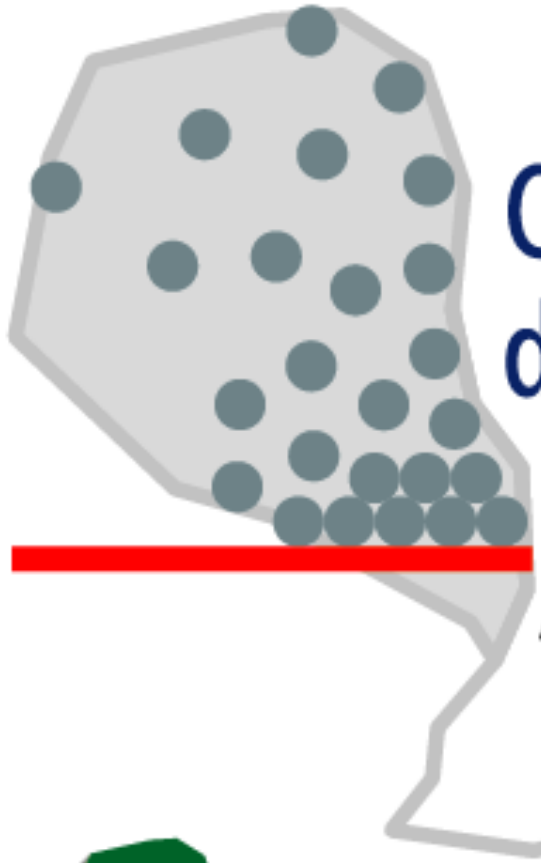


Congreso de Suelos Dispersivos y Sulfatados

Asunción, 24-25/10/19

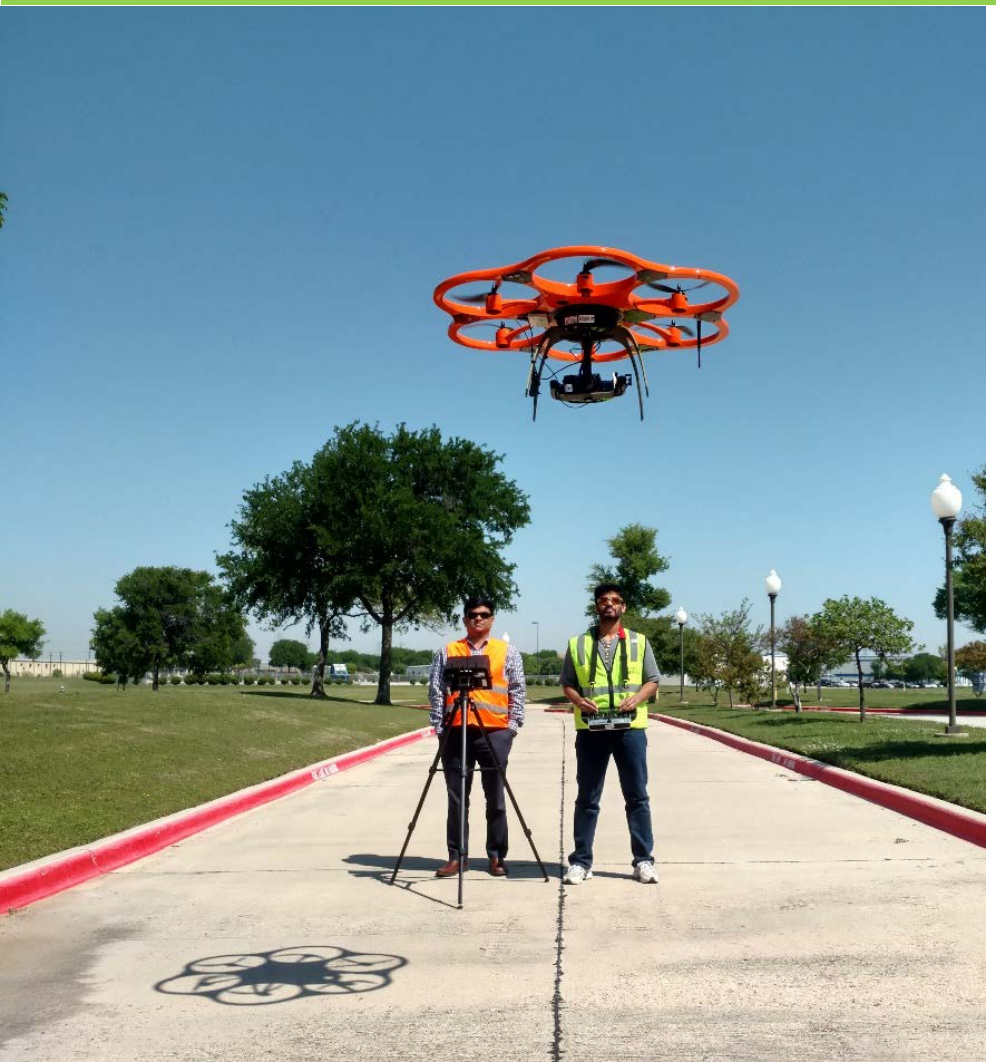
Sociedad Paraguaya de Geotecnia

ASOCIACIÓN PARAGUAYA DE CARRETERAS

COMITÉ NACIONAL PARAGUAYO

WORLD ROAD ASSOCIATION MONDIALE DE LA ROUTE

Novel Infrastructure Monitoring Using Multifaceted Unmanned Aerial Vehicle Systems - Close Range Photogrammetry (UAV - CRP) Data Analysis



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&
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UNIVERSITY OF TEXAS ARLINGTON

Presentation Outline

I. Introduction
   - Photogrammetry
   - Small Unmanned Aerial Vehicles (sUAV)

II. Research Objective

III. Infrastructure Monitoring

IV. UAV Flight Planning Rules (TxDOT FOM)

V. Pavement Monitoring

VI. Bridge Monitoring

VII. Rail Corridor Monitoring

VIII. Benefits of UAV-CRP Data Collection

Introduction

- Photogrammetry is the art and science of making measurements and 3-dimensional point clouds from two or more photographs
  - Smart phone cameras to sensor mounted satellites
  - Terrestrial and Aerial
- UAV Types
  - Rotary-wing – Lift from the continuous rotation of its blades
  - Fixed-wing – Single rigid wing across its body (Tahar and Ahmad 2012)
- Close Range Photogrammetry (CRP) – <1000 ft radius

Research Objective

- Unmanned Aerial Vehicles (UAV) coupled with Close Range Photogrammetry (CRP) – Infrastructure data
- Infrastructure condition monitoring
  - Qualitative
  - Quantitative

Infrastructure Monitoring

- Traditional Inspection methods – Tedious, Costly, and Dangerous (Sometimes)
- Infrastructure inspection and damage assessments (outside sensor embedment systems)
  - Helicopters and Small Aircrafts – Expensive
  - Small Unmanned Aerial Vehicles (sUAV or sUAV or Drones) – Major Advantages

- Diverse Infrastructure applications
- Aug 29th, 2016 FAA- Released set of new regulations on commercial use of Small Unmanned Aerial Systems (sUAV)

Infrastructure Monitoring

- Proactive monitoring – Preventive maintenance
  - Low life cycle cost of infrastructure
  - Higher return on investment
- Two types of monitoring
  - Qualitative – QA/QC
  - Quantitative – Infrastructure Characteristics
- Aerial Data Collection – 3-Dimensional Mapping Products of Infrastructure
  - Dense Point Cloud
  - Digital Elevation Model (DEM)
  - Orthomosaic

UAV Flight Planning Rules (TxDOT FOM)

Rule 1: Increase flight crew safety by locating their operations further from the roadway or railway

Rule 2: For roadways with a speed limit greater than 40 mph, the aircraft will cross the roadway at an altitude no less than 50 feet AGL

Rule 3: Take-off and landings between lanes of a divided highway is prohibited

Rule 4: The aircraft will not operate within six feet of any fixed object

Source: TxDOT FOM (2018)

UAV Flight Planning Rules (TxDOT FOM)

Rule 5: When working along a road right-of-way the aircraft is prohibited from entering into an adjacent railroad right-of-way without the approval of the UAS Coordinator

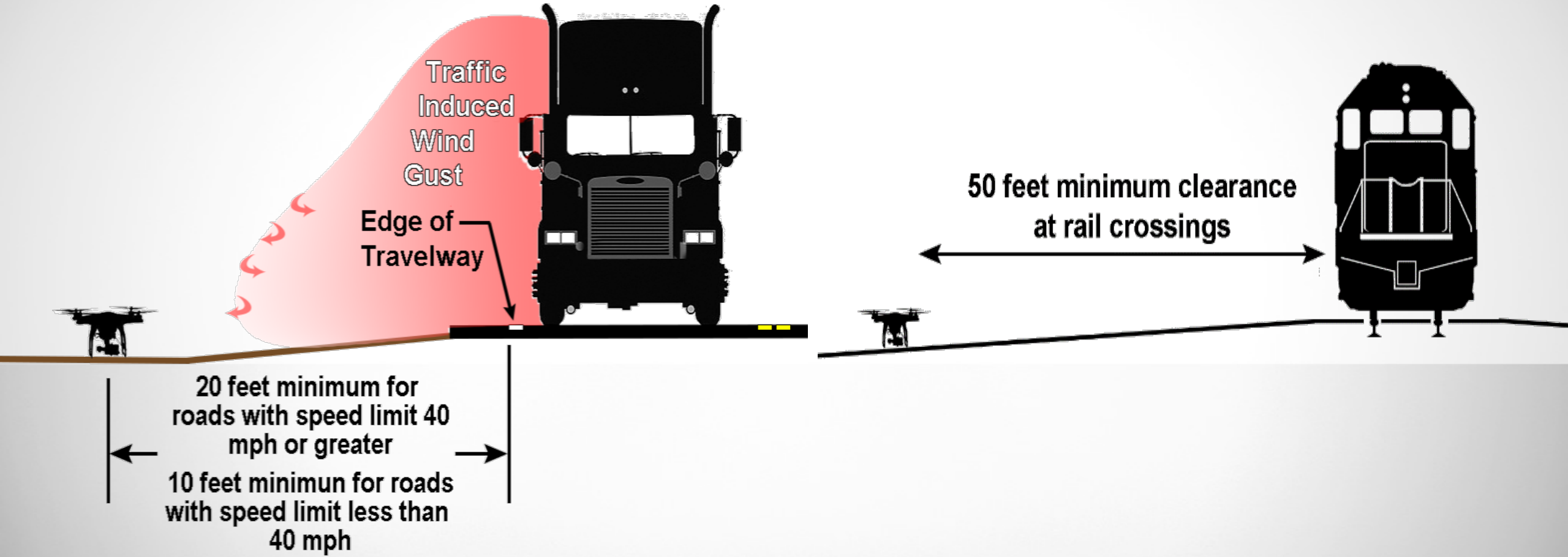
Rule 6: No aircraft will operate under the deck of an overpass bridge with traffic on a lower roadway without an approved traffic plan

Rule 7: The aircraft will not operate directly above a roadway when vehicles are present

Source: TxDOT FOM (2018)

Rule 1

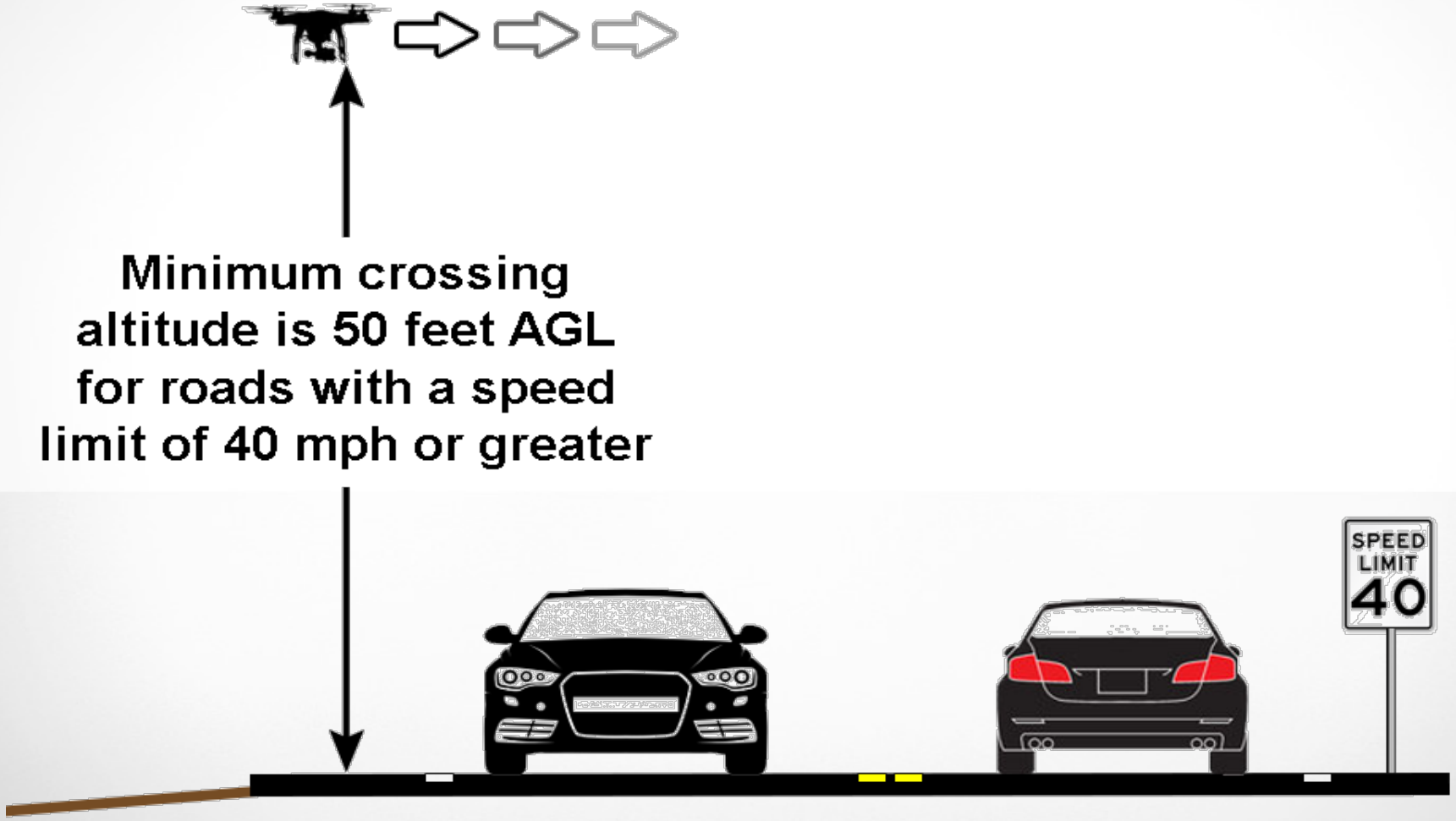
UAV Flight Planning Rules (TxDOT FOM)



Source: TxDOT FOM (2018)

Rule 2

UAV Flight Planning Rules (TxDOT FOM)



Source: TxDOT FOM (2018)

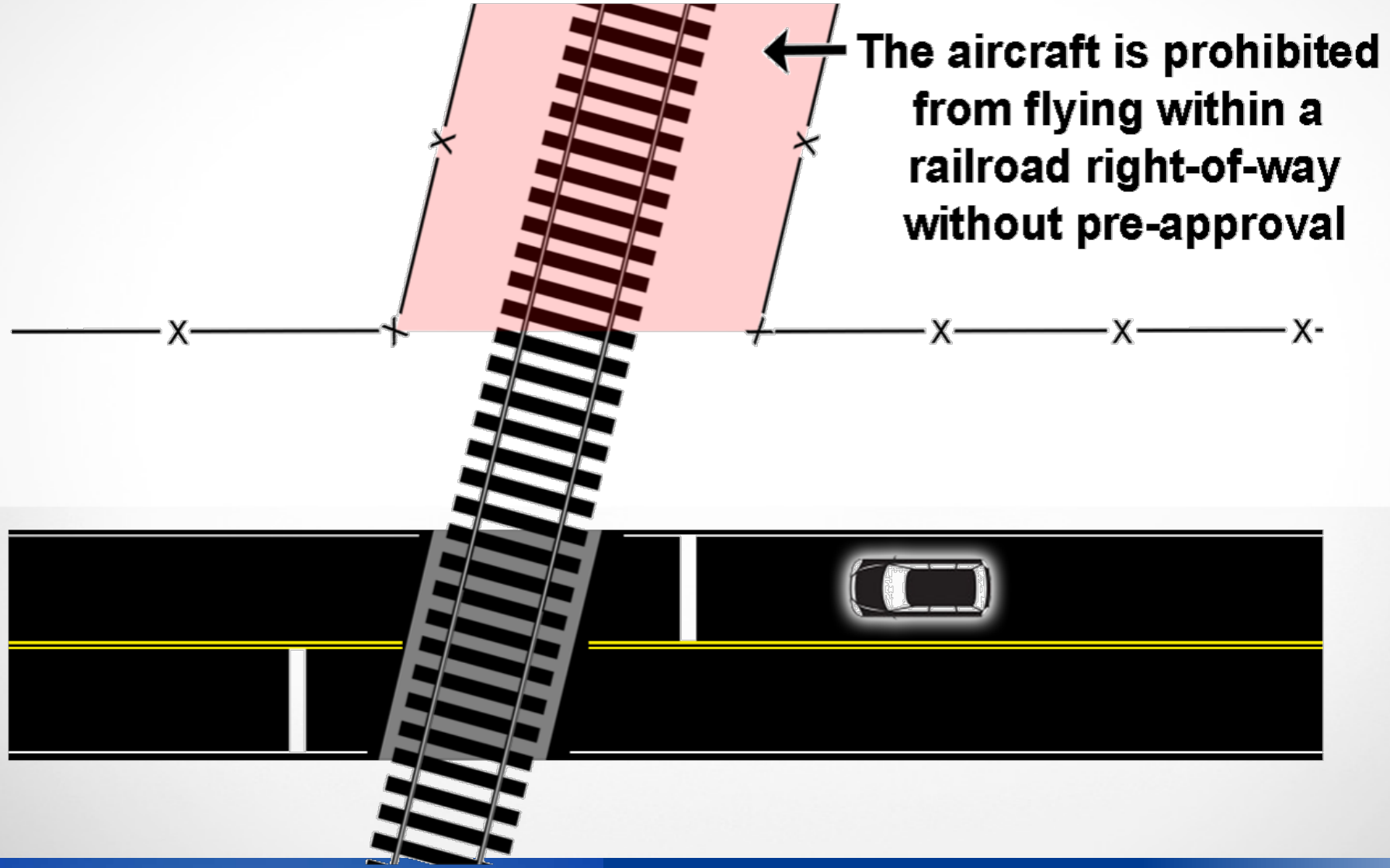
Rule 3

UAV Flight Planning Rules (TxDOT FOM)

Source: TxDOT FOM (2018)

Rule 5

UAV Flight Planning Rules (TxDOT FOM)



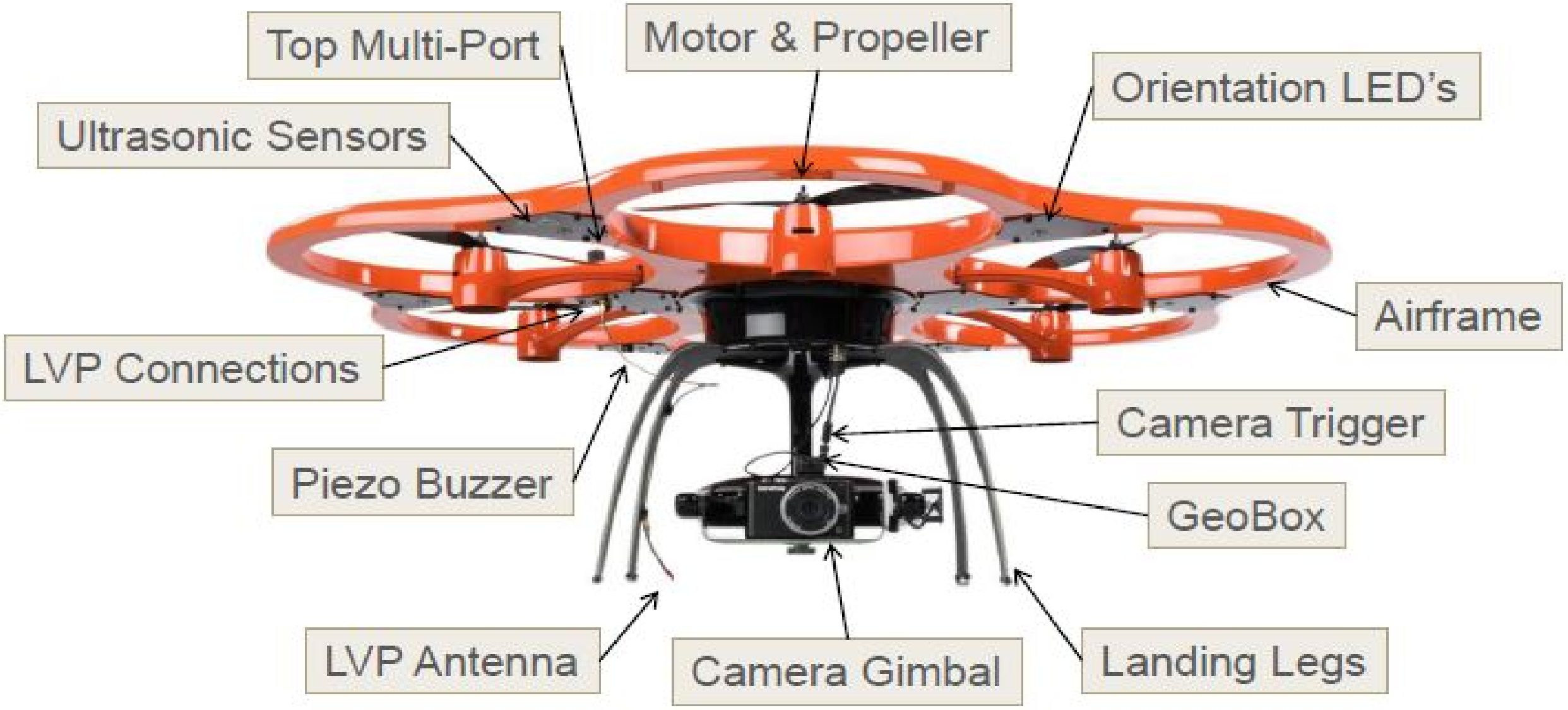
Source: TxDOT FOM (2018)

Rule 6

UAV Flight Planning Rules (TxDOT FOM)

Source: TxDOT FOM (2018)

Aibot X6 V2 Hexacopter

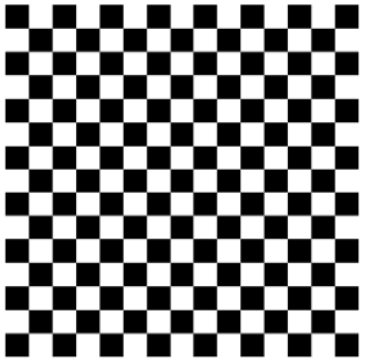


Total Calibration and System Error Analysis

- Total System Error Analysis – Comprehensive checks
- Compatibility of UAV and other accessories – Quality data

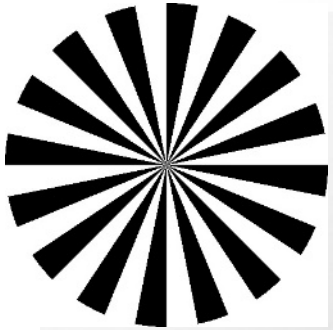
Specific Objectives: Studied

- Accuracy in geotagging the images
- Variation in the focal length of camera
- Thermal effect on lens
- Non-linear errors
- ‘Structure from Motion’ (SfM) errors
- To analyze resolution and resolving power of the system

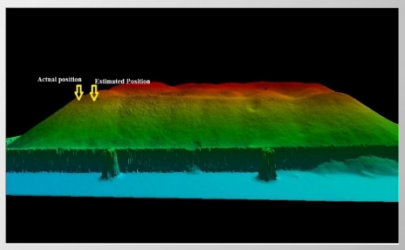


Checkerboard

Fluke 59 Max IR thermometer

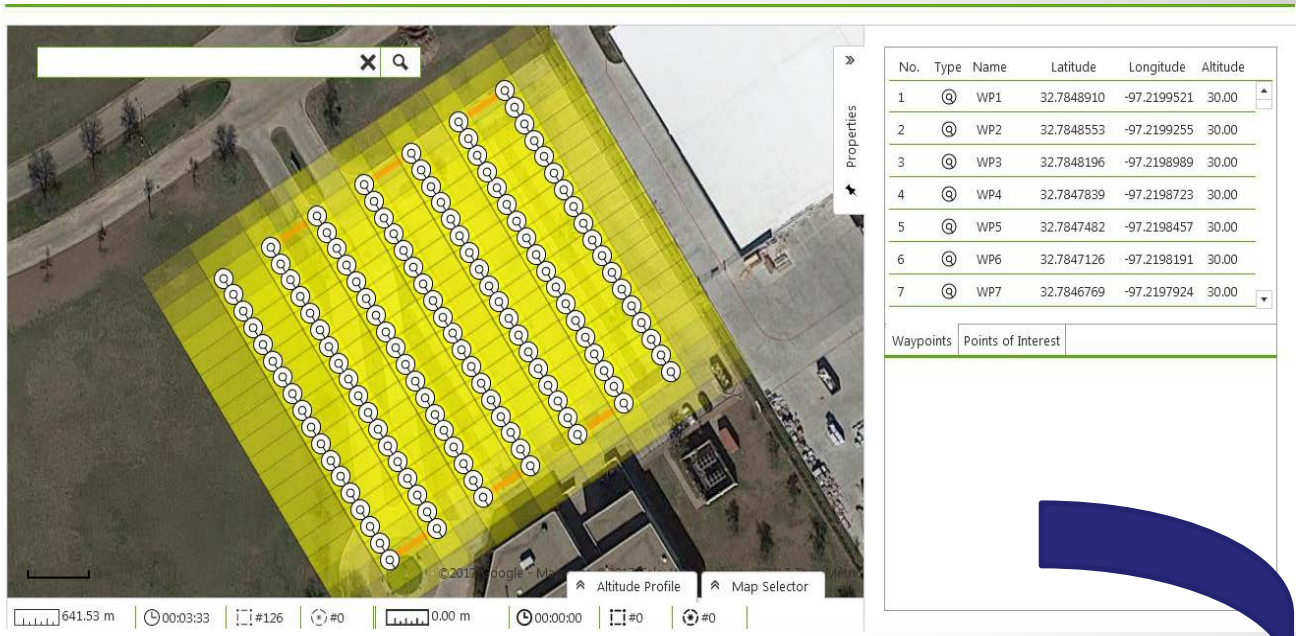


Siemens star



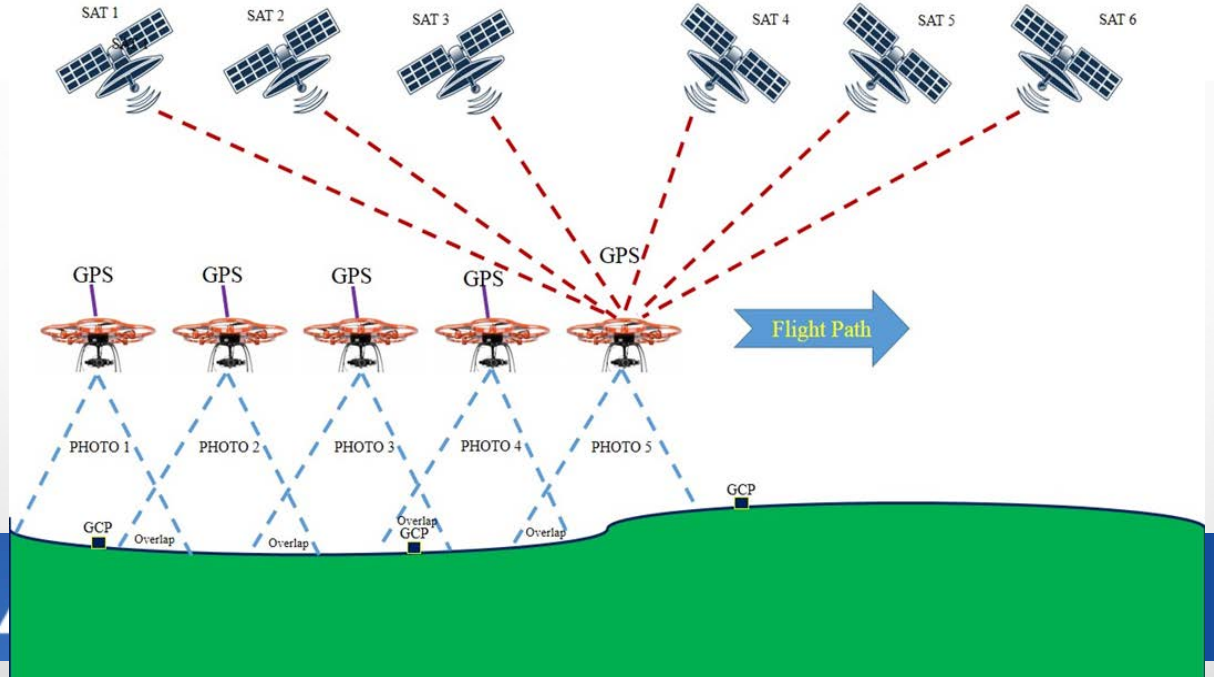
SfM error

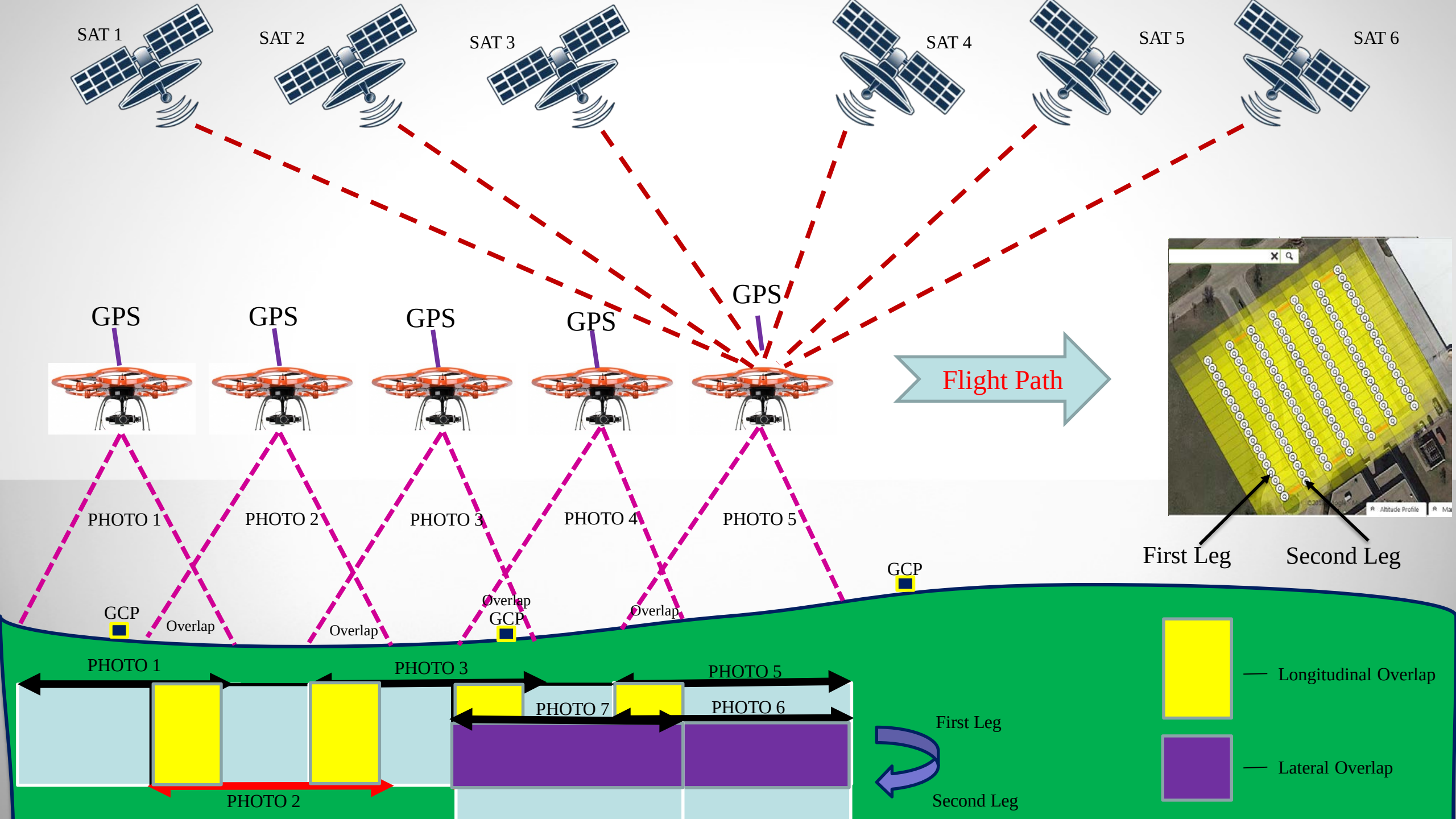
Field Data Collection Procedure with UAVs



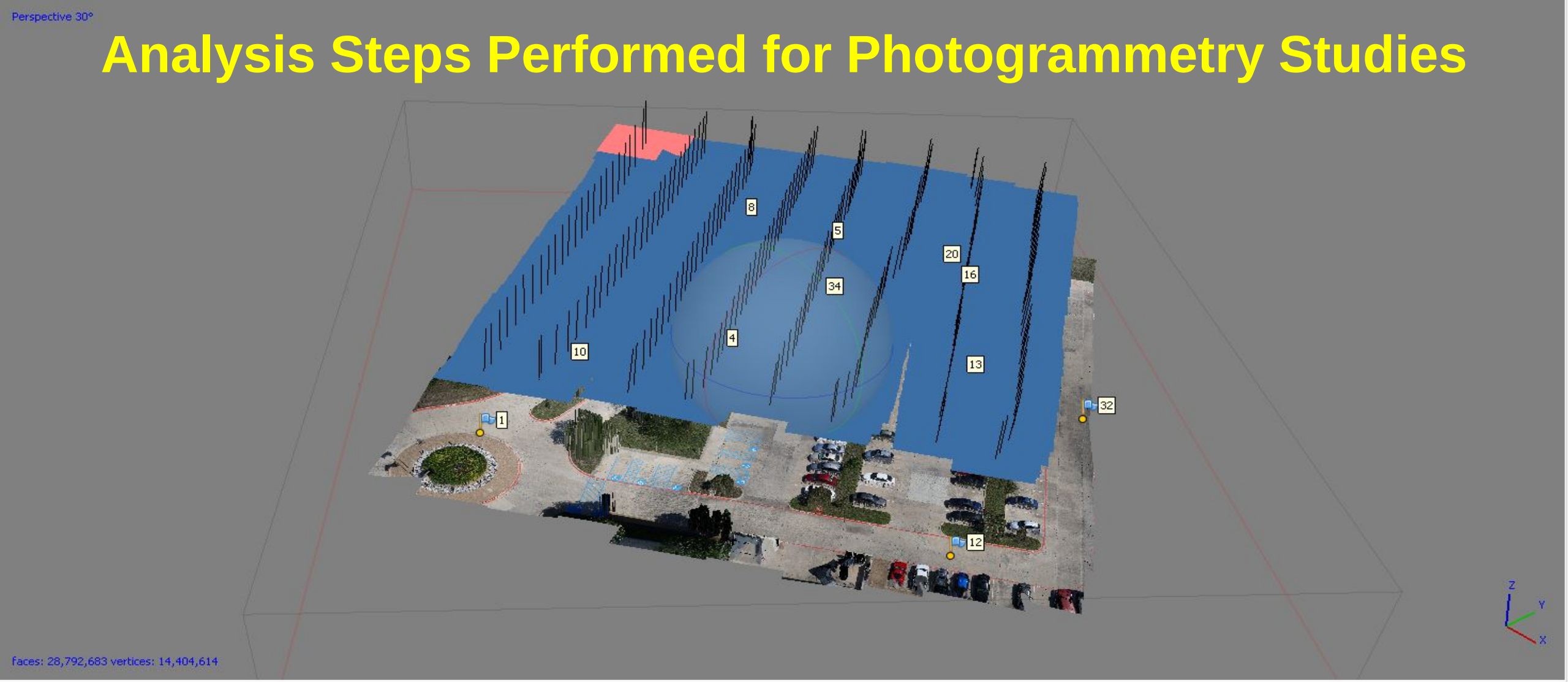
No.	Type	Name	Latitude	Longitude	Altitude
1		WP1	32.7848910	-97.2199521	30.00
2		WP2	32.7848553	-97.2199255	30.00
3		WP3	32.7848196	-97.2198989	30.00
4		WP4	32.7847839	-97.2198723	30.00
5		WP5	32.7847482	-97.2198457	30.00
6		WP6	32.7847126	-97.2198191	30.00
7		WP7	32.7846769	-97.2197924	30.00

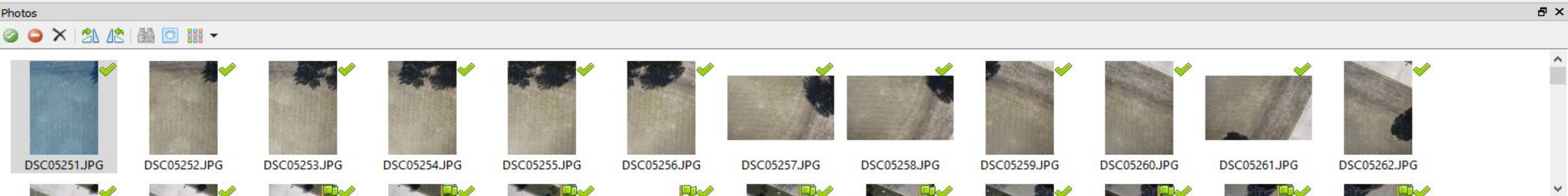
Waypoints | Points of Interest




SAT 1
SAT 2
SAT 3
SAT 4
SAT 5
SAT 6
GPS
GPS
GPS
GPS
GPS
Flight Path
PHOTO 1
PHOTO 2
PHOTO 3
PHOTO 4
PHOTO 5
First Leg
Second Leg
GCP
GCP
GCP
Overlap
Overlap
Overlap
Overlap
PHOTO 1
PHOTO 3
PHOTO 5
PHOTO 7
PHOTO 6
PHOTO 2
First Leg
Second Leg
Longitudinal Overlap
Lateral Overlap

Analysis Steps Performed for Photogrammetry Studies





■ - Estimated Position of Check Point **Analysis Software** + - Actual Position of Check Point

s Report

tion (TIN)

Source Points ...

Z Probe Location
- (●) Control X,Y
- ( ) Measured X,Y

Calculate DZ

Unique Name Field: Name

Measure Mode

Points that exceed limits of 90% CI
Points that exceed limits of 95% CI

Precision: 3

Control...	Control...	Measu...	Measu...	Surfac...	Z...	Delta X	Delta Y	Delta XY	Delta Z
6970933.337	501.738	2361908.017	6970933.347	501.661	Control	-0.137	-0.010	0.137	0.077
6970820.529	501.826	2361957.159	6970820.544	501.850	Control	0.021	-0.015	0.026	-0.024
6970757.890	500.719	2362180.095	6970757.799	500.762	Control	-0.069	0.091	0.114	-0.043
6970903.395	501.316	2362128.767	6970903.396	501.238	Control	-0.041	-0.001	0.041	0.078
6970883.960	501.303	2362097.948	6970883.956	501.260	Control	0.008	0.004	0.009	0.043
6971002.322	501.468	2362057.107	6971002.239	501.537	Control	-0.022	0.083	0.086	-0.069

Average Pixel Size:

	Y		Planimetric		Vertical	
-0.016	Mean Error *:	0.043	Mean Error *:	0.117	Mean Error *:	-0.096
[-0.210, 0.348]	Error Range:	[-0.023, 0.143]	Error Range:	[0.009, 0.349]	Error Range:	[-0.491, 0.078]
1.210	Skew:	0.341	Skew:	1.306	Skew:	-1.088
0.122	RMSE:	0.069	RMSE:	0.140	RMSE:	0.192
------	Y Accuracy Class:	------	Horizontal Accuracy Class:	------	Vertical Accuracy Class:	0.20
					Min Contour Interval:	0.60

17
17
0 of 18

* The Mean Error exceeds 25% of the RMSE. Further investigation of the error values is recommended to determine if the errors follow a normal error distribution.

View Disclaimer... Export Report

OK Cancel

Destination Class & Flags:

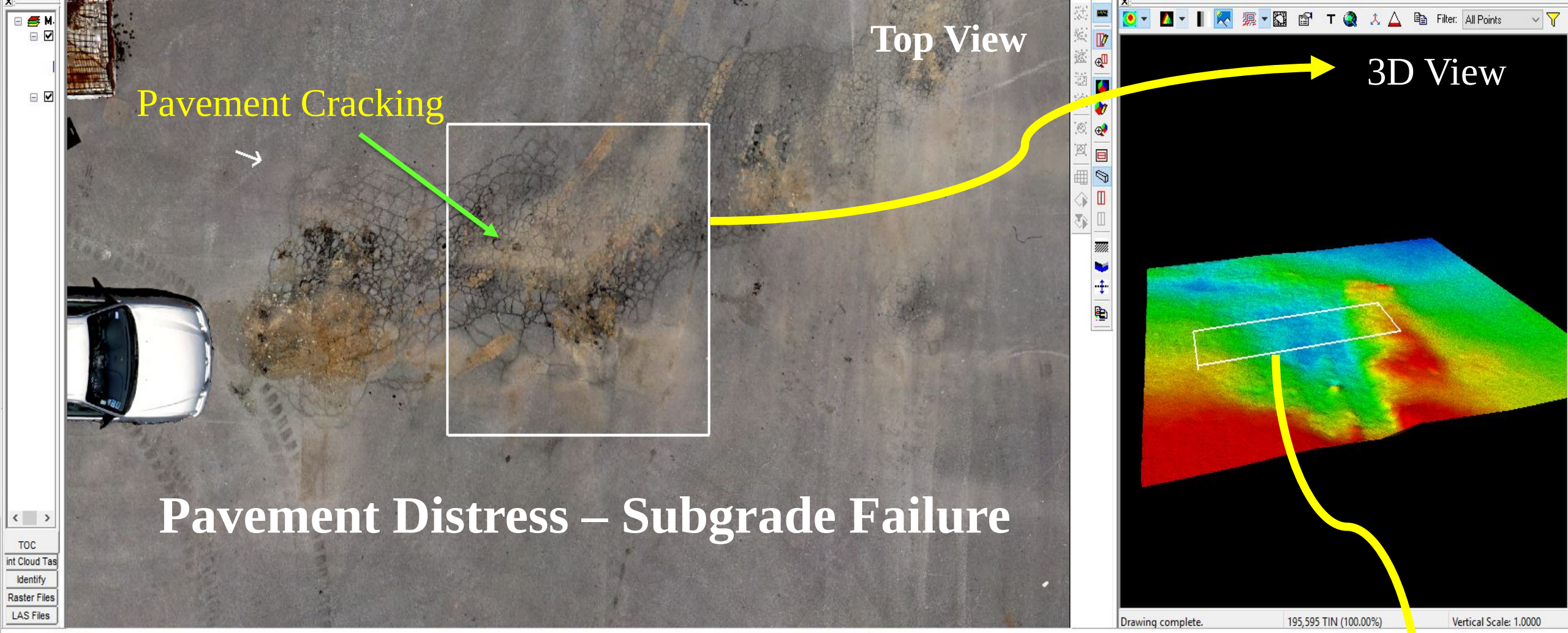
Asset Management

- Pavement Monitoring
  - Qualitative – Construction
  - Quantitative – Surficial Distress and Design Features
- Bridge Monitoring
  - Qualitative – Underbridge Inspection
  - Quantitative – Scour Depth and Spalling
- Rail Corridor Monitoring
  - Qualitative – Buckling
  - Quantitative – Rock Cut Slope Geometry and Washout

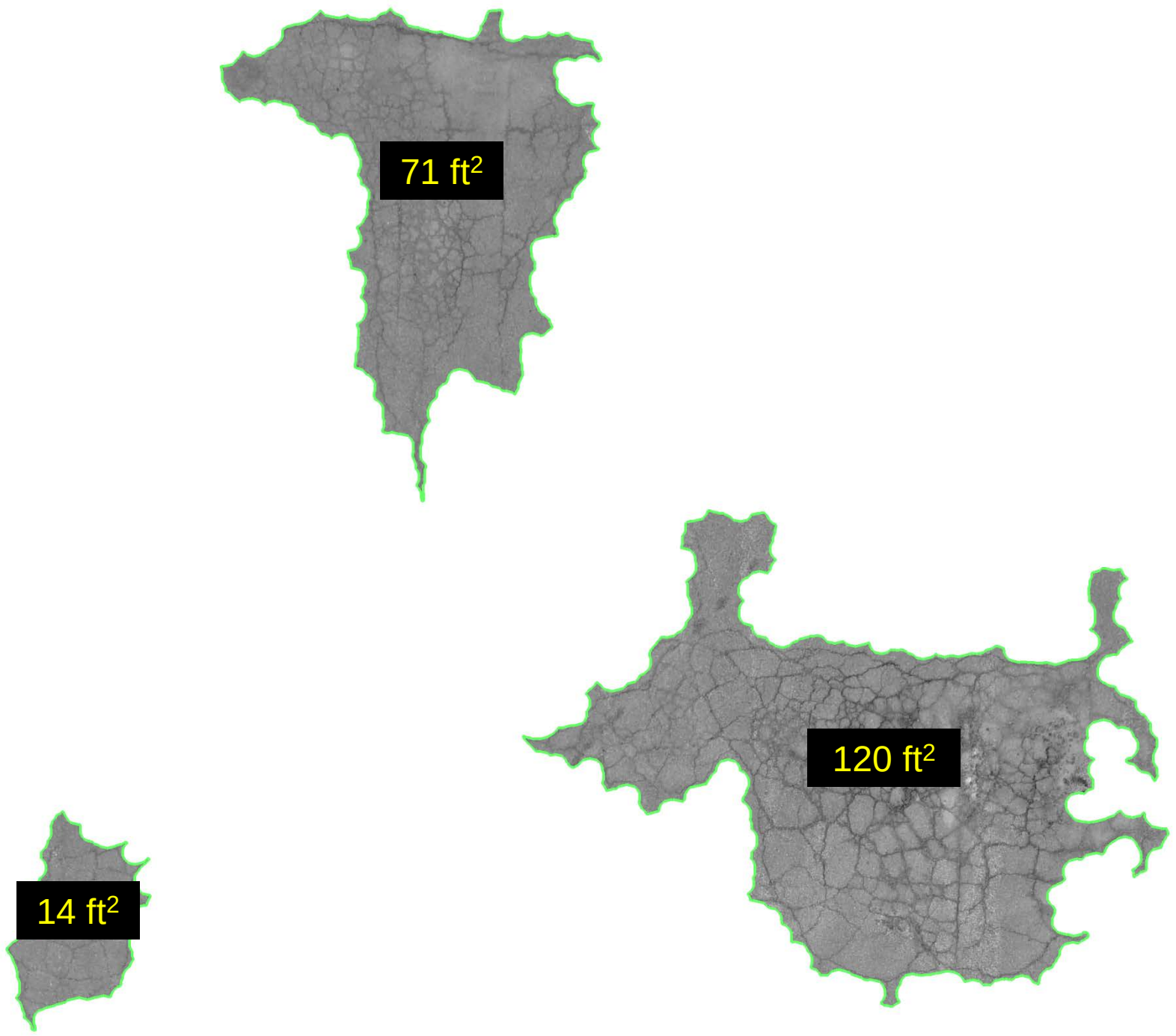
Pavement Infrastructure Management: Parameters

- ☑ Cracking percentage
- ☑ Cracking length
- ☑ Edge Distress – On-grade Drainage Inlets
- ☑ Rutting
- ☑ Pavement longitudinal & Cross Slope
- ☑ International Roughness Index (IRI)
- ☑ Faulting
- ☑ Present Serviceability Rating (PSR)

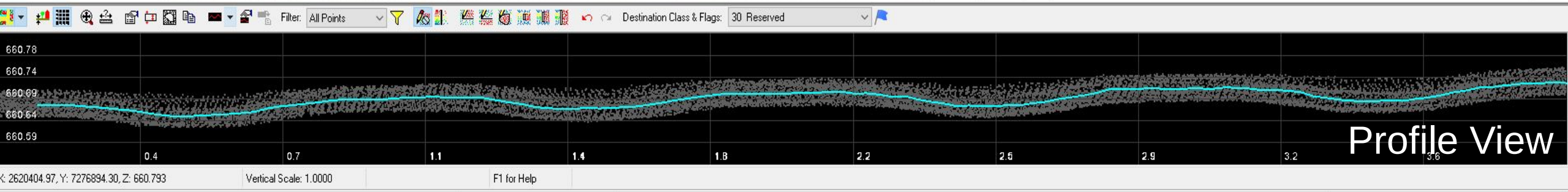
Pavement Construction Progress

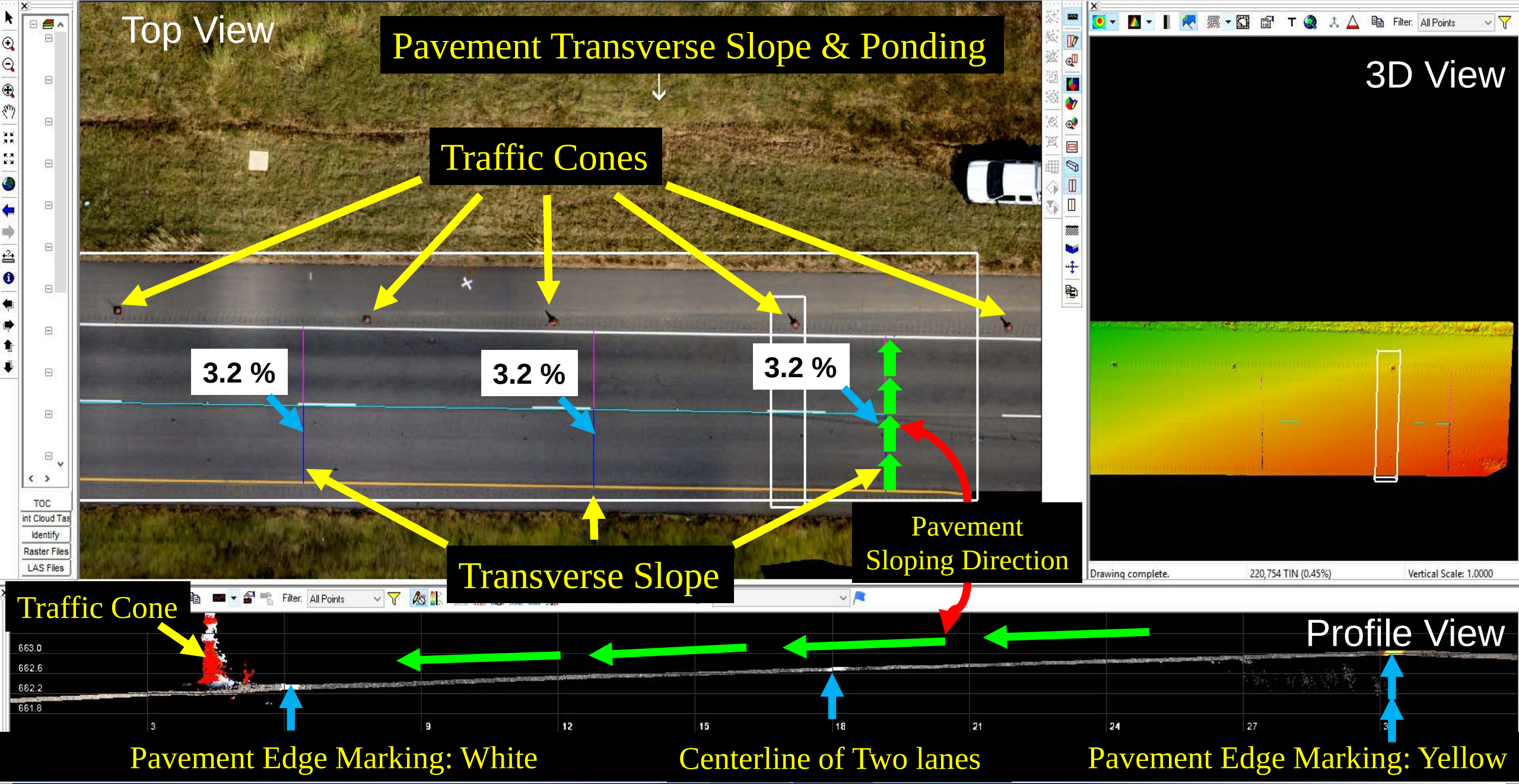

Top View
Pavement Cracking
3D View
Pavement Distress – Subgrade Failure
Filter: All Points
Drawing complete.
195,595 TIN (100.00%)
Vertical Scale: 1.0000
Destination Class & Flags:
709.31
709.15
709.08
709.00
0.6
1.2
1.8
2.4
2.9
3.5
4.1
4.7
5.3
5.9
3.36 inch
Profile View

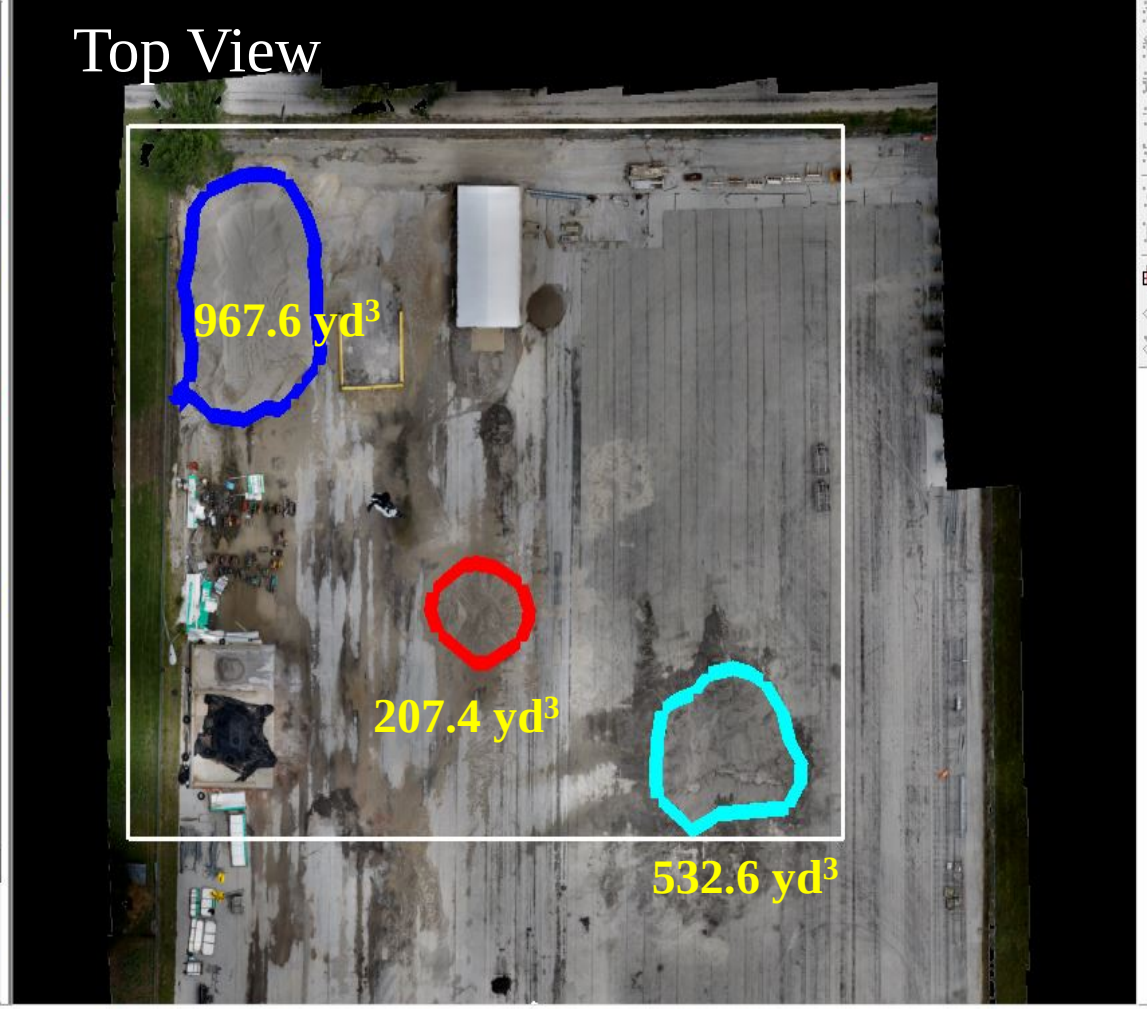
Pavement Cracking Detection

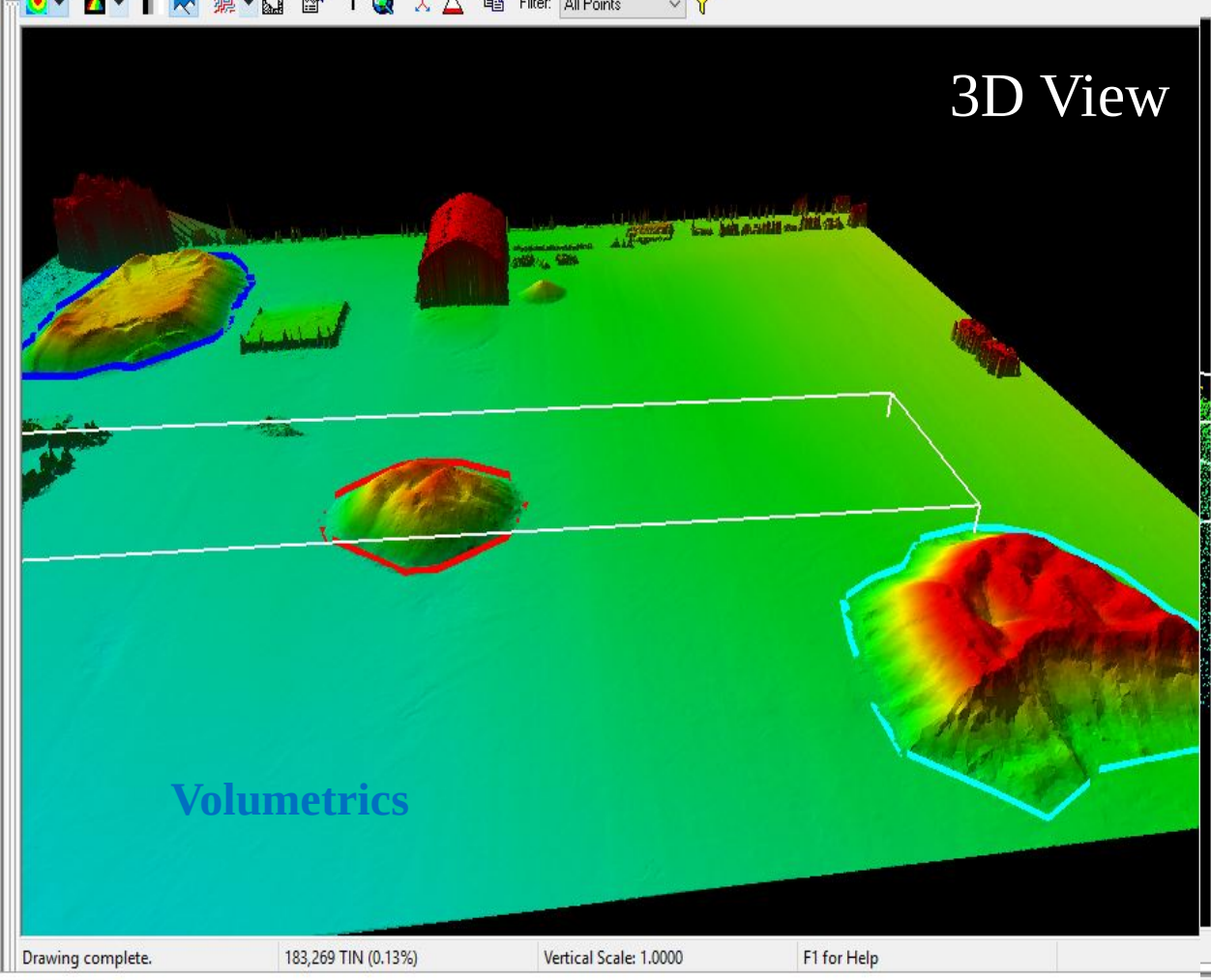


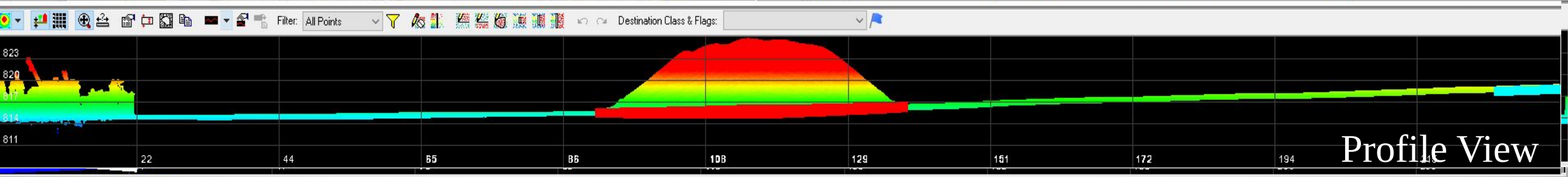
Rumble Strips




Top View
Pavement Transverse Slope & Ponding
Traffic Cones
3.2 %
3.2 %
3.2 %
Transverse Slope
Pavement
Sloping Direction
3D View
Drawing complete.
220,754 TIN (0.45%)
Vertical Scale: 1.0000
Traffic Cone
Profile View
663.0
662.6
662.2
661.8
3
9
12
15
18
21
24
27
Pavement Edge Marking: White
Centerline of Two lanes
Pavement Edge Marking: Yellow


Top View
967.6 yd³
207.4 yd³
532.6 yd³


3D View
Volumetrics
Drawing complete.
183,269 TIN (0.13%)
Vertical Scale: 1.0000
F1 for Help


Filter: All Points
Destination Class & Flags:
823
820
814
811
22
44
65
86
108
129
151
172
194
Profile View

Stockpile Volumetrics
(Comparison with Ground Truth Measurements)

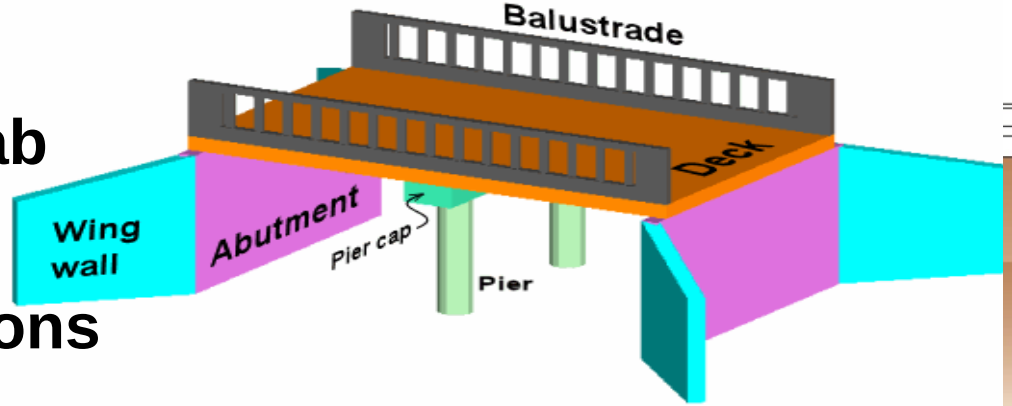
SNo	Site Description	Calculated Volume from UAV-CRP (yd^3)	Approximate Volume (yd^3)	Error (%)
1.	Site 1	1567.4	1545.0	1.4
2.	Site 2	11.3	11.0	2.3
3.	Site 3	804.3	825.2	2.5
4.	Site 4	5552.4	5547.0	0.1
5.	Site 5	104.0	101.4	2.5

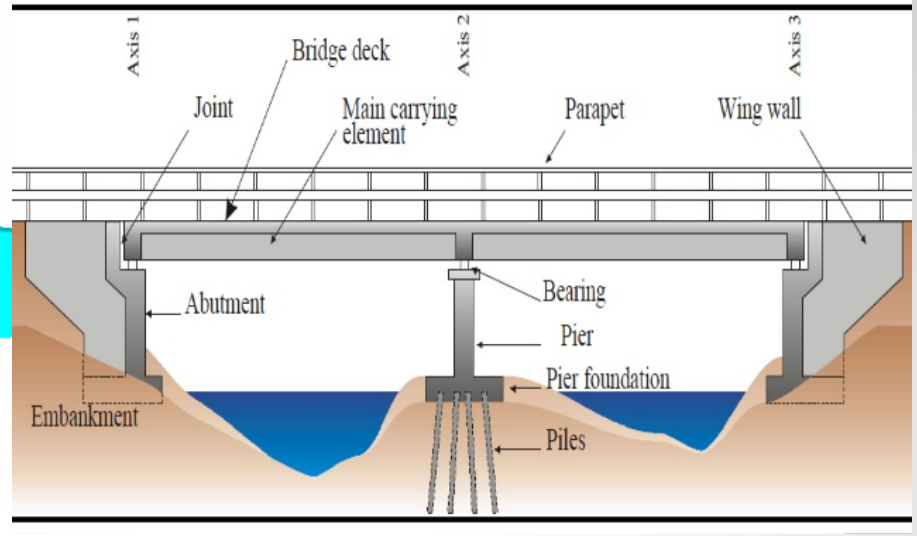
10 Min

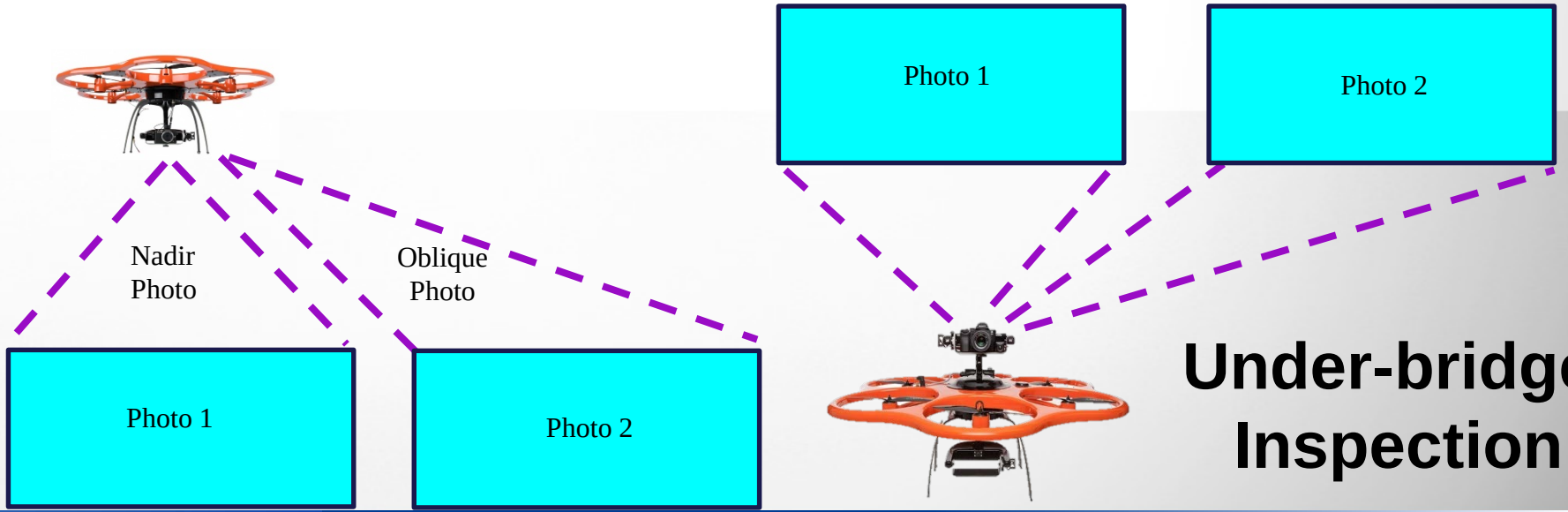
10 Min

Bridge Infrastructure Monitoring

- **Super-structure**
  - Bridge Deck
  - Approach Slab
  - Railings
  - Joint Conditions
- **Sub-structure**
  - Beams
  - Soffits
  - Bearings
  - Wing Walls
  - Abutment
  - Pile and Cap
  - Foundations

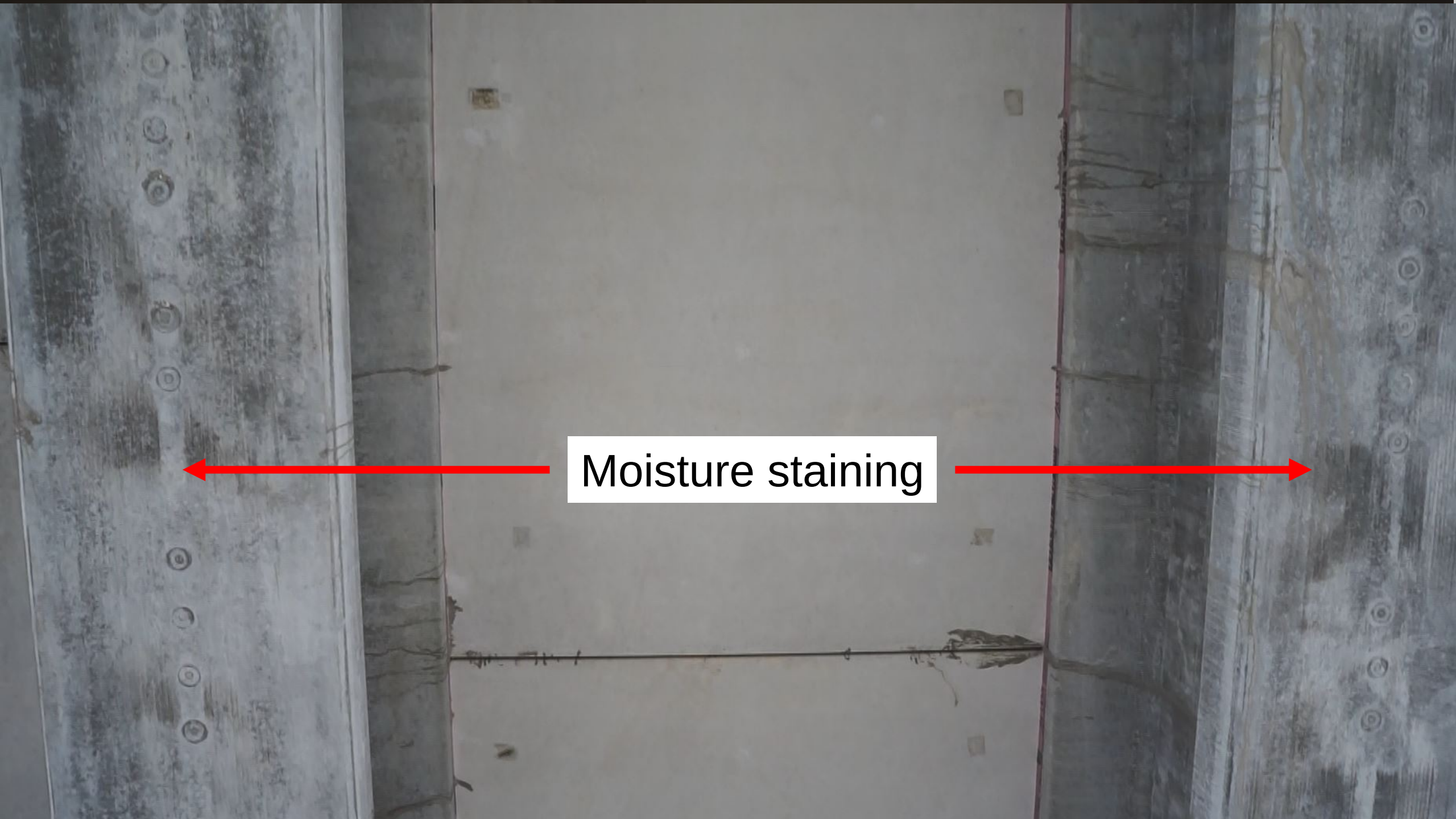






Under-bridge Inspection

Source: NJDOT, WSDOT

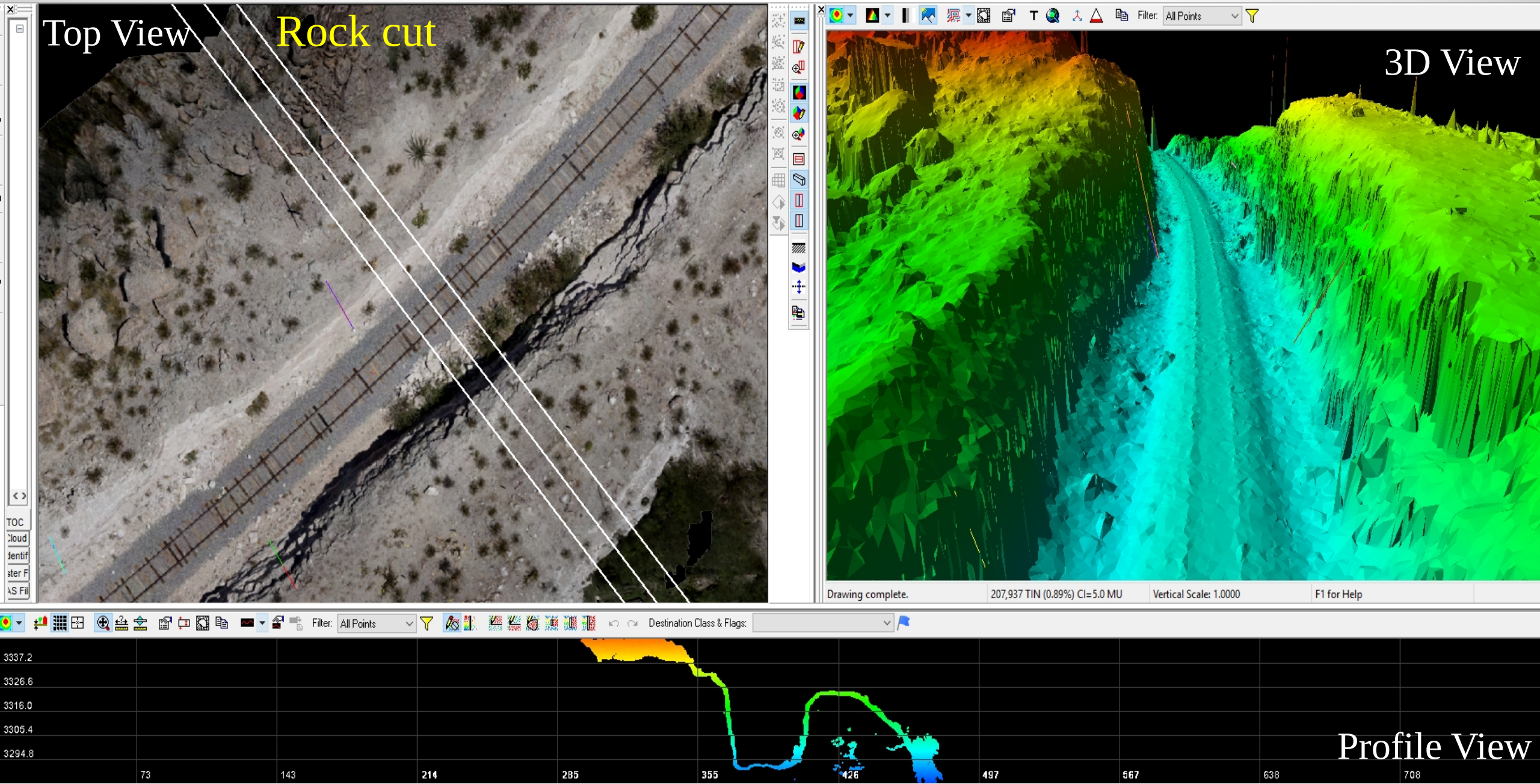

Moisture staining


Alpine
Alpine
Marfa
Candelaria
Ruidosa
Las Vibras
Shafter
Plata
Adobes
Rail Washout
Rock Cut
Área Natural Protegida Cañón y Sierra del Peguis
Presidio
Rail Bridge
Rail Road Crossing
Ojinaga
Big Bend Ranch State Park
Cuchillo Parado
Google
N
W
E
S

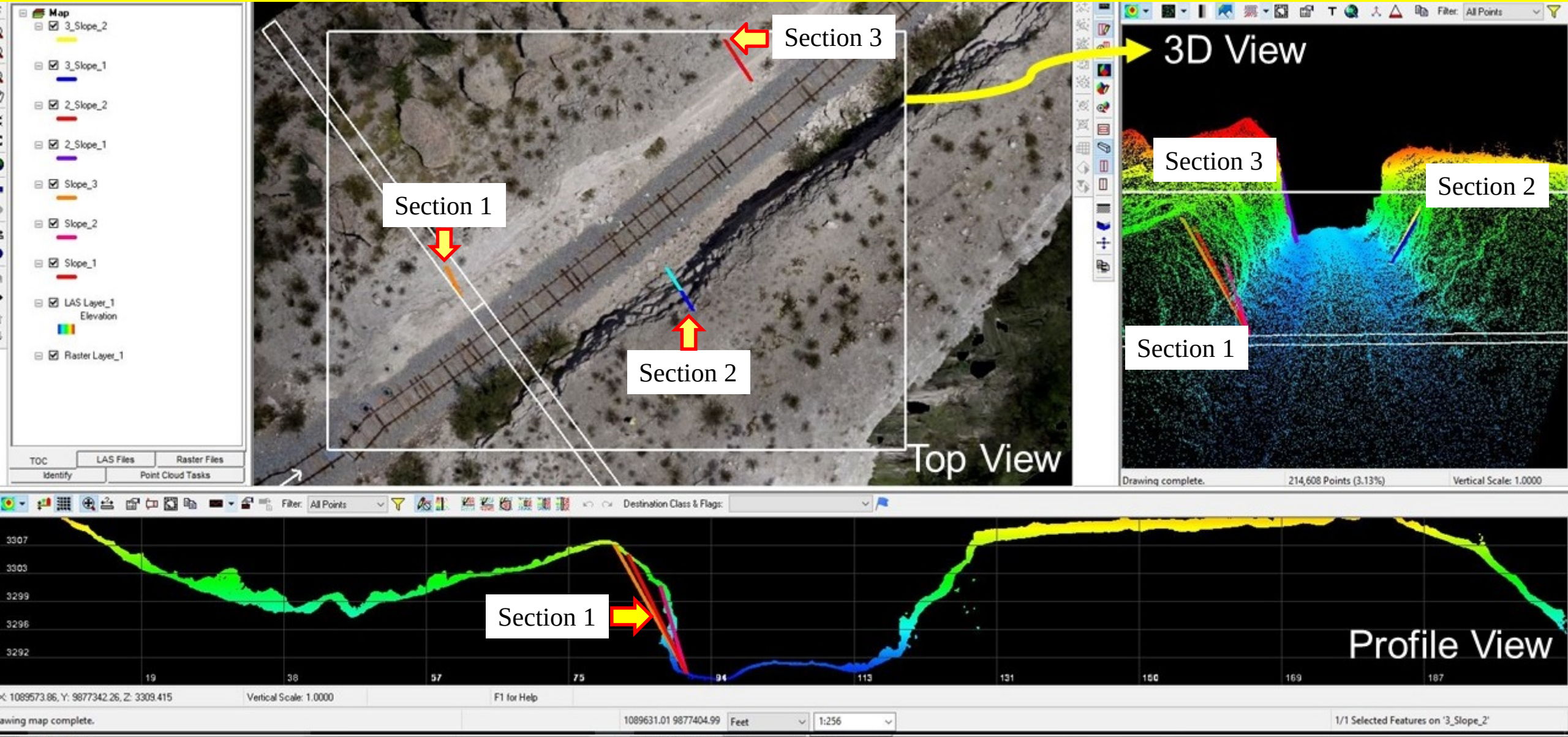
Railway Operations

UT ARLINGTON and MTRI

UAV – CRP for Rail Corridor Monitoring and Data Analysis

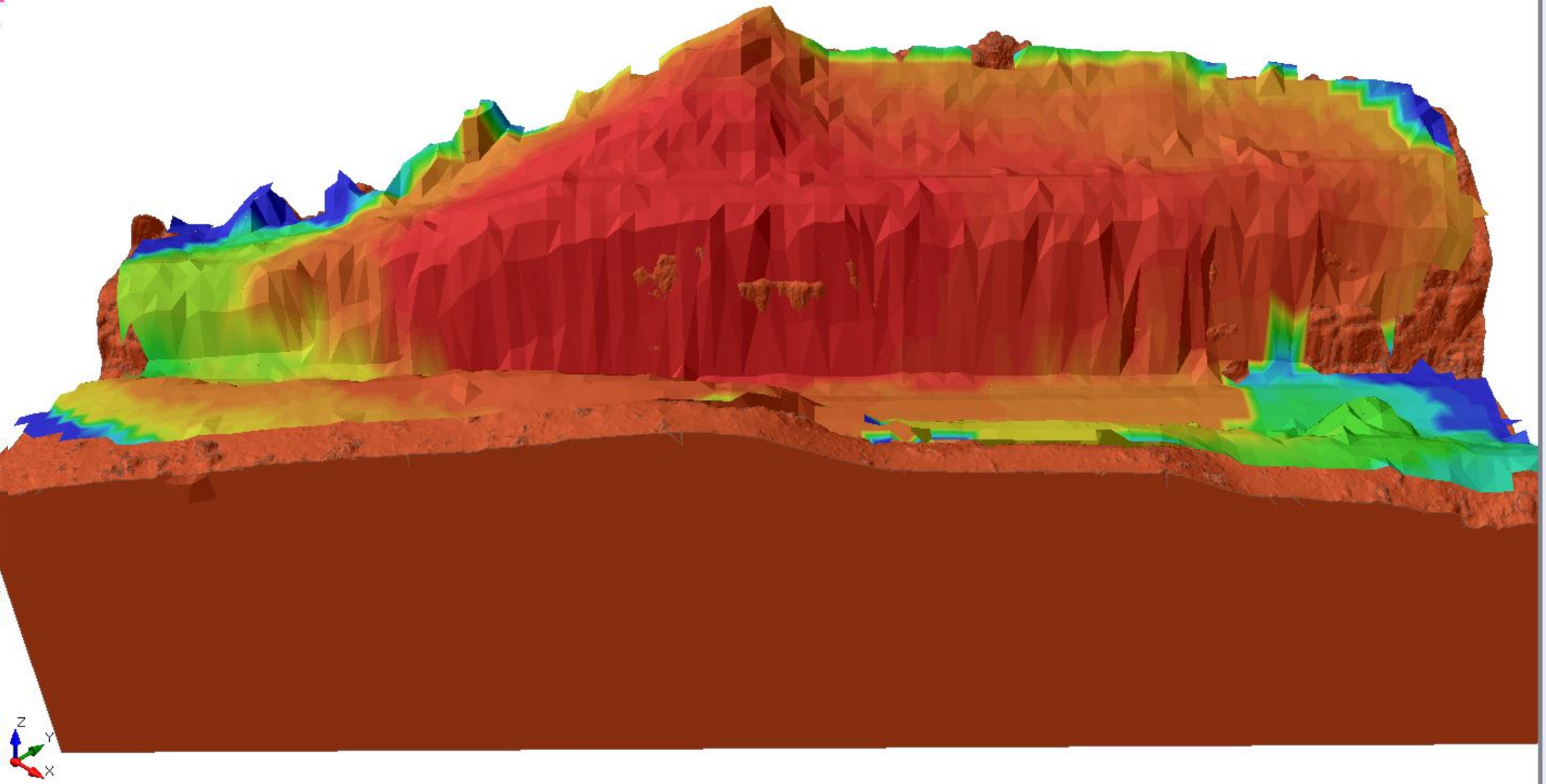


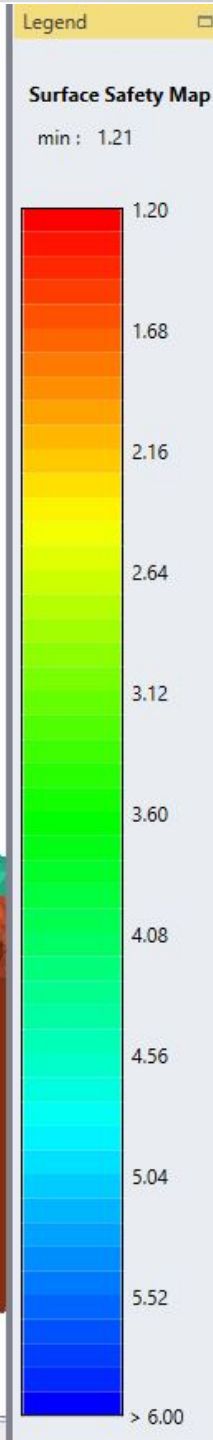
Rock Cut Area - Slope Stability Analysis



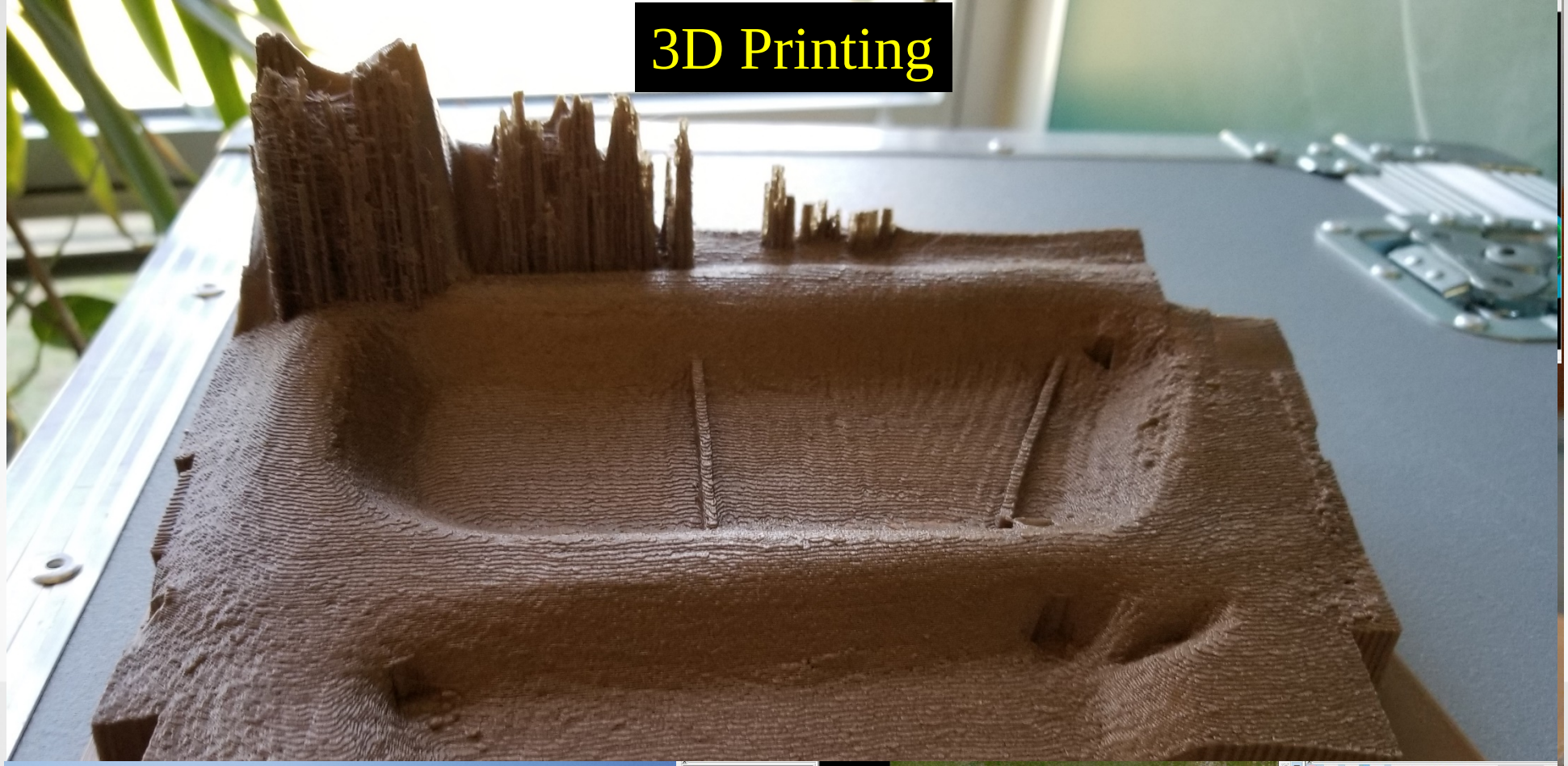
GLE FOS 1.214

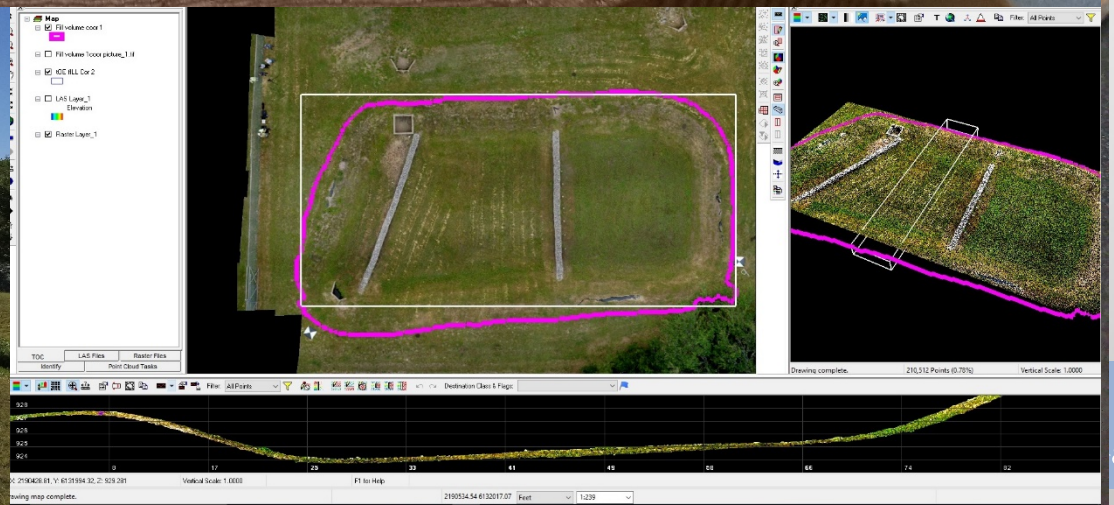
Slope Stability Analysis: Morgenstern–Price Method





3D Printing





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Concluding Remarks….

- Visualization tools and analyses – better perception of reality…Data driven…
- Site characterization – 2D and 3D visualization plots – Condition assessments for better infrastructure design
- Photogrammetry & UAV platforms: 3D Visualization plots – Geotechnical infrastructure condition assessment to asset management
- Proactive remote monitoring – Early damage detection
- Multidisciplinary nature of research – UAVs, 3D Printing, & AI tools (for identification of geotechnical issues by analyzing visualization data)

Thanks very much for your attention!

Acknowledgements

- UTA Research Team (Cody Lundberg, Ujwal Patil, & others)
- TxDOT
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