



Pavement Stitching and Data Transformation for Airports and Concrete Surveys

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Outline

- Define the Challenge
 - Airport Surveys
 - Concrete Rehab Surveys
- Solution
 - 2D/3D Image Stitching
 - Data Transformation
 - Data Exports
- Real project example



Spatial Mosaic

3D

Collecting complete surface data on a wide pavement:

- Lower resolution and one pass (e.g. LIDAR)
- Higher resolution and multiple passes

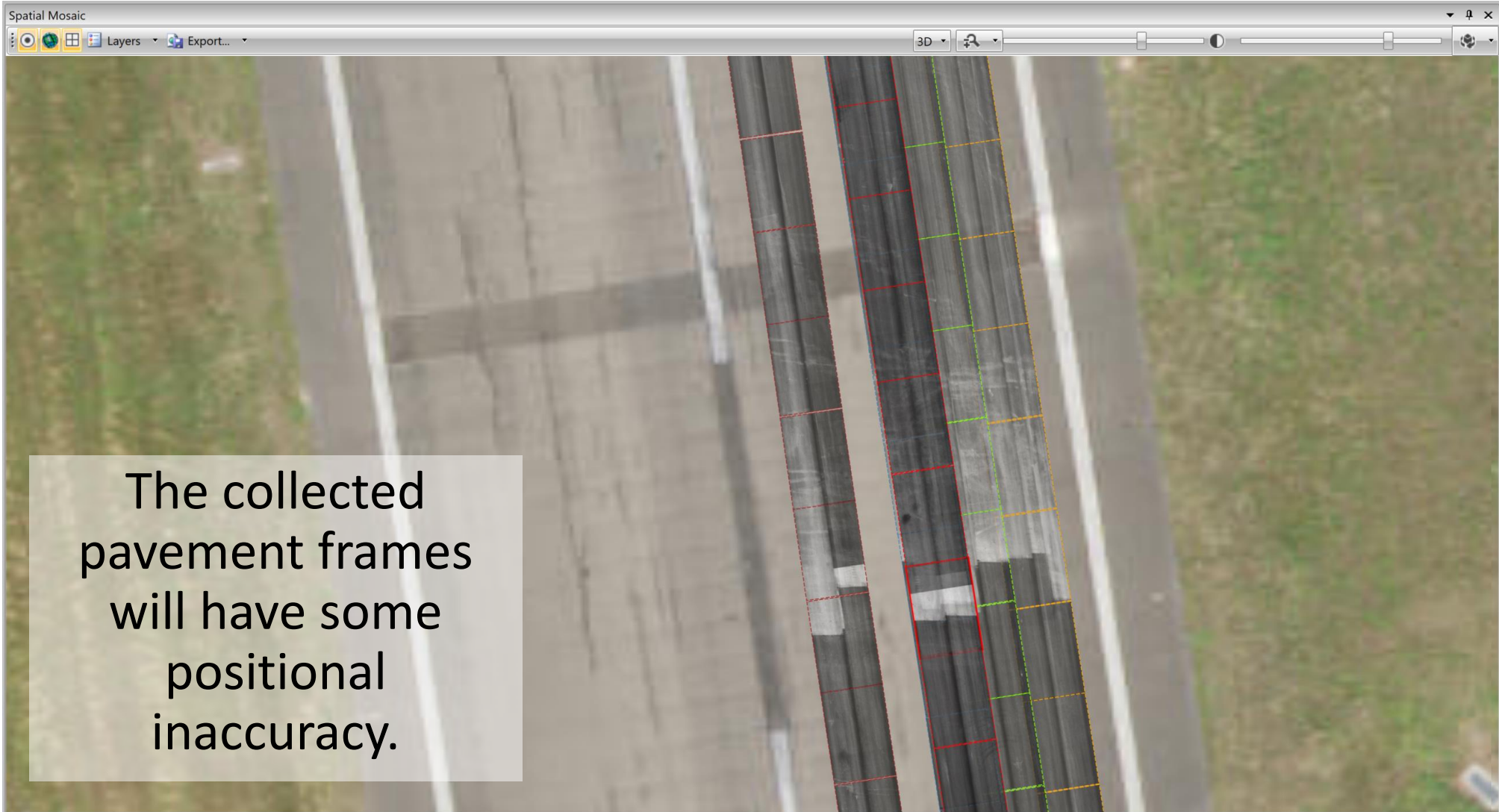
Visible	Session	Frames	Anchor	Status
<input checked="" type="checkbox"/>	20120815535818	151	0	
<input type="checkbox"/>	20120816003318	151	0	
<input type="checkbox"/>	20120816024618	151	0	
<input type="checkbox"/>	20120816061018	151	0	
<input type="checkbox"/>	20120816100918	151	0	






Start End From... To

Ranges Delete... Frames All Anchors


Map Spatial Mosaic








Visible	Session	Frames	Anchor	Status
<input checked="" type="checkbox"/>	 20120815535818	151	0	<input type="text"/>
<input type="checkbox"/>	 20120816003318	151	0	<input type="text"/>
<input type="checkbox"/>	 20120816024618	151	0	<input type="text"/>
<input type="checkbox"/>	 20120816061018	151	0	<input type="text"/>
<input type="checkbox"/>	 20120816100918	151	0	<input type="text"/>

Start End From... To Frames AVG Length %

 Ranges

 Delete...

 Frames

 All Anchors



Many airports have detailed slab inventories that have been tied down to ground control

Houston Airport (IAH), from Airport Improvement

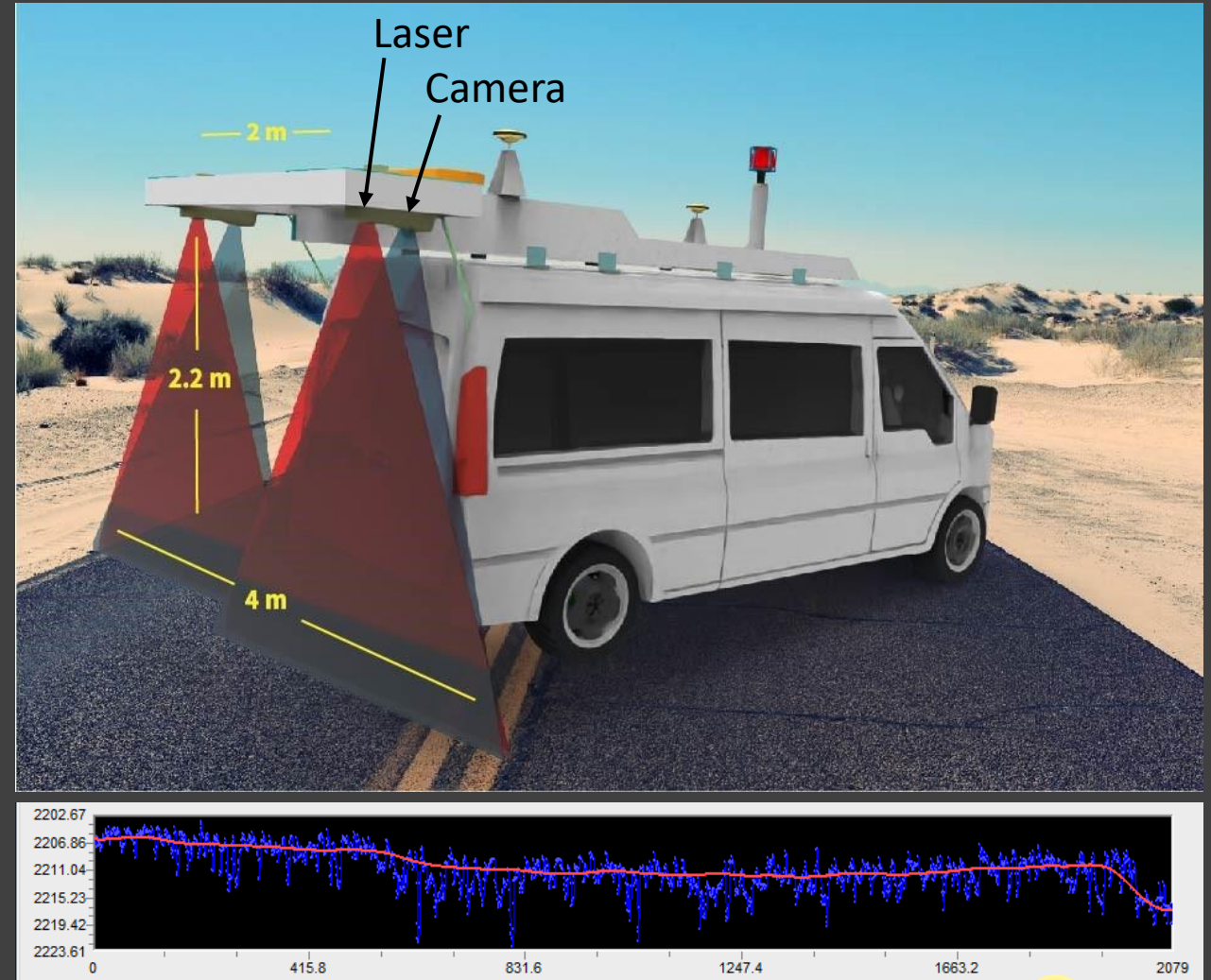
LCMS-2 Data Transformation

- Not just images
- We also have:
 - Joints
 - Fault heights
 - Surface defects including cracks
 - Classified distresses
 - Annotations

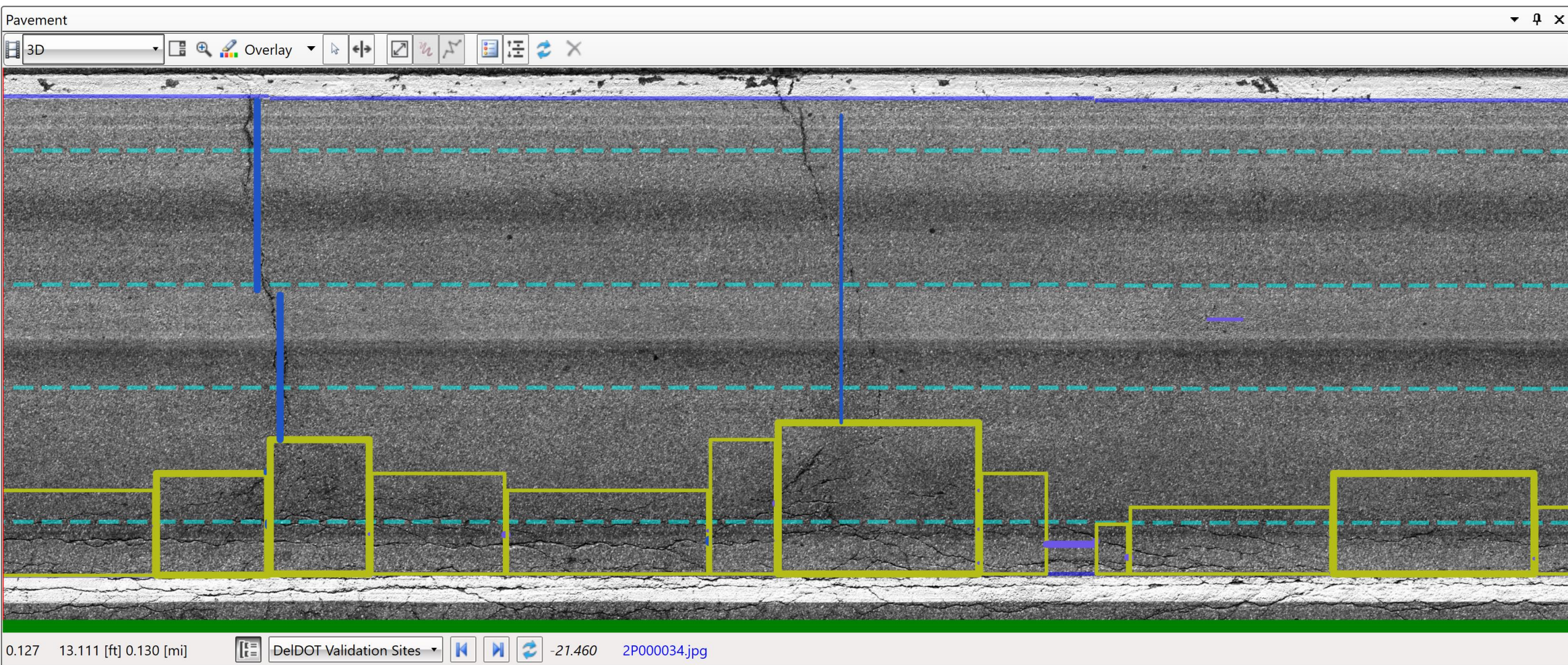


LCMS-2 Working Principle

- Not the same as LIDAR
 - No spinning mirror
 - No moving parts
- Laser illuminates line on pavement
- Camera takes pictures of the line rapidly, triggered by vehicle forward motion
- The individual profiles are stitched together into a 3D surface
- 0.25mm vertical accuracy
- 0.05mm vertical resolution



Extracted and rated data should be transformed



ICC Connect

OpenData ManagementView Reports Settings Help

Slab Repair Report

NetworkHDR_I95

Treatment decisions (i.e. slab repairs)

	StartChainage [mi]	EndChainage [mi]	Site Name	DistressType	Severity	PavementType	StartLatitude	StartLongitude
▶	2.496	2.494	SOUTHBOUND - MAINLINE - LANE 1 (LEFT)	Slab Repair	Full Slab, Full Depth Replacement	JCP	30.25049908	-81.59560289
▶	2.494	2.493	SOUTHBOUND - MAINLINE - LANE 1 (LEFT)	Slab Repair	Full Slab, Full Depth Replacement	JCP	30.25049908	-81.59560289
▶	2.493	2.490	SOUTHBOUND - MAINLINE - LANE 1 (LEFT)	Slab Repair	Full Slab, Full Depth Replacement	JCP	30.25049908	-81.59560289
▶	2.488	2.487	SOUTHBOUND - MAINLINE - LANE 1 (LEFT)	Slab Repair	Clean and Seal + Grind OR Full Depth Replacement	JCP	30.25041768	-81.59551764
▶	2.487	2.485	SOUTHBOUND - MAINLINE - LANE 1 (LEFT)	Slab Repair	Full Slab, Full Depth Replacement	JCP	30.25041768	-81.59551764
▶	2.485	2.484	SOUTHBOUND - MAINLINE - LANE 1 (LEFT)	Slab Repair	Clean and Seal + Grind OR Full Depth Replacement	JCP	30.25041768	-81.59551764
▶	2.484	2.483	SOUTHBOUND - MAINLINE - LANE 1 (LEFT)	Slab Repair	Clean and Seal	JCP	30.25037704	-81.59547498
▶	2.480	2.479	SOUTHBOUND - MAINLINE - LANE 1 (LEFT)	Slab Repair	Clean and Seal	JCP	30.25033635	-81.59543240
▶	2.479	2.478	SOUTHBOUND - MAINLINE - LANE 1 (LEFT)	Slab Repair	Clean and Seal	JCP	30.25033635	-81.59543240
▶	2.477	2.475	SOUTHBOUND - MAINLINE - LANE 1 (LEFT)	Slab Repair	Clean and Seal	JCP	30.25029570	-81.59538968
▶	2.475	2.474	SOUTHBOUND - MAINLINE - LANE 1 (LEFT)	Slab Repair	Clean and Seal	JCP	30.25029570	-81.59538968
▶	2.474	2.473	SOUTHBOUND - MAINLINE - LANE 1 (LEFT)	Slab Repair	Full Slab, Full Depth Replacement	JCP	30.25029570	-81.59538968
▶	2.473	2.471	SOUTHBOUND - MAINLINE - LANE 1 (LEFT)	Slab Repair	Clean and Seal	JCP	30.25025504	-81.59534708
▶	2.471	2.470	SOUTHBOUND - MAINLINE - LANE 1 (LEFT)	Slab Repair	Clean and Seal	JCP	30.25025504	-81.59534708
▶	2.470	2.468	SOUTHBOUND - MAINLINE - LANE 1 (LEFT)	Slab Repair	Clean and Seal	JCP	30.25021431	-81.59530446

384

DistressSlab Repair ReportCollections

Pavement

3D

Overlay

0.7759.875 [ft] 0.787 [mi]

-21.4602P000206.jpg

MAINLINE LANE 1 (LEFT)

vsa037\sdf3\22-1_HDR_I95-JacksonvilleFL_2021

Dew

HDR_I95_ALL_WGS84

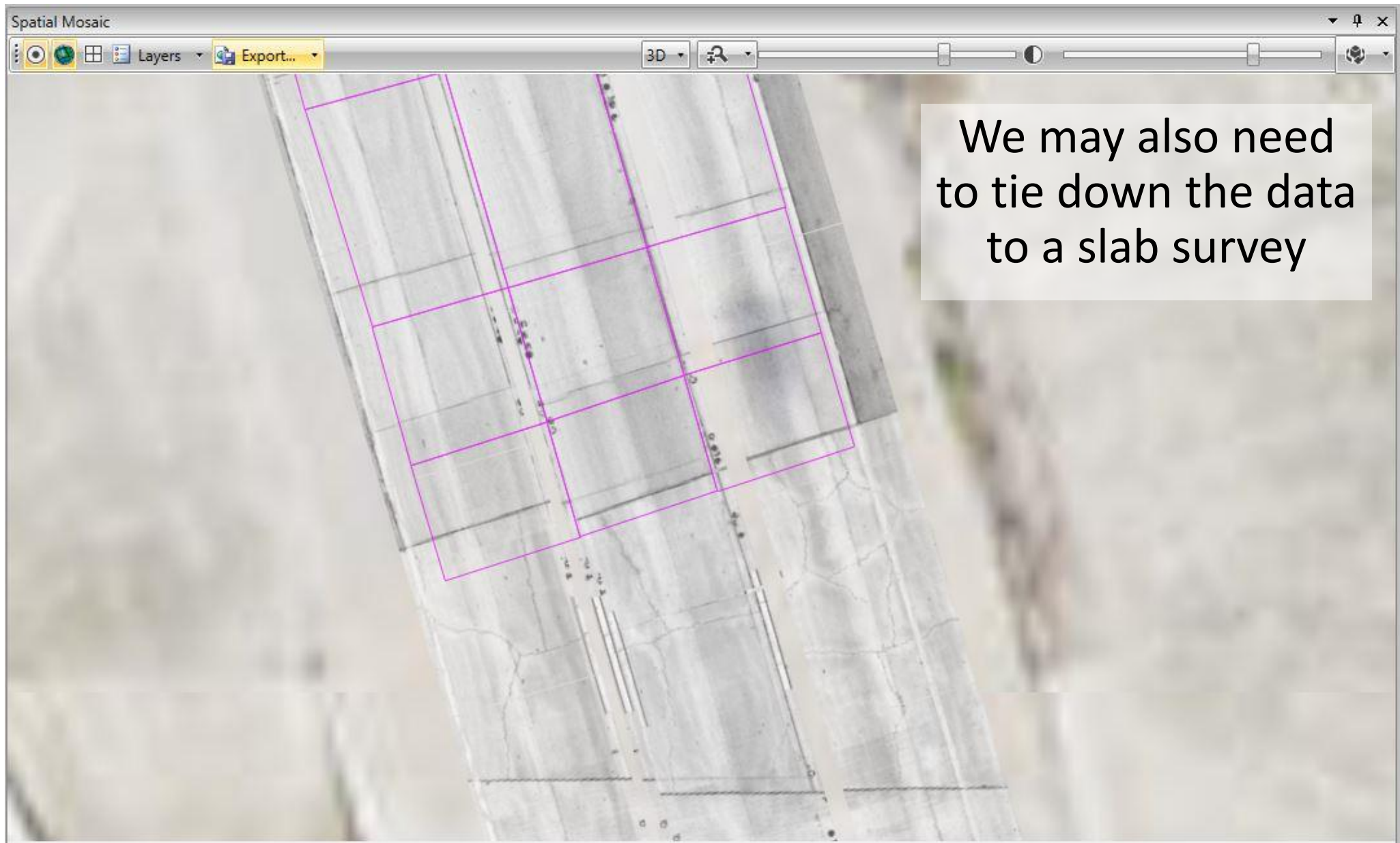
Forward

Select banner...

0.7780.7751G000205.jpg206 / 891 @ 20.002 [ft]

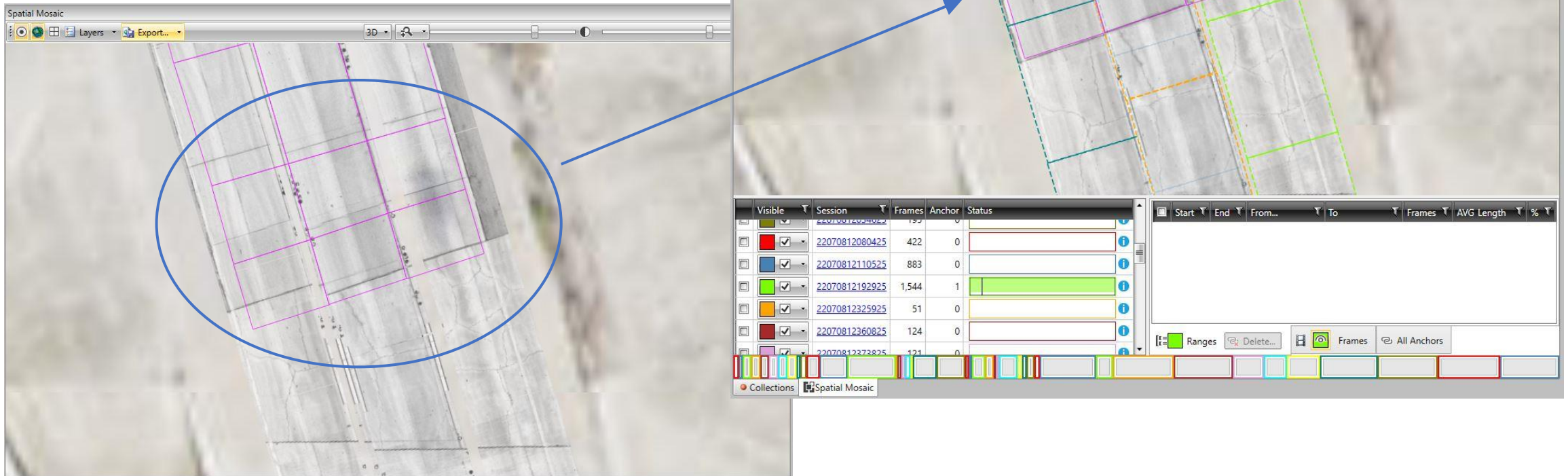
Chainage2.494

Distance0.778



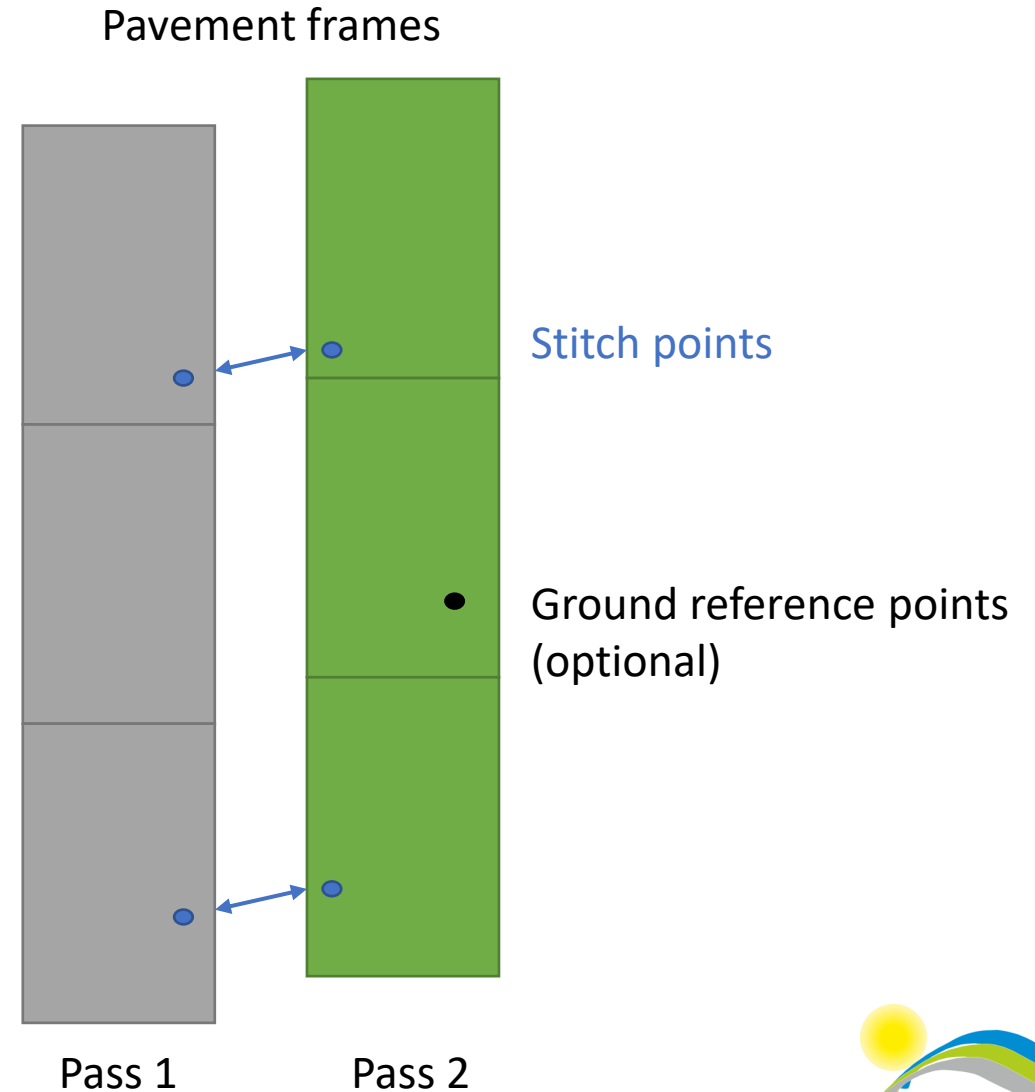
Connect™ Solution

Works with any LCMS data as long as GPS is embedded in FIS files or linked to DMI from another source



Transformation Process

1. Select stitch points to join adjacent sessions based on common features
2. Join to ground reference points if available
3. Convert all frame data to geospatial format
4. Apply modified affine transformation to images and data
5. Aggregate and export by region(s) of interest



Step-by-Step

Example: Adding stitch/tie points for second last session

The screenshot displays the Spatial Mosaic software interface. The main window shows an aerial photograph of a road with a purple grid overlay. The grid lines are spaced at regular intervals, and several points are marked on the grid. The interface includes a top toolbar with icons for 3D, zoom, and other functions. Below the main window is a table with columns for Visible, Session, Frames, Anchor, and Status. The table lists six sessions, each with a unique ID, a color-coded square, and a status bar. The status bar for the second last session (22070914262425) is highlighted in red. To the right of the table is a panel with a table of Start, End, From..., To, Frames, AVG Length, and % values. Below this panel is a toolbar with buttons for Ranges, Delete..., Frames, and All Anchors. At the bottom of the interface is a status bar with the text 'Collections' and 'Spatial Mosaic'.

Visible	Session	Frames	Anchor	Status
<input type="checkbox"/>	22070912134225	730	1	
<input type="checkbox"/>	22070912215625	1,049	0	
<input type="checkbox"/>	22070914143625	1,838	1	
<input checked="" type="checkbox"/>	22070914262425	1,899	0	
<input type="checkbox"/>	22070914475925	1,982	1	
<input type="checkbox"/>	22070916123125	1,885	1	

Start	End	From...	To	Frames	AVG Length	%

Ranges Delete... Frames All Anchors

Collections Spatial Mosaic

Step-by-Step

Example: Adding stitch/tie points for second last session

Link is created

Session shifts and warps

The screenshot displays the Spatial Mosaic software interface. The main window shows a 3D aerial view of a road with a purple grid overlay. The bottom panel contains a table with session data and a detailed view of the second last session.

Visible	Session	Frames	Anchor	Status
<input type="checkbox"/>	22070912134225	730	1	
<input type="checkbox"/>	22070912215625	1,049	0	
<input type="checkbox"/>	22070914143625	1,838	1	
<input checked="" type="checkbox"/>	22070914262425	1,899	1	
<input type="checkbox"/>	22070914475925	1,982	1	
<input type="checkbox"/>	22070916123125	1,885	1	

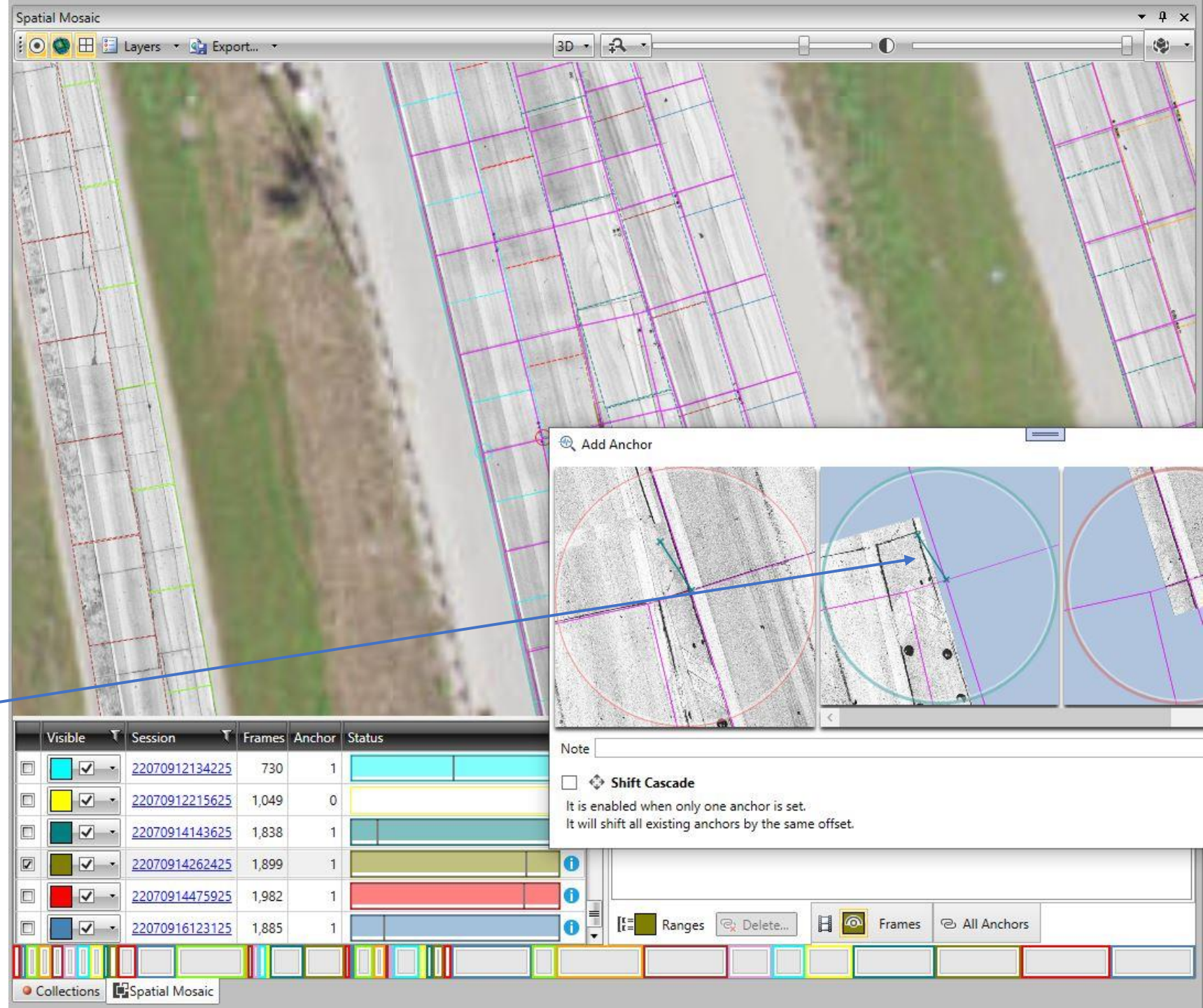
Start	End	From...	To	Frames	AVG Length	%
-0.004	6.050		2P001598	1,599	20.003	100.0
6.050	7.190	2P001598		302	20.003	100.0

Buttons: Ranges, Delete..., Frames, All Anchors

Step-by-Step

Example: Adding stitch/tie points for last session

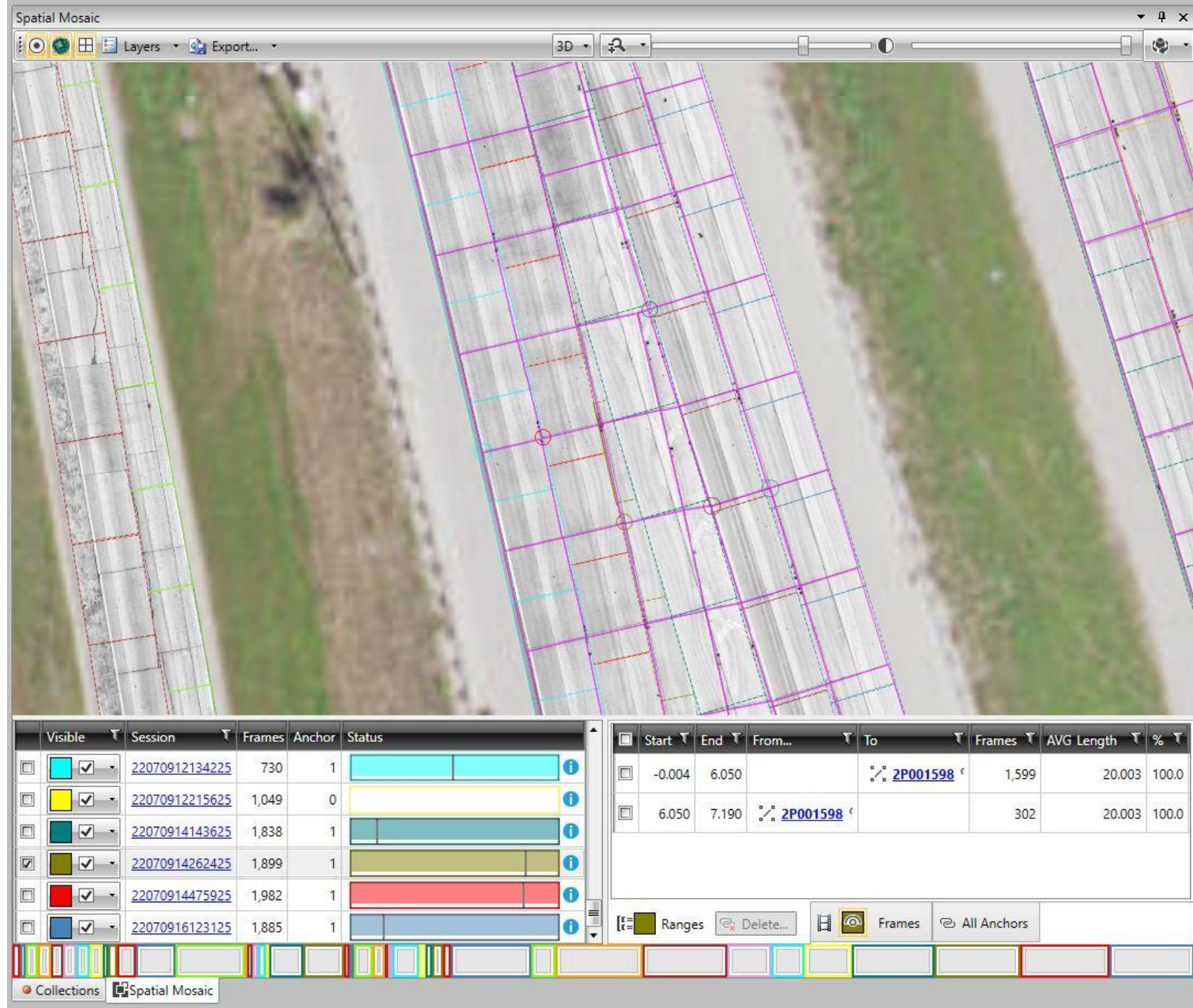
This session must be shifted down and to the right to match slab survey



Step-by-Step

Example: Adding stitch/tie points for last session

All sessions are now aligned to each other and to slab survey



Step-by-Step

Example: Adding stitch/tie points for last session

Hide LCMS frame lines
and leave slab definition
only

The screenshot shows the Spatial Mosaic software interface. The main window displays an aerial view of a road with a grid overlay. The grid is composed of purple lines forming a rectangular pattern. Several points are marked on the grid: a red circle, a blue circle, a yellow circle, and a green circle. The interface includes a toolbar at the top with icons for 3D, Layers, and Export. Below the main view, there is a table with columns: Visible, Session, Frames, Anchor, and Status. The table lists six sessions with their respective frame counts and anchor values. To the right of the table, there is a detailed view of the selected session (22070916123125) showing Start, End, From..., To, Frames, AVG Length, and % values. The bottom of the interface features a 'Collections' panel with a 'Spatial Mosaic' button.

Visible	Session	Frames	Anchor	Status
<input type="checkbox"/>	22070912134225	730	1	
<input type="checkbox"/>	22070912215625	1,049	0	
<input type="checkbox"/>	22070914143625	1,838	1	
<input checked="" type="checkbox"/>	22070914262425	1,899	1	
<input type="checkbox"/>	22070914475925	1,982	1	
<input type="checkbox"/>	22070916123125	1,885	1	

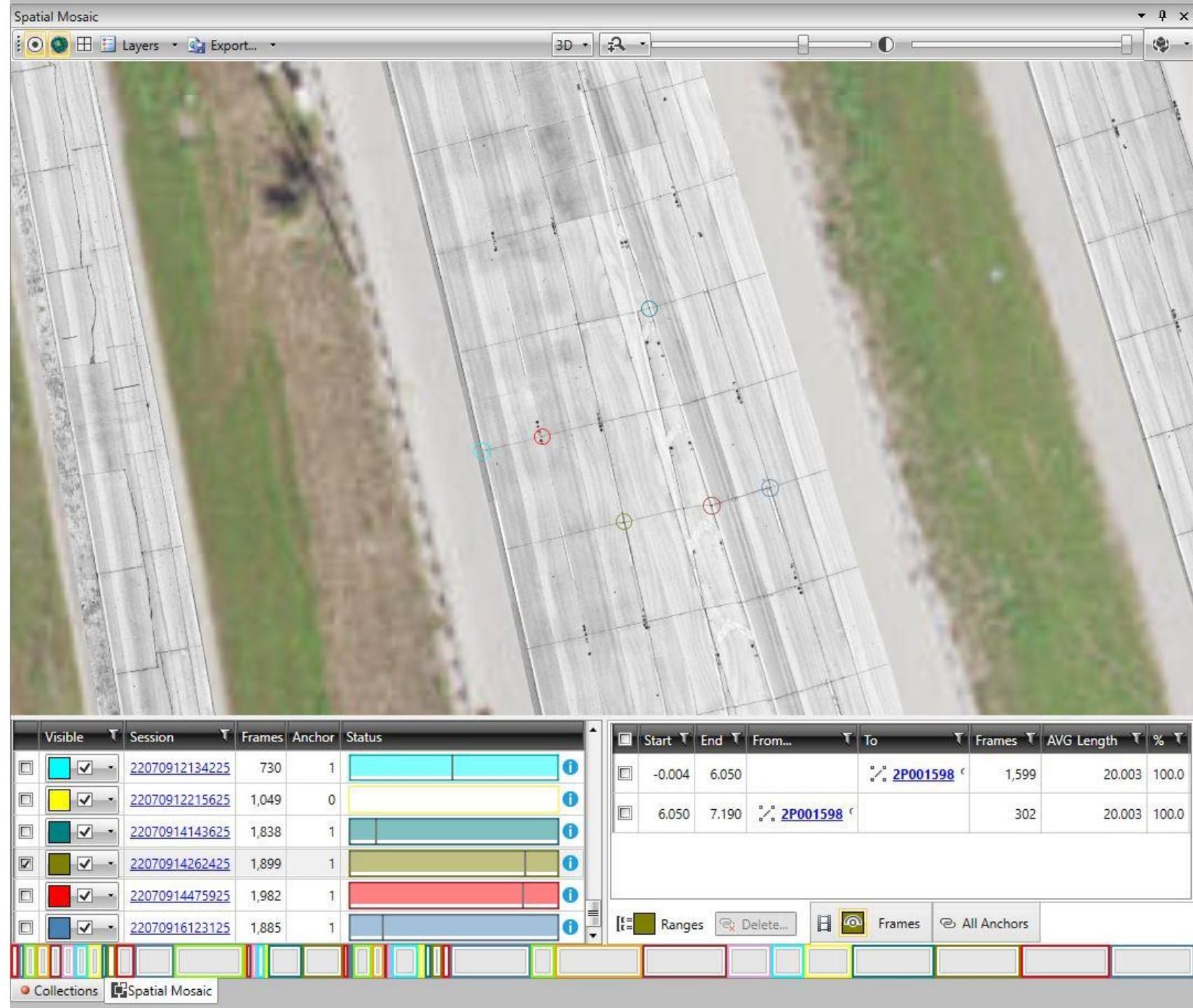
Start	End	From...	To	Frames	AVG Length	%
-0.004	6.050		2P001598	1,599	20.003	100.0
6.050	7.190	2P001598		302	20.003	100.0

Step-by-Step

Example: Adding stitch/tie points for last session

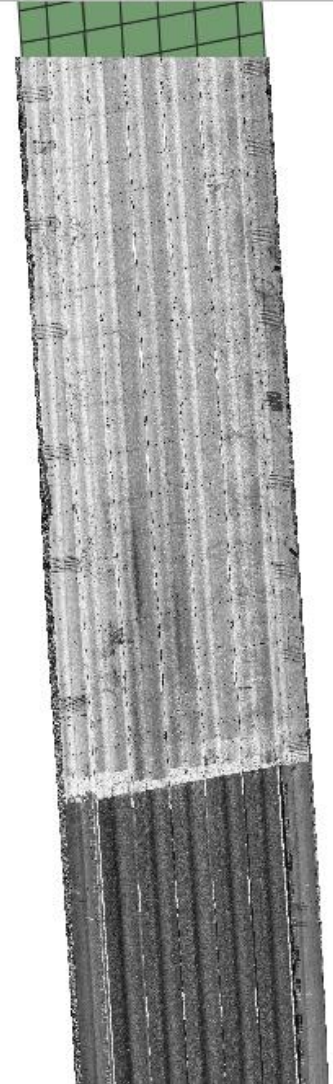
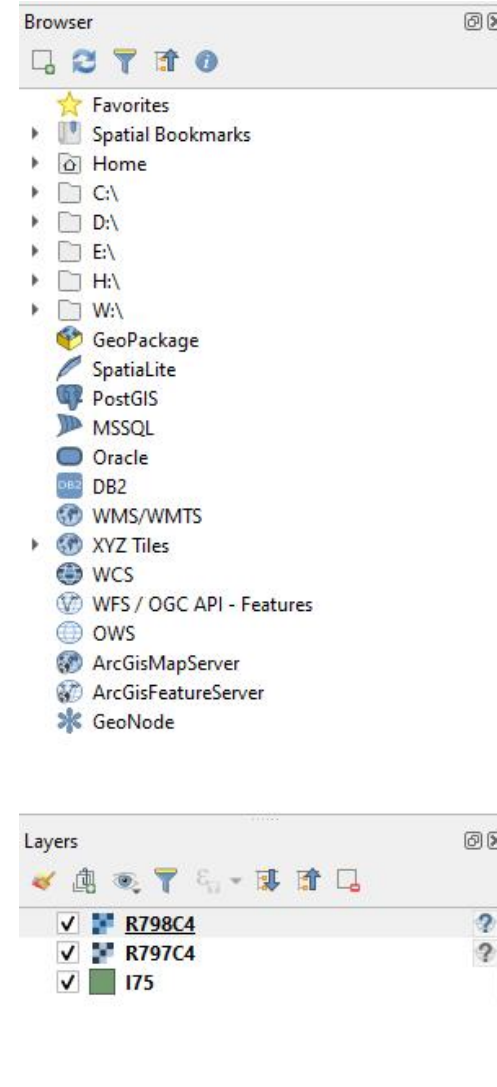
Hide slab definition

The transformation is complete

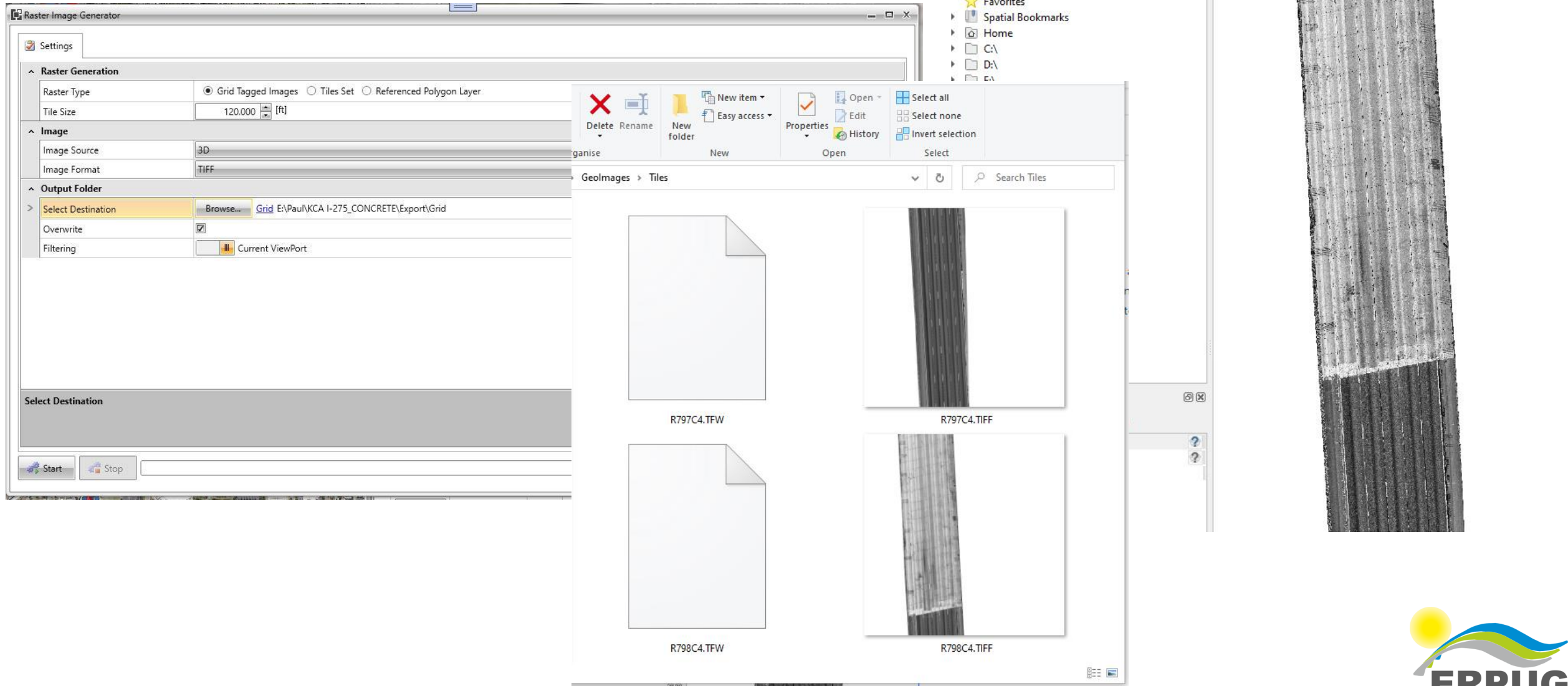


Outputs

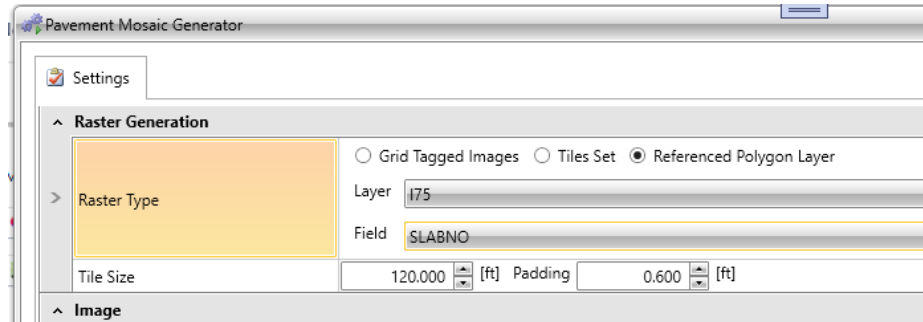
- Raster images for the entire area
- Raster images for areas defined by polygons (e.g. individual slabs)
- Vector data
 - Pavement distresses (e.g. ASTM D5340, D6433) trimmed to polygons
 - Distresses aggregated by and associated to polygons
 - Annotations (e.g. treatment decisions) linked to polygons



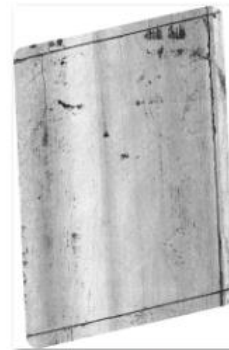
Raster Image Generation



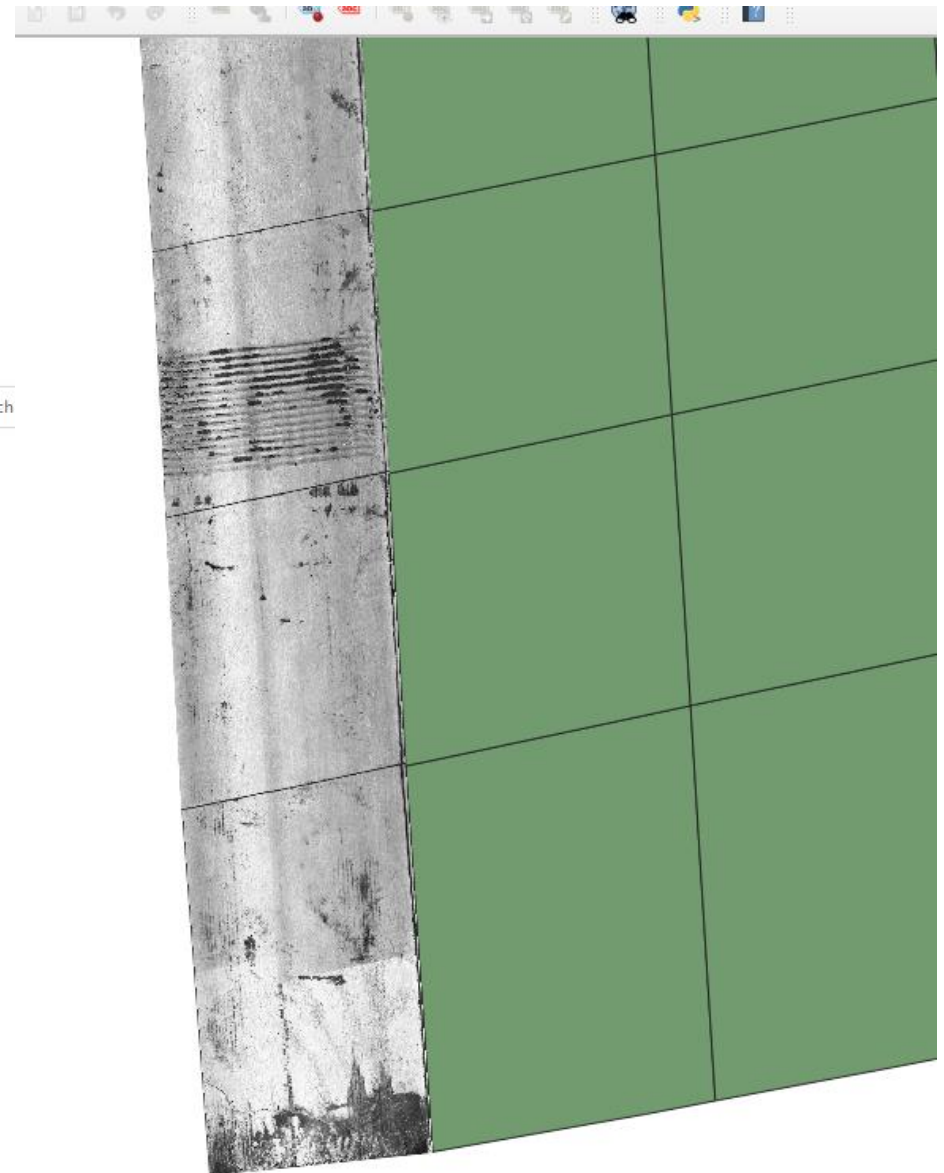
Pavement Tile Generation



A0005 21005.TIFF



A0010 14.TIFF



Pavement Tile Generation

This image is a composite of 5 LCMS frames

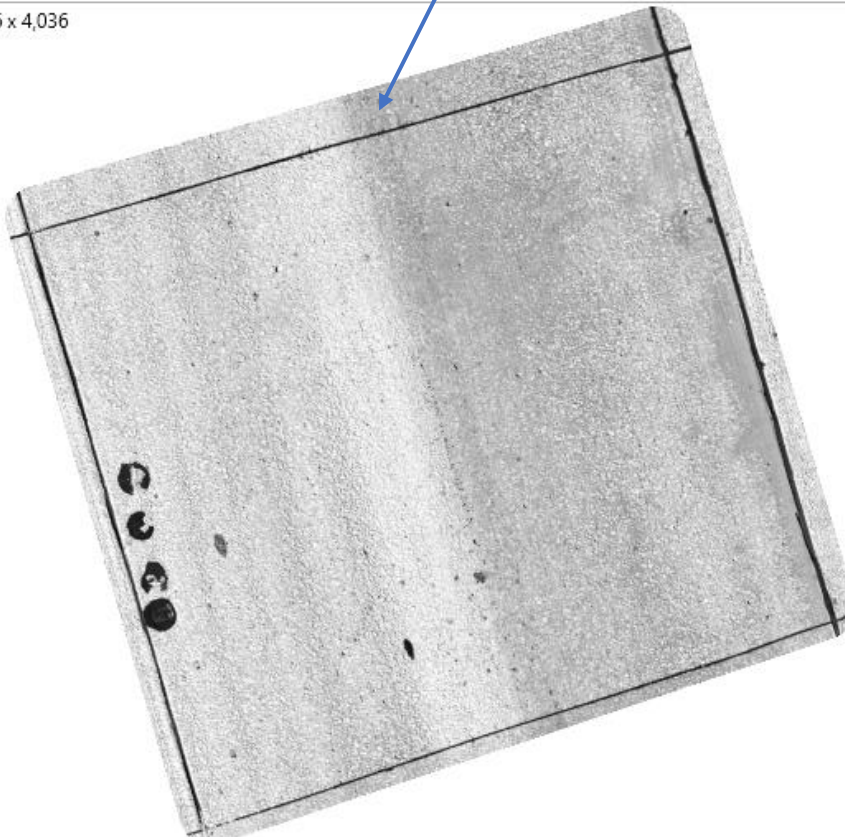
Add buffer around slab to show joint context

Raster Image Generator

Settings Show Preview

	ID	Area	Frames	Coverage	Image	Size (KB)	Duration
<input type="checkbox"/>	<input checked="" type="checkbox"/>	A0005 4	119.202	5	99.95	A0005 4.TIFF	24,355 00:00:10.1
<input type="checkbox"/>	<input checked="" type="checkbox"/>	B0005 5	121.291	5	100.00	B0005 5.TIFF	23,775 00:00:10.0
<input type="checkbox"/>	<input checked="" type="checkbox"/>	C0005 7	119.570	4	90.96	C0005 7.TIFF	24,284 00:00:10.0
<input type="checkbox"/>	<input checked="" type="checkbox"/>	A0010 10	140.711	5	100.00	A0010 10.TIFF	25,472 00:00:10.1
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	B0010 11	137.734	5	100.00	B0010 11.TIFF	25,329 00:00:17.6
<input type="checkbox"/>	<input checked="" type="checkbox"/>	C0010 12	132.669	6	90.10	C0010 12.TIFF	25,086 00:00:17.2
<input type="checkbox"/>	<input checked="" type="checkbox"/>	A0015 16	227.516	6	99.98	A0015 16.TIFF	12,629 00:00:15.5
<input type="checkbox"/>	<input checked="" type="checkbox"/>	B0015 17	227.136	6	100.00	B0015 17.TIFF	10,007 00:00:16.6
<input type="checkbox"/>	<input checked="" type="checkbox"/>	C0015 18	226.399	6	90.75	C0015 18.TIFF	20,466 00:00:05.8
<input type="checkbox"/>	<input checked="" type="checkbox"/>	F0005 21	140.018	5	100.00	F0005 21.TIFF	22,747 00:00:05.5
<input type="checkbox"/>	<input checked="" type="checkbox"/>	A0020 24	225.057	6	99.99	A0020 24.TIFF	19,875 00:00:05.9
<input type="checkbox"/>	<input checked="" type="checkbox"/>	B0020 26	229.384	6	100.00	B0020 26.TIFF	19,673 00:00:05.7
<input type="checkbox"/>	<input checked="" type="checkbox"/>	C0020 28	227.304	6	92.33	C0020 28.TIFF	5,587 00:00:06.2
<input type="checkbox"/>	<input checked="" type="checkbox"/>	F0010 29	199.756	6	99.87	F0010 29.TIFF	23,646 00:00:06.9
<input type="checkbox"/>	<input checked="" type="checkbox"/>	A0025 32	222.784	6	99.97	A0025 32.TIFF	19,778 00:00:06.3
<input type="checkbox"/>	<input checked="" type="checkbox"/>	B0025 34	226.420	6	100.00	B0025 34.TIFF	19,642 00:00:06.8
<input type="checkbox"/>	<input checked="" type="checkbox"/>	C0025 35	188.792	4	93.57	C0025 35.TIFF	22,579 00:00:05.5
<input type="checkbox"/>	<input checked="" type="checkbox"/>	C0030 38	73.723	5	93.54	C0030 38.TIFF	18,821 00:00:05.3
<input type="checkbox"/>	<input checked="" type="checkbox"/>	A0030 41	228.963	6	99.94	A0030 41.TIFF	19,535 00:00:04.9

4,096 x 4,036



Start Stop

20 / 20 (100.00%) Processed - 17 Generated

Vector Layer Generation

All distresses, faults, and annotation layers are preserved and translated/rotated to follow frames

The screenshot displays the QGIS desktop environment with several key components:

- Browser Panel:** Shows the file system structure with 'I75 Summary' and 'I75 Fault' layers highlighted.
- Layers Panel:** Lists the loaded layers: I75 Crack, I75 Fault, I75 Joint_Seal, I75 Pothole, I75 Slab_Repair, I75 Spalling, and I75 Summary.
- Attribute Table (I75 Summary):** Displays a table with columns OBJECTID and Fault_in. The first row (OBJECTID 1) is highlighted.
- Attribute Table (I75 Fault):** Displays a table with columns OBJECTID, Fault_in, and ID. The first row (OBJECTID 1) is highlighted.
- Processing Toolbox:** Shows a list of processing tools, including 'Vector creation', 'Vector general', 'Vector geometry', 'Vector overlay', 'Vector selection', and 'Vector table'.
- Identify Results:** Shows the results of a query, listing the OBJECTID, Fault_in, and ID for the selected feature.

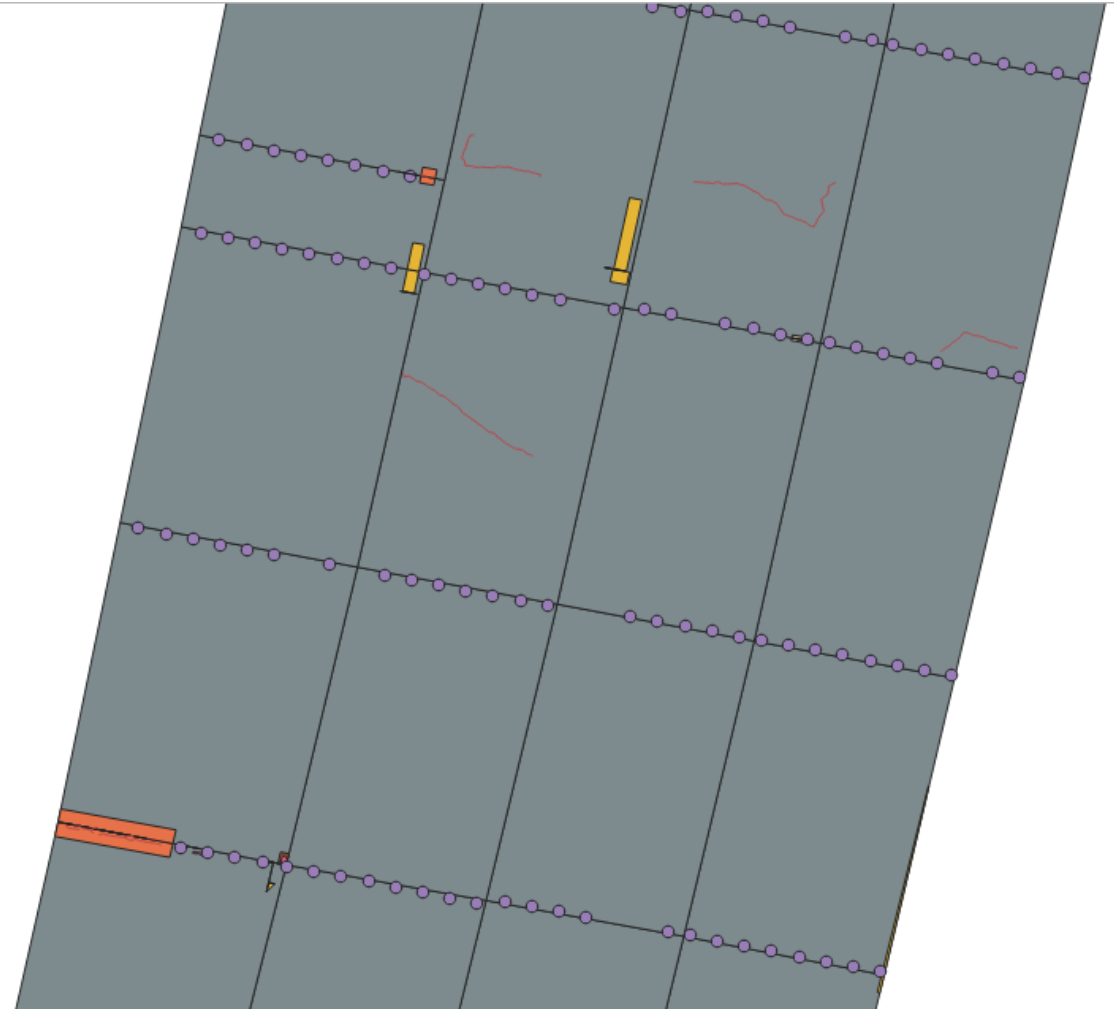
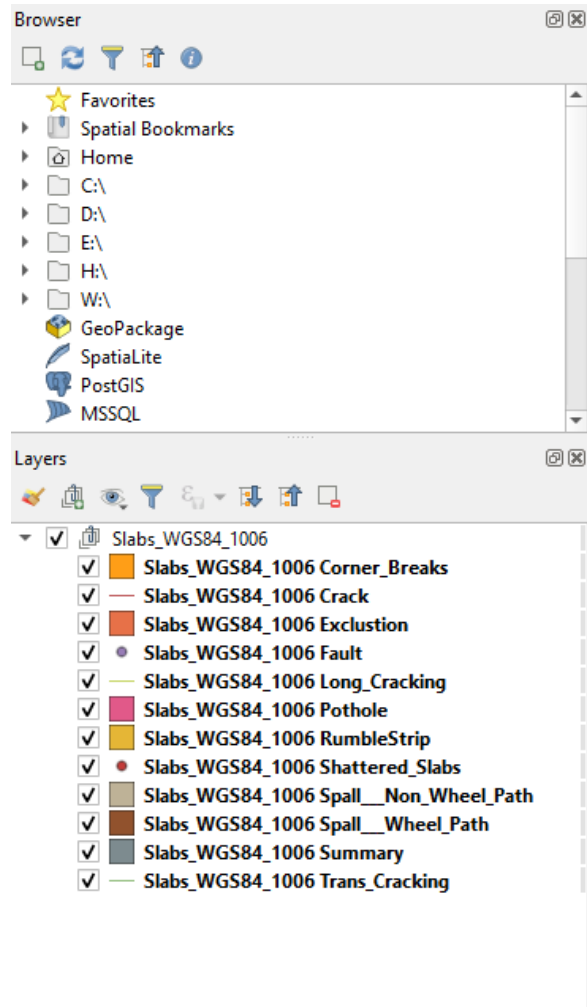
OBJECTID	Fault_in
1	48 D80
2	49 J60
3	50 B78
4	51 C80
5	52 D80
6	53 J60
7	54 C80
8	55 B78
9	56 C80
10	57 D80

OBJECTID	Fault_in	ID
1	-0.03936999999...	D8135 19781
2	-0.05905499999...	D8135 19781
3	0.03936999999...	D8130 19775
4	0.07873999999...	D8130 19775
5	0.00787399999...	D8130 19775
6	0.06692899999...	D8130 19775
7	0.01968499999...	D8130 19775
8	0.01574799999...	C8065 19777
9	0.01968499999...	C8065 19777
10	0.01574799999...	C8065 19777

Feature	Value
I75 Fault	
OBJECTID	467
(Derived)	
(Actions)	
OBJECTID	467
Fault_in	-0.007873999999999999
ID	J6040 19736

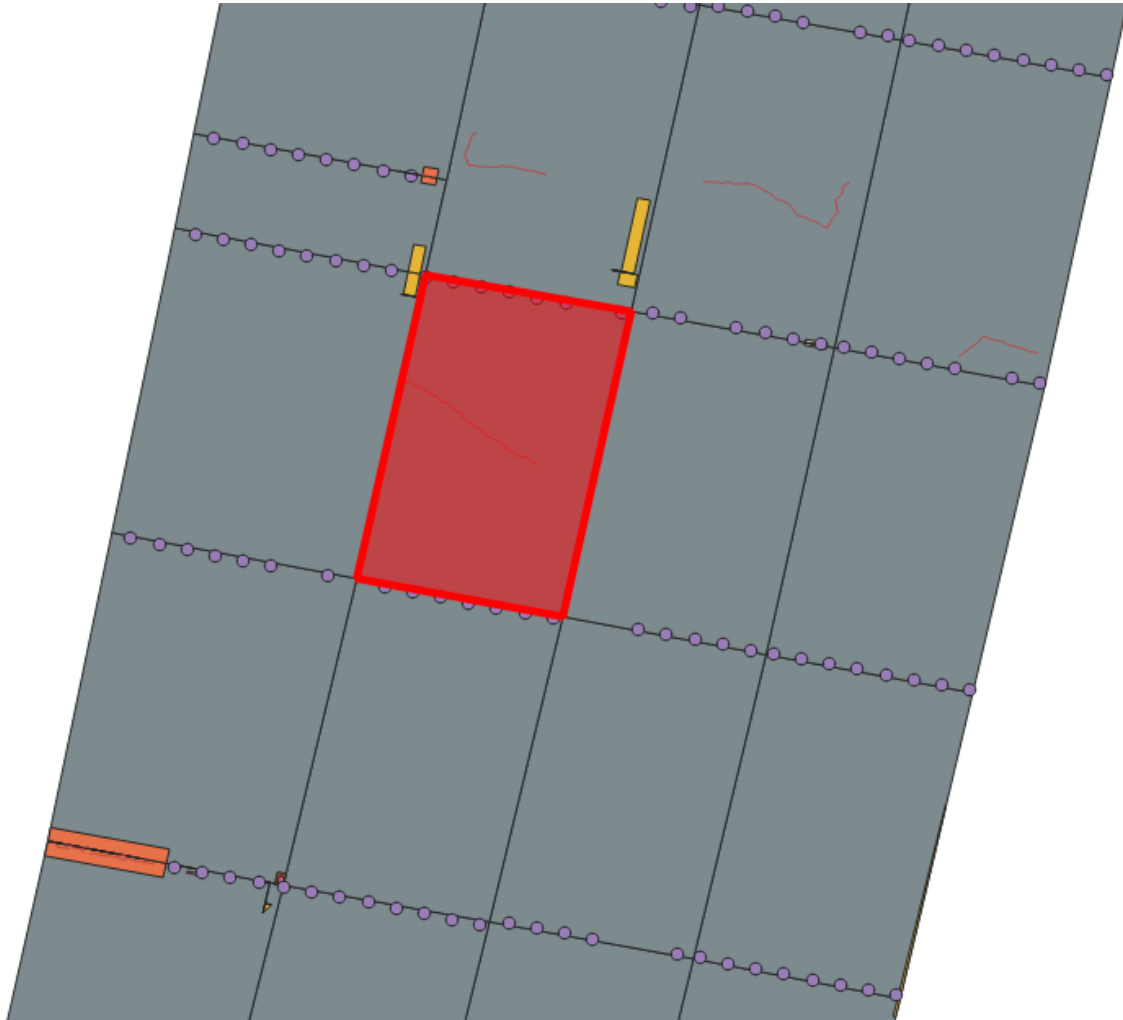
Vector Layer Generation

All distresses, faults, and annotation layers are preserved and translated/rotated to follow frames



Vector Layer Generation

All data is trimmed and aggregated to slab definition (or any other polygon); overlaps are eliminated using precedence rules



Processing Toolbox

Search...

- Recently used
- Cartography
- Database
- File tools
- Graphics
- Interpolation
- Layer tools
- Network analysis
- Raster analysis
- Raster terrain analysis
- Raster tools
- Vector analysis

Identify Results

Feature	Value
Slabs_WGS84_1006 Summary	
OBJECTID	1342
(Derived)	
(Actions)	
OBJECTID	1342
ID	1490 1490
ItemsCount	8
Crack_Count	1
Crack_CrackLength_ft	9.891308195164752
Crack_CrackAverageWidth_in	0.23404770429197458
Fault_Count	7
Fault_MIN_in	0.003936999999999995
Fault_MAX_in	0.11417299999999998
Fault_AVG_in	0.030933571428571425
Pothole_Count	NULL
Pothole_Area_ft_2	NULL
Blowups_N_A_Count	NULL
Corner_Breaks_N_A_Count	NULL

I-275 Rehab Survey in Florida, USA

- Survey all lanes on concrete sections selected by FDOT for treatment (~4-8 km sections)
- Measure cracking and rate other distresses from LCMS data as normal
- Apply stitching and transformation process
- Automatically apply FDOT criteria to recommend appropriate repair strategy for each slab

SLAB REPAIR AND REPLACEMENT CRITERIA

DISTRESS PATTERN	SEVERITY/DESCRIPTION		REPAIR METHOD	REFERENCE
CRACKING				
Longitudinal	Light	$< \frac{1}{8}$ ", no faulting, spalling $< \frac{1}{8}$ " wide	None	Figure 10.2
	Moderate	$\frac{1}{8}$ " $<$ width $< \frac{1}{4}$ ", spalling $< 3'$ wide	Clean and Seal	Figure 10.2
	Severe	width $> \frac{1}{4}$ ", spalling $> 3'$ faulting $> \frac{1}{8}$ "	Replace	Figure 10.3
Transverse	Light	$< \frac{1}{8}$ ", no faulting, spalling $< \frac{1}{8}$ " wide	None	Figure 10.2
	Moderate	$\frac{1}{8}$ " $<$ width $< \frac{1}{4}$ ", spalling $< 3'$ wide	Clean and Seal	
	Severe	width $> \frac{1}{4}$ ", spalling $> 3'$ faulting $> \frac{1}{8}$ "	Replace	Figure 10.3, 10.4 and 10.5
Corner Breaks	A corner of the slab is separated by a crack that intersects the adjacent longitudinal and transverse joint, describing an approximate 45° angle with the direction of traffic.		Full Depth	Figure 10.4 and 10.5
Intersecting Random Cracks (Shattered Slab)	Cracking patterns that divide the slab into three or more segments.		Full Depth	Figure 10.3 and 10.4
JOINT DEFICIENCIES				
Spall Nonwheel Path	Light	spall width $< 1\frac{1}{2}$ ", $< \frac{1}{8}$ slab depth, $< 12'$ in length	None	Figure 10.4 and 10.5
	Moderate	$1\frac{1}{2}$ " $<$ spall width $< 3'$, $< \frac{1}{8}$ slab depth, $< 12'$ in length	None	Figure 10.4 and 10.5
	Severe	spall width $> 3'$ or length $> 12'$	Full Depth	Figure 10.4 and 10.5
Spall Wheel Path	Light	spall width $< 1\frac{1}{2}$ ", $<$ than $\frac{1}{8}$ slab depth, $< 12'$ in length	None	Figure 10.4 and 10.5
	Moderate	$1\frac{1}{2}$ " $<$ spall width $< 3'$, $< \frac{1}{8}$ slab depth, $< 12'$ in length	Full Depth	Figure 10.4 and 10.5
	Severe	spall width $> 3'$ or length $> 12'$	Full Depth	Figure 10.4 and 10.5
SURFACE DETERIORATION				
Pop Outs Nonwheel Path	Small pieces of surface pavement broken loose, normally ranging from 1 to 4 in. diameter and $\frac{1}{8}$ to 2 in. in depth.			
	Light	Not deemed to be a traffic hazard	Keep under observation	
	Severe	Flying debris deemed a traffic hazard	Full Depth	Figure 10.4
Pop Outs Wheel Path	Small pieces of surface pavement broken loose, normally $> 3'$ diameter and 2" in depth.			
	Light	Deemed to be a traffic hazard	Full Depth	Figure 10.4
	Severe	Flying debris deemed a traffic hazard	Full Depth	Figure 10.4
MISCELLANEOUS DISTRESS				
Faulting	Elevation differences across joints or cracks.			
	Light	Faulting $< 4/32"$	None	
	Moderate	4 $<$ Faulting $< 16/32"$	Grind	
Lane To Shoulder Drop-Off	Severe	Faulting $> 16/32"$	Grind	
	Light	0 $<$ drop-off $< 1"$	None	N/A
	Moderate	1" $<$ drop-off $< 3"$	Build Up	
Severe	drop-off $> 3"$	Build Up		
Water Bleeding Or Pumping	Seeping or ejection of water through joints or cracks.		Install appropriate drainage, edge drain, permeable subbase, reseal joints, etc.	N/A
Blowups	Upward movement at transverse joints or cracks often accompanied by shattering of the concrete.		Full Depth	Figure 10.3 and 10.4



FDOT DESIGN STANDARDS
2013

CONCRETE SLAB REPLACEMENT

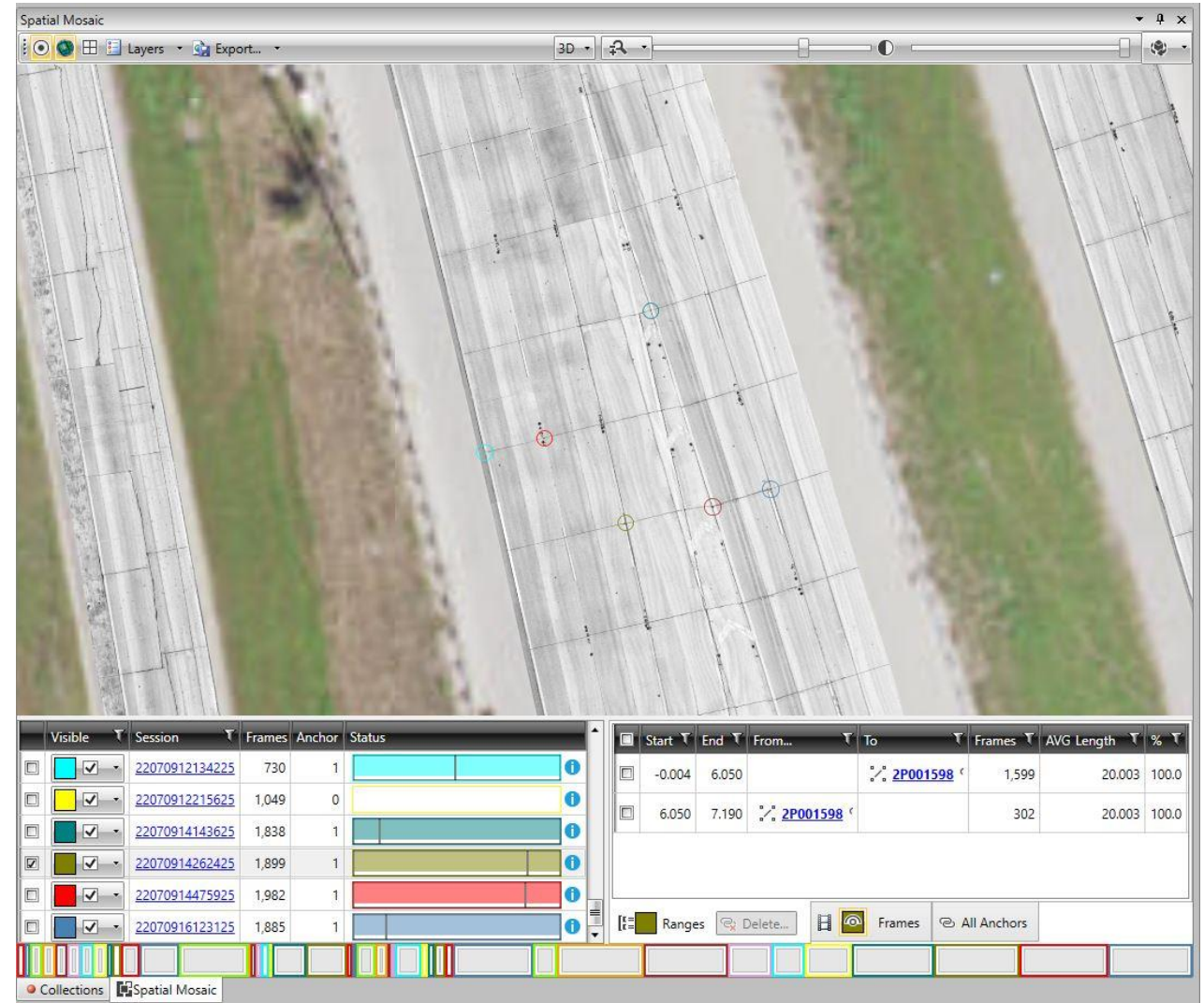
I-275 Rehab Survey in Florida, USA

- Rehab treatments are selected by software following FDOT treatment matrix
- Treatments are associated with each slab and exported as a spatial layer (GDB, SHP)
- Engineers conveniently load defects *and* recommended treatments in GIS or CAD software
 - ArcGIS, QGIS, etc.
 - AutoCAD, Microstation, etc.



Recap

- For any LCMS system, Connect™ software can be used to stitch any multi-pass or multi-lane data
- Data can be tied down to ground reference data
- Raster images can be exported by section or by area defined by a polygon
- Vector data is preserved and transformed to match



Questions?



Contact us:

<https://www.internationalcybernetics.com/contact-us>