RealSense

Best Known Methods for Optimal Camera Performance over Lifetime

Revision 1.3

November 2025

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Revision History

Revision Number	Description	Revision Date
001	Initial Release	February 2021
002	Update Tare Calibration	March 2021
003	Update RealSense brand and remove obsolete calibration types	November 2025

1 Introduction

1.1 Purpose and Scope of This Document

RealSense™ cameras leave the factory meeting all datasheet specifications. Due to shipping, handling, or adverse environments the depth accuracy may be impacted. The purpose of this document is to be a Reference Guide for RealSense Stereo Depth Cameras to ensure the positive Out of the Box (OOB) experience and keep the optimal performance over the lifetime. This document references other documents but will cover key steps in its guidance.

It is not in the scope of this document to discuss the details of depth or calibration deeply. Additionally, modules are out of scope of this documentation but described to ensure it is clear what is out of scope.

1.2 Organization

This document contains five main parts: definitions, tools, incoming, integration and outgoing considerations:

- **Definitions** – Overview of terminology.
- **Tools** – List of tools and sites to leverage the information in this document.
- **Unboxing Steps** – Steps and considerations when unboxing a depth camera.
- **Verifying the Health of Camera** – How to know if the camera is functioning correctly.
- **Camera Improvement Options** – Steps and considerations after mounting or integration depth products.

2 Overview

2.1 Definitions

Table 2-1. Terminology List

Term	Definition	Comment / Access
Module (Optical Head)	Stereo Module without a computing engine or housing. 	Available at: https://store.realsenseai.com/ or you can contact a RealSense Sales Representative.
ASIC Card	Depth computing subsystem that is paired with a module to activate compute vision processing. 	You can buy an ASIC card as a bundle with a module at: https://store.realsenseai.com/ or you can contact a RealSense Sales Representative.
Camera	A module and ASIC Card in a “peripheral-like” housing. 	Available at: https://store.realsenseai.com/ or you can contact RealSense Sales Representative.
Depth Quality Tool (DQT)	SW tool that measures depth camera quality.	Developers - RealSense
Calibration	Calibration is a method to get the RealSense module or camera to behave as expected.	There are three types of calibration processes that will be discussed in this document.

2.2 Tools Needed for Integration Process

Table 2-2. Integration Process Tools List

Tool	Locations	Considerations
RealSense™ SDK	Developers - RealSensehttps://www.intelrealsense.com/sdk-2/	The tool is in our SDK.
RealSense™ Self Calibration	RealSense™ Self-Calibration for D400 Series Depth Cameras	This is a link to the whitepaper on Self-Calibration.

RealSense™ OEM Calibration	V shape OEM calibration target and software: RealSense™ D400 Camera OEM Calibration Target	Highly recommended post module or camera integration. This tool is targeted for factory customers, but any user could benefit.
Mounting and Integration Guidelines	RealSense Stereo Series Product Family Datasheet	At time of publication this was located in section 7 of the datasheet.

2.3 Integration Considerations

Table 2-3. Integration Considerations

Considerations	Camera	Module
Integration Requirements	Mounting Only	Mounting, routing, thermal and enclosure must be completed.
Calibration Automatically Required	No. Expected to work OOB.	Yes. Post integration.

Note: All information (such as mounting and routing) for these considerations are in the RealSense Stereo Series Product Family Datasheet.

2.4 Camera Integration

RealSense Cameras D400 series are plug-and-play USB3.1 high quality stereo depth cameras. USB 2.0 is supported also. Just simply follow the mounting guidelines in the datasheet and gain access to the SDK and depth streaming will be enabled. RealSense™ SDK 2.0 is a cross-platform library for RealSense depth cameras. It is an open-source SDK and can be accessed at Developers - RealSense.

2.4.1 Camera Incoming Quality Considerations

1. Connect the camera to a host system. This requires all components in Figure **2-1**. Note: an USB-C to USB-C cable is also acceptable if the host has a USB-C port.

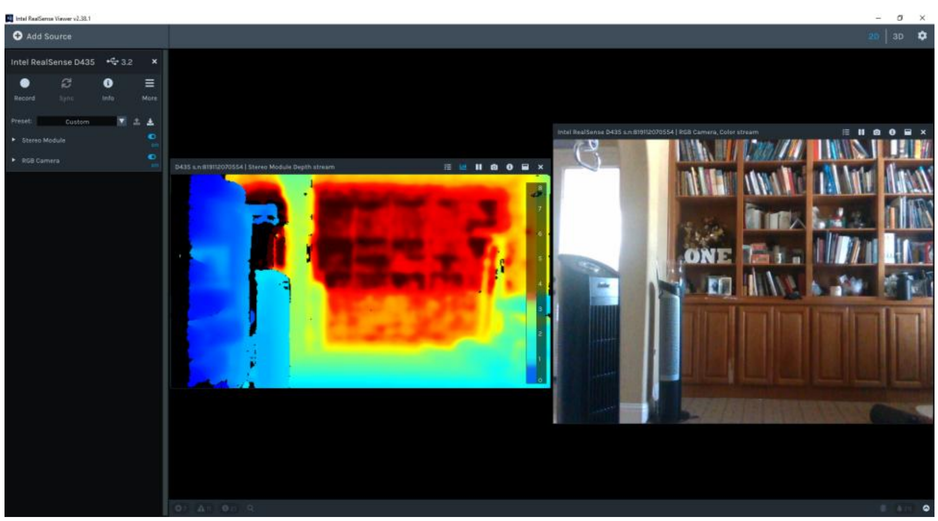
Figure 2-1. Camera USB Connection

2. To activate the camera please use the RealSense ™ SDK. The SDK can be found at: Developers - RealSense.
3. Once you download and install the SDK, there should be two tools installed on your Windows® system. The RealSense™ Viewer and the Depth Quality Tool for RealSense™ Cameras
4. Launch the Viewer (icon below) and enable your Stereo Module. The default is off. You can also enable your RGB camera although the focus of this document is depth.

RealSense.Viewer.exe

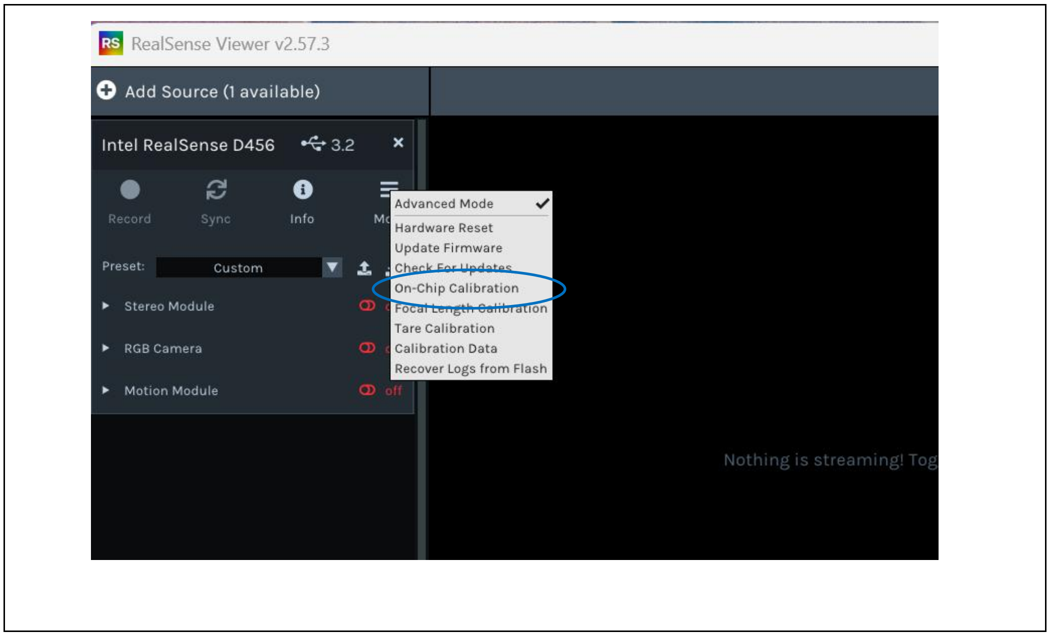
5. Once you enable the Stereo Camera a very colorful depth map should appear to the right of the controls. Blue should be objects “close” to the RealSense Camera and red will be the objects far away. That is the default color scheme.

Figure 2-2. RealSense Viewer Depth and RGB Images



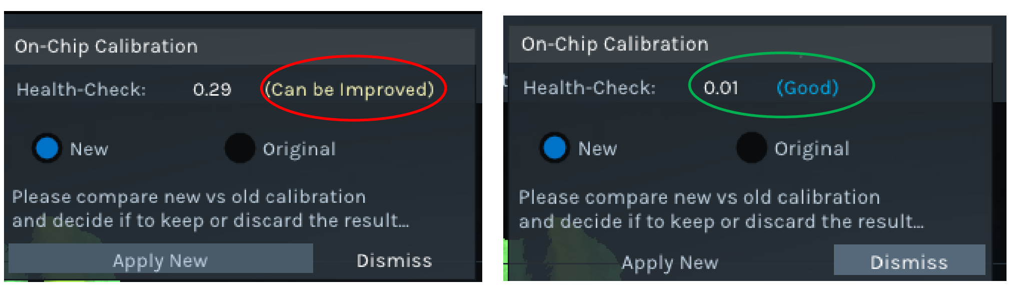
6. Next, RealSense suggests you verify the depth quality. RealSense has a locally running calibration tool called Self-Calibration that runs directly on the RealSense device. In the Viewer it is called "On-Chip Calibration." This calibration method improves the camera's depth quality but also gives information on the current health level of the camera. RealSense suggests you run this tool and verify that the camera health is good. It is in the "More" section of the viewer.

Figure 2-3. RealSense Viewer On-Chip Calibration



7. After you run On-Chip Calibration you will get a “Health-Check” number. For next steps see *Table 3-3. On-Chip Calibration Health Check Results Next Steps*

Figure 2-4. Health-Check Number



If you see the Health-Check number is “Good”, you are ready to go!

Otherwise Apply the new calibration and check again.

3 Keep Optimal Camera Performance over Lifetime

3.1 Camera performance

All RealSense camera sensor modules are built from factory to be extremely sturdy, encased in laser-fused steel cages, with the intent of maintaining calibration and performance over their lifetime. However, conditions can occur that lead to degradation over time, such as exposure to extreme temperature cycling, or excessive shock and vibe. Whatever the cause, provides a set of tools to recalibrate cameras back to their pristine factory condition and keep the best performance over lifetime. These tools include “Self-Calibration” and “OEM calibration”.

3.2 Calibration Types

To keep RealSense Cameras optimal performance, RealSense offers three types of calibration, namely, Self Calibration and OEM Calibration. For module integration and factory environments, RealSense strongly recommends the purchase of an OEM calibration target and learning the accompanying tools. Please work with the Sales and Support teams to gain access. Table 3-1 are the considerations when selecting a calibration type.

Table 3-1. Calibration Types

Characteristics	Self-Calibration	OEM Calibration
Calibration Execution Engine	RealSense Vision Processor D4	Host PC/SoC
Reference Target	• On Chip calibration - No • Tare Calibration - optional: if no ground truth is used a target can be used, download from Intel® RealSense™ Self-Calibration for D400 Series Depth Cameras Appendix A • Focal Length Calibration - required: same as above	V shape OEM calibration target: RealSense™ D400 Camera OEM Calibration Target
Typical time to Completion	less than 30sec	30 seconds, including 10 seconds device ramp up time
Calibrated Parameters	Intrinsic	Both intrinsic and extrinsic

Calibrated Subsystems	Depth only	Depth and RGB

3.3 When to Use Each Calibration

Self-Calibration is the most convenient and easiest calibration for users. It can be used when you open the box – incoming quality validation - or after the cameras are mounted on your devices in the field. The calibration is running on the VPU chip inside the camera. It calibrates only the depth camera.

OEM calibration is the most robust calibration method for RealSense stereo cameras. It requires a big V shape calibration target. It is used in the factory setup or in the lab. It is highly recommended if you purchase RealSense cameras modules and ASIC cards and build the camera enclosure yourselves. It will rectify all kinds of distortions introduced by mounting the modules into the new enclosures.

3.4 Self-Calibration

Self-Calibration includes three parts, namely On-Chip Calibration, Tare Calibration, and Focal length Calibration. Each can be used to correct a specific type of calibration error.

On-Chip Calibration is used to minimize depth noise. Tare Calibration is used to improve the depth accuracy. Focal length calibration can be used to improve the depth uniformity across the image.

3.4.1 On-Chip Calibration

Start by running On-chip calibration, as shown at *Figure 2 3. RealSense Viewer On-Chip Calibration*

After you run On-Chip Calibration you will get a "Health-Check" number, as shown at *Figure 2 4. Health-Check Number*

Table 3-2. Health Score Meaning

Health Score (ABS)	Score Meaning
0 < HC < 0.25	PASS
0.25 < HC < 0.75	HELP
0.75 < HC	FAIL

Table 3-3. Health On-Chip Calibration Health Check Results Next Steps

Health Check Value (Absolute Value)	Next Step	Notes
0.25 or less	Do nothing.	Changes can be accepted, but it is not required.

Between 0.25 and 0.75	Accept the changes in Self Calibration.	Run Self Calibration again and verify the absolute value of the health check.
0.75 or greater	Recalibrate the camera using OEM Calibration.	Note: OEM Calibration should help improve the camera's performance, but it requires OEM target.

Note[1]: On-Chip Calibration works best when the camera is pointed at scenes with texture over the central 20% of its FOV.

Note[2]: These numbers are guidelines and not absolutes. It is important for each camera to be validated as producing an acceptable depth map for the desired usage as depth map requirements vary based on usage.

3.4.2 Tare Calibration

Figure 3-1. RealSense Viewer Tare Calibration

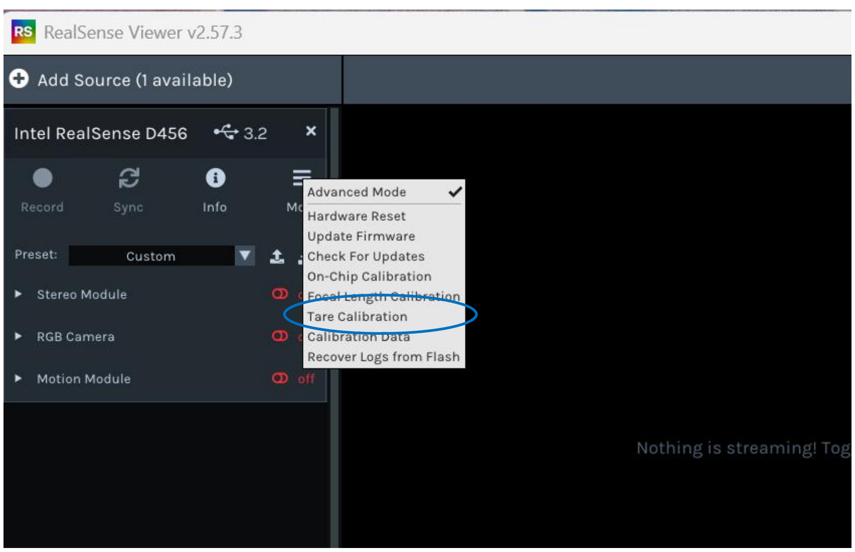


Figure 3-2. Tare Calibration Ground Truth

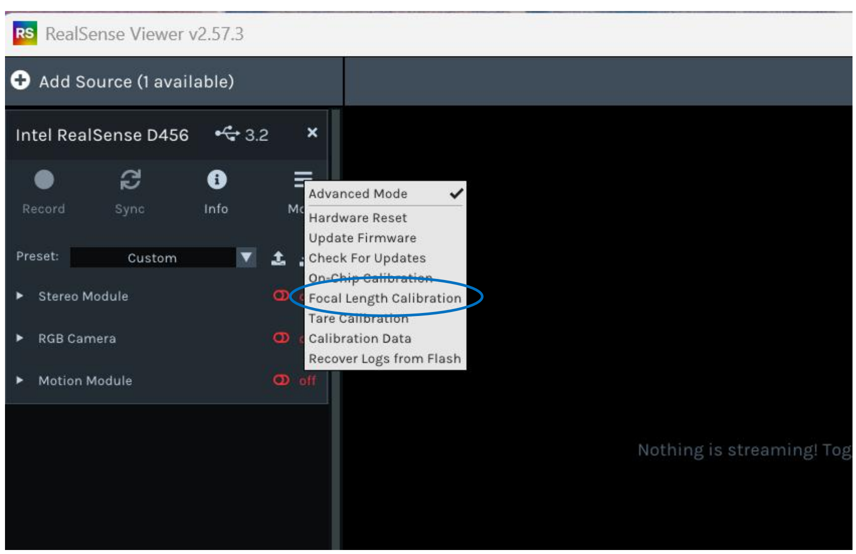
When you run the Tare Calibration, you will need to provide the ground truth distance. A laser range finder is a good tool to provide an accurate ground truth. Note that the ground truth must be measured from the camera's proper origin (Z=0 reference plane) which may not be coincident with the front cover of the enclosure. See the D400 datasheet (section 4.8) for the location of the depth reference plane for each camera model.

Alternatively, a ground truth target can be used to automatically compute and enter the ground truth distance to be used with the Tare function. This function is enabled using the "Get" button. Please see the Self-Calibration white paper Addendum A for details on the use of this function and downloadable versions of the ground truth target.

3.4.3 Focal length Calibration

Focal length calibration is rarely needed but can be used in cases where the depth image appears horizontally tilted (i.e., depth linearly varies across the image of a flat surface aligned parallel to the camera). Focal length calibration is run using the same ground truth target used for the Tare function.

Figure 3-3 RealSense Viewer Focal Length Calibration



Please see the Self-Calibration white paper Addendum B for further details on the use of Focal Length Calibration.

3.5 OEM Calibration Process

3.5.1 Launch OEM Calibration Tool

Locate the “OEM Calibration Tool” app icon on desktop. This application is available once you buy the target from https://store.realsenseai.com/buy- -realsense-d400-cameras-calibration-target.html. RealSense does not share the software without the target to ensure there is no confusion in the calibration process.

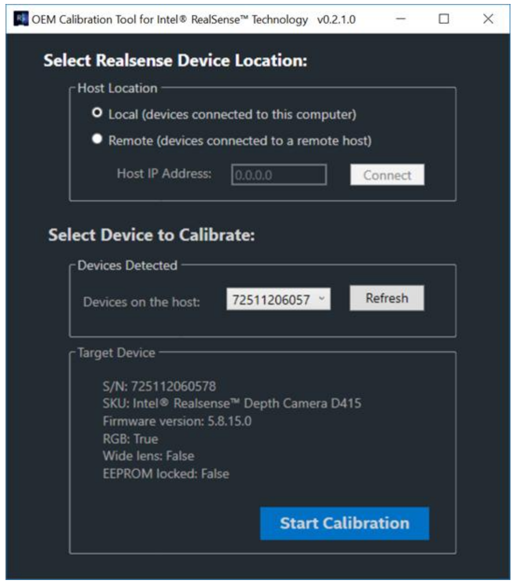
Figure 3-4. OEM Calibration Icon

3.5.2 Start the Process

Double click to launch the tool. All connected RealSense Camera devices will be listed in the drop-down combo box. The list is presented with each device’s serial number. If all devices are not listed, use the refresh button to refresh the list.

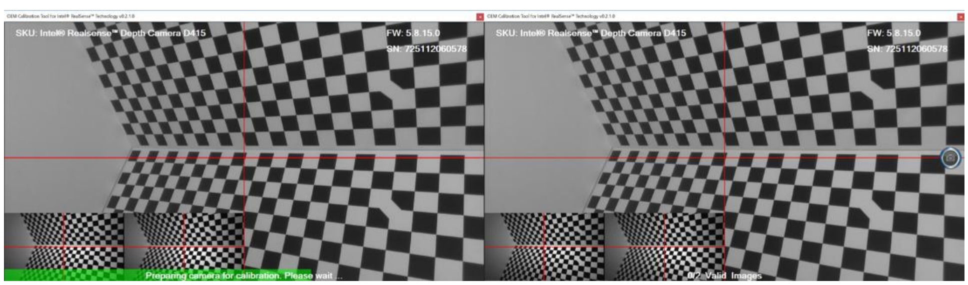
Choose the desired device to be calibrated from the list. Details of this device include its serial number, SKU and Firmware version. This ensures the right device is selected in case multiple cameras are connected to your host system.

Figure 3-5. OEM Calibration RealSense Device Details



Once the correct device is selected, click the "Start Calibration" button to start the calibration process. A window with live streaming appears. The SKU, FW version and serial number of the device is displayed in the top left and right corners of the Window. Wait a few seconds for the device to warm up and get ready for calibration.

Figure 3-6. OEM Calibration Process Start



Once the camera finishes warming up, a capture button appears on the right side of the Windows*. In the next steps, user will need to move the device to the two pre-defined locations and use this button to capture images for calibration.

3.5.3 Capture Images from Two Viewpoints

Images from two viewpoints from pre-defined positions are required for the OEM calibration algorithm.

Table 3-4. OEM Calibration Position Details

Placement	Description
Position #1	Distance Measurement: 60cm (+/- 1mm) Angle Measurement: 17deg (+/- .5 deg) – Right of midline
Position #2	Distance Measurement: 85cm (+/- 1mm) Angle Measurement: 17deg (+/- .5 deg) – Left of midline

Figure 3-7. Pre-defined Positions

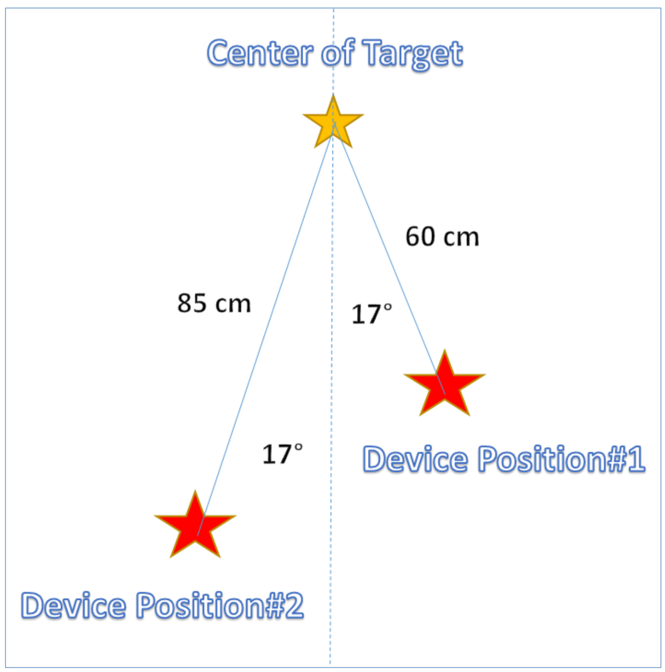
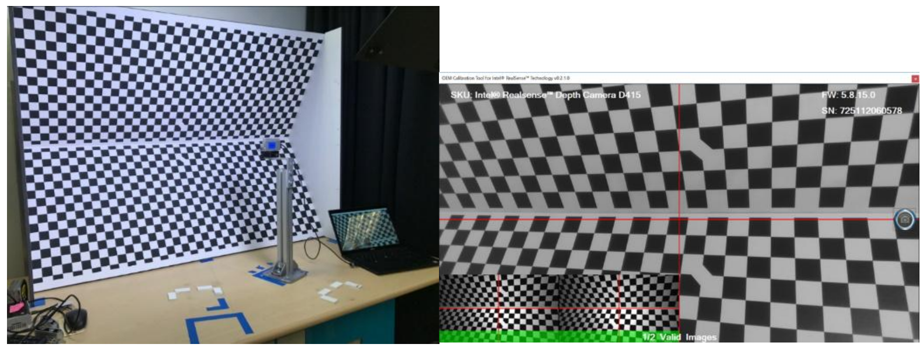


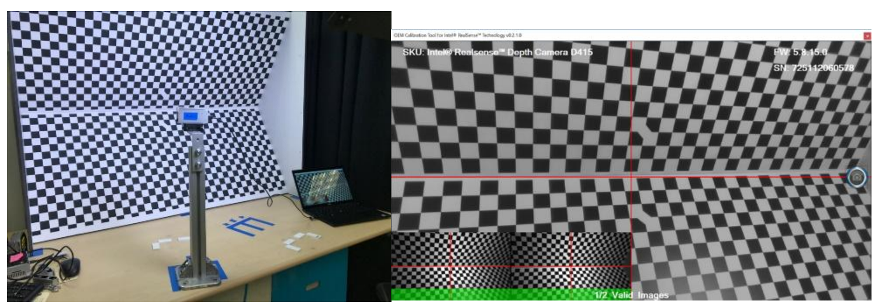
Figure 3-8. Marked Position Viewpoint #1 (Close Position #1)



Press the capture button at the right side to capture the image for this position. The software verifies the image and either accepts or rejects it. If it's accepted, it will display a green progress bar at bottom and the status message will be changed to "1/2 Valid Images". If it's rejected, then no progress will be made, and a red error message will appear on screen and instruct user to recapture image at this position.

Once the image for position #1 is successfully captured, move the camera to position #2.

Figure 3-9. Marked Position Viewpoint #2 (Far Position #2)

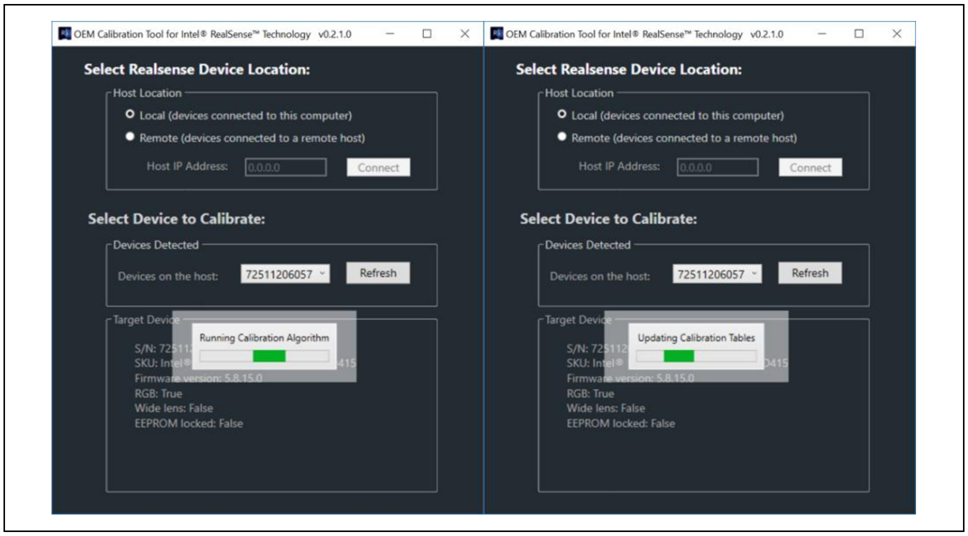


Repeat the process from Position #1

3.5.4 Running Calibration Algorithm

Once the images from the two viewpoints are captured, the OEM Calibration Tool will automatically start compute of the calibration algorithms can usually take 30 seconds.

Figure 3-10. Calibration Algorithm Run Window & Update



A message box will appear to indicate a calibration pass or fail.

Figure 3-11. OEM Calibration Success or Fail

If the calibration fails during any of these steps, it will display an error message box. In that case, user will need to execute this process again. suggests on executing OEM calibration up to three times. If failure continues then we suggest working with support teams. If the camera passes OEM calibration, RealSense suggest that DQT is executed again to ensure that the camera is functioning properly. If the camera passes DQT then it is ready to use. If not then contact your support team at: https://realsenseai.com/support . If you are an NDA customer, please use your Zendesk account.

3.6 Depth Quality Tool (DQT)

This application allows you to test the camera's depth quality metrics, including: Z-Accuracy, Sub-Pixel and Z RMS errors (spatial-temporal noise) and Fill Rate. You should be able to easily get and interpret several of the depth quality metrics, or record and save the data for offline analysis.

Once the RealSense SDK is installed the Depth Quality Tool (DQT) is also installed. Launch the DQT (icon below).

Depth.Quality.Tool.exe

For Z-accuracy, the tool requires an accurately known distance (ground truth) to be entered by the user to ensure the Z-accuracy is correct. The more accurate the ground truth the more trustworthy the Z-accuracy results. Do not underestimate the difficulty of inputting a good ground truth. A laser range finder is a good method.   also suggests that ground truth within the specified operating range of the camera. For example, Z-accuracy specification for D435 is 2% at 2 meters. This means a distance exactly 2 meters away would measure between 1.96 meters and 2.04 meters on a camera that is functioning properly. Most RealSense Depth Cameras commit to 2% accuracy at 2 meters. The D455 commits to 2% accuracy at 4 meters. The fill rate should be equal or greater than 99%. The RMS error should be equal to or less than 2%. The temporal noise should be equal or less than 1%.

The DQT will give clear placement instructions to yield the most accurate results. If the accuracy is better than the committed specification for your camera then it is ready to use. If the accuracy is worse than the specification, for example on D435 it is 4.8% at 2 meters then go to section 3.4 on **Error! Reference source not found.**.

Figure 3-12 Depth Quality Tool

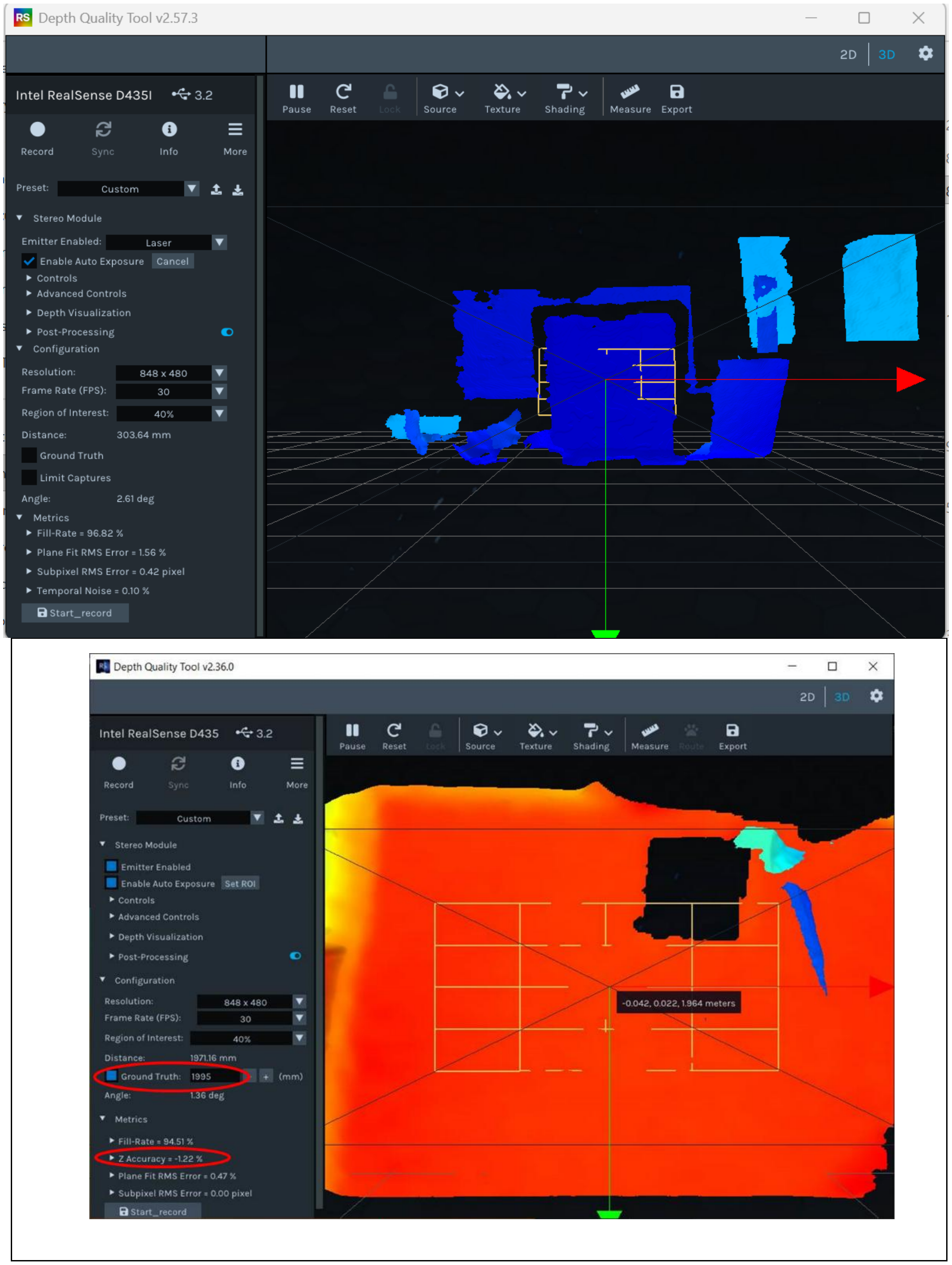
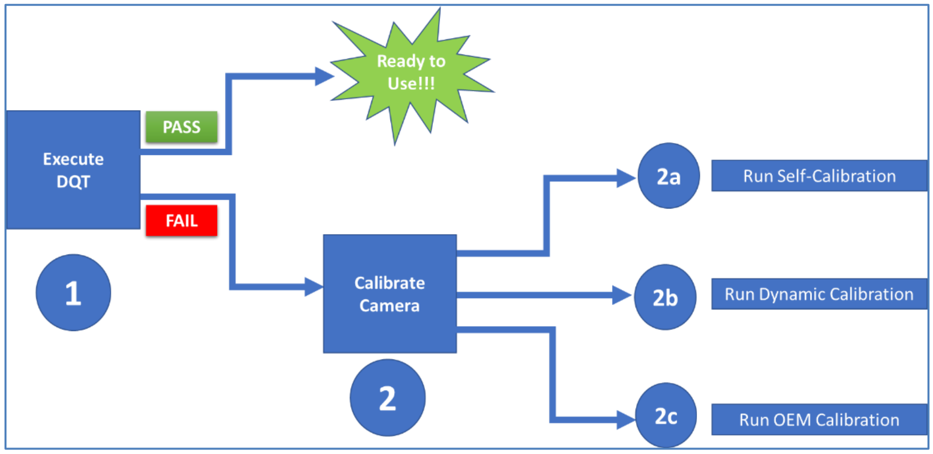


Figure 3-13 Depth Quality Tool Flow



Accuracy	Score Meaning
< 2%,	Pass
> 2%	Fail

Note: This is the complete flow for DQT, but if Self-Calibration has already been run then move to step 2b

Historically, RealSense Cameras quote the accuracy to be less than 2% error at 2 meters. The D45x specification is 2% at 4m. As stated earlier, the DQT is best when the measurement distance is very close to the operating range of the cameras.

4 Conclusion

RealSense Depth Camera products are robust and ready to use as a great solution for many compute visions challenges. Additionally, while this document has details on calibration techniques and product specs it is not comprehensive. Please ensure to reference the documents mentioned in the tools section of this document as well as the wealth of information on https://realsenseai.com.