UNIVERSAL ROBOTS

Calibration Guide

Original instructions (en)

PolyScope 5/X

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1. Preface

About this document

This document describes how to set up and perform Dual Robot Calibration on identical robots from Universal Robots. During Dual Robot Calibration, two robot arms are connected and perform coordinated movements to different positions to calibrate the robot kinematics.
This document also describes how to use key waypoints to correct programs automatically.

Terminology and abbreviations

In this document, the following terms and corresponding abbreviations are used:

- Corresponding Tool Position (CTP)
- Tool Center Point (TCP)

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2. Liability and Intended Use

2.1. Limitation of Liability

Description

Any information provided in this manual must not be construed as a warranty, by UR, that the industrial robot will not cause injury or damage, even if the industrial robot complies with all safety instructions and information for use.

2.2. Intended Use

Description



NOTICE

Universal Robots takes no responsibility and assumes no liability for unapproved uses of its robots or uses for which its robots are not intended and Universal Robots will provide no support for unintended uses.



READ MANUAL

Failure to use the robot in accordance with the intended use can result in hazardous situations.

- Read and follow the recommendations for intended use and the specifications provided in the User Manual.

Universal Robots robots are intended for industrial use, to handle tools/end effectors and fixtures, or to process or transfer components or products.

All UR robots are equipped with safety functions, which are purposely designed to enable collaborative applications, where the robot application operates together with a human. The safety function settings must be set to the appropriate values as determined by the robot application risk assessment.

The robot and Control Box are intended for inside use where, normally, only non-conductive pollution occurs i.e. Pollution degree 2 environments.

Collaborative applications, that rely upon power and force limiting safety functions, are only intended for applications, where the residual risks of the risk assessment are only low risk(s) of injury to people. The robot application risk assessment includes assessing the following:

- robot
- tool/end effector
- work piece
- obstacles
- associated equipment and machinery
- nearby machinery and operation
- and tasks both associated with the robot application and nearby equipment.

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WARNING

Using UR robots or UR products outside of the intended uses can result in injuries, death and/or property damage. Do not use the UR robot or products for any of the below unintended uses and applications:

- Medical use, i.e. uses relating to disease, injury or disability in humans including the following purposes:
  - Rehabilitation
  - Assessment
  - Compensation or alleviation
  - Diagnostic
  - Treatment
  - Surgical
  - Healthcare
  - Prosthetics and other aids for the physically impaired
  - Any use in proximity to patient/s
- Handling, lifting, or transporting people
- Any application requiring compliance with specific hygienic and/or sanitation standards, such as proximity or direct contact with food, beverage, pharmaceutical, and /or cosmetic products.
  - UR joint grease leaks, and can also be released as vapor into the air.
  - UR joint grease is not “food grade”.
  - UR robots do not meet any food, National Sanitization Foundation (NSF), Food and Drug Administration (FDA), or hygienic design standards.

  Hygienic standards, for example ISO 14159 and EN 1672-2, require a hygiene risk assessment be conducted.
- Any use, or any application, deviating from the intended use, specifications, and certifications of UR robots or UR products.
- Misuse is prohibited as the result could be death, personal injury, and /or property damage

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WARNING

Failure to consider the added risks due to the reach, payloads, operating torques and speeds associated with robot application, can result in injury or death.

- Your application risk assessment shall include the risks associated with the application's reach, motion, payload and speed of the robot, end effector and workpiece.

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3. Your Robot – Preparation

Description

This section describes how to mount two UR robot arms to a Calibration Horse and how to prepare them for dual calibration.

Calibration kits

You can order two different calibration kits:

- Purchase number: 185500
- Purchase number: 200977

The calibration kit (185500) includes a smaller calibration horse and can be used with the following robots:
All e-Series robots.

The calibration kit (200977) includes a larger calibration horse and can be used with the following robots:
UR10e, UR16e, and UR Series robots (UR8L, UR15, UR20, and UR30).

Calibration Kits Contain

- Calibration Horse with alignment pins
- Calibration Tool Connector with alignment pins
- Screws
- Go / NoGo tools
- Manual for dual arm calibration

Required items for Calibration

You need the following items to set up the robots for dual calibration:

- Two Universal Robots of the same type and software version.
- A Calibration Horse.
- A 0.5 m stand for the smaller Calibration Horse.
- A 0.81 m stand for the larger Calibration Horse.
- A network cable.
- A Dual Robot Calibration kit.



NOTICE

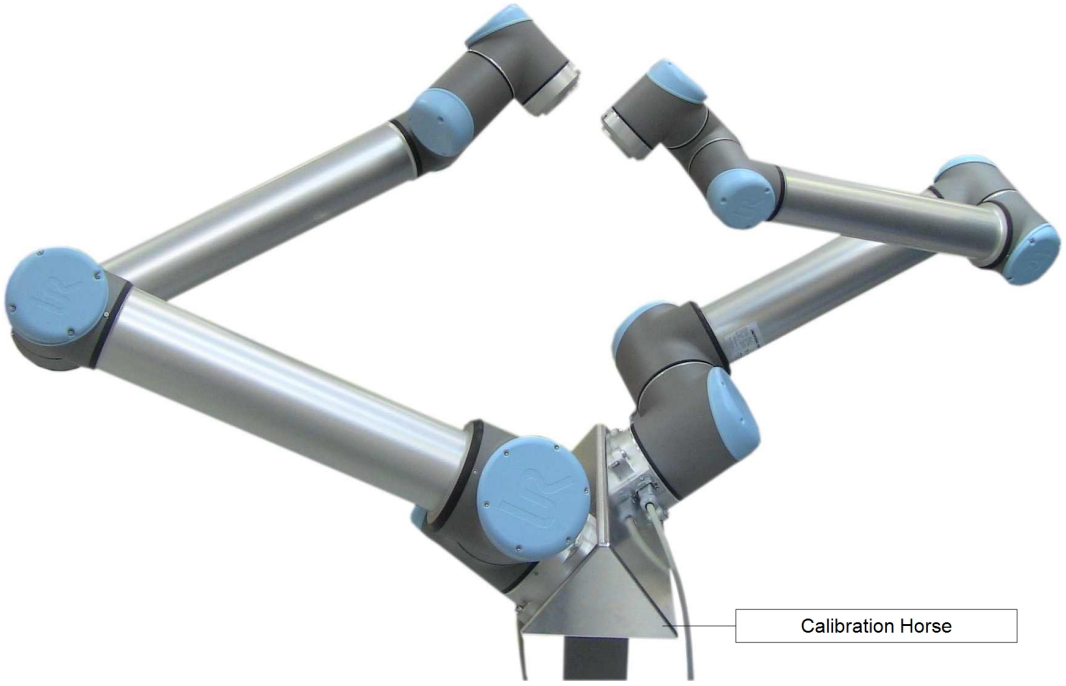
Robot software versions 5.8 and later save calibration results in the robot arm. Robots using older software versions save calibration results to the Control Box, so a calibrated robot arm and Control Box must be used together.

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3.1. The Calibration Horse

Description

The Calibration Horse connects one robot arm to another via the base, as illustrated in the image below. Using the Calibration Horse allows you to attach the two tool flanges. The result is a closed robot arm circuit that makes coordinated movements while performing a number of measurements.



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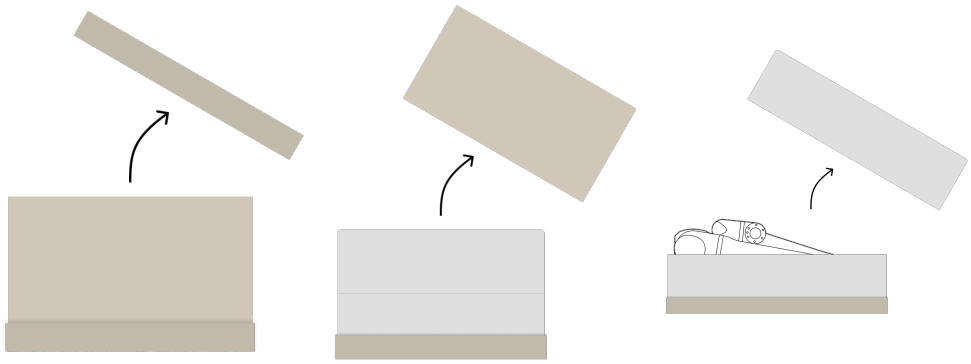
3.2. Lifting and Handling

Description

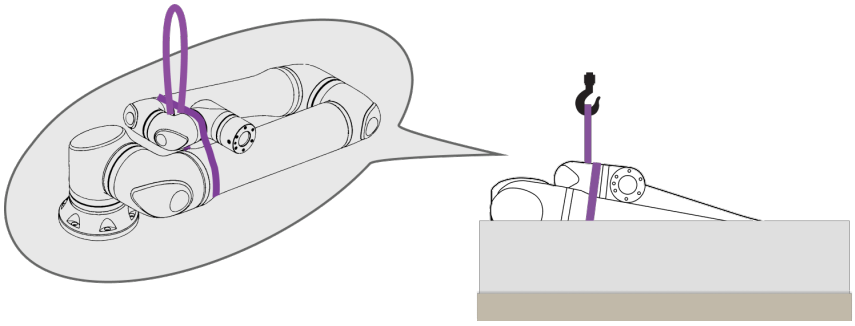
The robot arms come in different sizes and weights, so it is important to use the appropriate lifting and handling techniques for each model. Here you can find information on how to safely lift and handle the robot.

Proper lifting and handling

1. Transport the robot to the site using a forklift.
2. Open the box as illustrated.

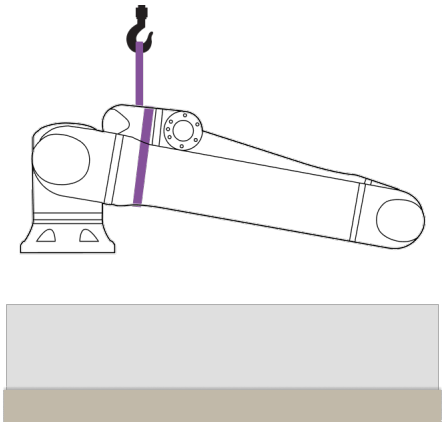


3. Securely strap the robot arm with the lifting sling.



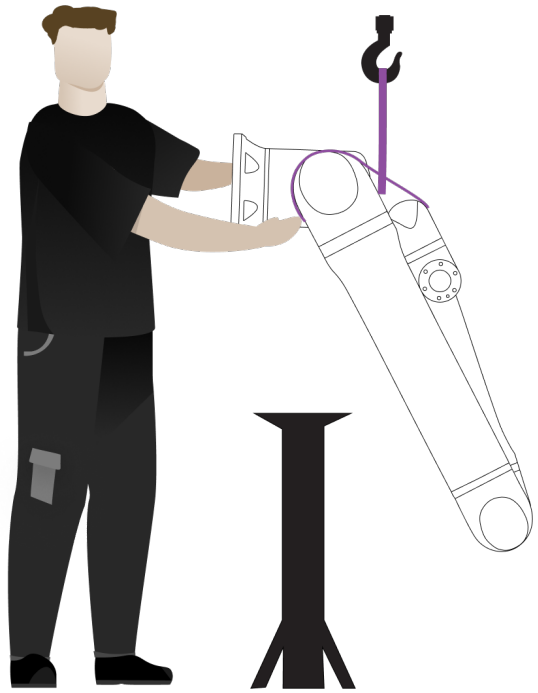
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4. Lift the robot arm out of the box using the strap and hook.



CAUTION
Use a lifting equipment when lifting heavier robot arm.

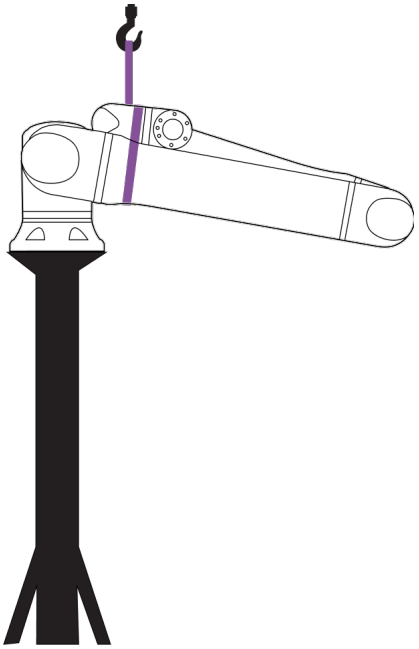
5. While the robot is lifted, support it to rotate and hang as illustrated.



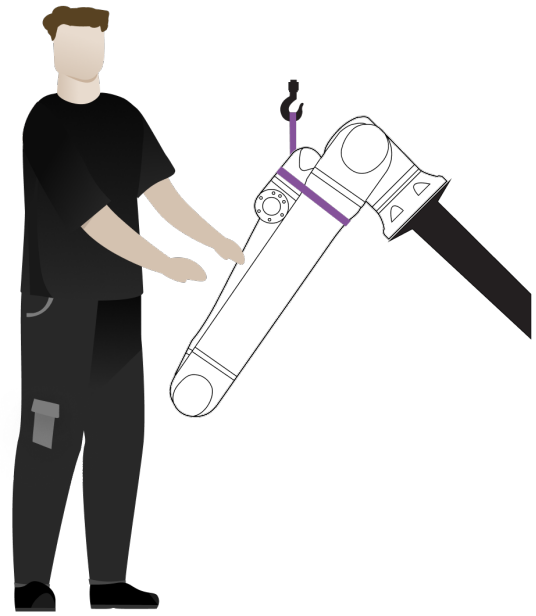
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Mounting the Robot Arm

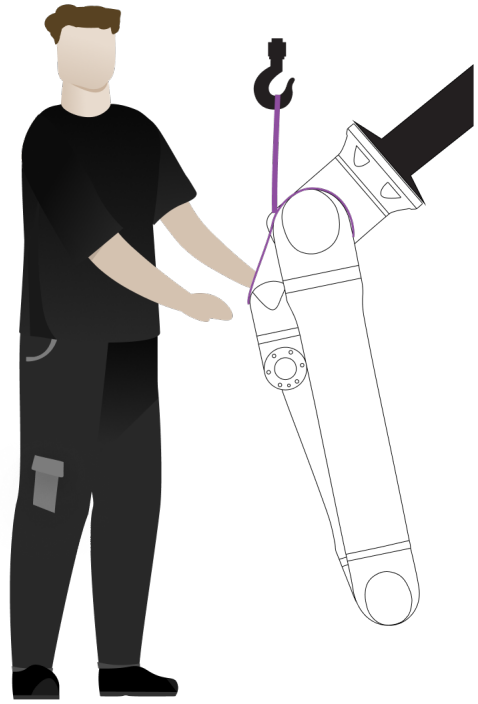
The robot arm can be mounted sideways, upside-down or in an angle (±45°).



Sideways mounting



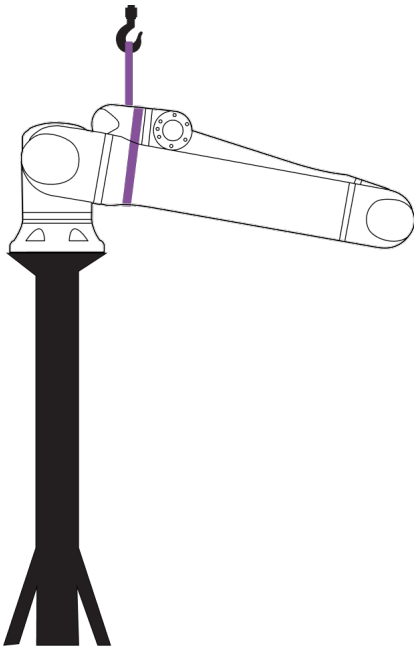
Angular mounting (±45°)



Upside-down mounting

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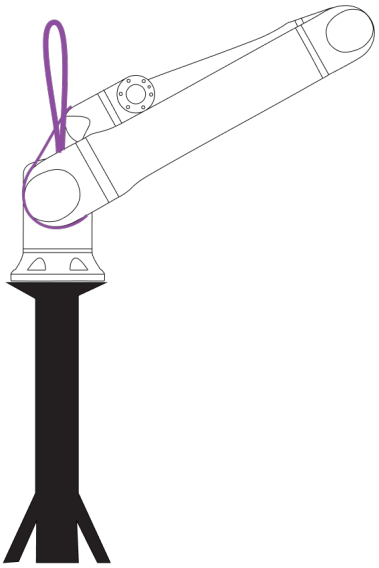
1. Mount the robot arm. Tighten the screws and apply torque as specified in the relevant user manual.



2. Remove the strap.
3. Power on the robot and reposition shoulder joint as intended.

> **NOTICE**
> For sideways mounting, no need to power on the robot.

4. Re-place the strap.



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3.3. Preparations PolyScope 5

Delete this text and replace it with your own content.

3.3.1. How to Mount Robot Arms to the Calibration Horse

Description

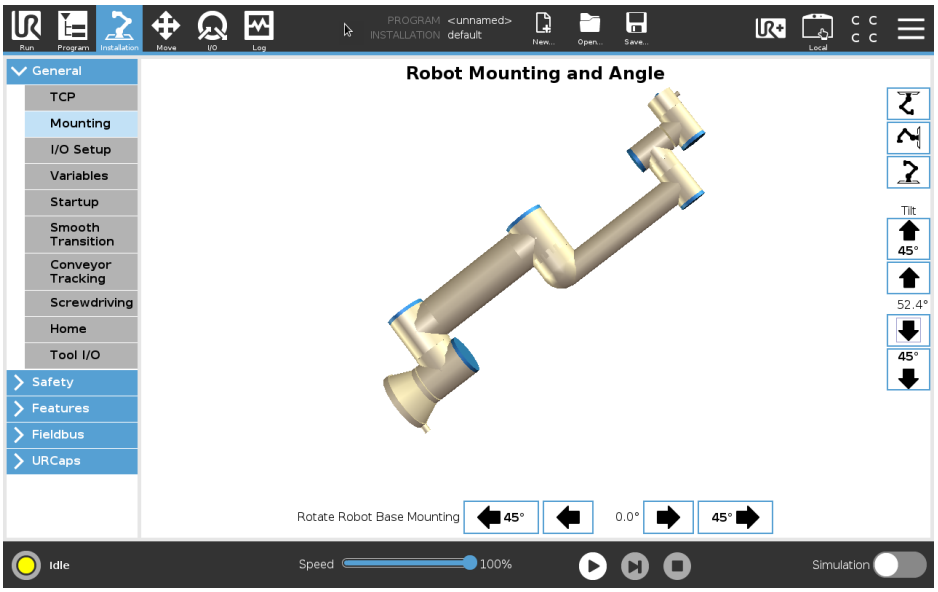
When you mount the arms for calibration, keep the following in mind:

- Mount the robots on the calibration horse.
- Refer to the user manual for the correct torque for mounting the robots.
- Mount the robots at approximately 52.4°.
- Use a custom installation before activating the robots.

To mount each robot arm in SW

1. Use the screws to mount each robot to the Calibration Horse.
2. Turn on the Control Box, then leave the robot arm in the Idle state (Yellow indicator).

   The screen below shows the robot arm in the Idle state.



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To configure the mounting software

1. On PolyScope, in the Header, tap **Installation**.
2. Under **General**, select **Mounting**.
3. Use the arrow buttons to set the Tilt and the Rotate Robot Base Mounting values according to the table below.

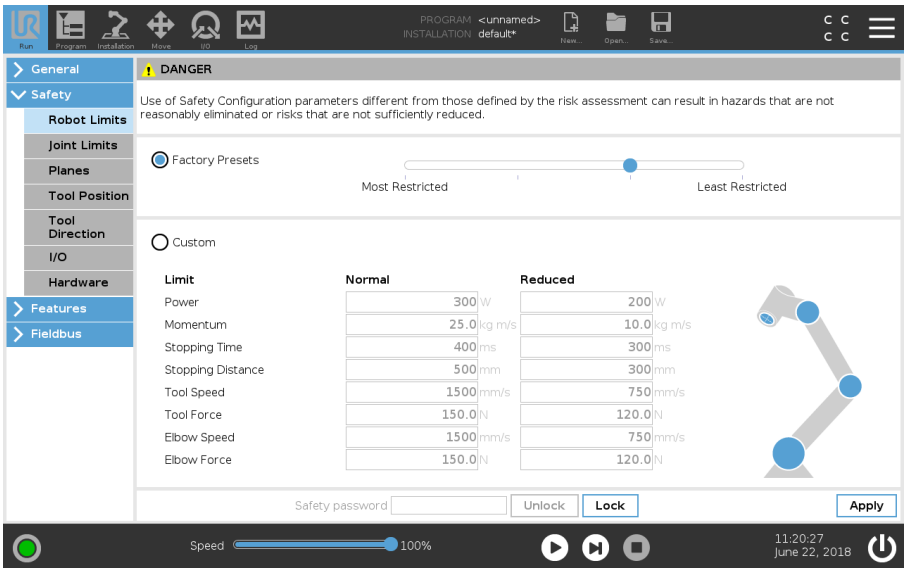
Use the following numbers for your robot:

Robot size	Tilt	Rotate Robot Base Mounting
UR3e	52.4°	270°
UR5e	52.4°	90°
UR10e	52.4°	90°
UR16e	52.4°	90°
UR8 Long	52.4°	90°
UR15	52.4°	90°
UR20	52.4°	90°
UR30	52.4°	90°

3.3.2. How To Prepare Robot Safety Settings

Description

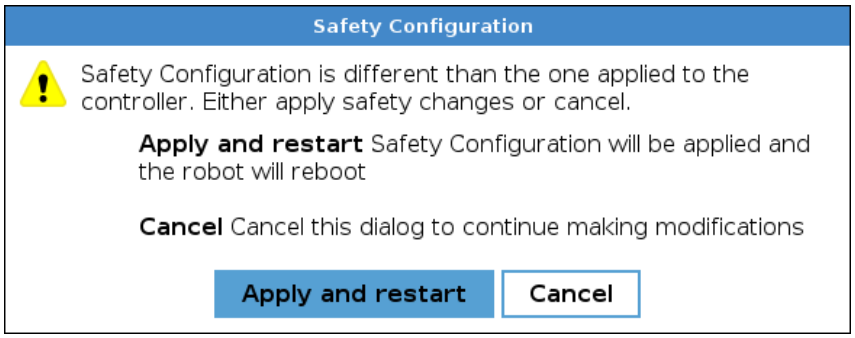
Configure the robot safety settings in PolyScope, as shown in the screenshot below.



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To configure the robot safety settings

1. Tap **Safety** and select **Robot Limits**.
2. Enter the password: `lightbot` and tap **Unlock**.
3. Tap **Apply** to unlock the **Safety Configuration**.
4. When the **Safety Configuration** dialog box appears, select **Apply and restart**.



3.3.3. How to prepare the robot network connection

Description

Select a method based on your connection type.

- Method 1 Manual: When the robots are already connected to a local area network.
- Method 2 Master/Slave: For robots connected directly with a single network cable.

Method 1: Manual Connection

Description

Use this method when the robots are already connected to a local area network.

NOTICE

Connecting the robots to a Local Area Network (LAN) can interfere with other devices sharing these IP addresses.

- Do not connect the robot to a LAN. Connect the two robots directly to each other.

NOTICE

Connection between the two networks can break down, causing the calibration screen to change.

- Follow the on-screen instructions to resolve the network conflict and restart the calibration process.

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Connecting the Manual network (Method 1)

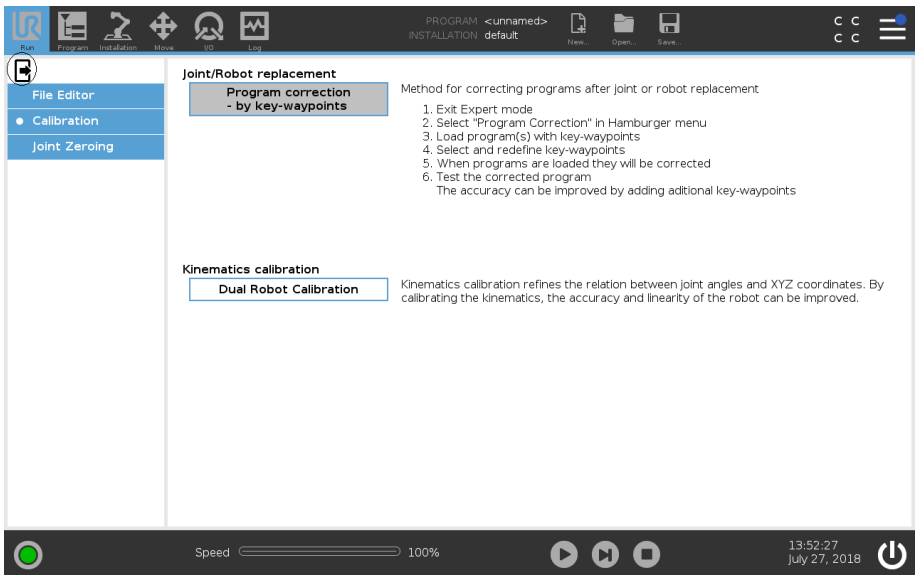
Define the network connection types as listed in the following table:

Network connection type	Definition
Master	The main robot in the calibration process. Uses a single cable.
Slave	The subordinate robot in the calibration process.
Manual	You select a Master robot and a Slave robot using a user-supplied IP address.

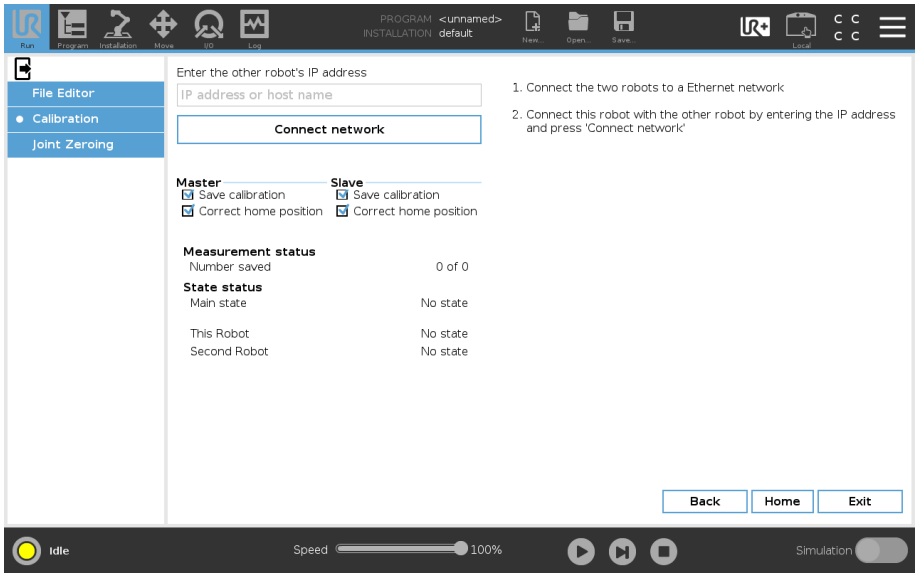
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To connect the Manual network

1. On PolyScope, in the Header, press and hold **Run** to access Expert Mode.
2. Enter the password and tap **OK**.
3. Under **Kinematics calibration**, select **Dual Robot Calibration**.



4. Choose the Master robot and the Slave robot:
   a. On the Master robot, tap **Master**.
   b. On the Slave robot, tap **Slave**.
5. On the Master robot, tap the IP address field and enter the IP address or host name of the Slave robot.
6. Tap **Connect network** to establish the network connection.



Method 2: Master/Slave Connection

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Description

Use this method only for robots connected directly with a single network cable.

NOTICE

The network communication between the Master robot and the Slave robot can break down, causing the calibration to stop.

- Follow the on-screen prompt to resume the process.

NOTICE

The Master / Slave network connection uses self-assigned IP addresses, which can interfere with local area network devices.

Connecting the Master / Slave network (Method 2)

Define the network connection types as listed in the following table:

Network connection type	IP Address
Master	10.17.17.18
Slave	10.17.17.19

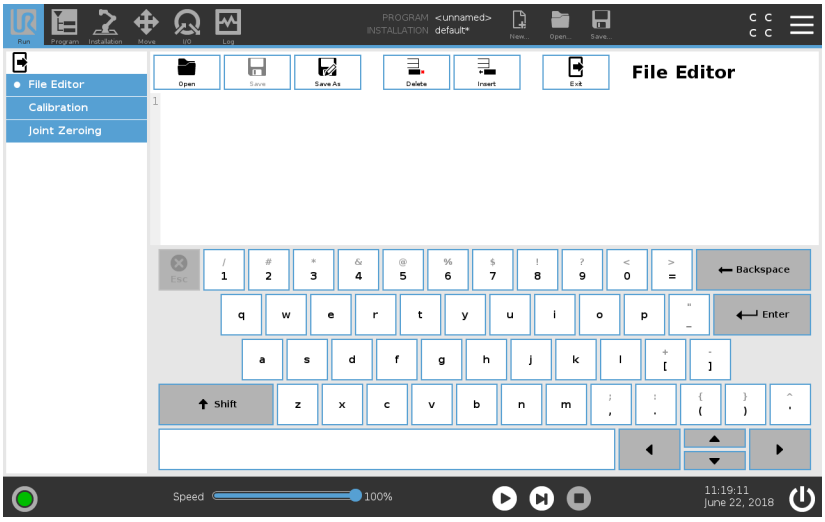
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To connect the Master / Slave network

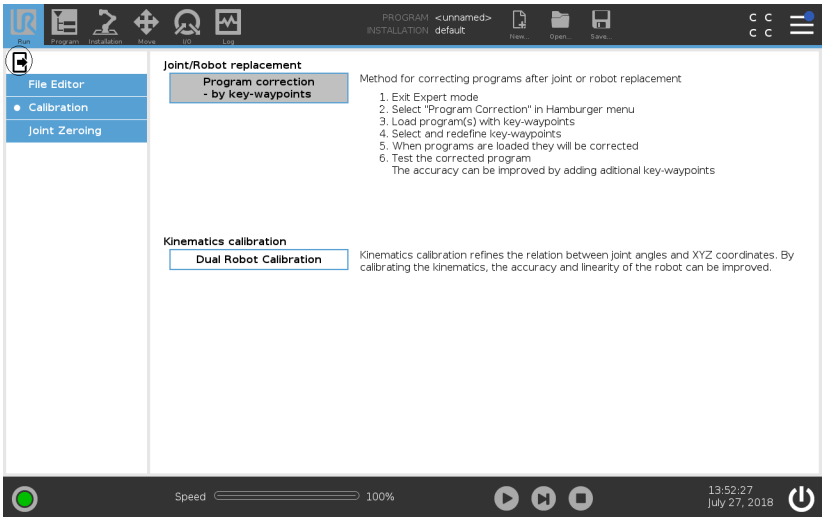
NOTICE

Verify that all installed services are enabled, such as Modbus. If they are disabled, the connection will fail.

1. Use a network cable to connect the Ethernet ports of the two robot Control Boxes.
2. On PolyScope, in the Header, press and hold **Run** to access Expert Mode.
3. Enter the password: `lightbot` and tap **OK**.

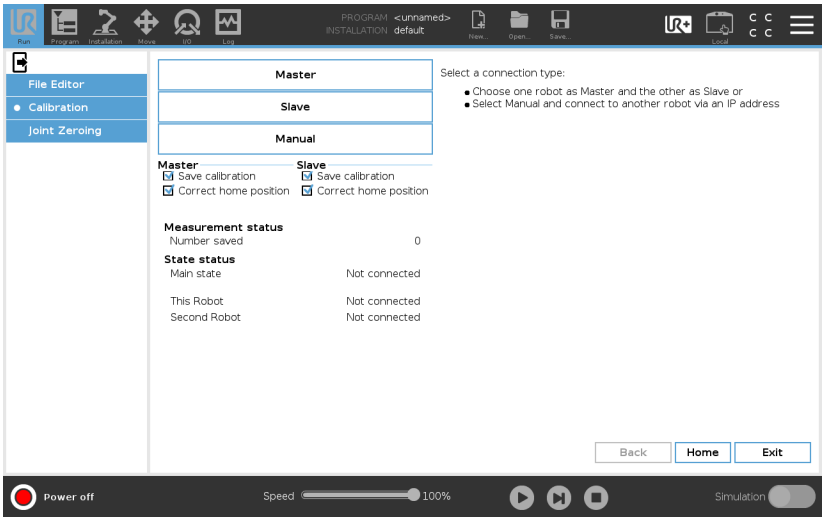


4. Under **Kinematics calibration**, select **Dual Robot Calibration**.

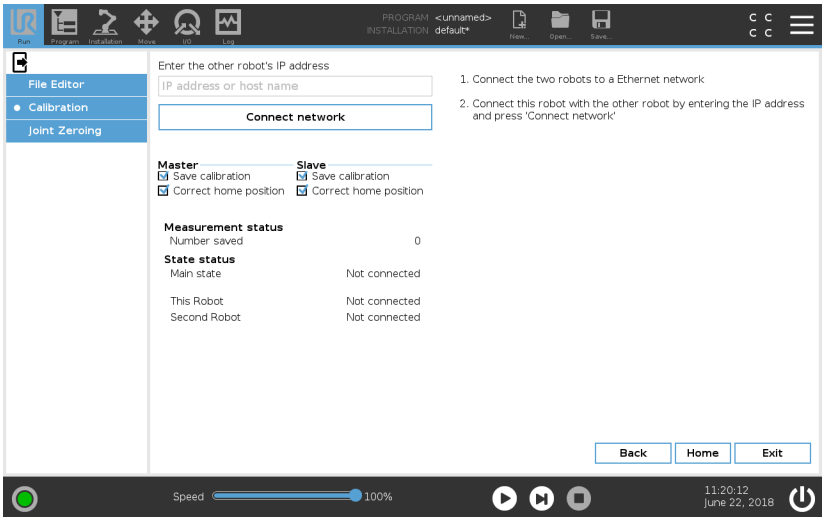


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5. Choose the Master robot and the Slave robot:
   a. On the Master robot, tap **Master**.
   b. On the Slave robot, tap **Slave**.



6. On the Master robot, tap **Connect network** to establish the network connection.



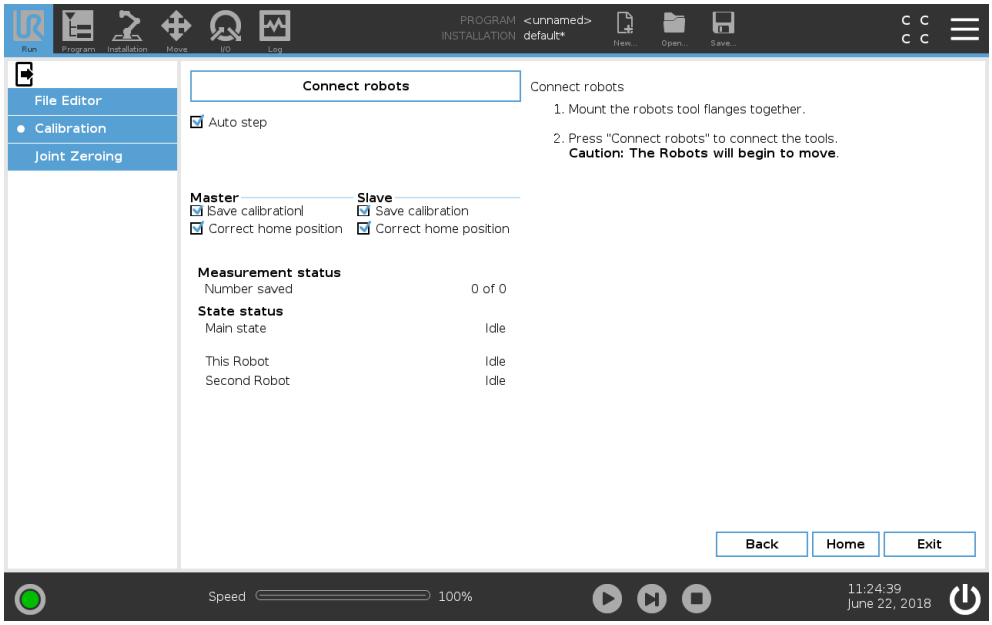
3.3.4. How to Attach the Calibration Connector

Description The Calibration Connector attaches the two robot arms via the tool flanges.

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To attach the Calibration Connector

1. Verify both robot arms are correctly attached to the Calibration Horse.
2. For each robot arm: On PolyScope, tap **Move** and tap **Home** to return each robot arm to the home position.
3. Tap **Proceed**.
4. The robot arms will move into a parallel position for connecting the Calibration Connector.
5. Attach the Calibration Connector to the designated Master robot.



As both robots move to bring the tool flanges close to each other, the Slave robot enters Freedrive.

6. Align the Slave robot's tool flange with the Calibration Connector.
7. Use the four screws and washers to attach the Slave robot's tool flange to the Calibration Connector.

The following illustrations show the Calibration Connector in use



Calibration Connector attached to the Master robot's tool flange (step 2).



Calibration Connector attached to the Master robot's tool flange and the Slave robot's tool flange (step 5).

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3.4. Preparations for Calibration in PolyScope X

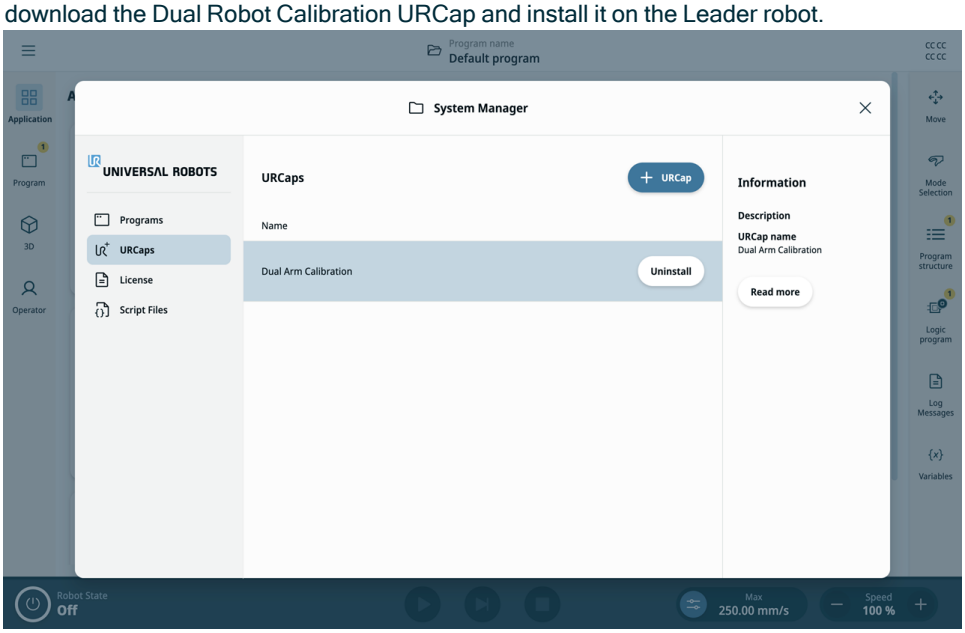
Description

What's in this chapter

- Mounting the Robot Arms to the Calibration Horse
- Preparing the Robot Safety Settings
- Attaching the Calibration Connector

Installing the dual arm calibration URCapX

To run dual robot calibration on PolyScope X, you or the service technician should request and download the Dual Robot Calibration URCap and install it on the Leader robot.



3.4.1. Mounting the Robot Arms to the Calibration Horse

Description

When mounting the arms for calibration, keep the following in mind:

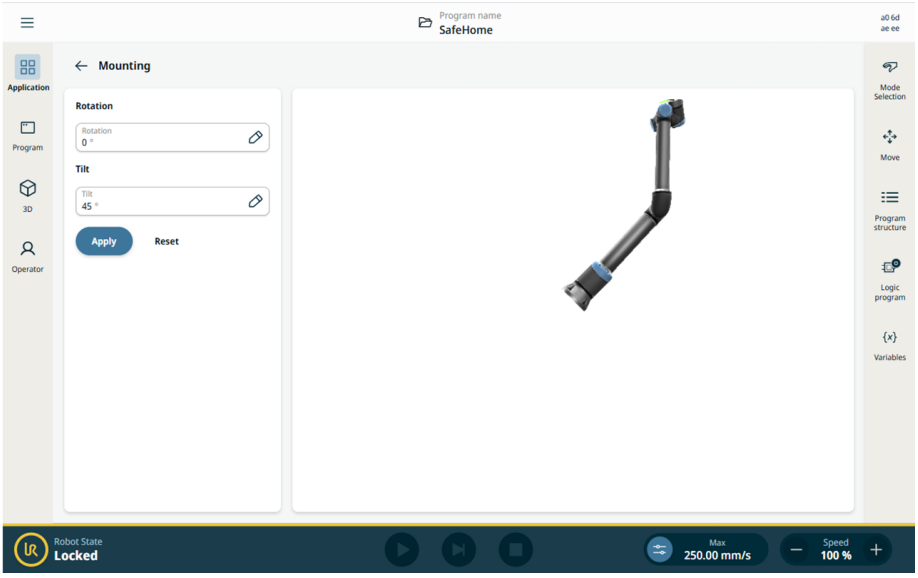
- Mount the robots on the calibration horse.
- Refer to the user manual for the correct torque for mounting the robots.
- Set the mounting angle in PolyScope at approximately 52.4°.
- Use a new application with default safety settings before activating the robots.

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To mount each robot arm in SW

1. Use the screws to mount each robot to the Calibration Horse.
2. Turn on the control box, then leave the robot arm in **Locked** state (yellow indicator).

   The screen below shows the robot arm in **Locked** state.



To configure the mounting software

1. On PolyScope X, in the **Application** tab, tap **Mounting**.
2. In the two fields, enter the **Tilt** and **Rotate Robot Base Mounting** values according to the table below.

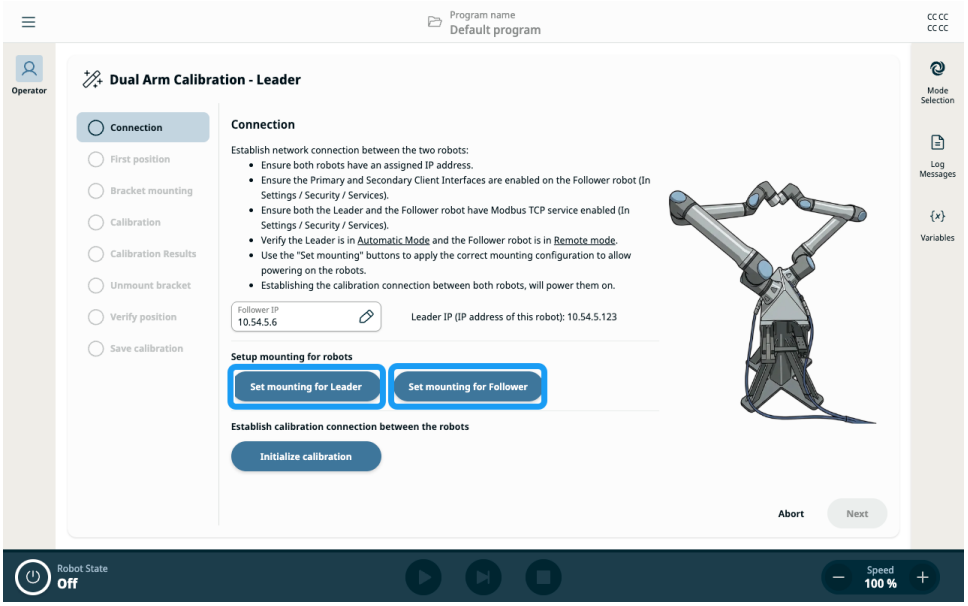
   Use the following values for your robot:

Robot size	Tilt	Rotate Robot Base Mounting
UR3e	52.4°	270°
UR5e	52.4°	90°
UR10e	52.4°	90°
UR16e	52.4°	90°
UR8 Long	52.4°	90°
UR15	52.4°	90°
UR20	52.4°	90°
UR30	52.4°	90°

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Set Mounting during calibration

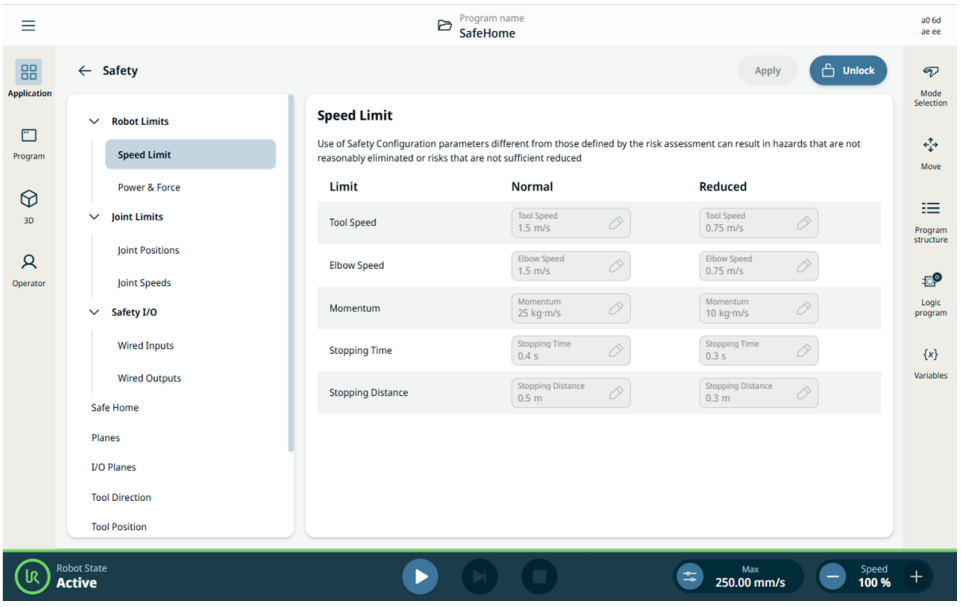
You can set the mounting from the calibration flow. The mounting parameters for both the Leader and Follower robots can also be configured by tapping the two **Set Mounting** buttons in the 6.2 Connection and Initialization on page 38 step of the calibration.



3.4.2. Preparing the Robot Safety Settings

Description

Configure the robot safety settings in PolyScope X as shown in the image below, or verify the robot uses the default safety settings.



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To configure the robot safety settings

1. Tap the **Application** tab, then **Safety**.
2. Go to **Speed Limit** under **Robot Limits**.
3. Tap **Unlock** and enter the password: `ursafe`.
4. Enter the safety configuration parameters. Tap **Apply**.
5. When the **Safety Configuration** dialog box appears, select **Apply and restart**.



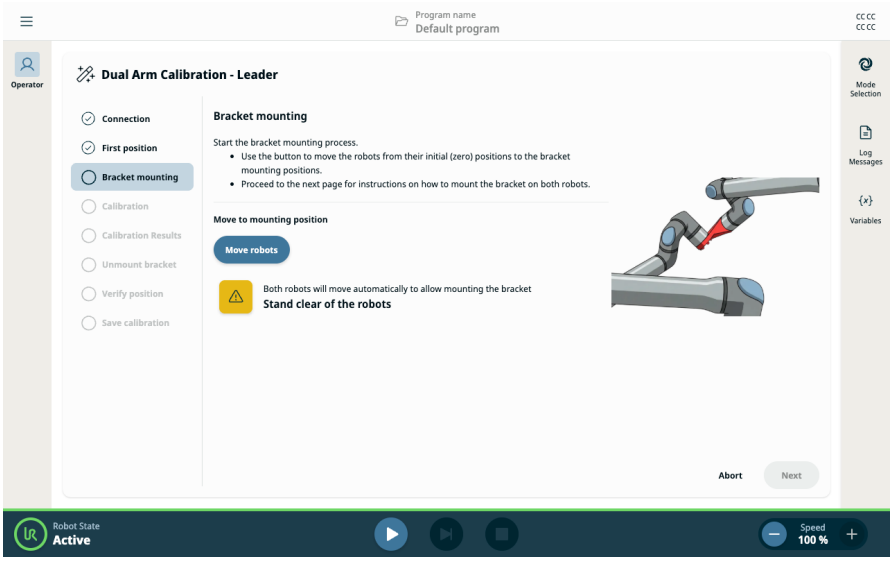
3.4.3. Attaching the Calibration Connector

Description

The Calibration Connector attaches the two robot arms via the tool flanges.

To attach the Calibration Connector

1. Verify both robot arms are correctly attached to the Calibration Horse.
2. Follow the instructions on the **Operator Screen** to reach the **Bracket mounting** step.



3. Tap **Move Robots**.

   The robot arms will move into a parallel position for connecting the Calibration Connector.
4. Attach the Calibration Connector to the Leader robot.

   As both robots move to bring the tool flanges close to each other, the Follower robot enters **Freedrive**.
5. Align the Follower robot's tool flange with the Calibration Connector.
6. Use the four screws and washers to attach the Follower robot's tool flange to the Calibration Connector.

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The following illustrations show the Calibration Connector in use



Calibration Connector attached to the Leader robot's tool flange (step 2).



Calibration Connector attached to the Leader robot's tool flange and the Follower robot's tool flange (step 5).

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4. Safety

Safety See the different types of safety messages and the specific safety settings for robot calibration.

4.1. Safety Message Types

Description Safety messages are used to emphasize important information. Read all the messages to help ensure safety and to prevent injury to personnel and product damage.



WARNING
Indicates a hazardous situation that, if not avoided, can result in death or serious injury.



WARNING: ELECTRICITY
Indicates a hazardous electrical situation that, if not avoided, can result in death or serious injury.



WARNING: HOT SURFACE
Indicates a hazardous hot surface where injury can result from contact and non-contact proximity.



CAUTION
Indicates a hazardous situation that, if not avoided, can result in injury.



GROUND
Indicates grounding.



PROTECTIVE GROUND
Indicates protective grounding.



NOTICE
Indicates the risk of damage to equipment and/or information to be noted.



READ MANUAL
Indicates more detailed information that should be consulted in the manual.

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4.2. General Safety Precautions

Description

For more information on safety, refer to the Safety section in the robot User Manual.



WARNING: ELECTRICITY

Installing or maintaining equipment connected to a power source can lead to electric shock.

- Disconnect the equipment from the power source before installation or maintenance.



WARNING

Incorrect connection of the power source or ground wires can result in equipment damage or personnel injury.

Damage caused by invalid power source connection is not covered by warranty.

Before starting the operation:

- Ensure that the power source wiring is correct.
- Ensure that the grounding is correct.



WARNING

Failure to verify and validate safeguarding and functionality can result in death or serious injury.

- Ensure all risk reduction works as intended and achieves the needed risk reduction.



WARNING

Failure to perform a risk assessment before installation and operation can result in personnel injury or equipment damage.

- Perform a risk assessment before installation and operation.
- Read the UR User Manual and UR Service Manual.



NOTICE

This product includes the Universal Robots e-Series robot. General safety considerations that are valid for the Universal Robots e-Series robot are also valid for this product.

- For more information on safety, refer to the Safety section in the Universal Robots e-Series robot User Manual.

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4.3. Dual Calibration Safety Precautions

Description

This section contains safety precautions specific to Dual Robot Calibration and Program Correction.



WARNING

Obstructing the robots during the dual calibration process can result in equipment damage or personnel injury.

- Stay clear of the robots once the calibration starts.



NOTICE

Incorrect dual calibration can cause the robot to become inaccurate.
Before saving the results:

- Pay attention to the generated statistics of the dual calibration.

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5. Dual Robot Calibration for PolyScope 5: Application

Description

Dual Robot Calibration uses two active robots of the same size working together:

- **Leader** – The robot with the Dual Robot Calibration **URCapX** installed. It controls the entire calibration flow.
- **Follower** – The second robot. It does *not* need the URCapX installed.

5.1. How To Calibrate The Robots

Description

Dual calibration is performed automatically, so you only need to start the process.

Do not disable the **Save Calibration** and **Correct Home Position** options.

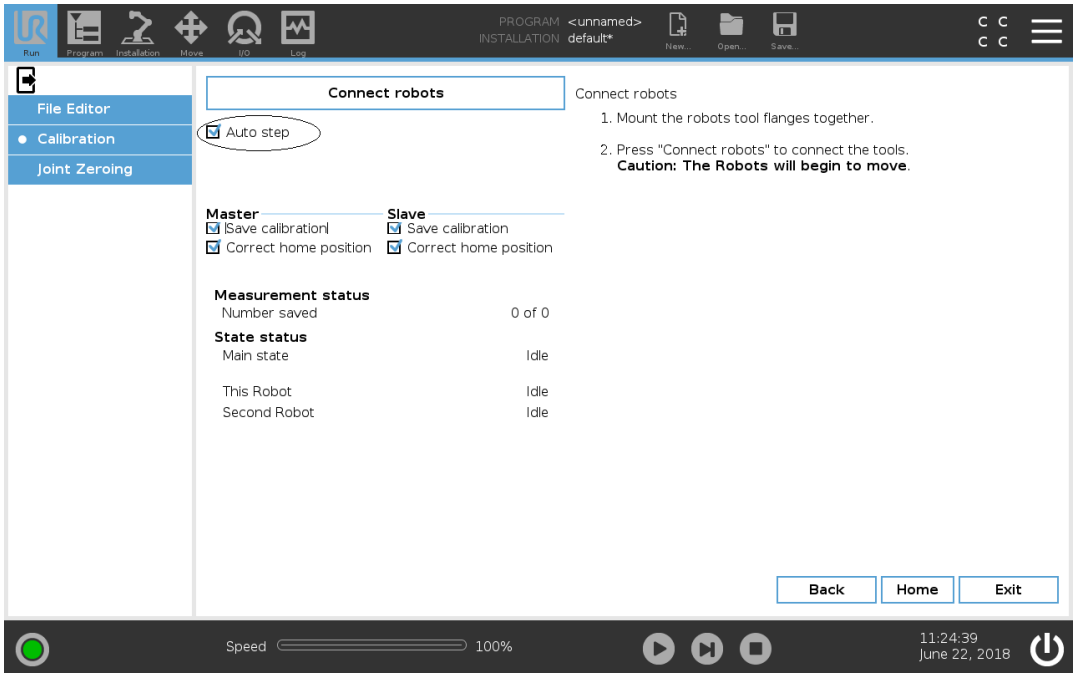
- **Save Calibration**: The calculated kinematic calibration is applied and saved on the robot.
- **Correct Home Position**: Estimates and sets the home position using the calibration (defines new joint offset angles).

These options are used by Universal Robots Service Engineers in specific scenarios.

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To start the calibration

1. Ensure the Calibration Connector securely attaches to both tool flanges.
2. If operator intervention is required during the calibration, you can disable the **Auto step** checkbox.
   a. The **Auto step** setting only applies to non-3PE TP.
   b. If your robot is connected to a 3PE TP, you cannot disable **Auto step**.
3. Tap **Proceed** and stand clear of the robots, as they start moving around.



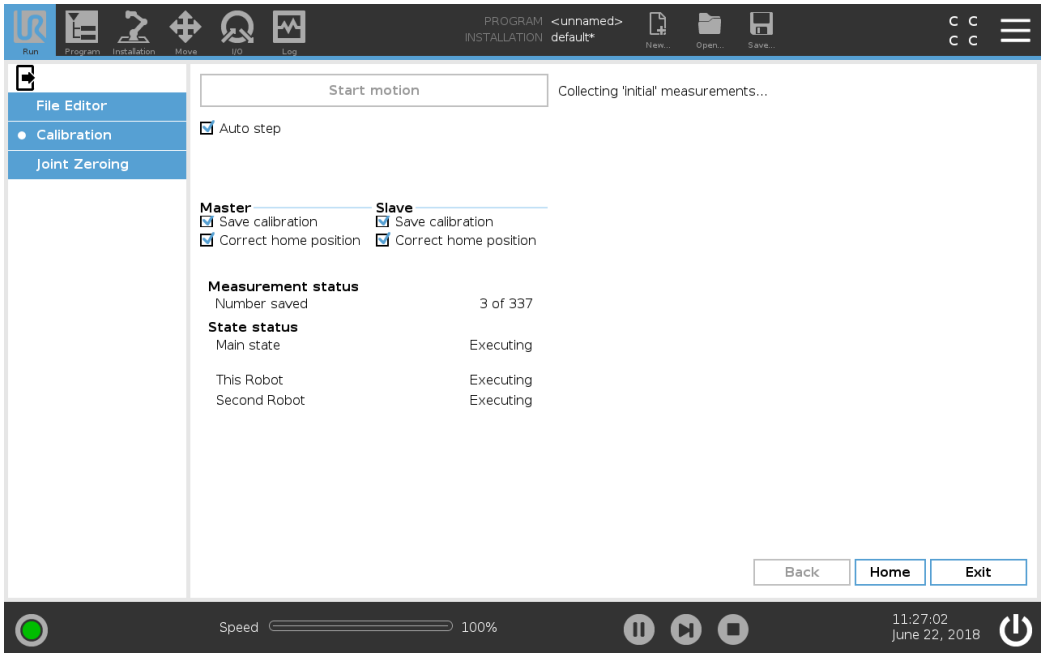
5.2. Measuring Positions and Calibration Statistics

Description

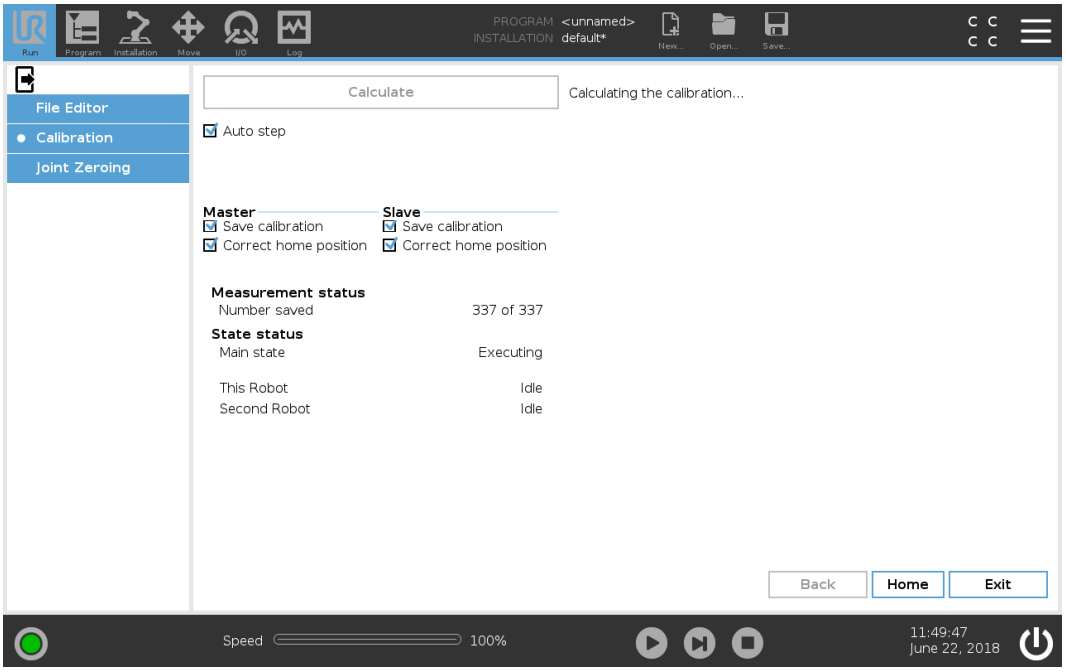
Measurements are collected during dual calibration as the robots continue to move around. A preliminary calibration is calculated, then replaced by the final calibration calculation.

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Collecting the measurements



Calculating the calibration



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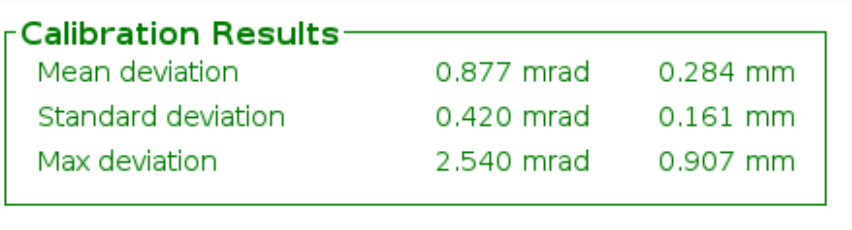
Calibration Results

At the end of the dual calibration, a **Calibration Results** box provides a report on the success of the calibration. If the **Calibration Results** box appears as green text, the calibration was successful. If the **Calibration Results** box appears as red text, the calibration was unsuccessful, and the procedure continues.

NOTICE

This is an example.

The **Calibration Results** provide statistics in millimeters (mm) and milliradians (mrad) that refer to the RMS deviation in Cartesian space, as follows:



- **Mean deviation**: The average deviation in millimeters and milliradians between the positions measured by the Leader and Follower robots.
- **Standard deviation**: The standard deviation calculated from the measurements above.
- **Max deviation**: The maximum measured deviation.

5.3. Validating Calibrated Robots

Description

This procedure has the following success criteria:

- Both robot tool flanges are disconnected from the Calibration Connector and completely free of screws, alignment pins, and similar hardware.
- The robot moves to home position.
- The robot moves to the *Go / NoGo* position.
- *Go / NoGo* is correct and validated with the tool.

NOTICE

Tapping **Proceed** before removing all screws from the Calibration Tool Connector on the Follower robot can lead to Protective Stops.

- Verify that all screws are removed and clear the Protective Stops. Then tap **Proceed** again.

CAUTION

Either robot can enter a Protective Stop while disconnecting.

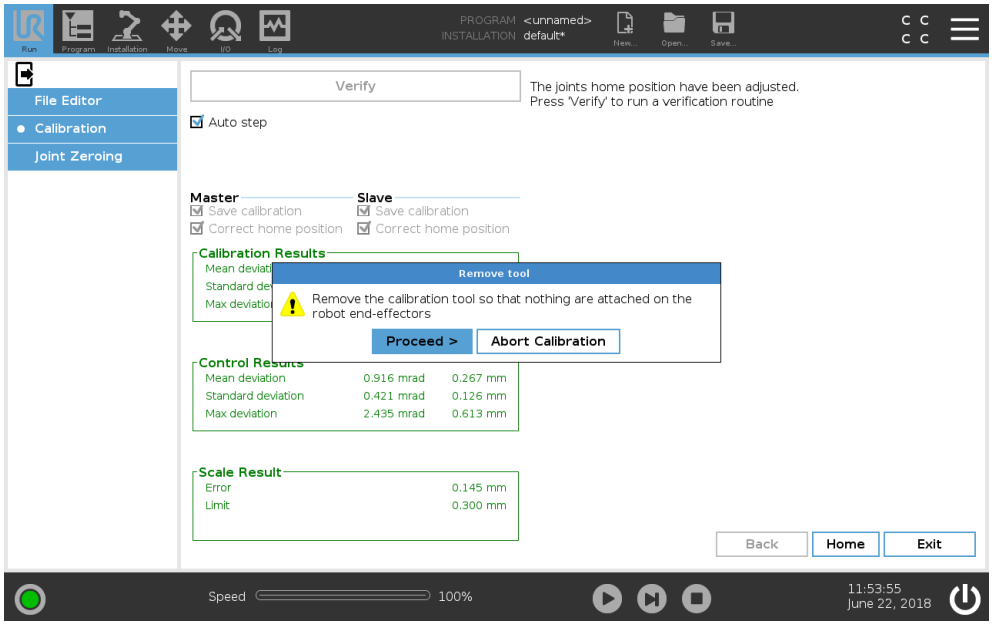
- Remove the Calibration Tool Connector and jog the robots to separate them manually.
- When the robots are separate and the Protective Stop is cleared, the disconnection dialog box reappears on PolyScope, and you can retry the step.

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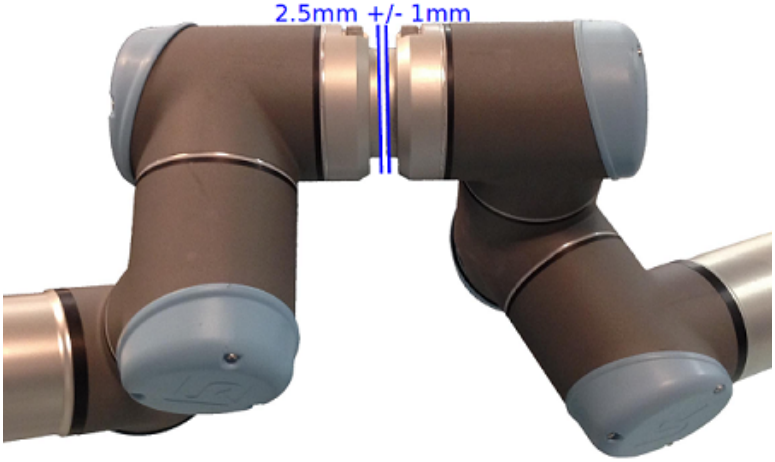
Validating Calibration Results

The results of the dual robot calibration are permanently saved after a successful validation. When the calibration is completed, remove the connector to continue the validation. PolyScope prompts you to remove the screws from the Follower robot's tool.

1. Remove the screws from the Follower robot's tool.
2. Tap **Proceed**.
3. The Follower robot enters Freedrive.
4. Move the robot away so that it cannot collide with the tool.
5. Tap **Proceed**.
6. Remove the tool from the Leader robot's tool.



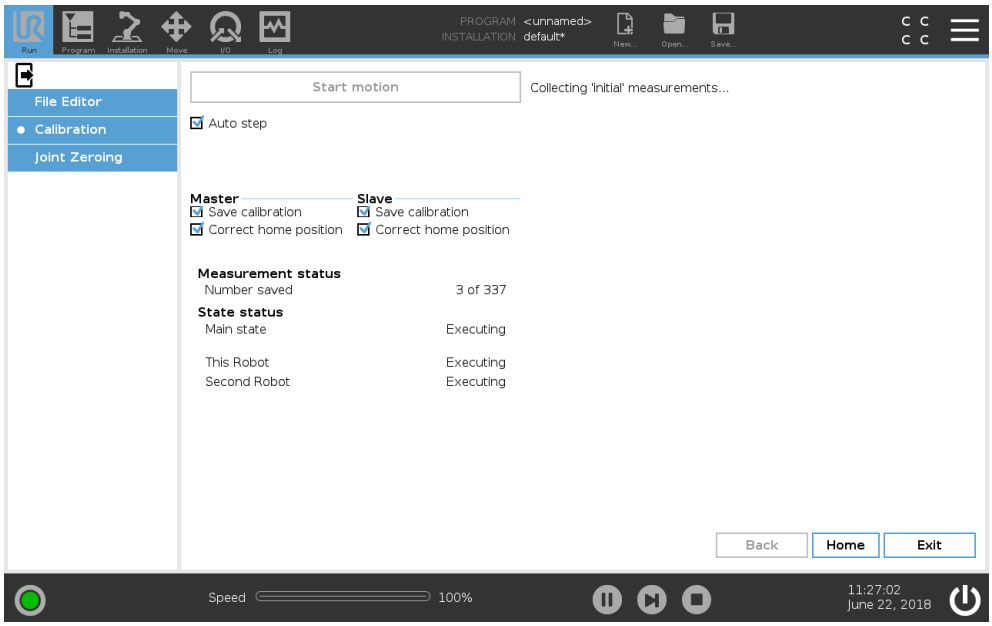
7. Tap **Proceed**.
8. The robots move to home position.
9. Verify that the robots are in home position.
10. The robots move into the *Go / NoGo* position.
11. Use the *Go / NoGo* tool to verify that the distance between the tool flanges is within 2.5 mm.
    - Verify that the 1.5 mm *Go* tool can pass between the robots' tool flanges.
    - Verify that the 3.5 mm *NoGo* tool cannot pass between the two robots' tool flanges.



12. When the **Verify position** dialog appears, tap **Proceed** to verify the robots' home position.

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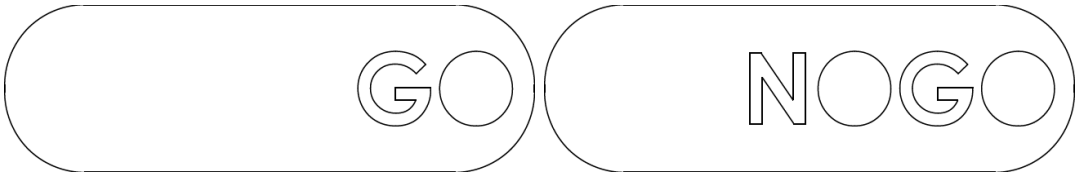
13. Save the calibration and tap **Exit**.
14. In the header under **Run**, tap the **Exit** icon to exit **Expert Mode**.



5.4. The *Go / NoGo* Tools

Description

The *Go / NoGo* tools are two pieces of cardboard of different thicknesses used to verify the success of the calibration. The *Go* tool passes through the space between a pair of correctly calibrated tool flanges. The *NoGo* tool cannot pass through that space.



After calibration, when the Calibration Connector is removed and the tool flanges approach each other, use the *Go / NoGo* tools to verify the distance between the tool flanges.

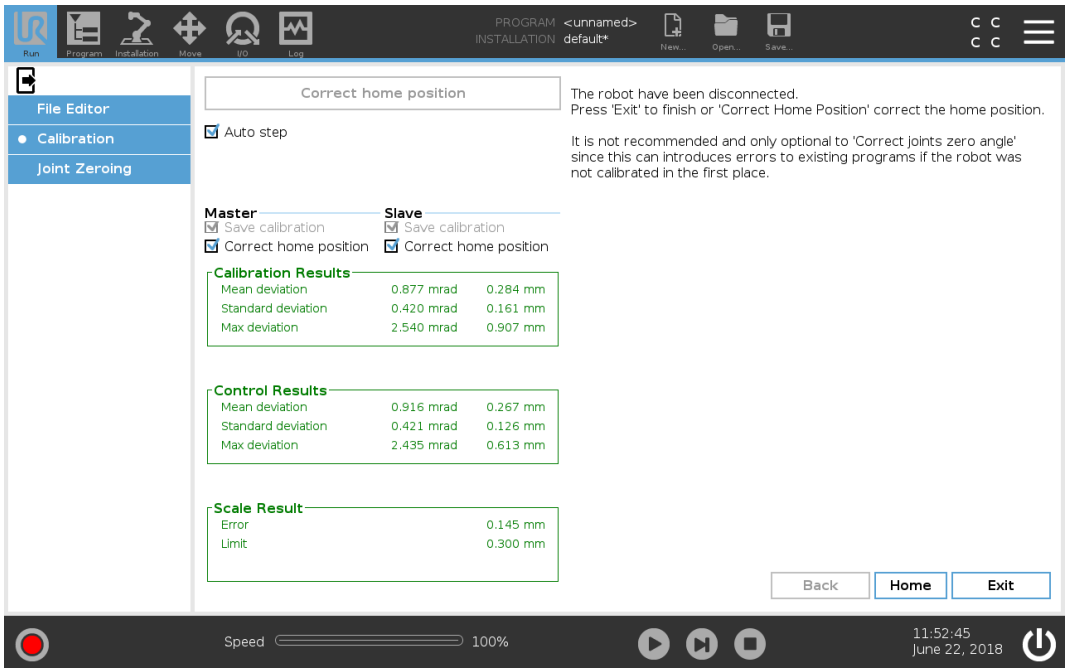
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5.5. Verifying a Successful Calibration

Description

The calibration is successful if the criteria listed below are met.

- The mean deviation is less than 1 mm and 2 mrad.
- The standard deviation is less than 0.5 mm and 1 mrad.
- The difference between the **Calibration Results** and **Control Results** is no more than 50%.
- In the **Scale Result**, the **Error** value is less than the **Limit** value.



5.6. Troubleshooting a Failed Calibration

Description

To find solutions for a failed calibration, use one or more of the troubleshooting methods listed below.

- Verify that security settings are set to the least restricted level.
- Remove the Calibration Tool Connector and unmount the robots from the Calibration Horse. Clean all surfaces on the robots, the Calibration Horse, and the Calibration Tool Connector. Remount the robots while making sure that nothing is stuck between the parts.
- If one or more joints have been replaced, verify that they are mounted correctly. For example, verify that the screw washers are on the correct side of the output flange.
- If one or more joints have been replaced, adjust the joint's zero position (see the Service Manual).

Start a new calibration when you finish troubleshooting.

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5.7. Resetting a Calibration

Description

You can manually reset or adjust a calibration by editing the following file:
`root/.urcontrol/calibration.conf`

1. Go to the console by pressing CTRL+ALT+F1.
2. Navigate to the folder with the calibration file.

Edit file

Before editing the file, back up your original calibration file by saving it under a different name.
To reset the calibration:

1. Set all numbers in delta arrays to zero and increase file_save_count by one.
2. Reboot the robot to apply the changes.

The example below illustrates setting all numbers in the delta arrays to zero.

```
[mounting]
delta_theta = [ 0, 0, 0, 0, 0, 0]
delta_a = [ 0, 0, 0, 0, 0, 0]
delta_d = [ 0, 0, 0, 0, 0, 0]
delta_alpha = [ 0, 0, 0, 0, 0, 0]
joint_checksum = [ 0xb86d04a5, 0x8d29526e, 0x21a274b7, 0x5134a655, 0xc44d7e89,
    0x1be4dbeb]
calibration_status = 2 # 0 == notInitialized / 1 == notLinearised / 2 == Linearised
joint_raw_offset = [ 0.1, -.81973522672052201e-05, 3.81973522672052201e-05,
    .81973522672052201e-04, 0, 1.3]
joint_selftest_data_crc = [ 0xfd8c0ed6, 0x9c3bef33, 0xfcca0113, 0x3ddc1b38, 0xad3f2781,
    0x848b8665]
file_save_count = 2
```

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6. Dual Robot Calibration for PolyScope X: Application

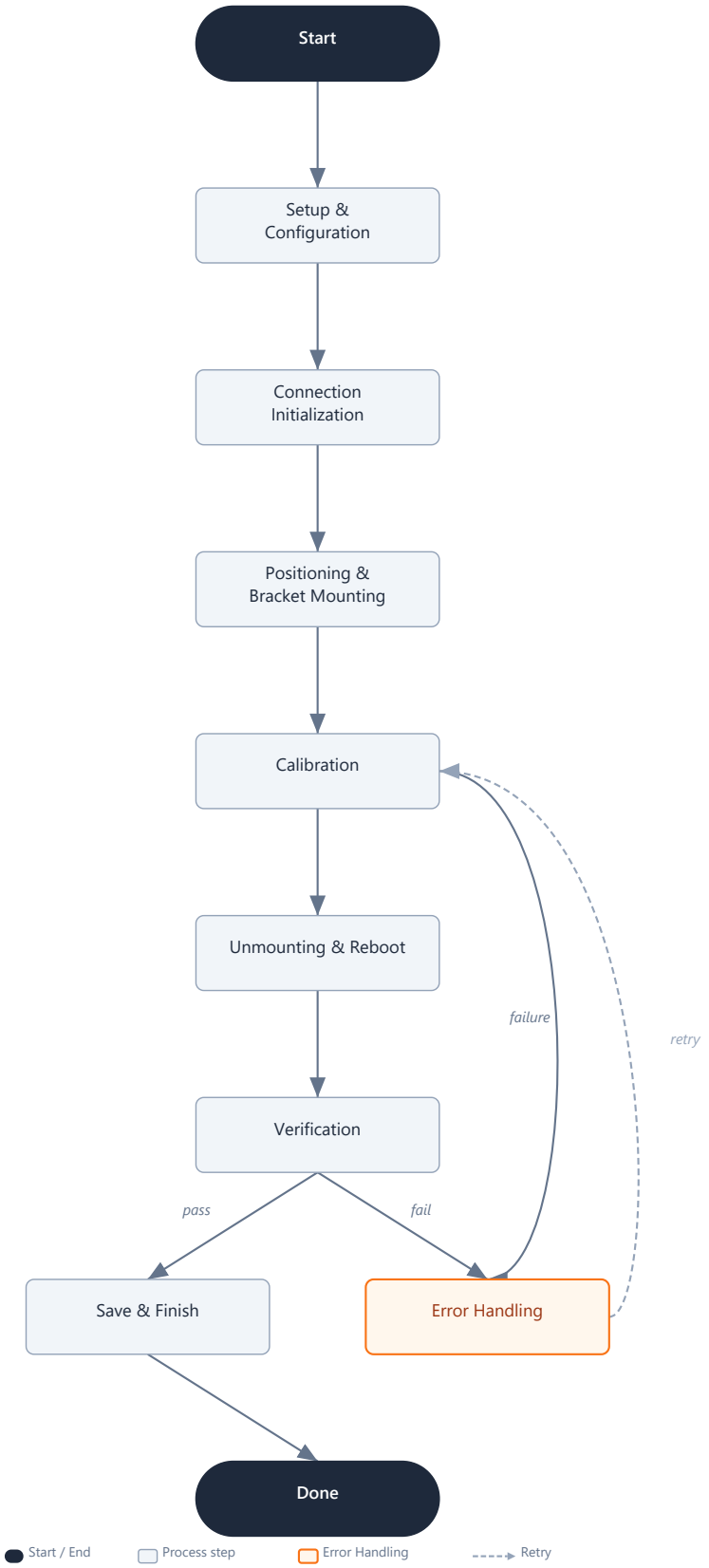
Description

Dual Robot Calibration uses two active robots of the same size working together:

- **Leader** – The robot with the Dual Robot Calibration **URCapX** installed. It controls the entire calibration flow.
- **Follower** – The second robot. It does *not* need the URCapX installed.

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Calibration flowchart



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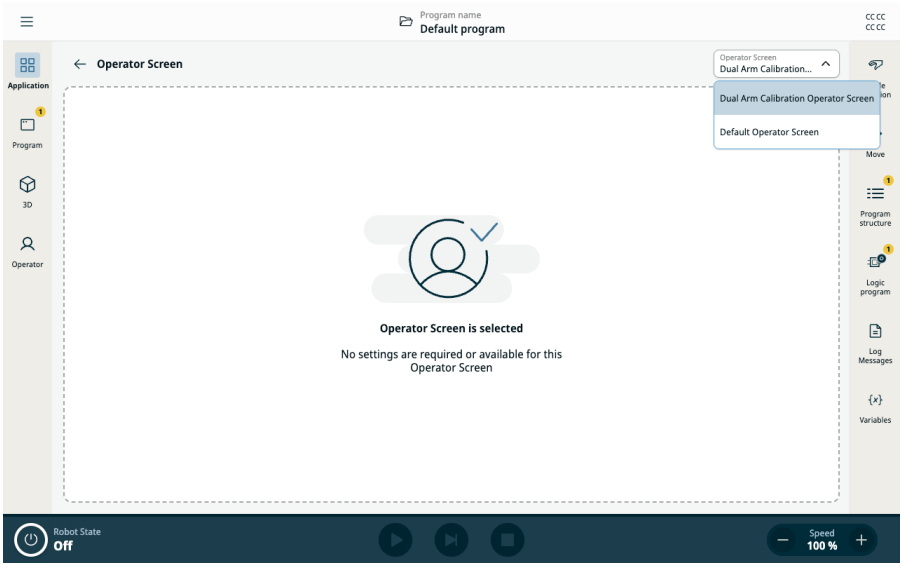
6.1. Setup and Configuration

Description

This section describes the basic setup and configuration process.

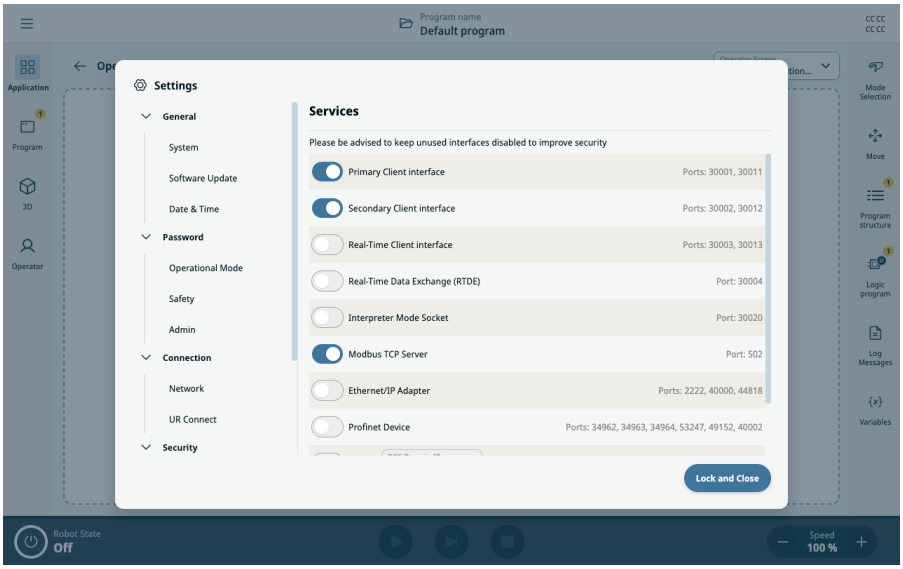
Set the Operator Screen (Leader only)

1. After you install the Dual Robot Calibration URCap on the Leader robot, navigate to the **Application** tab and go to the **Operator Screen**.
2. In the top right of the main screen, change the operator screen to **Dual Arm Calibration Operator Screen**.



Enable required services (both robots)

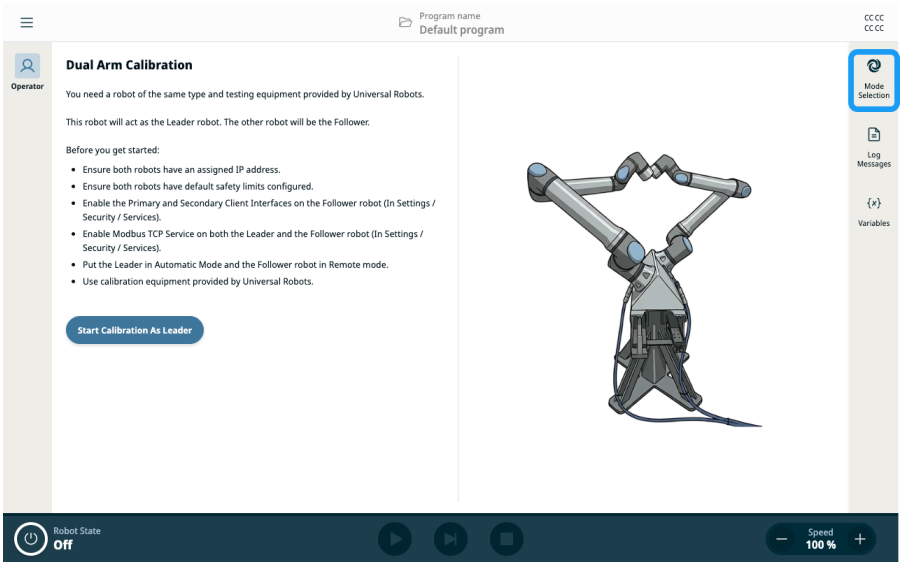
3. To enable the required services on both the Leader and Follower robots, tap the hamburger menu in the main navigation.
4. Navigate to the **Security** settings and go to **Services**.
5. Enable the following three services:
   - **Primary Client Interface**
   - **Secondary Client Interface**
   - **Modbus TCP Server**



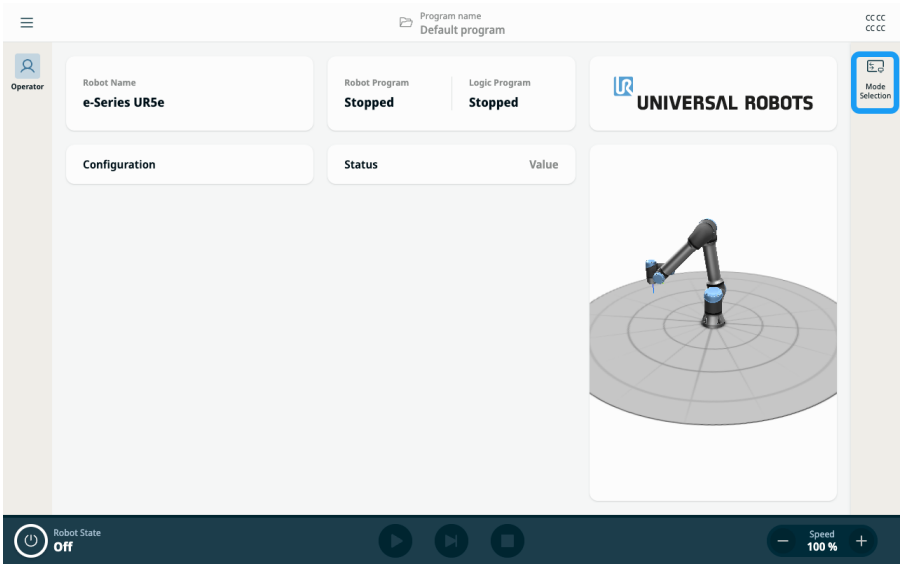
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Set the Mode Selection

6. For the Leader robot, tap the **Mode Selection** icon in the sidebar and set it to **Automatic Mode**.



7. For the Follower robot, set it to **Automatic Mode**, then switch to **Remote Mode**.



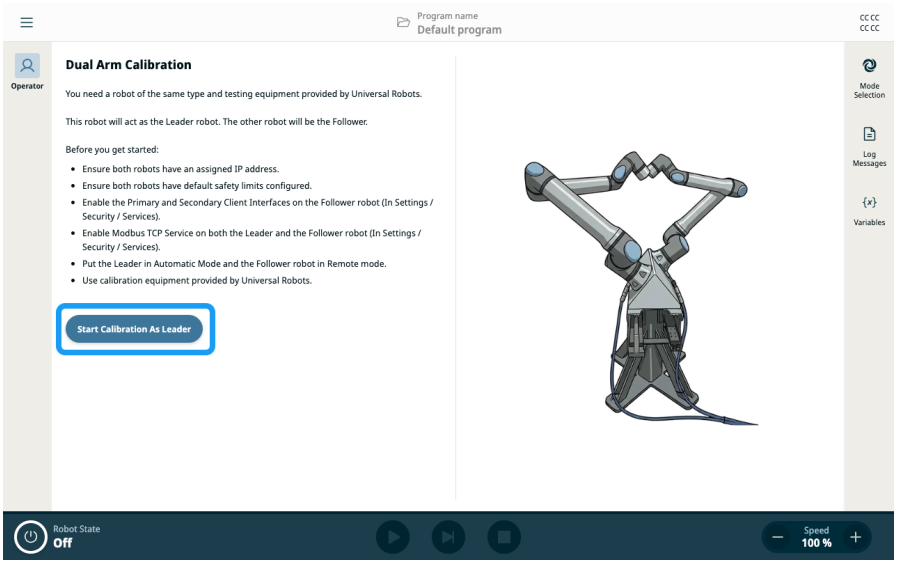
6.2. Connection and Initialization

Description The entire calibration flow is controlled from the robot designated as the Leader.

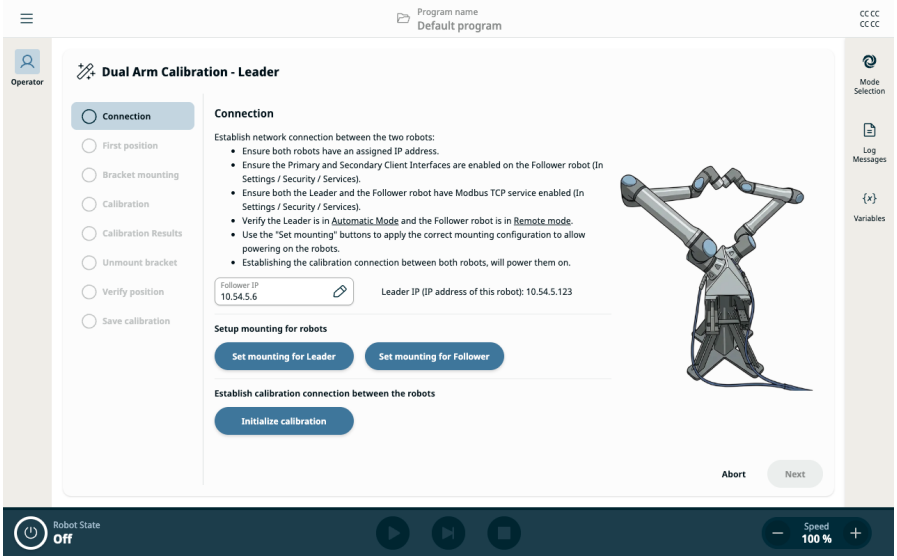
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Start calibration as Leader

1. On the **Operator Screen**, tap **Start Calibration As Leader** to open the connection screen.



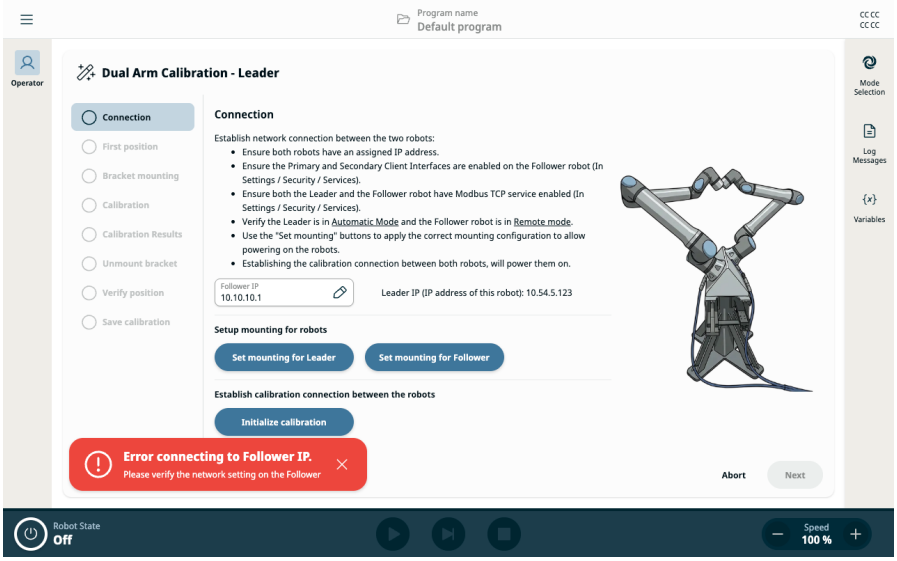
2. In the **Follower IP** field, enter the IP address of the Follower robot.



3. Set the correct robot mounting configuration using the two on-screen **Set Mounting** buttons.
4. Tap **Initialize Calibration**.

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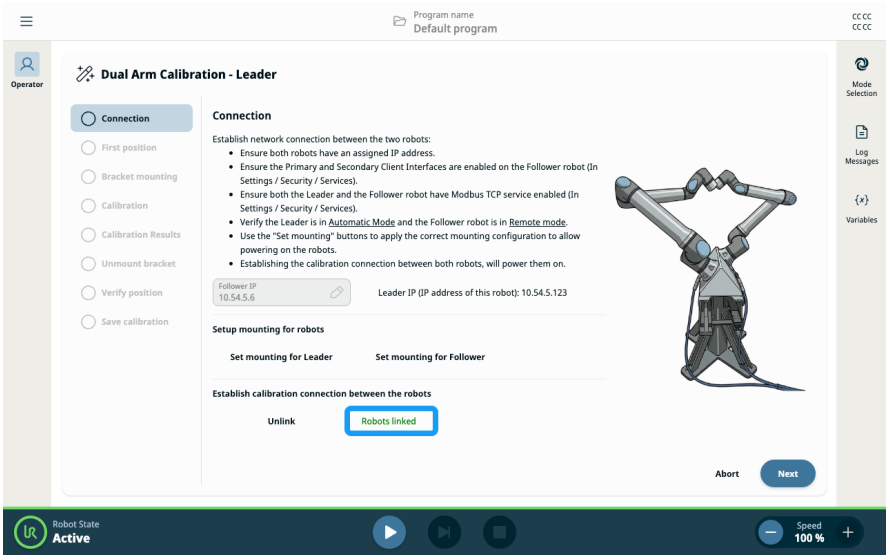
5. If you enter an incorrect IP address, you see the message **Error connecting to Follower IP**. This message may also appear for network issues.



> **NOTICE**
>
> If you see **Error connecting to Follower IP**, verify the IP address is correct and check for network issues.

Confirm Connection

6. If the connection is successful, the screen displays **Robots linked**.
7. Tap the **Next** button to continue.



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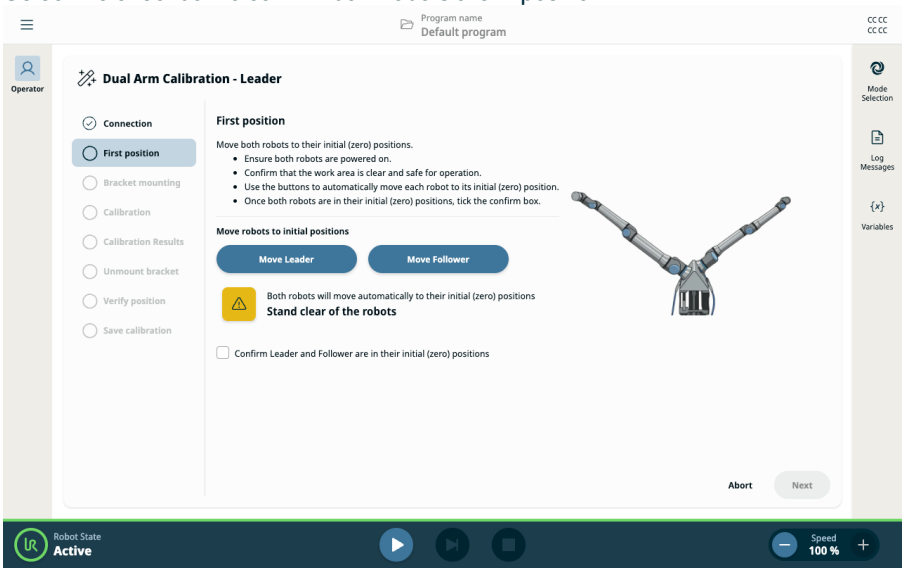
6.3. Positioning and Bracket Mounting

Description

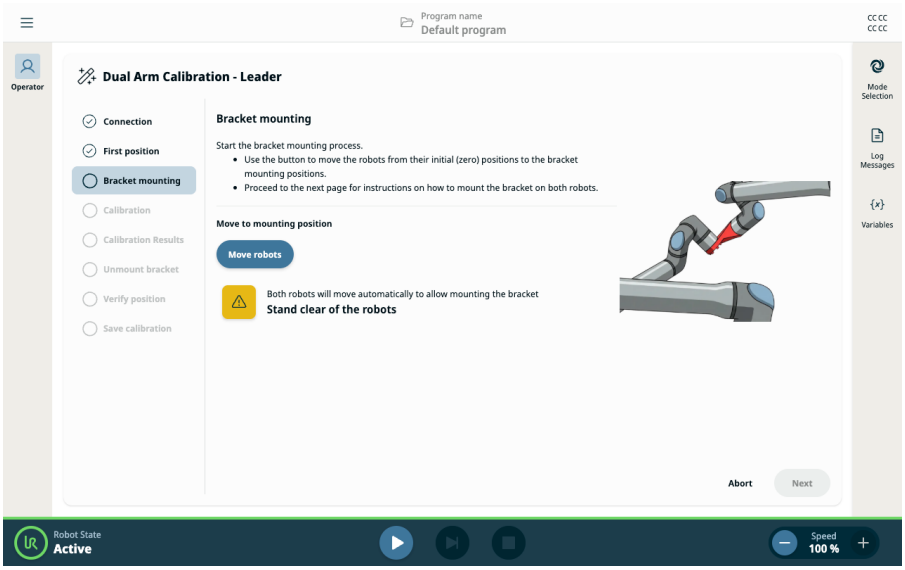
Positioning and bracket mounting start with the first position, which enables both robots to be moved to their initial positions.

Move robots to first position (zero position)

1. You are in the **First position** panel, which enables you to move both robots to their zero (initial) position.
2. Select the checkbox to confirm both robots are in position.

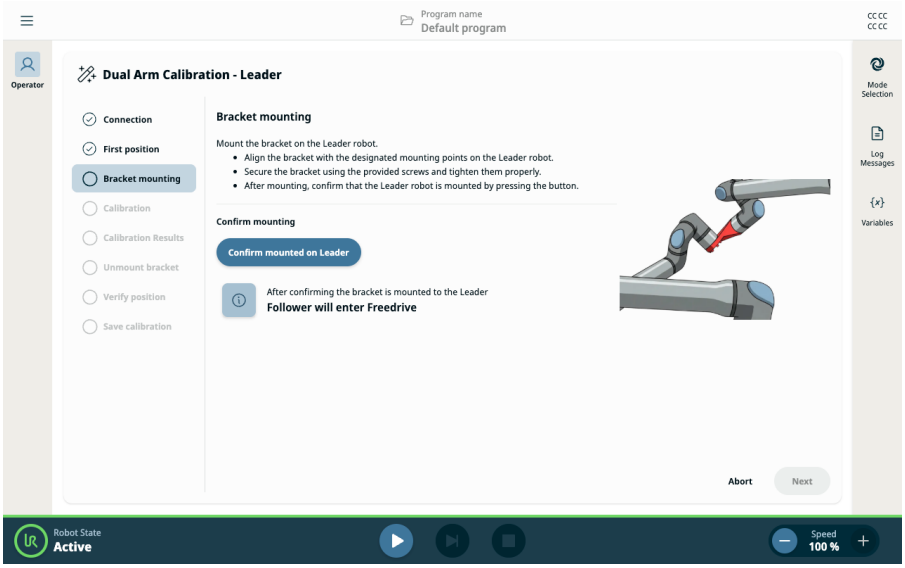


3. The **Bracket mounting** panel is activated.



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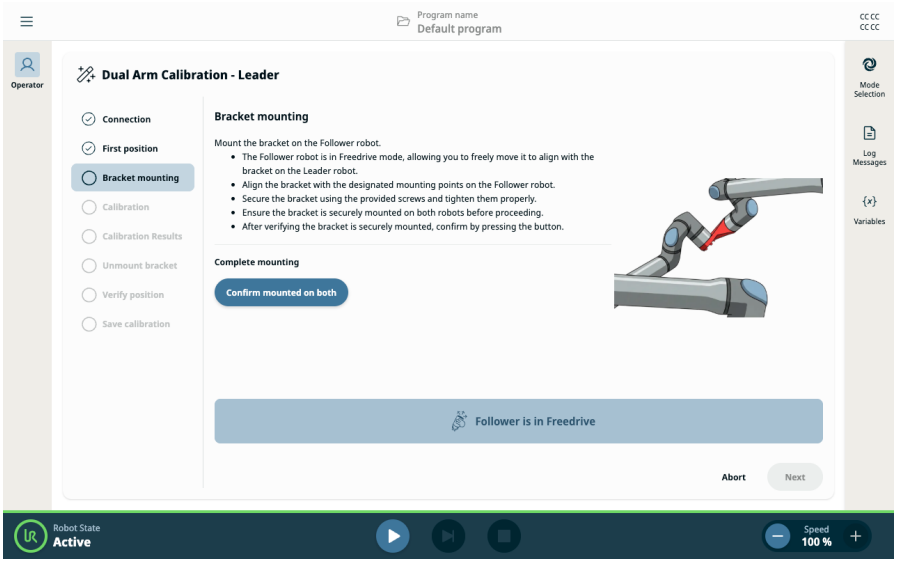
4. Tap **Confirm mounted on Leader** to proceed.



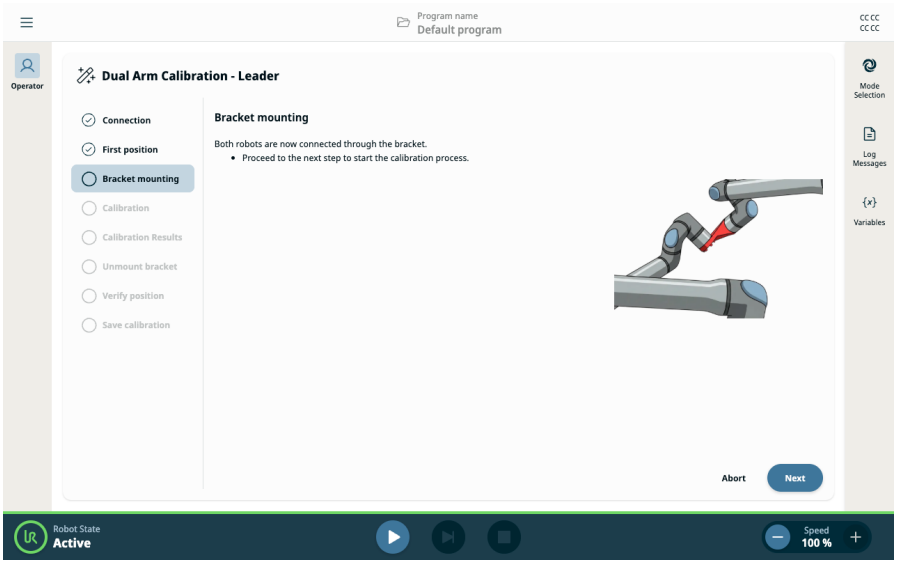
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Mount the calibration bracket

5. Follow the on-screen instructions to physically connect the two robots using the calibration bracket:
   - Align the robots according to the guided steps.
   - Secure the bracket to both robot arms.
   - Confirm each mounting step as prompted.



6. Tap **Next** to finish the bracket mounting steps.



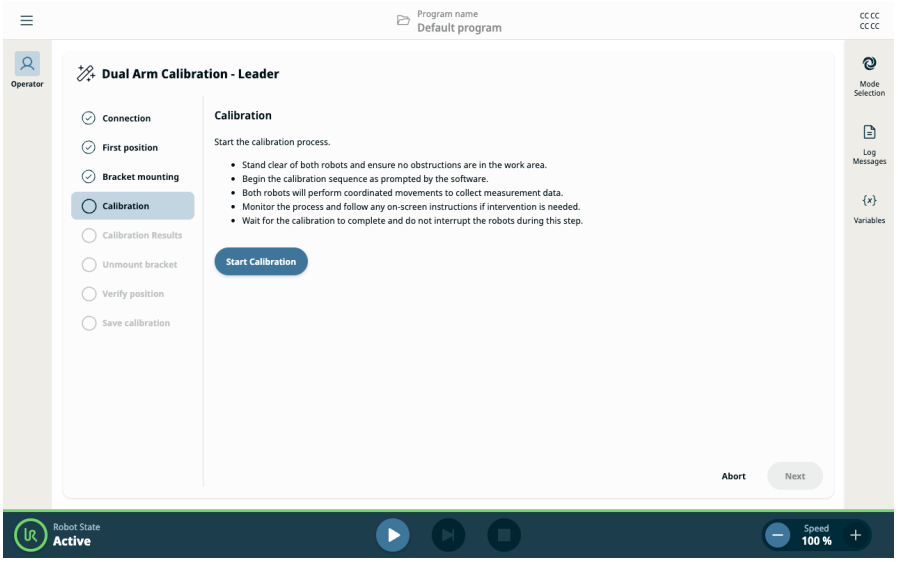
6.4. Calibration

Description The calibration process takes about 25 minutes.

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Start the calibration process

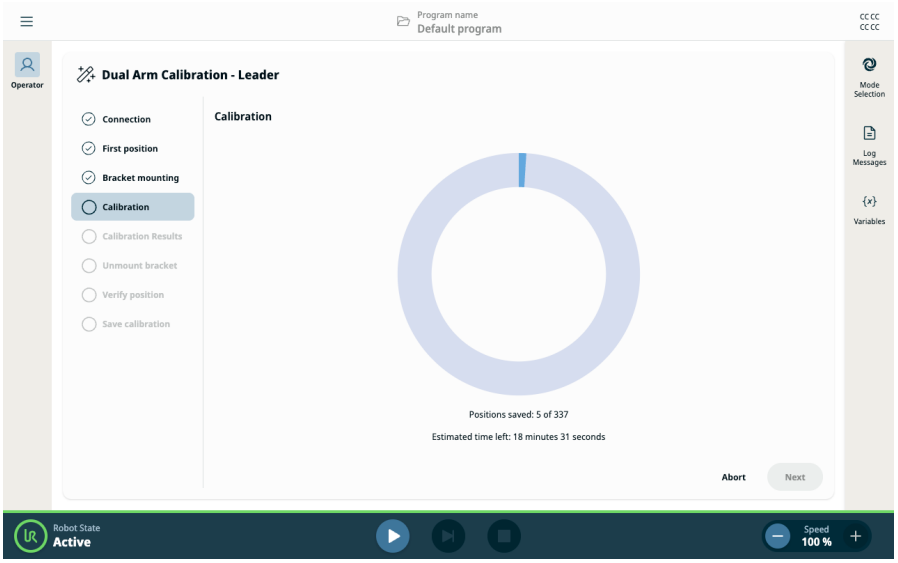
1. Once **Bracket mounting** is complete, tap **Start Calibration**.



The robots perform a series of automatic movements lasting approximately 25 minutes.

A circular progress bar shows the progress, along with:

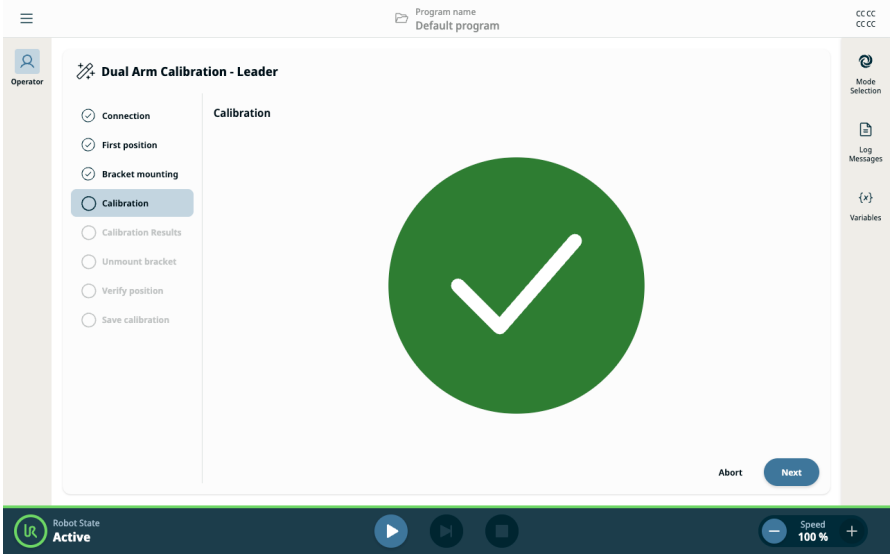
- **Number of positions saved**
- **Estimated time left**



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Calibration complete

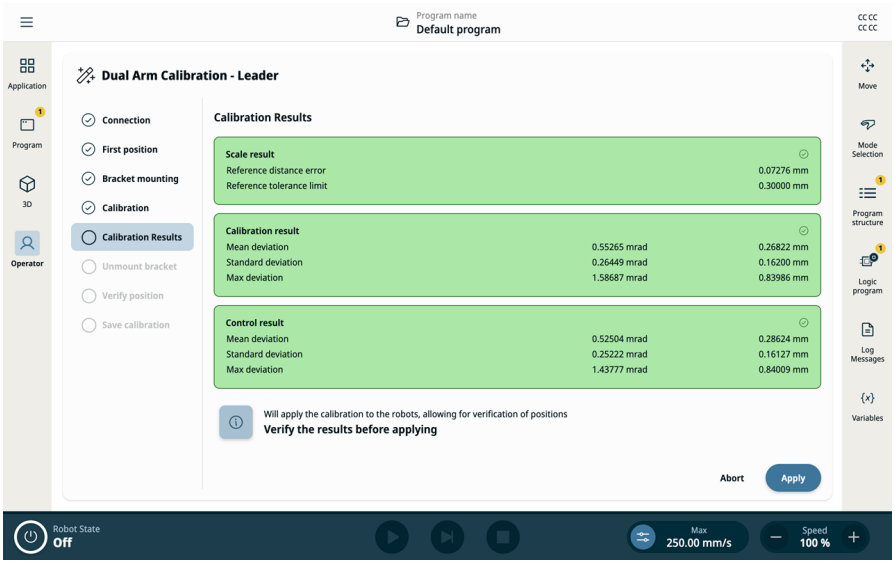
2. When calibration finishes, a large green check mark is displayed.



3. Tap **Next** to continue.

Review calibration results

4. The **Calibration Results** panel shows all measured values. All values must be green to proceed.
5. If any values are red, the **Apply** button is disabled, and you must tap **Abort** and retry or troubleshoot the issue.



6.5. Unmounting and Reboot

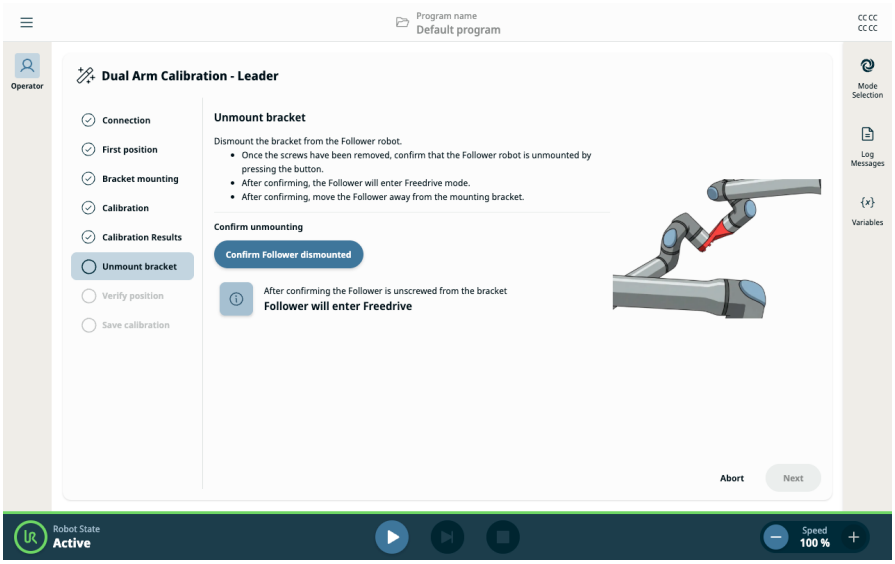
Description

After a successful calibration (all values green), the **Unmount bracket** panel is activated.

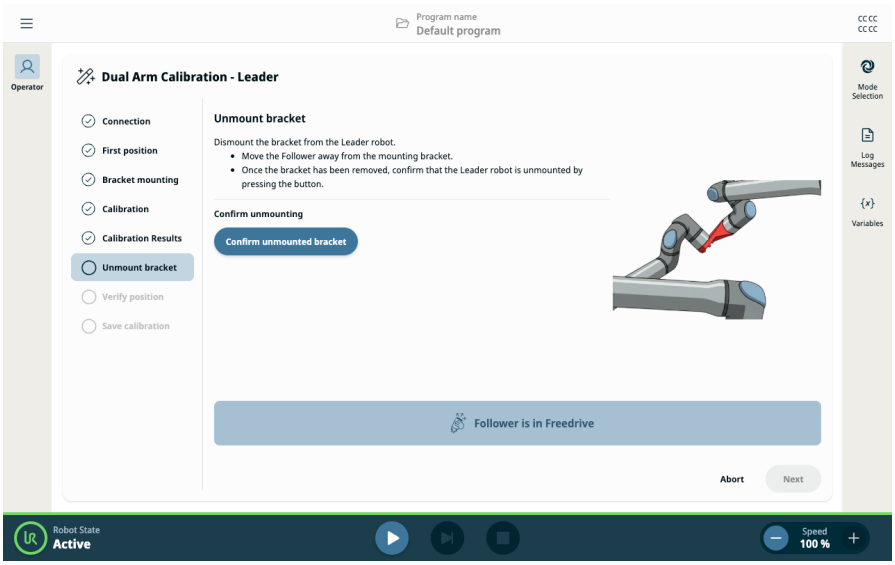
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Unmount the calibration bracket

1. Follow the on-screen steps to physically disconnect the bracket from both robots.



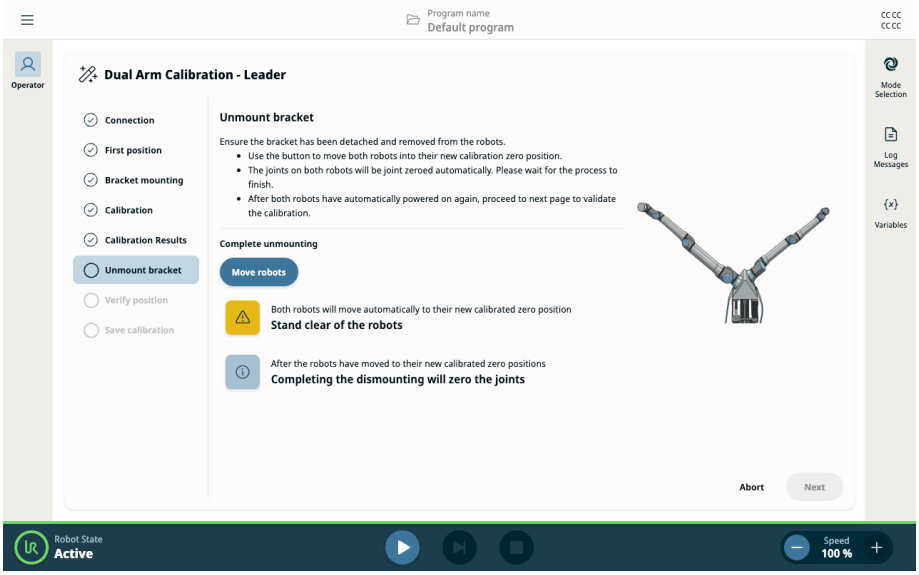
2. Tap the **Confirm unmounted bracket** button.



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Move robots and reboot

3. Tap the **Move Robots** button. This returns both robots to zero position and reboots both robot arms.

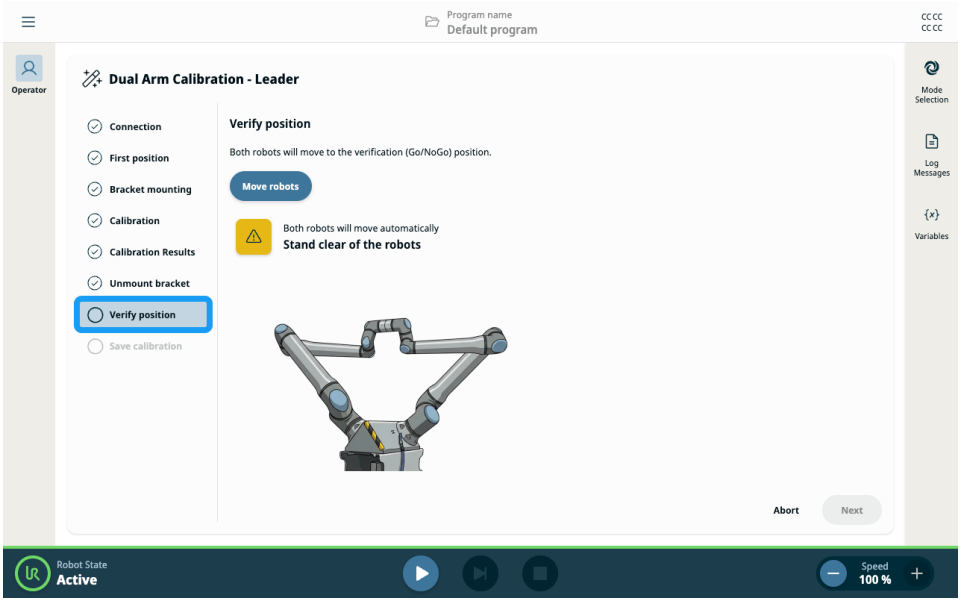


4. Wait until the system returns to the **Active** state before proceeding.

6.6. Verification

Description

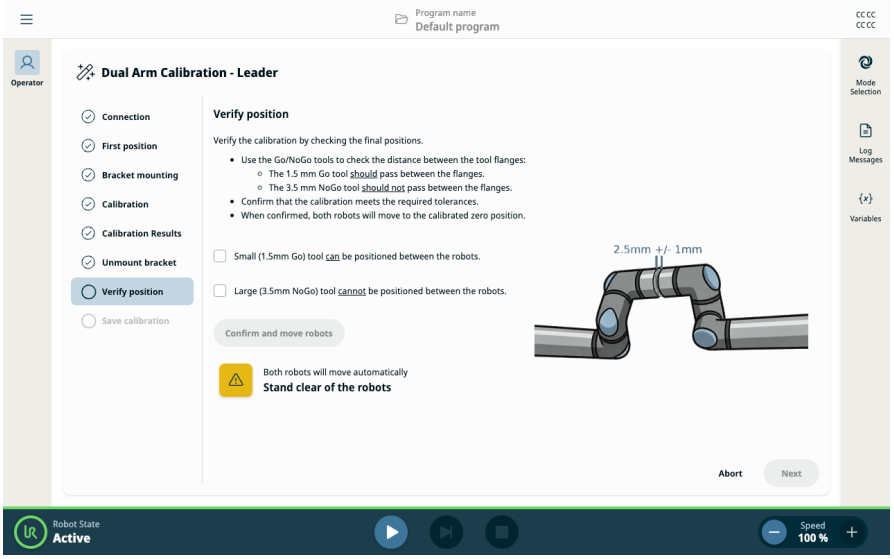
After a successful unmount and reboot, you can proceed to the verification process.



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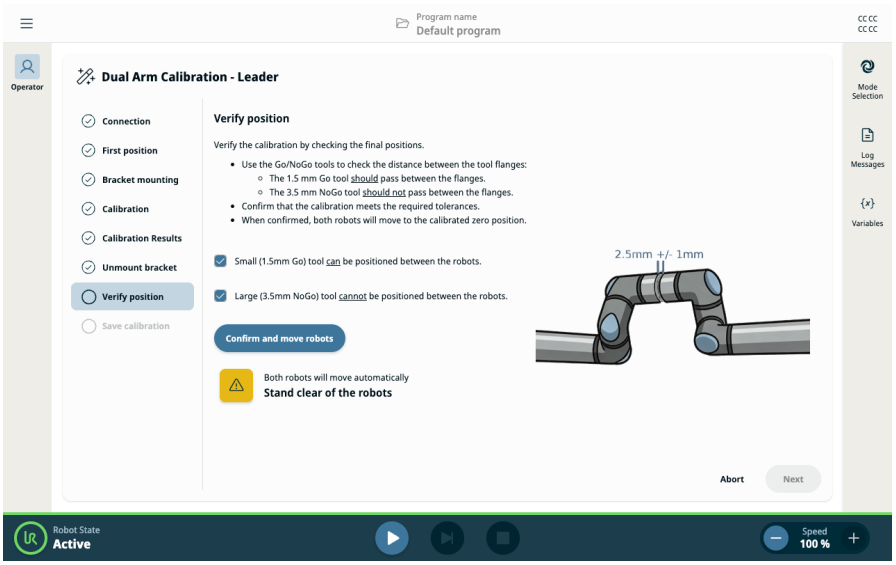
Perform Go/No-Go verification

1. Use a plastic gauge tool to measure the distance between the tool flanges:
   - Must be greater than 1.5 mm
   - Must be less than 3.5 mm



Confirm distance tolerances

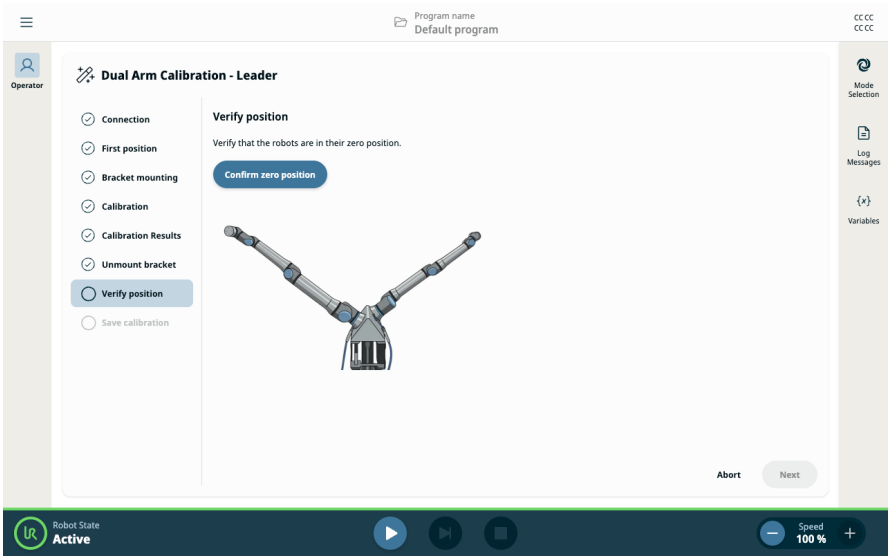
2. Check both checkboxes to confirm the distances are within tolerance. This enables the **Confirm and move robots** button.



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Visual alignment verification

3. Visually verify that both robots are straight in their zero position.
4. Tap **Confirm zero position** to enable the **Next** button.



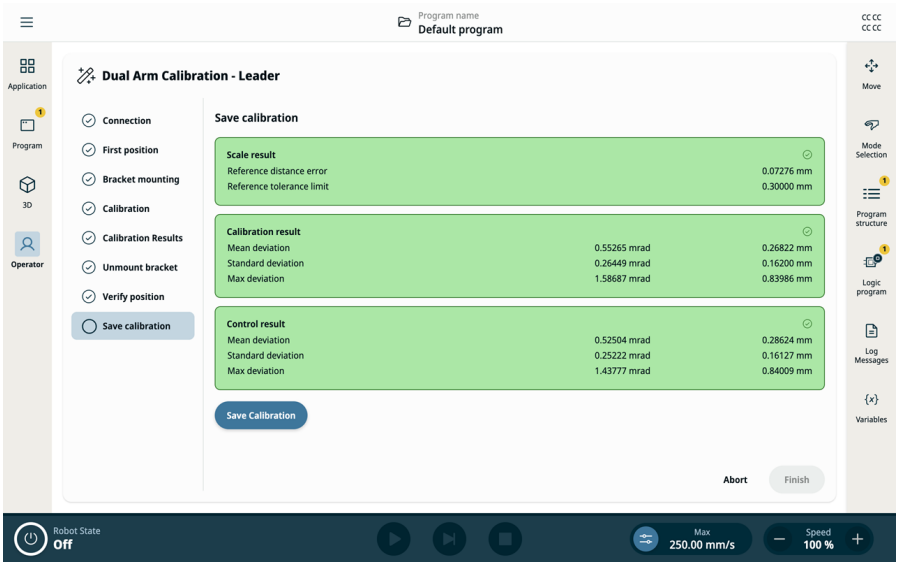
6.7. Save and Finish

Description This section concludes the calibration process.

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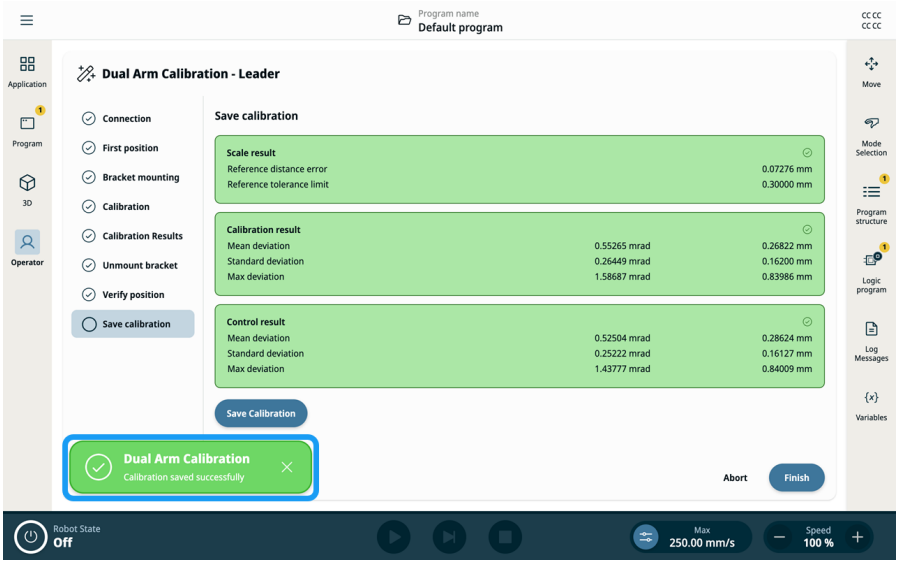
Save the calibration

1. The **Save Calibration** panel shows the final results one more time.



> **NOTICE**
> All values must be green to proceed.

2. Tap the **Save Calibration** button.
3. A **success snackbar** appears, and the **Finish** button becomes enabled.

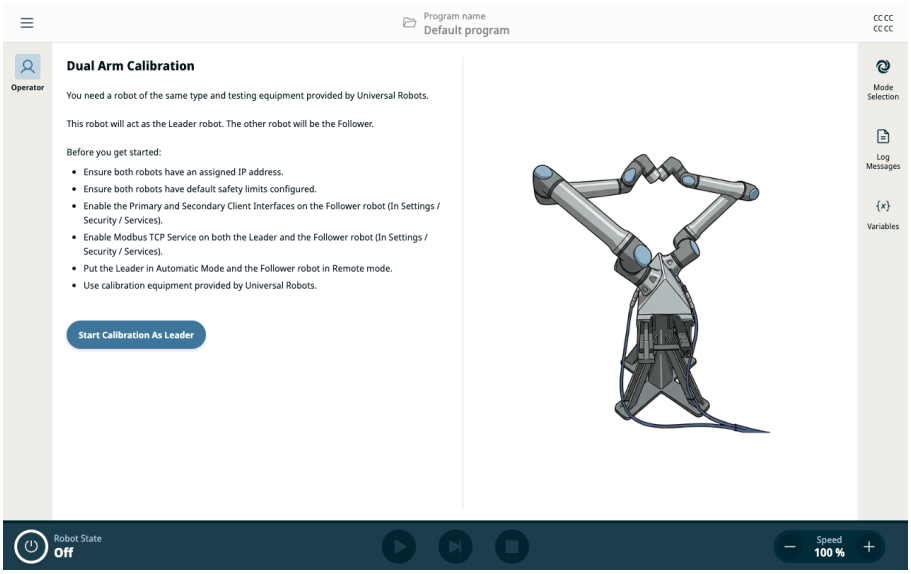


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Finish the process

4. Tap **Finish**.

   The system returns to the start screen.



Calibration is now complete.

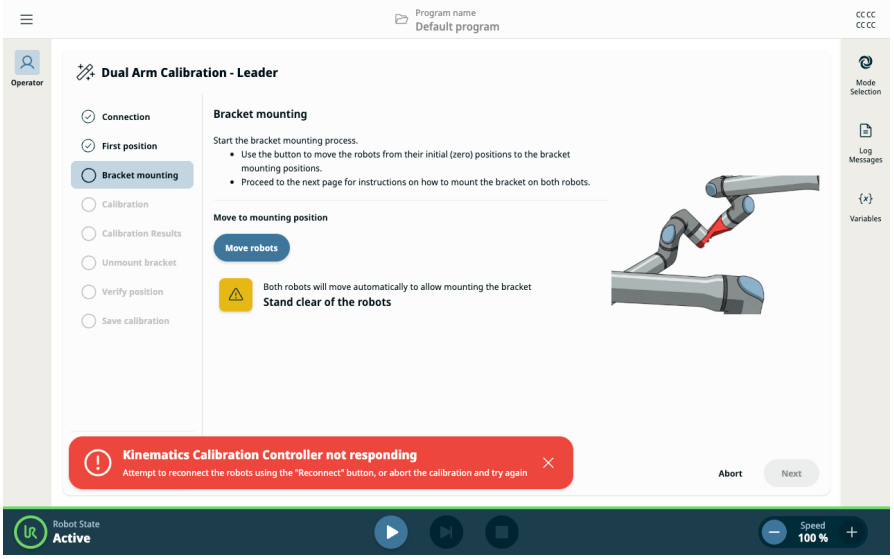
6.8. Error Handling

Description This section describes how to handle errors that occur during calibration.

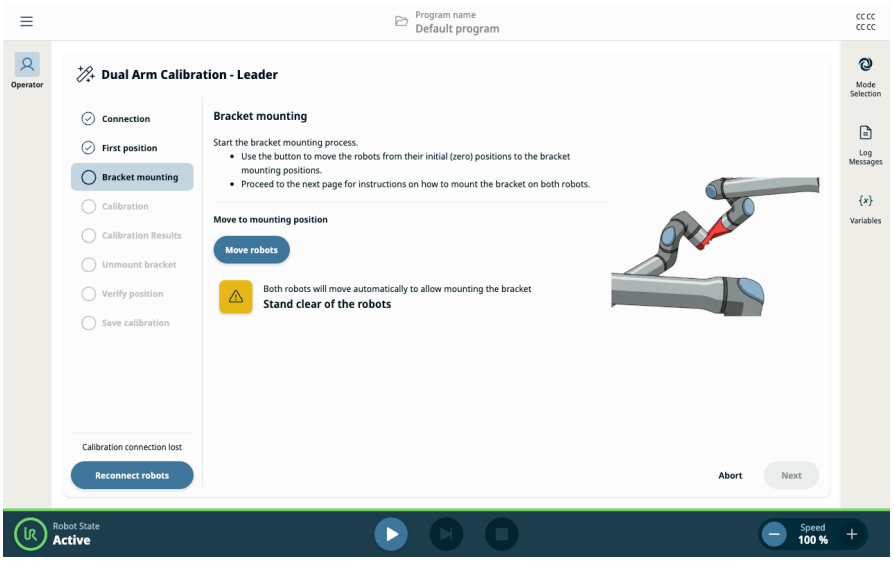
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If connection is lost during calibration

1. An error message is displayed if the connection between the robots is lost at any point or when other issues arise.



2. Tap the **Reconnect robots** button to attempt automatic reconnection.
3. If reconnection fails, the only option is to **Abort** and restart the calibration.



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7. Tool Drawings

Description

Two calibration mounts are available.

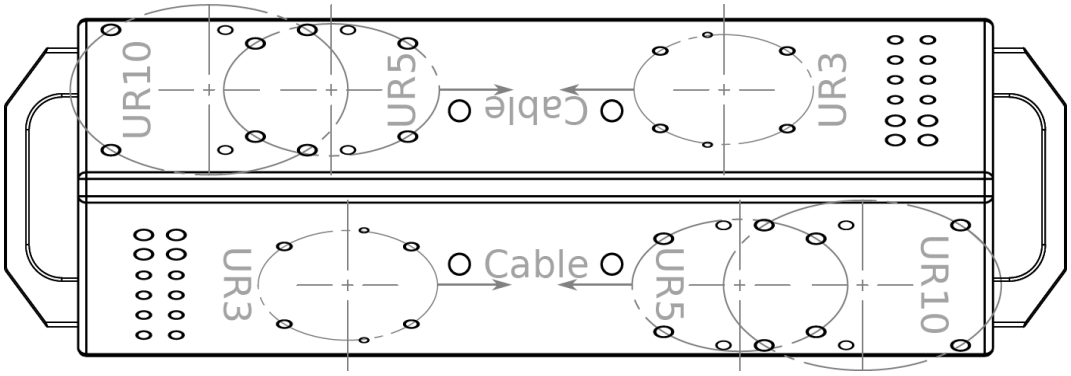
- Purchase number: 185500
- Purchase number: 200977

The calibration kit (185500) includes a smaller calibration horse and can be used with the following robots:
All e-Series robots.

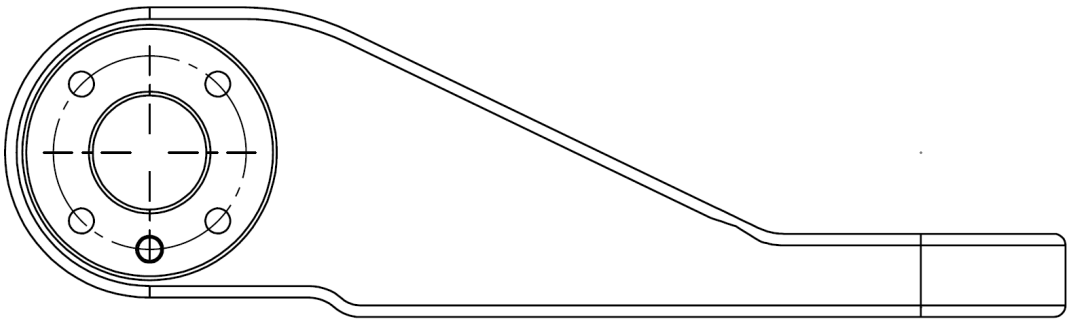
The calibration kit (200977) includes a larger calibration horse and can be used with the following robots:
UR10e, UR16e, and UR Series robots.

Calibration Horse (185500) Only e-Series

The UR3e and the UR10e robot arms are mounted in different positions.

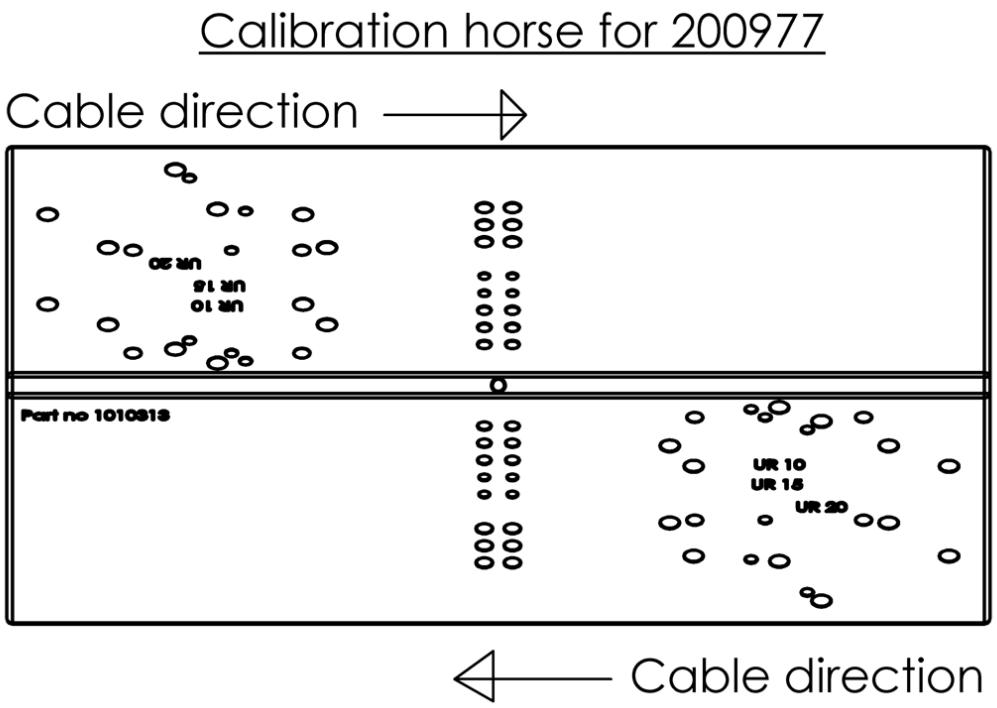


Calibration Connector (185500) Only e-Series

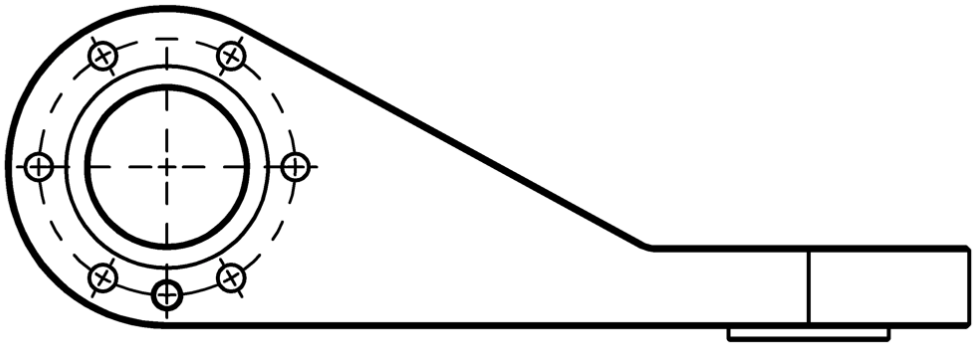


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Calibration Horse (200977) UR10e, UR16e and UR Series



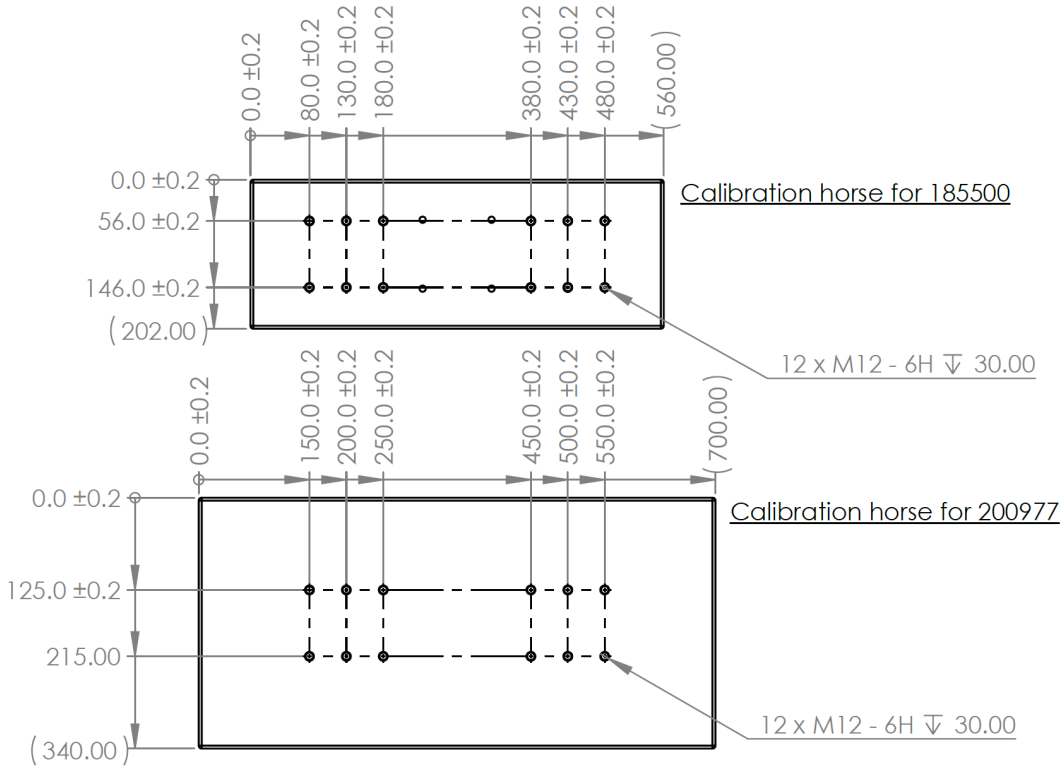
Calibration Connector (200977) UR10e, UR16e and UR Series



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8. Drill Holes for Horse Mounting

Drawing



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9. Copyright and Disclaimers

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9.1. Calibration And Programming of Robots Patent

Description

The Dual Robot Calibration method is covered by one, or more, of the following patents:

- CN103889663 B
- CN104991518 B
- EP2760642 B1
- EP2796249 B1
- JP6182143 B2
- MX343142 B
- RU2605393 C2
- US9248573 BB
- US9833897 BB

The Dual Robot Calibration method is also covered by one, or more, of the following patent applications:

- BR112014007077 A2
- SG10201502615Q A1
- SG11201400923Q A1
- TH141798 A

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