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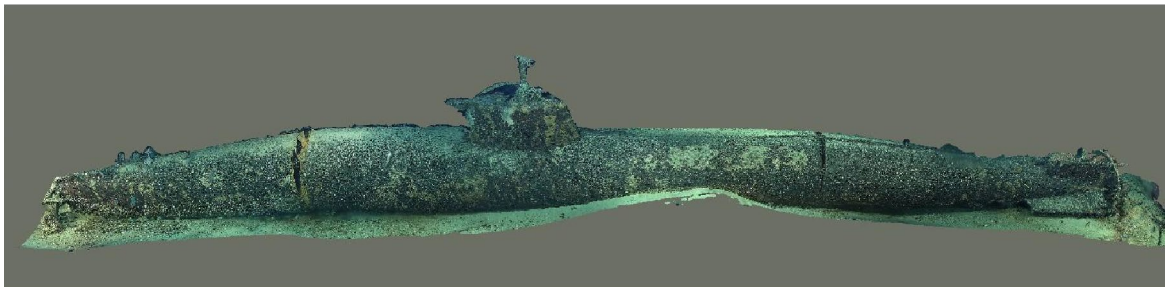
Photogrammetry Recommendations

Raymond Phipps[1], Phil Hartmeyer[2 3], Frank Cantelas[2]



Above: An Imperial Japanese Navy submarine Ko-hyoteki-class two-man submarine sunk by the USS *Ward* discovered by the Hawaii Undersea Research Laboratory in August 2002. Photomodel by Raymond Phipps.

U.S. Department of Commerce
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NOAA Ocean Exploration

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Executive Summary

What is photogrammetry?

Photogrammetry is a method of creating a three-dimensional (3D) model of an object(s) using two-dimensional images. Using software, such as Agisoft Metashape, these images are aligned in such a way that commonalities between the photos are identified and tied together. This allows the software to create meshes and textures for the model so that an accurate product of the object(s) can be made.

How is it collected?

There are a variety of ways to collect images for a photogrammetric model, to include cameras, drone footage, or ROV footage. To do this, a pre-planned route or flight path is established that will encircle the object(s) to provide as many different camera angles as possible, ensuring that the images overlap. This will allow for the most accurate model during post-processing. Once a series of images are taken of the desired object(s), the images or footage will be processed using photogrammetry software.

Where can it be applied?

Photogrammetry can be applied in a multitude of ways. In underwater archaeology, time on a site is limited. Creating a photogrammetric model of the site will allow archaeologists to further study the site and pose questions for future expeditions on that site. Photogrammetry is applicable for studying underwater geological features and comparing past and present models of the same geological feature to note changes. In marine biology, photogrammetry can be used to do comparative studies of coral species and to better understand benthic ecosystems of our oceans.

Intended audience

The intended audience of this document is NOAA Ocean Exploration staff and partners including marine archaeologists, remotely operated vehicle pilots, operations staff and expedition coordinators who seek to incorporate photogrammetric modeling as a cruise package deliverable. This paper will initially be shared internally with future plans to be submitted to the NOAA Central Library as a technical report after cross-divisional review. Note, the workflows presented focus on the industry-standard Agisoft Metashape photo modeling

software, and other softwares that may need NOAA IT approval before installation or incorporation onto a NOAA machine.

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Table of Contents

Executive Summary 1

What is photogrammetry? 1

How is it collected? 1

Where can it be applied? 2

Intended Audience 2

Table of Contents 3

Definitions 5

Related Documents 6

ROV Data Acquisition 6

Survey for Hazards 6

Turn Off Lasers 6

Do Not Zoom 6

ROV Positioning During Data Acquisition 7

Ship Moves 7

Navigation Waypoints 7

Model Processing Workflow 7

Data Management 7

ROV Download and Image Processing 10

Creating a Project 19

Adding Photos and Alignment 22

Aligning to a Grid 26

Removing Distortion 27

Creating a Mesh 31

Giving the Model Texture 32

Finished Products 35

Orthomosaic Creation 36

Animation Creation 37

Image Creation 42
Exporting Finished Models 42
Photogrammetry Snapshots 43
Model Metadata Information 44
UCH Site Summary 45
Basic Information 45
Dimensions 45
Model Information 45
Miscellaneous 46
Processed Models 46
Hardware and Software Recommendations 46
Agisoft Metashape Pro Edition vs Standard Edition 46
System Configuration Recommendations 49
Inhouse Photogrammetry Processing Purchase Recommendations 49
Software 49
Storage 50
Computing 50
Next Steps 51
Appendices 52
Appendix A: ROV Dive Planning for Photogrammetry Data Collection 52

Definitions

Term	Definition
Underwater Cultural Heritage (UCH)	Per the UNESCO 2001 Convention, UCH is defined as all traces of human existence of a cultural, historical, or archaeological nature which have been partially or totally immersed, periodically or permanently, under the oceans and in lakes and rivers[4]. This is synonymous with the NOAA Ocean Exploration definition of maritime heritage.
Agisoft Metashape	Agisoft Metashape is a stand-alone software product that performs photogrammetric processing of digital images and generates 3D spatial data to be used in GIS applications, cultural heritage documentation, and visual effects production as well as for indirect measurements of objects of various scales.[5] While the workflows in this document are specific to the Agisoft Metashape software package, they may inform other photogrammetric modeling software.
Mesh	When images are aligned, a point cloud is created that stores locations of the points. When creating a mesh, these points are converted into triangles, while still retaining the locations of the points, but are easier to work with.
Photo-Model	The product of the photogrammetric process, a three dimensional (3D) model of an object(s).
Orthomosaic	A photogrammetrically orthorectified set of images that have been aligned to create a seamless mosaic.
Frames Per Second (FPS)	Used to measure frame rate or the number of images consecutively displaced each second. This is important for picking out stills from footage.
Graphics Processing Unit (GPU)	An electronic circuit designed to accelerate computer graphics, and process multiple datasets simultaneously.

[4] https://en.unesco.org/underwater-heritage/2001

[5] https://www.agisoft.com/

Central Processing Unit (CPU)	The control center of a computer, the main processor that runs the computer's operating systems and applications.
Chunk	Chunk is a term used by Agisoft and is where photos are uploaded in
	Agisoft Metashape. These can be renamed to reflect the model within the chunk. If sections of an object are being modeled in multiple chunks, they can be merged using the "merge chunk" function.
Codec	A program that compresses data to enable faster transmission and decompresses received data. For the purposes of this document, the data is video files.

Related Documents

NOAA Ocean Exploration ROV Manual Appendix D. Photogrammetry: Structure From Motion (in-press)

ROV Data Acquisition

The purpose of this section is to outline the best practices for ROV data acquisition for photogrammetry. The topics that are listed and described below will help optimize the creation of photo models from the gathered ROV data.

Survey for Hazards

Before collecting data for photogrammetry, a survey of the site should be conducted to identify any hazards that may impact the ROV in any way. If hazards are identified, be sure to adjust the pre-planned flight path accordingly.

Turn Off Lasers

The scale lasers can create unwanted red dots on the end product. Be sure to turn these off prior to starting the photogrammetric flight path. Prior to turning these off, attempt to take photos of distinctive sections of the UCH site with the lasers on. Try to have one of the lasers at the end of the object on the site and the other going lengthwise of it. If this could be done to at least 3 objects on the UCH site it would help in scaling the photo model during the

post-processing phase. (NOTE: Be sure that the objects being measure are in the footage for the
ROV flight path)

Do Not Zoom

During the photogrammetric flight path, avoid zooming as these segments can cause distortion and stretching in the final product.

ROV Positioning During Data Acquisition

Maintain elevation in the water column as much as possible, this will help maintain a consistent shot of the object(s) being documented and ensure that the proper amount of overlap during post-processing of the data. Be aware of possible vertical reliefs from UCH, geological, or coral sites. Pre-planning should cover these possibilities and provide a series of plans to navigate them.

Ship Moves

During ship moves, maintain ROV position as much as possible in order to continue along the pre-planned flight path. Avoid zooming and any camera moves while in this position. If the ROV needs to move, attempt to return to the previous location if possible.

Navigation Waypoints

The archaeology lead and the ROV pilot should coordinate on where to drop waypoints to mark features and to take diagnostic measurements (e.g., length and width of the wreck)

Model Processing Workflow

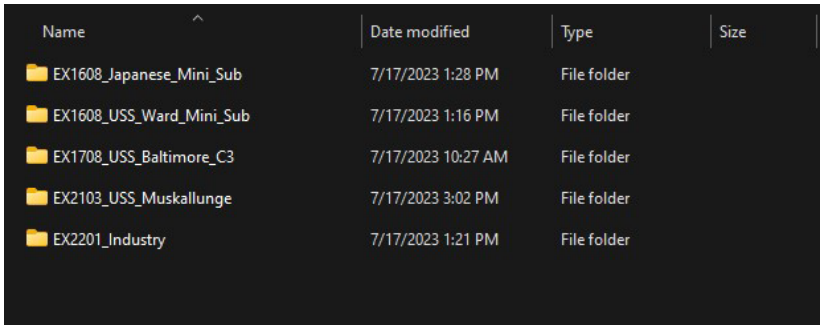
The following section outlines a step-by-step workflow for processing ROV footage of sites for photogrammetry. The workflow presented is based off of Kōtarō Yamafune's Agisoft Metashape workflow[6]. It will take the user through setting up specific folders for ease of access during the process, to downloading the footage and making it usable for Agisoft Metashape. From there each step in processing a photo model will be described in detail.

[6] Kōtarō Yamafune, *University of South Carolina Photogrammetry Workshop*, Columbia, South Carolina (25 May - 3 April 2022. Yamafune is an expert in photogrammetry and the photography of terrestrial and underwater archaeological sites. The workflow that has been used for this document is based on his recommendations from this workshop. Courtesy of Alyssa Saldivar, an East Carolina University graduate student, who was able to attend the workshop and provide detailed notes on Yamafune's workflow.

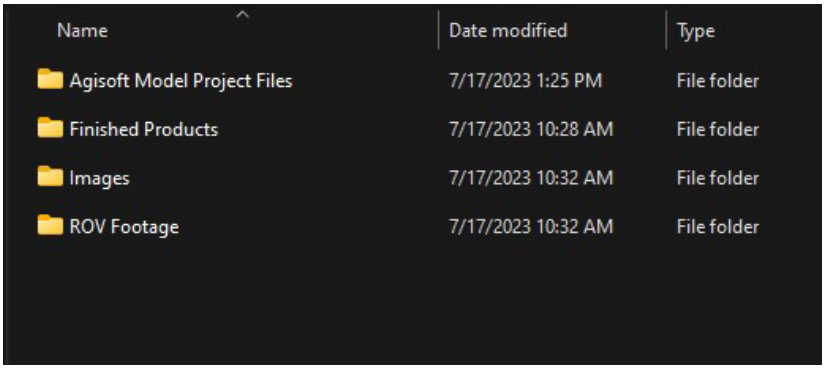
Data Management

All data should be stored on the marine archaeology Synology NAS Drive :/A and connected to the processing machine via a CAT5 ethernet cable. Once the following steps are created, run Free File Sync (or other data synchronization software) to duplicate all created folders on Synology NAS Drive :/B. This is called 'Mirror Synchronization' in Free File Sync and a walkthrough is available here. This data management strategy allows the processor to routinely backup the working files on NAS Drive :/A throughout processing. Once a model is complete, the model folder will be copied onto the :/R drive through VPN or when the processor is local to the office. Everything in the finished products folder will be copied to the NOAA Ocean Exploration Photogrammetry Google Drive folder.

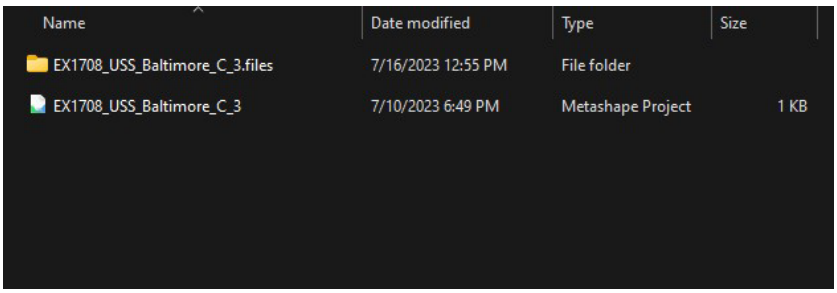
- Create a folder and include the expedition number and site name. It should look like the following: "EX1234_Site_Name"



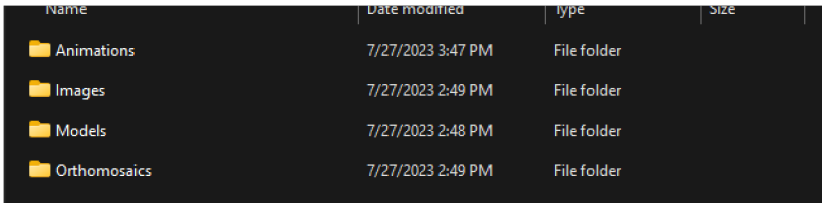
- In this main site folder create 4 new sub-folders and name them the following: "Agisoft Model Project Files", "Finished Products", "Images", and "ROV Footage".



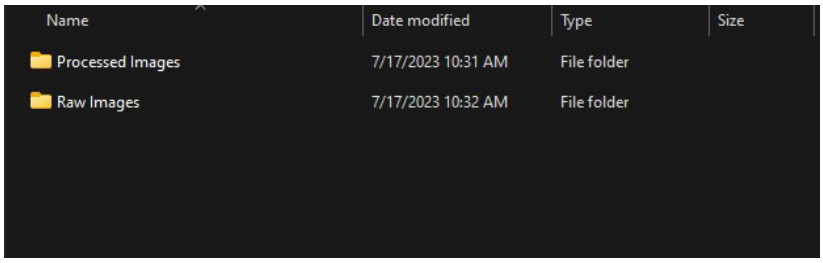
  - The "Agisoft Model Project Files folder" is where the Agisoft model and project will be saved.
    - The model and project should be saved as "EX1234_Site_Name"



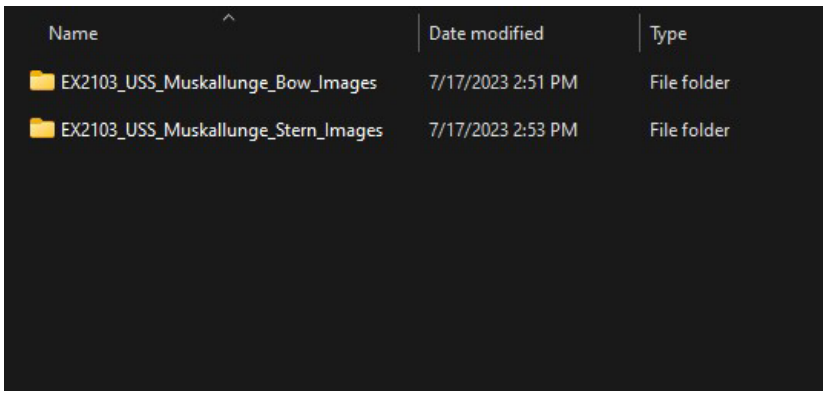
- All images, 3D printing files, PDFs, and final export products that will be used or shared should be housed in the “Finished Products” folder. Create four sub-folders, titled “Animations,” “Images,” “Models,” and “Orthomosaics.”



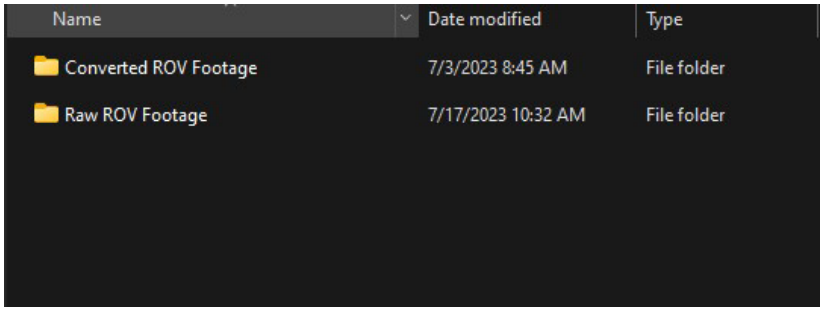
- In the “Images'' folder create two sub-folders titled “Processed Images” and “Raw Images.” Processed images refers to any raw images that have been exported out of Photoshop or other image-editing software for color correction, edits, or manipulation in any way by the model processor. Raw images are the images directly pulled from the ROV footage.



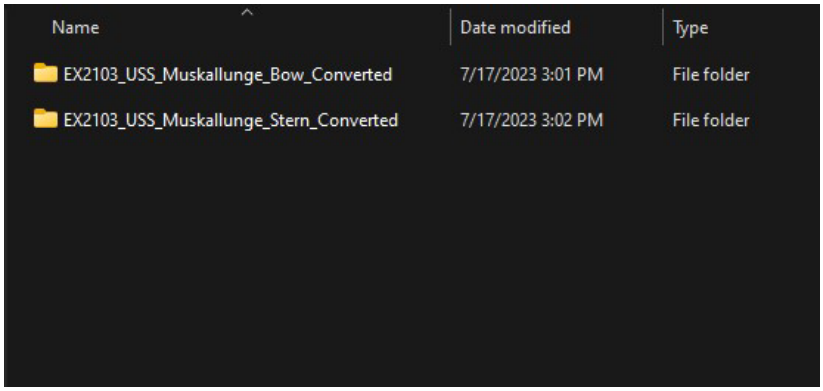
  - It may be necessary to create additional sub-folders under “Processed Images” and “Raw Images.” In some cases, ROV-collected imagery on a UCH site could be broken into multiple, disconnected sections.. The sub-folders would need to be named accordingly, for example “EX####_Site_Name_Bow_Images” and “EX####_Site_Name_Stern_Images.”



- In the “ROV Footage” folder create two sub-folders titled “Converted ROV Footage” and “Raw ROV Footage.” Upon initial download, the ROV footage will be moved from the local C:/Downloads folder to the “Raw ROV Footage” folder, and after conversion to an .mp4 file, those exported video files will be stored in the “Converted ROV Footage” folder.



  - It may be necessary to create additional sub-folders under “Converted ROV Footage” and “Raw ROV Footage.” In some cases, ROV-collected imagery on an UCH site could be broken into multiple, disconnected sections. The sub-folders would need to be named accordingly, for example “EX####_Site_Name_Bow” and “EX####_Site_Name_Stern.”



- Create a site sub-folder in the S&T Google Drive_Teams_SynergisticOceanExploration_MarineArchaeology_Photogrammetry_Models to copy all finished products from the :/A NAS drive

ROV Download and Image Processing

Before beginning model post processing, it is helpful to watch the entire dive. Video from Okeanos Explorer dives can be found on the Ocean Network Canada's Sea Tube website[7] and on the FTP site[8] maintained by the Global Foundation for Ocean Exploration (GFOE). These sites are accessible with a Collaboration Tools Account[9]. Sea Tube video is best for reviewing an entire dive and offers the opportunity to listen to dialog between the ROV pilots and the science team to understand how video was collected for modeling. Sea Tube video is continuous coverage of the entire dive.

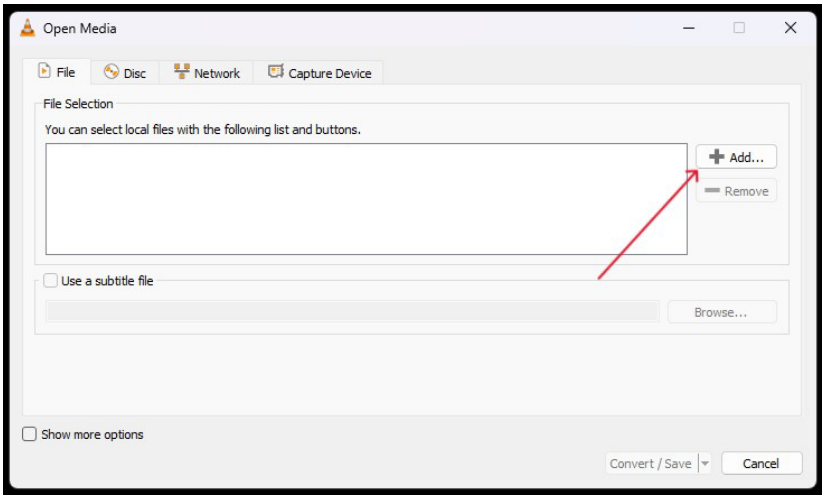
After reviewing in Sea Tube, video for modeling should be downloaded from the GFOE FTP site where it is available in full resolution and compressed format in five minute segments. If high resolution video is not available from the GFOE FTP site, or the dive occurred before 2015 and cruise information is not present on the GFOE FTP site, email oer.video@noaa.gov with the cruise and dive number requested. If cruise or dive number is unknown contact the NOAA Ocean Exploration marine archaeologist.

- Download ROV footage from https://exdata.tgfoe.org/OkeanosCruises/ ○ Identify the segments of ROV footage that are needed (NOTE: they are in 5-minute increments) for the model.
    - The downloads will be a .tar file. From the download folder on the computer, cut and paste the .tar file to the “Raw ROV Footage” folder created for the project.
- To use the ROV footage, it needs to be converted to a .mp4 file. To do this, VLC Media Player is the recommended application or an application equivalent to this. VLC Media Player is NOAA approved and can be installed on NOAA machines by calling NSDesk
    - Open VLC and select “Media” -> “Convert/Save”

[7] https://data.oceannetworks.ca/ExpeditionManagement

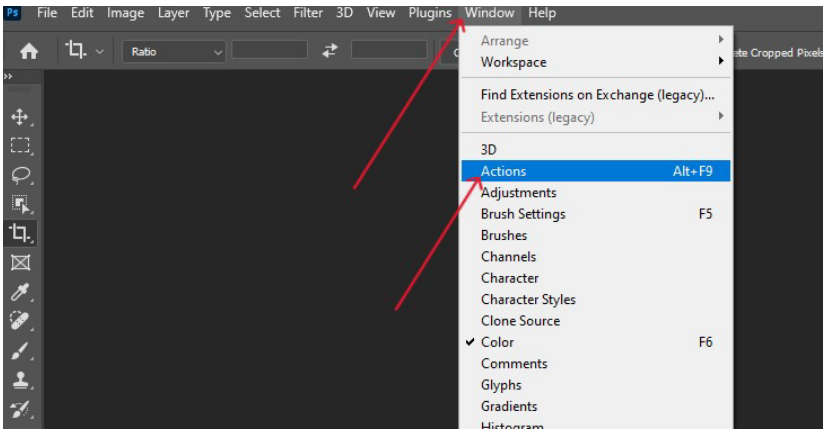
[8] https://exdata.tgfoe.org/OkeanosCruises/

[9] For information on accessing these data and to request a Collaboration Tools account visit https://oceanexplorer.noaa.gov/okeanos/collaboration-tools/science_annotations/welcome.html



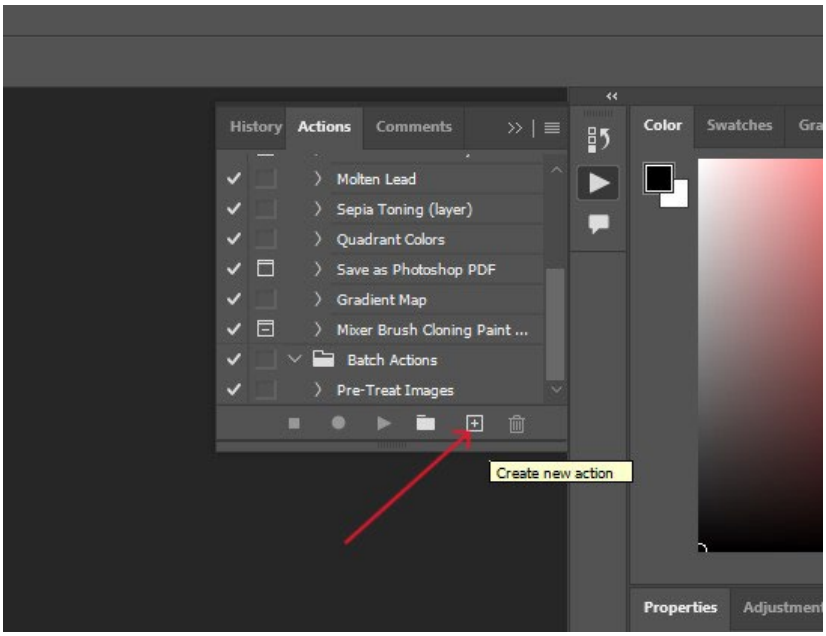
- This will open a “File Selection” menu. The “+ Add…” can be selected to choose the ROV .tar files. When the folder opens, change the file type to “All Files” to view the .tar files.
  - Once the desired file(s) are added, select the “Convert/Save” button at the lower right of the menu.
  - The “Convert Menu” will open. Here make sure under settings that “Convert” is selected. There is no need to select “Display the output”, or “Deinterlace”. Under “Profile” select “Video – H.264 + MP3 (MP4)”
  - For the “Destination File” select the “Converted ROV Footage” folder that was created for this project and press “Start.”
  - A menu may pop up, click “Overwrite” and the conversion process will initiate.

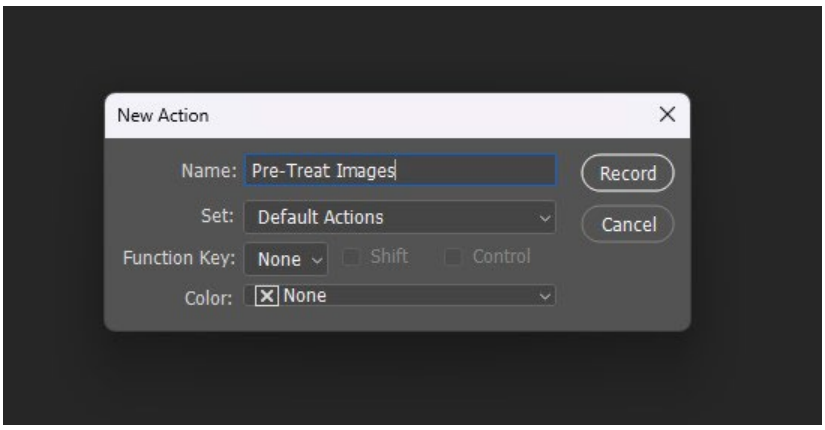
- The converted .mp4 file can now be loaded into Agisoft Metashape to render stills from the footage, but another option to do this is in Adobe Photoshop or another photo editing software like Adobe Bridge. This will allow for any color corrections that are needed. (NOTE: Color corrections are usually needed to remove unwanted color from underwater footage, typically caused by the water itself. For example, some footage might have a green, yellow, or even blue tint caused by the water. Color correction can be applied to an entire batch of photos using the same adjustments.)
  - To do this in photoshop, open up the application and click on the “Window” tab and select “Action.”



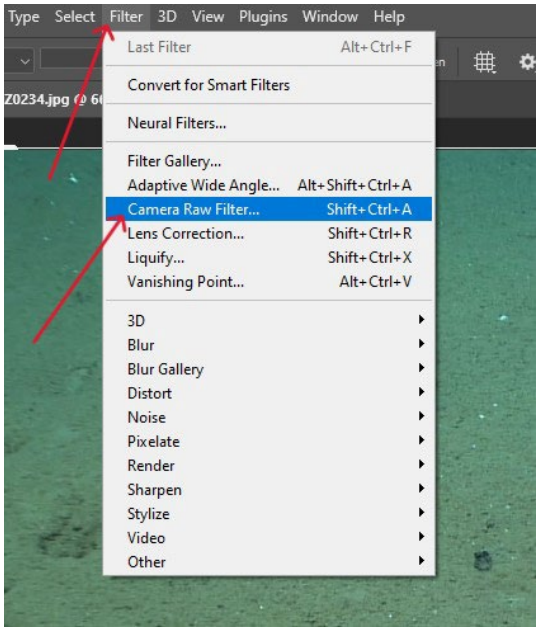
○ The “Actions” palette will appear. Select the folder icon at the bottom right of the palette and name the new set folder “Batch Actions.”

○ On the same palette, next to the folder icon is the “Create New Action” icon. Select that and name the new action “Pre-treat Images.” Be sure to change “Set” to “Batch Actions.” This action is now recording, as indicated by the red circle on the palette. Any editing within photoshop while this action is recording will be saved within the “Pre-treat Images” action.

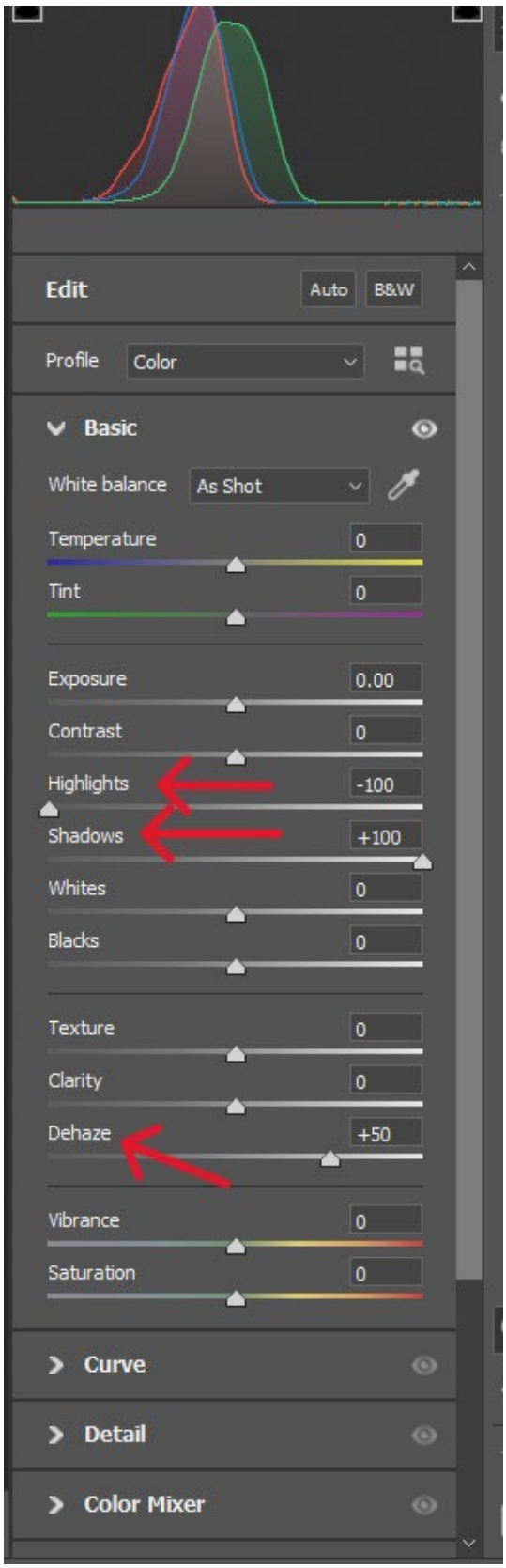




- To start, first load a single image from the “Raw Image” folder under the project folder. Once uploaded, go to the “Filter” tab and select “Camera Raw Filter…”

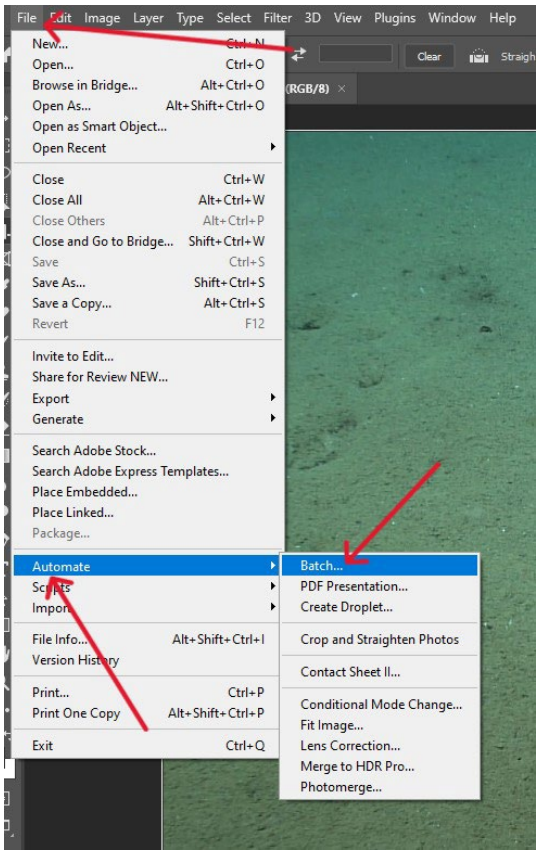


- The image will open in a new window with a color editing window on the right-hand side. Here adjustments will be made and recorded to be used for the “Pre-treat images” action. Under the “Basic” tab, set the following parameters: Highlights (-100), Shadows (+100), and Dehaze (+50). Everything else should remain the same. Adjusting these settings will provide the images with more defined edges of the site.



○ Once these adjustments have been made, go back to the action palette and stop recording. Exit out of the raw image filter and do not save. In the next step, the

action that was created will be implemented on the images in the “Raw Image” folder. To do this, select the “File” tab, hover over “Automate” and select “Batch” from that drop down menu.

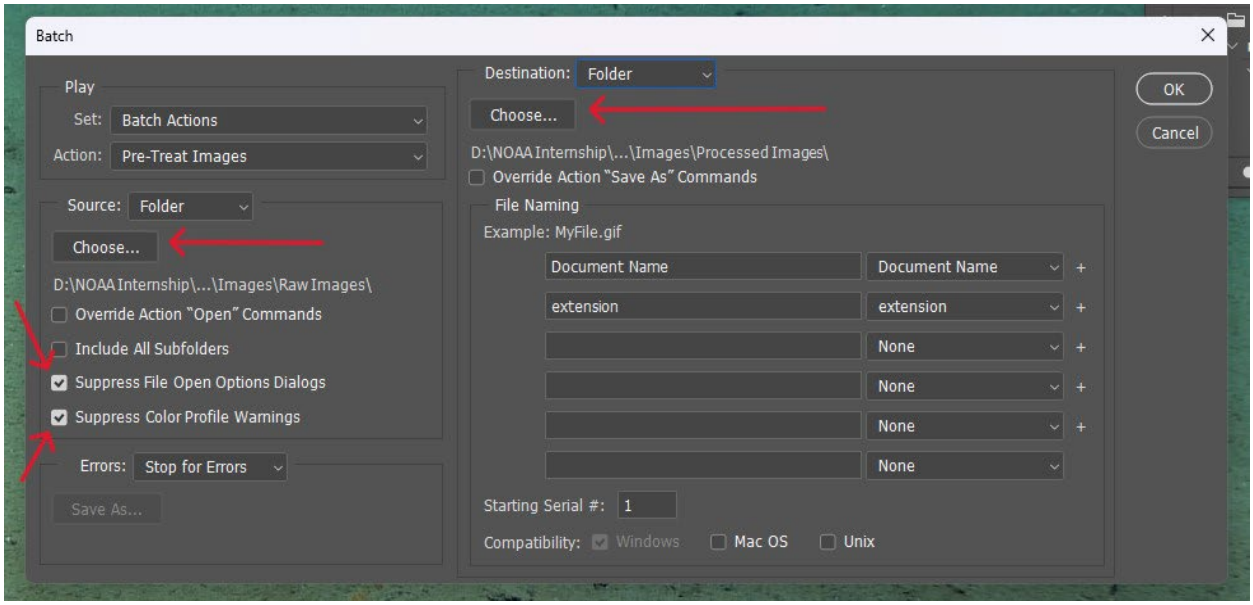


○ The “Batch” window will open. Under “Play” under “Set” select “Batch Actions" and for “Action” select “Pre-Treat Images.”

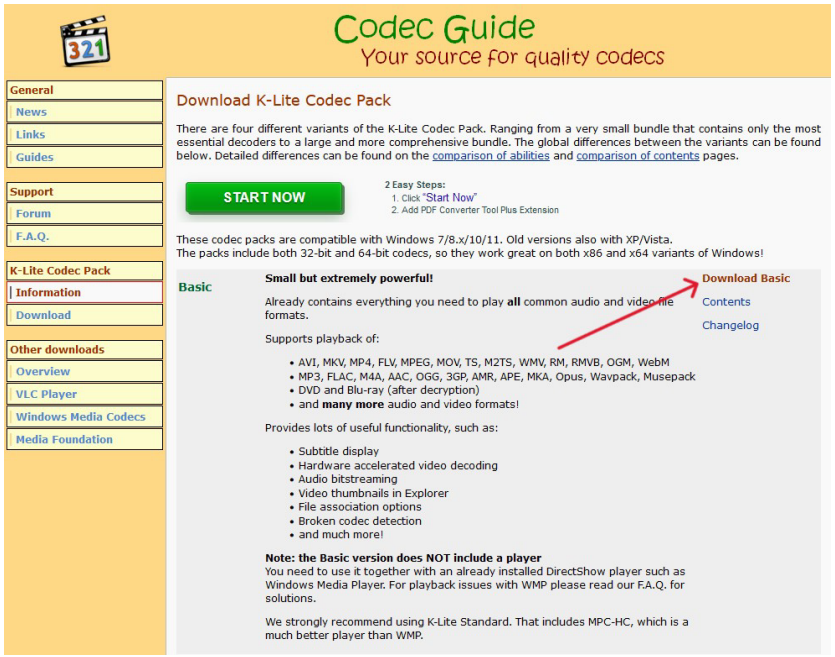
■ For “Source” ensure that “Folder” is selected and choose the “Raw Image” folder for the project that is being worked on.

■ There are four options to select below this. Only select “Suppress File Open Options Dialogs” and “Suppress Color Profile Warnings.” ■ Under “Destination” ensure that “Folder” is selected and choose the “Processed Image” folder for the project that is being worked on.

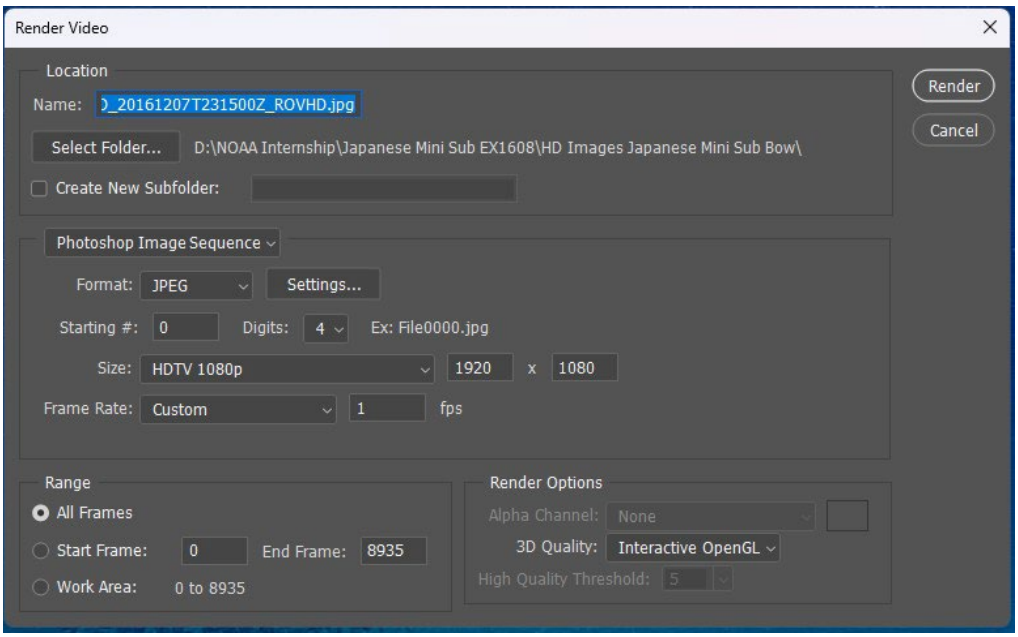
■ From here select “Ok” and the images will be processed.



- To use Agisoft Metashape, the proper codec is needed
    - K-Lite_Codec_Pack_1687_Basic needs to be downloaded. To do this simply search for the 'K-Lite Codec Pack' and download the basic codex.
        - This codec is a collection of audio and video codecs for Microsoft Windows DirectShow that allows the user's operating system and its software to play audio and video formats generally not supported by the operating system itself.



- Once downloaded, open Agisoft Metashape and select “File” -> “Import” -> “Import Video”
- A pop-up will open and will prompt you to select the Frames Per Second. For regular footage (footage that is taken by hand, such as underwater footage taken by a diver) “15” is optimal, for drone footage “5” is optimal, and for ROV footage “3” is optimal.
- Finally, these extracted images need to be sent to the “Raw Image” folder created for this project. t too ○ For Photoshop do the following:
- First, open Photoshop. Once open, either drag the .mp4 file(s) over or open them using “File” -> “Open”
- Once .mp4 file(s) are uploaded, select the file and then under “File” select “Export” -> “Render
- Select the “Raw Image” folder for this project and select it for the images to be sent too.
- The “Render Video” menu will open. Here, select the “Extracted Images” folder just created where the photos will be sent.



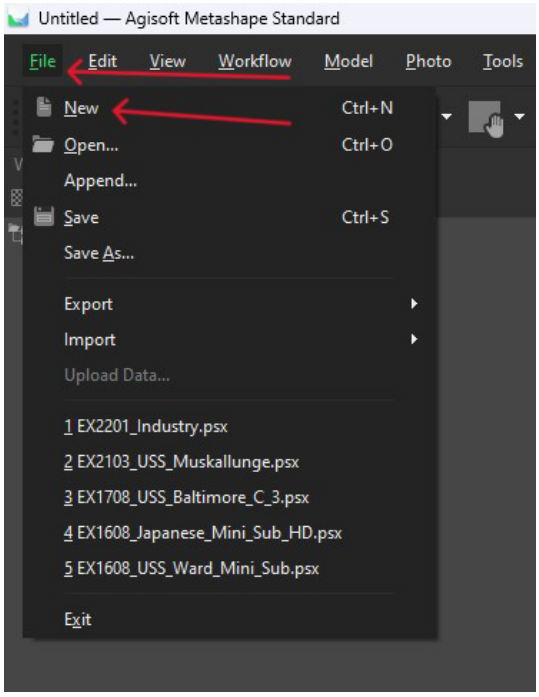
- For "Format" select "JPEG" and for document size select "1920 x 1080"
- "Frame rate" can be customized for ROV footage. Set the fps from 1-3, based on the speed of the footage.
- For the "Range" select "All Frames" (this can be customized if the beginning and ending frames desired are known).
- "Render Options" select "Interactive OpenGL"
- Once these are selected, click "Render" in the top right corner. The photos will be sent to the designated folder

- The next step is to go through the individual photos from the ROV footage. Duplicate photos from the same section of the site, anything that shows the frame or parts of the ROV, and zoom segments. Delete these as they are not wanted for the models. If some of these images make it into Agisoft during the modeling process, they can be individually deleted in Agisoft later on.

Creating a Project

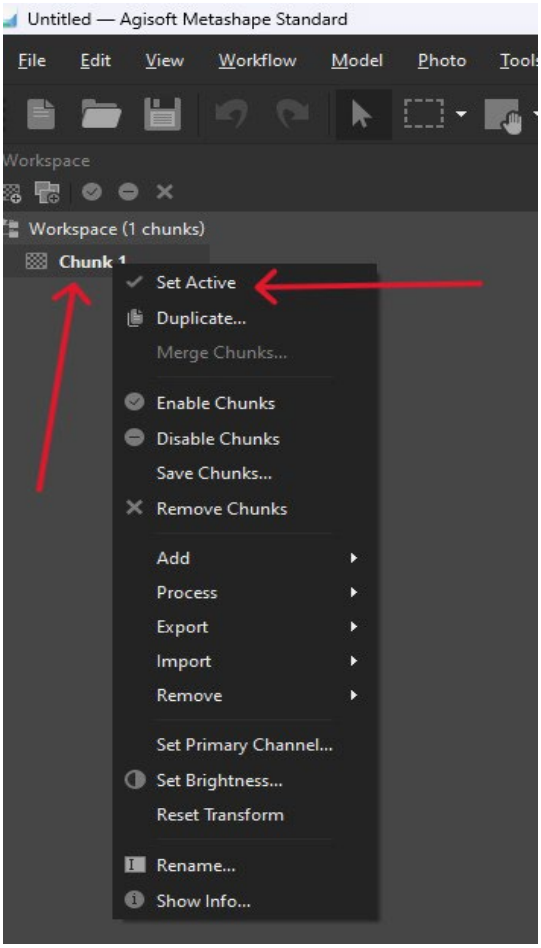
In this section, Agisoft Metashape will be opened and instructions on how to create a project will be given.

- Open up Agisoft Metashap and under "File" select "New."



- Once a new project is created, be sure to save it using “Save as.” Remember to name the project with the expedition number and the site name “EX1234_Site_Name.” Also, be sure to save frequently throughout this process.
- With Agisoft Metashape open, on the left hand side of the screen there is a “Workspace.” Within this workspace are sections referred to as a “chunk.” This is where the user will be working primarily. The processed ROV images will be uploaded here and subsequently be used to create a photo model. There can be multiple chunks added to a project workspace and can be renamed to reflect what is in the chunk. To add a new chunk, right click on the workspace and select “Add Chunk.”

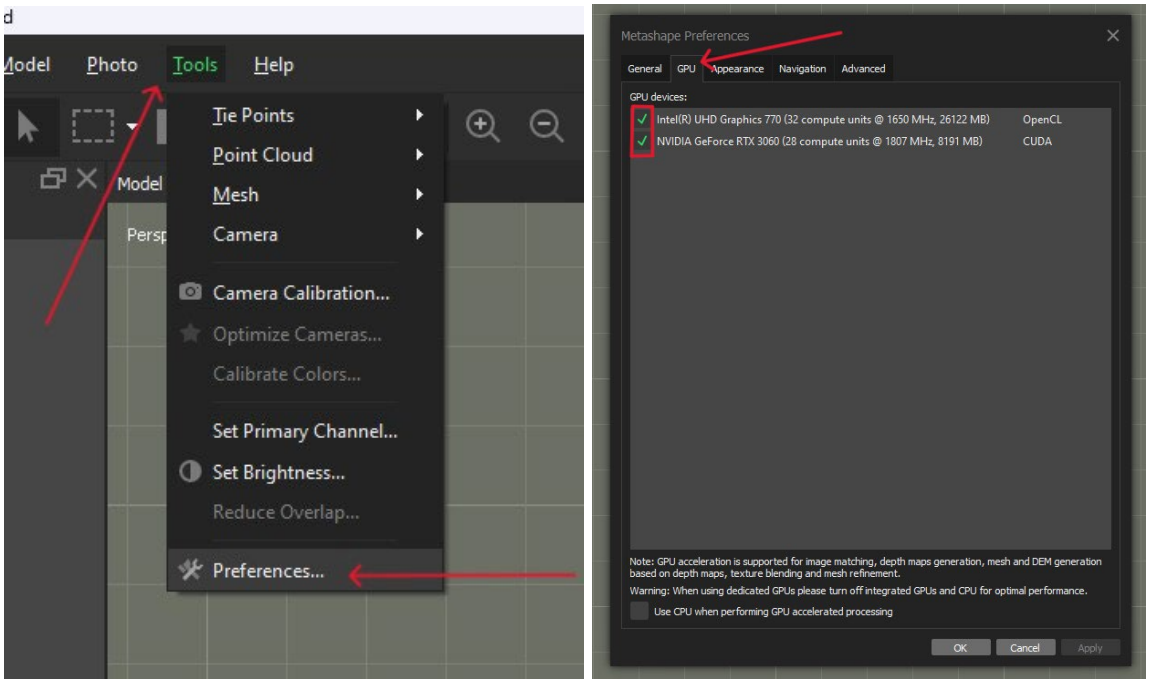
- If there are multiple chunks, be sure to set the one that is being used as the active one. To do this, right click on the chunk and select “Set Active.”



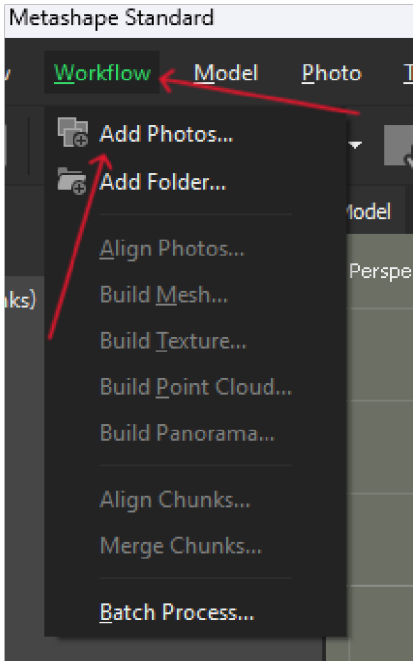
Adding Photos and Alignment

In this section, images will be uploaded to the Agisoft Metashape software to begin the alignment process. This will create a series of tie points that tie the forward and subsequent images together. Once completed, a point cloud will have been created.

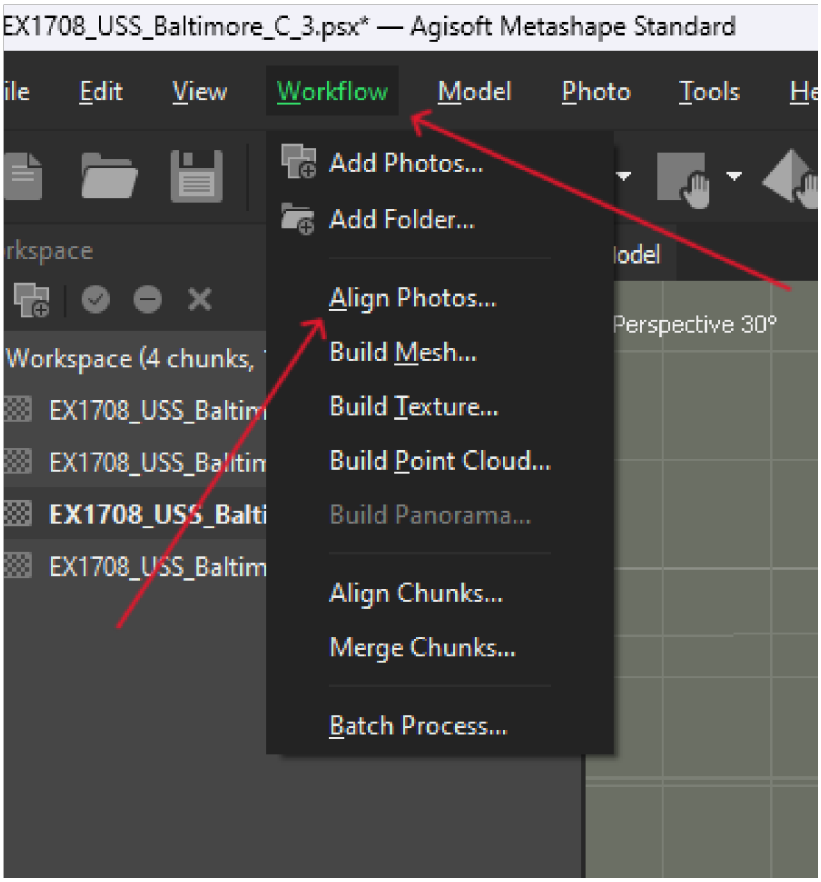
- First confirm that the Graphics Processing Unit (GPU) is being utilized in Preferences. The GPU is an electronic circuit designed to accelerate computer graphics, and process multiple datasets simultaneously. The CPU is the control center of a computer, the main processor that runs the computer’s operating systems and applications. Using a GPU is preferable as it greatly increases processing speed. To change to this do the following: ○ “Tools” -> “Preferences” -> “GPU”



- In Agisoft, under the tab “Workflow”, select “Add Photos”. Then select the photos that are to be used for the photogrammetric model.



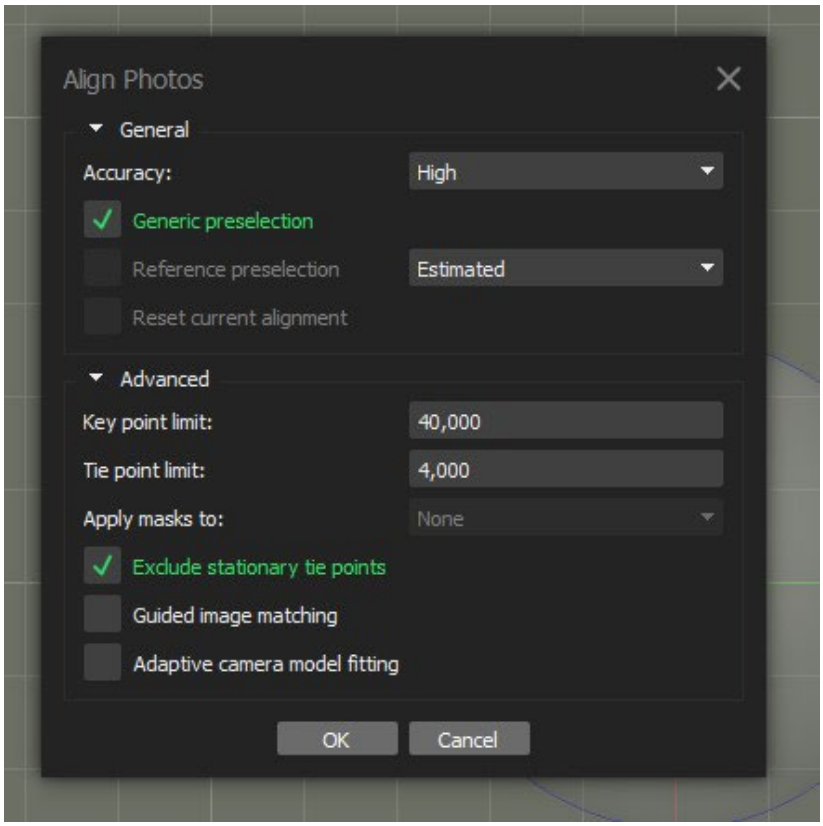
- First, to align photos, under “Workflow”, select the “Align photos” button.



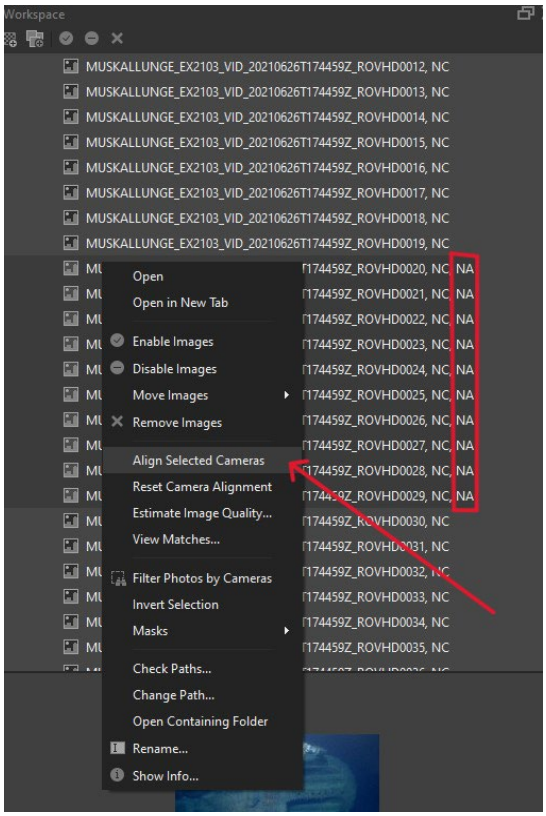
- Here the "Alignment" menu will open.
- Select "Generic Preselection" and nothing else.
  - Generic preselection helps process faster. Use this if there is 80% coverage from the previous image and 60% coverage from the next photo overlap. Keeping this on is the best option if the overlap is less than the desired amount mentioned above.
- For "Accuracy", selecting "High" is usually the best option (NOTE: The better the camera- the lower the accuracy. Remember to choose the accuracy setting carefully, too much information can clutter and ruin a model).[10]
  - **Highest**: should only be used if frames are extracted from a video. In some cases this can still be too much information for the software to process as it attempts to gather 100% of the info in the images.

[10] Kōtarō Yamafune. 2016. "Using Computer Vision Photogrammetry (Agisoft Photoscan) to Record and Analyze Underwater Shipwreck Sites." PhD diss. Texas A&M University. Underwater photogrammetry can be done with any type of camera that can be operated at the desired depth. Professional cameras (DSLR, SLR, Mirrorless) tend to have larger sensor sizes and more precise exposure control settings over the photos being taken, hence the recommendation for DSLR or SLR cameras.

        - **High:** should be used with Digital Single-Lens Reflex (DSLR) cameras or Single-Lens Reflex (SLR) cameras. This setting will gather 1/4th of the information.
        - **Medium**: should be used with higher end cameras such as Mirrorless Cameras. This setting will gather 1/16th of the information.
    - Key point limit (feature point)
        - Select the maximum number of points that Agisoft can detect. 40,000 is ideal
    - Tie point limit
        - Select the image connections. 4,000 is ideal
    - Select "Exclude Stationary tie point" (only if there are a lot of dust or scratches)
        - Use this for dust or scratches on camera images too. It excludes non-moving points.
        - Use this for drone or ROV footage when the ROV sleds and arms are in view.
    - Selecting "Guided image matching" is recommended for high resolution images that have between 50 to 100 megapixels per image in order to create an excessive amount of tie points that could be missed by the standard point detector.



- Once the alignment is completed, check the images to see which are not aligned. Images not successfully aligned will show “NA” at the end of the file name: Right click those images and select “Align Selected Cameras.“



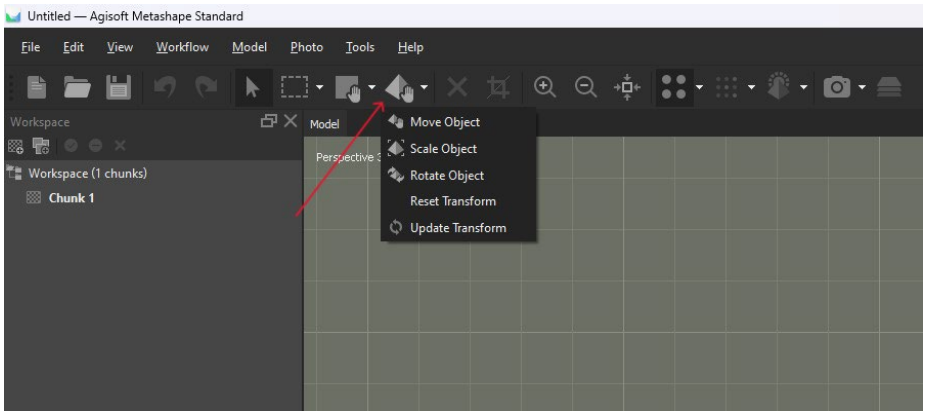
    - If that does not work, clicking “Reset Camera Alignment” in the same menu as above and then repeating the previous step can help.
    - Once aligned, verify if the realigned cameras are in line with the model (NOTE: Remember that aligning 100% of the images in the chunk is not always needed. Check the cameras that are far away to look for the “double ground” effect or overlapped sections of the model). Once that is complete be sure to **save** the project.

Aligning to a Grid

In this section, the model will be moved to fit on a grid map with the grid being the bottom/seafloor. This will help with scaling the model and taking measurements for research.

- Move the model so that it fits properly with the grid as the ground
    - This can be done using the orthographic view (shortcut is “5” on keyboard)
    - Use “1”, “3”, and “7” keys as shortcuts to get straight shots of each view

- To access the grid, go to the tab “Model” and hover over “Show/Move Items” and select “Show Grid”
- Move the model using the “Move Object” tool on the toolbar.



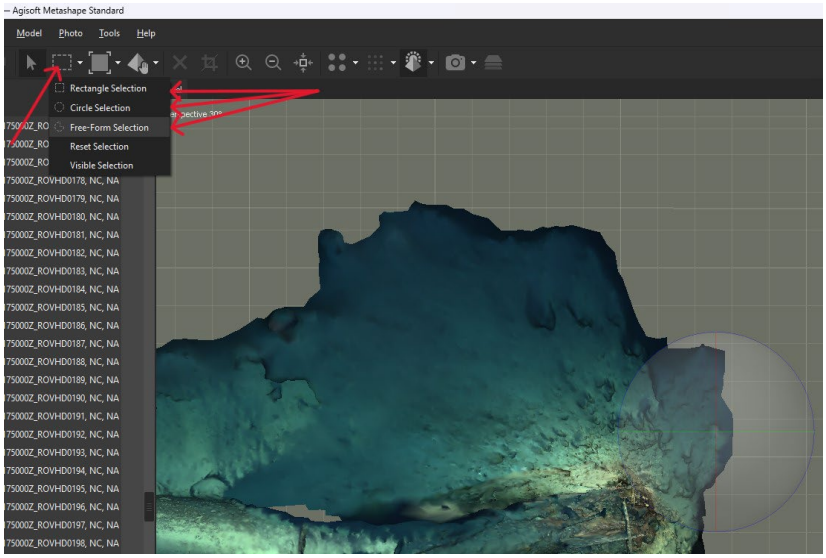
- Once this is complete be sure to **save** the project.

Removing Distortion

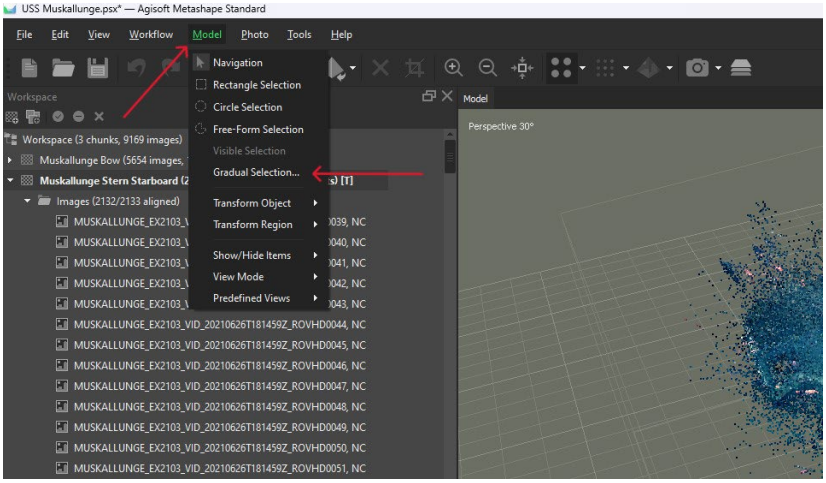
(READ THIS STEP IN ITS ENTIRETY BEFORE ATTEMPTING)

For this step, less accurate tie points will be removed. This entails looking for the Root Mean Square (RMS) value of normalized reprojection error and maximum reprojection error. This can be done by right clicking the chunk and clicking “show info”. To create a more accurate model, the goal is to lower these numbers.

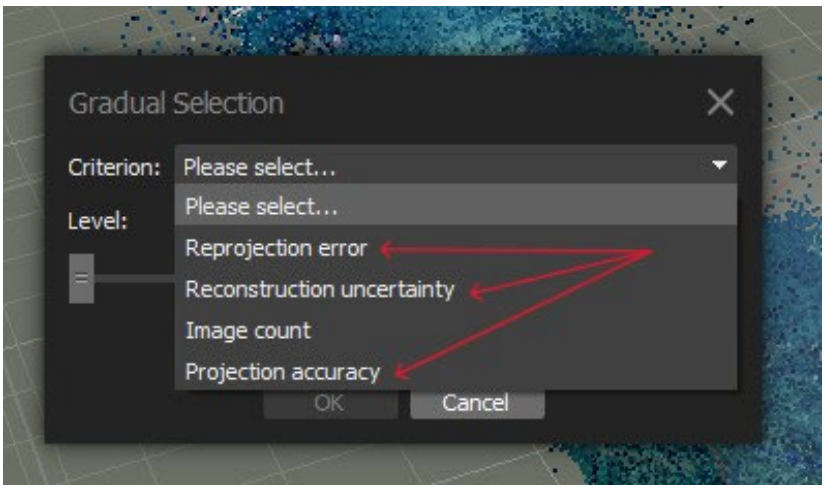
- To do this, first delete all any points that are far away that do not add anything to the model and are not associated with the object being modeled. Typically these points will be outside of the box that contains the model. To delete these points, select the dotted rectangle on the tool-bar and select from the three options, “Rectangle Selection,” “Circle Selection,” or “Free-Form Selection.” Click and drag the selection tool over the areas to be deleted and hit the “delete” key.



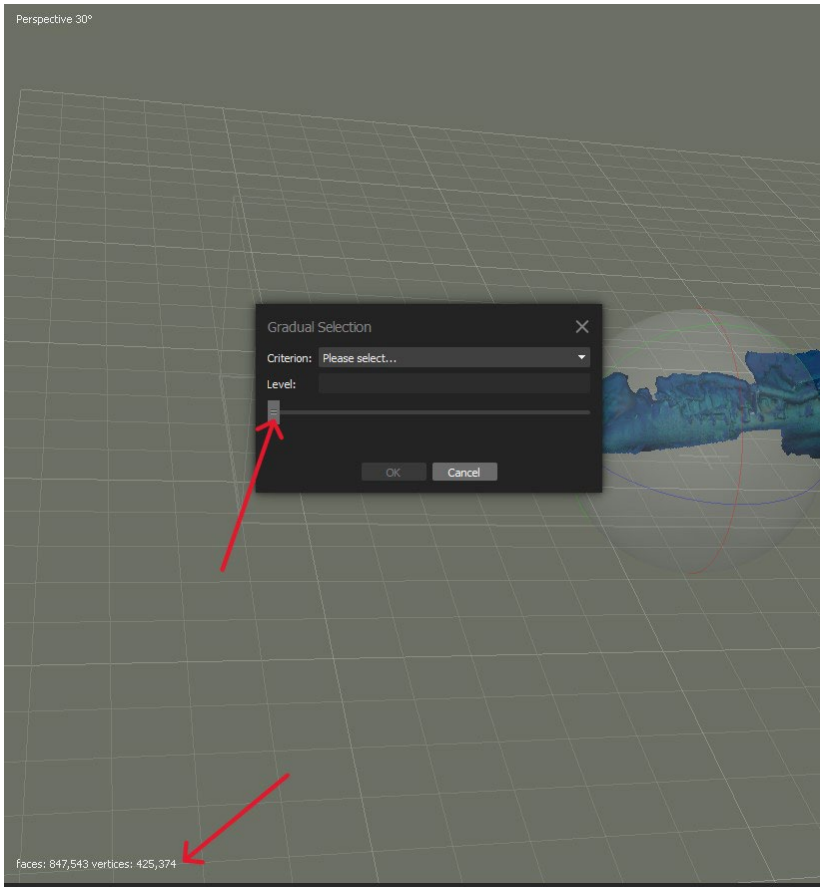
- Next, select the “Model” tab and select “Gradual Selections.”



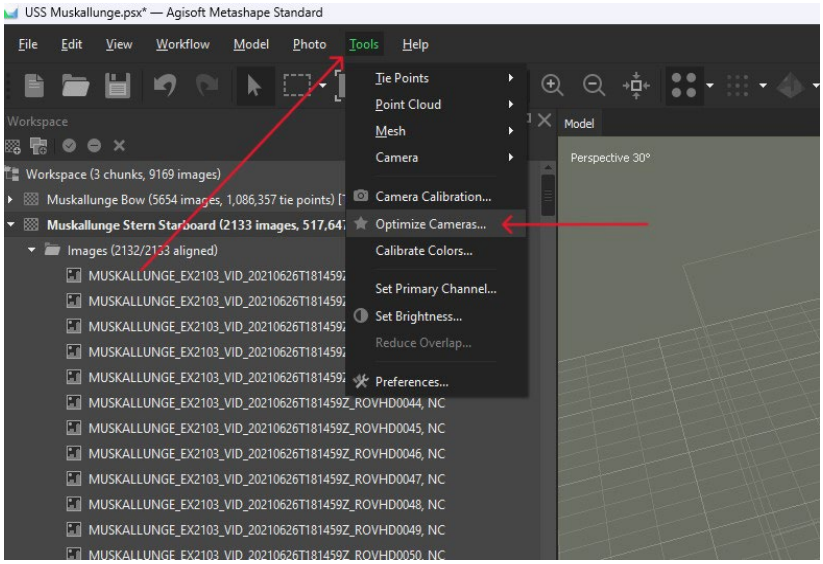
- There are four options, “Reprojection Error,” “Reconstruction Error,” “Image Count,” and
  “Projection Accuracy.” Click these in order, going from the top to the bottom but ignore “Image Count.”



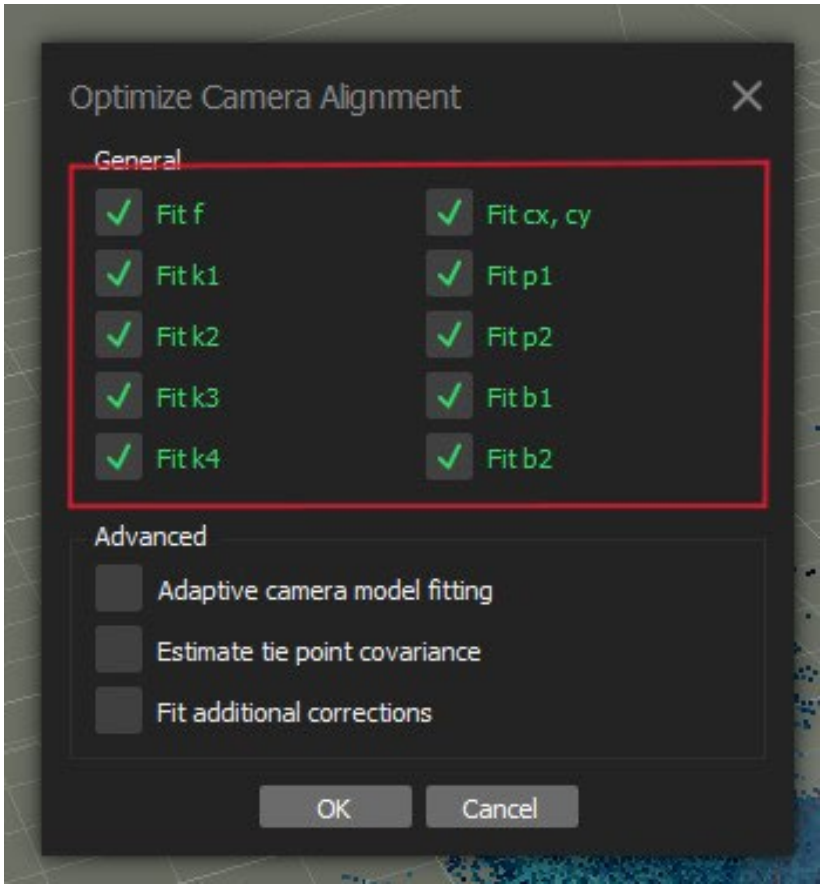
- Move the slide bar to select 10% of the points which can be seen at the bottom left of the screen. Once selected, delete these points.



- From here select the tab “Tools” and click on “Optimize Cameras”.



- Click all cameras, there should be 10. Then select “Optimize”.



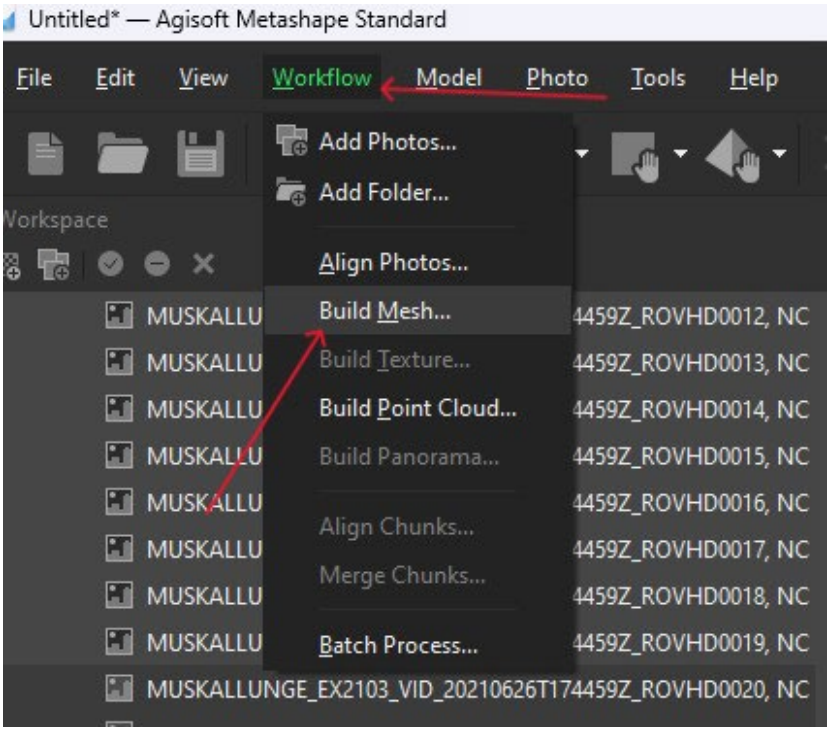
- Repeat this process for “Reprojection Error,” “Reconstruction Uncertainty,” and “Projection Accuracy” under “Gradual Selection” twice, selecting the same option back-to-back then moving on to the next.
- Once this step is complete be sure to **save** the project file.

Creating a Mesh

NOTE: Remember to skip Dense Cloud/Point Cloud as it has been outdated since 2018. It slows down the modeling process, and creates low quality meshes[11].

In this section, the point cloud that was created during the alignment process will be converted into a polygonal mesh. This mesh can then be trimmed to ensure that any unnecessary sections of the model are removed.

- On the tab “Workflow”, select “Mesh”

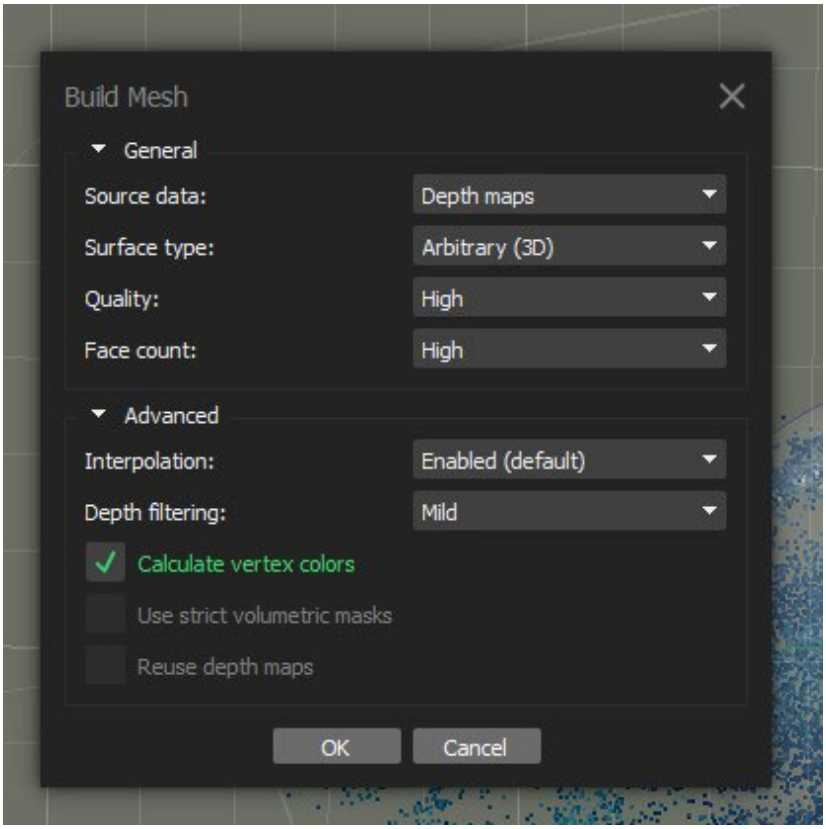


- On the “Mesh Menu”, under “General” set the settings to the following:
  - “Source Data” -> “Depth Map”
  - “Surface Type” -> “Arbitrary(3D)”
  - “Quality” -> “Medium”
    - For GoPro use “High”, for a higher quality camera use “Medium” (Lower Resolution cameras need to be set higher).
    - Face Count -> High
- The length stays the same no matter what is chosen. “0” is the highest number of mesh possible (infinite).

[11] Kōtarō Yamafune, *University of South Carolina Photogrammetry Workshop*, Columbia, South Carolina (25 May - 3 April 2022.

- Under Advance, set the settings to the following:
    - “Interpolation” -> “Enabled” (This fills in small holes)
- If the model has no holes (at all), select Extrapolated
    - “Depth Filter” -> “Mild”
- Having it set to “Mild” will prevent a depth cloud from being created of the sky with images of the sky or water with underwater images.
    - Select “Calculate Vortex Color” ●

      Gives the model color

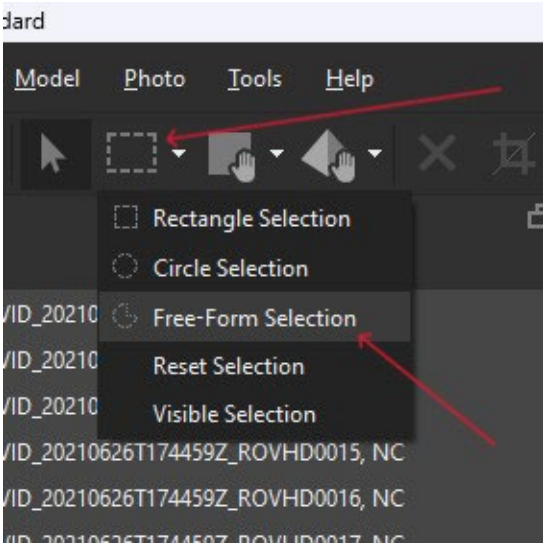


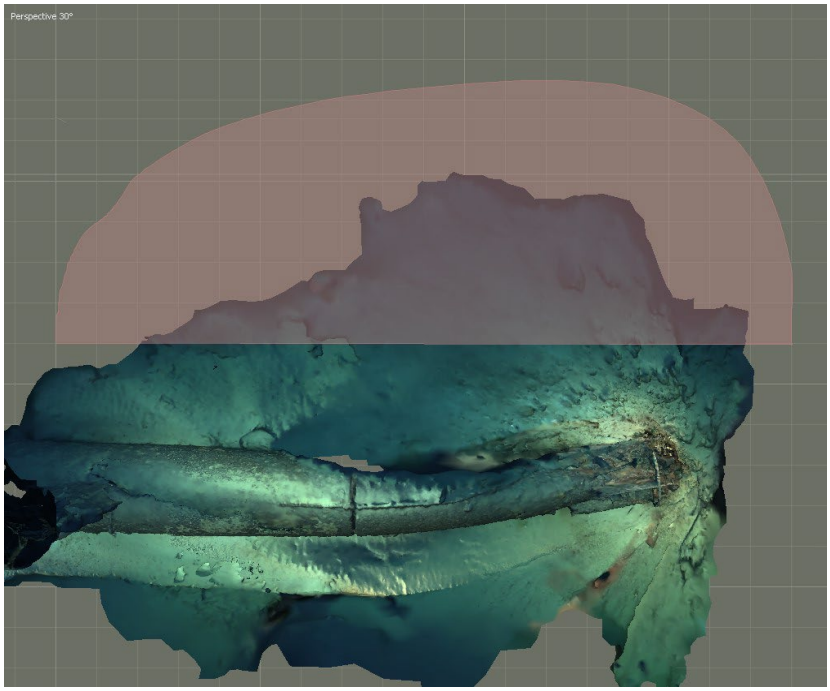
- Once this step is complete be sure to **save** the project file.

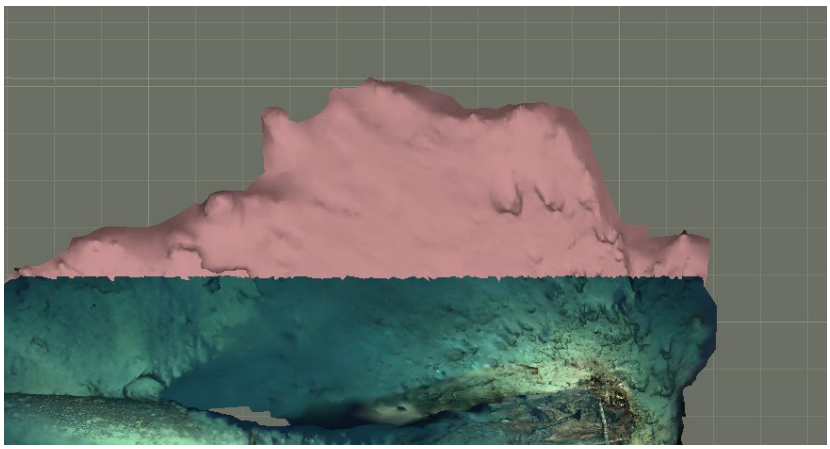
Giving the Model Texture

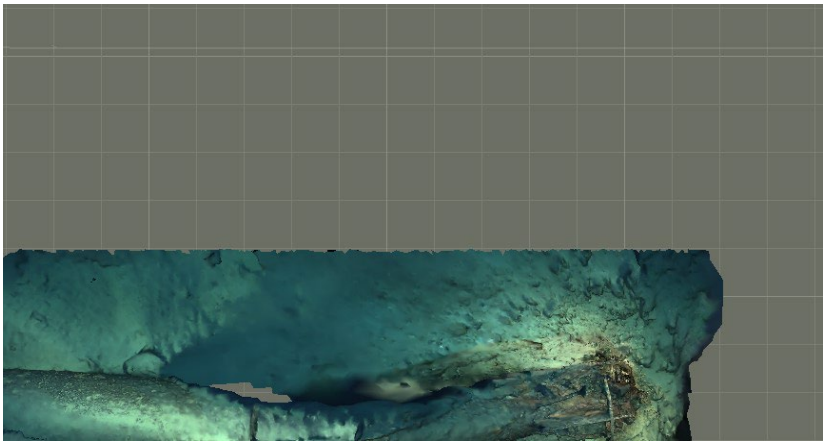
- Before moving forward with texture, be sure to delete any unnecessary areas of the model using the “Free-Form Selection” tool. If this isn’t done, the software will texture 100% of what is there (to include any background i.e. seafloor, water, etc.) This can cause the model to be less textured and not as crisp. To delete unnecessary areas of the, select the dotted rectangle on the tool-bar and select from the three options, “Rectangle Selection,” “Circle Selection,” or “Free-Form Selection.” Click and

drag the selection tool over the areas to be deleted and hit the “delete” key.









- Select the tab “Workflow” and select “Texture”, the Texture menu will pop up. Select the following settings

■ “Texture type” -> “Diffuse Map” (“Occlusion Map” is black and white)

■ “Source Data” -> “Image” (For “Occlusion Map” -> “3D Model”)

- Only use “Occlusion Map” if a Mesh is being run on “Medium” or “High”, otherwise the mesh will be a low quality black and white mesh.

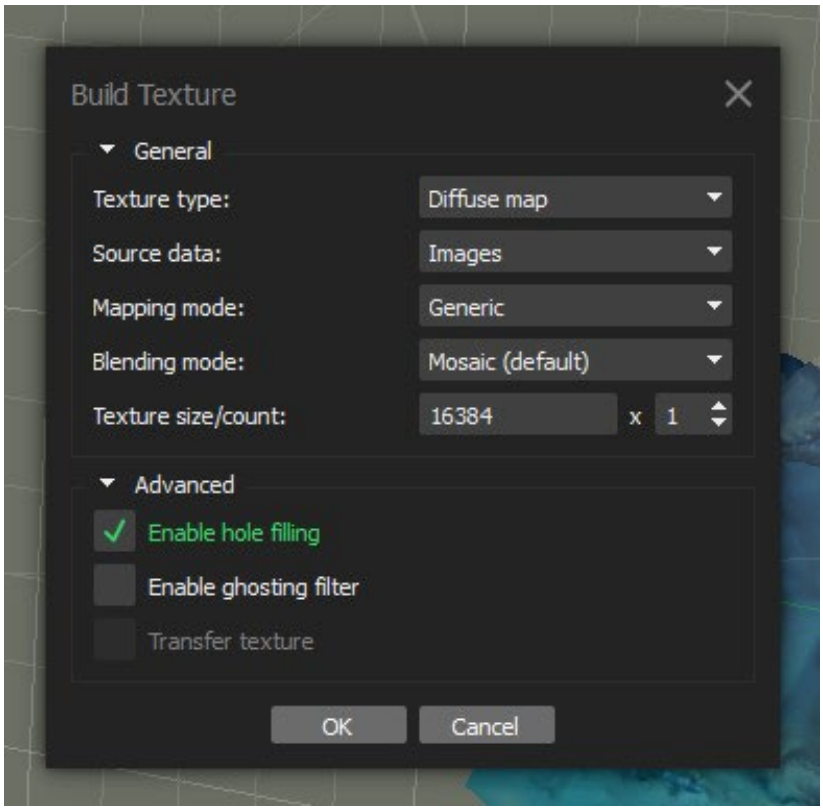
■ “Mapping Mode” -> “Generic”

■ “Blending Mode” -> “Mosaic” Or -> “Average” if there are cracks or voids in the model.

■ “Texture size Count” -> Dependent on the computer being used

- 4096 -> Regular Computer
- 8162 -> Gaming Computer
- 16384 -> Amazing Computer (See “Hardware Requirements”)
- Under Advanced set the following settings

- This option is enabled on default since it helps to avoid salt-and-pepper effect in case of a complicated surface with numerous tiny parts shading other parts of the model. Only in case of very specific tasks might it be recommended to switch the function off.[12]
- Enable Ghosting Filter
    - In case the scene includes some thin structures or moving objects which failed to be reconstructed as part of the polygonal model, it can be useful to switch on this option to avoid ghosting effect on the resulting texture.[13]



- Once this step is complete be sure to **save** the project file. The model has been created.

Scaling the Model

In this section, the model will be scaled based on a modeled scale bar or if there is a modeled object on the site and its measurements are known. It should be noted that this method of scaling is only available in Agisoft Metashape Professional Version.

[12] https://www.agisoft.com/pdf/metashape_1_5_en.pdf
[13] https://www.agisoft.com/pdf/metashape_1_5_en.pdf

- Locate the modeled scale bar or object, and go to the “0” marker on the scale or the extent of the object.
- Once located, right-click and select “Add Marker.” Do the same at the farthest extent of the scale bar or object.
- Locate the “Reference Tab” at the bottom of the workspace and highlight the markers that were created. Right-click them and create a scale bar.
- This scale bar will populate below. Here the space beneath “Distance” can be selected and the measurement can be imputed.
- To apply this, select “Update Transform” at the top of the workspace.
- Once this step is complete be sure to **save** the project file.

Finished Products

For each model that is processed, the final step in Agisoft Metashape is to export a standardized set of finished products. These products range from orthomosaic images of the model from different vantages, and animation of the model that includes fly over shots to 360 degree shots of the site and/or artifacts. Additionally, these models can be exported as a 3D model to be used internally or shared with partners who use software with 3D capabilities (CAD programs,
Blender, Maya, etc) or for 3D printing. Each of these finished products will be saved within the “Finished Products” folder under each project folder on the :/A drive within the NAS and subsequently duplicated onto the photogrammetry Google Drive under “Models Finished Products.”

Orthomosaic Creation

Here an orthomosaic of the model will be created where any geometric distortion will be corrected and the imagery will be color balanced to produce a seamless mosaic. It is important to note that to do this high quality photos are necessary. Agisoft fixes distortions based on the mesh, so it is extremely accurate once scaled. Orthomosaics are only available to Agisoft Metashape Professional Version users. This section should be updated when Professional Version is secured.

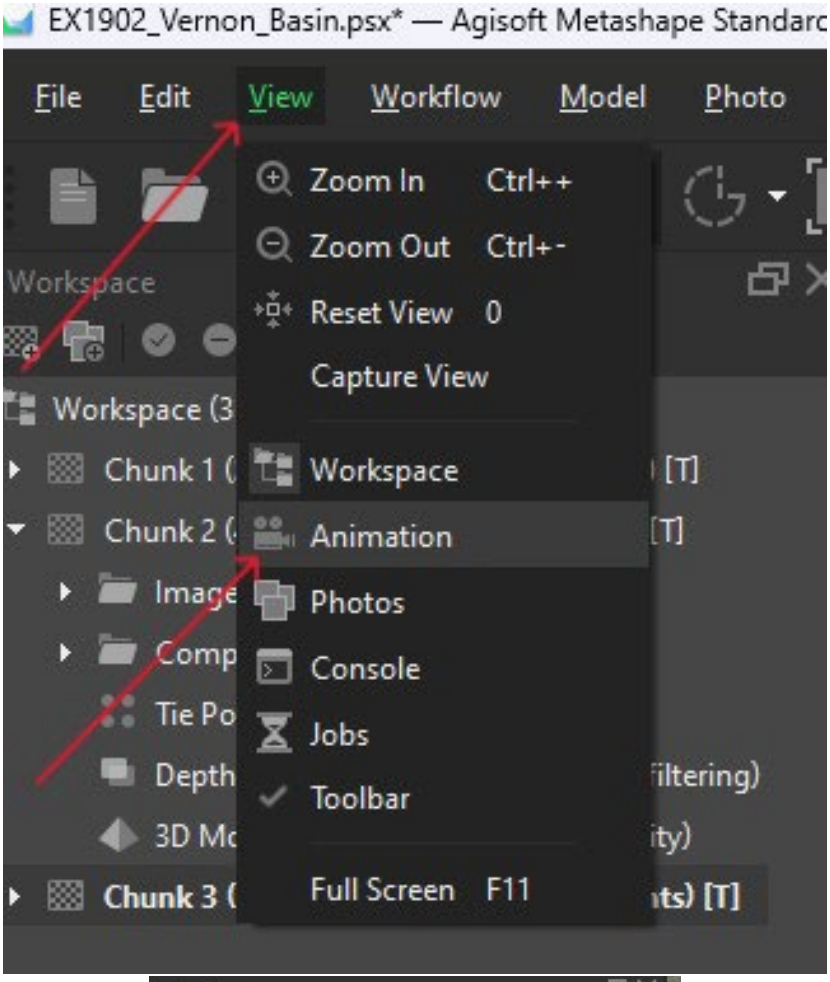
- Under the “Workflow” tab, select “Orthomosaic.”
    - In the window that opens, under “Projection” select “Geographic” and select “Coordinate system.”
    - For “Planar” select the vantage point that is desired for the orthomosaic.

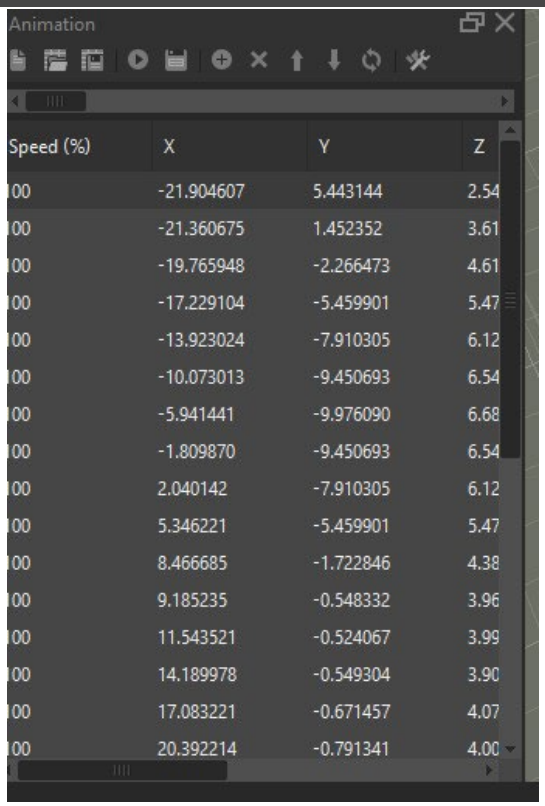
    - Leave “Refine Seamless” unchecked. If this setting is applied it has a chance to crash the computer. This setting creates a mosaic from the best of photos and takes a significant amount of time to process.
    - Ensure that “Enable Hole Filling” is selected
    - Select “Ghosting” if there are objects in the model that are unwanted, for example fish, crustaceans, divers, etc. If this is selected the processing time will increase exponentially.
    - Once the appropriate settings are selected, click “Ok” and the mosaic will be created and can be found under the chunk that it was created from.
- To export an orthomosaic, it must be done within the Agisoft Metashape Professional software. The reason for this is the orthomosaic was processed at the highest resolution possible and can be changed during this export process. If outside software is used to change resolution, the coordinates used for the orthomosaic will be unusable
    - Under the “File” tab, highlight “Export” and select “Export Orthomosaic.” Ensure that the naming convention that has previously been used is applied here (EX1234_Sitename_Bow/Stern/Midships/Miscellaneous) and set the “Max Dimensions” to 2000.
    - For “Total Size” select “Write World File.” This will save a TFW file which is the scaling and coordinate information.
    - Leave “Write BigTIFF File” unchecked
    - Once completed, select “Export”

Animation Creation

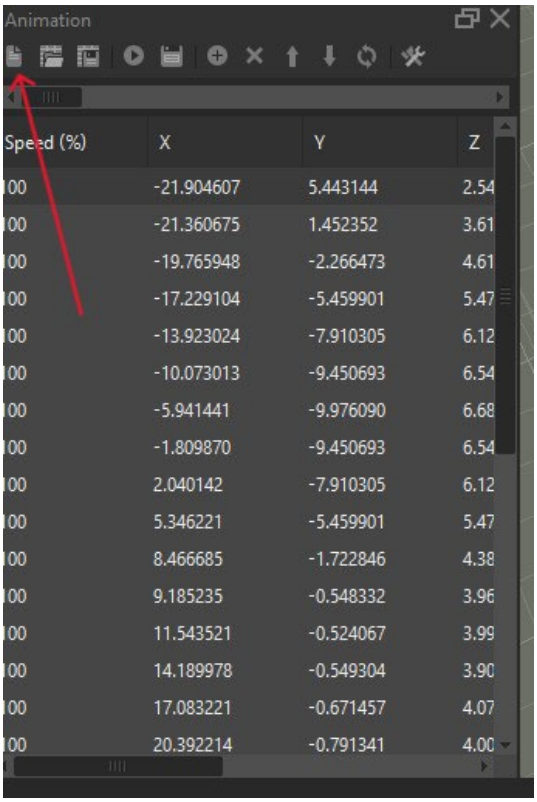
In this section, an explanation on how to create animations of the model will be outlined. Animations bring models to life and can be presentable as a video or converted into a GIF file using Adobe Express and embedded into Google Docs, Slides, Sheets and other Google Suite products and embedded into Adobe PDFs.

- Ensure that you set the chunk that you wish to animate as the active chunk. This can be done by right-clicking the chunk and selecting “Set Active.” Once this is done select the “View” tab select “Animation.” This will bring up the “Animation” palette at the bottom left section of the screen underneath the chunks.

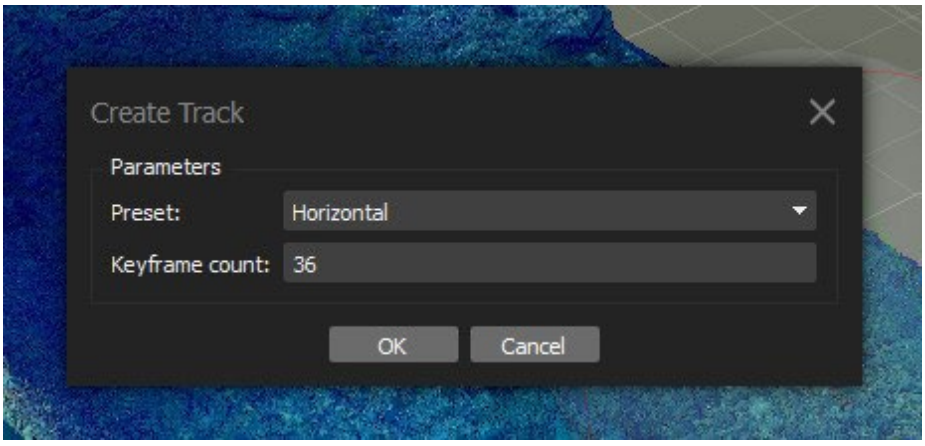

EX1902_Vernon_Basin.psx* — Agisoft Metashape Standard
File
Edit
View
Workflow
Model
Photo
Zoom In Ctrl++
Zoom Out Ctrl+-
Reset View 0
Capture View
Workspace
Animation
Photos
Console
Jobs
Toolbar
Full Screen F11
Workspace
Chunk 1
Chunk 2
Chunk 3


Animation
Speed (%) X Y Z
100 -21.904607 5.443144 2.54
100 -21.360675 1.452352 3.61
100 -19.765948 -2.266473 4.61
100 -17.229104 -5.459901 5.47
100 -13.923024 -7.910305 6.12
100 -10.073013 -9.450693 6.54
100 -5.941441 -9.976090 6.68
100 -1.809870 -9.450693 6.54
100 2.040142 -7.910305 6.12
100 5.346221 -5.459901 5.47
100 8.466685 -1.722846 4.38
100 9.185235 -0.548332 3.96
100 11.543521 -0.524067 3.99
100 14.189978 -0.549304 3.90
100 17.083221 -0.671457 4.07
100 20.392214 -0.791341 4.00

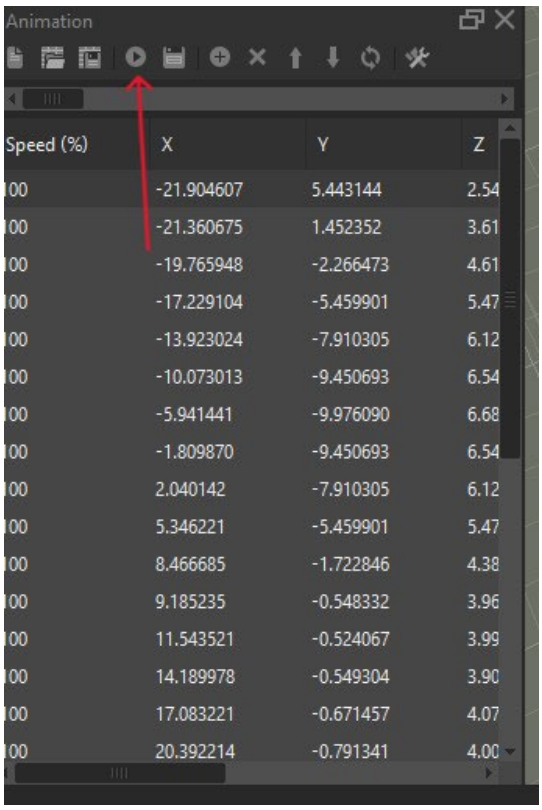
- There are two standard ways to create animations for a model: horizontal and vertical. These can be selected by selecting the “Create” button on the “Animation” palette.



- The “Create Track” window will open with a drop down menu to select either “Horizontal” or “Vertical.” Choose one that is suitable. For the “Keyframe Count,” select a number between 30 and 40. This is how many frames per degree for the animation.

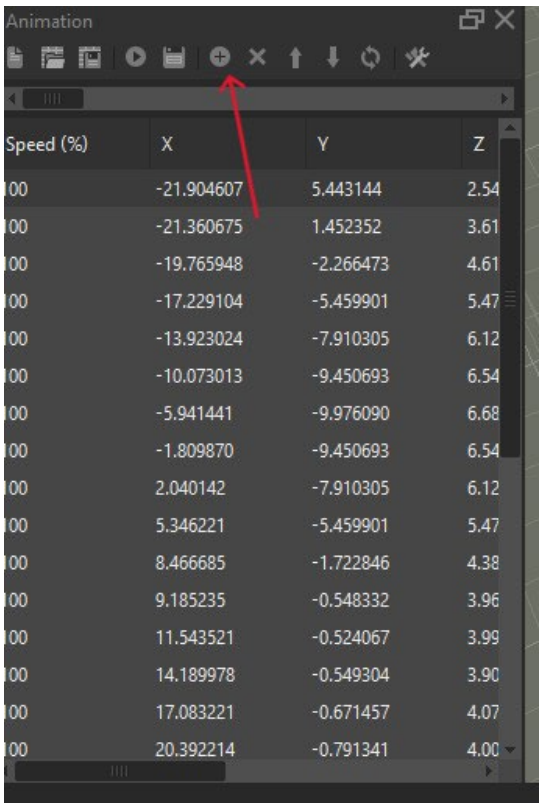


- Once these are selected, an animation will be created underneath the chunk. On the “Animation” palette, there is a play button that can be used to view the animation.

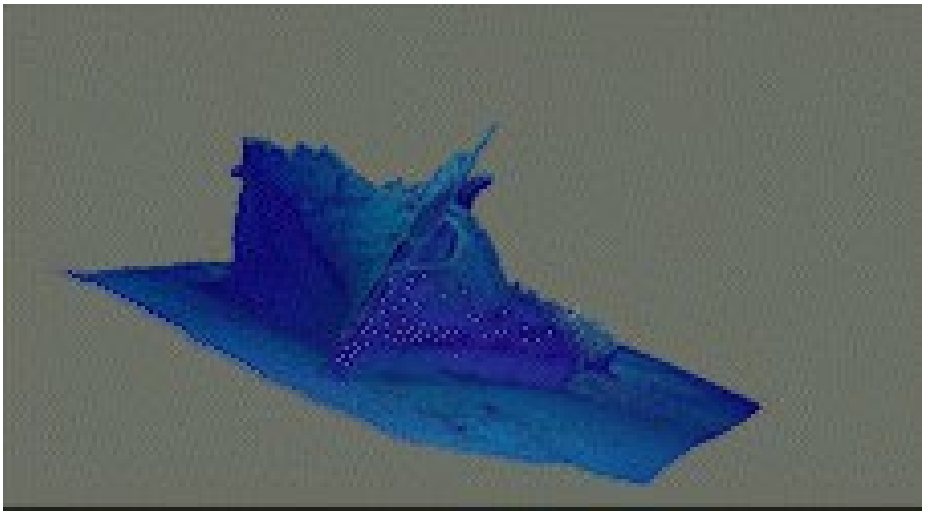


- While horizontal and vertical animations are standard, a customizable animation can be created to highlight specific features on a model. This can be done using the “+” option on the “Animation” palette. Before this is selected, make sure that the model is orientated in a way that will make for the best flight path. Plan out the flight path before

  this process begins. The model will have to be moved before the “+” button is selected. It is recommended that the “1”, “4”, and “6” keys on the keyboard are used to make adjustments to the model.



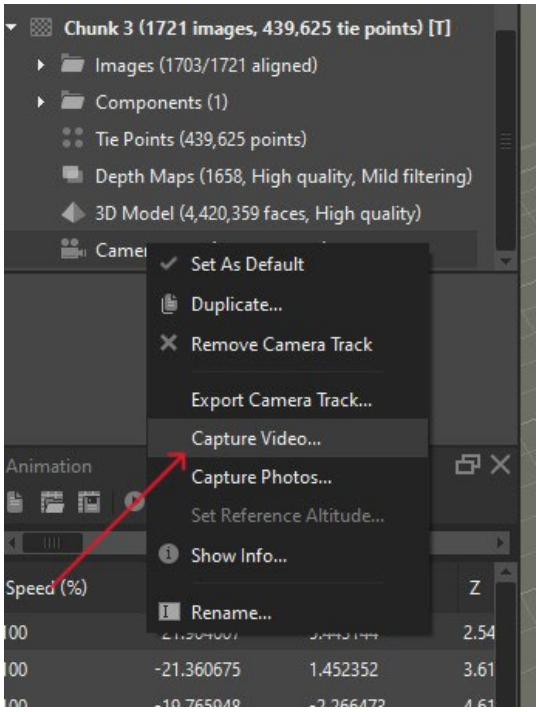
- Once the various viewpoints of the model are captured using the "+" button, select the play button. See the Vernon Basin example below:



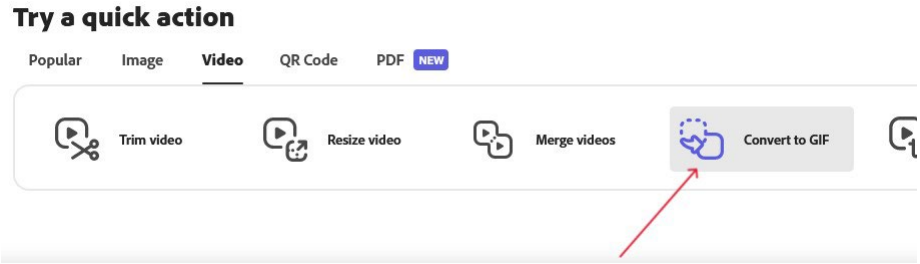
- Once the animation is made, it can be adjusted using the "Animation Settings" function.
  - For "Label" name the animation using the same naming convention for the project (EX1234_Site name_Animation).
    - "Duration" relegates the speed of the animation. The higher the number the slower the animation goes. Do not go past ○ Keep "Field of View" at 30 degrees.

- Select “Smooth Camera Track” as it makes the model less jumpy during animation.
- Leave everything else as is and select “Ok.”

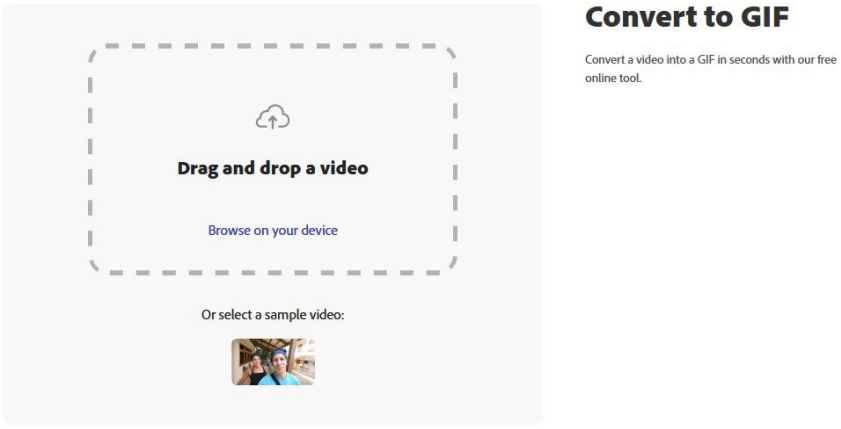
- To export an animation, right-click it under the chunk and select “Capture Video.”



- A documents folder will open, be sure to save this under “Finished Products” in an “Animation” folder for the respective project. The file will be saved as an AVI file using the same naming convention as the project (EX1234_Sitename_Animation).
- The AVI file can be converted to a GIF file if desired. This can be done through the Adobe Express application or an online GIF converter if Adobe Express cannot be installed.
  - To do this open Adobe Express and under “Try a Quick Action” select “Convert to GIF.”



  - From here either drag or browse the computer for the AVI file that is to be converted to a GIF file. Once uploaded, the file can be downloaded as a small, medium, or large file. It is recommended to download as a large file.



○ The GIF file can now be used to share or embed the model.

Image Creation

In this section, an overview of how to capture images of created models will be detailed.

- To take photos of the model, do the following:
  - ○ Under “Model” select “Show/Hide” anything not wanted in the photo. ○ Change the background if desired
    - ■ Under “Tools” highlight “Preferences” and select “Appearance.”
  - ○ Under the tab “View” select “Capture Model.”
    - ■ Choose the desired resolution and then select “Ok.”
  - ○ Save the captured images in the “Finished Product” folder under the project folder.

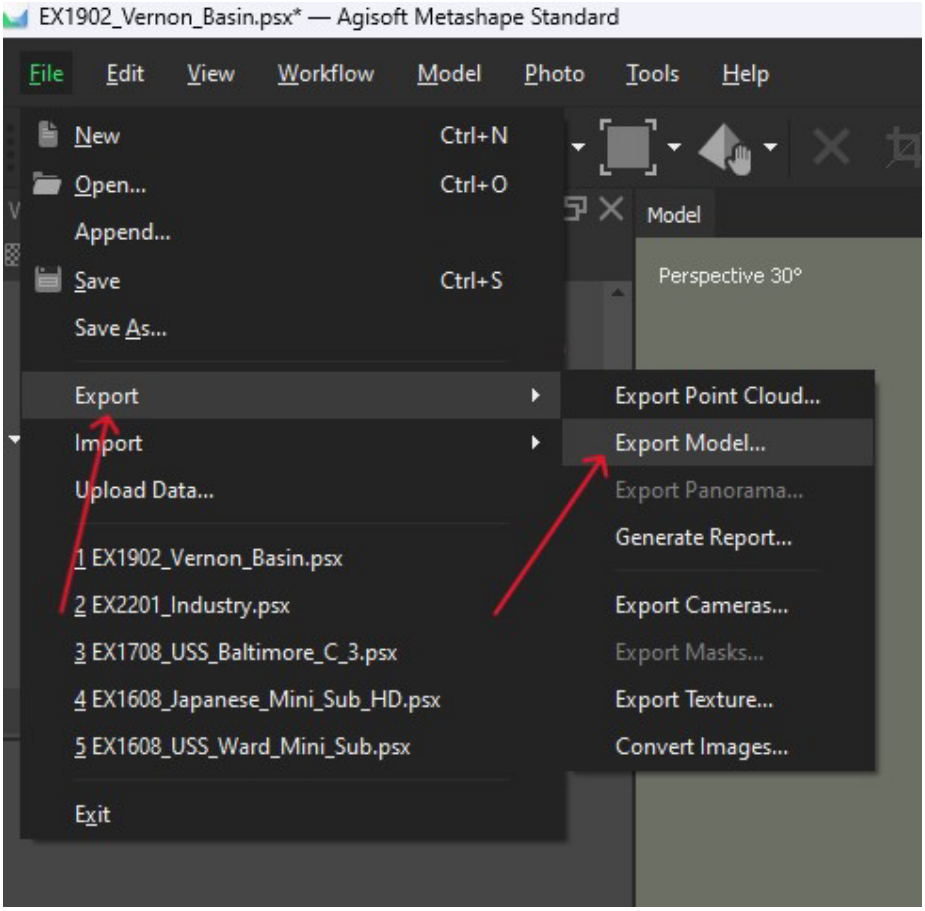
Exporting Finished Models

In this section, an overview will be given on how to export finished models from Agisoft Metashape as an .OBJ file, .XYZ file, and .3DS file. A .OBJ is an open format that has wide support and application to other 3D software. A .XYZ file is a multi-data file type that is used to extract coordinates from images and camera locations. A .3DS is a file used for models in Autodesk.

- For .OBJ files or .3DS files select the “File” tab and highlight “Export” and then select “Export Model.”
- A computer documents page will open prompting the selection of a folder to save the model. Select the “Finished Products” folder and save the model as either .OBJ file or

.3DS file under the “Model” folder. Be sure to name the .OBJ file or .3DS file using the same naming convention that has been used previously (EX1234_Site name_Model). Export both .OBJ and .3DS. With each created .OBJ file, a Material Library (MTL) file will be created. Ensure that this file is created and remains with its respective .OBJ file. This will ensure that the .OBJ file can be uploaded within other virtual 3D platforms.

- For an .XYZ file, repeat the steps above, but instead of selecting “Export Model,” select “Export Point Cloud” above it. Here the point cloud can be saved as an .XYZ file and saved using the same naming convention that has been used previously (EX1234_Site name_XYZ).

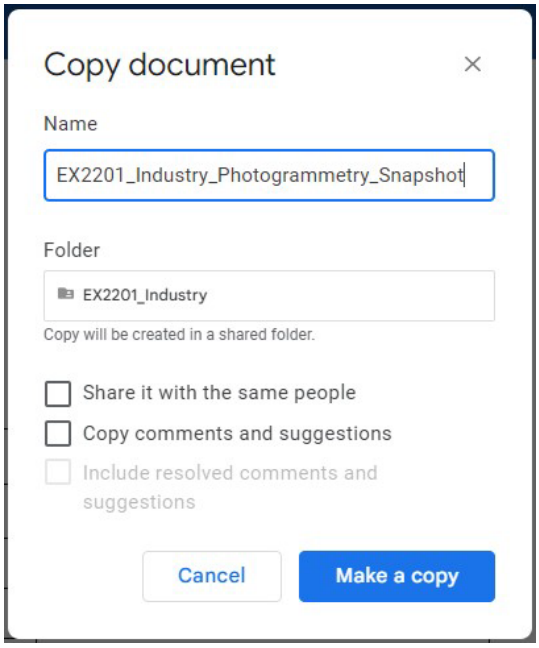


Photogrammetry Snapshots

After exporting finished products out of Agisoft Metashape, a Photogrammetry Snapshot will be created in Google Docs. The Snapshot is a summary document of the site that has been modeled and includes an animation, images, and the Model Metadata discussed in the section below. It is designed to be shared within the office and externally with partners interested in the site. There may be public-facing uses that include hosting this document on relevant oceanexplorer.noaa.gov project pages, and within the cruise data package for the respective

dive where the ROV video was used to process the model. Please consult the USS Baltimore (C-3) Photogrammetry Snapshot as an example.

To begin, locate the Photogrammetry Snapshot Template in the Photogrammetry_Models Google Drive Folder. Open this in Google Docs and select "File_Make A Copy". Name it using the established photogrammetry naming convention of cruisenumber_site: "EX1234_Site_Name".
Under the folder, have the new snapshot be saved under the respective site's model folder. Example below:



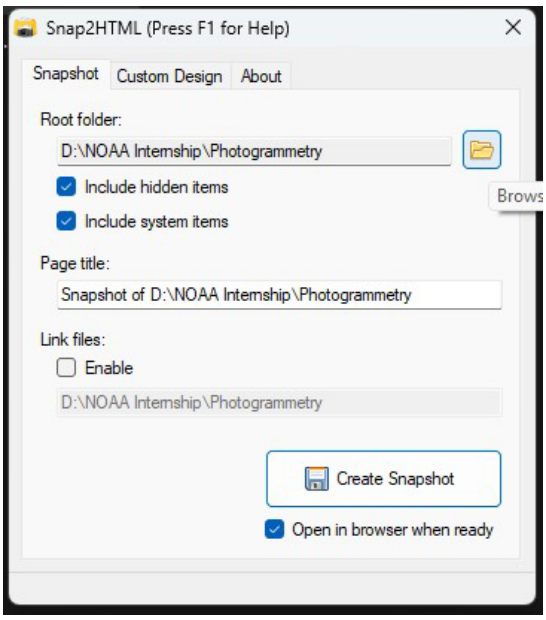
Once the Photogrammetry Snapshot is complete, download the file and save a .DOCX and .PDF to the Finished Products folder on the :/A NAS drive and backup :/A to :/B using Free File Sync. More information on model metadata required for every model is presented in the next section.

Snap2HTML Creation

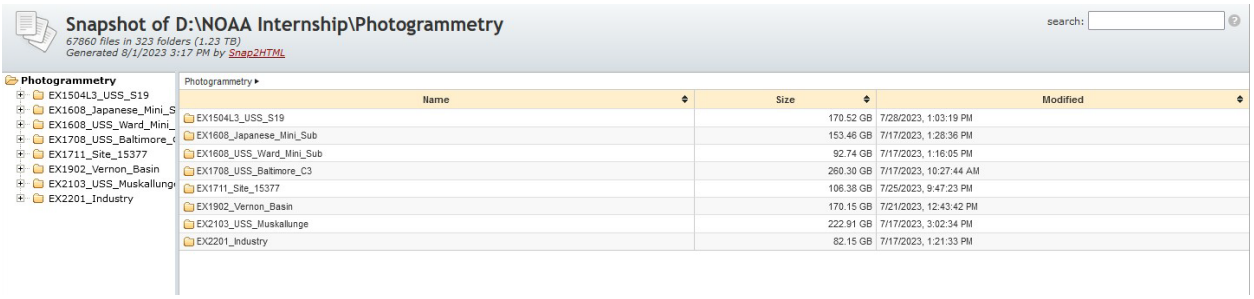
In this section, a step by step guide to creating a Snap2HTML will be given. This tool is used to create an interactive snapshot of folder structures on a harddrive, and saves it as an HTML. This will allow a user to look at the HTML of a specific model and verify if all of the respective data (Models, Finished Products, Images, Footage) is stored on the NAS :/R drive.

- To begin, download the “Snap2HTML” program from the following link: https://www.rlvision.com/snap2html/about.php

- Once downloaded, the software and settings menu will open. From here select the folder group that is to be turned into an HTML. Once selected, click “Create Snapshot.” The snapshot can then be saved in the desired location and shared with other parties.



- Once completed, open the HTML link and the folder snapshot will look like the image below. Add the Snap2HTML file to the respective model Google Drive folder and link to it in the Photogrammetry Log.



Model Metadata Information

All models should have the following standardized metadata included logged in the NOAA Ocean Exploration Photogrammetry Log. These metadata should be included wherever models are publicly shared.

UCH Site Summary

The UCH site summary is a short historical summary and archaeological interpretation of the site managed by the NOAA Ocean Exploration marine archaeologist. The four sections below provide a list of essential information by category that need to be included in a UCH Site Summary.

Basic Information

- Site name
- Site Type (UCH/Geological/Coral/Others)
- UCH Vessel Year Built
- UCH Vessel Year Sank
- Hull Material
- Official Number
- Cruise Number
- ROV Dive Number
- ROV Dive Date
- Location ● Depth (meters)

Dimensions

- Site Length (Meters)
- Site Width (Meters)
- Site Height (Meters)
- Site Orientation
- Model Length (Meters)
- Model Width (Meters) ● Model Height (Meters)

Model Information

- ROV used
- Camera information
- Video or Stills
- Number of Images Used and Format
- Image Alignment Percentage
- Number of Tie Points
- Link to raw images
- Software Used and Version
- Modeler/Affiliation
- Time to complete
- Model processor notes

Miscellaneous

- Images of available (Bow, Stern, Plan View, Individual artifacts, Area of focus)
- Available file format, location, and POC
- Links to model
- Link to NOAA Ocean Exploration project page

Processed Models

During the 2023 UCH Explorer-in-Training internship, Raymond Phipps generated 14 photo models from 8 UCH sites using this workflow and recommended hardware/software from past UCH dives: USS *Baltimore* (C-3), USS *Muskallunge*, *Industry*, the three piece Japanese mini-submarine NO-16, Japanese mini-submarine NO-20 that was sunk by USS *Ward,* the Vernon Basin shipwreck, Site 15377, and USS S-19. Some ROV footage used to process these models was acquired with photogrammetry in mind, but most were not. These public-frendly Photogrammetry Snapshots are part of the final deliverable package for each model processed.

Hardware and Software Recommendations

The recommendation to use Agisoft Metashape for photogrammetry is because of the softwares ability to process images quickly, while at the same time providing accurate results from both aerial, underwater, and close-range photography. Agisoft Metashape has a multitude of uses that allow the user to process images from RGB or multispectral cameras, into dense point clouds, textured polygonal models, georeferenced true orthomosaics and DSMs/DTMs. Further post processing enables the texturing of artifacts from the models, calculating vegetation indices and automatically classifying dense point clouds, etc.

Agisoft Metashape Pro Edition vs Standard Edition

Features	**Professional Edition**	**Standard Edition**
Core photogrammetry processing workflow		
Photogrammetric triangulation		

Dense point cloud generation and editing

NDVI and other vegetation indices calculation

4D modeling for dynamic scenes

GPU	1 - 2 NVIDIA or AMD GPUs with 1920 + unified shaders (Example: GeForce RTX 3080 or Radeon RX 6800 XT)

Source: **https://www.agisoft.com/downloads/system-requirements/**

Inhouse Photogrammetry Processing Purchase Recommendations

The following recommendations price out costs to be able to process photogrammetry models in house for NOAA Ocean Exploration. Each item below has been added to the Synergistic Team's FY24 budget request for S&T.

Software

Agisoft Metashape Professional - $3499

This is a one-time license purchase that would be issued to NOAA Ocean Exploration for installation on one machine with no expiration date. It includes 12 months of technical support.

Adobe Photoshop - $N/A

Adobe Photoshop is required to color correct batches of images. We would need one license off the NOAA Ocean Exploration or NOAA Research Adobe contract.

Storage

Synology 20TB NAS Storage System - $1000

Data management and storage is critical for photogrammetry model processing and requires a fast, stable solution. Using VPN or direct connection via CAT5 ethernet to access working files on the :/R drive severely affects processing speed and reliability. The :/R drive should be considered a final archive and backup for each completed model data package. The Synology Network Attached Storage (NAS) operates two Serial Advanced Technology Attachments (SATAs) that can transfer files up to 215 megabytes per second. The modeling software Agisoft is constantly writing and editing files where directed, and the NAS operating speed allows for efficient model creation, and sustainable file backup. The NAS will be utilized for other data heavy marine archaeology processing including GIS file storage and housed with the NOAA Ocean Exploration marine archaeologist.

Computing

Processing Laptop - $9000

The Synergistic Team requested $9000 to support Phil Hartmeyer's GIS, marine remote sensing data analysis and marine archaeology interpretation needs as lead for the marine archaeology portfolio. The $9000 was based on a similar computer purchase request by the Data Analysis and Synthesis Team and may be less. This machine can also be used to process photo-models using the Agisoft software. Laptop specifics should align with below:

Raymond Phipps's Desktop Computer Information

Case : Origin PC 5000D Airflow
Processors (CPU) : Intel Core i9-13900K 24-Cores 3.0GHz (5.8GHz TurboBoost)
Motherboard : MSI PRO Z790-A WIFI DDR5
Memory (RAM): 64GB CORSAIR VENGEANCE DDR5 (2x32GB) 5600MHz
System Cooling : iCUE H100i ELITE CAPELLIX XT Liquid CPU Cooler
System Fans : ORIGIN PC Standard Fan Kit
Graphics Cards (GPU): NVIDIA 8GB GeForce RTX 3060
Operating System : MS Windows 11 Home
Operating System Drive : 1TB Samsung 970 EVO Plus NVMe M.2
Power Supply : CORSAIR CS750 SERIES PLUS GOLD

Next Steps

Photogrammetry can be applied in a multitude of ways. In underwater archaeology, time on a site is limited. Creating a photogrammetric model of the site will allow archaeologists to further study the site and pose questions for future expeditions on that site. Photogrammetry is applicable for studying underwater geological features and comparing past and present models of the same geological feature to note changes. In marine biology, photogrammetry can be used to do comparative studies of coral species and to better understand benthic ecosystems of our oceans. Beyond securing the above hardware and software that will unlock Science and Technology Division's ability to process 3D photo models, several other considerations should be made:

SketchFab is a premiere public depository for photo models. It's public friendly, public forward, and models hosted there could be embedded into future oceanexplorer.noaa.gov web pages with full 3D manipulation capability for users. Federal agencies are using SketchFab to share model data including Scott Sorset (Archaeologist, Bureau of Ocean Energy Management-BOEM) who has published photo models he stitched from previous NOAA Ocean Exploration UCH ROV dives at BOEM's Virtual Underwater Museum and NOAA Thunder Bay National Marine

Sanctuary's collections of historic shipwreck models and artifacts. We recommend creating a NOAA Ocean Exploration SketchFab account where all models from program activities will be housed including photomodels routinely generated during Marine Archaeology NOFO projects with credit and link to the oceanexplorer.noaa.gov project landing page. Models are equally public-facing products as tools for scientific analysis and documentation. It's critical for NOAA Ocean Exploration to be able to self-host models on SketchFab and a discussion with the Department of Commerce should be had to discuss SketchFab's terms of service. Emily Crum should be included and help lead this conversation.

Conversations with the IT Help Desk should also be had to ensure Agisoft Metashape Professional, Free File Sync, Synology DSM (the dashboard software to access the NAS), and Adobe Photoshop are approved software packages and able to be installed on the pending computer upgrade for the NOAA Ocean Exploration marine archaeologist (Phil Hartmeyer).

Appendices

Appendix A: ROV Dive Planning for Photogrammetry Data Collection

- ☐ Establish a priority list for the dive based operations, taking into consideration community input and the capabilities of the EX/ROVs. What is priority and secondary? For example: Collecting data for a photo-model is priority and artifact documentation is secondary.
- ☐ Develop a plan(s) of action with the GFOE pilot team in advance of the dive. Recommend having at least two contingency plans in place. Provide GFOE pilot team with builders' plans of UCH site if available, historical documents to include context of sinking event, and 3D CAD models of the UCH site if available. This will help the pilots visualize the site before the dive.
- ☐ Discuss potential hazards on site such as current, visibility, snagging hazards (fishing nets, lines, etc.), overhead environments, and/or hazardous cultural material (oil, unexploded ordnance, etc).
- ☐ Based on the above information, plan the flight path of the ROV for photogrammetry. For the best possible model, it is recommended that multiple passes be made.
    - ☐ The first pass should include as much of the UCH site as possible to include where it meets on the seafloor, maintaining a distance of 5-10 meters for 360 degrees around the site. The speed of the ROV is dependent on the pilot's comfort to operate the vehicle safely on the site. It doesn't need to be a slow crawl, but should not be as fast as possible.
    - ☐ A second pass should begin at the same location as the first, but farther up on the site, possibly at the furthest extent of the site. The camera can be tilted down to capture the top of the site if necessary. The same speed and distance for the first pass apply here as well.

☐ If hazards are accounted for, additional passes can be made of the site from a plan view (top down) perspective following a longitudinal transect path of the site. This should be started from where the second pass ended and go from right to left or left to right.

☐ A similar path can be taken that goes laterally across the site.

☐ An auxiliary pass can be taken of a section(s) or an object(s) within the site. To do this a 360 degree rotation around these sections is needed.

(NOTE: These are recommendations and these sequences can be modified to suit the particular dive. For example if only one pass can be made and auxiliary passes, adjust as needed. Additionally, proceed with this guideline as the dive time permits and environmental constraints will allow).

☐ If possible, plan ship-moves prior to dive to ensure optimal coverage of the site for photogrammetric purposes.

☐ Lighting for photogrammetry purposes should avoid casting shadows. The brightest lights aren't necessary, but a consistently lit shot devoid of shadows is ideal.