2nd Kibo Robot Programming Challenge

Guidebook

Version 1.0 (Released Date: February 8th, 2021)

Japan Aerospace Exploration Agency (JAXA)

List of Changes

All changes to paragraphs, tables, and figures in this document are shown below.

Release Date	Revision	Paragraph(s)	Rationale
February 8th, 2021	1.0	All	-

Contents

1. Introduction

1.1. Purpose of Kibo-RPC

The Kibo Robot Programming Challenge (Kibo-RPC) is an educational program in which students solve various problems by moving free-flying robots (Astrobee and Int-Ball) with student's programming skill in the International Space Station (ISS). It is hoped that, by getting the opportunity to talk with professional scientists and engineers and watch the professional works up close, they will be inspired to develop their own educational and professional goals to a high level. Participants will have the chance to learn cutting-edge methodologies and to hone their skills in science, technology, engineering, and mathematics through this program.

This program is hosted by the Japan Aerospace Exploration Agency (JAXA) in cooperation with the National Aeronautics and Space Administration (NASA).

1.2. Educational Objective for 2nd Kibo-RPC

In 2nd Kibo-RPC, experience of moving an actual robot after simulating teaches students that a simulation can only approximate the real world at all. Thus, participants are expected to learn techniques for creating simulation programs that perform well in the real world while considering uncertainties and error. For these reasons, Students will be able to learn the necessity of controlling and correcting positions and orientation of a free-flying robot and how to perform assigned tasks in the onboard environment through simulation trials.

1.3. Previous Kibo-RPC

The 1st Kibo-RPC was held between October 2019 to October 2020. A preliminary Round was in each country/region to select a representative team in June 2020 and the representative teams from 7 countries/regions competed each other with own program on-orbit on October 8th, 2020. As an observer, Bangladeshi students also join this competition.

Table 1.3-1 Number of participating teams

Australia	14
Indonesia	37
Japan	12
Singapore	3
Taiwan	58
Thailand	151
UAE	38
Total	**313 teams** **1168 people**

- 1st Kibo-RPC Website
https://jaxa.krpc.jp/
- YouTube
https://youtu.be/UhTz_ukm1cE
- KUOA News
https://iss.jaxa.jp/en/kuoa/news/kibo-rpc_pre.html
https://iss.jaxa.jp/en/kuoa/news/kibo-rpc_final.html

*Students from Bangladesh participated as observers that adds up to **361** teams, and **1340** students participated.

Figure 1.3 Photos in the 1st Kibo-RPC

1.4. Introduction of robots in ISS

Some robots such as Astrobee and Int-Ball is in ISS. Participants create your own program for moving Astrobee to designated locations in the Kibo-RPC.

What is Astrobee?

Table 1.4-1 Astrobee

Astrobee, NASA's new free-flying robotic system, will help astronauts reduce the time they spend on routine duties, leaving them to focus more on the things that only humans can do. Working autonomously or via remote control by astronauts, flight controllers, or researchers on the ground, the robots can perform tasks such as taking inventory, documenting experiments, or moving small items or cargo throughout the station.
(https://www.nasa.gov/astrobee)

What is Int-Ball?

Table 1.4-2 Intball

Int-Ball is a free-flying camera robot aiming to reduce crew time ultimately to zero for routine video-shooting tasks by crew in the ISS/Kibo. Similar to current consumer-grade cameras, Int-Ball works closely with onboard crew to provide flexible views for ground operators. Int-Ball is perhaps the first human-friendly camera robot in space.
(http://iss.jaxa.jp/en/kiboexp/news/171214_int_ball_en.html)

2. Event Information

2.1. Participation

✓Please refer to the Entry Description regarding the participation.

2.2. Event Plan

2.2.1. Event Schedule

Feb 2021

Call for Participation
- We might have a guidance session for applicants.

Self-Learning
- Participants need to access to the Github repository provided by NASA to learn about the programming of the space robot (Astrobee).

Program Development
- Release of the web simulation environment is planned in April 2021.
- Participants create program for JAXA's simulation environment.

Jun 2021

Preliminary Round Early June
- It will be held in each country/region by domestic space agency to select the national representative.
- The winning team can go on to the qualification round.

Qualification Round Middle of June
(Specific date and locations are still under coordination)
- Qualification round will be carried out to select finalists for the Final Round. The number of the finalists is not decided yet.

Program Refine
- Finalists refine program for ISS final round.
- Release of web simulation for Final Round is planned in end of July 2021.

Sep 2021

Final Round Around September 2021
- It will be hosted by JAXA at Tsukuba Space Center.
- It is the event connected with ISS and broadcasted on YouTube.

Table 2.2.1 Event Schedule

2.2.2. Event Details

(1) Preliminary Round

All participants need to take part in a preliminary competition by simulator in the country/region to select a representative of your country/region.

- Teams submit a program for JAXA's simulation before this round.
- Teams compete against each other by speed and accuracy of a mission in simulations.
- One winning team is selected as a representative who can participate in the qualification round or the final round.
- The competition is judged based on JAXA's scoring factors and game rules.
- Details of game rules are written to a Rule Book which is published later.

Detailed information, such as venue and schedule, will be announced by the POC of each country/region since the event is different for each country/region.

(2) Qualification Round

All representative need to participate in a qualification round. In this round, teams which can exceed to the final round. Since the number of the finalists depends on the crew's schedule, it will be decided and announced later.

- Teams submit a program again that developed for the preliminary round, but it can be modified if needed.
- Teams compete with representatives from other country/regions on a simulator.
- Some finalists are selected for the Final Round.
- The scoring factors and game rules are the same as the Preliminary Round.
- Details of game rules are written to the Rule Book which is published later.

Information related to the event is announced by Kibo-RPC secretariat.

Table 2.2.2 Example for Finalist Selection at Qualification Round

(3) Final Round

Finalists selected at the Qualification Round can reach the Final Round.

- Each team's program developed for JAXA's simulation environment is uplinked to Astro-bee on ISS.
- Teams need to submit your own program to Kibo-RPC secretariat in advance.
- Teams can modify the program used in previous rounds before submitting.
- The competition will be judged based on JAXA's scoring factors and game rules.

Detailed information such as program submission date will be announced around the preliminary round.

Date: Around September 2021

Venue: Tsukuba Space Center (TKSC) (https://global.jaxa.jp/about/centers/tksc/index.html)

The final round will be streamed live in each Kibo-RPC country/region for participants who can't come to Japan.

Please ask the POC in each country/region about travel expenses and accommodation fee.

2.2.3. Release of Web site and Simulation

The web site including web-based simulation will be prepared in phases. Until issued your ID, please study in reference to the 1st Kibo-RPC Web Site. (URL)

Table.2.2.3 Release Schedule

Event	Date
Programming Manual	Middle of March, 2021
Open Web Site for Participants	April 1st, 2021
Simulation	April 1st, 2021
Update for Final Round	July ,2021

3. Game Description

3.1. Scenario

On October 2020, damaged International Space Station (ISS) and its Kibo Module, hit by a meteor shower and caused air leakage, went back to normal life. Kudos to young programmers in Asia-Pacific Region who repaired the leakage in the nick of time.

Now, the repairment turned out to be insufficient; the air leakage recurred, and fate of astronauts is once again in danger!

Since astronauts cannot come close to the leaking area, it is time for Astrobee to go for the repair mission again. The location of leak hole has been identified based on the previous mission, and programmers are wanted who can manipulate Astrobee with quick and precise control.

The flight controllers detected with various instruments in ISS that vicinity of leakage is strongly disturbed by air flow, and perpendicular approach to the hole is hardly possible. Debris in Kibo Module are preventing short and straight trajectory of Astrobee. Moreover, the direction of the hole was found NOT to be perpendicular to the surface of the wall. This time, complete repairment is needed for prevention of recurrence. No more air leak! Use Astrobee and detect the precise direction of the hole and weld it accurately and completely with Astrobee's laser.

Astronauts have started their evacuation sequences for emergency. When you succeed the mission, you need to report them to cancel the sequence and make their final check with their own eyes. You need a clear and strong message to get attention of the astronauts.

Emergency mission to the student programmers in Asia-Pacific Region.

!!Mission!!

Complete to repair air leak and report to astronauts!

*This story is fiction.

3.2. Game Overview

Teams create a program to move Astrobee from dock station to the specified places and point the laser a target. After that, teams report "mission complete" to a crew.

The score will be calculated by the combination of the accuracy of laser pointing on the target, the elapsed time. (Calculation method will be updated.)

3.3. Game flow

① Undock the docked Astrobee from the dock station near Airlock. (Mission starts with the un-docking command.)

② Move Astrobee from the dock station to Point-A (P-A).

③ Since there is Keep Out Zoon (KOZ) which imitate an air leak in front of the Airlock, you cannot irradiate the target from the front.(Fig.3.3-1) There are some patterns of the KOZ.(Fig.3.3-2)Information of the KOZ is written QR code near the target.(Fig.3.3-3) While using information of the QR code and AR tag, correct the position of Astrobee and hit the target in the center with the laser.(Fig.3.3-4) You can try to irradiate again and again, but don't forget the time limit.

④ Move Astrobee to Point-B (P-B: in front of the crew) and report "mission complete" to the crew with a speaker internal Astrobee.

⑤ Time limit is 5 minutes. (Mission finish with the mission complete command.)

(※) Keep Out Zone(KOZ)・・・The area Astrobee cannot move into. If Astrobee attempt to go there, it is rejected.

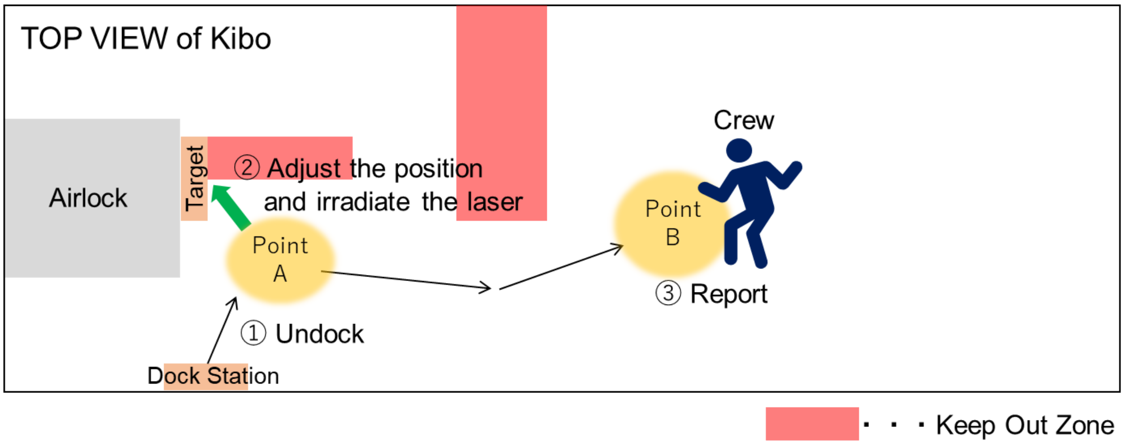


Figure 3.3-1 Game scenario

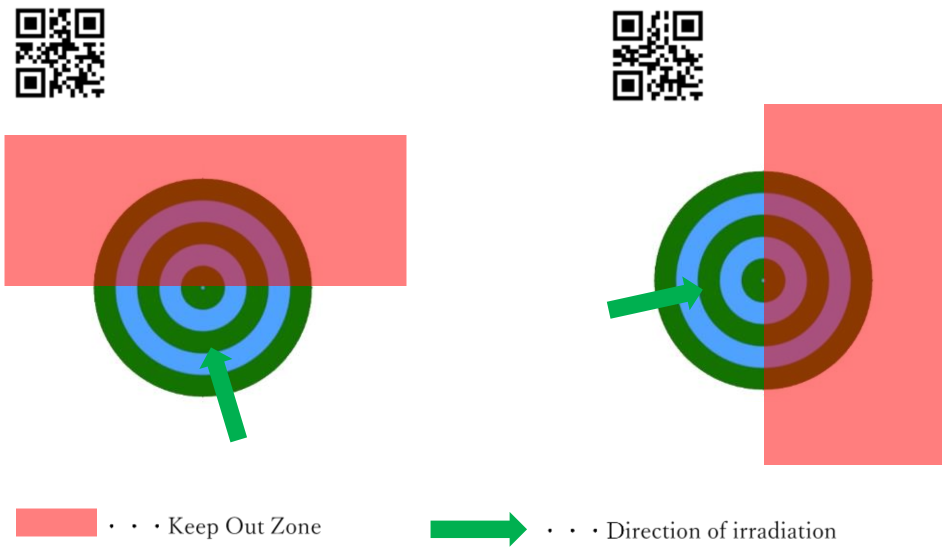
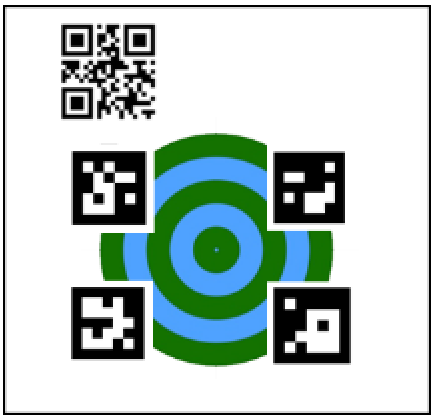


Figure 3.3-2 Example pattern of the KOZ in front of the Airlock



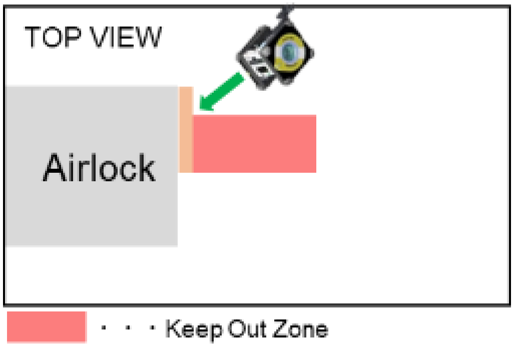


Figure 3.3-3Target

Figure 3.3-4 Irradiation target from diagonal direction

3.4. Released information in the future

The followings information will be released in a Rulebook.

1. Coordinates and orientations when docking
2. Coordinates and orientations of P-A
3. Coordinates and orientations of P-B
4. Coordinates of KOZ in front of the target
5. Coordinates of KOZ between P-A to P-B
6. Positional relation between QR code, AR tag and the target
7. Size of the AR tag
8. Size of the QR code
9. Size of the target

3.5. Evaluation standard

Your program is assessed based on the accuracy of laser irradiation and the elapsed time until completing the mission. 2 elements are evaluated each and your score is calculated between 0 to 100.

Accuracy	Distance between the center of the target and hit point.
Time	Time from undocking command to mission complete command.

3.6. Tips for Astrobee Characteristics

The tips for Astrobee characteristics will be provided in this section to be considered for successful runs.

3.6.1. Rendering of Astrobee

Figure 3.6.1-1 indicated Astrobee equipped with some external hardware components. The hardware surrounded with one-foot cube (about 32 cm wide) are used in the simulator and ISS final.

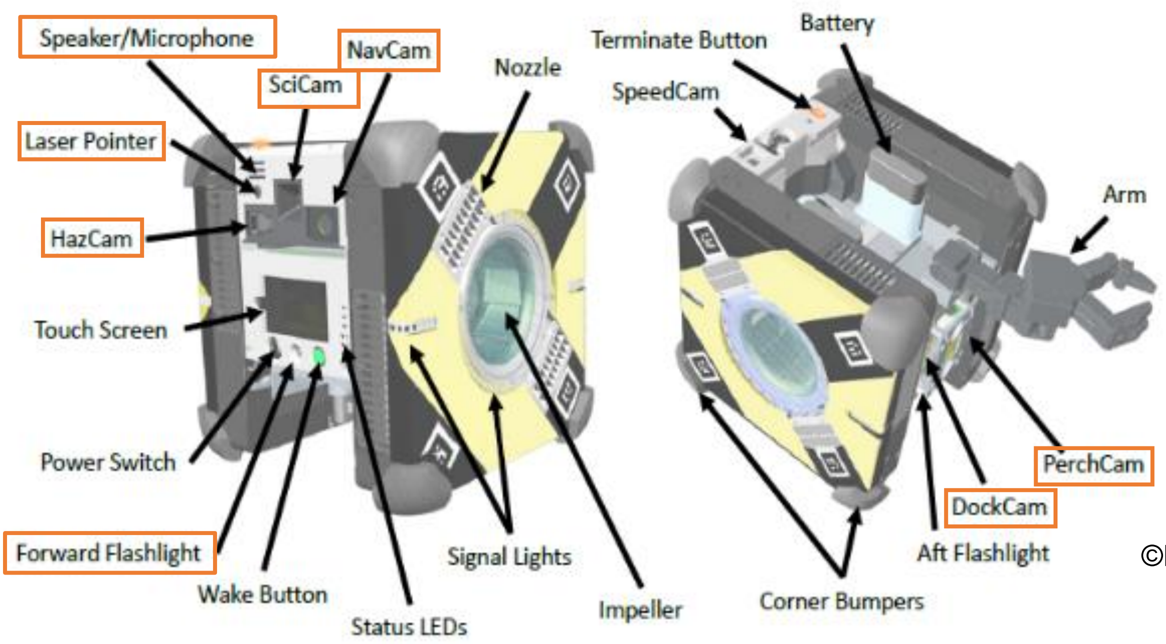


Table 3.6.1-1 Rendering of Astrobee

Name	**Explanation**
HazCam	A monochrome camera for detecting obstacles within 30cm
NavCam	A monochrome camera for image data processing and taking a photo after sending finish command
SciCam	A color camera for taking a video (The participants cannot utilize. In final round, Sci Cam is used to take color videos, and acts as Astrobee's eye.)
DockCam	A monochrome camera for docking to the dock station (In the simulator, it takes videos of rear.)
PerchCam	A monochrome camera for grabbing a handrail (You can create a program with this camera, if need.)
Laser Pointer	Irradiating the target (It has a distance from NavCam. Be careful when you create a program of image data processing. The detail of distance, please refer to Programming Manual clause 5.4)
Flashlight	Use this when read QR code and AR tag
Speaker	Report "mission complete" to a crew with your voice

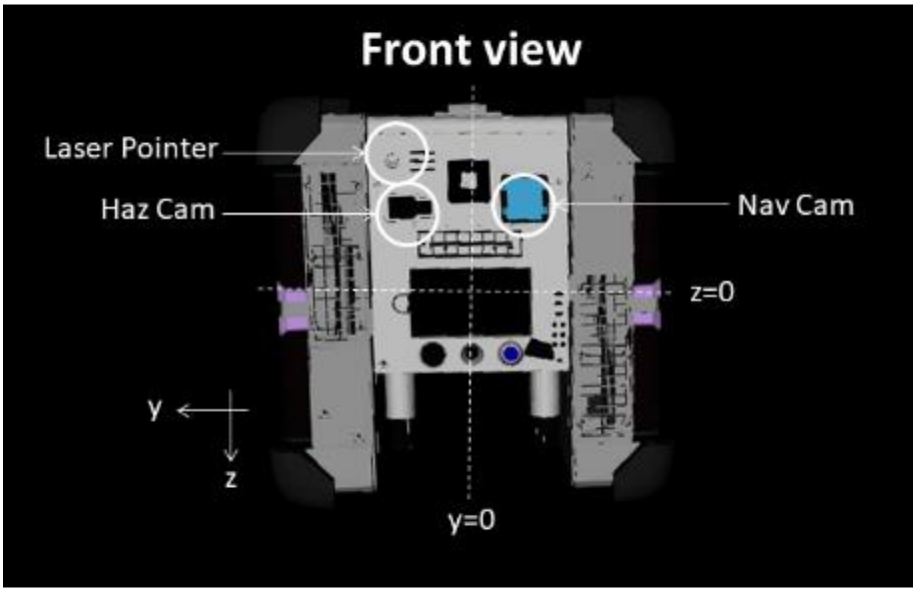


Figure 3.6.1-2 Astrobee Front View

Table 3.6.1-1 Distances from center point

	x[m]	y[m]	z[m]
Nav Cam	0.1177	-0.0422	-0.0826
Haz Cam	0.1328	0.0362	-0.0826
Laser Pointer	0.1302	0.0572	-0.1111

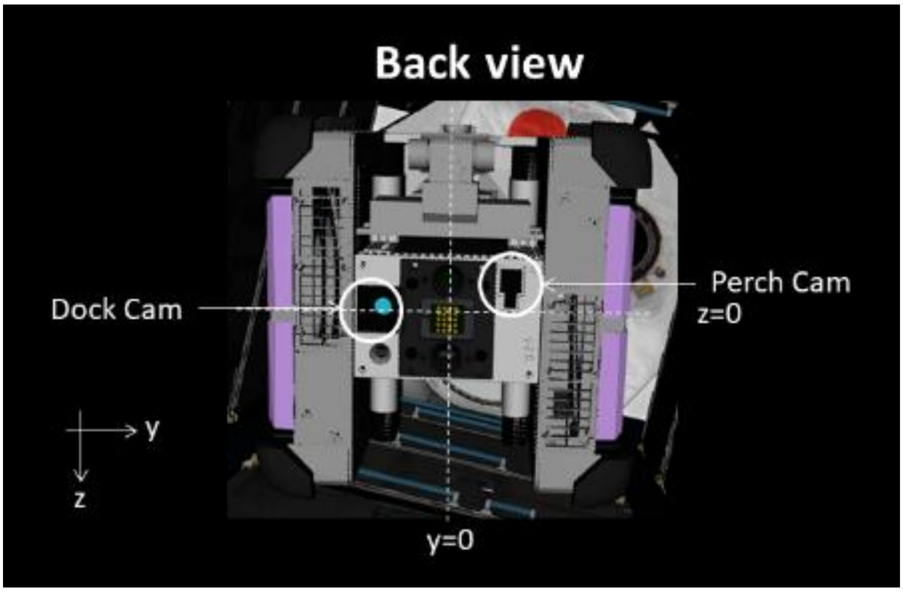


Figure 3.6.1-3 Astrobee Back View

Table 3.6.1-2 Distances from center point

	x[m]	y[m]	z[m]
Dock Cam	-0.1061	-0.054	-0.0064
Perch Cam	-0.1331	0.0509	-0.0166

3.6.2. Specification of Astrobee

* Mass: 10kg (Installed only two of the four batteries)
* Maximum Velocity: 0.5 m/s
* Maximum Thrust (X axis): 0.6 N
* Minimum moving distance: 0.05 m.
* Minimum rotating angle: 7.5 degrees.
* If the Astrobee detect the actual obstacles in front, Astrobee will automatically stop and then maintain its position and orientation. The moving path of Astrobee in process is also discarded.

3.6.3. References of Astrobee

- GitHub-1 (https://github.com/nasa/astrobee)
- GitHub-2 (https://github.com/nasa/astrobee_android)
- Website of Astrobee (https://www.nasa.gov/astrobee)