

Detailed Agisoft Metashape Workshop Instructions

Depending on your hardware capabilities, this workshop could take an entire day or more. To build this model, the authors used a Windows 10 machine with an AMD Ryzen 3900 CPU, 64GB RAM, one GeForce RTX 2080 8GB GPU, with Agisoft Metashape version 1.6.4. Total modeling time took ~2 hours.

For the purpose of generating a 3D model using Agisoft Metashape, a dataset of photos are provided for participant use in case they do not have photography equipment. The dataset consists of 72 jpeg photos of a Greek Cycladic figurine replica. The Greek Cycladic figurine was chosen because it only needs to be oriented on one axis (that is, there is no data to capture on the bottom), requires minimal photos to model which reduces processing time, and is a simple subject on which to learn.

All photographs were captured using a Canon EOS 5D Mark III camera and a 50mm prime lens mounted on a tripod (see below). Photos were captured in aperture priority mode with an ISO of 200, f stop of 22, and shutter speed usually around 1/13 to 1/20 of a second. In addition, the Foldio 360 25 inch lightbox and automated turntable were used capturing 24 images (or one image per 15 degrees of rotation) per sequence with the remote IR camera trigger with a 3.5 second delay between photos (to allow for object rotation on the turntable).

The photography dataset is provided as a zip archive and will need to be unpacked for use. 7zip is a free utility to unzip archives and is available for free download at <https://www.7-zip.org/>. Most Windows and Mac OSX machines also have native support to unzip archives.

Greek Cycladic Figurine photography dataset: <https://doi.org/10.15786/16543554>

Agisoft Metashape is a very powerful and professional photogrammetry application. If you are working with photogrammetry often and in a professional capacity, the professional version is recommended, but for workshop purposes, it's not required. For our purposes, downloading the trial version is more than sufficient. To do this, one must download Metashape here: <https://www.agisoft.com/downloads/installer/>

When first opened, Metashape will ask you if you want a 30 day trial license for the Professional version. If you want to be able to save, export, and use calibrated targets, all of which are covered in this workshop, select the 30 day trial. Metashape can be operated in Demo mode without a trial license, but you will not be able to save or export your work. One must have a decent computer in order to operate Metashape; otherwise, your processing time could be very lengthy.

Note that throughout these steps, your results may differ slightly from the examples below. Don't get caught up in replicating exact values (especially in the gradual selection process) as it is not necessary for generating good 3D point clouds, meshes, or models. Also, this workshop was designed with the use of Agisoft Metashape version 1.6.4. Last, many recommendations in this workshop are based on Cultural Heritage Imaging consultations and the United States Bureau of Land Management's best procedures (developed by Tom Noble in 2015 for Agisoft Photoscan version 1.1) for photogrammetric 3D modeling.¹

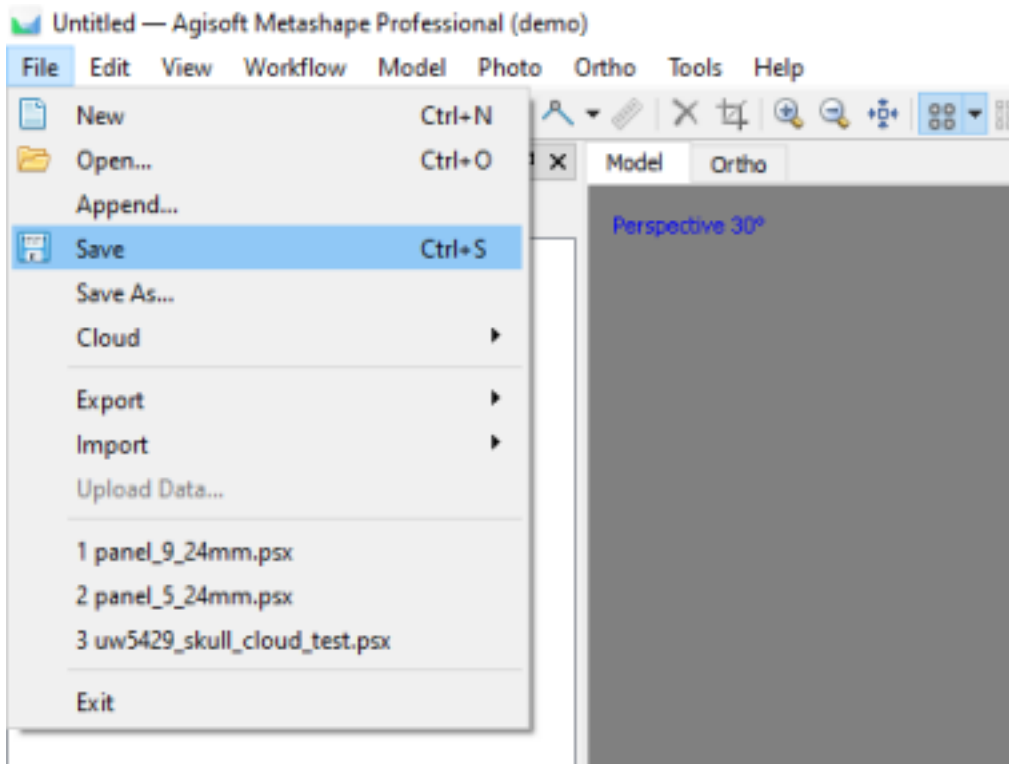
¹ Recommendations are based on expert advice received from Cultural Heritage Imaging during a weeklong photogrammetry training course. <http://culturalheritageimaging.org/>

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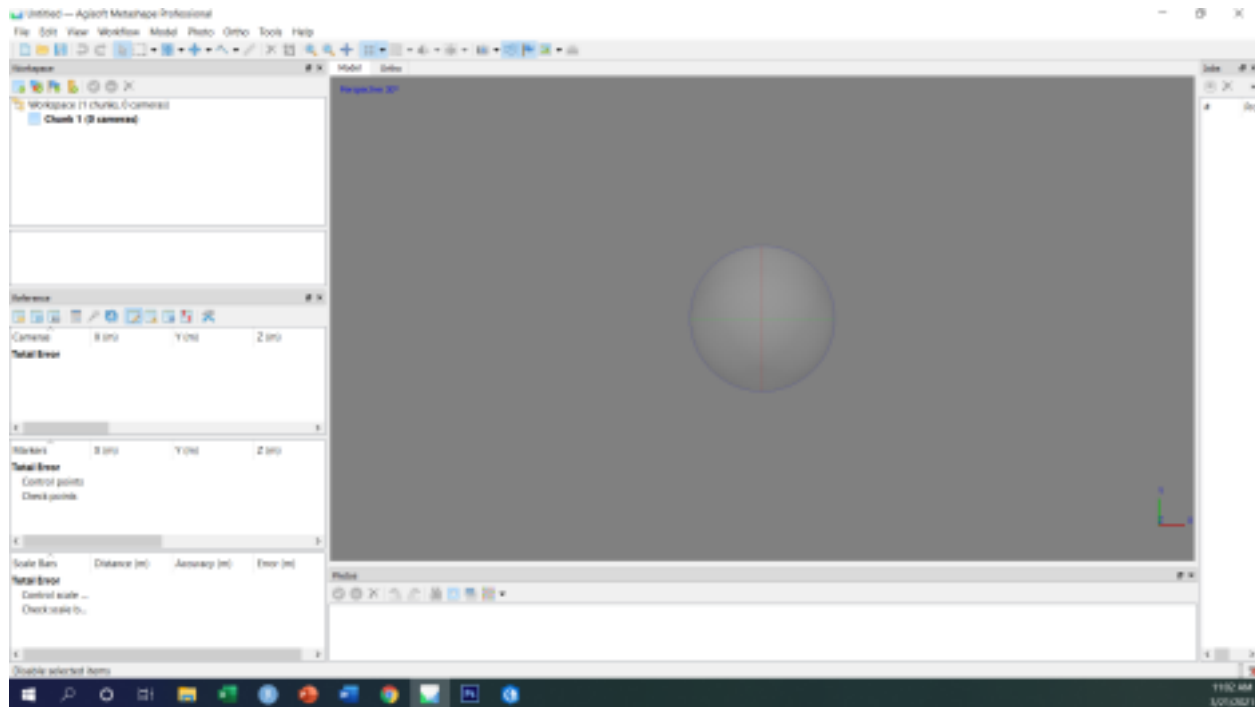
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Step 1: CREATE AND SAVE PROJECT FILE

Once you have installed Metashape, the first step is to save your project file from the File Menu. **SAVE YOUR WORK OFTEN!** This is a heavy computational application; some of these processes can take a considerable length of time and can crash.



Step 1b: FAMILIARIZE YOURSELF WITH METASHAPE INTERFACE



Like many other applications, Metashape has several windows/panes that can be organized and ordered to suit your personal preferences. Metashape processes data in “**chunks**,” which are listed in the Workspace pane. It is within each chunk that photos, scale bars, and other model components will eventually be listed.

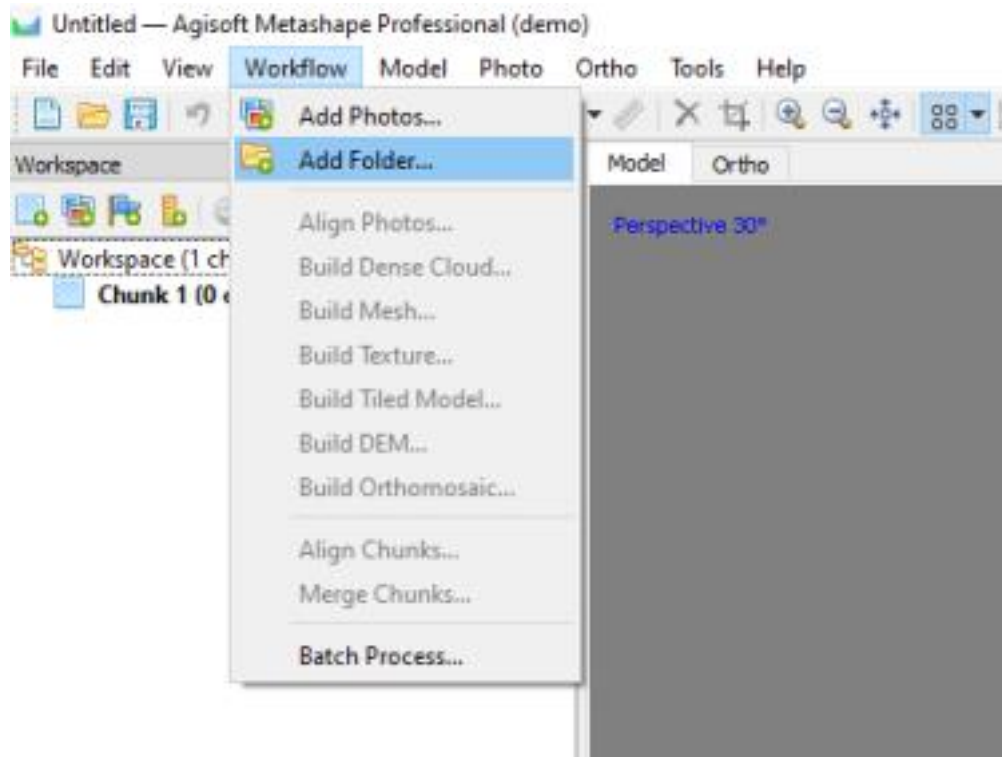
- **Reference pane:** where scale bars are created and assigned to the model. In this view, the Reference pane has been pinned below the Workspace. The default view is to have the Workspace and Reference panes accessible via tabs at the bottom left of the Metashape screen.
- **Photos pane:** where thumbnails of all of the photos associated with the project will be displayed.
- **Model view:** the large, gray area in the center of the window. This is where the 3D model will be displayed as you go through the different steps in the software.

At the top of your Metashape window are the file menus and tool bars. What each of the file menus, tool bars, and buttons are used for will be covered in more detail below.

Step 2: ADD PHOTOS OF YOUR OBJECT

This will add all photos in the folder to your project. There are two ways to add photos.

Method 1: Workflow > Add Folder (use the “Single Cameras” option when prompted).
Navigate to wherever your photos are located on your local machine.



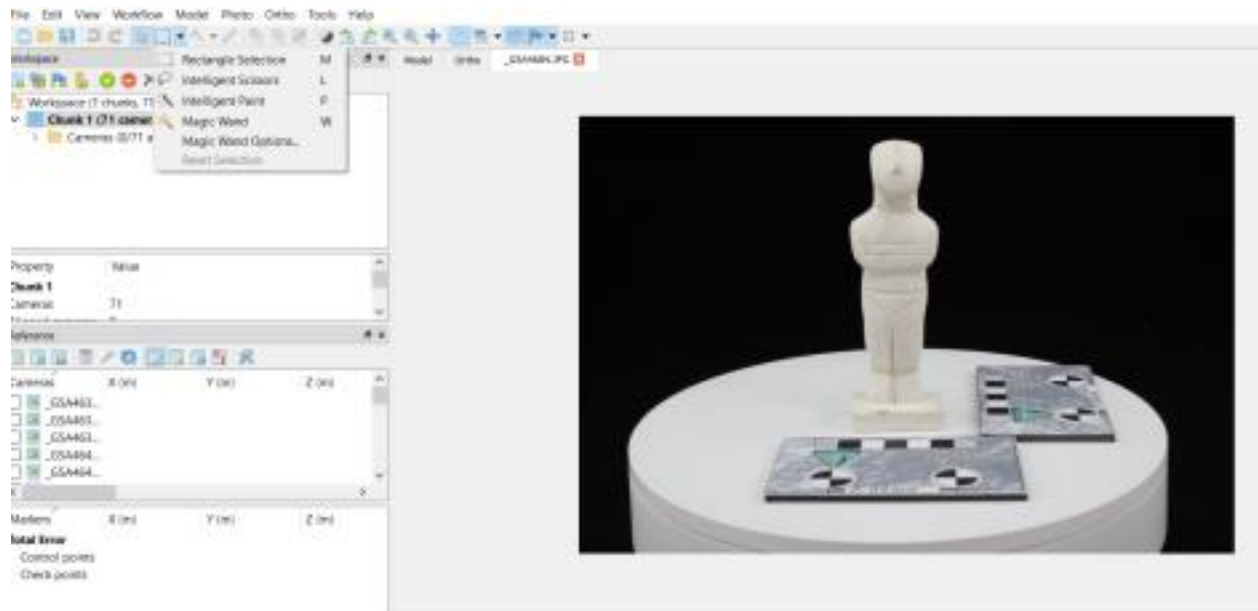
Method 2: Right-click on your “**Chunk 1**,” select “**Add**,” and then select “**Add Photos**.”

Once you add photos, you should see thumbnails of all images within the Photos pane. Double clicking on any photo will open it up in an individual photo tab (which opens on top of Model window). You can simply close this tab by clicking the red “X” if desired.

Step 3: MASKING PHOTOGRAPHS

Masking photographs is one of the most time-consuming aspects of Metashape. Although this step is not technically required, it is highly recommended as it will save you ample time in subsequent steps by masking out areas in your photos that you do not want to be part of your 3D model. Masking “crops” areas of photographs and then Metashape only processes the un-masked areas. For turn-table photos you should mask **two to eight** different images depending on the complexity of the object and whether you have flipped the object over. For the Greek Cycladic figurine, mask four photos: one photo each from the four “cardinal” directions (North, East, South, and West).

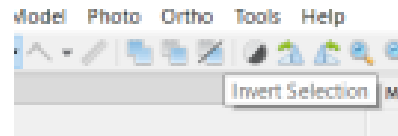
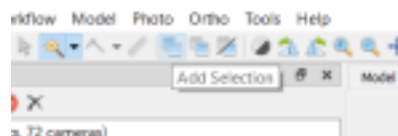
To mask, first double click a photo to open it in the photo tab. We will choose the front of the Greek Cycladic figurine to start. Once the photo is open, select the dropdown menu that has a dashed-square shape.



Menu Options

Rectangle Selection	Used to select a rectangle area. Can only create a rectangle/square. Best for simple, blocky objects.	
Intelligent Scissors	Used to create a polygon selection (very useful tool). Click to create a vertex, and continue creating vertices around the object. You complete the polygon by clicking your first vertex (or connecting to the first vertex).	
Magic Wand	Auto-selects large areas by color. In the example to the right, the black background was selected.	
Intelligent Paint	Works similar to the Magic Wand, but can be tricky to use.	

Once you have created a selection, then you need to tell Metashape how you want to create a mask using that selection. In the tool bar are three sets of blue/transparent squares. These represent: **Add Selection**, **Subtract Selection**, and **Invert Selection**.



Selecting **Add Selection** will add whatever area you have selected to your mask, and **Subtract Selection** removes masks from areas. **Invert Selection** is important because you can take selections (like the rectangle and Intelligent Scissors examples above) and invert the selection to select everything outside of the selected area:



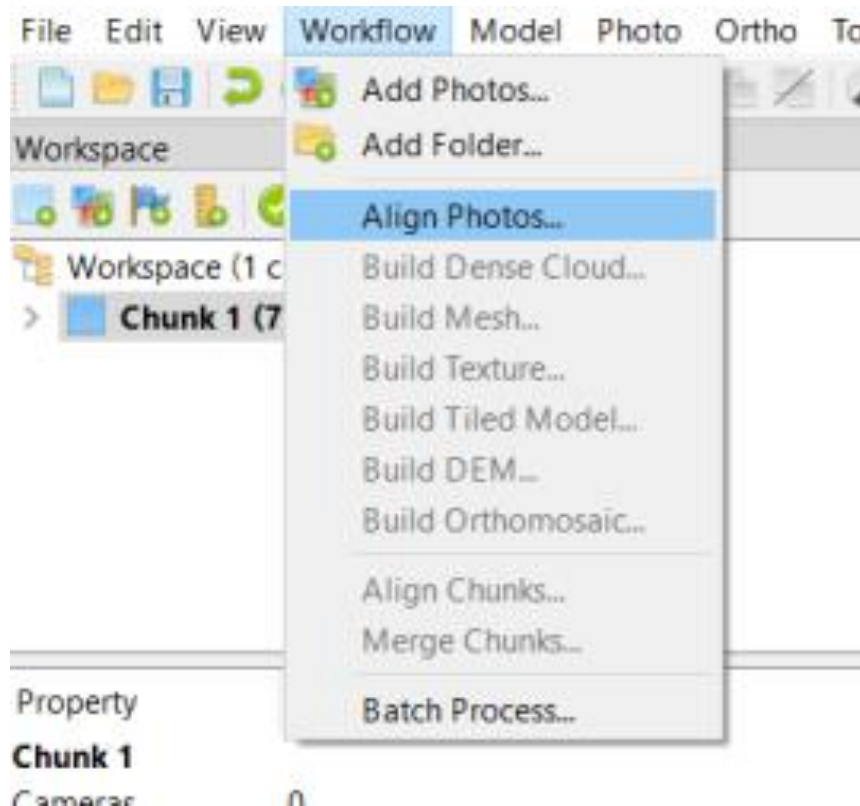
In most instances, you need to use a combination of all of the selection tools and Add/Subtract/Invert options to create a mask that excludes everything in the photograph except the object you want to model:



Repeat this process for the left, right, and back sides of the Greek Cycladic Figurine to create four masked photos.

Step 4: ALIGN PHOTOS

After masking photos you can begin the first step in the modeling workflow: **Workflow -> Align Photos**. Expand Chunk 1 and you should see all of your photos listed. Once there, you're ready to Align Photos (this process could take up to two hours or as little as twenty minutes once started depending upon your computer). A note to make in all of these steps is that the progress bars and the time left indicated on the progress displays are often very inaccurate, so don't pay too much attention to them. However, the Align Photos process could take a very long time (2+ hours) on some computers.



When prompted, set the following options:

- Accuracy: High
- Generic Preselection: Checked/Source

Under Advanced, leave the Key point limit at the default setting of 40,000 and the Tie point limit at the default 4,000. Also, **make sure to set the “Apply masks to” menu to “Tie Points.”**

Explanation of settings

- High: processes the images at 100% resolution
- Medium: down samples that resolution to 50%
- Low: down samples to 25% of original resolution

The setting of Highest actually up-samples the images by a factor of 4 and is generally not recommended because it will increase the processing time and can introduce additional inaccurate points into the point cloud. For purposes of practicing in a workshop setting, you can lower the Accuracy setting to Low and decrease the Tie Point limit down to 20,000. You can experiment with these settings as they are not gospel, just recommendations. Reducing these settings will greatly reduce processing time which might be necessary in a time-limited workshop or with lower powered computers. Checking Generic Preselection can also save compute time, but in some cases can also result in some (or many) photos not aligning. In the case of this particular dataset, checking Generic Preselection with an Accuracy setting of High will save processing time while rendering a very good sparse cloud without any problems so it is (in this case) not a problem. The settings above are recommended for the best results.

Key points and Tie points

Both **key points** and **tie points** are photogrammetric terms used in many software applications (i.e. they are not unique to Metashape). A **key point** (or keypoint descriptor) is a feature that photogrammetric software identifies in photos (by using an algorithm called SIFT, which stands for Scale-Invariant Feature Transform) of an object that it thinks is unique either because of the geometric shape or the texture. When the software application finds the same key point(s) in multiple (two or more) photographs, those become **tie points**. It then uses these tie points to identify 3D camera locations and positions which allow it to build the sparse point cloud. By raising or lowering those limits you are allowing the application to identify more or fewer points. It's possible to allow too few and it's also possible to allow too many.

After Step 4 has completed, you should see a sparse point cloud of the model, and you can look to see if all of your photos have aligned (they should). It will indicate (in the Workspace area) how many aligned out of the total. If not all photos aligned, you can re-run the photo alignment process.

Also, you may toggle on/off the “**Show Cameras**” button (pointed out below by the red arrow) to see where your cameras were aligned. You should see three distinct circuits of photos (three rings with twenty-four photos in each ring) as seen below. If you see a set of photos that do not appear to be oriented in circuits, you will need to re-run the Align Photos procedure as it will negatively affect your sparse cloud, dense cloud, geometric mesh, and texture in subsequent steps.

Step 5: GRADUAL SELECTION PROCEDURE AND MANUAL CLEAN-UP

The objective of this multi-step operation is to optimize the camera alignment and remove points which the program detected that are not accurate. Removing those inaccurate points will improve your model.

A. Manual Cleanup

Access the selection tools from the tool bar. Select stray points outside of the model (selected in pink) and delete these points ("X" from tool bar or Delete/Backspace key). You can use the Control key to add points to a current selection, or use the Shift key to remove points from the current selection. We suggest the Free-Form Selection tool as it will let you highlight an arbitrary area of points instead of a circle or rectangle. Whatever selection tool you choose, **be careful not to cut through your model when selecting points**. Remember, this is a 3D point cloud so anything behind the points you select to be deleted will also be selected and deleted. This process can be difficult with a small monitor and it does require a discerning eye to find single points in space so take your time, zoom in and out, and rotate the sparse cloud in all planes to find any outliers. After you are finished deleting points manually, **save your work**.

B. Gradual Selection: Image Count

The first step in Gradual Selection is to choose Image Count. Once clearly stray points are deleted manually, navigate to the Model Tab, and select Gradual Selection and Image Count. One of the biggest sources of error is when tie points only show up on two images. To remove these, select Image Count from the Criterion menu, and then move the scroll bar to **Level: 2** to select the points that only show up in two images. Delete these selected points ("X" button from toolbar, or delete/backspace), find the "Optimize Tool" in the Reference pane and then keep the default settings generated by Metashape. Click OK.

C. Gradual Selection: Reconstruction Uncertainty

Return to the Gradual Selection dropdown, but this time select Reconstruction Uncertainty. At this point, you will be prompted to select a level. The lower the level, numerically, the more points you will be removing. You can slide the level back and forth and watch to see how many points are being selected in the lower corner of the Model pane. Initially, this will be a pretty high number. **A level of 10 is ideal** but it's not always possible because you may simply remove too many points. If the level is over 10, enter 10 into the Level box. Delete the selected points, and then optimize again following the same procedure as before.

D. Gradual Selection: Projection Accuracy

Return to Gradual Selection dropdown and select Projection Accuracy. This time around the level we'll select should be in the recommended **2-4 range**. Once again, keep an eye on how many points you're selecting (a lower numeric level selects more points). In this case, we'll go with 4, delete the points using the X icon in the menu bar, and then another camera optimization as before.

E. Gradual Selection: Reprojection Error

Return to Gradual Selection dropdown and select Reprojection Error. In this step, we're looking for an error rate of **no more than 1**. In our example the Reprojection Error is less than 1, so we don't have to do any additional steps (click cancel to exit at this point). However, if you do have a Reprojection Error greater than 1, enter 1 into the Level, hit OK, and delete the selected points. Once again Optimize Alignment following the previous steps.

At this point in the process, you should have a clean sparse point cloud.

Step 6: BUILD DENSE CLOUD

After performing Gradual Selection, you are ready for the next major step in the workflow, building a dense point cloud. Navigate to **Workflow->Build Dense Cloud**. For the time constraints associated with this workshop select Medium Quality, but for objects you might be building at your own institution you will want to select High. Change **Depth Filtering** to **Aggressive**, and keep the **Calculate point colors** setting enabled. Once those are selected, hit OK.

Depth filtering is a setting that will remove more points at the Aggressive level and fewer at the Mild level. If you have poor photos, Aggressive can be helpful but if not, Mild might work too.

Step 7: CLEANING DENSE POINT CLOUD

After the dense cloud is constructed there will be stray points/noise around the object you are modeling. The only way to prevent this noise from entering the final product is to trim these points manually. Use the same selection tools as when you were trimming the sparse cloud. Be extra careful not to delete portions of the model you don't want to get rid of. Save the model before you start cleaning the dense cloud.

STEP 8: BUILD MESH

At this point, you should have a clean Dense Point Cloud and you can proceed to build your 3D surface. This is called a **Mesh**, and Metashape creates thousands (or millions) of triangles/faces between the points within the Dense Point Cloud. To Build Mesh: **Workflow->Build Mesh**.

Under the **Source Data** menu, select **Dense Cloud**. Surface Type should always be **Arbitrary 3D** (unless you're using UAV data which we won't be in this case). If you're using the Dense Cloud as the source data, Quality is not selectable. Face count will default to the same resolution as the Dense Cloud, but you can increase this (from Medium to High) if

desired. For this workshop we will keep face count at Medium. Expand the Advanced menu and be sure **Interpolation** is enabled and check the **Calculate vertex colors** box. Press OK.

STEP 9: CLEAN MESH (IF NECESSARY)

In some cases, your mesh may have some noise that need cleaning or trimming. If this happens, you will need to trim the noise off of the bottom of the model using the appropriate selection tool and then deleting those portions. This is done the same way as manually deleting points from the point cloud. Be careful not to trim into your model, or you will introduce a hole that the application will have to fill and it will detract from its veracity.

You can also use **Tools->Mesh->Close Holes** and/or Smooth to help clean the Mesh.

STEP 10: SCALE MODEL (IF DESIRED)

If you would like to be able to make three dimensional measurements on your 3D model (or to place it in context of other physical objects), one of the necessary steps is to apply scale using scale bars. In this example, we have two calibrated scale bars included in each photograph. To add Scale, double click the first photograph to open it.

Right-click in the center of the target, select "Place Marker, then select "New Marker." This will create "Point 1".

In the same photograph, right click in the center of the 2nd target and select "Place Marker" and "New Marker." This will create "Point 2".

Close the first photograph and open the 2nd photograph. Two red lines will be visible. Navigate to the center of the first marker and right-click. Select "Place Marker" and then select "point 1." Do the same for "point 2."

After adding the locations of point 1 and point 2 in at least two photographs, the locations of those points across all the remaining photographs will be displayed like this:

Importantly, in at least one additional photograph, click the point icons and adjust them to be in the center of the target. The icons will change from gray shapes to green flags. Do the same steps for adding points 3 and 4 onto the other scale bar. After adding all points each photograph should look like this:

The next step is to navigate to the Reference Pane. Select point 1 and point 2, right click, and then "Create Scale Bar." Do the same for points 3 and 4.

Once the two scale bars are created, enter in the distances hand written on each scale bar (visible in the photographs) into the "Distance(m)" columns. The scale bars we use here display distances between points in meters.

After the distances are added for both scale bars, hit the double arrow symbol (next to Optimization). This will update the scaling/referencing for the model. Your model is now scaled to real-world units and can be measured!

Step 11: BUILD TEXTURE (IF DESIRED)

Once you have your mesh the way you want it, if you want to build texture (color) you will need to run that process from the Workflow menu by selecting **Build texture** and simply keeping the default values in every case. If you don't want texture, this step can be skipped and you may go on to Step 12.

You should now have a textured and scaled final model that should look similar to the one below.

Step 12: EXPORT (OBJ, STL, PLY options are most common)

This is the final step in the process. At this point, you should have a clean geometry (and possibly texture) for your model in Metashape.

You can now export your 3D model in a number of 3D file formats. If you want to include the geometry and the texture, you should export it as an .obj file which includes what is called a materials file (an .mtl), a texture file (in this case, as a .jpeg), and a geometry file (the .obj file). To do this, go to the File menu and select **Export > Export Model**.

From here, you can choose from a number of 3D file formats, but the Wavefront obj format is suggested for web delivery and downloads because it includes both geometry and texture. Give your file an appropriate name and hit OK.

On the following screen, keep the defaults, but also enable the Vertex normals box and then hit OK. Obviously you may change the comment field if you wish to do so.

Depending on where you chose to save your file, you'll actually now have three files that make up your 3D model; **an .obj file** (which is your geometry/mesh file), **an MTL** (or materials file, much like a manifest), and a **.jpeg file** (your texture file). You can choose to export the texture file in a different image format in the previous step, including JPEG, PNG, TIF, and EXR. **All three of these files are necessary to view your 3D model with texture in any other application as well as for web delivery so it is suggested to bundle them in a single directory.**

One could also choose to export their model as a .ply or a .stl, which are also both common 3D file formats. However, an .obj file is the most versatile format for web delivery if you want to include texture and geometry.

Once you have it saved as an OBJ, you can open the file in a variety of open source 3D software applications including Meshlab, Meshroom, Blender, Maya, and more. Bear in mind that the obj file, once again, consists of the geometry (the OBJ file itself), the materials file (the mtl file), and the texture file (in this case, a jpeg file). All three are necessary for a complete view of the 3D object in a third party application.