Drone RGB and Multispectral Data Processing Protocol

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Abbreviations

- CRP Calibrated Reflectance Panel
- DJI SZ DJI Technology Co., Ltd.
- GCP Ground Control Point
- GNSS Global Navigation Satellite System
- GPS Global Positioning System
- RGB Red, Green, Blue
- RTK Real Time Kinematic
- UAS Unoccupied Aircraft System

Scope

This document describes the UAS data processing workflow developed for RGB and multispectral imagery simultaneously collected on DJI Matrice 300 (M300) RTK platform. The workflows outlined in this document are designed for use with RGB imagery acquired with DJI Zenmuse P1 camera and multispectral imagery from MicaSense RedEdge-MX or Dual sensors (see 'Drone Data Collection Protocol' on the <u>TERN protocols page</u>). The M300 is equipped with GNSS RTK (Global Navigation Satellite System Real Time Kinematic) which can be used with the D-RTK 2 base station to determine the position of the UAS with centimetre-level accuracy. This enables high georeferencing accuracy without the use of ground control points (GCPs) or ground surveys. This protocol describes two approaches to processing RGB and multispectral imagery using Agisoft Metashape Pro:

- 1. Automated processing using a Python workflow
 - The workflow is described in 'Summary of processing workflow using Agisoft Metashape'.
 - User input is required to select images for MicaSense reflectance calibration.
 - Equivalent Metashape toolbar commands are listed for all steps.
 - A prototype to create a custom widget in Agisoft Metashape for the same workflow is described is 'Appendix 6: Processing workflow using a custom Metashape window'.
- 2. Step-by-step workflow using the Metashape graphical user interface (GUI)

The primary data products from this workflow are co-registered RGB and multispectral orthomosaics.

Summary of processing workflow using Agisoft Metashape

Table 1: Summary of automated processing workflow on Agisoft Metashape Pro

1 N/A Metashape Preferences Tools -> Preferences General: Update Theme' to Classic 2 N/A Save Metashape project as .psx file Tools -> Preferences Suggested naming: 'YYYYMMDD_ PiotName.psx' (YYYYMMDD – date of data Save project in imagery/metashape/ within the TERN piot folder. 2 N/A Save Metashape project as .psx file File -> Save As Suggested naming: 'YYYYMMDD_ PiotName.psx' (YYYYMMDD – date of data Save project in imagery/metashape/ within the TERN piot folder. 2 N/A Run script to add RGB and multispectral imagery and to start the processing workflow. See Table 2 for steps completed in Suggested naming: 'YYYYMMDD_ PiotName.psx' (PYYYMMDD – date of data Save project in imager/metashape/ within the TERN piot folder. 3 N/A Process rgb and multispec chunks to generate orthomusaic tiff Tools -> Run Script (metashape_proc.py) Note: One-time setup required to install extension python packages listed in section: _rgb/fnevid_raw/ iirgb/setuh to animages' Default is relative to project location: _rgb/fnevid_raw/ iii. Strengt hvidu to smooth com/medum/hgb/ iii. Strengt hvidu to strengt in gest closels - section: _rgb/fnevid_raw/ iii. Strengt hvidu to strengt in gest closels - section: _rgb/fnevid_raw/ iii. Strengt hvidu to strengt in gest closels - section: _rgb/fnevid_raw/ iii. CSV of updated go sitems or hypid (blockshifted) and micasens (if nodes required) section: _rgb/fnevid_raw/ iii. CSV of updated gostions for rgb (f blockshifted) and micasens fif auto	#	Chunk	Processing Step	Metashape Menu	Summary
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6 Click on 'Resume Processing' in the toolbar to complete the processing workflow. See Table 2 for more inform	6	<u> </u>	C	lick on 'Resume Processing' in the too	blbar to complete the processing workflow. See Table 2 for more information.

alibration from XMP meta data, Load camera ction). script. oft Metashape setup'. n default path arguments) ult is low. as appropriate for forested sites.): /metashape/) nicasense (imagery/metashape/) mera group 'Calibration Images' and to pected before reflectance calibration. images to be used (from either before or after d 'Remove Cameras'. must be unmasked. e main window, 'Reset Mask', select panel area area to be masked. Now select 'Invert Mask'. g Tools -> Set Primary Channel).

Chunk	Processing step	Equivalent step on Metashape GUI	Summary
Chulik	FIOCESSING SLEP	Equivalent step on Metashape Gor	For more information on Metashape commands refer to the Metashap
NA	Add Chunk	Workspace pane	Right-click and select 'Add Chunk' and rename as 'rgb'
rgb	Add images	Workflow -> Add Folder	Navigate to folder containing images and select all images to be added. Select 'Sir
NA	Add Chunk	Workspace pane	Right-click and select 'Add Chunk' and rename as 'multispec'
multispec	Add images	Workflow -> Add Folder	First double click on multispec chunk to make it active. Select toolbar command and navigate to folder (with subfolders) of all MicaSense In the next dialog, select 'Multi-camera system' option.
multispec	Locate panels, Select Calibration images	Tools -> Calibrate Reflectance	User input to select micasense calibration images (Table 1)
	If blockshift enabled	Update P1 Camera positions	Calculate difference between D-RTK2 base station position recorded on field and Apply difference to all cameras. Convert CRS to target projected CRS. Save shifted
	Estimate Image Quality	Photos pane – context menu	Right click on an image from the context menu, select 'Estimate Image Quality' – Remove Images with Quality < 0.7 (Hardcoded value).
	Camera calibration	Tools -> Camera calibration	Lever-arm offsets (m) for p1 from single gimbal position: 0.087, 0.0, 0.0 (m) (Under GPS/INS Offset, 'Enable Reference' under Reference Column, and enter al
	Set camera accuracy	Reference pane - Settings	Under 'Measurement Accuracy' set Camera accuracy (m) to 0.1 m
	Align Photos	Workflow -> Align Photos	Settings - Accuracy: High, Generic preselection – unchecked, Reference preselection
	Optimise alignment	Reference pane – Optimize Cameras	Default settings (Following are unchecked: Fit b1, b2, k4 & all Advanced)
	Build dense cloud	Workflow -> Build Point Cloud	Set Quality: Medium, Depth Filtering: Mild. Note: On Metashape v1.x.x the point cloud is referred to as Dense Cloud.
ngh	Build Mesh	Workflow -> Build Mesh	Set Source data: Point cloud, Surface type: Height field, Face count: Medium.
rgb	Decimate mesh	Tools->Mesh->Decimate Mesh	Decimate model to half of original face count.
	Smooth mesh	Tools -> Mesh -> Smooth Mesh	Strength: 50 (low), 100 (medium), 200 (high). Note that settings are yet to be tested in sites with complex/dense vegetation.
-	Export Model	Workspace pane – 3D Model context menu	Export model – necessary so that it can be used as surface for multispec chunk. N Naming: <proj_name> _rgb_smooth_<strength_value>.obj</strength_value></proj_name>
	Build orthomosaic	Workflow -> Build Orthomosaic	Set Surface: Mesh. Refine seamlines: True.
	Export orthomosaic	Workspace pane – Orthomosaic context menu	Pixel size rounded to 2 decimal places. Big Tiff, Tiled, overviews enabled. Naming: <proj_name>_rgb_ortho_<resolution_in_m>.tif</resolution_in_m></proj_name>

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Single cameras'
se images.
d that from AUSPOS. ed_p1_pos.csv in project folder.
– and Apply to 'All images'.
above values for X, Y, Z).
ction: Source.
Model exported in target CRS.

Church	Descentions store	Envirolant dan an Matachana Cill	Summary	
Chunk	Processing step	Equivalent step on Metashape GUI	For more information on Metashape commands refer to the Metashape Pro Us	
	Interpolate micasense image position	Tools->Run Script metashape_upd_cam_pos_only.py	Micasense and p1 mage timestamps used to interpolate micasense camera positi Updated micasense positions saved in interpolated_micasense_pos.csv in project Remove cameras that triggered outside flight area. Load updated camera position	
	Camera Calibration	Tools -> Camera calibration	Lever-arm offsets (m) for MicaSense sensor (in Gimbal 2) from single gimbal posit RedEdge-MX: -0.097, -0.03, -0.06 MicaSense Dual: -0.097, 0.02, -0.08	
	Set camera accuracy	Reference pane - Settings	Under 'Measurement Accuracy' set Camera accuracy (m) to 0.1 m	
	Estimate Image Quality	Photos pane – context menu	Estimate Image Quality from the context menu. Remove Images with Quality < 0.7 (Hardcoded value).	
-	Set Primary Channel Set Brightness	Tools -> Set Primary Channel Tools-> Set Brightness	Set NIR as Primary Channel. Set optimal Brightness values for better display of im	
multispec	Raster transform	Tools -> Set Raster Transform	Relative reflectance values, B1 is B1/32768 for band 1 and repeat for all bands.	
	Reflectance Calibration	Tools -> Calibrate Reflectance	Check 'Use reflectance panels' and 'Use sun sensor'. Click OK.	
	Align Photos	Workflow -> Align Photos	Settings - Accuracy: High, Generic preselection – unchecked, Reference preselect	
	Optimise alignment Reference pane – Optimize Cameras		Default settings. (Following are unchecked: Fit b1, b2, k4 & all Advanced)	
	Import Model	File -> Import -> Import Model	Import rgb model created earlier. Import model in the target CRS (was exported l	
	Build orthomosaic	Workflow -> Build Orthomosaic	Set Surface: Mesh. Refine seamlines: True.	
	Export orthomosaic	Workspace pane – Orthomosaic context menu	Pixel size rounded to 2 decimal places. Big Tiff, Tiled, overviews enabled. Naming: <proj_name>_multispec_ortho_<resolution_in_m>.tif</resolution_in_m></proj_name>	

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Agisoft Metashape setup

Update Preferences

- 1. Open Agisoft Metashape Pro. Access Tools -> Preferences.
- 2. In the General tab, update Theme to 'Classic'. Select 'Write log to file' and browse to enter the path and a name for the .txt file.

General	GPU	Network	Appearance	Navigation	Advanced	
User Inte	rface					
Languag	e:		E	nglish		×.
Default v	view:		М	odel		~
Theme:			C	assic		N
			\checkmark] High DPI mod	e	
Shortcut	s:			Cu	stomize	
Stereosco	opic Displa	у				
Mode:			A	naglyph		~
Parallax:			1.	0		
Measurer	nents					
Latitude/	'longitude	format:	D	ecimal degrees		~
Units:			C	oordinate system	n units	\sim
			\checkmark	Use derived ur	nits	
Miscellan						
		ates on progr	am startup			
✓ Write	e log to fil	e:				

Figure 1: Update Metashape Preferences. Select theme 'Classic' for display to match the screenshots in this document. Choose a path to save the log file.

3. In the GPU tab, make sure all GPUs are selected. Uncheck the box 'Use CPU when performing GPU accelerated processing'.

Note: GPU acceleration is supported for image matching, depti based on depth maps, texture blending and mesh refinement. Warning: When using dedicated GPUs please turn off integrate Use CPU when performing GPU accelerated processing		-	
Use CPU when performing GPU accelerated processing	ОК	Cancel	Apply

Figure 2: When using dedicated GPUs disable integrated CPU and GPUs. In the GPU tab, disable the option 'Use CPU...' as shown above.

- 4. In the Advanced tab, ensure that the following settings are checked. Project Files:
 - Keep depth maps (see note below) Export/Import:
 - Strip file extensions from camera labels
 - Load camera calibration from XMP meta data
 - Load camera orientation angles from XMP meta data Miscellaneous:
 - Enable rich Python console

Note: Depth maps add to project file size, and if the goal is to run the workflow described here once (no reruns to test point cloud/mesh settings), this option can be disabled. However, if there is a need for example, to test different quality settings for Point Cloud generation reusing depth maps would save processing time. For this, however, 'Keep depth maps' must be selected **prior to starting the workflow** and hence the recommendation. For information on the Metashape settings, please refer to Appendix C in the Agisoft Metashape user Manual (Agisoft 2022a).

Vetashape Preferences
General GPU Network Appearance Navigation Advanced
Keep key points
Keep depth maps Store absolute image paths
Export / Import
Strip file extensions from camera labels
Load camera calibration from XMP meta data Load camera orientation angles from XMP meta data
Load camera location accuracy from XMP meta data
Load GPS/INS offset from XMP meta data
Load thumbnails from EXIF meta data Load satellite RPC data from auxiliary TXT files
Miscellaneous
Enable fine-level task subdivision
Enable VBO support
Enable mipmap generation Enable rich Python console
Copy last shape description for new shapes
Max basemap cache size: 100MB Clear
Tweaks Cleanup Projects Reset All Settings
OK Cancel Apply

Figure 3: Update Advanced Preferences. The settings to be checked are highlighted above.

Install external packages

The Python scripts described in this protocol use 3 site packages: exifread, numpy and pyproj, that must first be installed in Metashape. Note that the package versions must be compatible with the version of Python within Metashape Pro (See Agisoft\Metashape Pro\python\ to find the Python version).

- Package wheels are available on the <u>TERN GitHub repository</u> for Python versions 3.8 (Metashape Pro v 1.7.x and 1.8.x) and Python 3.9 (Metashape Pro 2.x). Download the zip file and unzip to extract the wheels. Install each package as follows.
- Open a Command (cmd) window as an Administrator. Change directory to folder where the wheel files were extracted. Install the 3 packages using:
 "<path to metashape pro>\python\python.exe" -m pip install <
 path to wheel file>
 Example:
 "C:\Program Files\Agisoft\Metashape Pro\python\python.exe" -m
 pip install ExifRead-2.3.2-py3-none-any.whl
 Note: Ensure that pip is updated if necessary, using:
- Note: Ensure that pip is updated if necessary, using:
 C:\Program Files\Agisoft\Metashape Pro\python\python.exe -m
 pip install --upgrade pip

Automated processing workflow

Python script metashape_proc.py is used to run the Structure from Motion workflow on the P1 and MicaSense imagery and generate co-registered orthomosaic tiff files (Table 1 and Table 2). Arguments and default values for metashape_proc.py are shown in Table 3.

Argument Type	Argument	Value	Default
Required	-crs	EPSG code of output projected coordinate reference system. Find the <u>EPSG code</u> of the required coordinate system.	NA
	-multispec	Path to multispectral images level0_raw folder	Relative to project location: /multispec/level0_raw
	-rgb	Path to RGB level0_raw folder containing the MRK files	Relative to project location: /rgb/level0_raw/
Optional	-smooth	Strength value to smooth the RGB 3D model. Select one of low, medium or high as appropriate for the vegetation on site. For more information see notes below and examples in 'Appendix 2: Setting the smoothing strength value'.	Low
	-drtk	Update 'rgb' image positions based on post-processed DRTK coordinates (blockshift). Path to txt file containing field and AUSPOS Cartesian coordinates for DRTK (See 'Appendix 3: Process D-RTK2 base station data').	None (image positions are not updated)

Table 3: Arguments and default values used in the Python workflow metashape_proc.py

Table 4: Example Arguments fo	or metashape_proc.py
-------------------------------	----------------------

Arguments	Interpretation
-crs "7855"	Use GDA2020 MGA Zone 55 as output projected CRS. Use defaults for image folder locations and smoothing strength. Blockshift is not enabled.
-rgb "G:\SASMDD0009\20220517\imagery\rgb\level0_raw\test" - multispec "G:\SASMDD0009\20220517\imagery\multispec\level0_raw\test" -crs "7854"	Use input paths as specified for rgb and multispec. Use GDA2020 MGA Zone 54 as output projected CRS. No blockshift.
-crs "7855" -drtk "G:\ :\SASMDD0009\20220517\drtk\auspos.txt"	Use GDA2020 MGA Zone 55 as output projected CRS. Use defaults for image folder locations, smoothing strength. Blockshift using coordinates in the auspos.txt file.

Setting the Strength value to smooth the RGB 3D model

Orthomosaics can be built using either a digital elevation model (DEM) or a mesh generated from the 3D point cloud. The methods and parameters used depend on the complexity of vegetation, and the purpose of the orthomosaic (e.g., is geometric accuracy of trees in the orthomosaic important for the analysis, or should the trees look 'aesthetically pleasing'?). Further testing is required to establish optimal settings for different environments. Here a polygonal mesh (3D model) is generated from the dense cloud, decimated, and smoothed to remove artefacts (e.g., on the edges between tree crowns and ground in complex vegetated environments). This smoothed surface generated from the RGB model is used as the projection surface for both RGB and multispectral imagery. See 'Appendix 2: Setting the smoothing strength value' for examples of models of different sites generated with varying smoothing strengths.

- Strength values are 50, 100, 200 respectively for low/medium/high
- low: for low-lying vegetation (grasslands, shrublands)
- medium or high: as appropriate for forested sites

Run Script

- 1. Download scripts metashape_proc.py and upd_micasense_proc.py from the <u>TERN GitHub</u> <u>repo</u>.
- 2. Open Agisoft Metashape Pro. Save project in format 'YYYYMMDD_ PlotName.psx' where YYYYMMDD is the date of data acquisition and PlotName is the name of TERN plot. *Example:* 20211012_SASRIV0001.psx.
- 3. Switch to the 'Console' tab to view progress of the script.
- 4. Select **Tools -> Run Script** (Ctrl+R). Under '**Script**', navigate to the location of the Python scripts and select **metashape_proc.py**.
- 5. Under 'Arguments', enter the arguments as necessary. Note that the -crs "<EPSG code>" is a required argument. See Table 3 for a list of arguments and default values. All argument values must be in double quotes "". It might be helpful to open a .txt file, type and save the arguments, and then copy-paste under 'Arguments'.
- 6. Click OK.
- 7. Note: If the Metashape window then closes without any error, this is due to a typo in the Arguments entered. Check that the argument values are in double quotes. See Table 3 for a list of arguments and default values. Use a txt file to type and check the arguments.

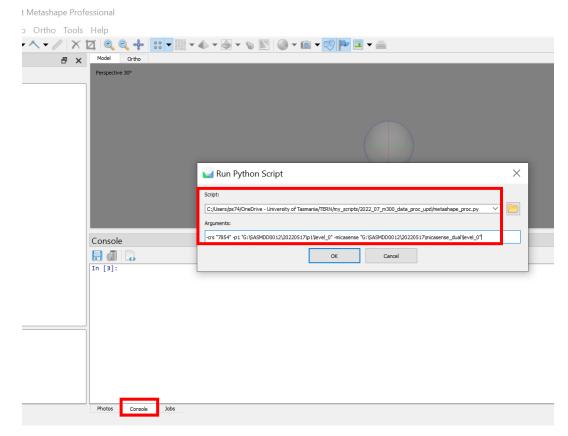


Figure 4: Automated Python workflow: use Tools-> Run Script to run metashape_proc.py. Enter Arguments as required and select OK.

8. Monitor progress through the Progress Dialog and the Console tab.

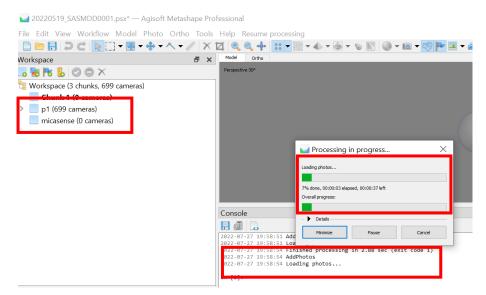


Figure 5: Monitor progress using the Console tab. In the Workspace pane above note that the p1 and micasense chunk creation is in progress.

9. When the rgb and multispec chunks are created, the script will be paused for user input on Calibration Images for the multispectral data. Select OK on the dialog that appears.

The following section goes over the steps to locate the calibrated reflectance panel (CRP) and select calibration images for the multispectral imagery.

- P/P P			
Eile Edit View Workflow Model Photo Ortho Tools Help Resume proces			
□ ≥ □ ッ < ↓ □ + ● + ◆ + ∧ + / × ↓ Q Q ∳ :: +			
	X Model Ortho	рл. 20230404122913 ВД-20230404122952 9031	2 0069
	Perspective 30°	DJI_20230404122913_0045	
B Workspace (2 chunks, 355 images)		*	V
> rgb (134 images)		Q.II_20230404122814_0007	DJI_20230404123052_0
> multispec (221 images)		DIT_20230404122814_0007 DIT_20230404122815_001_20230404122915_001_20230404122915_001_20230404122915_001_20230404122915_001_20230404122915	
			DJ1_20230404123017_0085
		DII_20230404122816_0008	0JI_20230404123050_0
		дл. 20230404122816_0008 D.Л. 20230404122917_004720204041229 D.Л. 20230404122949_0029	9_0067
		01_2023404122049_0029	DJI_20230404123019_0086
		D11_20230404122818_0009	DJI_20230404123048_0
		្លារា_20230404122818_0009 	7_0066
		DT_20230404122847_0028	DJI_20230404123021_0087
			D11 20220404122046 (
		дл.,2012/04/1228/9_0010 дл.,2012/04/1228/9_0010 дл.,2012/04/1228/9_002/	5_0065
		DJI_20230404122845_0027	,DJI_20230404123022_0088
			0 ^{31_20200404123022_0000}
	Console		
	🗄 🚳 🔒		
		+ 1M OPTIMIZE: XXXXXXXXXX 1.420/9 -> 4.918236-14 + Calibration initialized, mean error = 6.95543e-14 pix, max error = 3.21555e-13 pix	
		lm optimize: xxx 0.0717379 -> 0.0100092 Vignetting initialized, mean	
	2023-05-08 13:53:3	l m optimize: xxxx	
	2023-05-08 13:53:3	1 m optimize: xxxx- 0.076985 -	
	2023-05-08 13:53:3	vignetting initialized, mean in optimize: xxxxxxxx Complete Steps 1 to 3 listed on the Console and	
		calibration initialized, mean U click on 'Resume Processing' in the toolbar	
		Vignetting initialized, mean	
	2023-05-08 13:53:3	Calibration initialized, mean	
	2023-05-08 13:53:3	<pre>Im optimize: xxxx- 0.10397 -> Vignetting initialized, mean error = 0.000055229, Max error = 0.0227949</pre>	
		+ lm optimize: xxxxxxxxxxxx 1.4518 -> 4.89522e-14 + Calibration initialized, mean error = 6.92289e-14 pix, max error = 3.21555e-13 pix	
		+ lm optimize: xxx 0.106733 -> 0.00783894 + Vignetting initialized, mean error = 0.00929807, max error = 0.0360581	
	2023-05-08 13:53:3	; lm optimize: xxxxx	
Property Value	2023-05-08 13:53:3	Un optimize: xxx 0.138157 -> 0.08560156 Vignetting initialized, mean error = 0.08664361, max error = 0.0200655	
rgb	2023-05-08 13:53:3	Finished processing in 149.183 sec (exit code 1)	
Cameras 134	2023-05-08 13:53:3	SaveProject: path = F:/metashape_v2_test_pypojpipline/pyproj_pipline.psx Saving project	
Aligned cameras 0 Coordinate system WGS 84 (EPSG::4326)	2023-05-08 13:53:3 2023-05-08 13:53:3	3 saved project in 1.932 sec 3 Finished processing in 1.932 sec (exit code 1)	
Rotation angles Vaw, Pitch, Roll	2022.05.09 12:52:2	2. Add images completed	
	2023-05-08 13:53:3	3 **********************	
	2023-05-08 13:53:3	5 ####################################	
	2023-05-08 13:53:3	3 Step 1. In the Workspace pane, select multispec chunk. Select Tools-Calibrate Reflectance and 'Locate panels'. Press Can 3 Note: The csv of the calibration panel will have to be loaded if this is the first run on the machine. See the protocol	for more information.
	2023-05-08 13:53:3	3 Step 2. In the Workspace pane under multispec chunk open Calibration images folder. Select and remove images not to be u 3 Step 3. Press the 'Show Masks' icon in the tool bar and inspect the masks on calibration images.	sed for calibration.
	2023-05-08 13:53:3	Complete Steps 1 to 3 and pross so "Resume Processing' to continue. Reflectance calibration will be completed in the script	
	2023-05-08 13:53:3	3 #####################################	
		8 #####################################	
	In [1]:		
Workspace Reference	Photos Console	Jobs	
	2010010		

Figure 6: After the images are added, the script is paused for user input on micasense calibration. The steps to be completed are listed on the Console tab.

MicaSense: Select calibration images

10. Prior to interpolating MicaSense positions and deleting extra images, Calibration Images must be located and moved to the 'Calibration images' camera group so that they do not get deleted. Complete steps as per Appendix 4: Reflectance Calibration to select the images to be used for calibration.

Complete processing

11. Click on the 'Resume Processing' button on the toolbar to complete the processing workflow.

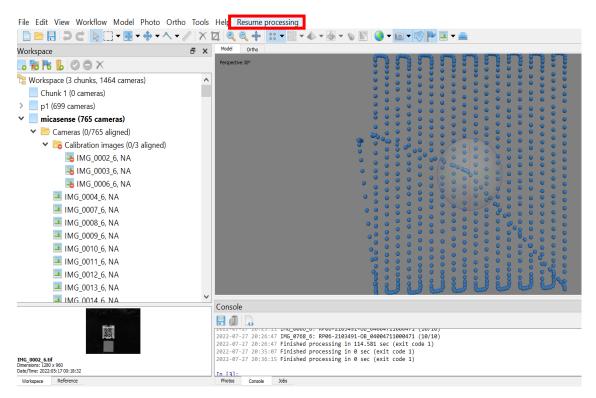


Figure 7: Click on 'Resume processing' in the toolbar to complete the automated workflow.

12. Progress will be displayed on the Metashape progress dialog.

	60. O	• • • • •	
	Processing in progress	×	0000
	_ 313		2 0 ° 0
	Analyzing photos		
			· · · · · · ·
	14% done, 00:01:17 elapsed, 00:07:25 left		
	Overall progress:		000
			8 0 8
	- Details		
	,		
	Minimize Pause	Cancel	
	. o		
	8 é 1		
	ğ e		8888
	A 6		6 Carl Carl
Console			
H 🕼 🗔			
	ed project in 1.955 sec		
2022-07-27 20:42:43 Fir 2022-07-27 20:42:43 Ana	ished processing in 1.956 sec (ex	it code 1)	
	lyzing photos Analyzing photos		
	*******		******
In [3]:			
Photos Console Jobs			

Figure 8: Script progress displayed in the progress dialog and on the Console tab.

- 13. The remaining steps are completed in the order listed in Table 2. As an estimate of the processing times, processing the rgb chunk for a 150 m x 150 m plot takes around 6 hours and multispec chunk around 3 hours. Workstation specs: 8 core intel i9-11900 2.5 GHz, 16 GB dedicated graphics memory (NVIDIA Quadro RTX5000), 2 TB SSD, 128 GB RAM.
- 14. When the processing is complete, the RGB and multispectral orthomosaic tif are saved in the <sensor>/level1_proc/ folders. If rgb/ and multispec/ folders are not found, files are saved in the project folder. Intermediate files are also saved in the project folder.

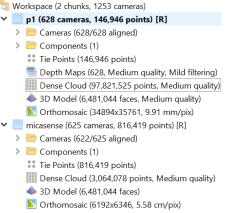


Figure 9: Workspace pane when p1 and micasense processing is complete.

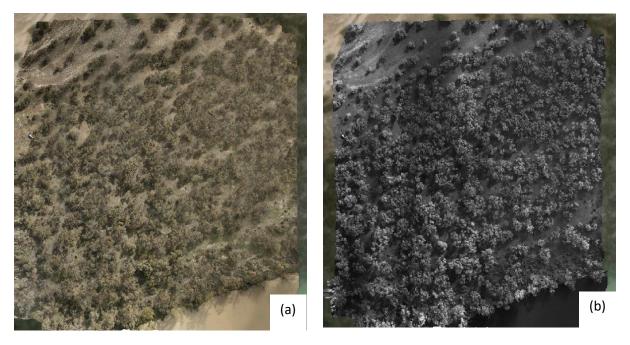


Figure 10: (a) P1 orthomosaic of a Eucalypt Woodlands TERN plot in Calperum, SA (b) Multispectral orthomosaic of the plot with MicaSense Redge-MX Dual NIR band visualised as grey band. The sunlit and dark strips in this orthomosaic are lighting artefacts due to varying cloud cover during the drone flight.

In case of any errors in the workflow, the Console tab (Figure 11) or the log file (selected in Agisoft Metashape) will have details on the error and processing step that it appeared on. To fix the error and restart processing using the Metashape GUI, refer to 'Summary of processing workflow using Agisoft Metashape' for equivalent Metashape Toolbar commands. To restart the workflow using a Batch Process refer to 'Appendix 5: Metashape Batch Process'.

2022-07-21 12:25:36 AnalyzePhotos 2022-07-21 12:25:36 analyzing photos... Analyzing photos... 2022-07-21 12:25:41 finished in 367.76 see 2022-07-21 12:31:43 Finished processing in 367.761 sec (exit code 1) 2022-07-21 12:31:43 SaveProject: path = G:/SASMDD0002/20220519/proc/metashape/tmp.psx 2022-07-21 12:31:43 Saving project... 2022-07-21 12:31:43 Saving project in 0.135 sec 2022-07-21 12:31:44 Finished processing in 0.136 sec (exit code 1) 2022-07-21 12:31:44 Vector([0.0, 0.0, 0.0]) 2022-07-21 12:31:44 Update GPS/INS offset for 2022-07-21 12:31:44 Vector([0.087, 0.0, 0.0]) for P1 2022-07-21 12:31:44 Aligning Cameras 2022-07-21 12:31:44 MatchPhotos: accuracy = High, preselection = reference, keypoint limi 2022-07-21 12:31:44 Matching photos... 2022-07-21 12:31:44 saved matching data in 0.003 sec 2022-07-21 12:31:44 scheduled 35 keypoint detection groups 2022-07-21 12:31:44 4838 or bsJ used (bs.12-8) 2022-07-21 12:31:44 scheduled 100 keypoint matching groups 2022-07-21 12:31:44 saved matching partition in 0.007 sec 2022-07-21 12:31:44 loaded keypoint partition in 0 sec 2022-07-21 12:31:44 loaded matching data in 0.001 sec 2022-07-21 12:31:44 Detecting points... 2022-07-21 18:02:12 orthomosaic updated in 0.155 sec 2022-07-21 18:02:13 prinished processing in 1745.1 sec (exit code 1) 2022-07-21 18:02:13 SaveProject: path = 6:/SASMDD0002/20220519/proc/metashape/tmp.psx 2022-07-21 18:02:14 saved project in 1.371 sec 2022-07-21 18:02:14 inished processing in 1.371 sec (exit code 1) 2022-07-21 18:02:14 ExportRaster: path = 6:\SASMDD0002\20220519/p1level_1\tmp_p1_ortho_01.tif, image_format = TIFF, resolution_x = 0.01, resolution_y = 0.01, save_alpha = off 2022-07-21 18:02:14 ExportEdster: path = 6:\SASMDD0002\20220519/p1level_1\tmp_p1_ortho_01.tif, image_format = TIFF, resolution_x = 0.01, resolution_y = 0.01, save_alpha = off 2022-07-21 18:02:14 ExportEdster: path = 6:\SASMDD0002\20220519/p1level_1\tmp_p1_ortho_01.tif 2022-07-21 18:02:48 Exported orthomosaic... 2022-07-21 18:06:48 Finished processing in 247.694 sec (exit code 1) 2022-07-21 18:06:48 Chunt p1 processing complete! 2022-07-21 18:06:48 6 2022-07-21 18:06:48 Chunn p1 processing complete! 2022-07-21 18:06:48 G 2022-07-21 18:06:48 Interpolate Micasense position based on P1 with blockshift[0. 0. 0.] 2022-07-21 18:06:48 Loading micasense images 2022-07-21 18:06:49 100 2022-07-21 18:06:51 200 2022-07-21 18:06:51 300 2022-07-21 18:06:55 300 2022-07-21 18:06:53 500 2022-07-21 18:06:53 500 2022-07-21 18:06:54 600 2022-07-21 18:06:55 700 2022-07-21 18:06:55 700
2022-07-21 18:06:55 800
2022-07-21 18:06:56 Get P1 position
2022-07-21 18:06:57 ImportReference: path = G:\SASMDD0002\20220519\proc\metashape\interpolated_micasense_pos.csv, columns = nxyz, delimiter = ,, skip_rows = 1, items = Referenc
2022-07-21 18:06:58 Finished processing in 0.037 sec (exit code 1)
2022-07-21 18:06:58 SaveProject: path = G:\SASMDD0002/20220519\proc\metashape\tmp.psx 2022-07-21 18:06:58 Finished processing in 0.037 sec (exit code 1) 2022-07-21 18:06:58 SaveProject: path = G:/SASMOD00002/20220519/proc/metashape/tmp.psx 2022-07-21 18:06:58 SaveProject: path = G:/SASMOD0002/20220519/proc/metashape/tmp.psx 2022-07-21 18:06:58 Deleting Micasense images that triggered outside P1 capture times 2022-07-21 18:06:58 SaveProject: path = G:/SASMOD0002/20220519/proc/metashape/tmp.psx 2022-07-21 18:06:58 SaveProject: path = G:/SASMOD0002/20220519/proc/metashape/tmp.psx 2022-07-21 18:07:01 SaveProject in 2.751 sec 2022-07-21 18:07:01 Execting primary channel to RedEdge-M, NIR (5.5mm) 2022-07-21 18:07:01 Updating Micasense GPS offset 2022-07-21 18:07:01 Updating Micasense GPS offset 2022-07-21 18:07:01 Updating tumbmalis... 2022-07-21 18:07:02 Finished processing in 1.212 sec (exit code 1) 2022-07-21 18:07:02 SaveProject: path = G:/SASMDD0002/20220519/proc/metashape/tmp.psx 2022-07-21 18:07:03 Saved project... 2022-07-21 18:07:03 AnalyzePhotos 2022-07-21 18:07:03 analyzing photos... Analyzing photos... 2022-07-21 18:07:03 finished in 144,478 sec 2022-07-21 21:43:58 loaded partition in 0.146 sec 2022-07-21 21:43:58 boundaries extracted in 0.021 sec 2022-07-21 21:44:08 377 images blended in 10.04 sec 2022-07-21 21:44:13 loaded partition in 0.107 sec 2022-07-21 21:44:21 323 images blended in 8.946 sec 2022-07-21 21:44:21 loaded partition in 0.084 sec 2022-07-21 21:44:25 boundaries extracted in 0.013 sec 2022-07-21 21:44:25 boundaries extracted in 0.013 sec 2022-07-21 21:44:31 325 images blended in 6.082 sec 2022-07-21 21:44:31 orthomosaic updated in 56.814 sec 2022-07-21 21:44:33 updating orthomosaic... 2022-07-21 21:44:30 updated in 56.814 sec

2022-07-21 21:44:33 Updating orthomosaic... 2022-07-21 21:44:33 Orthomosaic updated in 0.051 sec 2022-07-21 21:44:47 SaveProject: path = G:/SASMDD0002/20220519/proc/metashape/tmp.psx 2022-07-21 21:44:47 SaveProject in 3.346 sec 2022-07-21 21:44:51 Finished processing in 3.347 sec (exit code 1) 2022-07-21 21:44:51 Finished processing in 3.347 sec (exit code 1) 2022-07-21 21:44:51 Exporting orthomosaic... 2022-07-21 21:44:51 Sportmaster: path = G:/SASMD00002/20220519/micasense_dual\level_1\tmp_micasense_dual_ortho_05.tif, image_format = TIFF, raster_transform = RasterTransformValue, i 2022-07-21 21:44:51 Exporting orthomosaic... 2022-07-21 21:44:51 Exporting orthomosaic... 2022-07-21 21:44:51 Exporting orthomosaic... 2022-07-21 21:47:19 Exported orthomosaic at G:\SASMD00002\20220519\micasense_dual\level_1\tmp_micasense_dual_ortho_05.tif 2022-07-21 21:47:19 Exported orthomosaic at G:\SASMD00002\20220519\micasense_dual\level_1\tmp_micasense_dual_ortho_05.tif

Figure 11: Monitor script progress on the Console tab.

Step-by-step processing using the Metashape GUI

This section describes the workflow using Metashape GUI commands. Python script **metashape_upd_cam_pos_only.py** is used to update the rgb and multispec camera positions. The rest of the workflow is completed manually using Metashape Toolbar commands.

Add images

Open Agisoft Metashape Pro. Save project with file name format 'YYYYMMDD_ PlotName.psx' where YYYYMMDD is the date of data acquisition and PlotName is the name of TERN plot. *Example:* 20211012_SASRIV0001.psx.

- 1. In the Workspace pane, right-click on 'Chunk 1' and rename to 'rgb'.
- Choose Workflow -> Add Folder and add level0_raw folder under rgb/. (Please note that the folder and chunk naming is different in the below screenshots which followed an older naming convention.)
- 3. In the dialog that opens next, select 'Single cameras' and OK.

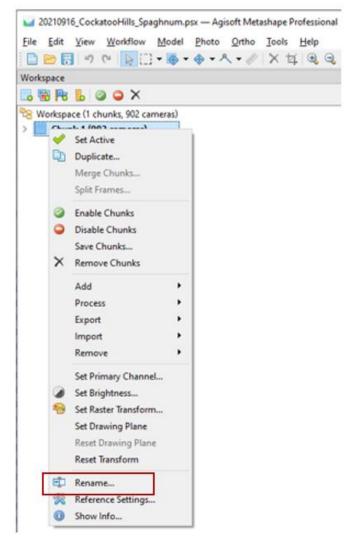


Figure 12: Use the context menu and rename chunk.

屋 Untitled* — Ag	isoft Metashape Profe	ssional	Value Add Photos		
<u>F</u> ile <u>E</u> dit <u>V</u> iew	Workflow Model	<u>P</u> hoto <u>O</u> rtł	Please select data layout:		
1 🖻 🔚 🔊	🗟 Add Photos	T	Single cameras		
Workspace	🔁 🛛 Add Folder				
Mdd Folder			Dynamic scene (4D)		
← → × ↑ → TERN2_SSD (G:) >	SASMDD0002 > 20220519 > p1				
-	· · · · ·				
	Name	Date modified			
This PC	level_0	17/05/2022 11:50 AM			
3D Objects	level_1	3/06/2022 10:01 AM	n l l l l l l l l l l l l l l l l l l l		
Desktop					
Documents					
Downloads					
Music Pictures					
Videos					
Local Disk (C:)					
DATA (D:)					
DATA (E)					
DATA (F:)					
TERN2_SSD (G:)					
Groups (N:)					
ps74 (\\homedrive.its.utas.edu.au\h					
👳 Research (R:)					
👳 FinAdmin (S:)					
TERN2_SSD (G:)			OK Cancel		
A Network	×				
Folder: level_0	Folder: level_0				
			Select Folder Cancel		

Figure 13: Use Workflow-Add Folder and select 'Single cameras' to add P1 images.

- 4. Right-click in the Workspace pane to 'Add Chunk'. Right-click on the new Chunk and rename to 'multispec'. Active chunks are shown in bold. If the multispec chunk is not active, double click on it.
- 5. Add multispectral imagery by choosing Workflow -> Add Folder and add level0_raw/ folder from the multispectral sensor.

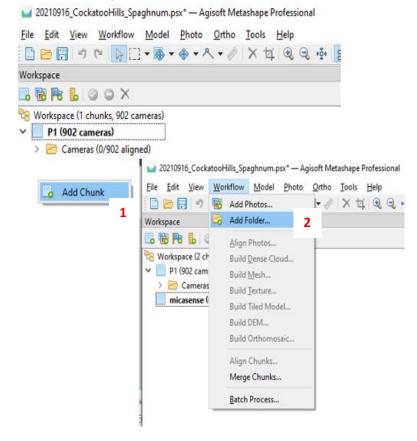


Figure 14: Add folder containing MicaSense images

6. After the photos have been loaded (takes several minutes for large datasets), the following window appears. Select 'Multi-camera system' and click OK.

Please select data layout:	
Single cameras	Arrange images based on meta data add 1657 cameras
Multi-camera system	Create sensor from each subfolder add 2000 cameras
Dynamic scene (4D)	
	OK Cancel

Figure 15: Select 'Multi-camera system' and arrange images based on metadata

7. Any Calibration images automatically detected using the panel QR code will be moved to the 'Calibration images' folder under multispec chunk. Click OK.

🖬 Agi:	soft Metashape X
1	Calibration images were moved to separate folder.
	ОК

Figure 16: Any calibration images detected using the QR code will be moved to a separate folder.

8. In the main 'Model' window, check that the layout of the flight is as expected. MicaSense data acquisition is started using a target altitude tolerance so there will be images outside of the flight area. These images will be automatically removed in the Python workflow ('Interpolate MicaSense camera positions').

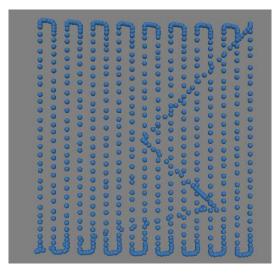


Figure 17: Check layout of flight in the Model window

MicaSense reflectance calibration

- Prior to interpolating MicaSense positions and deleting extra images, Calibration Images must be located and moved to the Calibration Images folder so that they do not get deleted. Complete steps per Appendix 4: Reflectance Calibration to select the images to be used for calibration.
- After images have been selected and masks checked as per the step above, complete reflectance calibration. Open the Calibrate Reflectance dialog again (Tools->Calibrate Reflectance). Ensure that 'Use reflectance panels' and 'Use sun sensor' are checked. Click OK.

ages			Pane	l Calibration	
	Panel RP06-2103491-OB (10/10) RP06-2103491-OB (10/10) RP06-2103491-OB (10/10)		1 2 3 4 5 6 7 8 9 10	Band Blue-444 Blue Green-531 Green Red-650 Red edge-705 Red edge-705 Red edge-740 NIR	Reflectance 0.469217 0.469736 0.471322 0.471882 0.472499 0.472115 0.472066 0.472005 0.472108 0.4721188
arameters		Locate panels			Select panel
Use reflectance	panels	Use sun s	ensor		

Figure 18: Complete reflectance calibration. Select the correct panel. Check 'Use reflectance panels' and 'Use sun sensor' parameters.

Interpolate MicaSense camera positions

MicaSense camera locations are based on navigation-grade GPS. Before processing the imagery, the camera positions must be interpolated using the P1 positions georeferenced using the on-board GNSS RTK. If post-processing of the D-RTK2 base station is required, the script can blockshift P1 camera positions based on the D-RTK 2 coordinates from the AUSPOS report, and interpolate MicaSense camera positions based on the shifted P1 positions.

Install packages as described in section 'Install external packages'. Refer to Table 5 for information on the arguments and default values. The following steps will be done using python scripts **metashape_only_upd_cam_pos.py** and upd_micasense_pos.py.

- Update camera positions in 'rgb' chunk based on AUSPOS D-RTK coordinates (if enabled using -drtk).
- Convert coordinates to target projected coordinate reference system.
- Interpolate MicaSense positions using P1 camera positions (sub-second available from MRK file).
- Transform MicaSense coordinates to projected coordinate system to interpolate based on P1 coordinates and timestamps.
- Assign altitude of 0 m to MicaSense images captured outside of P1 acquisition time. Use this value to delete these MicaSense images. (Hence the need to first locate Calibration images in the previous section to prevent their deletion).

Table 5: Arguments and default values for metashape_only_upd_cam_pos.py to update P1 and interpolate MicaSense
camera positions

Argument	Argument	Value	Default
Туре			
		EPSG code of output	
Required	-crs	projected coordinate	NA
		reference system	
Optional	-drtk	Update P1 coordinates using the DTK base station post- processed cooridnates. Pass txt file containing field and AUSPOS Cartesian coordinates for DRTK (See 'Appendix 3: Process D-RTK2 base station data')	None (P1 positions not updated)

Run Script

- 1. Download scripts metashape_only_upd_cam_pos.py and upd_micasense_proc.py from the <u>TERN GitHub repo</u>.
- 2. Switch to the 'Console' tab to view progress of the script.
- Select Tools -> Run Script (Ctrl +R). Under 'Script', navigate to the location of the two Python scripts (metashape_only_upd_cam_pos.py and upd_micasense_pos.py) and select metashape_only_upd_cam_pos.py.

🖬 Run Python Script	×
Script:	
a_proc_upd/metashape_only_upd_cam_pos.py	~ 🖻
Arguments:	
-crs "7854"	
OK Cancel	

Figure 19: Run script to update camera positions in rgb and multispec chunks.

- 4. Under 'Arguments', enter the arguments as necessary. Note that the -crs "<EPSG code>" is a required argument. See Table 5 for arguments and default values. All argument values must be in double quotes "". It might be helpful to type and save the arguments in a .txt file, and copy-paste under 'Arguments'.
- 5. Click OK.

Note: If the Metashape window then crashes without any error message, this is likely due to a typo in the Arguments entered. Check that the argument values are in double quotes. See Table 3Table 5 for a list of arguments and default values. Use a txt file to type and check the arguments.

Console	F ×
2022-07-28 11:23:39 Script start	~
2022-07-28 11:23:39 G:\SASMDD0003\20220518\micasense\level_0 does not exist. Now looking for micasense_dual instead	
2022-07-28 11:23:39 6	
2022-07-28 11:23:39 Interpolate Micasense position based on P1	
2022-07-28 11:23:39 With blockshift for P1: [0. 0. 0.]	
2022-07-28 11:23:39 Loading micasense images	
2022-07-28 11:23:39 0	
2022-07-28 11:23:40 100 2022-07-28 11:23:42 200	
2022-07-25 11:23:42 200 2022-07-28 11:23:43 300	
2022-07-20 11:2:3:45 300	
2022-07-20 11:23:49 100	
2022-07-28 11:23:52 680	
2022-07-10 11:23:55 Get P1 position	
2022-07-28 11:23:59 ImportReference: path = G:\SASMDD0003\20220518\tmpproc\metashape\interpolated micasense pos.csv, columns = nxyz, delimiter = ,, skip row:	s
= 1, items = ReferenceItemsCameras, crs = GDA2020 / MGA zone 54	-
2022-07-28 11:24:00 Finished processing in 0.06 sec (exit code 1)	
2022-07-28 11:24:00 SaveProject: path = G:/SASMDD0003/20220518/tmpproc/metashape/tmpproc_20220518_SASMDD0013.psx	
2022-07-28 11:24:00 Saving project	
2022-07-28 11:24:00 saved project in 0.632 sec	
2022-07-28 11:24:00 Finished processing in 0.632 sec (exit code 1)	
2022-07-28 11:24:00 Deleting MicaSense images that triggered outside P1 capture times	
2022-07-28 11:24:01 SaveProject: path = G:/SASMDD0003/20220518/tmpproc/metashape/tmpproc_20220518_SASMDD0013.psx	
2022-07-28 11:24:01 Saving project	
2022-07-28 11:24:03 saved project in 2.95 sec	
2022-07-28 11:24/03 Finished processing in 2.971 sec (exit code 1)	
2022-07-28 11:24:04 End of skript. Updated micasense camera positions imported in Reference pane.	
In [1]:	
	\checkmark

Figure 20: Monitor script progress through the Console tab.

- 6. Monitor the Console tab for progress of the script.
- 7. When the script is complete, in the Workspace pane note that the multispec chunk now has fewer cameras as the extra images have been deleted. In the Reference pane, note that the

CRS has been updated to the selected projected CRS. The coordinate columns will have updated values based on the P1 RTK locations.

The following sections go over the rest of the workflow on the Metashape GUI.

Zenmuse P1 (RGB)

In the Workspace pane, double click on the 'rgb' chunk to make it active (chunk label must be in bold).

Camera Calibration: GPS/INS Offset

Select Tools-> Camera Calibration to enter lever-arm offsets. The GNSS RTK georeferencing provides the coordinates to the single gimbal position. The offsets from this position to Gimbal 1 (in dual gimbal mount) must be entered to account for the offset in gimbal position (Figure 22). For more information on this setting refer to the Agisoft Metashape Pro manual (Agisoft 2022a).

 In the GPS/INS Offset tab, check 'Enable Reference'. Enter offsets. Offset (m): X: 0.087, Y and Z: 0.

20210916_CockatooHills_Spaghnum.psx" — Agisoft M	letashape Professional	
Eile Edit View Workflow Model Photo Ortho	Jools Help	
🗎 🖻 🗒 🤊 🕫 💽 🖓 ヤ 🗒 🖻	Markers +	
Reference	Tie Points	
	Dense Cloud	
Α	Mesh +	
Cameras E	0014	
	io G Orthomosaic • ·	
	io Lens •	
□ DJ 20210916132837 0004 45		
DJ_20210916132838_0005 45	Camera Calibration	
	Optimize Cameras	
DJI 20210916132840 0007 45	Galibrate Reflectance	
DJI_20210916132841_0008 45	6 Calibrate Colors	
🗹 🗵 DJI_202109161 😈 Camera Calibration		– 🗆 X
🗹 🖪 DJI_202109161		
ZenmuseP1 (35mm)	Camera type:	Frame v
DJ_202109161 902 images, 8192x5460	Pixel size (mm):	0.00439486 x 0.00439486
DU_202109161	Focal length (mm):	35
DU_202109161	Enable rolling shutter compensation	Film camera with fiducial marks
DJI_202109161	Initial Adjusted Bands GPS/INS Offset	
DI_202109161		
DI_202109161	Reference Accuracy	Adjusted Variance
DJ 202109161	X (m): 0.087 0.05	
	Y (m): 0 0.05	
	Z (m): 0 0.05	
	Yaw (*): 0 2	
	Pitch (*): 0 2	
	Roll (*): 0 2	
	Enable reference	Adjust GPS/INS offset

Figure 21: Update GPS offsets for P1 from the single gimbal position

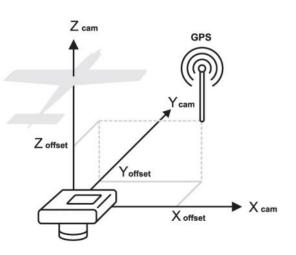


Figure 22: GPS offsets as defined in Agisoft Metashape (Source: Agisoft 2022a)

Inspect camera settings in the Reference pane

In the Reference pane, check that the Coordinate System has been updated (EPSG was input to the py script in section 'Run Script').

Reference					
😕 🖻 🖬 🖉 🖉 🖏 👘 🖉 🗐 🖉					
Cameras Convert	Easting (m)	Northing (m)	Altitude (m)	Accuracy (m)	
DJI_20210916132833_0001	456647.607080	5324170.942460	670.099069	10.000000	
DJI_20210916132835_0002	456647.558042	5324171.334233	670.066069	10.000000	
DJI_20210916132836_0003	456647.356864	5324173.837679	670.074069	10.000000	
DJI_20210916132837_0004	456647.010082	5324177.312032	670.095069	10.000000	
DJI_20210916132838_0005	456646.602745	5324181.587374	670.117069	10.000000	
DJI_20210916132839_0006	456646.162676	5324186.514085	670.117069	10.000000	
Image: Control of Con	Coordinate	Reference System / MGA zone 55	(EPSG::785	5)	×
DJI 20210916132848 0014 <	Rotation an	ngles:		Yaw, Pitch, Roll	~
Markers Easting (m) Northi Total Error Control points Check noints	Items	IS		Markers	
Scale Bars Distance (m) Accuracy (m) Total Error Control scale Check scale b		-	ОК	Cancel	

Figure 23: Check that the CRS has been updated as per input to the script.

• Click on 'Settings' icon. Update 'Camera accuracy' to 0.1m which is the expected accuracy for M300 GNSS RTK.

🖬 20210916_CockatooHills_Spaghnum.psx* — Agi:	oft Metashape Professional	
<u>File Edit View W</u> orkflow <u>M</u> odel <u>P</u> hoto	<u>O</u> rtho <u>T</u> ools <u>H</u> elp	
🗋 🖻 🗒 🤊 (*) 💽 🗆 🖷 🔛	▼ ∥ X ¼ 🔍 🤤 🍁 🔡 🗸 🌢 🔻	
Reference		æ ×
2 1 2 2 2 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3		
Cameras	ettings ing (m) Northing (m) Altitude (r	n) ^
DJI_20210916132833_0001	456647.619210 5324170.955755 670.099116	5
DJI_20210916132835_0002	Mathematical Reference Settings	×
DJI_20210916132836_0003	Coordinate System	
DJI_20210916132837_0004 DJI_20210916132838_0005		212
DJI 20210916132839_0006	GDA2020 / MGA zone 55 (EPSG::7855)	~ 🛠
DJI_20210916132840_0007	Camera reference	
DJI_20210916132841_0008	GDA2020 / MGA zone 55 (EPSG::7855)	· · · · · · · · · · · · · · · · · · ·
DJI_20210916132842_0009	Marker reference	
DJI_20210916132843_0010 DJI_20210916132844_0011	GDA2020 / MGA zone 55 (EPSG::7855)	~
DJI_20210916132845_0012	Rotation angles:	Yaw, Pitch, Roll ~
JI_20210916132847_0013	-	
DJI_20210916132848_0014	Measurement Accuracy	Image Coordinates Accuracy
DJI_20210916132849_0015	Camera accuracy (m): 0.1	Marker accuracy (pix): 0.5
<	Camera accuracy (deg): 10	Tie point accuracy (pix): 1
	Marker accuracy (m): 0.005	
	Scale bar accuracy (m): 0.001	
	Miscellaneous	
t	Capture distance (m):	
	ОК	Cancel
L		

Figure 24: Update camera accuracy to 0.1 m

Disable cameras with low Image quality

In Metashape, Image Quality can be calculated based on the sharpness in the most focused part of the picture. Metashape recommends that images with low quality value be excluded.

- In the 'Photos' tab, select 'Details' view. Right-click on any image to 'Estimate Image Quality'. In the 'Analyze Photos' dialog, select Apply to 'All cameras'.
- When this step is complete, sort photos based on 'Quality' column. Inspect images with Quality less than 0.7. Right-click on these image(s) to 'Disable cameras'.

20210916132833.000	Image: Constraint of the second sec	2 DJI 20210916132836.000	B DJI 2021091	6132837 0004 DJI J	0210916132838 0005 D	JU 202109161328	39 0006	^			
	Photos									é	Ð
	0 0 × 2 1	🏭 🖸 🖷 🖬 🕶									
Sec. 1	Label	Size	Aligned	Quality	Date & time	Make	Model	Focal length	F-stop	ISO	
	DJI_20210916132833	0001 8192x5460			2021:09:16 13:28	DJI	ZenmuseP1	35	F/3.5	1600	J
JJ_20210916132840_000	I DJI_2021091613	Open			2021:09:16 13:28	DJI	ZenmuseP1	35	F/3.5	1600)
	I DJI_2021091613	Open in New Tab			2021:09:16 13:28	DJI	ZenmuseP1	35	F/3.5	1600)
	DJI_2021091613	Enable Cameras			2021:09:16 13:28	DJI	ZenmuseP1	35	F/4	1600	1
W. L. OP 1	🔳 DJI_2021091613				2021:09:16 13:28	DJI	ZenmuseP1	35	F/4	1600	1
MAX 2 MA	🔳 DJI_2021091613 🎴	Disable Cameras			2021:09:16 13:28		ZenmuseP1	35	F/4	1600	
JI 20210916132847 00"	DJI_2021091613	Move Cameras			2021:09:16 13:28		ZenmuseP1	35	F/4	1600	
JI_20210910132847_00	■ DJI_2021091613 ×	Remove Cameras			2021:09:16 13:28		ZenmuseP1	35	F/4	1430	
Shares Alexand	DJI_2021091613	Align Selected Cameras			2021:09:16 13:28		ZenmuseP1	35	F/4	1270	
	JJI_2021091613	Reset Camera Alignmen			2021:09:16 13:28		ZenmuseP1	35	F/4	1010	
iotos Console Ja	DJI_2021091613	Estimate Image Quality			2021:09:16 13:28		ZenmuseP1	35	F/4	1010	1
	DJI_2021091613	Adjust Color Levels			2021:09:16 13:28		ZenmuseP1 ZenmuseP1	35	F/4	900 800	
	DJI_2021091613	View Matches			2021:09:16 13:28 2021:09:16 13:28		ZenmuseP1 ZenmuseP1	35	F/4 F/4	800	
	DJI_2021091613	Filter Photos by Camera:	•		Analyze F		Zenmuseri	33	F/4 ×	800 800	
	 DJI_2021091613 DJI_2021091613 DJI_2021091613 DJI_2021091613 	Masks Export Depth	•		Parameters					800 800 800	
	DJI_2021091613 Photos Console	Check Paths Change Path Open Containing Folder	-		Apply to	nasked ima	ge regions				:
	•	Rename Show Info			All came	eras d cameras	-	i tire workspace Irrent photo			-

Figure 25: Estimate image quality for all cameras.

• Review the camera layout in the main window. Remove images captured when the drone was turning at the end of flight lines.

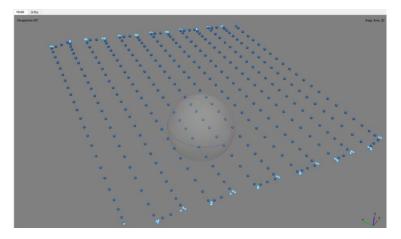


Figure 26: Remove extra images at the end of flight lines

Note on Batch processing: Many of the following steps can be automated using a batch script through Workflow -> Batch Process menu. See 'Appendix 5: Metashape Batch Process' for an example using Batch Process once both the chunks have been setup. Here, the steps are listed separately for the RGB and multispectral chunks.

Align Photos

Image alignment is done to estimate the exterior and interior orientation parameters based on bundle block adjustment (please refer to Agisoft 2022a for more information on this process).

Select Workflow->Align Photos. Use the settings as shown in the image below:

- Accuracy: 'High'
- **Reference preselection**: 'Source'. Select overlapping pairs of images based on the measured camera coordinates. This is recommended as camera locations georeferenced with high accuracy are available.
- Uncheck 'Generic preselection'. When enabled, overlapping pairs of images are selected by matching photos at a lower accuracy setting first. However, in drone surveys of TERN plots, where only a few tie points might be detected at the image matching stage, using only Reference preselection without Generic preselection is recommended by Metashape.
- Use default limits for key point and tie points. *These indicate the upper limit of feature points on every image during the image matching process.*

At the end of this step, a tie point cloud will be generated which can be used to visualise the alignment results.

🖬 Align Photos	×
▼ General	
Accuracy:	High \checkmark
Generic preselection	
Reference preselection	Source ~
Reset current alignment	
Advanced	
Key point limit:	40,000
Tie point limit:	4,000
Apply masks to:	None
Exclude stationary tie points	
Guided image matching	
Adaptive camera model fitting	
ОК	Cancel

Figure 27: Align Photos with Accuracy: High, Reference preselection set to Source.

Optimise Camera Alignment

This step performs a full bundle adjustment on the aligned images based on available measurements and camera accuracies and can improve the results of the alignment.

- In the Reference pane, ensure that all cameras to be used for optimisation are checked (this is the default setting). Camera accuracy settings were updated earlier in this workflow.
- Click on the 'Optimize Cameras' icon.
- Use the default settings (shown in figure below):
 - General: Fit f, k1, k2, k3, cx, cy, p1, p2
 - Disable Advanced settings

For more information on the values being optimised, refer to the Agisoft Manual (Agisoft 2022a).

File Edit View Workflow Model Photo	Ortho Tools He	p			
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Reference					
😕 🖬 📾 🗰 🥕 🖎 🗊 🗔 🖼 🖷 🗐 🔗					
Cameras Optimize Cameras	Easting (m)	Northing (m)	Altitude (m)	Accura	🖬 🖬 Optimize Camera Alignment 🛛 🔷 🖓
DJI_20210916132833_0001	456647.607080	5324170.942460	670.099069	0.1000	
DJI_20210916132835_0002	456647.558042	5324171.334233	670.066069	0.1000	General
JI_20210916132836_0003	456647.356864	5324173.837679	670.074069	0.1000	
JI_20210916132837_0004	456647.010082	5324177.312032	670.095069	0.1000	Fit f Fit cx, cy
DJI_20210916132838_0005	456646.602745	5324181.587374	670.117069	0.1000	🗹 Fit k1 🗹 Fit p1
DJI_20210916132839_0006	456646.162676	5324186.514085	670.117069	0.1000	Fit k2
DJI_20210916132840_0007	456645.660848	5324192.196141	670.135069	0.1000	
JI_20210916132841_0008	456645.154852	5324197.778014	670.139069	0.1000	Fit k3 🗌 Fit b1
DJI_20210916132842_0009	456644.640741	5324203.390928	670.128069	0.1000	Fit k4 Fit b2
DJI_20210916132843_0010	456644.164996	5324208.455662	670.125069	0.1000	
DJI_20210916132844_0011	456643.661620	5324213.893202	670.124069	0.1000	Advanced
DJI_20210916132845_0012	456643.155398	5324219.363925	670.109069	0.1000	
DJI_20210916132847_0013	456642.644089	5324224.789534	670.109069	0.1000	Adaptive camera model fitting
DJI_20210916132848_0014	456642.106789	5324230.321914	670.110069	0.1000	Estimate tie point covariance
DJI_20210916132849_0015	456641.584285	5324235.702706	670.100069	0.1000	
DJI_20210916132850_0016	456641.051472	5324241.390344	670.102069	0.1000	Fit additional corrections
DJI_20210916132851_0017	456640.557454	5324246.754878	670.096069	0.1000	
DJI_20210916132852_0018	456640.072296	5324251.806339	670.106069	0.1000	(
DJI_20210916132853_0019	456639.549126	5324257.201007	670.096069	0.1000	0
DJI_20210916132854_0020	456639.031795	5324262.679211	670.088069	0.1000	(
DJI_20210916132855_0021	456638.503918	5324268.194659	670.099069	0.1000	(
DJI_20210916132856_0022	456638.003804	5324273.503414	670.112069	0.1000	0
DJI_20210916132858_0023	456637.495444	5324279.105481	670.107069	0.1000	OK Cancel
✓ III 20210916132859 0024	456636.989074	5324284.545222	670.104069	0.1000	OK Cancel



Build Point Cloud

A dense cloud can be built using the estimated camera positions. Depth maps calculated for the overlapping image pairs are used to generate a dense point cloud.

Select Workflow -> Build Point Cloud (if using Agisoft Metashape Pro version 1.x, select Workflow -> Build Dense Cloud instead), and enter settings as follows:

- **Quality**: Medium. *Higher quality settings result in a more detailed geometry but require longer processing times.*
- **Depth filtering**: Mild. Depth filtering mode sets the level of noise filtering, Mild or Moderate are useful for these datasets. Whereas Aggressive could remove more points than intended and Disabled will result in a very noisy point cloud.

👿 metashape_proj_manual_v2.psx — Agisoft Metashape Professional

File	Edit View	Wor	kflow	Model	Photo	Ortho	Tools	Help					
1	🖻 🗒 🔊	6	Add P	hotos		- 🤌	Xt	1 🔍 🤇	Ξ				
Work	cspace	2	Add F	older				8 ×]				
-	Vorkspace (2 ch multispec (7 rgb (711 im) P Images () P Compor 88 Tie Point		Build I Build I Build I Build I Build I Build I Build I Align I Merge	Photos Mesh Texture Tiled Mod Point Clou DEM Orthomos Panorama Chunks e Chunks Process	ıd aic		' General ource dat uality: Reuse o ' Advance epth filter Calcula	a: depth map ed ing: te point co	DS	ЬК	Depth maps Medium Mild Cancel		×
									1		2 240 10	100	100.1

Figure 29: Build point cloud using mild filtering and medium quality

Orthomosaic generation

Orthomosaic can be built using different orthorectification surfaces, for example:

- 1. Ground surface generated from lidar point cloud.
- 2. Ground points classified in the photogrammetric point cloud in Metashape, and the resulting surface built from ground points can be used as the orthorectification surface.
- 3. The dense photogrammetric point cloud can be used to reconstruct a 3D polygonal mesh model which can be used as the surface.
- 4. The surface model as above smoothed to remove artefacts due to sharp differences in height e.g., canopy edges.

The surface used depends on the intended use of the orthomosaic e.g., is geometric accuracy of trees in orthomosaic important for the analysis? It is also likely to be determined by the complexity of vegetation on the site. For example, classifying ground points in the photogrammetric point cloud tends to have poor results in densely vegetated sites. Further research/testing is required to establish optimal settings for different environments. Here a polygonal mesh is generated from the dense cloud. The mesh is smoothed to remove artefacts (e.g., on the edges between tree crowns and ground in complex vegetated environments) and used to project both the RGB and multispectral imagery.

Build Mesh

Select Workflow->Build Mesh.

- Source data: Point cloud (if using Metashape Pro version 1.x, select Dense Cloud) •
- **Surface type**: Height field. The surface type is optimised for modeling planar surface rather than an arbitrary object.
- Face count: Medium. Used to identify the maximum number of polygons in the final mesh. A low value might be appropriate (in which case the decimate mesh step below could be skipped) *but needs further testing to compare results* (To do list).
- Use default values for other settings.
- On Metashape Pro version 2.x, in the dialog box that appears next, click on 'Yes' to build the mesh from the point cloud.

File		View		kflow	Model	Photo	Ort	🖬 Build Mesh				×
Refer	📂 闭 ence	2		100000000000000000000000000000000000000	hotos older		-	General				_
B				Alian	Photos			Source data:		Point cloud		~
Came				Build I	Dense Clo	ud		Surface type:		Height field (2.5	D)	~
		210916 210916			Mesh			Quality:				~
					Texture			Face count:		Medium (5,432,	177)	~
Image: Constraint of the system Image: Constraint of the system <td colspan="2">Build DEM Build DEM Build Orthomosaic Align Chunks Merge Chunks</td> <td></td> <td>All vertex colors volumetric masks</td> <td>Enabled (default</td> <td></td>	Build DEM Build DEM Build Orthomosaic Align Chunks Merge Chunks			All vertex colors volumetric masks	Enabled (default							
		L v F f	t is red Jsually vhen Proces rom F Contir	comme y the ge Mesh is ssing tin Point Clo nue buile	ometry of built base	the mode d on the P er in comp from the	l is more oint Clou parison to Point Clo	Build Point Clou oud?	OK rce data. M usage is low ud and Build N			
								Ye	s N	10		

Figure 30: Build mesh from dense cloud. Surface type: Height field, face count: Medium.

The aim is to create a smooth surface to project the images. With the medium quality mesh, this is done by decimating and smoothing the mesh surface as follows.

Decimate Mesh: Select Tools-> Mesh->Decimate mesh. Enter an appropriate value, for example, to halve the number of faces in the original mesh.

Smooth Mesh: Select Tools ->Mesh->Smooth mesh. The strength of smoothing depends on the complexity of canopy, hence smoothing must be done in iterative steps. Three values are recommended for low, medium, and high smoothing: 50, 100 and 200 respectively. Further testing on data from densely vegetated sites is required to ensure these settings are appropriate for those environments (see To do list).

To smooth the mesh in iterative steps, start with a small Strength value, inspect the smoothed model, build orthomosaic from each mesh to compare the results. To avoid overwriting the default mesh, first duplicate the mesh using the context menu.

🖬 Smooth Mesh	×
General	
Strength:	100.00
Apply to selected faces	
▼ Advanced	
Fix borders	
Preserve edges	
OK	Cancel

Figure 31: Smooth the mesh in iterative steps.

Export Model

The RGB smoothed model will be used as the surface for MicaSense orthomosaic generation as well to ensure consistency.

- Right click on the smoothed 3D model to export the model.
- Under **Coordinate System** enter the output projected target CRS. Use default values for other settings.
- Save as obj file in the Metashape project directory. Recommended naming format: <project_name>_rgb_smooth_<smooth_strength_value>.obj

V Export Model - Wavefront OB	X X
Coordinate System	
GDA2020 / MGA zone 54 (EPSG::7	7854) 🗸 🌾
Shift: E: 0 N: 0	A: 0
Export Parameters	
Vertex colors	Convert to 8 bit RGB
Vertex normals	Cameras
Vertex confidence	Markers
Export texture IPEG	
Raster transform:	None 🗸
✓ Include comment Generated	with Agisoft Metashape
Binary encoding Precision:	6
Use UDIM texture layout	
Save alpha channel	
Clip to boundary shapes	
OK	Cancel

Figure 32: Export smoothed model as .obj file in the target projected CRS.

Build Orthomosaic

In this step the images are stitched together by merging the original images projected on to the smoothed mesh.

- Using the context menu in the Workspace pane, ensure that the smoothed 3D Model is set as default.
- Select Workflow->Build orthomosaic.
- Surface: Mesh.
- Enable '**Refine seamlines'**: this will ensure the automatically created seamlines bypass complex vegetation and avoid visual artefacts in the orthomosaic.
- Use the default pixel size (m).

🥁 Build Orthomosaic	×
Projection	
Type: Geograph	nic O Planar O Cylindrical
GDA2020 / MGA zone 54 (EPSG	S::7854) 🗸 🌾
Parameters	
Surface:	Mesh ~
Blending mode:	Mosaic (default) 🗸 🗸
Refine seamlines	
Enable hole filling	
Enable ghosting filter	
Enable back-face culling	
Pixel size (m):	0.00967108 X
Metres	0.00967108 Y
O Max. dimension (pix):	4096
Region	
Setup boundaries:	- X
Estimate	- Y
Total size (pix):	x
ОК	Cancel

Figure 33: Build orthomosaic using the smoothed mesh

Export Orthomosaic

After the Orthomosaic is generated, in the Workspace pane, right-click on the orthomosaic and select Export Orthomosaic -> Export JPEG/TIFF/PNG.

- Update the Pixel size (round the default resolution to 2 places).
- Select options: 'Write tiled TIFF', 'Write BigTIFF file', 'Generate TIFF overviews'
- Accept other default settings
- Save the tiff in rgb/level1_proc/ directory. Recommended naming format is <project_name>_p1_ortho_<resolution_in_m>.tif

Workspace		🖬 Export Orthomos	saic		Х	
🖪 🗟 🍽 🔓 🕥 🔾 🗙		Coordinate System				
 Workspace (3 chunks, 3544 cameras) P1_api (902 cameras, 627,927 points) [R] 		GDA2020 / MGA zor	ne 54 (EPSG::7854)	~ 🖗	112	
> Cameras (902/902 aligned)		Raster				
> Components (1) 8 Tie Points (627,927 points)		Pixel size (m):	0.01		x	
🗐 Depth Maps (902, Medium quality, Mild filter	ing)	Metres	0.01		Y	
Dense Cloud (224,231,365 points, Medium qu model (14,892,771 faces, Medium quality)	ality)	O Max. dimension	(pix): 4096			
Set As Default		Split in blocks (pi:	x): 10000 x	(10000		
> micase Duplicate }]	Raster transform:	None	\sim		
Merge		Background color:	White	~		
Remove Orthomosaic Remove Orthophotos		Region				
Update Orthomosaic		Setup boundarie	s: 477193.688 -	477549.932	x	
Reset Orthomosaic		Reset	6231105.147 -	6231493.460	Y	
Export Orthomosaic 🔹 🕨	Export JPEG/TIFF/PNG	Total size (pix):	35624 ×	38831		
Generate Contours Generate Seamlines Generate Prescription Map Export Orthophotos	Export Google KMZ Export Google Map Tiles Export GeoPackage Export MBTiles	Clip to boundary Write KML file Write tile scheme	Write World file	Write World file		
E Rename	Export World Wind Tiles Export Tile Map Service Tiles	Compression	[
③ Show Info	Export me map service mes	Image description:			4	
		TIFF compression:	LZW	~		
1		JPEG quality:	90	* *		
		Write tiled TIFF	✓ Write BigTIFF file	e		
		Generate TIFF o				
		Save alpha chan	nel			
			Export Cancel]		

Figure 34: Export Orthomosaic and save as tiff file in rgb/level1_proc/

RedEdge-MX/MicaSense Dual (Multispectral)

In this section, screenshots are included only where settings/parameters vary from the steps used for RGB imagery processing in the previous section.

Camera Calibration: GPS/INS Offset

Select Tools-> Camera Calibration.

- Enter lever-arm offsets (from the single gimbal position). In the GPS/INS Offset tab, check 'Enable Reference'. Enter offsets (m) as follows:
 - o MicaSense RedEdge-MX (X, Y, Z): -0.097, -0.03, -0.06
- × Camera Calibration Frame Camera type: RedEdge-M, Blue (5.5n ~ 2730 images, 1280x960 Pixel size (mm): 0.00375 x 0.00375 5.5 Focal length (mm): RedEdge-M, Green 2730 images, 1280x Enable rolling shutter compensation Film camera with fiducial marks RedEdge-M, Red (5 GPS/INS Offset Slave Offset Adjusted Bands Initial 2730 images, 1280x Reference Adjusted Variance Accuracy RedEdge-M, Red er X (m): -0.097 0.05 2730 images, 1280x -0.03 0.05 Y (m); RedEdge-M, NIR (5 -0.06 0.05 Z (m): 10 2730 images, 1280x 2 Yaw (°): Pitch (*): 2 Roll (°): 2 Enable reference Adjust GPS/INS offset ~ Camera label Resolution Camera model Focal length Date & time IMG_0007_1 1280x960 RedEdge-M 5.5 2021:04:07 01:16:38 30008_1 1280x960 RedEdge-M 2021:04:07 01:16:39 5.5 30009_1 1280x960 RedEdge-M 5.5 2021:04:07 01:16:40 IMG_0010_1 1280x960 RedEdge-M 5.5 2021:04:07 01:16:41 IMG_0011_1 1280x960 RedEdge-M 5.5 2021:04:07 01:16:42 IMG_0012_1 1280x960 RedEdge-M 5.5 2021:04:07 01:16:43 IMG 0499 1 1280x960 RedEdge-M 5.5 2021:04:07 01:24:50 IMG_0500_1 1280x960 RedEdge-M 2021:04:07 01:24:51 5.5 IMG_0501_1 1280x960 RedEdge-M 5.5 2021:04:07 01:24:52 IMG_0502_1 1280x960 RedEdge-M 5.5 2021:04:07 01:24:53 < OK Cancel
- MicaSense Dual (X, Y, Z): -0.097, 0.02, -0.08

Figure 35: Enter GPS offsets for MicaSense from the single gimbal position

Inspect camera settings in the Reference pane

- In the Reference pane, check that the Coordinate System has been updated (as per the EPSG input to the py script in 'Update Camera positions using python script').
- Click on 'Settings' icon. Update 'Camera accuracy' to 0.1m.

Change Primary Channel and adjust Brightness

For multispectral imagery the main processing steps (e.g., Align photos) are performed on the primary channel. Change the primary channel from the default Blue band to NIR band which is more detailed and sharp.

- Select Tools-> Set Primary Channel. Choose NIR band from the dropdown list.
- Adjust image brightness and contrast for better display. Select Tools-> Set Brightness and click Estimate and then OK.

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	Dense Cloud	•	🖬 Image Brightness	×
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	DEM	•	Image brightness (%): 400	Estimate
	Orthomosaic	•	Image contrast (%): 130	÷
	Lens	•	inage contrast (76).	•
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	🖉 Optimize Cameras			
	Calibrate Reflectance			
	Calibrate Colors		OK Can	cel Apply
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	Set Brightness			
	Set Raster Transform			
🥁 Set Primary Channe	el	×		
Primary channel: Chann	nel 5 - NIR	~		
ОК	Cancel Apply			
	Preferences			

Figure 36: Update Primary channel to NIR and estimate Image brightness.

Disable cameras with low Image quality

- In the 'Photos' tab, select 'Details' view. Right-click on any image to 'Estimate Image Quality'. In the 'Analyze Photos' dialog, select Apply to 'All cameras'.
- When this step is complete, sort photos based on 'Quality' column. Inspect images with Quality less than 0.7. Right-click on these image(s) to 'Disable cameras'.
- Review the camera layout in the main window. Remove images that were captured when the drone was turning at the end of flight lines.

Align Photos

Select Workflow->Align Photos.

- Accuracy: 'High'
- Reference preselection: 'Source'.
- Uncheck 'Generic preselection'.
- Use default limits for key point and tie points.

Optimise Camera Alignment

In the Reference pane, ensure that all cameras to be used for optimization (by default, all) are checked. Click on the 'Optimize Cameras' icon. Use default settings (Figure 28).

Set Raster Transform

To generate an orthomosaic with the reflectance value normalised between 0 and 1, a raster transform must be applied. The pixel values are proportional to % reflectance, with a pixel value of 32768 being equal to 100% reflectance (65535 is equal to 200 % reflectance). So, to generate the reflectance values the pixel values must be divided by 32768.

- Select Tools -> Set Raster Transform.
- To generate an orthomosaic with relative reflectance, in the Transform tab, enter the expression B<num>/32768 for each band as shown in the figure below. A pixel value of 32768 is equal to 100 % reflectance and 65535 is equal to 200 % reflectance. To extract reflectance values normalised to 0 1 range, divide the source value by 32768 (Agisoft 2022b).
- Select 'Enable transform'.

Eile Edit View Workflow Model Photo Ort		ols <u>H</u> elp Markers	•							
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IMG_0151_1	580	Calibrate Colors	b2 · Green	- 4				<u></u>		
IMG_0152_1	580	Calibrate Colors	B3 - Red	3	B3/32768			~	~	
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IMG_0154_1	580	Set Brightness	B5 - NIR	5	B5/32768			~	~	
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		Run Script								
Aarkers Easting (m) Northing (ОК	Cancel	Apply			

Figure 37: Update Raster Transform to generate an orthomosaic with relative reflectance values. Check 'Enable Transform'.

Import Model

Select File->Import->Import Model and select the .obj file that as exported during RGB imagery processing (Export Model). Under Coordinate System select the target CRS used during export.

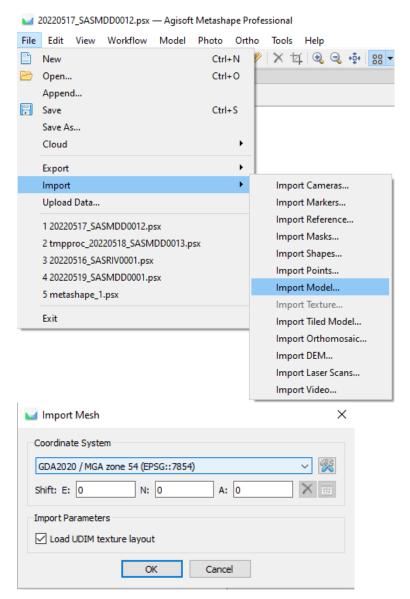


Figure 38: Import smoothed RGB model into multispec chunk

Build Orthomosaic

Select Workflow->Build orthomosaic.

- Surface: Mesh
- Enable 'Refine seamlines'
- Accept other default settings

Export Orthomosaic

Right-click on the orthomosaic and Export JPEG/TIFF/PNG.

- Under Raster Transform, select 'Index value' to export the relative reflectance values
- Update Pixel size with the desired resolution of the orthomosaic
- Select options: 'Write tiled TIFF', 'Write BigTIFF file', 'Generate TIFF overviews'
- Accept other default settings
- Save the file in the level1_proc/ folder under multispec/. Recommended naming is <proj_name>_multispec_ortho_<resolution_in_m>.tif.

GDA2020 / MGA zone 54 (EF	PSG::7854) ×	41 S
Raster		_
Pixel size (m):	0.05	X
Metres	0.05	Y
Max. dimension (pix):	4096	
Split in blocks (pix):	10000 x 10000	
Raster transform:	Index value	\sim
No-data value:	-32767	
Region		
Setup boundaries:	477193.688 - 477549.890	X
Reset	6231105.147 - 6231493.431	Y
Total size (pix):	7124 x 7765	
Clip to boundary shapes		
Write KML file	Write World file	
Write tile scheme		
Compression		
Image description:		
TIFF compression:	LZW	~
JPEG quality:	90	•
	Write BigTIFF file	•
Generate TIFF overviews		

Figure 39: Export orthomosaic. Set Raster transform to 'Index value' to export values set using the formula in previous step.

To do list

- 1. Surface used to project images: test and compare results using low quality mesh, medium quality mesh with decimating and smoothing, etc. on different datasets.
- 2. Compare orthomosaic from smoothed mesh and Lidar DEM by digiting tree canopies and comparing canopy metrics.
- 3. Test smoothing strength values (low, medium, high) and orthomosaic generation in sites with high vegetation structure/complexity.
- 4. Processing data on revisits: Test adding revisit data as different camera groups in Metashape and use one set of cameras (from the first visit) for alignment.
- 5. Test dense cloud classification (settings suggested by Matt Dell) with low-strength smoothing in sites with dense vegetation. Noting that in previous tests, classifying ground points in Metashape did not lead to good results in these sites with ultra-high resolution drone data.
- 6. Batch script to install external packages.
- 7. Low priority (revisit if D-RTK2 processing is done frequently for TERN datasets): script to create text file and do some of the D-RTK2 processing in a single step.

References

Agisoft 2022a, Agisoft Metashape Professional Edition User Manual, Agisoft, viewed 8 May 2023, < https://www.agisoft.com/downloads/user-manuals/>

Agisoft 2022b, MicaSense RedEdge MX processing workflow (including Reflectance Calibration) in Agisoft Metashape Professional, Agisoft, viewed 19 August 2022, <<u>https://agisoft.freshdesk.com/support/solutions/articles/31000148780-micasense-rededge-mx-processing-workflow-including-reflectance-calibration-in-agisoft-metashape-pro#3.-Input-reflectance-(albedo)-values-of-the-calibration-panel-for-the-bands.></u>

Appendix 1: Note on folder structure

The automated Python workflow relies on the following folder structure. Raw data must be saved in <plot>/YYYYMMDD/imagery/<sensor>/level0_raw/ (Table 6). Orthomosaic generated using the automated workflow will be saved in rgb/level1_proc/ and multispec/level1_proc/

Table 6: Automated Python workflow relies on the following directory structure for raw data. Processed data and Metashape project will be stored as shown below.

Data	Path
Raw data	<pre><plot>/YYYYMMDD/imagery/<sensor>/level0_raw/</sensor></plot></pre>
	Example:
	SASMDD0001/20220519/imagery/rgb/level0_raw/
Data products	<pre><plot>/YYYYMMDD/imagery/<sensor>/level1_proc/</sensor></plot></pre>
	Example:
	SASMDD0001/20220519/imagery/multispec/level1_proc/
Metashape project	plot/YYYYMMDD/imagery/metashape/
	Example:
	SASRIV0001/20220516/imagery/metashape/
DRTK logs	plot/YYYYMMDD/drtk/

Appendix 2: Setting the smoothing strength value

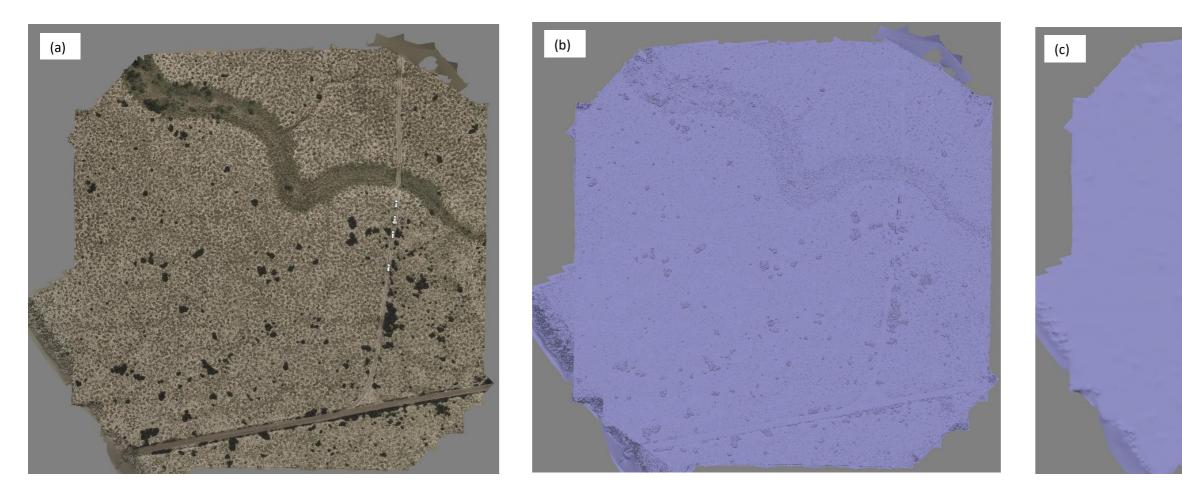


Figure 40: (a) High resolution 3D model of a Samphire shrubland TERN plot. (b) 3D model visualised without shading. (c) Model decimated and smoothed with 'low' strength value 50 to create an orthorectification surface.



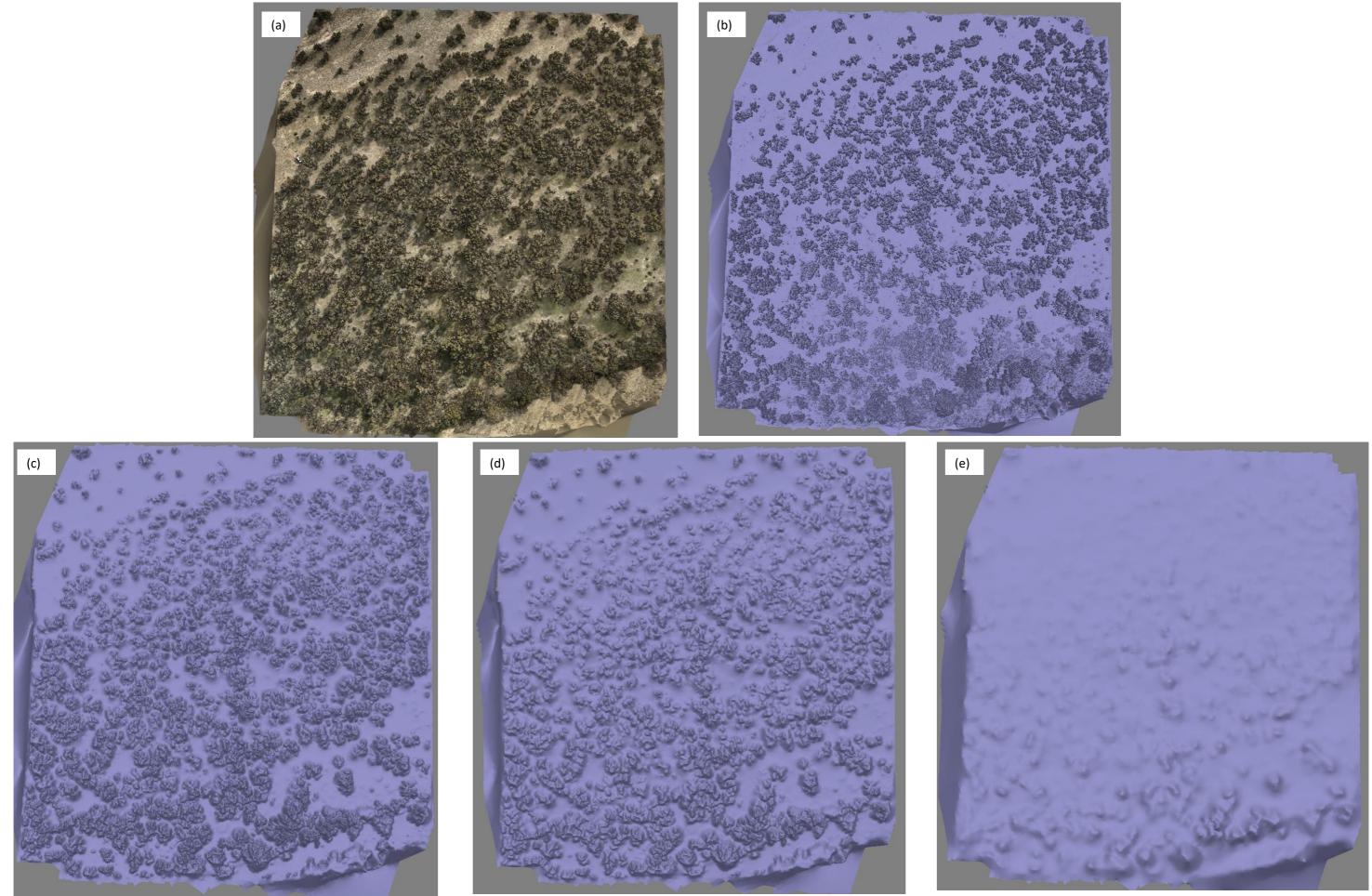


Figure 41: (a) High resolution 3D model of a Eucalypt Woodlands plot in Calperum with average vegetation height ~ 15 m. (b) The 3D model visualised without shading. (c), (d), (e) Default model when decimated and smoothed with low, medium, and high strength values respectively.

Appendix 3: Process D-RTK2 base station data

Raw GNSS data from the D-RTK2 can be post-processed using AUSPOS to refine the position of the base station. **Note** that if the D-RTK2 battery was changed, the base location recorded would change although the base station was not moved. In this case the logs (before and after the battery change) must be processed separately.

- Connect the D-RTK2 via USB to a laptop/computer and copy the RTCM .DAT files from the DRTK2 'rtcmraw' directory on the device and copy D-RTK2 log files to <plot>/<YYYYDDMM>/drtk/
- 2. RTK files must be converted to RINEX format and consolidated into a single OBS file (an OBS file created for every hour of observations). The merged OBS file must be submitted to AUSPOS for processing.
- RTK files will be converted and consolidated using RTKLIB. Download RTKLIB version 2.4.3 b34 from <u>http://www.rtklib.com/</u>.
- 4. Open command prompt on Windows. Either use the path to convbin and teqc executables in the following commands or update PATH environment variable to include path to the RTKLIB location using:

set PATH = %PATH%;<path to rtklib location>

5. **convbin.exe** converts the DAT file to RINEX format and generates OBS and NAV files. Replace 'OUTPUT_DIR' with the drtk/ folder.

```
convbin.exe -r rtcm3 -v 2.11 *.DAT -d OUTPUT_DIR -od -os
-oi -f 2
convbin.exe -r rtcm3 -v 2.11
RTK029_202109160400_13ALH63005007V.DAT -d
P:\test_cui_rtklib -od -os -oi -f 2
```

Note that **teqc.exe** can be used to consolidate multiple OBS files into one file that can be sent to AUSPOS for processing.

```
teqc.exe ENTER_LIST_OF_OBS_FILES_HERE > DRTKBase.obs
teqc.exe RTK*.obs > DRTKBase.OBS
```

Or, if only some of the OBS files are to be used, list them separately:

teqc.exe RTK027_202109160256_13ALH63005007V.obs
RTK028_202109160300_13ALH63005007V.obs
RTK029_202109160400_13ALH63005007V.obs > DRTKBase.OBS

- 6. Decimate OBS file which was sampled at 1 second to 30 seconds as required by AUSPOS. teqc.exe -0.int 1 -0.dec 30 DRTKBase.OBS > DRTKBaseSubSamp30.OBS
- Go over the Checklist at <u>https://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/auspos</u>. Under 'AUSPOS Submission', click on 'Submit your data to AUSPOS'.

- 8. Enter the following information (Figure 42):
 - Click 'Choose File(s)' to select the OBS file(s).
 - Leave the Antenna Height as 0, Antenna Type as 'DEFAULT (NONE)'.
 - Enter the email address to which the AUSPOS report will be sent.

Online GPS Processing Service

	Load RINEX Files*	DRTKBaseSubSamp30.OBS	Choose File(s)	
File Name	Height (m)	Antenna Type	Status
DRTKBaseSubSamp30.OBS	Scan 0		DEFAULT(NONE) x	Success
	Email Address*	poornima.sivanandam@utas.e	du.au	
	No valid antenna type fo DRTKBaseSubSamp30			
	enquiry about the status • Name: DRTKBas	te job number 999 should you need to		
		Clear		

Figure 42: Submit OBS file on AUSPOS. Leave Antenna Height as 0, Antenna Type as DEFAULT (NONE).

- 9. The output report will be received via email; save the report(s) in the drtk/ folder.
- 10. Create a .txt file in drtk/. Copy and paste the Cartesian coordinates for D-RTK2 from the RINEX OBS file and AUSPOS report (See section Cartesian, GDA2020).

11. In the .txt file, the first line must be the comma separated cartesian coordinates from RINEX OBS file and the second line the coordinates from AUSPOS report.

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Figure 43: Create .txt file with D-RTK2 Base coordinates from the field the OBS file, and the coordinates from the AUSPOS report. Note that the coordinates must be separated by commas in the .txt file.

12. This txt file can be used in the Python workflow (see 'Summary of processing workflow using Agisoft Metashape') to update camera positions. On Agisoft Metashape the difference between the AUSPOS and field positions for the base station will be applied to blockshift the P1 camera station positions.

Appendix 4: Reflectance Calibration

Images of the calibrated reflectance panel must be located and moved to the Calibration images camera group. When panel codes are not detected automatically, masks must be selected manually on all bands of each calibration image. It is also recommended to check that the masks have been set correctly even for cases where panels have been automatically located. This section covers the steps involved.

Note that the following screenshots are from 10-band MicaSense Dual sensor and hence may look different to what is displayed for 5-band RedEdge-MX.

 Select Tools -> Calibrate Reflectance. Select 'Locate panels'. This step is necessary to locate the panels even if calibration images have been automatically moved to the Calibration Images group.

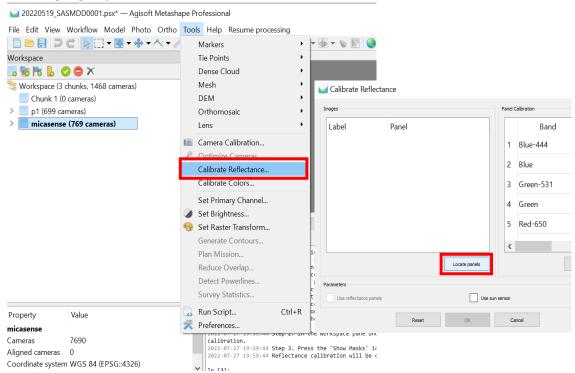


Figure 44: Calibrate reflectance. Select Locate Panels to locate images and set masks for the panels.

- 2. When the 'Locate panels' step is complete:
 - a. check that the 'Panel' is the CRP model that was used in the field (look for the correct serial number e.g., 'RP06...'). The first time this is done, the csv with the panel reflectance values will have to be uploaded. Select the correct csv file from the local drive. If panel reflectance values are unavailable, contact <u>MicaSense</u>.
 - b. Check that all panel images were located for all bands. For example, in Figure 45 'RP06... (10/10)' for 10-band Dual sensor indicates that the calibrated panel was located in all 10 bands of the image (or (5/5) for RedEdge-MX images). If not all bands were located, the display will indicate how many bands the panels were located in (x/10). The mask will have to be manually selected (following steps).
- 3. Click '**Cance**I'. Before reflectance calibration is done, panel masks must be checked, and calibration images chosen from either pre or post flight.

Calibrate Reflecta	ince				
mages			Panel C	alibration	
Label	Panel			Band	Reflectance
BING_0002_6			1	Blue-444	0.469217
	RP06-2103491-OB (10/10) RP06-2103491-OB (10/10)		2	Blue	0.469736
			3	Green-531	0.471322
			4	Green	0.471882
			5	Red-650	0.472499
			6	Red	0.472115
			7	Red edge-705	0.472066
			8	Red edge	0.472005
			9	Red edge-740	0.472108
			10	NIR	0.471188
			<		>
		Locate panels			Select panel
arameters					
Use reflectance panels		Use sun sens	or	_	
	Reset	ок	Cance	4	

Figure 45: When the panel/images have been located, press Cancel.

- 4. In the Workspace pane, navigate to the Calibration Images group within 'multispec' chunk. Inspect the photos and identify the ones to use for reflectance calibration.
 - a. These images must be sharp and without shadows on the panel.
 - b. Check that the entire panel is covered in the image. (If it is not, remove the image by using the context menu and 'Remove Camera').
 - c. Click on '**Show Masks**' in the photo menu and inspect the mask set by default. Only the panel must be unmasked.

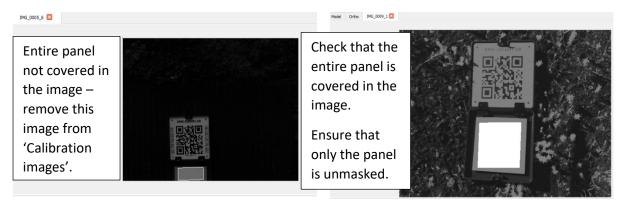


Figure 46: Open calibration images from the folder in multispec chunk to choose images from either pre or post flight. Select images where the entire panel is covered.

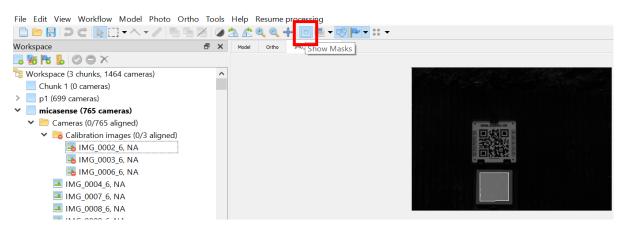


Figure 47: Use the 'Show Masks' icon to inspect the default mask set for the calibration images.

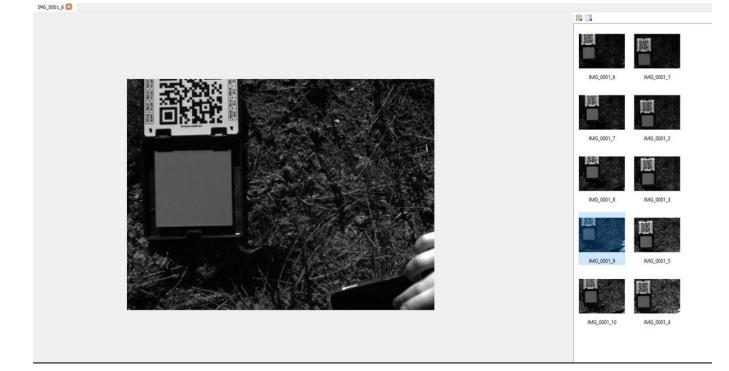
- 5. Create panel mask manually: When the panel code is not fully visible in the calibration image, the panel will not be located automatically in those bands of an image (In Figure 48, panels were located only in 9/10 bands of IMG_0000 and in 7 bands of IMG_0001). In these cases, as well as when the automatically detected mask was incorrect, mask needs to be created manually.
- 6. Steps to update the panel mask are shown in Figure 49 and Figure 50.

mages		Pane	el Calibration	
	Panel 6 RP06-2103491-OB (9/10) 6 RP06-2103491-OB (7/10)	Locate panels	Band Blue-444 Blue Green-531 Green Red-650 Red edge-705 Red edge Red edge-740 NIR	Reflectance 0.469217 0.469736 0.471322 0.471882 0.472499 0.472005 0.472108 0.472108 0.471188
arameters				
Use reflectant	ce panels	Use sun sensor		

Figure 48: Calibrated panel was not located in all bands of these 2 calibration images. The band images must be examined, and mask set manually as required.

File Edit View Workflow Model Photo Ortho Tools Help	
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Workspace Rectangle Selection	1. In the Photo menu, click on 'Rectangle
🗠 🗟 🍋 🔚 🥥 🔾 X 👘 🧰	Selection'.

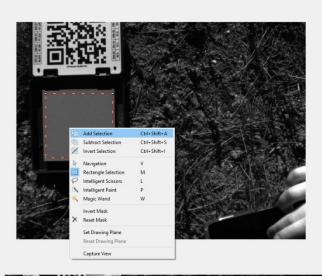
- multispec (986 images, 2,994,564 tie points) [R]
 Images (984/986 aligned)
 Calibration images (0/2 aligned)
 IMG_0000_6, NA
 IMG_0001_6, NA
- 2. Select the calibration image. Note that if images were not located through 'Locate panels' they must first be selected and moved to a 'Calibration images' camera group. Select the band for which mask is to be set/updated. On Metashape v2.x, this can be done using the panel of images on the right. On earlier versions, use Tools-Set Primary Channel to set and display each band iteratively.



 Select the relevant band for which mask is to be set/updated. On Metashape v2.x, this can be done by navigating the right panel of images for all bands On Metashape v1.x.x, use Tools - Set Primary Channel to iteratively select each band and update the mask.

Figure 49: Steps to manually create panel mask when panel was not automatically located, or when default mask is incorrect.









- If a mask has already been set and it is incorrect, first reset this by right clicking on image and selecting 'Reset Mask' (Not shown in image).
- 5. Select the panel area (using rectangular selection tool enabled in step 1).

6. Right click on the image and select 'Add Selection'.

7. Right click on the image and select 'Invert Mask'.

- 8. The mask should now only contain the panel area.
- 9. Repeat steps for other bands and other calibration images.
- Mask images can be saved using right click on image in the Workspace Pane, select Masks - Export Mask. Save as single channel mask image. This will save mask images of all bands.

Figure 50: Continuation of steps to create panel mask.

- 7. Ensure that the above steps are repeated for other channels. On Metashape v1.x.x change the channel displayed using Tools -> Set Primary Channel. On Metashape Pro v2.x, use the right pane to open other bands and update masks. Repeat the above process for all bands on other calibration images.
- 8. Ensure that the calibration images selected were taken at a time (either from before or after flight) that best represents the illumination condition during the flight. Finally, select images that will not be used for calibration, right-click and select 'Remove Cameras'.

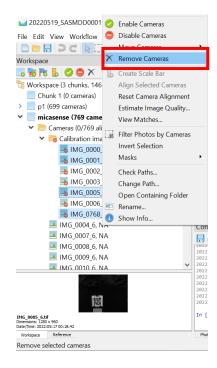


Figure 51: Remove images that are not to be used for calibration.

Appendix 5: Metashape Batch Process

To run Metashape processing in a batch, the commands in Table 2 can be added as a Batch Process using the following example workflow.

1. Select Workflow -> Batch Process. In the dialog select 'Add' to add jobs.

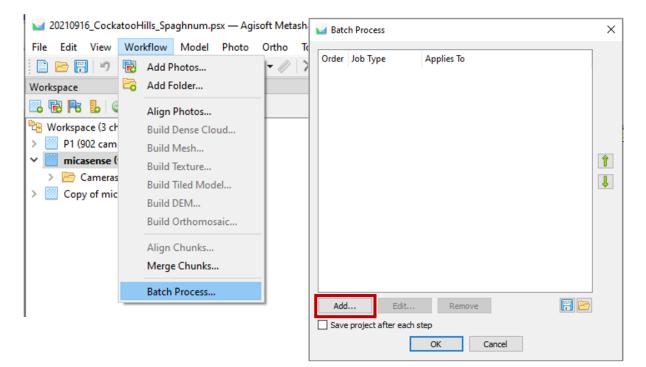


Figure 52: Start a batch process

- 2. In the Add Job dialog, select the job type from the dropdown list. Select the chunk(s) to run the job on. In the Parameters box, update the settings. Click OK.
- 3. Repeat the steps to add more jobs. When all jobs have been added, check that the order of the jobs and the chunks they apply to are correct. Use the arrow keys to change the order of the steps. Check the 'Save project after each step' box. Click Ok.
- 4. Run the batch process in the background (click on Background). Progress can be monitored using the Console tab.

Mdd Job	×	🖬 Bato	ch Process			×
Job type: Align Photos Apply to: Selection P1 (902 cameras) Selection Composition of the selection Composition of the selection of the se	v v ras)	Order ⊻ 1 ⊻ 2 ⊻ 3 ⊻ 4		Applies To P1, micasense P1, micasense P1, micasense P1, micasense		Ĩ
Parameters:						Ţ
Property	Value					
✓ General						
Accuracy	High					
Generic preselection	No					
Reference preselection	Source					
Reset current alignment	No					
✓ Advanced						
Key point limit	40,000	Add	Edit	Remove		F
Key point limit per Mpx	1,000					
Tie point limit	4,000	🗹 Save	e project after each s	tep		Save
Apply masks to	None			OK (Cancel	
Exclude stationary tie points	Yes			- Cit		
Guided image matching	No					
Adaptive camera model fitting	Cancel					

Figure 53: Add jobs, select chunks, and update parameters for each job. Select OK. Add more jobs as required. Select 'Save project after each step'. Click OK to start the jobs.

Appendix 6: Processing workflow using a custom Metashape window

This section describes another approach where a custom processing menu is used to run the same workflow. User input is still required to inspect and select calibration images, information on these steps is provided on-screen.

- Install package PySide2 in Metashape (see 'Install external packages')
- Copy metashape_proc_widget.py and upd_micasense_pos.py to
 C:\Users\<username>\AppData\Local\Agisoft\Metashape Pro\scripts\
- Open Agisoft Metashape Pro. Switch to the 'Console' tab to view progress of the script.
- A custom option 'Metashape processing menu' would appear on the toolbar. Click on it to open the 'Metashape processing' window. There are four steps to complete as shown in Figure 54. These steps are described in the rest of this section.

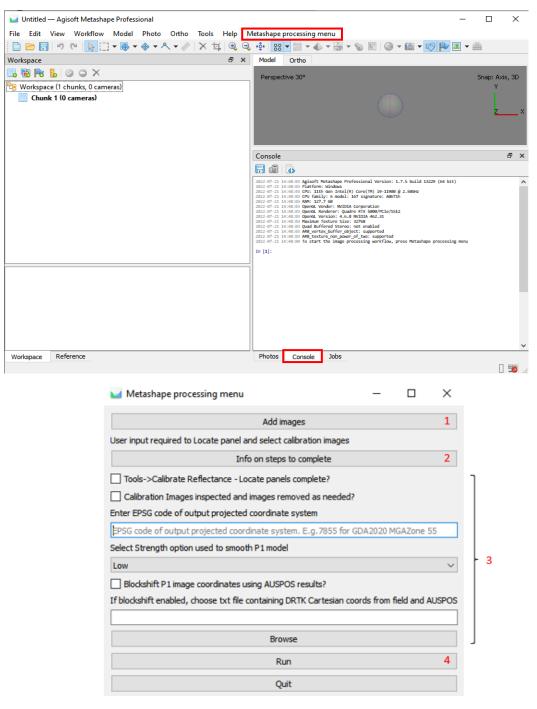


Figure 54: 'Metashape processing menu' appears on the toolbar when Metashape Pro is opened. The four steps in the workflow are shown above.

Add images

1. Click on Add images in the custom window. In the dialog that opens, click on 'Create chunks'. Select the folder where the rgb/ and multispec/ folders are located. This will create chunks rgb and multispec and add the images. The progress dialog displays the overall progress.

🖬 Metashape Pro 🛛 ? 🛛 🗙	Choose TERN plot folder where p1/ and micasense/ folders are located.							×
	\leftarrow \rightarrow \checkmark \uparrow \square \Rightarrow This PC \Rightarrow TEI	~	ē	2	Search SASMDD0008			
Adding images	Organize 🔻 New folder		^					0
	TERN	^	Name	Date mod	ified		Туре	Size
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	Research (R:) EinAdwin (C:) Folder: 20220516		< Processing in progress Loading photos P9% done, 00:03:55 elapsed, 00:00:59 left Overall progress:	X	[Selec	t Folder Can	cel

Figure 55: Step 1: 'Add Images' and select the folder with the rgb/ and multispec/ folders

When all the images have been added, a dialog appears to 'Specify the project name' (default location of imagery/metashape in the plot folder). Enter a name in the format YYYYMMDD_PlotName.psx (YYYYMMDD is the date of data collection) and click Save.

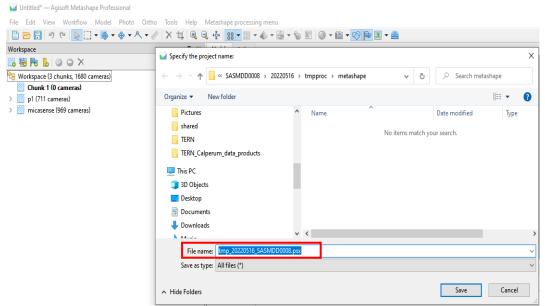


Figure 56: After the images have been added, when prompted enter a name for the Metashape project.

Select calibration images

2. The next step requires user input to select the calibration images for micasense reflectance calibration. In the Metashape processing window, click on 'Info on steps to complete'. Complete Steps 1 to 3 listed. Note that this window can be left open while the steps are completed using the Metashape toolbar. (For screenshots of these steps, refer to MicaSense reflectance calibration.) Select OK when done.

🥁 Metashape processing menu		-		×			
	Add images						
User input required to Locate panel an	d select calibration images						
Info	on steps to complete						
Tools->Calibrate Reflectance - Loc	ate panels complete?						
Calibration Images inspected and i	🖬 Metashape Pro					_	×
Enter EPSG code of output projected EPSG code of output projected coord Select Strength option used to smooth Low Blockshift P1 image coordinates us If blockshift enabled, choose txt file of	Step 2: In the Workspace pa Step 3: Press the 'Show Mas Reflectance calibration will b	ane, sele ane unde sks' icon i	ect micase er micaser in the too	nse chur I bar and	nk. Select Tools-Calibrate Relectance and 'Locate panels'. Once t k open Calibration images folder. Select and remove images not t d inspect the masks on calibration images. Enter other inputs in the Metashape processing menu and dick 'R OK	o be use	
					UK .		
	Browse						
	Run						
	Quit						

Figure 57: Step 2: Follow onscreen information to Locate panel and select calibration images.

Run the processing workflow

- 3. Check both the buttons to mark the steps complete. Enter the EPSG code of the output projected CRS. Select Strength value to be used to smooth the RGB 3D model. If blockshift of P1 images is necessary, select the option and browse to select the txt file containing the cartesian coordinates from the field and AUSPOS (See Process D-RTK2 base station data).
- 4. Select Run.

🥁 Metashape processing menu	_		\times	
Add images				
User input required to Locate panel and select calibration images				
Info on steps to complete				
✓ Tools->Calibrate Reflectance - Locate panels complete?				
Calibration Images inspected and images removed as needed?				
Enter EPSG code of output projected coordinate system				
7854				
Select Strength option used to smooth P1 model				
Low			~	
Blockshift P1 image coordinates using AUSPOS results?				
If blockshift enabled, choose txt file containing DRTK Cartesian coords from field and AUSPOS				
Browse				
Run				
Quit				

Figure 58: Enter the EPSG code for the projected target CRS, select a smoothing strength for the P1 3D model. Click Run to start the workflow.

5. Progress will be displayed on the Metashape progress dialog. When processing is complete, the RGB and multispectral orthomosaic tif are saved in the <sensor>/level1_proc/ folders. Intermediate files are saved in the project folder.

In case of any errors in the workflow, the log file (selected in Agisoft Metashape) and the Console tab will have details on the error and processing step that it appeared on. To fix the error and restart processing using the Metashape GUI, refer to 'Summary of processing workflow using Agisoft Metashape' for equivalent Metashape Toolbar commands. To restart the workflow using a Batch Process refer to 'Appendix 5: Metashape Batch Process'.

Revision History

Date	Revision	Changes	
24/09/2021	1.0	Initial version	
04/11/2021	1.1	Updated after review by Darren	
15/11/2021	1.2	Updated after Oval trial flight	
18/11/2021	1.3	Formatting updates	
09/02/2022	1.4	Updates following review by Shaun Levick	
12/05/2022	1.5	Update to D-RTK 2 processing when base station battery was changed.	
		Highlight that MRK files must be copied to a path when more than 1 flight.	
		Specified GPS/INS fields in Summary table.	
02/08/2022	2.0	Updates following Calperum campaign in May 2022	
03/11/2022	3.0	Updates following reviews from team	
08/05/2023	3.1	Changes for Metashape Pro 2.x.x release. Minor updates to workflow	
		(e.g., single option 'drtk' instead of 'blockshift' and 'drtk').	