

Week 4 – ABB Robot Teaching Robot and Cell Calibration

Advanced Robotic Systems – MANU2453

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- Creating a Tool Frame for Sharp-Tipped Calibration Tool
- Calibrating the Sharp-tipped Calibration Tool
- Creating a Frame for the Workpiece / Work Cell
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- Creating a Tool Frame for the Actual Tool
- Calibrating the Actual Tool

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Introduction

- The robot programming method shown previously, i.e. using **teaching pendant**, is acceptable for **simple tasks**.
- However, if the **work piece is complicated**, for e.g. marine propeller and aerospace engines, then it would take **many hours or days** to program the robot using the teaching pendant.



<http://www.blue-sky-technologies.com/impeller-seal-repair>

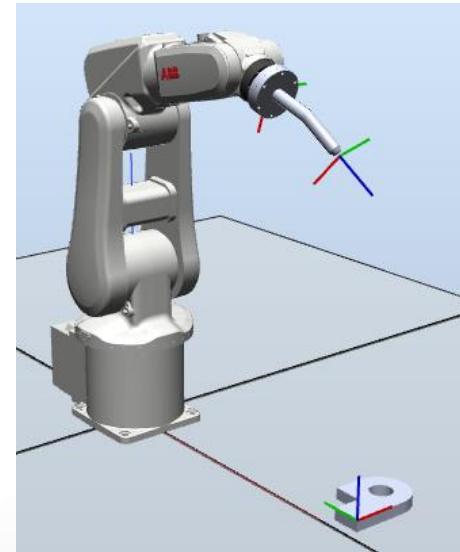


<http://www.millercastings.com/casestudyfrntbear/>

- This means that the **production line has to be stopped**, which is highly undesirable.

Introduction

- There is a **better alternative** which is getting more popular nowadays – **Offline programming**.
- In offline programming, we:
 - a. Import CAD files for tools and workpiece.
 - b. Set up a **virtual robot cell**.
 - c. Teach the robot in the virtual environment.
 - d. Generate the robot codes.
 - e. Upload the robot codes to the actual robot.
- Disruption to the production line is therefore minimised.
- In order to accomplish task b., there is a **need to know where the tool and workpiece would be** in actual situation.
- In this handout, we will learn how to do that – This is also referred to as **robot cell calibration**.

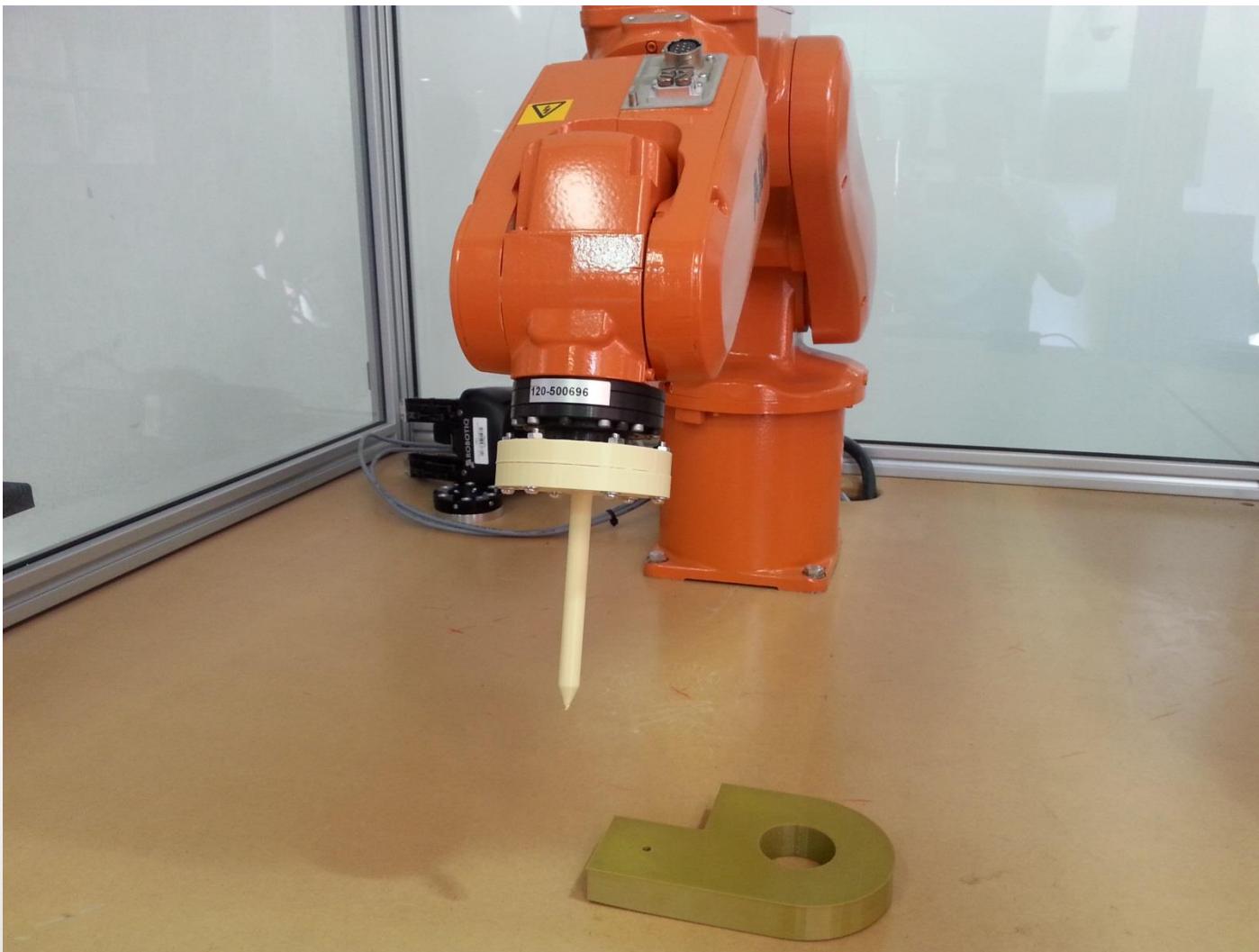


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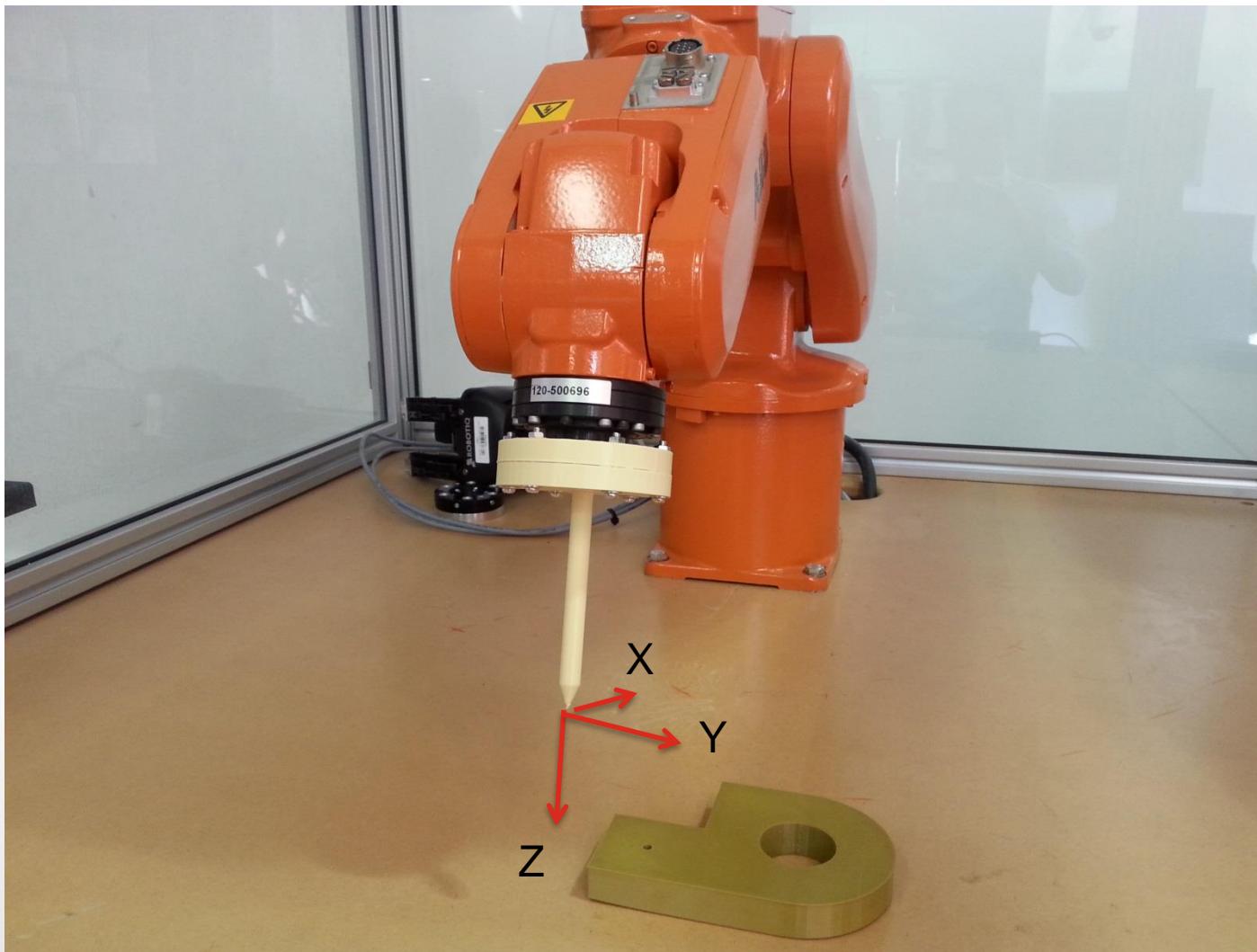
Create Sharp-Tipped Tool Frame

- First of all, we will create and calibrate a sharp-tipped calibration tool.



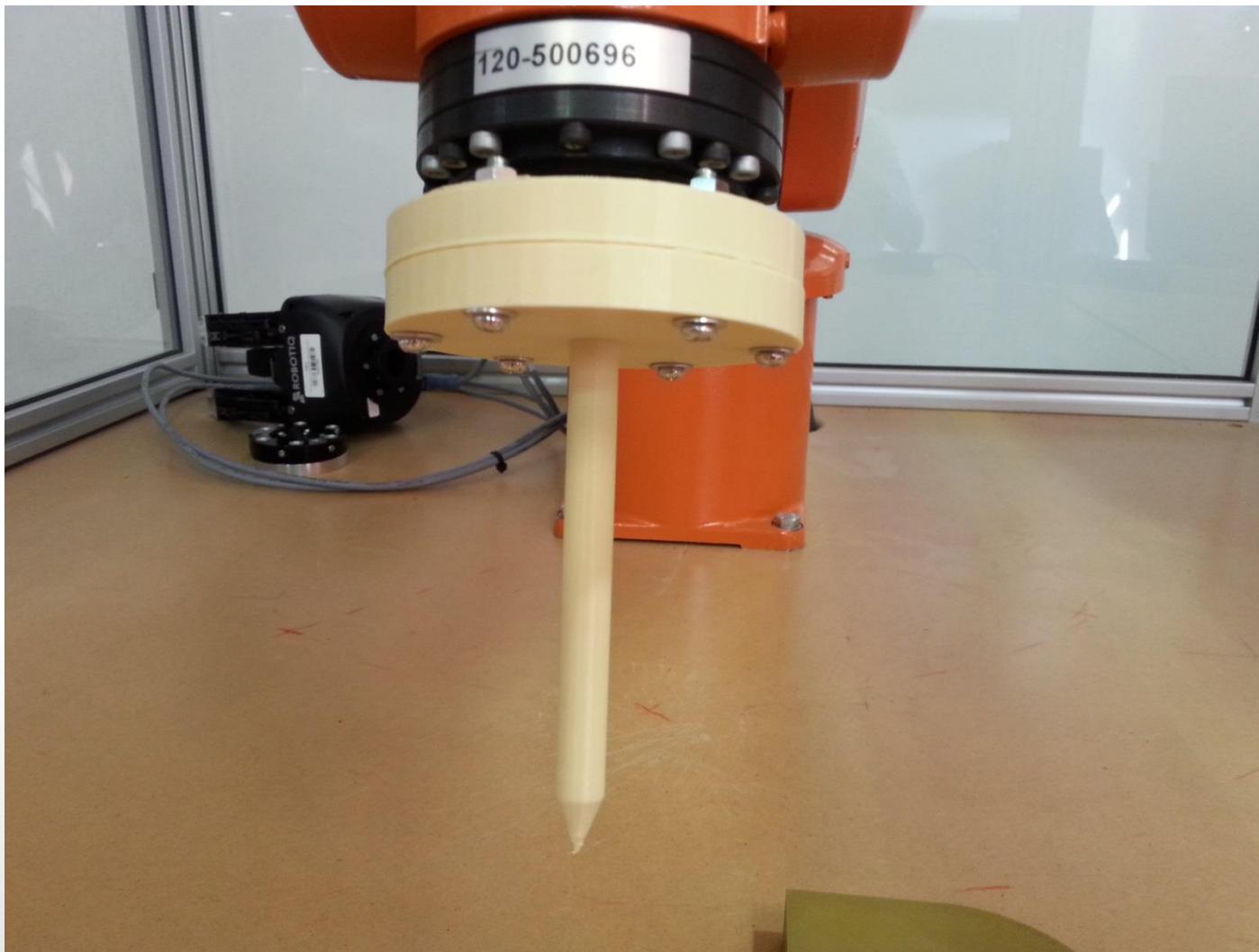
Create Sharp-Tipped Tool Frame

- That is, we want to find out where the sharp tip is, and place a frame there.



Create Sharp-Tipped Tool Frame

- We will later use the sharp tip to point to certain points on the workpiece.



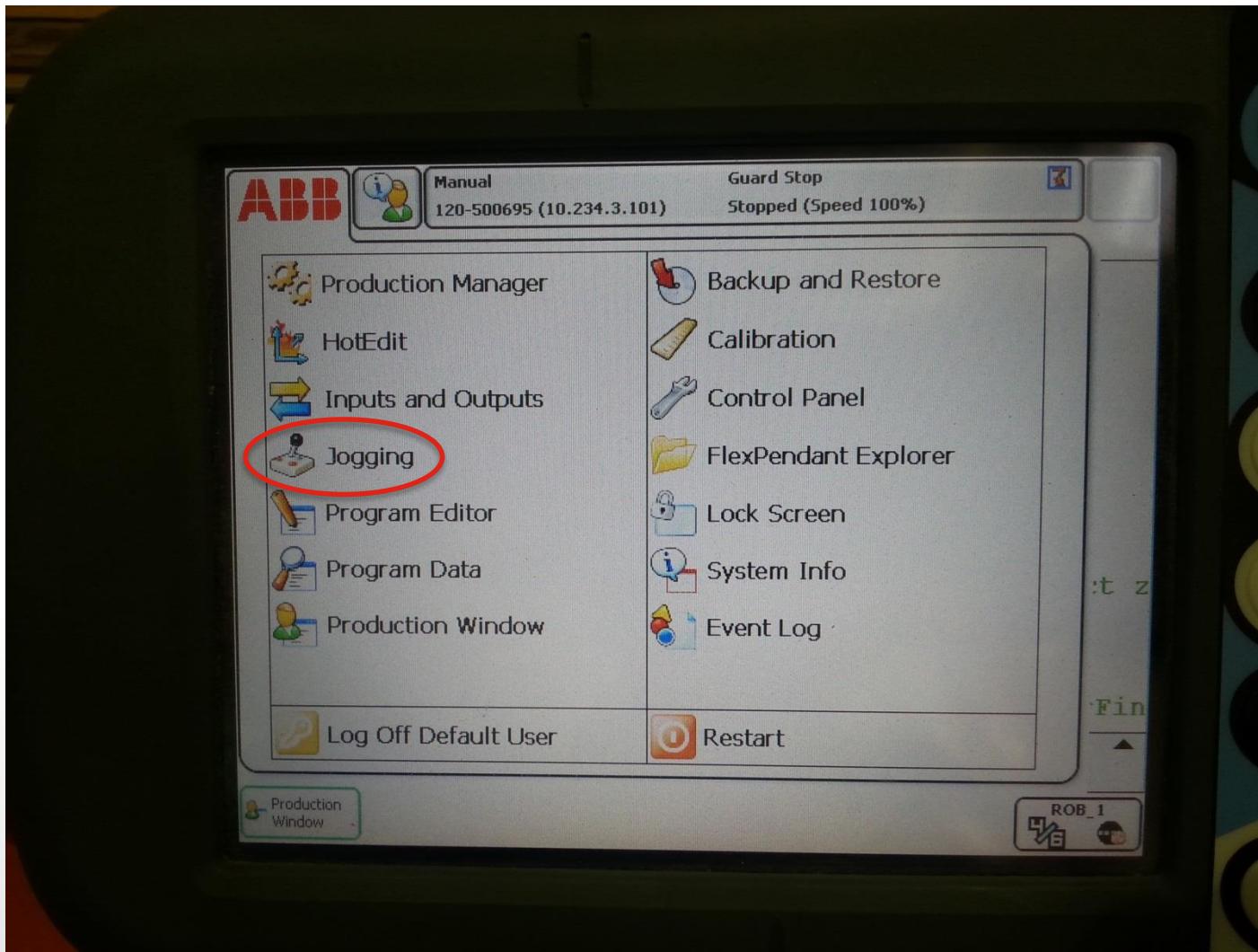
Create Sharp-Tipped Tool Frame

- First of all, activate the **manual mode** of the robot by turning the key at the controller to the upright position:



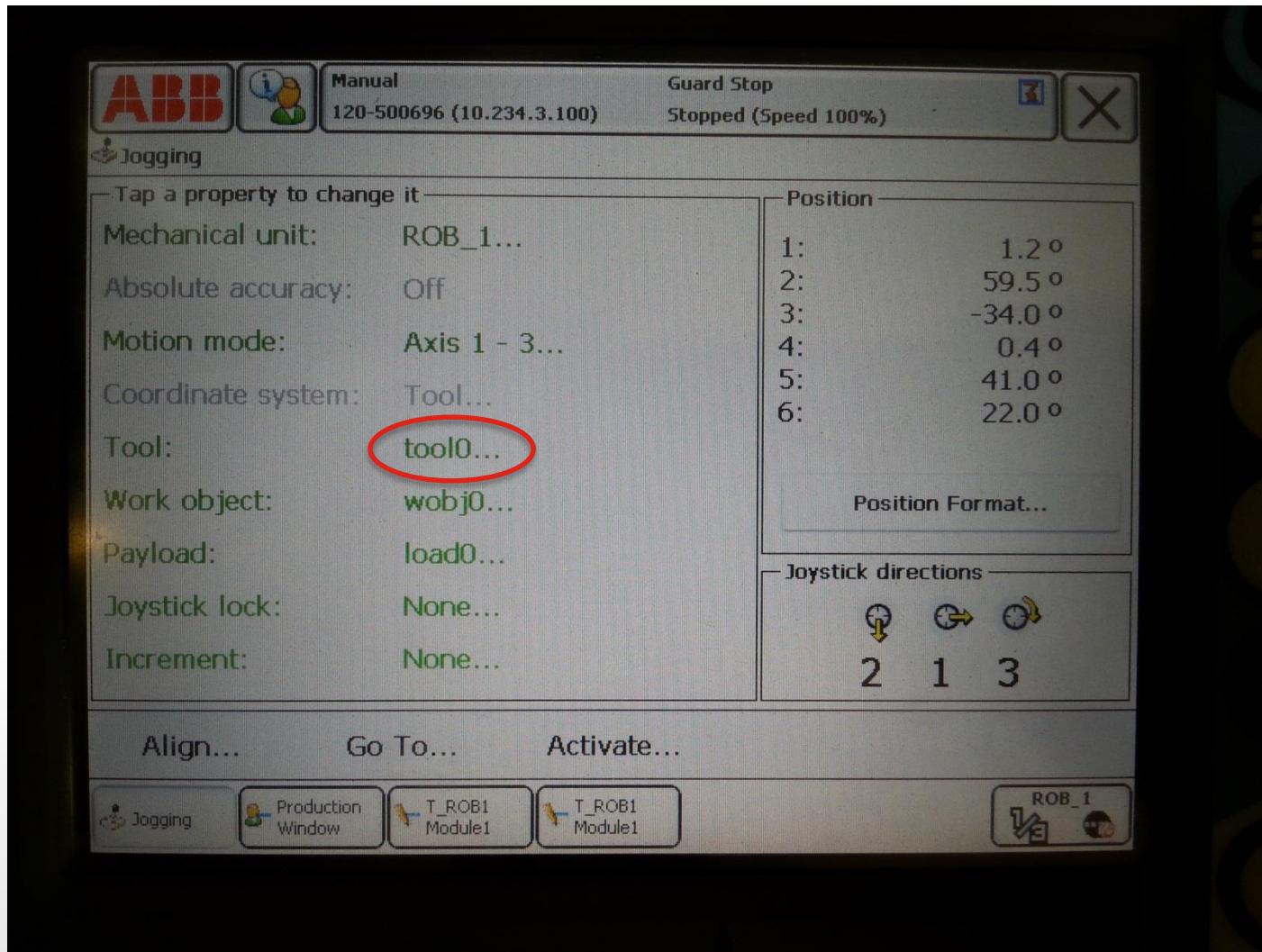
Create Sharp-Tipped Tool Frame

- On the teaching pendant, press “Jogging”



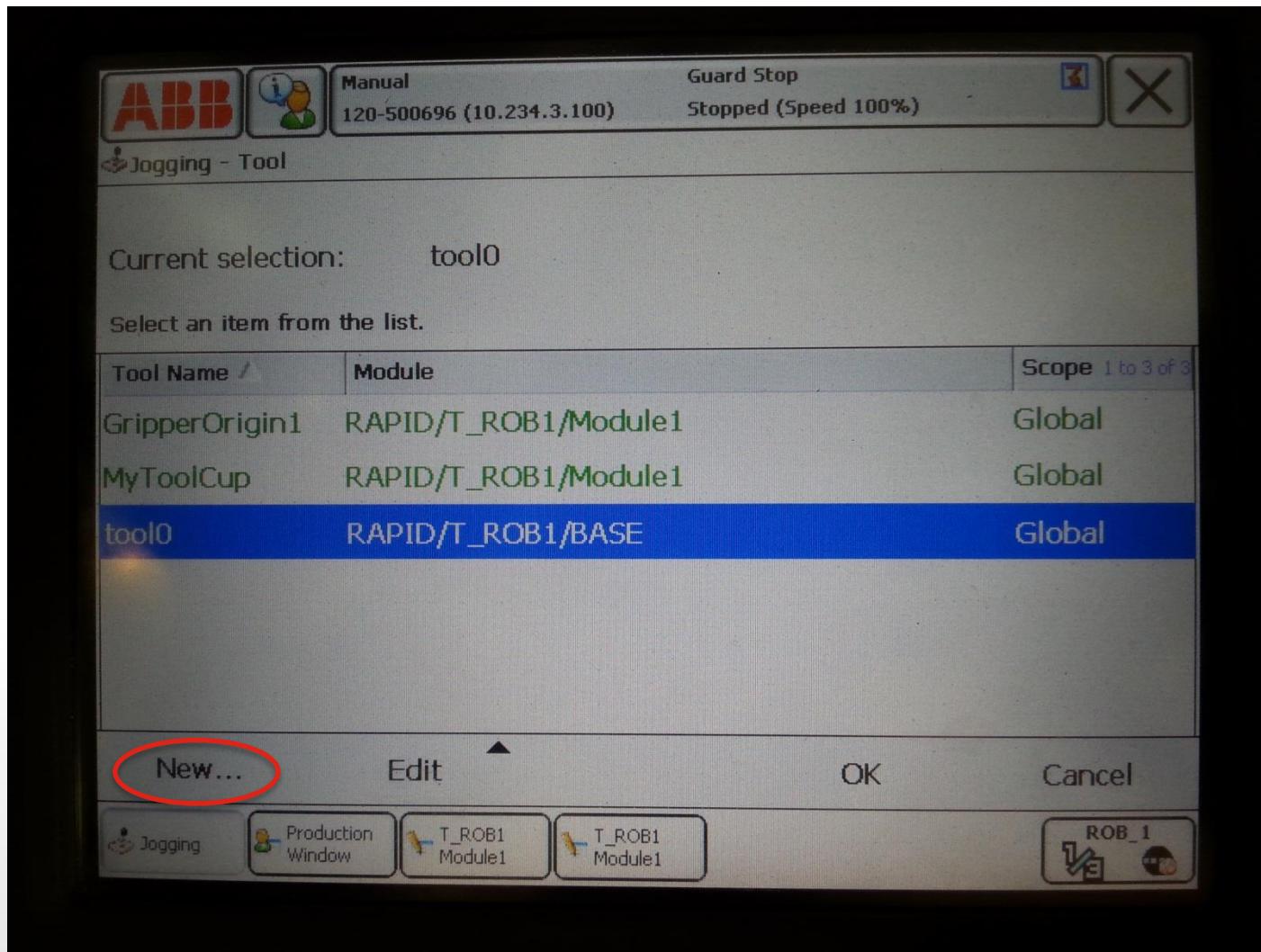
Create Sharp-Tipped Tool Frame

- Click “tool0” on the screen.



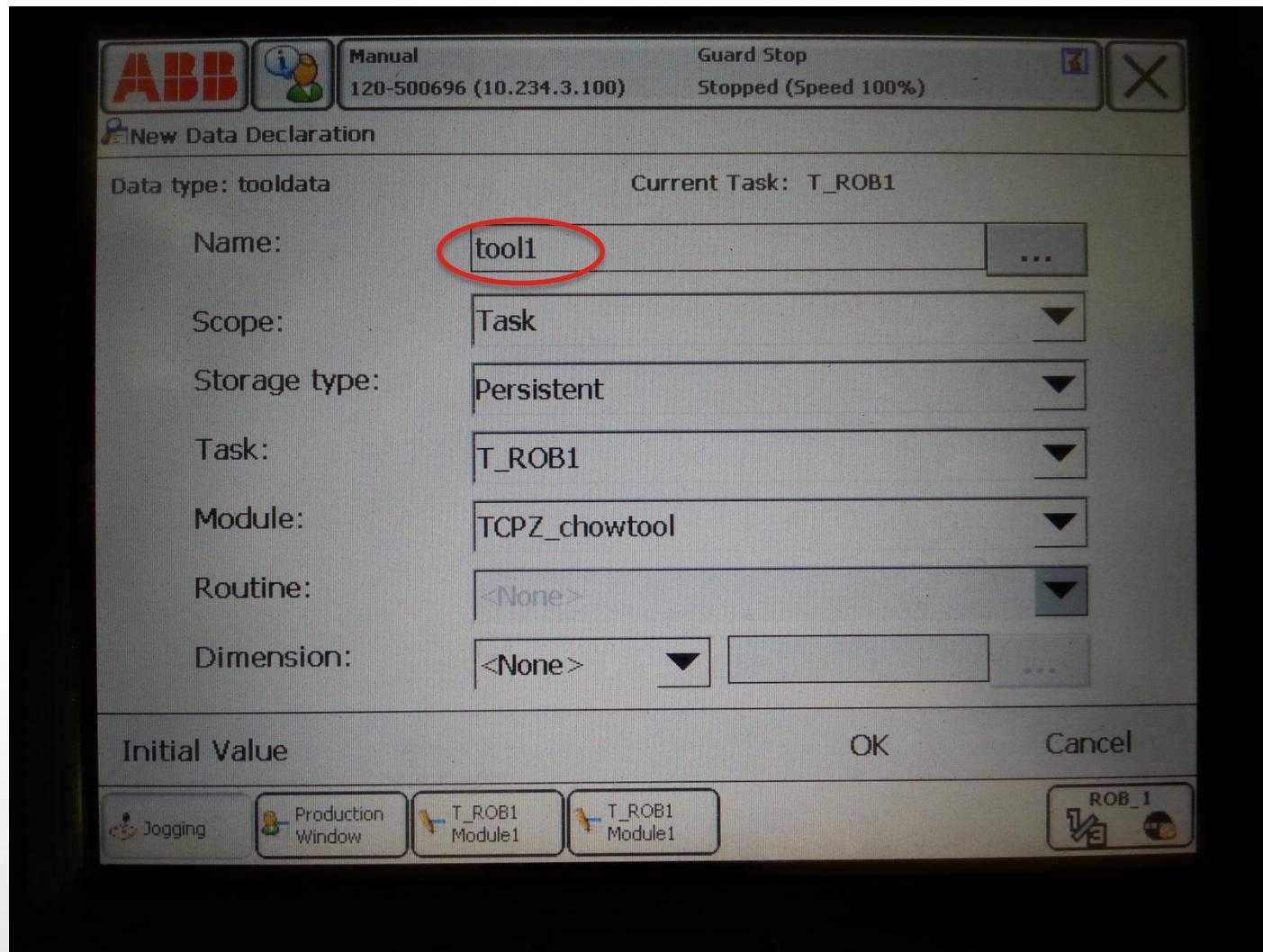
Create Sharp-Tipped Tool Frame

- We will reach the next screen. Click “**New**” to create a new tool.



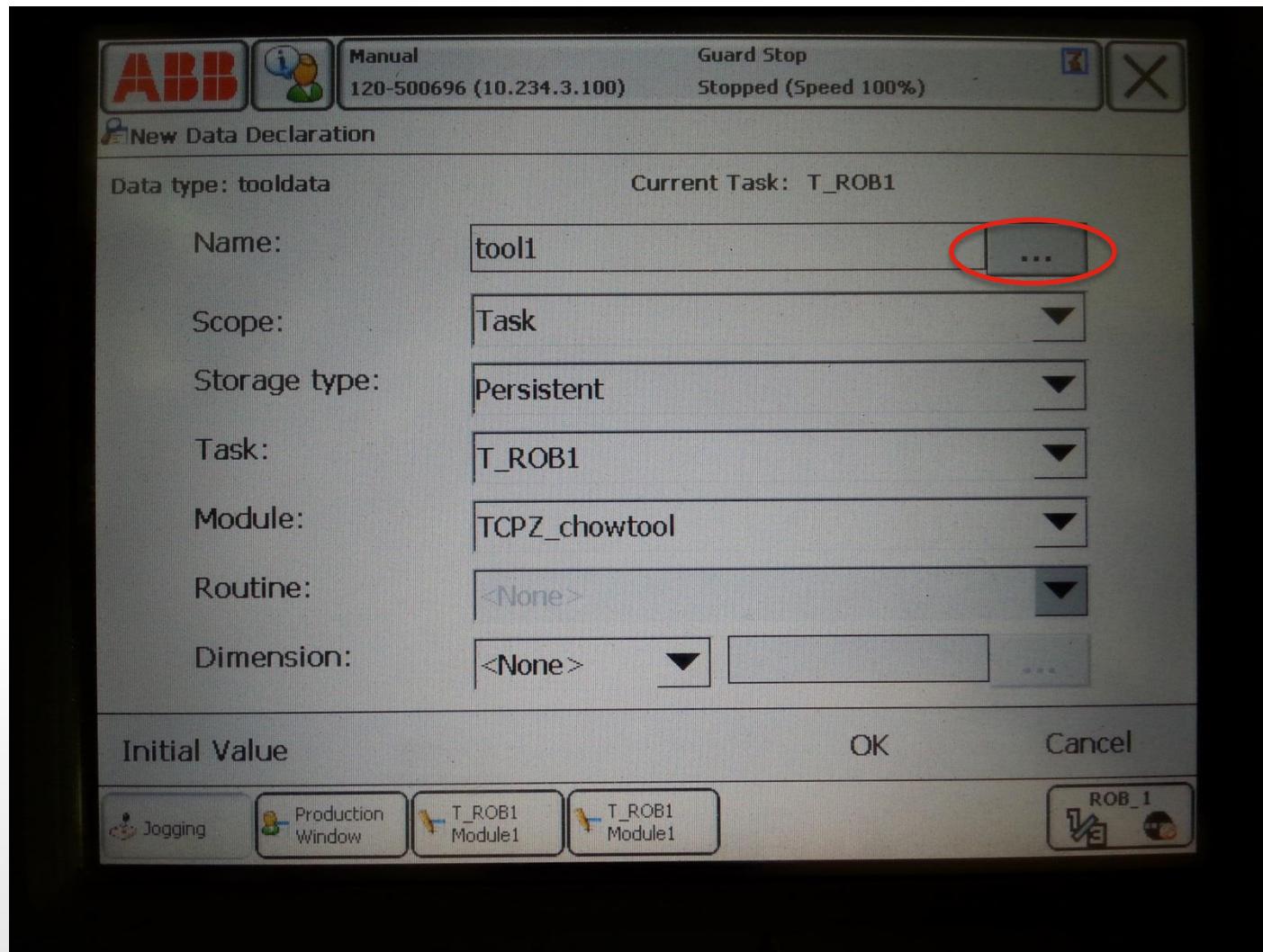
Create Sharp-Tipped Tool Frame

- In the new screen, the tool name is by default tool#.



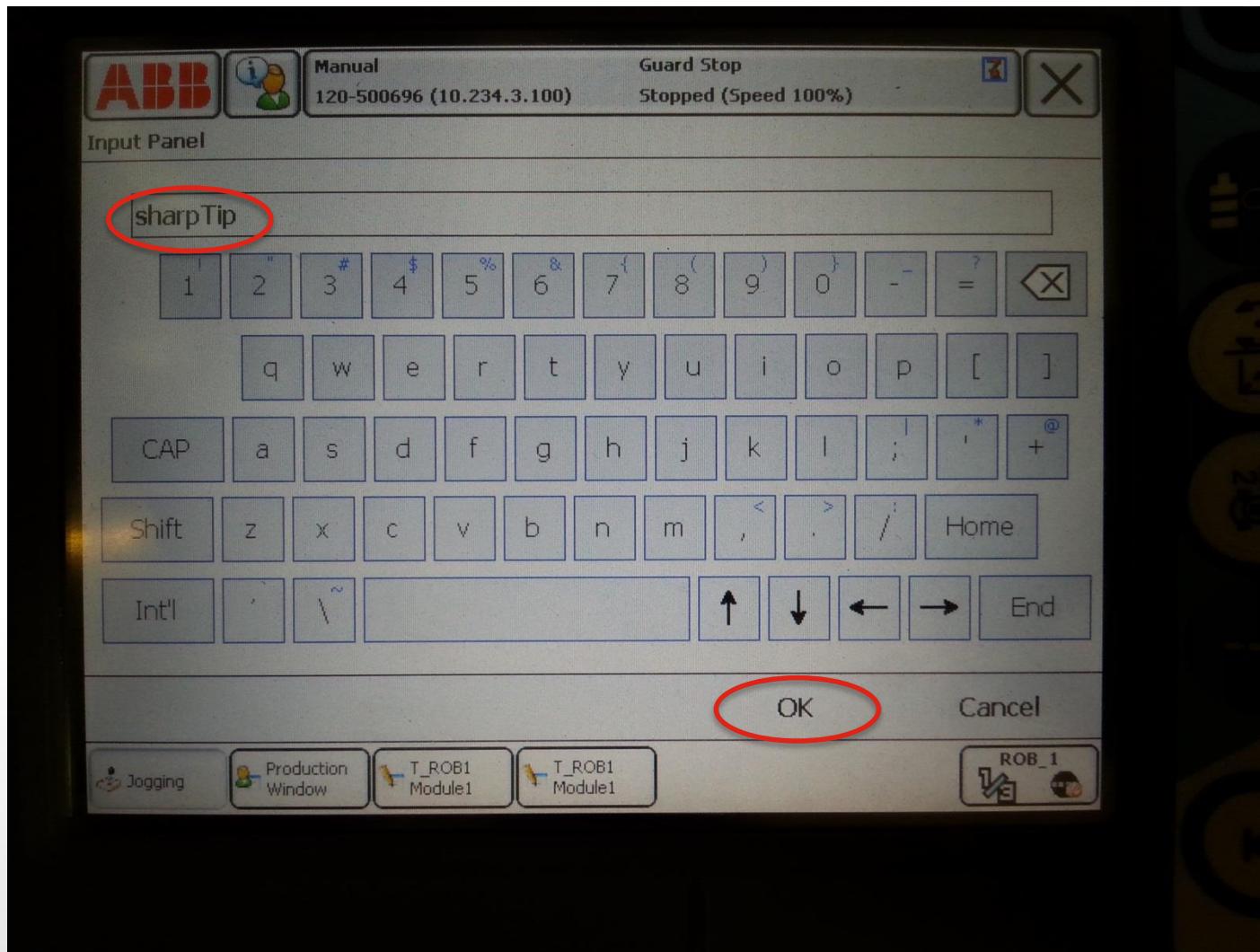
Create Sharp-Tipped Tool Frame

- We want to change the name to be more meaningful. Click the “...” button.



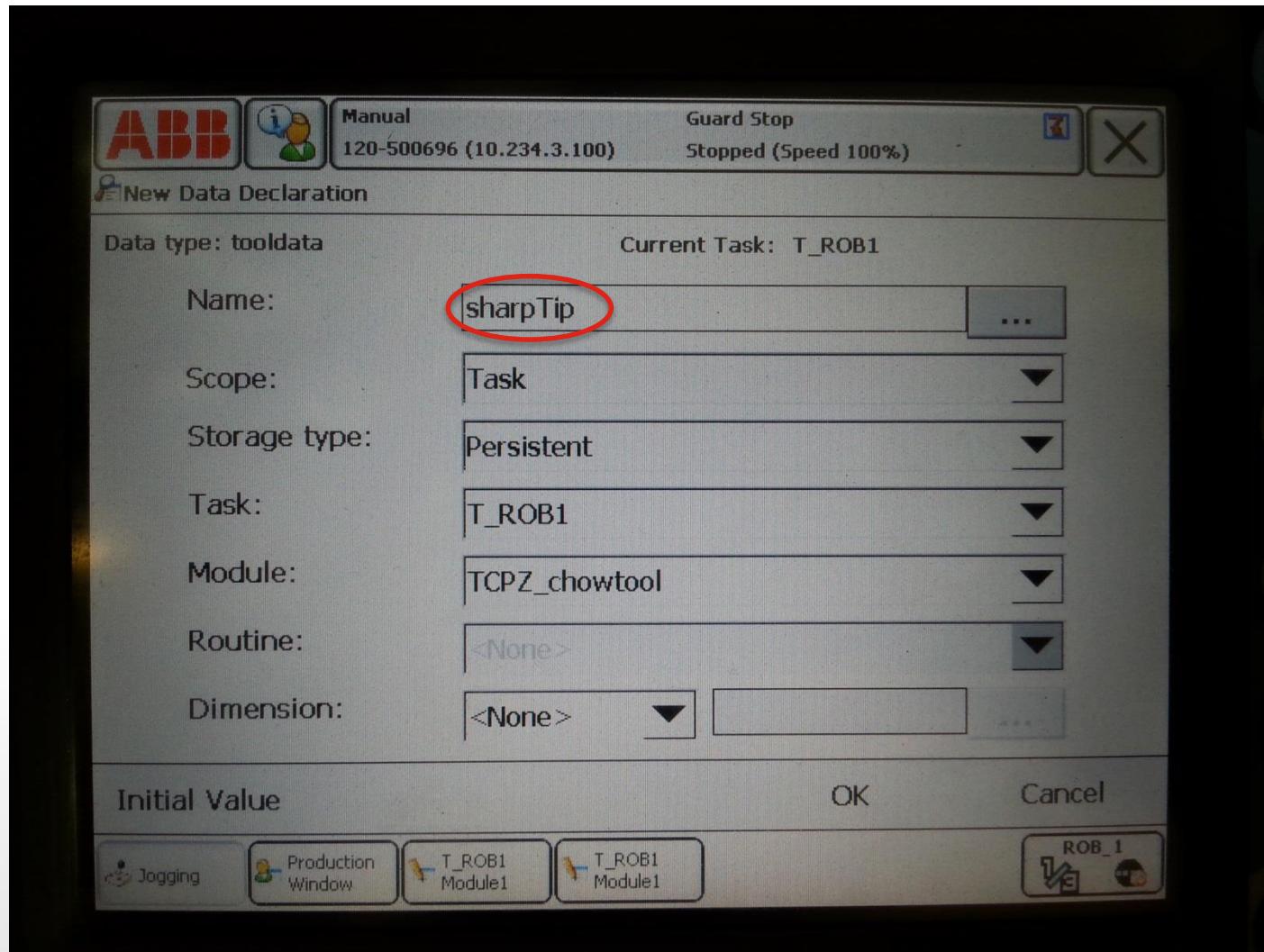
Create Sharp-Tipped Tool Frame

- Type in a name, and click “OK”.



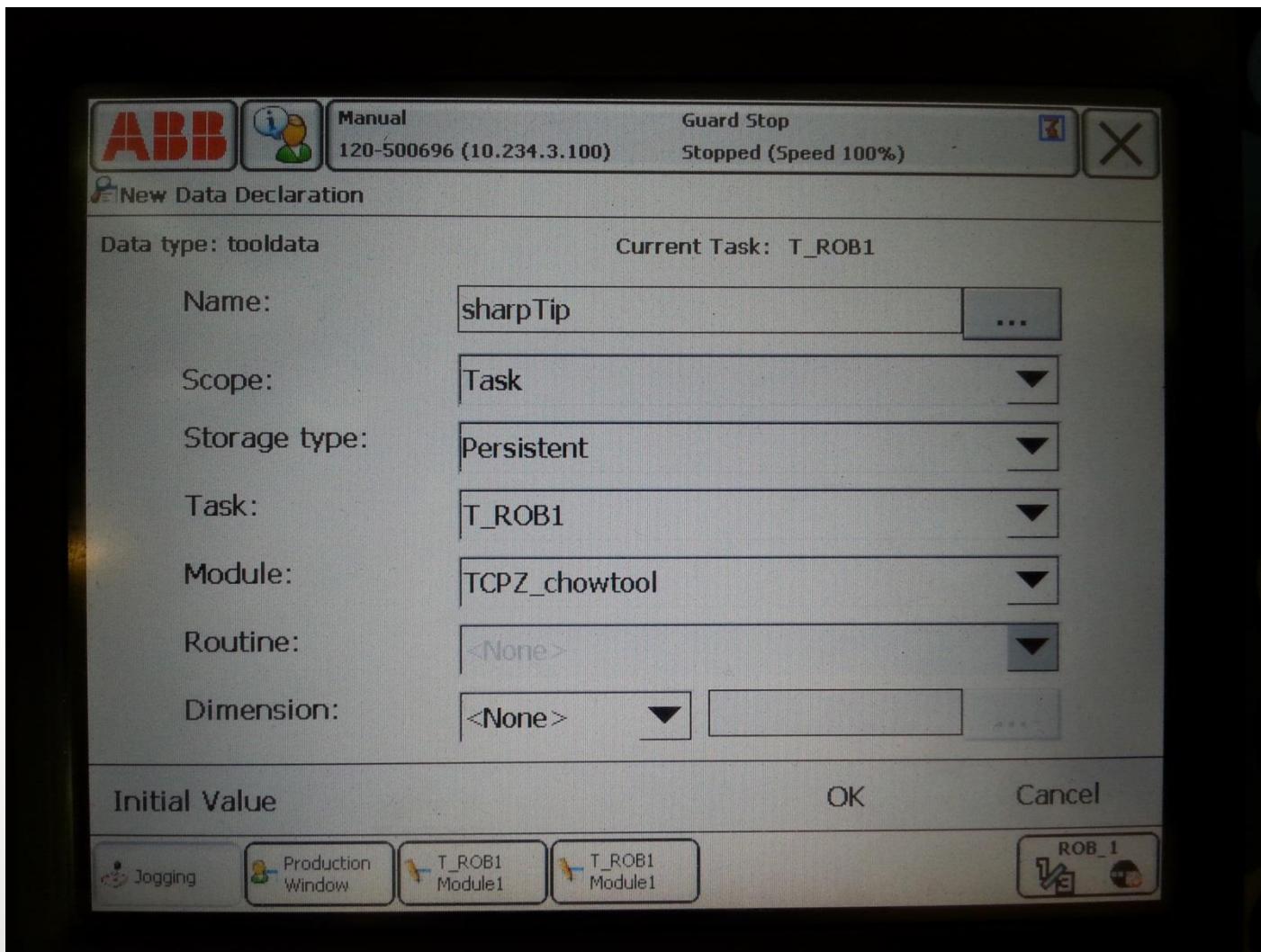
Create Sharp-Tipped Tool Frame

- The tool name is now updated.



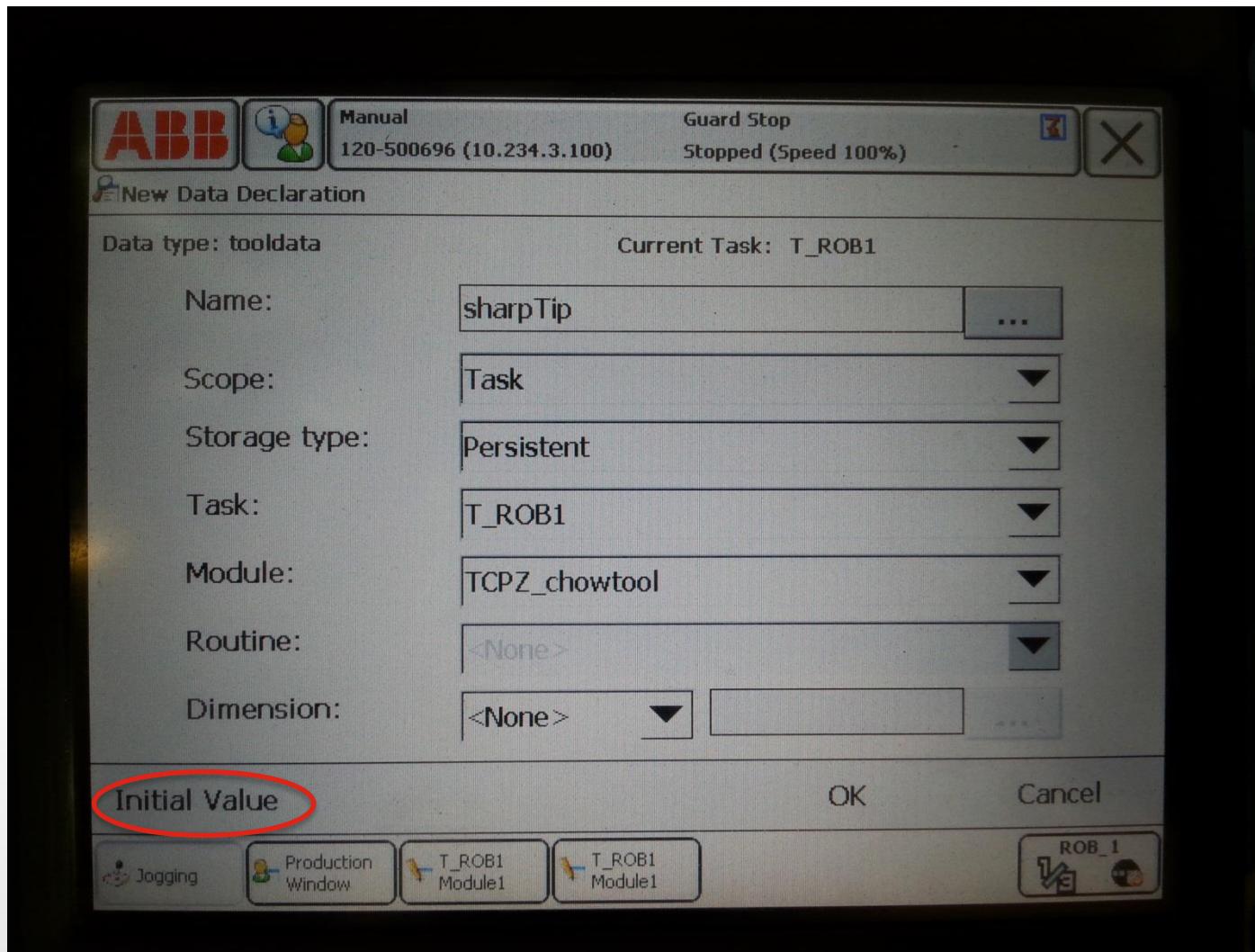
Create Sharp-Tipped Tool Frame

- Next, we need to provide the **mass** of the tool. This is important so that the robot knows what current/torque to provide to move the tool.



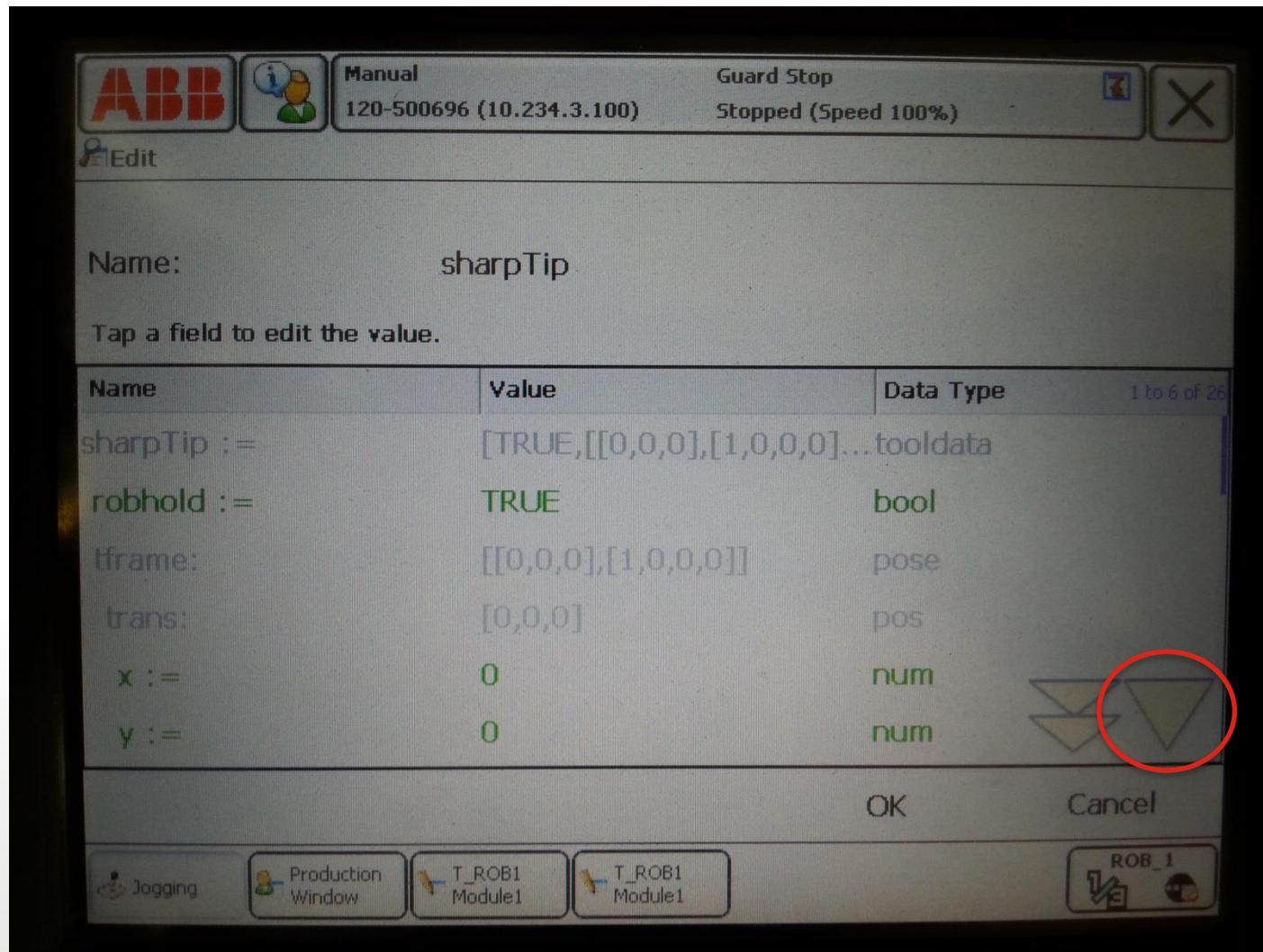
Create Sharp-Tipped Tool Frame

- Click “Initial Value”.



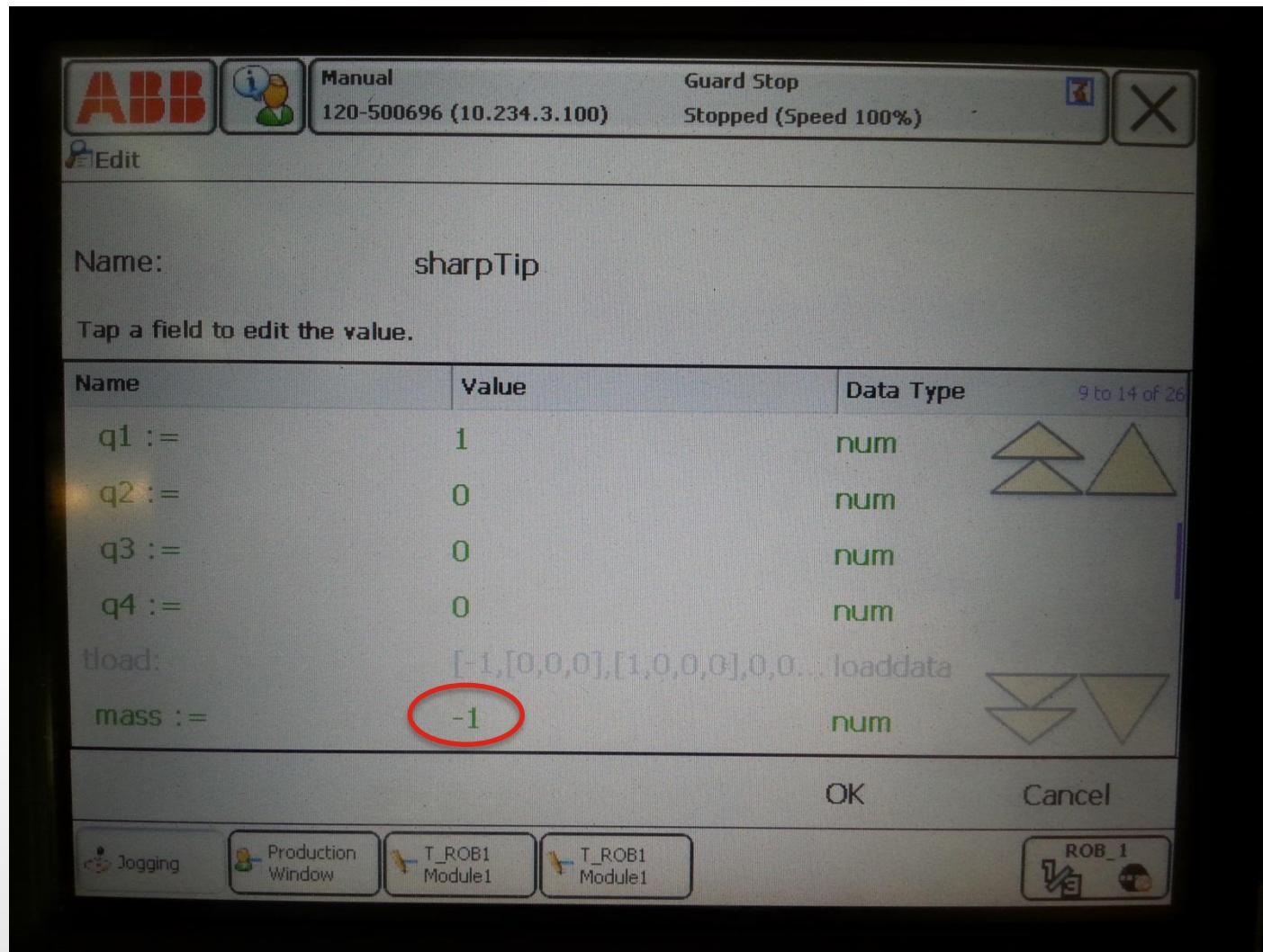
Create Sharp-Tipped Tool Frame

- The initial values are now shown. Click the arrow to move to the bottom.



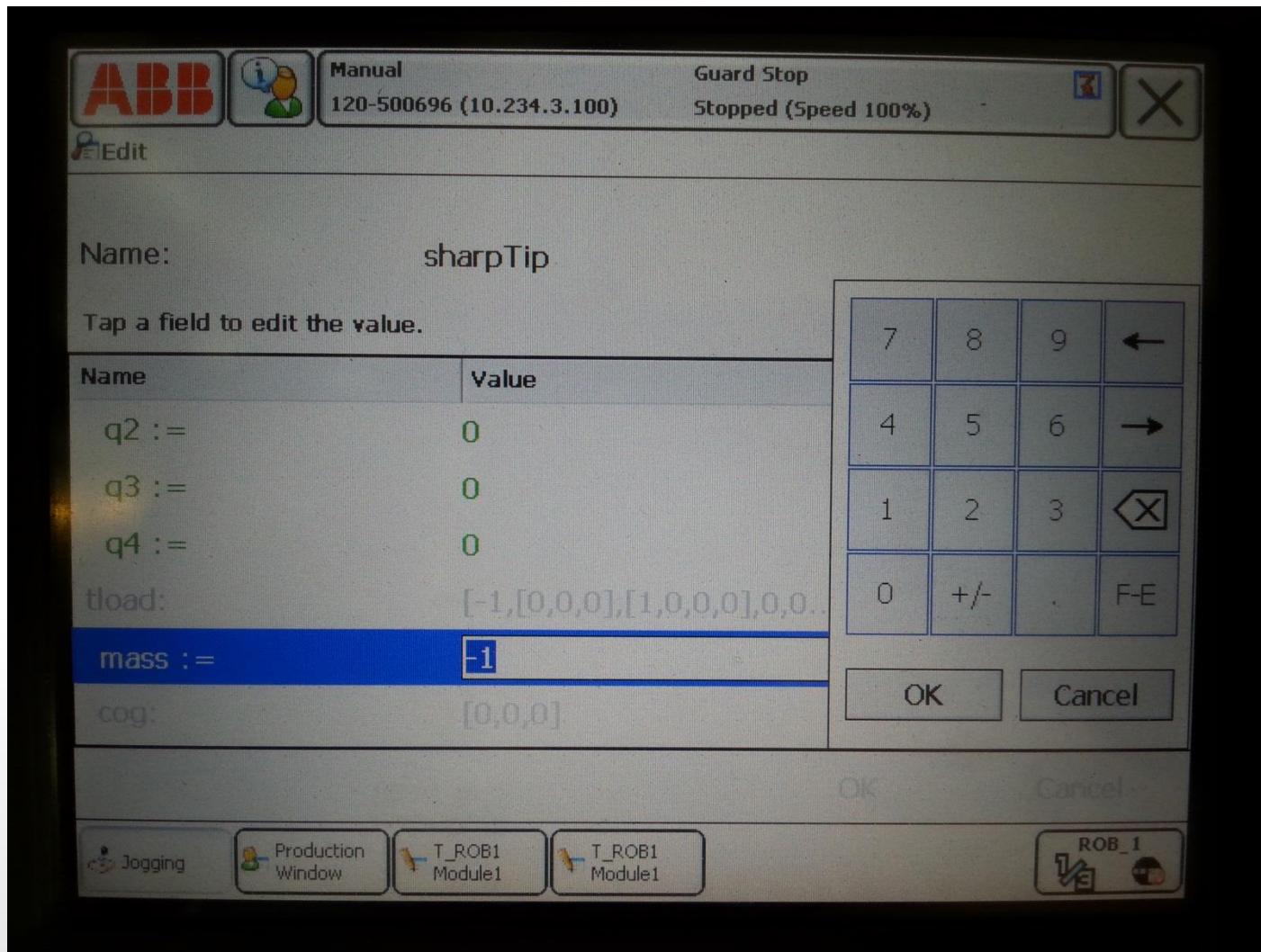
Create Sharp-Tipped Tool Frame

- The tool mass is shown as “-1” at the moment. We **need to change** this.



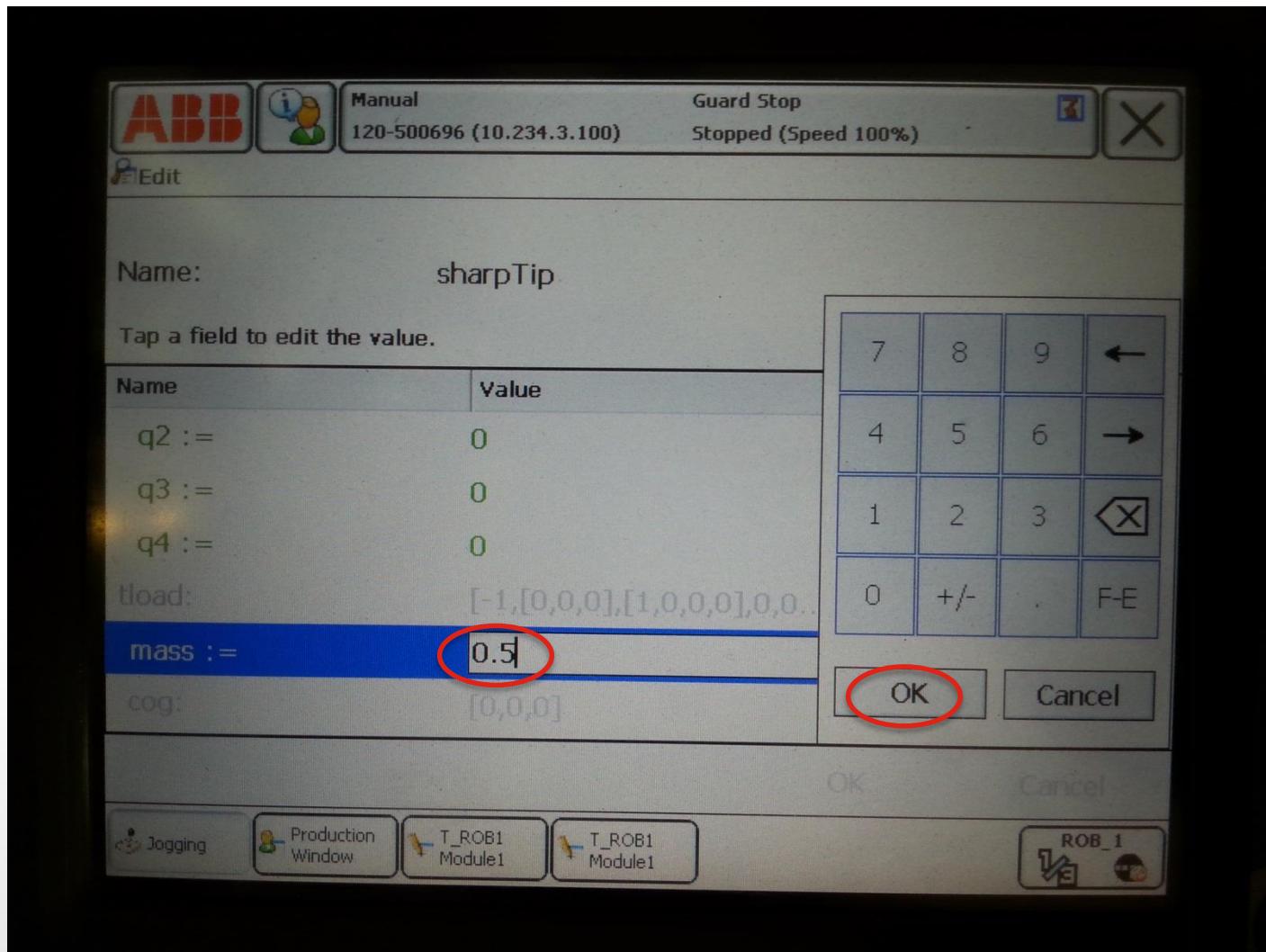
Create Sharp-Tipped Tool Frame

- Click “-1” and a key pad will appear.



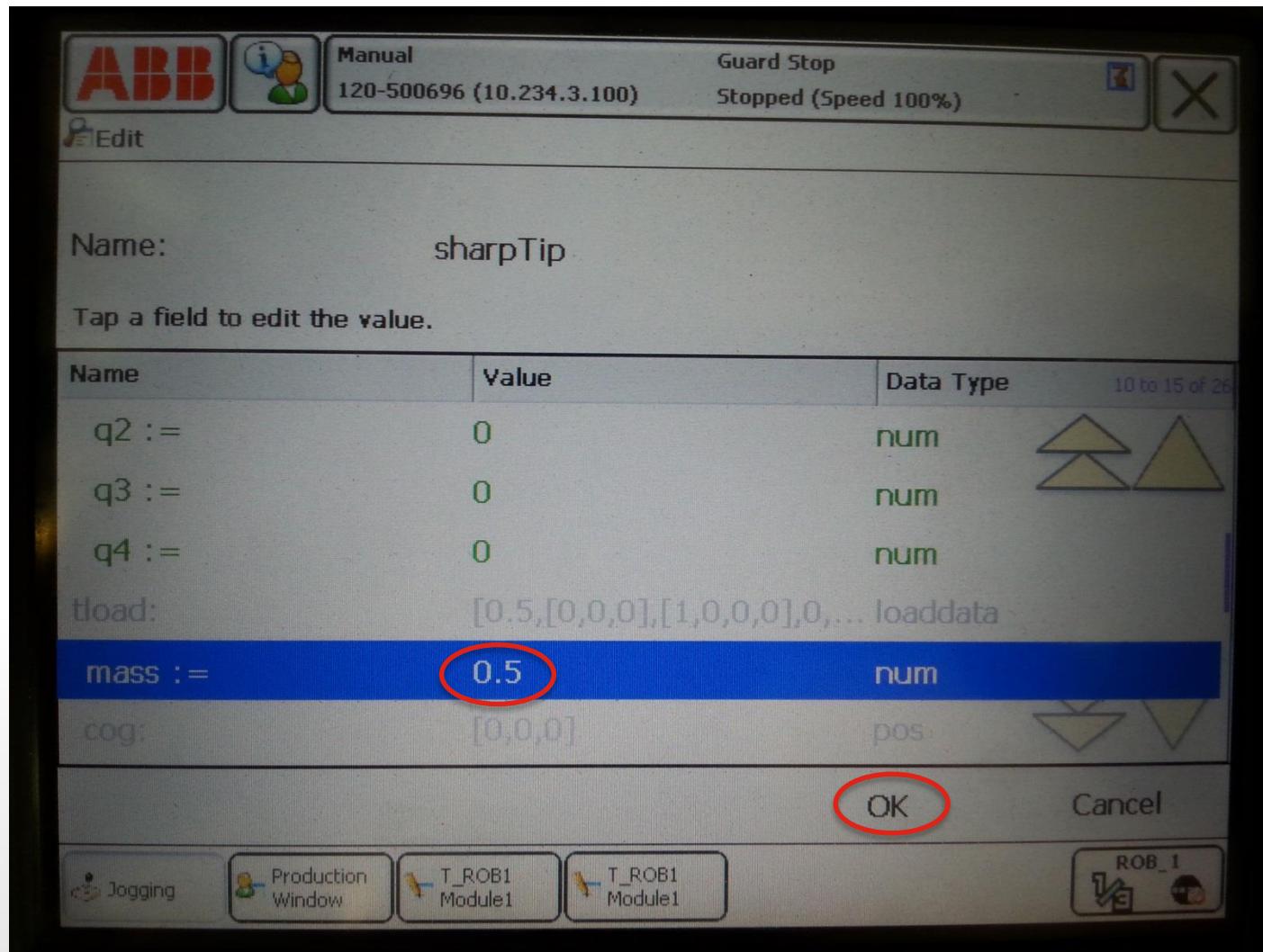
Create Sharp-Tipped Tool Frame

- Enter a reasonable value (or measured value) then click OK.



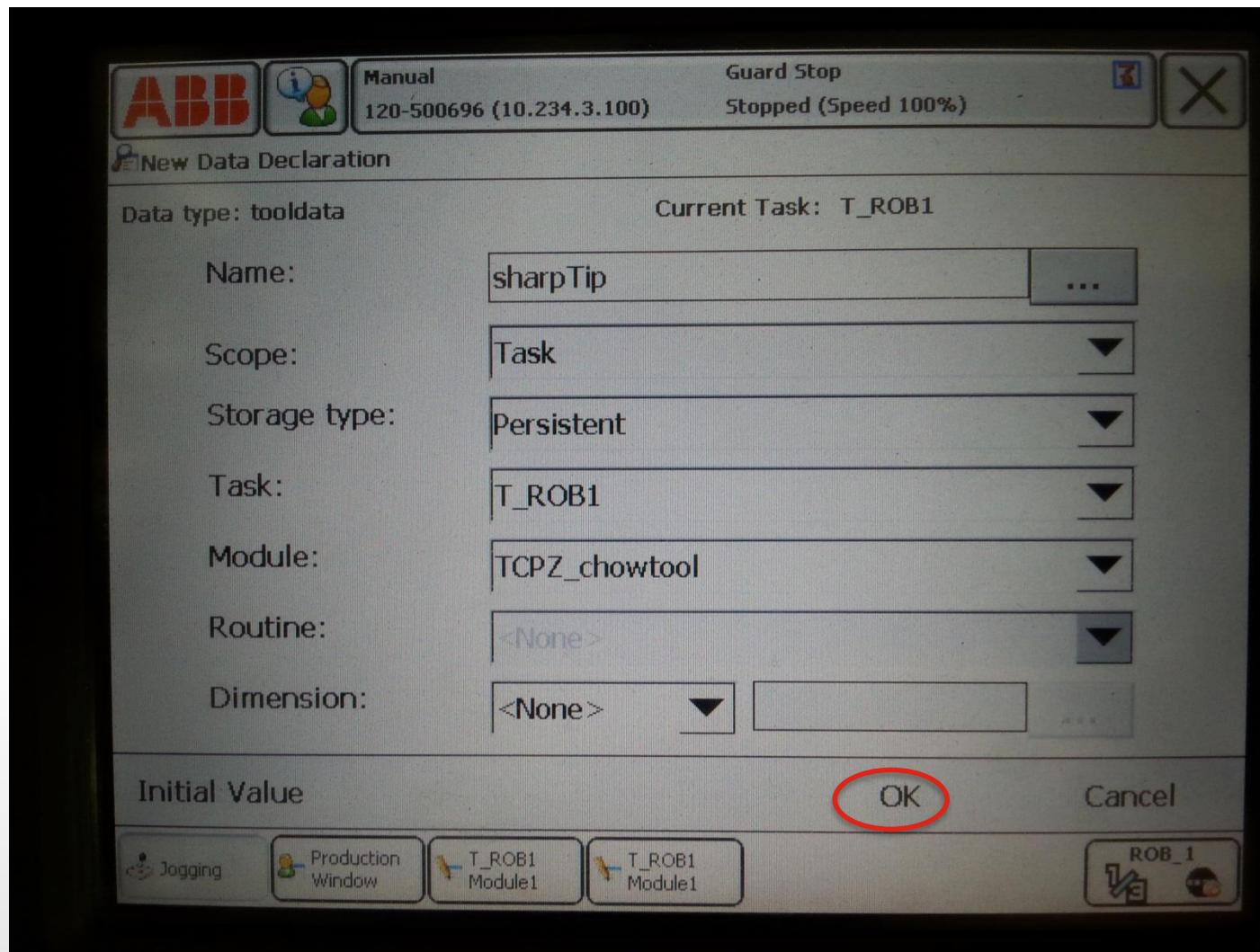
Create Sharp-Tipped Tool Frame

- Now the tool mass is updated. Click OK to exit.



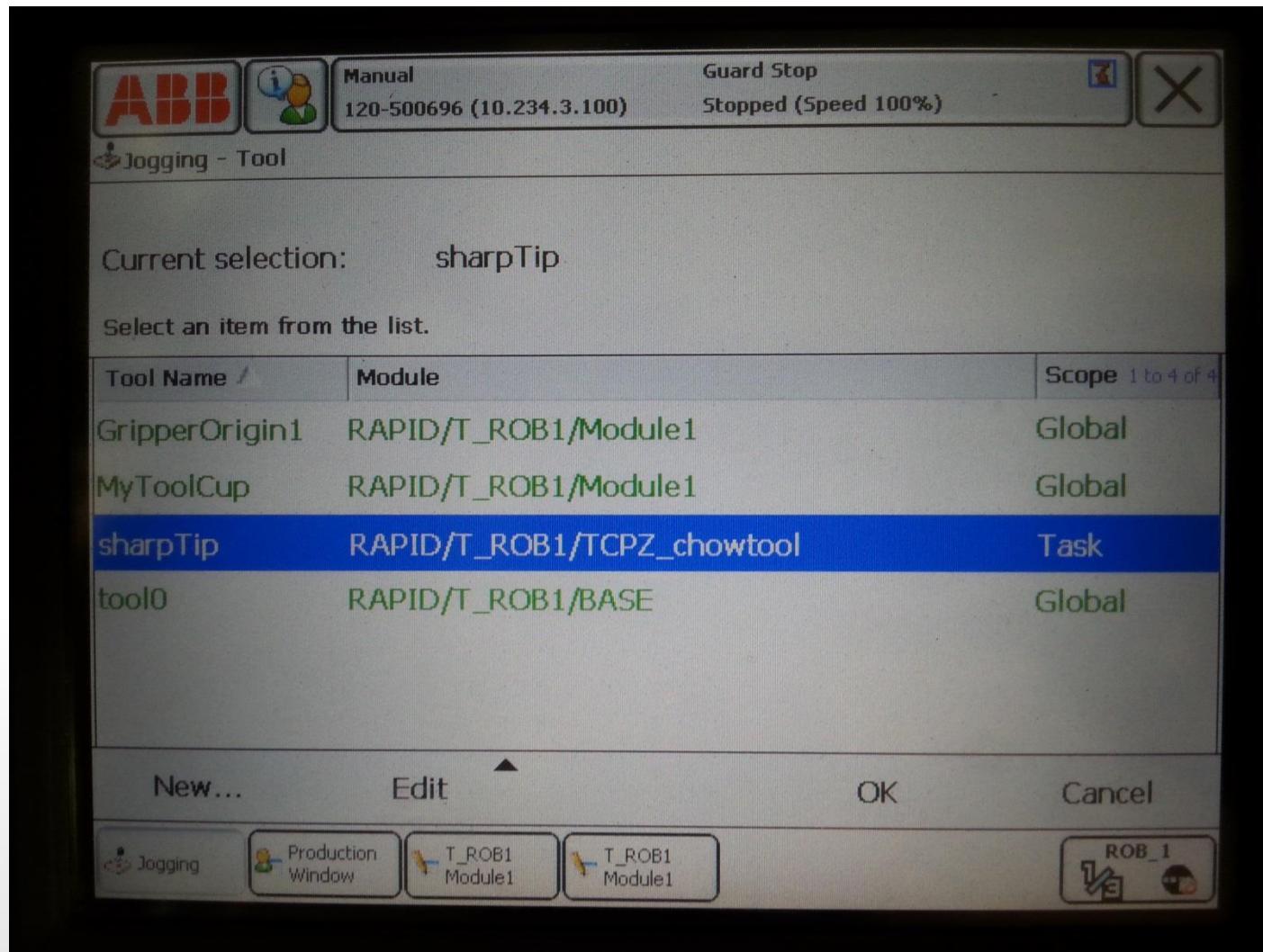
Create Sharp-Tipped Tool Frame

- Click OK again on the following screen.



Create Sharp-Tipped Tool Frame

- Now the sharpTip is in the list of tools.

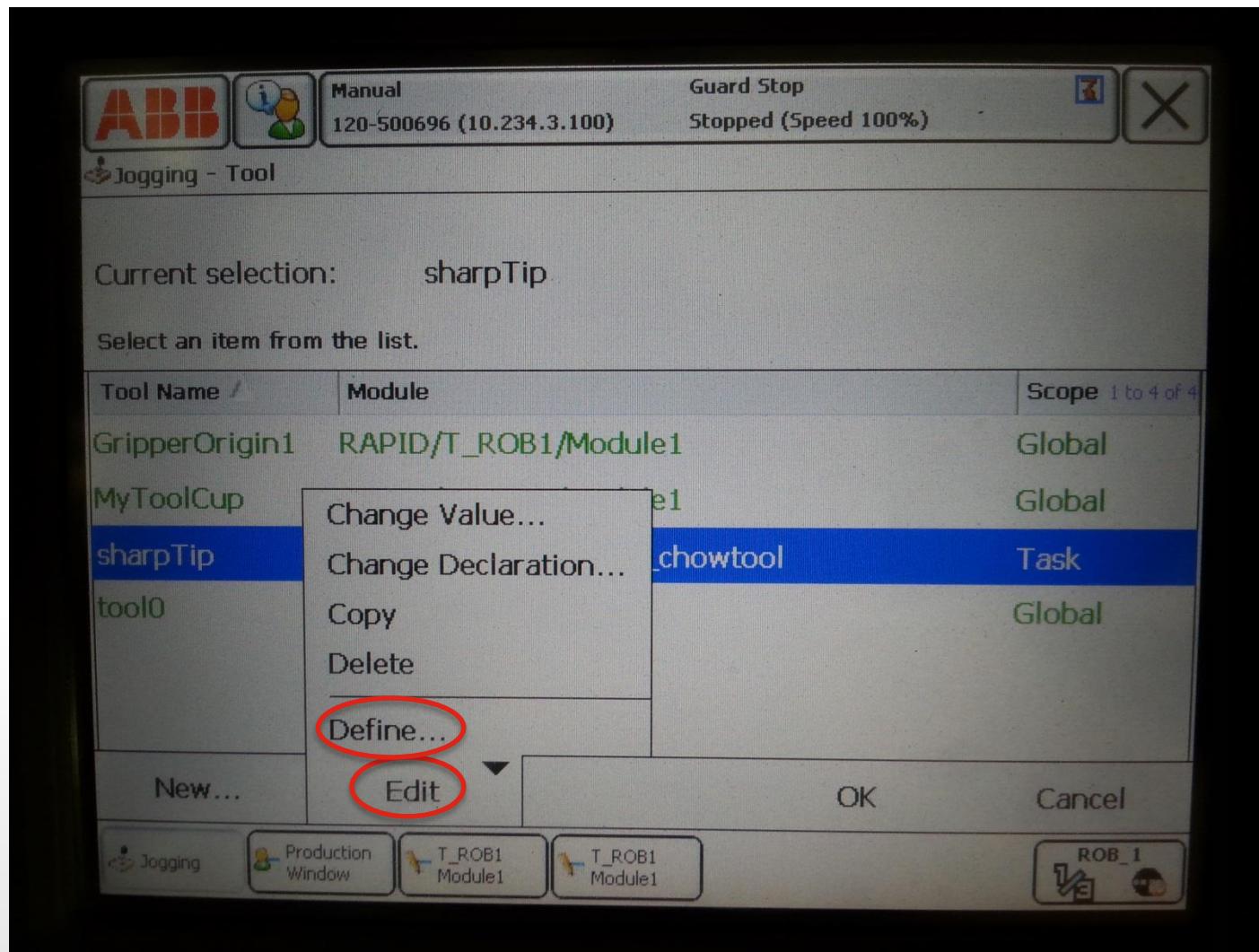


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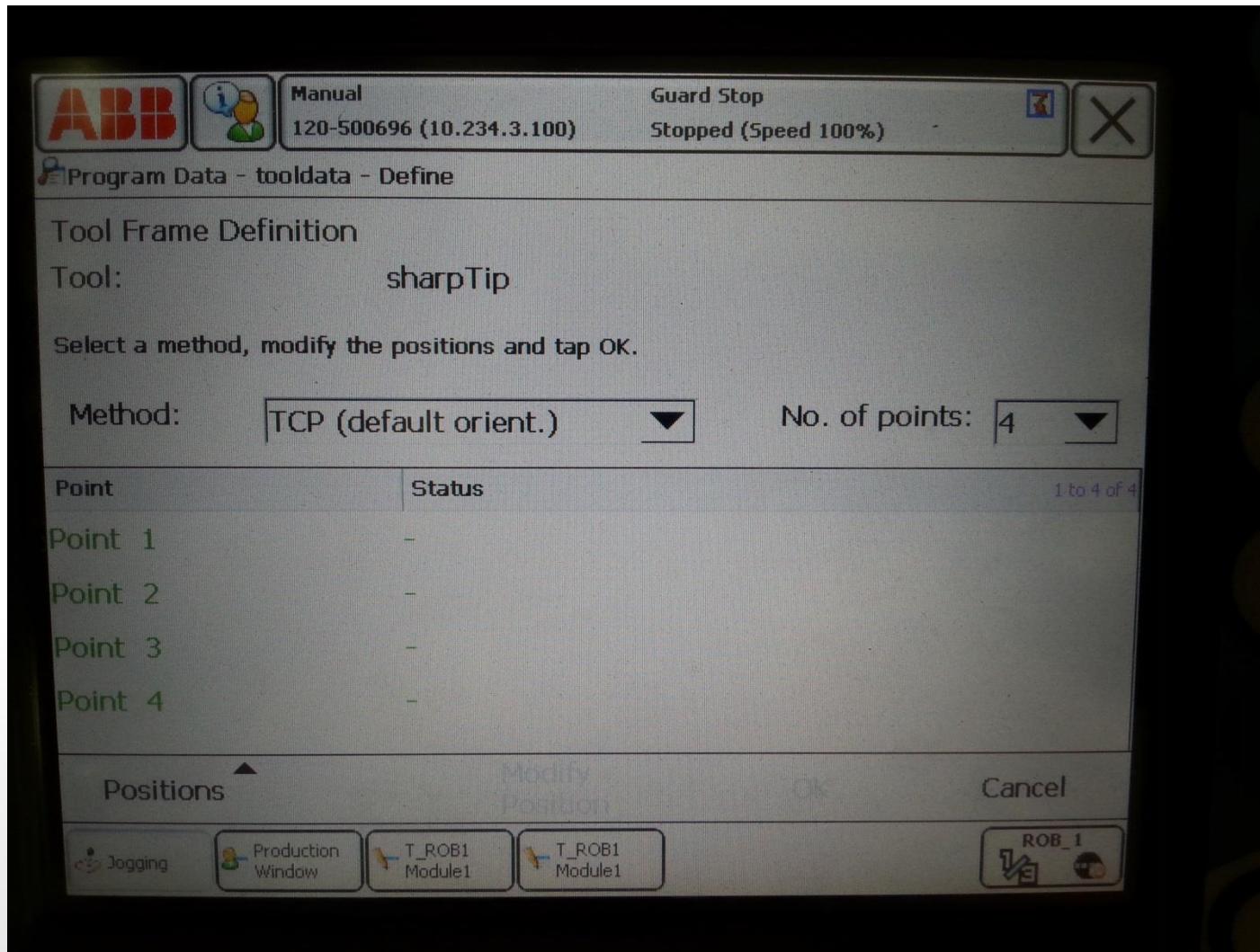
Calibrate Sharp-Tipped Tool

- We are now ready to **calibrate** sharpTip. Click “Edit” then “Define”.



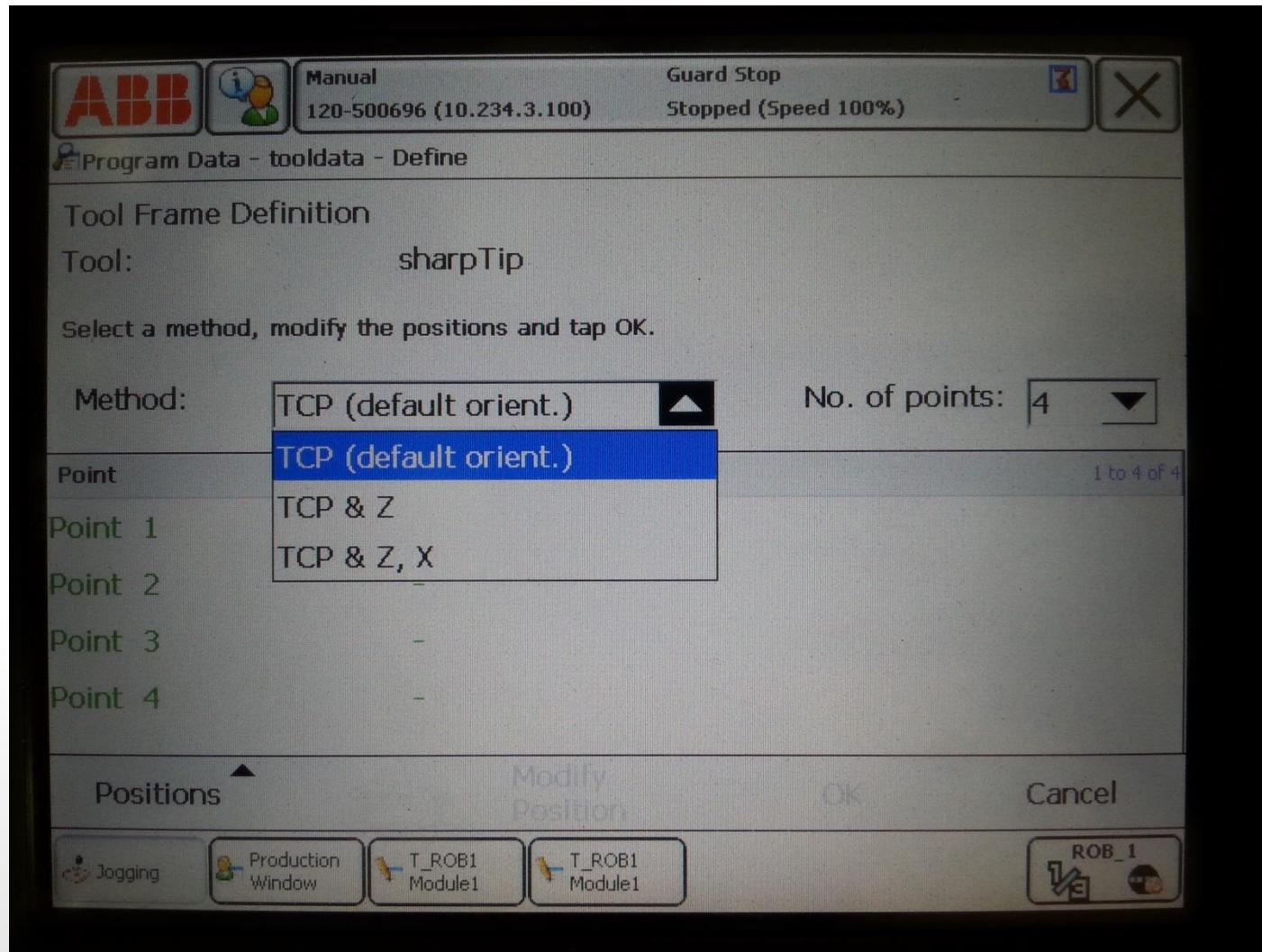
Calibrate Sharp-Tipped Tool

- We will see the following window.



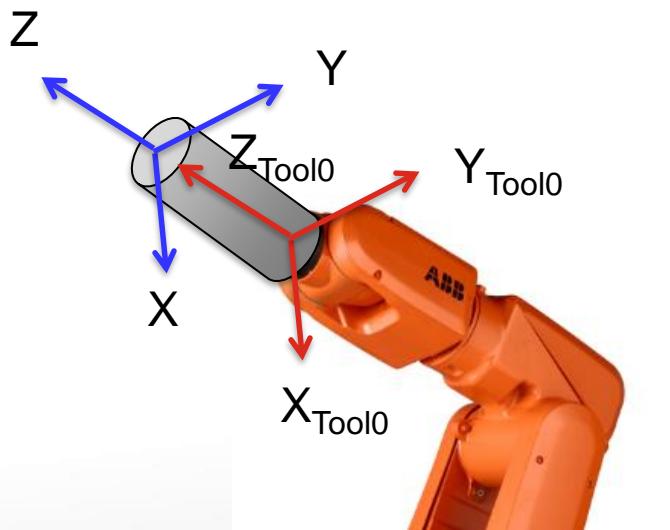
Calibrate Sharp-Tipped Tool

- There are several **options** for the calibration method.

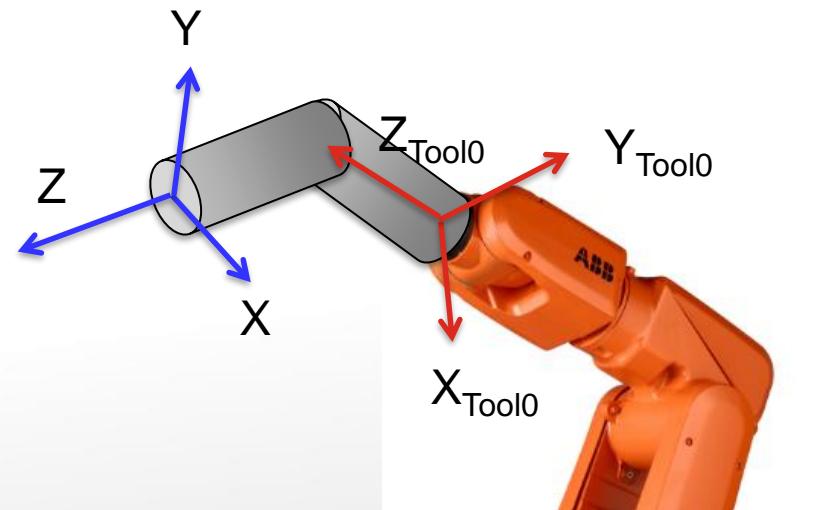


Calibrate Sharp-Tipped Tool

- TCP (default orientation) means that the orientation follows that of Tool0.
- TCP & Z means that Z-axis is user defined.
- TCP & Z, X means that Z-axis and X-axis are user defined.

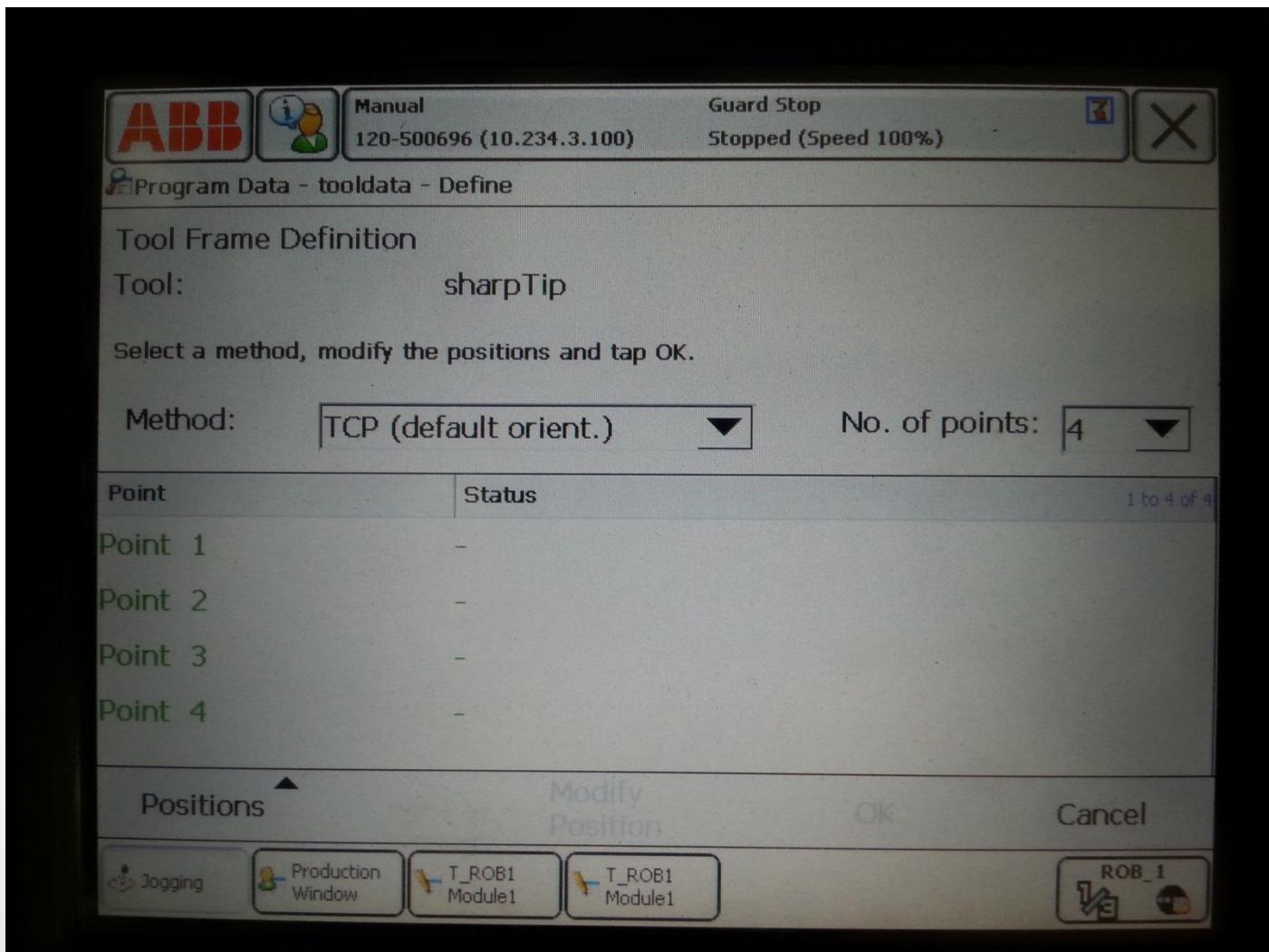


TCP (Default Orientation)



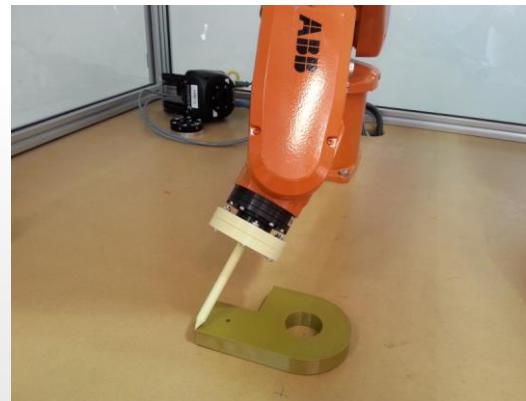
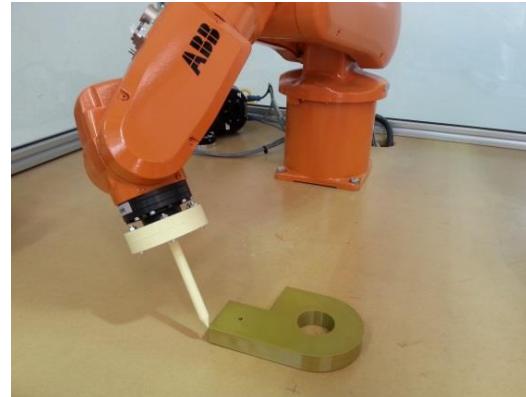
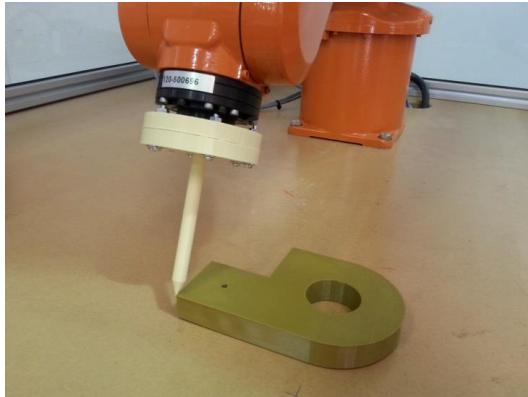
TCP & Z, or TCP & Z, X

Calibrate Sharp-Tipped Tool

- For the sharp tip, we select “TCP (Default Orientation)”.

Calibrate Sharp-Tipped Tool

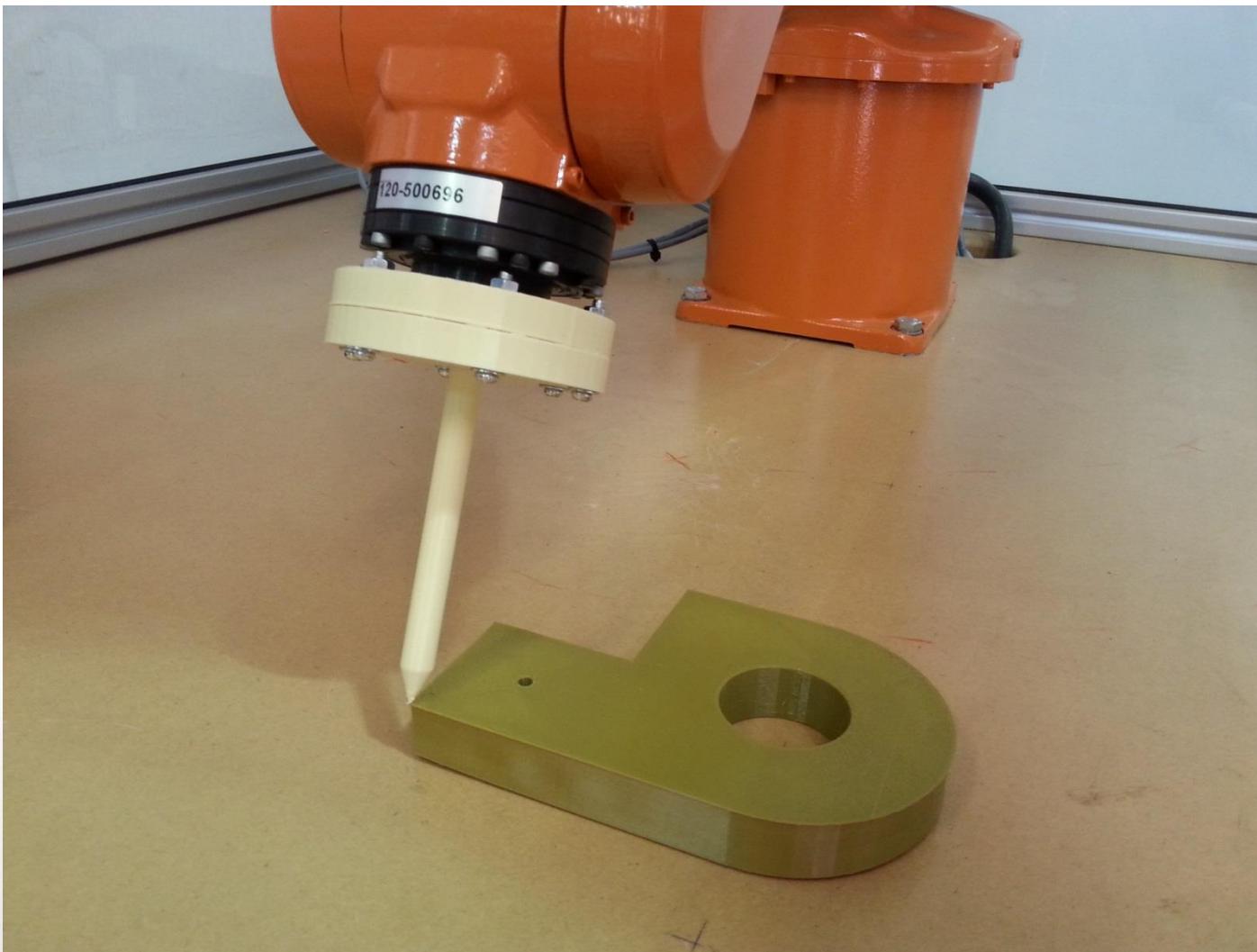
- The idea is to jog the robot to **one single point** but at four different orientations.
- Here we use the **corner of the object** as the target point.



- The robot will figure out where the end of tool is.

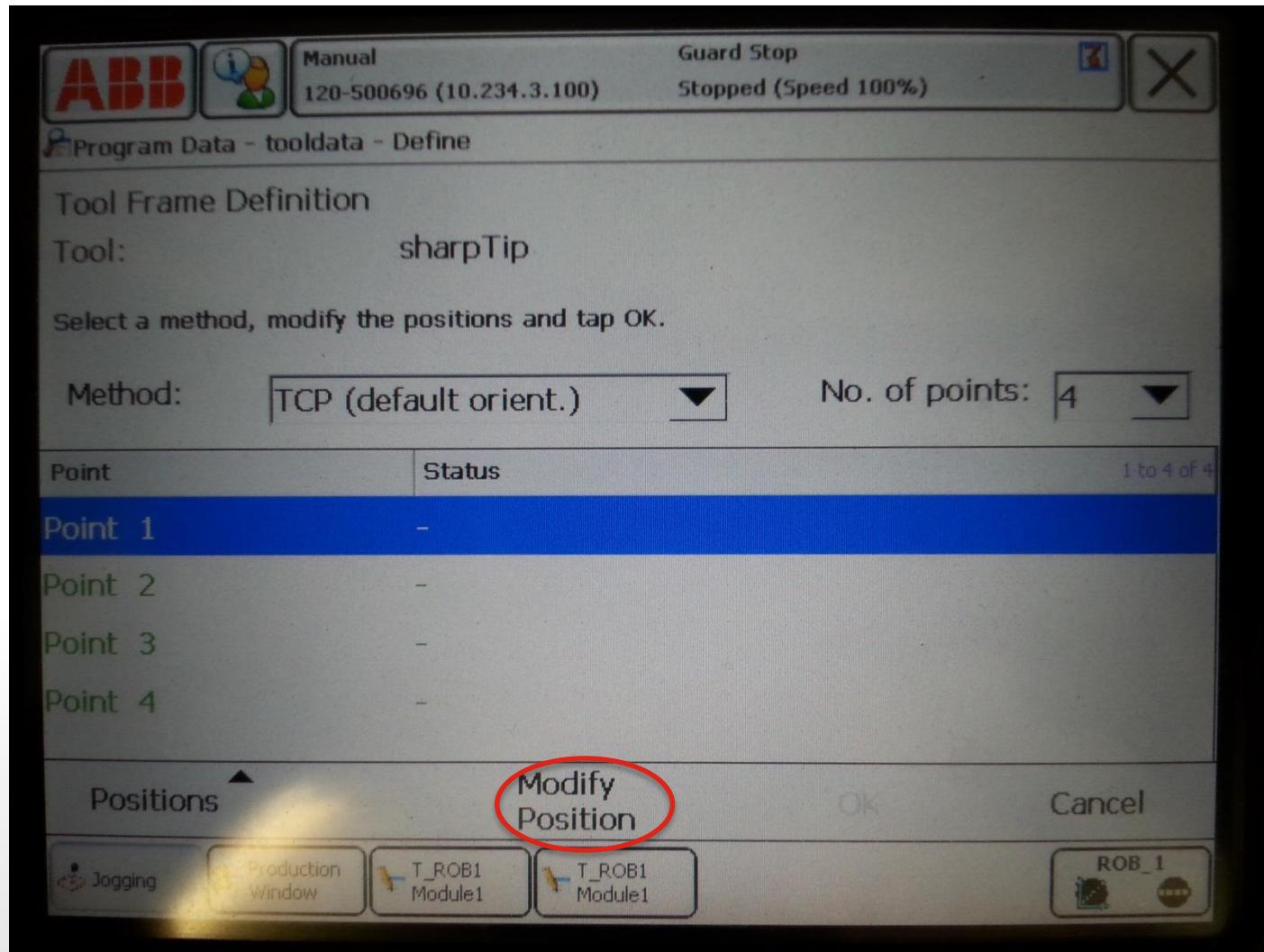
Calibrate Sharp-Tipped Tool

- Jog robot / sharpTip to the target point at the **first** orientation.



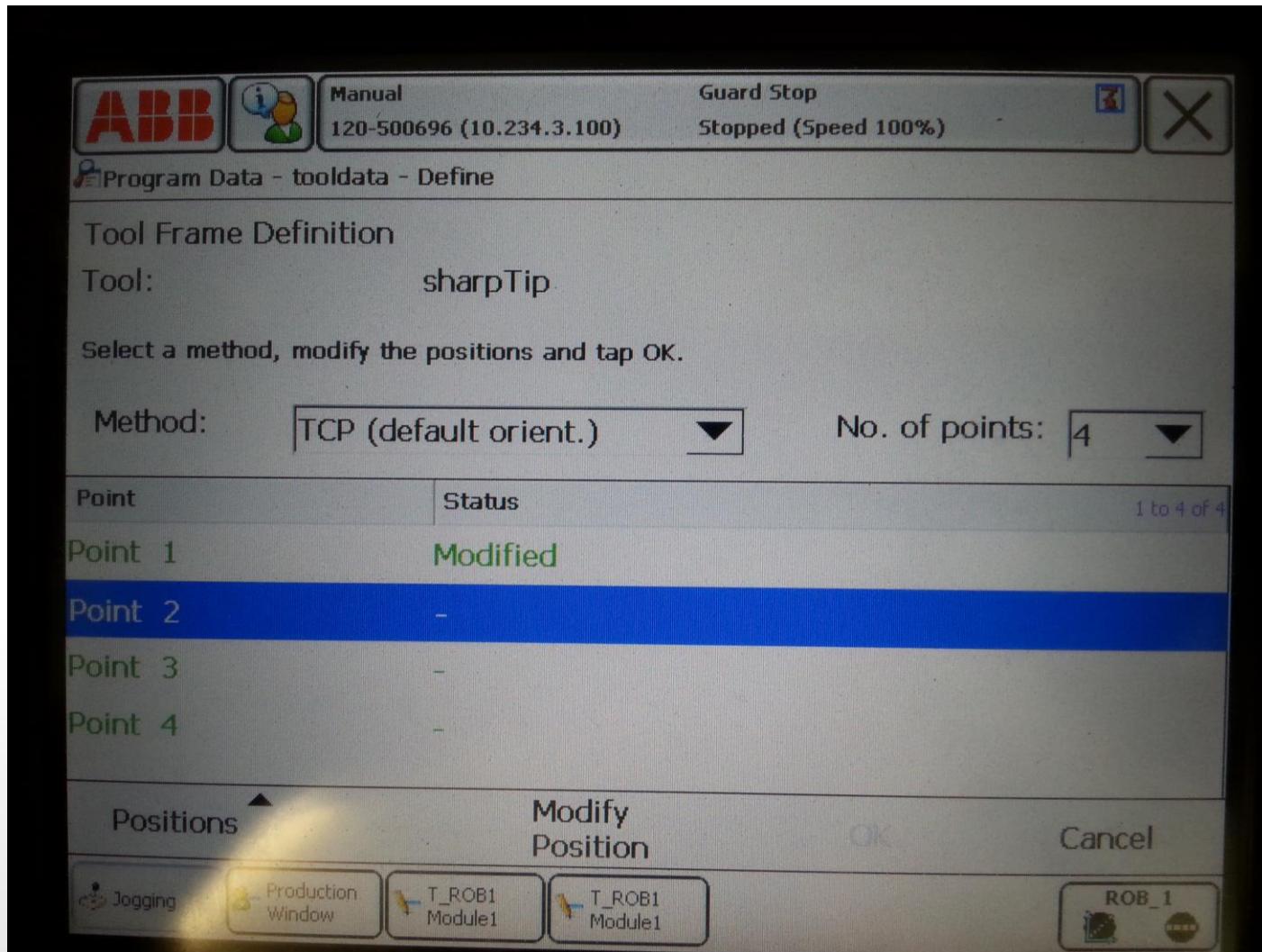
Calibrate Sharp-Tipped Tool

- On the teaching pendant, select Point 1 and click “Modify Position”.



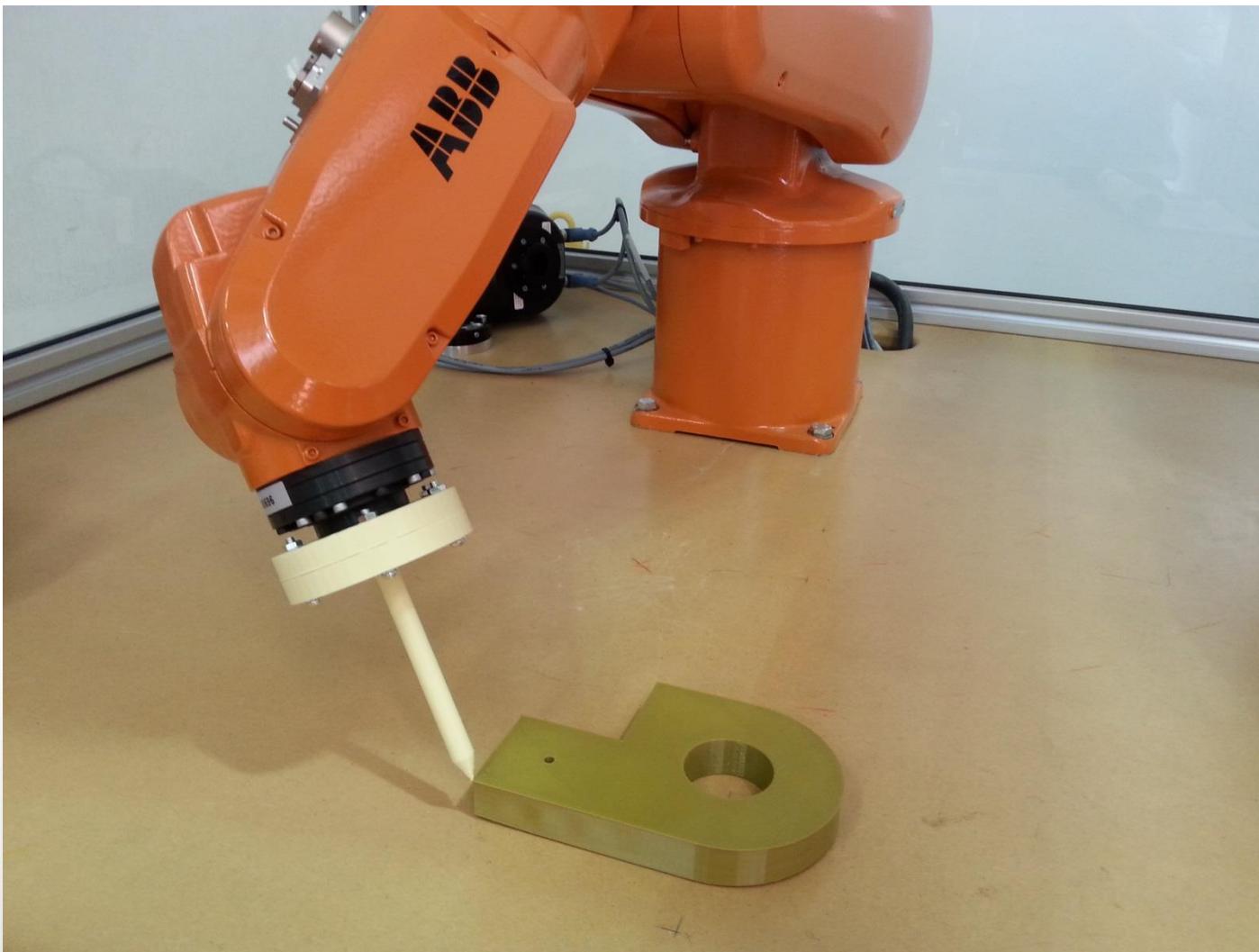
Calibrate Sharp-Tipped Tool

- Point 1 is now modified.



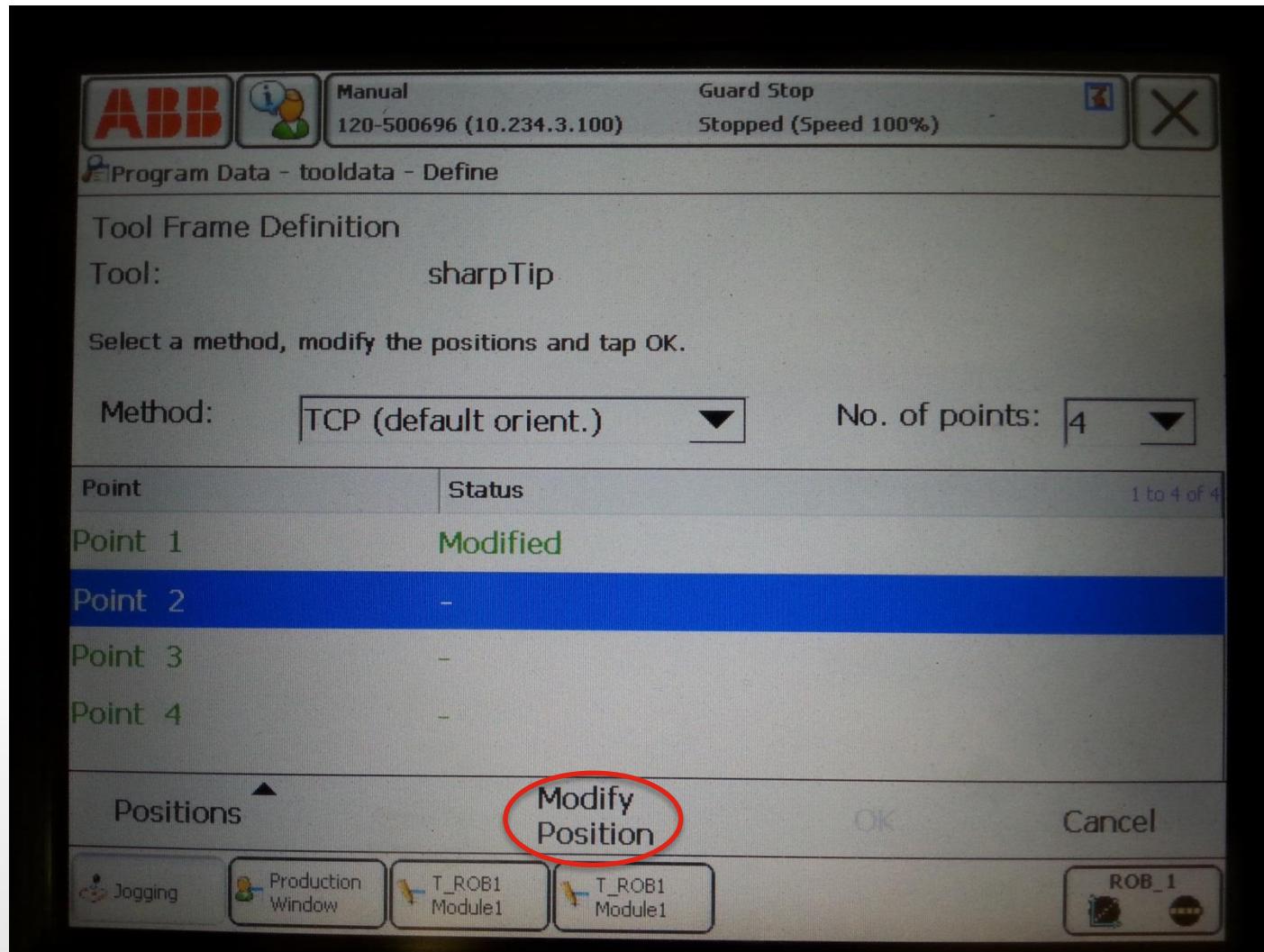
Calibrate Sharp-Tipped Tool

- Jog robot / sharpTip to the target point at the second orientation.



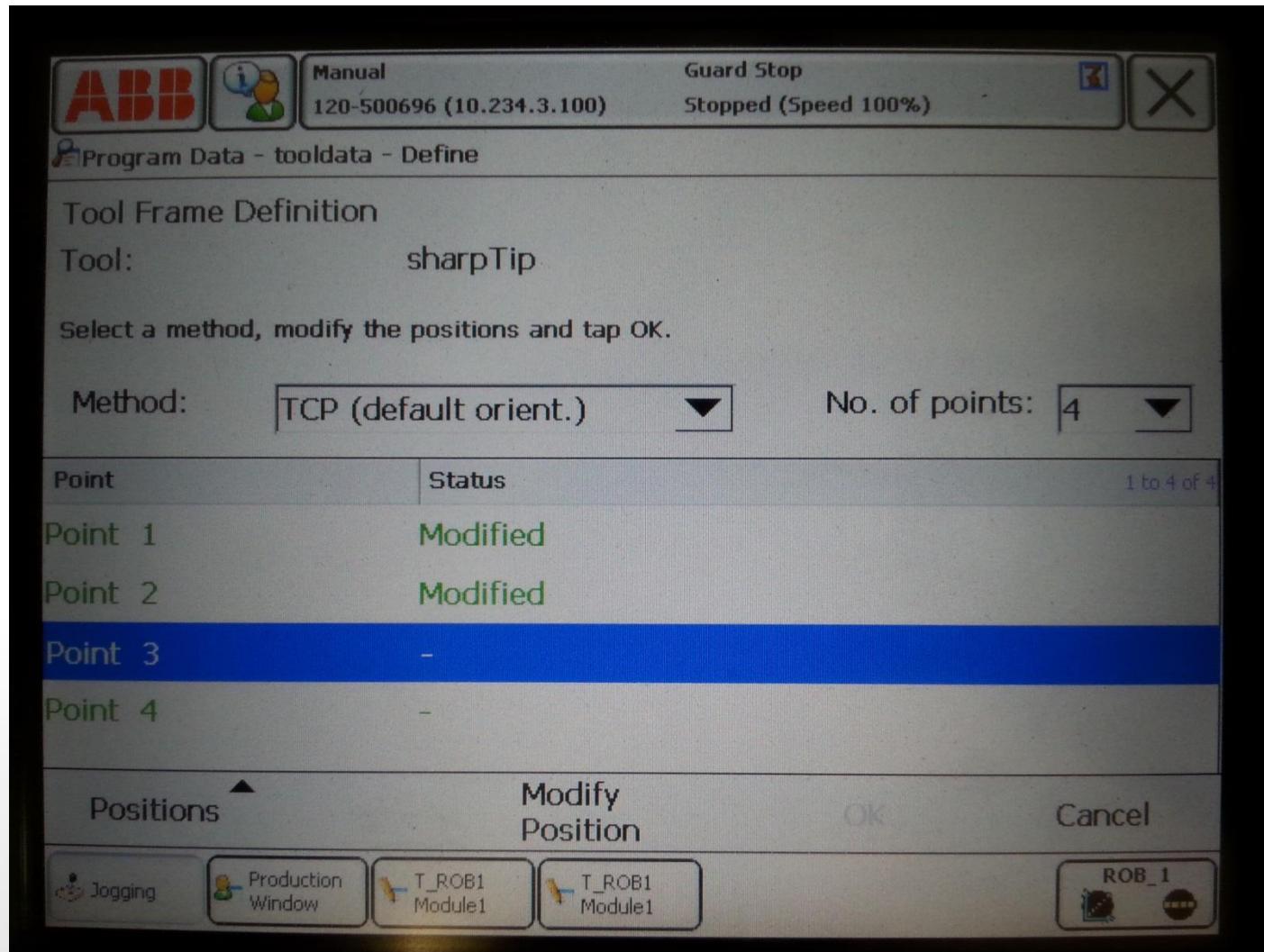
Calibrate Sharp-Tipped Tool

- On the teaching pendant, select Point 2 and click “Modify Position”.



Calibrate Sharp-Tipped Tool

- Point 2 is now modified.



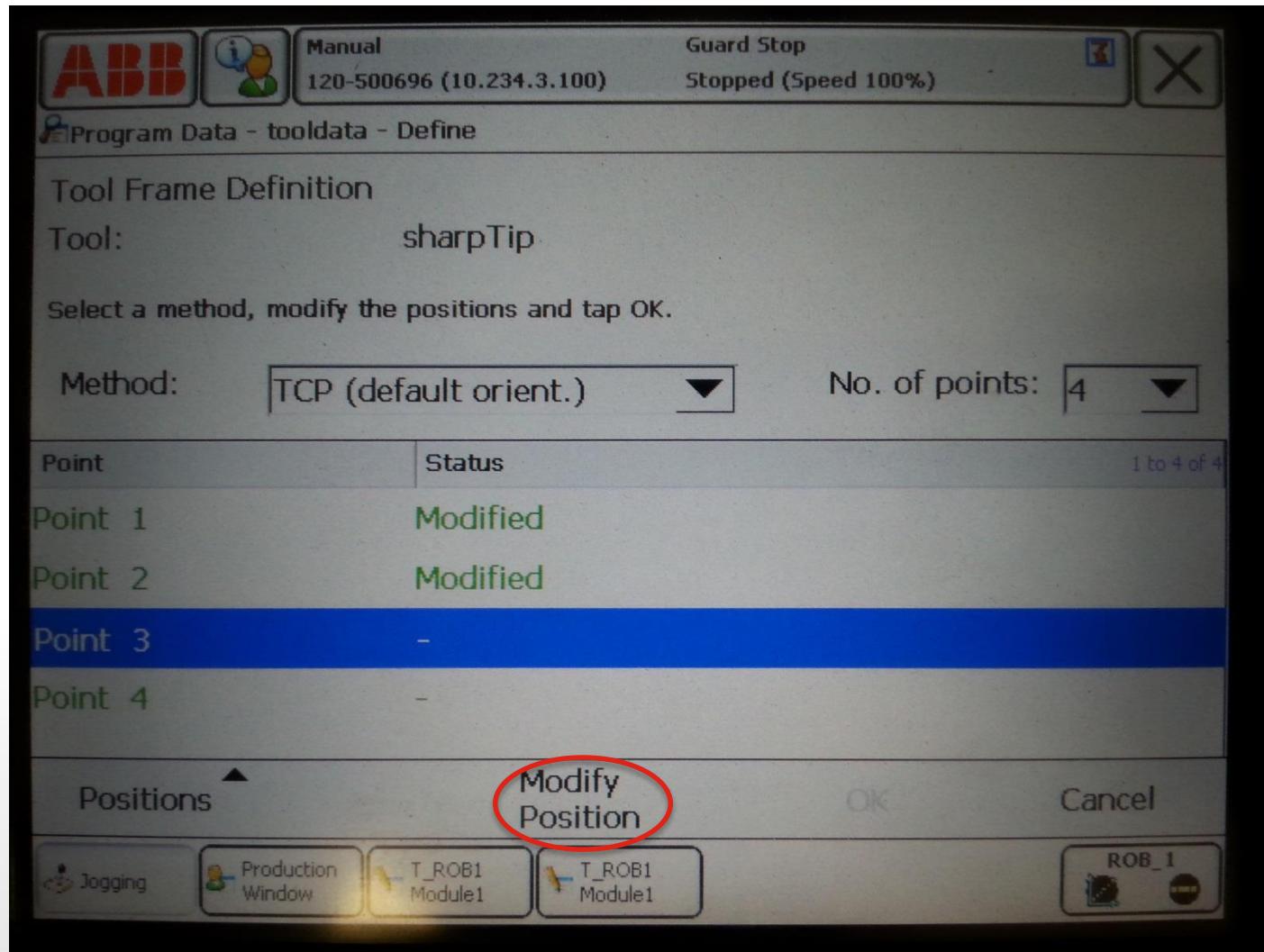
Calibrate Sharp-Tipped Tool

- Jog robot / sharpTip to the target point at the third orientation.



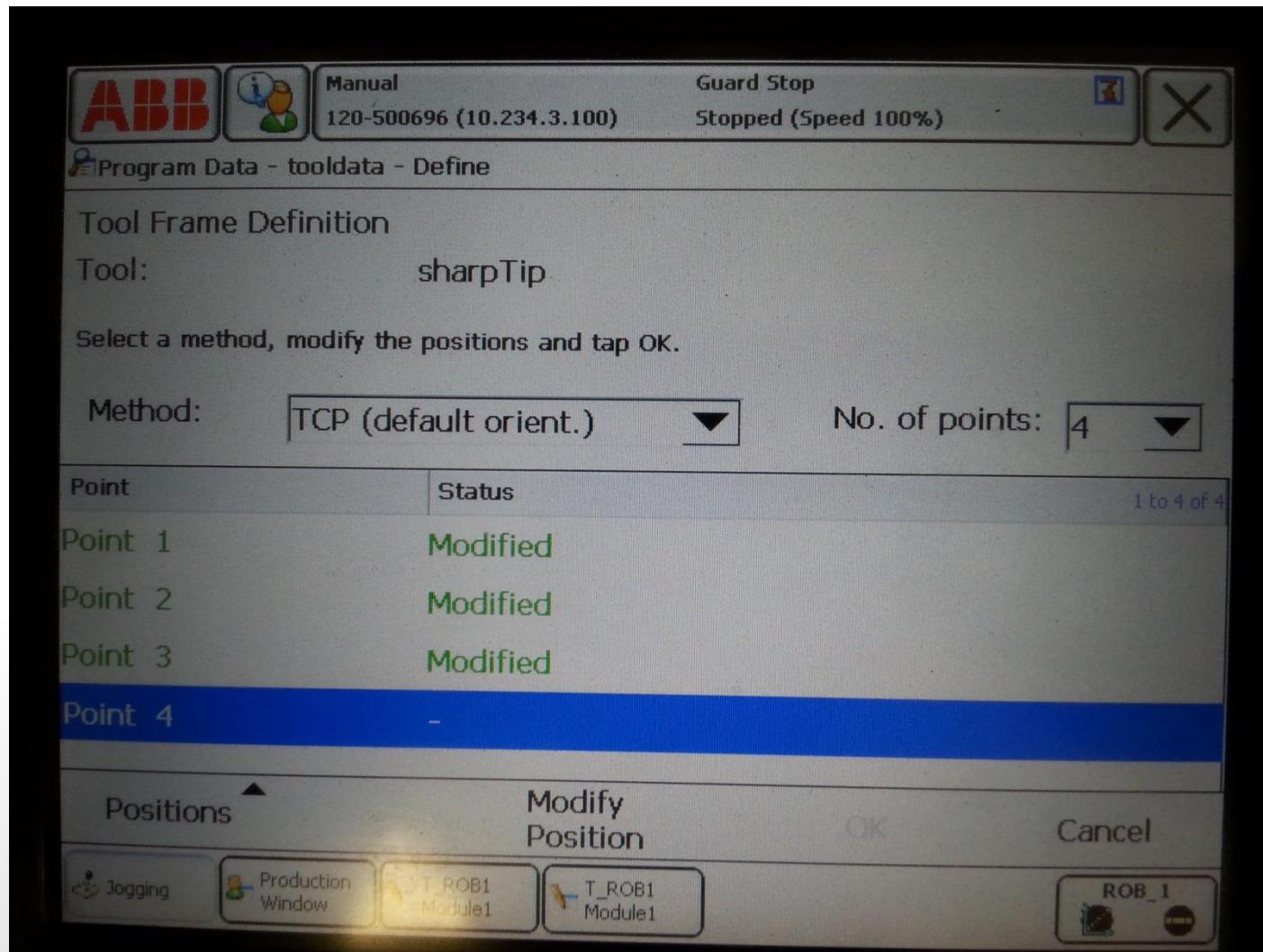
Calibrate Sharp-Tipped Tool

- On the teaching pendant, select Point 3 and click “Modify Position”.



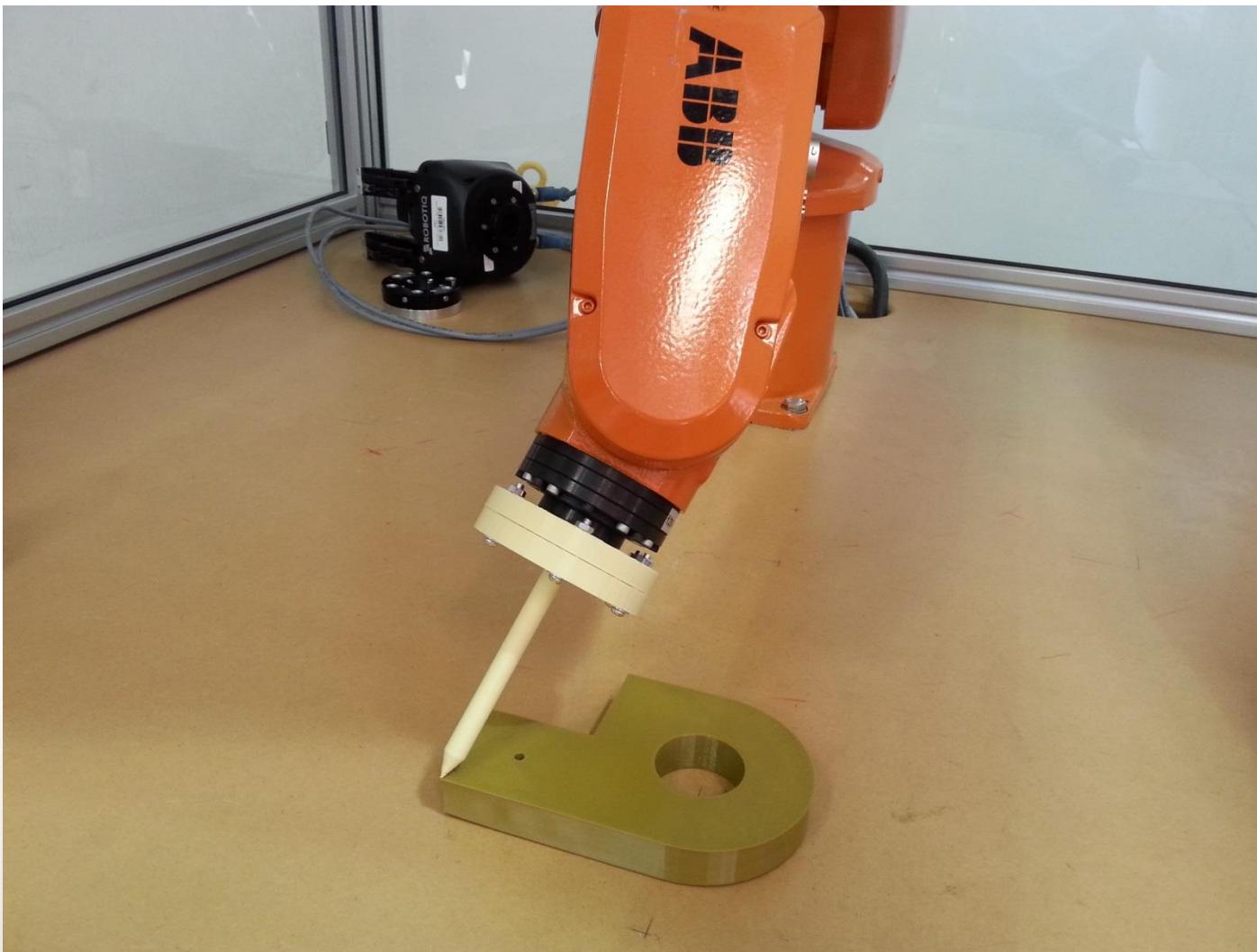
Calibrate Sharp-Tipped Tool

- Point 3 is now modified.



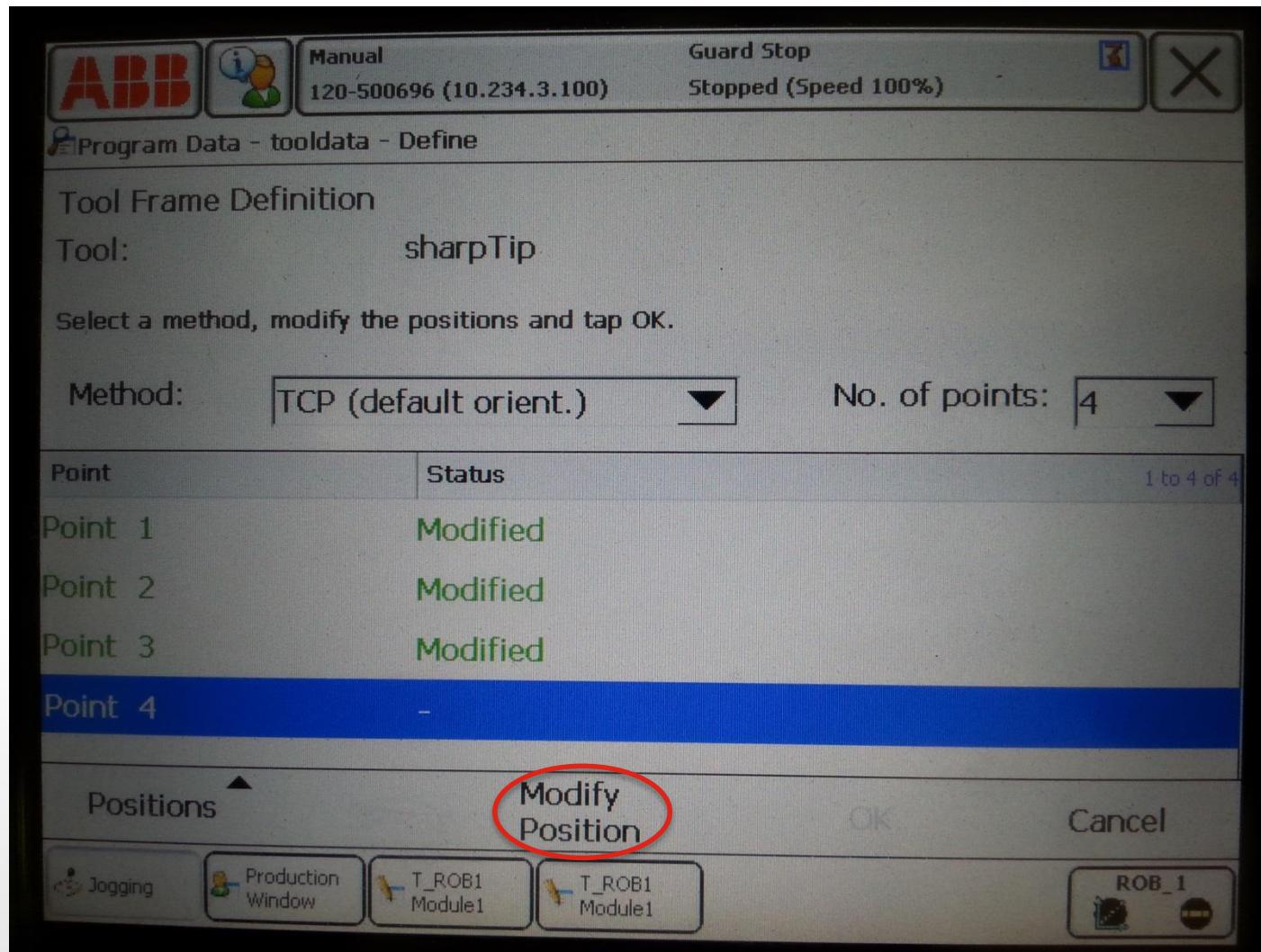
Calibrate Sharp-Tipped Tool

- Finally jog robot / sharpTip to the target point at the fourth orientation.



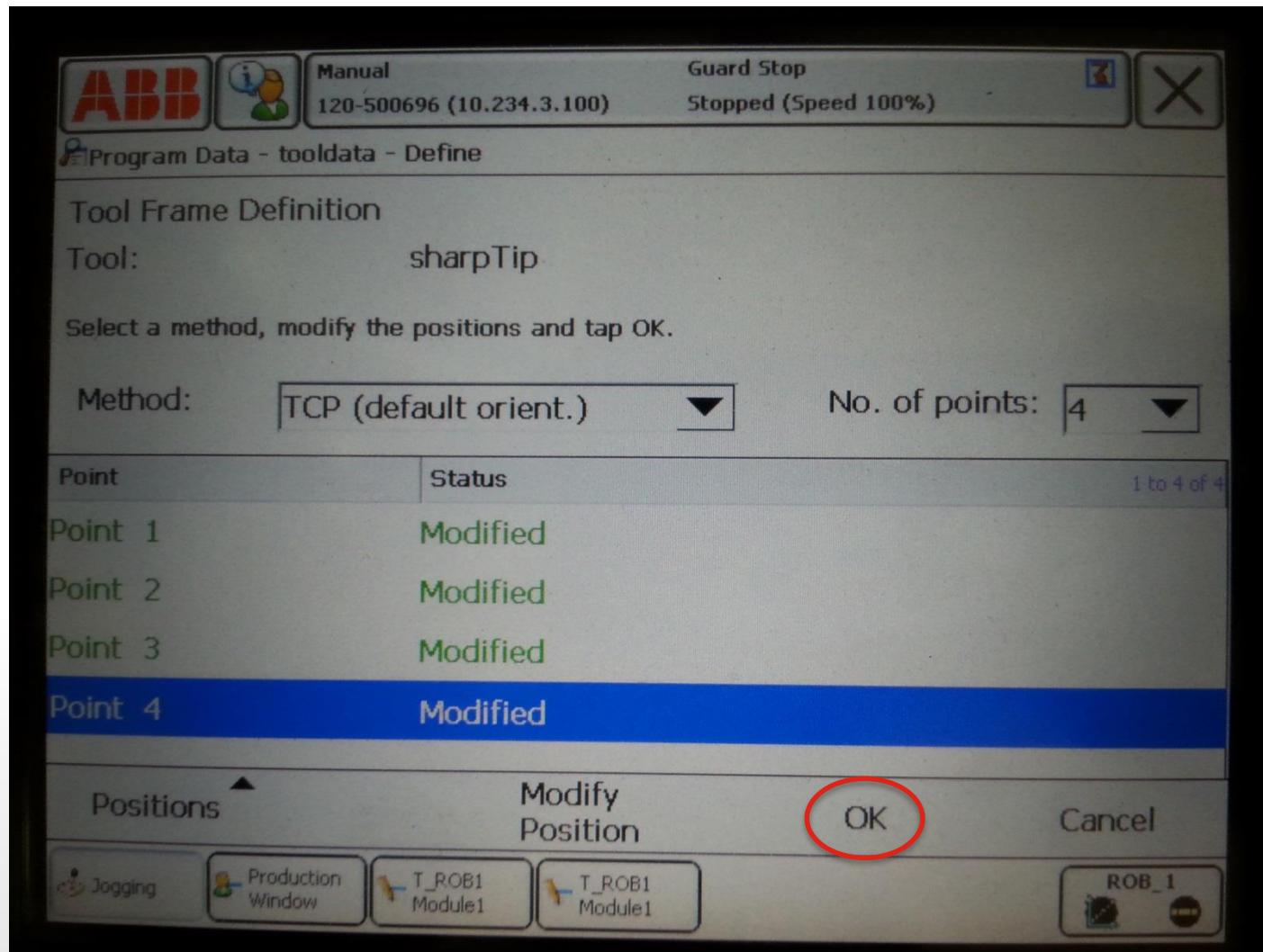
Calibrate Sharp-Tipped Tool

- On the teaching pendant, select Point 4 and click “Modify Position”.



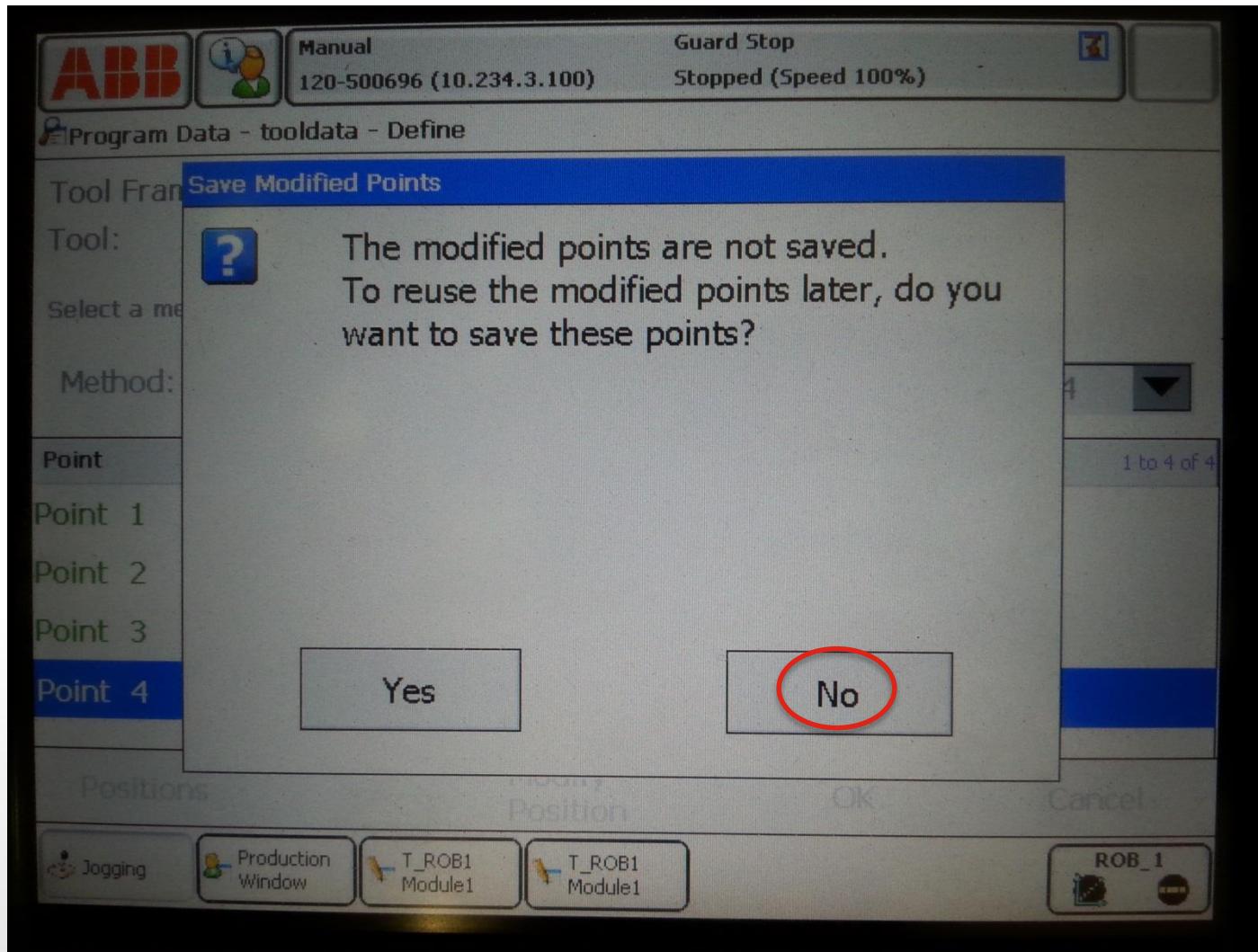
Calibrate Sharp-Tipped Tool

- Point 4 is now modified. Click “OK” to finish.



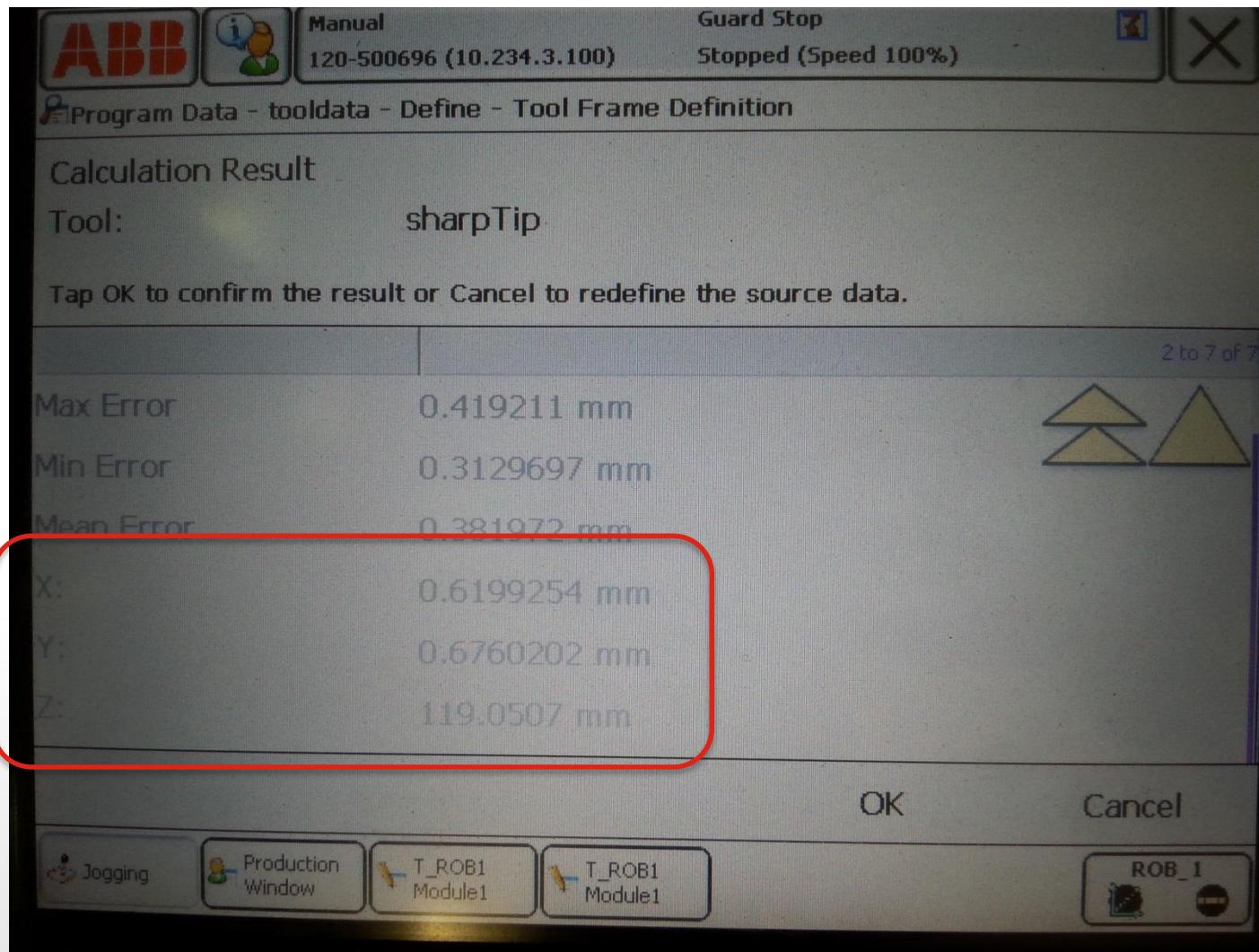
Calibrate Sharp-Tipped Tool

- The window might ask if we wish to save the points. Click “No”.



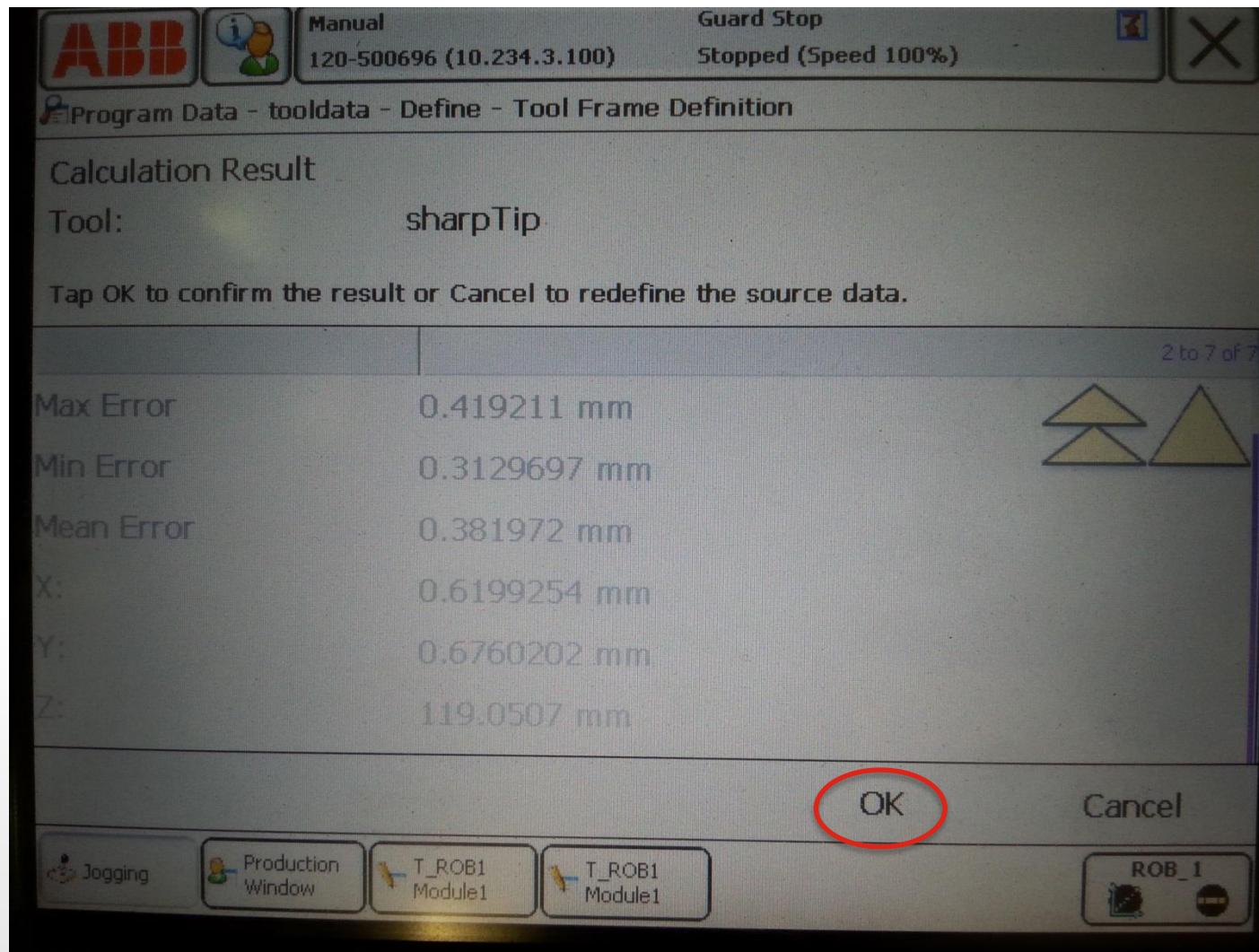
Calibrate Sharp-Tipped Tool

- The location of the sharpTip tool is finally computed.



Calibrate Sharp-Tipped Tool

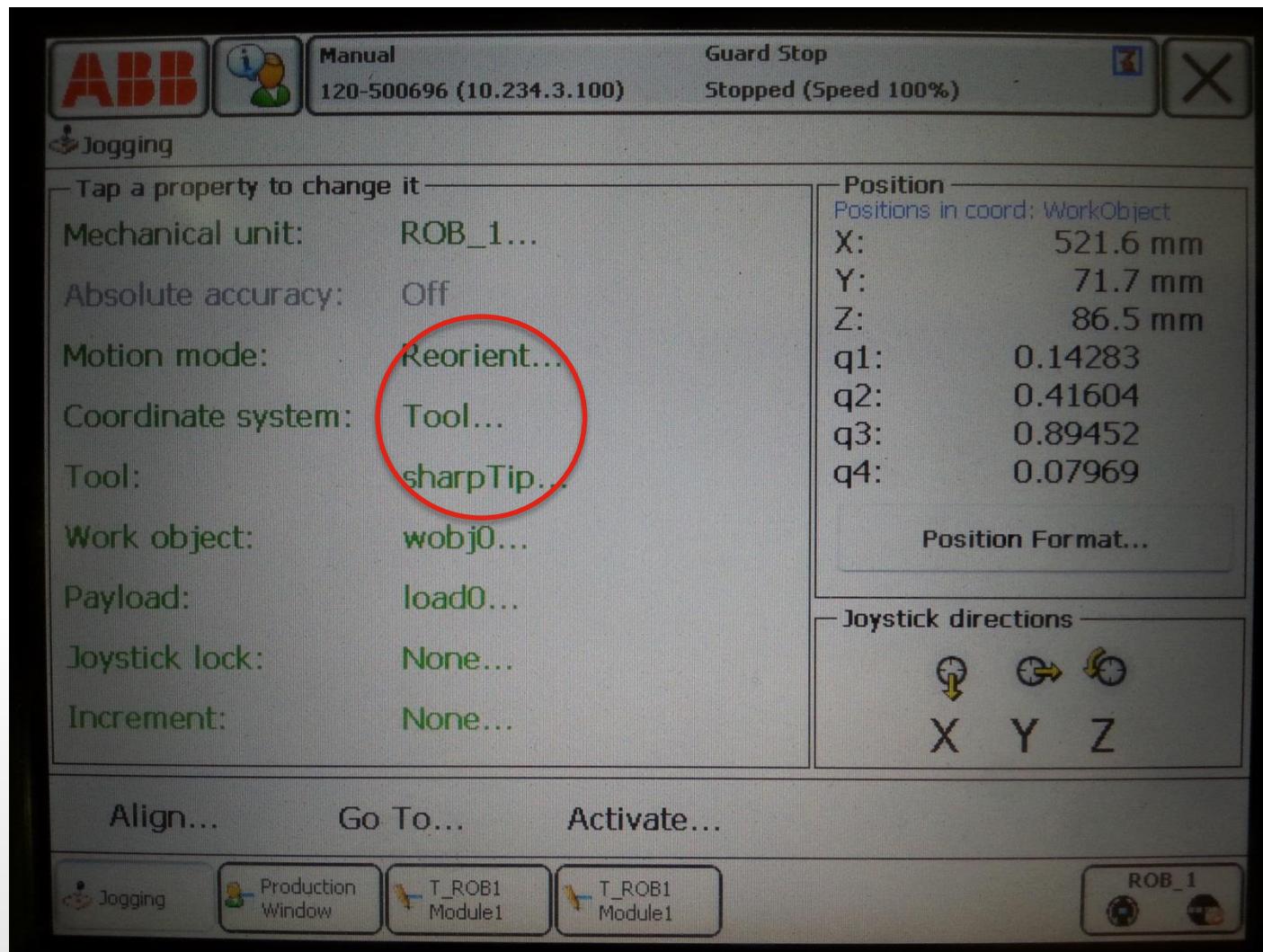
- Click **OK** to exit.



Calibrate Sharp-Tipped Tool

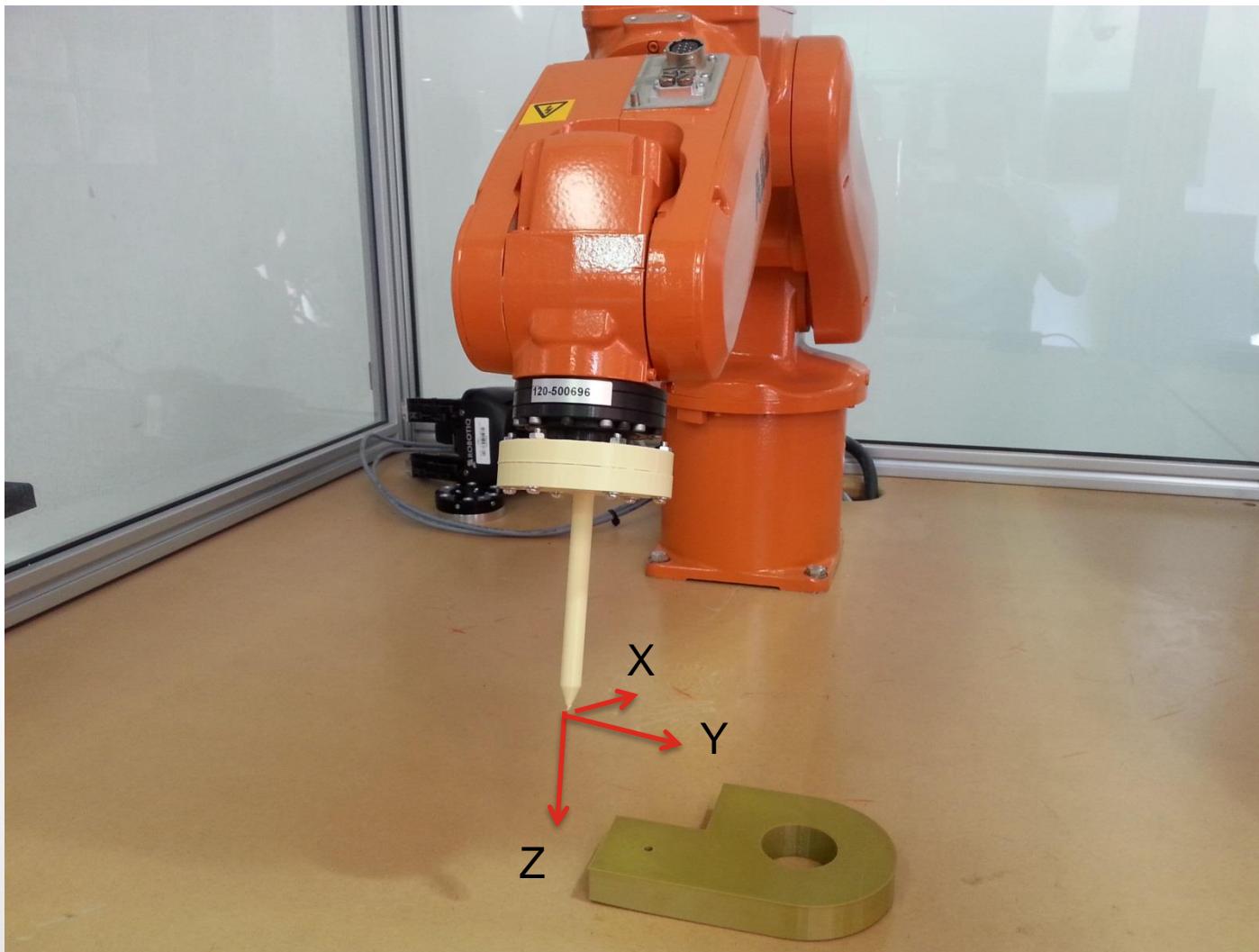
- We can verify that the tool is correctly calibrated by jogging in the linear or re-

orient mode using sharpTip as the tool frame.



Calibrate Sharp-Tipped Tool

- Observe the motion of the robot according to the sharpTip frame.

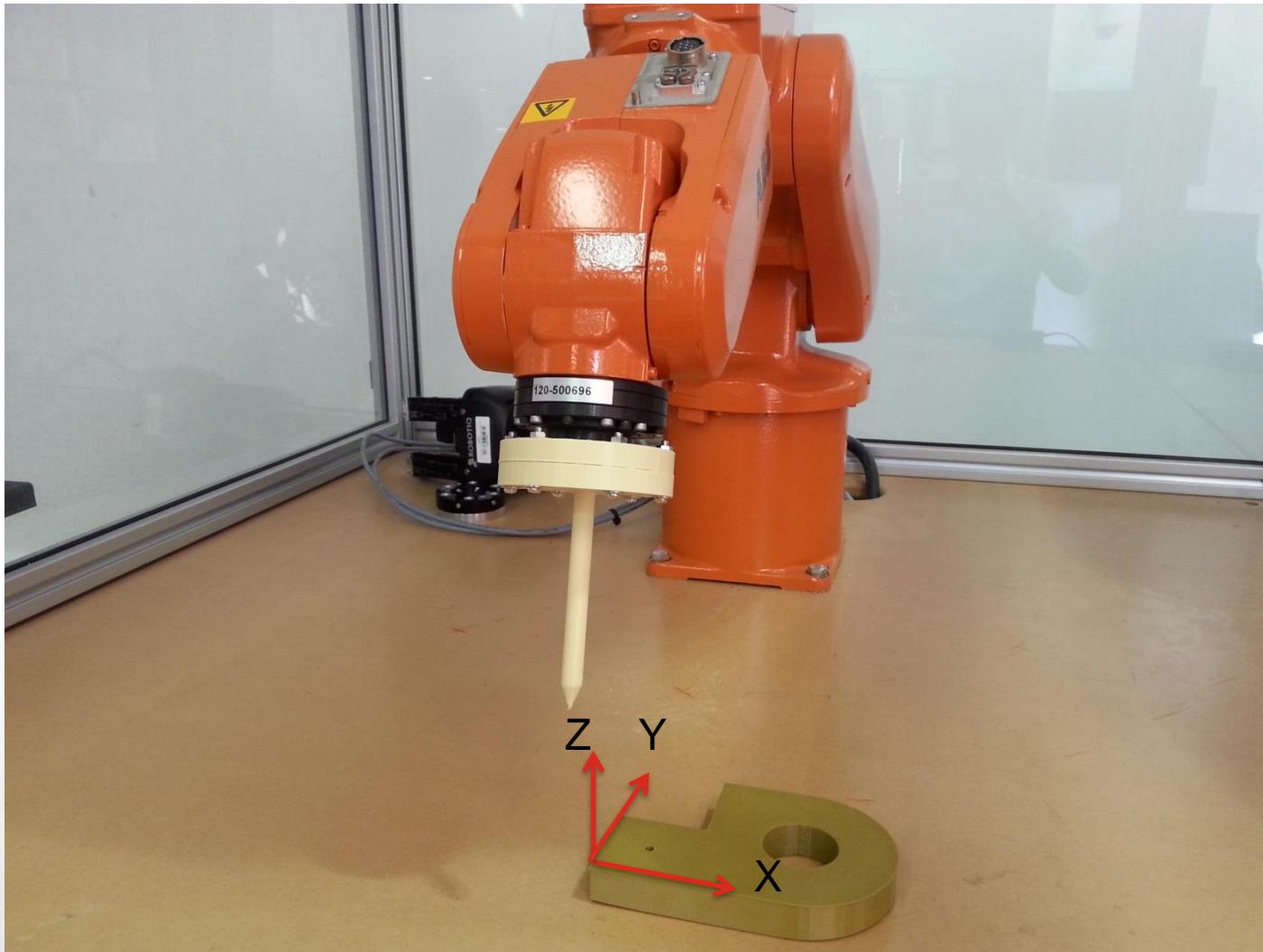


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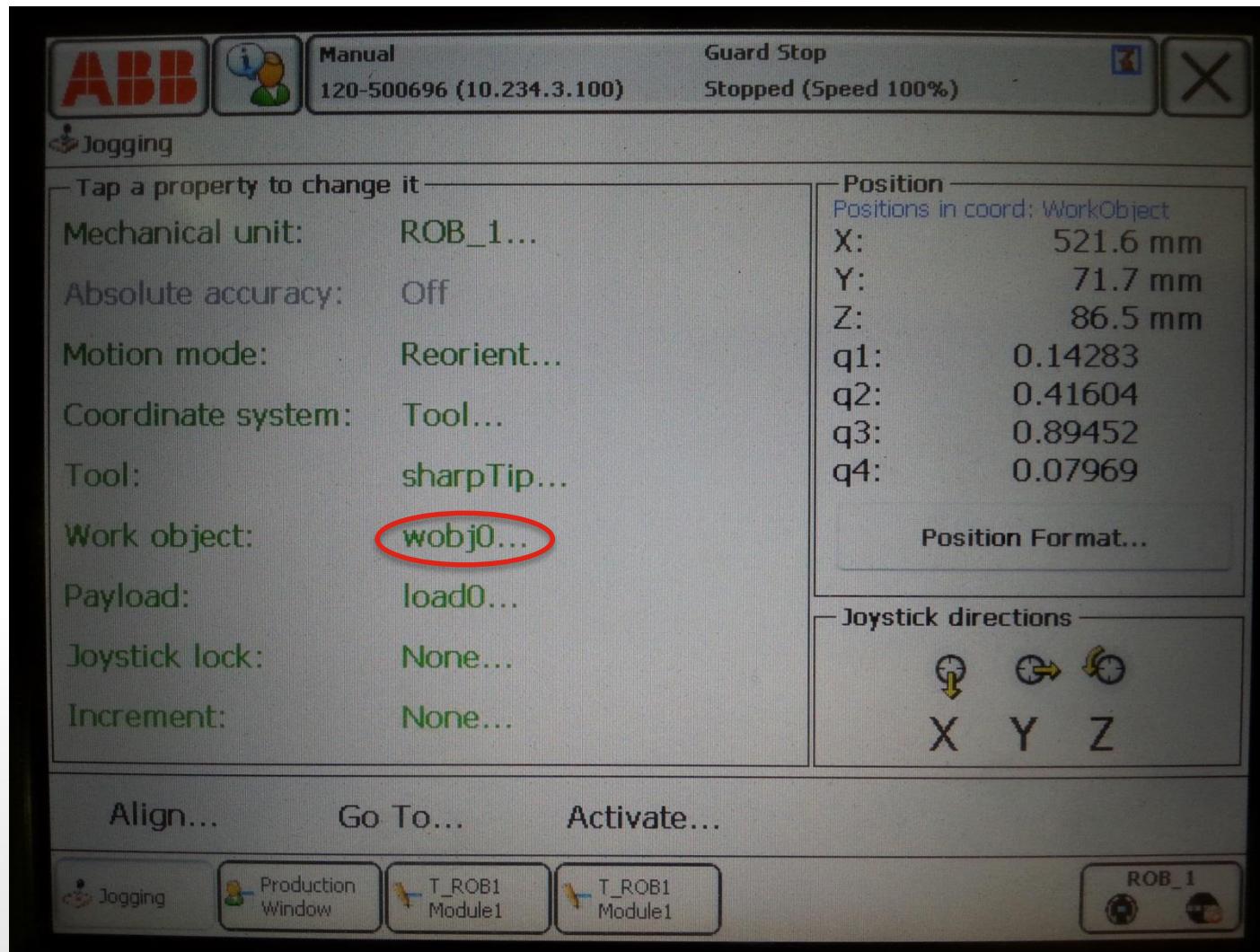
Create Frame for Workpiece

- Next, we would like to create a frame on the workpiece.



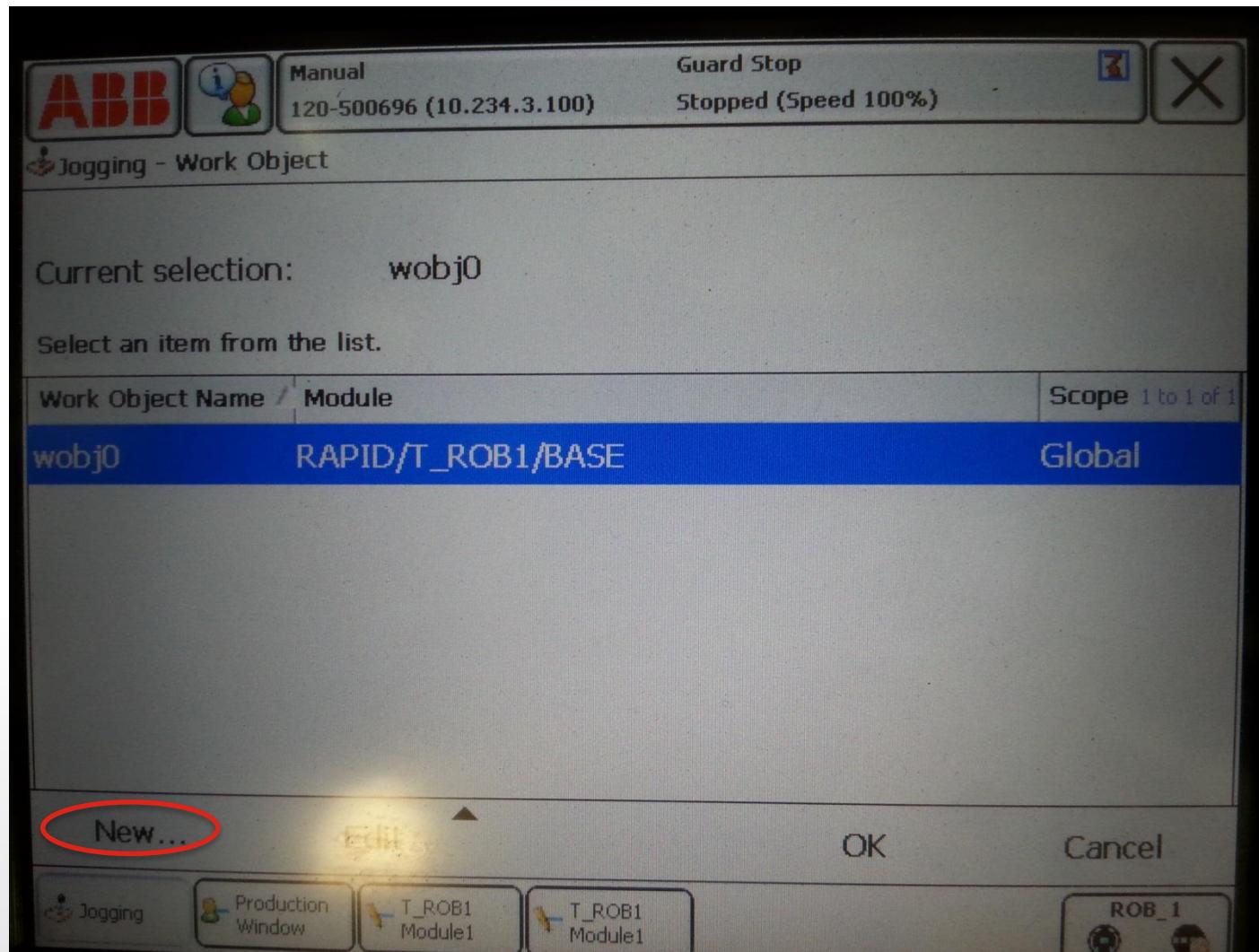
Create Frame for Workpiece

- On the “Jogging” page, click wobj0 beside the work object.



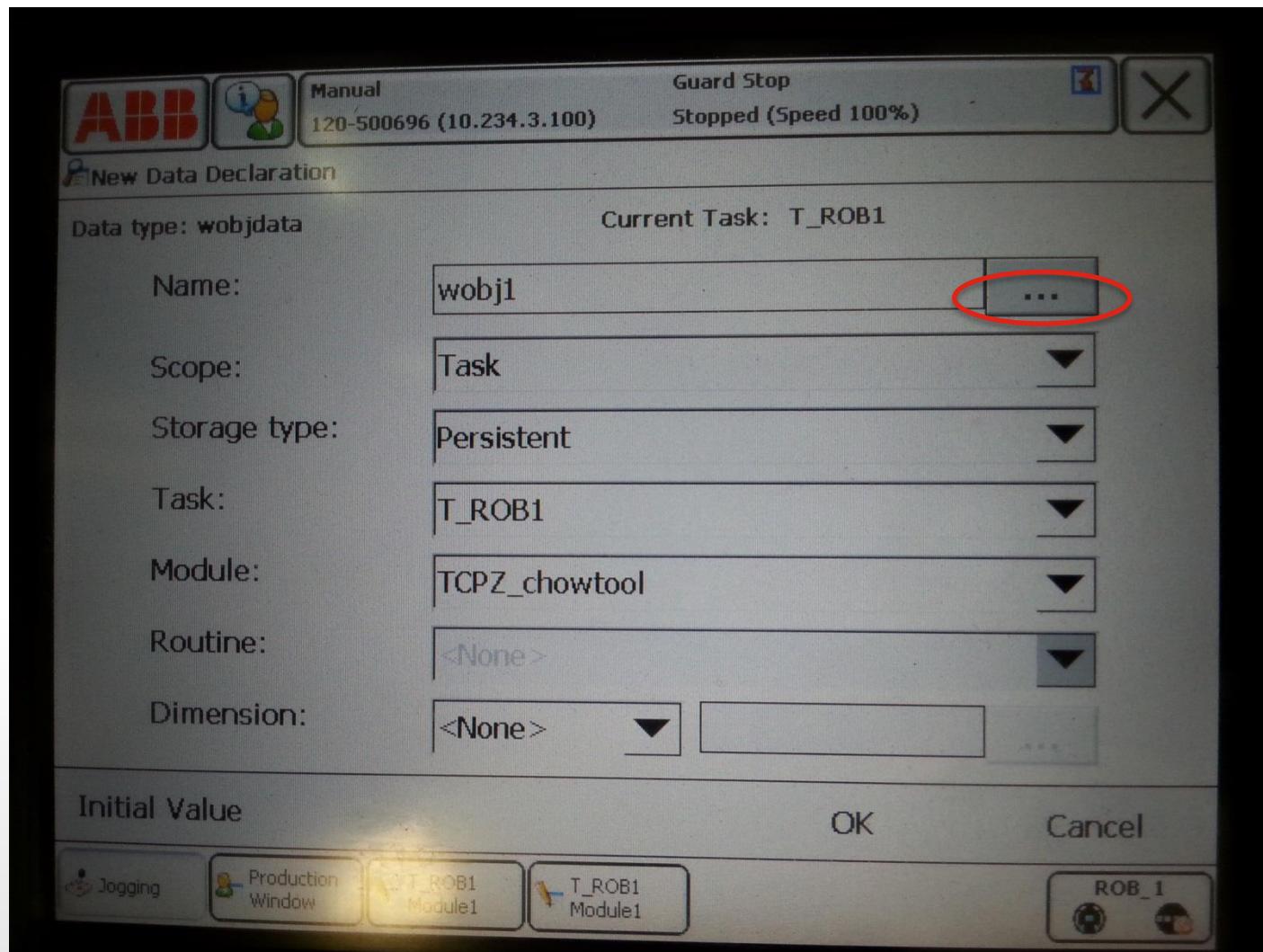
Create Frame for Workpiece

- A list of work objects will appear. Click “New”.



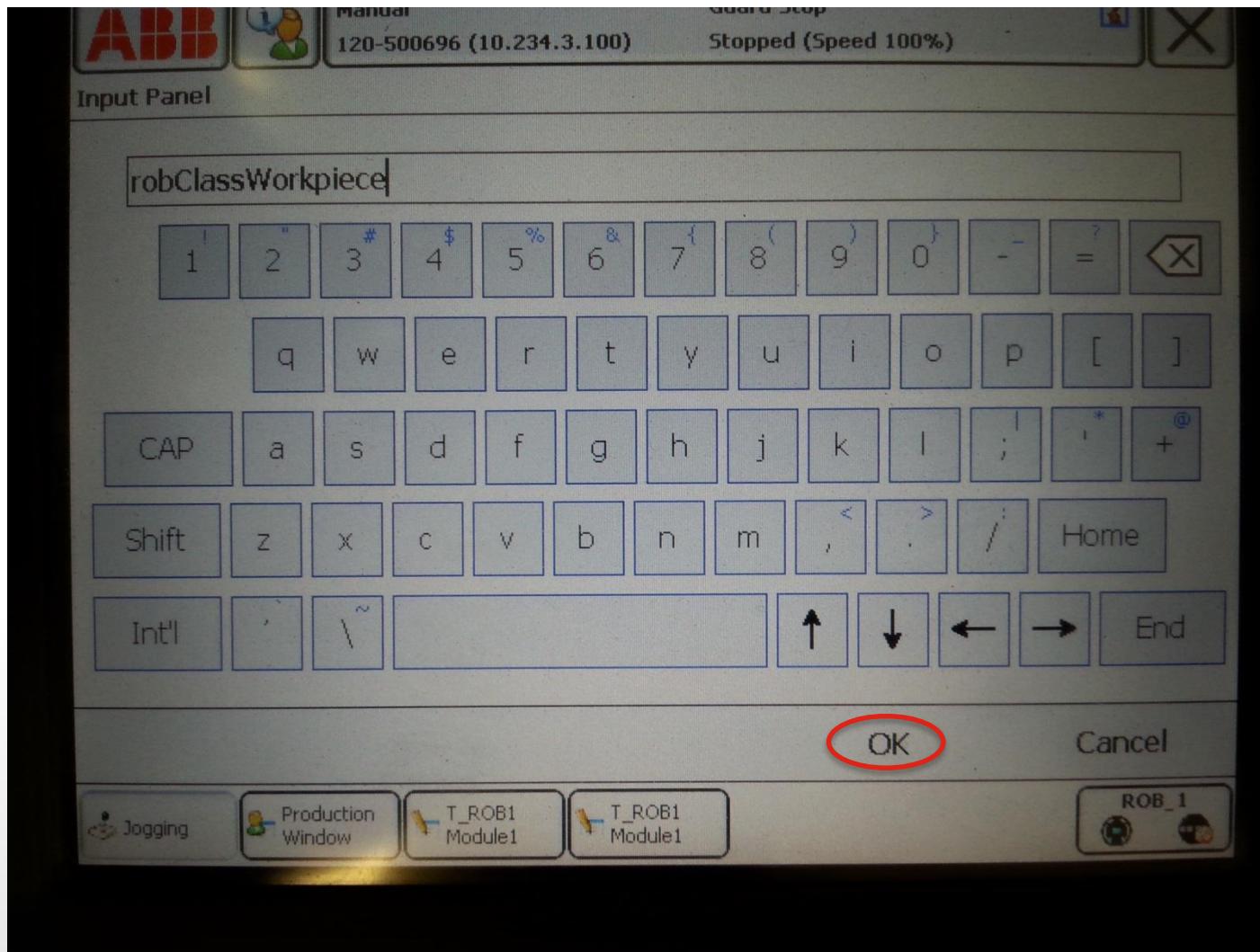
Create Frame for Workpiece

- The name of the newly created frame is by default wobj#. Click “...” to change it.



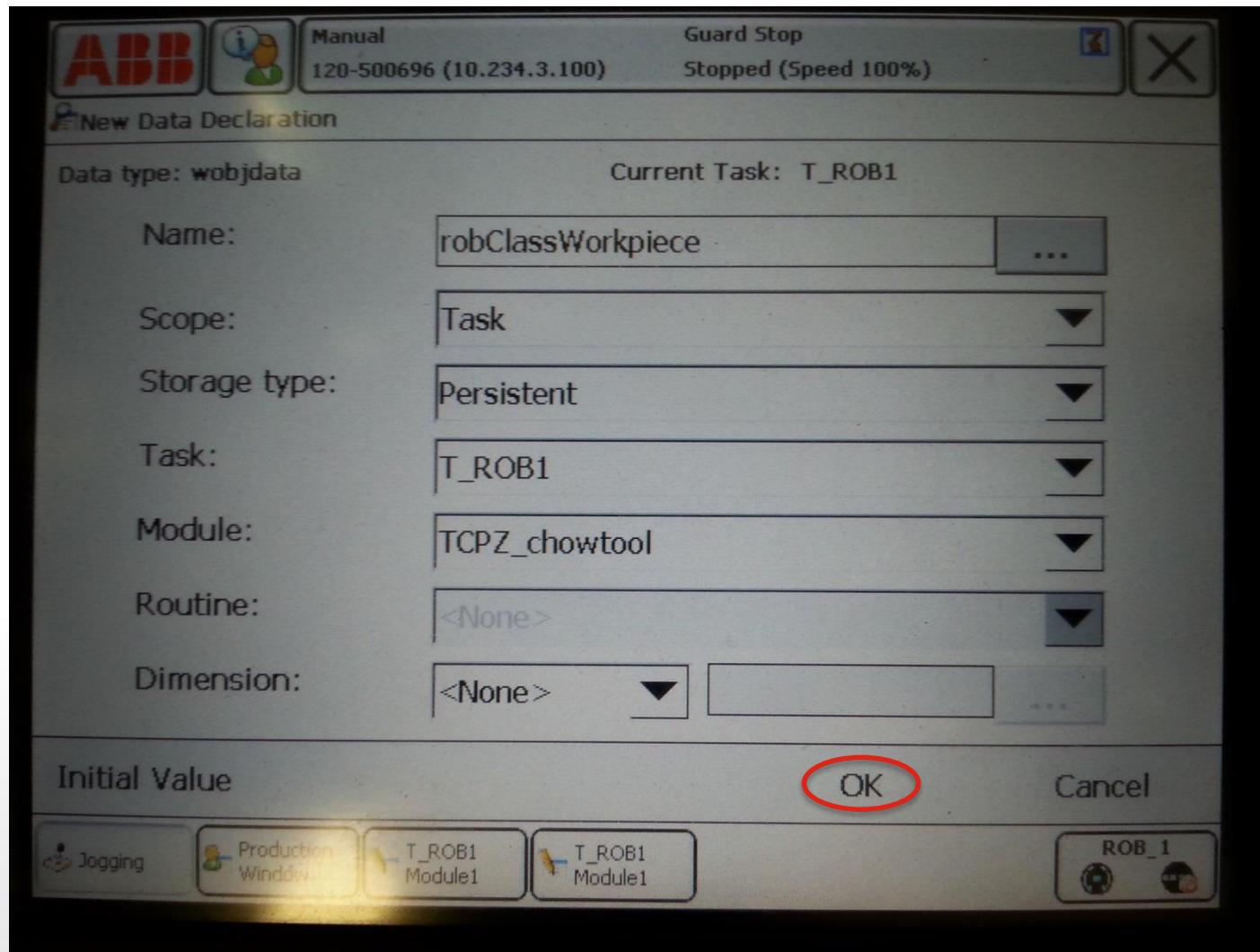
Create Frame for Workpiece

- Key in any meaningful name and click “OK”.



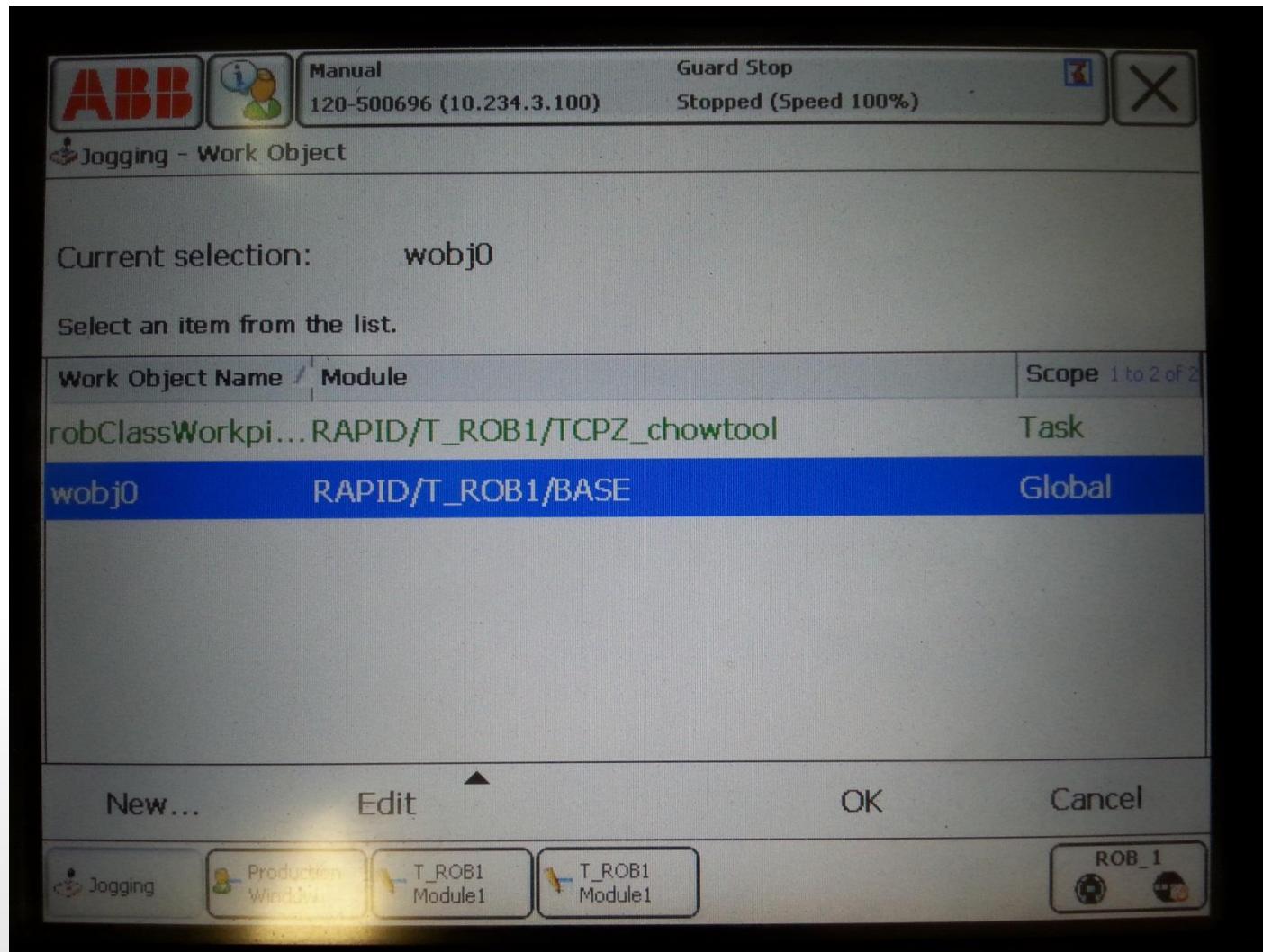
Create Frame for Workpiece

- Click “OK” again on the next window.



Create Frame for Workpiece

- robClassWorkpiece is now on the list of work object.

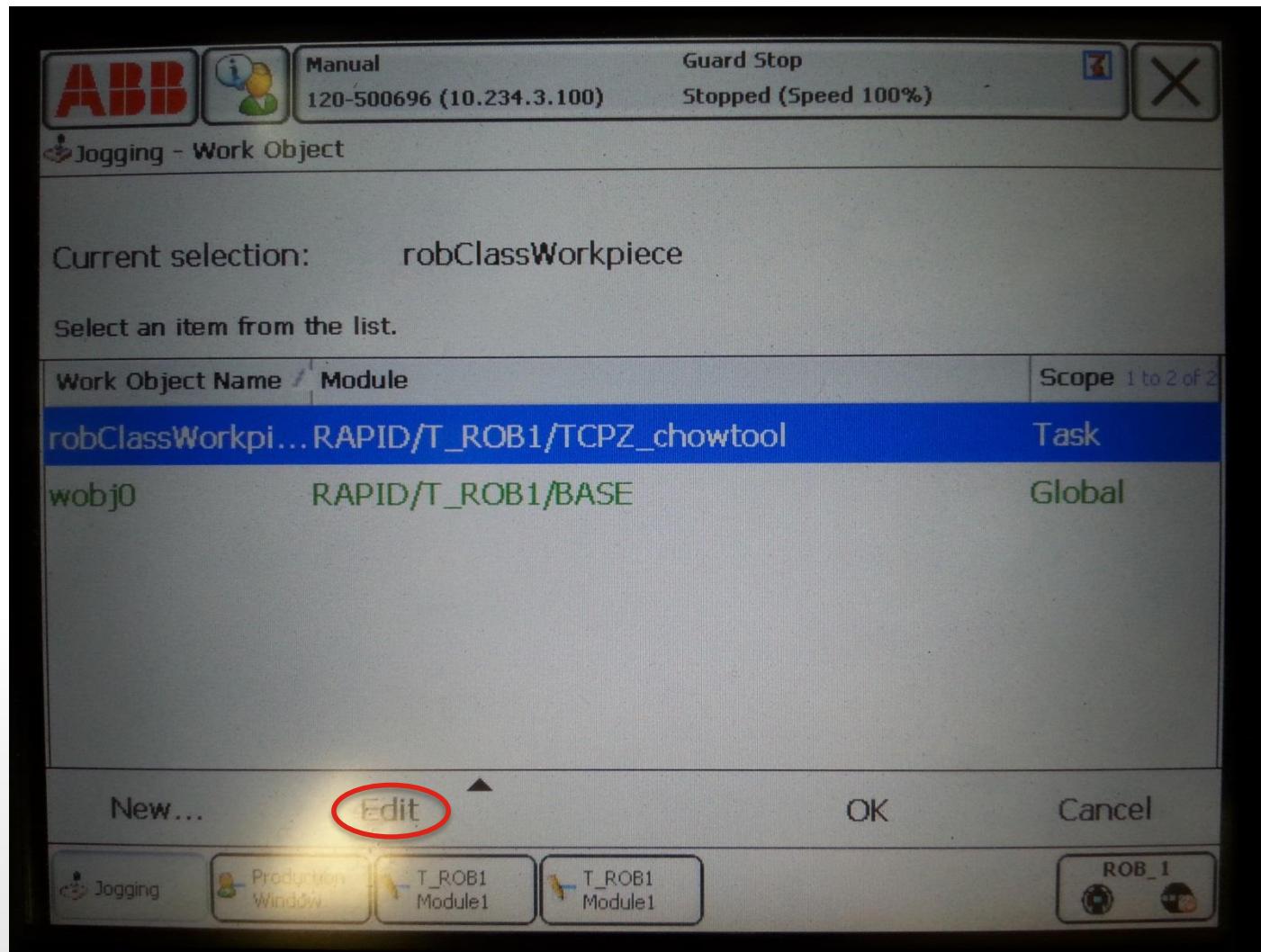


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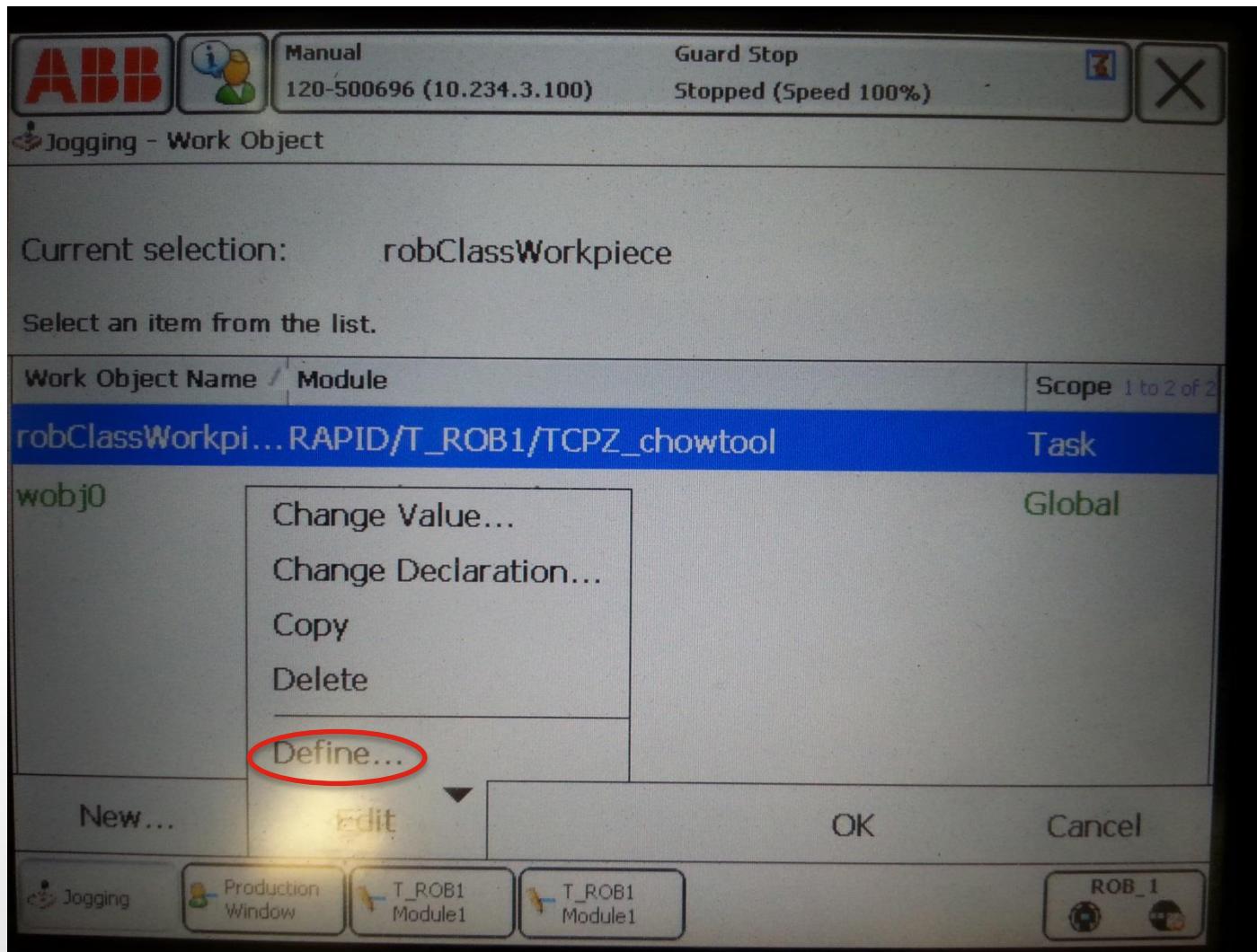
Calibrate Frame for Workpiece

- Choose robClassWorkpiece and click “Edit”.



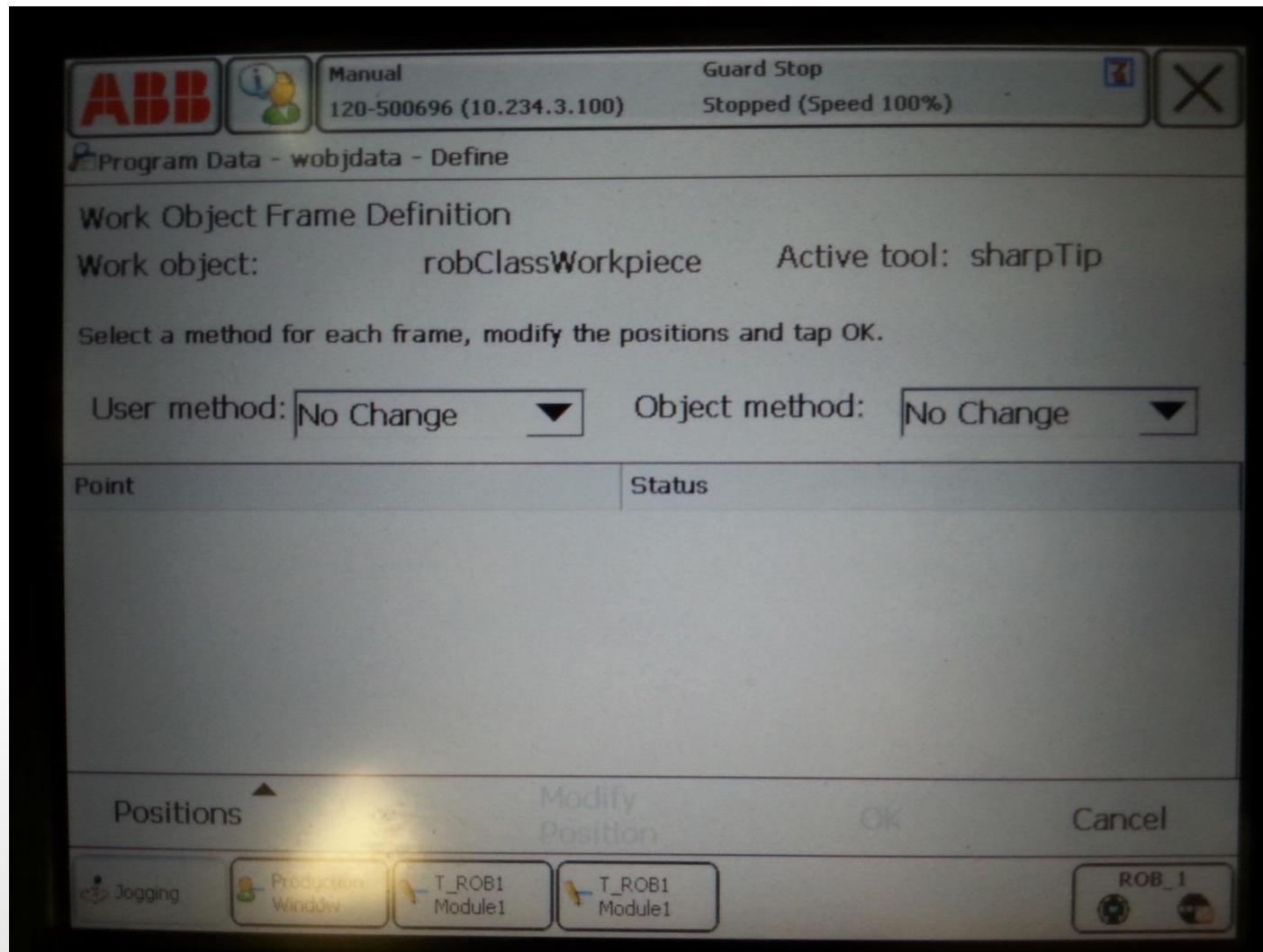
Calibrate Frame for Workpiece

- On the pop-up menu, choose “Define”.



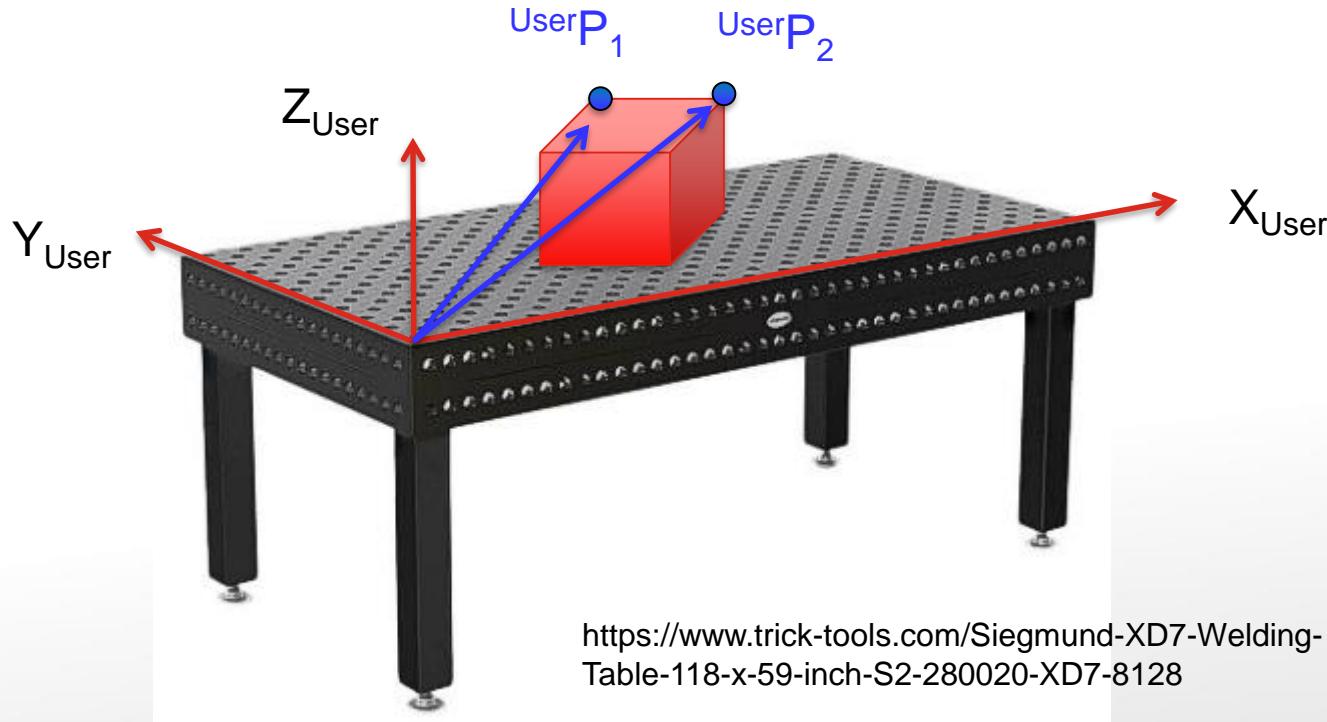
Calibrate Frame for Workpiece

- In the next screen, there are “user method” and “object method”.



Calibrate Frame for Workpiece

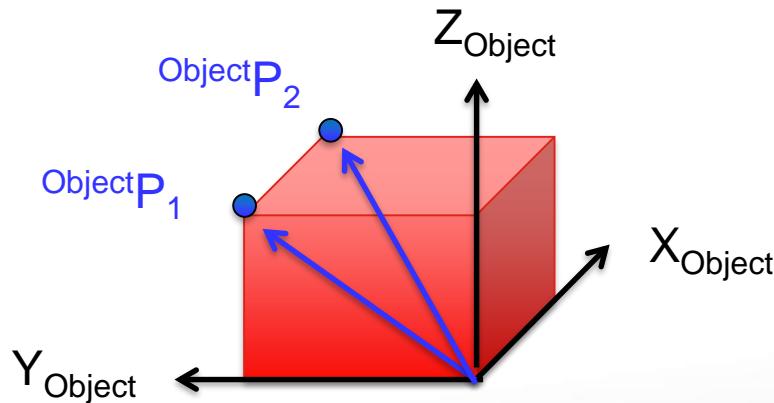
- “user method” is used to find the frame of the worktable.
- Target points on the workpiece are then given **with respect to the worktable frame**.



- This method is accurate if there are **good fixtures** to put the workpiece at the same location all the time.

Calibrate Frame for Workpiece

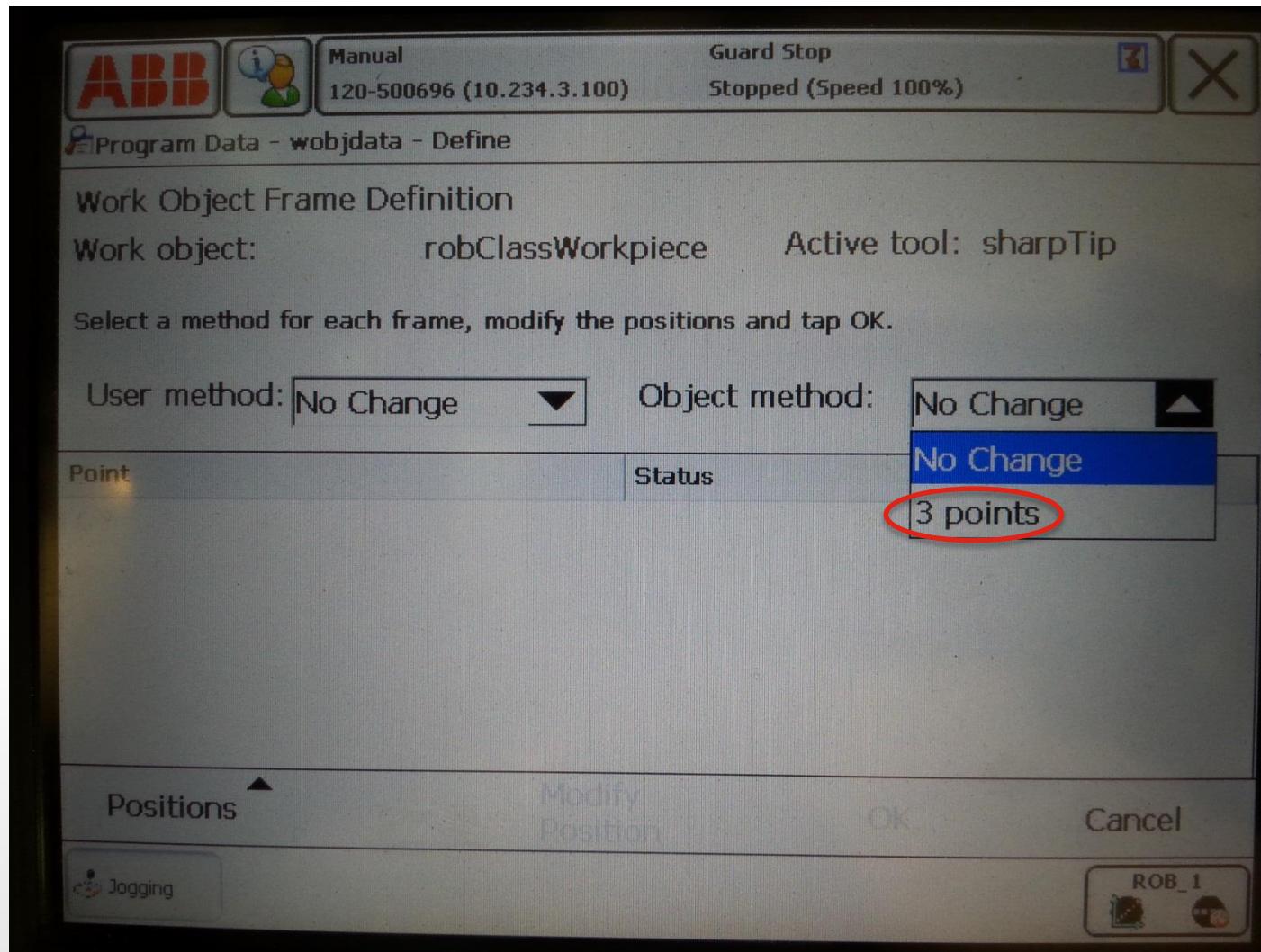
- “Object method” is used to find the frame of the workpiece itself.
- Target points on the workpiece are then given **with respect to the workpiece frame**.



- This method offers a higher accuracy.

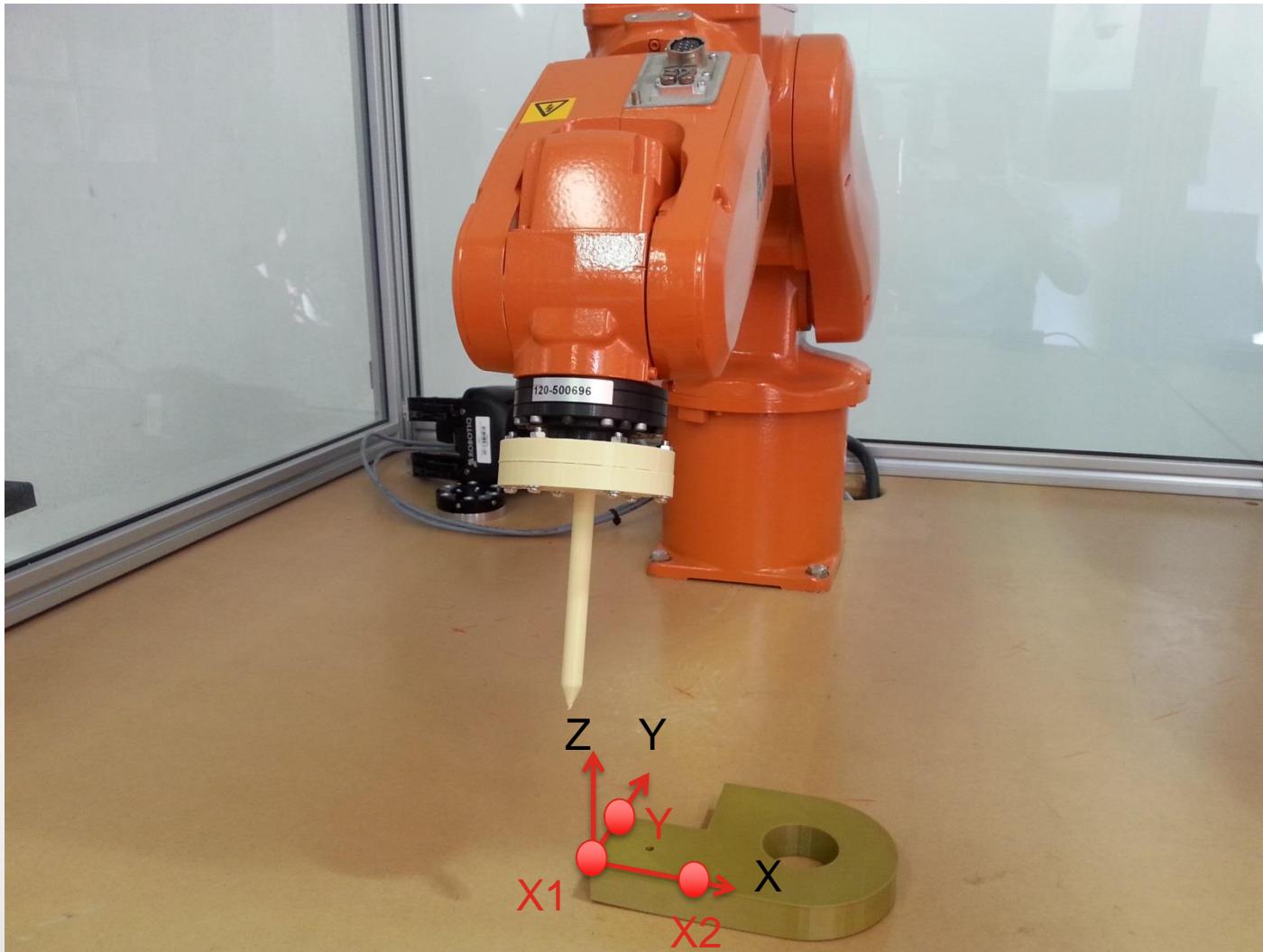
Calibrate Frame for Workpiece

- In this exercise, we use “Object method”. Select “3 points” as shown.



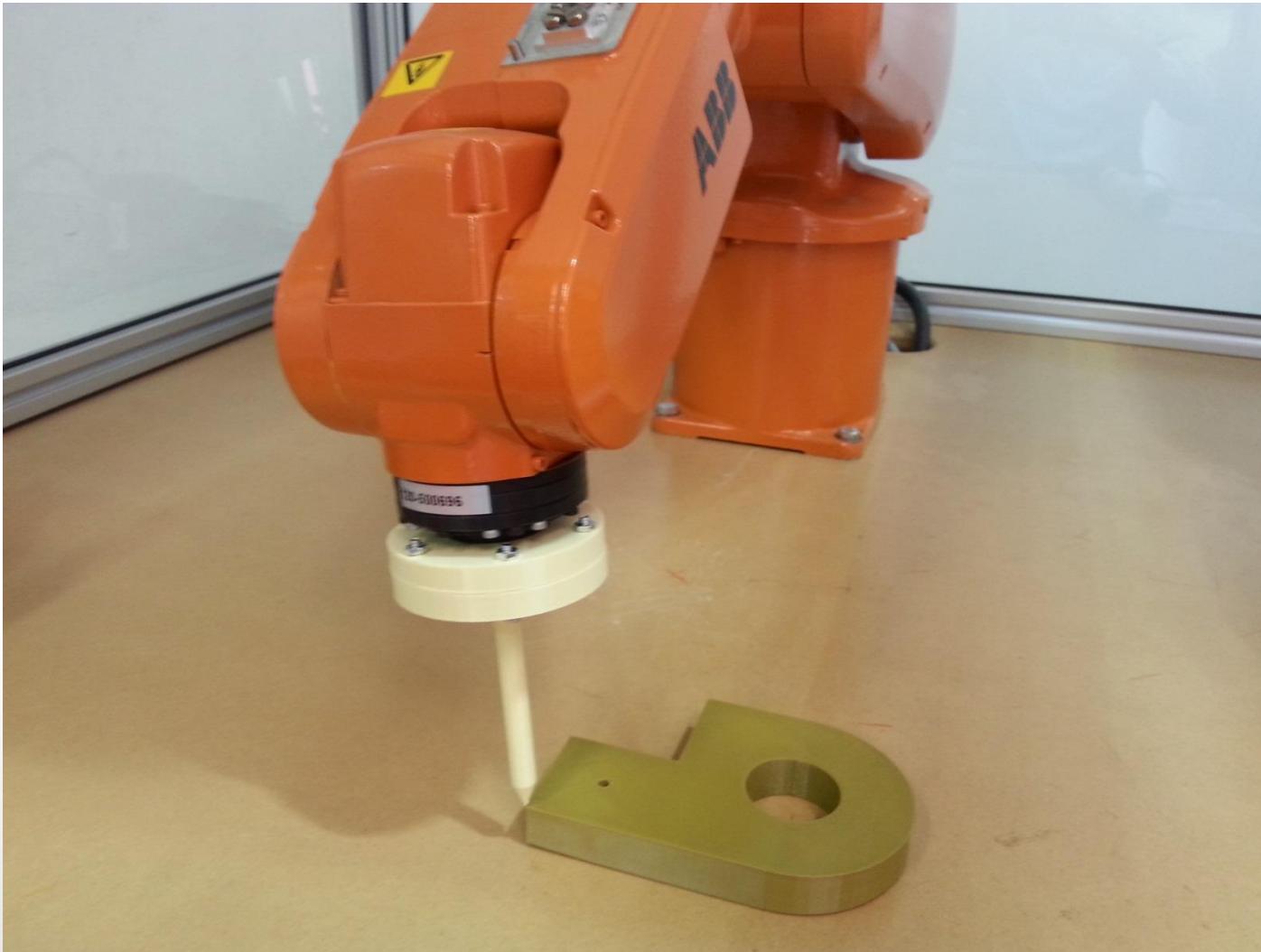
Calibrate Frame for Workpiece

- The idea is to move the sharp tip to **three points**: X1, X2 and Y to define the frame.



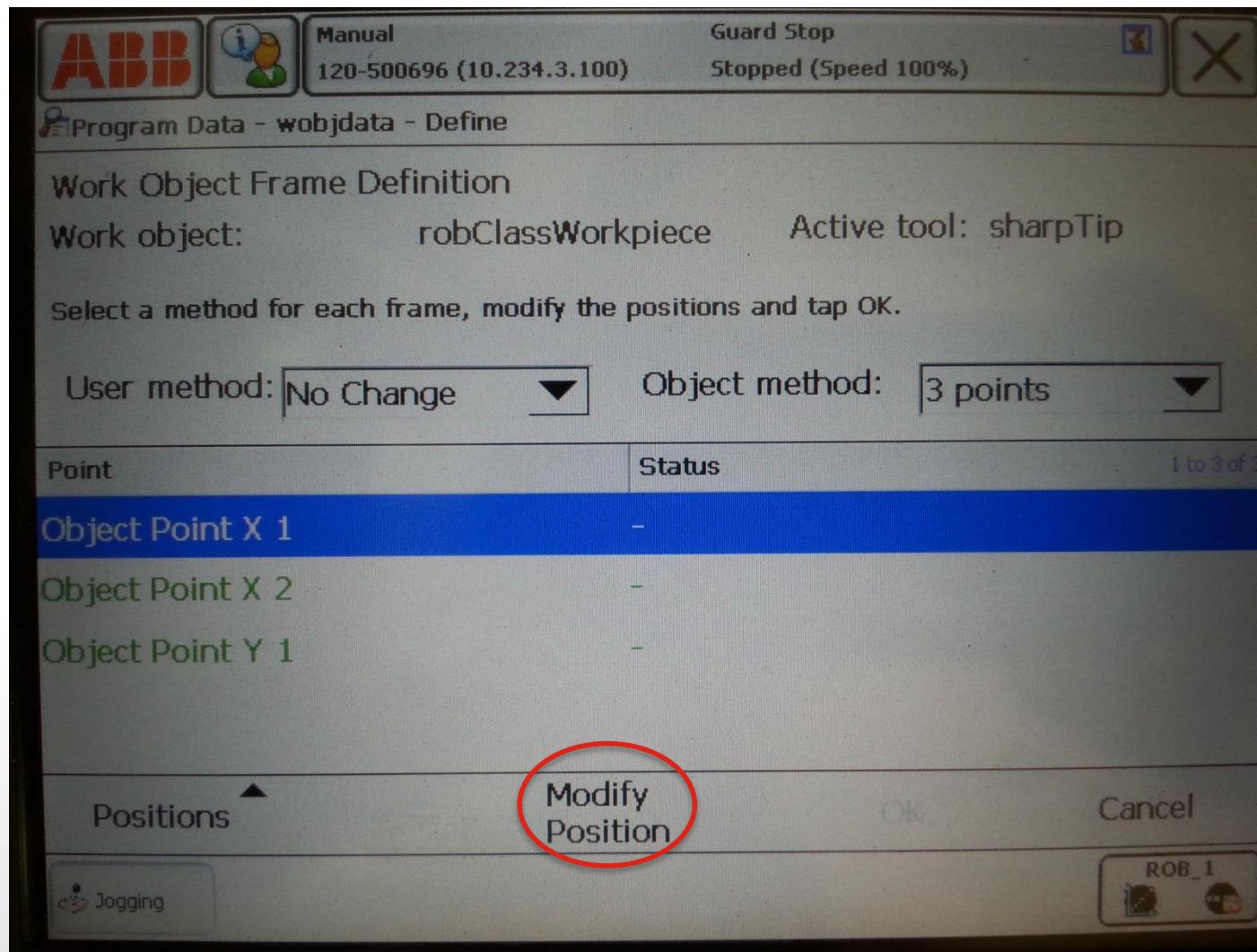
Calibrate Frame for Workpiece

- Jog the robot to the origin (first point on X).



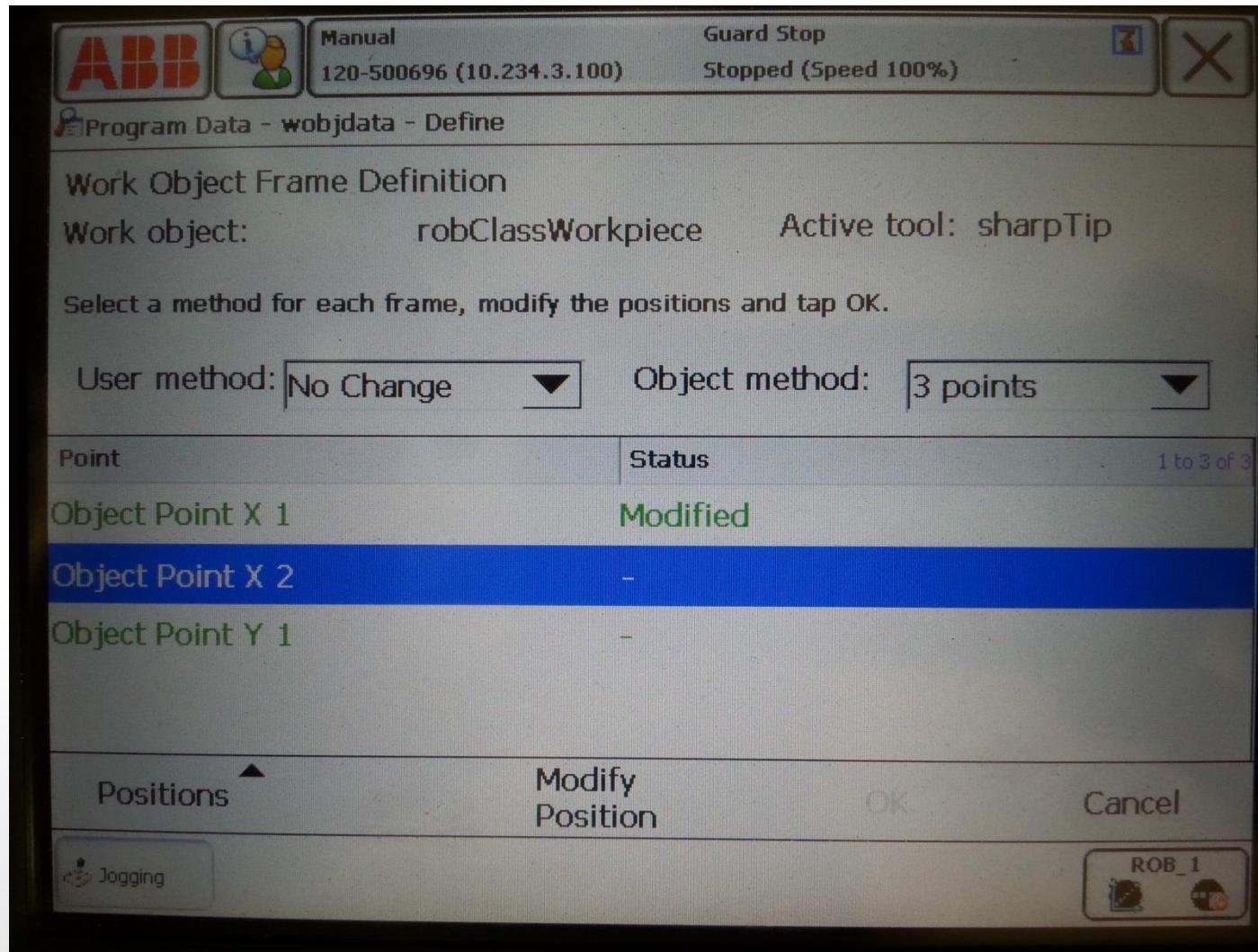
Calibrate Frame for Workpiece

- On the teaching pendant, select Object Point X1 and click “Modify Position”.



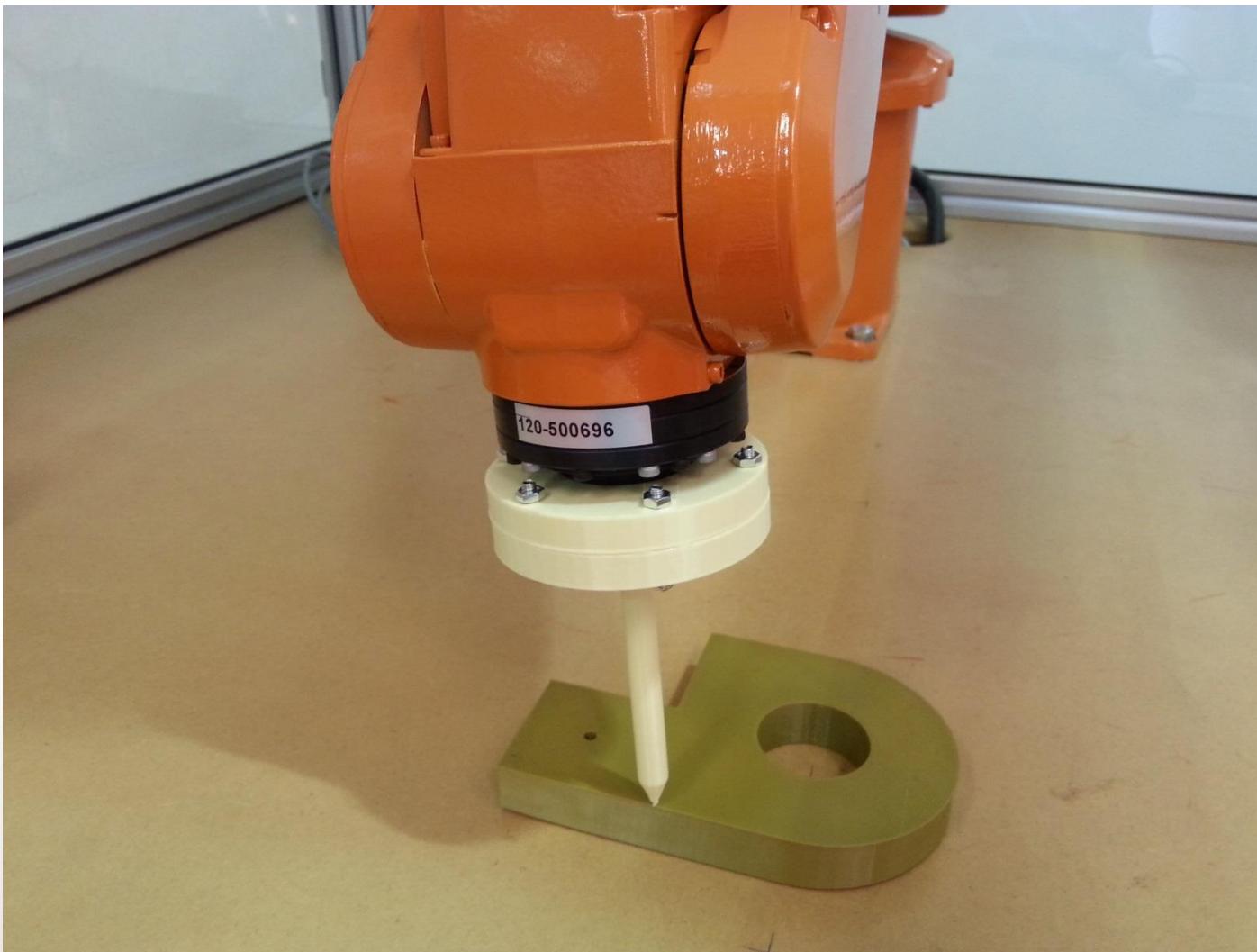
Calibrate Frame for Workpiece

- Object Point X1 is now modified.



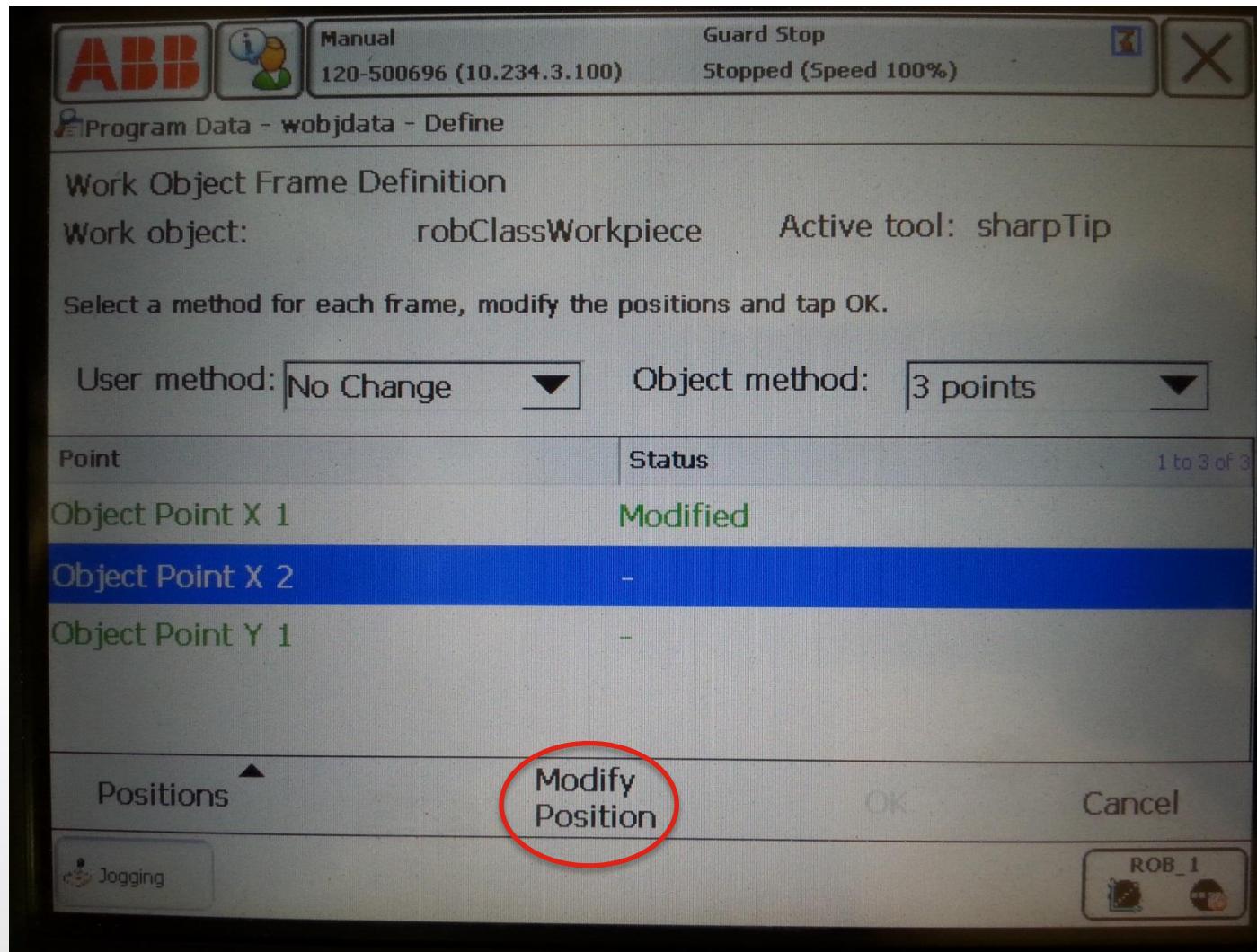
Calibrate Frame for Workpiece

- Jog the robot to the second point on X.



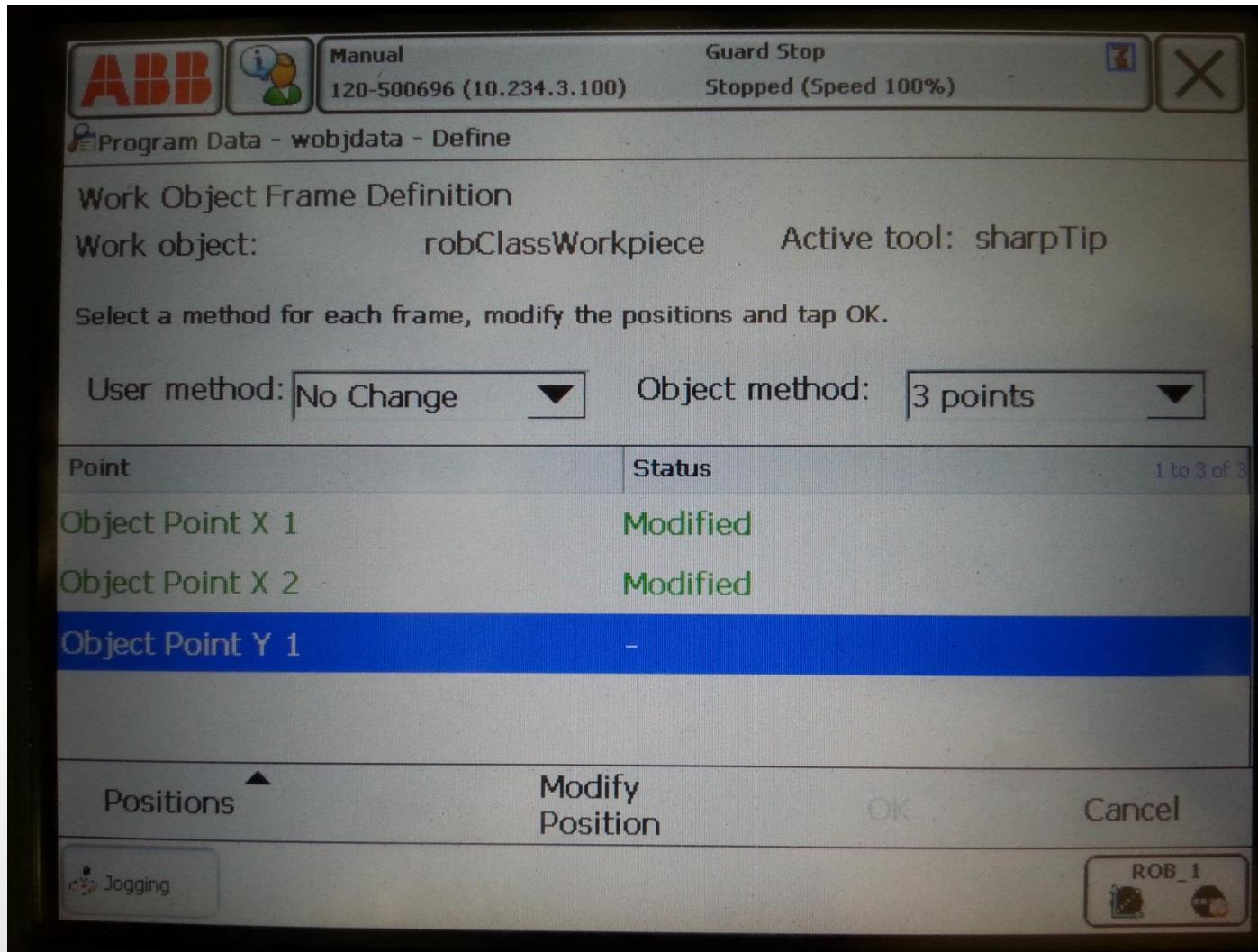
Calibrate Frame for Workpiece

- On the teaching pendant, select Object Point X2 and click “Modify Position”.



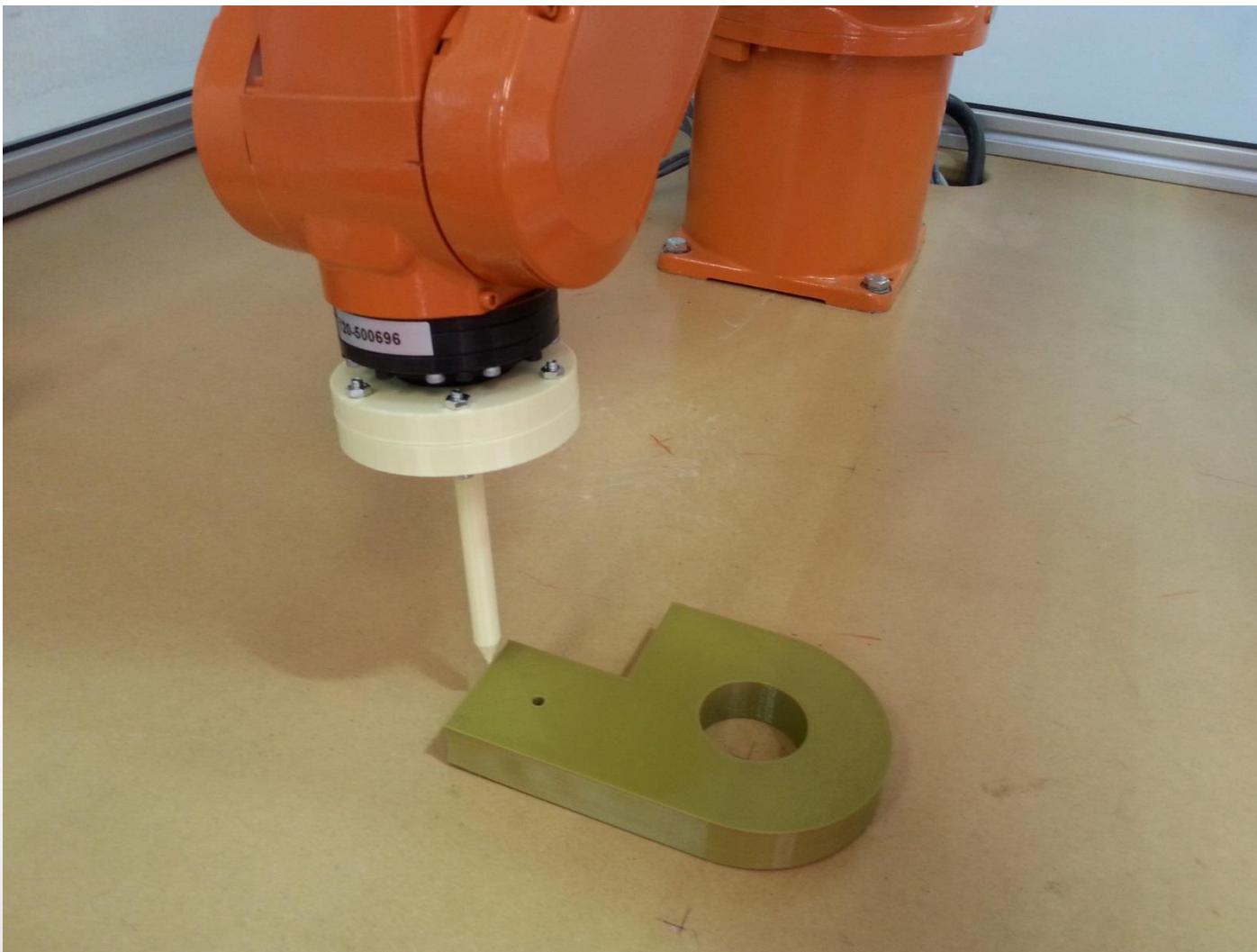
Calibrate Frame for Workpiece

- Object Point X2 is now modified.



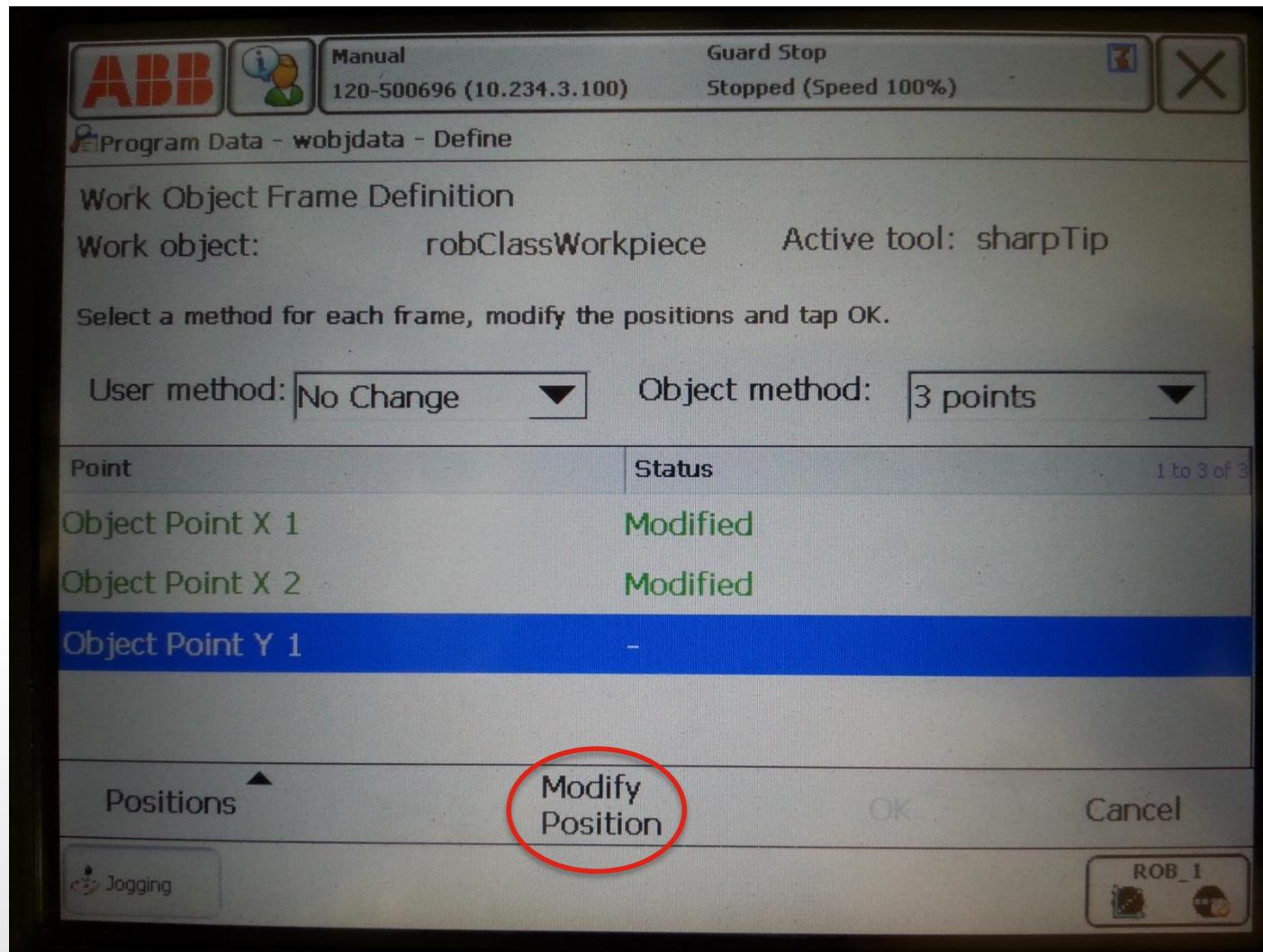
Calibrate Frame for Workpiece

- Lastly, jog the robot to a point on the Y axis.



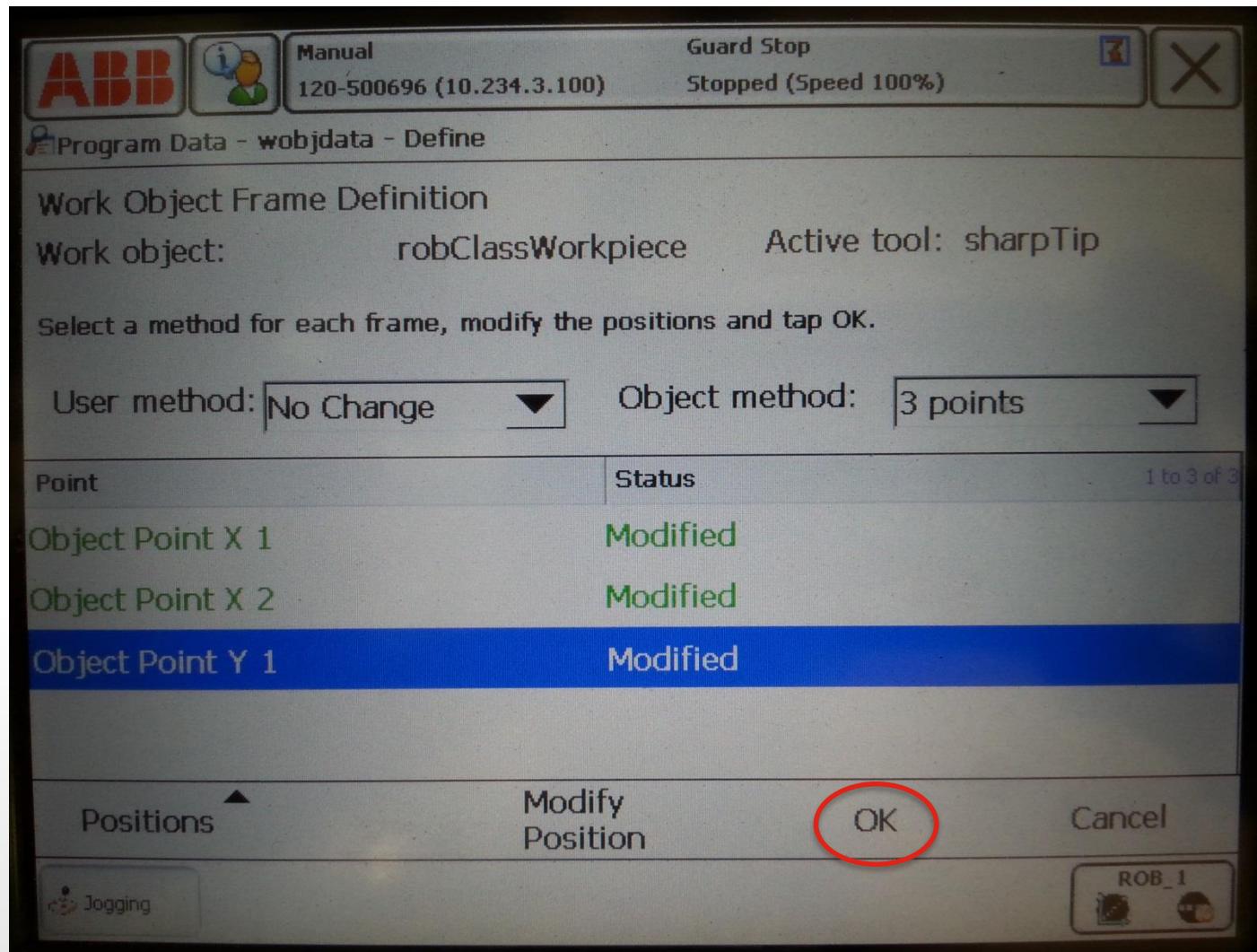
Calibrate Frame for Workpiece

- On the teaching pendant, select Object Point Y1 and click “Modify Position”.



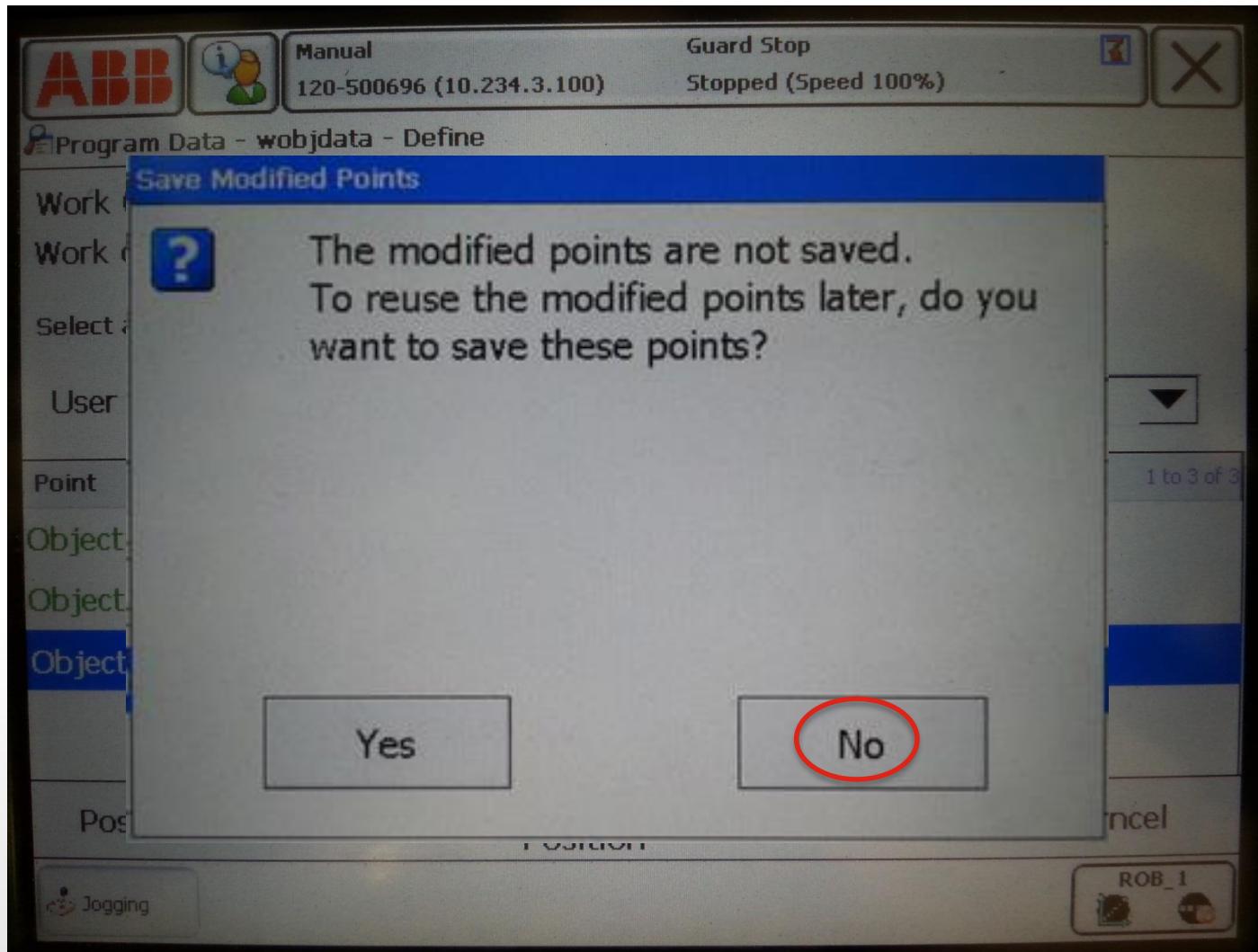
Calibrate Frame for Workpiece

- Object Point Y1 is now modified. Click “OK” to calculate the frame.



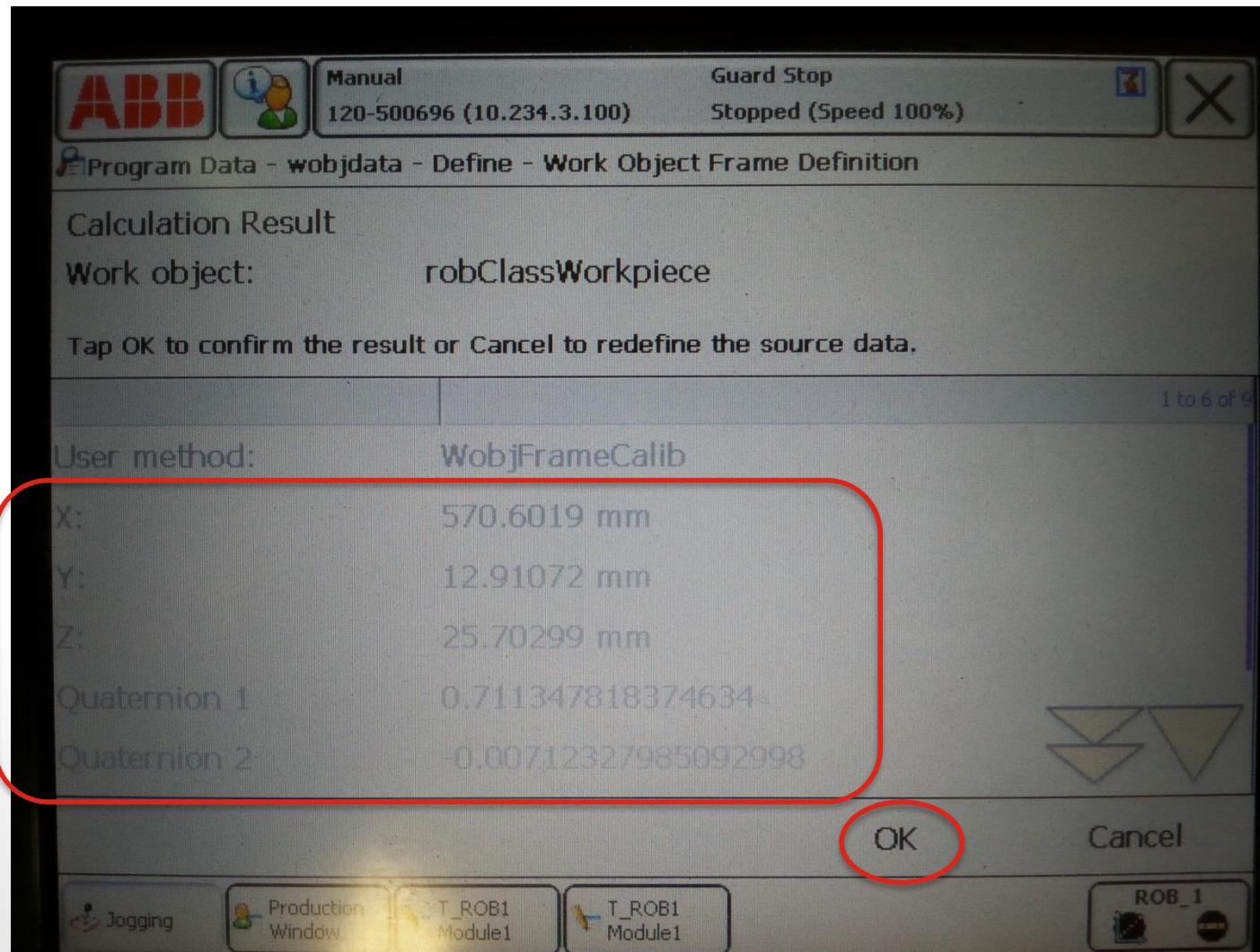
Calibrate Frame for Workpiece

- To the following question, click “No”.



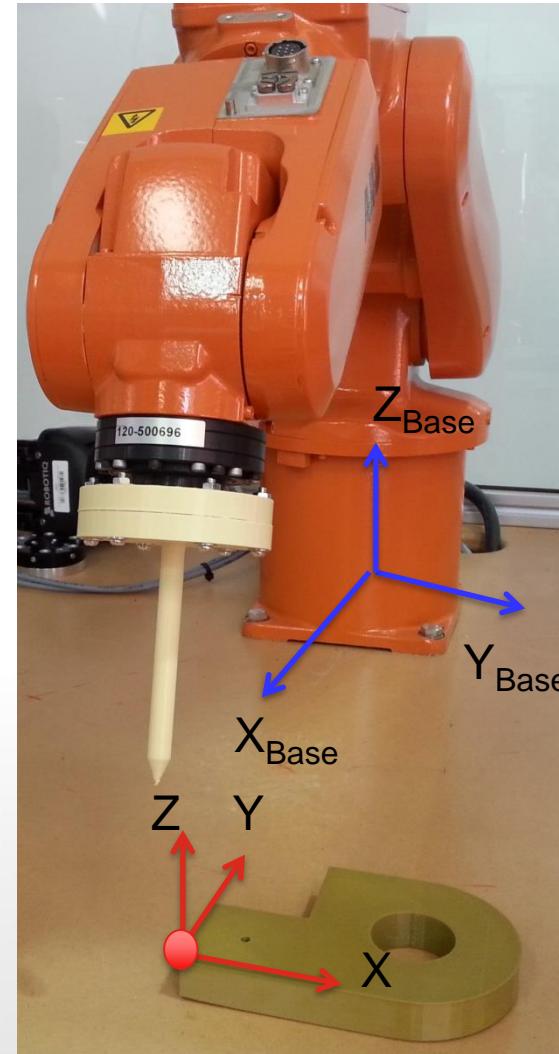
Calibrate Frame for Workpiece

- Finally, the robClassWorkpiece frame is calculated. Click “OK”.



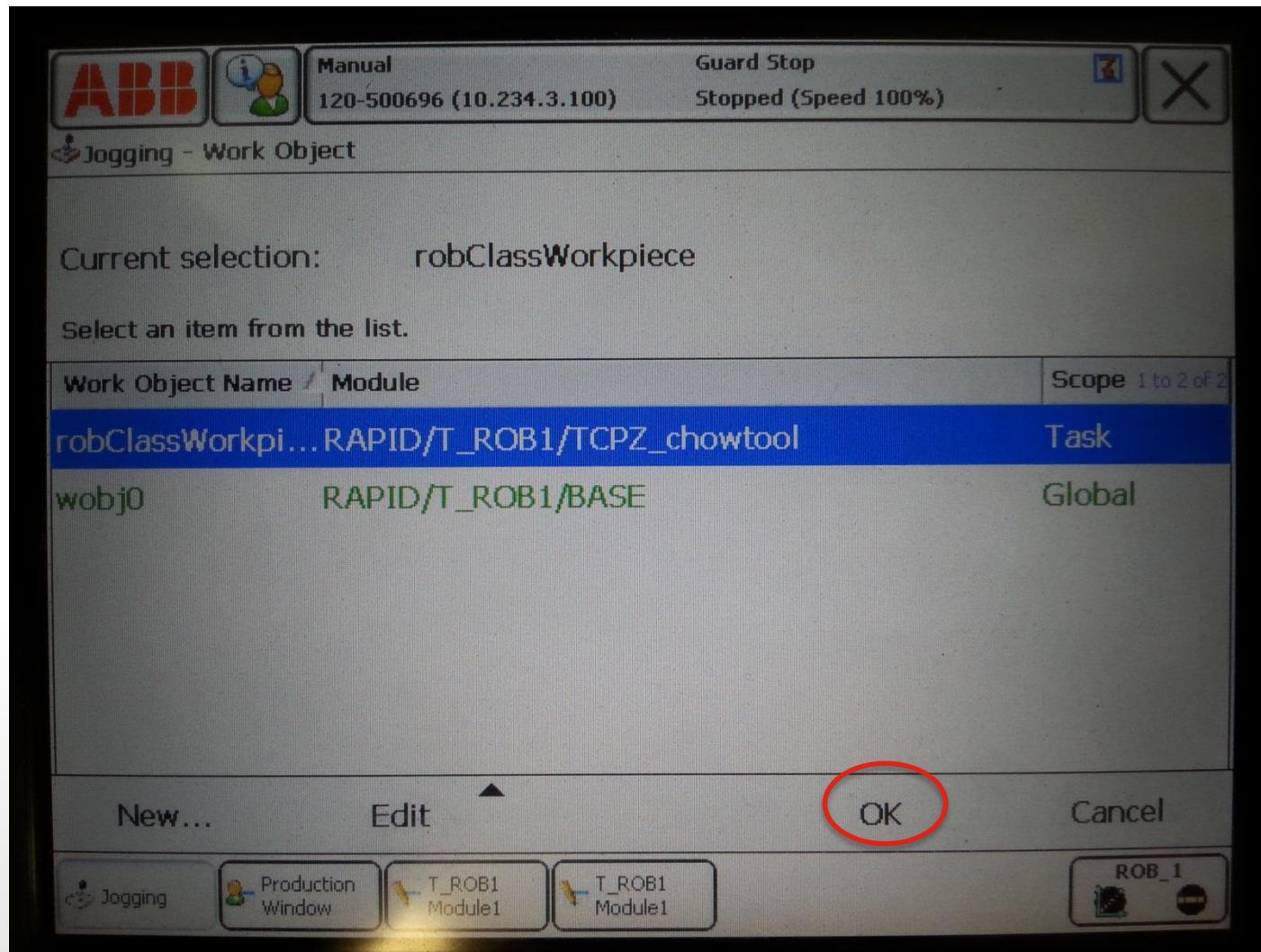
Calibrate Frame for Workpiece

- Write down the values. In this example:
 - X = 570.602 mm
 - Y = 12.9107 mm
 - Z = 25.703 mm
 - Q1 = 0.711348
 - Q2 = -0.00712328
 - Q3 = -0.00124353
 - Q4 = 0.702803
- All the above values are with respect to the robot base frame.



Calibrate Frame for Workpiece

- robClassWorkpiece is now specified. Click “OK” again.

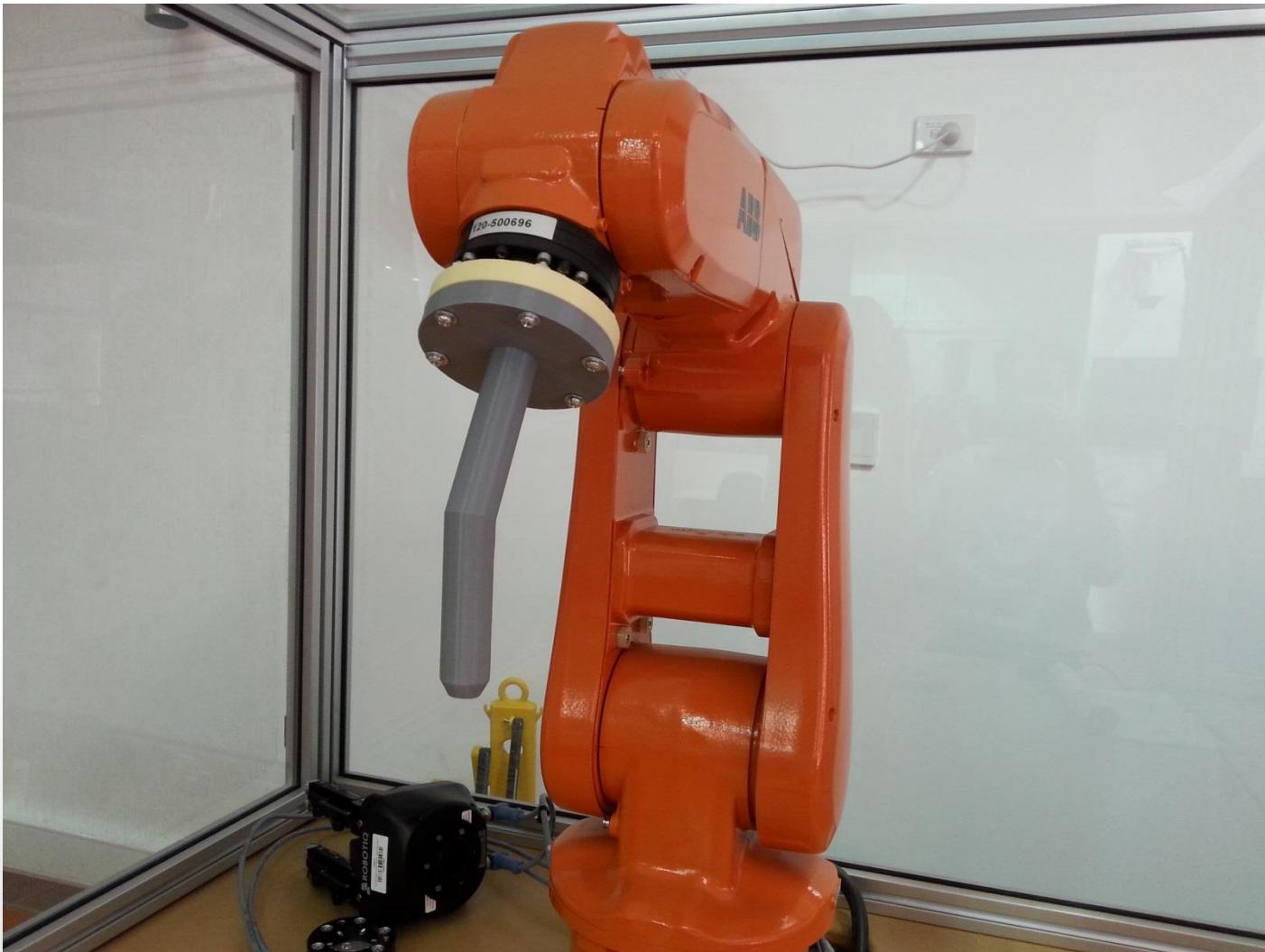


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- Introduction
- Creating a Tool Frame for Sharp-Tipped Calibration Tool
- Calibrating the Sharp-tipped Calibration Tool
- Creating a Frame for the Workpiece / Work Cell
- Calibrating the Workpiece / Work Cell
- **Creating a Tool Frame for the Actual Tool**
- Calibrating the Actual Tool

Create Frame for Actual Tool

- We now swap the sharpTip with the **actual tool**.



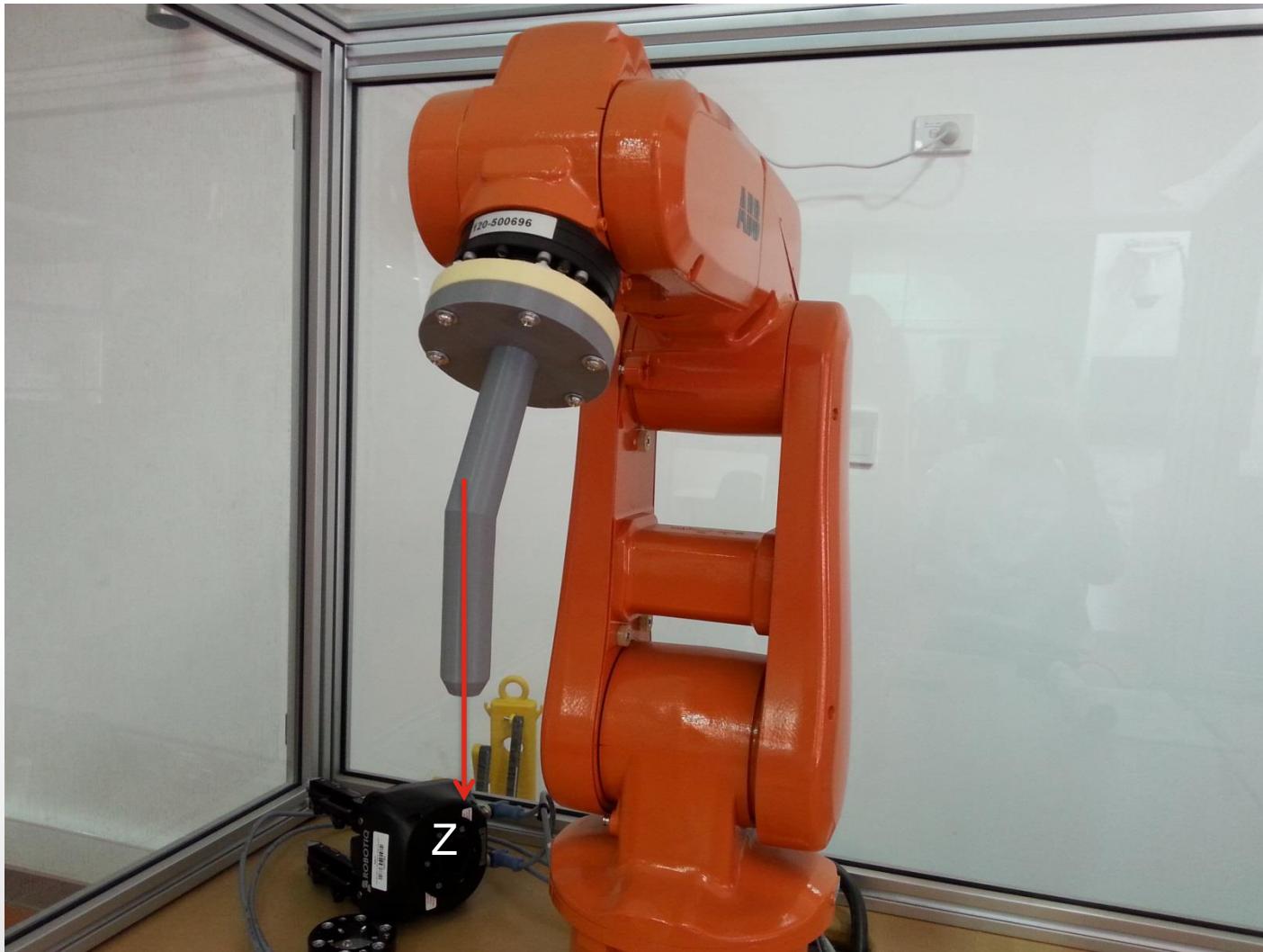
Create Frame for Actual Tool

- We will also later **calibrate a frame** for the actual tool.



Create Frame for Actual Tool

- It is desired to have the tool's **Z-axis** passing through the tool **axially**.



Create Frame for Actual Tool

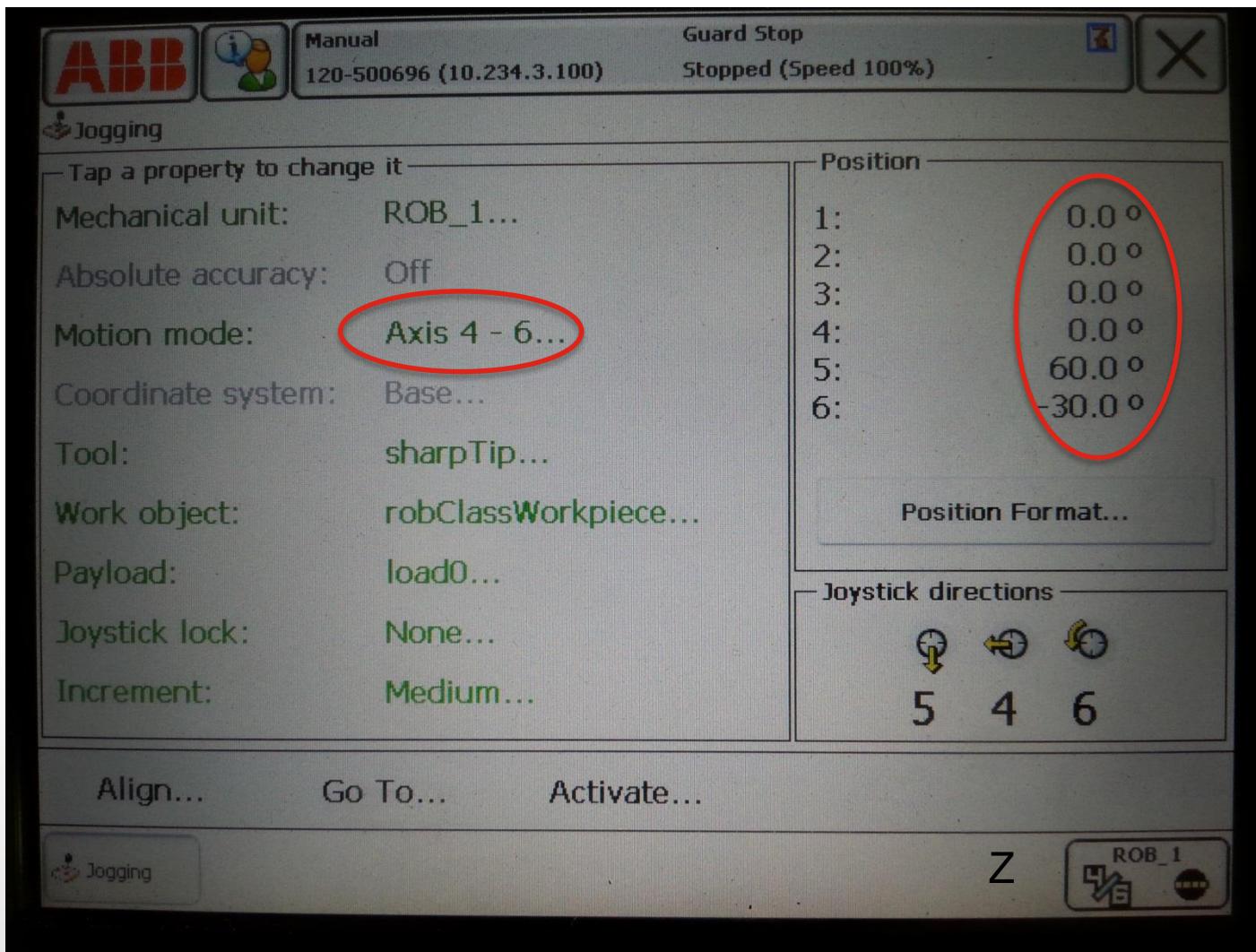
- Therefore we first jog the robot such that the far-end of the welding torch is in

a vertical position.



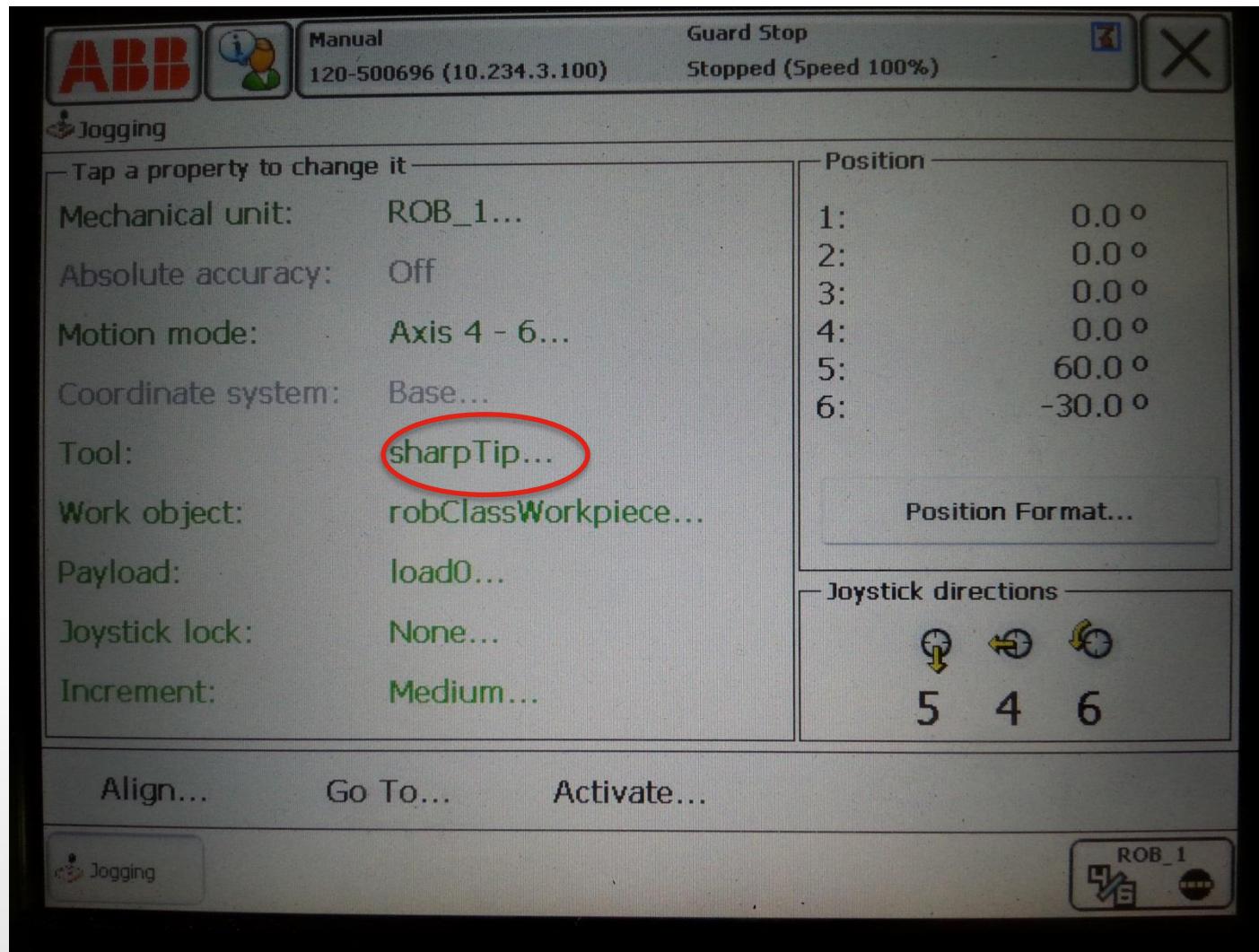
Create Frame for Actual Tool

- This is done by jogging the **joints** to certain angles based on the **initial understanding** of the tool (e.g. technical drawing)



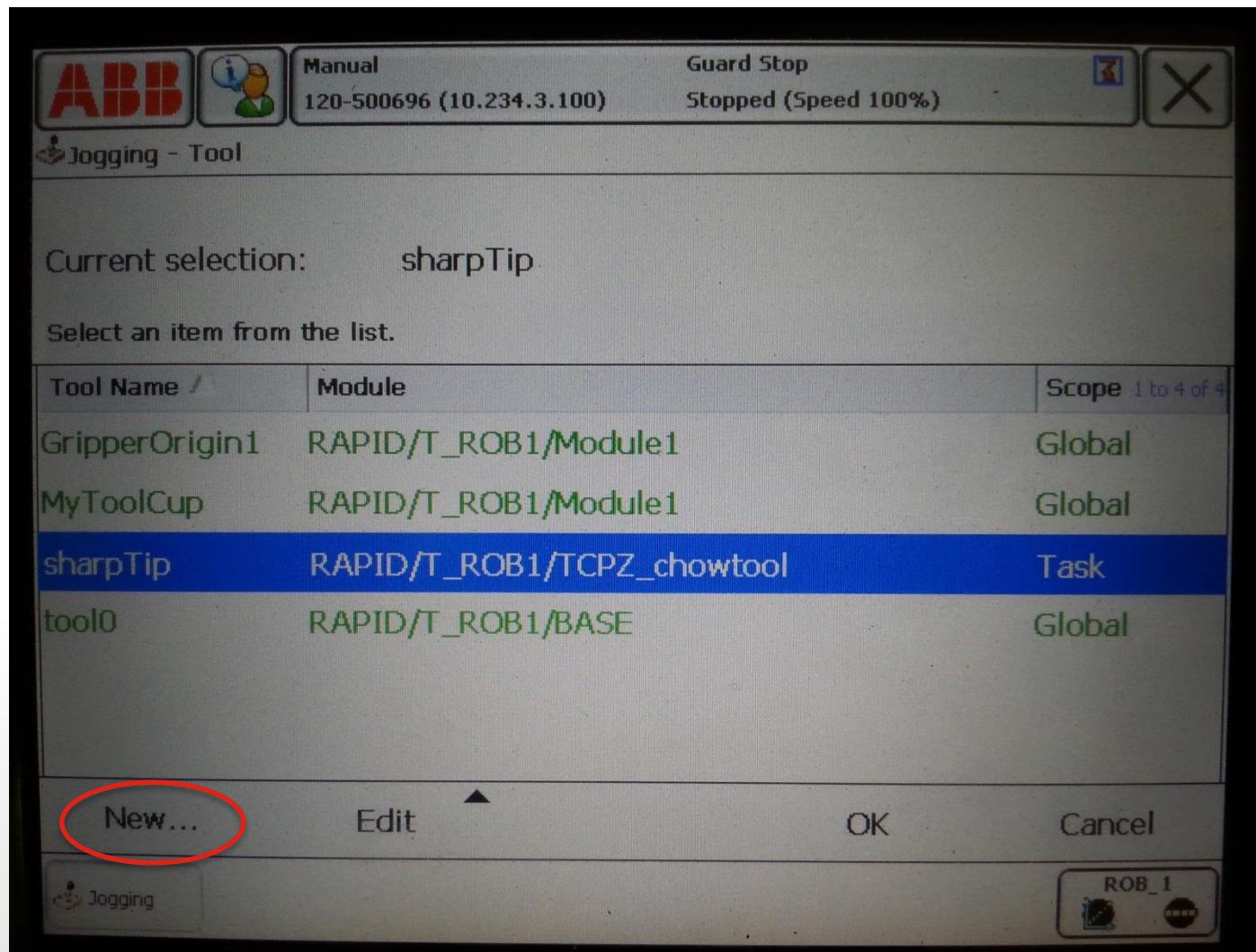
Create Frame for Actual Tool

- Next, we will need to create the frame in the list of tools. Click any tool.



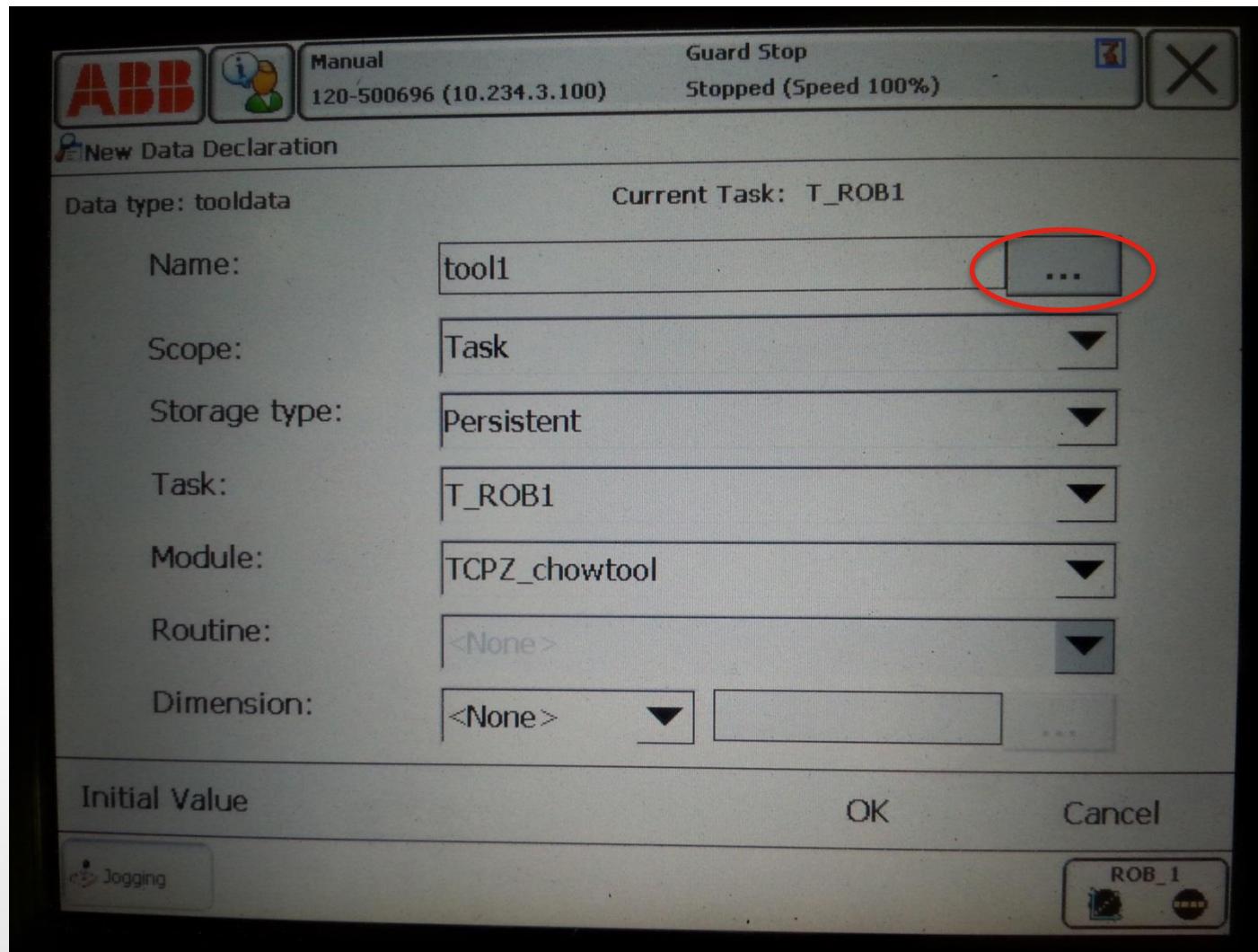
Create Frame for Actual Tool

- In the next window, click “New”.



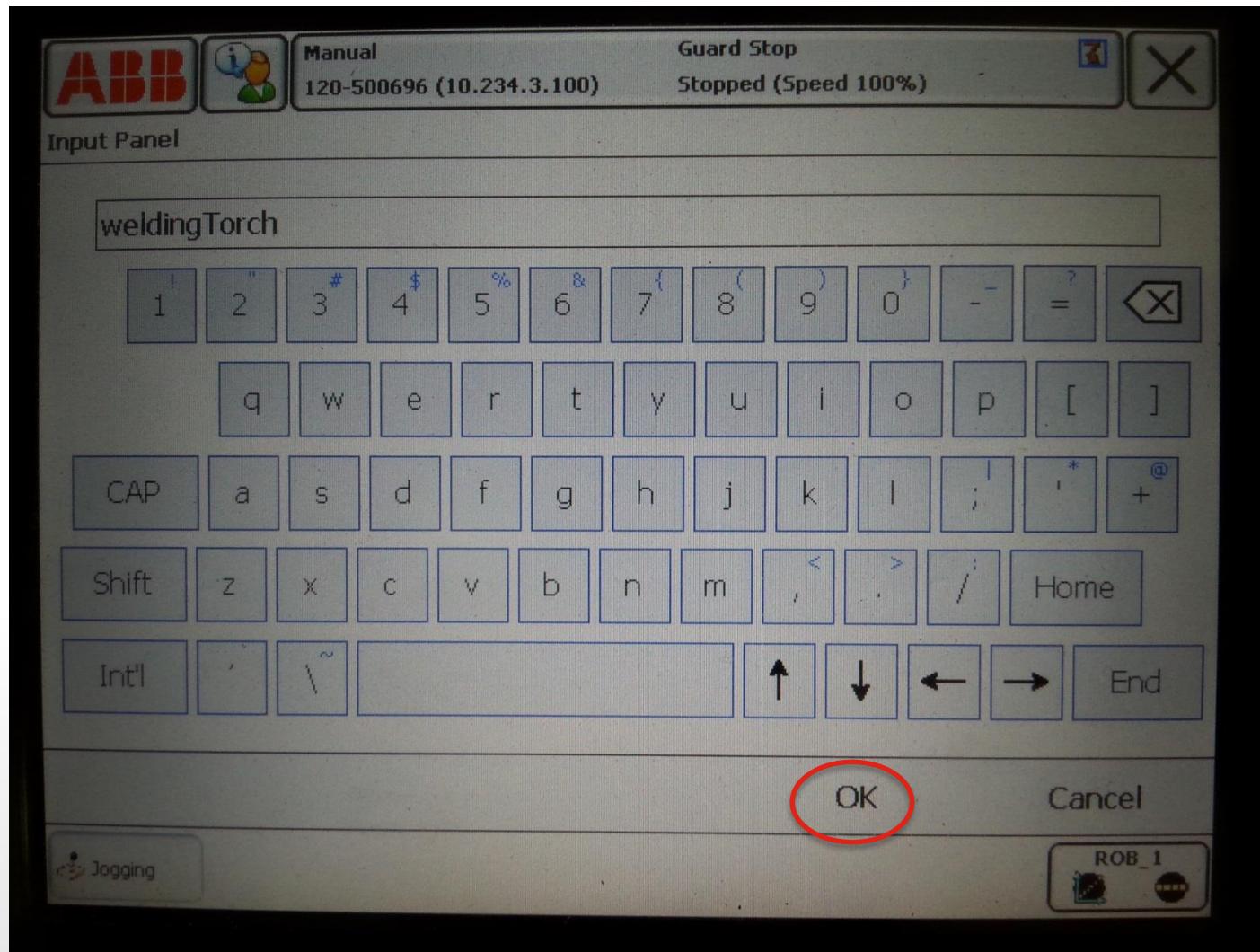
Create Frame for Actual Tool

- To change the tool name to be more meaningful, click “...”.



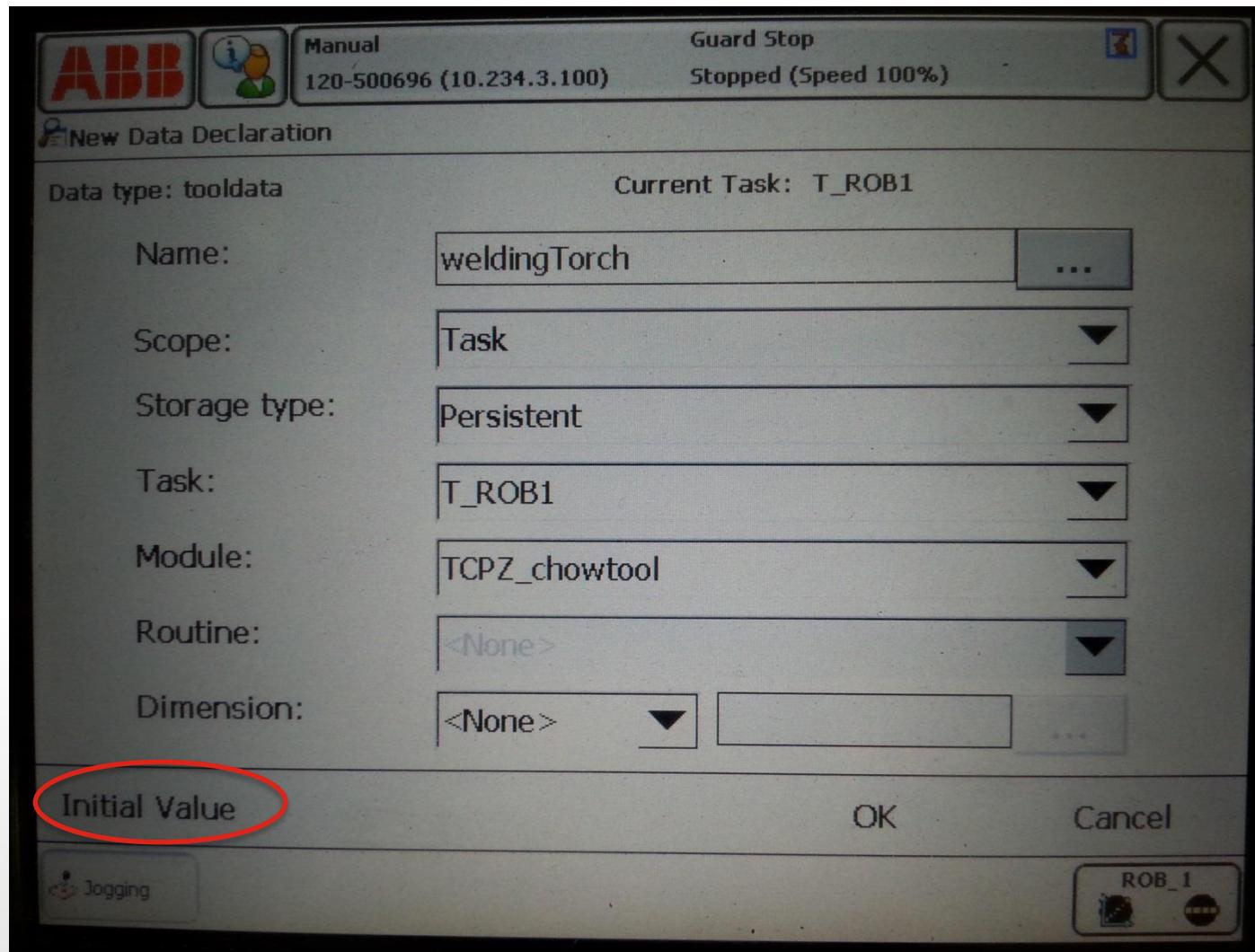
Create Frame for Actual Tool

- Rename it as “weldingTorch” then click “OK”.



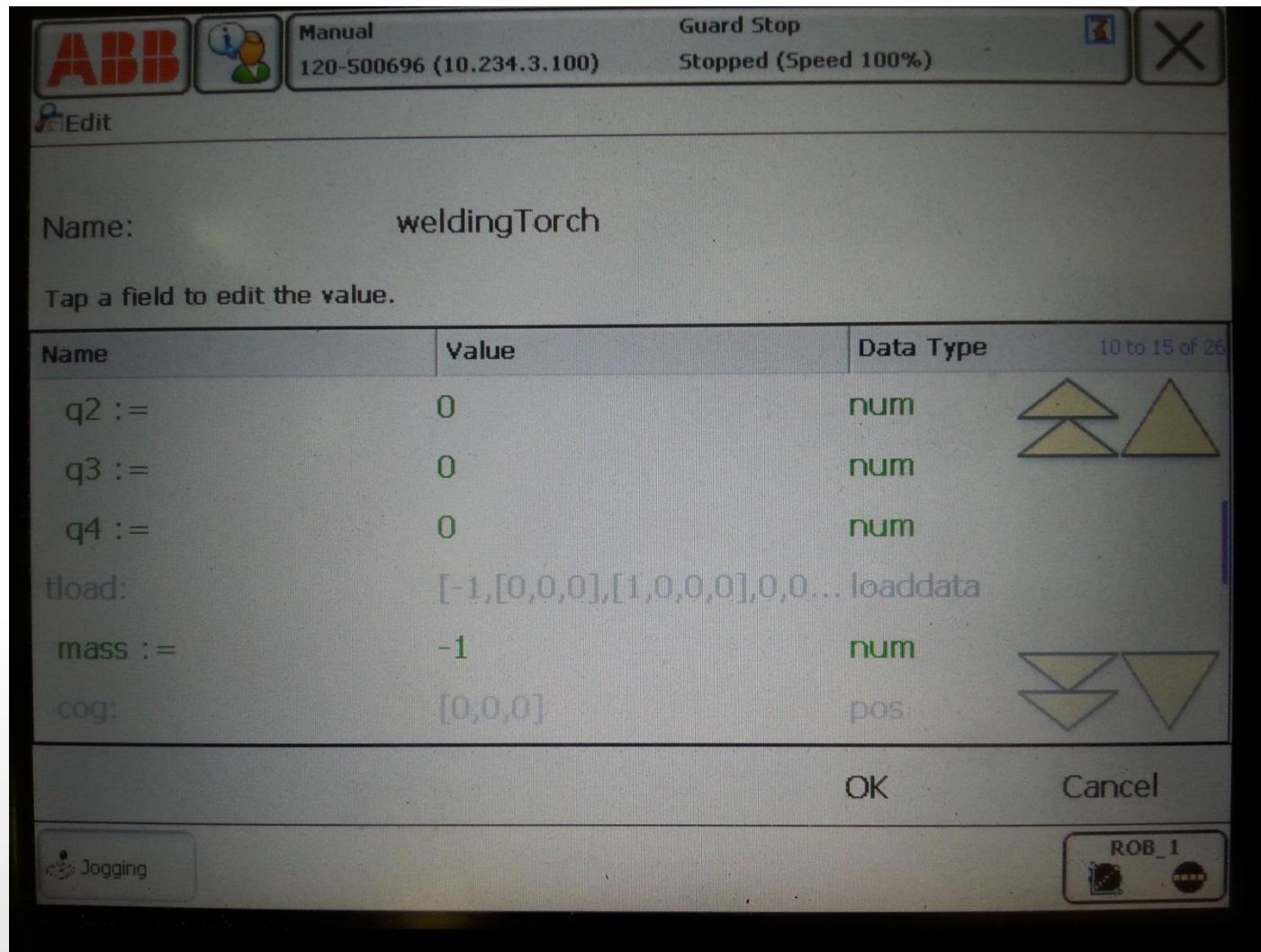
Create Frame for Actual Tool

- Click “Initial Value” on this window.



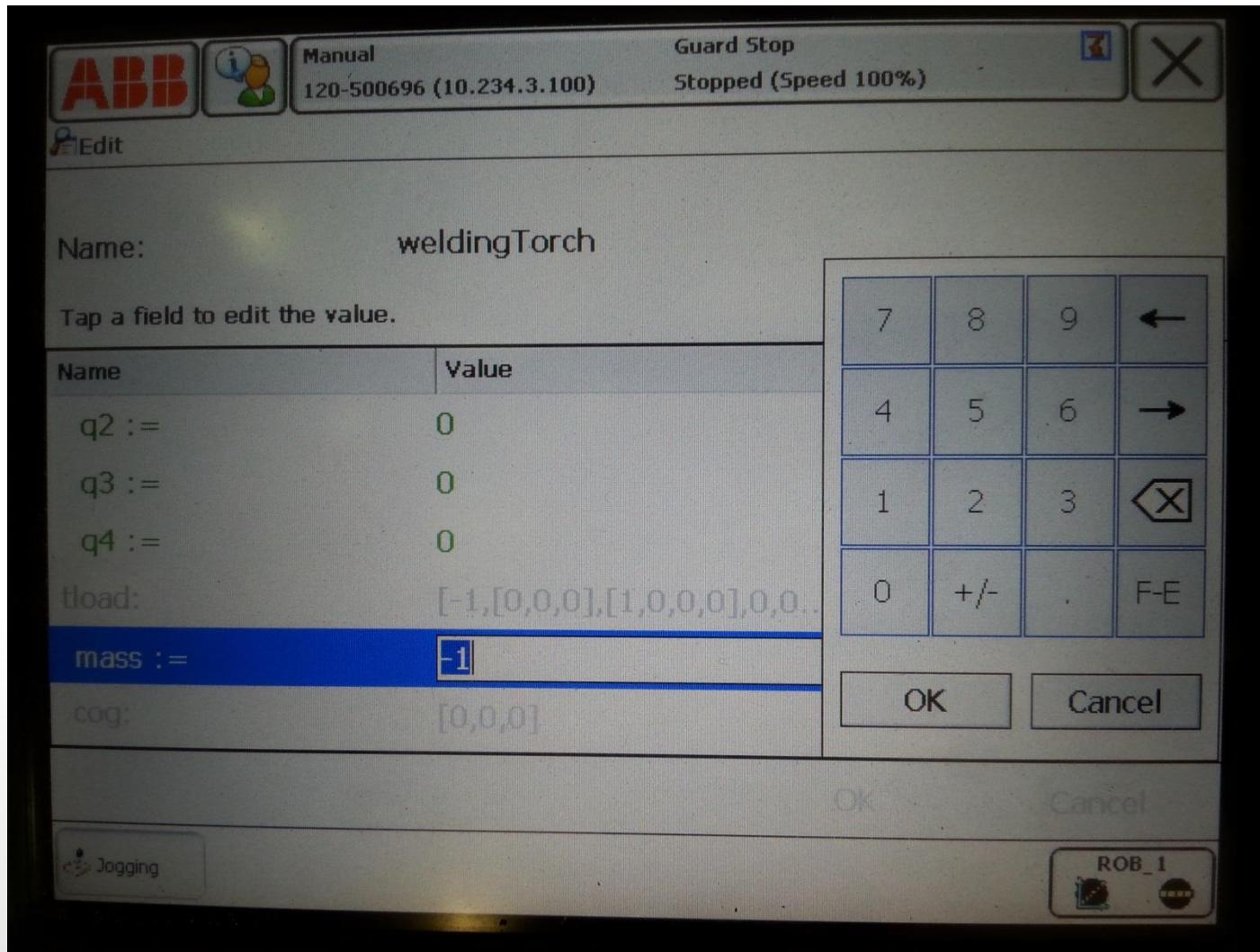
Create Frame for Actual Tool

- As with the sharpTip earlier, we need to give a **mass** for the weldingTorch.



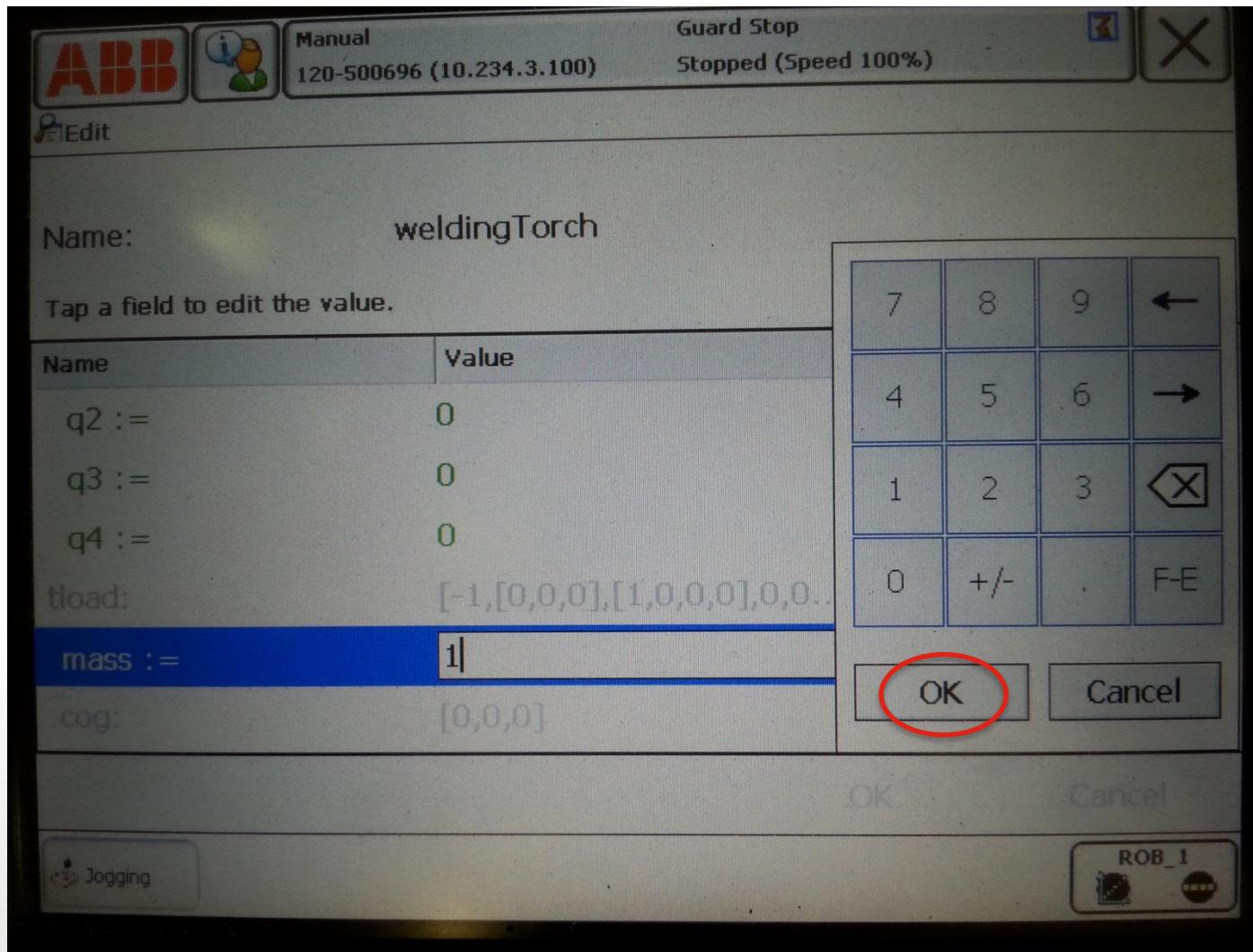
Create Frame for Actual Tool

- Click “-1” and then key in the actual mass.



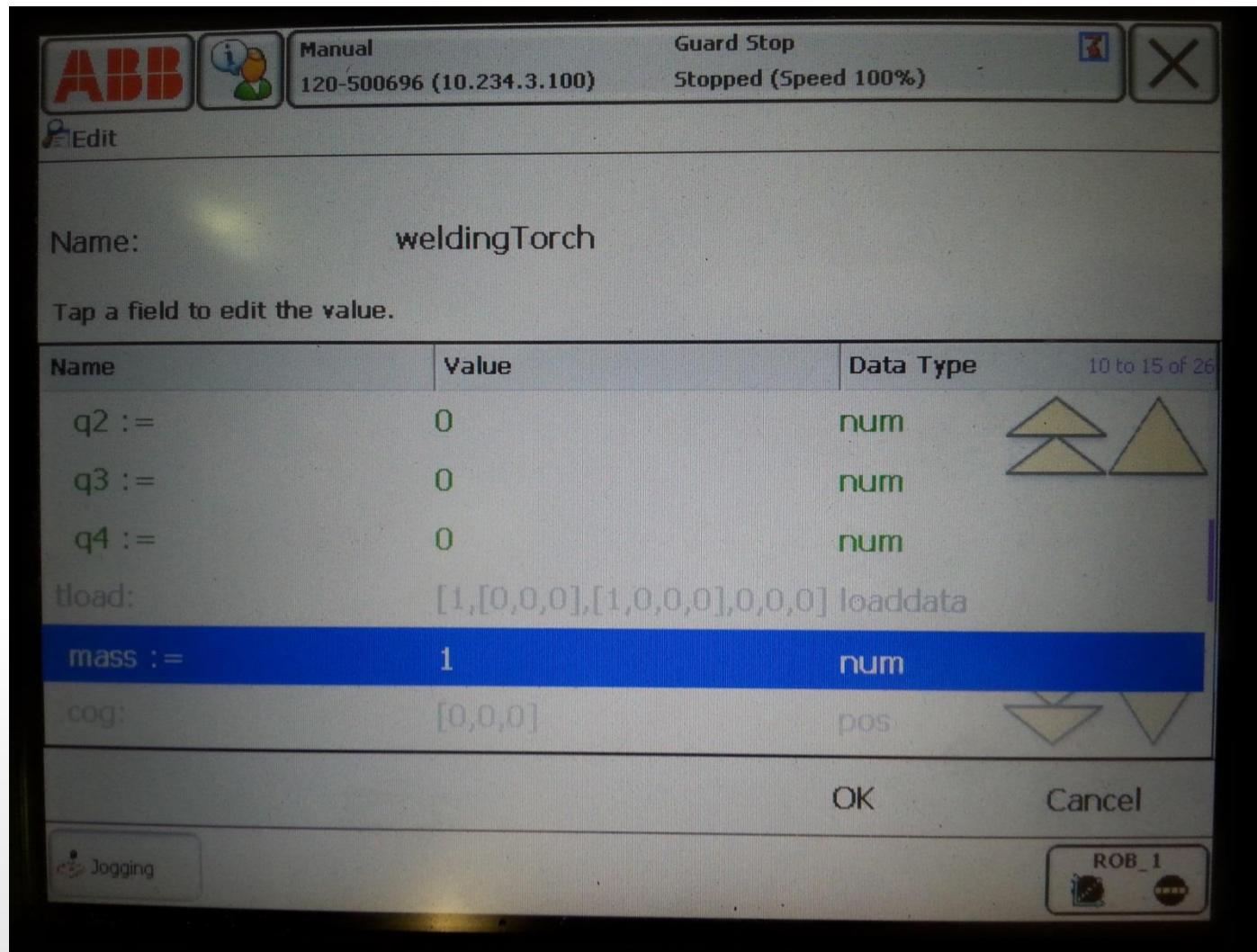
Create Frame for Actual Tool

- Click “OK”.



Create Frame for Actual Tool

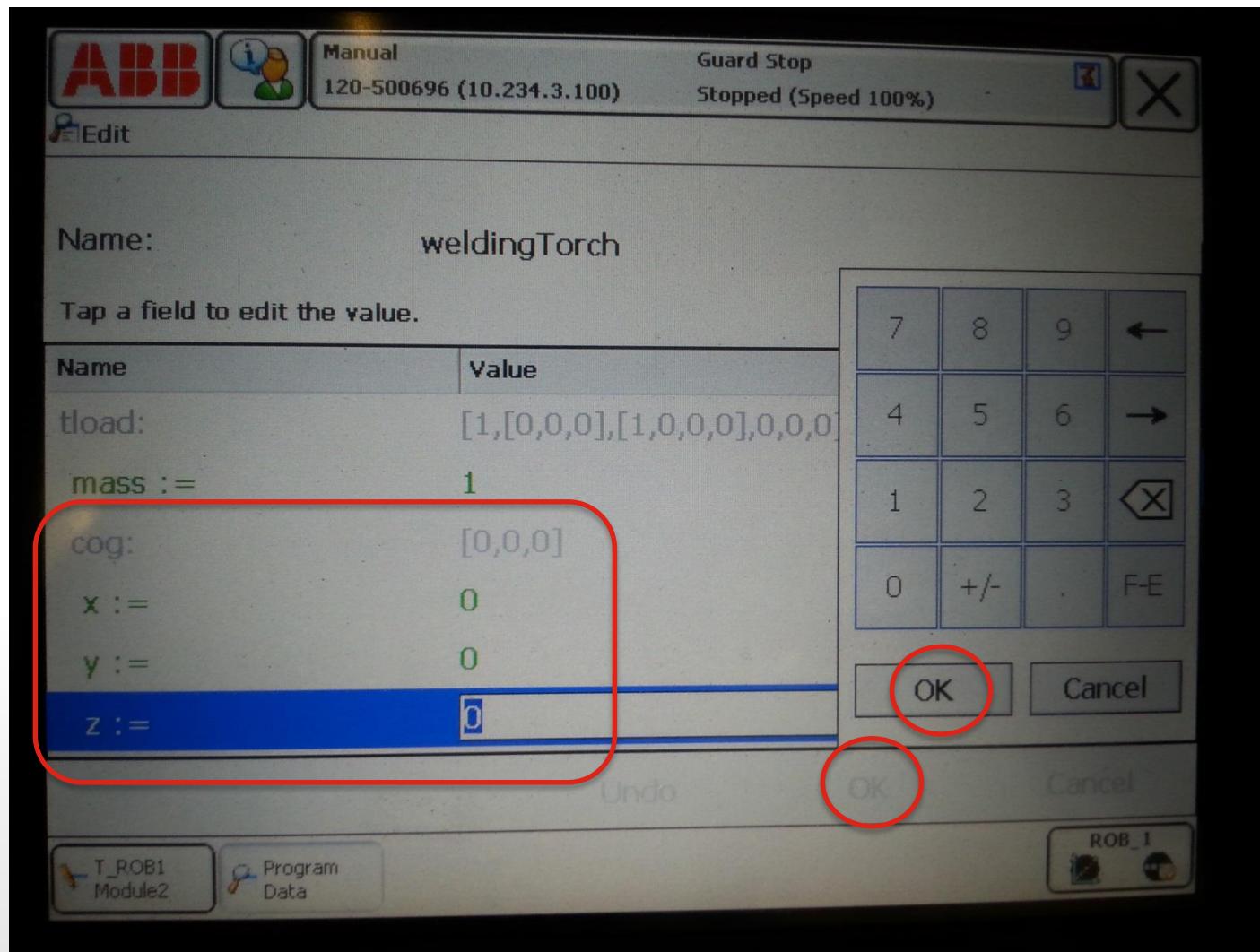
- Now the mass is defined.



Create Frame for Actual Tool

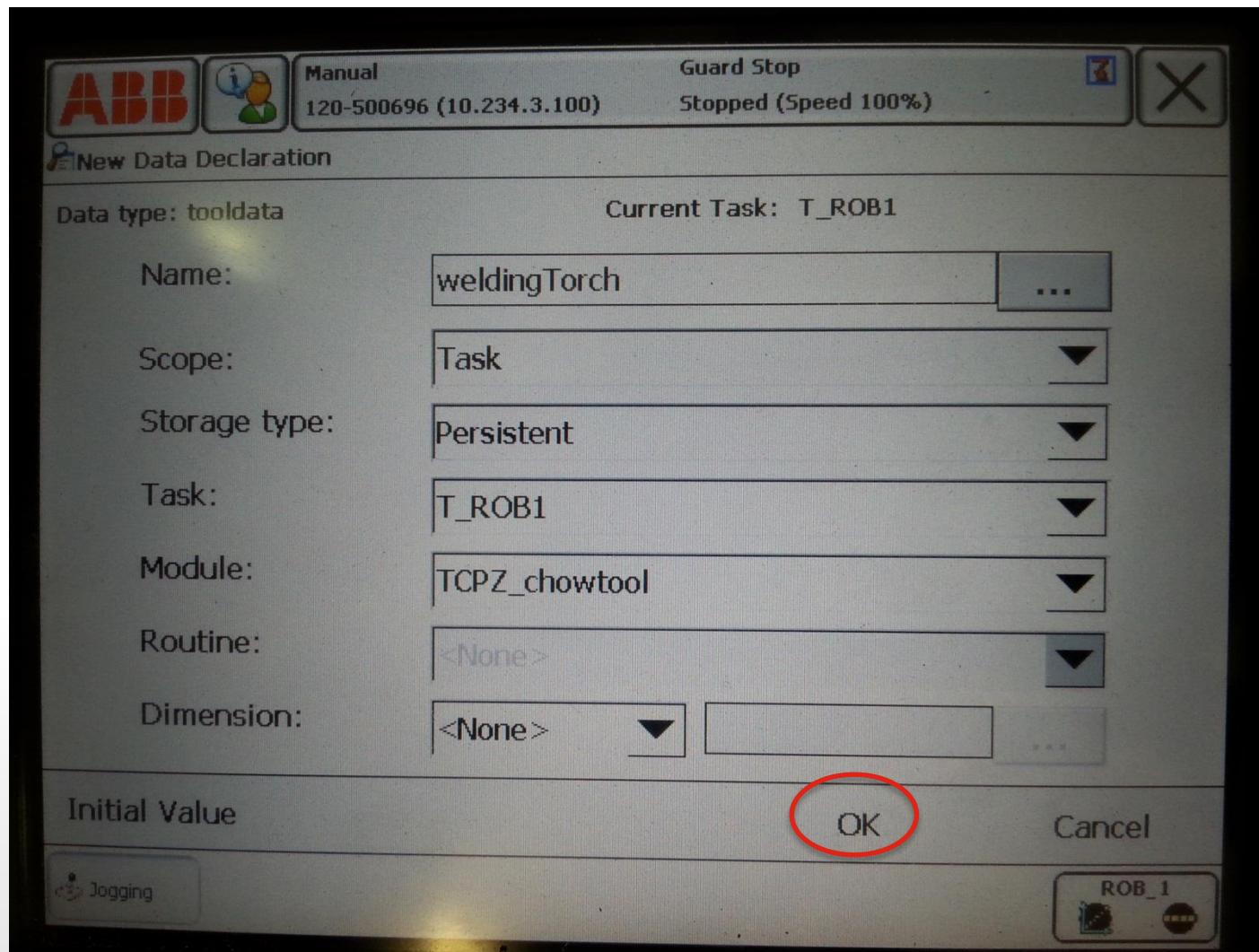
- We also need to provide the center of gravity. Give a reasonable value, then

click
“OK” and
“OK”
again.



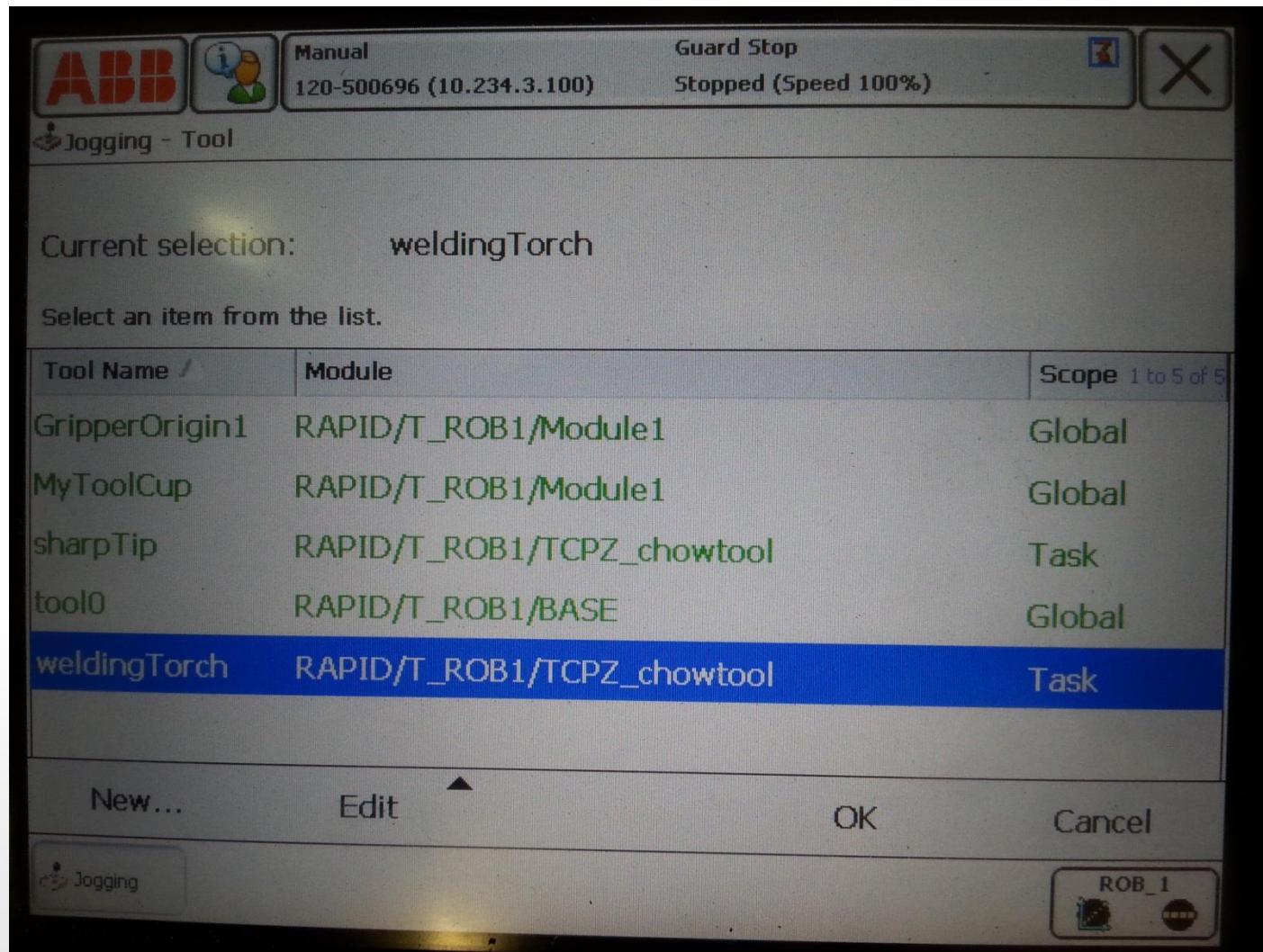
Create Frame for Actual Tool

- Click “OK” again on the next window.



Create Frame for Actual Tool

- Now the tool frame is created.

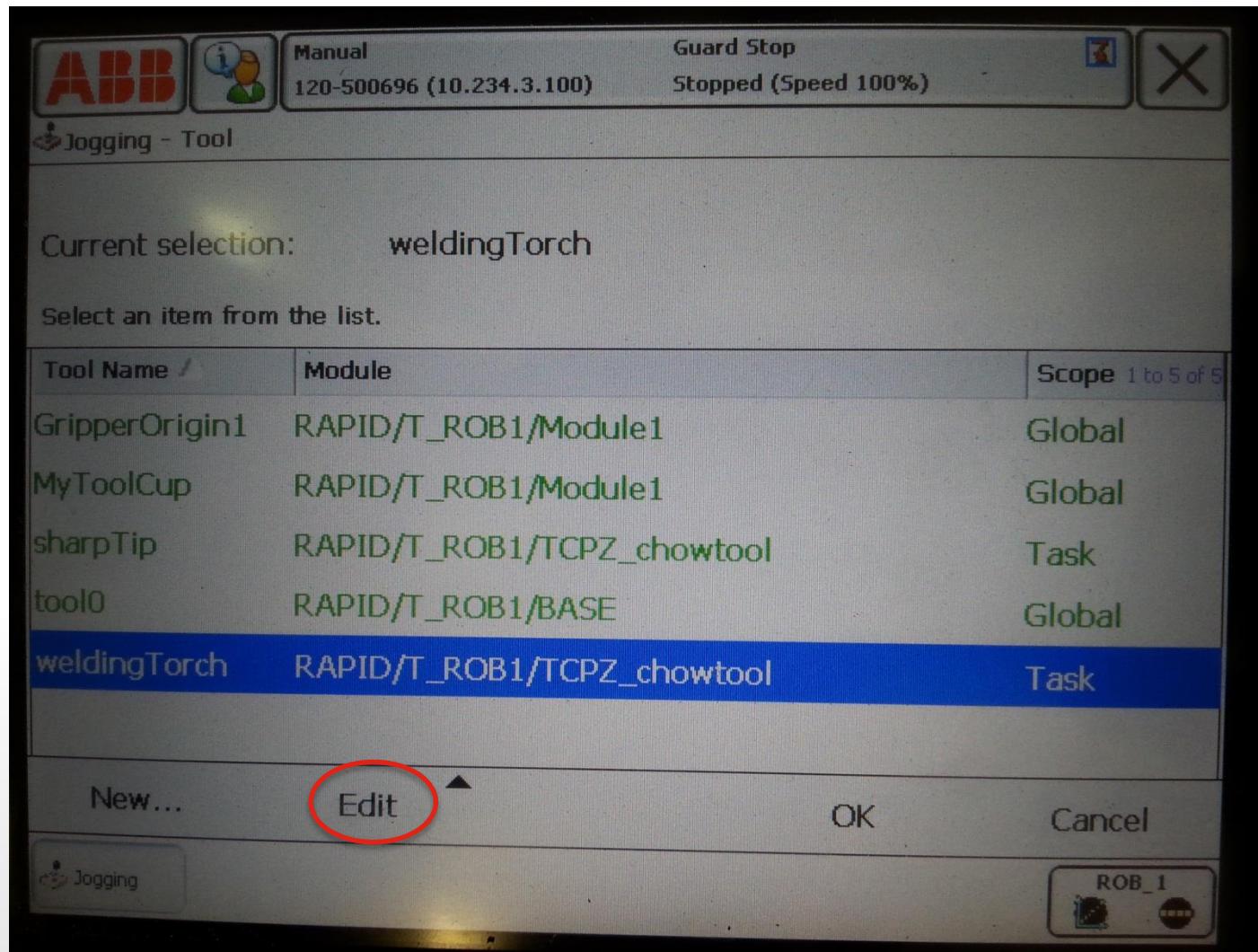


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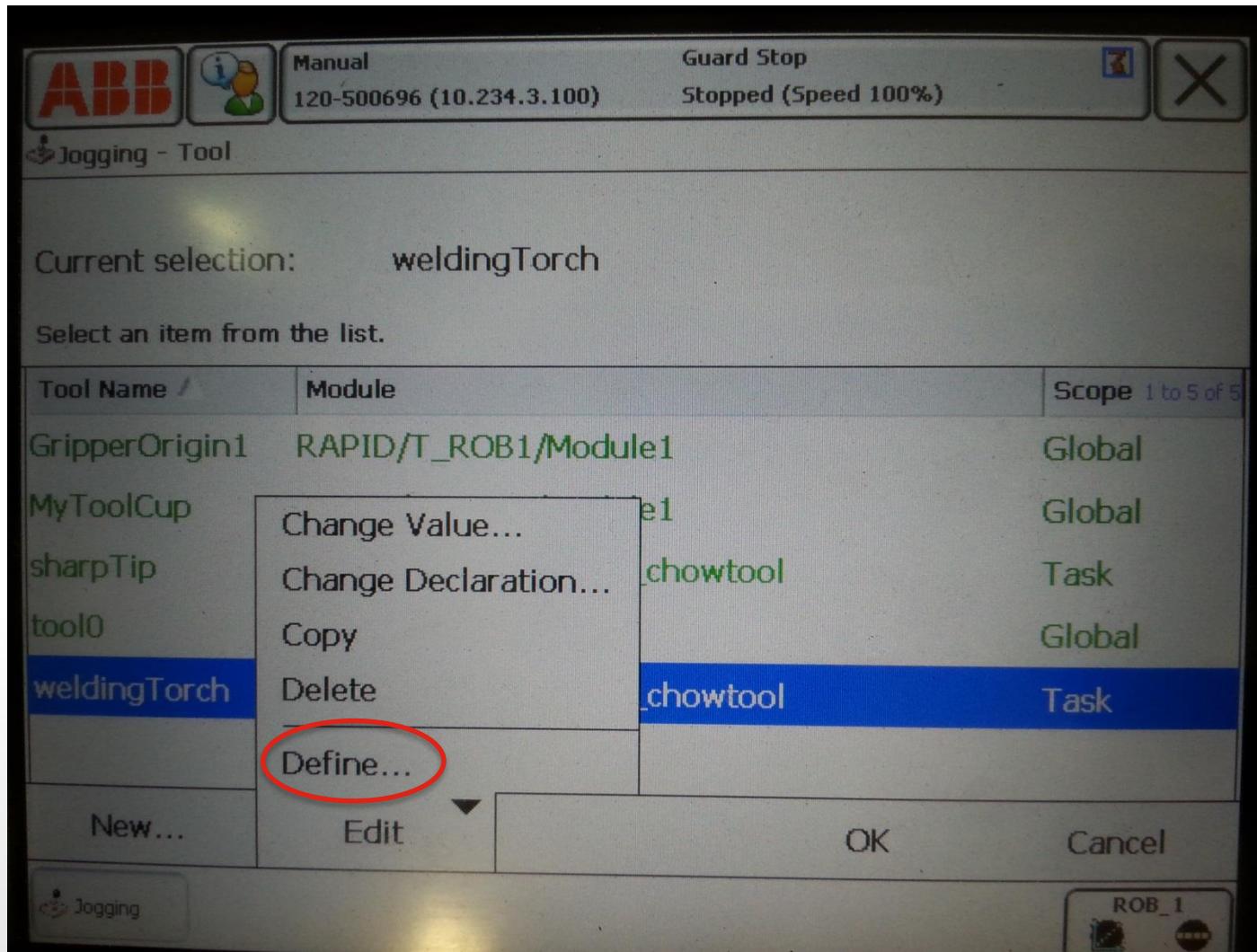
Calibrate Frame for Actual Tool

- To calibrate the tool, click “Edit”.



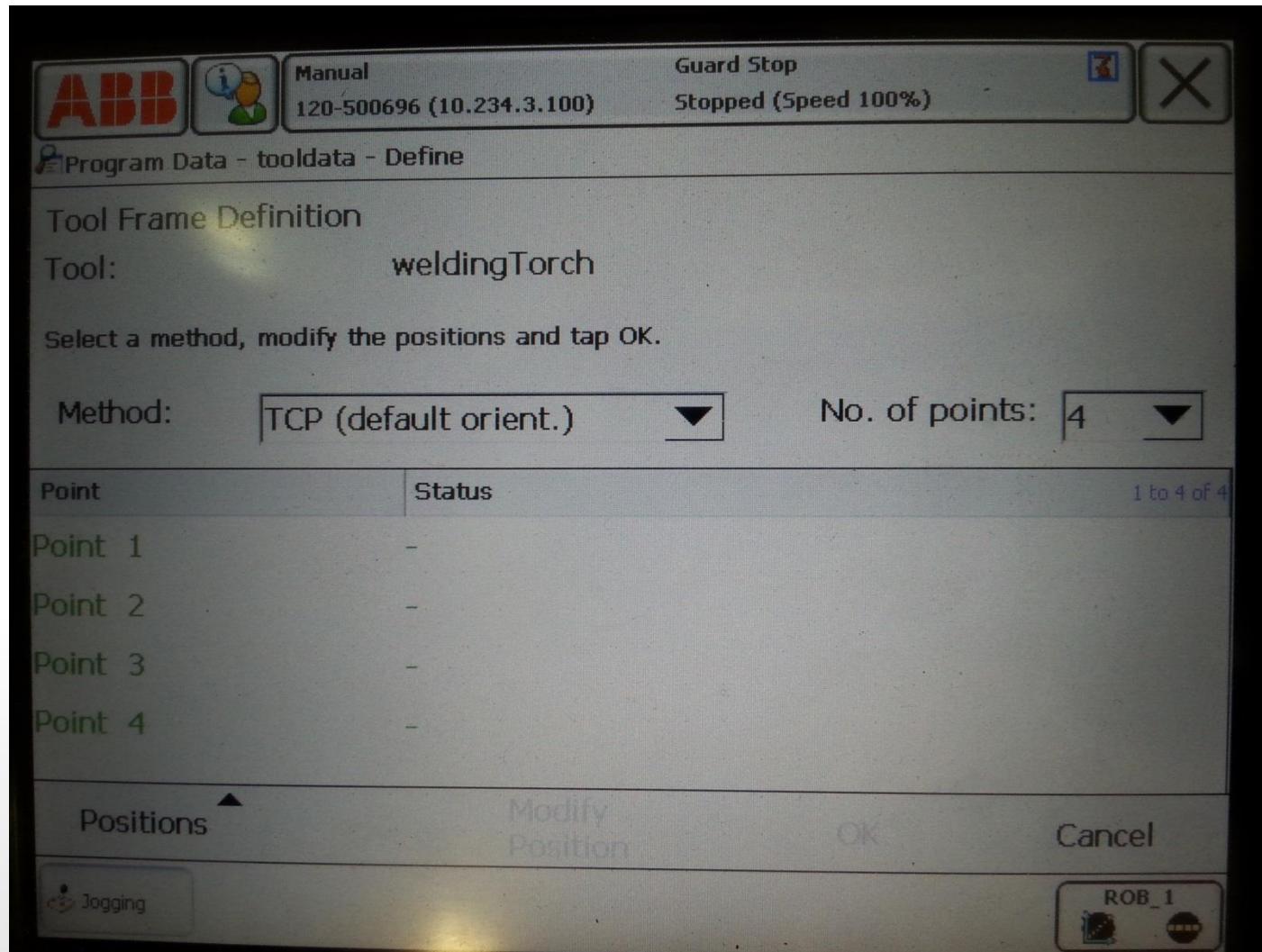
Calibrate Frame for Actual Tool

- On the pop-up menu, choose “Define”.



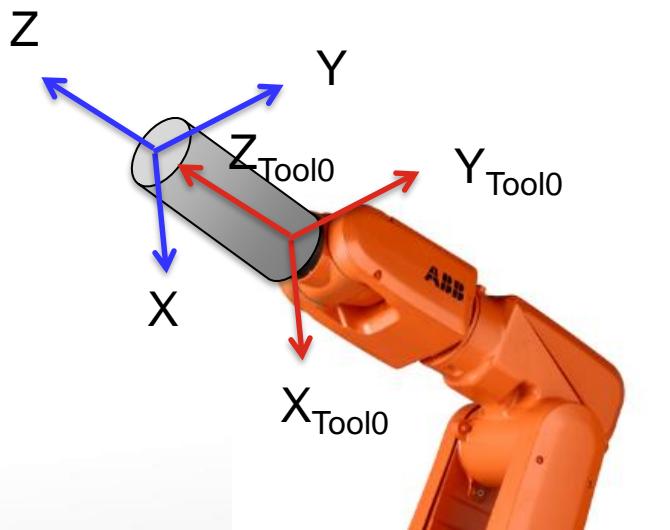
Calibrate Frame for Actual Tool

- We can again choose the method for calibration.

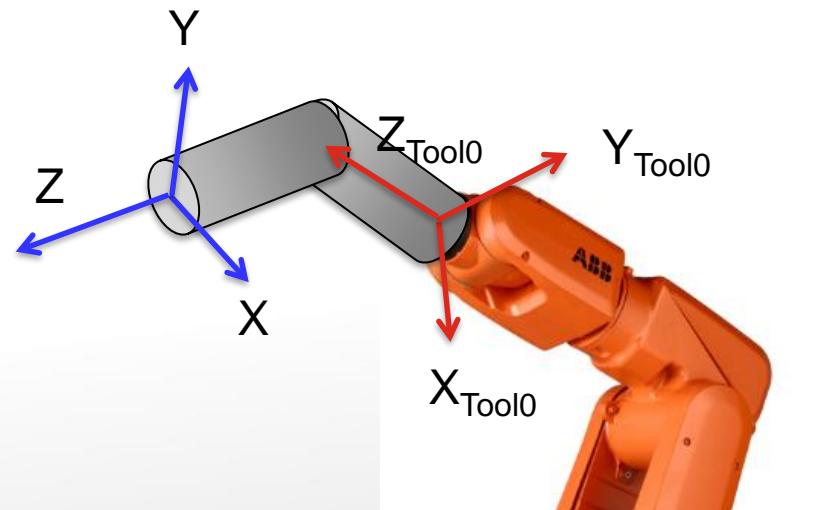


Calibrate Frame for Actual Tool

- TCP (default orientation) means that the orientation follows that of Tool0.
- TCP & Z means that Z-axis is user defined.
- TCP & Z, X means that Z-axis and X-axis are user defined.



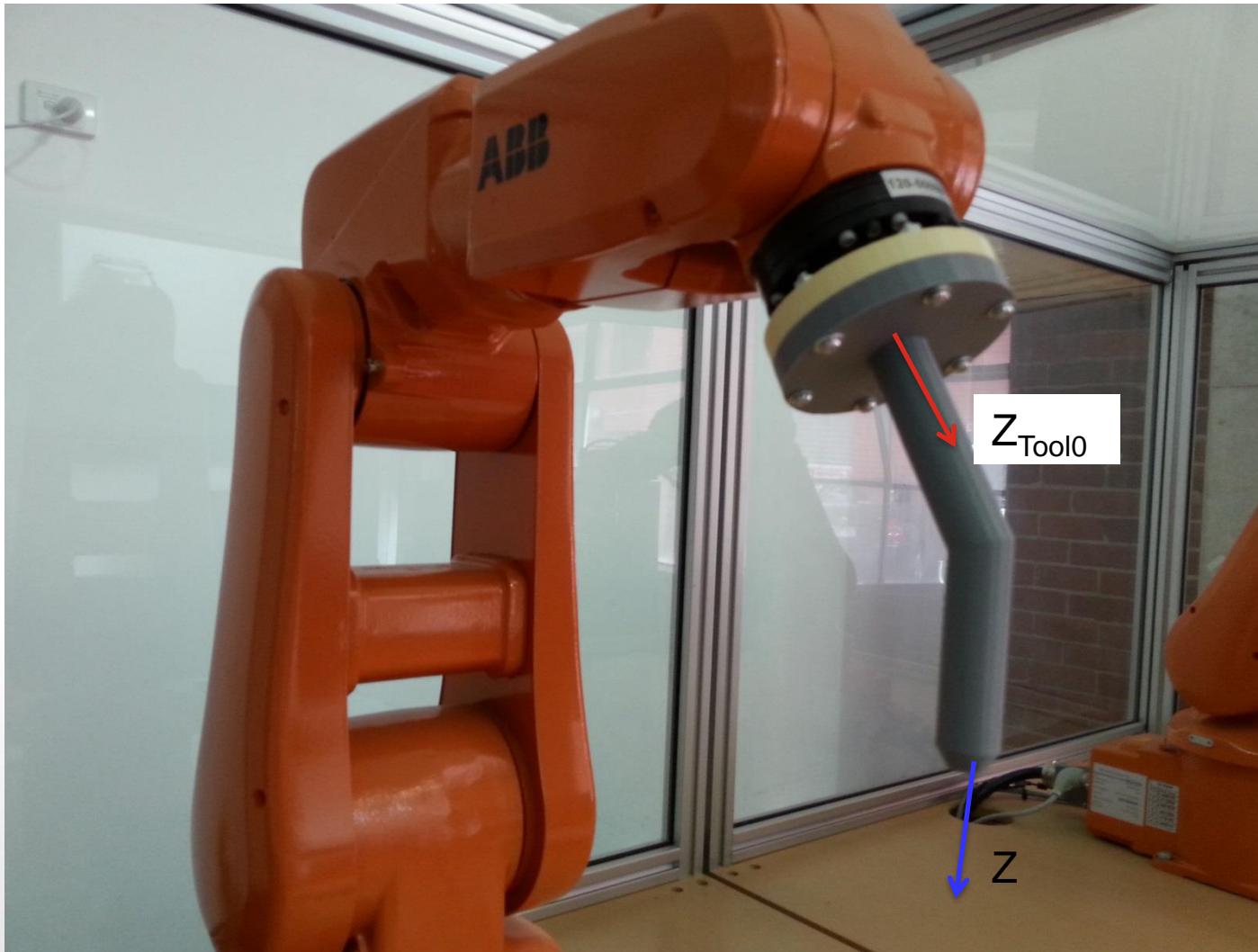
TCP (Default Orientation)



TCP & Z, or TCP & Z, X

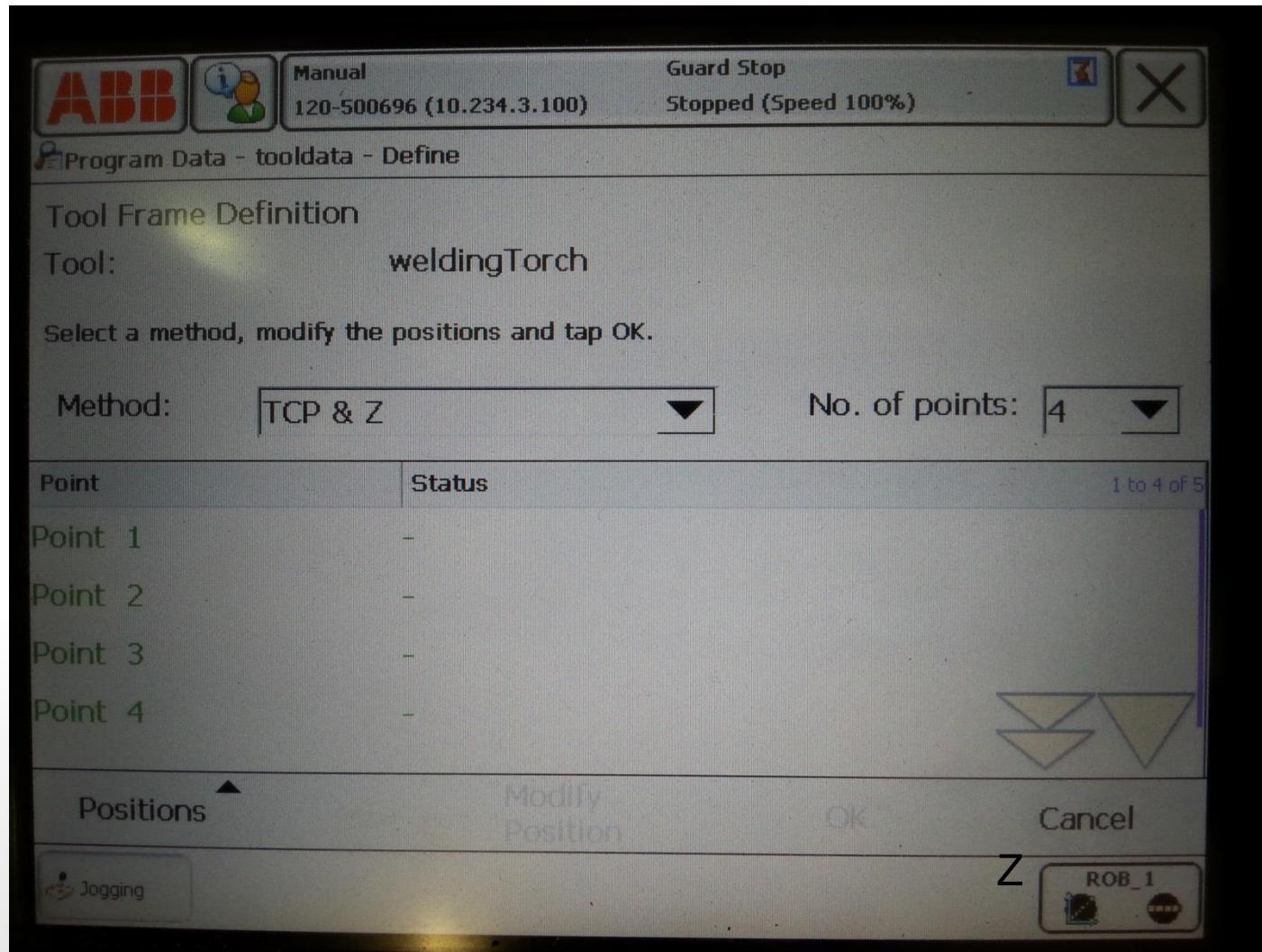
Calibrate Frame for Actual Tool

- Because the weldingTorch is “crooked”, we want to define our own Z-axis.



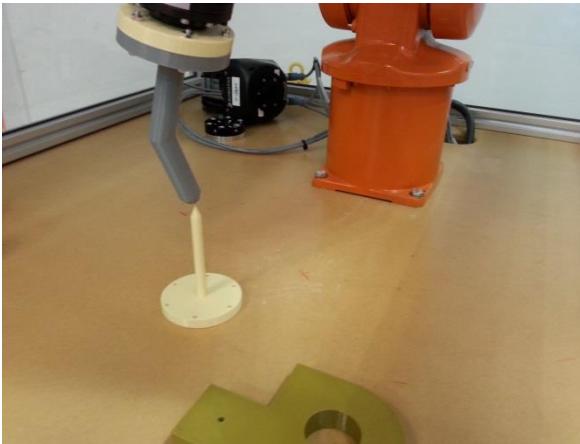
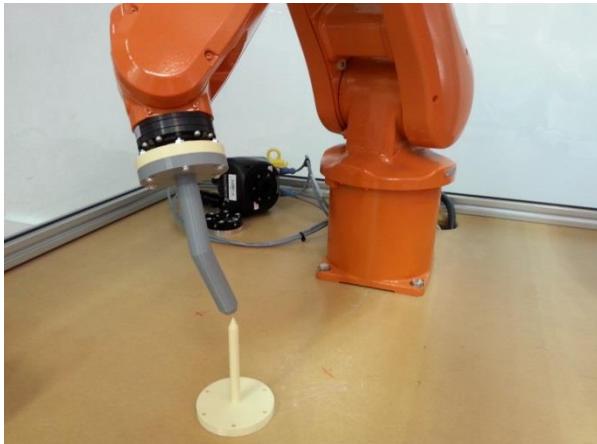
Calibrate Frame for Actual Tool

- Therefore we choose “TCP & Z” as the method.



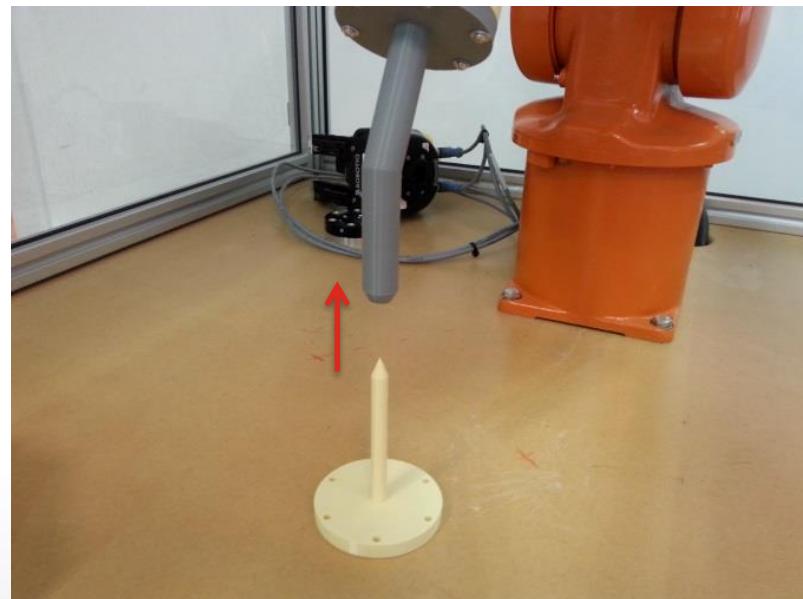
Calibrate Frame for Actual Tool

- The idea is to jog the robot to 1 single point (here: end of sharp tip) at 4 different orientations, and teach one more point on the Z-axis.



Calibrate Frame for Actual Tool

- Instead of teaching the points in usual order, we actually teach the **fourth orientation** and the **z-point** first, as the tool is already in the **upright position**.



- This is to make it easy to teach the robot the **point along the z-axis**.

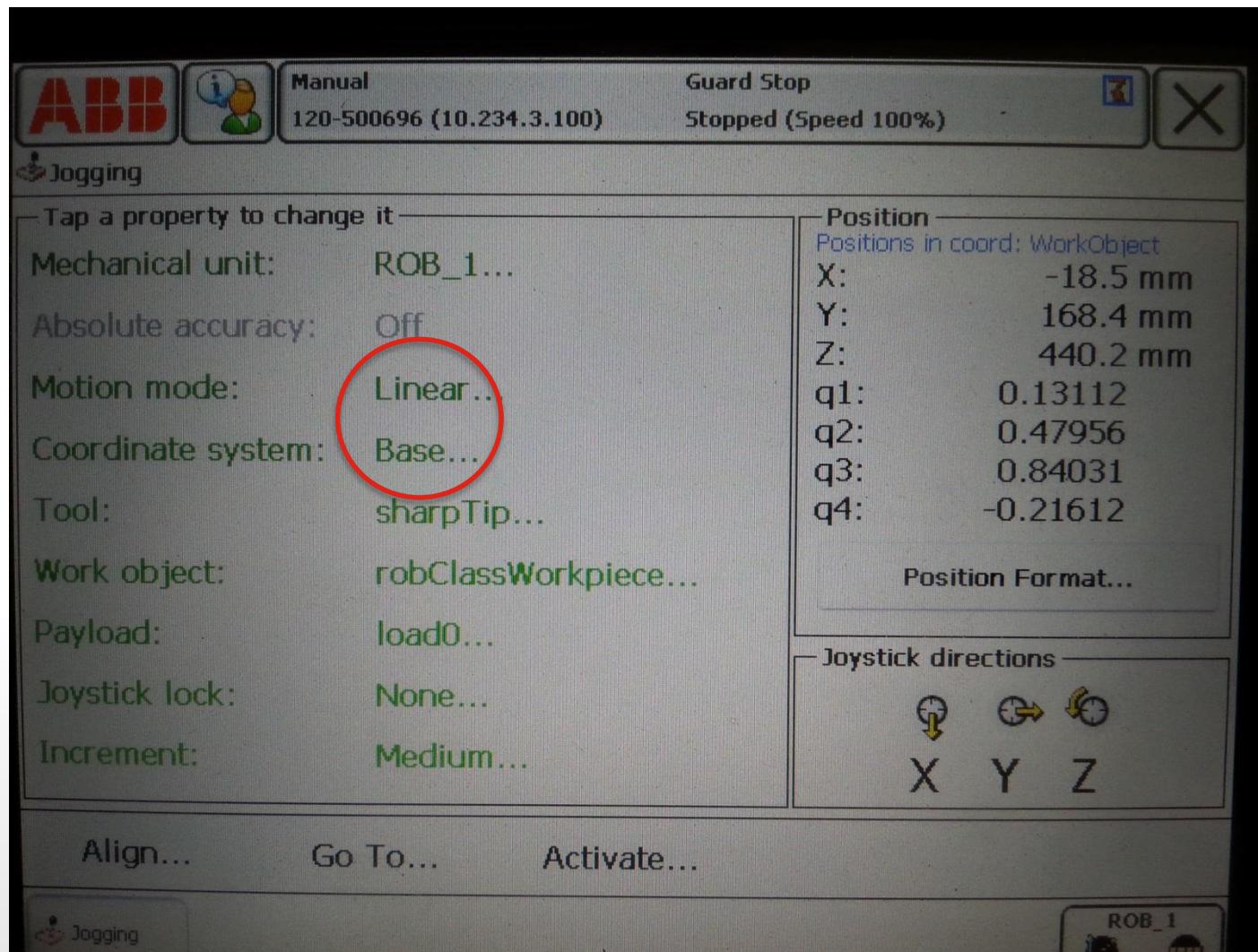
Calibrate Frame for Actual Tool

- Recall that the welding torch is currently in a vertical position.



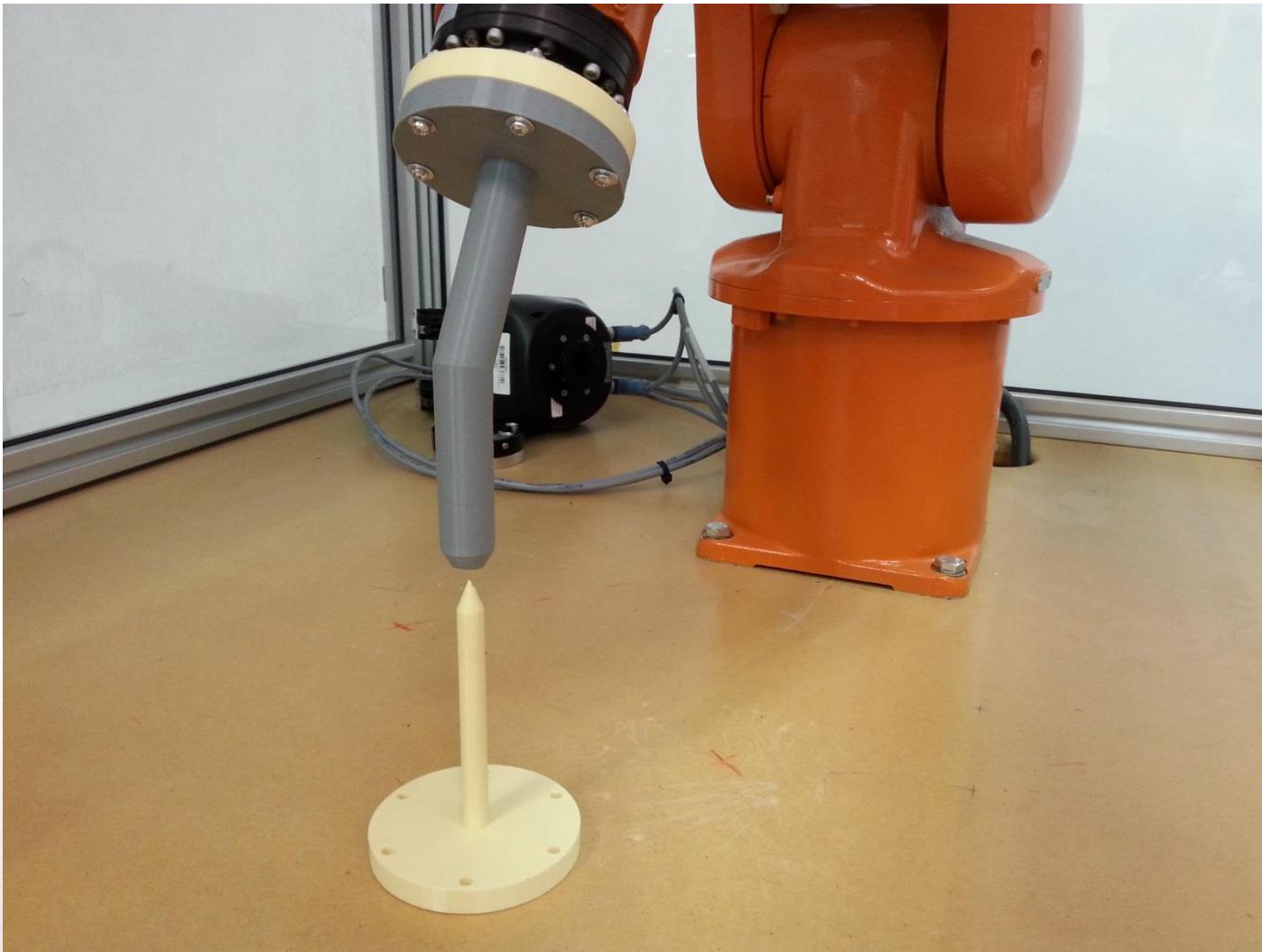
Calibrate Frame for Actual Tool

- It is recommended to use the “**Base**” coordinate system because the z-axis is vertically upwards.



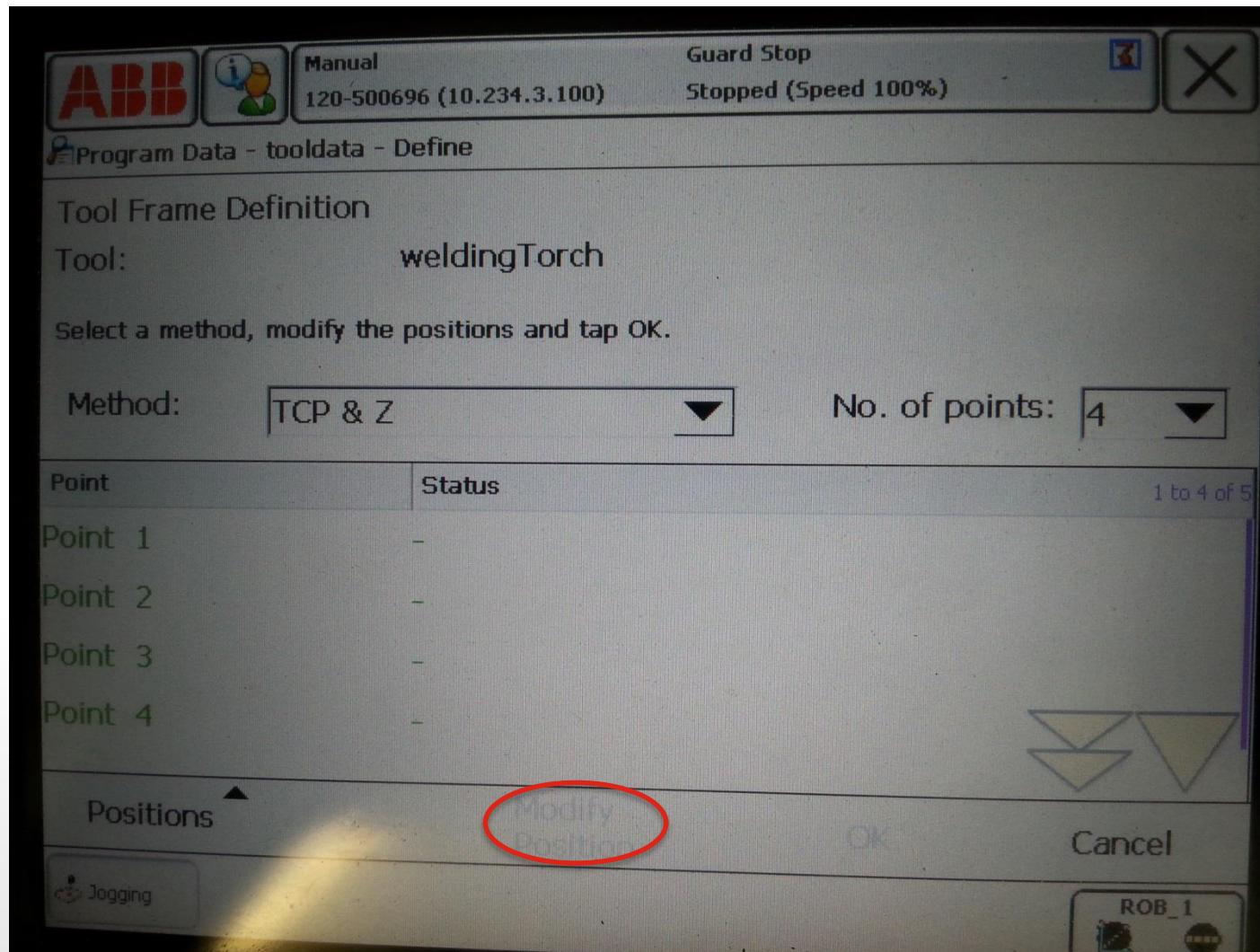
Calibrate Frame for Actual Tool

- Jog the robot to the target point at upright position, which is the 4th orientation.



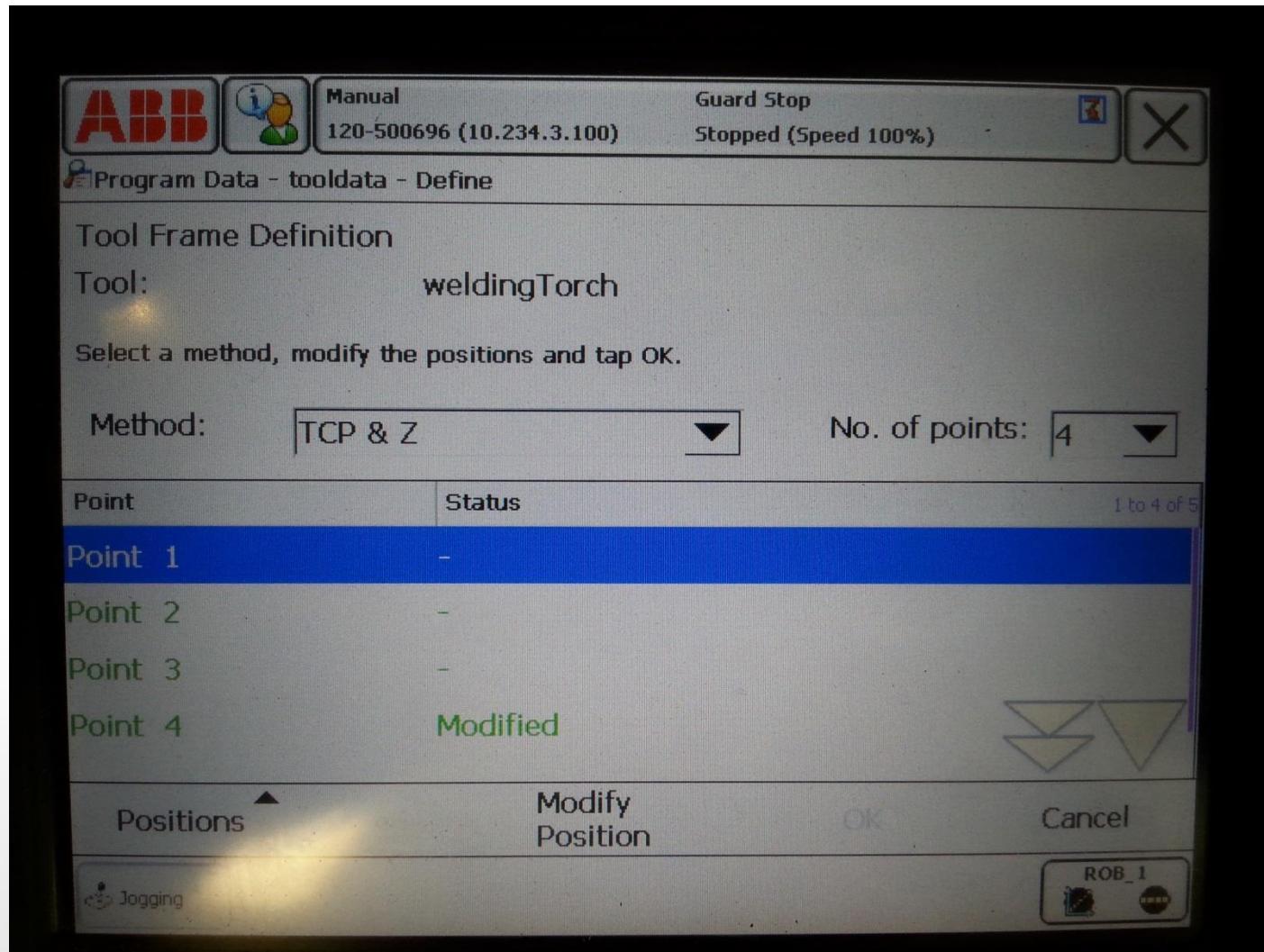
Calibrate Frame for Actual Tool

- On the teaching pendant, choose Point 4 and click **Modify Position**.



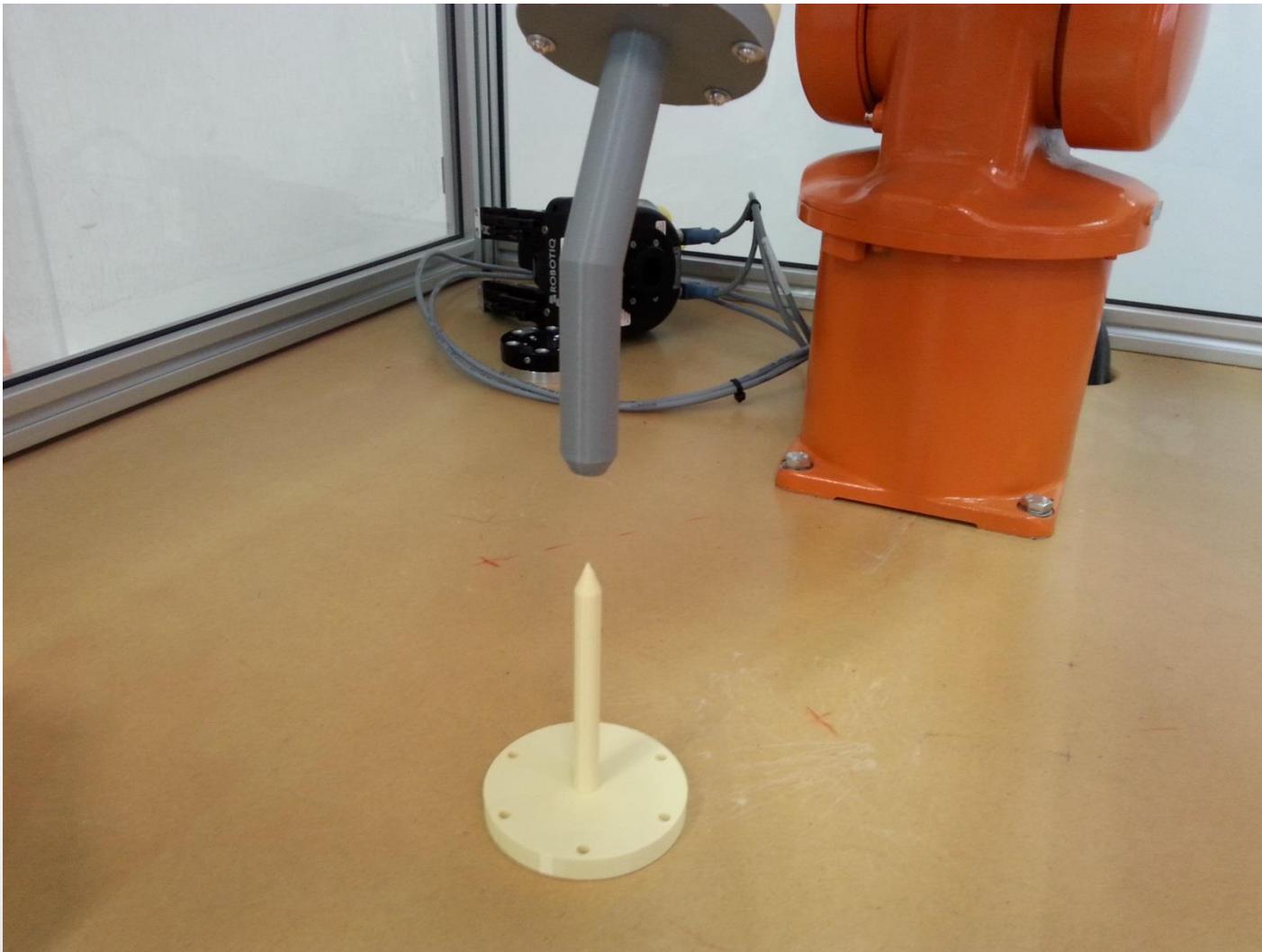
Calibrate Frame for Actual Tool

- Point 4 is now modified.



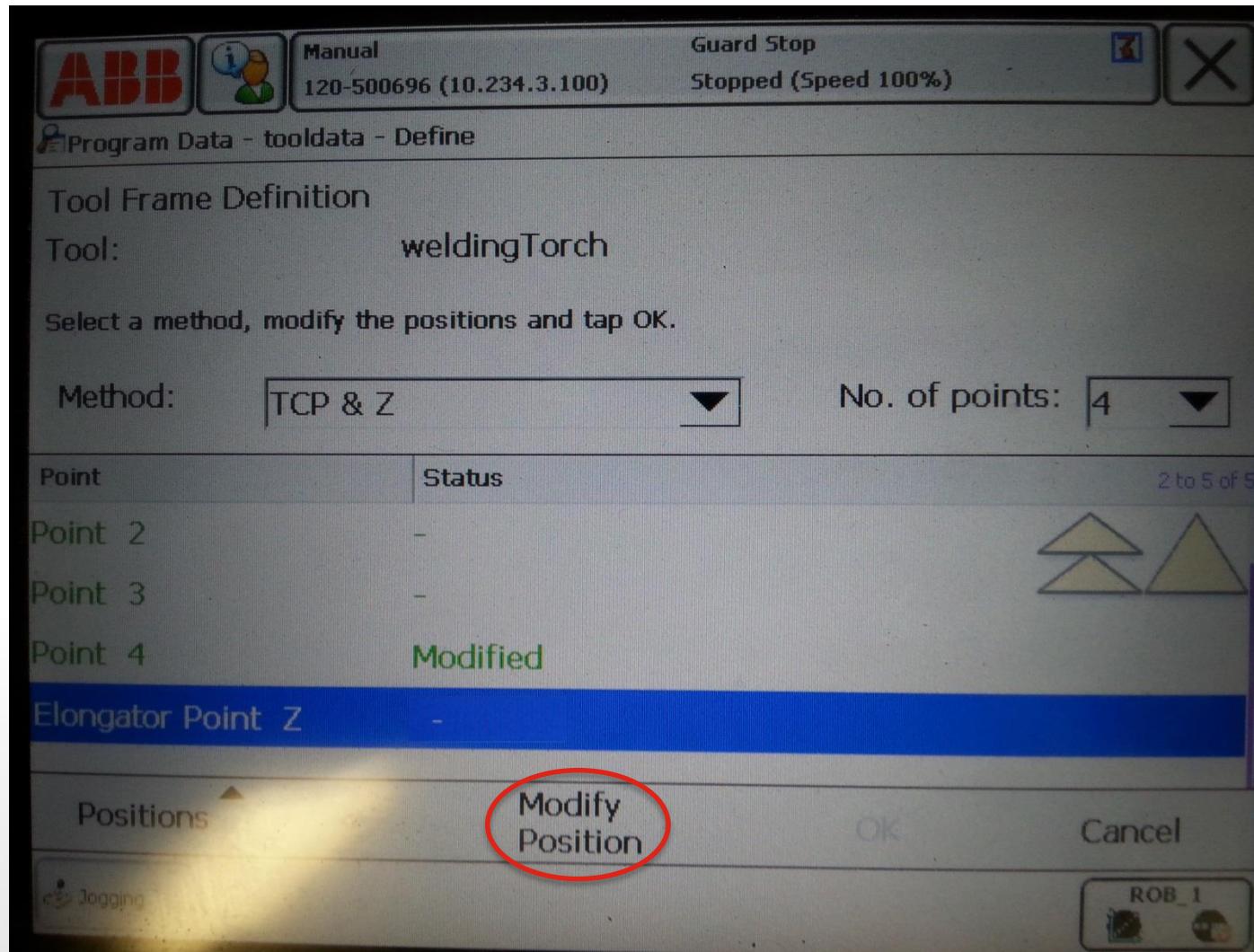
Calibrate Frame for Actual Tool

- Next, jog the tool **vertically up** (Recall we are using Base frame now).



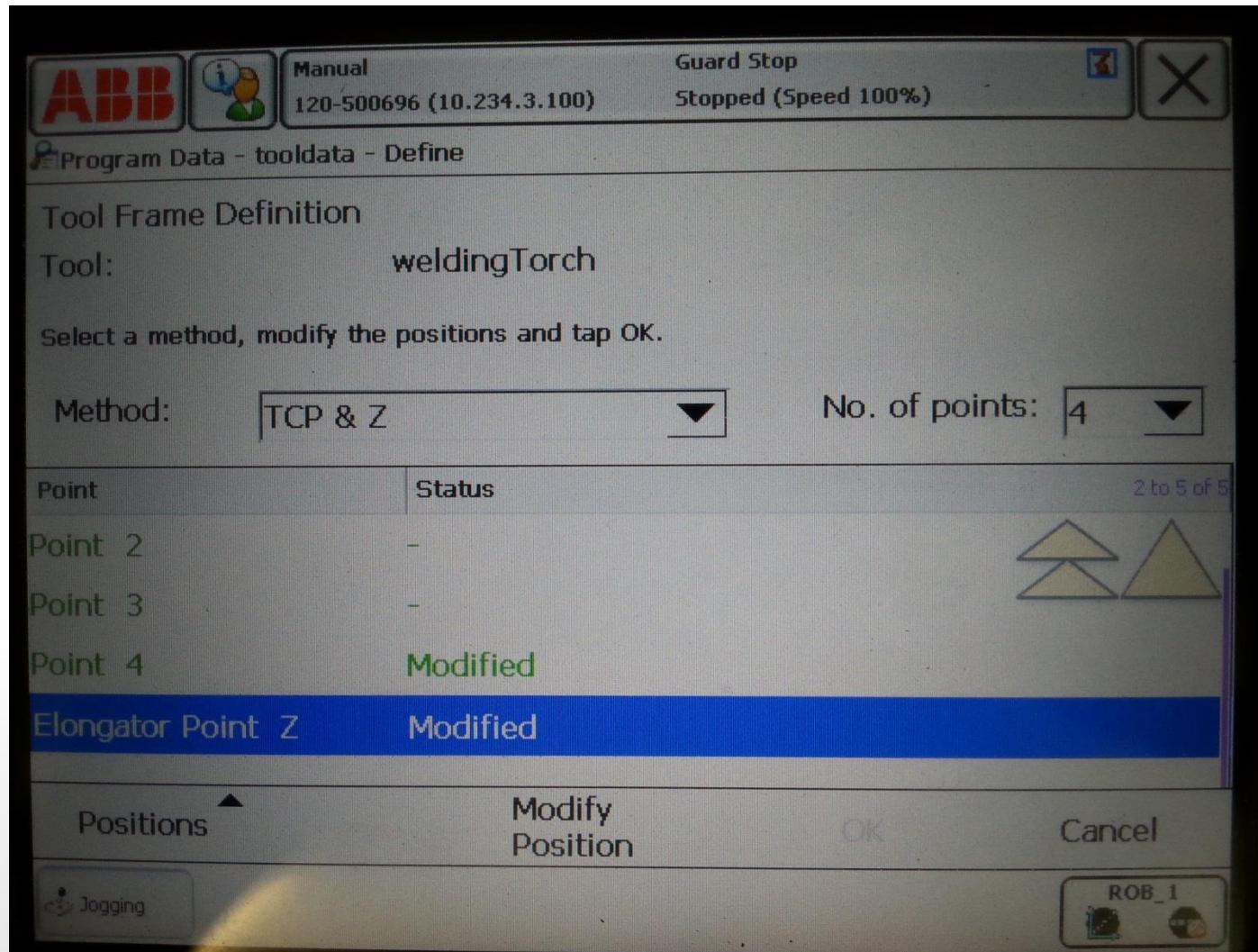
Calibrate Frame for Actual Tool

- On the teaching pendant, choose Elongator Point Z and click Modify Position.



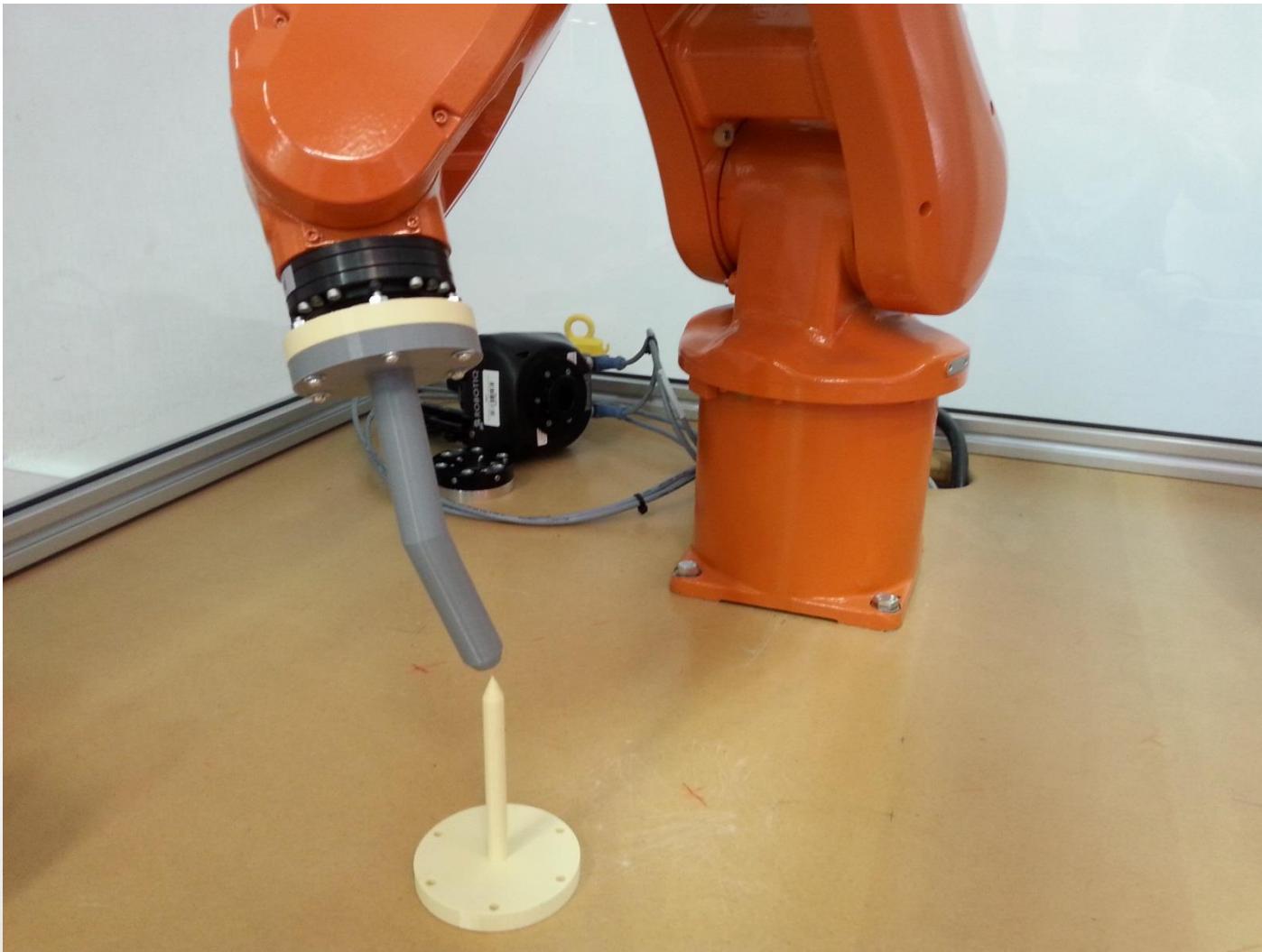
Calibrate Frame for Actual Tool

- The Z-Point is now modified.



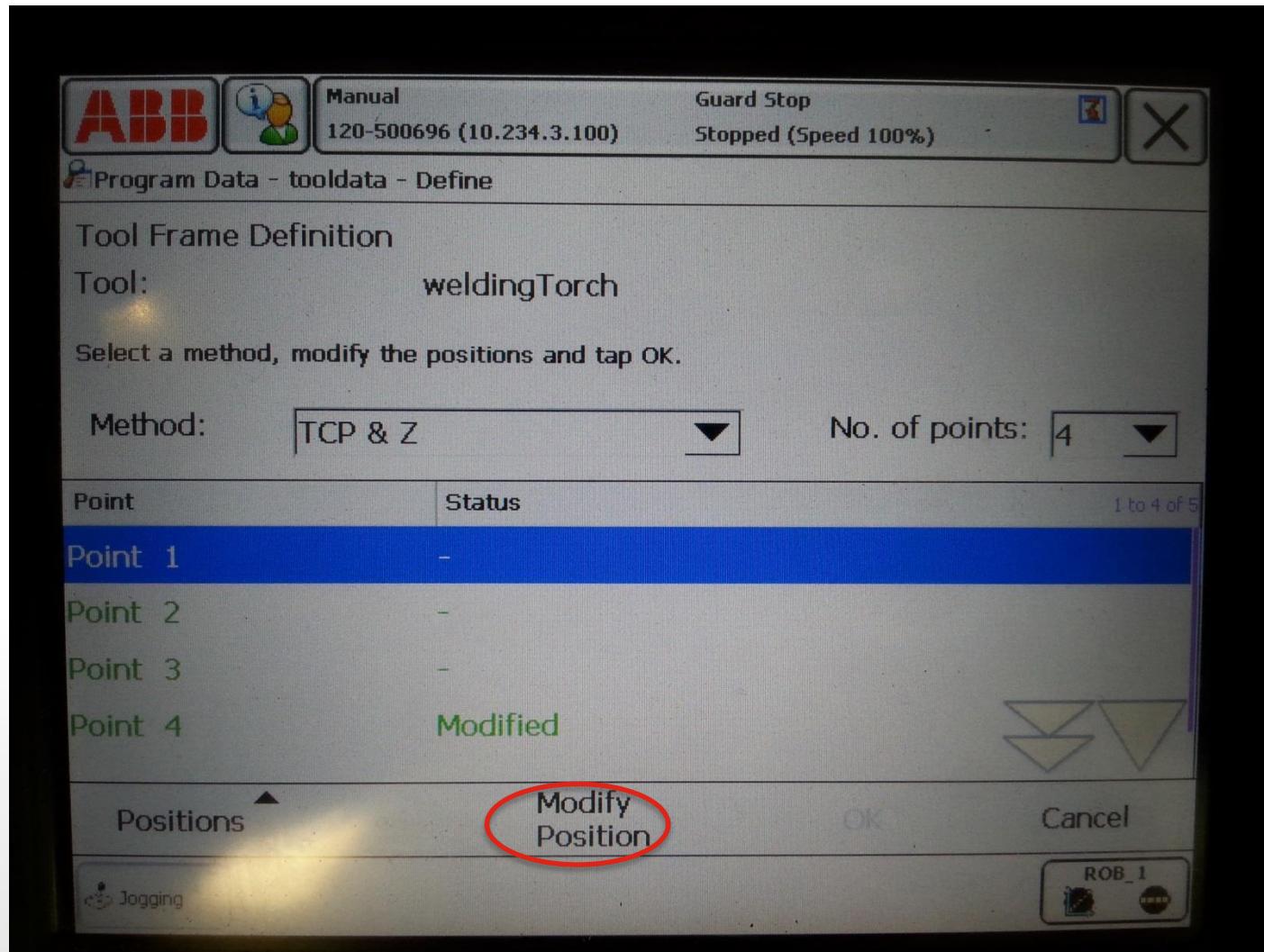
Calibrate Frame for Actual Tool

- Now we jog the robot / tool to the first orientation.



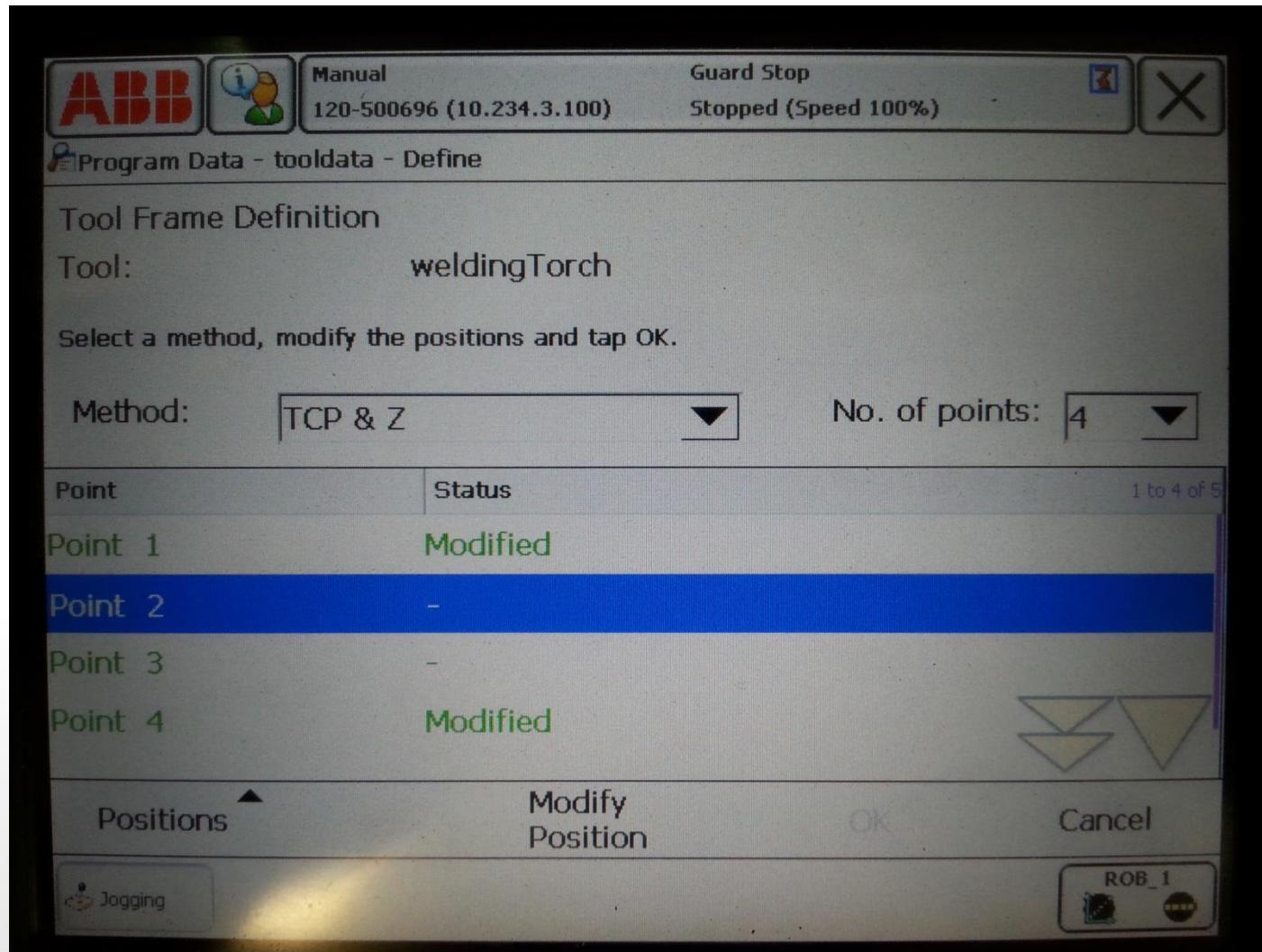
Calibrate Frame for Actual Tool

- On the teaching pendant, choose Point 1 and click **Modify Position**.



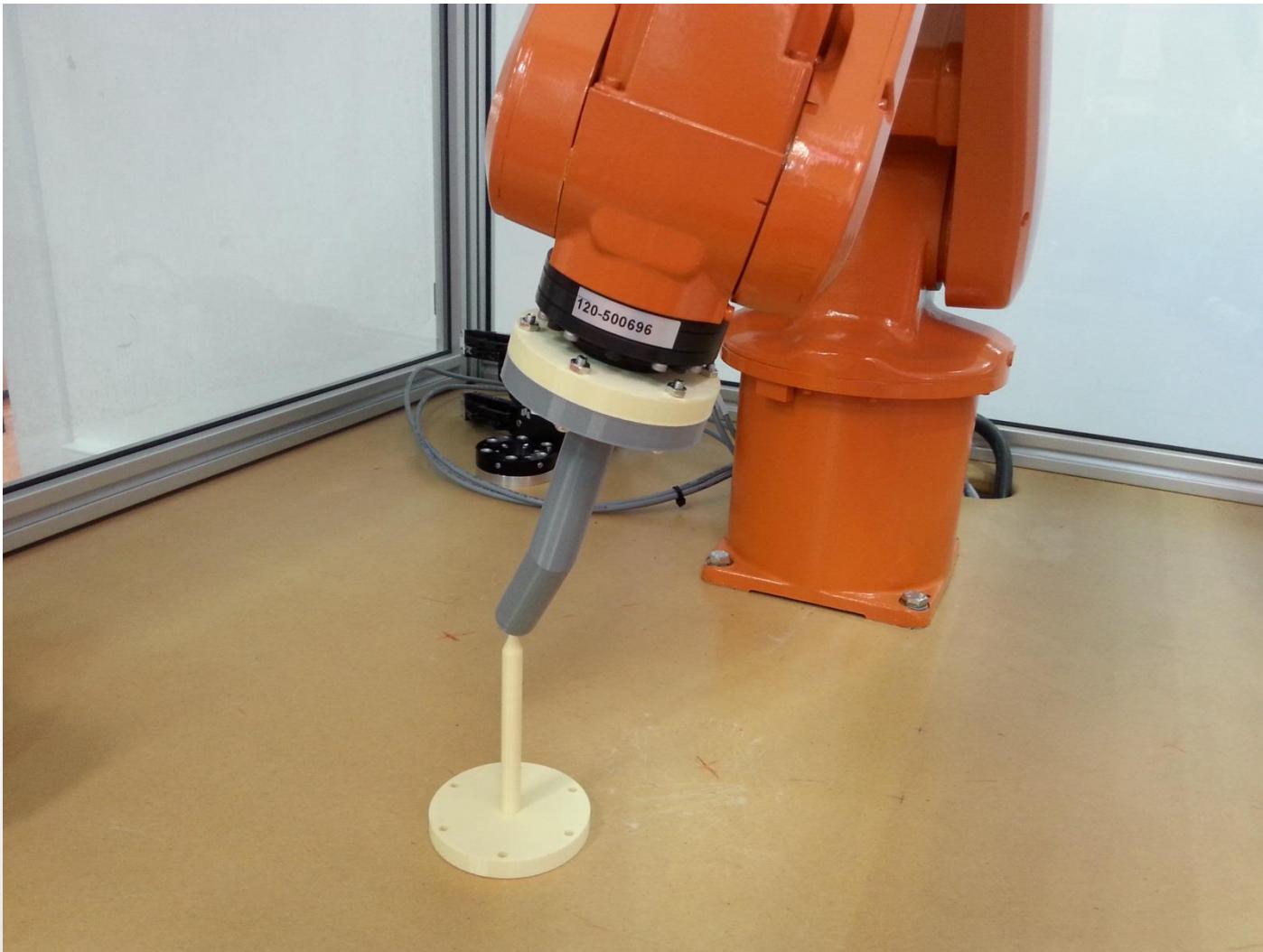
Calibrate Frame for Actual Tool

- Point 1 is now modified.



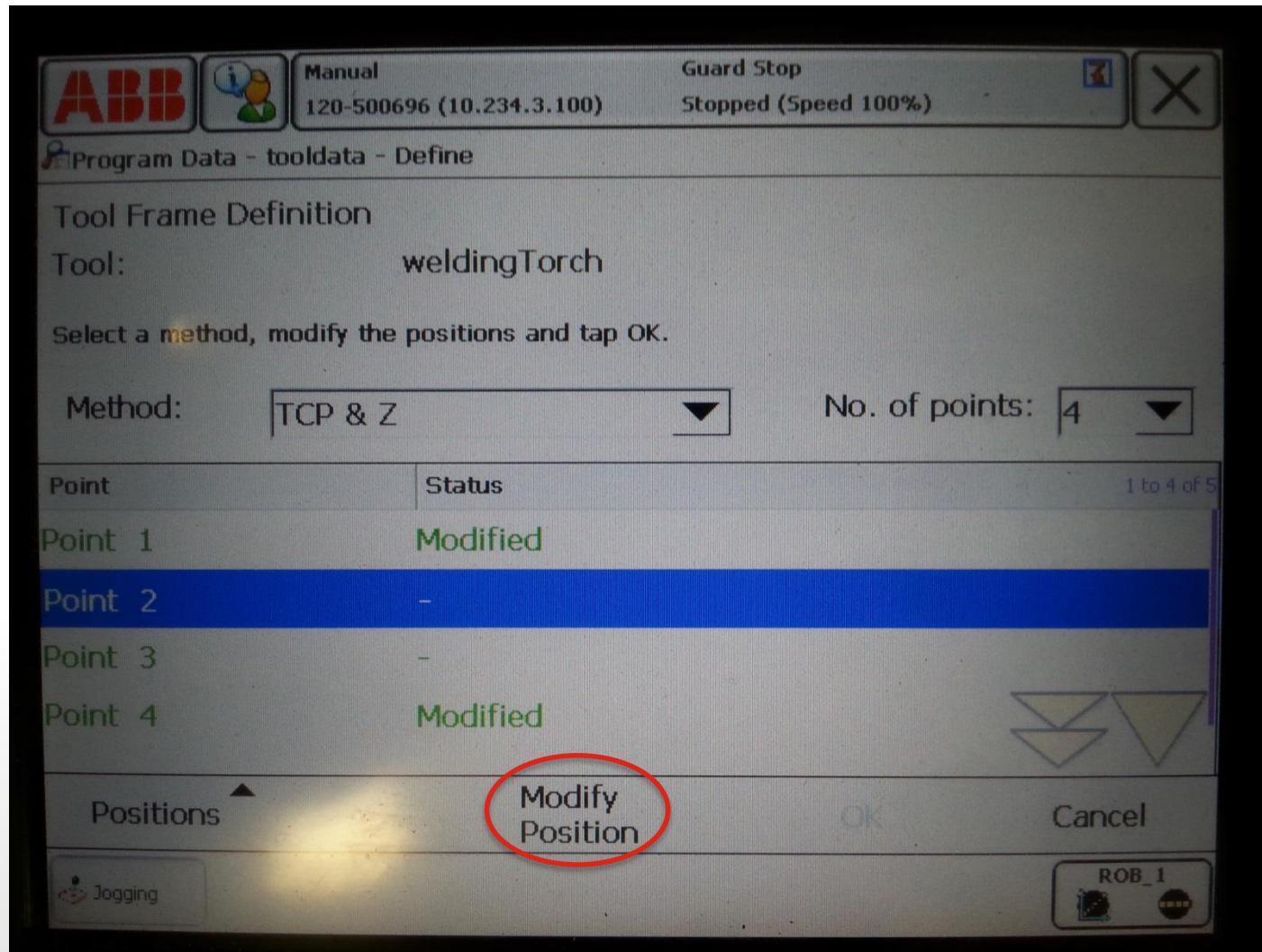
Calibrate Frame for Actual Tool

- Now we jog the robot / tool to the second orientation.



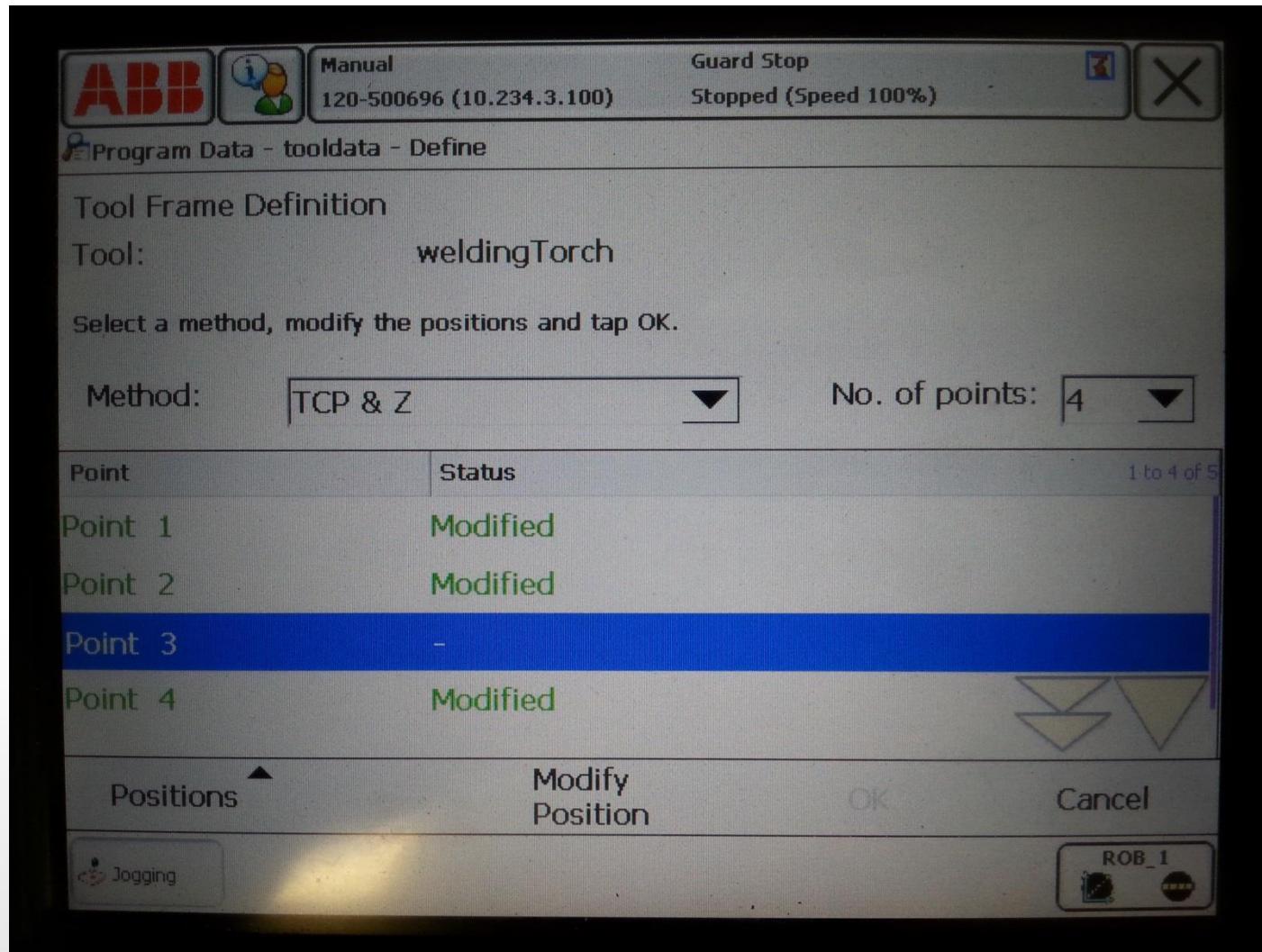
Calibrate Frame for Actual Tool

- On the teaching pendant, choose Point 2 and click **Modify Position**.



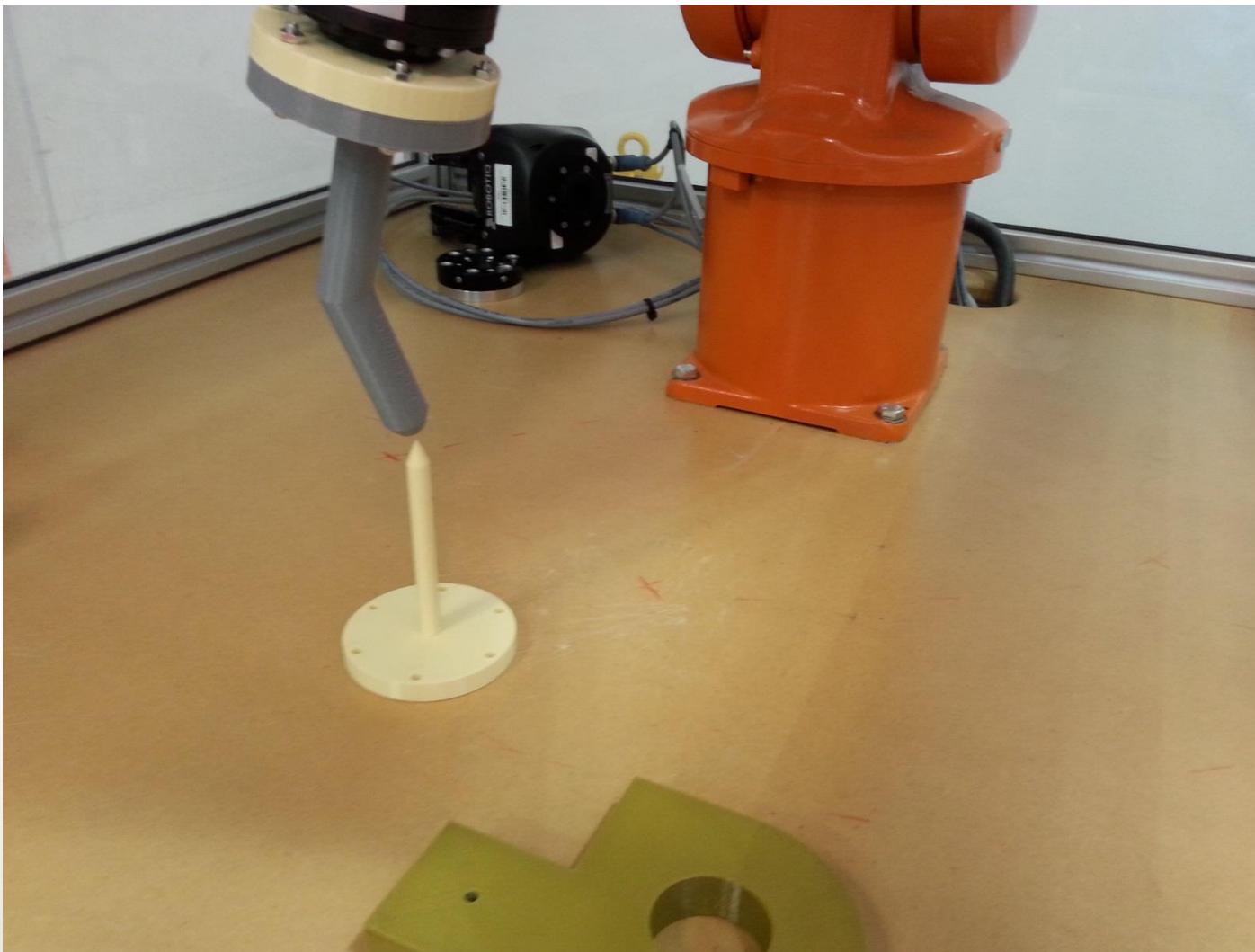
Calibrate Frame for Actual Tool

- Point 2 is now modified.



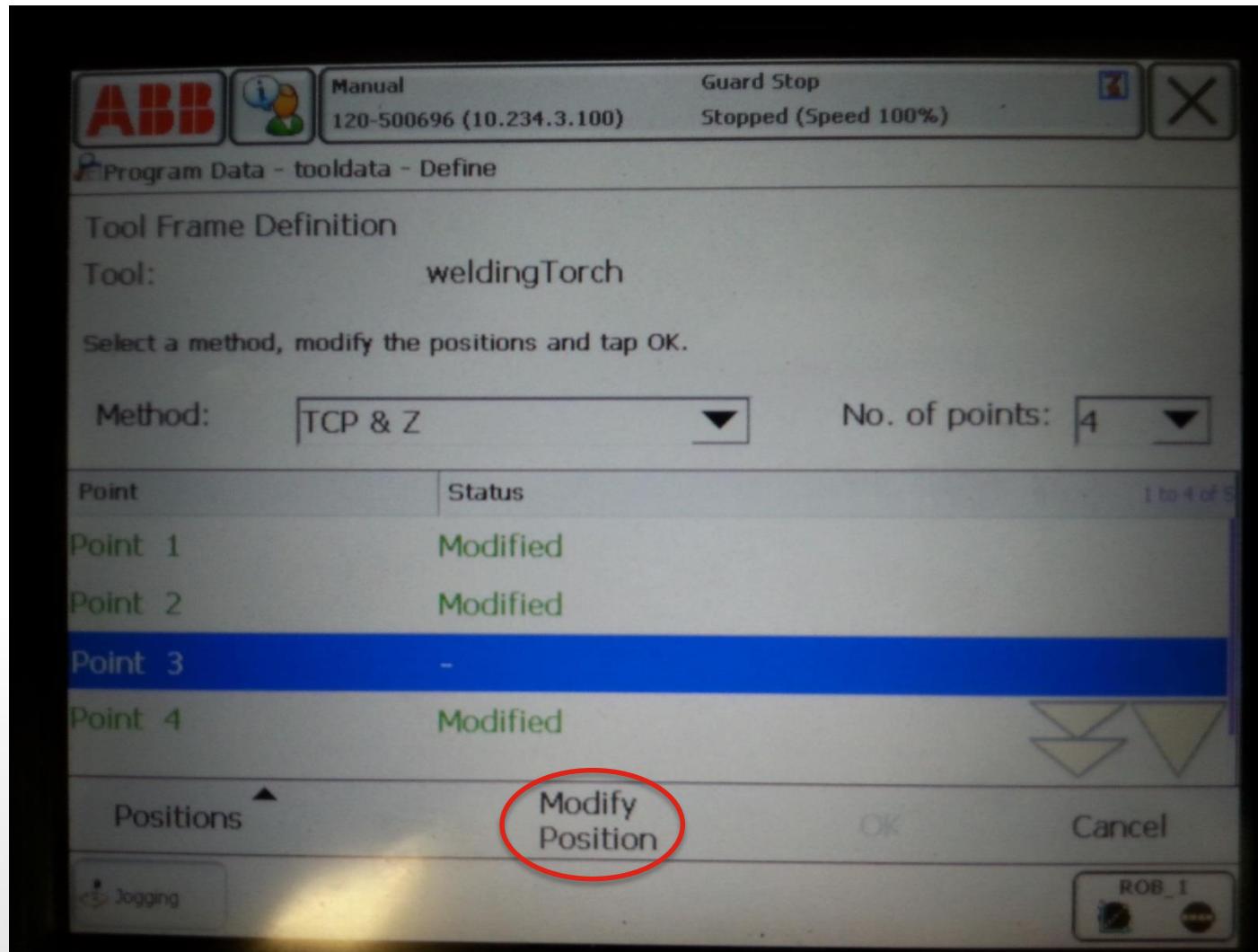
Calibrate Frame for Actual Tool

- Now we jog the robot / tool to the third orientation.



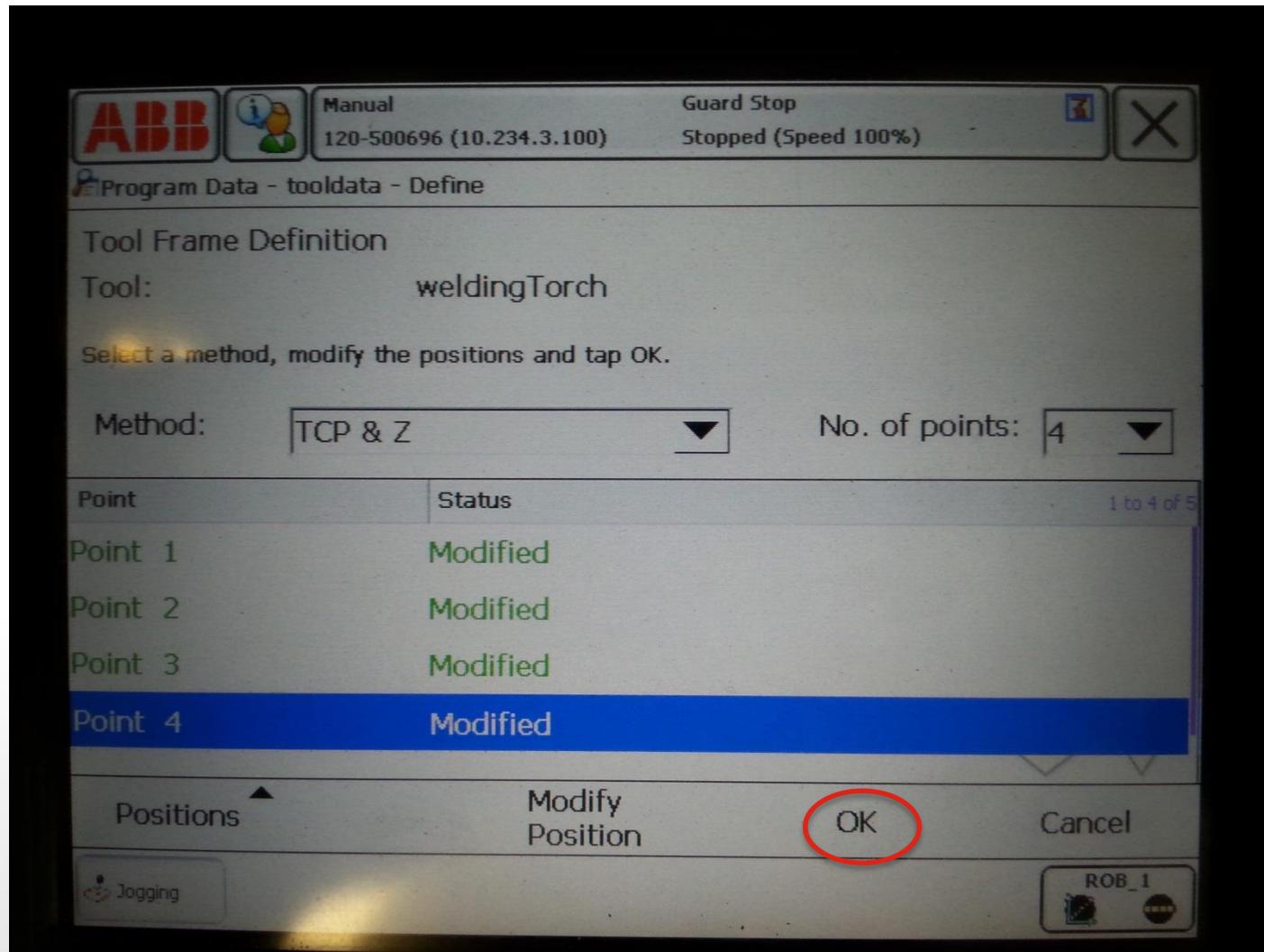
Calibrate Frame for Actual Tool

- On the teaching pendant, choose Point 3 and click **Modify Position**.



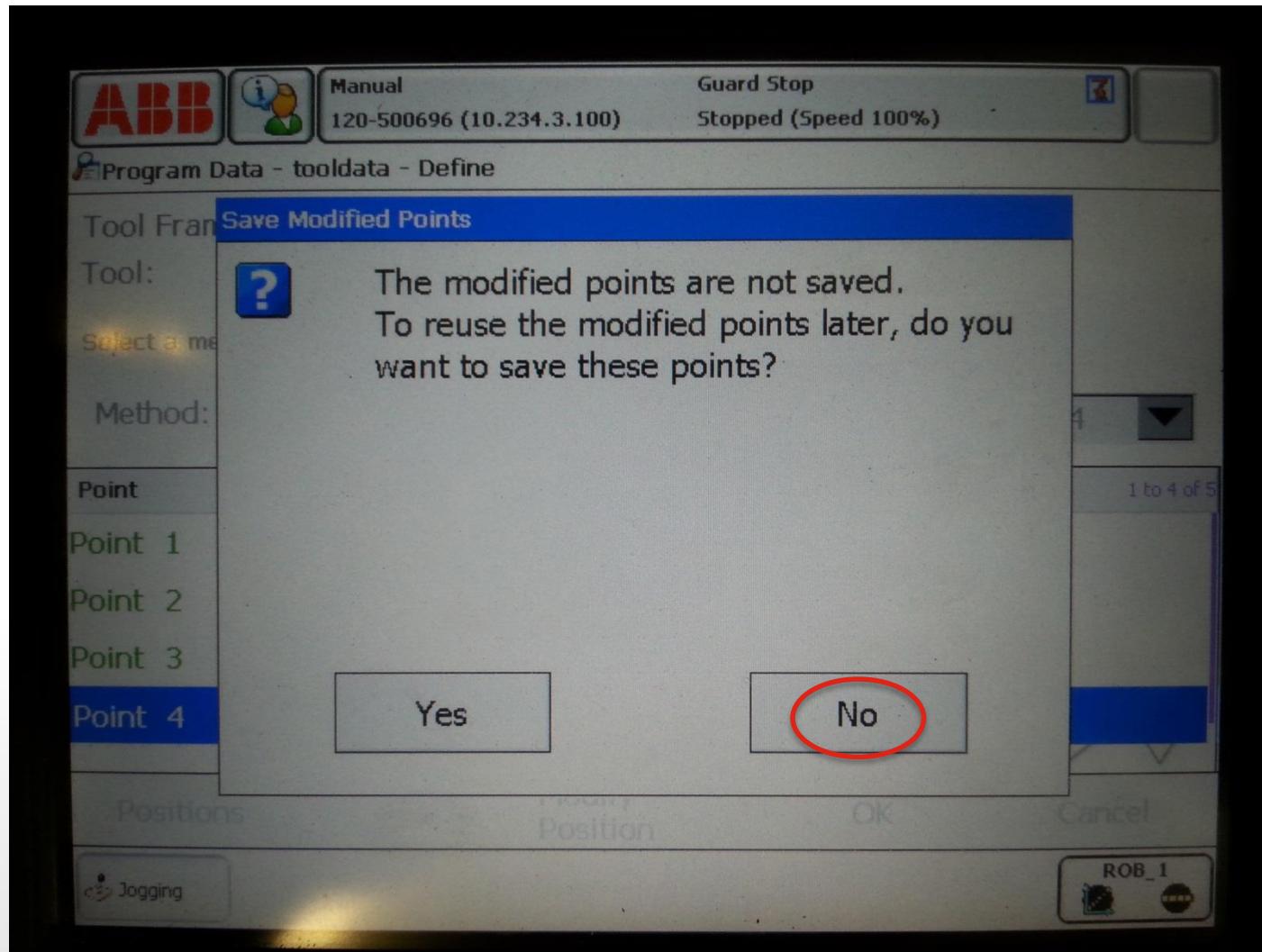
Calibrate Frame for Actual Tool

- Point 3 is (and all points are) now modified. Click “OK”.



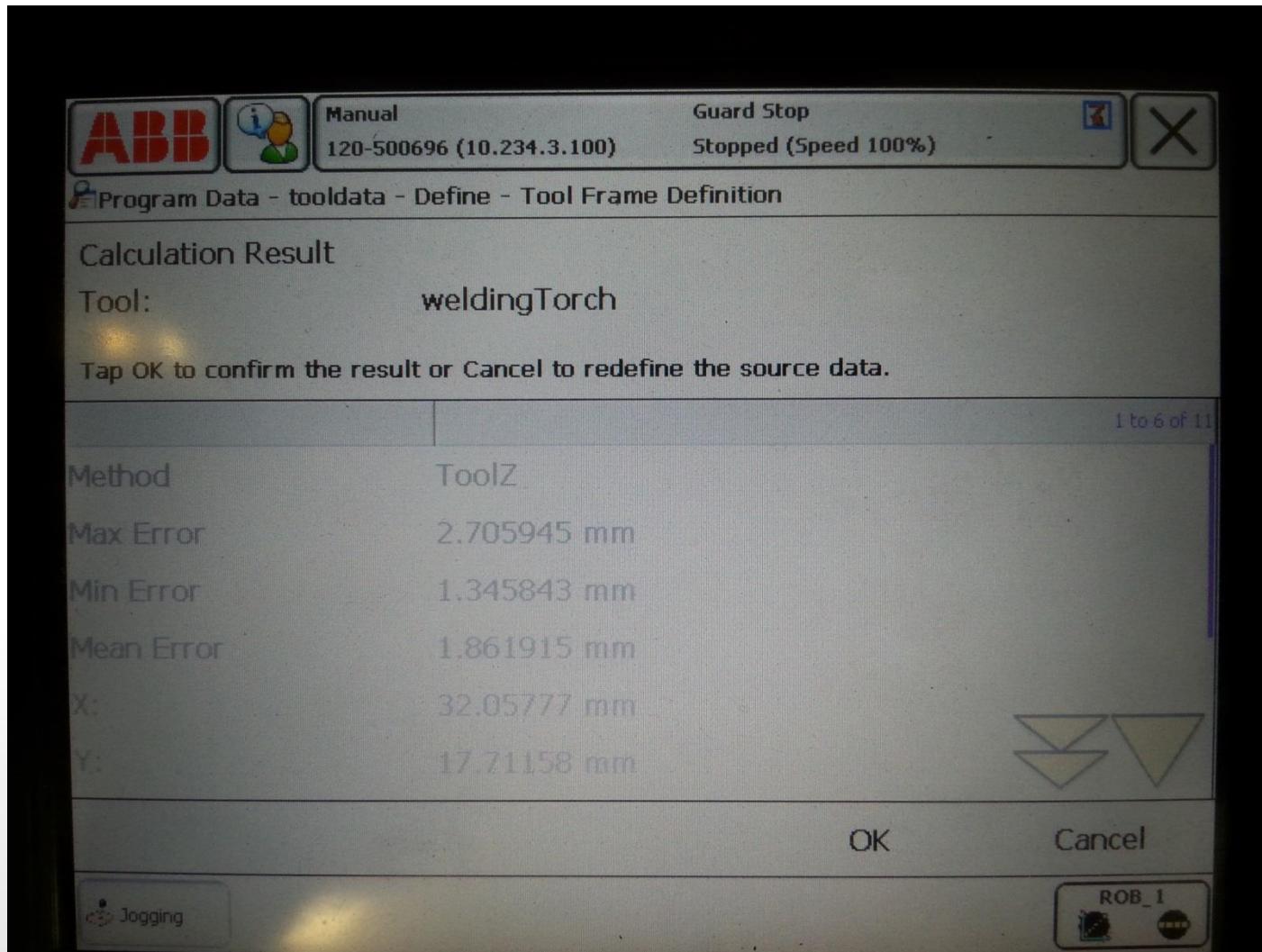
Calibrate Frame for Actual Tool

- To the next question, click “No”.



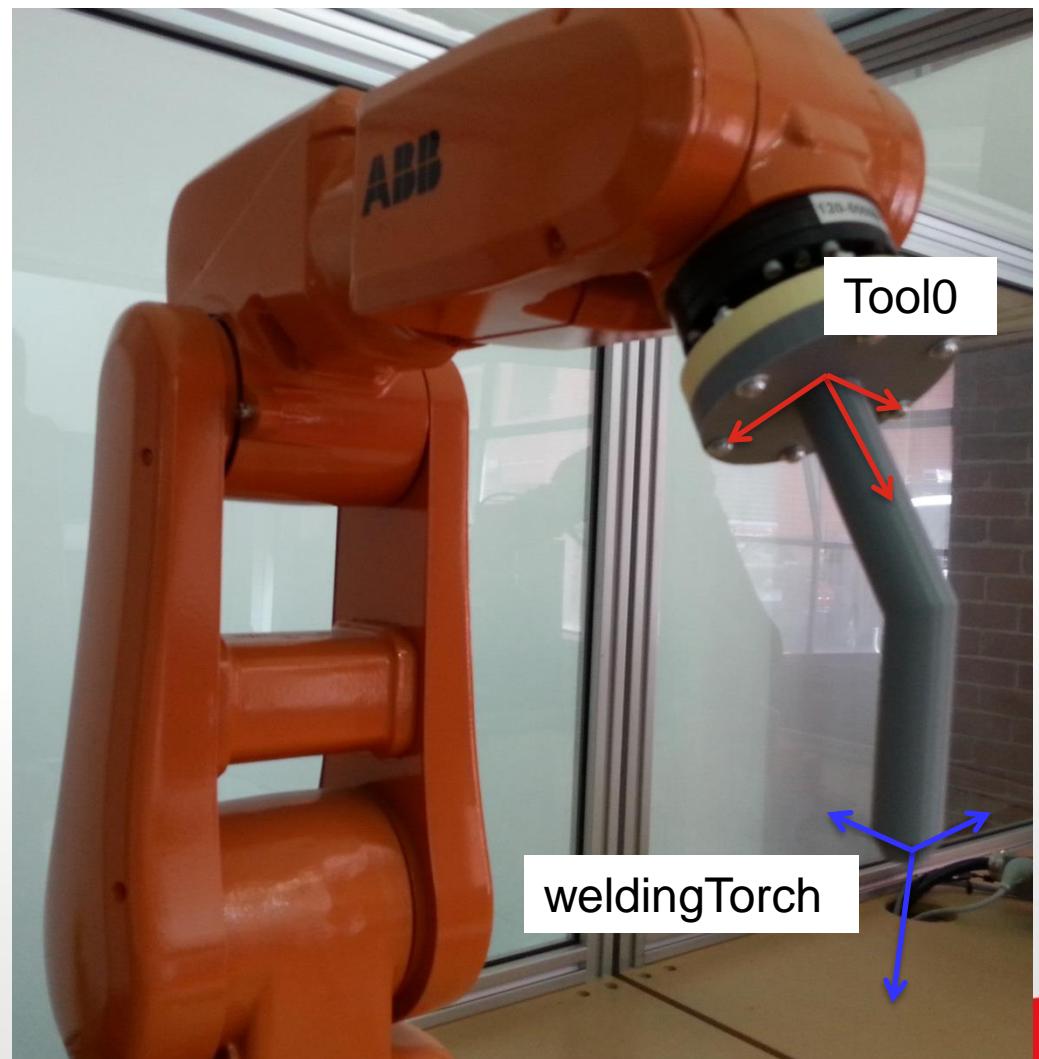
Calibrate Frame for Actual Tool

- The tool frame is now calculated.



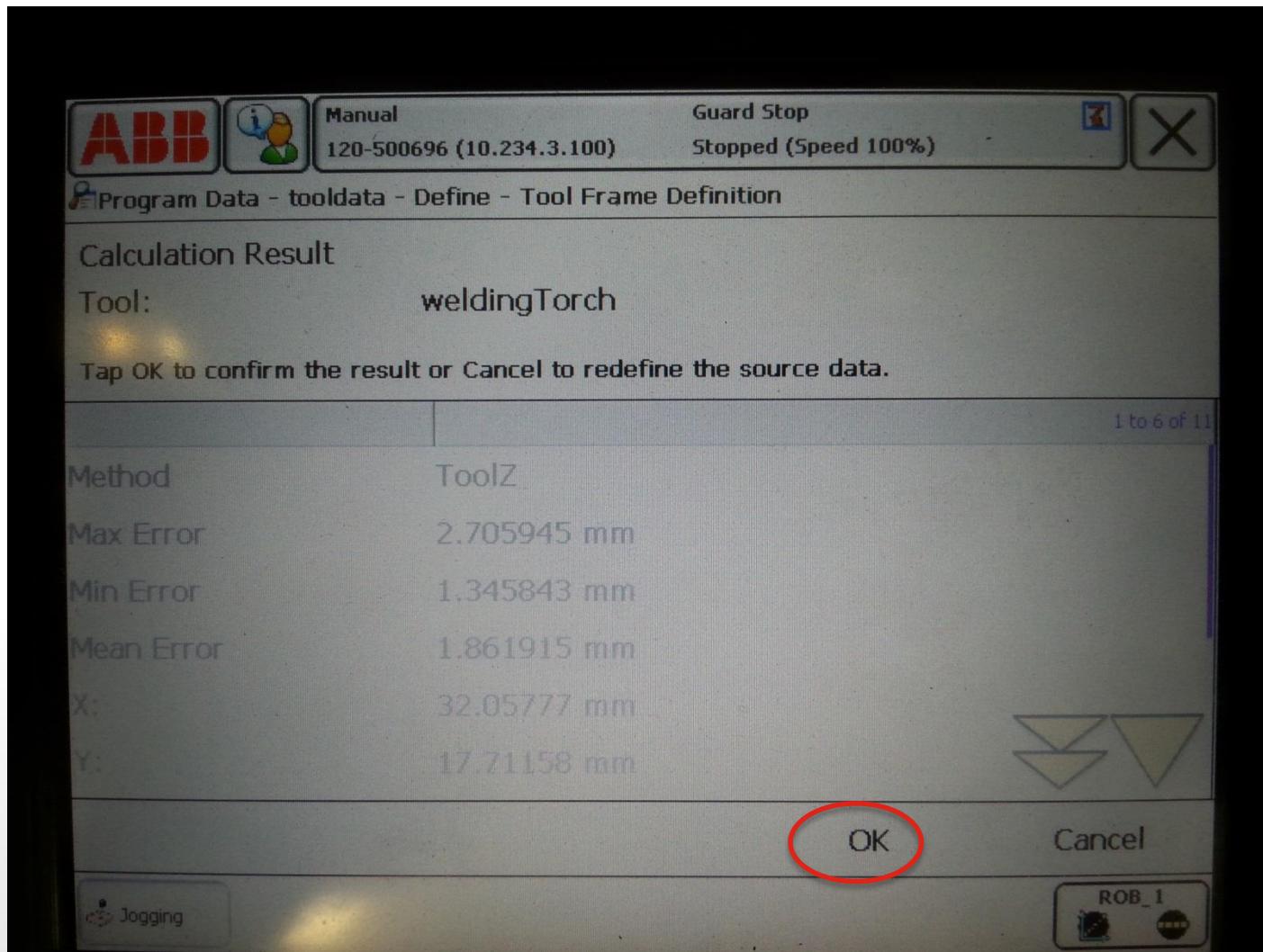
Calibrate Frame for Actual Tool

- Jot down the values. In this example:
 - X = 32.0578 mm
 - Y = 17.7116 mm
 - Z = 155.729 mm
 - Q1 = 0.965595
 - Q2 = -0.12255
 - Q3 = 0.227539
 - Q4 = 0.0288786
- These values are **with respect to the Tool0** of the robot.



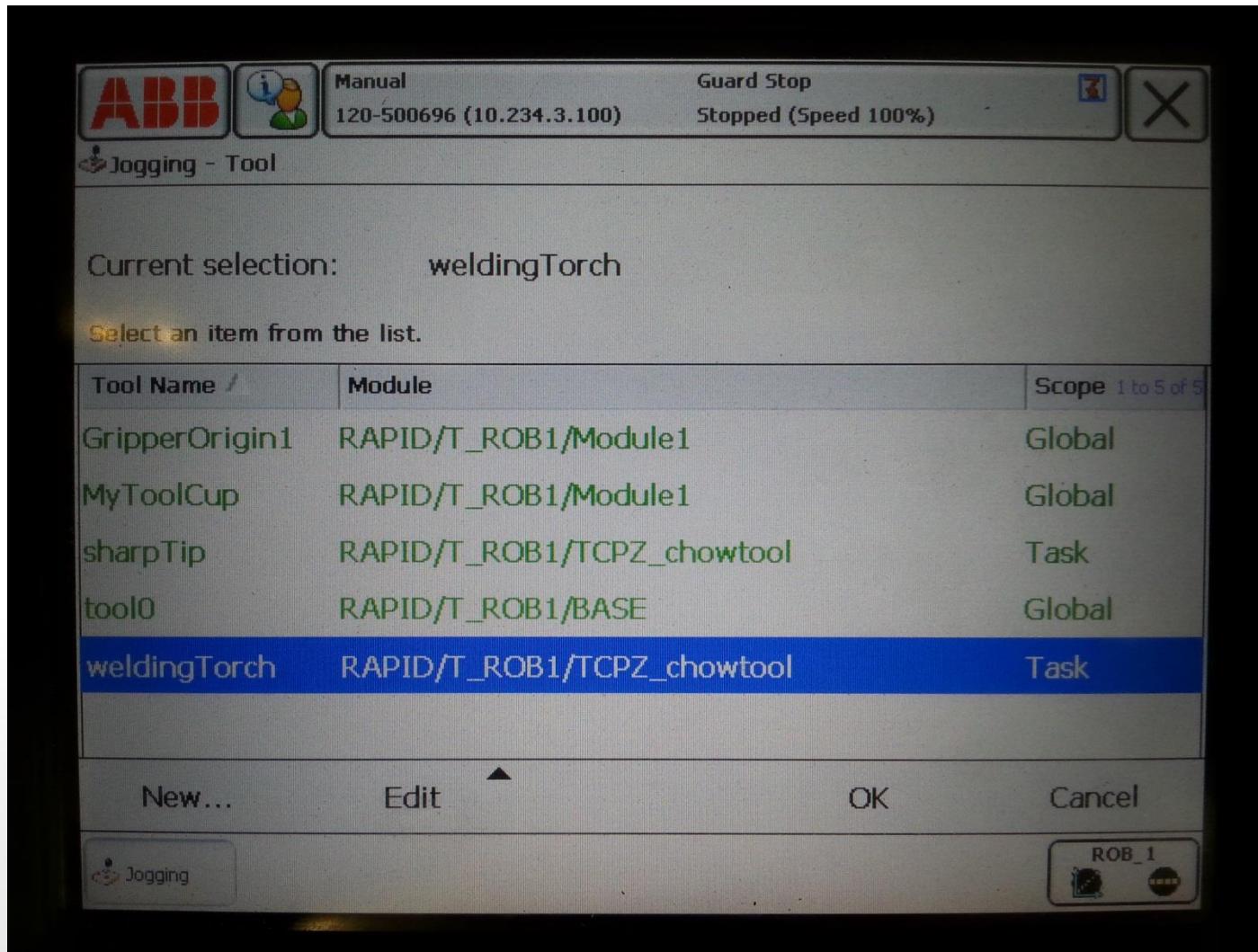
Calibrate Frame for Actual Tool

- Click “OK” to exit.



Calibrate Frame for Actual Tool

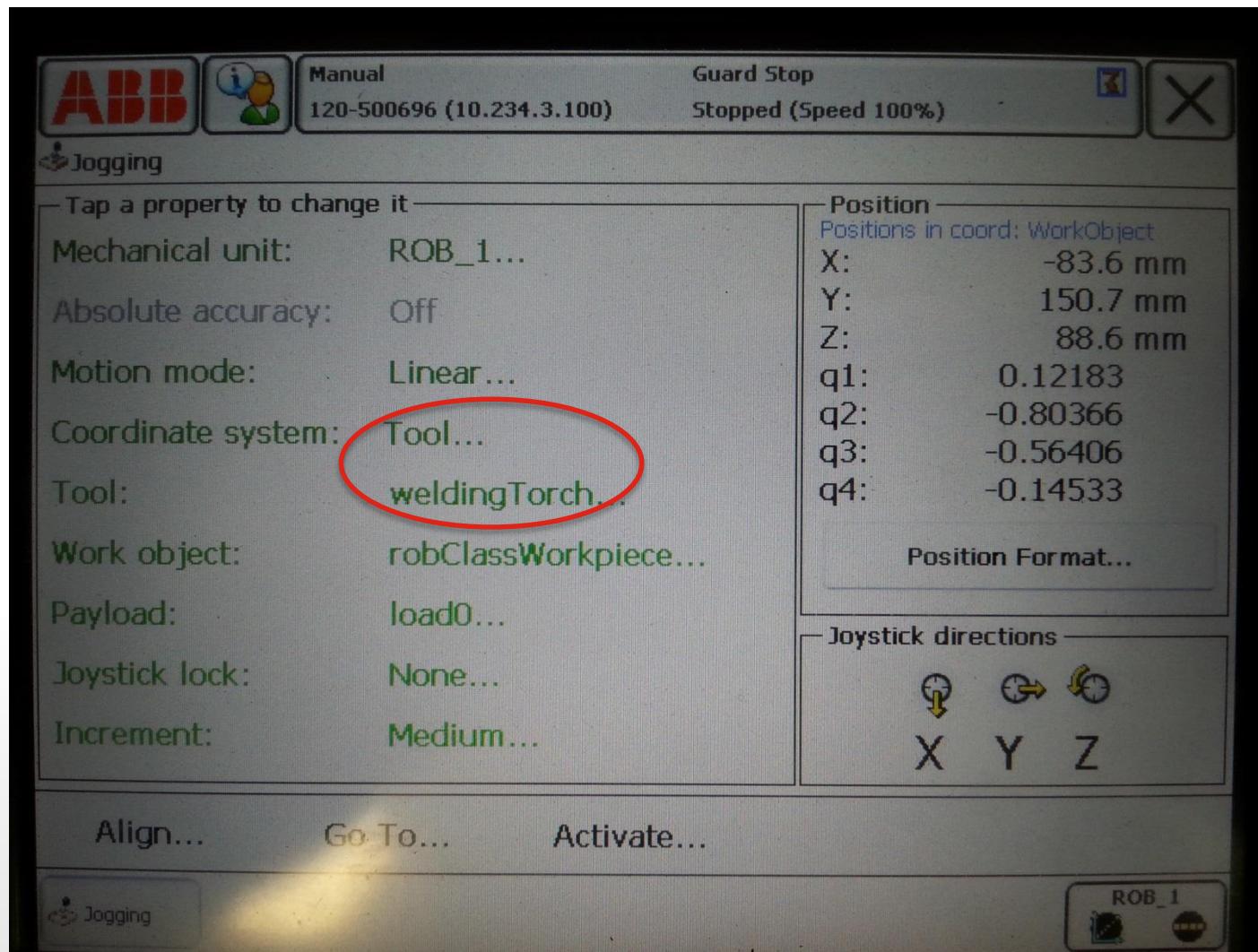
- The tool is now fully defined.



Calibrate Frame for Actual Tool

- We can verify that the tool is correctly calibrated by jogging in the linear or re-

orient mode using welding Torch as the tool frame.



Calibrate Frame for Actual Tool

- Observe the motion of the robot according to the weldingTorch frame.



Thank you!

Have a good evening.

