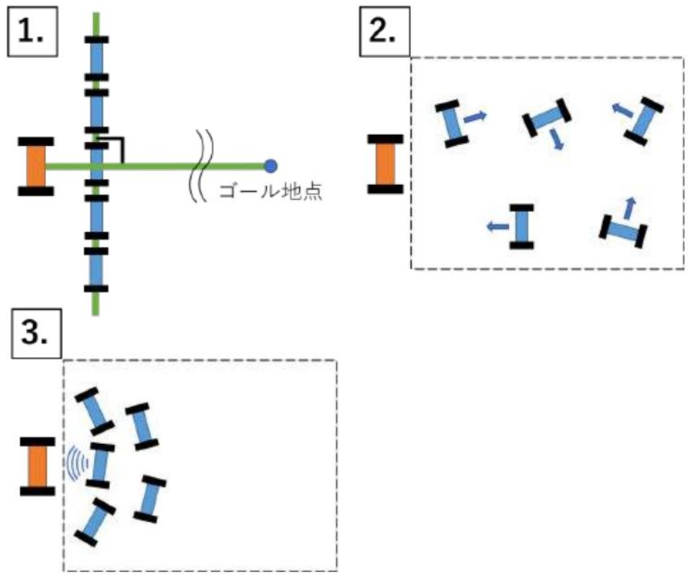

Figure 4.4.3 **Image diagram of unexplored area search subsequence (orange: master unit, blue: slave unit)**

• **Initial placement guidance for**

child units Before searching, the parent unit sends a command to align the child units in the direction of the goal as seen from the parent unit and perpendicular to the straight line connecting the parent unit and the goal (Figure 4.4.4) . Specify the latitude and longitude of each handset to specify its location. **The specific flow is shown below.**

0.Number **of slave units, distance between base unit and center slave unit (hereinafter referred to as center slave unit), distance between slave units and slave units**

The separation is predetermined (Figure 4.4.4).

1. **From the azimuth angle ÿ of the goal as seen from the base unit, the angle ÿ between the straight line connecting the base unit and the goal, and the straight line connecting the base unit and the point where the slave unit is placed, the position of the slave unit as seen from the base unit is determined . Find the azimuth of the point (Figure**

4.4.5). 2. **From the azimuth of the point where the handset is placed, the distance between the base unit and the center handset, and the distance between the handset and handset, calculate the x -axis parallel to the latitude line and the y-axis parallel to the longitude line with the base unit as the origin.** Find the coordinates **of the point where the slave device is placed in the used coordinate system (referred to as**

the rover coordinate system) . (Figure 4.4.6) 3. **From these coordinates and the latitude and longitude of the parent unit, determine the latitude and longitude of t**

Find. 4. **The**

parent unit directs the slave unit to the latitude and longitude.

5.1 . **~ 4. Perform this for all slave devices.**

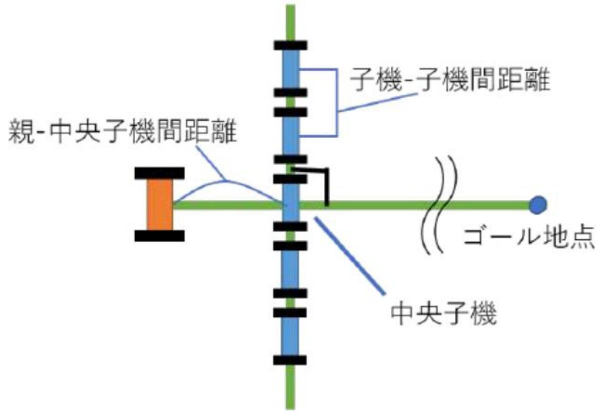

Figure 4.4.4 **Initial arrangement (orange: parent unit, blue: slave unit)**

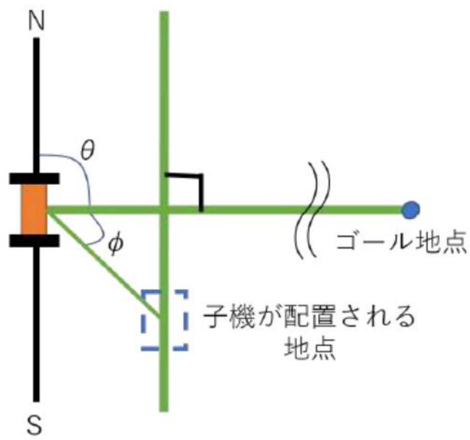

Figure 4.4.5 **Azimuth of the point where the slave unit is placed as seen from the base unit (orange: base unit)**

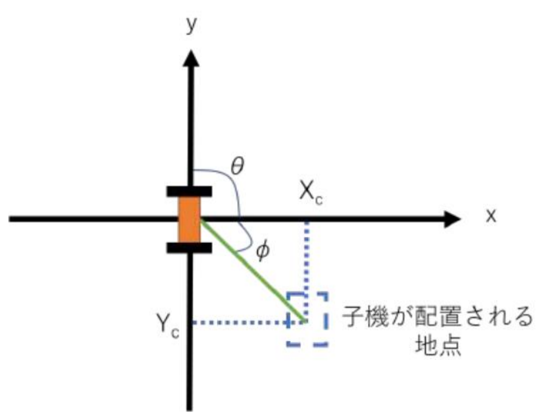

Figure 4.4.6 Rover coordinate system (orange: parent unit)

• Slave unit search command

In order to avoid collisions between the slave units as much as possible and to eliminate uneven search locations, the slave unit searches for target coordinates one after another from the base unit that has aggregated the information of the slave units. teeth

Drive to each target point while conducting the following safety evaluations. The specific flow is shown below.

1. The child reaches the target coordinates specified in the parent unit after reaching the initial position or before

The machine (called A) requests the next target coordinates from the base machine.

2. The base unit generates target coordinate candidates for multiple directions and distances from the coordinates of A. concrete

There are a total of 51 targets from the current coordinates, which are a combination of 5, 10, and 15 [m] and 17 azimuths

obtained by dividing one revolution (360 degrees) into 17 equal parts starting from a certain azimuth generated

by a random number. Generate as a

coordinate candidate. 3. Exclude those that meet the following conditions from target coordinate

candidates. • The target point is outside the specified search area •

The line segment connecting the coordinates of A and the target point intersects at least one line segment

connecting the coordinates of a slave device other than A at that point and the target coordinates (or

Considering the GNSS coordinate error , the line segment is actually given a width of 5 [m])

4. Among the remaining target coordinate candidates, select coordinates with less safety evaluation data around the

target coordinate. Send this to A as the next target coordinate.

5. After receiving the next target coordinates, A starts searching. (Run step 1 again as soon as you reach the target point)

Also, Figure 4.4.7 illustrates the above flow, and 1. to 4. match the numbers in the diagram . (5. is omitted)

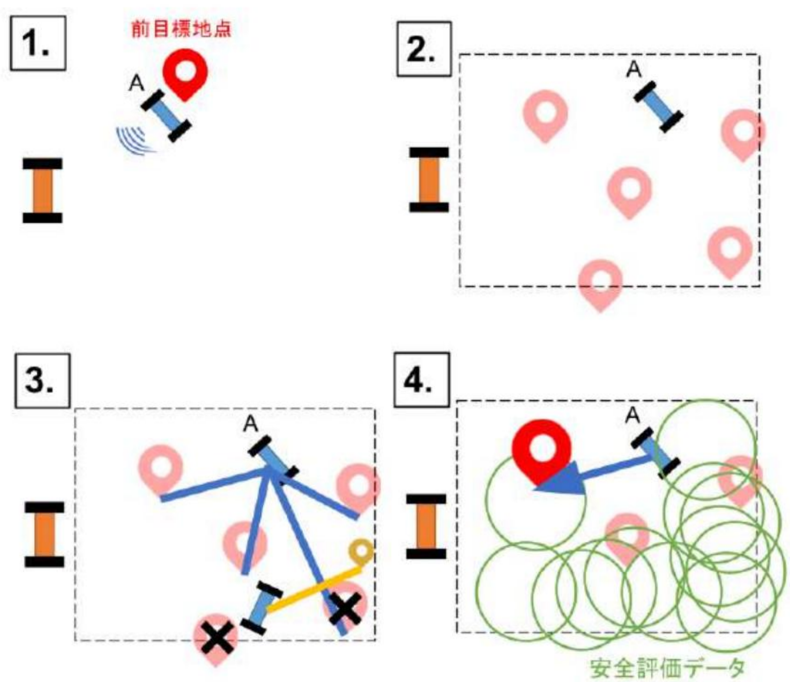

Figure 4.4.7 Child device search command

(orange: parent device, blue: child device (especially the child device where A seeks the next target)

• Safety evaluation

When the slave unit is heading toward the target coordinates, **the route it has traveled is evaluated once every 5 seconds (*) based on the acceleration sensor values during that time. The evaluation is based on the following results confirmed in preliminary experiments.**

If the terrain is rough, the variance ÿ of the acceleration during running is large. If the ground is bumped into, the variance of the acceleration while running is small.

In addition, since the stuck judgment that occurs when the vehicle enters an area where it cannot drive, such as tall grass, is important for safety evaluation, the stuck judgment, reversal judgment, and rollover judgment are checked separately from the above evaluation formula. However, it is evaluated as a ground with major problems.

Regarding the preliminary experiment, four types of terrain around the university (hereafter referred to as ``rough concrete (Figure 4.4.8)'', ``flat concrete (Figure 4.4.9)'', ``flat sandy ground** (Figure 4.4.10)'', and `` **We calculated the variance of the acceleration values obtained from the driving test data on a sandy area with hills (Figure 4.4.11) . **The terrain was rough because the higher the dispersion, the less stable the speed. In addition, since if you are hit, you will remain in place, so if the dispersion of velocity is low for a certain period of time, the terrain will be easier to hit.**

Figure 4.4.8 **Rough concrete**

Figure 4.4.9 **Flat concrete**

Figure 4.4.10 **Flat sandy land**

Figure 4.4.11 **Sand land with hills**

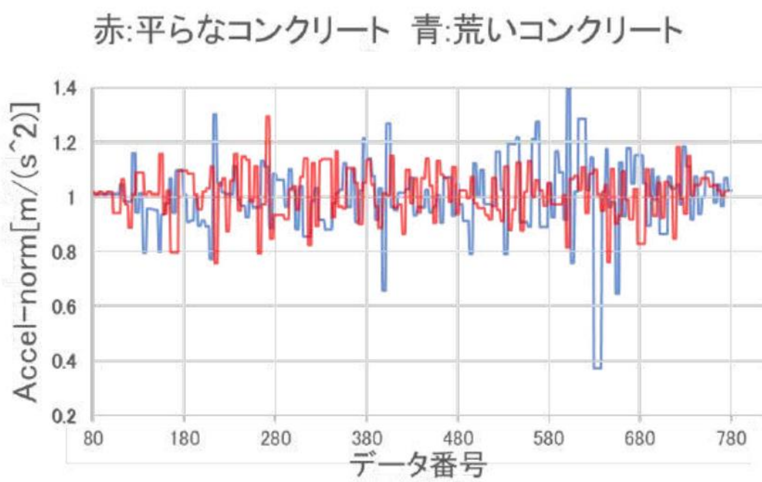

Figure 4.4.12 **Change in acceleration obtained in driving experiment (concrete)**

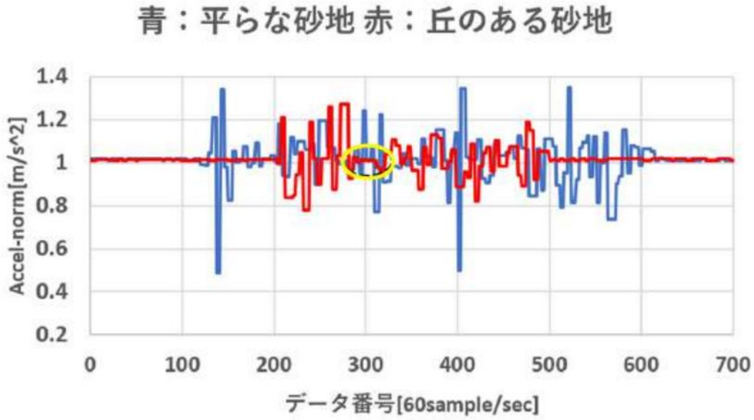

Figure 4.4.13 **Change in acceleration obtained in driving experiment (sandy ground)**

Figure 4.4.12 shows the changes in acceleration obtained in driving experiments in two types of concrete environments with different roughness. The vertical axis is the acceleration norm, and the horizontal axis is the data number. As can be seen from the figure, when comparing the two environments , it can be clearly seen that in "Rough Concrete", the acceleration norm fluctuates greatly and the running becomes unstable, especially in the latter half of samples 500 to 680.

Similarly, Figure 4.4.13 **shows the acceleration trends obtained in driving experiments in two sandy environments with different relief . Focusing on the acceleration of the "sandy area with hills" (red) in the range surrounded by the yellow circle** (270 to 320 samples) in this **figure, the acceleration reaches 1.3 just before the circle, then around 1.0 for a while, then** 50 **It can be seen that the value of the sample fluctuates around 0.9** ~ 1.1. **This is the timing when the handset is running on a sandy hill and getting stuck in the sand. When the handset gets stuck in the sand, it cannot increase speed and tends to stagnate there, so the norm of acceleration inevitably** approaches 1. **In order to treat areas such as ``rough concrete'' and ``sandy soil with hills'' as unsuitable for driving, and to remove them from the driving route of the main unit, we set a standard formula for evaluation values based on the preliminary experiment data.**

.

The evaluation function set this time is as follows.

$$Safety\ Evaluation = \begin{cases} -5000\left(\dfrac{a-M}{M}\right)^3 & if\ a \leq M \\ 4000(a-M)^3 M^{0.1} & otherwise \end{cases}$$

a is the average of the variance of acceleration for each of the past 30 samples (approximately 1 second) over the past 1 second (the average is used to ensure that instantaneous collisions are reflected in the safety evaluation data), and M is the threshold , and M=0.5. If you plot this graph , it will look like Figure 4.4.14.

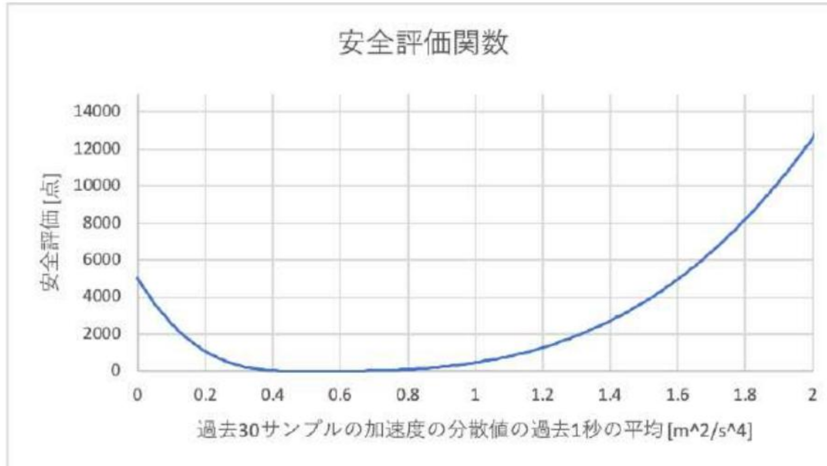

Figure 4.4.14 **Safety evaluation function**

The lower the safety evaluation value in this figure, the higher the safety . Looking at the figure, the value increases when the average of the past 1 second of the variance value is close to 0 or exceeds 1.0, but these correspond to "ground that bumps into" and "rough ground", respectively, and are safe on each. The evaluation value is large (low safety) . The reason why the lower the safety, the higher the safety evaluation value is, is that it is used as the travel cost in the Dijkstra method used to derive the best route.

In addition, this evaluation is linked to the GNSS coordinates at the time of the evaluation, but **considering the error of the GNSS coordinates, which is approximately 5 m in radius , the evaluation is performed within a circle with a radius of 5 m** (hereinafter referred to as the safety evaluation circle).) **are treated as having the same evaluation. The safety evaluation circle is represented by elements as shown in Figure 4.4.15. The circle has information on the evaluation value, coordinates (latitude and longitude), and azimuth . By sending this data to the base unit, it becomes the information source for searching for the best route. Regarding duplication of safety evaluation circles, etc., details will be described in the next section, ``Derivation of the best route."**

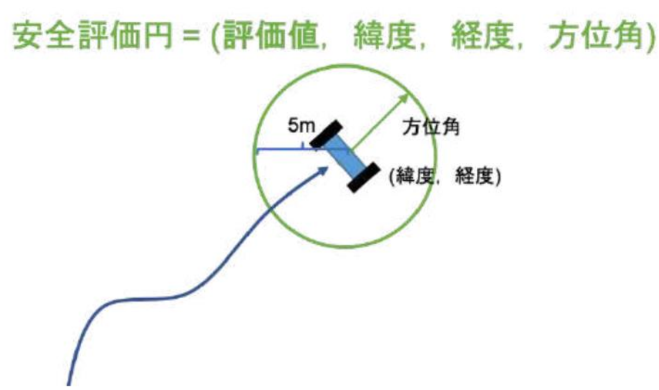

Figure 4.4.15 **Safety evaluation circle**

***"About 5 seconds" is a value that depends on the time interval during which continuous LoRa communication between multiple aircraft is** possible. **It is desirable to be fast.**

However, considering the GNSS error and the traveling speed of the slave unit, it does not need to be extremely fast.

• **Deriving the best route**

The base unit searches for the best route based on the safety information collected by the slave unit. This time, we used Dijkstra's method to find the shortest path. Dijkstra's algorithm is an algorithm that finds a path that minimizes the weight of a graph of nodes and edges when each edge has a weight. It is known that when searching for a route using brute force, the calculation becomes enormous as the scale increases, but the route can be found efficiently by using the following steps of Dijkstra's algorithm.

1. **Let V be the entire set of vertices, and let** S be the set of vertices for which the shortest path (shortest distance) from the starting point has already been determined.
2. **Among the vertices whose path is currently known, move the vertex p whose distance from the starting point is the minimum to S. (Figure 4.4.15.ÿ)**
3. **For each vertex remaining in V that is in contact with vertex p, update the shortest distance from the starting point based on the shortest distance already found. (Figure 4.4.15.ÿ)**
4. **Repeat steps 2 and 3 until the shortest path from the starting point to all vertices is determined (until V becomes empty) .**

This time, the node divides the specified search area from the base unit into a grid pattern, and uses GNSS to create the node. A code is installed. Also, the edge does not have a direct weight, but the difference in node evaluation between two points is used as the weight of the edge between those two points. Note that this method cannot be applied when the weights are negative . Figure 4.4.16 below shows the procedure **for** the general Dijkstra method , and shows how to calculate the shortest path from the starting point A to the ending point E with the smallest total movement weight. **Figure 4.4.17 is an image of the generation of nodes and edges for applying Dijkstra's method in this best route search . The specified search area is divided into a grid of 5 m in length and width, and the intersection points are converted into latitude and longitude.The nodes are the nodes, and the edges connect the minimum two and maximum four nodes closest to each node . be. Also, the weight of each side can be found using the safety evaluation circle described in the previous section. Specifically, we extract the safety evaluation circle that overlaps the latitude and longitude of each node, and calculate the average of the evaluation values. At this time, a weighted average is used to calculate the difference between the theoretical azimuth from the previous node and the current node and the azimuth of the extracted safety evaluation circle. In particular, the closer the azimuth of the safety evaluation circle is to the theoretical azimuth, the more important the evaluation results will be. The best route is calculated by** applying Dijkstra's algorithm **to these nodes, edges, and the weights of each edge based on the safety evaluation** as shown in Figure 4.4.18. **In this case, the starting point is the grid point where the current parent machine coordinates are closest, and the goal is all the grid points on the right side (the best one among the calculated best routes is adopted).**

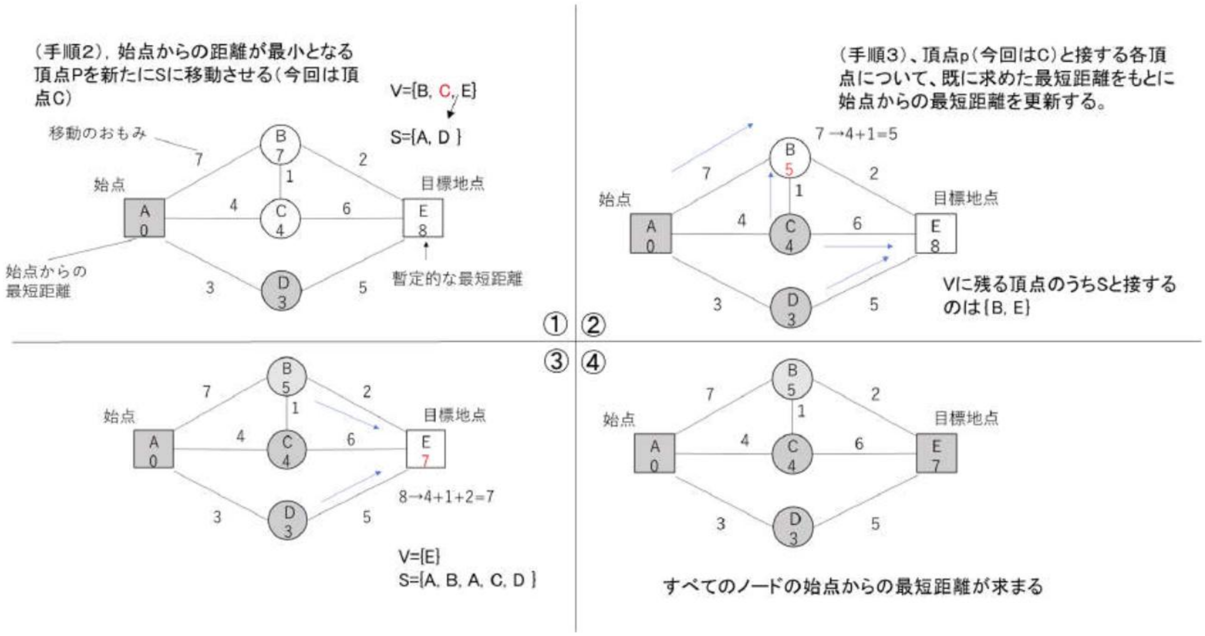

Figure 4.4.16 **Dijkstra method**

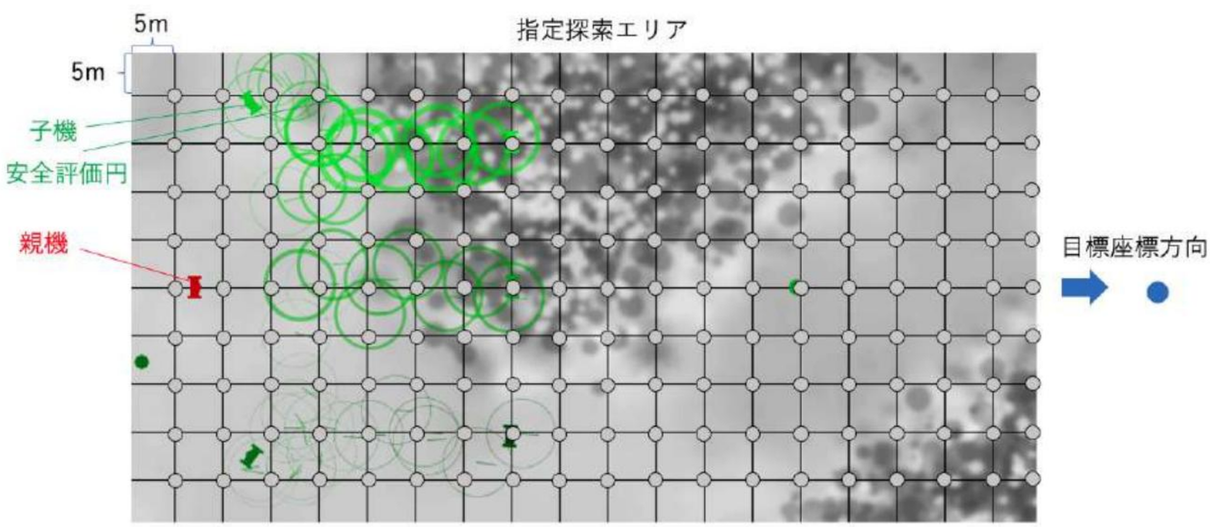

Figure 4.4.17 **Image of node and edge generation of Dijkstra method in search**

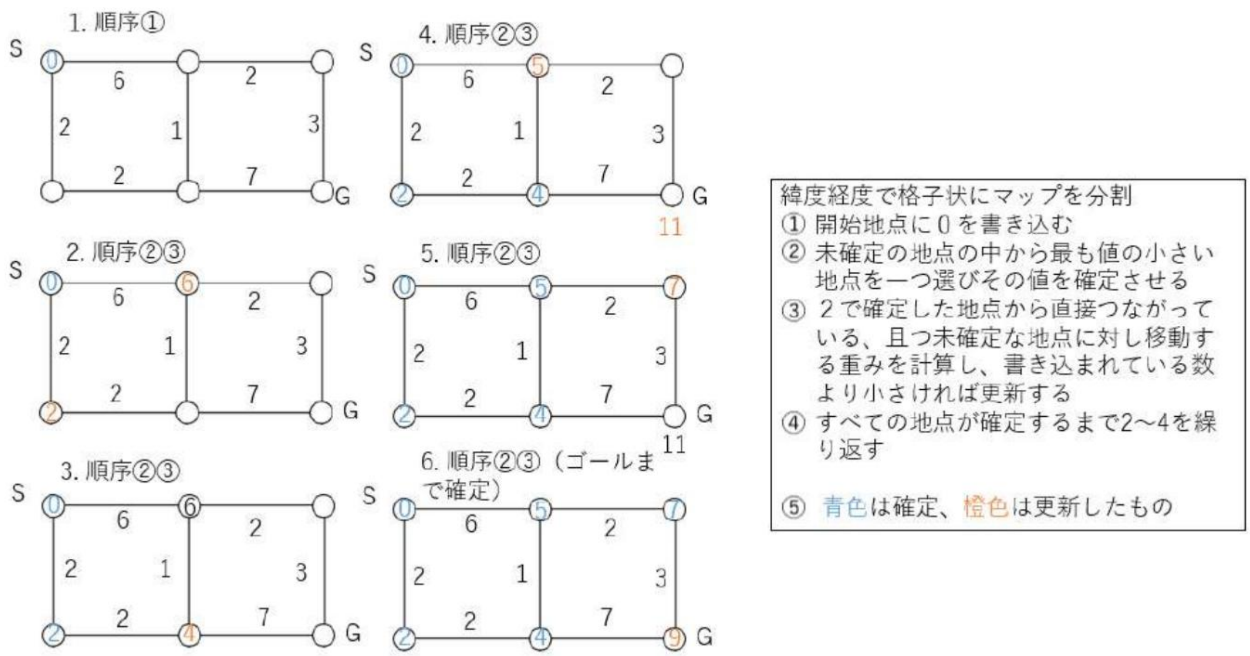

Figure 4.4.18 **Application of Dijkstra method to lattice points**

• Moving the parent device and child device

The base unit sets multiple relay target coordinates that follow the route found in the best route search. and travel to the final target coordinates. The child device sends its coordinates to the parent device and From the base unit, select multiple relay target coordinates that take the best route from one point to the next initial position. The route is then sent to the slave device and the vehicle runs along that route.

Chapter 5 **Test item settings**

number	Verification item name	Corresponding self-examination items Request number(s)	Scheduled implementation date
V1	**Mass test**	S1	6/25
V2	**Aircraft storage and release test**	S2	6/25
V3	**Quasi-static load test**	S3, M10	7/1
V4	**Vibration test**	S4	7/29
V5	**Separation impact test**	S5	7/29
V6	**Opening impact test**	S5, M10	7/1

V7	**parachute drop test**	S6	6/1
V8	**Long distance communication test**	S7	7/31
V9	Communication device power ON/OFF test	S8	6/23~6/25
V10	**Communication frequency change test**	S9	6/23~6/25
V11	End-to-end exam	S10	8/5
V12	**Landing impact test**	M1, M10	6/28
V13	**Driving performance confirmation test**	M2	7/22
V14	**Power durability test**	M3	7/1
V15	**Inversion rollover recovery test**	M4	7/2
V16	**Communication establishment test between parent unit and slave unit**	M5	7/19
V17	**Best route derivation test**	M6, M8	7/30
V18	**Handset route evaluation test**	M7	7/29
V19	**Handset initial position placement test**	M9	7/30
V20	**Number of handset variation test**	M11	8/3
V21	**Specified route driving test**	M12	7/29
V22	**Control history report creation test**	M13, M14	8/5

Chapter 6 **Examination Contents**

1. Test content to meet system requirements

v1. Mass test

• Purpose :

Confirm that the combined mass of the base unit and parachute satisfies the specified mass of 1050 [g] or less. •

Test details

Measure the base unit and parachute with a mass meter and **confirm that the mass is less than the mass stated in the regulations** (1050 [g]). • Results

The total

weight of the main aircraft and parachute **was 911 [g], including the two hot bonds used to reinforce the completed aircraft , which was confirmed to be less than the regulation of 1050 [g]. Figures 6.1.1 to 6.1.4 show the mass measurement results.**

Figure 6.1.1 **Mass of parachute and parent unit**

Figure 6.1.2 **Mass of base unit only**

Figure 6.1.3 **Mass of parachute only**

Figure 6.1.4 **Mass of two hot bonds**

In addition, a video link of the mass test is shown below. •

Link https://youtu.be/q3JYM_SeqOU

•

Considerations It was found that the total weight of the main unit, including the mass of the parachute, met the regulations.

v2. Aircraft stowage/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 • **Test content The following four items must be carried out .** (1) **Measure the inner diameter of the carrier into which the base unit will be placed.** (2) **Measure the height of the base unit.** (3) **Confirm that the base unit with deceleration function can be stored in and released from the carrier. Repeat this 5 times and confirm that there are no problems.** (4) **When storing the main unit, measure the time taken to store it and confirm that it can be stored within 5 minutes.**

• **Storage**

procedure 1. **Fold the**

parachute 2. **Gather the parachute string so that it does**

not get tangled 3. **Place the folded parachute on the side**

of the base unit 4. **Store it in the carrier**

• **Results**

Figure 6.2.1 shows how the inner diameter of the carrier was measured. The carrier used was the same size as the tournament-specified carrier (146 mm), and we confirmed that the base unit we developed could be stored in the carrier without any problems.

Figure 6.2.1 **Inner diameter of carrier**

Figure 6.2.2 shows how the main unit was measured. The height of the base unit is 238 [mm], **which satisfies the 240 [mm] limit stated in the regulations .**

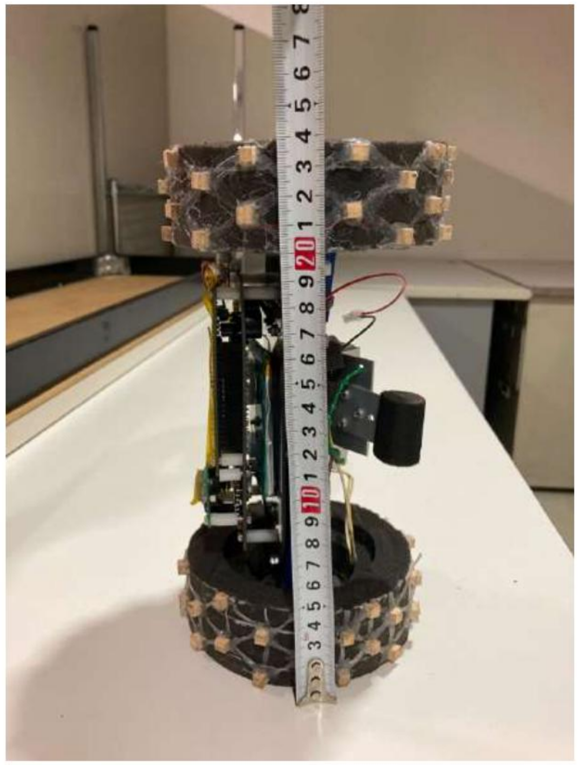

Figure 6.2.2 **Height of base unit**

As shown in Table 6.2.1, it was confirmed that 5 out of 5 times the main unit would be released due to its own weight after being stowed.

Table 6.2.1 **Results of carrier release experiment**

trial times	storage time	Release under self-weight	YouTube link
First time	1 minute 32 seconds	success	https://youtu.be/XzavsdyKfLQ
Second time	1 minute 31 seconds	success	https://youtu.be/o-OOvW863vA
3rd time	1 minute 45 seconds	success	https://youtu.be/U7KAbnW2FTs
4th time	1 minute 32 seconds	success	https://youtu.be/c4JoEtLezEE
5th time	1 minute 20 seconds	success	https://youtu.be/XpcPtM7DigE
success rate	100%(5/5)	100% (5/5)	

• **Consideration**

• **Based on the above results, the following three points were confirmed.**

1. **Meet regulations regarding carrier inner diameter and height**
2. **Smooth carrier storage and release is possible.**

3.The **process to store the base unit must be within 5 minutes.**

v3. Quasi-static load test

• **Purpose :**

Confirm **that the quasi-static load (hereinafter referred to as static load) at the time of launch does not cause any problems with the hardware and software of the parent unit** and that they operate normally.

• **Test details: The static load caused by a rocket is simulated by placing the base unit, which is assumed to be mounted on a rocket, in a bag with a string attached to it and turning it in the manner of throwing a hammer.** As **stated in Section 5.2 of the regulations, the static load is 10 [G] applied to the base unit in the height direction of the base unit for** 10 seconds. **After that, confirm that the hardware is not damaged. Additionally, by checking that each sequence operation from release determination to parachute separation operates normally, we confirm that there is no damage to the motor or servo motor. In addition, the sensor and motor outputs in this test are considered 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: The norm of acceleration when the aircraft is at rest is 0.95** [G] to 1.05 [G] (gravitational **acceleration** 1 **[G] ±5% allowable measurement error, and the x, y, and z axis**

values change depending on the aircraft's attitude. - Light sensor: Determines that the light is hitting when the light is being irradiated (sensor value indicates HIGH).•Buzzer: The sound can be turned on/off.•GNSS: **GNSS from one or more satellites. Receive information and confirm that the coordinates point to the test location.•LoRa: Check the transmission and reception of character strings from the base unit to the slave unit and from the slave unit to the base unit.**

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

This test was conducted three times in total, and by acquiring time series data of the magnitude of acceleration applied to the base unit for each trial, we confirmed that a static load of 10 [G] was applied. ÿÿ 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 6.3.4. In these figures, the horizontal **axis shows time and the vertical axis shows the L2 norm [G] of acceleration.** From these graphs, **it can be confirmed that a static load of approximately 10 [G] or more is applied for more than 10 seconds by swinging the base unit .**

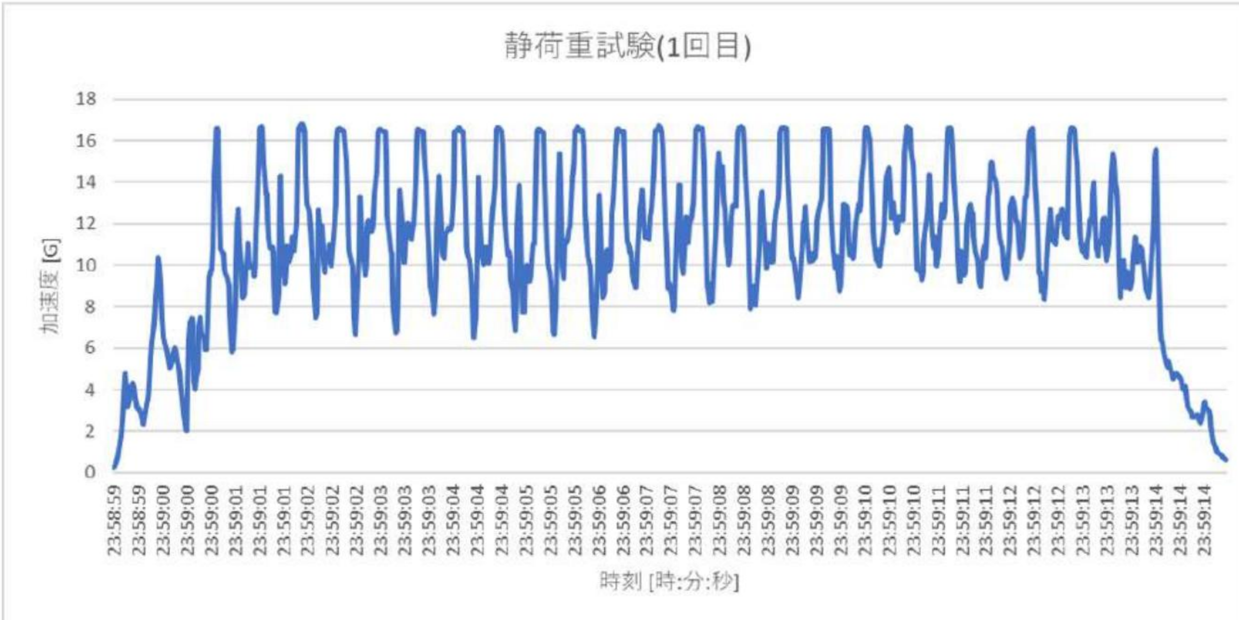

Figure 6.3.1 **Acceleration graph for the first static load test**

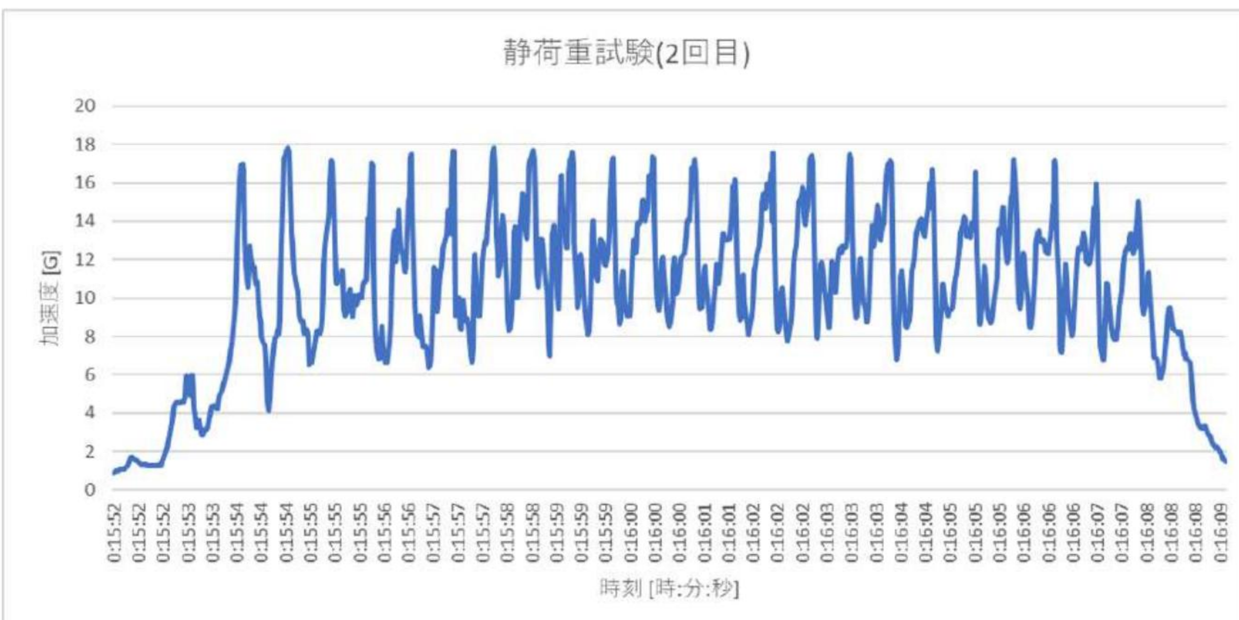

Figure 6.3.2 **Acceleration graph for the second static load test**

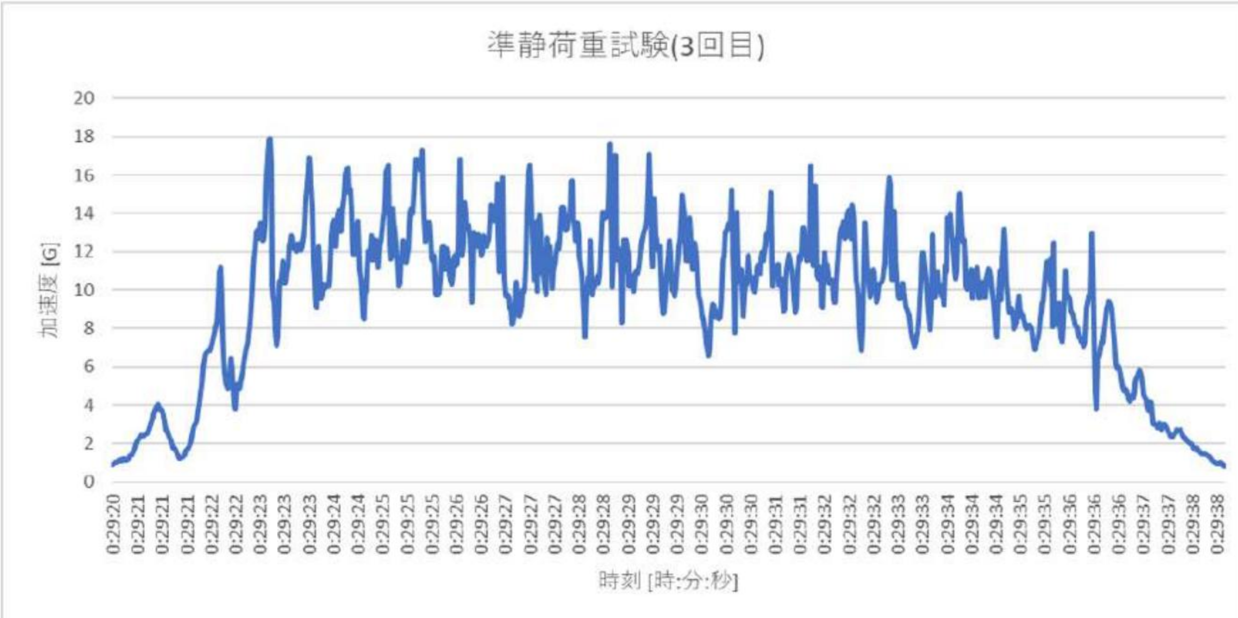

Figure 6.3.3 **Acceleration graph for the third static load test**

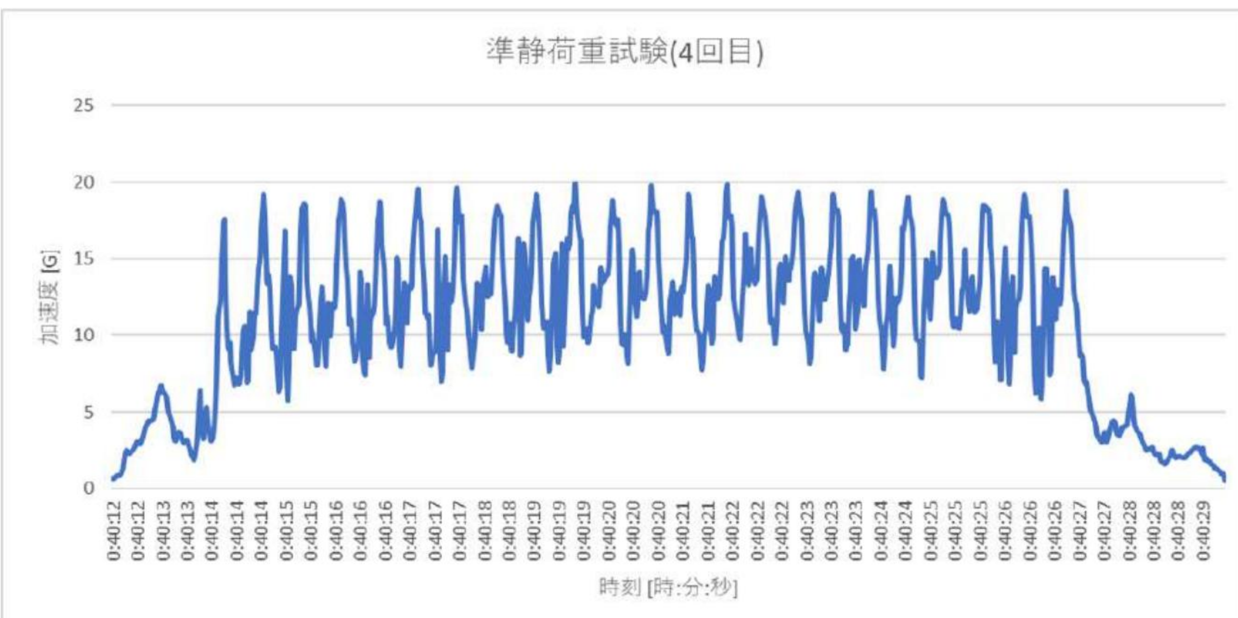

Figure 6.3.4 **Acceleration graph for the fourth static load test**

Table 6.3.1 shows the damage to the main unit and the presence or absence of failure of each part after applying a static load.

Table 6.3.1 **Static load test results**

Number of times	Sequence Operation	External damage to the base unit	Motors	Sensors	YouTube video Link
1st time	Transition normally	Normal	Normal	No problem	https://yout u.be/ ZO7gl MWg8FE
2nd time	Transition normally	Normal	Normal	No problem	https://yout u.be/ bDRo ay1Y1Z8
3rd time	Transition normally	Normal	Normal	No problem	https://yout u.be/ txsgxL fw4dk
4th time	Transition normally	Normal	Normal	No problem	https://yout u.be/ E3x6A cTqckI
Success rate	100% (4/4)	100% (4/4)	100% (4/4)	100% (4/4)	

***We confirmed that the GNSS sensor obtained normal values after the quasi-static load test. The video from that time is posted below.** GNSS sensor confirmation video: https://youtu.be/qvrRHaB9VMc

- **Considerations The above results confirmed that the base unit can withstand a static load of 10 [G] and operates normally without any hardware or software problems caused by the shock during launch .**

v4.Vibration test

- **Purpose:**

  Assuming a launch using a rocket, confirm that no abnormalities will occur in the main unit due to the vibrations generated during launch.

- **Test details**

  The main unit is stored in a carrier, and a vibration testing device is used to apply random vibrations that occur when the rocket ascends. After the test, we carry out the sequence from parachute detachment to flight, check the operation of all sensors and power systems, and check for damage to the main unit. The details of the vibrations to be applied are as follows.

  10G random vibration ranging from 30Hz to 2000Hz

  (This is also written as 15G in the latest regulation version, but

It is recognized **that it is quite difficult for the participating organization MTG to emit a sine wave vibration of 15G, and the vibration has been changed to 10G. Please check with the operator.)**

We actually input the above settings into the vibrator and applied a load to the aircraft.

• **Results**

[1st time (implemented on

7/29)] Figure 6.4.1 shows the acceleration transition of the applied random vibration. The horizontal axis of the graph represents time [sec], and **the vertical axis represents acceleration [G]. Also, C indicates the target acceleration and A1 indicates the actually measured acceleration.**

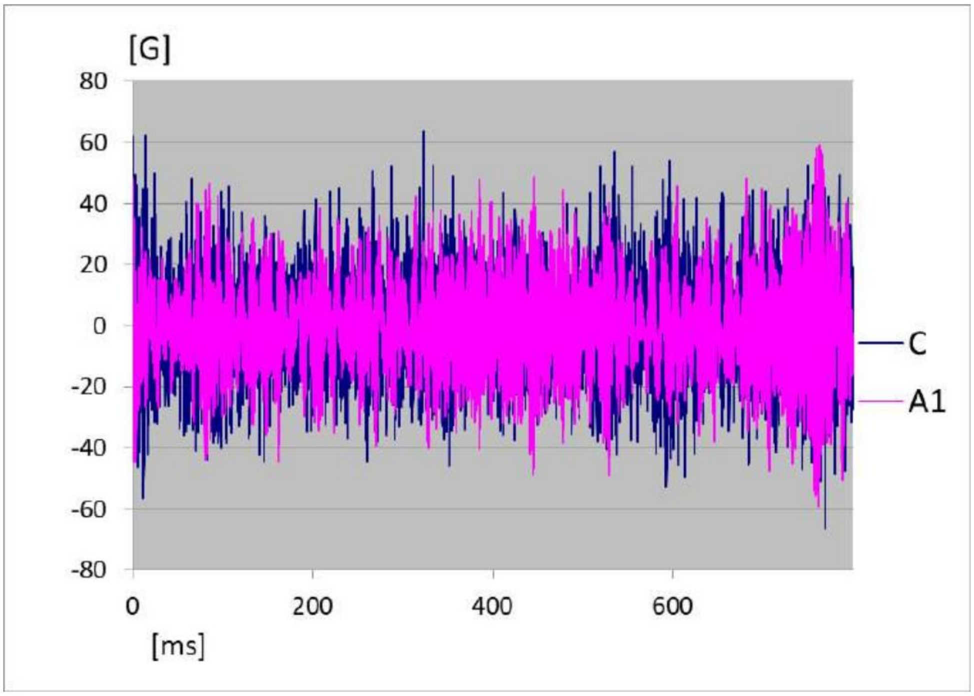

Figure 6.4.1 **Random vibration acceleration (second time)**

In addition, Figure 6.4.2 shows a PSD (power spectral density) graph for random vibration. **The vertical axis is acceleration rms [G^2/Hz], and the horizontal axis is each frequency [Hz]. In addition, the effective value of the random vibration this time was 14.6972 [Grms], which** satisfies the target value of 14.5903 **[Grms] for** the effective value when setting **the standards of the ARLISS CanSat division (added to the test content). The test can be executed.**

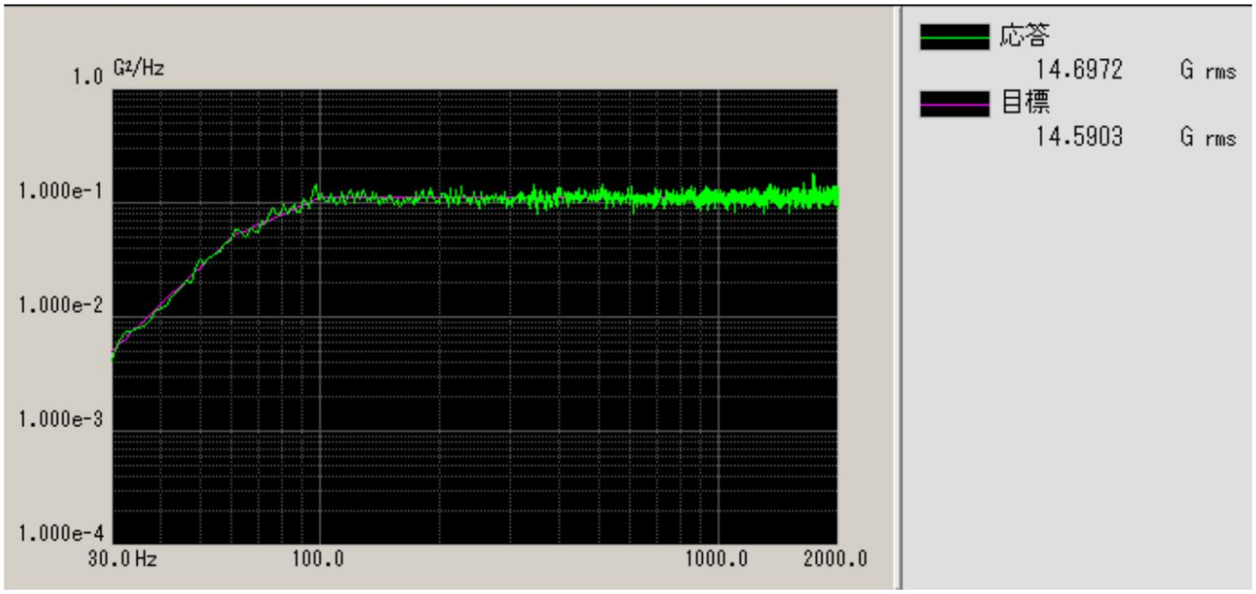

Figure 6.4.2 **PSD graph (second time)**

After applying vibration using a vibration testing device from the carrier storage, check whether the base unit operates normally. Below is a video of the experiment taken.

The times of each event in the video are shown below.

https://youtu.be/WcV-ZAsKR-8

0:00 ~ **Carrier storage** 2:50
~ **Weight measurement**
3:07 ~ **Preparation of vibration test equipment** 18:04 ~ **Start of random vibration** 25:30 ~ **Start of shock vibration** 31:50 ~ **Carrier release** 32:05 ~ **Fall judgment** 33: 14 ~
Landing judgment 33:35 ~ **Parachute detachment (failure) (obtaining light, acceleration, gyro sensor values and barometric pressure sensor values)** 34:40 ~ **Confirm transition to mission sequence (confirm normal operation of LoRa)** 36:09 ~ **Confirm that there is no damage to the main unit** 37:25 ~
Check the drive system (not working) 38:00 ~ **Investigate the cause of the drive system not working** 40:45 ~ **The cause is the connector that supplies power from the motor battery. Confirmed possibility of poor contact** 41:38 ~ **Oral explanation of current view of the cause of the drive system not working** 42:45 ~ **Each sensor (GNSS, 9-axis sensor, barometric pressure sensor, light sensor, buzzer, LoRa,)**

Table 6.4.1 below shows the confirmation results of various operations.

Table 6.4.1 **Vibration/separation impact test results**

	Release judgment	Landing judgment	Parachute separation	Navigation (until establishing communication)	Operation of sensors	Motor and servo motor operation
Result	Success	Success	Failure (motor and servo do not operate)	Success	Normal	Failure (motor and servo do not operate)

[Second time (implemented on 8/19)] • **Figure 6.4.3 shows the acceleration transition of the second random vibration applied.**

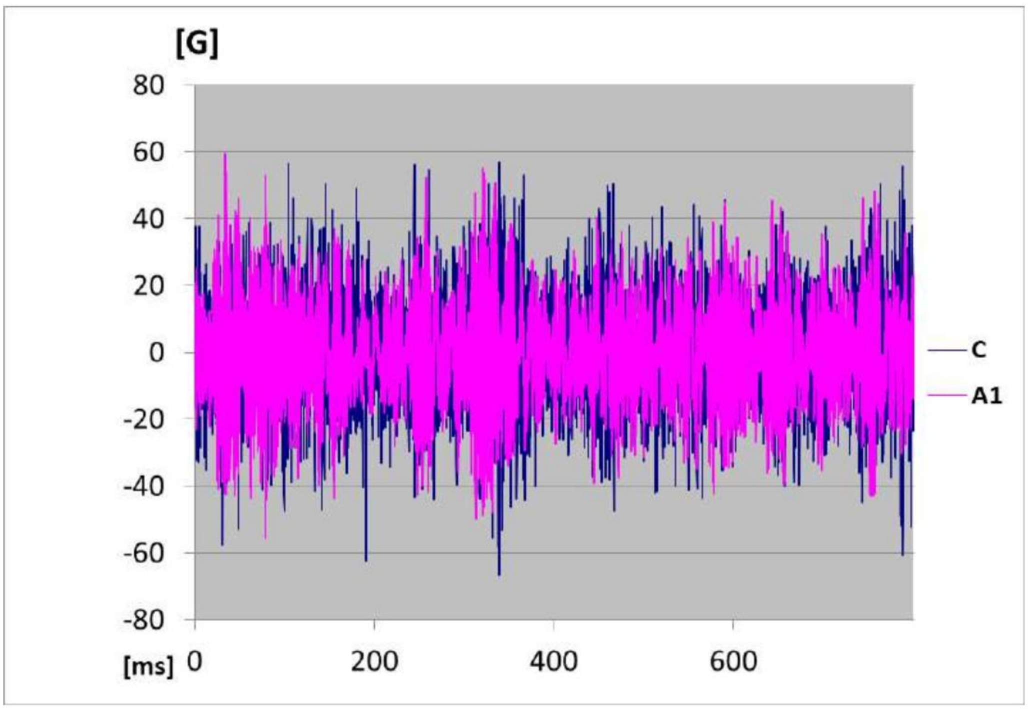

Figure 6.4.3 **Random vibration acceleration (second time)**

In addition, Figure 6.4.4 **shows** the second result of the PSD (power spectral density) graph for random vibration . **The effective value of the second random vibration was 14.6528 [Grms], and the test was performed with a standard that met** the target value of 14.5903 [Grms] **for the effective value when setting the standards of the ARLISS CanSat division (added to the test contents). is made of.**

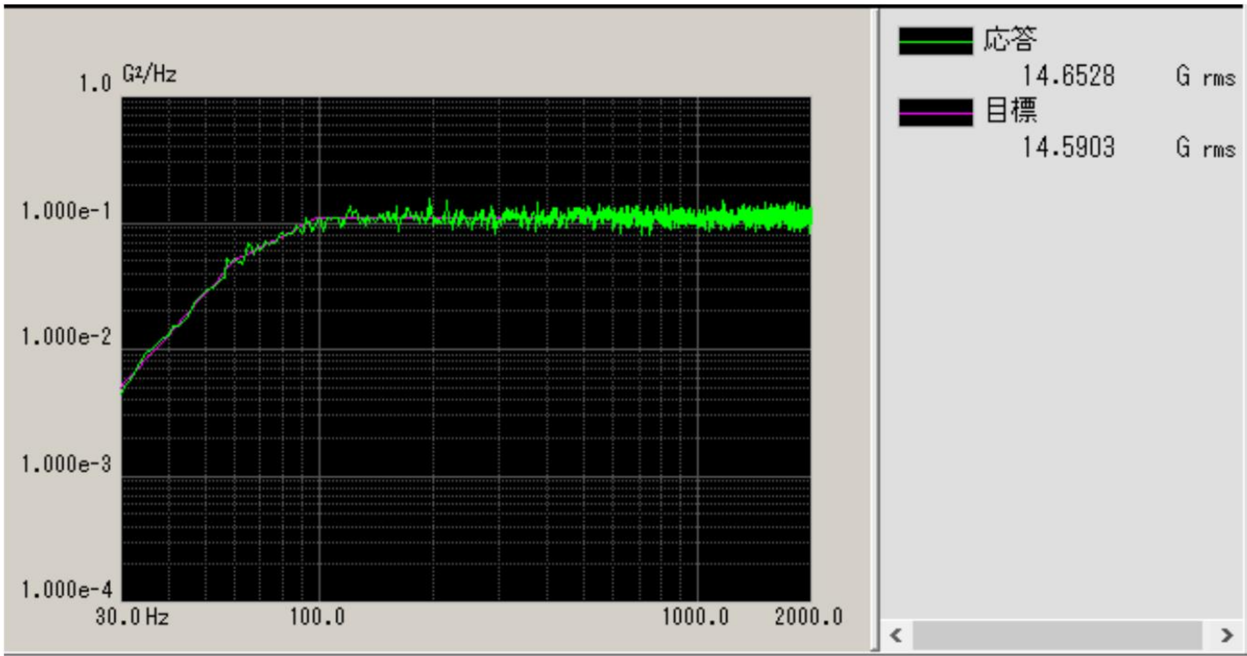

Figure 6.4.4 **PSD graph (second time)**

After applying vibration using a vibration testing device from the carrier storage, check whether the base unit operates normally. Below is a video of the experiment taken.

The times of each event in the video are shown below.

https://youtu.be/sL6krjd4_aw

0:00 ~ **Carrier storage** 2:10
~ **Weight measurement**
3:05 ~ **Preparation of vibration test**
equipment 29:40 ~ **Start of random**
vibration 34:40 ~ **Start of shock**
vibration 41:45 ~ **Carrier**
release 42:40 ~ **Fall**
judgment 42: 50 ~
Landing judgment 43:05 ~ **Parachute**
detachment 43:50 ~ **Confirm transition to mission sequence (confirm normal operation of**
LoRa) 44:35 ~ **Confirm that there is no damage to**
the main unit 45:40 ~ **Confirm**
drive system 46:02 ~ **Each sensor (GNSS, 9-axis sensor, atmospheric pressure sensor, light sensor,**
buzzer, LoRa,) 48:44 ~ **Long**
distance driving confirmation 54:10 ~ **GPS confirmation**

Table 6.4.1 below shows the confirmation results of various operations.

Table 6.4.2 **Result of vibration/separation impact test (2nd**

	time) Release judgment	Landing judgment	Parachute operation	Separation Navigation (until establishing communication)	Disconnection	Motor and servo motor operation
Result Success	Success Success	Success Normal	Normal			

• **Discussion**

This time, as a result of adding random vibration in the vibration test and shock vibration in the isolated impact test, a problem was found in the drive system. As stated in the video, the likely cause was that the motor battery was not able to supply power. Below is a link to a video of confirmation of the aircraft's drive system after making minor adjustments to the connector part and the position of the battery inside the battery.

Drive system confirmation **after vibration test :** https://youtu.be/vJnb6g50QvI

As shown in this video, we were able to confirm that the motor and servo motor of the aircraft operated normally after making minor adjustments to the motor battery connector and the position of the battery inside the

battery. Based on the above, **it is thought that the flaw in this test was in the power supply from the motor battery . Therefore, during the actual ARLISS event, we will take measures such as repairing the connector and creating a new battery box to ensure that the connection is stable to prevent misalignment of the battery in the supply section and poor connection of the connector. We**

are also planning to retest on August 19th, where we will conduct another vibration test (v4) and separation impact test (v5) to confirm that the system requirements are met.

[Postscript after the second (8/19) exam]

After the first test, we reviewed the aircraft's battery box and made improvements to prevent batteries from shifting. Specifically, we increased the robustness of the power supply by inserting copper plates in areas where batteries would shift within the box and create spaces. We also carefully reinforced the connector part using hot bonding and other methods.

As a result, as mentioned above, we were able to confirm that all the check items were met without problems and that there were no problems with long-distance driving after checking the drive system and sensors. It was confirmed that the aircraft was able to withstand the load of separation impact.

v5. Separation impact test

• **Purpose**

When assuming a rocket launch, the impact of the rocket separation may cause abnormalities in the parent aircraft. Confirm that this does not occur.

• **Test content**

(V4) **Apply shock vibration of 40 [G] using the same vibration test equipment as in the vibration test . After the test, we confirmed that the sequence from release from the carrier, landing, parachute separation, and establishment of communication with the slave unit, and that the base unit operated normally. The type of shock is ARLISS regulation.**

According to item 1.4 of the section, **apply shock vibration in the negative direction: [Target]392** [m/s^2]->392/9.8 [1G]=40 [G].

• **Results**

[First test (held on Friday, July 29th)] **Figure 6.5.1 shows the acceleration transition of the shock vibration obtained by the aircraft. The horizontal axis is time** [sec] and **the vertical axis is acceleration [G].**

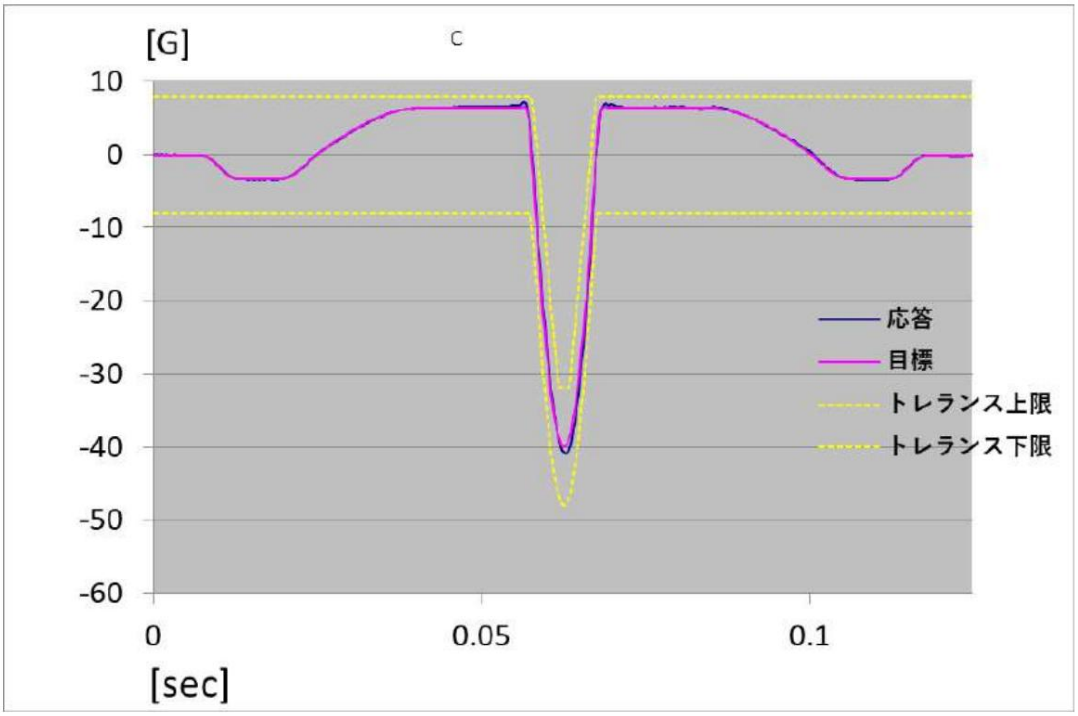

Figure 6.5.1 **Acceleration of shock vibration (1st time)**

After applying shock vibration, we confirmed whether the base unit operated normally. The results are the same as the (V4) vibration test , so they are omitted here. **Also, the experimental video for this test is the same as the (V4) vibration test.**

[Second test (conducted on Friday, August 19th)] **Figure 6.5.2 shows the acceleration transition of the shock vibration obtained by the aircraft in the second test .**

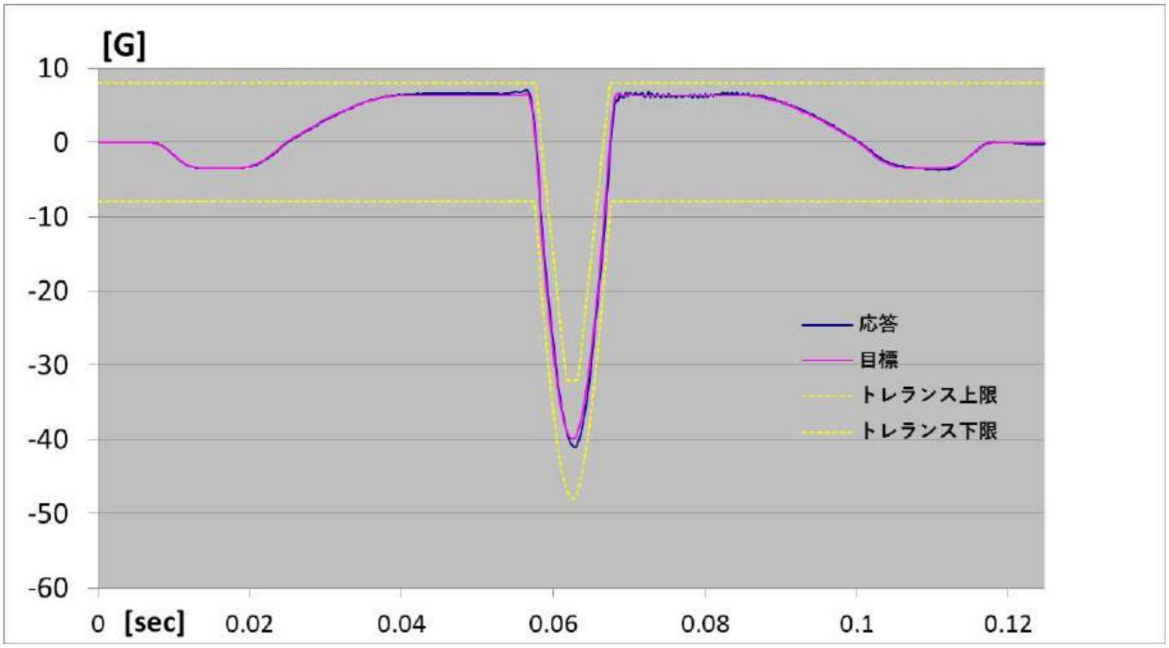

Figure 6.5.2 **Shock vibration acceleration (second time)**

After applying shock vibration, we confirmed whether the base unit operated normally. The results are the same as the (V4) vibration test , so they are omitted here. **Also, the experimental video for this test is the same as the (V4) vibration test.**

• Discussion

Since this was done at the same time as the vibration test, the description of the discussion will be integrated into the vibration test (v5).

v6. Umbrella opening impact test

• Purpose:

To confirm that the joint between the parent unit and the parachute can withstand the impact when the parachute is

opened. • Test

details Fix the base unit, 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 (12 [G]) when the parachute was opened . After applying the shock, we carry out the sequence from parachute release to flight, confirming the operation of all sensors and power systems, and checking for damage to the main unit. The value of 12** [G] **was independently set based on the acceleration log during the opening of the past ARLISS/ACTS. In addition, the sensor and motor outputs in this test are considered 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: The norm of acceleration when the aircraft is at rest is 0.95** [G] to 1.05 **[G] (gravitational acceleration** 1 **[G]±5% of allowable measurement error, and the values of the x, y, and z axes change depending on the attitude of the aircraft.•Light sensor: Determines that the light is shining under normal conditions (sensor value indicates HIGH), and manually** When **the light sensor**

is covered, it is judged that there is no light

(the sensor value shows LOW) . - Buzzer: The sound can be turned on/off. **- GNSS: Receives GNSS information from one or more satellites and Coordinates point to the test location**

•LoRa: Check the transmission and reception of character strings from the parent device to the slave device and from the slave device to the parent device

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

(Reference) Basis for **the acceleration (12 [G]) given in the umbrella opening impact test**

In determining the opening impact, the Salamander team's second pitch of ACTS2021 **The log of the lower test (Figure 6.6.1) was used as a reference. When we checked the magnitude of the acceleration at time [11:27:12] in the graph , it was 11.16 [G], and based on this we set it to 12 [G]. The parachute used by the Salamander team is the same as the parachute used in the main drop test, and it is expected that the same degree of impact from opening will be applied to it .**

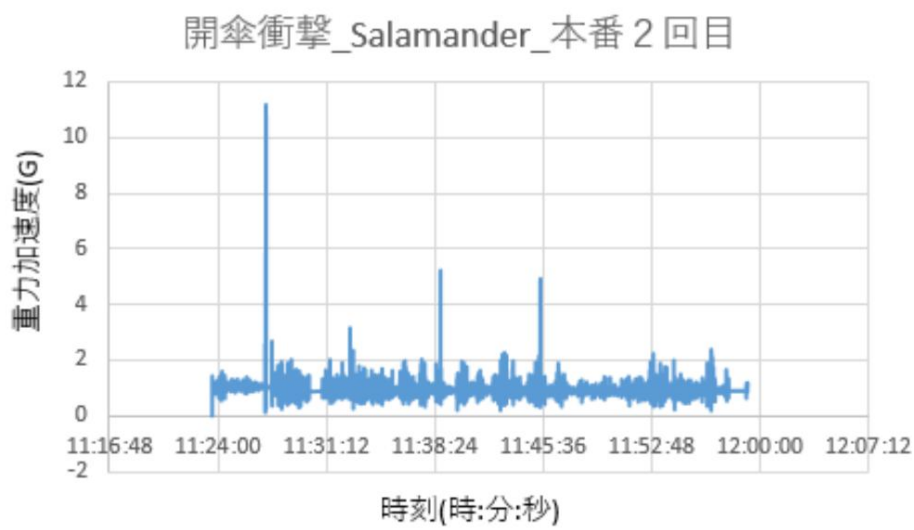

Figure 6.6.1 **Opening impact log** ACTS2021 Salamander **from the second drop test**

• **Results**

Graphs for each test are shown in Figures 6.6.2 to 6.6.4. The horizontal axis shows the elapsed time **[s], and the vertical axis shows the L2 norm of acceleration [G].**

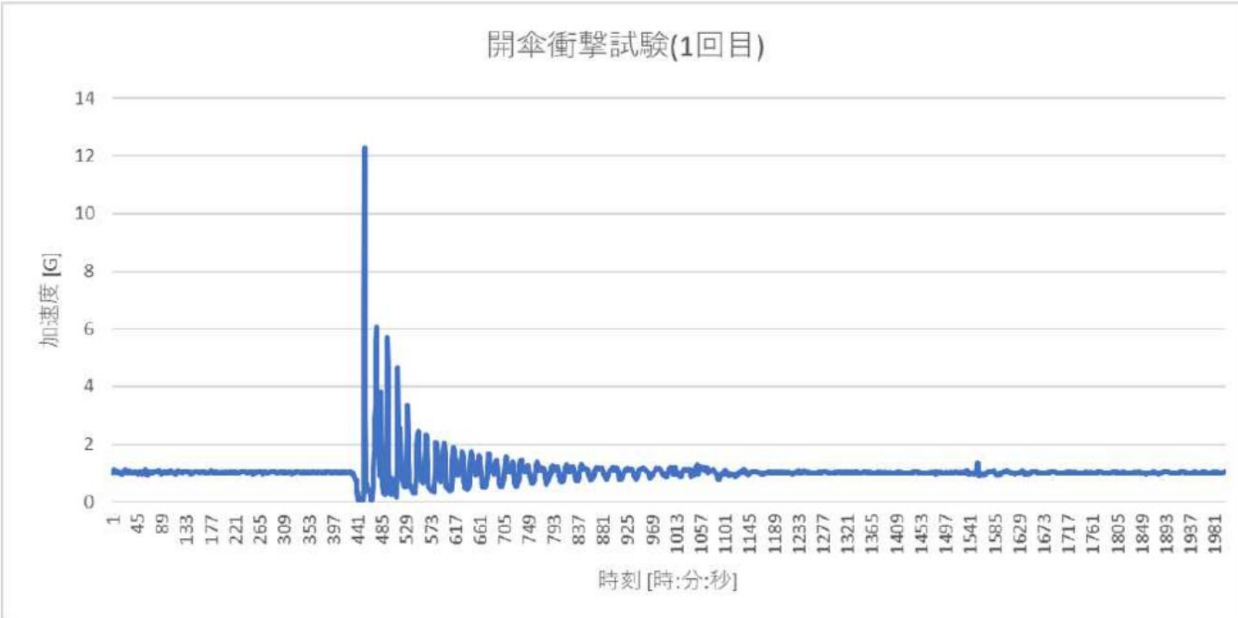

Figure 6.6.2 **Acceleration graph for the first opening impact test**

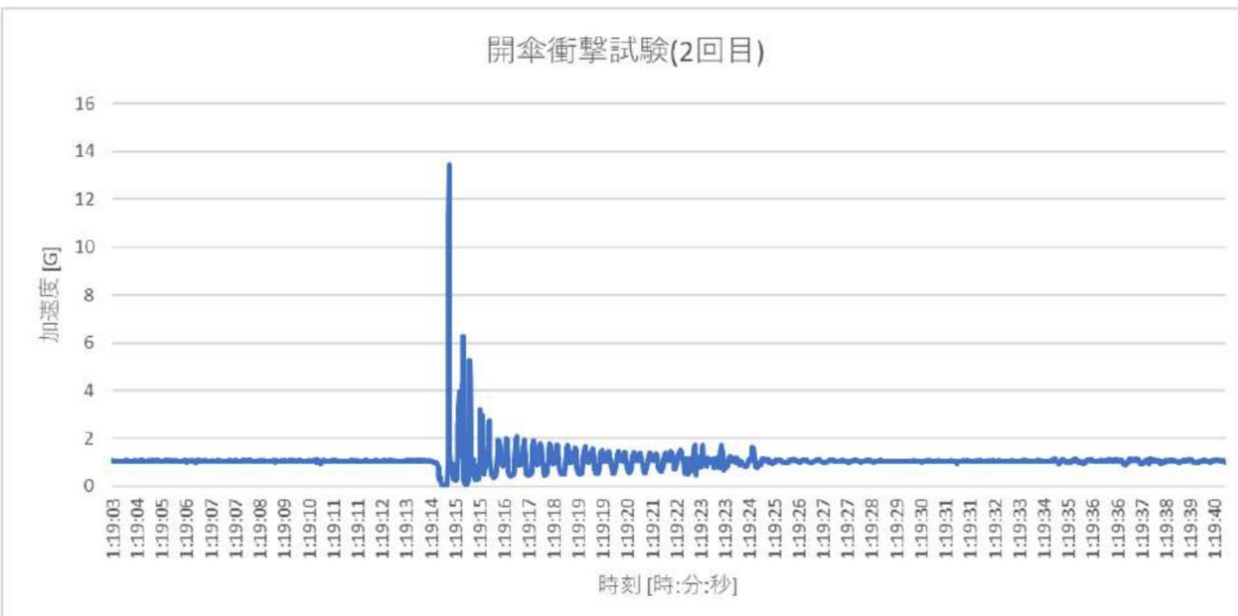

Figure 6.6.3 **Acceleration graph for the second opening impact test**

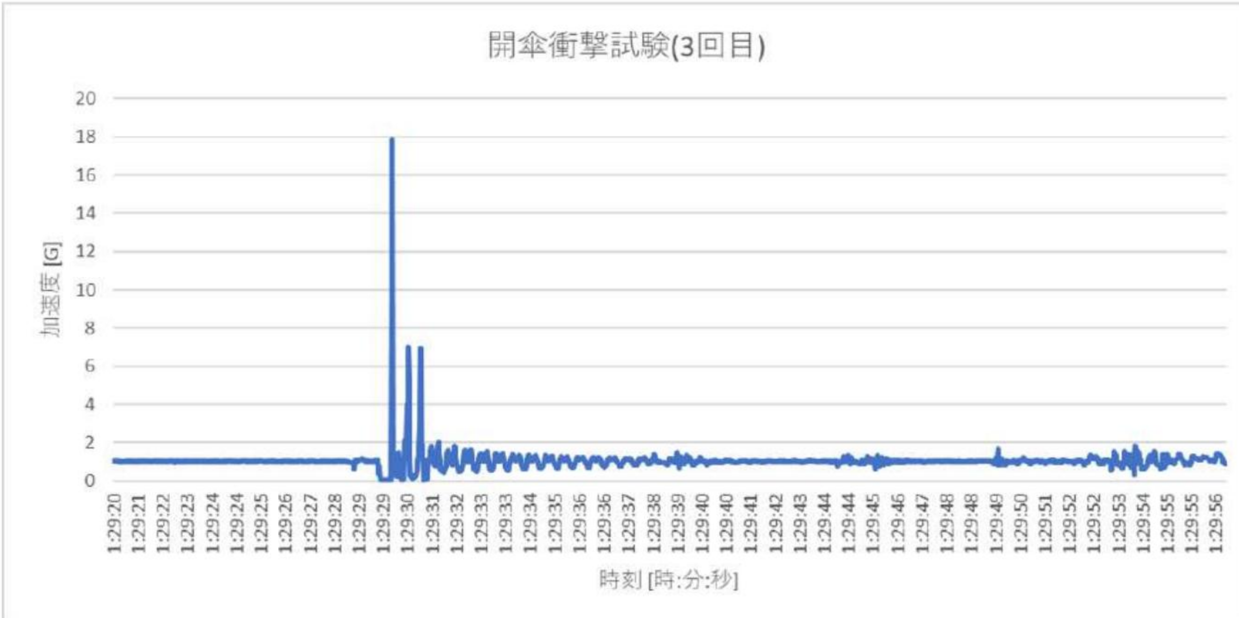

Figure 6.6.4 **Acceleration graph for the third opening impact test**

Table 6.6.1 below shows the results for each trial.

Table 6.6.1 **Opening impact test results**

Number of times	**Sequence operation**	**External damage to the base unit**	**Sensors**	**Motors**	**Maximum acceleration** [G]	YouTube **link**
1st time	**transition successfully**	**none**	**Normal**	**Normal**	12.2592	https://yo utu.be/crl Cuh0b8v 8
2nd time	**transition successfully**	**none**	**Normal**	**Normal**	**13.4387**	https ://yo utu.be/Ns 5SfvBZa _0
3rd time	**transition successfully**	**none**	**Normal**	**Normal**	**17.8367**	https ://yo utu.be/_ MMc1XjP R6M
Success rate	100% (3/3)	100% (3/3)	100% (3/3)	100% (3/3)		

***We confirmed that the GNSS sensor obtained normal values after the umbrella opening impact test. The video from that time is posted below.** GNSS sensor confirmation video: https://youtu.be/IwPy0Rfxjjw

• Consideration

From the above, the parent unit can **withstand a shock of 10 [G], which is the maximum expected shock when the parachute is deployed. It has been confirmed that it is durable.**

v7.Parachute drop test

• Purpose:

To confirm that the parachute, which is a deceleration mechanism, deploys and decelerates without problems when released from the carrier, and that the falling speed regulations (5.0 [m/s] or more) are met . • Test details: A ``pseudo parent unit'' that has

been stored in a

carrier will be released from a height of approximately 27.3 m above the ground on the 7th floor of West Building 6, University of Electro-Communications . This ``pseudo base unit'' has the same weight, shape, and height as the base unit actually under development. The "pseudo master unit" is shown in Figure 6.7.1. This test does not involve the circuitry or software of the base unit itself, and is only a test of the performance of the parachute and the hardware performance of the base unit, so even if this test is conducted using this ``pseudo base unit,'' it will not reflect the actual performance. It can be said that the same results as when using the main unit can be obtained.

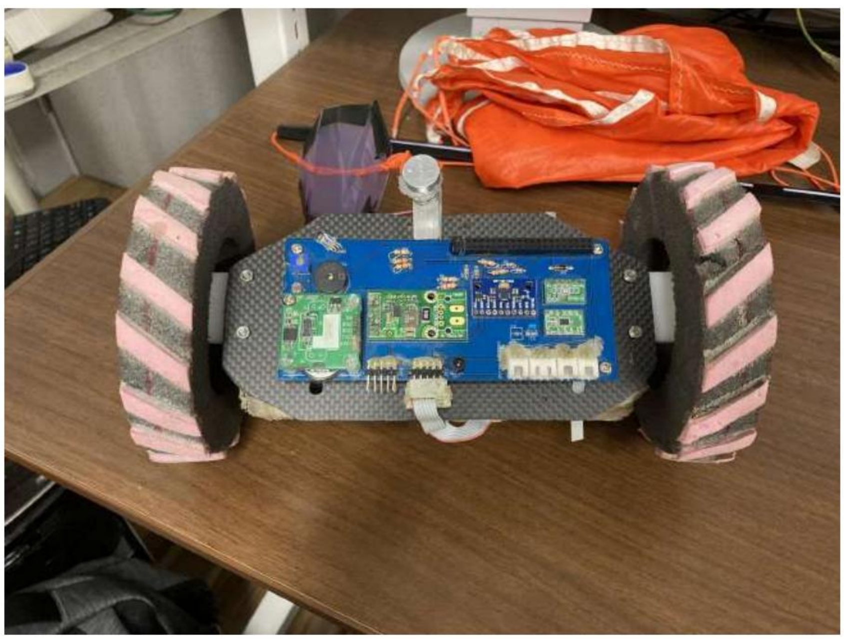

Figure 6.7.1 **Pseudo master unit**

The following will be confirmed in this test.

• Normal opening of parachute • Deceleration by parachute

Table 6.7.1 **Transit time between each floor**

floor	transit time
7 ÿ 6	00:09:56-00:10:37

6 ÿ 5	00:10:37-00:11:12
5 ÿ 4	00:11:12-00:11:30
4 ÿ 3	00:11:30-00:12:04
3 ÿ 2	00:12:04-00:12:40
2 ÿ 1	00:12:40-00:13:19

(Added at the time of main examination) A trial in which the terminal velocity was reached due to deceleration of the parachute in the supplementary test Since this was confirmed, Table 6.7.1 has been changed to reflect that trial. The details of the trial are below. The results are listed in Table 6.7.2 and Table 6.7.3 for the fifth time.

These two items will be confirmed based on videos taken with a video camera. Especially the speed when falling As shown in **Figure 6.7.2, the parachute is released from the carrier with the parachute** attached. **The object falls and the time it takes to reach the terminal velocity is measured. From the experimental video, The time taken to pass between each floor was calculated from the video. (Table 6.7.1) From this, on the 4th floor and below, Since the speeds are about the same due to the deceleration of the chute, the test is at the terminal speed. The line was confirmed. After the base unit passes the equivalent of the third floor of a building (8.4 [m] from the ground)** until it lands. **Measure the time taken from the video and calculate the terminal velocity during the experiment using the following formula.**

$$h = 8.4 \ \ [\mathrm{m}]$$

$$v = \frac{h}{t} \ \ [\mathrm{m/s}]$$

Also, the terminal velocity during free fall **is calculated as 23.1 [m/s] from the following formula .**

$$v = \sqrt{2gh}$$

$$h = 27.3\ [\mathrm{m}], \qquad g = 9.81\ [\mathrm{m/s^2}]$$

$$\therefore\ v = 23.1\ [\mathrm{m/s}]$$

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

• **Results**

The test results are summarized in Table 6.7.2. Parachutes were confirmed to be deployed on all four occasions.

Table 6.7.2 **Parachute drop test results**

Trial episode	**Deploying the parachute**	YouTube link
First time	**success**	~~https://youtu.be/NmcMuzZN7-c~~
Second time	**success**	~~https://youtu.be/OwRJrntttz0~~
Third time	**success**	~~https://youtu.be/ bRitHR0sgw~~
4th	**success**	~~https://youtu.be/hnDE0Lf5w5E~~
5th time	**success**	~~https://youtu.be/8UlhkgmfAFI~~
success rate	100% (5/5)	-

In addition, the calculation results of the falling speed are shown in Table 6.7.3. For each fall, from the video to the fall We estimated the time it would take to reach the target and calculated the speed from this time.

Table 6.7.3 **Parachute falling speed**

Number of tests	Calculation speed	Corresponding part of the video
First time	8.4 [m] / 1.57 [s] ÿ 5.4 [m/s]	00:08:88~00:10:45
Second time	8.4 [m] / 1.27 [s] ÿ 6.6 [m/s]	00:10:73~00:12:00
Third time	8.4 [m] / 1.15 [s] ÿ 7.3 [m/s]	00:16:18~00:17:33
4th	8.4 [m] / 1.63 [s] ÿ 5.2 [m/s]	00:11:67~00:13:30
5th time	8.4 [m] / 1.40 [s] = 6.0 [m/s]	00:11:16~00:12:56

The maximum falling speed is 7.3 [m/s] , **which is the free fall speed of** 23.1 [m/s]. **It was confirmed that deceleration was caused by the parachute. In addition, the falling speed of the parachute Verify whether the aircraft can withstand high temperatures through the V6 opening impact test and the V12 landing impact test. I agree.**

• **Consideration**

When released from the carrier, the parachute, which is the deceleration mechanism, deploys without any problems and decelerates. It was confirmed that

v8. Long distance communication test

• **Purpose**

Understand the maximum communication distance of LoRa installed in the master unit and slave unit, and take measures against loss of the unit. Check if LoRa is enabled.

• **Test content**

Two LoRa devices* start communicating every 10 seconds until communication becomes impossible. Increase the distance between them. Then, the location where each LoRa exists at the time when communication is interrupted is determined. Deriving the maximum communication distance from GNSS information at a point and determining whether LoRa is effective as a lost countermeasure confirm.

***In the video, one LoRa is connected to the PC and the main device. These two devices will be used as the main device during the actual performance. It is the same as the one placed on the slave unit.**

• **Results**

Table 6.8.1 shows the respective GNSS coordinates when communication between CanSat and PC (ground station) is disconnected. show. Figure 6.8.1 shows the coordinates on a map.

Table 6.8.1 **Long distance communication test results**

PC (ground station) coordinates	North latitude:35.6424317 East longitude: 139.5234383
CanSat coordinates	North latitude:35.6382133

	East longitude:139.5497117
Maximum communication distance	2.43km
At the start of the exam	https://youtu.be/xNb9ci-zh1M
At the end of the exam	https://youtu.be/WEVOyvStdpw

Figure 6.8.1 **Position of PC and base unit during long distance communication test**

• **Consideration**

I was able to confirm the maximum communication distance of LoRa. During the ARLISS performance, CanSat **will be released from the rocket at a height of** about 4 km above the ground, and **it is thought that it will be able to** receive GNSS coordinates from a height of about 2.43 [km] above the ground. **v7. Parachute drop test shows that the maximum terminal velocity after opening the parachute is 7.3 [m/s], so it takes about 5 minutes to land from** an altitude of 2.43 [km] . Since the CanSat is tracked **by car** at **a speed of about 50 km/h (4 km can be traveled in 5 minutes), it is thought that it is possible to see the CanSat before or after the time it touches down, thus preventing it from being lost. It can be said that**

v9. Communication device power 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

The Wi-Fi module plugged into **the** Orange Pi PC **installed in the base unit** becomes an access point, and the Wi-Fi communication status is turned on from the state where it is communicating with the PC. **Switch to OFF. Confirm that the Wi-Fi communication status is switched OFF and that you can freely turn it ON/OFF on the terminal . First, change**

the Wi-Fi communication mode of the rover program. When you start **the rover program and transition to the waiting sequence (Waiting), the access point of the base unit is displayed on Wi-Fi Analyzer, a software that visualizes surrounding access points, indicating that the** Wi-Fi communication status will be switched to OFF. **Confirm by disappearing. next,**

Transition the sequence from Waiting on the terminal. Then, the Wi-Fi communication status will be switched to ON, and **you can confirm that the base unit and PC are communicating by displaying the base unit's access point** on the Wi-Fi Analyzer .

- LoRa

LoRa **can be put into sleep mode (stops outputting radio waves) by controlling the GPIO pin of the Orange Pi PC. Therefore, confirm that you can freely turn LoRa's sleep mode on and off by controlling the relevant GPIO pin .**

First, enter a command into the terminal and confirm that data can be sent and received from the ground station to LoRa on the aircraft side. Next, change the LoRa communication status from ON to OFF from the rover's program and confirm that it cannot send or receive data. **Finally, check the communication status Turn it from OFF to ON and check that you can send and receive again.**

- **Results**

The results of Wi-Fi and LoRa communication device power ON/OFF tests are shown in Table 6.9.1. concrete **The result was as follows.**

- Wi-Fi

In the Waiting sequence, perform the microcontroller's Wi-Fi communication using the same procedure as in the actual production. I turned it off. I checked whether it was actually turned off using a smartphone app tool (Wi-Fi Analyzer) that checks Wi-Fi radio waves. We also confirmed that the Wi-Fi communication function was automatically turned on after **the Waiting sequence ended.**

- LoRa

Initially, **it was possible to send messages from the base LoRa to the ground station LoRa .** After inputting **a command to put LoRa into sleep mode in the rover program on the base unit , we confirmed that when we sent a message from LoRa on the base unit, it did not reach the ground station.** Next, **after entering a command to cancel LoRa's sleep mode into the rover program on the base unit ,** we confirmed that it was possible to send messages from LoRa on the base unit to LoRa on the ground station.

Table 6.9.1 Communication device power ON/OFF test results

test	result	YouTube link
Wi-Fi power ON/OFF	success	https://youtu.be/cfm3YVHNuL0
Power ON/OFF of LoRa	success	https://youtu.be/giuXQaihxVw

- **Consideration** • Wi-Fi

After switching the Wi-Fi communication status from ON to OFF without any problem and transitioning to the sequence Can be turned from OFF to ON.

• LoRa

You can switch the LoRa communication status from ON to OFF and from OFF to ON without any problems.

v10. Communication frequency change test (*safety)

• **Purpose**

Communication to be used when there is a possibility of communication frequency interference with other wireless communication.

Check that the frequency can be changed.

• **Test details •**

The

frequency of the access point installed on the Wi-Fi module connected to the Orange Pi PC **installed** in the Wi-Fi main unit **is measured using software called Wi-Fi Analyzer, which visualizes surrounding access points. confirm. After that, change the frequency of the base unit's access point and restart** the Orange Pi PC. **Then, use the Wi-Fi** Analyzer **to confirm that the Wi-Fi frequency set by the base unit has been changed. •**

LoRa

Prepare two LoRas (A and B) with matching frequencies. Change the frequency of A and confirm that data transmission and reception with B is no longer possible. Next, by changing the frequency of B's LoRa to match that of A, confirm that data transmission and

reception

is possible again. • **Results The results of Wi-Fi and LoRa frequency change tests are shown in Table 6.10.1. Also, t**

We have summarized the explanations for each YouTube video.

Table 6.10.1 **Communication frequency change test results**

test	result	YouTube link
Wi-Fi frequency change	**success**	https://youtu.be/DAmqArNHHTc
LoRa frequency change	**success**	https://youtu.be/giuXQaihxVw

Wi-Fi test YouTube video explanation 0:00 ~ **Exam**

explanation 0:30 ~

Check the frequency (channel number) of the base unit's access point

ÿ Check that the channel number is 7.

0:56 ~ **Wi-Fi frequency (channel number) change operation**

ÿ Change from channel number 7 to channel number 1

1:42 ~ Restart create_ap service 3:07 ~

Connection with base unit restored

3:12 ~ **Confirm that Wi-Fi frequency has been changed**

ÿ Check that the channel number is 1.

LoRa exam YouTube video explanation 0:00 ~ **Exam explanation**

0:30 ~ **Confirm data transmission and reception**

1:27 ~ **Change the frequency of one LoRa(A) and confirm that transmission and reception are not possible**

ÿ Change the frequency channel of A to 25 (0x19)

2:25 ~ **Confirmed that communication between LoRas is possible by changing the frequency of the other LoRa (B) to the changed frequency**

ÿ Change B frequency channel to 25(0x19)

• **Consideration**

We confirmed that the frequency of both the Wi-Fi module and LoRa communication module can be changed.

v11. End-to-end exam

• **Purpose:**

To confirm that the main unit can carry out the entire mission sequence as a continuous flow. • Test details The main unit must be able to autonomously control the entire sequence of missions, including mass measurement, carrier storage, release determination, landing determination, parachute detachment, and navigation, including the unexplored area search subsequence. Check. Note that the number of trials for the unexplored area search subsequence is two.

• **Results**

Table 6.11.1 below shows the results for each trial. The number of seconds played for each stage **of the end-to-end test (mass measurement, carrier storage, etc.) in the video is listed in the video summary section. Figure 6.11.1 shows the results of the unexplored area search sequence in the test. The terrain safety evaluation data sent from the slave unit to the base unit is represented by a circle with a radius of 5 [m] centered around the coordinates where the record was taken, and the line is displayed thicker as the point is determined to be more difficult to drive. Ru. Note that blue, orange, and purple are data for each of the three slave units. (The purple circle is hard to see, but it exists below the orange circle on the far** left). **The blue pins are the optimal routes calculated by the parent device based on this data, and are dotted so as to proceed from the upper left point to the lower right. The point where the base unit actually traveled is represented by a brown line.**

Table 6.11.1 End-to-End test results

Attempts Mass	Carry Release	Arrival Party	Mini	malist	Full	YouTube Ri			

	Measurement A	Storage/ Discharge	Output judgment	Land judgment	Rashi u - Cut and release	Big game - S tion	Musuccess judgment	Success judgment	Link
1st success	success	success		success	success	failure	•	×	https://youtu.be/MZ6cigwoeOk

Figure 6.11.1 **Evaluation record of the child device in the first end-to-end test (blue, orange, and purple circles for each child device), the derived optimal route (blue pin), and the driving route of the parent device (brown line))**

- **Regarding the first consideration ,** everything from mass measurement to parachute separation went smoothly, and we moved on to navigation. **However, in the unexplored area search sequence for navigation, the base unit succeeded in deriving the best route after establishing communication, arranging the initial position, and searching for the slave unit, but the base unit was unable to properly acquire GNSS and the best route was reached . I was unable to drive along the route .** There are three specific problems: (*1. and 2. **are the same as those confirmed in the first best route derivation test)**

1. **Stable communication cannot be established with the child device in the purple circle, and the safety evaluation received by the parent device There was only one data point.**
2. **Only the first few search points were sent from the base unit to the slave unit, and the slave unit was waiting for the next search point to be sent from the base unit, so the search seemed to be stopped midway. I fell into a situation.**

3. Due to the main unit being on standby for a long time, the average GNSS score is concentrated at the standby point, and the GNSS after the start of driving is not updated well, and even though the recorded GNSS remains near the standby point , it is not displayed on the video. In Figure 6.11.1, I ran into the edge of the ground (grass area) located at the bottom left . This can also be said to be a problem caused by the fact that the target point generated by the best route search is close enough that the coordinates cannot be updated while the vehicle is driving.

Regarding 1. and 2., there is a problem with the LoRa communication environment. Specifically, it is known that there is a limit to the congested transmission and reception capability of multiple LoRas. To solve this problem, we are currently trying to reduce the number of times of transmission and reception by changing the data format of commands between the parent and slave devices to reduce the character length, and by examining the timing of sending unnecessary commands within the algorithm. Regarding 3., because the coordinates returned by the GNNS sensor are the average of estimated coordinates received from multiple satellites, for a while after the vehicle starts running from a stopped state, the estimated coordinates received in the past will drag down the average coordinates. This is because the In response to this, we are considering eliminating this tension by resetting the GNSS records once the vehicle starts driving .

2. Test content to meet mission requirements

v12. Landing impact test (*Mission side)

• **Purpose:**

Confirm that the main unit is undamaged and can continue its mission even after landing impact. • **Test details** V7. The maximum

terminal velocity

when falling using a parachute calculated in the parachute drop test is 7.30 [m/s]. Based on this terminal velocity, use the following formula to calculate the height required to provide the impact expected during landing in the actual event.

$$\frac{1}{2}mv^2 = mgh \iff h = \frac{1}{2g}v^2$$

$$h = \frac{1}{2 \times 9.8} \times 7.30^2 = 2.72\ [\mathrm{m}]$$

From the above, the height corresponding to the actual fall impact is 2.72 [m]. In this test, the base unit was free-falled from a height of approximately 3 m higher than this, giving the same landing impact as the actual test. After the base unit lands, check the operation of all sensors and power systems, and check for damage to the base unit.

In addition, the sensor and motor outputs in this test are considered 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: The norm of acceleration when the aircraft is at rest is 0.95 [G] to 1.05 [G] (gravitational acceleratio

1 [G] ± 5% allowable measurement error, and the values of the x, y, and z axes vary depending on the attitude of the aircraft

•Light sensor: Under normal conditions, it determines that there is light (sensor value indicates HIGH), and when you cover the light **sensor** with your hand, it determines that there is no light (sensor value indicates LOW) .•Buzzer: Sound can be turned on/off

•GNSS: Receives GNSS information from one or more satellites, whose coordinates point to the test location.

•LoRa: Check the transmission and reception of character strings from the parent device to the slave device and from the slave device to the parent device

<Motors> •Servo motor: Can control the stabilizer vertically or horizontally •Motor: Rotates to the extent that the aircraft can travel

Figure 7.12.1 **Measuring the drop position**

Figure 7.12.2 **Distance from the ground to the dropping position**

• **Results**

Table 7.12.1 below shows the results for each trial.

Table 7.12.1 **Landing impact test results**

Trial period	**External damage to the main unit**	**Sensors**	**Motor sequence operation**		YouTube link
First time	**None**	**A normal value was obtained.**	**It worked normally.**	**It worked normally.**	https://youtu.be/trlRL8l-8hw
Second time	**None**	**A normal value was obtained.**	**It worked normally.**	**It worked normally.**	https://youtu.be/HyG4J3OMdbE
Third time	**None**	**A normal value was obtained.**	**It worked normally.**	**It worked normally.**	https://youtu.be/GWT85gvdU2Q
4th	**None**	**A normal value was obtained.**	**It worked normally.**	**It worked normally.**	https://youtu.be/SnpKzFLbWNY
5th time	**None**	**A normal value was obtained.**	**It worked normally.**	**It worked normally.**	https://youtu.be/qdXpdXnCEPM
Success rate	100% (5/5)	100% (5/5)	100% (5/5)	100% (5/5)	

***We confirmed that the GNSS sensor obtained normal values after the landing impact test. The video from that time is posted below.** GNSS sensor confirmation video: https://youtu.be/rPdgc_NBD8k

• Consideration

Currently, even if the impact of landing is applied, the appearance condition, acquisition of sensor values, power system, seat There is no problem with the operation of the Kens.

v13. Driving performance confirmation test

• **Purpose**

Confirm that CanSat has the necessary driving performance to reach the destination.

• **Test content**

Driving on sand or gravel and escaping from ruts, and driving without stopping in the middle. Make sure that it is possible. Please check each on the parent device and child device.

• **Results**

The results are shown in Tables 7.13.1 and 7.13.2 below.

Table 7.13.1 **Results of driving performance test of base unit**

Trial time	Situation to measure running performance	Running on the ground	YouTube link
1st	flat sandy area	success	https://youtu.be/VYS-blr4yJc
Second time	gravel road	success	https://youtu.be/be3KT8ci1qY
Third time	Escape from the rut (8cm)	success	https://youtu.be/SsTVtdyb_m8
4th		success	https://youtu.be/1QhAfsMdI6s
5th time		success	https://youtu.be/hdEFr-Z7N5c
success rate		100%	

Table 7.13.2 **Results of child unit running performance test**

Trial time	Situation to measure running performance	Running on the ground	YouTube link
1st	flat sandy area	success	https://youtu.be/qghQRhu236E
Second time	gravel road	success	https://youtu.be/xZZ6Bi_rV4I
Third time	Escape from the rut (8cm)	success	https://youtu.be/OLzQ3DuHpKs
4th		success	https://youtu.be/9ym2kbtoLbs
5th time		success	https://youtu.be/Yy8pSi0IVKw
success rate		100%	

• **Consideration**

Experimental results show that it is possible to continue driving under different road conditions, and that CanSat is able to reach its mission. It was confirmed that the vehicle had the driving performance necessary to continue running the vehicle.

v14. Power durability test

• **Purpose**

The battery capacity installed in the aircraft is large enough to prevent the battery from running out during the mission. Make sure there are no. •

Test details Adjust

the left-right ratio of the motor strength so that it moves in a circle, and move the aircraft on the spot. Measure the time from the timing of control start until control stops (until one of the batteries runs out). **The guideline for determining sufficient battery capacity is the total time of operations in the navigation sequence, including exploration, from the start of the rover program. in particular,**

• **Time from starting the base unit to discovering the base unit after launch: 120 minutes**

• **This includes standby sequence, fall sequence, parachute detachment sequence, and navigation sequence to ensure communication probability. • Navigation sequence** a. **Establish communication after placing the slave unit around the base unit: Maximum 3 minutes (timeout**

formula)

b. Initial placement of slave units: Maximum of 3 minutes (timeout type)

c. Search time: 7 minutes (timer type) d. **Next initial placement: Approximately 5 minutes** e. **Preliminary time:**

Approximate time of 10 minutes was set. On top of that, considering that the search is executed 5 times to achieve full success, the parent device will take 120 + 3 + 7 + 5 + 10= **142 minutes to fill 3 hours until the parent device is discovered.** It is assumed **that the maximum time + reserve time is 120** + 10 = **130 minutes, which is sufficient. Since the handset only needs to consider the time of the navigation sequence, we assume that 3** + 7 + 5 + 10 = 25 minutes **is enough to fill the 2 hours, taking into account the 10 minutes of reserve time .**

Use the following batteries that are the same as those used in the actual performance. The secondary battery is fully charged. Use an unused primary battery. • Main unit ÿ **Power supply for control circuit**

Lithium battery (secondary battery) x 1 ÿ **Power supply for motor**

"Energizer Ultimate **Lithium" (lithium ion primary battery, AA type)** x 6

• **Slave unit**

ÿ **Power supply for control circuit Lithium battery (secondary battery)** x 1 ÿ **Power supply for motor**

"eneloop pro **BK-4HCD/4SA" (secondary battery, AAA type)** x 4

• **Results**

Tables 7.14.1 and 7.14.2 show the power supply voltage of the master unit and slave unit before the start of the test and after the end of the test.

Table 7.14.1 **Base unit power durability test results**

	Power supply for circuits	Power supply for motors and servo motors	YouTube link
4.18 V **before test start**		10.78V	https://youtu.be/Z-QDgQy0c-k
3.48 V **after test**		7.16V	https://youtu.be/1w9pi3yZRP0

Table 7.14.2 **Result of slave power durability test**

	Power supply for circuits	Power supply for motors and servo motors	YouTube link
4.17 V **before test start**		5.53V	https://youtu.be/s7sMSoPppSA
3.62 V **after test**		5.10V	https://youtu.be/xGwN4ZOl9Vg

- **Consideration**

The test results show that the battery capacity installed on the aircraft is large enough to be used during the mission. It can be said that the battery will not run out.

v15. Inversion rollover recovery test

- **Purpose**

  Must be able to return to a running position if the parent unit or slave unit flips over or rolls over while driving. Check.

- **Test content**
  - **Reverse return**

    Program the inversion return sequence after the parent unit or slave unit is inverted. Execute and return to a running posture.

  - **Rollover recovery**

    Program the rollover recovery sequence after the parent unit or slave unit has been rolled over. Execute. Return to a position where you can run.

- **Results**

Table 7.15.1 **Results of master unit reversal recovery test**

number of times	result	YouTube link
First time	success	https://youtu.be/qsuu787t2Kk
Second time	success	https://youtu.be/lA1RM64nS-o
Third time	success	https://youtu.be/IFS1K2YdssE
4th	success	https://youtu.be/JphGIzcGwOQ
5th time	success	https://youtu.be/LyiKLAs9kvA
success rate	100%(5/5)	

Table 7.15.2 **Result of handset reverse recovery test**

number of times	result	YouTube link
First time	success	https://youtu.be/sYdKEupKLtc
Second time	success	https://youtu.be/mptq77DDVFk
Third time	success	https://youtu.be/t5ml5aN6eWs
4th	success	https://youtu.be/FjEEODQTzqc
5th time	success	https://youtu.be/bXqRHQ8ot7Q
success rate	100%(5/5)	

Table 7.15.3 **Results of main unit rollover recovery test**

number of times	result	YouTube link
First time	success	https://youtu.be/T2a0kWutgEw
Second time	success	https://youtu.be/tt0EXa8T5SQ
Third time	success	https://youtu.be/VX7PtN3Am-4
4th	success	https://youtu.be/IvO0R53l41g
5th time	success	https://youtu.be/1gi5YOeRCok
success rate	100%(5/5)	

Table 7.15.4 **Result of handset rollover recovery test**

number of times	result	YouTube link
First time	success	https://youtu.be/J7M3zRHFoXo
Second time	success	https://youtu.be/LmPl3wZujxI
Third time	success	https://youtu.be/362E2HdOqB4
4th	success	https://youtu.be/mO4lrXtFlW8
5th time	success	https://youtu.be/rDTJx_eDUoc
success rate	100%	

•

Considerations It was confirmed that both the parent unit and slave unit were able to return to a running state after being reversed or rolled over.

v16. Communication establishment test between base unit and slave unit

• Purpose

The master unit establishes communication with each slave unit and performs sequences that require communication such as navigation. Verify that the process can transition to an executable state. • Test details

Set the base unit to

the communication establishment sequence, and set the group of slave units around it to the communication establishment sequence in the same way as the base unit. Check the logs of both the machine and the slave machine. • Results

Table 7.16.1 **Results of communication establishment test between base unit and slave unit**

number of times	result	YouTube link
First time	https://youtu.be/sK3JMy4JX0g	success
Second time	https://youtu.be/rb5y9IAUPUY	success
Third time	https://youtu.be/bGjLWa6RsTM	success

• Considerations

We were able to confirm through testing that communication between the base unit and slave units could be established at the start of a mission.

v17. Best route derivation test

• Purpose:

The parent unit allows multiple handsets to explore unexplored areas without colliding with each other, and determines whether the parent unit is the best based on safety evaluation information obtained from road conditions or situations in which the handsets find it difficult to drive. Check whether you were able to derive the route.

• Test details Multiple

handsets are asked to search within a designated area such as a field with numerous minor obstacles, and safety evaluation information is sent to the base unit. Then, from the information obtained, we use logs to determine whether the best route can be derived, excluding points where the parent unit has a large dispersion of acceleration norm when driving on poor road conditions, and points where the slave unit has overturned, reversed, or got stuck. confirm. Note that at least the first test is conducted without human intervention, but in the several tests, route calculations are performed in various situations, such as intentionally turning the handset over or upside down. **Check.**

• **Results**

Table 7.17.1 below shows the results for each trial. In addition, Figure 7.17.1 shows the results of the unexplored area search sequence in the test . The terrain safety evaluation data sent from the child device to the parent device is represented by a circle with a radius of 5 m centered on the coordinates where the record was taken, and the line is displayed thicker as the point is determined to be more difficult to drive . Note that blue, orange, and purple are data for each of the three slave units. (The purple circle is hard to see, but it exists below the orange circle on the far left). The blue pins are the optimal routes calculated by the base unit based on these data, and are dotted so as to proceed from the upper left point to the lower right. The points where the base unit actually traveled are represented by brown lines.

Table 7.17.1 **Best route derivation test results**

number of times	YouTube link	result
First time	https://youtu.be/0q7QVasFxQE	**Successful (however, there are areas for improvement in the exploration algorithm of the slave unit)**

Figure 7.17.1 **Evaluation record of the child device in the first best route derivation test (blue, orange, purple circles for each child device), the derived optimal route (blue pin), and the driving route of the parent device (brown line)**

• Regarding

the results of the first **consideration , looking at Figure 7.17.1, the base unit receives safety evaluation data from the slave unit, and among them, the points evaluated to be highly safe (points with thin circles)), it can be seen that the best route is calculated that passes through as much as possible. In this sense, we consider this trial a success. However, some problems have been identified. There are two specific problems : (*These questions are the same as questions 1 and 2 that were confirmed in the first End-to-End exam .)**

1. **Stable communication cannot be established with the child device in the purple circle, and the safety evaluation received by the parent device There was only one data point.**
2. **Only the first few search points were sent from the base unit to the slave unit, and the slave unit was waiting for the next search point to be sent from the base unit, so the search seemed to be stopped midway. I fell into a situation.**

Regarding these, there are problems with the LoRa communication environment. Specifically, it is known that there is a limit to the congested transmission and reception capability of multiple LoRas. To solve this problem, we are currently trying to reduce the number of times of transmission and reception by changing the data format of commands between the parent and slave devices to reduce the character length, and by examining the timing of sending unnecessary commands within the algorithm.

v18. Handset route evaluation test

- **Purpose:**

  When the handset runs on the ground, check whether safety can be evaluated correctly based on the road surface conditions and the conditions in which the aircraft is difficult to drive.
- **Test details • Road**

  surface condition evaluation

  The handset is driven on the ground under various conditions, and the log of the aircraft is checked to see if the aircraft's condition is correctly evaluated for safety, such as road surface conditions and situations where the aircraft is unable to run due to collisions. The road surface conditions used in the test are shown below. • Flat concrete • Severely uneven concrete

  • Ground that is easy to hit (stuck condition) •

  Evaluation of aircraft running condition Put the child unit in a rollover/inversion condition, and

  correct the condition as a point where it should not drive.

  Check the aircraft logs to see if the safety evaluation has been completed correctly.
- **Results**

  Table 7.18.1 below shows the results for each road surface condition, and Table 7.18.2 shows the results for each aircraft condition.

Table 7.18.1 **Road surface condition evaluation results**

Road condition	YouTube link	safety evaluation (every 5 seconds. **The lower the safety)**	**Results (conclusions from safety evaluation)**
Flat ground	https://youtu.be/nL ZSL1EnAmA	Rating 1: 563, Rating 2: 1185, Rating 3: 10	Correct because **it is " relatively safe** "
Very uneven ground	https://youtu.be/pR W28vHJxmI	Rating 1: 4833, Rating 2: 4913, Rating 3: 6487	Correct because **"security is relatively low** "
Easy to run into	https://youtu.be/Jo	Rating 1: 4054,	**"Relatively low safety**	

Ground (stack state) dZ_vKQhLg		Rating 2: 2559	**It is correct because**

Table 7.18.2 **Aircraft running condition evaluation results**

Aircraft status	YouTube link	**Results (recorded in safety assessment)**
rollover condition	https://youtu.be/ZuzifOfK O7w	**Record success**
Inverted state	https://youtu.be/keTzHDU GET4	**Record success**

- **Consideration**
  - **Regarding the evaluation of road surface conditions, there are two types of ground: "flat ground" on which the aircraft can easily travel. Between ``highly uneven ground'' and ``ground that is easy to hit,'' the latter has a higher safety rating. It can be seen that the record of The higher the rating, the more difficult the surface is to drive on. Because of this setting, it is not possible to perform a safety evaluation of the aircraft that distinguishes road conditions. It turns out that**
  - **Regarding the evaluation of driving conditions, record the detection of reversal and rollover conditions and safety evaluation. I confirmed that the recording was completed. In addition, in distinction from evaluation of road surface conditions, It has been determined that this is a prohibited location.**

v19. Handset initial position placement test

- **Purpose**

The child device cannot be placed at the position specified by the parent device at the start of the unexplored area search subsequence. Check whether the

- **Test content**

Set up the slave units separately around the base unit, and ask the base unit to place the slave units at their initial positions. Send the command. The base unit then checks whether the slave unit is placed at the position specified by the base unit. Check the log that shows the specified coordinates and the coordinates where the slave unit stopped.

- **Results**

Table 7.19.1 below shows the results for each trial.

Table 7.19.1 **Result of initial placement test of handset**

number of times	YouTube link	**result**
First time	https://youtu.be/lc1TuFta Fkg	**success**
Second time	https://youtu.be/op9a9Tvz 0_Q	**success**

Third time	https://youtu.be/5L9xBnx5wrE	success
success rate	-	100% (3/3)

•

Considerations In accordance with the algorithm for guiding the initial placement of the child unit described in the algorithm section, the parent unit sends running commands so that the child unit is in front of the parent unit and aligned perpendicular to the straight line connecting the parent unit and the goal. We were able to confirm that this was possible and that the slave unit was able to accomplish this.

v20. Number of handset variation test

• Purpose: If the slave unit is unable to continue the mission because it is upside down or stuck in a rut, or if the slave unit's battery is exhausted or it is too far away from the base unit, communication with the base unit may be interrupted. If the mission becomes difficult, check whether the master unit can judge each status and change the number of slave units that can continue the mission. At the same time, confirm that the slave device whose communication has been cut off is stopped so that it will not perform any further operations. • Test details After establishing communication between the base unit and slave unit, set the slave unit to the following state and check whether the base unit was able to change the number of aircraft that can continue the mission accordingly. Also, confirm from the log that the slave unit that lost communication has stopped its navigation sequence. • Reverse state Intentionally reverse the handset. • Difficulty driving: Place the handset in a depression from which it cannot escape on its own. •

Communication disconnected state Remove LoRa from the slave device and reproduce the situation where communication is impossible.

• Results

Table 7.20.1 below shows the results for each trial.

Table 7.20.1 **Results of test for changing number of handsets**

	YouTube link	result
Difficult to drive	https://youtu.be/ZvJkIgL 2OwA	success
Communication disconnected state	https://youtu.be/6an0_a-i CYs	success

• Consideration

When the handset has difficulty running or is in a communication disconnected state, the former makes it difficult for the handset to run

In the latter case, the parent device recognizes that it can no longer connect with the child device over time and sets it in a disconnected state, and in both cases, the parent device communicates with the child device and records it. It has been confirmed that the mission can be continued after removing the command from the target. It was also confirmed that both slave units had completed their missions and transitioned to the test sequence so that they would not operate any further.

v21. Specified route driving test

- **Purpose**

When traveling on the best route derived by the base unit, or when the slave unit travels to the coordinates specified by the base unit. Check whether each type of aircraft can travel along the specified route.

- **Test details: Run**

the parent unit and slave unit along the coordinates of the route you want to run, and record the coordinate log of the run. Compare the predetermined routes and confirm that the travel route does not deviate significantly.

- **Results**

Tables 7.21.1 and 7.21.2 below show the results for the base unit and slave unit, respectively.

Table 7.21.1 **Results of main unit designated route driving test**

YouTube link	**result**
https://youtu.be/DNtxA4So4GQ	**success**

Table 7.21.2 **Results of handset specified route running test**

YouTube link	**result**
https://youtu.be/6JaJyv01fB8	**success**

- **Discussion**

Figure 7.21.1 shows the results of the parent unit designated route driving test. The specified route is represented by a blue pin , and the route was specified in the order of GNSS coordinates of Sÿ1ÿ2ÿ3ÿ4. **The brown line is the GNSS record when the base unit actually traveled the specified route, and the orange circle represents the GNSS error, a circle with a radius of approximately 5 [m].** Looking at this, the route traces a trajectory tracing **the points S ÿ 1 ÿ 2 ÿ 3 ÿ 4 ,** and the GNSS coordinates of the designated route **are included in** the error circle of the route actually traveled. **I can see that it has become something. In other words, the base unit is able to run as if it were following a specified route. Figure 7.21.2 shows the results of the handset specified route driving test. The**

specified route is indicated by a blue pin.

The route was specified in the order of GNSS coordinates: Sÿ1ÿ2ÿ3ÿ4ÿS. The brown line is the GNSS record when the handset actually traveled the specified route, and the orange circle **represents the GNSS error, a circle with a radius of approximately 5 [m]. Looking at this, the route** traces a trajectory tracing the points Sÿ1ÿ2ÿ3ÿ4ÿS, and the GNSS coordinates of the specified route are the errors of the actual route traveled.

You can see that it is contained within the circle. In other words, the slave unit is able to run as if it were following a specified route.

Figure 7.21.1 Main unit designated route Specified route for driving test (blue) and actual driving route (brown/orange)

Figure 7.21.2 Handset designated route Specified route for driving test (blue) and actual traveling route (brown/orange)

v22. Control history report creation test

• Purpose:

After the mission, the log data obtained will be submitted in order to submit the specified control history report. Create a control history report from • Test content A control history report to be submitted will be actually created from the log data related to the control history obtained in the End-to-End test. • Results Table 7.22.1 is a partial excerpt of the control history of the base unit from the log data of the first End-to-End test. I have added comments in red to important points in the sequence movement for advancing the mission and the analysis of the sequence for the mission. In addition, the visualization record of the unexplored area search subsequence of the End-to-End test generated from **this history and** other sensor records **is** posted as Figure 7.22.1 of the End-to-End test (V11) results. , **please refer to that.**

Table 7.22.1 End-to-End test first **control history report**

Machine Translated by Google

```
uccess: Setup WiringPi finished! –> プログラム起動
GPS Sensor is Ready!
Pressure Sensor is Ready!
PoseJudgment: ( rollOverThresholdY: 0.65, rollOverThresholdZ: 10, turnOverThresholdX: 9999,
turnOverThresholdZ: 0.5 )
Log file: log/20220805_0426_log_nineaxis1_e2e_0000_2.csv
Log file: log/20220805_0426_log_gps1_e2e_0000_2.csv
Log file: log/20220805_0426_log_pressure1_e2e_0000_2.csv
Log file: log /20220805_0426_log_lora1_e2e_0000_2.csv
This rover is used as PARENT rover!ild rovers num =
Log file: log/20220805_0426_log_safty_evaluation1_e2e_0000_2.csv
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                          ÿ ÿÿÿÿ ÿ ÿ ÿ ÿ ÿ
                               ÿÿ ÿ



         === Team Dolphins ===

   [0m[30m[43m Takadama Lab. ARLISS 2022 [0m

alias 'ww' = 'motor 100'
alias 'hh' = 'motor 0'
alias 'ss' = 'motor -100'
alias 'aa' = 'motor 0 100'
alias 'dd' = 'motor 100 0'
alias 'test' = 'start testing'
alias 'wait' = 'start waiting'
alias 'fall' = 'start falling'
alias 'sepa' = 'start para_separating'
alias 'poli' = 'start policy_learning'
alias 'navi' = 'start navigating'
alias 'detect' = 'start goal_detecting'
alias 'posetest' = 'start pose_detection_testing'
alias 'lighttest' = 'start light_detection_testing'
alias 'pidww' = 'magnet_pid
drive' alias 'pidhh' = 'magnet_pid
stop;motor 0' alias 'kaisan' = 'start testing;servo 1;nineaxis
monitor start' alias 'kaisan2' = 'nineaxis
monitor stop' alias 'seikaju' = 'start
static_load_testing' alias 'encoder' =
'encoder_l;encoder_r' alias 'goto ' = 'call moving_to_cooridnate drive'

[5C[F
```

```
> wait
= start waiting
Waiting Mode :light,
1 [1m[04:28:45] [36mSequence: [32m'waiting' -> 待機シーケンス起動
[0mTime: 04:28:46
Light count: 0/10 (LOW)

Time: 04:28:47
Light count: 0/10 (LOW)

Time: 04:28:48
Light count: 0/10 (LOW)

Time: 04:28:49
Light count: 0/10 (LOW)

Time: 04:28:50
Light count: 0/10 (LOW)

Time: 04:28:51
Light count: 0/10 (LOW)

Time: 04:28:52
Light count: 0/10 (LOW)

Time: 04:28:53
Light count: 0/10 (LOW)

Time: 04:28:54
Light count: 0/10 (LOW)

Time: 04:28:55
Light count: 0/10 (LOW)

Time: 04:28:56
Light count: 0/10 (HIGH)    -> 放出後で光を検知

Time: 04:28:57
Light count: 1/10 (HIGH)

Time: 04:28:58
Light count: 2/10 (HIGH)

Time: 04:28:59
Light count: 3/10 (HIGH)

Time: 04:29:00
Light count: 4/10 (HIGH)

Time: 04:29:01
Light count: 5/10 (HIGH)

Time: 04:29:02
Light count: 6/10 (HIGH)
```

```
Time: 04:29:03
Light count: 7/10 (HIGH)

Time: 04:29:04
Light count: 8/10 (HIGH)

Time: 04:29:05
Light count: 9/10 (HIGH)

[1m[04:29:05] [36mSequence: [32m'falling'-> 落下シーケンス起動

[0mTime: 04:29:06 Pressure count: 1/10 (1.01e+03 hPa)
Gyro count: 0/10
GPS position: 35.6404483, 139.5442433

Time: 04:29:07
Pressure count: 2/10 (1004.947 hPa)
Gyro count: 0/10
GPS position: 35.6404483, 139.5442450

Time: 04:29:08
Pressure count: 3/10 (1005.016 hPa)
Gyro count: 0/10
GPS position: 35.6404483, 139.5442450

Time: 04:29:09
Pressure count: 4/10 (1005.039 hPa)
Gyro count: 0/10
GPS position: 35.6404467, 139.5442467

Send data 35.6404483,139.5442467 by gps sender!
Time: 04:29:10
Pressure count: 5/10 (1004.894 hPa)
Gyro count: 0/10
GPS position: 35.6404483, 139.5442467

Time: 04:29:11
Pressure count: 6/10 (1005.104 hPa)
Gyro count: 0/10
GPS position: 35.6404500, 139.5442483

Time: 04:29:12
Pressure count: 7/10 (1005.077 hPa)
Gyro count: 0/10
GPS position: 35.6404567, 139.5442500

Time: 04:29:13
Pressure count: 8/10 (1005.009 hPa)
Gyro count: 0/10
GPS position: 35.6404583, 139.5442567

Time: 04:29:14
Pressure count: 9/10 (1005.116 hPa)
```

```
Gyro count: 0/10 GPS
position: 35.6404600, 139.5442600

Send data 35.6404583,139.5442583 by gps sender!
Time: 04:29:15
Pressure count: 10/10 (1004.927 hPa)
Gyro count: 0/10 GPS
position: 35.6404583, 139.5442583

Time: 04:29:16
Pressure count: 11/10 (1005.126 hPa)
Gyro count: 0/10 GPS
position: 35.6404583, 139.5442600

Time: 04:29:17
Pressure count: 12/10 (1005.096 hPa)
Gyro count: 0/10 GPS
position: 35.6404600, 139.5442550

Time: 04:29:18
Pressure count: 13/10 (1005.08 hPa)
Gyro count: 0/10 GPS
position: 35.6404617, 139.5442567

Time: 04:29:19
Pressure count: 14/10 (1005.18 hPa)
Gyro count: 0/10 GPS
position: 35.6404617, 139.5442550

Send data 35.6404617,139.5442550 by gps sender!
Time: 04:29:20
Pressure count: 15/10 (1005.058 hPa)
Gyro count: 0/10 GPS
position: 35.6404617, 139.5442550

Time: 04:29:21   -> 着地後で静止状態を検知
        Pressure count: 16/10 (1005.134 hPa)
Gyro count: 1/10 GPS
position: 35.6404617, 139.5442533

Time: 04:29:22
Pressure count: 17/10 (1005.195 hPa)
Gyro count: 2/10 GPS
position: 35.6404617, 139.5442500

Time: 04:29:23
Pressure count: 18/10 (1005.142 hPa)
Gyro count: 3/10 GPS
position: 35.6404600, 139.5442483

Time: 04:29:24
Pressure count: 19/10 (1005.178 hPa)
Gyro count: 4/10 GPS
position: 35.6404583, 139.5442467
```

```
Send data 35.6404583,139.5442450 by gps sender!
Time: 04:29:25
Pressure count: 20/10 (1005.103 hPa)
Gyro count: 5/10
GPS position: 35.6404583, 139.5442450

Time: 04:29:26
Pressure count: 21/10 (1005.231 hPa)
Gyro count: 6/10
GPS position: 35.6404567, 139.5442433

Time: 04:29:27
Pressure count: 22/10 (1005.094 hPa)
Gyro count: 7/10
GPS position: 35.6404567, 139.5442417

Time: 04:29:28
Pressure count: 23/10 (1005.168 hPa)
Gyro count: 8/10
GPS position: 35.6404550, 139.5442417

Time: 04:29:29
Pressure count: 24/10 (1005.138 hPa)
Gyro count: 9/10
GPS position: 35.6404533, 139.5442400

Send data 35.6404533,139.5442400 by gps sender!
Falling completed! (by gyro and pressure)
[1m[04:29:30] [36mSequence: [32m'para_separating'-> パラシュート切り離しシーケンス
[0mPara separating... (1/5)
Send data 35.6404500,139.5442400 by gps sender!
Para separation... (2/5)
Para separation... (3/5)
Send data 35.6404517,139.5442417 by gps sender!
Para separation... (4/5)
Send data 35.6404567,139.5442383 by gps sender!
Para separation... (5/5)
Para separation finished!
Error: Failed to get parameter 'navigating_method' from config file!
The config value of 'navigating_method'
is PolicyLearning Method is Magnet.
This rover is used as PARENT rover!ild rovers num =
Error: Failed to get parameter 'wait_avoid_child_time' from config file!
Log file: log/20220805_0426_log_safty_evaluation5_e2e_0000_2.csv
Log file: log/20220805_0426_log_policy_learning1_e2e_0000_2.csv
[1m[04:29:45] [36mSequence: [32m'policy_learning' > 'magnet_calib rating'-> ナビゲーションシーケンス，地磁気のキャリブレーション開始
[0m [1m[04:29:45] [36mSequence: [32m'policy_learning' > 'magnet_calibrating' >
'waking' [0mWaking
finished! [1m[04:29:51] [36mSequence: [32m'policy_learning' >
'magnet_calibrating' [0mMagnetCalibrating: Turning right...
MagnetCalibrating: Turning left...
MagnetCalibrating: Turning stopped!
```

```
min: (-81, -231, -343)
max: (95, -58, -266)
Command:
nineaxis minmax -81 -231 -343 95 -58 -266
--------------------

filtered min: (-81, -227, -338)
filtered max: (93, -59, -268)
Command:
nineaxis minmax -81 -227 -338 93 -59 -268
MagnetCalibrating has been finished!
[1m[04:30:03] [36mSequence: [32m'policy_learning'        -> 未踏エリア探索サブシーケンス開始
[0mTime: 04:30:03
Type/Mode/Id: parent/START_PAIRING/0000           -> 親機・子機間通信確立開始
                                  Current Azimuth: 280.889

** Start pairing **
Time: 04:30:04
Type/Mode/Id: parent/WAIT_PARING/0000 Current
Azimuth: 281.151

Time: 04:30:05
Type/Mode/Id: parent/WAIT_PARING/0000
Current Azimuth: 283.066

[1CTime: 04:30:06
Type/Mode/Id: parent/WAIT_PARING/0000 Current
Azimuth: 281.981

[3CTime: 04:30:07
Type/Mode/Id: parent/WAIT_PARING/0000 Current
Azimuth: 284.821

Success! lora cmd push: rssi **
Successfully paired with 0001. (2 unit left) ** Success!
lora cmd push: rssi **
Successfully paired with 0003. (1 unit left) ** Success!
lora cmd push: rssi * *
Successfully paired with 0002. (0 unit left) ** ** Checked
connection from children(3/3) ** -            -> 親機・子機間通信確立成功
                             [31m Minimum success clear! [m  -> ミニマムサクセス成功
** Child(LoRaID: 0001) go to (35.6405108, 139.5443683) **        -> 子機初期位置配置開始
        ** Child(LoRaID: 0002) go to (35.6404272, 139.5443279) ** **
Child(LoRaID: 0003) go to (35.6403436, 139.5442875) ** ** Move
children to initial position ** Success! lora
cmd push: rec Execute
retransmission process toward 0001.
Success! lora cmd push: rec
Execute retransmission process toward 0002.
Success! lora cmd push: rec
Success! lora cmd push: done **
Moved ID: 0003 to init pos! (1/3) ** Success!
lora cmd push: done ** Moved ID:
0001 to init pos! (2 /3) ** Success! lora cmd
push: done
```

** Moved ID: 0002 to init pos! (3/3) ** **
Moved all children! ** - -> 子機初期位置配置成功

essfeff95.28723, 15.00015 ** Set search area! [origin: (35.6405760, 139.5442838), azimuth: 110.7878804,
goal: (35.6402906,
139.5447417)] ** ** Child(LoRaID: 0001) go to (35.6405348,
139.5443238) ** ** Child(LoRaID: 0002) go to (35.6402058,
139.5446430) * * ** Child(LoRaID: 0003) go to (35.6404073,
139.5447371) ** ** Start children search! ** -> Start -> 子機探索命令開始

Success! lora cmd push: rec
Success! lora cmd push: done ** Child
(LoRaID: 0001) finish searching! ** ** Child(LoRaID: 0001) go to [LatLng: (35.6402756, 139.5445301), Vec: (32.6938110, 23.3523601)] ** Execute retransmission process toward 0002.
Success! lora cmd push: rec
Execute retransmission process toward 0001.
Success! lora cmd push: saft
Execute retransmission process toward 0001.
** Get safty evaluation data! [LoRaID: 0002, LatLng: (35.6404000, 139.5443333), Vec: (11.1350339,
16.7264245), data: 87] ** -> First reception of evaluation data of slave unit (2nd unit) -> 子機(2機目)の評価データを初受信
Success! lora cmd push: rec
Success! lora cmd push: saft
** Get safty evaluation data! [LoRaID: 0003, LatLng: (35.6403250, 139.5442717), Vec: (8.8879923,
26.5093977), data: 281] ** - -> 子機(3機目)の評価データを初受信
Success! lora cmd push: saft
** Get safty evaluation data! [LoRaID: 0002, LatLng: (35.6404000, 139.5443333), Vec: (11.1350339,
16.7264245), data: 87] **
Success! lora cmd push: saft
** Get safty evaluation data! [LoRaID: 0002, LatLng: (35.6403783, 139.5443867), Vec: (16.5089339,
17.2702939), data: 956] **
Success! lora cmd push: saft
** Get safty evaluation data! [LoRaID: 0002 , LatLng: (35.6403550, 139.5444450), Vec: (22.3603286,
17.8231904), data: 15] **
Success! lora cmd push: saft
** Get safety evaluation data! 5445000), Vec: (27.9998247, 18.6590253), data: 227] ** Success! lora cmd push: saft ** Get safty
evaluation data! [LoRaID:
0002, LatLng: (35.6402950, 139.5445450), Vec: (33.1887694, 20.8567 587), data : 27] ** Success! lora cmd push: saft ** Get safty
evaluation data! [LoRaID:
0002, LatLng: (35.6402950, 139.5445450), Vec: (33.1887694, 20.8567587), data: 27] ** Success! lora cmd push: saft ** Get safty
evaluation data! [LoRaID:
0002, LatLng: (35.6402950, 139.5445450), Vec: (33.1887694, 20.8567587), data: 27] ** Success! lora cmd push: saft ** Get safty
evaluation data ! [LoRaID:
0001, LatLng: (35.6405000, 139.5444100), Vec: (13.6713188, 3.8564611), data: 46] ** -
-> 子機(1機目)の評価データを初受信
Success! lora cmd push: saft
** Get safty evaluation data! [LoRaID: 0001, LatLng: (35.6404750, 139.5444650), Vec: (19.3106577,
4.6922843), data: 931] **
Success! lora cmd push: saft

<snip>

```
** Get safty evaluation data! [LoRaID: 0002, LatLng: (35.6404900, 139.5444883), Vec: (21.7858382,
4.1365525), data: 94] **
Execute retransmission process toward 0003.
** Get safty evaluation data! [LoRaID: 0001, LatLng: (35.6403883, 139.5445417), Vec: (30.5259860,
12.8034762), data: 61] **
** Child(LoRaID: 0001) finish searching! **          -> 子機(1機目)が親機の指定した探索点の一つに到着
Execute retransmission process toward 0001.             -> ここから子機(1機目)との接続が不安定に
Execute retransmission process toward 0003.             -> ここから子機(3機目)との接続が不安定に
Execute retransmission process toward 0003.
Execute retransmission process toward 0001.
Execute retransmission process toward 0003.
Execute retransmission process toward 0003.
** Get safty evaluation data! [LoRaID: 0002, LatLng: (35.6404900, 139.5444883), Vec: (21.7858382,
4.1365525), data: 94] **

<snip>

** Get safty evaluation data! [LoRaID: 0002, LatLng: (35.6404900, 139.5444883), Vec: (21.7858382,
4.1365525), data: 94] **
** Get safty evaluation data! [LoRaID: 0002, LatLng: (35.6404900, 139.5444883), Vec: (21.7858382,
4.1365525), data: 94] **
Execute retransmission process toward 0001.
Execute retransmission process toward 0001.
Execute retransmission process toward 0001.
Execute retransmission process toward 0001.
Execute retransmission process toward 0001.
Execute retransmission process toward 0001.
Success! lora cmd push: rec
Success! lora cmd push: done
** Child(LoRaID: 0002) finish searching! **          -> 子機(2機目)が親機の指定した探索点の一つに到着
** Finished to search unexplored area! (search record num: 21) **     -> 親機が指定した探索時間が過ぎ,
子機の探索が完了したのでここから最適経路導出

## Cost ##
10000000,   46,   448    449, 515, 515,    308, 246, 10000000, 10000000, 10000000
10000000,   46,   488,   303,   449,   208, 88, 10, 10000000,
10000000,   87,   376,   362, 286, 399,   173, 102, 39,   12, 13, 10000000
   29,   58,   376,   349, 285, 260,   48,   21, 82, 79,   16, 10000000
   89,   88,   277,   168,   142,   76, 86,   46,   10000000
   89,   89,   142,   138,   56,   10000000
## Minimum cost ##
10000046,   92,   534,   983, 1387, 1280, 1140, 10000894, 10000894, 10000894
10000000,   46,   534,   871, 1241, 1166, 972, 894, 894, 10000894
   0,   87,   422,   725, 984, 1029, 957, 884, 894, 10000894
   29,   58,   434,   621, 1009, 855, 871, 892, 900, 610, 807, 831, 910, 951, 939,   10000897
   119,   118,   335,   521, 689, 827, 904, 990, 995,   10000900
   208,   208,   260,   10000939
## Shortest route ##
(35.6404920, 139.5442446)[(-0.0005206, 10.0001700)] -> (35.6404500, 139.5442250)[(-0.0002600,
14.9997280)] -> (35.6403921, 139.5442571)[(15.0006852, 19.9995869)] -> (35.6403182,
139.5443408)[(14.9999745, 24.9999609)] -> (35.6403023, 139.5443925)[(19.9998718, 24.9999413)] ->
(35.6403055, 139.5444343)[(29.9999622, 14.9999622)] -> (35.6403804, 139.5446063)[(35.0000299,
10.0000023)] -> (35.6403645, 139.5446580)[(40.0000645, 9.9999218)] -> (35.6402964,
```

139.5446087)[(39.9999290, 20.0000352)] -> (35.6403210, 139.5446808)[(45.0001148, 14.9999471)] -> (35.6403041,
139.5447320)[(5 0.0004911, 14.9997195)] -> GOAL -> Derived optimal route Start to move! ** -> 導出された最適経路
-> 親機が最適経路移動を開始

[1m[04:43:31] [36mSequence: [32m'policy_learning' > 'escaping' -> 草地にスタック，サーボの草地用のフィルム装着忘れから脱出不能と判断し中断
[0mRetrying escaping... (1/4)
Retrying escaping... (2/4)
Retrying escaping... (3/4)

• Discussion It

was confirmed that it is possible to create a control history report from the obtained log data in order to submit a specified control history report **after the mission.** In addition, **it can be seen that the sequence log** makes it easy to analyze what needs to be fixed in the future (at what stage is the problem occurring, what is the cause of the problem, etc.). **Using this log, we aim to improve the sequence** algorithm and increase the success rate of end-to-end tests.

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

1. **Each person in charge (hardware, software, overall schedule, etc.)** 1.1.

[Whole team] ÿ **Regular MTG: Every Wednesday** ÿ **BBM completion: 5/24** ÿ **PM completion: 6/20** ÿ Static load test: 6/23~6 /30 ÿ **Vibration test: Early July** ÿ **Preliminary examination report submission: 7/7** ÿ **End-To-End test: 7/10~9/7** ÿ **Main examination report submission: 8/8**

ÿ **FM completion:** 1.2. **[Software]**

ÿ **Image processing system completed: 6/20** ÿ **Control system completed: 6/20** ÿ **Communication system completed: 6/1** ÿ **Inversion/rollover recovery test: 7/2** ÿ **Communication device power ON**

ÿ **Communication frequency change test:**
6/23~6/30 ÿ **Best route derivation test:**
7/1~7/7 ÿ **Communication establishment**
test between base unit and slave
unit: 7/4 ÿ **Slave unit route evaluation**
test: 7/8 ÿ **Slave unit initial**
position placement test: 7/13 ÿ
Specified route driving test: 7/8
ÿ **Slave unit number change test: 7/15**
ÿ **Long distance**
communication test:
7/15 ÿ **Control history report test:**
7/15 1.3. **[Hardware]** ÿ **General shape**
determination: ~6/2 ÿ **BBM**
aircraft creation: ~5/21 ÿ PM aircraft
creation: 6/2~6/20 ÿ Mass test: 6/22~6/23 ÿ
Carrier storage Test: 6/22~6/23 ÿ
Parachute drop test: 6/23~6/30 ÿ
Driving performance confirmation
test: 6/25 ÿ
Opening impact test: 6/23~6/30 ÿ
Landing impact test: 6/ 23~6/30 1.4. **[Circuit]** ÿ
Selection of sensor used: 4/30 ÿ
BBM universal board mounting:
5/24 ÿ **PM printed circuit board**
design: 6/2 ÿ **PM printed circuit board ordering: 6/6** ÿ **Printed circuit board mounting : 6/15** ÿ **Circuit ma**

2. **Gantt Chart** ÿ

Team schedules are managed using the Gantt chart below.

https://docs.google.com/spreadsheets/d/1Liq_D6biy94feRNC
DsqdklPMmMJ1u1S0WUqk_Ri7f3M/edit?usp=sharing

ÿ **The current task is entered on the "Main" sheet. The progress of each item is managed in the progress column, and the meaning of each item is as follows.**

Backlog: Haven't started work yet
InProgress: Working
Test & **Confirming: Check if the task is completed**
Done: Finished (painted in gray)

Canceled: Task canceled (blacked out, meaning a task that is no longer needed)

Chapter 8: Impressions of the responsible teacher (as of this review)

This year, multiple child rovers will explore in advance the location where the parent rover is scheduled to proceed, and send this information to the parent rover, allowing the parent rover to calculate the safe and best route and travel. We are working on ways to do this. Although all experiments have been completed and the mission success rate has increased, the number of child rovers is small and there are some areas where communication between the child rovers and the main unit is incomplete. I think some countermeasures are needed. We will continue to provide guidance on this part, so we appreciate your consideration.

Chapter 9 **Tournament Results Report** (1)

Purpose

We will confirm whether **this CanSat can autonomously control the sequence from carrier release determination to goal determination and mission accomplishment .** At the same time, after the CanSat (base unit) lands, we will establish communication with the slave unit and verify whether it is possible to control the travel of a safe route by using the travel data from the slave unit's advance search according to **the sequence. did.**

(2) Results

Summarize the tournament results in ARLISS. Table 9.1 **shows** the degree of achievement of the success criteria .

Table 9.1 **Success Criteria Achievement**

	Level Minimum Success	full success
First time	●	-
Second time	●	ÿ

• First launch

<Success Criteria Achievement

Status> Minimum •

Success: Full Success: X

<Control

overview> September 14, 2022

(There is a difference between the time setting in OrangePi and the actual time, and the posting time in OrangePi is 07:23. The timestamp in OrangePi is described below .)

07:08:20 **Program start**

07:34:17 **Base unit release judgment**

07:44:28 **Base unit landing judgment/parachute separation process started**

07:44:44 Parachute detachment process completed/optimum route search sequence started

07:44:56 **Waiting for pairing with slave unit (the mission ended here because the parent unit's tire came off)**

<Aircraft trajectory>

Below is the aircraft trajectory data plotted from GPS data. The red line shows the trajectory of the parent device. In addition, the part of the additional experiment on the right had the tire removed, but the circuit was still functioning, so this is the trajectory of the additional experiment conducted after the mission was completed using the execution program of the main unit (explanation is omitted).).

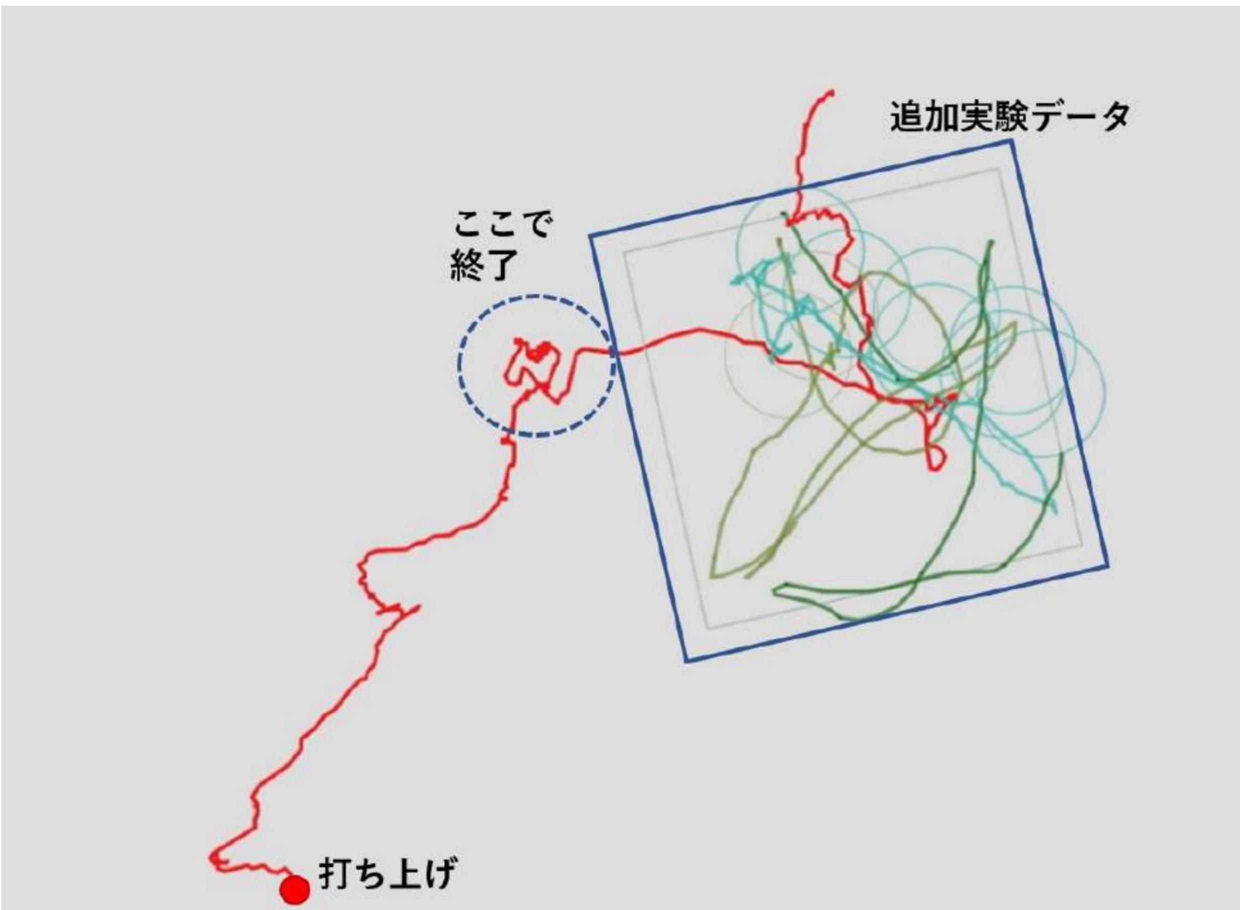

Figure 9.1 **Trajectory of the first drop**

<Control history log>

```
=== Team Dolphins === ÿProgram start [0m[30m[43m Takadama
  Lab. ARLISS 2022
```

...Omitted to display settings...

[1m[07:08:19] [36mSequence: [32m'waiting' ÿ **wait sequence (waiting to fire)** [0mTime: 07:08:20
Light count: 0/10 (LOW)

Time: 07:08:21
Light count: 0/10 (LOW)

Time: 07:08:22
Light count: 0/10 (LOW)

···omission···

Time: 07:34:05
Light count: 0/10 (LOW)

Time: 07:34:06
Light count: 0/10 (LOW)

Time: 07:34:07
Light count: 0/10 (HIGH) **ÿEmission, light sensor starts counting**

Time: 07:34:08
Light count: 1/10 (HIGH)

Time: 07:34:09
Light count: 2/10 (HIGH)

···omission···

Time: 07:34:15
Light count: 8/10 (HIGH)

Time: 07:34:16
Light count: 9/10 (HIGH)

Wi-Fi has been restarted!
Warning: LoRaRM92a has already stopped sleep mode!
LoRa has been restarted!
[1m[07:34:17] [36mSequence: [32m'falling' **ÿEmission determination by optical sensor complete** Falling **sequence**
start [0mTime: 07:34:18

Pressure count: 1/10 (578.607 hPa)
Gyro count: 0/10 GPS
position: 40.8750783

Time: 07:34:19
Pressure count: 2/10 (579.0068 hPa)
Gyro count: 0/10 GPS
position: 40.8750783

···omission···

Time: 07:44:18
Pressure count: 600/10 (878.9586 hPa)
Gyro count: 0/10 GPS
position: 40.9119950

Send data (40.9119950
Time: 07:44:19
Pressure count: 601/10 (878.8744 hPa)
Gyro count: 0/10 GPS
position: 40.9120000

Time: 07:44:20
Pressure count: 602/10 (878.8754 hPa)
Gyro count: 1/10 **ÿ Landing, gyro count start** GPS
position: 40.9120000

Time: 07:44:21
Pressure count: 603/10 (878.8691 hPa)
Gyro count: 2/10 GPS
position: 40.9119983

···omission···

Time: 07:44:27
Pressure count: 609/10 (878.8713 hPa)
Gyro count: 8/10 GPS
position: 40.9120333

Time: 07:44:28
Pressure count: 610/10 (878.8312 hPa)
Gyro count: 9/10 GPS
position: 40.9120417

Falling completed! (by gyro and pressure) **ÿGyro count finished, paraseparating sequence started**
[1m[07:44:29]
[36mSequence: [32m'para_separating' [0mPara separating...
(1/5)
Para separation... (2/5)
Para separation... (3/5)
Para separation... (4/5)
Send data (40.9122200
Para separation... (5/5)
Para separation finished!
Error: Failed to get parameter 'navigating_method' from config file!
The config value of 'navigating_method' is PolicyLearning
Method is Magnet.
Error: Failed to get parameter 'wait_avoid_child_time' from config file!
Log file: log/20220914_0708_log_safty_evaluation2.csv Gps auto
reset is truned ON.
Log file: log/20220914_0708_log_policy_learning1.csv [1m[07:44:44]
[36mSequence: [32m'policy_learning' > 'magnet_calibrating' **ÿEnd of paraseparating sequence, start of optimal route derivation sequence** [0mMagnetCalibrating:
Turning right...
MagnetCalibrating: Turning left...
MagnetCalibrating: Turning stopped! min: (53
max: (85
Command:

nineaxis minmax 53 -199 26 85 -154 79
----

filtered min: (54 filtered
max: (82
Command:
nineaxis minmax 54 -196 29 82 -156 66
MagnetCalibrating has been finished!
[1m[07:44:56] [36mSequence: [32m'policy_learning' [0mPush
message: 6f626f6f74 ** Start pairing
** **ÿ Parent unit Pairing waiting state (Because the tires of the parent unit were damaged) mission completed)**

- Second launch

<Success Criteria Achievement Status> Minimum Success: •

Full success: ÿ

<Control

overview> September 15, 2022

(There is a difference between the time setting in OrangePi and the actual time, and the posting time in OrangePi is 11:24. The timestamp in OrangePi is described below .)

10:57:12 **Program start**

11:24:57 **Base unit release judgment**

11:33:43 **Base unit landing judgment/parachute separation process started**

11:33:58 Parachute detachment process completed/optimum route search sequence started

11:34:21 **Waiting for pairing with handset**

11:40:18 **Confirmation of communication establishment with slave unit 03**

11:40:36 **Confirmation of communication establishment with slave unit 01**

11:40:42 **Confirmation of communication establishment with slave unit 02 (minimum success achieved)/Initial position arrangement Subsequence start**

11:42: **19Confirmation of arrival of slave unit 02 initial position**

11:44:14Slave **unit 03 communication disconnected/Slave unit search started**

11:44:26 **Remote unit 01 communication disconnected**

11:49:11 **Mission ended because communication with all slave units was disconnected.**

<Aircraft trajectory>

Due to a GPS problem, correct logs could not be output.

<Control history log>

=== Team Dolphins === **ÿProgram start** [0m[30m[43m
Takadama Lab. ARLISS 2022

...Omitted to display settings...

[1m[10:57:12] [36mSequence: [32m'waiting' **ÿwait sequence**

[0mTime: 10:57:13
Light count: 0/10 (LOW)

Time: 10:57:14
Light count: 0/10 (LOW)

···omission···

Time: 11:24:47
Light count: 0/10 (LOW)

Time: 11:24:48 **ÿLight sensor count start**
Light count: 0/10 (HIGH)

Time: 11:24:49
Light count: 1/10 (HIGH)

Time: 11:24:50
Light count: 2/10 (HIGH)

···omission···

Time: 11:24:55
Light count: 8/10 (HIGH)

Time: 11:24:56
Light count: 9/10 (HIGH)

Wi-Fi has been restarted!
Warning: LoRaRM92a has already stopped sleep mode!
LoRa has been restarted!
[1m[11:24:57] [36mSequence: 'falling' **ÿ Release judgment DONE falling sequence start**
[0mTime: 11:24:58
Pressure count: 1/10 (623.319 hPa) 0/10
count : GPS Gyro
position: 40.8708983 -119.102085

Time: 11:24:59
Pressure count: 2/10 (623.7852 hPa)
Gyro count: 0/10 GPS
position: 40.8710217 -119.1020417

···omission···

Time: 11:33:33
Pressure count: 515/10 (879.14 hPa)
Gyro count: 0/10
GPS position: 40.8760000 -119.08356

Time: 11:33:34
Pressure count: 516/10 (879.141 hPa)
Gyro count: 1/10 **ÿ Gyro count start**
GPS position: 40.8760367 -119.083515

Time: 11:33:35
Pressure count: 517/10 (879.1457 hPa)
Gyro count: 2/10
GPS position: 40.8760650 -119.0834867

···omission···

Time: 11:33:41
Pressure count: 523/10 (879.1013 hPa)
Gyro count: 8/10
GPS position: 40.8762783 -119.0831667

Time: 11:33:42
Pressure count: 524/10 (879.1646 hPa)
Gyro count: 9/10
GPS position: 40.8763083 -119.0830733

Send data (40.8763383 -119.0829817) by gps sender!
Falling completed! (by gyro and pressure)
[1m[11:33:43] [36mSequence: [32m'para_separating' **ÿ Paraseparating sequence start**
[0mPara separating... (1/5)
Para separation... (2/5)
Para separation... (3/5)
Para separation... (4/5)
Send data (40.8761617 -119.0837650) by gps sender!
Para separation... (5/5)
Para separating finished! **ÿ Para separating finished!**
Error: Failed to get parameter 'navigating_method' from config file!

[1m[11:33:58] [36mSequence: [32m'policy_learning' > 'magnet_calibrating'ÿ
Appropriate route search sequence start

```
[0m[1m[11:33:58] [36mSequence: [32m'policy_learning' > 'magnet_calibrating' > 'waking' [0mWaking
finished!
[1m[11:34:03]
[36mSequence: [32m'policy_learning' > ' magnet_calibrating'

[0mMagnetCalibrating: Turning right...
MagnetCalibrating: Turning left...
MagnetCalibrating: Turning stopped! min: (-36
44 max: (113 177            -426)
Command:                    -368)

nineaxis minmax -36 44 -426 113 177 -368
--------------------

filtered min: (-32 filtered        48        -420)
max: (98 172                        -379)
Command:
nineaxis minmax -32 48 -420 98 172 -379
MagnetCalibrating has been finished!
[1m[11:34:16] [36mSequence: [32m'policy_learning' [0mPush
message: 6f626f6f74 ** Start pairing
** Time: 11:34:21

Type/Mode/Id: parent/WAIT_PARING/0000 ÿWaiting for pairing

Time: 11:34:27
Type/Mode/Id: parent/WAIT_PARING/0000

Send data (40.8761333 -119.0838300) by gps sender!
Time: 11:34:33
Type/Mode/Id: parent/WAIT_PARING/0000

···omission···

Time: 11:39:47
Type/Mode/Id: parent/WAIT_PARING/0000

Send data (40.8771467 -119.0854183) by gps sender!
Time: 11:39:53
Type/Mode/Id: parent/WAIT_PARING/0000

040000012345670001234567001 80d
RoverID: 3 Mode: SYN_RECEIVED              AckNum: 1 SynNum: 0
SndUna: 0        SndNxt: 1 RcvNxt: 1 canReceive: 0
```

Ack: 0 Syn: 1 Fin: 0 RecAckNum: 0 RecSynNum: 0
RecSec: 0
pause
Send!
Time: 11:39:59
Type/Mode/Id: parent/WAIT_PARING/0000

Time: 11:40:06
Type/Mode/Id: parent/WAIT_PARING/0000

04000001234567000123456700180d
RoverID: 1 Mode: SYN_RECEIVED AckNum: 1 SynNum: 0
SndUna: 0 SndNxt: 1 RcvNxt: 1 canReceive: 0
Ack: 0 Syn: 1 Fin: 0 RecAckNum: 0 RecSynNum: 0
RecSec: 0
Time: 11:40:12
Type/Mode/Id: parent/WAIT_PARING/0000

04000001234567000123456700180d
RoverID: 2 Mode: SYN_RECEIVED AckNum: 1 SynNum: 0
SndUna: 0 SndNxt: 1 RcvNxt: 1 canReceive: 0
Ack: 0 Syn: 1 Fin: 0 RecAckNum: 0 RecSynNum: 0
RecSec: 0
Time: 11:40:18
Type/Mode/Id: parent/WAIT_PARING/0000

80000101234567010123456701050f727373698b1e
Connection established with LoRaID 0003! **ÿ Confirm communication establishment with slave device 03**
Rover ID: 3 Mode: ESTABLISHED AckNum: 2 SynNum: 1
SndUna: 1 SndNxt: 2 RcvNxt: 2 canReceive: 0
Ack: 1 Syn: 0 Fin: 0 RecAckNum: 1 RecSynNum: 1
RecSec: 1
Time: 11:40:24
Type/Mode/Id: parent/WAIT_PARING/0000

Send!
Time: 11:40:30
Type/Mode/Id: parent/WAIT_PARING/0000

Time: 11:40:36
Type/Mode/Id: parent/WAIT_PARING/0000

80000101234567010123456701050f727373698b1e

Connection established with LoRaID 0001! ÿ **Confirm communication establishment with slave device 01**

RoverID: 1 Mode: ESTABLISHED AckNum: 2 SynNum: 1

SndUna: 1 SndNxt: 2 RcvNxt: 2 canReceive: 0

Ack: 1 Syn: 0 Fin: 0 RecAckNum: 1 RecSynNum: 1

RecSec: 1

Time: 11:40:42

Type/Mode/Id: parent/WAIT_PARING/0000

80000101234567010123456701050f727373698b1e

Connection established with LoRaID 0002! ÿ **Confirm communication establishment with slave device 02**

RoverID: 2 Mode: ESTABLISHED AckNum: 2 SynNum: 1

SndUna: 1 SndNxt: 2 RcvNxt: 2 canReceive: 0

Ack: 1 Syn: 0 Fin: 0 RecAckNum: 1 RecSynNum: 1

RecSec: 1

** Checked connection from children(3/3) **

[31m Minimum success clear! [m ÿ**By establishing communication, the minimum success was met.**

Push message: 1f676f746f2a34302e383737303539362a2d3131392e30383532363836

** Child(LoRaID: 0001) go to (40.8770596 -119.0852686) ** ÿ **Search direction to each child device instructions**

Push message: 2f676f746f2a34302e383737303432342a2d3131392e30383531353139

** Child(LoRaID: 0002) go to (40.8770424 -119.0851519) **

Push message: 3f676f746f2a34302e383737303235332a2d3131392e30383530333534

** Child(LoRaID: 0003) go to (40.8770253 -119.0850354) **

** Move children to initial position ** ÿ **Initial position placement subsequence start**

Time: 11:40:48

Type/Mode/Id: parent/WAIT_TO_MOVE_CHILDREN_INIT_POS/0000

1.01235E+24

Rover ID: 3 Mode: ESTABLISHED AckNum: 2 SynNum: 1

SndUna: 1 SndNxt: 2 RcvNxt: 2 canReceive: 1

Ack: 0 Syn: 0 Fin: 0 RecAckNum: 1 RecSynNum: 2

RecSec: 0

Time: 11:40:54

Type/Mode/Id: parent/WAIT_TO_MOVE_CHILDREN_INIT_POS/0000

Time: 11:41:00

Type/Mode/Id: parent/WAIT_TO_MOVE_CHILDREN_INIT_POS/0000

Send!
Time: 11:41:06
Type/Mode/Id: parent/WAIT_TO_MOVE_CHILDREN_INIT_POS/0000

80000201234567020123456700007f6
RoverID: 1 Mode: ESTABLISHED AckNum: 2 SynNum: 2
SndUna: 2 SndNxt: 3 RcvNxt: 2 canReceive: 1
Ack: 1 Syn: 0 Fin: 0 RecAckNum: 2 RecSynNum: 2
RecSec: 0
Time: 11:41:12
Type/Mode/Id: parent/WAIT_TO_MOVE_CHILDREN_INIT_POS/0000

80000201234567020123456700007f6
RoverID: 2 Mode: ESTABLISHED AckNum: 2 SynNum: 2
SndUna: 2 SndNxt: 3 RcvNxt: 2 canReceive: 1
Ack: 1 Syn: 0 Fin: 0 RecAckNum: 2 RecSynNum: 2
RecSec: 0
Time: 11:41:18
Type/Mode/Id: parent/WAIT_TO_MOVE_CHILDREN_INIT_POS/0000

Time: 11:41:24
Type/Mode/Id: parent/WAIT_TO_MOVE_CHILDREN_INIT_POS/0000

Time: 11:41:30
Type/Mode/Id: parent/WAIT_TO_MOVE_CHILDREN_INIT_POS/0000

Send!
Time: 11:41:36
Type/Mode/Id: parent/WAIT_TO_MOVE_CHILDREN_INIT_POS/0000

Time: 11:41:42
Type/Mode/Id: parent/WAIT_TO_MOVE_CHILDREN_INIT_POS/0000

Time: 11:41:48

Type/Mode/Id: parent/WAIT_TO_MOVE_CHILDREN_INIT_POS/0000

80000201234567020123456700 07f6

RoverID: 2 Mode: ESTABLISHED AckNum: 2 SynNum: 2

SndUna: 2 SndNxt: 3 RcvNxt: 2 canReceive: 1

Ack: 1 Syn: 0 Fin: 0 RecAckNum: 2 RecSynNum: 2

RecSec: 0

Time: 11:41:55

Type/Mode/Id: parent/WAIT_TO_MOVE_CHILDREN_INIT_POS/0000

Time: 11:42:01

Type/Mode/Id: parent/WAIT_TO_MOVE_CHILDREN_INIT_POS/0000

Send!

Time: 11:42:07

Type/Mode/Id: parent/WAIT_TO_MOVE_CHILDREN_INIT_POS/0000

Time: 11:42:13

Type/Mode/Id: parent/WAIT_TO_MOVE_CHILDREN_INIT_POS/0000

Time: 11:42:19

Type/Mode/Id: parent/WAIT_TO_MOVE_CHILDREN_INIT_POS/0000

0000020123456702012345670 21f050f7372756e2a332a34302e383738303036372a2d3131392
e303836313238330f646f6e654e37

RoverID: 2 Mode: ESTABLISHED AckNum: 3 SynNum: 2

SndUna: 2 SndNxt: 3 RcvNxt: 3 canReceive: 1

Ack: 0 Syn: 0 Fin: 0 RecAckNum: 2 RecSynNum: 2

RecSec: 1

Success! lora cmd push: srun

Success! lora cmd push: done

** Moved ID: 0002 to init pos! (1/3) ** **ÿ1 unit arrives at initial position**

Time: 11:42:25

Type/Mode/Id: parent/WAIT_TO_MOVE_CHILDREN_INIT_POS/0000

···omission···

Time: 11:44:14

Type/Mode/Id: parent/WAIT_TO_MOVE_CHILDREN_INIT_POS/0000

Warning: Forced disconnection due to timeout! (LoRaID: 0003)ÿ1 device communication disconnected

Time: 11:44:20

Type/Mode/Id: parent/WAIT_TO_MOVE_CHILDREN_INIT_POS/0000

Time: 11:44:26

Type/Mode/Id: parent/WAIT_TO_MOVE_CHILDREN_INIT_POS/0000

2.01235E+24

RoverID: 2 Mode: ESTABLISHED AckNum: 3 SynNum: 2

SndUna: 2 SndNxt: 3 RcvNxt: 3 canReceive: 1

Ack: 0 Syn: 0 Fin: 0 RecAckNum: 2 RecSynNum: 3

RecSec: 0

Warning: Forced disconnection due to timeout! (LoRaID: **0001)ÿCommunication with another device disconnected**

** Moved all children! ** ÿSince communication between two devices was disconnected, one child device moved to the route evaluation subsequence.

comebackGoal: 2.68e+03 15

** Set search area! [origin: (40.8768714 -119.0851468) 10.5826873 goal: azimuth:
(40.8771116 -119.0849062)] **

Push message: 6f706f732a34302e383736383436372a2d3131392e30383439373137

** Start children search! ** **ÿStart child device search**

Time: 11:44:32

Type/Mode/Id: parent/CHILDREN_SEARCH/0000

Time: 11:44:38

Type/Mode/Id: parent/CHILDREN_SEARCH/0000

Time: 11:44:44

Type/Mode/Id: parent/CHILDREN_SEARCH/0000

Send!

Time: 11:44:50

Type/Mode/Id: parent/CHILDREN_SEARCH/0000

Time: 11:44:56

Type/Mode/Id: parent/CHILDREN_SEARCH/0000

2.01235E+24

RoverID: 2 Mode: ESTABLISHED AckNum: 3 SynNum: 2

SndUna: 2 SndNxt: 3 RcvNxt: 3 canReceive: 1

Ack: 0 Syn: 0 Fin: 0 RecAckNum: 2 RecSynNum: 3

RecSec: 0

Time: 11:45:02

Type/Mode/Id: parent/CHILDREN_SEARCH/0000

Time: 11:45:08

Type/Mode/Id: parent/CHILDREN_SEARCH/0000

Time: 11:45:14

Type/Mode/Id: parent/CHILDREN_SEARCH/0000

Push message: 6f706f732a34302e383736393330302a2d3131392e30383439393137

** Send my position data! **

Send!

Time: 11:45:20

Type/Mode/Id: parent/CHILDREN_SEARCH/0000

Time: 11:45:26

Type/Mode/Id: parent/CHILDREN_SEARCH/0000

Time: 11:45:32

Type/Mode/Id: parent/CHILDREN_SEARCH/0000

00000201234567030123456701126f736166742a312a2d332a3332322a313537cc67

RoverID: 2 Mode: ESTABLISHED AckNum: 3 SynNum: 2

SndUna: 2 SndNxt: 3 RcvNxt: 3 canReceive: 1

Ack: 0 Syn: 0 Fin: 0 RecAckNum: 2 RecSynNum: 3

RecSec: 0

Success! lora cmd push: saft

** Get safty evaluation data! [LoRaID: 0002 -119.0861667) LatLng: (40.8780664

Vec: (114.9950320 -108.8124561) RoverState:

STUCKED] ** **ÿReceive route evaluation data from slave device**

Time: 11:45:39

Type/Mode/Id: parent/CHILDREN_SEARCH/0000

Time: 11:45:45

Type/Mode/Id: parent/CHILDREN_SEARCH/0000

...Omitted (continue searching while receiving some data)...

Time: 11:48:46

Type/Mode/Id: parent/CHILDREN_SEARCH/0000

Time: 11:48:52

Type/Mode/Id: parent/CHILDREN_SEARCH/0000

Warning: Forced disconnection due to timeout! (LoRaID: 0002)ÿ **Communication with the last device has been terminated** ** Terminate because the number of connected children has reached 0 **

Error: Connection does not exist!
Time: 11:48:58

Type/Mode/Id: parent/ABORT/0000

Send!
Time: 11:49:04

Type/Mode/Id: parent/ABORT/0000

Time: 11:49:11

Type/Mode/Id: parent/ABORT/0000

** Abort policy learning sequence! ** ** Closed connections with all children! **ÿ **Mission ended because communication with all child devices was cut off.**

- **Trajectory during additional**

experiments The trajectory during additional experiments conducted after the second mission was completed and after confirming that the GPS function was normal is shown. Although this is not related to the actual trial, the results are shown as the goal we were trying to achieve.

As in the diagram shown for the first drop, the red line shows the trajectory of the parent device, and the three lines in shades of green show the trajectories of the child devices. In addition, the large square area indicates the area in which the base unit wants to travel, and the light green circles are the terrain route evaluation data sent by each slave unit. The darker the circle, the more difficult it is to drive. As shown in the figure, it can be seen that the three slave units evenly evaluate the area in which the parent unit wants to drive. In addition, the red dots indicate the midpoints of the derived optimal route, and it can be seen that the base unit is able to travel near these points.

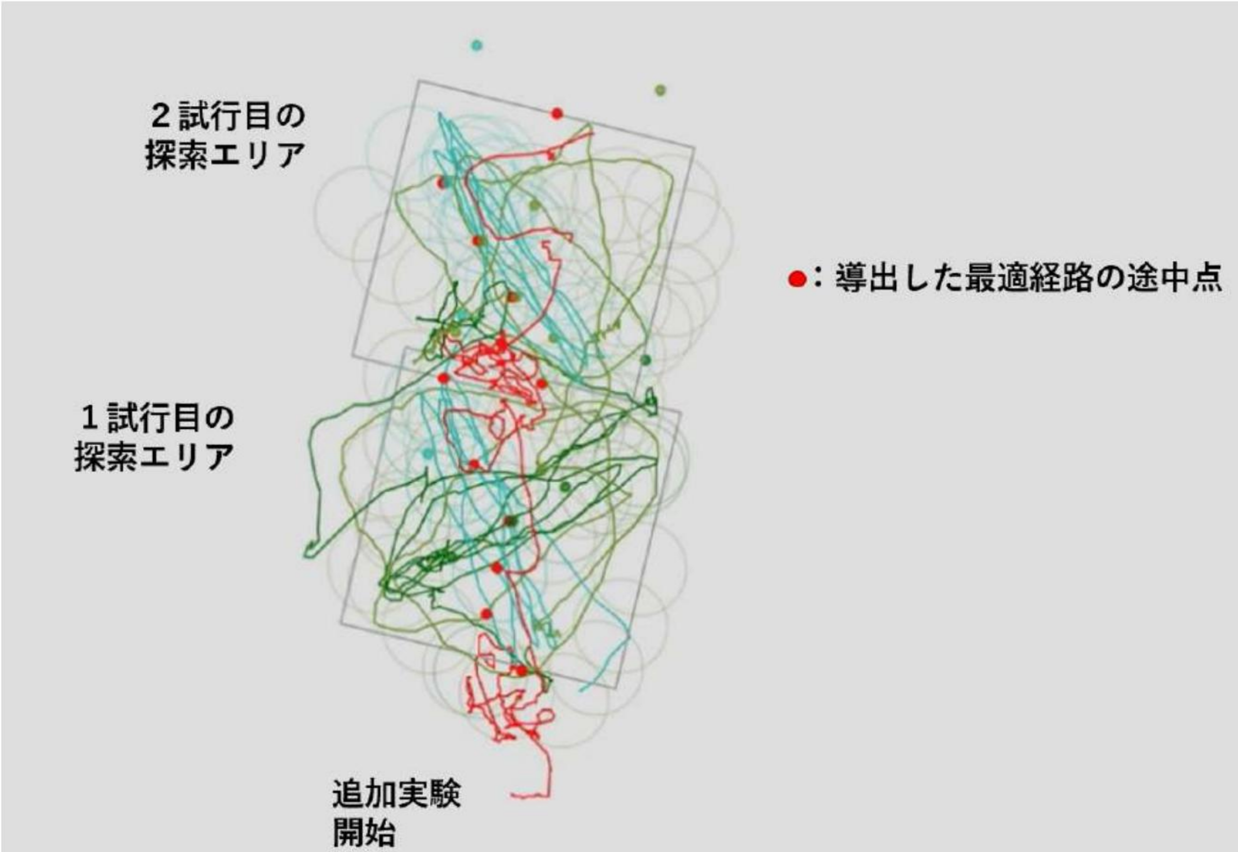

Figure 9.2 **Aircraft trajectory in additional experiment after second drop**

(3) Discussion

• First **Drop As**

can be seen at the end of the control history for the first drop, the aircraft's tires were worn out by the time we discovered it, making it impossible to continue the mission. I thought of several reasons for this, but further analysis suggests that rather than the parachute coming off at the moment it landed, it was probably because the parachute could not be released properly and was hit by strong winds, causing the parachute to be dragged around. Based on this result, we reviewed the tire connection part of the aircraft (especially the part where the set screw engages the tire shaft) and improved it to make it a more robust tire connection. As a result, the tire did not come off during the second drop attempt described below .

• Second drop

Based on what we learned from the first drop, we made the tire connection more robust. In the second trial, no damage was observed around the tires, indicating that the improvements were successful. However, as a result, communication with the slave units was gradually cut off from the initial positioning stage, and eventually communication with all slave units was cut off during the search stage. This is due to the fact that the child units all started traveling in a direction further away from the parent unit, based on actual on-site observations. In addition, the direction we aimed **was quite different from the initial position we had originally envisioned . This coordinate system malfunction is thought to have arisen from the GPS sensor. Probably during the second drop, the values acquired by the GPS sensor changed accidentally when calculating the coordinates of the initial position. Therefore, because the coordinates of the initial arrangement were calculated based on the recognition that the parent unit was located quite far from its original position, it is assumed that the slave unit traveled far away from the parent unit. This is also the reason why only one aircraft started searching after the initial positioning, and then communication was cut off . When the GPS sensor was checked after the mission ended, there was no particular difference in the output. Therefore, in the additional experiment (trajectory shown in Figure 9.2), it was found that the search could be performed normally by sending the correct coordinates to the slave device.** Based on the results of **this additional experiment ,** we believe that a coordinate calculation error due to an accidental G

Chapter 10 **Summary**

(1) Points of ingenuity and effort (hardware, software, management aspects) 1Hardware /**circuit aspects**

• About hardware

• The main issue of this mission is after landing and deploying the parachute, so we devised the part that connects the parachute mechanism to ensure that this can be done. Specifically, the connection part did not touch the ground, and the nail part at the end of the parachute that was tied to the aircraft body could easily come out. As a result, during the second drop, we were able to complete the process from landing to detaching the parachute without

any problems. • About

circuits • Each year, circuit malfunctions often caused bottlenecks that delayed the development and testing of aircraft, causing work to stop. For this reason, the circuitry in this aircraft was designed with great care to avoid any malfunctions. Additionally, in order to make the circuit smaller, the circuit installed in the handset was designed to utilize both sides of the circuit to avoid increasing its width.

2 **soft side**

- In this mission, we will use inter-machine communication, which is essential for transmitting safety evaluation data, etc. I used LoRa. However, since this communication standard is based on the premise of infrequent communication, it was not compatible with this mission, which required communication with multiple aircraft every few seconds . Therefore, by implementing a new API based on the original communication standard on top of the existing API, it has become possible to perform more stable communication than before.

3Management **aspect**

- This time, we had to be especially conscious from a management perspective that we had to secure a certain number of aircraft. The mission required not only the base unit but also at least three slave units to be in perfect working condition , so in fact, the United States had three base units and seven slave units. went. As a result, only one main unit and three slave units operated normally during the last launch, so considering that the number of aircraft required to be manufactured was quite high considering that the number of aircraft that had been manufactured was at the limit. It can be said that it was an enormous mission.

(2) Issue 1

Hardware/circuit aspect

- In this mission, we focused on creating a framework in which the driving data of multiple slave units is sent to the base unit and the base unit uses that data to drive, so the shape of the slave unit is the same as that used by the base unit. There is room for improvement in terms of whether the driving data was appropriate and whether an appropriate sensor was selected. The future challenge is to improve the circuitry and hardware in order to better ensure that the base u

2 **soft side**

- We are working on implementing LoRa-related communications, which are essential for carrying out missions, until around the end of August, and we are thinking about the important safety evaluation method for slave units and algorithms for the base unit to run based on the safety evaluation data. , the implementation period was shortened. Therefore, next time I would like to implement detailed device-related issues from an earl

3Management **aspect**

- The cost of this mission was unusual. As more aircraft were produced, costs increased proportionately. Because the focus was on how to make the mission successful and neglecting the cost aspect, it is undeniable that it could have been accomplished at a slightly lower cost. Additionally, given the number of aircraft needed, the start of the full-scale testing required for the mission was delayed much later than originally planned, which was a major point of reflection.

(3) Future outlook

• **Mission aspect**

Although our mission this time may be different from the original intention of CanSat, we achieved mutual cooperation among three or more rovers by installing it on **the ground . Through this project, I felt that there are many things that can be accomplished through mutual cooperation between multiple aircraft. In addition to the wide-ranging exploration conducted in this project, we would like to pass on the technology so that it can be connected to more advanced mission settings.**

• **Development**

aspect If you are going to do a mission like we did, where the theme is mutual cooperation between three or more aircraft, I think it would be a good idea to estimate and use it in units of several years rather than completing it in one year. ÿÿ If you use the same handset every year but change what it does each year, you may be able to reduce overall costs, so I would encourage organizations whose mission is to control multiple machines at the same time to consider this.