

Processing Scanned Aerial Imagery with Metashape (part 2)



Introduction

Historical aerial imagery is a valuable resource for mapping and monitoring change over time. The above example illustrates how a portion of the Manti-La Sal forest has changed within the last few decades. The Forest Service is in the process of scanning all of their historical film stored at the Aerial Photography Field Office (APFO) in Salt Lake City, UT. The film archive includes millions of photographs dating back to 1955. Once the film is scanned, the next big step is getting the images orthorectified so they can be used with other aerial imagery and geospatial data. Since Metashape doesn't require a priori information about the images, it is a very effective tool for orthorectifying historical imagery. In the previous exercise, we prepared the images for Metashape by using either ArcMap or ERDAS Imagine and Microsoft Excel. In this exercise, we will go through the steps to create an orthomosaic in Metashape.

Objectives

- Learn the steps of creating an orthomosaic in Metashape

Required Data

- Metashape_scanned_aerial.zip – this is the same data used in part 1 of this exercise and should contain the clipped images and a KMZ file (1979_GCPs.kmz) for reference points.

Prerequisites

- The outputs from the part 1 exercise and the following software applications are needed to complete this exercise: Agisoft Metashape and Google Earth.

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Part 1: Set up Metashape project file

In this section, we will set up the Metashape preferences and project file by loading the images, entering in known information about the camera, and specifying the coordinate system.

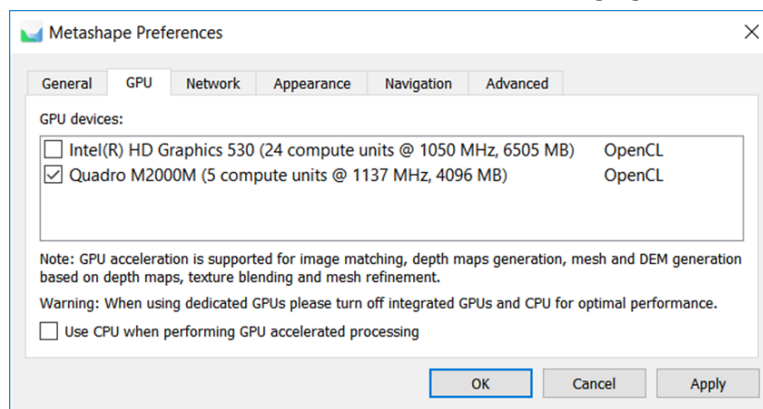
A. Adjusting Preferences

Before we start processing the images, let's make sure that Metashape is set up correctly. If you have a powerful graphics card (GPU), we'll want to enable it within Metashape. We also need to make sure that you are using the same theme as was used to create the graphics in this exercise.

1. Launch Metashape from the **Start** menu (Start, All Programs, Agisoft, and Agisoft Metashape Professional).
2. Open up Metashape Preferences by clicking **Tools** and **Preferences**.
3. With the **General** tab selected, find the dropdown for **Theme** and change it to **Classic** (see following note).

NOTE: We'll be using the Classic theme for these exercises to ensure that we're all using the same interface. However, feel free to check out the Dark and Light themes, but just remember that some of the tool locations and button symbols are different from what are shown in this exercise.

4. Click **GPU** tab. If you only see your integrated GPU device listed (usually Intel...) then place a checkmark next to it and place a checkmark at the bottom next to **Use CPU when...** However, if multiple GPUs are listed, uncheck your integrated (Intel) GPU and place checkmarks next to only your most powerful GPUs, such as NVIDIA Quadro or other series. Also, in this case, leave the **Use CPU when...** box unchecked (see following figure for example). Click **OK**.



5. If needed, restart Metashape to switch to the Classic theme.

B. Load images

1. Launch Agisoft Metashape from the start menu by clicking **Start, All Programs, Agisoft,** and then selecting **Agisoft Metashape Professional**.
2. Add the scanned images by going to the main menu in Metashape and selecting **Workflow** and then **Add Photos**.

- i. Navigate to the **02_clipped_images** folder in your exercise data and select the 22 images in the list and then click **Open**. The photos should now be added to both the Photos pane and the Workspace pane. Alternatively, you can drag and drop the JPEG or TIFF images into the Photos or Workspace panes.
3. View one of the images by double clicking on it in either in the Photos pane or the Workspace pane (click on the arrow next to **Chunk 1** and then **Cameras** to display the list of images).
 - i. Navigate around the image by using your mouse (scroll wheel for zooming and left button for panning).
 - ii. To get back to the 3D model view, click on the **Model** tab at the top of the main viewer or close the image tab by clicking on the "X" in the image tab.

C. Enter camera information and coordinate system

Since these are scanned images, Metashape won't be able to automatically pull in information (image location, focal length, and pixel size) from the images. Nevertheless, Metashape can estimate these values and process the images even without this information. One item that we can add about the camera is the focal length, which is oftentimes printed on the scanned image.

1. In file explorer, navigate to the 01_imagery folder of your exercise data and right-click one of the JPEGs. Select **Open** from the list of options or double left click to preview the image.
2. In the photo viewer, try to find information about the camera focal length (CFL) by using your system mouse to zoom in and pan around the outside border of the image.
3. Once you locate the CFL (see following figure) make note of the value. Usually the focal length is listed in millimeters (mm). Most aerial film cameras used focal lengths between 152.4 to 304.8 mm and so we know that 209.94 would be referring to mm (see following figure).



4. Return to Metashape and go to the main menu and click on **Tools** and then select **Camera Calibration**.
5. In the **Focal length (mm)** field, enter in the focal length found on the image (209.94).

NOTE: Of course, it is good to specify the focal length if the value is known. However, if you can't find any reference for the focal length, you can leave this field empty and Metashape will estimate it for you after aligning the images.

6. Click **OK** to close the camera calibration window.
7. Click on the **Reference** tab (most likely located in the bottom left of Metashape). The Reference pane should now be visible.
8. In the Reference pane, click on the settings button (see following figure and note).



9. In the Reference Settings window, click on the **Coordinate System** dropdown and select **WGS 84 (EPSG::4326)** if available. If it's not, select **More...** and then select WGS 84 from the list of Geographic Coordinate Systems (see following note).

NOTE: Since we will be using Google Earth to obtain the reference coordinates, we will use WGS 84 as the coordinate system. However, Metashape allows the user to specify which coordinate system to use when exporting many of the products (e.g., point clouds and orthomosaics).

10. While we are within the reference settings, let's go ahead and change the marker accuracy to 0.1 meter. This gives a more realistic accuracy value for our Google Earth reference data.
11. Use the default values for the other fields and click **OK**.
12. Save your project file by selecting **File** and then **Save**.
 - i. Navigate to the 03_outputs folder in your exercise data and give your project file a name (e.g., Manti_LaSal_1979) and then hit **Save**. This will save both a PSX file and a .FILE (see following note).

NOTE: Both the PSX and .FILE folder are needed to open a saved Metashape project. You can open it up by double clicking the PSX file in File Explorer. The .FILES folder stores all of the actual products, so it can get quite large. Be sure to keep both the PSX and .FILE folder in the same directory.

Part 2: Process images in Metashape

A. Align the images

1. In the main menu, click on **Workflow** and then select **Align Photos**.
2. In the Align Photos window, click on **Advanced** to expand the options and then specify the following settings:
 - i. Accuracy: **Medium**
 - ii. Generic preselection: **enabled**
 - iii. Reference preselection: **enabled** and **Sequential** selected in the dropdown
 - iv. Key point limit: **40,000**
 - v. Tie point limit: **4,000**
 - vi. Guided image matching and Adaptive camera model fitting: **disabled**
3. Click **OK** to run alignment. This may take a couple of minutes to process (speed will vary depending upon your workstation).
4. Once alignment is complete, go to the **Workspace** pane and verify that all images have correctly aligned. You may need to expand **Chunk 1** and then **Cameras** to find this information. It should show that 22/22 images aligned. If an image didn't align, an **NA** will be next to the image name. Don't worry about NC (not calibrated), seeing that we haven't calibrated the camera yet (see following note).

NOTE: If an image doesn't align, it is likely due to the quality of the image or not enough image overlap. You can sometimes get more images to align by increasing the key point limit and rerunning Align Photos. You may want to try going up as high as 200,000 with the key point limit. You could also try rerunning Align Photos on the high accuracy setting to see if more key points can be matched at the higher resolution. Another option is to manually place tie points, but this can be very time consuming.

B. Build a mesh and non-georeferenced mosaic

This is an optional step when working with your own imagery but can really help with identifying and placing markers when no photo index file is available. The goal here is to create a non-georeferenced mosaic of the scanned images to more easily figure out where the set of images are located geographically. Once located on a reference image, such as within Google Earth or ArcMap, we can use the mosaic and reference image to find good locations for placing control points on individual images. Afterwards, we'll create a completely new orthomosaic that will be georeferenced.

1. In the main menu, click on **Workflow** and then select **Build Mesh**.
2. In the Build Mesh window, click **Advanced** and then specify the following settings:
 - i. Source data: **Sparse cloud**
 - ii. Surface type: **Height field (2.5D)**
 - iii. Face count: **Low**
 - iv. Interpolation: **enabled**
 - v. Calculate vertex colors: **on**
3. Click **OK** to build the mesh. This should just take a few seconds to complete.
4. Return to the main menu and click on **Workflow** and then select **Build Orthomosaic**.
5. In the Build Orthomosaic window specify the following:
 - i. Type: **Planar**
 - ii. Projection plane: **Top XY**
 - iii. Rotation angle: **0**
 - iv. Surface: **Mesh**
 - v. Blending mode: **Mosaic**
 - vi. Refine seamlines, Enable back-face culling, and Setup boundaries: **unchecked**
 - vii. Enable hole filling: **checked**
 - viii. Pixel size: **use default** (see following note)

NOTE: If you are processing hundreds of photos, you may want to reduce the resolution (increase pixel size) to more quickly create the non-georeferenced mosaic. Doubling the pixel size will create a mosaic in about fourth the time and a fourth of the file size. However, the trade-off is that reducing the resolution of the mosaic may make it slightly more difficult to spot good features to use as control points.

- ix. Click **OK** to build the orthomosaic. This should only take a minute or so to complete. Click on the Ortho tab in the main viewer or double click **Orthomosaic** in the Workspace pane to view the orthomosaic.
6. Save your project file.

Part 3: Locate and place markers

In this section, we will use Google Earth for a reference image source and locate features that are visible in both Google Earth and the 1979 imagery. This can be a challenge when working with historical aerial imagery, especially for sites with substantial change. However, the nice thing about Metashape is that we only need to locate a minimum of 3 markers for the entire project area. The Metashape help documentation mentions that 10 to 15 markers are recommended for best results, but for this exercise, we will only be placing 5 markers. Please see **Appendix A: Marker Placement** if you need additional help locating the markers.

A. Locate markers

1. Open the markers in Google Earth by navigating to the exercise material in file explorer and double clicking on `MLS_1979_markers.kmz`. Google Earth should open and automatically navigate to the 5 markers.
2. Before we start using Google Earth let's change a couple settings. Click on **Tools** in the main menu and select **Options**. Change the following settings in the **3D View** tab.
 - i. Show Lat/Long: **Decimal Degrees**
 - ii. Units of Measurement: **Meters, Kilometers**
3. Select **OK** to close the Options window.
4. In Google Earth, locate the markers in the **Places** panel. You may need to expand the `MLS_1979_markers.kmz` to be able to see the 5 points. Take a closer look at each of the points by double-clicking them in the **Places** panel.
5. Zoom out to see all 5 points.
6. These next steps work best if both Google Earth and Metashape can be viewed side by side on your screen, so resize your windows for both applications to be visible (having dual monitors really helps here).
7. While viewing the non-georeferenced mosaic in Metashape, try to locate the same features between Google Earth and Metashape. It may also be helpful to rotate the Google Earth viewer so the imagery is oriented the same direction. You can also use the 1979 image outline in Google Earth to help out.

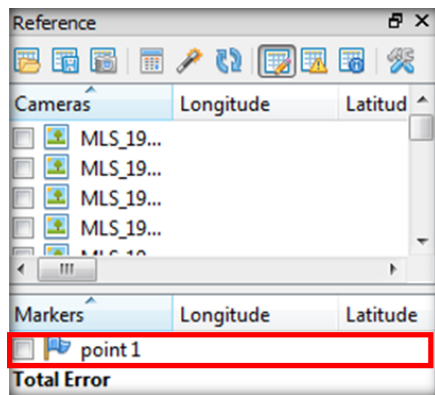
B. Place markers

1. Zoom in on the point 1 location in Google Earth and Metashape. Point 1 is located on the inside edge of a road, halfway through the sharp turn (interestingly enough, the road was cut off by soil erosion sometime between 1979 and present).
2. In Metashape, right click the location of point 1 and select **Open Image** (see note). The image used for that particular spot on the mosaic will open in the main viewer.
3. Relocate the feature again on the individual image, right click where the marker should be placed, and select **Add Marker** (see following note).

NOTE: Click the **Show Marker** button in the main menu if you don't see a flag appear.



- We now need to enter in the coordinates for this point. Click on the **Reference** tab (bottom left) to open up the reference pane and locate **point 1** under Markers (see following figure).



- In Google Earth, right click on point 1 and select **Properties**. You should now be able to see the latitude and longitude coordinates of point 1. With the description tab selected, you should also be able to see the elevation that has been previously entered (see following note).

NOTE: The elevation data is obtained in Google Earth by placing the cursor on top of a point and viewing the information displayed at the bottom of the viewer. An easy way of keeping track of recording these values is by entering them into the description section for each point. If you happen to not see the elevation information, make sure that the Tour Guide bar is collapsed.

- In Metashape, make sure that the View Source button (see following figure) is selecting in the Reference pane.



- Double click in the empty field under the **Longitude** column for point 1 and enter in the longitude value as seen in Google Earth. Do the same, but now for the **Latitude** and **Altitude** fields (see following note).

NOTE: Be careful to not switch up the lat/long values while entering them into Metashape since they are listed in Metashape in the reverse order (long/lat). You can also copy and paste the values (don't include the degree symbol) from Google Earth to avoid typos.

- Metashape automatically places point 1 on each image that it intersects. We now need to fine-tune the placement of point 1 on those images. To filter only images that intersect point 1, go to the Reference pane, right click **point 1**, and select **Filter Photos by Markers**. Now, only images intersecting point 1 are displayed in the Photos pane (see following note).

NOTE: Images with a green flag show that you have already manually placed or adjusted the point on that image. A blue flag means that Metashape has placed a marker, but that you still need to refine the location. And a squiggly grey marker means that a marker might fall on the image, but you need to move it to the correct location.

- In the **Photos** pane, double click the next image with a blue flag (MLS_1979_104) to open it in the viewer. Metashape should automatically navigate to the location of point 1.

- i. While using Google Earth as reference, click on point 1 on the first image in Metashape and drag it to the correct location (see following note and figure). The flag should turn green after you have dropped it.

NOTE: It can oftentimes be very challenging to locate good reference points when working with historical imagery. For this first marker, we used the edge of a road at the center of the turn radius for reference. This is certainly not an ideal feature, but may be the best option for this portion of the model. If possible, try to locate features that haven't moved over time such as boulders, fencing, cattle guards, or buildings.



- ii. Double click on the last filtered image with a blue flag and nudge point 1 to the same position as it was placed on the other two images.
- iii. Cycle back through the three images by double-clicking them one at a time in the Photos pane. Adjust the point a little more if you see any discrepancies from image to image.
10. In Metashape, click on the **Ortho** tab at the top of the main viewer to view the non-georeferenced orthomosaic again for placing the next marker.
11. Repeat steps 1 through 10 for the remaining four markers (see following note).

NOTE: Feel free to use your own reference points if you spot features that work better than the ones provided in the KMZ. To create your own reference points in Google Earth, click on the pushpin button in the main toolbar and then drag the symbol in the main viewer to the desired location. You can save your points to a KMZ file by right clicking on the items in the **Places** panel and selecting **Save Place As...**

12. Review the placement and coordinates of all points. The Marker table in the Reference pane should look like the following figure.

Markers	Longitude	Latitude	Altitude (m)
<input checked="" type="checkbox"/> point 1	-111.565000	39.260747	2161.000000
<input checked="" type="checkbox"/> point 2	-111.543677	39.255153	2277.000000
<input checked="" type="checkbox"/> point 3	-111.559464	39.251544	2248.000000
<input checked="" type="checkbox"/> point 4	-111.534992	39.239597	2598.000000
<input checked="" type="checkbox"/> point 5	-111.541862	39.227162	2924.000000

13. Save your project file before proceeding.

Part 4: Create Final Products

In this section, we will first improve the model by optimizing the camera and then we will create a dense point cloud, mesh, and final orthomosaic.

A. Optimize camera

The goal of this step is to update the image locations to the correct geographic coordinates and to calibrate the images to remove lens and scanning distortions. Since we'll be relying on the control points for this, it is critical that no major mistakes were made while placing the points and entering in coordinates.

1. It is best to proceed with a copy of the original chunk in case if you need to go back and make updates to the original markers. To do this, go to the **Workspace pane**, right click **Chunk 1**, select **Duplicate...**, and then click **OK**.
2. Right click **Chunk 1** again and select **Rename**. Go ahead and rename it **Original**.
3. Right click the **Copy of Chunk 1** and select **Rename**. Rename it **Update and Calibrate**.
4. Make sure the Update and Calibrate chunk is active by double clicking it in the Workspace pane. The active chunk shows up in bold font in the Workspace pane.
5. Go to the **Reference pane** and place a checkmark next to each marker. Click the **Update** button in the toolbar (see following figure and note).



6. In the Reference pane in Metashape, locate the **Error (m)** column for the markers. These values indicate the distance between the coordinates that you entered and the estimated positions of the markers.
7. In the same table, locate the **Error (pix)** column, which tells you the average reprojection error, or how far off the placement of the marker is, in pixels, from one image to the next based on the initial alignment of the images (see following figure).

Markers	Longitude	Latitude	Altitude (m)	Accuracy (m)	Error (m)	Projections	Error (pix)
<input checked="" type="checkbox"/> point 1	-111.565000	39.260747	2161.000000	1.000000	1.195356	3	0.216
<input checked="" type="checkbox"/> point 2	-111.543677	39.255153	2277.000000	1.000000	0.921893	2	0.156
<input checked="" type="checkbox"/> point 3	-111.559464	39.251544	2248.000000	1.000000	1.144583	3	0.242
<input checked="" type="checkbox"/> point 4	-111.534992	39.239597	2598.000000	1.000000	0.333093	2	0.195
<input checked="" type="checkbox"/> point 5	-111.541862	39.227162	2924.000000	1.000000	0.627603	3	0.288
Total Error					0.904839		0.230
Control points							

8. Click the **Optimize Camera** button in the Reference toolbar (see following figure).



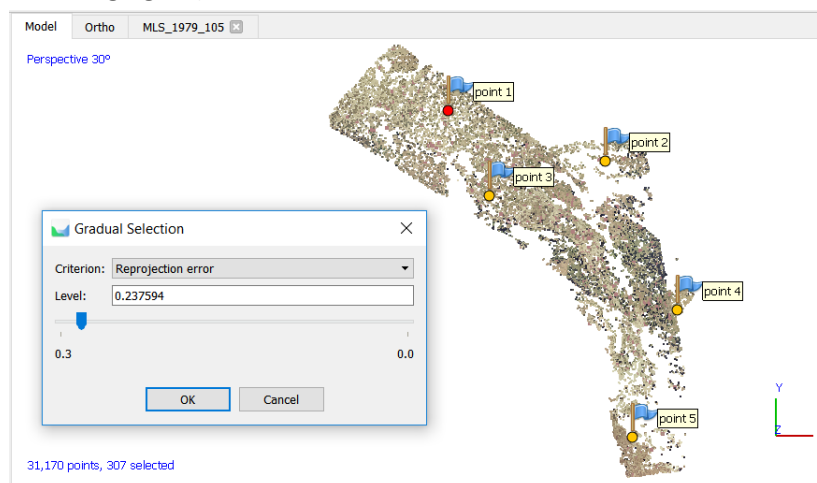
9. In the Optimize Camera Alignment window, place checkmarks in the following boxes:
 - i. Fit f (this is the parameter for the focal length)
 - ii. Fit cx, cy (these are the parameters for the principal point offset)
 - iii. Fit k1, k2, and k3 (these are the radial distortion coefficients)
 - iv. Fit p1 and p2 (these are the tangential distortion coefficients)
10. Click **OK** to optimize camera alignment.

11. Review the Error columns for the markers again and note how the accuracy should have improved since the camera optimization was based on your markers.
12. In the main viewer, make sure that the **Model** tab is selected and click the Point Cloud button to display the tie points (see following figure and note).



NOTE: After optimizing the cameras, it is good to rotate the sparse point cloud (tie points) around to make sure that no points are shooting off above or below the model. If you do see this happening, there is likely a major error with the placement of your markers. If this occurs, it is best to delete the copied chunk and go back to your original chunk to figure what's causing the issue.

13. Click on **Model** in the main menu and select **Gradual Selection**.
14. Select **Reprojection error** and then move the slider to the right until about 1-2% of your total points are selected (around 300-600 points for this exercise). Use the total and selected point counts in the lower left corner of the main viewer to calculate when about 1-2% have been selected. Also, the selected points will turn a subtle red in the sparse point cloud (see following figure).



15. Click **OK** to close the Gradual Selection window.
16. Hit the Delete button on your keyboard to remove the selected tie points.
17. Click on the Optimize Camera Alignment tool again and rerun it using the same parameters used previously (see following note).

NOTE: In some cases, you'll want to run the Gradual Selection and Optimize Camera steps multiple times to filter out bad tie points and improve the model. With each run, the reprojection error should progressively get lower. Usually, only run this a handful of times to not remove too many tie points. Getting the level below 0.3 pixels is the goal, but for some datasets, a level of 1 might be all that is possible. For more details about camera optimization, please see the **BLM_optimize_workflow.pdf** found in the exercise data.

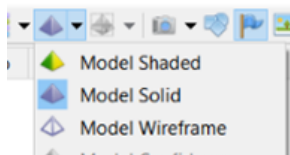
B. Build dense point cloud and mesh

1. In the main menu, click on **Workflow** and then select **Build dense cloud**. Expand the advanced section and then use the following settings:

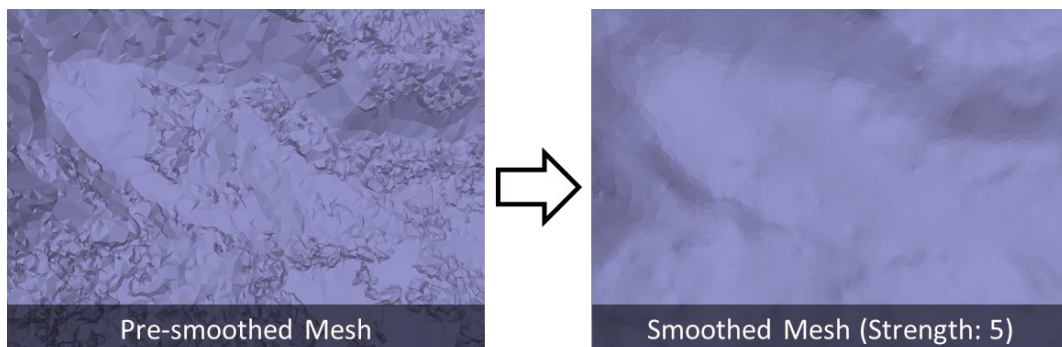
- i. Quality: **Medium** (*usually medium is about right for scanned images; if set above this, bad points and holes in the dataset may appear due to limitations of the scanned images*)
- ii. Depth filtering: **Mild** (*this may help to get rid of a few outliers, but not remove too much detail*)
- iii. Calculate point colors: **on**
- iv. Calculate point confidence: **off** (*this can be used for filtering out potentially inaccurate points from the dense point cloud, but will be left off for this exercise*)
2. Click **OK** to build the dense point cloud (this may take a couple minutes to complete).
3. Review the dense point cloud by clicking on the Dense Cloud button (see following figure) while viewing the model.



4. Build a mesh by clicking on **Workflow** and then selecting **Build Mesh**. Expand the advanced section and then use the following settings:
 - i. Source data: **Dense cloud**
 - ii. Surface type: **Height field** (*this is recommended for aerial imagery*)
 - iii. Face count: **Low** (*using a detailed mesh for creating the orthomosaic can result in smearing artifacts in the orthomosaic and so we will use the low face count setting here*)
 - iv. Interpolation: **Enabled**
 - v. Point Classes: **All**
 - vi. Calculate vertex colors: **On**
5. Click **OK** to build the mesh. This should only take a few seconds.
6. Review the mesh by clicking on the shaded, solid, or wire mesh buttons (see following figure).



7. The mesh is still a little more detailed than what is needed and so we will smooth it out by going to the main menu and clicking on **Tools, Mesh**, and then selecting **Smooth Mesh**.
8. Change the Strength to 5 and hit **OK**. The following figure shows the before/after results.

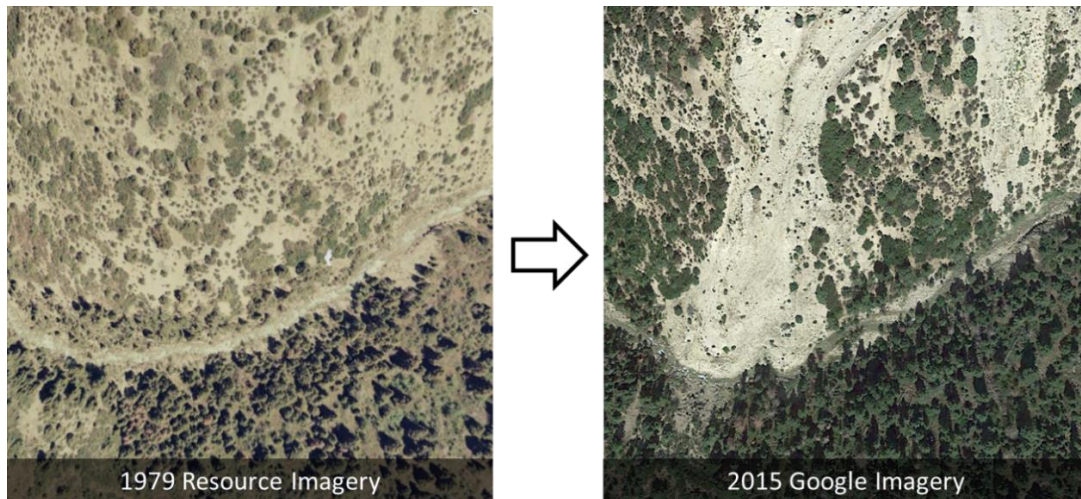


C. Build and Export Orthomosaic

1. In the main menu, click on **Workflow** and then select **Build Orthomosaic**. Specify the following settings:
 - i. Projection: **Geographic - WGS 84** (we are using WGS 84 here since we will be exporting the orthomosaic for viewing in Google Earth; however, a local projection could also be specified here if you plan to use in ArcMap or with other GIS data)
 - ii. Surface: **Mesh**
 - iii. Blending mode: **Mosaic**
 - iv. Enable hole filling: **on**
 - v. Refine seamlines and Enable back-face culling: **off**
 - vi. Pixel size: **leave default values** (by default, it creates the highest resolution orthomosaic as possible; since we are using WGS 84, it is displayed in degrees, but you can click on the Meters button to see the meter equivalent (should be around 0.25 meters))
 - vii. Region: off (this is useful if you only want to export an orthomosaic for a portion of the model).
2. Click on **OK** to start building the orthomosaic. This may take a couple of minutes to complete.
3. To view the orthomosaic, go to the Workspace pane (bottom left of screen) and double click on **Orthomosaic** that is within the **Update and Calibrate** chunk (expand chunk if necessary). In the main viewer, you can zoom and pan around the 2D image using your system mouse.
4. Export the orthomosaic by right-clicking on it in the Workspace pane and selecting **Export Orthomosaic** and then **Export Google KMZ** (see following note).

NOTE: You could also export the orthomosaic as a TIFF image if you would like to load it into other software application such as ArcMap or ERDAS. Other products that could be exported too are the 3D model, mesh, and point clouds.

5. Leave the default values and click the **Export** button.
6. Navigate to the **03_outputs** folder of the exercise folder, give the file a name (e.g., MLS_1979_orthomosaic) and then click on **Save**. This should only take a minute to create.
7. Save your final Metashape project file.
8. In file explorer, navigate to the newly created orthomosaic and double click the KMZ to open in Google Earth.
9. Compare your orthomosaic with the imagery available in Google Earth by turning it on/off in the Places Panel. Has much changed in this area since 1979? See if you can locate, in Google Earth, where the landslide in the following figure occurred. Do you see any other areas where landslides or other changes have occurred since 1979?



Congratulations! You have successfully completed this exercise by orthorectifying the scanned aerial imagery from 1979. In this exercise, you learned how to set up the project file, align the scanned images, find and place markers, build a mesh, and create the final orthomosaic. In this exercise, the historical imagery allowed us to get a glimpse of the landscape in 1979, prior to some of the more recent landslide events. By orthorectifying the imagery, we were able to do a direct comparison with recent imagery and more accurately locate sites of change. This is only one of the many applications for historical imagery and Metashape.

Appendix A

It can be challenging to georeference historical imagery to newer aerial imagery, especially for landscapes where major change has occurred. The following images may be useful for making sure that you are placing the markers on the correct features in the 1979 imagery.

