Rockfall and Geohazard Site Characterization Using UAVs, Photogrammetry and LiDAR

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Outline

- State of Practice
- UAV technology
- Common Workflows
- Examples / Case Studies
  - Change Detection with Aerial LiDAR
  - Change Detection with Terrestrial LiDAR
  - Change Detection with Terrestrial Photogrammetry
  - UAV 3D model data for 3D numerical modelling
- Geotechnical Asset Management
- Emerging applications - Flying underground, BIM, and automation

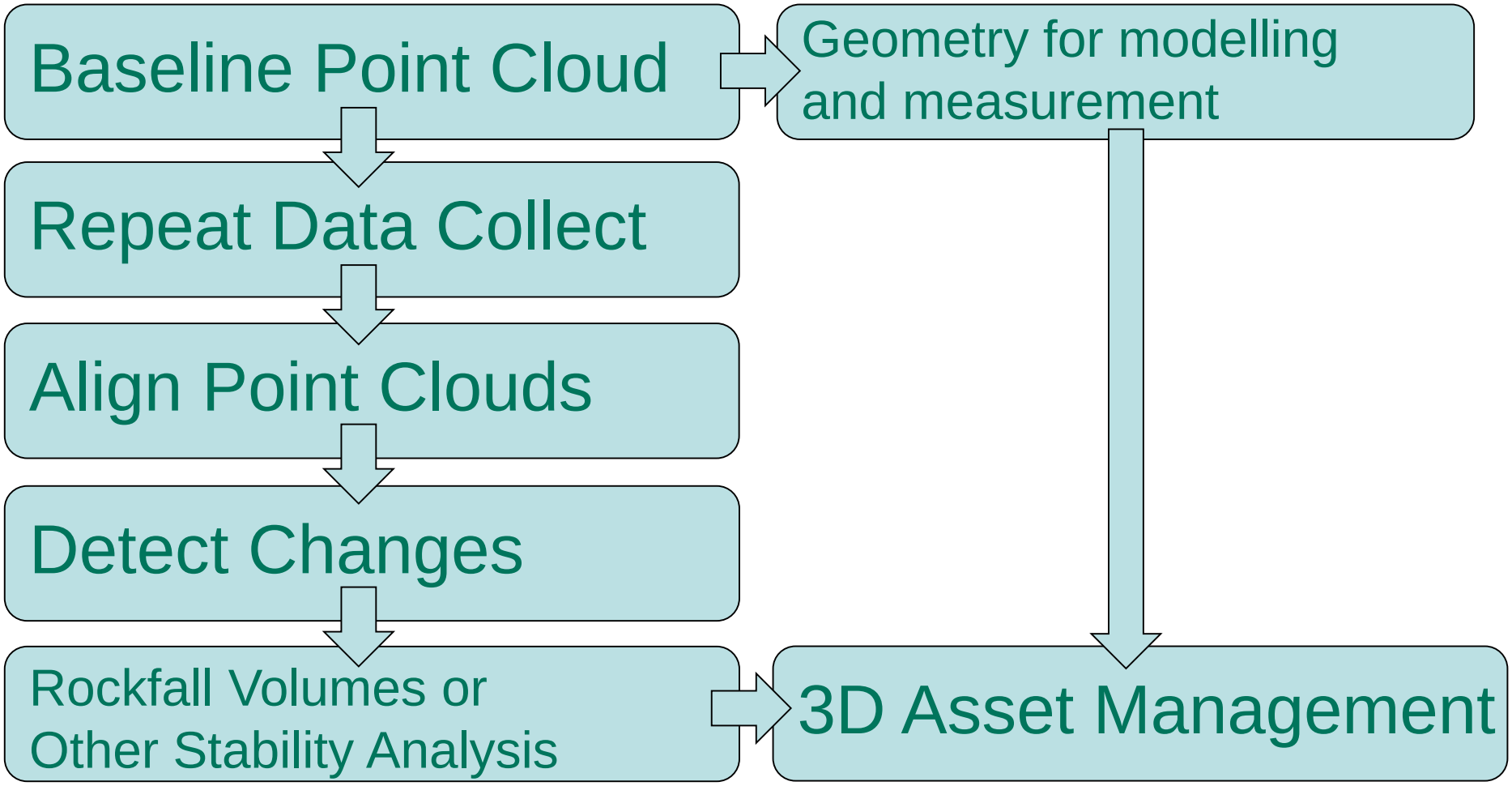
State of Practice for Scanning with UAVs

- Presentations last year by Radford University and ATS International summarized the use of UAVs quite well
- Most work right now is done with Photogrammetry and almost all of that is using Structure From Motion
- As units get smaller and UAVs get better, LiDAR and RTK GPS being added
- Less common sensors include Thermal, Near Infrared and bathymetric LiDAR
- Scale is highly flexible from hand specimen to entire highway alignment

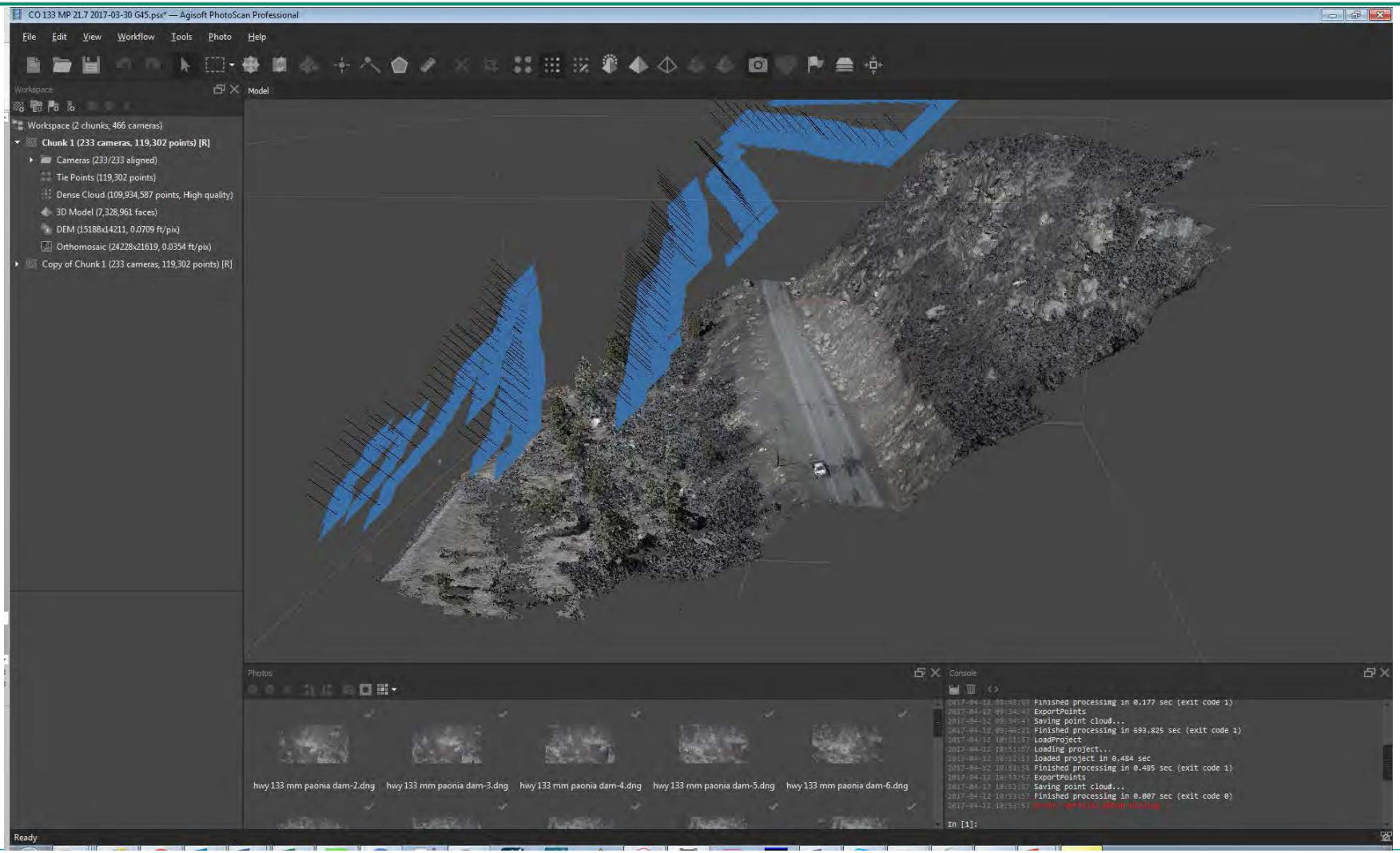
UAV Units

eBee

Common workflow

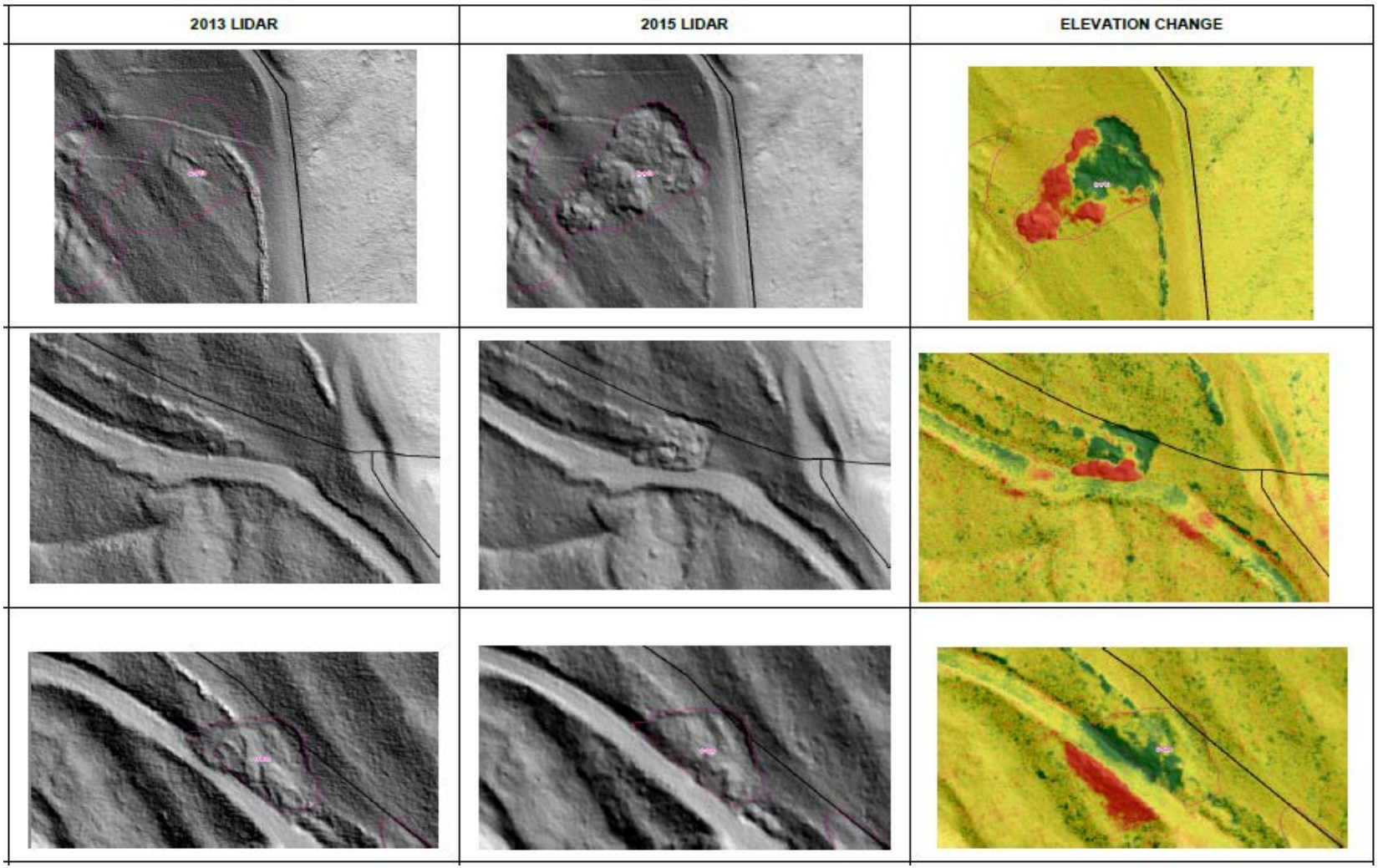


Baseline Point Cloud

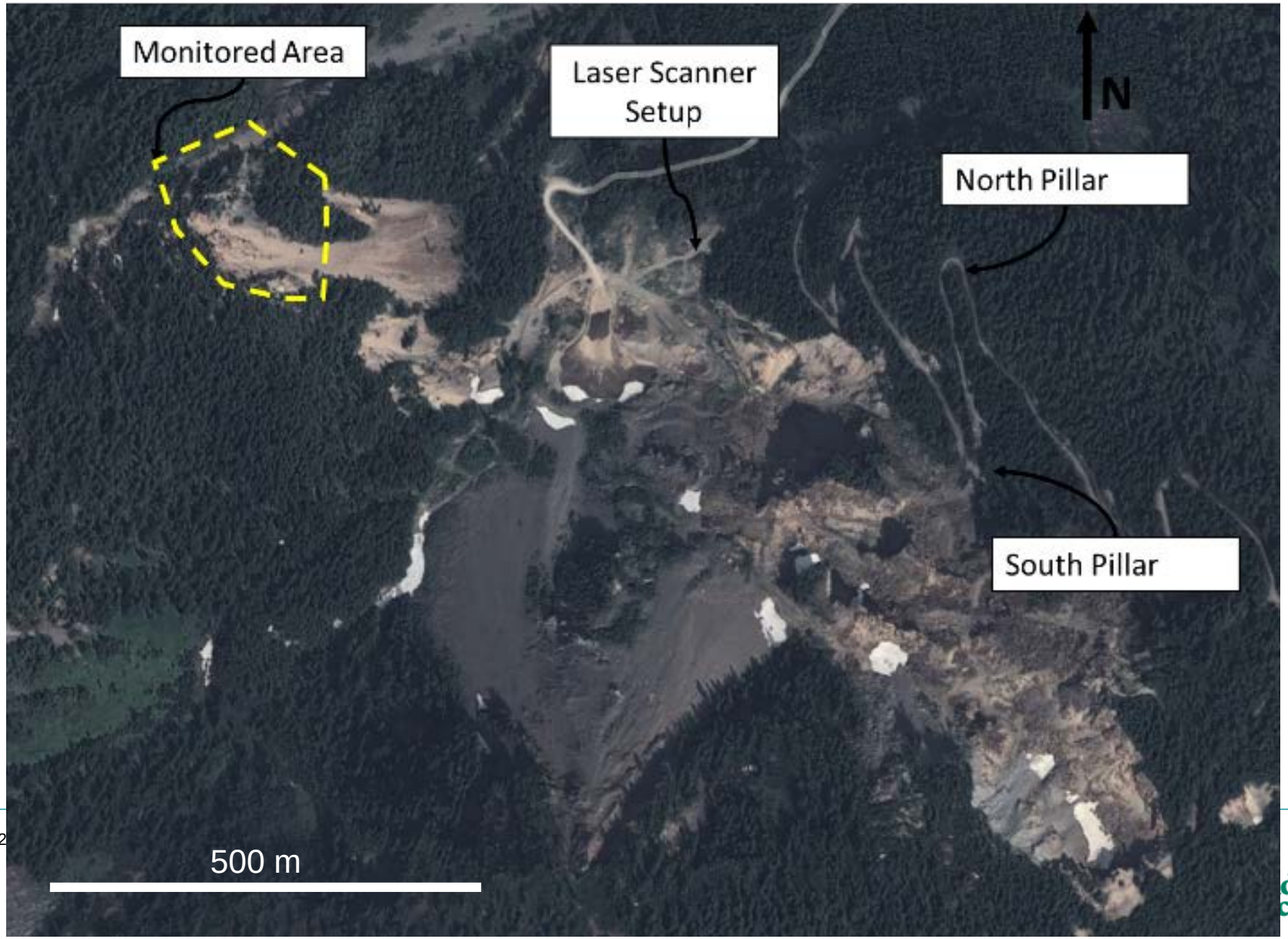


Repeat Data Collect

Change Detection Case Study – Aerial LiDAR

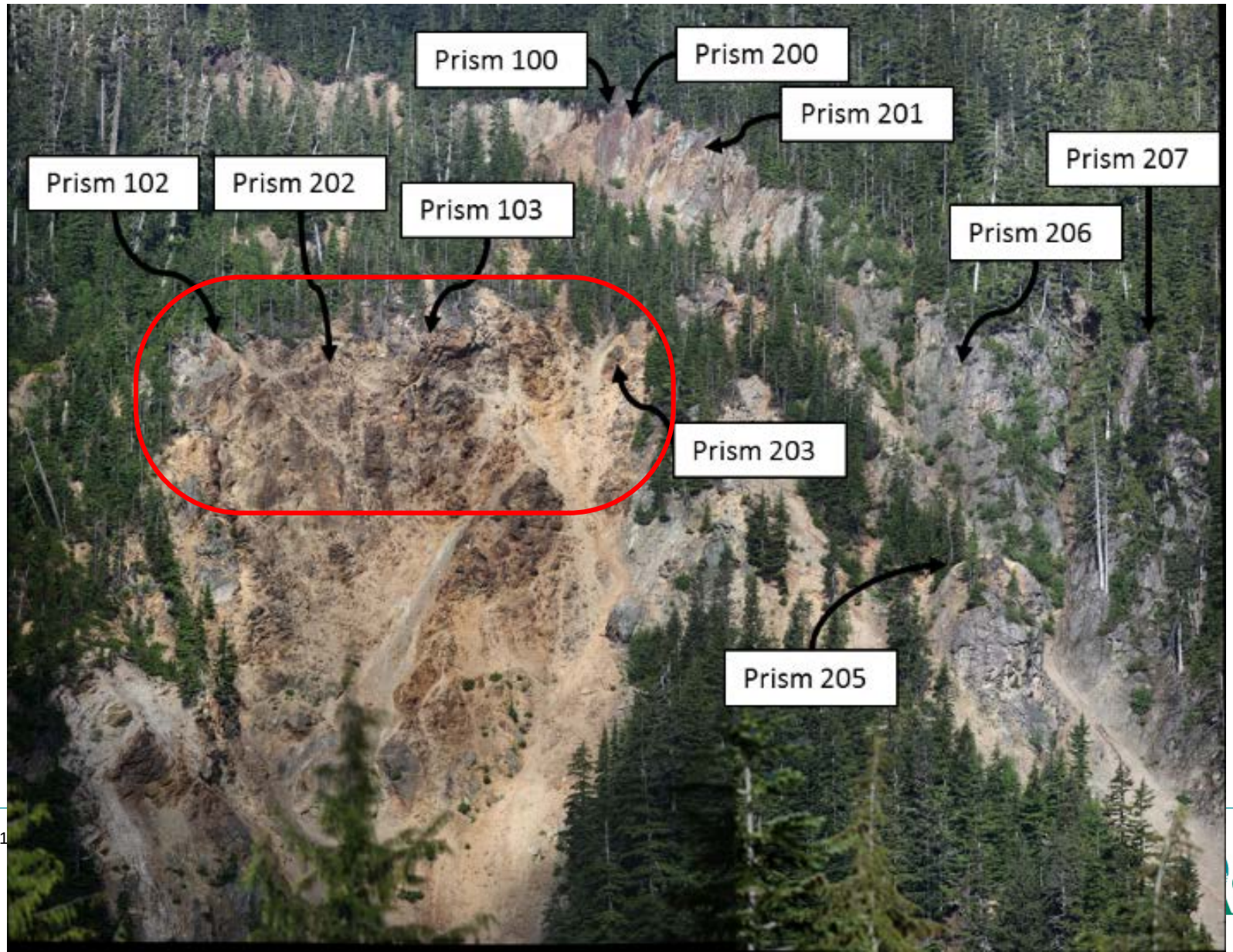


Change Detection Case Study – Terrestrial LiDAR



Site flyover video

Change Detection Case Study – Terrestrial LiDAR



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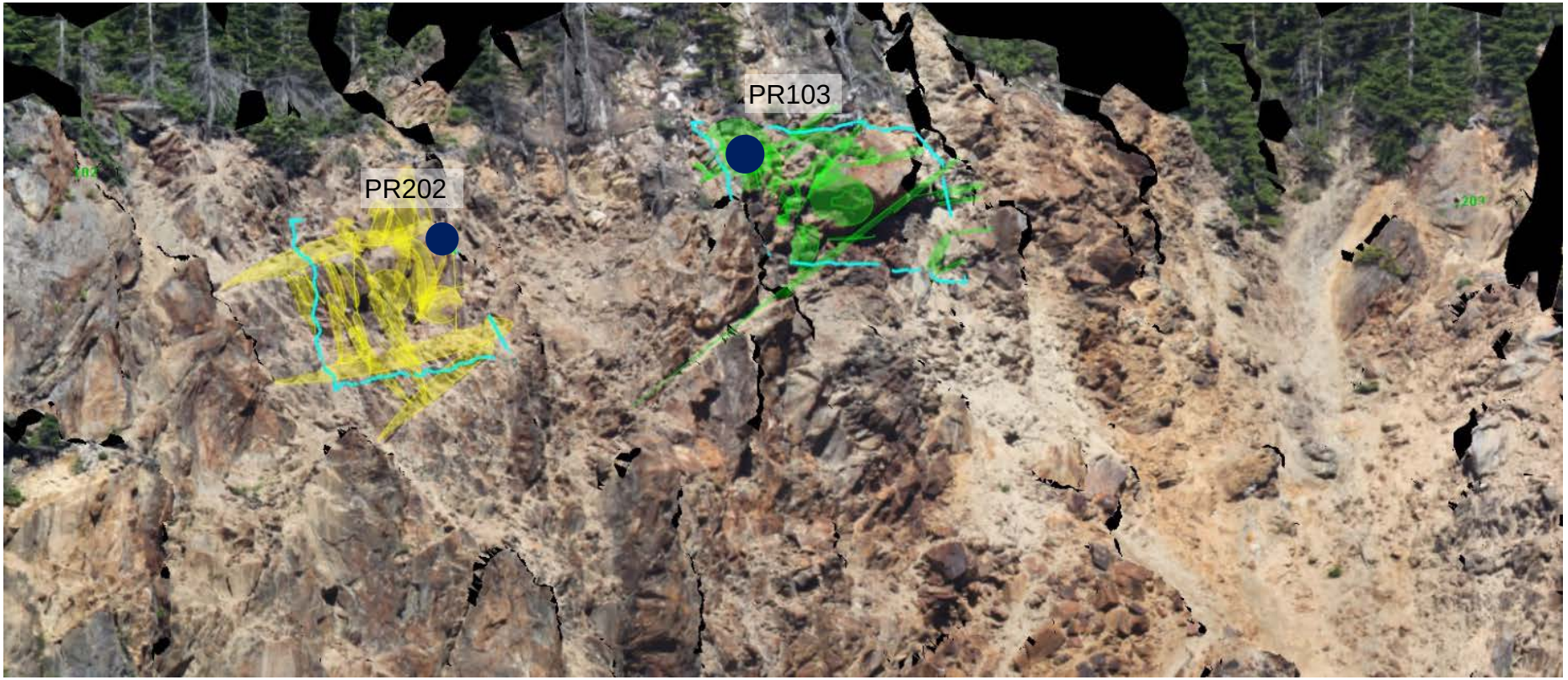
Change Detection Case Study – Terrestrial LiDAR



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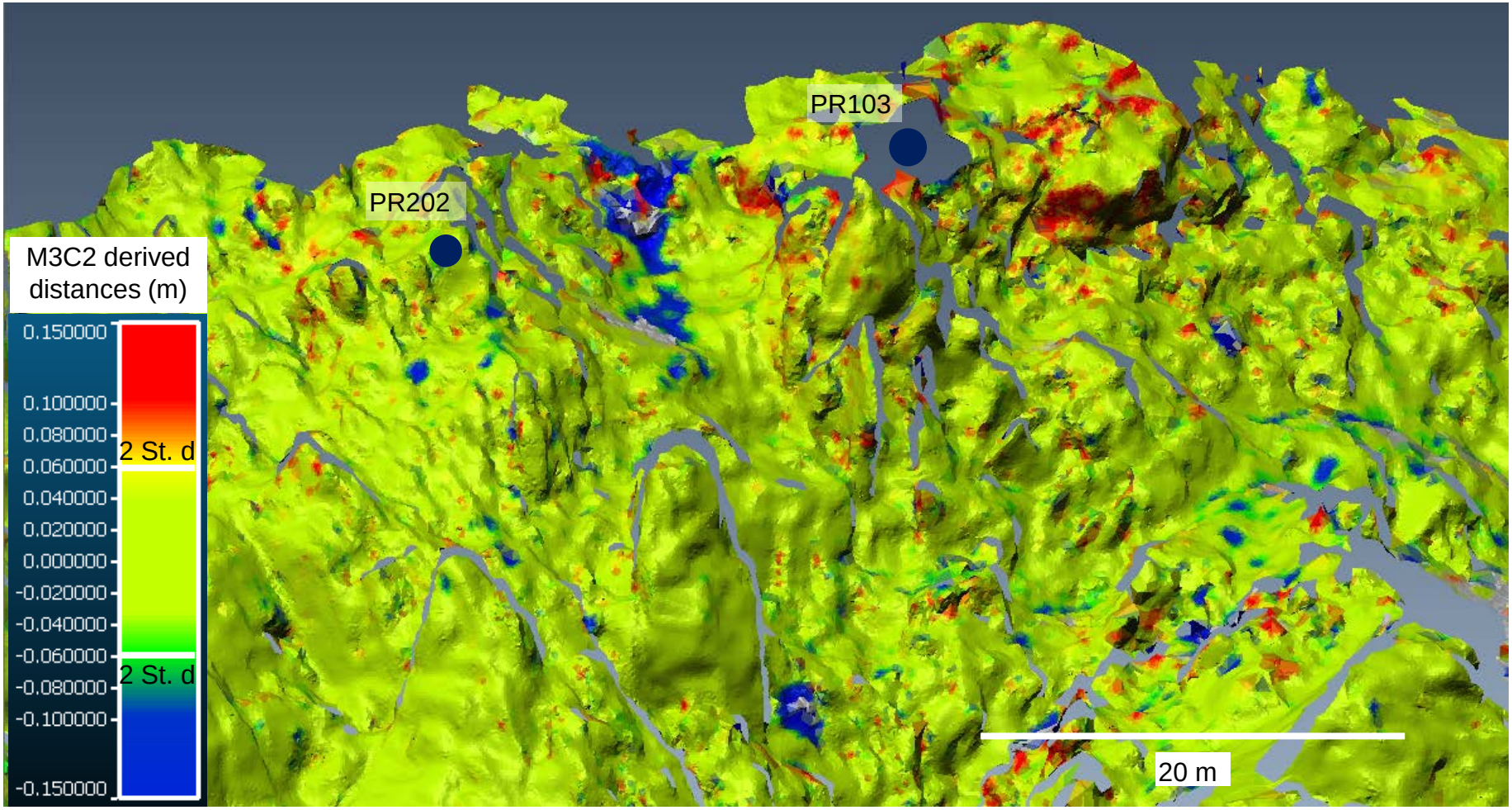
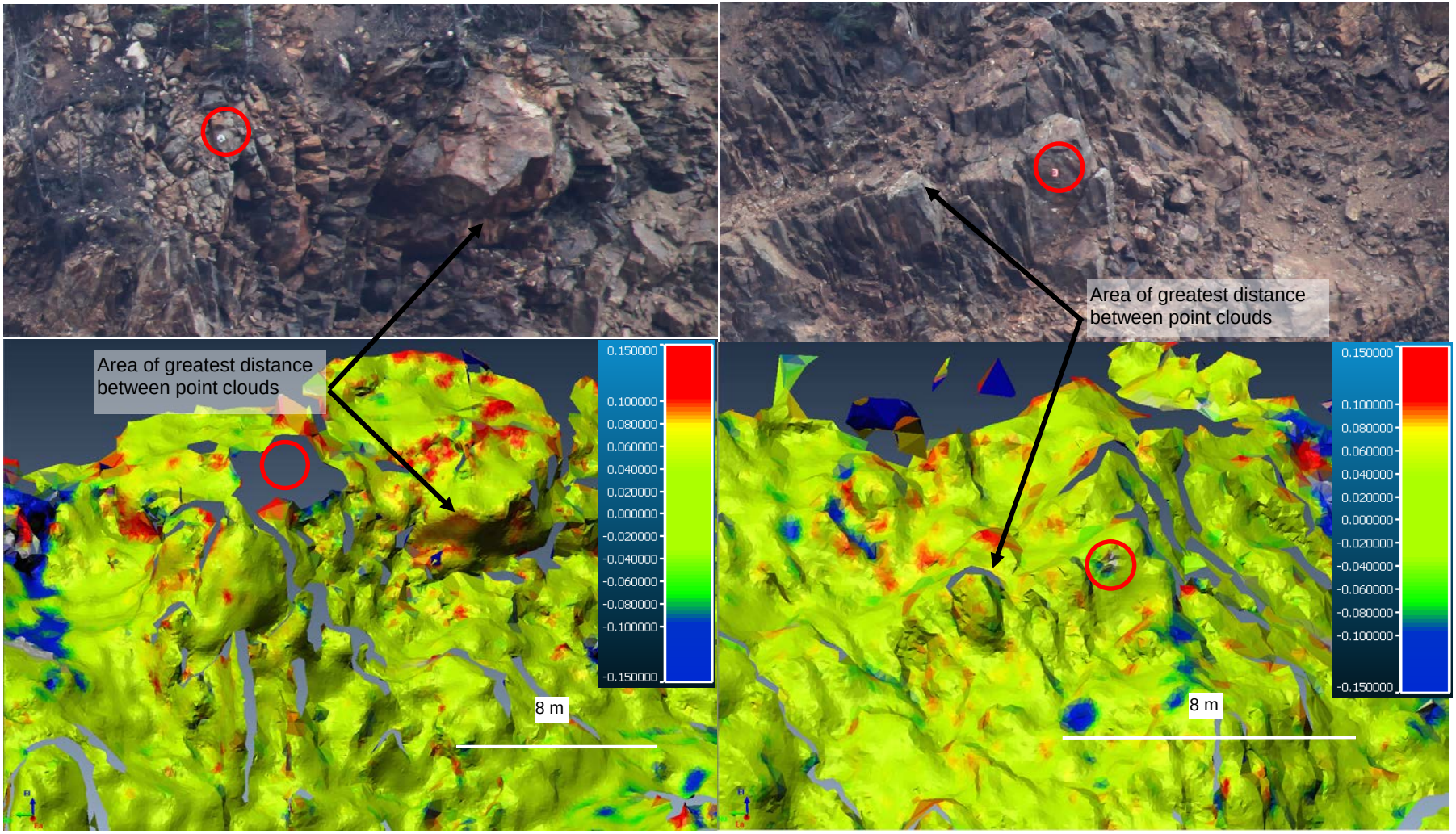


Change Detection Case Study – Terrestrial LiDAR



Change Detection Case Study – Terrestrial Photogrammetry

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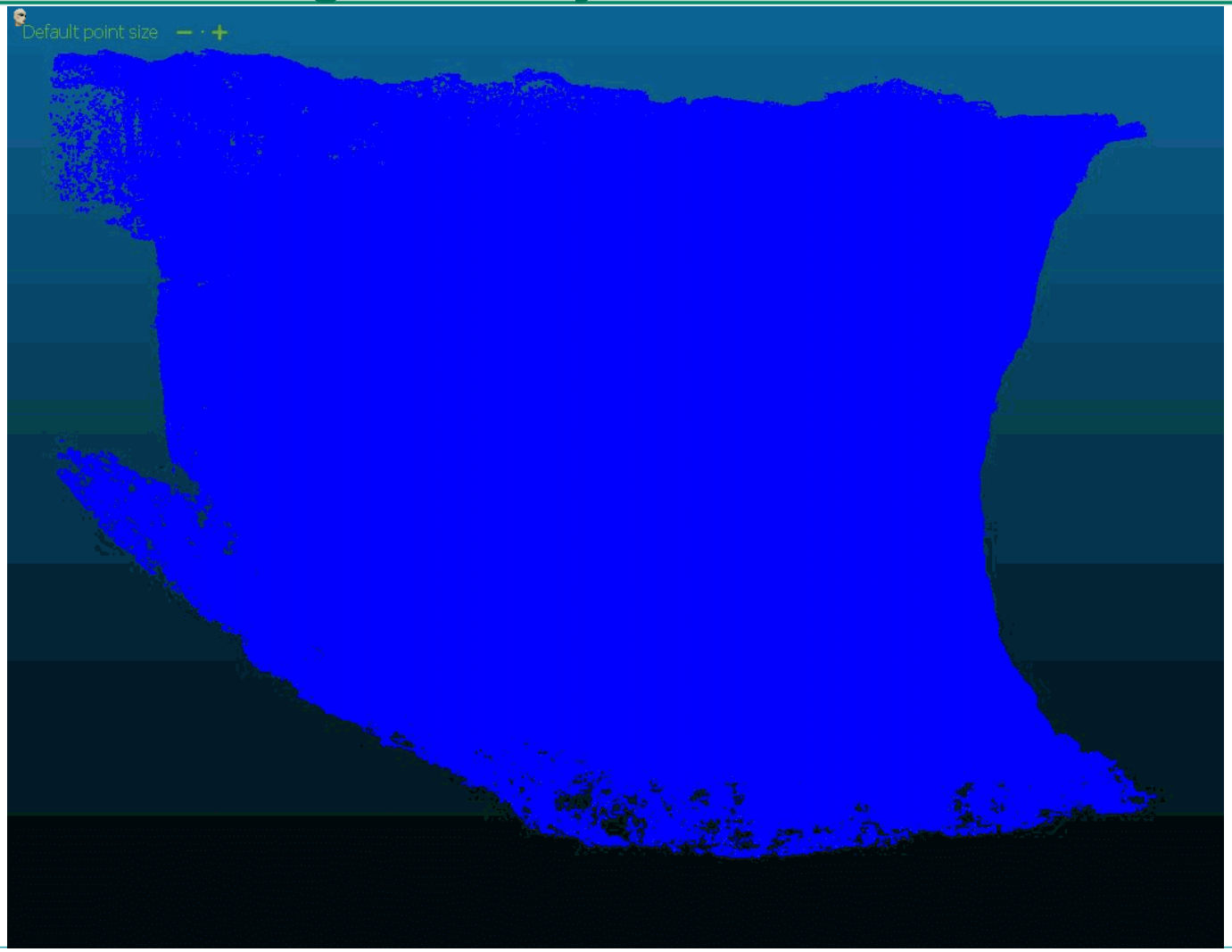
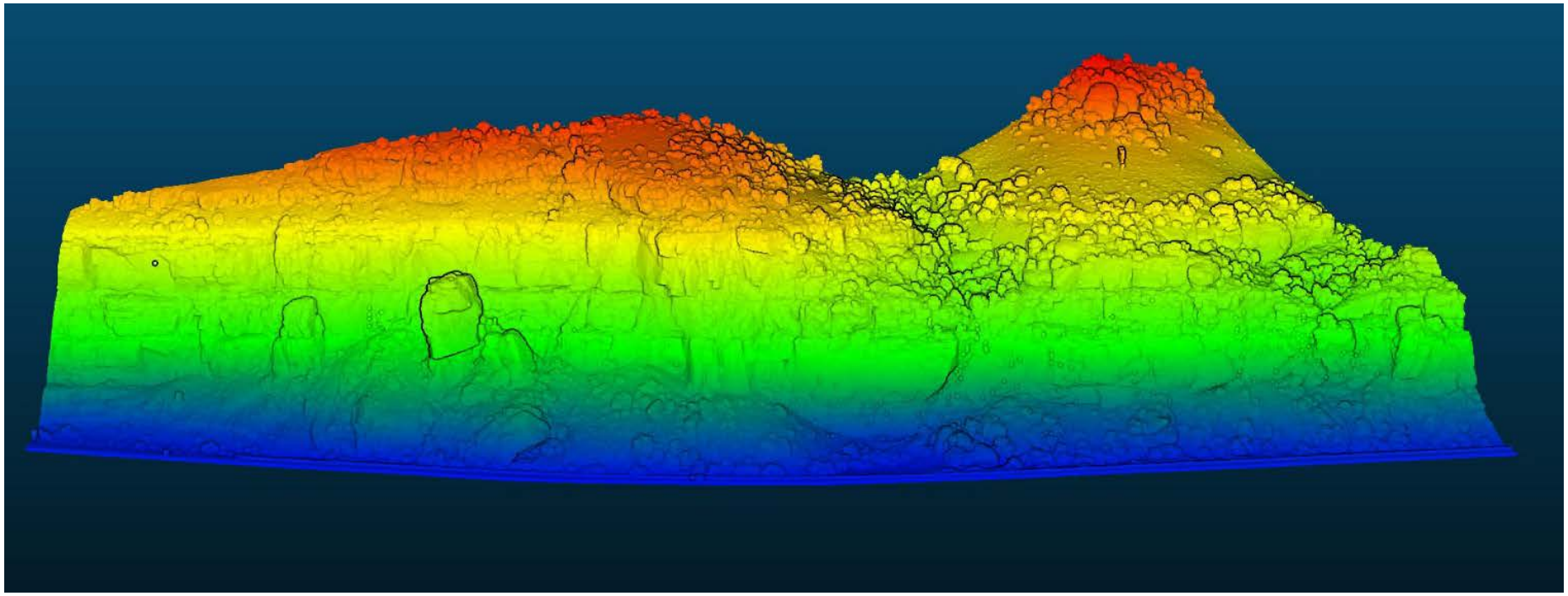
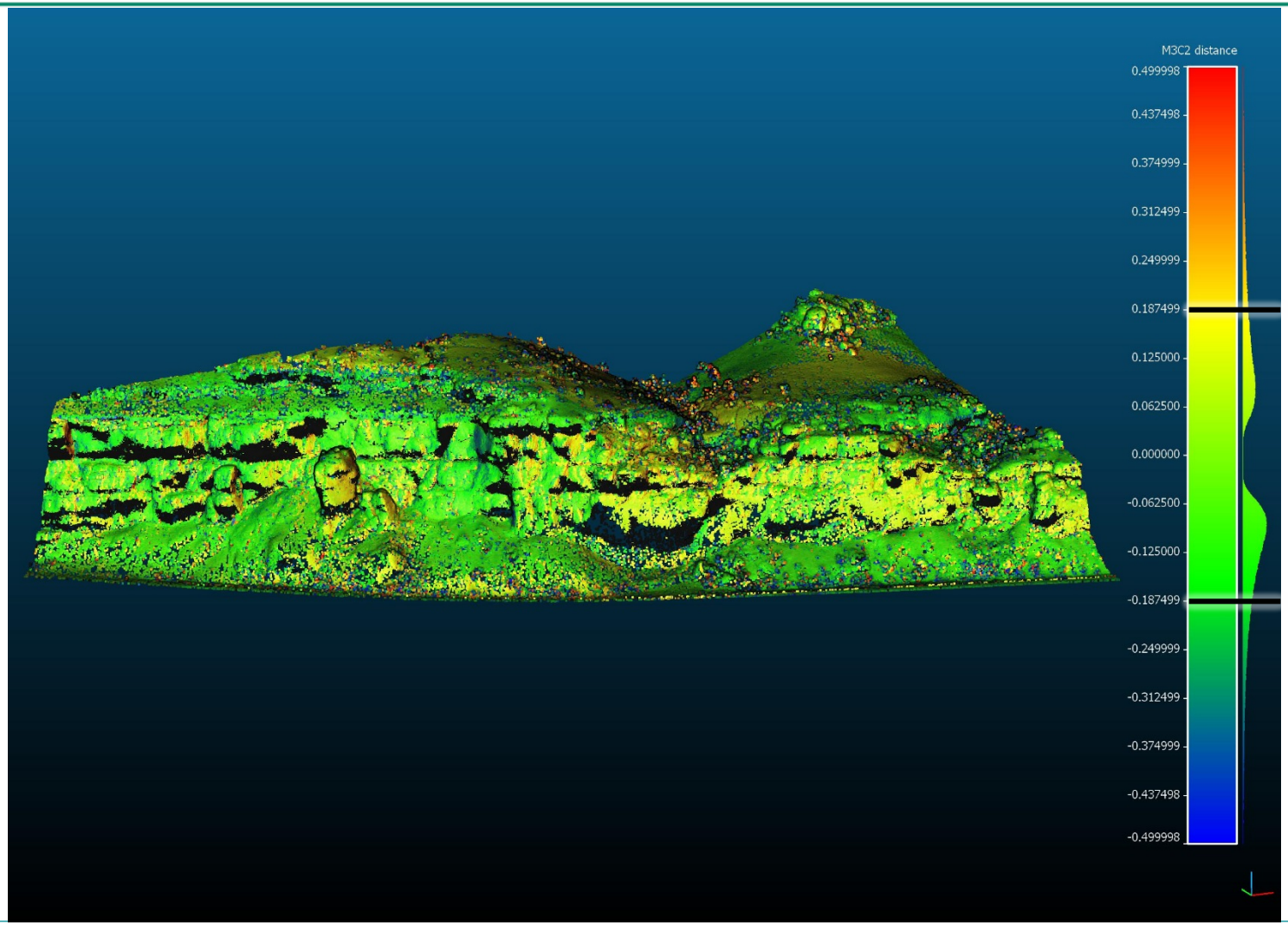


I-70 – Debeque Canyon MP 53 Test Site

UAV LiDAR Data Set – I-70 Debeque Canyon



UAV LiDAR Data Set – Limits of Detection

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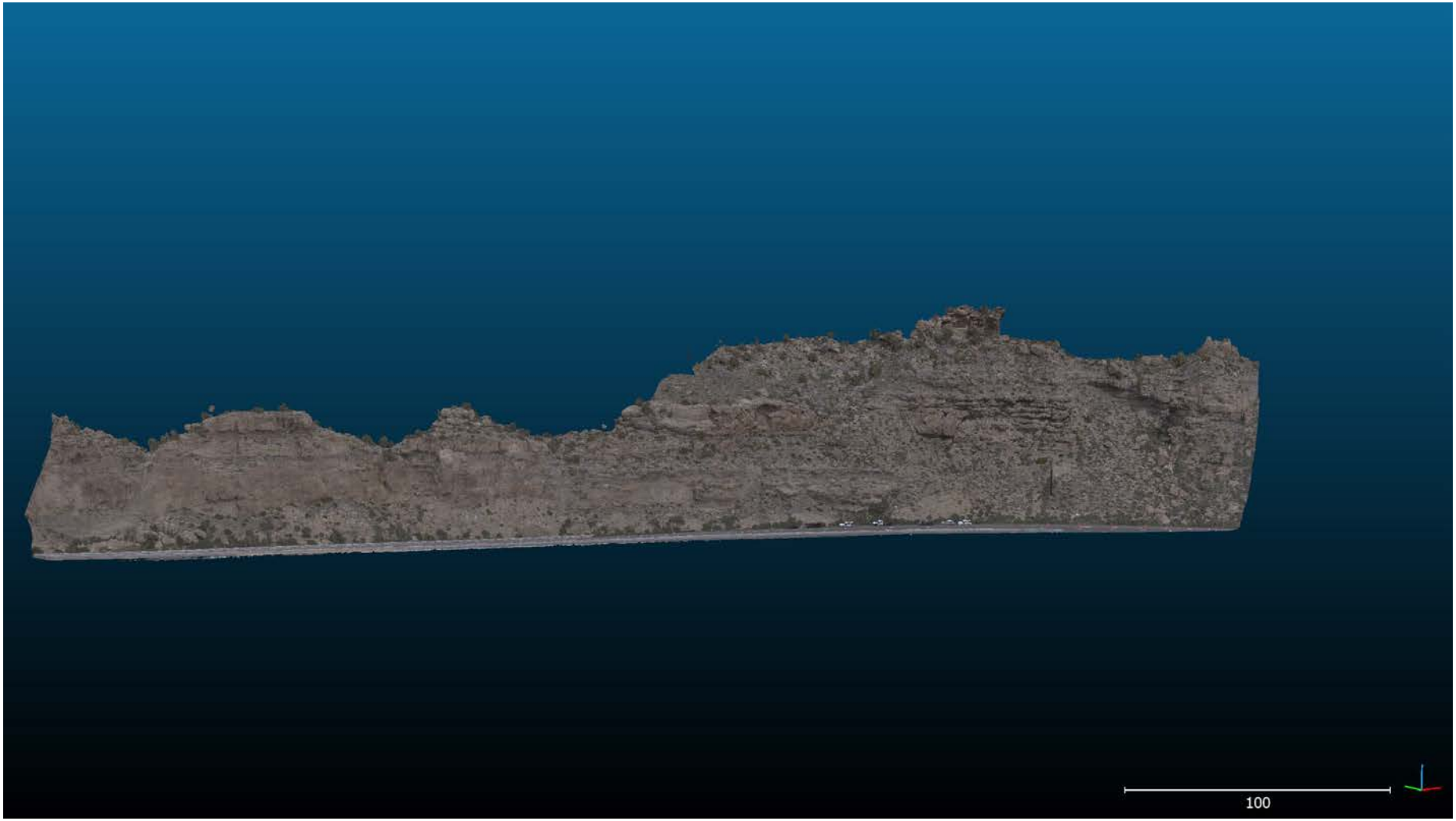
UAV Photogrammetry Data Set – I-70 Debeque Canyon



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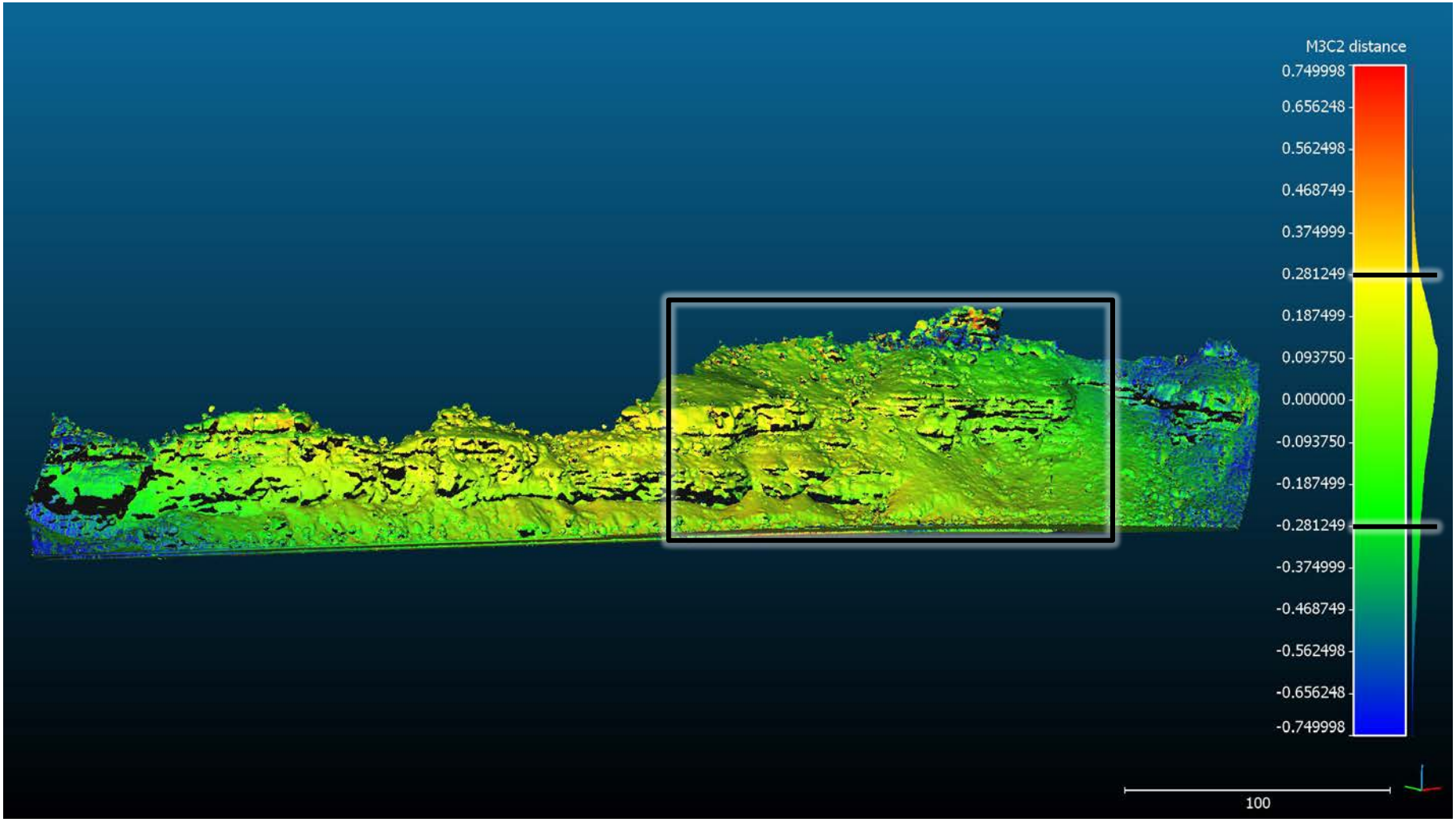
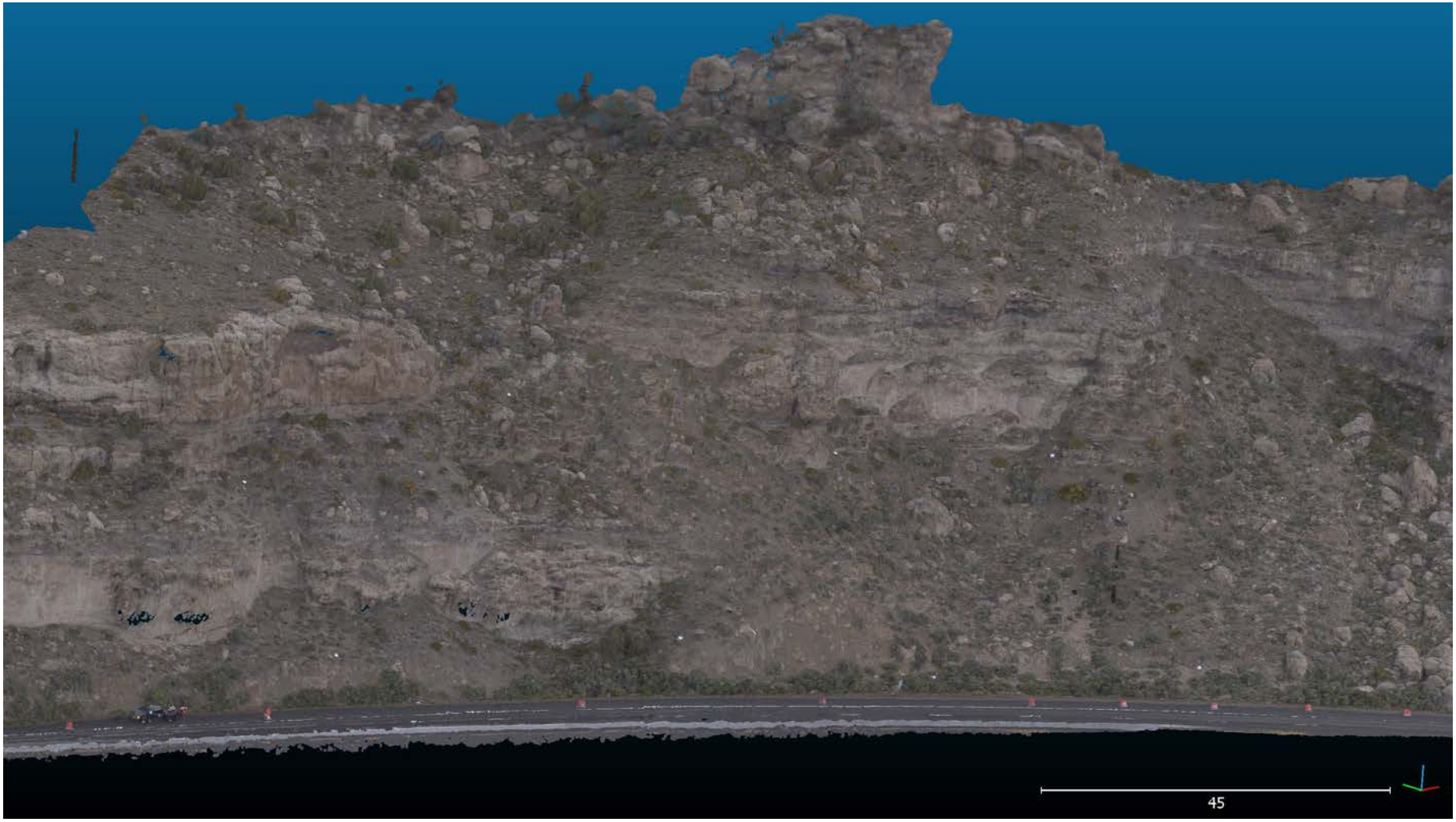
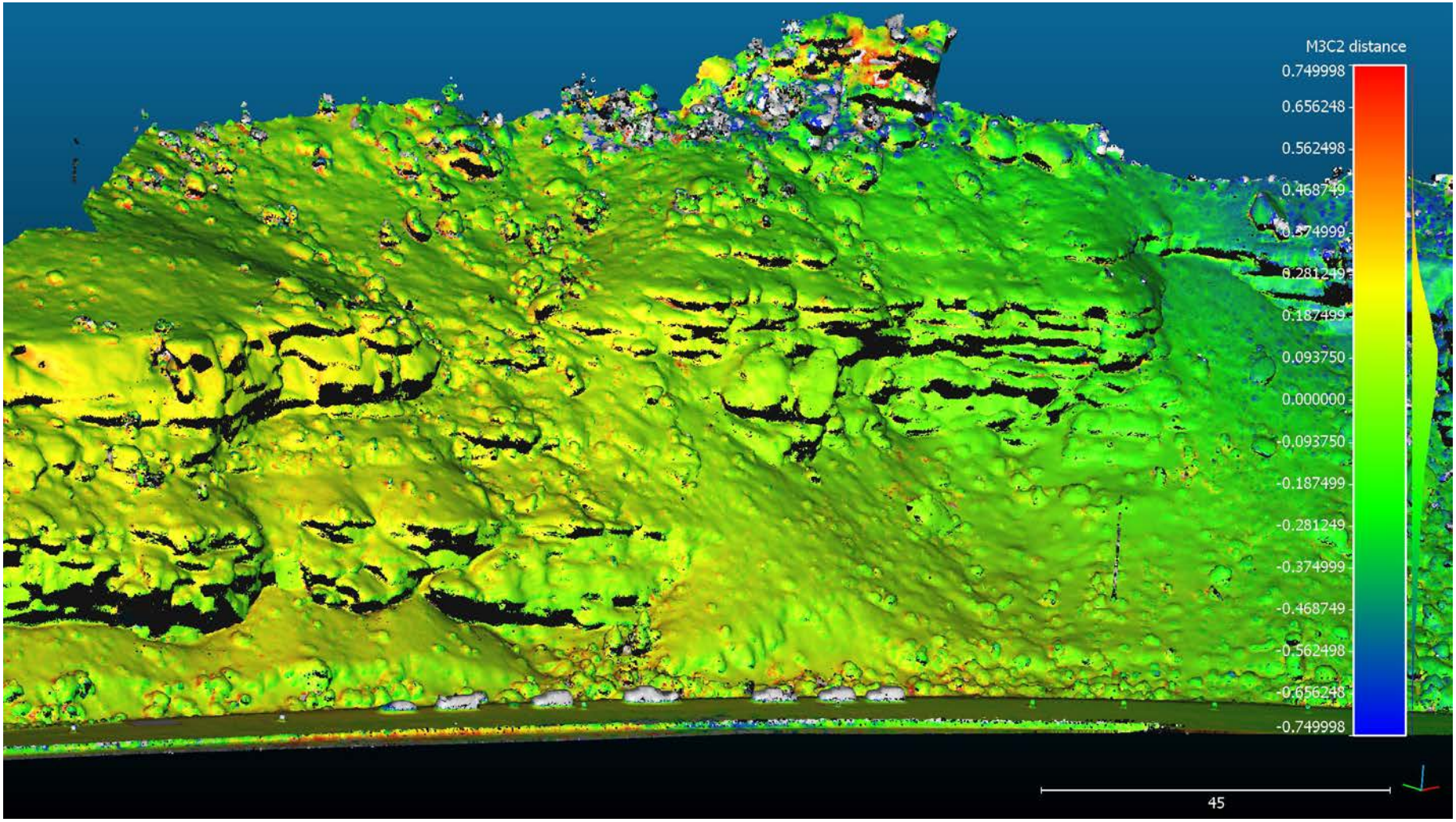


April 26, 2017

April 27, 2017



Difference – April 26 to April 27, 2017



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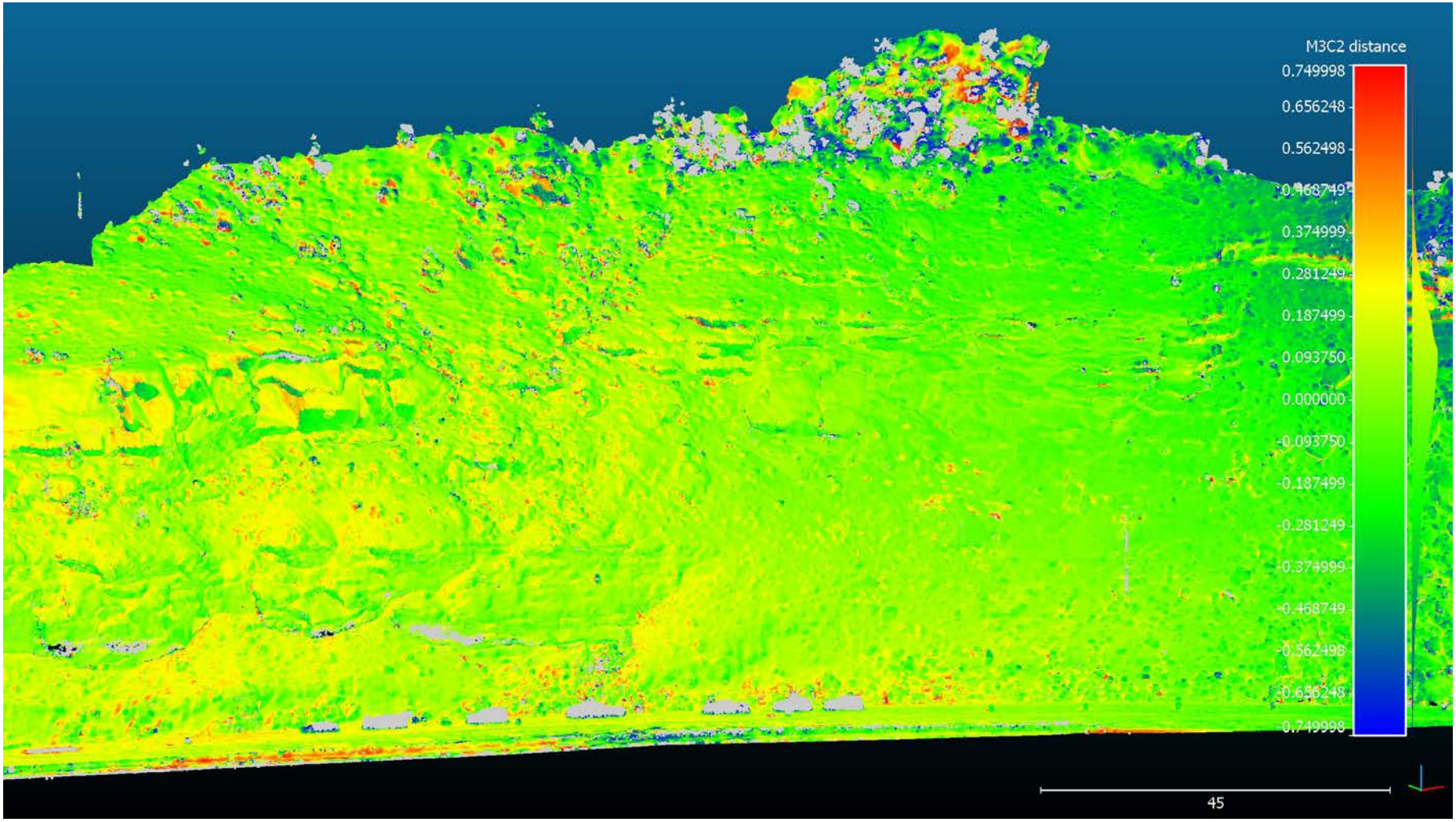

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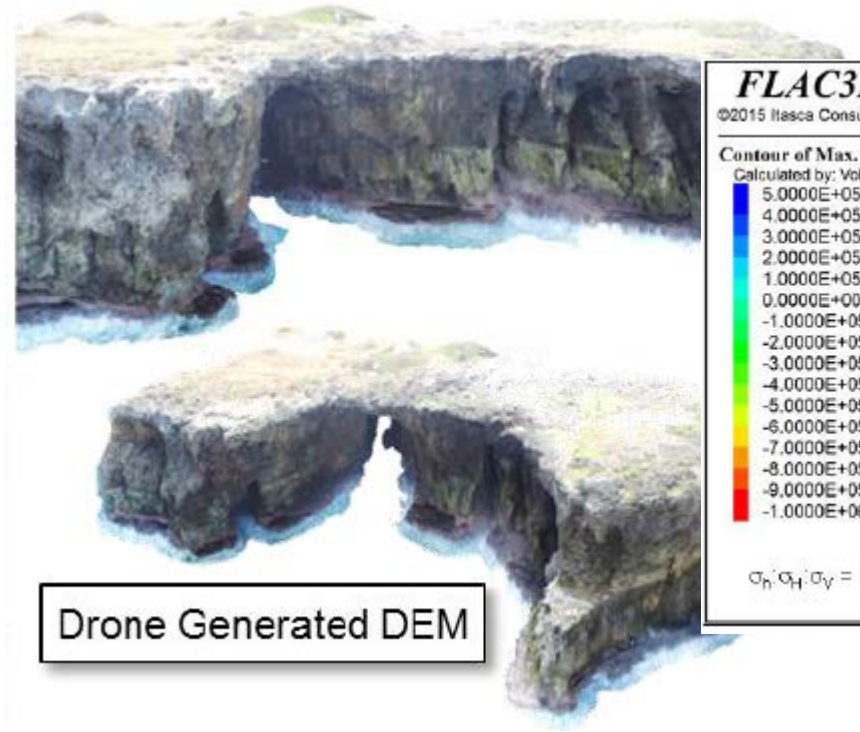
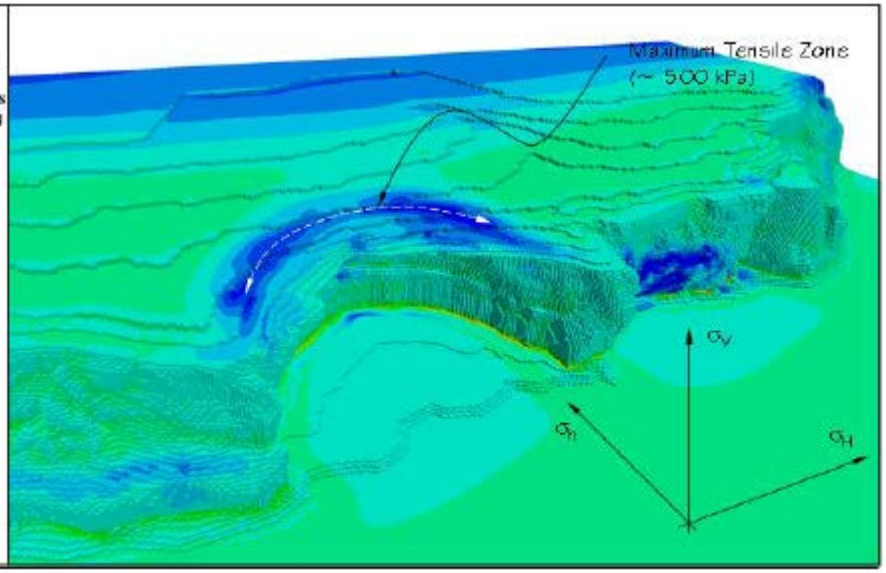
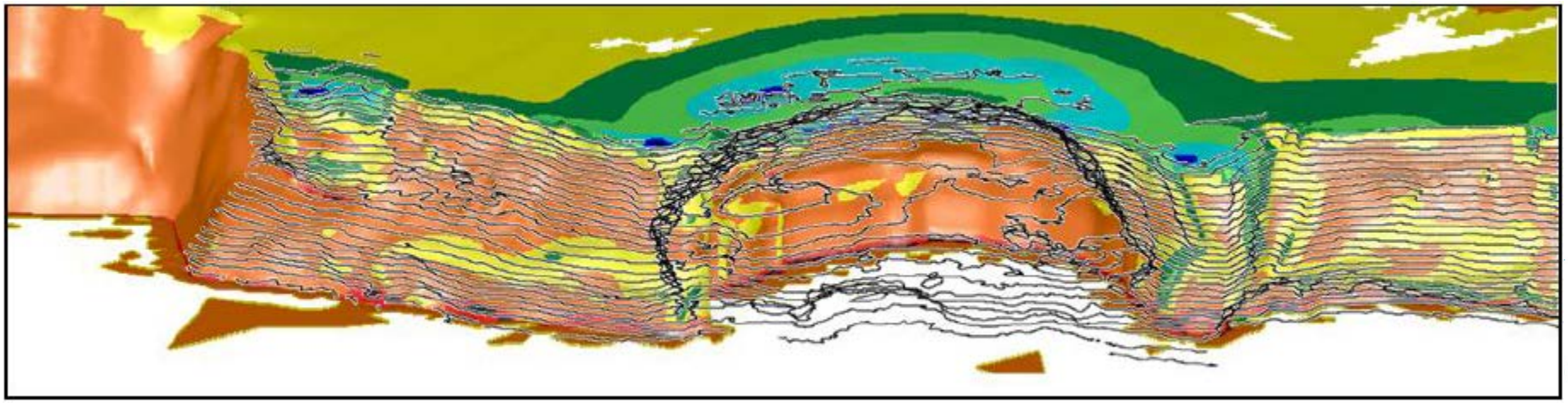
Preliminary Findings – Limits of Detection

- Resolution
  - UAV LiDAR ~10 cm/point (~4 in/point)
  - UAV Photogrammetry ~2 cm/pixel (~3/4 in/point)
- Approximate Limits of Detection / Registration Error
  - UAV LiDAR ± 6 cm (2.5 in)
  - UAV Photogrammetry ± 30 cm (12 in)
  - Photogrammetry – Registration is Key

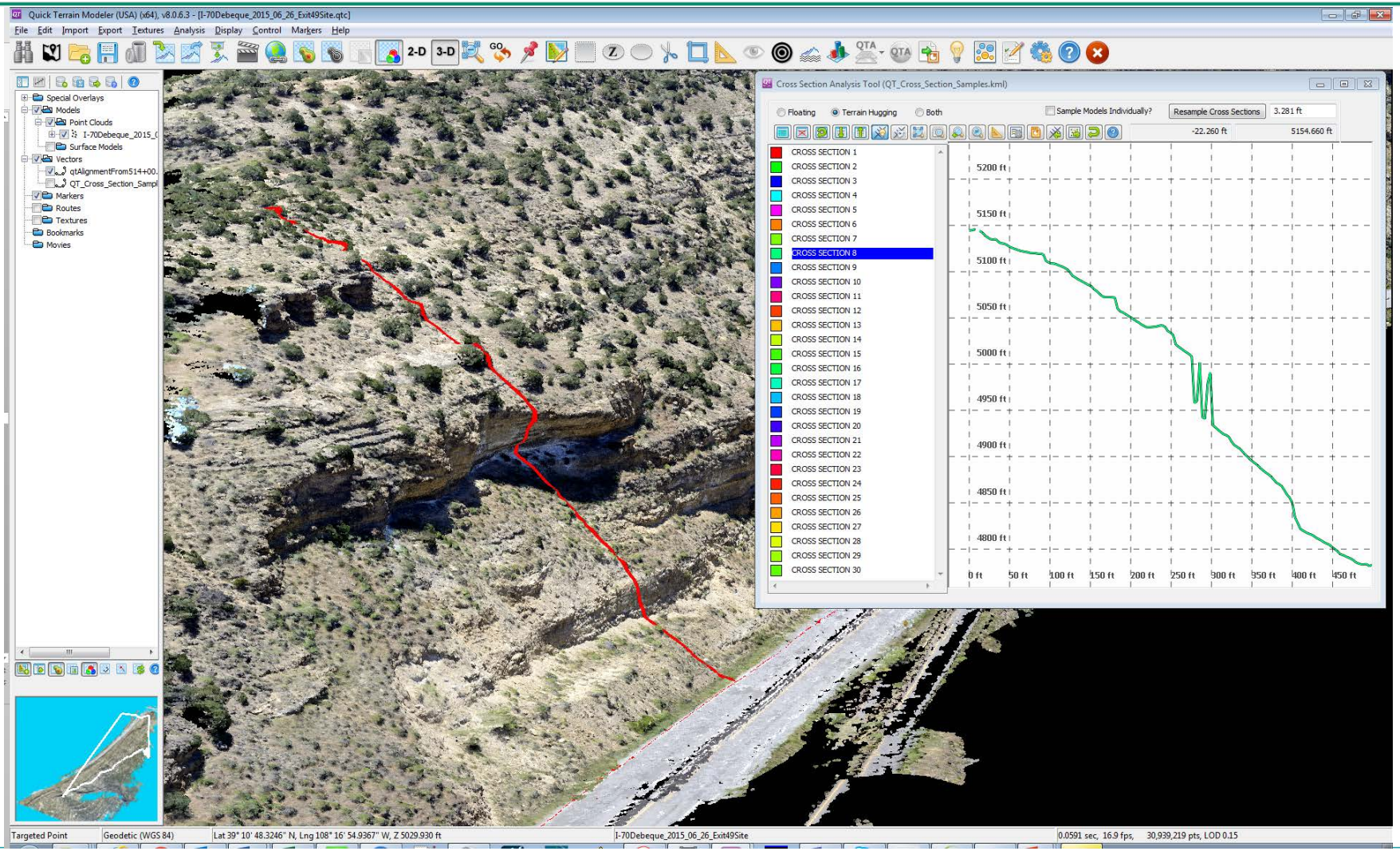
Case Study – UAV Data for Numerical Modelling







Rapid Generation of Rockfall Simulation Runs



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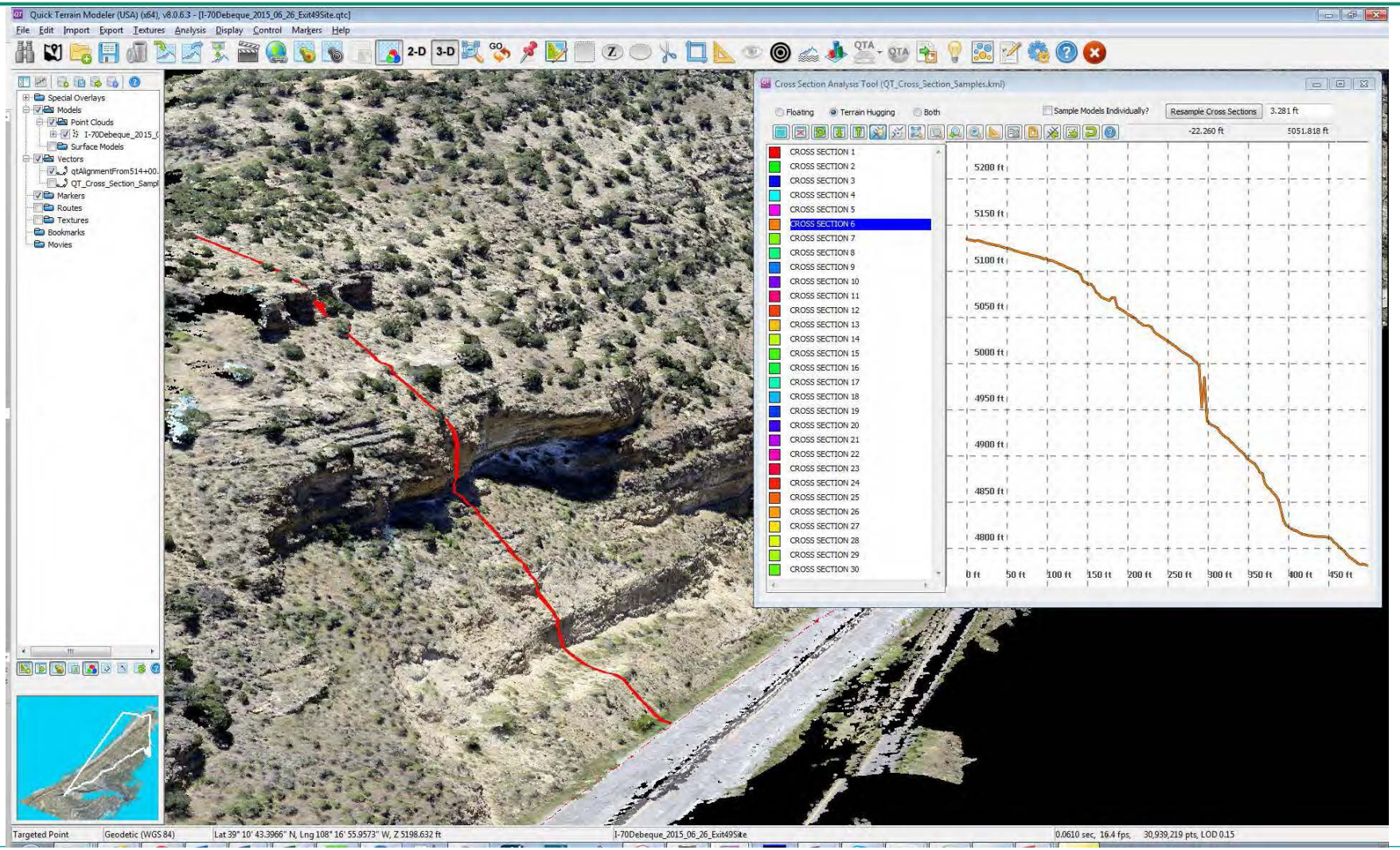

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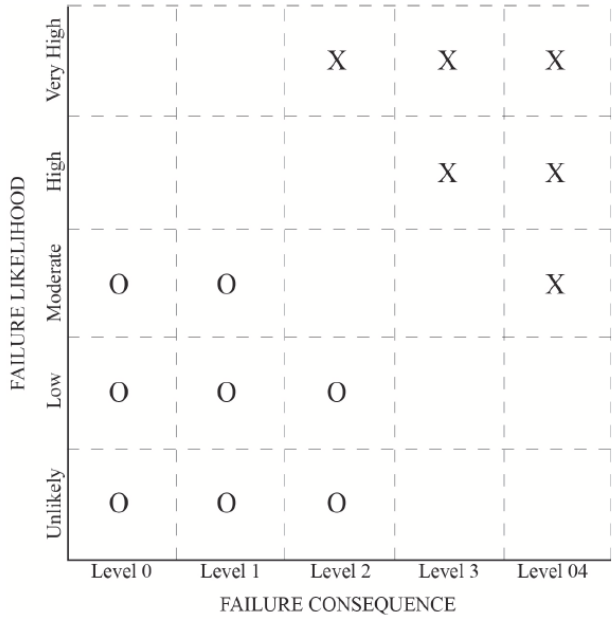
Geotechnical Asset Management

- GAM Still in Development Stages
- Currently – Inventory of Features (Hazard Identification)
- Score/Rating – Not a Probability

	Unlikely	Likely	Very Likely
Major	Medium	High	Extreme
Moderate	Low	Medium	High
Minor	Low	Low	Medium



Source: Vessely, 2013

Modified Colorado RHRS and UAV Data

- Measurable
- Quantifiable

- May be Quantifiable
- Potential to Visually Assess

Colorado Rockfall Hazard Rating Field Worksheet

Sight Information				
ROUTE NO	SEGMENT ID NUMBER	ENGINEERING REGION	MAINTENANCE SECTION	DATE
COUNTY	BEGIN MILE POST	END MILE POST	R / L OF CENTERLINE	RATER

Actual Values		*Remarks*
Slope Height _____	Ditch Depth _____	Major rockslide potential:
Slope Angle _____	Sight Distance _____	Dominating rockfall mode: Block-in-matrix / Sedimentary rock / Crystalline rock
Ditch Slope _____	Speed Limit _____	Dominating sight distance: Horizontal / Vertical
Ditch Width	ADT	Mitigation effectiveness: A B C D F

Rating Cut Slope / Total Slope (Circle one)

			3 Points	9 Points	27 Points	81 Points
Slope	Slope Height		25 to 50 ft	50 to 75 ft	75 to 100 ft	>100 ft
	Rockfall Frequency		> 2 years	1 to 2 years	Yearly, seasonal	Year round / severe events
	Average Slope Angle Score		0 to 2	2 to 4	4 to 8	> 8
	Launching Features		None (smooth slope)	Minor (< 2 ft. surface variation)	Many (2 to 6 ft. surface variation)	Major (> 6 ft. surface variation)
	Ditch Catchment		95% to 100% / Class 1	65% to 94% / Class 2	30% to 64% / Class 3	< 30% / Class 4 / > Major launching features
Climate	Annual Precipitation		< 10 inches	10 to 20 inches	20 to 35 inches	> 35 inches
	Annual Freeze Thaw Cycles		1 to 5	6 to 10	11 to 15	16 or more
	Seepage / Water		Dry	Damp / wet	Dripping	Running water
	Slope Aspect		N	E, W, NE, NW	SE, SW	S
Geology	Sed. Rock	Degree of Under-Cutting	0 to 1 ft	1 to 2 ft	2 to 4 ft	> 4 ft
		Jar Slake	6	5	3 to 4	1 to 2
		Degree of Interbedding	1 to 2 weak interbeds, < 6 in.	1 to 2 weak interbeds, > 6 in.	> 2 weak interbeds, < 6 in.	> 2 weak interbeds, > 6 in.
	Crys. Rock	Rock Character	Homogenous / massive	Small faults / strong veins	Schist / shear zones < 6 in.	Weak pegmatite / micas / shear zones > 6 in.
		Degree of Overhang	0 to 1 ft	1 to 2 ft	2 to 4 ft	> 4 ft
		Weathering Grade	Fresh	Surface staining	Slightly altered / softened	Core stones
	Discontinuities	Block Size / Volume	<1 ft / <1 cy	1 to 2 ft / 1 to 3 cy	2 to 5 ft / 3 to 10 cy	>5 ft / >10 cy
		Number of Sets	1	1 plus random	2	> 2
		Persistence, Orientation	< 10 ft and dips into slope	> 10 ft and dips into slope	< 10 ft and daylights out of slope	> 10 ft and daylights out of slope
		Aperture	Closed	0.1 to 1 mm	1 to 5 mm	> 5 mm
		Weathering Condition	Fresh	Surface staining	Granular infilling	Clay infilling
		Friction	Rough	Undulating	Planar	Slickensided
	Block in Mat.	Block Size (x3)	< 1 ft	1 to 2 ft	2 to 5 ft	> 5 ft
		Block Shape (x3)	Tabular	Blocky	Blocky to angular	Rounded and smooth
		Vegetation (x3)	Fully vegetated	Patchy vegetation	Isolated plants	None
Total Hazard Score:						
Traffic	Sight Distance		> 80 %	60 % to 80 %	40 % to 60 %	< 40 %
	Avg. Vehicle Risk		0 to 24%	25 to 49%	50 to 74%	75% or more
	No. of Accidents		0 to 2	3 to 5	6 to 8	9 and over
Total Risk Score:						

Additional Rater's Comments:

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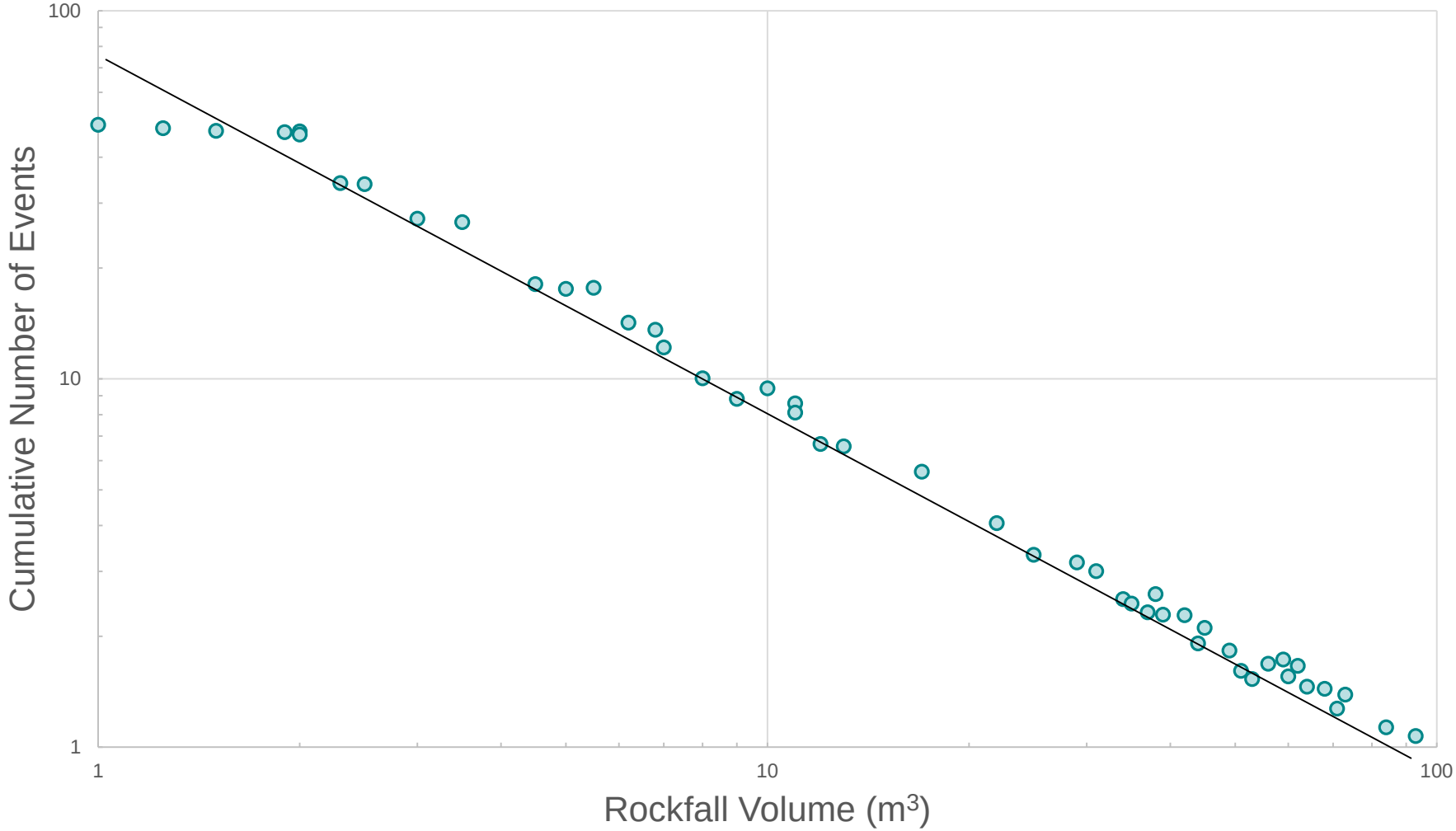
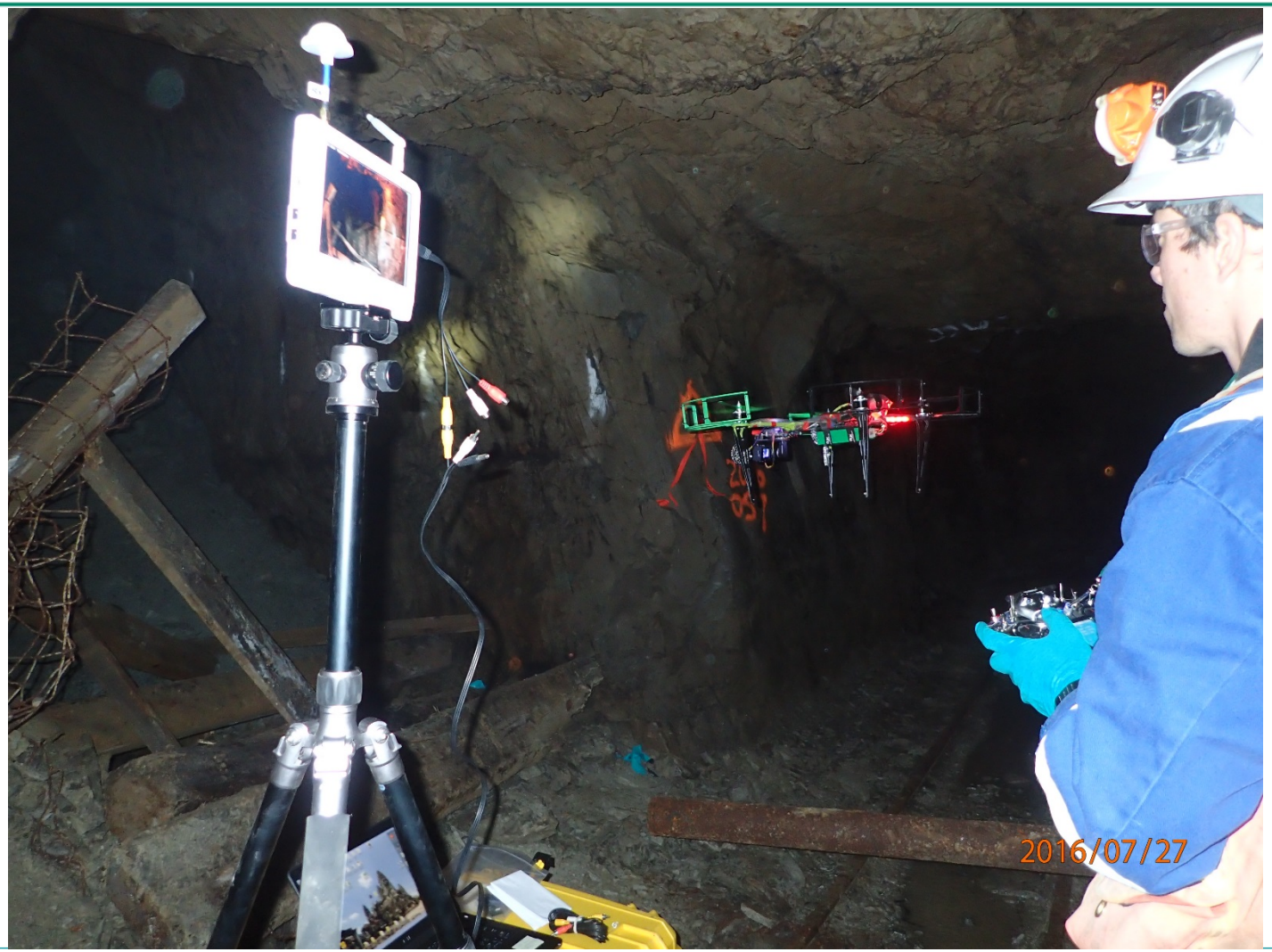
Rockfall Magnitude-Cumulative Frequency



Difficult / Limited Access

Emerging Applications – Drones Underground



Emerging Applications– Drones Underground

Applicable to tunnel inspections

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Emerging Applications– Drones Underground

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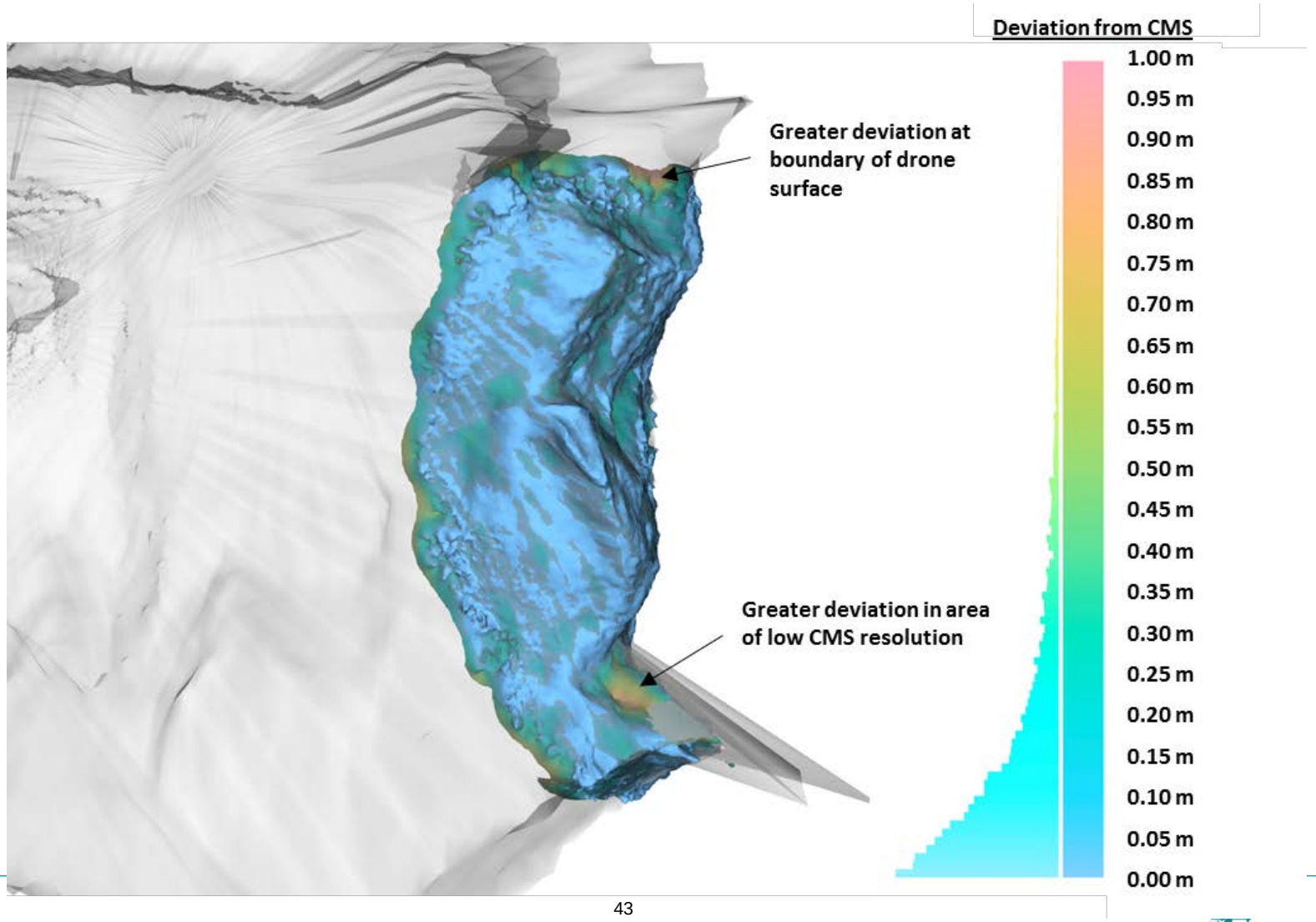
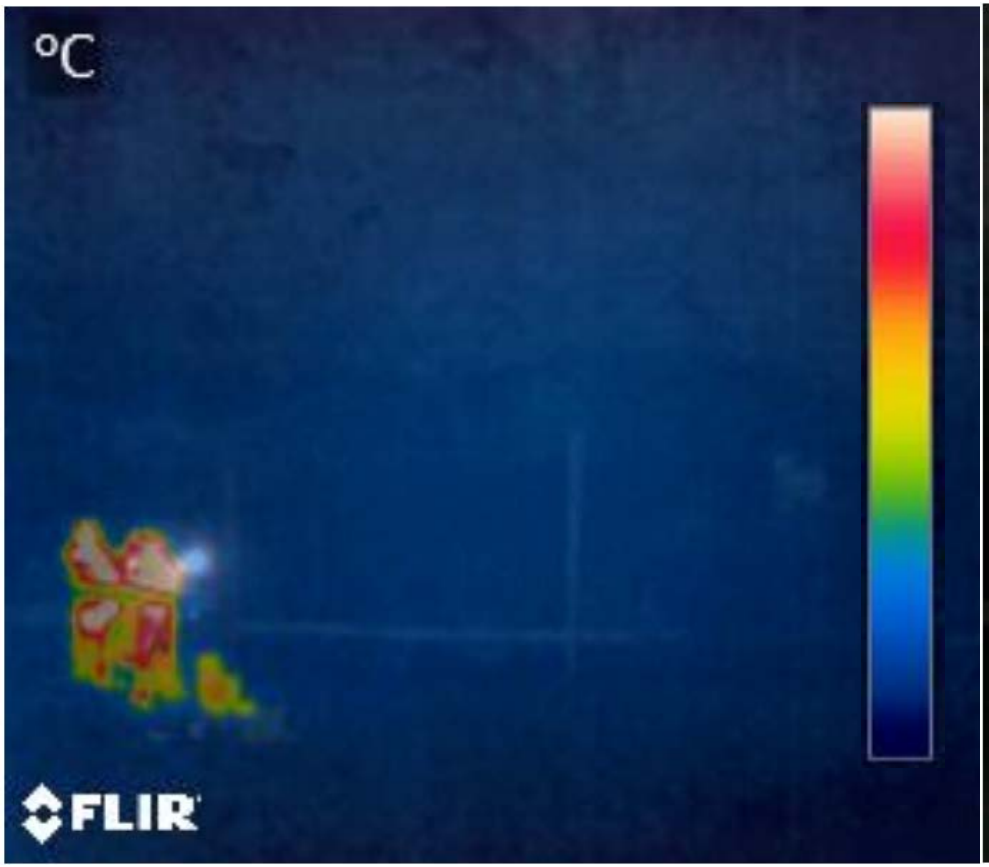
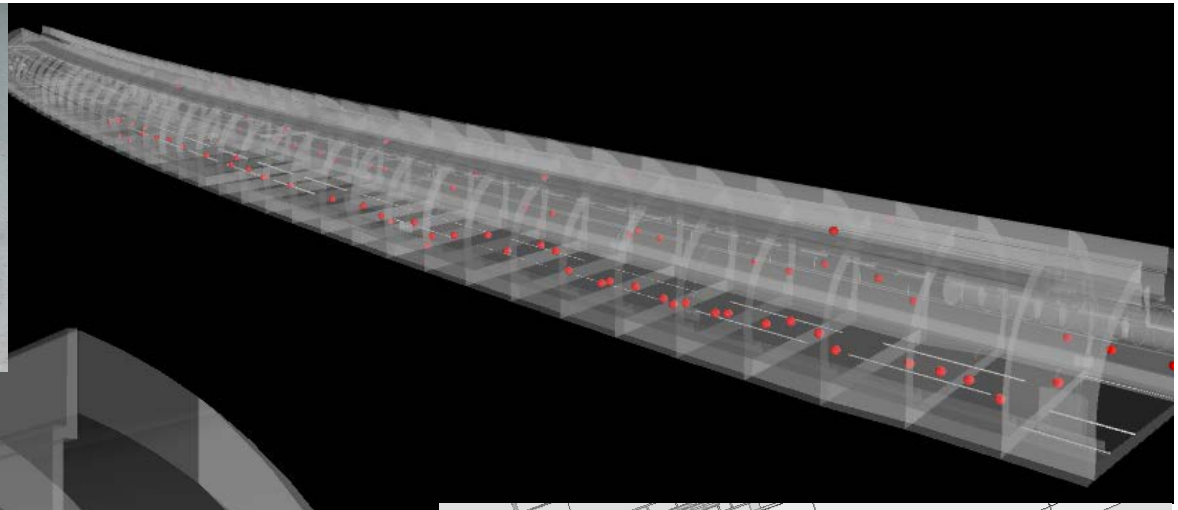
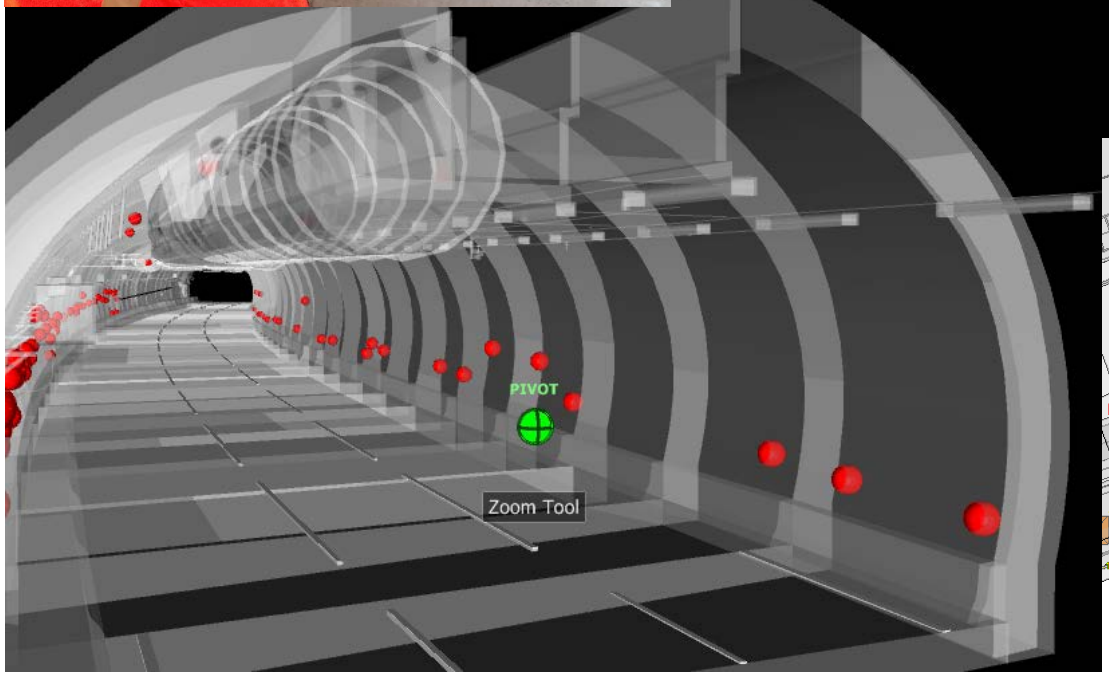


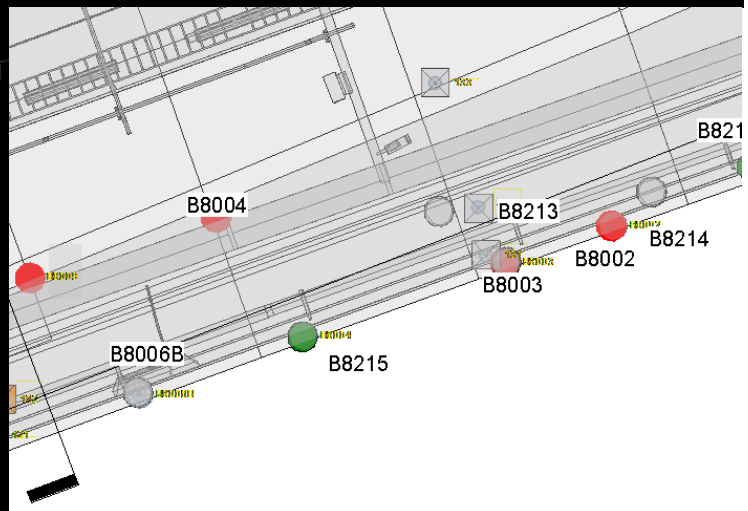
Emerging Applications– Drones Underground – Looking for Seepage with Thermal Imager



Emerging Applications– Input into BIM Systems







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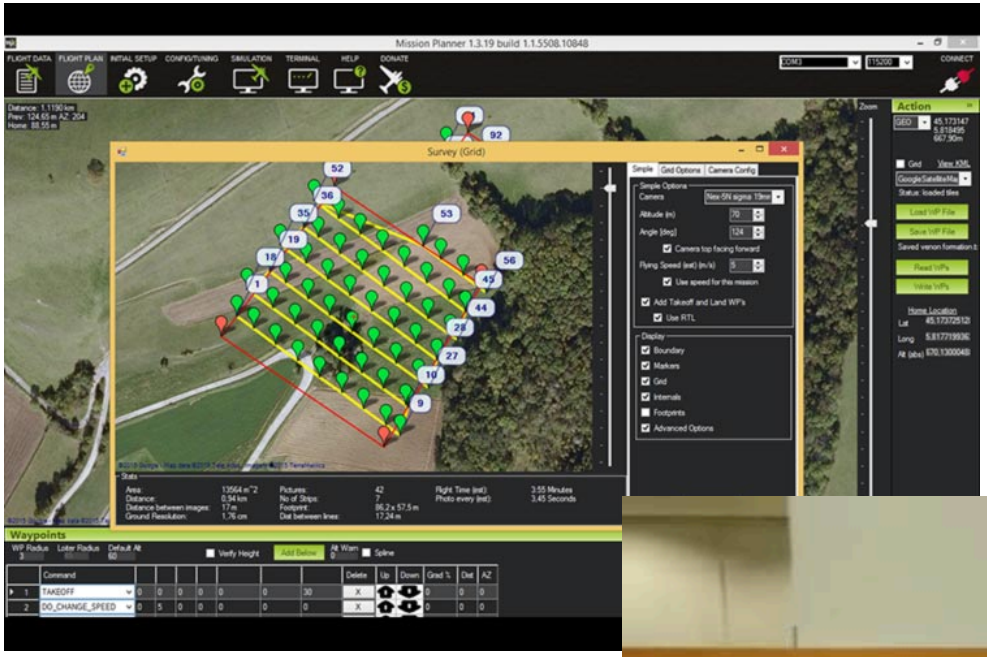
Emerging Applications - Automation



Questions?

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