USING IMAGERY TO COLLECT ASSET MANAGEMENT DATA

at Toronto Pearson International Airport

Presenter: Alain Duclos, MASc., P.Eng.
Date: Sept 25, 2022
Location: SWIFT 2023 - Winnipeg

ACKNOWLEDGMENT

- Greater Toronto Airports Authority
  - Kevin Chee
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- UAV8
  - Tyson Morelli
- Englobe
  - Michel Parent

OUTLINE

- Introduction
- Background Information
- Challenges and Concerns
- Different Survey Methods at Pearson
  - Traditional manual visual inspection – Inspector on foot
  - Laser Crack Measurement System (LCMS) – High Speed Vehicle
  - Small Unmanned Aircraft System (sUAS) – Drone
- Lessons Learned
- Next Steps and Questions

Toronto Pearson – Canada's Largest Airport

Toronto Pearson

INTRODUCTION

- 2022 Passenger Volume ------------------------- 35.6 Million PAX.
- Ranking in North America* --------------------- 2nd busiest airport
- Total airside paved areas ----------------------- approx. 5.8 million m^2
- # of aircraft movements **---------------------- approx. 336,800
- Cargo processed ***------------------------------ 388,700 metric tonnes
- Direct Jobs created -------------------------------50,000
- GDP contribution to Ontario --------------------$42 Billion CAD

** In terms of international passengers, 29.6 Million PAX prior to COVID.*

*** 2022 Data*

**** 2020 Data*

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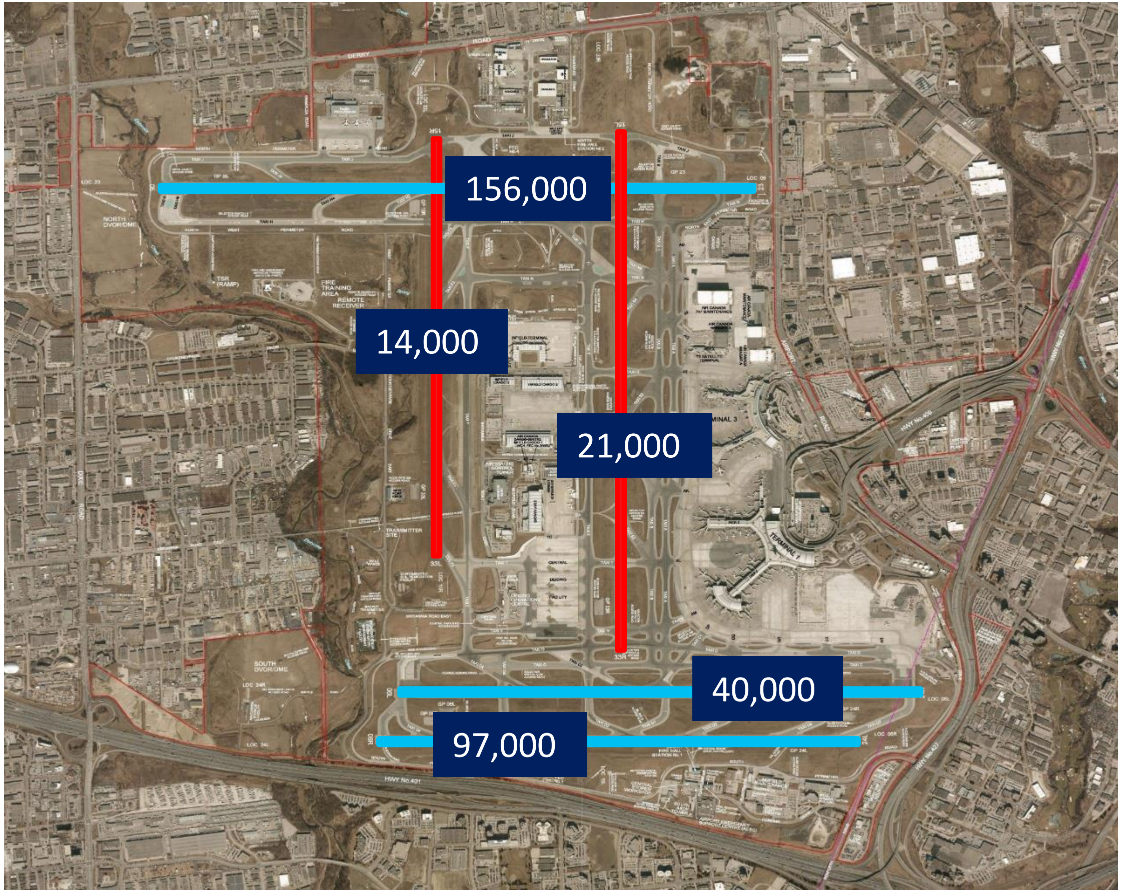

2022
Traffic
Movement

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BACKGROUND INFORMATION

- In 2000, GTAA decided to move from Transport Canada – Airport Pavement Structural Condition Surveys method to ASTM's Pavement Condition Index Surveys method – ASTM D5340 for Airport Pavement and ASTM D6433 for Roads and Parking Lots Pavement.
- MicroPAVER was selected to manage pavement surfaces, to predict current & future pavement conditions, and to provide a systematic method for maintenance and rehabilitation needs.

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BACKGROUND INFORMATION cont'd

- Typically, visual pavement survey was done "manually" by experienced inspectors using standard survey data sheet/handheld tablet to record all observable pavement distresses. It will take 3 to 5 days to complete for a runway.

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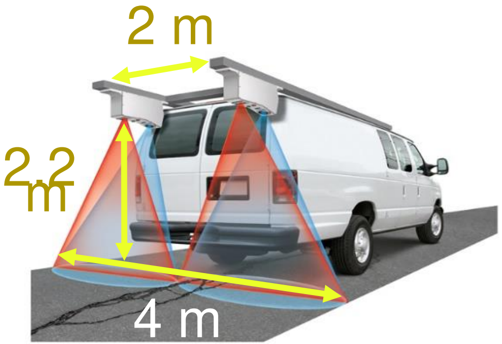
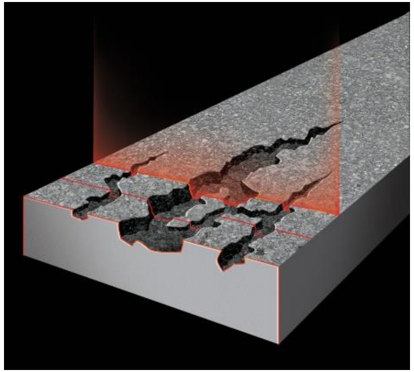
BACKGROUND INFORMATION cont'd

- In 2014, LCMS was introduced for runway inspection to minimize runway downtime and operation impact
- LCMS data collection parameters (resolution and depth range) were adjusted to complete inspection up to 80km/h covering the entire runway in 4 to 6 hours (closure window)





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BACKGROUND INFORMATION cont’d

- In 2021, Obtaining high-density survey grade 3D mapping was added to LCMS as a trial. The 3D mapping must be in NAD27, UTM Zone 17N, XYZ coordinates at a minimum spatial spacing of 100mm longitudinally and transversally across the entire runway surface. Absolute accuracy must be as follows:
  - X: in the range of $\pm$ 10mm or better at each point
  - Y: in the range of $\pm$ 10mm or better at each point
  - Z: in the range of $\pm$ 5mm or better at each point

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BACKGROUND INFORMATION cont'd

- In 2022, a trial was funded by Transport Canada's Innovation Centre and the Federal Government's ISED program to carry out airfield condition assessment on Runway 15R33L using sUAS - Drone to baseline surface conditions and defects (cracking, spalling, raveling and vegetation only) on a high-resolution Orthomap.
- Drone's optical imagery/RGB was collected at 1mm and 2mm Ground Sampling Distance (GSD) at an Above Ground Level (AGL) of 16m with a minimum of 70/70 image overlap.

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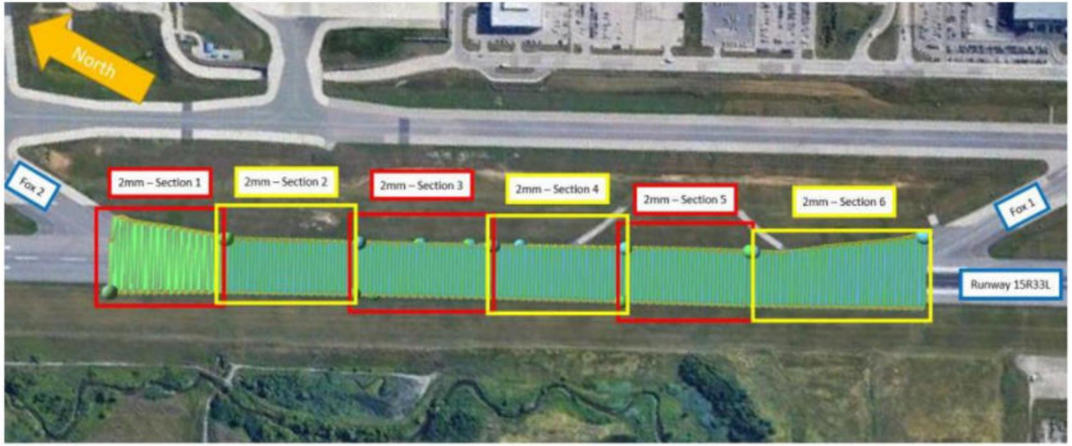
BACKGROUND INFORMATION cont'd



A 6 hour closure was arranged for the drone inspection and the imagery area was approx. 7 hectares on RWY 15R33L between F2 and F1. The 2mm flights were split into 6 semi-equal sized sections shown in the top photo, averaging 26 minutes per section.

The 1mm flights were split into 3 sections shown in the bottom photo, averaging 30 minutes per section.

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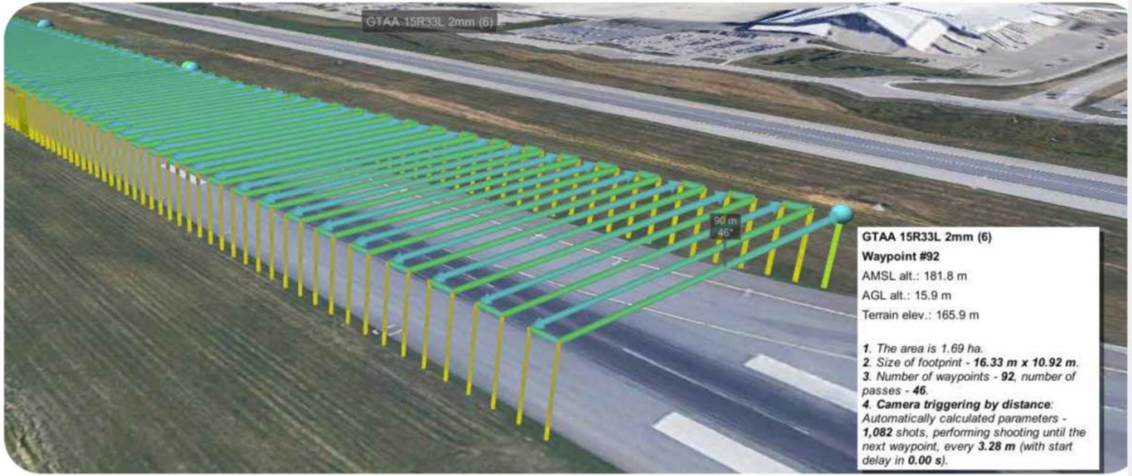
BACKGROUND INFORMATION cont'd

A customized Digital Surface Model is shown on the right side of the image. Green lines represent the drone flight lines, maintaining a consistent height above the ground and consistent overlap between passes.



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CHALLENGES AND CONCERNS FOR DATA COLLECTION

- Minimize operation impact to Canada’s busiest airport due to surface closure
- Reduce closure duration to accommodate increased traffic volume
- Day of operations, if airport configuration is on North/South or East/West
- Establish sufficient local survey control points prior to the inspection
- Delay due to weather conditions such as wind, rainfall, low-vis, etc.
- Surface Contamination such as rubber buildup
- Mechanical issues of inspection equipment prior to or during inspection

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LASER CRACK MEASUREMENT SYSTEM (LCMS) cont'd

Limitations and Lessons Learned cont'd

- Based on the current experience, below is the LCMS distress identification capability to identify each distress as per ASTM D5340

Paver Distress Number	ASTM D5340 Asphalt Distress Type	Distress Cause Classification	Distress Type Category	LCMS Identification Capability	LCMS Notes
41	Alligator Cracking	Load	Cracking	Good	Analysis required to specify crack type and identify sealed cracks
42	Bleeding	Other	Material	Good	Visible on ROW/LCMS images, easier to confirm distress onsite
43	Block Cracking	Climate/Durability	Cracking	Good	Analysis required to specify crack type and identify sealed cracks
44	Corrugation	Other	Profile	Poor	Best to locate during LCMS survey, difficult to see on the images
45	Depression	Other	Profile	Poor	Best to locate during LCMS survey, difficult to see on the images
46	Jet Blast Erosion	Other	Other	Good	Visible on ROW/LCMS images, easier to confirm distress onsite
47	Joint Reflection Cracking	Climate/Durability	Cracking	Good	Analysis required to specify crack type and identify sealed cracks
48	Long. & Trans. Cracking	Climate/Durability	Cracking	Good	Analysis required to specify crack type and identify sealed cracks
49	Oil Spillage	Other	Other	Good	Visible on ROW/LCMS images, easier to confirm distress onsite
50	Patching	Climate/Durability	Other	Good	Obvious to see on ROW/LCMS images
51	Polished Aggregate	Other	Texture	Poor	Onsite assessment required, difficult to see on the images
52	Raveling	Climate/Durability	Texture	Fair	Obtained from LCMS data processing, onsite validation suggested
53	Rutting	Load	Profile	Good	Excellent rut depth calculation from LCMS data
54	Shoving	Other	Profile	Fair	Signs visible on ROW/LCMS images, must be confirmed onsite
55	Slippage Cracking	Other	Cracking	Good	Analysis required to specify crack type and identify sealed cracks
56	Swell	Other	Profile	Poor	Best to locate during LCMS survey, difficult to see on the images
57	Weathering	Climate/Durability	Texture	Fair	Obtained from LCMS data processing, onsite validation required

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SMALL UNMANNED AIRCRAFT SYSTEM (sUAS)

Key Statistics on RWY 15R33L (F2-F1) are collected as follows:

- Total No. of Optical Images in 1mm – Section 3 only: 948
- Total No. of Optical Images in 2mm – Section 1 to 6: 5,098
- Total Size: 131 GB
- Average Image Size: 24MB
- Footprint, 1mm image: 8x5m
- Footprint, 2mm image: 16x10m
- Crack defect shows in Green, avg. crack width < 6mm
  shows in Yellow, 6mm ≤ avg. crack width ≤ 24mm
  shows in Red, 24mm < avg. crack width

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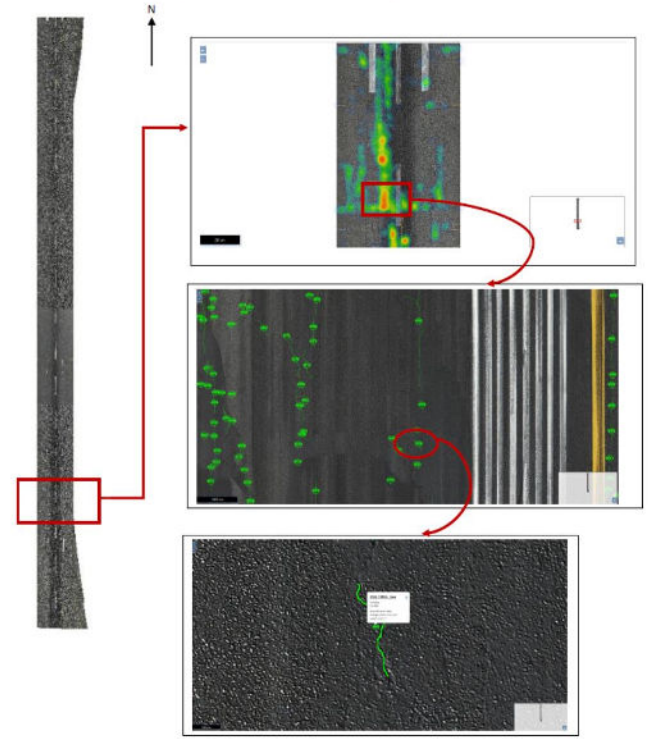
SMALL UNMANNED AIRCRAFT SYSTEM (sUAS) cont'd

Below is an example of the crack map on the 2mm-Runway orthoimage found on AUTOSPEX™:

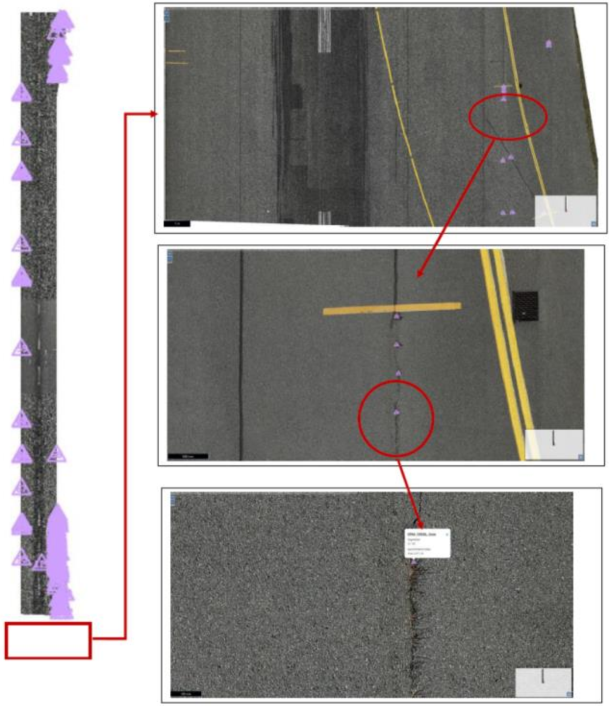


Example of Cracking Defects-2mm GSD

Below is an example of spalling defects on the 2mm-Runway orthoimage found on AUTOSPEX™:

Example of Spalling Defects-2mm GSD

Below is an example of vegetation defects on the 2mm-Runway orthoimage found on AUTOSPEX™:



Example of Vegetation Defects-2mm GSD

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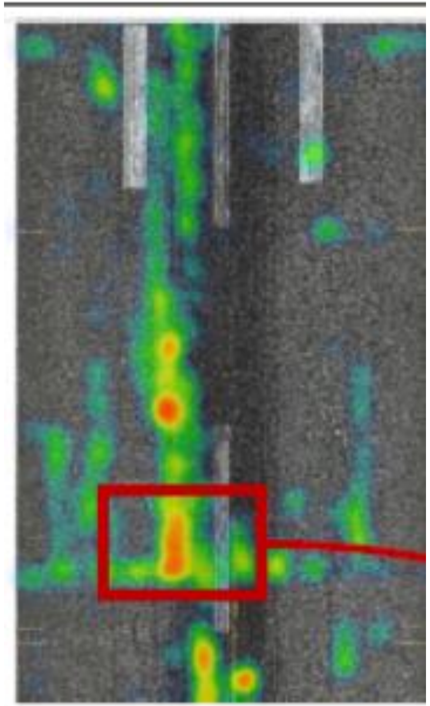
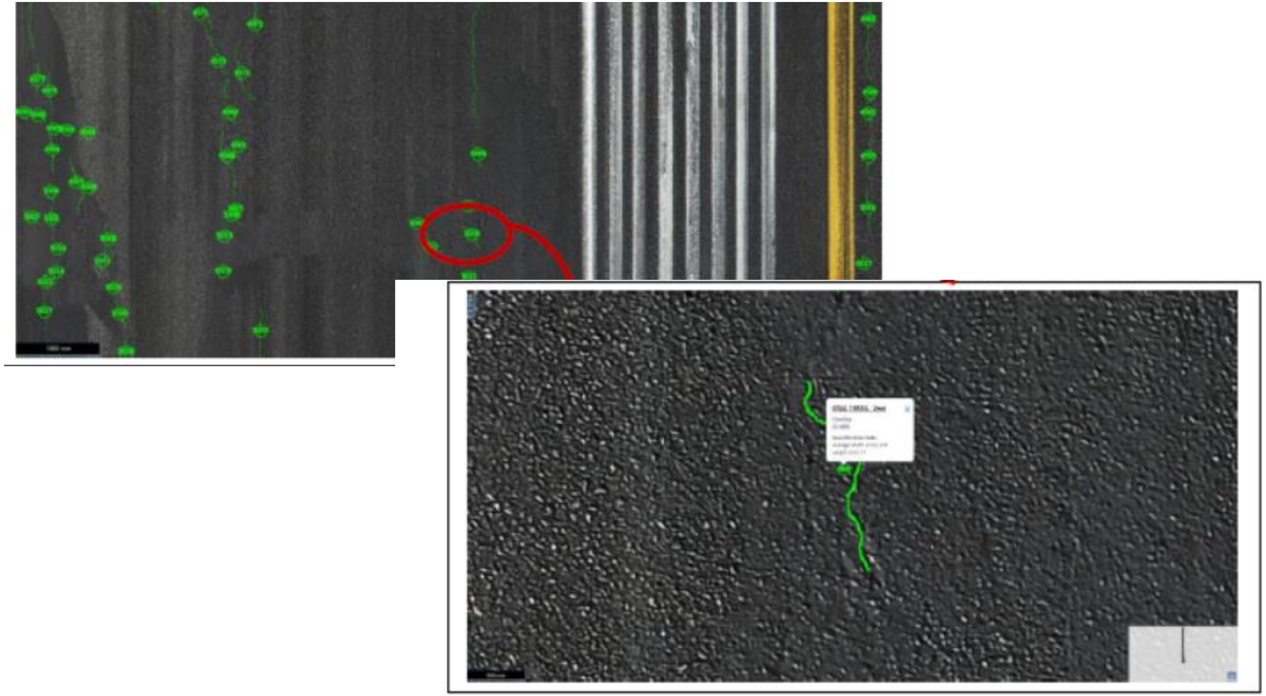
SMALL UNMANNED AIRCRAFT SYSTEM (sUAS) cont'd





Example of Cracking Defects-2mm GSD

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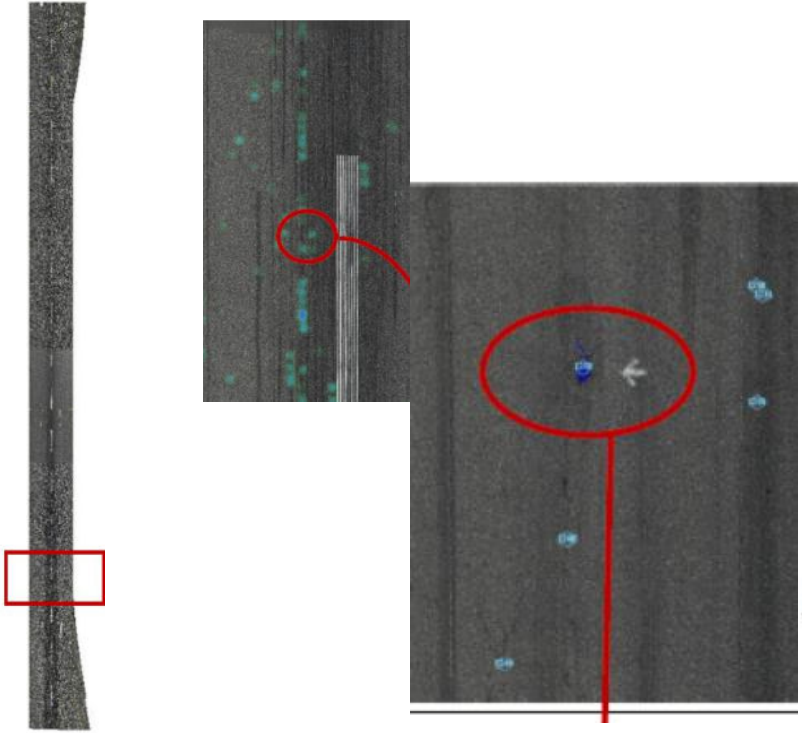
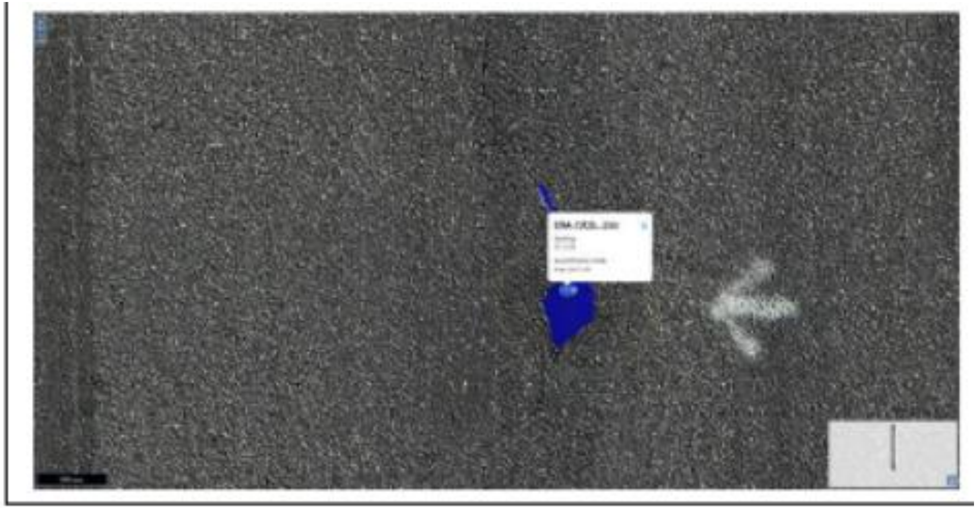
SMALL UNMANNED AIRCRAFT SYSTEM (sUAS) cont'd





Example of Spalling Defects-2mm GSD

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SMALL UNMANNED AIRCRAFT SYSTEM (sUAS) cont'd

A total of 3 types of surface defects are observed by Drone:

1. Cracking
2. Spalling/Raveling
3. Vegetation

Summary of Defects

Type of Defect	1mm Ortho	2mm Ortho
Cracking (CRK)	581 Defects	7,101 Defects
Spalling (SPL)	21,981 Defects	3,167 Defects
Vegetation (VEG)	Not analyzed	170 Defects

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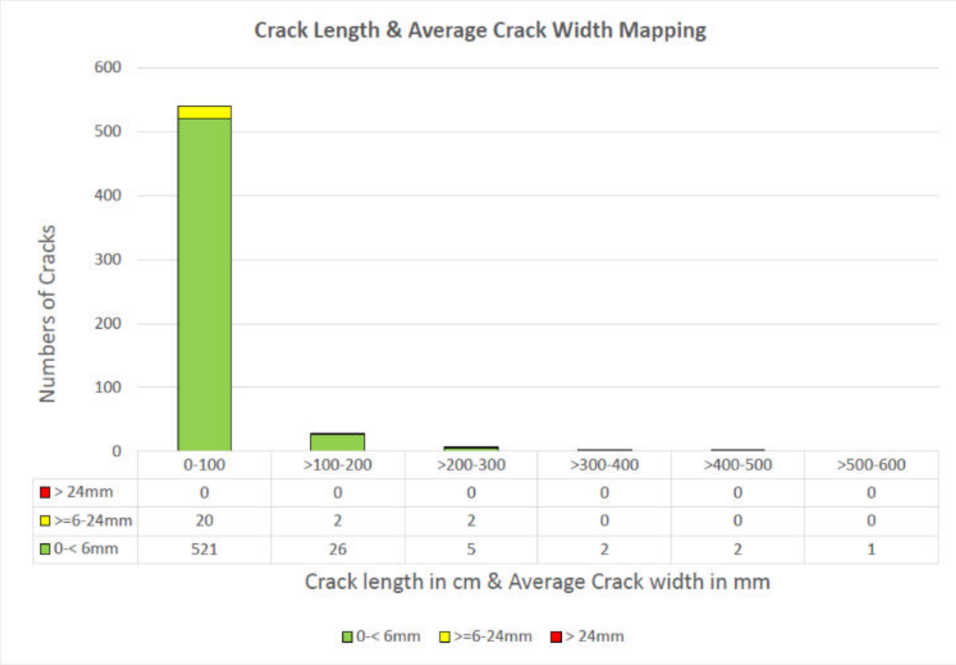
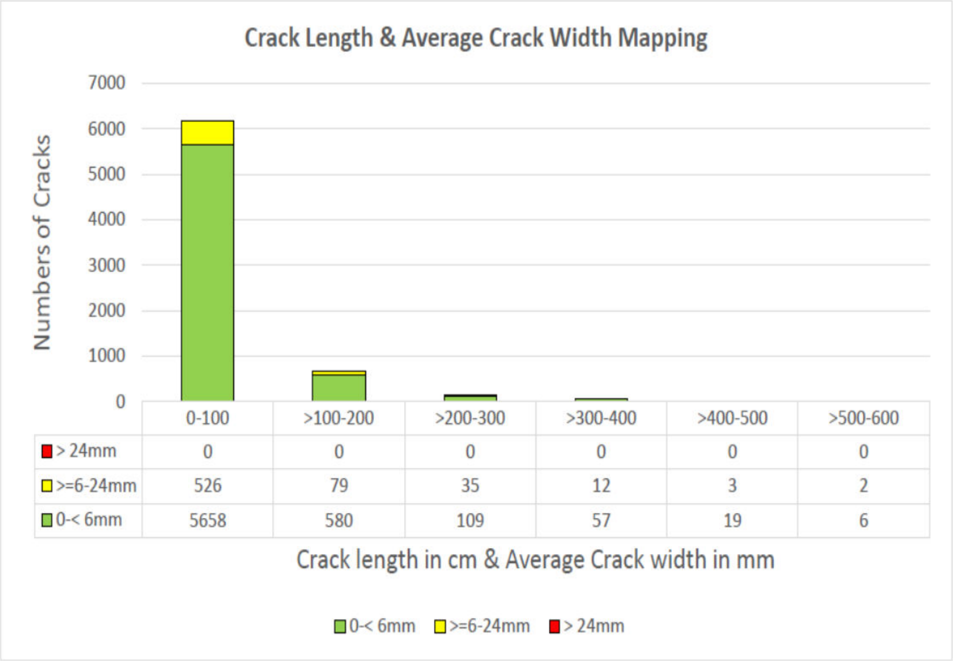
SMALL UNMANNED AIRCRAFT SYSTEM (sUAS) cont’d



	0-100	>100-200	>200-300	>300-400	>400-500	>500-600
> 24mm	0	0	0	0	0	0
>=6-24mm	20	2	2	0	0	0
0-< 6mm	521	26	5	2	2	1

Crack Length & Average Width Mapping Histogram- 1mm GSD



	0-100	>100-200	>200-300	>300-400	>400-500	>500-600
> 24mm	0	0	0	0	0	0
>=6-24mm	526	79	35	12	3	2
0-< 6mm	5658	580	109	57	19	6

Crack Length & Average Width Mapping Histogram- 2mm GSD

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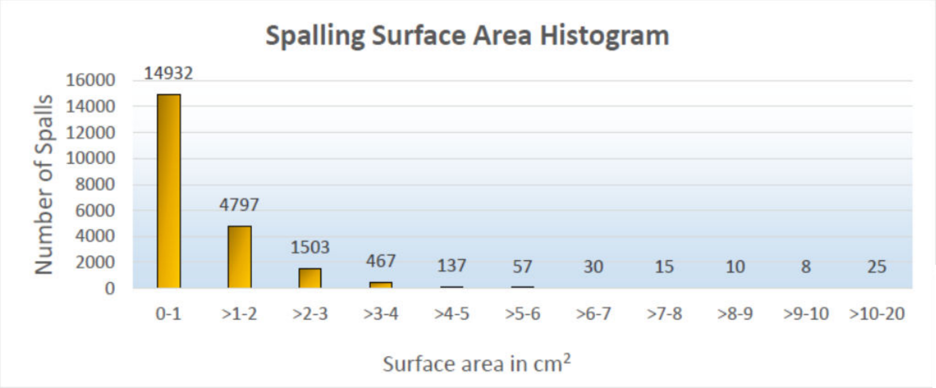
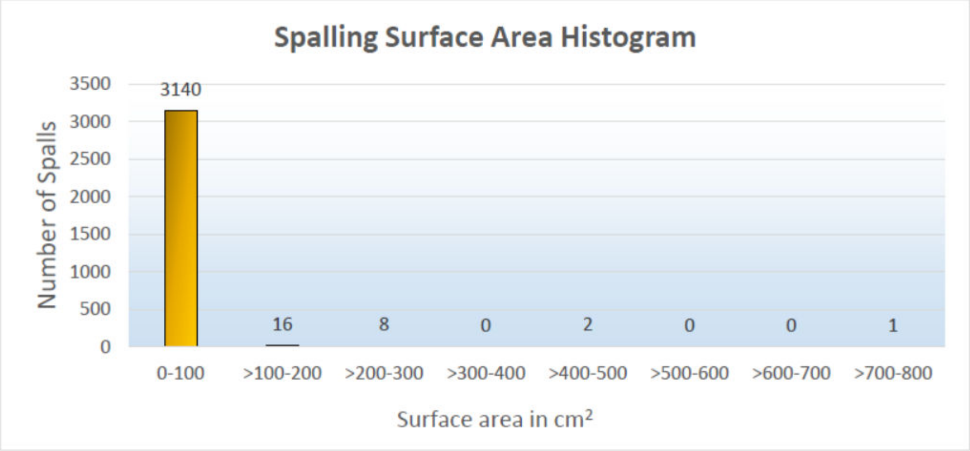
SMALL UNMANNED AIRCRAFT SYSTEM (sUAS) cont'd



Spalling Surface area Histogram-1mm GSD



Spalling Surface area Histogram-2mm GSD

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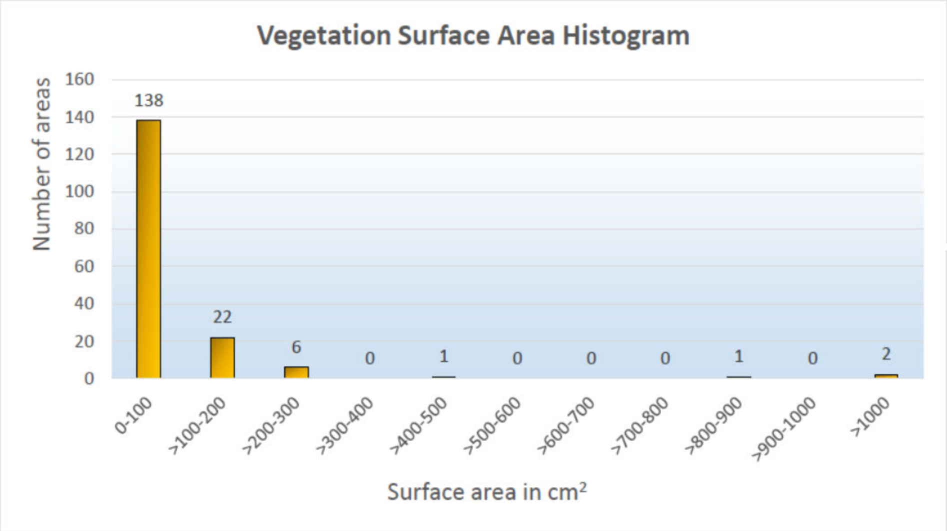
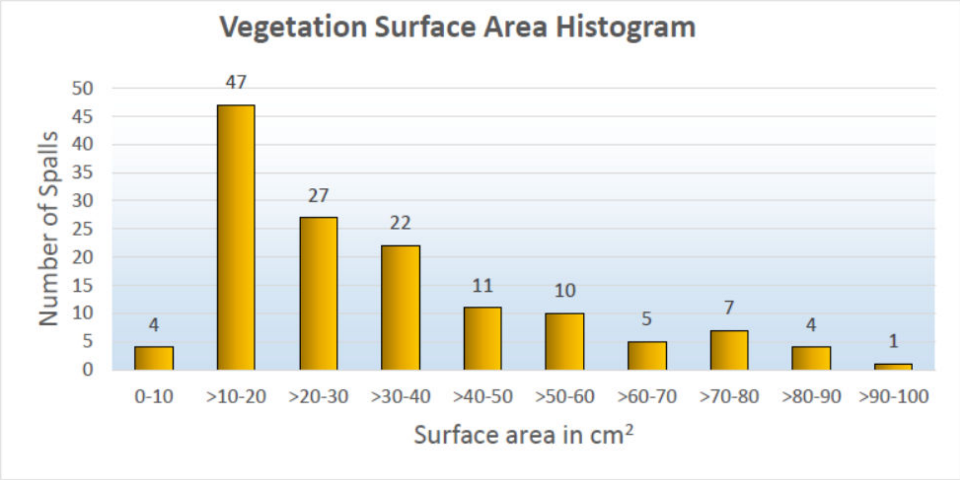
SMALL UNMANNED AIRCRAFT SYSTEM (sUAS) cont'd



Vegetation Surface area Histogram-2mm GSD



Vegetation Surface area Histogram (less than 100 sq.cm)-2mm GSD

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SMALL UNMANNED AIRCRAFT SYSTEM (sUAS) cont'd

Limitations and Lessons Learned

- Due to limited closure time, RTK base was not positioned on a known survey control point. A known coordinate would increase survey accuracy and repeatability.
- First time to process Spalling/Raveling distress. This machine learning module was able to find most of the defects for the 1mm dataset. 2mm dataset was unable to identify Raveling to the same proficiency as 1mm dataset.

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SMALL UNMANNED AIRCRAFT SYSTEM (sUAS) cont'd

Limitations and Lessons Learned cont'd

- Stringers or Splotches of crack sealant on the surface that appeared as cracks or spalls after running the initial model. These false indications were able to be eliminated during the checking/verification stage.
- Any joints or sealed cracks were not identified under current model. A model could be developed to identify these defects in the future.
- Spalling defect and Cracks quantification are more accurate in 1mm data than in 2mm data.

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SMALL UNMANNED AIRCRAFT SYSTEM (sUAS) cont'd

Limitations and Lessons Learned cont'd

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51	Polished Aggregate	Other	Texture	Poor	Onsite assessment required, difficult to see on the images	Poor	Higher vertical resolution and onsite validation required
52	Raveling	Climate/Durability	Texture	Fair	Obtained from LCMS data processing, onsite validation suggested	Poor	Higher vertical resolution and onsite validation required
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Comparison of Pavement Condition Index (PCI) between LCMS, Manual Visual Inspection, and Drone are summarized as follows:

	Pavement Condition Index LCMS			Pavement Condition Index Visual			Pavement Condition Index Drone			Δ PCI Visual LCMS	Δ PCI Visual Drone	Δ PCI LCMS Drone
	Section	Rating	Sample	Section	Rating	Sample	Section	Rating	Sample			
	77	Satisfactory	73	89	Good	90	89	Good	88	12	0	-12
			81			94			94			
			79			86			92			
			79			93			88			
			78			91			85			
			70			81			85			
	68	Fair	67	78	Satisfactory	75	76	Satisfactory	82	9	2	-8
			70			87			82			
			65			65			69			
			62			73			81			
			70			77			75			
			75			82			62			
			70			85			80			
	79	Satisfactory	77	88	Good	87	83	Satisfactory	80	9	5	-4
			78			89			85			
			78			85			77			
			82			91			86			
			83			90			87			
Average PCI	**74.87**	**Satisfactory**		**85.00**	**Satisfactory**		**82.54**	**Satisfactory**				

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BENEFITS OF DRONE SURVEYS

- Excellent stitching of individual images into one consolidated image that can be used for analysis (better than LCMS)
- Excellent automated crack detection models
- Surveys can be done two to three times as quickly as manual visual surveys depending on accuracy level desired
- High quality image provides good correlation with manual VCS survey and provides a record of condition
- Online Autospex software very useful. Distress cloud feature helps to easily visualize where the distresses are concentrated
- Possible to extract pavement marking condition and inset light condition
- 100% Survey

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CHALLENGES WITH DRONE SURVEYS

- Currently much more costly than LCMS or VCS methods
- Takes twice as long in the field as LCMS surveys (1 mm accuracy)
- Analysis time is quite long – similar to LCMS. Manual VCS method provides instantaneous results when using tablets in the field
- Spalling/ravelling and vegetation distresses that are provided are not useful for calculating PCI according to ASTM method

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NEXT STEPS

- Distress identification capability for concrete pavement should also be reviewed
- Traditional Manual Visual Inspection must be used to validate any type of High Speed Imagery Collection method
- Texture related distresses such as Polished Aggregate, Raveling and Weathering are not able to be detected and quantified. Better image quality and further strengthening of the algorithm model will improve the results
- Further evaluate the benefit of increased (1 mm) accuracy of survey versus the added cost and time/runway availability

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NEXT STEPS cont'd

- Sealed crack identification will be a great feature to be added.
- Vectorized crack data in polyline method will be easier and faster to work with instead of polygon format.
- Automated distress identification models need to be improved to prevent double counting of distresses in the same area.
- Utilizing this imagery for pavement markings verification, lighting verification, primary security fence line verification, etc. would be beneficial for other stakeholders.

Q&A
Thank you

Presenter: Alain Duclos, MASc., P.Eng.
Date: Sept 25, 2023
Location: SWIFT 2023 – Winnipeg