
ASTROBEE FACILITY

KIBO ROBOT PROGRAMMING CHALLENGE 5/21/2020 CHECKOUT ACTIVITY REPORT



NASA AMES RESEARCH CENTER

ABSTRACT

This is a report on JAXA's Kibo Robot Programming Challenge (RPC) Checkout activity which took place on 2020-05-21. This activity is an on-orbit test for the upcoming competition organized by JAXA and to be run by September 2020. It aimed to check the multiple aspects of the operation of Bumble in support of this competition.

The activity had three primary objectives: a) verification of four different positions to be visited during the competition, namely Start Position, P1, P2, and P3, b) demonstration of Bumble autonomously moving from the Start Position to P3 without keep-in/keep-out zones and c) demonstration of Bumble autonomously moving from the Start Position to P3 with JAXA's defined keep-in/keep-out zones. The report emphasizes the confirmation of JAXA's previously calculated and commanded coordinates for each position and the Astrobee Facilities Team (AFT) estimation of new coordinates in case those coordinates did not match JAXA's desired target positions per ground and crew procedures.

Four estimated coordinates are proposed and various suggestions on operation procedures are given to improve the maneuverability of Bumble during the actual day of the competition.

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1 TEST SESSION OBJECTIVES

The Kibo Robot Programing Challenge (RPC) Checkout activity had multiple objectives summarized as follows:

- Verification of four different positions to be visited during the competition, namely Start Position, P1, P2, and P3:
In order to complete this objective, JAXA both intended to move Bumble through manual teleoperation using Ground Data System (GDS) graphical user interface (GUI) and verify the readability of its AR tag/Target and QR codes via their HLP's APK.
- Demonstration of Bumble autonomously moving from the Start Position to P3 without keep-in/keep-out zones (KIZ/KOZ):
In order to complete this objective, JAXA would have Bumble place at Bay 1 of the JEM facing the airlock and command it to visit each of the verified positions in a) autonomously via its APK. In this case, the Bumble would not consider KIZ/KOZ defined by JAXA.
- Demonstration of Bumble autonomously moving from the Start Position to P3 with JAXA's defined keep-in/keep-out zones:
In order to complete this objective, JAXA would have Bumble place at Bay 1 of the JEM facing the airlock and command it to visit each of the verified positions in a) autonomously via its APK. In this case, the Bumble would consider KIZ/KOZ defined by JAXA.

2 TIMELINE SUMMARY

JAXA's Kibo-RPC Checkout (C/O) Activity took place on 2020-05-21 and it had a preliminary start at 07.45 GMT with crew members powering up Honey and Bumble. The actual C/O activity started at 10.20 GMT and finished at approximately 11.40GMT after starting closing procedures.

The timeline of operations performed for this activity is summarized below:

Event	Crew Step	Move / Plan		Start (GMT)	Success	Redo	Notes / Action
		Test	Step				
1				07 : 45	x		Chris powers on Honey and Bumble
2	1		1	10 : 20	x		
3			2	:			
4	2		9	: 36	x		Chris finished printing AR/QR tags
5				: 38	x		JAXA grabs control of Bumble
6				: 41	x		Chris finished printing AR/QR tags
7	3		7	: 48	x		Chris is ready to monitor Astrobee as JAXA maneuvers it
8				: 51	x		JAXA undocks Bumble
9				: 58	x		JAXA moves to P3
10				11 : 03	x		JAXA moves Bumble to point to AR tag
11				: 11			JAXA turns on laser
12				:			JAXA tries to read AR tag
13				: 15	x		JAXA moves to P2 (Chris moves Bumble)
14				: 18	x		JAXA moves to P1 (Chris moves Bumble)
15				: 20			Chris move Bumble to Start position
16				: 26			ARC grabs control and tries to move Bumble to Start position
17				:			Bumble does not register features
18				: 38			Start closing procedures

FIGURE 1. KIBORPC CHECKOUT ACTIVITY ON 2020-05-21 TIMELINE SUMMARY

3 OPERATIONS

The operations towards the KiboRPC Checkout activity can be summarized in the following subsections. Prior to the activity, two dry runs were completed. These dry run rehearsals intended to establish clear communication media between Tsukuba, Ames, and the ISS as well as familiarize JAXA with the operation of the GDS interface. The more fluent JAXA is using GDS the easier would be for them to recover from an unexpected event.

3.1 BEFORE/DURING/AFTER THE ACTIVITY:

JAXA and Ames sustained two rehearsal sessions of the activity. During these rehearsals, JAXA learned how to use features on GDS pertaining to the activity and practiced how to communicate during the actual activity. JAXA also submitted the HLP application to command Astrobee, an Android Package (APK), they will use during the activity; JAXA also submitted ground and crew procedures which were followed during the rehearsals. After these rehearsals, JAXA and Ames agreed on the roles each member would play during the activity and communication protocols and media each will follow.

During the pre-activity commanding, the AFT attempted to use the `krpc_co-MobNav.json` recording profile but the recording failed. Additionally, a computer restart was needed to recover. The `MobNavSAMPLED.json` profile was attempted and the same result was observed. Another attempt using the `"krpc_co_imgsampler.json"` profile was successful.

Per ground procedure, JAXA had control over Bumble using GDS after Ames indicated that the system was ready to operate. The data saving profile used was `"krpc_co_imgsampler.json"`. JAXA successfully undocked Bumble autonomously via GDS commanding. JAXA successfully

teleoperated Bumble via GDS to move to position P3. Position P3 did not correspond to their intended location (i.e. in front of the AR tag at the bottom right of the airlock). JAXA then teleoperated Bumble via GDS to their intended location. JAXA successfully read their AR/Target via APK commanding. After this step, Bumble appeared to be lost from JAXA's P3 intended location and JAXA decided to visit the remaining positions P2, P1, and Start Position with the help of crew. JAXA was not successful in reading the QR code on P2 via APK commanding. JAXA was successful in reading QR code on P1 via APK commanding. Bumble appeared to be lost once placed on Start Position by crew, and JAXA decided to terminate the activity due to limited time available.

Right after terminating the activity, Ames started the data download process. Ames then sent the data to building 8 data for the previously agreed review process that will clear Ames to share the recorded data to JAXA. Ames also inspected the rosbag data acquired during activity to check its integrity. On 2020-05-26 JAXA and Ames held debrief of the activity and discussed the early results. After this debrief, Ames performed analysis of the data recorded.

3.2 SUCCESSFUL ITEMS:

This activity accomplished several successes over previous activities with similar goals. The robot's localization was reliable while the robot was docked. Sufficient sparse-map features were registered and integrated into the robot's EKF. As a result of this reliable localization, undocking and movement to the manually teleoperated position was also successful. The optical flow demonstrated to be working well, especially since the localization system seemed to rely solely on it during the time the robot was facing the circular window at the airlock and the moved, upon teleoperated GDS command to the actual location where the AR tag/target was located.

Thanks to the joint JAXA-NASA dry-run activities during which the different roles were defined and assigned, the JAXA-ARC communication worked well. However, it may be improved by using a chat/teleconference system between these parties. Having 2 sets of data saving profiles was a good measure to mitigate the risk of missing data if one of them wouldn't work. Both of the data saving profiles created were previously tested on the ground with Bsharp but during the activity, although the `krpc_co_MobNav.json` profile was suggested by the Astrobee Facility Team, we ended up using `krpc_co_imgsampler.json` which was precisely created as a backup.

A satisfactory result of the activity was the coordination with the JSC imagery group, which was in constant communication with ARC. The communication and procedure protocols enabled an adequate enabling/disabling of these sensors during the activity. This allowed both parties to know the status of the robot's cameras at all times.

3.3 ITEMS REQUIRING ATTENTION:

There are still some outstanding issues we acknowledge require further improvement based on the performance observed in this activity.

3.3.1 CONTROL STATION (GDS) START-RECORDING BUTTON NOT SELECTABLE

There was an instance where the start-recording button was not selectable for the Kibo-RPC team as expected. This was a known bug in older versions of the GDS software. This has been fixed and the newer software will be distributed to the Kibo-RPC team.

3.3.2 DATA RECORDING ERROR

Although having two saving data profiles ready to be used, the `krpc_co-MobNav.json` profile produced errors after it was set to start recording data. This profile is a combination of JAXA's profile and ARC's usual `MobNavSAMPLED.json` which has been used previously for LoMo activities. We quickly tested the `MobNavSAMPLED.json`, but it also produced errors. Ultimately the "`krpc_co_imgsampler.json`" profile was used successfully and no loss of science resulted.

3.3.2.1 HYPOTHESES 1: RAM LIMITATION

A possible reason why this may have happened is because Astrobee's Mid Level Processor (MLP) is the one in charge of running the bulk of the navigation, localization, execution, and data saving processes of the robot. Having a large number of topics being saved while simultaneously running those other processes may have caused an overuse of the MLP's resources. The map being used was bigger than before which increases the use of RAM.

3.3.2.2 HYPOTHESES 2: GDS STRING LIMITATION AND DATA BAGGER ISSUE

Follow on testing has shown that attempting to record data using a profile with a name longer than 18 characters can result in GDS being unable to handle state messages coming from the Data Bagger subsystem on Astrobee. The result from this is GDS falling into an incorrect state due to not being able to process feedback messages from Astrobee. Ultimately, this results in a duplicate command being issued causing the Bagger subsystem in Astrobee to die. At the moment, no validation is implemented on the Flight Software side to avoid this situation. The short term solution will be to restrict file names to less than 18 characters.

3.3.2.3 LOCALIZATION PERFORMANCE

At this activity, Bumble showed a rate of seen raw sparse-mapping features of 25fps (features per second), the worst case scenario was 7 to 10 fps (the highest possible rate is 150fps). During this activity the Astrobee Facilities Team also checked the localization in Honey and found it was not working adequately. Given the resources and time constraints, further investigation of the issue was not possible during the activity and it has been left for possible future crewless activities and on-the-ground checks.

3.3.2.4 PARAMETER TUNING

The localization system has the capability to reset its EKF bias among other features to help relocalize the robot. There is a possibility that the localization system is rejecting sparse-mapping features that have been registered by the robot because it considers them outside of its tuned error tolerance. The corresponding set of parameters should be revised and tuned accordingly if necessary.

3.3.2.5 BIAS RESETTING BY OPERATOR WHEN NEEDED

A few possible ways to reduce the risk of the robot not being able to localize include: 1) not commanding the robot to move or ask the crew to move it before it has localized and 2) ask the crew to move the robot slowly, particularly if the crew is requested to rotate the robot since it is more prone to lose localization when rotated quickly.

3.3.2.6 IMPROVED MAP

The map used during the Kibo-RPC Checkout activity was updated from a previous Localization and Mobility (LoMo) activity. During the Kibo-RPC Checkout activity, more images were taken from locations where JAXA is interested in visiting constantly, namely Start Position, P1, P2, and P3. These images were used to further augment the coverage of the existent map and therefore, improve the localization of the robot if it visits these positions. After reviewing the recorded rosbags with the augmented map, it was found that the robot should be able to localize itself in 7339 images out of 10315 images with a mean of 84 features. Figure X summarizes these results obtained from a sparse map evaluation tool developed by the Astrobee Flight Software Team. According to this results, the robot should localize in 71% of all the images included in the newly generated map.

```
moravar@ubuntu:~/Code/astrobee/freemover/tools/ekt_bag/scripts$ python sparse_map_eval ~/data/2020-05-21/bags/20200521_1054_rpc_co_ingrammer_string_bag ~/data/2020-05-21/merged/20190523_0614_0712_0724_0828_1101_20200513_0521_briish_hist.map
Localized 7339 / 10315 images with mean of 84 features. (=====) 100%
Time per Frame: 0.09129 s
CPU Time per Frame: 0.09181 s
Run time: 942.312
```

FIGURE 2. SPARSE MAP EVALUATION TOOL RESULTS

3.3.2.7 IMPROVED POSITIONING WITH RESPECT TO THE WALLS & TARGETS

Due to the additional images acquired during the Kibo-RPC C/O activity, especially those around the vicinity of JAXA locations of interest (Start Position, P1, P2, and P3), an improved map has been created including those images. This will reduce the likelihood of the robot not localizing at those locations since new sparse mapping features have been added, allowing for the robot's localization to register and integrate them during the activity instead of detecting them but then rejecting them.

3.3.2.8 ATTEMPT CREW-LESS ACTIVITIES TO GAIN CONFIDENCE IN LOCALIZATION

The Astrobee Facilities Team has submitted a request to be allocated time in order to carry out operations on board the ISS without crew attending the robots. If granted and allocated, these activities will vastly help the maintenance of on-orbit assets (dock, Astrobee robots, etc.) and the validation of on-orbit operations. As a result, the Astrobee Facilities Team would be able to carry out dry-runs of the Kibo-RPC activity and iterate over specific points in JAXA's procedure and thereby, increase the confidence of success during the actual competition.

3.3.3 APK SNAPSHOT FAILED

When the Kibo-RPC team commanded their application (APK) to process a snapshot, the command completed quickly instead of the expected 10 seconds it should have taken. It has not yet been confirmed if imagery was recorded in the expected HLP data directly.

3.3.3.1 HYPOTHESIS: APK INSTALL PERMISSIONS

Follow on testing has shown that an improper install command can result in the APK not having the correct directory permissions to record data to the HLP. This can be corrected with improved APK install commands along with improved validation testing.

3.3.4 P2 QR CODE NOT RECOGNIZED

When commanded, the robot could not recognize the QR code at the P2 location.

3.3.4.1 HYPOTHESIS 1: DISTANCE TO TARGET TO LARGE

The distance to the target was larger than previous successful attempts

3.3.4.2 HYPOTHESIS 2: INSUFFICIENT LIGHTING

It's possible that the lighting, and in particular the source of the lighting, may have impacted the ability to recognize the QR code.

3.3.5 RESTRICTED ACCESS TO HIVEMIND SERVER FOR POST-ACTIVITY DATA ACCESS

It was realized that Astrobee users require a NASA network VPN account (non-HOSC) to access the data server the AFT has made available from NASA Ames for the purpose of distributing data to users. As a temporary workaround, NASA Large File Transfer tools were used for distribution.

4 ANALYSIS PERFORMED

Ames was focused on confirming or suggesting new estimated positions “Start, P1, P2, and P3” based on JAXA’s ground procedures and what was recorded with the `krpc_co_imgsampler.json` data profile (rosvag). The data collected during the activity was contained in 125 rosvags of approximately 90MB and 16 seconds each. These were merged into a single rosvag of approximately 13GB and it has been cleared to share with JAXA.

Each rosvag contains the following topics:

```
/comm/dds/command
/command
/gnc/ekf
/mgt/ack
/mgt/img_sampler/nav_cam/image_record
/rosout
/rosout_agg
```

Ames analyzed the images contained in the topic `/mgt/img_sampler/nav_cam/image_record` and the robot’s estimated pose using the `/gnc/ekf` topic.

Since we were interested only in verifying the coordinates of JAXA’s targeted positions, we replayed a collection of bags that contained images and poses from the vicinity of those positions (Start, P1, P2, P3). We retrieved the pose of Bumble by analyzing the images from the recorded bags with internally developed tools as well as Rviz and echo the topic containing the robot’s pose given by the recorded EKF. Additionally, we also used the Plan Editor on GDS as a ground truth to the coordinates given by JAXA’s ground procedure. By comparing these coordinates with those given by the recorded rosvag’s EKF pose output we were able to determine if the desired target positions and the actual positions attained during the activity were in accordance to the centimeter level.

Based on our analysis, we determined new target positions (Start, P1, P2, P3), consistent with 2 requirements:

- The robot shall be close enough to the AR/QR tags in order to read them
- The robot shall be not too close to the AR/QR tags in order to keep the robot localized

The first requirement may be interpreted as able to be within Bumble’s `nav_cam` field of view and the second may be interpreted by having the pose reported by the recorded bag’s EKF not moving over a tolerance of +/- 5 centimeters while looking at the target position.

5 RESULTS

The coordinates corresponding to JAXA's targeted positions as per JAXA's ground procedure are presented in Figure 3. These positions are presented as a trajectory plan within GDS' Plan Editor in Figure 4.

	position			orientation		
	x	y	z	x	y	z
Start Position	10.95	-3.4	4.85	0	0	-90
P1	10.7	-5.3922	4.4826	0	0	180
P2	10.9789	-7.7128	5.55	0	-90	0
P3	10.96	-9.68	5.04	0	0	-90

FIGURE 3. COORDINATES CORRESPONDING TO EACH TARGET POSITION PER JAXA'S GROUND PROCEDURE

As can be seen from Figure 4, the robot did go to its intended destination. By comparing the coordinates corresponding to P3 per ground procedure to the location where the crew procedure indicates the AR tag/target should go, it becomes clear that there was a mismatch at this location. With this result in mind, we revisited the recorded data as explained in Section **Error! Reference source not found.** and estimated a new position P3 according to the two requirements we established above. We repeated this process throughout the four JAXA target positions and summarized our results and recommendations as follows.

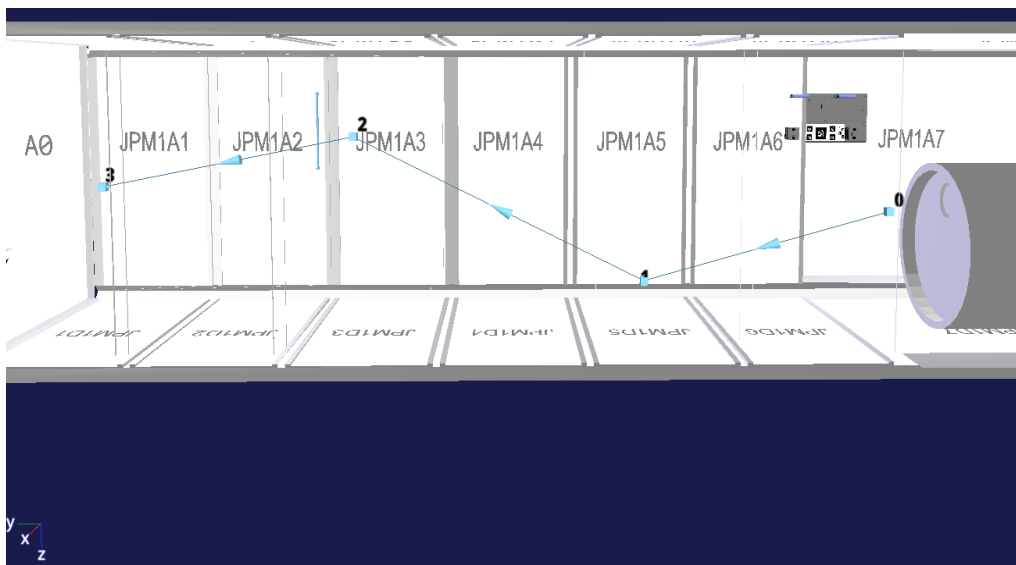


FIGURE 4. REPRESENTATION OF JAXA'S TARGET POSITIONS PER GROUND PROCEDURE

1. **Result:** Analyzing the rosbags “20200521_1054_krpc_co_imgsampler_string_{17..18}.bag” we compared the position of the AR tag given by the crew procedure and the location of P3 given by the ground procedure and we identified a mismatch between the two locations.

Recommendation: Ames suggests a new P3 with coordinates x: 11.35, y: -9.50, z: 5.40, R: 0, P: 0, Y: -90. The view of the AR tag/target from the recorded rosbags and the estimated pose by the recorded EKF is shown in Figure 5.

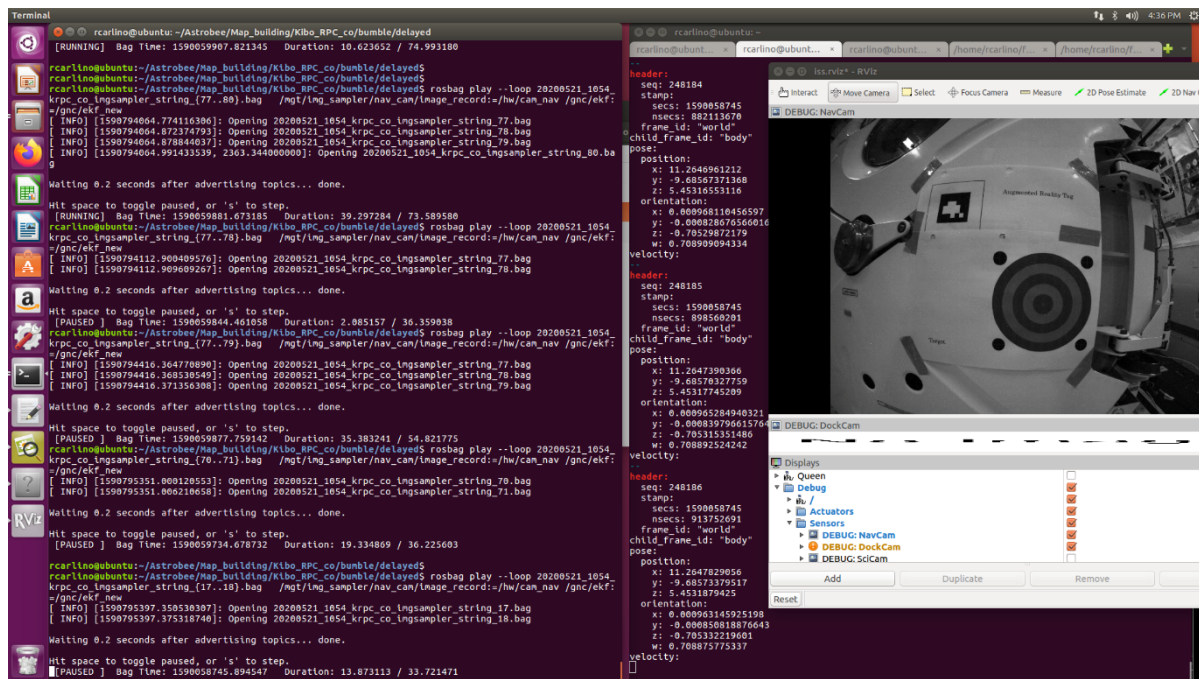


FIGURE 5. VIEW OF AR TAG/TARGET FROM RECORDED ROSBAGS

2. **Result:** Analyzing the rosbags “20200521_1054_krpc_co_imgsampler_string_{62..63}.bag” we compared the position of the QR code given by the crew procedure and the location of P2 given by the ground procedure and we identified that the QR code in location P2 was not read successfully as it appears that Bumble was too far from the code.

Recommendation: Ames suggests a new estimated P2, closer to the QR code. This new estimated P2 has coordinates x: 11.10, y: -7.60 z: 5.40, R: 0, P: -90, Y: 0. From Figure 6, it can be clearly seen how the QR code is visible from the nav_cam but it is far enough such that JAXA's APK was unsuccessful at reading it. Our new estimated coordinates for position P2 should locate the robot closer to the QR code.

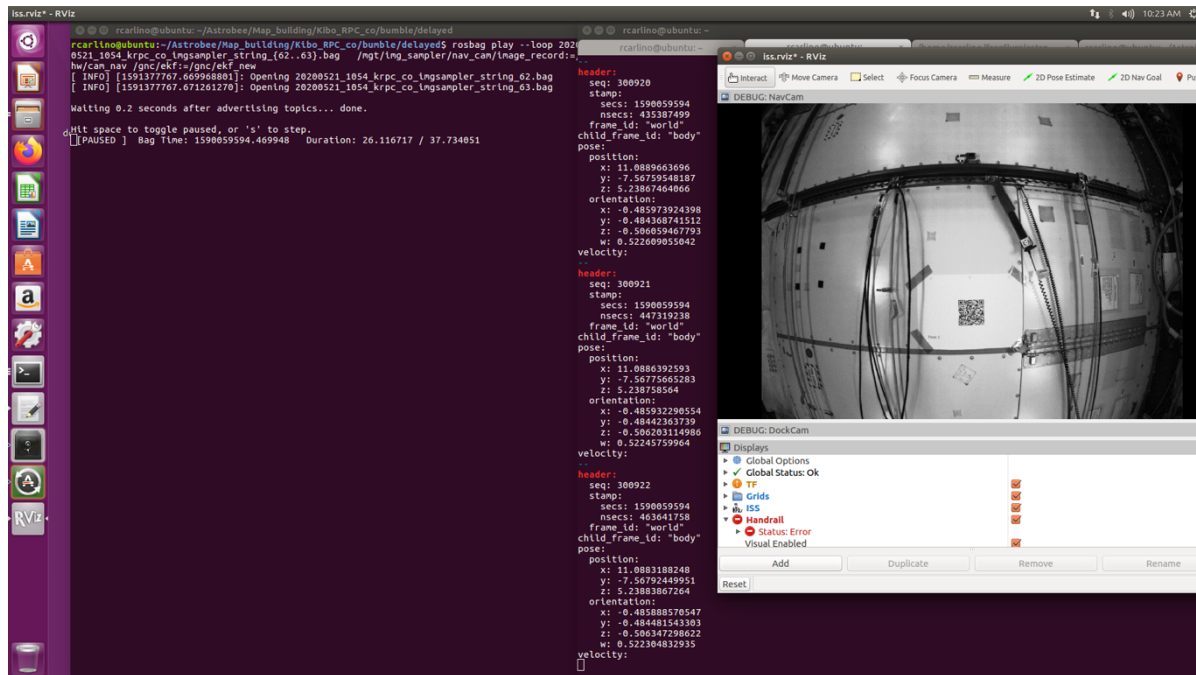


FIGURE 6. VIEW OF QR CODE CORRESPONDING TO P2 FROM RECORDED ROSBAGS.

- Result:** Analyzing the rosbags “20200521_1054_krpc_co_imgsampler_string_{70..71}.bag” we compared the position of the QR code given by the crew procedure and the location of P1 given by the ground procedure and we determined that the robot in location P1 appears to be close enough to read the QR code successfully.

Recommendation: Ames suggests a new P1 that is similar to JAXA’s P1. The new estimated coordinates for P1 correspond to x: 10.70, y: -5.20, z: 4.50, R: 0, P: 0, Y: 180. This estimated coordinates for P1 are within a few centimeters of the originally proposed position P1 by JAXA. The view of the QR code from the position held by the crew member can be seen in Figure 7.

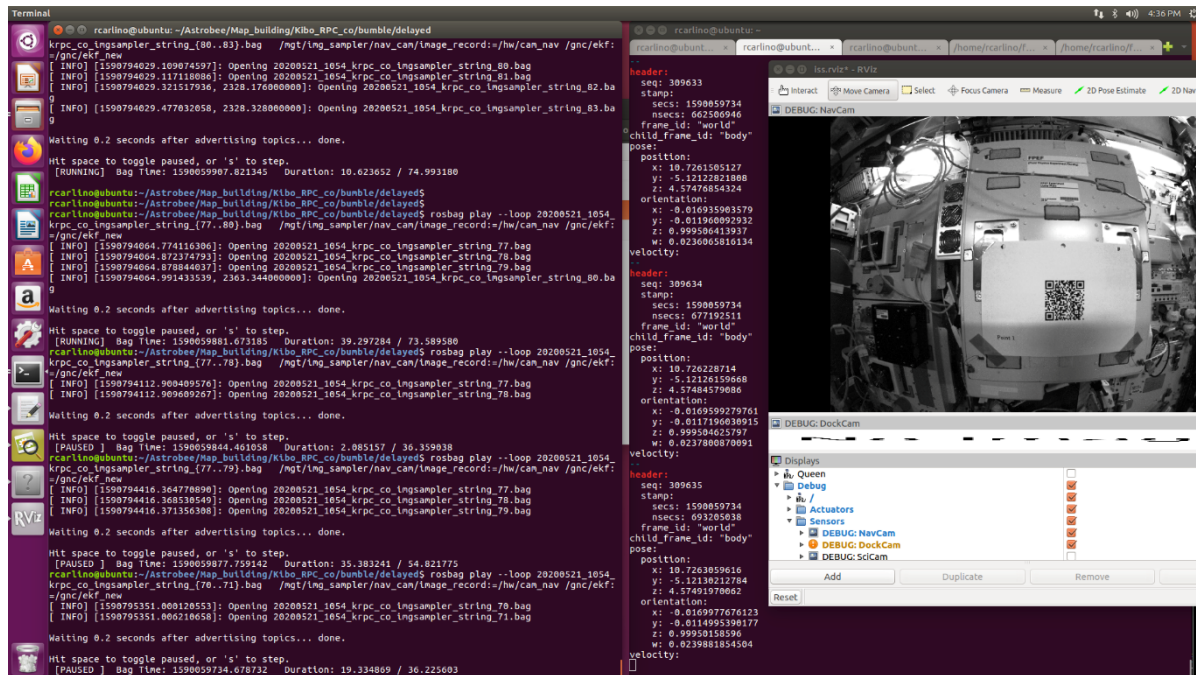


FIGURE 7. VIEW OF QR CODE CORRESPONDING TO P1 FROM RECORDED ROSBAGS.

- Result:** Analyzing the rosbags “20200521_1054_krpc_co_imgsampler_string_{77..78}.bag” we compared the position of the QR code given by the crew procedure and the location of P1 given by the ground procedure and we determined that JAXA's Start Position seems to be too close to the JEM entry node.

Recommendation: Ames suggests a new Start Position that is farther from the JEM entry node (i.e. in between Bay 1 and Bay 2). This new suggested coordinates for the Start Position correspond to x: 10.95, y: -4.00, z: 4.95, R: 0, P: 0, Y: -90. Ames believes having the robot placed farther from the JEM entry node will facilitate the crew's support of the activity as well as allow the robot to register more sparse-map features. Figure 8 shows the view from the JEM entry as placed by the crew member.

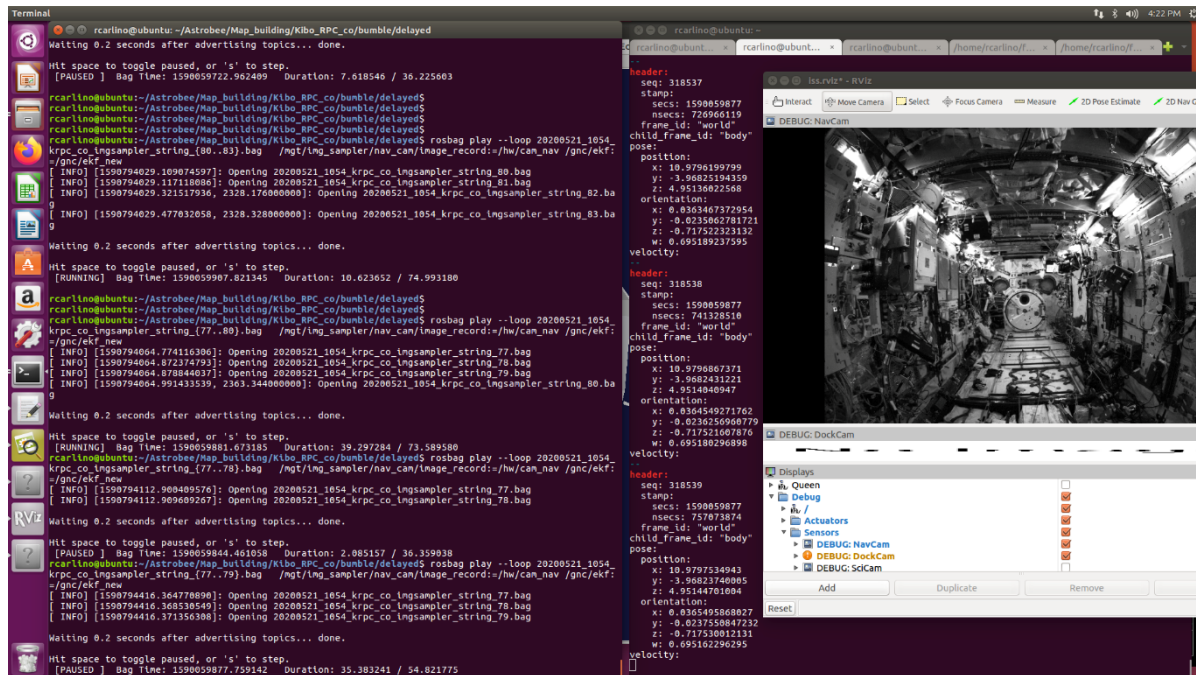


FIGURE 8. VIEW OF THE JEM TOWARDS THE AIRLOCK WHILE BUMBLE IS POSITIONED AT BAY 1 FROM RECORDED ROSBAGS.

A summary of the coordinates corresponding to each targeted position comparing those given by JAXA's ground procedure and this analysis are presented in Table I. A view of the target positions suggested by Ames as a trajectory plan in GDS' Plan Editor is shown in Figure 9. In this figure it can be seen that the position P3 corresponds to a location from which the robot may be able to localize and simultaneously see the AR tag/target. It also shows how the suggested Start Position is within Bay 1 and Bay 2 of the JEM, giving ample space to the crew member to comfortably follow the activity while keeping the crew member outside of the field of view of the nav_cam.

	Position						Orientation					
	x		y		z		R		P		Y	
Position	JAXA	ARC	JAXA	ARC	JAXA	ARC	JAXA	ARC	JAXA	ARC	JAXA	ARC
Start	10.95	10.95	-3.4	-4.00	4.85	4.95	0	0	0	0	-90	-90
P1	10.70	10.70	-5.3922	-5.20	4.4826	4.50	0	0	0	0	180	180
P2	10.9789	11.10	-7.7128	-7.60	5.55	5.40	0	0	-90	-90	0	0
P3	10.96	11.35	-9.68	-9.50	5.04	5.40	0	0	0	0	-90	-90

TABLE I. SUMMARY OF COORDINATES FOR EACH TARGET POSITION.

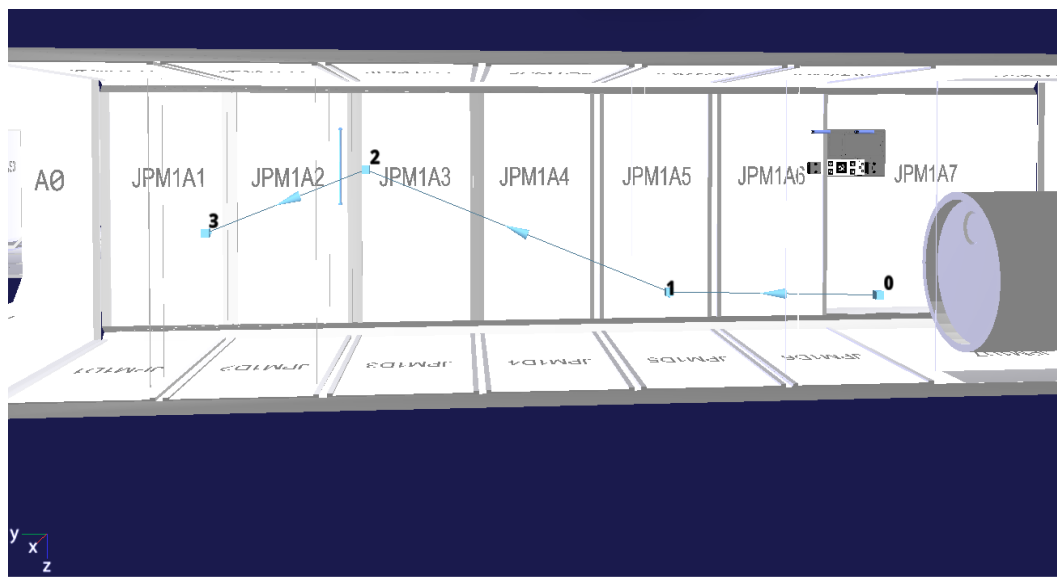


FIGURE 9. DESCRIPTION OF AMES' SUGGESTED NEW ESTIMATED TARGET POSITIONS

6 CONCLUSIONS

After the analysis of the operations from the Kibo RPC checkout, Ames determined that for the benefit of more efficient future ISS sessions, the JAXA commanding team should become more

proficient with the use of the GDS tool to control (e.g. Idle propulsion mode) and maintain localization parameters (e.g. Reset EKF, Reacquire Position). Ames suggests having an additional ground dry-run during which Ames will explain these functionalities and features to JAXA.

After analyzing the data from the Kibo RPC checkout, Ames was able to confirm or suggest new estimated coordinates for the positions for JAXA's Kibo RPC activity. Position P3 defined by the ground procedure seemed to have a mismatch with the one presented in the crew procedure. Ames suggests a new position P3, with the AR tag in the field of view of the nav_cam. Positions P2 and P1 were in the vicinity of the QR codes, being in the field of view of the nav_cam. However, for position P2 Ames suggests a coordinate closer to the QR code, in order to get a successful reading, and for position P1 Ames suggests a coordinate a bit farther, in order to reduce localization loss. Finally, for Start Position, Ames suggests a location farther from the JEM entry Node, in order to provide sufficient room for crew to supervise the activity.

7 LESSONS LEARNED

7.1 GDS USER TRAINING FOR OFF-NOMINAL COMMANDING

The Astrobee Facility Team has to make sure that Astrobee Guest Scientists are familiar with the use of the GDS tool to command and control the Astrobee robots and its subsystems. There were some instances in the activity where additional GDS commanding may have recovered the localization system.

7.2 IMPROVED APK VALIDATION TESTING

Some additional functionality and install/uninstall testing of the user APK may have identified the snapshot issue. Ames should extensively validate the APK configurations and settings of the robot before the on-orbit activity, in addition to the ground validation currently performed.

7.3 ADDITIONAL BACK-ROOM COMMUNICATION BETWEEN AFT AND THE USER

We also learned that a better and faster mode of communication between the Astrobee Facility Team and the Guest Scientist Team during the on-orbit activity needs to be implemented. This may include a chat and/or a teleconference number

7.4 OPS LESSONS LEARNED KIBO-RPC CHECKOUT & FINALS PLANNING

The three main lessons learned from the May 21, 2020 JAXA Robotic Programming Competition Checkout (Kibo-RPC Checkout) are 1) the procedure review process, 2) clarifying the responsible entities for submitting timeline activities, and 3) understanding who is responsible for crew time.

Before submitting the procedures through the ODF process, it is encouraged that ARC be in direct communication with JAXA to help develop the procedure. This worked well for the Kibo-RPC Checkout. However, once the procedure is submitted from JAXA to NASA through the MSFC ODF office for formal approval, the ODF office, Astrobee SpOC, and Astrobee Ops Lead need to be in communication. For the Kibo-RPC Checkout the Astrobee Ops Lead was not included in the formal review process due to misunderstandings. In the end this caused some confusion and delay in the final procedure review process. This has been cleared up, so this issue has been resolved. There was no impact to the Checkout event.

Regarding timeline/PPO Planning, for the Kibo-RPC Checkout there was some confusion who (JAXA or ARC/MSFC) who would submit planning products for what activities. Eventually this was mostly cleared up and is outlined in the table below with a few clarifications to yet be understood (note by the "?"). Also, any supporting documents that are submitted for the crew to reference during the main event (Test/Flight Plan type documents) should be submitted by JAXA since this is a JAXA activity. ARC can help develop and review such products, but JAXA should submit these products.

Last, to be clarified in the future is the question of who does the crew time count for (JAXA/ARC/NASA). Because this is a JAXA sponsored event, it could be assumed that all crew time counts as JAXA time, but this was not clear for all activities after the May 21 Checkout session. For example, we charged eight (8) batteries days before Kibo-RPC Checkout, but it was never clarified who this time counted against. Battery charge time (even for SPHERES) is something that happens when needed, questions are never asked, so maybe this is not important. It was not mandatory to have these batteries charged for the Kibo-RPC Checkout, but having them available if needed was highly recommended by the Astrobee team, and it is highly recommended for the Finals event as well. However, which did raise questions are the Astrobee ON/OFF activities that were needed for the Checkout and will likely be needed for the Finals. It is currently not clear who this time counts again.

The following table illustrates the activities that should be considered for the Kibo-RPC Final Round Operations. The tasks with an asterisk (*) in the far-left column were required for the Kibo-RPC Checkout May 21, 2020 and will also be required for the Finals event. Item "0" the **ASTROBEE-OBT-REV** represents the Crew OBT that was not required for the Checkout activity but could be required for the Finals event if crew are first time Astrobee users.

- Listed for items 8 and 13 are activities representing the finals “ROBO-PRO- RUN1” event. The equivalent Checkout activity (ASTROBEE-LOCAL-OPS) was 80 minutes rather than the 75 minutes listed below required for the ROBO-PRO- RUN1. - The battery charge activities totaling 30 minutes account for eight (8) batteries being charged. Two batteries are charged at a time.			
	Activity	Duration (hrs:min)	Timeline Submitting/Supporting Responsibility
	Crewed Activities		
0	ASTROBEE-OBT-REV	00:30	Required for crew/first time Astrobee users
1*	ASTROBEE-BATT-CHARGE	00:10	JAXA(Crew Time charge)/NASA(Crew support)
2*	ASTROBEE-BATT-SWAP	00:05 x 3	JAXA(Crew Time charge)/NASA(Crew support)
3*	ASTROBEE-BATT-STOW	00:05	JAXA(Crew Time charge)/NASA(Crew support)
4*	CARGO-CTB-XFER	00:15	NASA
5*	Astrobee Activation	00:05	NASA/ARC (?)
6	00:05	00:25	JAXA(Crew Time charge)/NASA(Crew support)
7	Set up for Kibo-RPC Rehearsal	00:55	JAXA(Crew Time charge)/NASA(Crew support)
8*	ROBO-PRO- RUN1	1:15	JAXA(Crew Time charge)/NASA(Crew support)
9	ROBO-PRO RH-CLOSEOU	00:15	JAXA(Crew Time charge)/NASA(Crew support)
10*	ASTROBEE-OFF	00:05	NASA/ARC (?)
	Non-Crewed Activities/Resources	1:15	
11*	ASTROBEE-PWR-TRK	continuous	ARC

12*	ASTROBEE-PD HIGH-CMD	04:00	ARC (commanding before Finals event)
13*	ASTROBEE-PD LOW-CMD	1:15	ARC (commanding during Finals event)
14*	ASTROBEE-PD HIGH-CMD	24:00	ARC (post event data download)

8 FORWARD STEPS

The actions moving forward for the outstanding issues from this activity are listed in this section.

8.1 NAV-CAM DISTRIBUTION:

The AFT is looking for a solution such that we can forward Nav-Cam snap-shots to SSIPC within 30 minutes of being taken. Our tasks involve testing JAXA's APK image capture feature and coordinate with Building 8 for imagery review.

8.2 SCI-CAM DISTRIBUTION:

There is interest in streaming Astrobee Sci-cam to Building 8's decoder while being observed by SSIPC. Currently, the AFT is testing the connectivity between the HOSC and Building 8.

8.3 APK RECORDING:

JAXA's APK accesses the nav_cam to take pictures of the AR/QR codes and target. In order to do so, the APK is required to create a hierarchy of folders to comply with the Guest Scientists APK guidelines. Although JAXA's APK seems to be doing it properly, during the activity this was unsuccessful. The AFT is currently reviewing and testing the issue to ensure this functions as expected next time.

8.4 IMPROVED MAP:

An improved map based of the images gathered during the activity has been created. It is titled "merged_20190523_0614_0712_0724_0828_1101_20200513_0521.brisk.hist.map"

8.5 RAW DATA DELIVERY:

There were 125 rosbags created during the activity, each of them of approximately 16seconds or 100MB. They were already sent to JAXA via NASA Large File Transfer (LFT).

8.6 GDS PROFILE BUTTONS NOT WORKING:

In GDS, the set profile button and start recording buttons were not enabled. This software bug has been identified and it is currently under review.

8.7 AR/QR TAG READABILITY DISTANCE:

The AFT has suggested to revise the range of distances at which JAXA's APK is able to correctly read and decode the AR/QR codes. JAXA has requested AFT runs these tests at the Granite Lab at ARC. The permits required to access the facilities due to the COVID-19 pandemic are being requested.

8.8 IMPROVED GDS TRAINING DOCUMENTATION

The AFT will draft a training document that described GDS commanding that can address off-nominal situations.

9 ASTROBEE FACILITIES TEAM

Andres Mora, Roberto Carlino, Ruben Garcia, Aric Katterhagen, Simeon Kanis, Jonathan Barlow, Ernie Smith, Jose Cortez, Don Soloway, Sonny Hwang, and Jose Benavides.

10REVISION HISTORY

Date	Version	Notes	Released by
06/05/2020	Version 1	N/A	Astrobee Facility Team, internal review

6/08/2020	Version 2	Astrobee report template format	
06/08/2020	Version 2.1	Modified section 3, added section 8.	
6/12/2020	Version 2.2	Added input from Andres and Ruben	
6/15/2020	Version 2.3	Added input from Aric	Jose V. Benavides
