Guidelines for Calibrated Scale Bar Placement and Processing

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To support highly accurate measurement of 3D data of an object or a site, it is essential for practitioners of photogrammetry to learn the correct placement and use of calibrated scale bars.

As you prepare to image a subject, you start by placing the scale bars on, around, or next to the object or site. When you have taken a series of overlapping images that include the scale bars, you are ready to process the image set to create a 3D model. Agisoft PhotoScan Pro finds the exact center of the targets on the scale bars in your photos, enabling highly accurate measurement of any feature of the imaging subject.

Scale Bars

NOTE: This document provides some tips that work with any target-based calibrated scale bars. The set of scale bars shown here is available from [Cultural Heritage Imaging (CHI).](link) This unique scale bar design was developed and field-tested by a senior team of photogrammetry experts from the US Bureau of Land Management. These bars are calibrated by CHI staff to 1/10mm accuracy or better, with the actual calibrated measurement between each target written on the scale bar. If you are interested in purchasing this set, you can [order them from the CHI web site](link).

How to Place Scale Bars

Place the scale bars in a scene or around an object of interest so the targets can be clearly seen in multiple overlapping images. You should consider the scale bars to be part of the "area of interest" for your photogrammetry project, and make sure that your set of overlapping images extends beyond the placement of the scale bars.

The scale bars have targets that are used as *markers* when the bars are placed in a scene or around a subject. When your set of overlapping photos includes the bars, these markers serve as reference points for scale definition, and also help the processing tool align images accurately.

The scale bars do not need to appear in every photo. They should be well covered by overlapping photos with good geometry so that their calibrated values can be used to provide accurate scale for the whole photogrammetry project.

Important Note: Do not move the scale bars during photogrammetric image capture of your project. If a scale bar is accidentally bumped or moved, remove it from the scene. Do not attempt to place it back in the scene, as it will not be in exactly the same place. Scale bars must be in a constant location relative to your project in order to be used accurately.

Examples of Placement

The following figures show some ways of placing scale bars.

Figure 1: On the left, three scale bars in place around a smaller subject. On the right, two scale bars placed on the outside of a large painting. Two additional scale bars (not shown) are placed on the far side of the painting.

Figure 2: Scale bars in place around a small kiosk-style building. Some are placed on the ground around the subject, and some are on the subject.

When using scale bars placed on the ground, outside the primary subject area, you must take additional overlapping photos that include the scale bars in order to use them for accurate measurement in your project.

In larger projects, place the scale bars as far away from each other as possible so that you can validate the scale across the entire project.

Figure 3: Four scale bars in place near an area of rock art and inscriptions to be imaged. These scale bars are placed near, but not covering, the inscriptions that appear above them on the rock.

How Many Scale Bars to Use in Your Project

While photogrammetry software can add scale to your project with a single scale bar, it is advisable to place a minimum of three scale bars in your project. We recommend four. Two bars provide a basic check, and three or more add confidence and statistical reassurance. Using four bars is ideal, especially for larger projects and outdoor environments, because it is all too easy for a scale bar to be moved by the wind, kicked, or otherwise displaced during capture. If this happens, the project will still have the integrity of three valid scale bars.

# Processing Data with Scale Bars

The processing workflow in Agisoft PhotoScan Pro Version 1.2 includes these basic steps:

- Set the scale bar accuracy
- Detect the targets on the scale bars in the image set to generate markers in each photo that includes scale bars.
- Create scale bars objects between specific markers.
- Add the calibrated scale bar distance data for the scale bar objects.

Each of these steps is described further below. More information on placing markers and creating scale bars can be found in the *Agisoft PhotoScan Pro User's Guide, Chapter 4, Referencing and Measurement.*

Set the Scale Bar Accuracy

Beginning with version 1.2 of PhotoScan Pro, it is possible to set the scale bar accuracy. The Scale bars from Cultural Heritage Imaging are calibrated to 1/10 mm accuracy or better. You should set the Scale Bar Accuracy to 0.0001 if you are using these scale bars. Otherwise, set this value to whatever accuracy is correct for the scale bars you are using. (the default value is 0.001)
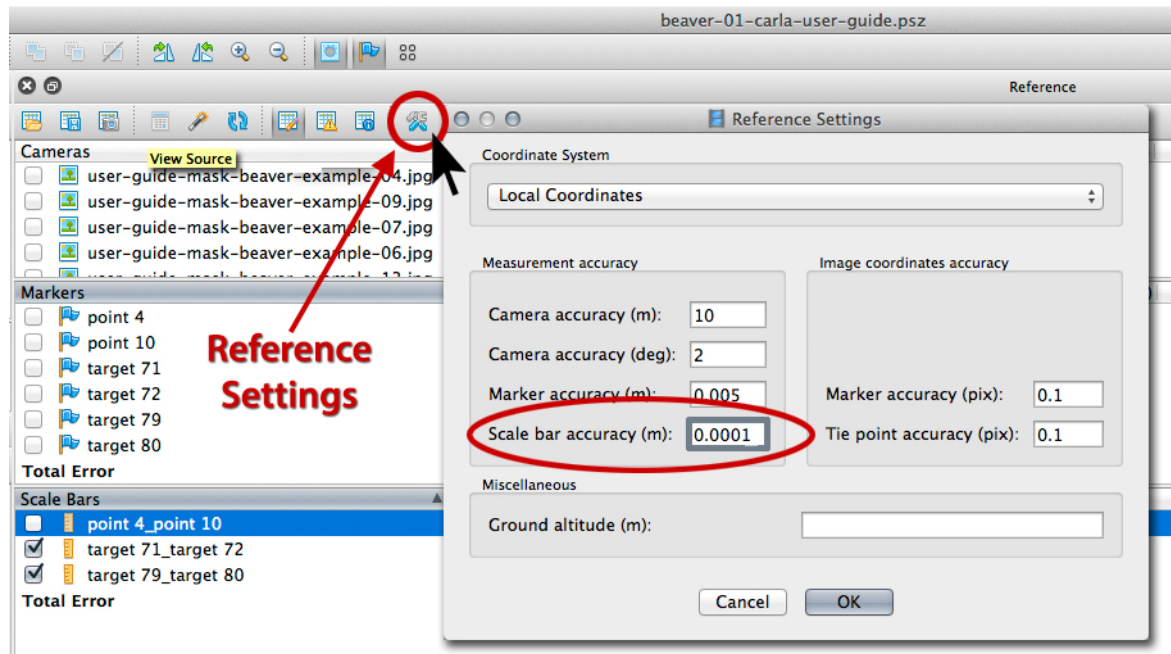
Detecting Markers

After aligning photos, and optimizing your project, use the Detect Markers dialog to detect the targets on the scale bars, and use them to automatically generate markers. Make sure the Reference Pane is visible and choose **Tools > Markers > Detect Markers**.
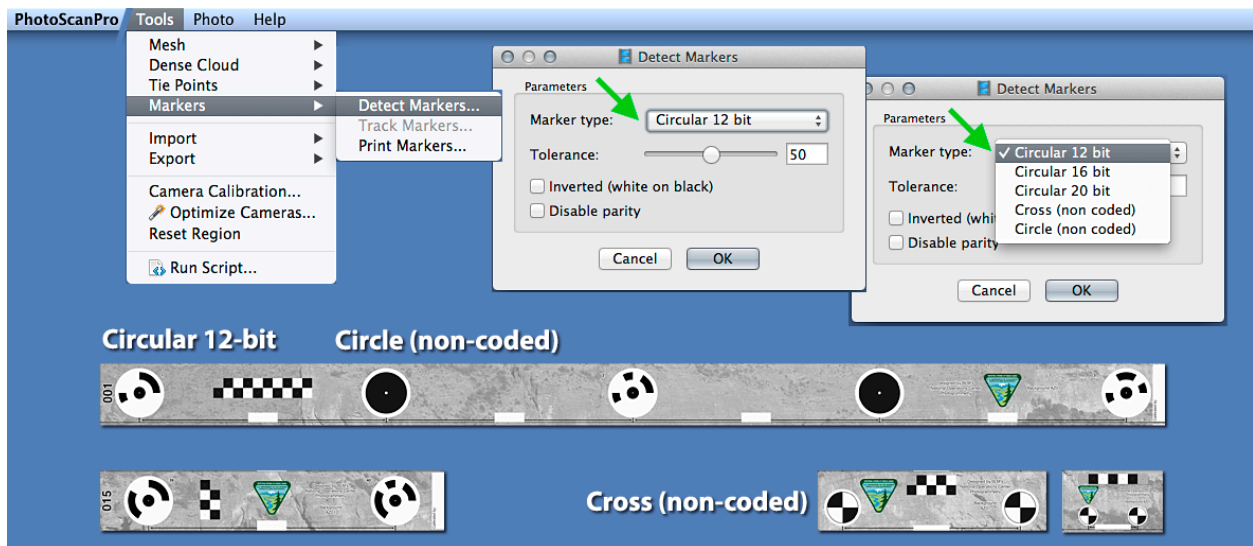
Figure 4: Detect markers for scale bars.

TIP: We suggest that you start with a tolerance of 20, and make it higher if not all targets are detected.

This graphic also shows the different kinds of markers that may appear on scale bars.

The scale bars from CHI include all three kinds of marker targets supported by PhotoScan, as shown in the figure. Marker targets can be circular coded, circular non-coded or non-coded cross.

An advantage of coded targets is that they are always named consistently. Coded targets are named "target xx," where xx is the number of the coded target, printed on the scale bar. Non-coded targets are named sequentially in the order the software identifies them, and labeled "point xx," but the numbering is not reproducible in different projects.

TIP: If you are using both circular coded and circular non-coded targets, you should detect the coded markers (the circular 12-bit marker in this example) before you detect any non-coded circular markers. This is because the center of the circular coded marker is a circle, and it will be detected as a non-coded circle if there is not already a marker present from detecting the coded markers. Then when coded markers are detected, you may have duplication of markers.

The centers of coded and non-coded circular targets are placed with high precision because the center of the circle can be detected algorithmically.

The centers of non-coded cross-type targets with calibrated distances, as well as the corners of small scales made up of black and white squares are placed with high precision because the center point of the cross can be detected algorithmically by the software.

Although you will rarely use these scale markers for setting scale in your project, you should retain any detected scale markers. They mark additional known points that can aid the software in the photo alignment and camera calibration.

To see the markers that are generated in each image, click the **Edit Markers** icon in the top toolbar (the blue flag). Each marker is labeled as a target or point, with an index number.
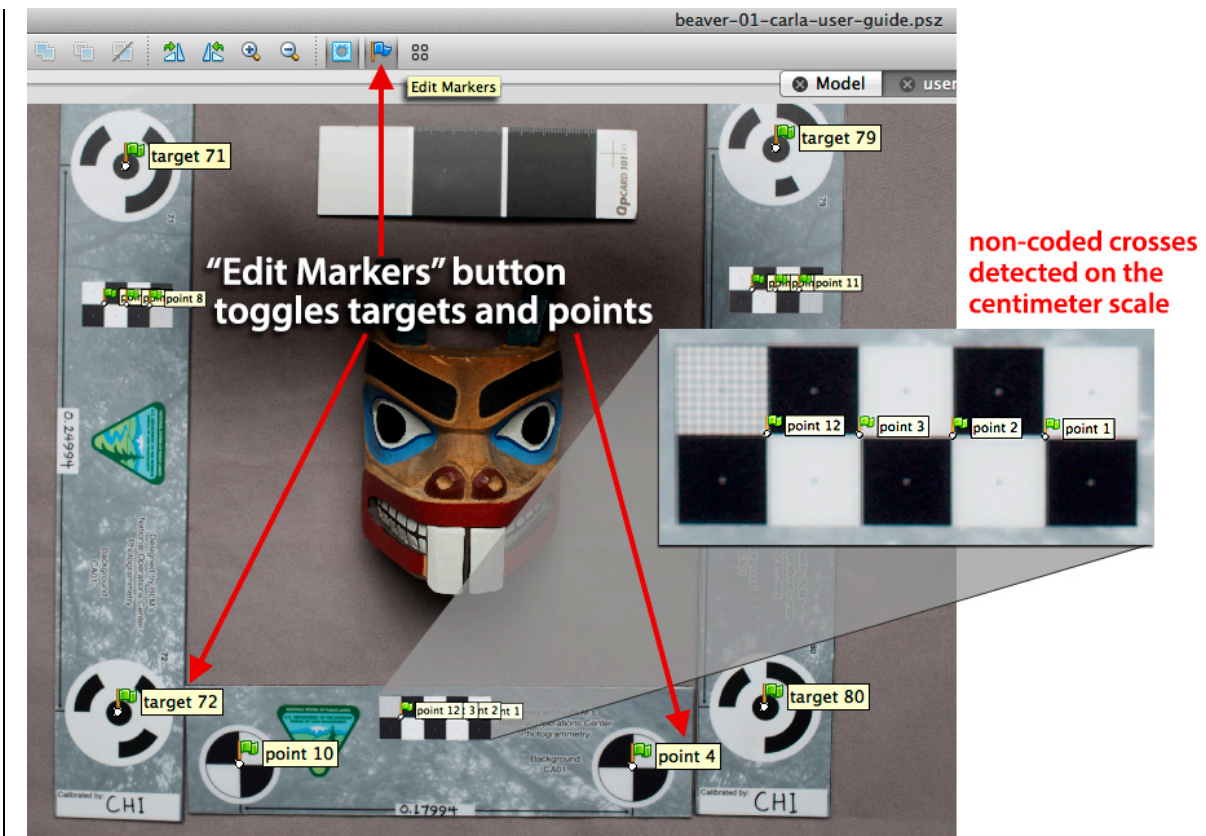
Figure 5: Detected coded and non-coded cross targets. Corners in the centimeter scale are also detected.

For more information on markers, see the *Agisoft PhotoScan Pro User's Guide, Chapter 4, Referencing and Measurement.*

Examining and Editing Markers

After you detect the markers, you can see information about each marker in the Markers area of the Reference Pane, as shown in Figure 6.

Markers	Projections	Error (pix)
☐ 🚩 point 4	9	0.075
☐ 🚩 point 10	9	0.095
☐ 🚩 target 71	9	0.069
☐ 🚩 target 72	8	0.048
☐ 🚩 target 79	9	0.103
☐ 🚩 target 80	9	0.052
Total Error		

Figure 6: The Markers area of the Reference Pane after markers have been detected.

- The **Error (pix)** value is the estimated error in units of pixels for that marker's placement. You should check these values to evaluate the quality of the automatic marker detection.

- The **Projections** value is the number of photos in which the marker was detected. We recommend a minimum of three projections for any marker that is used to set scale for the project.

Check the Error for Each Marker

You can sort by error to find the most extreme ones in your project. You can review the markers on a photo, remove them or change their position.

 If you intend to use a marker to set scale, we recommend that you remove projections on photos with the most error, or move projections until the marker error is below 0.4 pixels. (See "Creating Scale Bar Objects" below for instructions on creating the scale bars and setting their distance values)

Beginning with PhotoScan version 1.2, it is possible to see information about all the images that have a projection for any given marker, and to see the error in pixels for each projection on each photo. To view this information, right click on a marker in the workspace or in the reference pane and choose "Show Info…" from the menu.
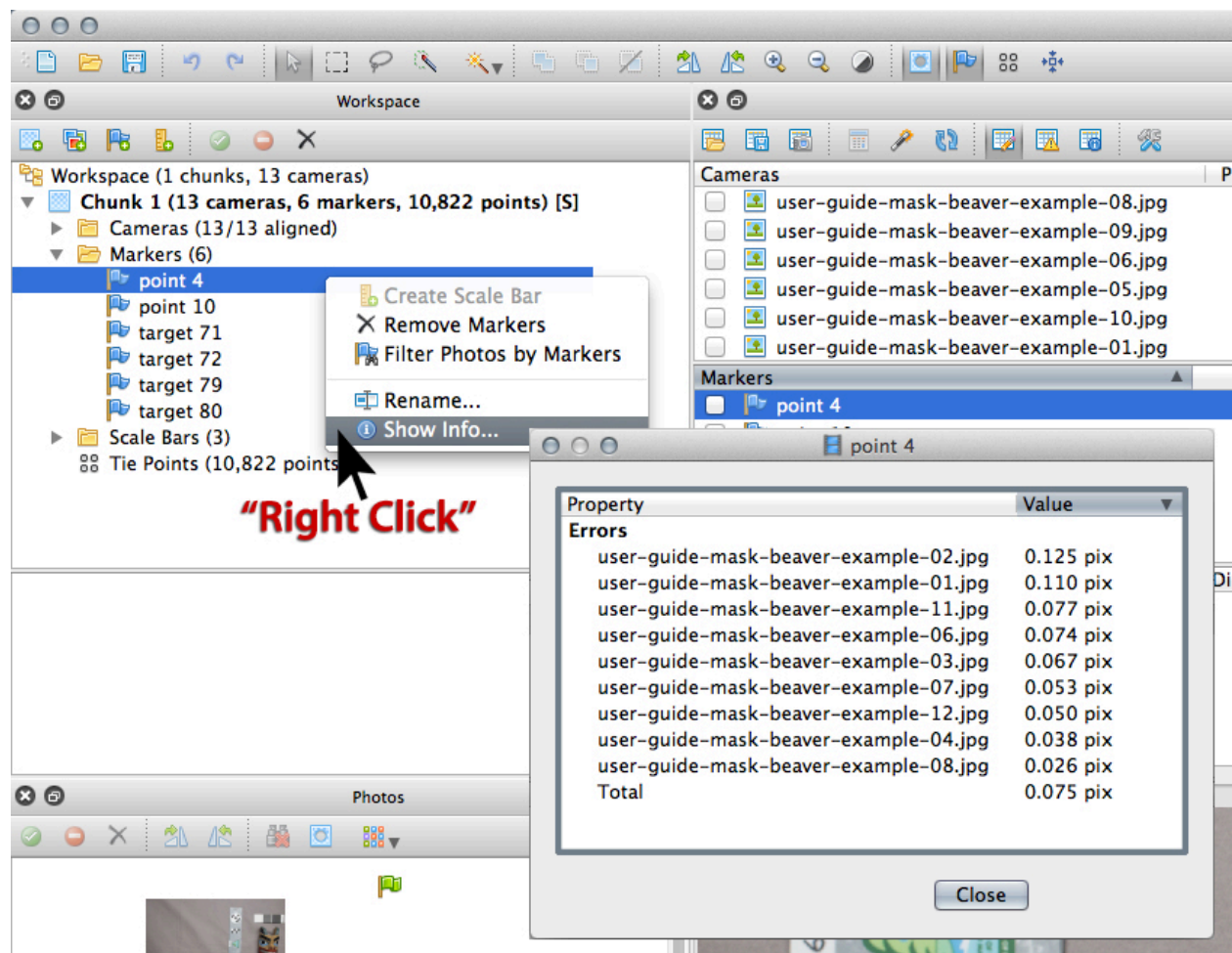

Figure 7: "Show Info…" box for a marker.

You can sort the "Values" for pixel errors in the info dialog box. You can remove the marker from photos that have high pixel error. Starting in PhotoScan version 1.2.5, you can double

click on an image name in the info dialog box and that image will appear in the main window. We recommend that you have a minimum of 3 projections for any marker you plan to use to create scale. (See below on how to add and remove markers)

TIP: After sorting the pixel errors for each photo with a projection for a marker, you can remove the marker from any photo that has a high pixel error. Removing the marker affects the number of projections for that marker, so be sure to check that you have enough.

You can also find all the images that have projections for a specific marker by right-clicking on that marker and choosing **Filter Photos by Markers**. Then check the marker placement for the images that have a green or blue flag (indicating the marker is being used). To do this, double-click on the image in the Photos Pane, and then zoom in on the target in the main window area.

When you have made any change to a marker in a photo, click **Update** in the Reference Pane toolbar to update the pixel error estimate.

Check the number of projections for each marker

Markers should appear in three or more images if you have a good image set with proper overlapping images. If you see fewer than three projections for a marker, you can place the marker by hand on additional photos. Alternatively, you can choose not to use that marker for creating scale bars.

As described above, there are two ways to find the photos that have projections for a given marker. You can use **Filter Photos by Markers** or the "Show Info" dialog box. You can then remove markers that have high error, or reposition them. If you do not have enough markers, you can place them by hand.

PhotoScan sometimes detects additional photos that have a marker and shows them with a gray flag, because there is not enough certainty about the position. These potential markers are not used in the project unless you place the marker explicitly in the additional photo or photos, as shown in Figure 8. If you don't have enough projections, one way to add more is by explicitly placing any potential markers in a photo.

The green flag by photo 13 in Figure 8 indicates that the marker for target 72 is being used in this photo. The gray flag indicates that a potential marker was detected, but it is not being used.

To convert a potential marker to a used marker, double-click to select the photo with the gray flag. In the main window area, hover over the base of the flag for the suggested marker until it turns red. You can then right click to bring up the context menu. To place the marker, choose **Place marker** from the right-click context menu.
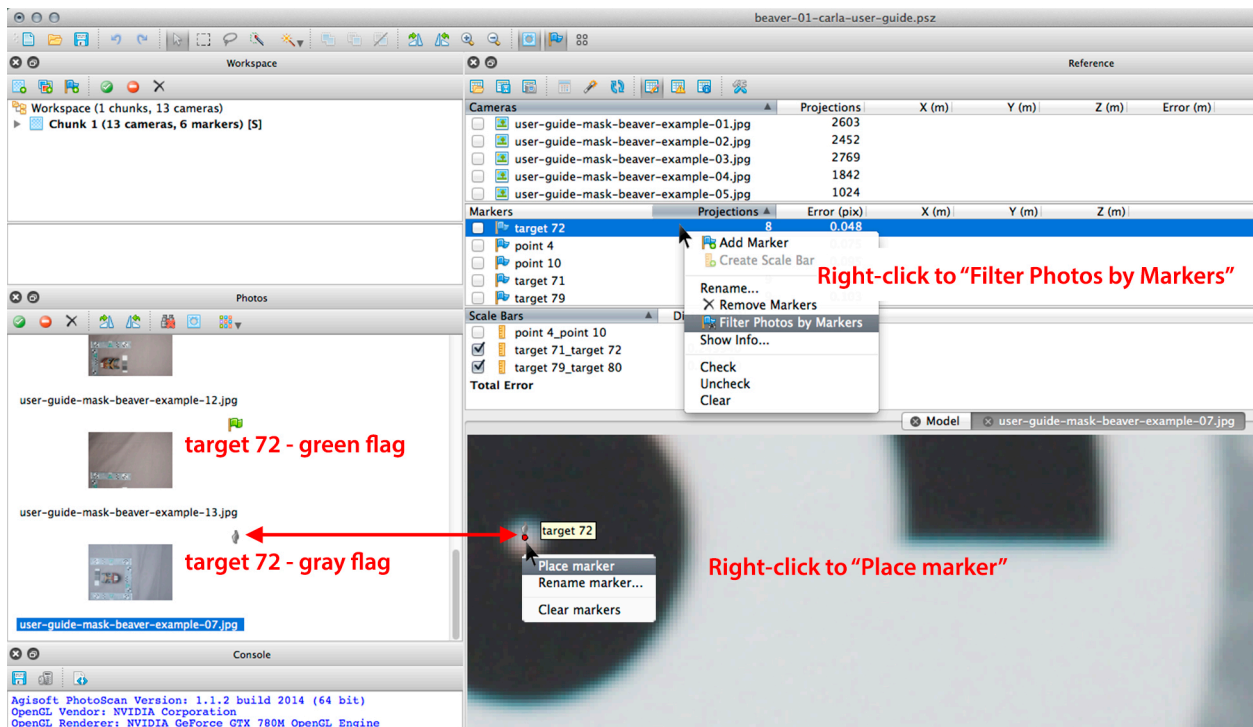
Figure 8: Placing markers by hand.

Creating Scale Bar Objects

The processing software uses a *scale bar object* to represent the physical scale bar with targets that was used to create the markers. You must create these scale bar objects from marker pairs, after all markers have been generated.

To create scale bar objects, select two markers in the Reference Pane, then right-click and choose **Create Scale Bar**.

Each scale bar object that you create should correspond to a physical calibrated scale bar that you used when capturing your image set.
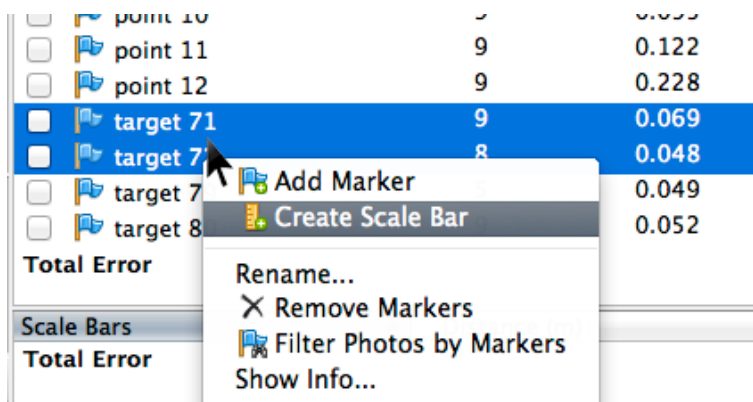

Figure 9: Creating a scale bar from target 71 to target 72.

Adding Scale Bar Distances

Select **View Source** in the Reference Pane toolbar to view the scale bar objects you have created. Each scale bar object is associated with a **Distance** value that you can set to the

exact distance in meters between the two markers on your physical scale bar. This is the information that provides the scale for the whole 3D project.
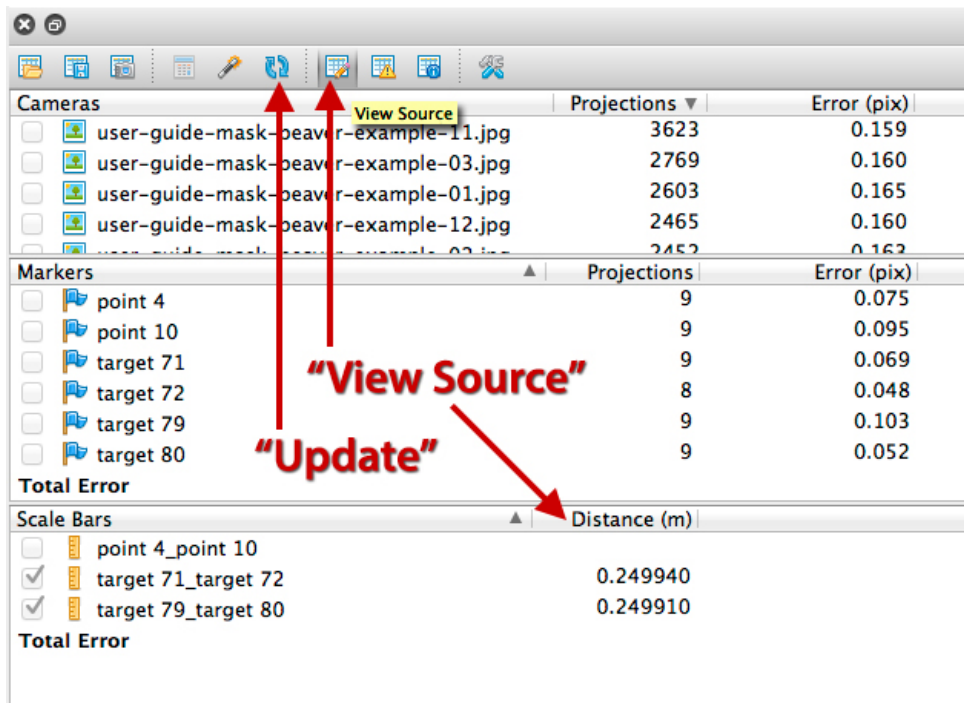

Figure 10: Updating information about markers and scale bars.

The **Distance** value is initially blank. In order to set the scale for the model, you must enter a distance value for one or more scale-bar objects. The distance between markers in the object should match the known distance between targets on the physical scale bar.

To enter a known distance value:

- Select a scale-bar object.

- Double-click in the **Distance (m)** column.

- Enter the known distance between targets for the corresponding calibrated scale bar.

TIP: While a project can be scaled using the known distance from a single scale bar, more scale bars are strongly recommenced. Two bars provide a basic check, and three or more add confidence and statistical reassurance.

TIP: When you make any changes to markers or scale-bar objects, such as manually placing or moving markers or entering scale bar distances, click **Update** to see the effect of those changes on the error and estimated distances.

Check estimated scale bar distance values

In a well-shot project with crisp photos and proper image overlap, the difference between the estimated distance value for each scale-bar object and the known target distance in the corresponding calibrated scale bar should be less than the precision of the scale bar. In the case of the scale bars from CHI this is 1/10mm (0.0001 meter).

Each time you update the source data, the tool refines the scale of the entire model. It then uses the current scale and project geometry to estimate distances for all defined scale-bar objects.

To show the estimated distance values that are based on the current scale, click the **View Estimated** icon in the tool bar.
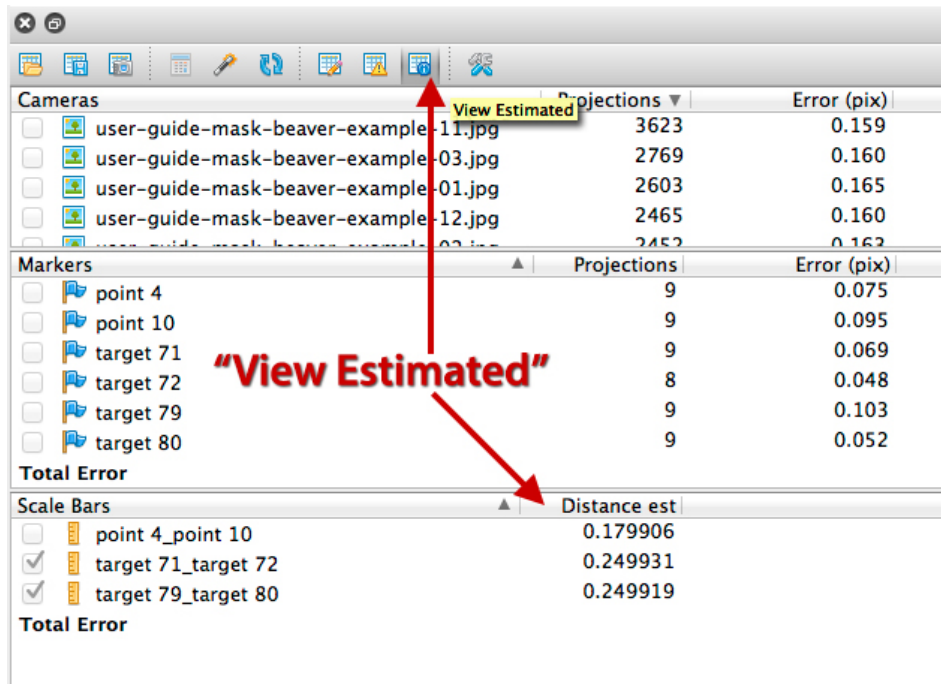

Figure 11: Show estimated distance between markers in scale-bar objects.

In Figure 11, the distance values you entered are replaced by the estimated values based on the current project scale. The tool estimates values for all scale-bar objects, based on the current scale it has developed for the model.

- The check marks show those objects for which you have entered distance data. For these objects, the estimated distance value is adjusted to conform with the current scale in the model.

- The unchecked objects have only estimated data, because no data has been explicitly entered for them.

You can evaluate the accuracy of the current scale by seeing how closely the estimated distance values for scale bar objects match the known distances between targets in the physical scale bars that you used to generate the image set.

TIP: Enter known marker distances for all except one of the scale-bar objects that correspond to your physical scale bars. This enables you to compare the wholly estimated value with the adjusted values.