ARLISS2022 development review report

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• Purpose of creating CanSat and reason for participating in the competition The purpose of our laboratory's creation of CanSat is to improve cooperativeness and technical ability through team development. The ultimate goal was to make the ARLISS mission a success, and in order to achieve that goal, we also participated in the Noshiro Convention.

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Chapter 1 Mission Statement

Adaptive stuck avoidance rover for autonomous exploration

After landing, use GPS information to drive towards the goal point determined by runback. At this time, two stages are established: a learning phase and a route planning phase. In the learning phase, the aircraft moves to the switching point while taking multiple terrain images using a camera attached to the front of the aircraft. By acquiring and comparing various feature images such as edge images and images with one or two colors such as Red extracted from RGB for each captured image, the similarity to the route taken in the learning phase and We acquire a sparse model that enables the identification of important feature image types. In the route planning phase, similar processing is performed on images taken at each point, and a sparse model is used to create a route similar to the terrain traveled in the learning phase, that is, a feature value of the terrain image that can be traveled. Select the route you have chosen and drive toward the goal.

The significance and purpose of the mission is described below. In recent years, exploration of the Moon and Mars has become more active, and exploration using rovers is also being carried out. Communication delays are an issue in the rover's movement. Mars is very far from Earth, and communication delays of about 20 minutes may occur, and the time during which signals can be communicated is limited. Therefore, the rover is required to plan its route autonomously. However, there is a possibility that the vehicle will become stuck due to obstacles such as soft ground or rocks and become unable to travel, so it is important to autonomously avoid getting stuck. In order to avoid getting stuck and navigate a safe route, it is necessary to be aware of the environment around the rover, but if a small rover similar to CanSat is assumed, a low spec. It is necessary to use a powerful CPU to process information such as images and recognize the environment. Additionally, challenges when using deep learning include the difficulty of obtaining a sufficient amount of data on site, and the fact that the learned controller becomes a black box, making it impossible to explain the calculation process leading to the output. , and the inability to investigate the cause in the event of failure. Therefore, we use a method called ``sparse modeling.'' Sparse modeling is based on the assumption that the essential information contained in everything is very small (sparseness), and it is based on the assumption that the essential information contained in everything is sparse (sparseness). This is a method of identifying and extracting information. There are three points that make this method suitable for CanSat.The first point is that, unlike learning, it focuses on the relationships between data, so it does not require a large amount of data.The second point is that it does not require a large amount of data. Because it does not require large amounts of data, it is fast and consumes little power. Third, the calculation process is easy to explain. Due to the nature of deep learning, which involves extracting features from a large amount of data, the calculation process is extremely complex. On the other hand, a sparse model expresses the input-output relationship as simply as possible, making it possible to explain the calculation process. Therefore, if the expected results are not obtained, it is possible to investigate the cause. This mission aims to select a safe route by installing a camera on the rover and processing the images obtained. Specifically, there are two stages: a learning phase and a route planning phase, as shown in Figure 1.1. In the learning phase, images are taken and a sparse model is created under the assumption that the route being traveled is somewhat safe. Even if it gets stuck, it will avoid getting stuck and then continue collecting images. Since no images are taken during avoidance maneuvers, most of the images collected should be safe to some extent. In the route planning phase, the model obtained in the learning phase is compared with the currently captured image, and a route with more similar characteristics, that is, a safer route that is similar to the route that could already be taken in the learning phase, is selected. Aim for a high route.

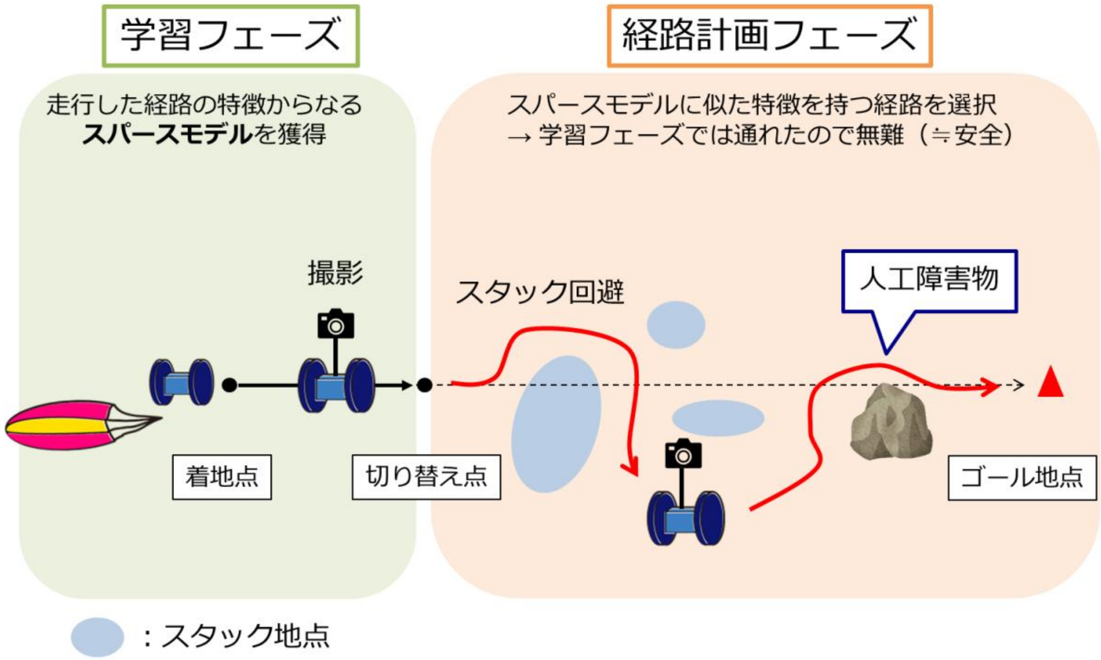


Figure 1.1 Mission overview

Chapter 2 Success Criteria 2.1
Success Criteria

minimum success	A single image is taken, and various feature images are obtained from that image, such as an edge image and an image in which one or two colors such
middle success	as Red are extracted from RGB. The rover travels to the switching point while taking multiple images. By acquiring feature images for the captured images and comparing them using the feature images obtained through minimum success as a reference, it is possible to select a route with a small difference from the reference and identify the
full success	types of important feature images. Obtain a sparse model that Drive toward the goal point while selecting a route. If stuck, perform retraining and update the sparse model. When CanSat and a human are able to merge, in order to confirm that the appropriate route has been selected, the aircraft avoids obstacles placed in front of the aircraft by the humans while traveling. If you are unable to
advanced success	merge, avoid obstacles such as ruts. In the acquired sparse model, the control history shows which features are emphasized and the degree of danger changes appropriately as obstacles enter the field of view. The basis for avoidance behavior in full success is shown. Also, finish within 10 meters.

2.2 Mission sequence

The diagram shows the flow from carrier storage to mission accomplishment. Here, the work performed by humans is surrounded by a dotted line. During the avoidance phase (4), humans need to set up obstacles, but because the learning phase (3) takes about 15 minutes, there is no special time set for people to meet up. If you are unable to merge, check to see if you were able to avoid natural obstacles such as ruts.

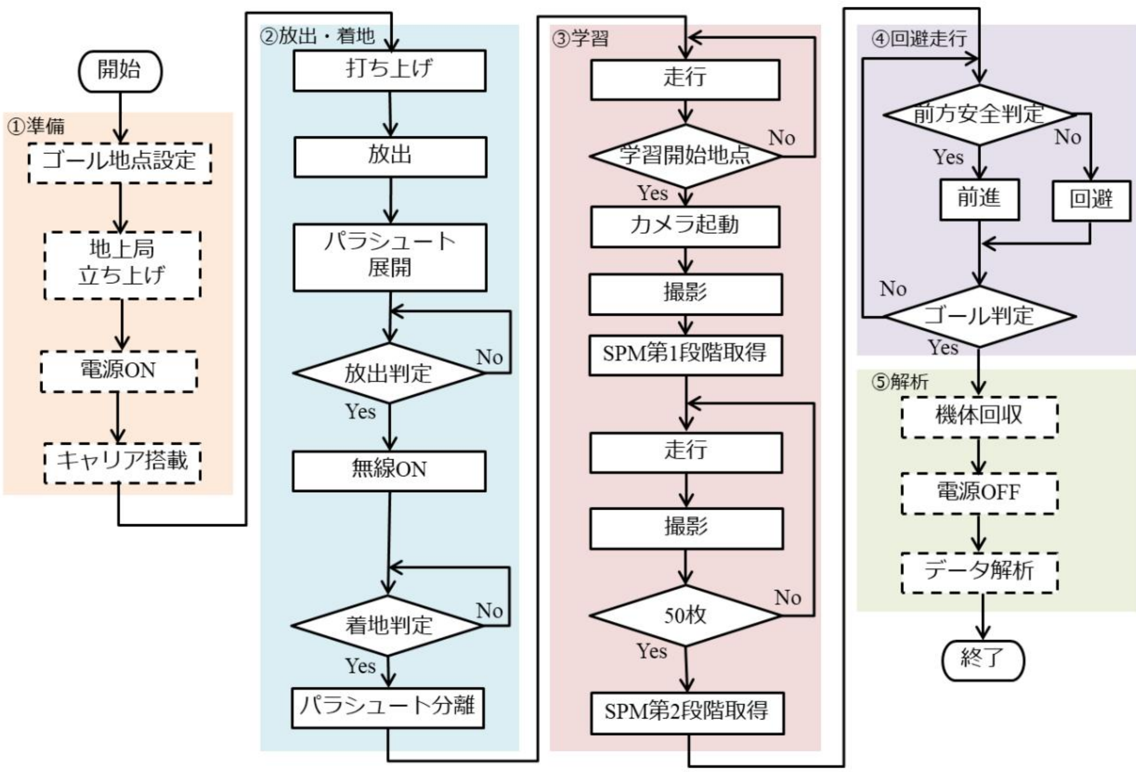


Figure 2.2.1 Mission sequence

2.3 Principle

(A) Principle of sparse modeling

This section explains the principles of sparse modeling. Sparse modeling is a type of machine learning that is characterized by ``inferring (modeling) the whole thing from a small amount of (sparse) information.''

Let's think concretely using a formula. A general optimization problem is expressed by the following formula.

$$( ) = ÿ ÿ ( ]^{2} \quad (2.1)$$

True value: = [1 2 ÿ Weight matrix: = [1 2 ÿ)], Features: = [1 2 ÿ] (2.2)

Optimization problems like the one above seek a weight matrix that minimizes the objective function, but in sparse modeling, in addition to this, the goal is to set as many components of the weight matrix as 0. and

Ru. To do this, give the objective function ( ) as follows.

$$( ) = ÿ ÿ (\quad)^{2} + ÿ| |_{0} \quad (2.3)$$

Here, | | 0 in the second term of the above equation represents the number of non-zero components in the weight matrix, and this is called the L0 norm. By incorporating this into the objective function, learning proceeds in the direction of minimizing the number of nonzero components in the weight matrix. The fewer non-zero components there are, the more weight matrix components will have a value of 0, and the fewer feature components will actually be used in the entire objective function. This is the basic concept of sparse modeling. Note that the larger the coefficient ÿ of this L0 norm, the stronger the effort to reduce nonzero components in the objective function ( ).

(B) How to use sparse modeling in CanSat This section shows

how to use sparse modeling in this year's mission. This year's CanSat will need to learn from multiple images and determine whether there is a possibility that the aircraft will get stuck on the spot. However, when conventional machine learning is used to determine the possibility of stacking, it is necessary to prepare and train a large number of images of stacking and non-stacking. Since it is difficult to prepare the large number of images used for learning and the computational cost required for learning in space exploration, it is necessary to apply algorithms that complete learning with a small number of images and a small amount of calculation. That's what I thought. Therefore, we focused on sparse modeling. There are two main types of learning: preliminary

learning and on-site learning. During preliminary training, we prepared an in-vehicle camera image of the aircraft moving normally and an image showing the point where the aircraft gets stuck, and used them as ``stuck cases'' and ``non-stuck cases'' respectively. Perform labeling. During on-site learning, while the aircraft is moving, the surroundings are photographed using an in-vehicle camera. If the aircraft does not get stuck at the location shown at the time the image was taken, that image is learned as a ``non-stuck case''. After the vehicle starts, it accumulates a certain number of images, and when it finishes, it performs the image labeling and learning described above. Using the model acquired through this learning, it is possible to infer the possibility of getting stuck in any image taken while driving.

Ru. In this CanSat aircraft, we focused on the lower half of the captured image, divided that region in half, and further divided the upper region into three. Using the images obtained, we created a model for each window. The system learns and infers images taken while driving in real time. By performing inference in each of the three windows, it becomes possible to select a route with a lower chance of getting stuck.

In implementing the above principle, we divided the process of determining the risk of stacking from images into two steps and utilized the principles of sparse modeling in each step. In the first step, features are extracted from the captured image, and in the second step, the risk of stacking (hereafter referred to as ``risk'') is calculated from the features. These will be explained in the next section.

(C) Principle of first stage sparse modeling

In the first stage, we calculate features that characterize the captured image and, in turn, suggest the possibility of stacking. For this purpose, we applied an anomaly detection algorithm, which is one of the practical examples of sparse modeling.

This article provides an overview of anomaly detection in sparse modeling. First, learn. The essence of learning here is to divide the given image into patches and find the basis vectors and their coefficients that are common to the group of images. Each basis vector here corresponds to one component of the weight matrix, and limiting the number of basis vectors (or reducing the L0 norm of the extraction matrix) reduces the number of non-zero components of the weight matrix. This corresponds to reducing the amount. At this stage, the set matrix of basis vectors is called the dictionary, and the set matrix of the coefficients of the basis vectors is called the extraction matrix.

= (2.4)

: 1 patch of image for dictionary creation, : dictionary, : extraction matrix

= [1 2], = [1 2 ÿ]

: basis vector ÿ 2 , : coefficient of basis vector ÿ

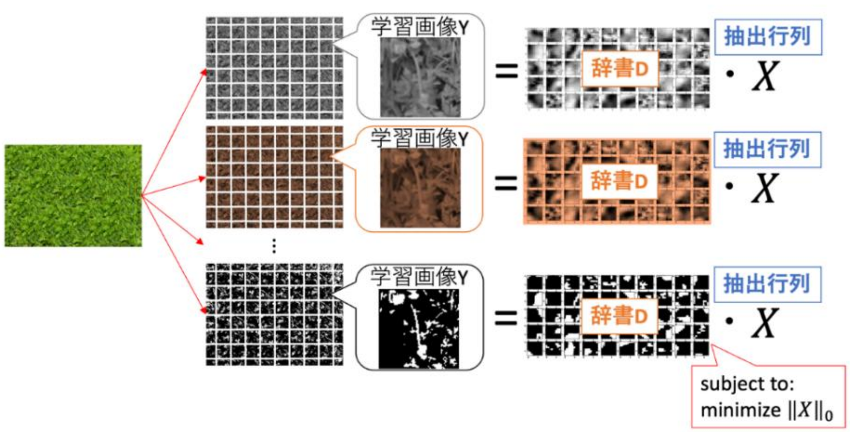


Figure 2.3.1 Relationship between original image and dictionary

The images used to create the dictionary are topographic images that are not stacked. In addition, in this mission, in order to learn and infer as many elements as possible from limited images, all images are subjected to image processing (currently 10 types including R component extraction and edge extraction, including unprocessed images). (assumed degree). At this stage, training is performed using these 10 or so types of images as source images, and the dictionary and scanner are used as source images.

Decompose into a parsed expression. This is a method based on the assumption that each feature image can be expressed by combining a small number of typical patterns called a dictionary.

Next, perform inference. The essence of the inference here is to use the derived dictionary to restore the image to be inferred. From the image to be inferred, find the dictionary and its coefficient matrix in the same way as during learning. Next, we attempt to reconstruct the image by combining the coefficient matrix used here and the dictionary obtained through learning. If the image to be inferred and the image used for learning are completely the same, the dictionary and coefficient matrix will be the same, so the original image to be inferred should be completely restored. However, the greater the difference between the inference target image and the image used for learning, the lower the reconstruction accuracy and the greater the difference between the inference target image and the reconstructed image. This is the principle of anomaly detection, and sparsity can be thought of as limiting the number of basis vectors that can be created and inferring through a dictionary.

Specifically, in this mission, if the captured images can be reconstructed correctly, they can be considered to contain the same features as the normal images used for dictionary learning, that is, they can be considered to be terrain that does not stack. This is because the images during learning are given as topographic images that are not stacked. On the other hand, if the difference is large, it can be considered an abnormality, that is, the terrain is at risk of getting stuck. In this way, normality or abnormality is determined based on the size of the difference between the original image during learning and the reconstructed image taken during inference, but rather than simply considering the difference, it is also possible to evaluate the difference from various angles. It is necessary to perform a highly reliable evaluation by evaluating from the beginning.

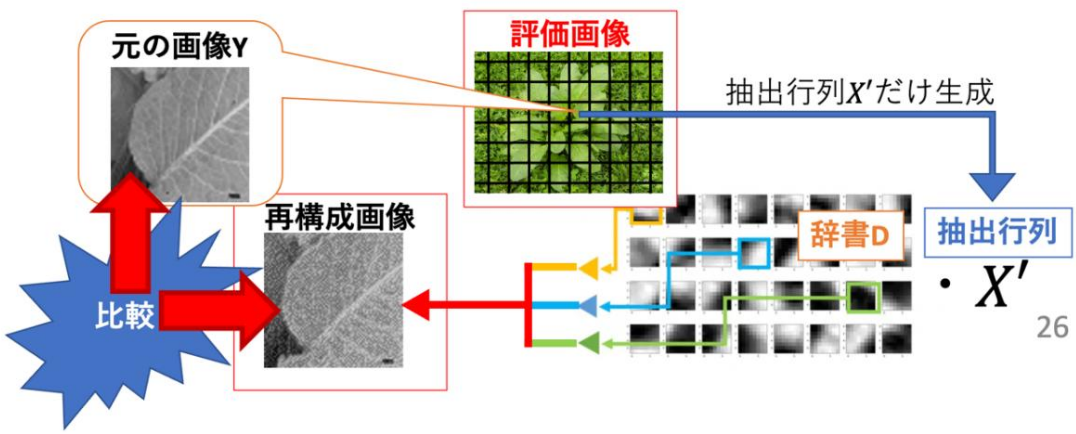


Figure 2.3.2 What is reconfiguration?

In this mission, we calculate the difference between each pixel value of the image to be inferred and the image reconstructed using the trained dictionary, and calculate the features of the distribution (mean, median, variance, kurtosis, skewness).•The most frequent value) is used as the feature quantity of the image. As mentioned above, in order to secure the number of features, 10 types of processing, such as edge extraction, are applied to the image to be inferred, and a total of 60 types of features are output to the second stage. There is. However, there is a possibility that the image processing and feature types may change.

(D) Principle of second stage sparse modeling

This section presents the algorithm for the second half of the process of determining stack risk. In the second stage, we first extract only those useful for the mission from the 60 types of features output in the first stage, and then calculate the risk of stacking. This makes it possible to create a model (function) that calculates the degree of risk for images taken at a certain point in time, and this model is used to plan routes.

This can be achieved by learning and inferring a Lasso regression model using the reconstruction error features derived in the first step as input and the stack risk as output. At this stage, we standardize the feature values such as average value and variance before proceeding. By performing inference, it is possible to extract only the features that are useful for

the mission. Training is performed using a total of 250 images, using frames cut out from videos shot in advance. Of these, 200 are images of the aircraft moving without getting stuck, and 50 are images of obstacles

placed in front of the aircraft. The label of an unstacked image is -100, and the label of a stacked image is 100. By making the label values sufficiently larger than the standardized feature values between 0 and 1, we increased the scale of the weight matrix values and made it easier to evaluate sparsity. In inference, the feature values are input, and estimated values are derived using the learned weight matrix. It is suggested that the closer the estimated value is to -100, the closer the feature values would be to those without stacking, leading to the conclusion that the risk of stacking is lower. Conversely, the closer the estimated value is to 100, the closer the feature values are to the feature

values in the case of stacking, leading to the conclusion that the risk of stacking is high. Through the above sparse modeling, the degree of danger is calculated for each of the three windows of interest in each image, with larger negative values considered safer and larger positive values considered more dangerous. be able to. In this mission, we are able to calculate the degree of risk for a single image in matrix form, and use this degree of risk matrix in route planning. Note that the label values were intentionally determined so that the midpoint was 0. If all the components of weight w become 0 due to learning failure, the calculated risk level will be y=0, which suggests that the possibility of stacking could not be determined. This is because I made it.

2.4 Algorithm

We will describe the details of the algorithm from the start to the end of the mission. The flow was also shown in Mission Sequence, but here it is classified into states, and state transitions are shown in Figure 2.4.1.

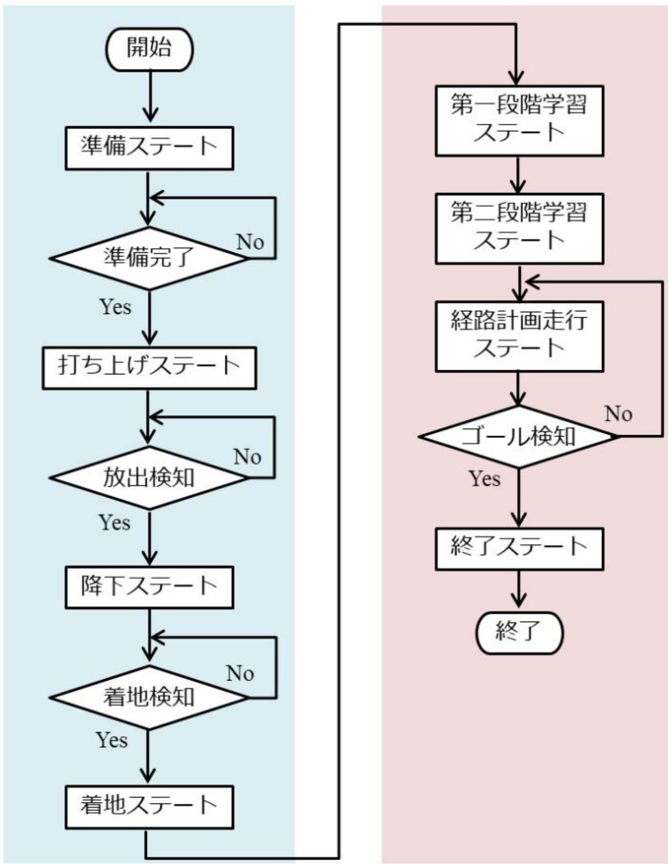


Figure 2.4.1 Overall algorithm

1. Ready state

When you run the program, wireless communication begins. When the flight pin is inserted, CanSat detects that it is stored in the carrier and moves to the next state.

2. Launch state

Stop wireless communication. When the CanSat is released from the carrier and the parachute opens, the flight pin is removed from the circuit board and the voltage applied to the microcontroller's GPIO pin changes. Release is determined by detecting this voltage change, and when release is detected, the system moves to the next state.

3. Descent state

Start wireless communication. When CanSat lands and the total value of the three-axis acceleration obtained from the acceleration sensor is less than 1 m/s 2 for 200 consecutive control cycles, it is considered to have landed. Note that the acceleration is 0 m/s when the ^{2} vehicle is stationary. When landing is determined, move to the next state.

4. Landing state

The parachute separation mechanism is used to burn off the tentacles and separate the sheet from the main body. Then, it escapes by rotating the motor from above the seat and moving toward the goal, correcting its posture.

5. First stage learning state

In the first stage learning state, a feature image is created from the image, a dictionary is acquired through learning, the image is reconstructed, and the differences are found. In the first learning state, there is no movement, so there is no stacking.

First, start the camera and take a single image. By performing processing on that image, we obtain characteristic images (currently 10 types). Then, using the concept of sparse modeling, these feature images are decomposed into a dictionary matrix and a sparse representation that shows how to com$\boldsymbol{D}$bine small numbers of dictionaries. $\boldsymbol{X}$

$$\boldsymbol{Y} = \boldsymbol{D}^T \boldsymbol{X} \tag{2.5}$$

Next, the obtained dictionary matrix is $\boldsymbol{D}$ used to infer whether the features of another $\boldsymbol{Y}'$ image are similar to the original image. To do this, we take the image again and reconstruct it using the dictionary matrix acquired in the first stage of learning. $\boldsymbol{D}$

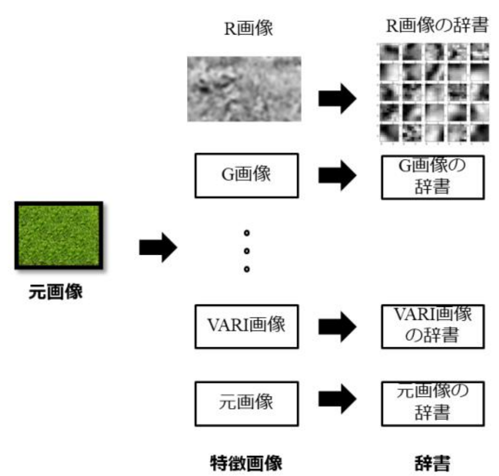


Figure 2.4.2 Sparse model first stage: Dictionary acquisition

Next, the difference between the reconstructed image and the original image is expressed as a histogram, and six types of features are extracted from the obtained histogram: mean, median, variance, kurtosis, skewness, and mode. This allows us to evaluate the difference between the reconstructed image and the original image from six different angles.

From the above, we can extract 6 types of features from each of the 10 types of feature images, and obtain a total of 60 features. Ta. In the next state, only the features useful for the mission are extracted from these features.

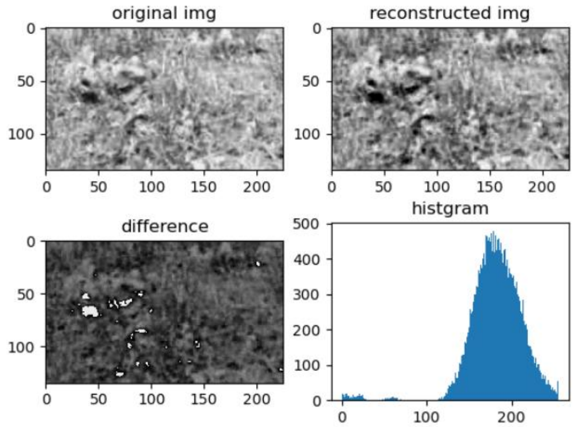


Figure 2.4.3 Sparse model first stage

6.Second stage learning state

In this state, the degree of risk can be calculated by assigning weights to each of these feature quantities and calculating the sum. The purpose is to obtain a model (function) that can be used. The specific method is described below.

First, run toward the goal while acquiring images, acquire a certain number of images, and set the point immediately after acquiring a certain number of images as the switching point. After that, it stops at the switching point, performs the image reconstruction described in the previous section on all acquired images, and calculates 60 feature quantities. If stuck in this state, a stack avoidance operation is performed. At this time, most of the images collected should be safe to some extent because no images are taken during the avoidance maneuver. After that, in order

to extract only the features that are effective for the mission, we will train and infer a Lasso regression model using the reconstruction error feature as input and the stack risk as output. This makes it possible to calculate the degree of risk for each image.

The degree of risk is expressed as a value between -100 and 100. At this time, the smaller the value, the safer it is. Since it is assumed that the images obtained in this state are not stacked, "-100" is given as the training data corresponding to each image. Each feature is weighted so that the sum of the weighted features matches the training data, and the weights of features with low contribution are set to 0 and dropped. Furthermore, multiple risk levels are calculated for each image. This is because the image

is divided into several small areas (currently, the ground is divided into six) and the risk level is calculated for each of these small areas. Furthermore, even if a case occurs where the risk level is below -100 or above 100 for some reason, in order to avoid introducing arbitrary elements into learning, the inferred value will not be corrected, and the magnitude of the value will be Stack The presence or absence of danger shall be met.

7. Route planning state

Use the acquired sparse model to drive while calculating the degree of risk. We will explain the specific steps. First, take a

picture of the front while driving. The captured image is divided into several regions (currently, the ground is divided into six regions), the necessary feature images selected by the sparse model are obtained, and the feature amount of the reconstruction error is calculated. This calculates the degree of risk for each area. The calculated risk level is expressed as a matrix as shown below.

$$risk = \begin{bmatrix} r_1 & r_2 & r_3 \\ r_4 & r_5 & r_6 \end{bmatrix} \tag{2.6}$$

Route planning is performed for the matrix representing the above risk level (hereinafter referred to as the risk level matrix). In this mission, we first calculate the goal direction. Obtain the latitude and longitude of your own position using a GPS sensor, and calculate the azimuth angle in the direction of the goal (angle with north as zero degrees and east as positive) from the latitude and longitude of the goal position given in advance. Furthermore, the CanSat's own orientation and angle are calculated from the angular velocity sensor. From these azimuth angles toward the goal and CanSat's own azimuth angles, it is possible to calculate the angle toward the goal as seen from the front of the CanSat.

After the goal direction is known, the danger level of the corresponding direction is extracted from the danger matrix, and it is determined whether it is less than a threshold value (currently less than 70). If it is below the threshold, it determines that the goal direction is safe and moves in that direction.

If the degree of danger in the goal direction is greater than the threshold, that is, it is judged to be unsafe, it is determined whether the degree of danger in other directions is less than the threshold. If there is something below the threshold, it moves in that direction. However, if the degree of danger is above the threshold in all directions, the attitude angle of CanSat is changed by a certain amount or more (currently 90 degrees), the danger matrix is calculated again, and the route is planned. cormorant.

In this way, by calculating the goal direction, determining whether the degree of danger in that direction is below the threshold, and driving accordingly, you can always head toward the goal, even if it is dangerous. This makes it possible to avoid such places.

8. End state

When it is determined that the goal point has been reached, the run ends. In route planning state 7, the direction and angle of the goal point are checked each time, and at that time, the distance between the own position and the goal position is also calculated. When this distance approaches zero, it is determined as a goal.

Chapter 3 Setting requirements

3.1 System requirements (requirements for ensuring safety and regulation)

request number	Self-examination items (ARLISS launch safety standards)
S1	The mass of the aircraft to be dropped satisfies the standard or below.
	Satisfy that S2 volume is below carrier standard
S3	Meets the requirement that it can be dropped from the carrier by its own weight.
S4	Satisfies that emissions from the carrier can be detected
S5	Quasi-static loads during launch do not impair functionality to meet safety standards. This has been confirmed through testing.
S6	Verify that the functions required to meet safety standards are not impaired by vibration loads during launch. This has been confirmed through testing.
S7	In order to meet safety standards due to the impact load when the rocket separates (when the parachute is deployed) Tests have confirmed that the functionality of the device is not impaired.
S8	It has a deceleration mechanism to prevent it from falling at dangerous speeds near the ground, and its performance has been confirmed through tests. coming
	Measures against S9 loss have been implemented, and their effectiveness has been confirmed through testing.
S10	We have confirmed that the communication function stops within the carrier.
S11	Satisfy that wireless communication can be started after detection of emission from carrier
S12	Satisfy the ability to change wireless communication to the specified channel
S13	Satisfy having a power source that can supply sufficient electricity to carry out the mission
	We have been able to conduct an end-to-end test that simulates the loading of the S14 rocket, the start of the mission, and recovery after launch, and there will be no major design changes related to safety in the future.
S15	After the mission, it is possible to submit the specified control history report to the management and examiners and explain the logs and acquired data.
S16	It has been confirmed that autonomous control is performed without human intervention during the mission.

3.2 Mission requirements

number	Required items
M1	It has been confirmed that the impact load upon landing does not impair the functionality required to accomplish the mission.
	It has been confirmed that M2 landing can be detected.
	It has been confirmed that the parachute can be separated using the M3 separation command.
	It has been confirmed that the camera lifts upward when the M4 parachute is separated.
	It has been confirmed that the attitude of M5 CanSat can be detected.
	M6 It has been confirmed that it is possible to recover after being reversed or rolled over.
	It has been confirmed that the attitude of the M7 can be changed so that the circuit board is at the top of the aircraft.
	M8 We have confirmed that it is possible to obtain GPS information for your current location.
	M9 We have confirmed that the GPS information of the goal point can be recognized.
	M10 It has been confirmed that it can run on steps and grass without getting stuck.
	It has been confirmed that M11 stacks can be detected.
	It has been confirmed that images can be taken using the M12 camera.
	M13 It has been confirmed that characteristic images can be calculated from captured images.
	We have confirmed that you can obtain the M14 sparse model.
	We have confirmed that a safe route can be selected using the M15 sparse model.
	M16 We have confirmed that it is possible to drive towards the goal by selecting the route.

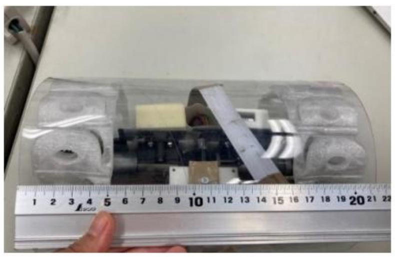
Chapter 4 System specifications

4.1 Aircraft appearance

The aircraft specifications are shown in Table 4.1 below. The aircraft used for this mass test is shown in Figures 4.1.1 and 4.1.2. When measuring the mass, calculate the total of all parts carried during the drop, including the fuselage and parachute. was measured. We also installed the sensors, microcontroller, and circuit board that will be used this year and conducted a mass test. This confirmed that the aircraft was within the regulation range.

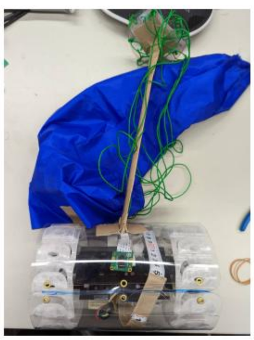
Table 4.1 Aircraft specifications

	When	After sheet separation
Total length	stored	215
[mm] Height	215	190
[mm] Weight [g]	135 966	-



Front view

Front view



Bird's eye view

Bird's eye view

Side view

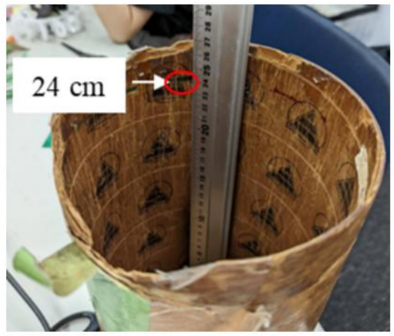
Side view

(a) When stored

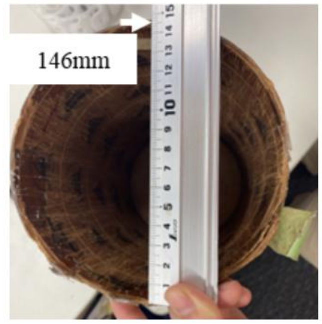
(b) After sheet separation

Figure 4.1.1 Aircraft

(a) How it is stored



(b) Height of the void can

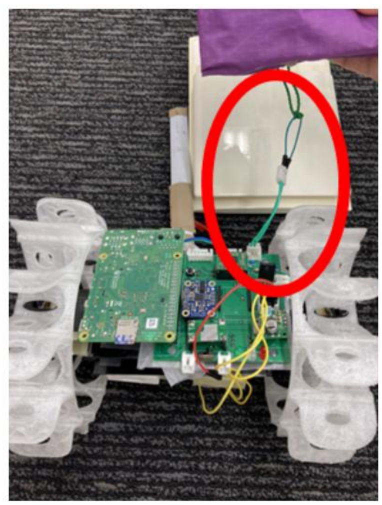


(c) Diameter of void can

Figure 4.1.2 Appearance of the stored aircraft

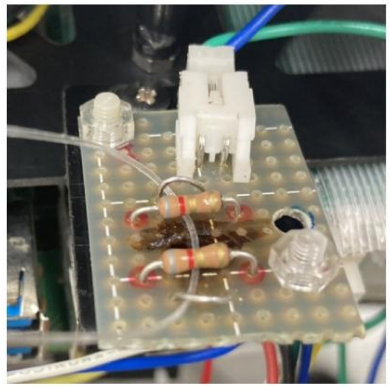
4.2 Aircraft interior/
mechanism (A)

Release detection mechanism Release detection is performed using a flight pin. As shown in Figure 3.3(a), a string with a flight pin attached to the tip is tied to the hem of the parachute. The flight pin is then attached to the connector on the circuit board, as shown in Figure 3.3(b). When the parachute actually opens, the string is pulled and the flight pin is pulled out from the connector on the circuit board. At this time, the voltage applied to the GPIO pin of Raspberry Pi 4 Model B changes to detect the emission.



Flight pin tied to parachute Flight pin connected Figure 4.2.1 Release detection mechanism

(B) Parachute separation
mechanism To separate the parachute, the sheet wrapped around the fuselage was unfixed by burning off the legs with the heat of the resistance, and the sheet and the fuselage were separated by elastic force. In the burnout circuit, the wire is passed through two resistors and two nichrome wires to prevent power from concentrating on one point. The tension is handled by three holes in the separation sheet, and it is considered to have sufficient strength as it has not failed even once during all tests, including the impact of opening an umbrella.



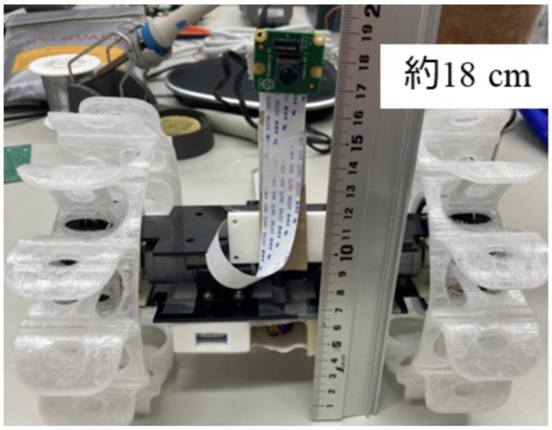
Installation location of the burnout circuit Enlarged view of the burnout circuit Figure 4.2.2 Parachute separation mechanism by burnout

Hole in separation sheet path of tegus

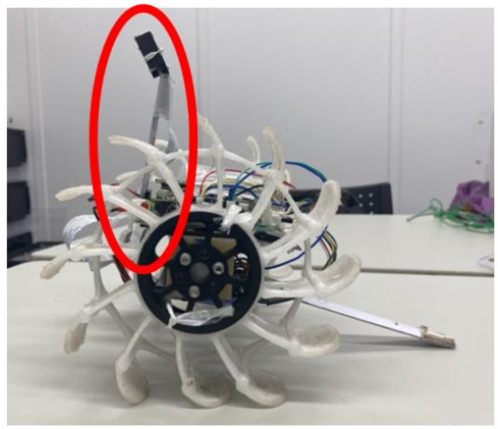
Figure 4.2.3 Separation sheet

(C) Camera advancement mechanism

In this mission, processing will be performed using images of the surrounding terrain taken by a camera. Photograph the surroundings When moving, it is preferable to be able to get far into the field of view regardless of small obstacles in front of you, so we created a mechanism that uses a measuring tape to passively advance upwards in the aircraft body after separating the sheets. In addition, in order to obtain topographical images, the camera was made to face diagonally downward during extension.



Front



side

Figure 4.2.4 Camera advancement mechanism

4.3 Installed equipment

(A) System diagram

The system diagram and equipment used are shown below.

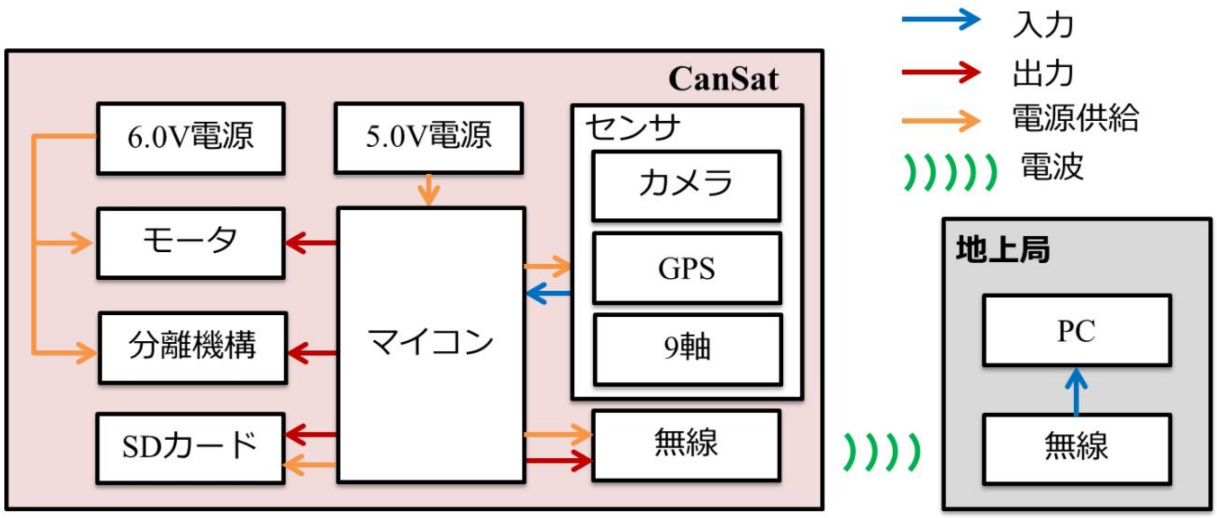


Figure 4.3.1 System diagram

Table 4.3.1 Equipment used

device	Model number	specification
Microcomputer	Raspberry Pi 4 Model B	DC5V / 1.7A (Max) *Excluding GPIO
GPS	GYSFDMAXB	DC5V/40mA, serial communication
7.4V ÿ 6V step down (For motor) 3.7	D36V28F6	Brand: Pololu
V ÿ 5 V boost (for microcontroller)	details unknown	Input voltage: DC 6.3V-50V
9-axis acceleration sensor	Bno055	Output voltage: DC 6V (accuracy 4%)
camera	Raspberry Pi Camera Module V2	Output current: 3A (long-term recommended value 2.5A)
Motor	C1S605800014503	Conversion efficiency: 85-95%
Motor driver Wireless	TB6612FNG	Brand: IS
communication module	ES920LR	Input voltage: DC 2.5V-5.0V

(B) Power supply used

The power supply used and its safety measures are shown below. Note that the controller for motors that draw large currents For inverters, there is reverse voltage protection up to 40V, output undervoltage and overvoltage protection, overcurrent protection, and short circuit protection. We adopted Pololu's D36V28F6, which has a protective function.

Table 4.3.2 Power supply used

Purpose of use	Product	Model number	Number of pieces
Microcomputer	name Lithium ion polymer battery 3.7V 3000mAh lithium	HXJNLDC 103665	1 piece
motor	ion polymer battery 7.4V 900mAh	SIGP 900-2S1P-7.4V-25C	1 piece

Table 4.3.3 Safety measures

situation	Safety measure
transportation	Store the battery in a special battery storage case to prevent damage to it.
storage	Do not store in places with high temperatures
Use	Check that the outer coating of the battery is not damaged.
	Measure the voltage frequently with a tester and be careful to avoid overcharging or overdischarging. do
	In the event of a fire, do not approach it and extinguish it with plenty of water prepared in advance.

Chapter 5 Test item settings

number	Verification item name	Corresponding self-examination items Request number(s)	Implementation date (Scheduled date)
V1	Mass test	S1	6/29
V2	Aircraft storage and release test	S2, S3	6/29
V3	Quasi-static load test	S5	8/25
V4	Vibration test	S6	7/11
V5	separation/parachute opening impact test	S7	8/25
V6	parachute drop test	S8, M1, M2	7/12
V7	Landing impact test	M1	6/29
V8	Wireless ON/OFF test	S4, S10, S11	7/6
V9	Wireless CH change test	S12	7/6
V10	Communication distance test	S9	7/1
V11	Ground station recording test	S15	7/4
V12	SD card recording test	S15	7/15
V13	GPS sensor accuracy test	S9, M8	7/4
V14	9 axis sensor test	S11	7/4
V15	Sensor integration test	S9, S15	7/4
V16	battery test	S13	8/26
V17	Parachute separation test	M3, M4	7/7
V18	Posture change/maintenance test	M5, M6, M7	7/7
V19	Driving performance test	M10	7/8
V20	Stuck detection test	M11	7/10
V21	Sparse model acquisition test	M12, M13, M14, M15	7/10
V22	Driving test	M8, M9, M10	7/10
V23	End-to-end exam	All items (mainly S14, S16)	7/15
V24	Obstacle avoidance test	M15	8/27

Chapter 6 Contents of the exam

(V1) **Mass test •**

Purpose

Confirm that the combined mass of CanSat and parachute is less than the specified mass. • Test content

Measure the CanSat and parachute using a mass meter and confirm that the mass is less than the mass stated in the regulations (1050g). • Results

The total weight of CanSat and parachute is 965g, less than the regulation of 1050g
We confirmed that this is the case. Figure 7.1.1 shows the mass measurement results.

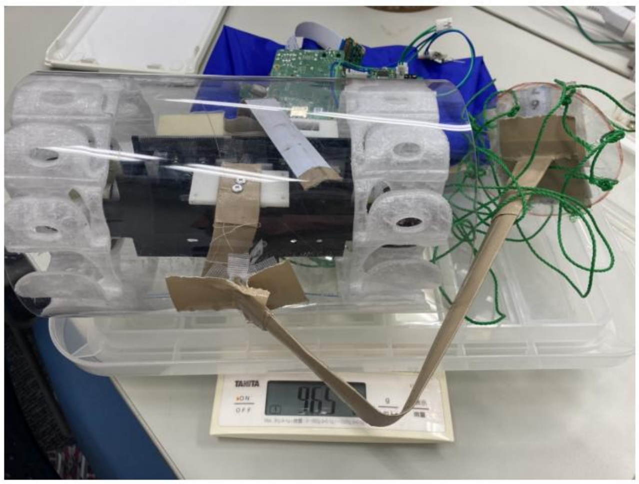


Figure 6.1 Mass test

• Discussion

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

(V2) **Aircraft storage and release test**

• Purpose

Confirm that the CanSat can enter the carrier and that the CanSat can fall from the carrier under its own weight.

• Test details Insert

the CanSat into a void can with an inner diameter of 146 mm and a height of 240 mm, and confirm that it can be inserted. Turn the carrier downward and confirm that the CanSat falls from the carrier by its own weight.

• Results

As shown in Table 7.2.1, it was confirmed that CanSat was released under its own weight two out of two times after being stowed.

Table 7.2.1 Results of carrier release experiment Experiment

number of times	video Release judgment https://youtu.be/Hc6CsqwrTq 8 https://	
1	youtu.be/PhcK_0DhZD 4	was able to release it by itself
2		was able to release it by itself

• Discussion

The video confirmed that CanSat can be stored in a carrier and that it falls under its own weight.

(V3) **Quasi-static load test**

• Purpose:

Confirm that it can withstand quasi-static loads during rocket launch.

• Test details: With

the aircraft stored in the carrier, the carrier is tied to a rope and a hammer throw is performed.
A static load inside the rocket is realized by uniform circular motion centered on a person, as shown in the figure. Here, the static load of the rocket is 10 G, and the centrifugal force can be expressed as (mv2)/r. Here, m is 1050g. Add 10 G to the aircraft by adjusting the turning radius and turning speed. In addition, the sensor used to obtain the values was ATR's AMWS020B, which was fixed to the top of the aircraft and measured the direction of distal force of the rotation circle, the direction from the top to the bottom of the aircraft, and acceleration. The Z-axis directions of the sensors were made to match.

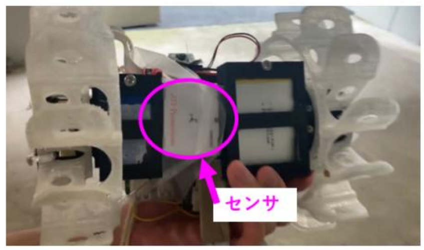
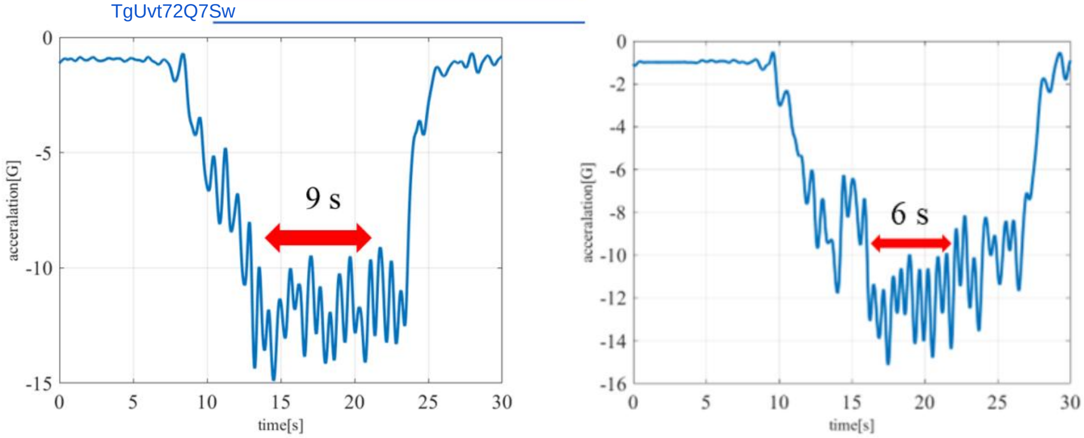


Figure 6.3.1 Sensor fixed position

•Results

Below is a URL showing a video of the test, and a diagram showing the acceleration values in the Z-axis direction obtained by the sensor. URL1: https://youtu.be/TgUvt72Q7Sw URL2: https://youtu.be/TgUvt72Q7Sw



(a) First time (b) Second time

Figure 6.3.2 Acceleration Z of quasi-static load test

The acceleration waveform shows that 10G was applied for 9 seconds the first time and 6 seconds the second time. The video shows that CanSat was able to obtain sensor values and information obtained from the camera during and after applying a 10G load due to the centrifugal force caused by CanSat rotation. No damage was confirmed.

• Consideration

It was confirmed that CanSat can withstand quasi-static loads during launch.

(V4) **Vibration test**

• Purpose:

Confirm that it can withstand vibrations when mounted on a rocket.

• Test details: The

aircraft will be directly attached to a vibrator and a vibration experiment will be conducted. recommended for this exam A vibration exciter was used to apply vibration frequencies of 1 Hz to 2300 Hz and accelerations of up to 15 G to the aircraft, which exceeded the test conditions. Additionally, the sensor used to obtain the values was ATR's AMWS020B, which was attached to two locations: the aircraft body and the vibration machine stand. The fuselage side was fixed to the top of the fuselage so that the direction of vibration matched the X-axis direction of the acceleration sensor. In addition, the vibration exciter table side was also fixed to the side of the vibration exciter table so that the direction of vibration and the X-axis direction of the acceleration sensor matched.

• Results A

video of the test is shown at the URL below, and the vibration exciter and expected vibration load are shown below. The diagram below is shown below.

URL (1st time): https://www.youtube.com/watch?v=xlA0tbq5I9s URL (2nd time): https://youtu.be/xlA0tbq5I9s

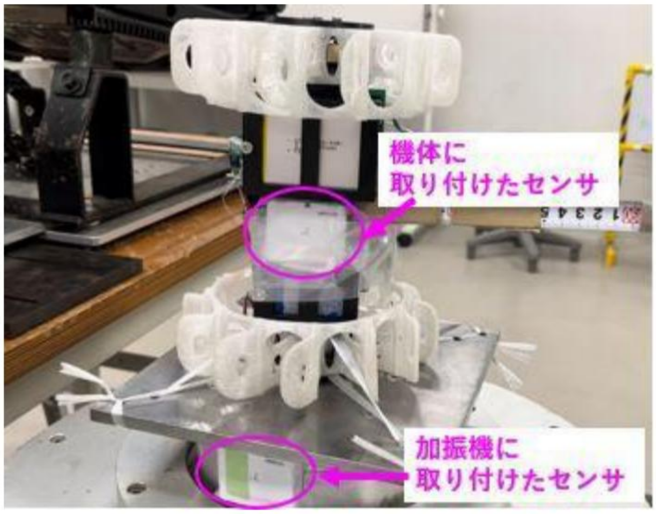
Calculate the sweep speed on a single road as follows.

$$s\left[\mathrm{oct/min}\right]=\frac{\log_2(2300\mathrm{Hz}/1\mathrm{Hz})}{4\mathrm{min}}=2.5\ \left[\mathrm{oct/min}\right]$$

The figure shows that an acceleration exceeding the test conditions was applied. The video also confirmed that the CanSat operated normally and was not damaged even after applying sine wave vibrations of 1 to 2300Hz and a maximum of 15G to the CanSat due to the vibration of the exciter.

• Consideration

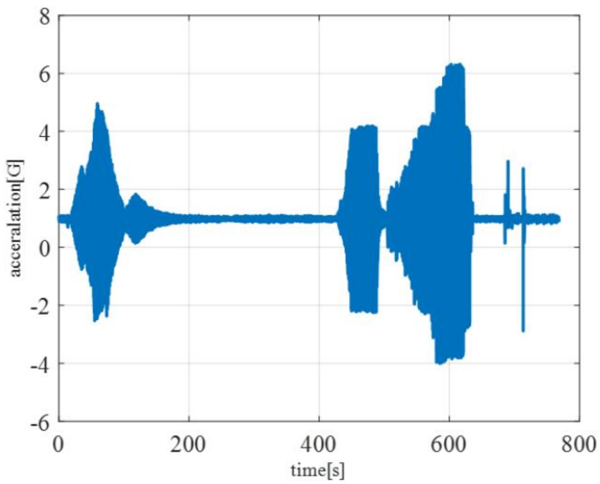
It was confirmed that CanSat can withstand the vibration load during launch.



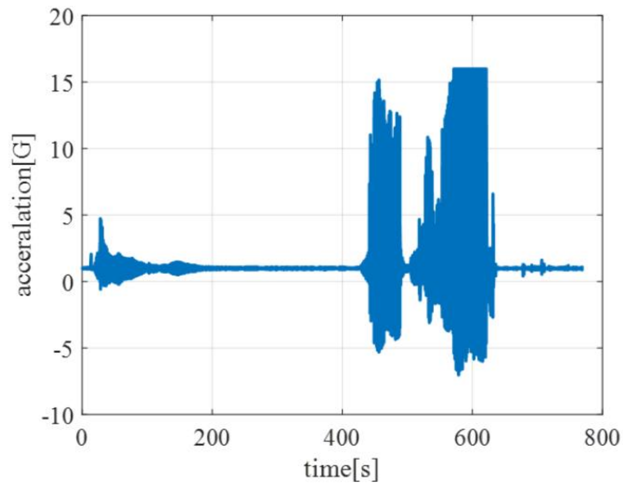
(a) Fixing to the vibrator and fixing position of the sensor

(b) Fixed position to the vibrator

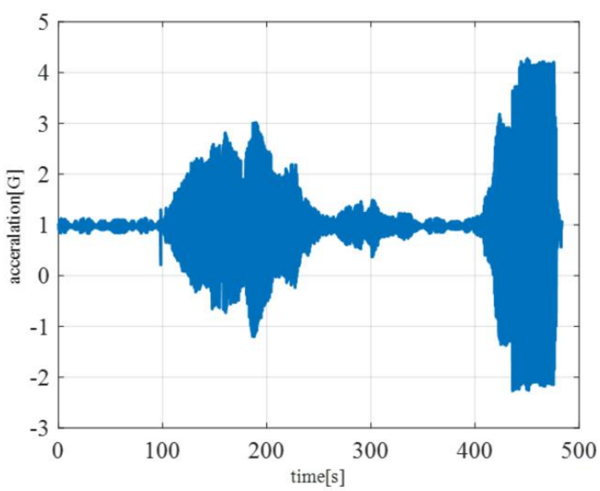
Figure 6.4.1 Experimental environment



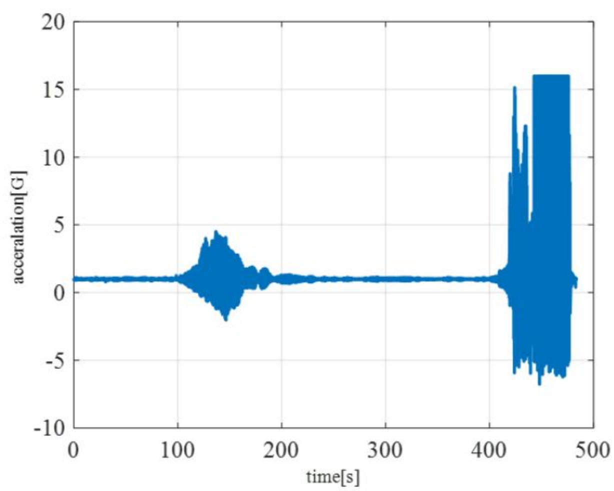
Acceleration X applied to the shaking table (1st time)



Acceleration X applied to the aircraft (1st time)



Acceleration X applied to the shaking table (2nd time)



Acceleration X applied to the aircraft (2nd time)

Figure 6.4.2 Vibration test acceleration X

(V5) Separation/parachute opening impact test

• Purpose:

To confirm that the separation sheet and the aircraft can withstand the impact of being ejected from a rocket and the impact of opening a parachute. • Test details: Shock load applied during separation from the rocket, assuming a launch near the rocket.

Make sure that it can withstand Here, we assume that it can withstand the recommended 40 G. The same impact was applied when the parachute opened. This shows that the fuselage and the connection to the parachute can withstand this.

Connect the fuselage and the parachute with a string, apply a force downward from a height and drop it, so that when the strings are stretched together, 40 G is applied in the direction of the string. The sensor used to obtain the values was ATR's AMWS020B, which was fixed to the top of the aircraft.

• Results

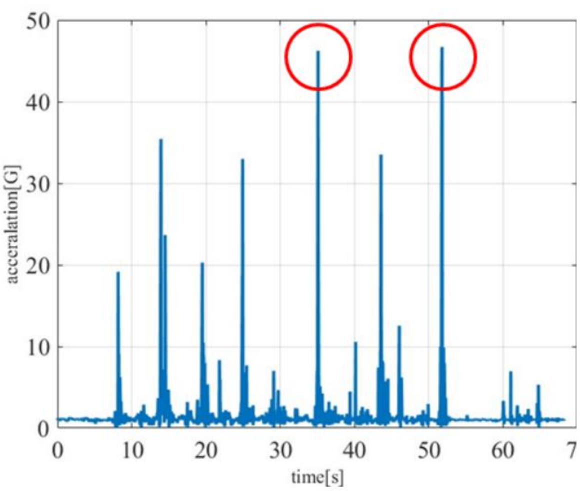
Below is a video of the test and the resulting acceleration of the impact force actually applied to CanSat. Show. It can be seen that a force exceeding 40G was applied twice.

URL: https://youtu.be/xwXZ-LhN_4Q

From the video, the parachute and CanSat remain connected even when the impact force is applied, and there is no damage. was not seen. Furthermore, the acquisition of sensor values was performed normally.

• Consideration

The impact of the CanSat being ejected from the carrier and the impact of the parachute opening. It was confirmed that it could withstand damage.



resultant acceleration

Fixed position of sensor

Figure 6.5.3 Separation/parachute opening impact test

(V6) **Parachute drop test**

- Purpose

Confirm that the parachute opens and decelerates.

- Test content

CanSat with parachute is stored in the carrier and lifted from a height of approximately 19m. Let it fall with it facing down. Height h from when the parachute opens until it lands and time t, and calculate the falling speed v. A parachute has a final falling speed of 6 m/s or more. It is designed to be at the bottom. Therefore, repeat the trial 5 times and calculate the average terminal velocity

$\overline{v}$ Calculate and confirm that $\overline{v}$ is between 5m/s and 6m/s.

- Results

A video of the test is shown at the URL below.

From the video of the test, the terminal velocity is considered to be reached at a point 4m from the ground (moving motion). In the painting, time is defined as the time when the object passes the second horizontal line on the wall (counting from the ground). Let t0 be the time it hits the ground, and measure the time when it hits the ground as t1. Then, use the following formula to calculate the terminal Calculate the speed.

$$= 4/(t_1 - t_0) \quad [m/s]$$

Then, find the average value of the terminal velocity calculated from the 5 tests, and if the value is 5 m/s or more It was confirmed that the speed was less than 6m/s.

URL (1st time): https://youtu.be/nB3F5uFzJeI

URL (2nd time): https://youtu.be/FHyPsV4-8iQ

URL (3rd time): https://youtu.be/F7FKxiMvnxc

URL (4th time): https://youtu.be/_qcOSrCD8M4

URL (5th time): https://youtu.be/TNjBmRy6BwQ

- Consideration

It was confirmed that the parachute was able to open and decelerate. The average value of the terminal velocity is The speed was 5.57m/s, confirming that the speed was being decelerated correctly.

Table 6.6 Parachute drop test results

	result	height *h* [m]	time *t* [s]	terminal velocity *vf* [m/s]
1st time	Successful opening	Four	0.71	5.63
2nd time	Successful opening	Four	0.70	5.71
3rd time	Successful opening	Four	0.73	5.47
4th time	Successful opening	Four	0.75	5.33
5th time	Successful opening	Four	0.70	5.71
Average value				$\overline{v} =$ 5.57

(V7) **Landing impact test**

• Purpose:

To confirm that CanSat does not malfunction due to impact from falling.

• Test details: After

allowing the CanSat to fall freely so that the falling speed is equivalent to the terminal speed of the parachute, it is confirmed whether the CanSat operates normally. Assuming the terminal velocity is 5.0 m/s, this

$v = \sqrt{2gh}$

It can be seen that in order to reach the terminal velocity, it is sufficient to allow the object to fall freely from 1.3 m.

This allows us to reproduce the impact force upon landing.

• Results A

video of the test is shown at the URL below. Communication continues even after falling. sensor is moving

I confirmed that it was created. It was also confirmed that there was no damage to the aircraft.

URL (1st time): https://youtu.be/JV6V3o0gHfE URL (2nd time):
https://youtu.be/rOIiKP_voeM URL (3rd time): https://youtu.be/
TtBqD1N72Wo URL (4th time): https://youtu.be/8hCL3UKXKTI URL
(5th time): https://youtu.be/KGI-V6n0g14

• Discussion

We confirmed that the product continued to operate without failure even after being dropped.

(V8) **Wireless ON/OFF test**

- Purpose:

Confirm that the wireless communication module changes from ON to OFF after a certain period of time, and then changes from OFF to ON by removing the flight pin.

- Test details In

this mission, based on the regulations to turn off the power of the radio at the time of launch, wireless communication will start when the program is executed, and will stop after a certain period of time. This is to prevent interference with the rocket's wireless communications during launch. After launch, the CanSat is released from the carrier and resumes wireless communication when it detects that the flight pin attached to the CanSat's circuit board has come loose. In this test, after running the program, we will perform wireless communication and confirm at the ground station that the communication data can be received. Then, assuming that the CanSat has been released from the carrier, the flight pin is removed, and the ground station confirms that wireless communication has resumed and communication data can be received again.

- Results

A video of the test is shown at the URL below.

URL (1st time): https://youtu.be/7Bpo8LY8sP0 URL (2nd time): https://youtu.be/EGUwNEab6Os

From the video, you can see that after a certain period of time has passed after running the program, the wireless communication module changes from ON to OFF and wireless communication stops, and when the flight pin is removed, it changes from OFF to ON and wireless communication stops. We have confirmed that it will reopen.

- Consideration: Changing the wireless communication module from ON to OFF using software, and turning it OFF? It was confirmed that the switch was turned on.

(V9) **Wireless CH change test**

• Purpose:

To prevent communication interference and crosstalk, the channel of the wireless communication module can be changed. Make sure that.

• Test details

This mission uses LoRa as the wireless communication module installed on CanSat. Therefore, confirm that the LoRa channel can be changed. In this test, we will change the LoRa channel on TeraTerm and confirm that LoRas on the same channel will be connected, but LoRas on different channels will not be connected.

• Results

A video of the test is shown at the URL below.

URL (1st time): https://youtu.be/FYYu8QZRR_M URL (2nd time): https://youtu.be/zPDDBU7EN_I

From the video, we confirmed that the LoRa channel can be changed. Furthermore, we confirmed that LoRas on the same channel can communicate, but LoRas on different channels cannot.

•

Consideration: To prevent communication interference and crosstalk, the channel of the wireless communication module can be changed. This was confirmed.

(V10) **Communication distance test**

• Purpose:

Measure the maximum communication distance between CanSat and the ground station (PC) to prevent lost data.

• Test details A wireless

communication module (LoRa) is connected to the ground station (PC) and CanSat, respectively, and communication is performed. Afterwards, we moved on foot along the Tama River with the CanSat and moved it away from the ground station. Then, calculate the distance between the ground station installation point and the point immediately before communication is interrupted.

• Results The

results are shown in Figure 7.10. The upper left point represents the grounding point of the ground station, and the lower right point represents the point immediately before communication was interrupted. When calculated using the distance measurement function of Google Maps based on the GPS coordinates between the two points, it was found that communication of 4.9 km was possible.

Figure 6.10 Communication distance test

• Consideration

We confirmed that the communication distance was sufficient at the ARLISS conference.

(V11) **Ground station recording test**

• Purpose

Confirm that CanSat can correctly transmit information to the ground station. The time, latitude, and longitude are acquired from the GPS sensor, and this information can be sent to the base station, and this test was conducted to confirm whether this series of information is being transmitted correctly. ÿÿ

• Exam content

Check whether CanSat is correctly transmitting its GPS sensor values to the ground station. The validity of the results is described in the test item (V13) GPS sensor accuracy test. The series of tests was conducted a total of three times.

• Results

The test was conducted three times in total. Videos of each test are shown at the URL below.

First exam URL: https://youtu.be/Q91XMO-0YIo 2nd exam URL: https://youtu.be/2KNp9B8_zLA 3rd exam URL: https://youtu.be/VS5QB7t7s8A

First, in the video of the first test, each configuration of the experimental equipment is explained from 0:00 to 0:41. Then, starting at 1:03, the GPS sensor values are explained, and it can be seen that the latitude and longitude are displayed as GPS sensor values from CanSat to the ground station.

Furthermore, in the video of the second test, each configuration of the experimental equipment is explained from 0:00 to 0:25. Then, starting at 2:11, the GPS sensor values are explained, and it can be seen that the latitude and longitude are displayed as the GPS sensor values from CanSat to the ground station. Finally, in the video of the third test, each

configuration of the experimental equipment is explained from 0:00 to 0:35. Then, starting at 2:16, the GPS sensor values are explained, and it can be seen that the latitude and longitude are displayed as the GPS sensor values from CanSat on the ground station.

• Discussion

We conducted a total of three tests, and in all of them, we activated the GPS sensor on the aircraft and read the values. We were able to confirm that the information was correctly transmitted to the ground station after it was acquired.

(V12) **SD card recording test**

• Purpose:

Confirm that the degree of mission accomplishment can be evaluated from the control history. specifically Check whether it can be determined whether the success criteria criteria have been met.

• Exam content

Save the values obtained by the sensors installed in Cansat to the SD card. At this time, confirm that the sensor values are correctly saved on the SD card. Also, check that the images and npz files saved as control history (learning/route planning/travel history) are correctly saved in the folder.

[Contents saved on SD card] • Sensor acquisition history (control_result.txt)

ÿ It will be saved as shown below. Regarding the camera, 0 is displayed when the camera is not activated, and Captured! is displayed when the camera is activated.

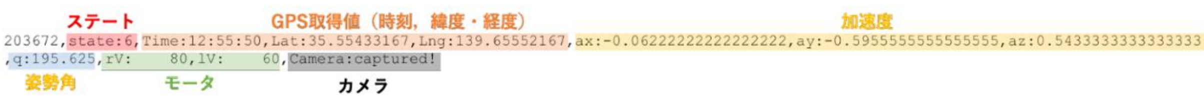


Figure 6.12 Sensor acquisition history

• Learning / route planning / travel history (camera_result)

ÿ first_spm •

firstimg0.img • Save

the original image for the first stage learning. • processed •

Saves the image

output as a result of performing feature processing on the original image. • evaluate

• Save the images taken to create npz for the second stage of sparse modeling.

ÿ second_spm •

Save the training npz file for second stage sparse modeling. ÿ planning • planning_pic •

When planning

and driving a route

using a trained model, save images taken for route planning. • planning_npz • When planning and driving a route

using a trained

model, saves the npz file that is created one by one through the first stage of sparse modeling.

• Results

A video of the test is shown at the URL

below. URL: https://youtu.be/i9KblLmoVzw

((V23) End-toEnd test video, relevant section: 5:30~7:12) From the video, it was confirmed that the sensor values were saved in control_result.txt. We also confirmed that learning/route planning/travel history was saved in the camera_result folder.

Also, please refer to the Google Drive below for the raw data saved on the SD card for this test. https://drive.google.com/drive/folders/1kVsXDjSwLKLDpyBzv2Mr4vigTzDrQMhm?us p=sharing

• Conclusion

We were able to confirm that data could be saved correctly to the SD card.

(V13) **GPS sensor accuracy test**

• Purpose

Check the accuracy of the values obtained from the GPS sensor.

• Exam content

Compare the time obtained from the GPS sensor and smartphone, as well as the latitude and longitude values obtained from the GPS sensor and Google Maps, and confirm that they match. Here, the latitude and longitude of Google Maps is selected and obtained from the positional relationship of surrounding buildings on the map, without using the smartphone's GPS sensor.

• Results A

video of the test is shown at the URL below. (Applicable parts 1st time, 2nd time 2:30~3:11) You can confirm that the time obtained from GPS and the time displayed on the PC match. Also, from the video to the video You can confirm that the

latitude and longitude obtained from GPS at the time match the values obtained by rounding off the latitude and longitude on Google Maps to the third decimal place. Furthermore, when this error was converted to the actual distance at the site shown below, it was calculated to be 9.03 m (see Figure 7.11), confirming that it satisfies the specifications.

URL (1st time): https://www.youtube.com/watch?v=2KNp9B8_zLA URL (2nd time): https://www.youtube.com/watch?v=VS5QB7t7s8A Site used for calculation: https://keisan.casio.jp/exec/system/1257670779

Figure 6.13.1 GPS error distance conversion result (1st time)

Figure 6.13.2 Distance conversion result of GPS error (2nd time)

• Consideration

We were able to confirm that measurements can be made with an accuracy that does not interfere with the actual use of the CanSat aircraft.

(V14) **9-axis sensor test**

• Purpose:

Confirm that the values obtained when shaking the acceleration sensor fluctuate, and confirm that the acceleration sensor can be used to determine CanSat's landing. Also, check if the compass sensor points in the correct direction and check if the goal direction can be detected.

• Test details In this

test, the aircraft on which the acceleration sensor was installed was shaken, and the Check that the value is changing.

• Results A

video of the test is shown at the URL below.(Relevant parts: 1:15~2:15 for the first time, 1:35~2:30 for the second time)The values obtained by the acceleration sensor. The unit is m/s2.In addition, in this test, the acceleration value of only the object excluding gravitational acceleration was obtained from the acceleration sensor.This processing to exclude gravitational acceleration was used to calculate the acceleration used this time. This is done inside the sensor Bno055. In the video, when you shake the

acceleration sensor, you can see whether the value obtained from the acceleration sensor fluctuates from the initial value.

URL (1st time): https://www.youtube.com/watch?v=2KNp9B8_zLA URL (2nd time): https://www.youtube.com/watch?v=VS5QB7t7s8A

• Discussion

From the video, we confirmed that the sensor value fluctuates when the acceleration sensor is shaken, which can be used to determine CanSat's landing.

(V15) **Sensor integration test**

• Purpose

Verify that the GPS sensor, acceleration sensor, wireless communication module, and motor operate correctly when integrated.

• Test details

Obtain the values of all sensors installed in CanSat every 0.5 seconds and check them on the screen output. Repeat this twice.

• Results

A video of the testing process is shown at the URL below. Throughout this video, we confirmed the simultaneous operation of various sensors, and from the video we can see the GPS sensor, acceleration sensor, wireless communication module, and motor. We can confirm that it works correctly when integrated.

URL (1st time): https://www.youtube.com/watch?v=2KNp9B8_zLA URL (2nd time): https://www.youtube.com/watch?v=VS5QB7t7s8A

• Discussion

In both cases, GPS sensor, acceleration sensor, wireless communication module, motor We confirmed that it works correctly when the data is integrated.

(V16) **Battery test**

• Purpose:

Check if there is enough power to carry out the mission.

• Exam content

Check the operation time of CanSat. The first 30 minutes will be used as a preparation state before dropping, simulating the state in which it is stored in the carrier, and then the motor output and sensor values will be acquired as in the actual mission, and the total operating time will be determined.

• Results

The video of the test is shown at the URL below. The motor power lasted for 65 minutes (35 minutes from the start of motor output). We also confirmed that the power supply for the sensor and microcomputer lasted for more than 2 hours.

URL: https://www.youtube.com/watch?v=hdU3gdHCSkU

• Consideration

CanSat operated for approximately 1 hour, confirming that it had sufficient power to carry out its mission. We also confirmed that the power supply for the microcomputer lasted for over two hours, which was sufficient operating time to search for the aircraft.

(V17) **Parachute separation test**

• Purpose:

To confirm that the parachute and seat can be separated from the aircraft by burning.

• Test details By

performing a burnout, the parachute and the
Make sure that the sheets can be separated.

•Results

The following URL shows what the test
looked
like. Rollover URL (1st time): https://youtu.be/yM63e1L9oI0
URL (2nd time): https://youtu.be/kvvGjqmeiUs

Reverse URL (1st time): https://www.youtube.com/watch?v=0dCSTGRGKkI URL (2nd time): https://www.youtube.com/watch?v=CHx9WiVSSpY

•

Discussion We confirmed that the parachute and sheet could be separated from Cansat by burning.

(V18) **Posture change/maintenance test**

• Purpose:

Regardless of the attitude of CanSat when it lands, the circuit board should be at the top of the aircraft.
Verify that CanSat can change its attitude.

• Exam content

Flip and roll over CanSat. From that state, move the circuit board to the top of the aircraft.
Verify that CanSat can change its attitude.

•Results

The following URL shows what the test looked like. The video shows that by rotating the tires after burning out, the CanSat changed its attitude so that the circuit board was at the top of the aircraft, regardless of the

aircraft's attitude. Rollover URL (1st time): https://youtu.be/yM63e1L9oI0 URL (2nd time): https://youtu.be/kvvGjqmeiUs

Reverse URL (1st time): https://www.youtube.com/watch?v=0dCSTGRGKkI URL (2nd time): https://www.youtube.com/watch?v=CHx9WiVSSpY

•

Discussion We confirmed that CanSat can change its attitude so that the circuit board is at the top of the aircraft, regardless of its attitude after landing.

(V19) **Driving performance test**

- Purpose

Confirm whether CanSat has the required running performance to travel.

- Exam content

Investigate whether CanSat can overcome steps of various heights. Also, run the CanSat on grass and check that the tires do not slip on the grass or get caught in long grass.

- Results

The situation during the test is shown below.

Successfully

climbed over the step by 5 cm : https://youtu.be/XpQuFg7CHro 6 cm success: https://youtu.be/BKgA8QXLOEQ
8 cm failure: https://youtu.be/unEALUBSzT8

1st **run on grassland :** https://youtu.be/-9LoAItMEVw 2nd time: https://youtu.be/P2bn5A_PHkg

- Discussion

We were able to confirm that the vehicle had the driving performance required for the mission, with no problems when driving on steps or grassy areas.

(V20) **Stack detection test**

- Purpose

Check if CanSat can detect the stack.

- Exam content

Let the CanSat get stuck on purpose and check if it can be detected by accelerometer information.

- Results

The situation during the test is shown below. 1st time: https://youtu.be/luaFDlG93p0
2nd time: https://youtu.be/luaFDlG93p0 3rd time: https://youtu.be/5GXoDsCNexw

It was possible to detect stacks, and there were no false positives.

- Discussion

We confirmed that stacking can be detected using an acceleration sensor.

(V21) **Sparse model acquisition test**

- Purpose:

Check whether internal processing is performed correctly and a sparse model can be obtained.

- Test details A

single original image is taken and 10 types of feature processing are performed on it. Next, perform the first stage of sparse modeling for each feature process (RGB, r, g, b, rb, rg, gb, edge, edge emphasis, HSV) to create a dictionary. Next, it takes eight photos while driving and uses a dictionary to reconstruct the images. These errors are considered as a histogram, and six types of features (mean, variance, median, mode, skewness, and kurtosis) are extracted from the histogram. By performing the second stage of sparse modeling using these features, we will confirm that a model in which only important features are extracted can be obtained. Also, confirm that a risk map is created using the model.

- Results A

video of the test is shown at the URL below. URL

(1st time): https://youtu.be/Lf1Bzs28fxc URL (2nd time): https://youtu.be/FxKA_VT_LOA From the video, you can see that we were able to obtain a sparse model in which only limited features were extracted from the 60 features that were originally in one window. You can check it. It can also be confirmed that a risk map consisting of 6 windows was created using the sparse model.

- Conclusion

We confirmed that the sparse model was acquired successfully.

(V22) **Driving test**

- Purpose

Confirm that CanSat can autonomously move toward the goal based on GPS information. So When doing so, check whether you are selecting an appropriate route.

- Exam content

We demonstrated that CanSat can autonomously move toward the goal based on GPS information provided in advance. confirm. At that time, check whether you are selecting an appropriate route.

- Results A

video of the test is shown at the URL below. URL (1st time): https://youtu.be/aOxyN0eDg1Y URL (2nd time): https://youtu.be/XEKMVIQXGjcFrom the video, when the program starts, CanSat acquires GPS information, and after landing is determined, communication begins based on the acquired GPS information. We were able to confirm that it was able to travel autonomously to the vicinity of the location.

- Consideration

We have confirmed that CanSat can autonomously travel to the vicinity of the communication start point based on GPS information given in advance.

(V23) **End-to-end test**

- Purpose

Verify that CanSat can perform all mission sequences autonomously.

- Exam content

The mission sequence, from the simulated drop to the run to the goal, Confirm that it can be executed autonomously.

- Results

The video of the test is shown at the URL below.

URL (1st time): https://youtu.be/gfw0-T4AgOc

URL (2nd time): https://youtu.be/i9KblLmoVzw

In addition, the test contents and results for each state are shown below.

Table 6.23 End-to-end test results details

	state	contents of the test	result	Applicable location
Once Eye	preparation	Start of communication with ground station	success	0:00~1:20
		GPS acquisition information	success	
		Successfully stopped communication due to storage detection		
		Loaded onto carrier	success	
	Release/descent	Communication resumed due to release detection	Success	1:20~1:50
	landing	By landing detection Parachute separation & detachment	Success	1:50~2:01
	1st stage sparse model ng	by sparse modeling Feature extraction	Success	2:01~2:40
	2nd stage sparse model ng	by sparse modeling Limitation of features	Success	2:40~2:46
	Route planning & driving	The acquired sparse model Route planning & driving used	Success	2:46~3:10
Twice Eye	preparation	Start of communication with ground station	success	0:00~2:38
		GPS acquisition information	success	
		Successfully stopped communication due to storage detection		
		Loaded onto carrier	success	
	Release/descent	Communication resumed due to release detection	Success	2:38~3:05

	landing	Parachute separation and detachment based on landing detection	Success 3	05~3:25
	1st stage sparse modeling	Feature extraction using sparse modeling	Success 3	25~3:59
	2nd stage sparse modeling	Limiting features by sparse modeling	Success 3	59~4:06
	Route planning & driving	Route planning and driving using the acquired sparse model	Success 4	06~4:20

From the video, it was confirmed that the test content was completed in all states.

• Discussion

Although it was confirmed that the entire mission could be executed without stopping, the route planning results cannot be said to be very accurate. The reason for this is that CanSat is rotating and is not moving toward the target. However, this is thought to be due to the fact that part of the npz file obtained when driving on sandy soil was used during learning. Since the test was conducted on concrete, the environment was very different compared to sand, and it is thought that the entire area was judged to be dangerous. Therefore, in the future, we will conduct more experiments and verifications on sandy soil in preparation for the tournament, and will continue to examine whether it is possible to plan routes with higher accuracy on sandy soil rather than on concrete.

(V24) **Obstacle avoidance test**

• Purpose:

Detect obstacles using sparse modeling and confirm that they have been avoided.

• Test content •

Pre-learning ÿ

Taking 250 pre-learning images of the test environment ÿ Image reconstruction using a dictionary and analysis of error histograms ÿ Saving analysis data as npz files

• Obstacle avoidance

ÿ Place the trained aircraft in front of a new obstacle that was not used in the preliminary training ÿ Launch the aircraft toward the obstacle and confirm that it will continue straight until it detects the obstacle ÿ Obstacle When an object is detected, the vehicle changes course to avoid a collision. make sure that

• Test location: On-campus sports field (sandy ground)

• Results

The video below shows the experiment and results.

Overall explanation/pre-learning (non-stack): https://youtu.be/79O0NQhHhkI Pre-learning (stack): https://youtu.be/xVPxQ7FLUE8 Obstacle avoidance run 1st time: https://youtu.be/BGW_nICK2yUObstacle avoidance run 2nd time: https://youtu.be/sIheoky7vhQObstacle avoidance run 3rd time: https://youtu .be/dxr1KAVhOncObstacle avoidance run 4th time: https://youtu.be/3LKAIUOLH-w

In all of the four trials above, there were unknown obstacles that were almost never used in the preliminary training. Successfully detected and avoided objects.

• Discussion

Using the model obtained through sparse modeling, we were able to calculate the degree of risk for each part of the image. The purpose of this test was achieved because we were able to confirm multiple times that actual obstacles could be avoided by avoiding the calculated high-risk locations. However, in the actual ARLISS test, it is expected that not only obstacles like

those handled in this test will become obstacles, but also obstacles such as ruts on the ground caused by driving vehicles. Since it was not possible to prepare such an environment, we decided to place obstacles in this experiment, but depending on the situation, it may be possible to obtain data on a riverbed where ruts are likely to occur, or to obtain data from source images on the Internet etc. Extracting soil images and subjecting them to preliminary training

, it is necessary to consider conducting preliminary training after arriving at ARLISS site. In any case, the number of sheets to be learned is at most 250, and learning can be completed within 10 minutes. This experiment confirmed that it was possible to acquire a learning model more easily than with conventional machine learning, and even to avoid obstacles, proving the usefulness of route planning using sparse modeling. It can be said that it was done.

Chapter 7 Gantt chart (process management)

The Gantt chart was designed with holidays and university exam periods in mind.

The software team's Gantt chart is shown in the link below. https://docs.google.com/spreadsheets/d/1C_1jUWo3PLpPjGpk8Lxsy-iNEe2i63xG/edit?usp=sharing&ouid=108776090185371206503&rtpof=true&sd=true

The Gantt chart for the hardware team is shown in the link below. https://docs.google.com/spreadsheets/d/1walXvFJme9ZO64s9SVMCn-3hZjqIZIhx/edit?usp=sharing&ouid=108776090185371206503&rtpof=true&sd=true

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

1.Safety standards review

request number	Self-examination items	Self-examination results	Comments from the responsible teacher (if there are any noteworthy items)
	ARLISS2022 Safety Standards		
S1	The mass of the aircraft to be dropped meets the criteria.	☑	
S2	volume meets carrier standards	☑	
S3	Tests have confirmed that the quasi-static loads during launch do not impair the functionality required to meet safety standards.	☑	
S4	Tests have confirmed that the vibration load during launch does not impair the functionality required to meet safety standards.	☑	
S5	Tests have confirmed that the functionality required to meet safety standards is not impaired by the impact load during the rocket separation (when the parachute is deployed).	☑	
S6	Has a deceleration mechanism to prevent it from falling at dangerous speeds near the ground, and its performance has been confirmed through testing.	☑	
S7	Measures against loss have been implemented, and their effectiveness has been tested. (Countermeasure examples: location information transmission, beacons, fluorescent color paint, etc.)	☑	
S8	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 launch (devices that are FCC certified and have a power output of 100 mW or less do not need to be turned off. Also, when using a smartphone, it is necessary to comply with the regulations for turning off the power of radio equipment at the time of launch. (Things that can be turned off with wear switch)	☑	
S9	I am willing to adjust the wireless channel and I have confirmed that I can actually make the adjustment.	☑	
S10	We have been able to conduct end-to-end tests simulating the loading of the rocket, the start of the mission, and recovery after launch, and there will be no major design changes in the future.	☑	
	If you wish to participate in the Comeback Competition, please be sure to meet the following requirements:		

M3	It has been confirmed that autonomous control is performed without human intervention during missions.	☑	
After the	M4 mission, it is possible to submit the specified control history report to the management and examiners and explain the logs and acquired data.	☑	

1.Responsible teacher's impressions

Amid restrictions on activities due to the coronavirus pandemic, we were working more than usual while managing safety, such as limiting the number of people and working hours. Even under such circumstances, I believe that we were able to make technical proposals and mission proposals that were academically valuable and included unique ideas, without being bound by past activities. Although the number of people infected with the coronavirus is increasing, we would like you to gain experience in demonstrating the results you have developed in the field.

Chapter 9 Tournament Results Report

1. Purpose

Through team development, we will improve our technical skills and cooperation, and at the same time, we will achieve success in our mission and leave results in the competition. It is to do so.

2. Results/discussion

[Success Criteria]

minimum success	Take one image and use it to create edge images, RGB to Red, etc.1,2 Acquire various feature images such as images with extracted colors.
middle success	The rover travels to the switching point while taking multiple images. Obtain feature images for the captured images and use the features obtained through minimum success. By comparing images using images as a standard, routes with small differences from the standard can be selected. Developing a sparse model that enables selection and identification of important feature image types. Make a profit.
full success	Drive toward the goal point while selecting a route. To confirm that the appropriate route has been selected, a human operator performs a mechanical check while driving. Avoid obstacles placed in front of your body.
advanced success	With the obtained sparse model, we can understand why it is an obstacle in full success. Explain how you reached your decision. Also, finish within 10 meters.

Present the results briefly.

	minimum success	Middle success	full success	advanced success
Content	Feature images acquisition	sparse Acquiring models	To the goal driving towards	goal Within 10m
1st drop	×	×	×	×
Second drop	ÿ	•	ÿ	×

The detailed results are shown below.

The first drop failed because the power supply for the microcomputer was disconnected from the circuit due to the impact of landing. The cause of failure is , There was a poor connection between the power supply for the microcomputer and the circuit. After the first attempt failed, the second attempt was made with a microcomputer. The power supply and circuit were directly connected using a connector and soldering. This will cause contact failure. Prevented mission failure.

After taking the above countermeasures, the problem of poor contact with the power supply was resolved by the second injection, and the project was almost fully successful. I was able to achieve it. However, the first reference image taken was a blank image due to a camera malfunction. Because of this, the minimum success is marked as ÿ. However, pure white ÿ stackability

Because the ground was low, there was no major impact on mission execution. In addition, CanSat stopped before achieving advanced success because the acceleration sensor malfunctioned midway and the direction of travel was significantly bent, and the capacity of the power supply for the motor was insufficient. ÿÿ

Acquired data

The first drop ended in failure, so all the results shown below are from the second drop.

[Travel route and distance to goal]

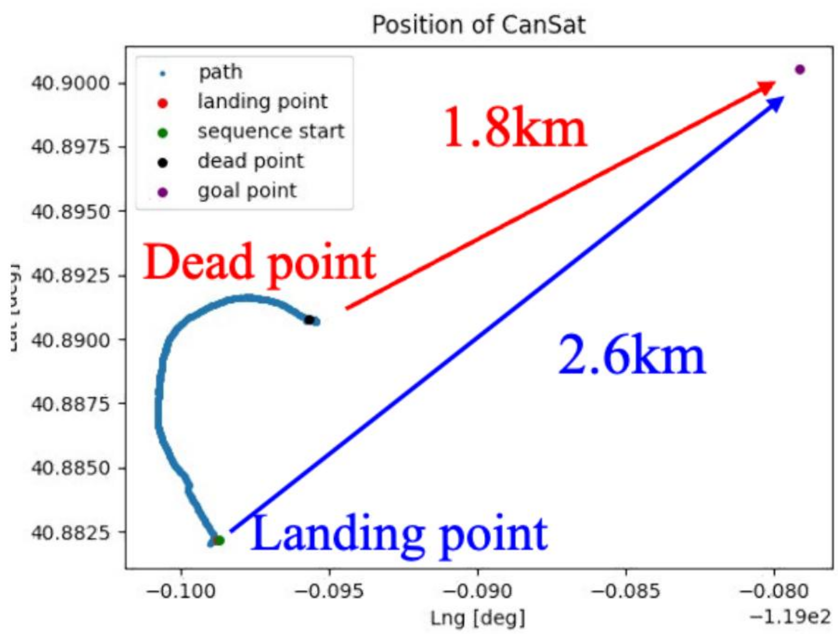


Figure 9.2.1 Travel route and distance to goal point

ÿaccelerationÿ

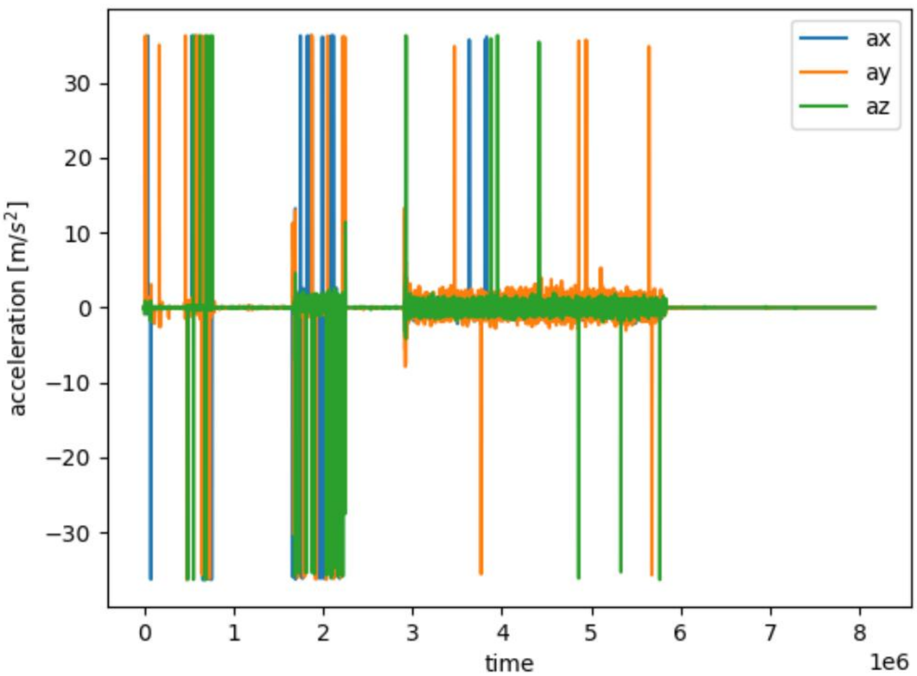


Figure 9.2.2 Acceleration

[Posture angle]

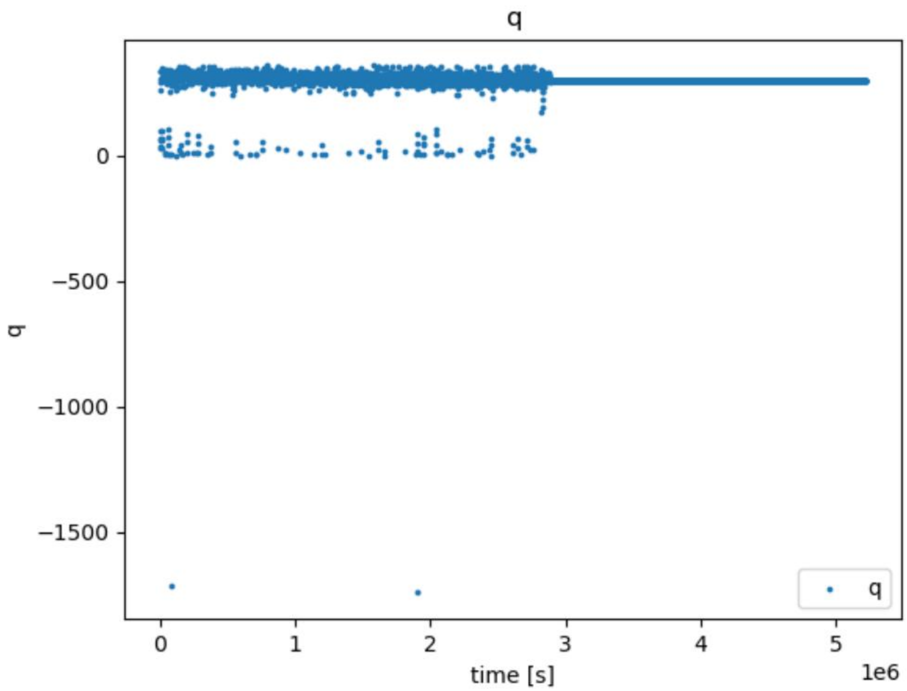


Figure 9.2.3 Attitude angle

[Acquired sparse model (selected features)]
• • indicates selected features, × indicates unselected features.

Table 9.2.1 Features selected by sparse modeling

	Eh Ji	RGB VI	IOR HSV b			g yellow		Eme Ral de	purple r	
Median value	•	•	•	•	•	•	•	•	•	×
Average value	•	•	•	•	•	•	•	•	•	×
Mode •		•	•	•	•	•	•	•	•	×
Variance	×	×	×	×	×	×	×	×	×	×
Kurtosis	×	×	×	×	×	×	×	×	×	×
Skewness	×	×	×	×	×	×	×	×	×	×

[Calculated risk level]

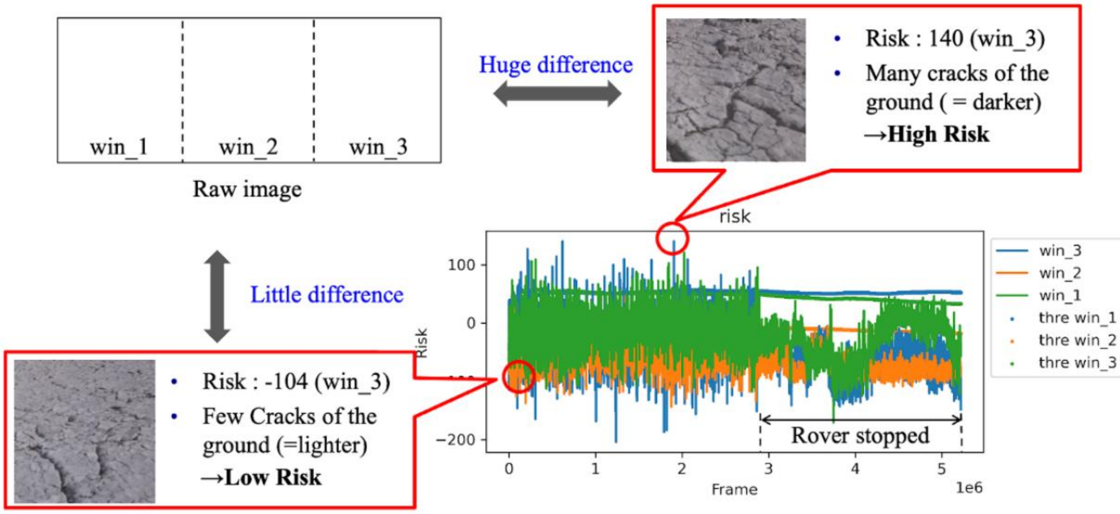


Figure 9.2.4 History of risk calculated by mission execution

Chapter 10 Summary

1. Points of improvement/effort (including issues)

Software group/circuit group

[Management-related materials]

a. RAM (red highlights are development tasks, blue highlights are test tasks)

task	Takahashi PM	Fukui soft Group leader/ circuit Unit leader	Fujii soft	Inoue soft	Hayashide soft	Murayama hard· circuit
algorithm Consider	I	R	C	C	C	
Release/landing Algorithm study	I	R				
GPS sensor development	I	R	R			
9-axis sensor development	I	R	R			
LED development	I	R	R			
communication module Selection & development	I	R			C	
motor development	I	R	C			
parachute separation Algorithm development	I	R				
sparse modelin First stage development	I	R		C		
sparse modelin Second stage development	I	R			C	
route planning Algorithm development	I	R	C			
mission function development	I	R	C	C	C	
conceptual design (Created by BBM)	I	R				C
Schematic creation	I	R				C
PCB layout create	I	R				C

Circuit modification/order acceptance	I	R				C
Communication distance test	I	R			C	
Ground station recording test	I	R				C
Wireless ON/OFF test	I	R				
GPS accuracy test	I	R				C
9-axis sensor test	I	R				C
wireless channel change test	I	R				
Sensor integration test	I	R				C
battery test	I	R			C	C
parachute separation test	I	R	C	C	C	
Posture change/maintenance test	I	R	C	C	C	
SD card recording test	I	R				
sparse model Acquisition exam	I	R				
Driving test	I	R	C	C	C	
Stuck detection test	I	R	C	C	C	
Obstacle avoidance test	I	R	C	C	C	
EtoE exam	I	R	C	C	C	C

- Software group Gantt chart: Software/circuit group Gantt chart.xlsx
- Software Team DSM: Software/Circuit Team DSM
- Software Team PERT/Critical Path: Software/Circuit Team PERT/Critical Path.pptx

[Review and reflection on role/task division]

- RAM

ÿ At the Gantt chart stage, evenly distribute the exam so that everyone can experience the exam.
However, due to individual circumstances (research, part-time work, exams, etc.) and members' new models,
Due to the coronavirus infection, not everyone will be able to participate in the exam.

Ta. This year in particular, the deadline for submitting the examination report is quite tight, and this is thought to be due to the fact that the exam has to be completed intensively. I felt that in the activities from next year onwards, it was necessary to have enough time so that all members could be evenly

involved in the exam. ÿ Looking only at RAM, I felt that there was a bias regarding development tasks. However, since the first and second stages of sparse modeling were the most important and difficult points in this mission, it is thought that there was no problem in terms of task assignment. Based on the above, I feel that we were able to clearly allocate development tasks to each member and proceed with development with a sense of responsibility.

• Gantt chart ÿ Good

points • As I

mentioned in my review of using RAM, I felt that I was able to do a relatively good job of allocating resources to members. ÿ Bad points •

The schedule was

tight. I felt that improvements to the schedule were needed in the future.

• DSM ÿ It

turned out that circuit design is a very important part related to all tests. Therefore, we should have identified any problems in advance by repeating tests using the completed circuit before the aircraft was completed. (During the actual test, it was thought that the 9-axis sensor values were incorrect due to the influence of the motor's magnetism. We should

have verified this many times in advance.) ÿ The algorithm study part is the most important part of all items. Ta. Because the mission was highly difficult and we did not have much time for development, we conducted algorithm study and development simultaneously. Although this form may be a common method for project progress, we should have investigated the algorithm a little more deeply before proceeding with development. In particular, the batteries were changed a month before the tournament, so we should have thought deeply about them in advance. I feel that if we had discussed the battery with the hardware team in advance, we would not have had to worry about the size and weight of the battery.

• PERT/Critical Path ÿ Creation of the

mission function was the most important for mission execution. Furthermore, it was extremely difficult to create the mission function because all development elements had to be included in the creation of the mission function. In order to create the mission function, we were able to proceed with the development in parallel by largely dividing it into para-separation, sensor/circuit development, and sparse modeling development. However, as a result, there was a delay in the critical path, which made the overall schedule extremely tight, which is something we should reflect on.

• Hardware group

task	Takahashi PM	Yoshinari Hard Team Leader/ Treasurer	Small West Hard	Shindo Hard	Murayama Hardware/Circuit
Conceptual design (BBM model)	I	R	C	C	C
Tire material selection	I	R	R		

Battery selection	I	R	C	C	C
Paper-based structural design	I	R	C	R	R
tire design	I	R	C	R	C
Housing design	I	R	C	C	C
Battery case design I		R	C	C	R
Upper and lower board design	I	R	C	C	R
Safety based on assembly Analysis	I	R			
Housing production	I	R	C	C	C
Flange manufacturing	I	R			
Tire manufacturing (external)	I	R	C	R	C
Tire manufacturing (internal)	I	R	C	C	C
Battery case manufacturing	I	R	C	C	C
Upper and lower board manufacturing	I	R			
Yakikiri production	I	R			R
Parachute production	I	R	R	R	C
Integration of parts/assembly of the body stand up	I	R	C	C	C
Mass test	I	R	C	C	C
Aircraft storage release test	I	R	C	C	C
Quasi-static load test	I	R	C	C	C
Vibration test	I	R	C	C	C
Separation impact test	I	R	C	C	C
Parachute Drop Test I		R	C	C	C
Open umbrella impact test	I	R	C	C	C

Landing impact test	I	R	C	C	C
Test on driving performance I		R	C	C	C
End to End Exam	I	C	C	C	C
2nd machine manufactured	I	R	C	C	C

Hard Group: Hard Group DSM

Hard Team: Hard Team Critical Path

- About role/task division
  - RAM (Responsibility Matrix)
    - ÿ If you schedule tasks without clear roles, the participation status and knowledge of members will be affected. Roles should not be clearly defined, as this can create imbalances in knowledge and experience and impede work efficiency. I felt that it was necessary to discuss this with members at an early stage.
  - DSM(Design Structure Matrix)
    - ÿ The mass test results will affect the re-design, so carefully consider the mass at the design stage. I should have done the calculations.
  - PERT/critical path
    - ÿ If there is a delay in the design or production of the main body, we can help by working on the production of the parachute. , we were able to reduce work stagnation.
- Review the Gantt chart
  - Level of task detail
    - ÿ Tasks are described clearly and in detail, but new tasks can be created when problems increase. The number of requests increased, and it was not possible to add them and update the schedule. Consider reworking the design. In addition, you should set a schedule with plenty of leeway.

2. Future outlook

Although half of the members will retire, the team will continue to work on new projects with cosmic significance next year. We are planning to take on the mission. In addition to novelty, we are more aware of actual space exploration, The team worked together to develop an aircraft with operational stability that would not break down during launch. I want to appear.