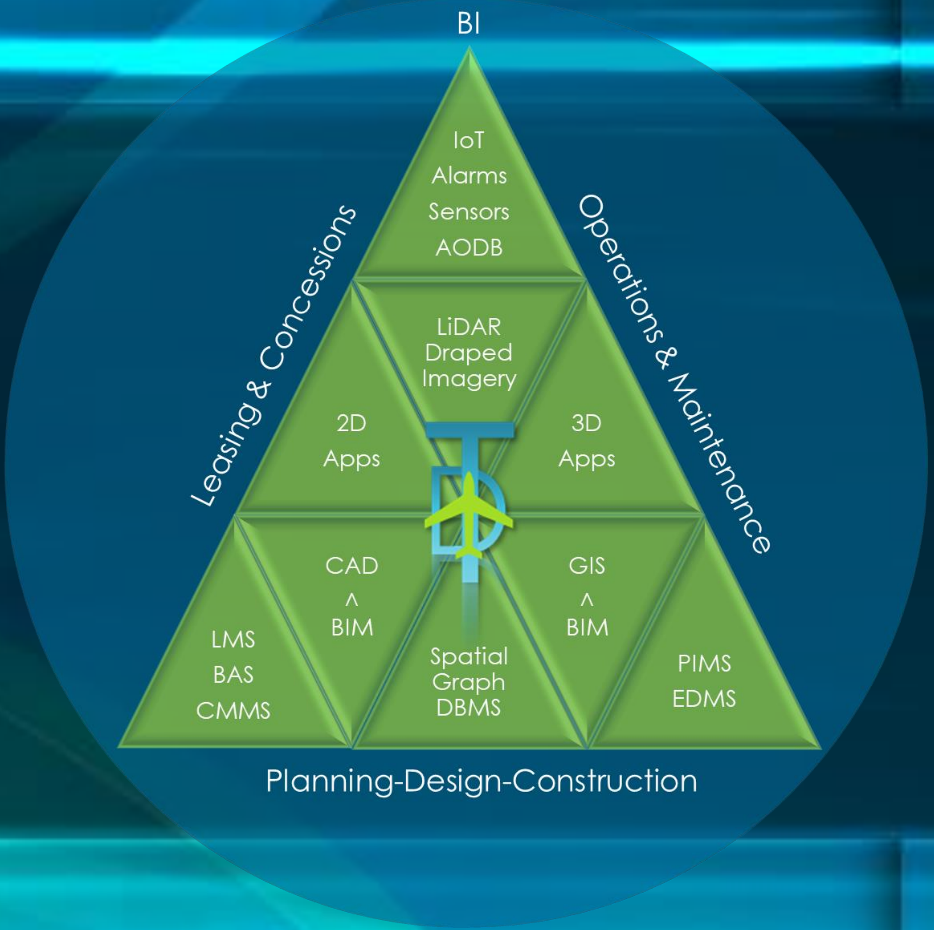
18 OCTOBER 2023

LiDAR with Draped Imagery Enabling 3D Digital Twins

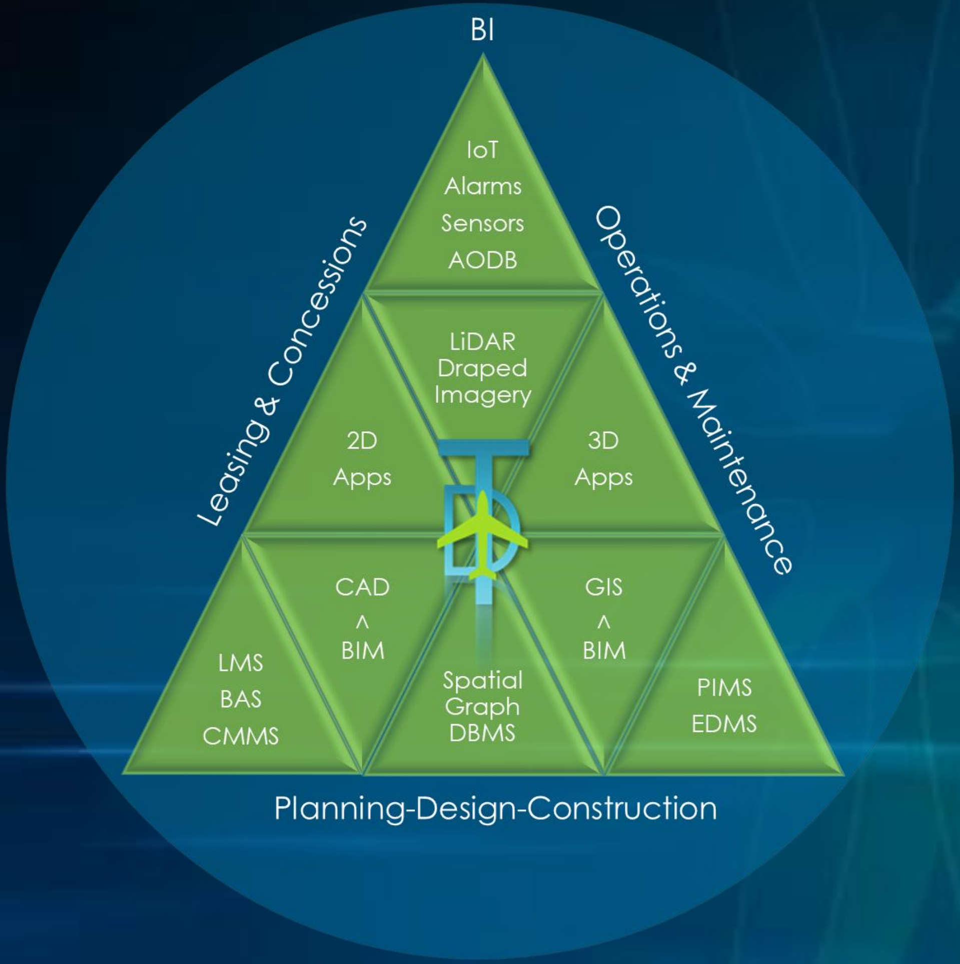


www.AirportDigitalTwin.org Webinar Series

By: Ed Maghboul & John White, x-Spatial
Francesco Martinelli, Trimble/Applanix

AirportDigitalTwin.org

Webinar Series



1. Jul 19: **BIM Processing**
2. Jul 26: **Information Integration**
3. Aug 2: **Enabling Integrated SMS**
4. Aug 9: **Holistic Business Intelligence**
5. Sep 27: **Roadmap for Airport Owners**
6. Oct 18: **LiDAR with Draped Imagery**

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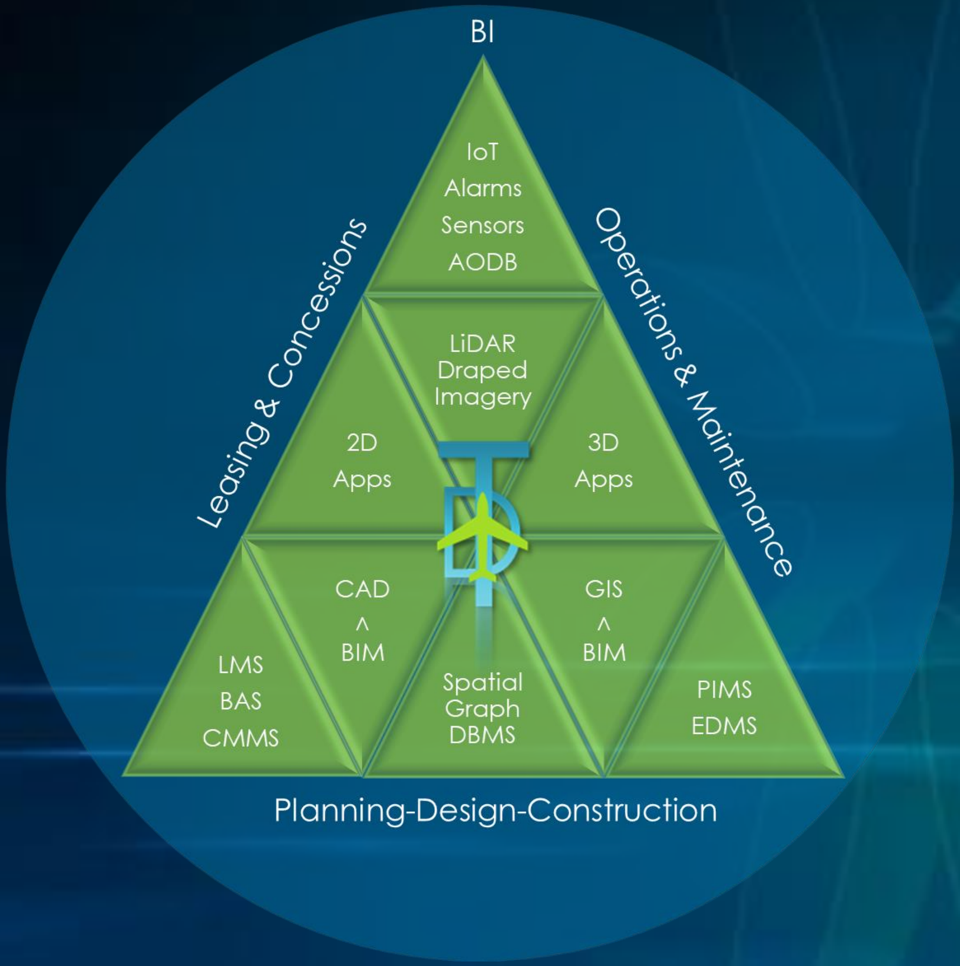
Webinar Outline



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6. Oct 18: **LiDAR with Draped Imagery**

- Introductions & Background
- Sample Airport Use Cases Leveraging LiDAR with Draped Imagery
  - Outdoors
  - Indoors
- Leveraging Artificial Intelligence (AI) Machine Vision for Feature Extraction
- Best Practices for Capturing & Processing LiDAR with Draped Imagery to Sustain Airport Digital Twins

AirportDigitalTwin.org
Integrated Solution Providers Enabling Airport Owner Digital Twins
Simplify i3
AEGIS
BIM
AirportDigitalTwin.org Proprietary Information

Integrating Best of Breed Technologies

Microsoft Azure

Simplify i3 simplifyi3.com powered by EPIC

SMS

X·SPATIAL

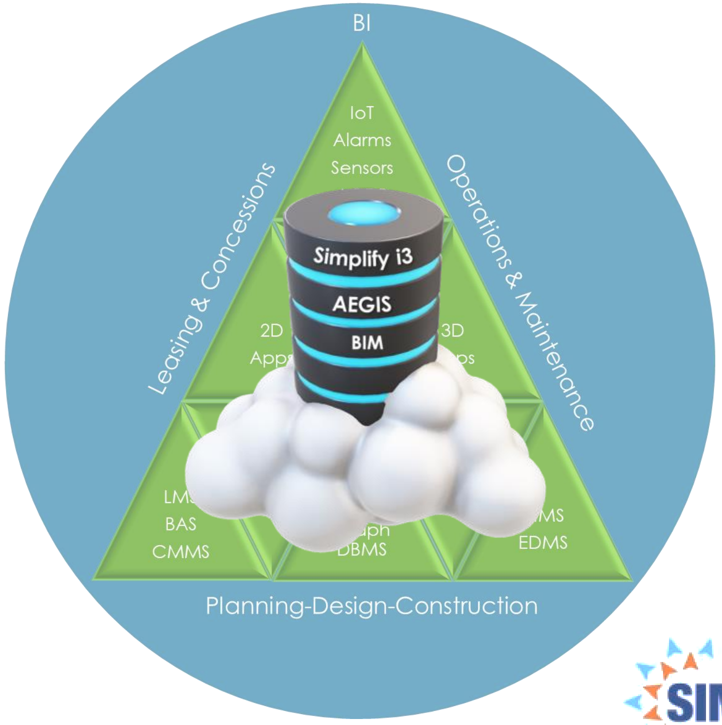
Microsoft

ORACLE

PDBM CONSULTING PROJECT LIFE CYCLE BIM SERVICES

aws

Google



esri

AUTODESK

ANGULARJS by Google

Trimble

SOLV3D

SIMATRON SOLUTIONS LLC

iOS

android

Adobe CF

Safe Software

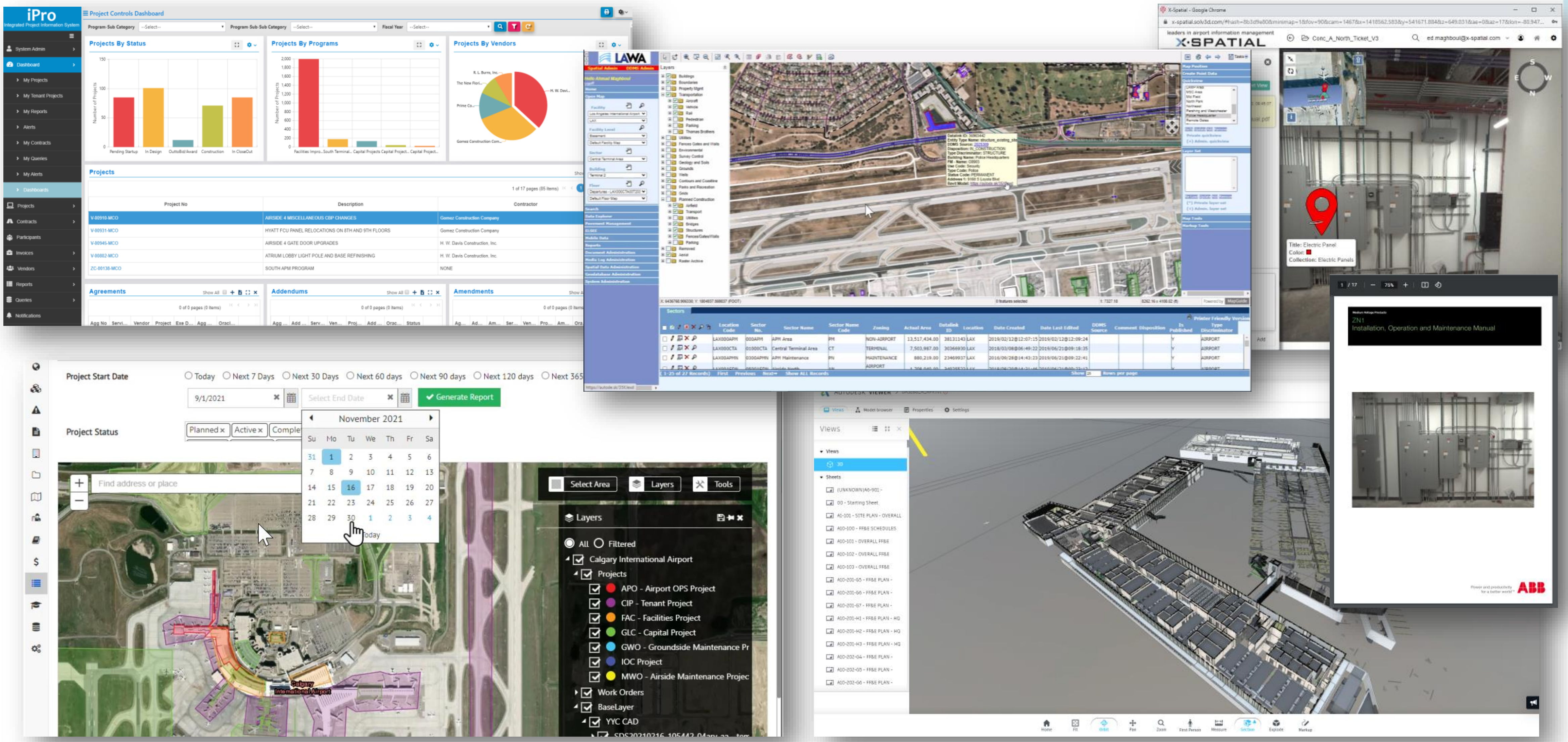
SAP

crystal reports

amadeus

IntellAct

Sustainable Airport Digital Twin Solutions



Introductions:

Welcome About Us Q&A Solution Webinars

www.AirportDigitalTwin.org

Our Subject Matter Experts (SME)s

David Tamir

Brings 4 decades of systems engineering and business process improvement experience from the Space Shuttle Program and over 30 airports; including airport owner's perspective at Orlando. Founded and led the AAAE Airport Digital Twin Working Group in development of the *Digital Twin Roadmap for Airport Owners.* Leads this AirportDigitalTwin.org Team in helping airport owners succeed.

Linked-In Profile

Dr. Prasad Chittaluru

Brings 4 decades of experience in infrastructure data management. Awarded a prestigious National Academy of Science Small Business Innovation Research (SBIR) grant to invent and develop Simplify i3. Specializes in infrastructure owner business process improvement through digital twin technologies. Has served airports including at Orlan

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Linked-In Profile

Ed Maghboul

Brings 4 decades of spatial information technology experience including airports at Los Angeles, Boston, San Francisco, Charlotte, and others. Leads x-Spatial and its development of the Airport Enterprise Geospatial Information System (AEGIS), achieving industry leading interoperability between Autodesk and Esri for airport enterprise ma

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Linked-In Profile

Dr. Behzad Mohammadi

Brings 4 decades of spatial information technology experience including airports at Los Angeles, Boston, San Francisco, Charlotte, and others. Chief architect and developer of the x-Spatial Airport Enterprise Geospatial Information System (AEGIS), achieving industry leading interoperability between Autodesk and Esri for airport enterprise management.

Linked-In Profile

Dr. Ali Diba

Brings 3 decades of experience implementing Esri's technologies with many awards and recognitions. His expertise are especially key to airport digital twins by leveraging Esri's Business Intelligence (BI) analytics solutions for correlating various disparate information over the spatial common denominator. He is x-Spatial's Esri techn

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Linked-In Profile

John White

Brings 3 decades of experience in effective infrastructure project and full lifecycle data management. Has proven airport owner experience from Brussels, as well as airport consulting experience leveraging x-Spatial's solutions at Los Angeles, Boston, and Charlotte. Has developed best practices for sustaining airport terminal LiDAR sc

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Linked-In Profile

Jorge Quiroz

Brings over 2 decades of experience in helping multiple domestic and international airports adopt BIM as a tool for design and construction, so the data captured during these phases can be leveraged to feed airport enterprise asset management system, including Digital Twin. Jorge served as the BIM Director on the airport owner's side for

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Don Murray

Brings 4 decades of data processing automation experience. Co-founder of Safe Software, the inventors of the data Feature Manipulation Engine (FME) -- an industry leader for data integration middleware used in the AEC, airports, and other industries.

Linked-In Profile

Hans Dorries

Brings over 2 decades of experience converging on airport business process modeling and simulation, which are keys to achieving predictive analytics via digital twins. Leads Simatron Solutions, leveraging state of the art modeling and simulation tools and methods.

Linked-In Profile

Suresh Sanka

Brings over 2 decades of progressive experience in digital twin technology development including applications for airports at Orlando, Harlingen, Buckeye, and Boca Raton. Leads the Simplify i3 product development. Brings hands-on experience in web, mobile, cloud, and standalone applications leveraging .NET, Java, low code platforms, and databases such as SQL Server, Oracle, and PostgreSQL.

Udi Segall

Brings over 2 decades of technology application expertise, converging on video analytics middleware to improve airport Business Intelligence (BI). Founder and CEO of IntellAct, a provider of actionable intelligence solutions that monitor, analyze and accelerate aircraft and passenger turn-around processing. Leveraging Artificial Intelli

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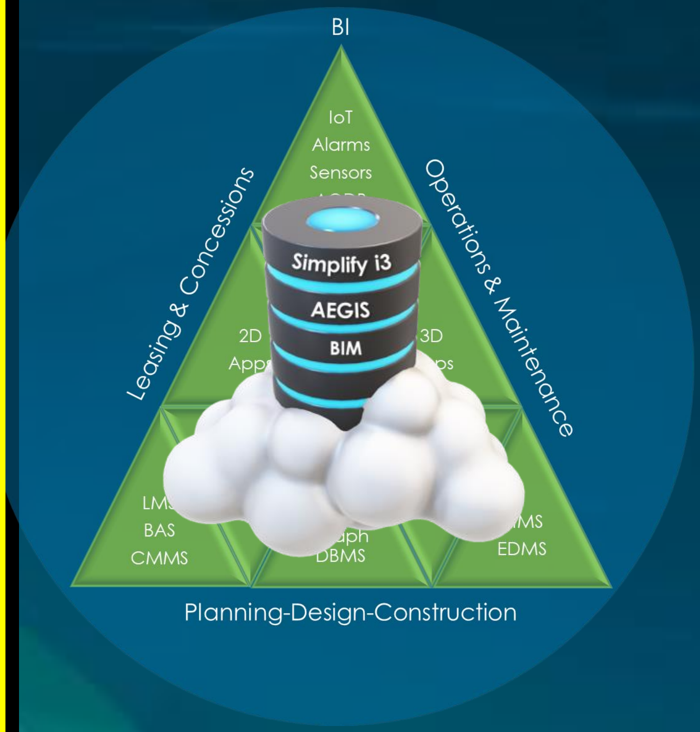
Francesco Martinelli

Brings over 2 decades of experience in LiDAR scanning, including airports such as LAX and CLT. Leads Trimble/Applanix TIMMS scanning solutions involving 360 degree imagery draped over LiDAR. Also brings expertise with leveraging robotic/semi-automated scanning platforms, to advance sustainability of digital twins with on-going facility modifications.

X·SPATIAL

Trimble. Applanix



ARP-DT Skeleton

Correlates information

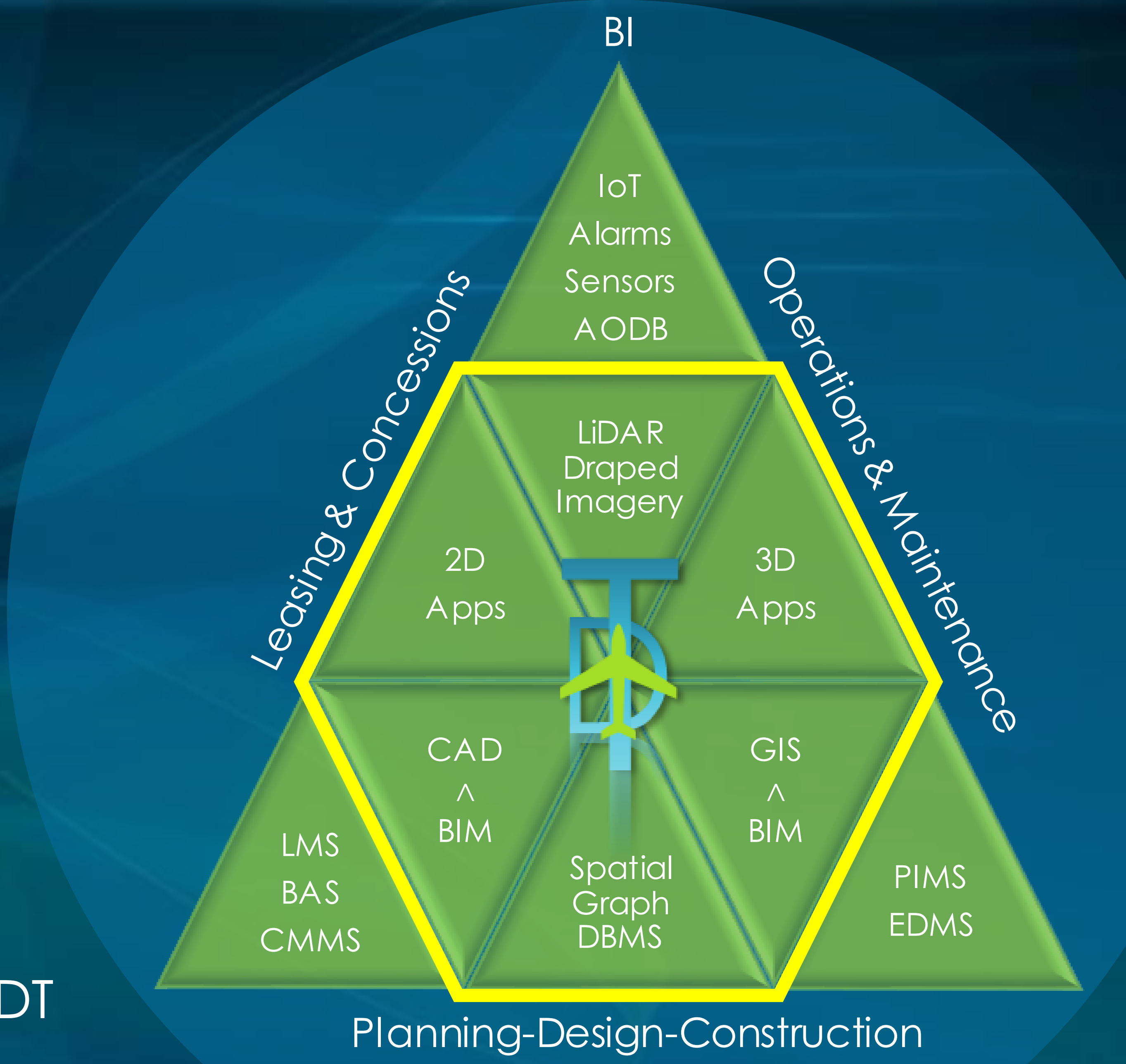
via common denominator

Spatial

Database

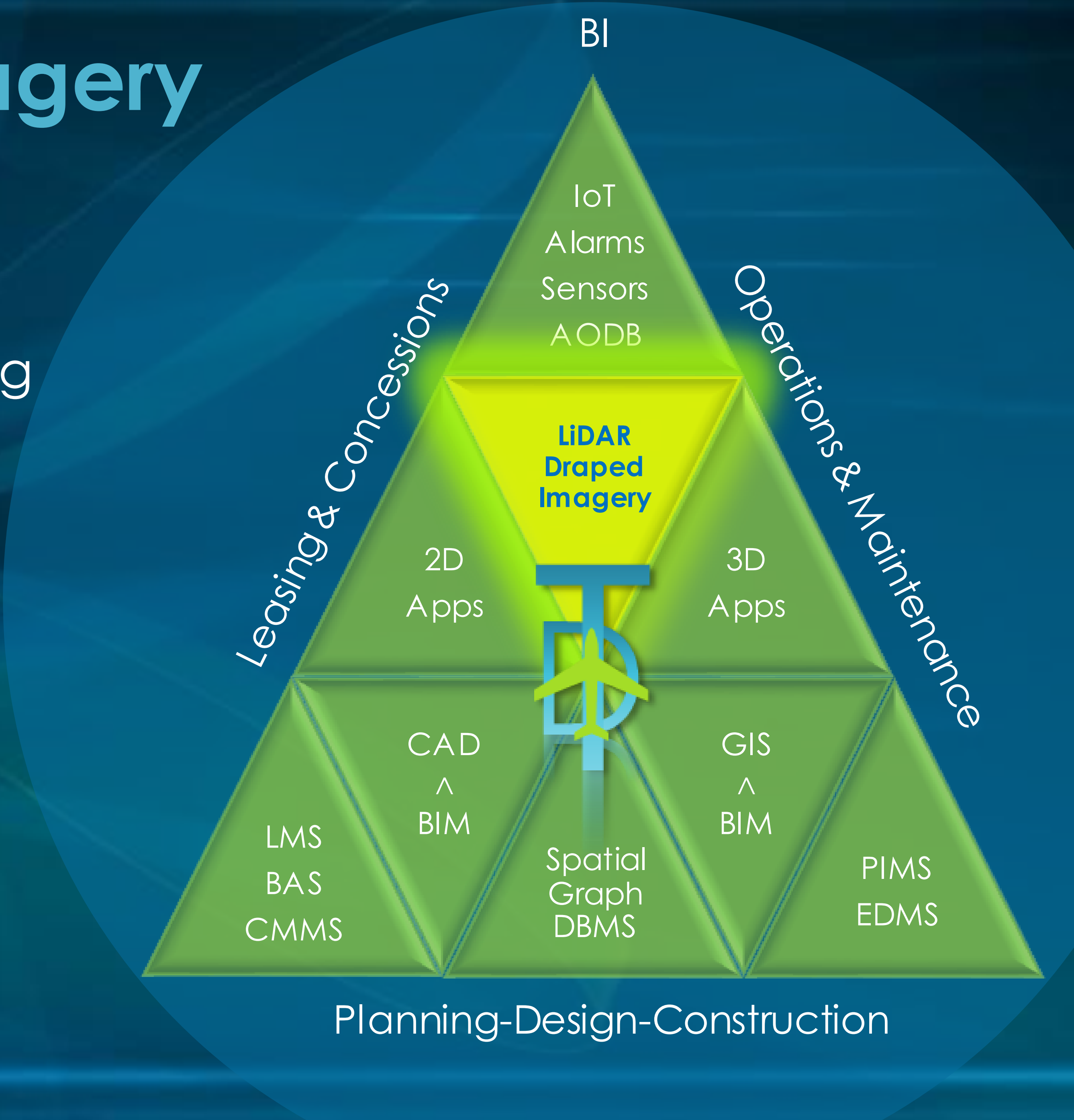
key

to achieving ARP-DT

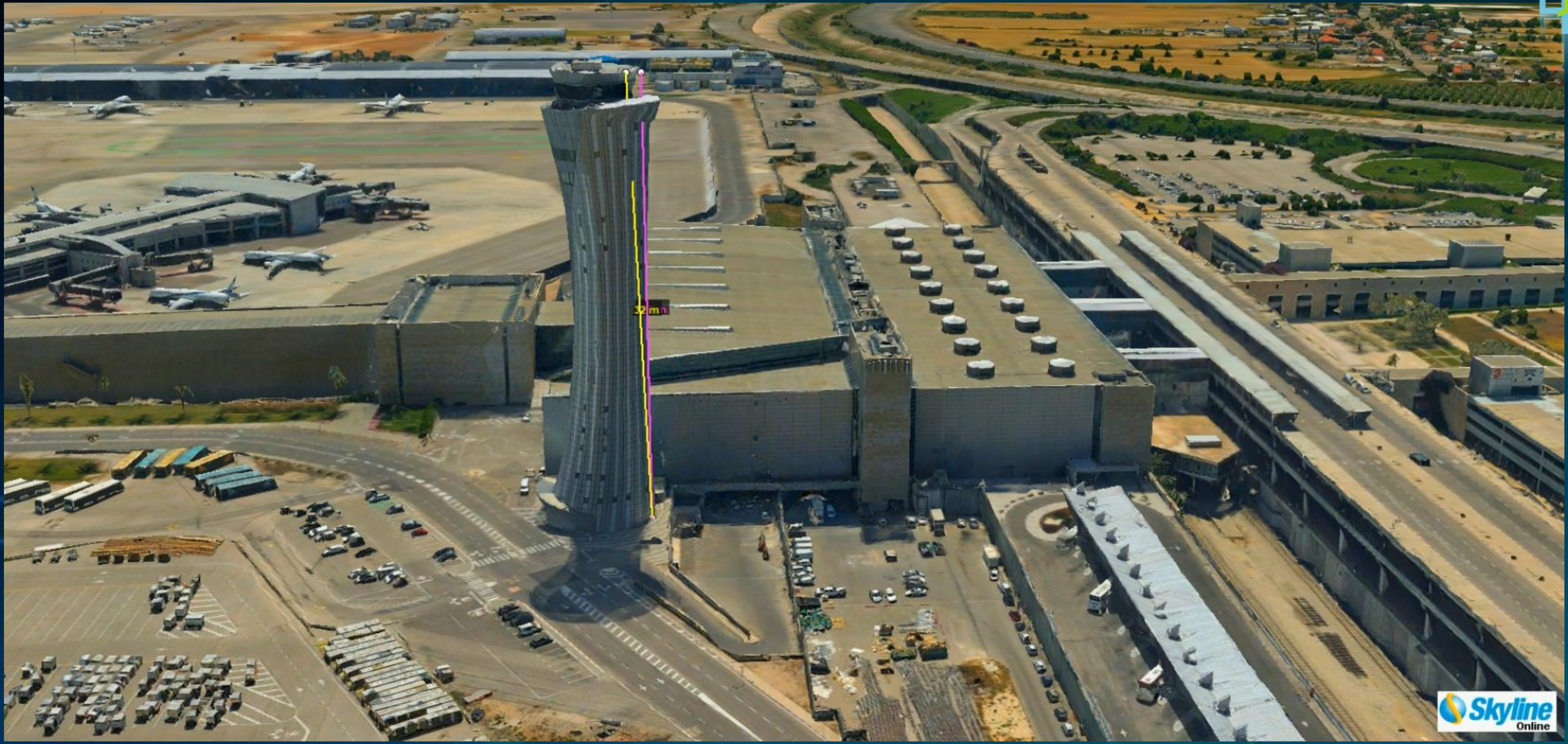


LiDAR with Draped Imagery

- Survey Automation Tools
- Ground Control Points (GCP)s
  Enable On-Going Updates Splicing
  - Outdoor
  - Indoor
- GIS Integration
  - 2D/3D Linked Views
  - 2D/3D Linked Assets
- 3D Measurement Tools
- Improved Situational Awareness



3D Aerial Imagery via LiDAR & PhotoMesh



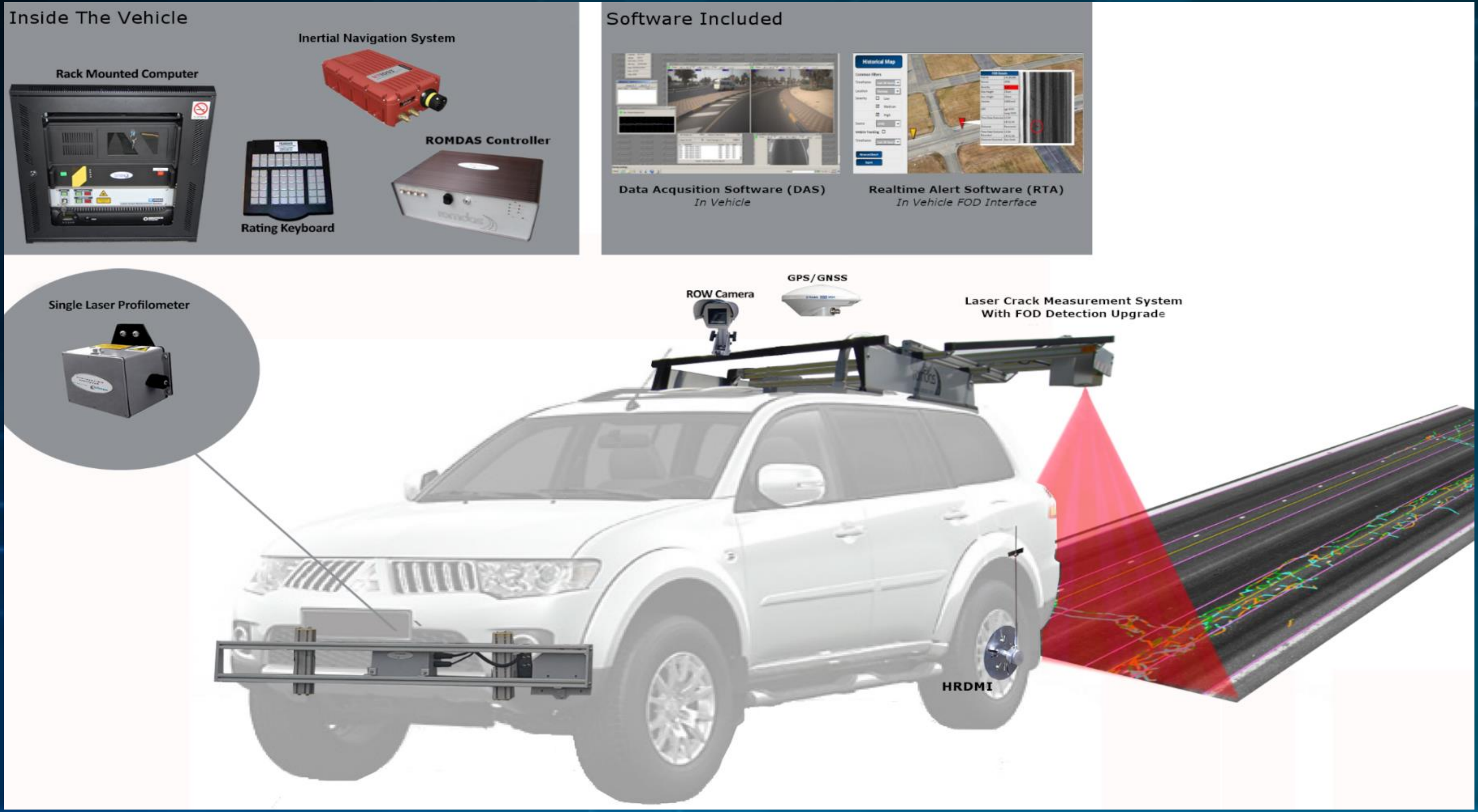
Courtesy of Skyline Software Systems

Airfield LiDAR with Imagery

Trimble. Applanix

Airfield LiDAR with Imagery

Trimble Applanix

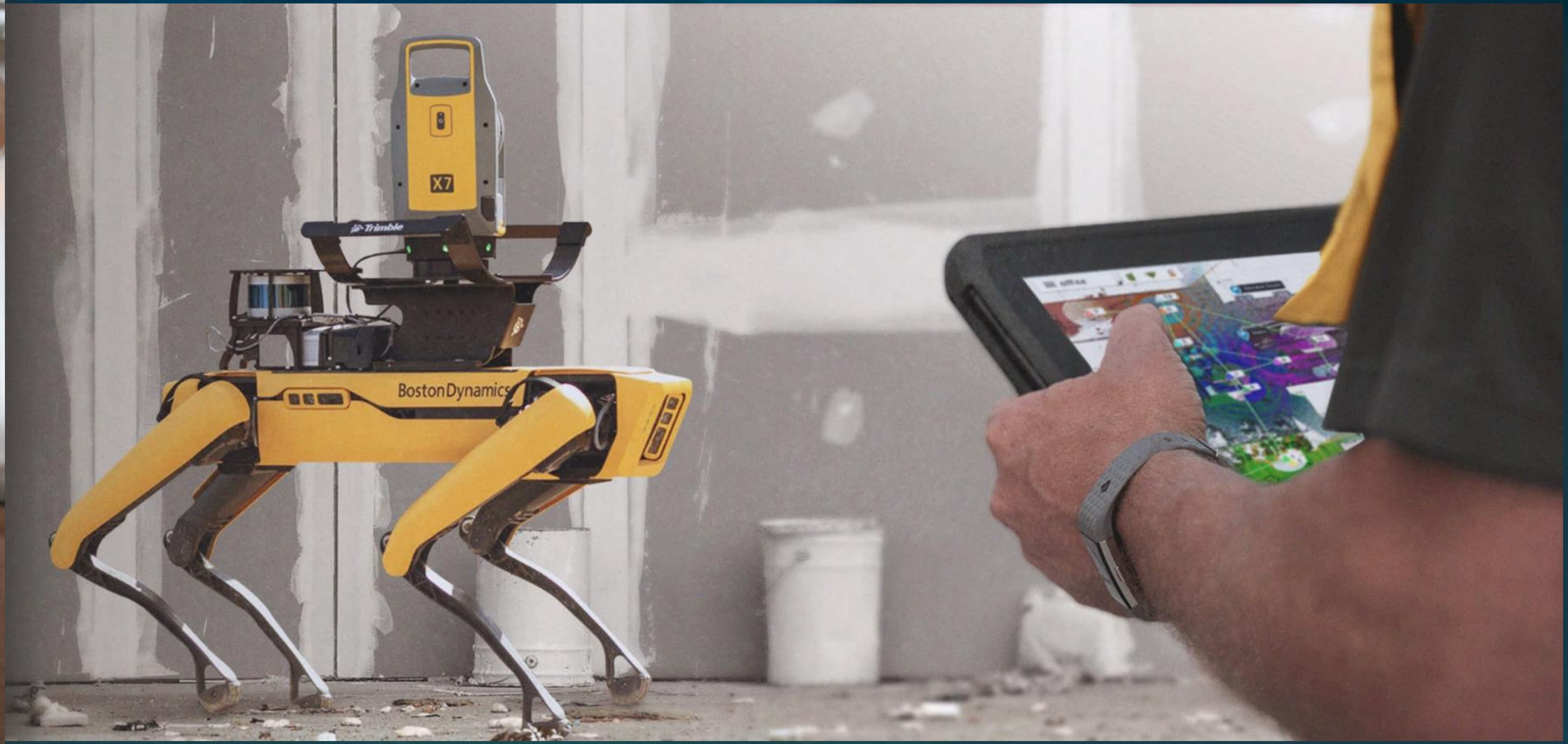


Airfield LiDAR with Imagery

Trimble. Applanix

Facility LiDAR with Imagery

Trimble. Applanix

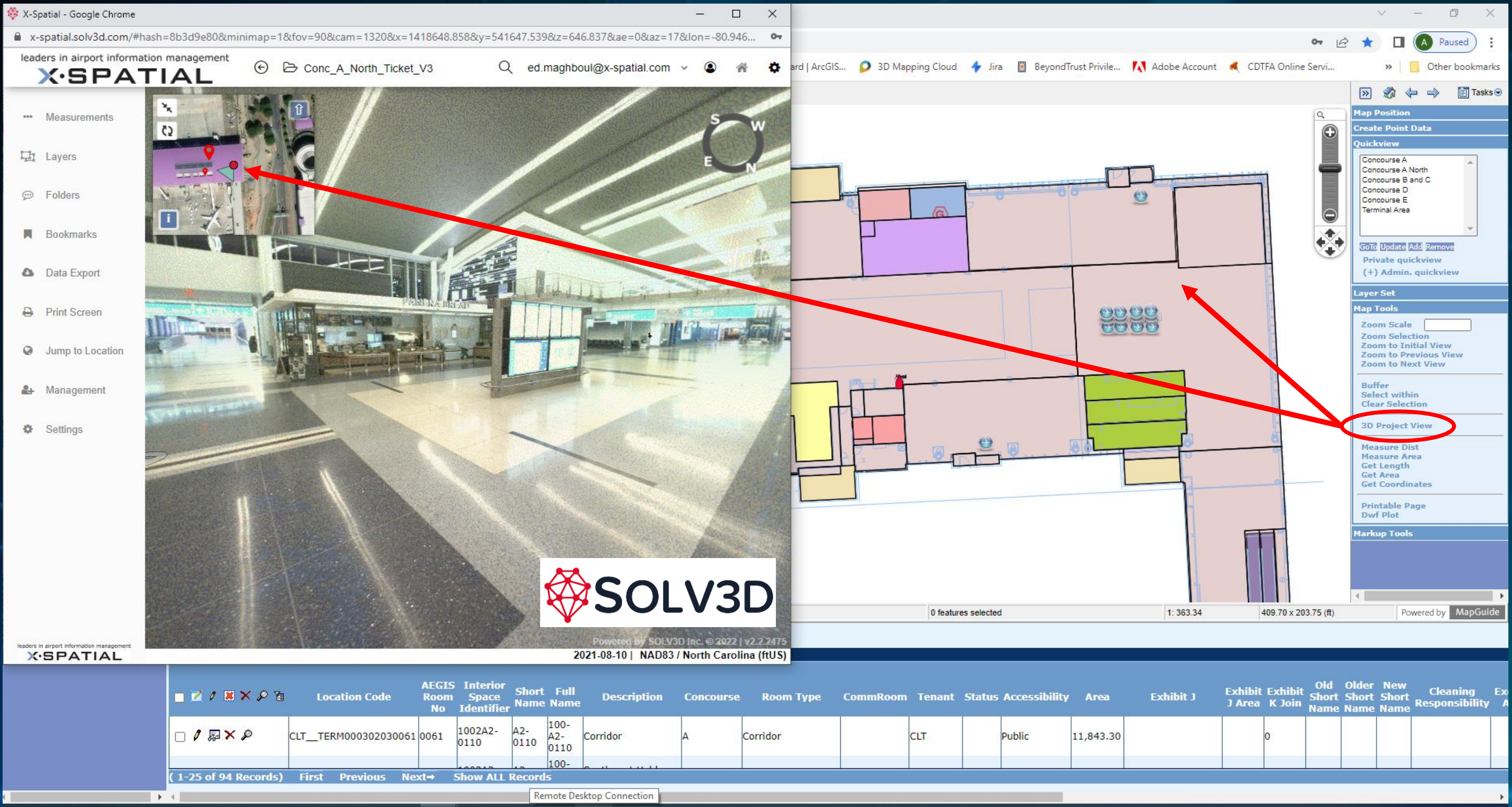


via Robotic Platforms

LiDAR with Imagery

Trimble Applanix X·SPATIAL

Integrated with GIS



Integrated with GIS

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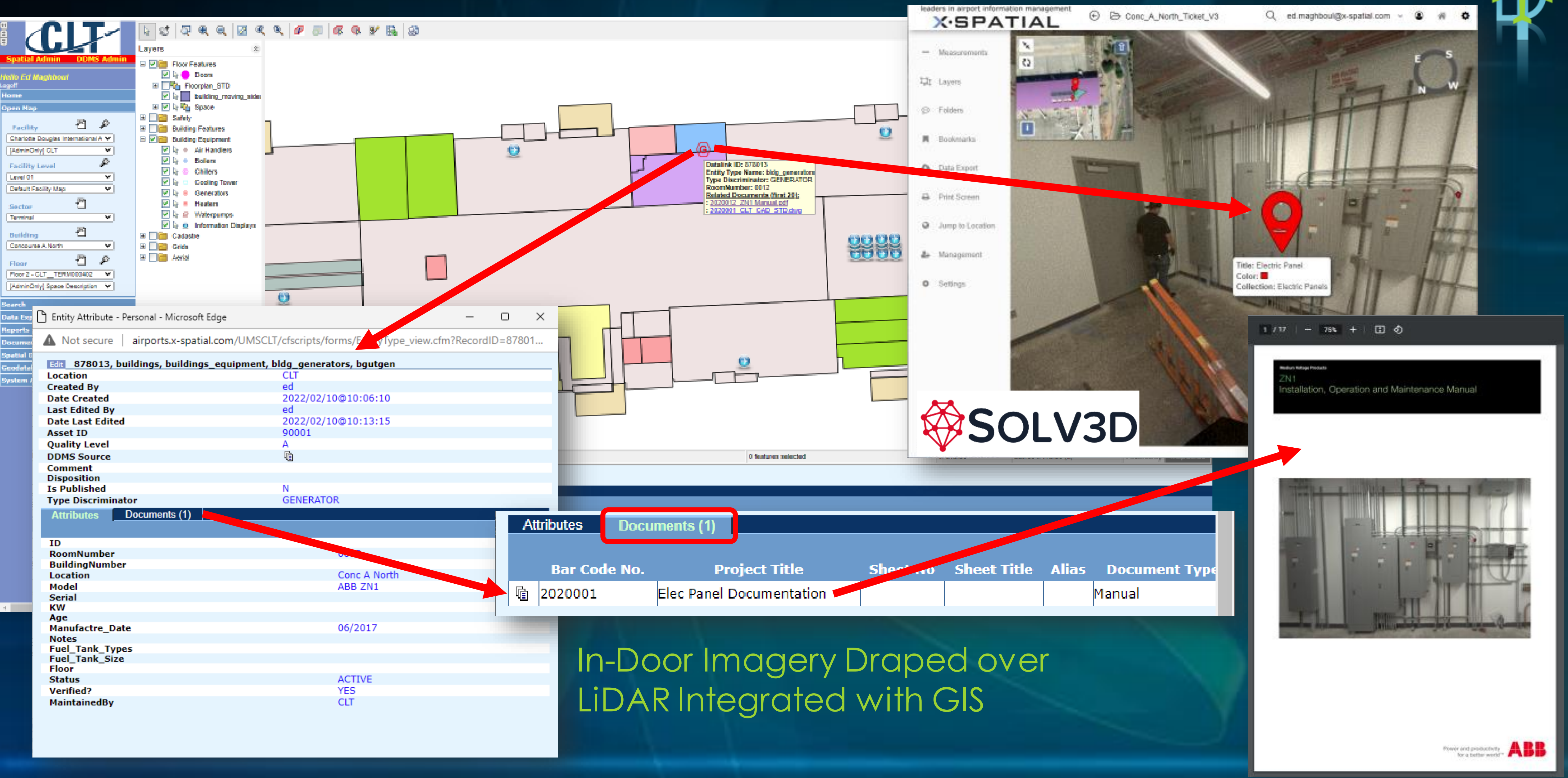

In-Door Imagery Draped over LiDAR Integrated with GIS

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Machine Vision Feature Extraction

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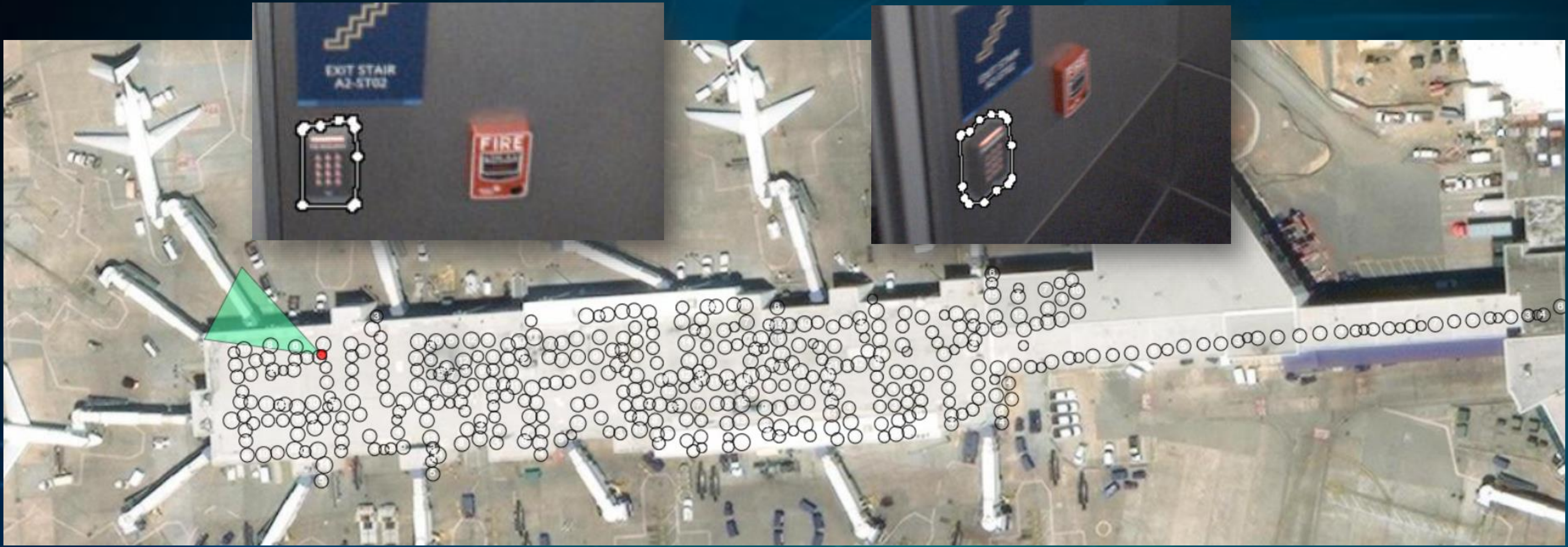
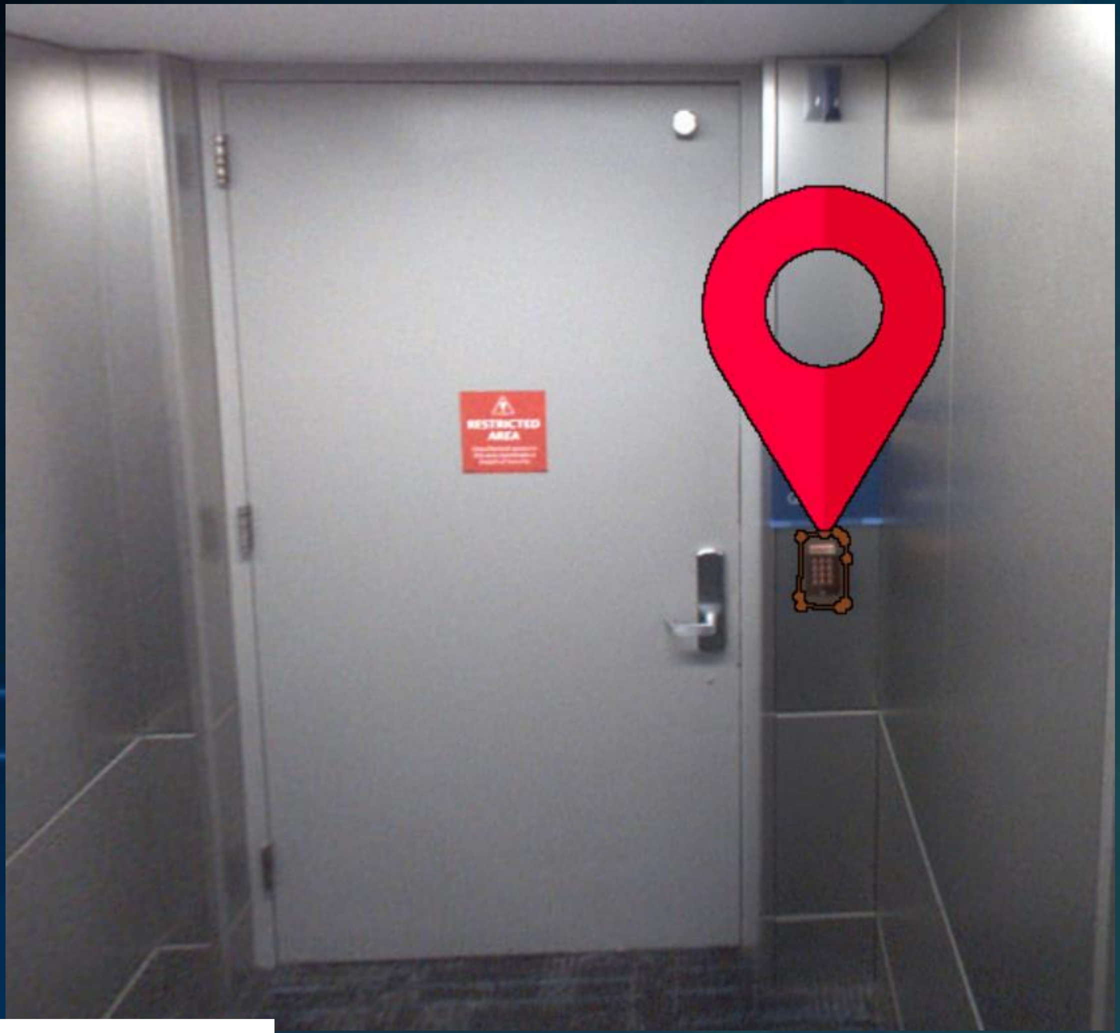


Leveraging LiDAR Draped Imagery from Across Terminal
for Feature Extraction (e.g., Badge Reader)
via Artificial Intelligence (AI) Machine Vision

SOLV3D

Machine Vision Feature Extraction

X·SPATIAL



SOLV3D

True Positive

False Positive

Machine Vision Feature Extraction

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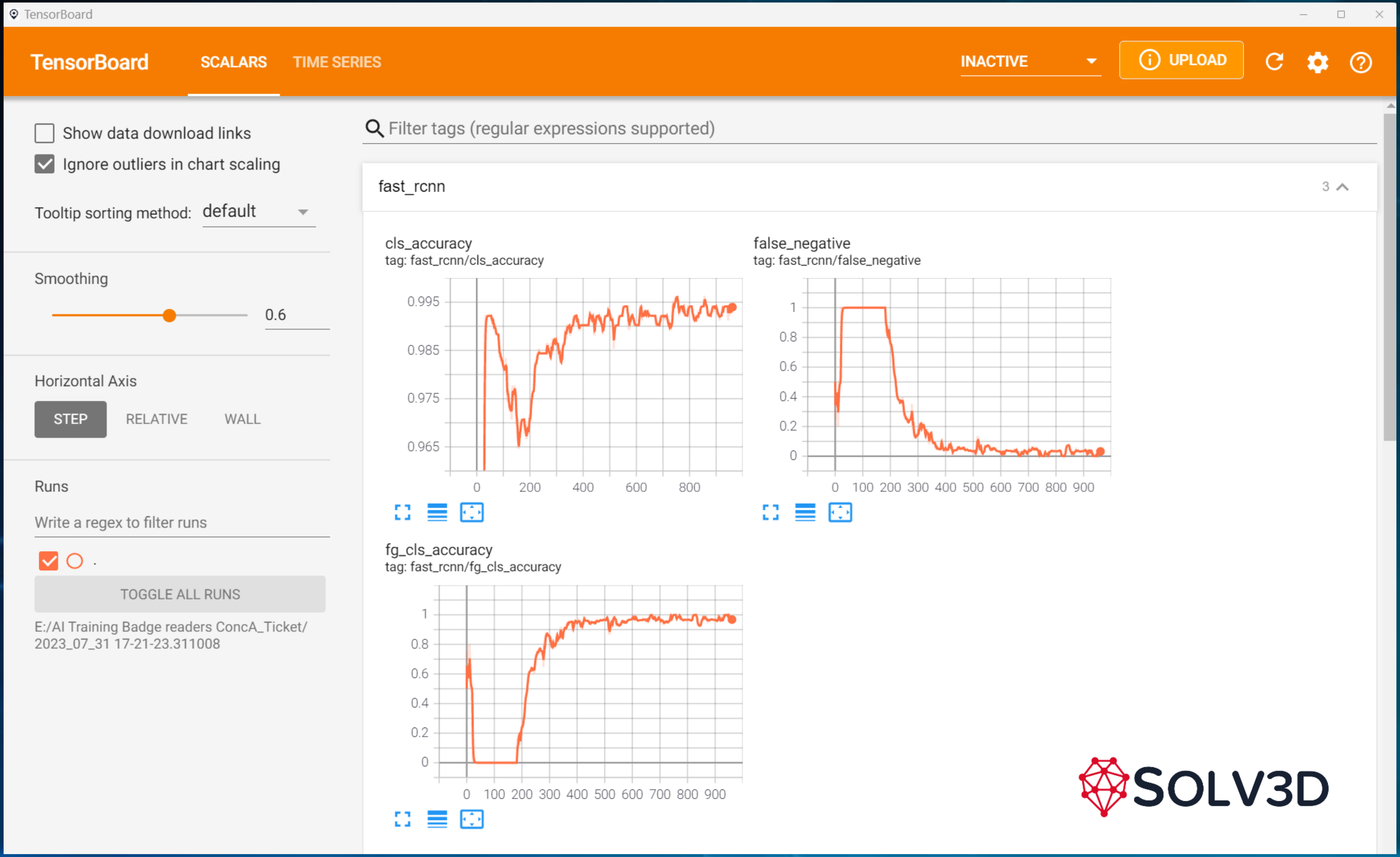

Machine Vision Learning Curves

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Machine Vision Feature Extraction

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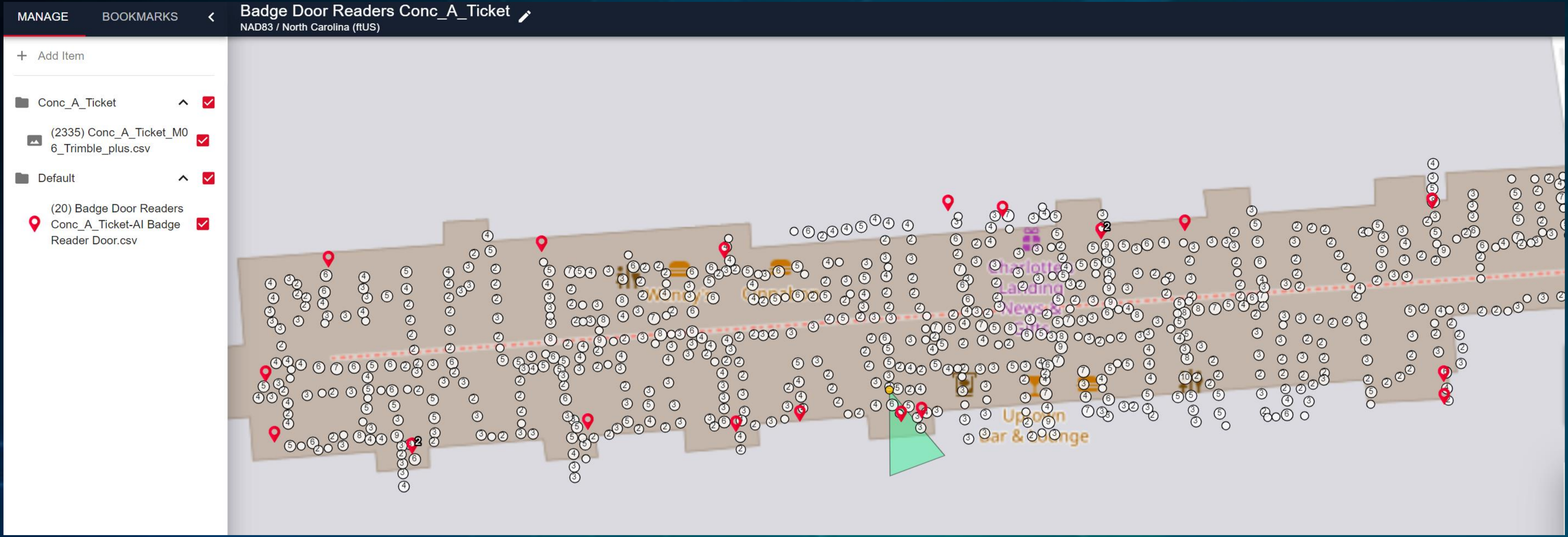


SOLV3D

Auto-Extracted Badge Readers with X-Y-Z Coordinates
via Artificial Intelligence (AI) Machine Vision

Best Practices for Capturing & Processing LiDAR with Draped Imagery to Sustain Airport Digital Twins

Reality Data Capture and Processing at Airports

X·SPATIAL   Trimble. Applanix   SOLV3D

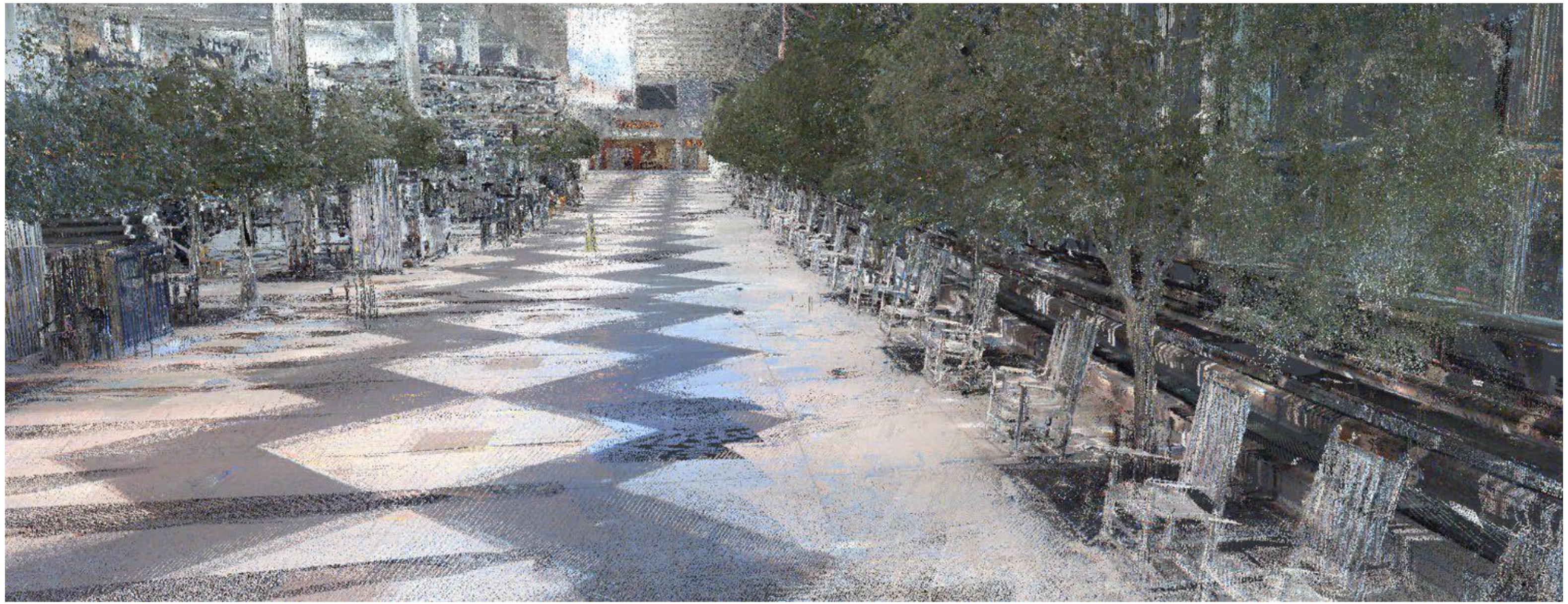
Airport Scanning

A Sustainable Approach for Comprehensive Reality Data Capture and Utilization

Create a sustainable, accurate, up-to-date 3D Master Model.

It is crucial to consider the following key factors:

- Scanner Selection
- Use of permanent Indoor Ground Control Points (IGCPs)
- Post Processing software of the scanned data
- Harmonizing software for optimizing the point cloud, format conversion, cleaning, and publishing
- Indoor scanning and Temporal indoor scanning Guidelines



Key Aspects of Your Reality Capture Project

- **Data Collection Method:**
  Select the appropriate data collection method (Trolley, backpack, handheld) and ensure accurate correlation to real-world coordinates for georeferencing.

- **Real-world Accuracy with Survey Control and Indoor Ground Points:**
  Ensuring Real-world accuracy throughout the airport for foundational and future Scanning missions with the Survey Control Network and Indoor Ground Control Points.

- **Post-Processing: Enhancing Data Accuracy and Alignment:**
  Ensures accurate data alignment from multiple missions, georeferencing, trajectory estimation, point cloud registration, quality control, and error correction for data accuracy.

- **Streamlined Data Integration and Workflows:**
  Assess seamless data integration from diverse sources, temporal changes, and platforms to streamline project workflows and publishing.

- **Standards and Guidelines:**
  Essential for creating a solid foundation for your scanning projects.

Choosing the Right Scanner and Inertial Measurement Unit (IMU) for Data Accuracy

Accurate Georeferencing for Every Point in a Master 3D Model

Selecting the Optimal IMU and Platform for a Highly Accurate Master 3D Model

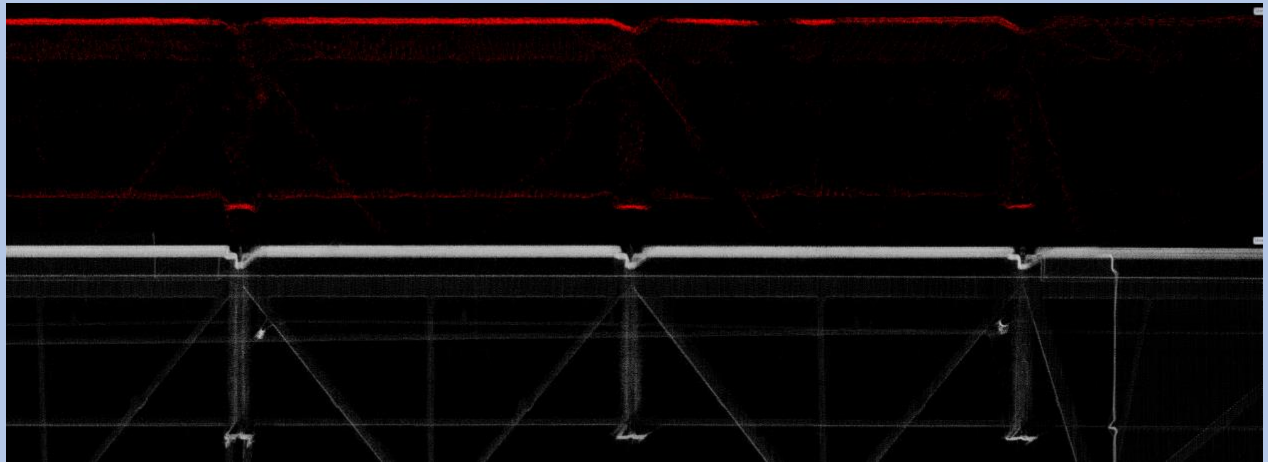
Mounting the IMU on a trolley ensures optimal performance and stability, particularly when comparing SBET and SLAM with varying IMU quality.

Enhanced Accuracy with SBET (Smoothed Best Estimated Trajectory):

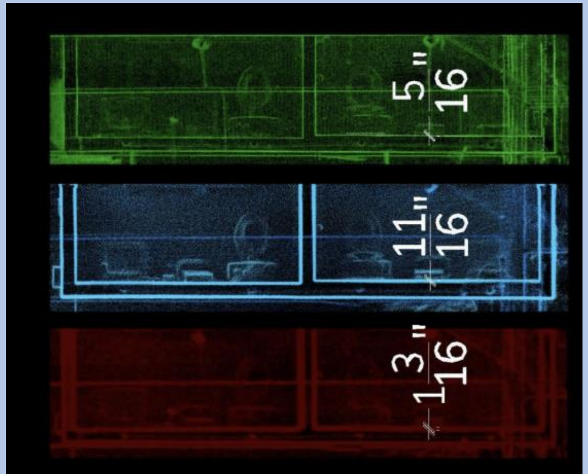
SBET, combined with a high-quality IMU, achieves exceptional georeferencing accuracy, closely aligning point cloud data with real-world coordinates, thereby reducing the need for extensive point cloud smoothing and preserving fine details and data quality.

Accuracy and Smoothing in SLAM (Simultaneous Localization and Mapping):

Lower-quality IMU integration, combined with SLAM, leads to reduced trajectory accuracy, necessitating extensive point cloud smoothing to compensate for errors, which, in turn, causes the loss of fine details and sharp features in the data.



Fine detail vs. smoothing



Scanner Selection: Trimble Indoor Mobile Mapping Solution (TIMMS)

Advantages of a Scanning Trolley-Based Scanning Technology

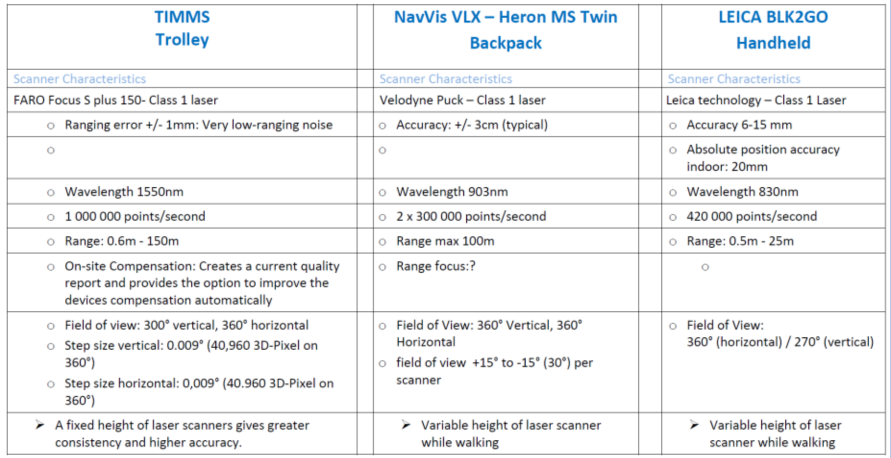
Higher Quality Equipment: The trolley accommodates advanced, higher-quality equipment for precise and detailed data capture.

Less Physical Strain: The trolley reduces operator fatigue by bearing the equipment's weight, allowing longer scanning sessions.

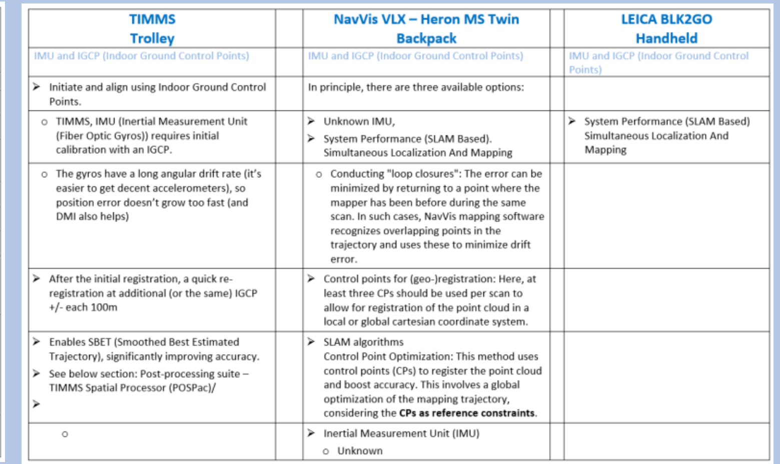
Stability: The trolley provides a stable platform, minimizing scan errors due to movement or vibration.

Consistency: Trolley systems maintain a consistent height and orientation, ensuring uniform scanning coverage and accuracy with easy operation.

TIMMS Trolley	NavVis VLX – Heron MS Twin Backpack	LEICA BLK2GO Handheld
TIMMS Sensors	NavVis Sensors	
➢ FARO Focus S plus 150	➢ Velodyne Lidar's Puck	➢ Leica Technology
➢ Ladybug-Spherical-Camera	➢ Unknown camera	➢ Leica High-Resolution Camera
➢ Initiate and align using Indoor Ground Control Points.	➢ Initiate and align using Indoor Ground Control Points.	➢ No IGCP used
➢ IMU (Inertial Measurement Unit (Fiber Optic Gyros))	➢ Unknown type of IMU model	➢ Unknown type of IMU model



TIMMS Trolley	NavVis VLX – Heron MS Twin Backpack	LEICA BLK2GO Handheld
Scanner Characteristics	Scanner Characteristics	Scanner Characteristics
FARO Focus S plus 150- Class 1 laser	Velodyne Puck – Class 1 laser	Leica technology – Class 1 Laser
○ Ranging error +/- 1mm: Very low-ranging noise	○ Accuracy: +/- 3cm (typical)	○ Accuracy 6-15 mm
○	○	○ Absolute position accuracy indoor: 20mm
○ Wavelength 1550nm	○ Wavelength 903nm	○ Wavelength 830nm
○ 1 000 000 points/second	○ 2 x 300 000 points/second	○ 420 000 points/second
○ Range: 0.6m - 150m	○ Range max 100m	○ Range: 0.5m - 25m
○ On-site Compensation: Creates a current quality report and provides the option to improve the devices compensation automatically	○ Range focus:?	○
○ Field of view: 300° vertical, 360° horizontal ○ Step size vertical: 0.009° (40,960 3D-Pixel on 360°) ○ Step size horizontal: 0,009° (40.960 3D-Pixel on 360°)	○ Field of View: 360° Vertical, 360° Horizontal ○ field of view +15° to -15° (30°) per scanner	○ Field of View: 360° (horizontal) / 270° (vertical)
➢ A fixed height of laser scanners gives greater consistency and higher accuracy.	➢ Variable height of laser scanner while walking	➢ Variable height of laser scanner while walking



TIMMS Trolley	NavVis VLX – Heron MS Twin Backpack	LEICA BLK2GO Handheld
IMU and IGCP (Indoor Ground Control Points)	IMU and IGCP (Indoor Ground Control Points)	IMU and IGCP (Indoor Ground Control Points)
➢ Initiate and align using Indoor Ground Control Points.	In principle, there are three available options:	
○ TIMMS, IMU (Inertial Measurement Unit (Fiber Optic Gyros)) requires initial calibration with an IGCP.	➢ Unknown IMU, ➢ System Performance (SLAM Based). Simultaneous Localization And Mapping	➢ System Performance (SLAM Based) Simultaneous Localization And Mapping
○ The gyros have a long angular drift rate (it's easier to get decent accelerometers), so position error doesn't grow too fast (and DMI also helps)	○ Conducting "loop closures": The error can be minimized by returning to a point where the mapper has been before during the same scan. In such cases, NavVis mapping software recognizes overlapping points in the trajectory and uses these to minimize drift error.	
➢ After the initial registration, a quick re-registration at additional (or the same) IGCP +/- each 100m	➢ Control points for (geo-)registration: Here, at least three CPs should be used per scan to allow for registration of the point cloud in a local or global cartesian coordinate system.	
➢ Enables SBET (Smoothed Best Estimated Trajectory), significantly improving accuracy. ➢ See below section: Post-processing suite – TIMMS Spatial Processor (POSPac)/ ➢	➢ SLAM algorithms Control Point Optimization: This method uses control points (CPs) to register the point cloud and boost accuracy. This involves a global optimization of the mapping trajectory, considering the **CPs as reference constraints**.	
○	➢ Inertial Measurement Unit (IMU) ○ Unknown	

Indoor Ground Control Points

Survey Control Network

CLT's Control survey network establishes a common, consistent network of physical monuments that are the basis for CLT's horizontal and vertical location.

Indoor-Ground-Control-Points (IGCP)

- CLT Terminals and Buildings are environments where the accuracy, integrity, continuity, and consequent suitable availability of GNSS signals cannot be assured.
- Supplemental Indoor-Ground-Control-Points are densification or extension of the survey control network required for future scanning projects.

CLT Project

- 20 permanent Survey Control Points (CDIA CAP) on the ramp level, around the perimeters of the buildings.
- 74 permanent IGCPs on the ramp level inside/outside the buildings.
- 276 (temporary) IGCPs on all other levels inside the buildings.
- The color-coded tags for IGCPs did not distinguish between those required for current and future scanning projects and the temporary line-of-sight IGCPs

Name 263
Concourse EXTERIOR TERMINAL BAGGAGE
Level RAMP
Description PK NAIL SET IN CONCRETE @ DOOR TO M1-0210

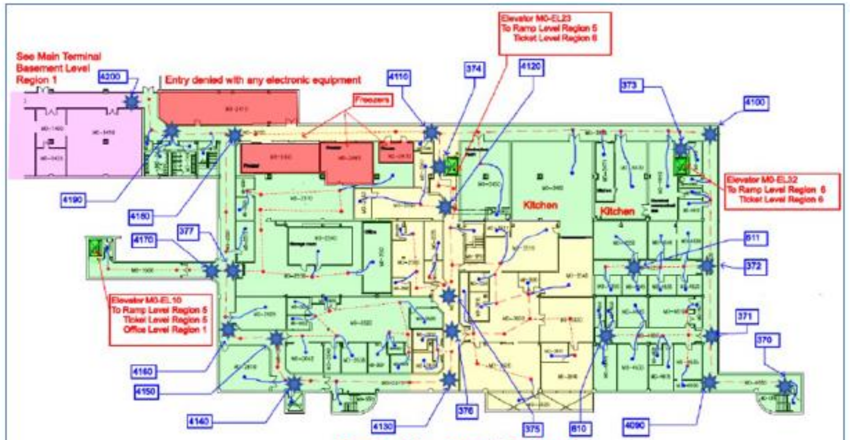
wood.

NC State Plane 1983
Northing 540785.02
Easting 1419119.00
Elevation 729.48

WGS 1984
Longitude 80° 56' 42.3314" W
Latitude 35° 13' 12.9543" N
Ellipsoid H 623.13

NAME	LATITUDE	LONGITUDE	Altitude	SD LAT	SD LONG	SD ALT	Building	Floor	Region	Marker
259	1,522,041,044	-8,094,534,287	1,901,008,484	0.02	0.02	0.02	Terminal	Ramp	5	PK NAIL SET IN CONCRETE
263	1,522,026,510	-8,094,509,205	1,899,310	0.02	0.02	0.02	Terminal	Ramp	5	PK NAIL SET IN CONCRETE
264	1,522,010,023	-8,094,486,418	1,898,526,088	0.02	0.02	0.02	Terminal	Ramp	5	PK NAIL SET IN CONCRETE
265	1,521,997,874	-8,094,510,121	1,898,994,361	0.02	0.02	0.02	Concourse B	Ramp	1	PK NAIL SET IN CONCRETE
266	1,521,928,509	-8,094,503,909	189,924,826	0.02	0.02	0.02	Concourse B	Ramp	2	PK NAIL SET IN CONCRETE
267	1,521,950,831	-8,094,523,309	189,890,475	0.02	0.02	0.02	Concourse B	Ramp	1	PK NAIL SET IN CONCRETE
268	1,521,964,539	-8,094,496,604	1,899,493,625	0.02	0.02	0.02	Concourse B	Ramp	1	PK NAIL SET IN CONCRETE
269	1,521,916,157	-8,094,508,384	1,895,158,039	0.02	0.02	0.02	Concourse B	Ramp	2	PK NAIL SET IN CONCRETE
271	1,521,919,509	-8,094,530,035	1,898,874,879	0.02	0.02	0.02	Concourse B	Ramp	2	PK NAIL SET IN CONCRETE
272	1,521,902,572	-8,094,509,214	1,899,208,636	0.02	0.02	0.02	Concourse B	Ramp	2	PK NAIL SET IN CONCRETE
273	1,521,890,669	-8,094,511,101	189,904,252	0.02	0.02	0.02	Concourse B	Ramp	3	PK NAIL SET IN CONCRETE
275	1,521,865,633	-8,094,545,329	1,908,054,864	0.02	0.02	0.02	Concourse B	Ramp	3	PK NAIL SET IN CONCRETE
277	1,521,830,998	-8,094,549,309	1,898,842,288	0.02	0.02	0.02	Concourse B	Ramp	4	PK NAIL SET IN CONCRETE
278	1,521,837,984	-8,094,507,941	1,898,838,608	0.02	0.02	0.02	Concourse B	Ramp	4	PK NAIL SET IN CONCRETE
279	1,521,817,671	-8,094,557,789	1,898,882,499	0.02	0.02	0.02	Concourse B	Ramp	4	PK NAIL SET IN CONCRETE
280	1,521,811,318	-8,094,513,608	1,898,771,857	0.02	0.02	0.02	Concourse B	Ramp	4	PK NAIL SET IN CONCRETE
281	1,521,793,257	-8,094,517,248	1,898,643,974	0.02	0.02	0.02	Concourse B	Ramp	4	PK NAIL SET IN CONCRETE
282	1,521,800,913	-8,094,501,017	1,898,857,201	0.02	0.02	0.02	Concourse B	Ramp	4	PK NAIL SET IN CONCRETE
286	1,522,022,755	-8,094,336,947	1,899,261,367	0.02	0.02	0.02	Terminal	Ramp	6	PK NAIL SET IN CONCRETE
289	1,522,034,969	-8,094,254,005	1,898,741,682	0.02	0.02	0.02	Terminal	Ramp	6	PK NAIL SET IN CONCRETE
290	1,522,014,352	-8,094,278,856	1,897,898,298	0.02	0.02	0.02	Terminal	Ramp	6	PK NAIL SET IN CONCRETE
291	1,522,027,136	-8,094,303,940	1,898,846,838	0.02	0.02	0.02	Terminal	Ramp	6	PK NAIL SET IN CONCRETE
292	1,521,994,686	-8,094,303,082	189,881,331	0.02	0.02	0.02	Terminal	Ramp	6	PK NAIL SET IN CONCRETE
293	1,522,001,748	-8,094,276,576	1,898,342,698	0.02	0.02	0.02	Terminal	Ramp	6	PK NAIL SET IN CONCRETE
295	1,521,960,375	-8,094,264,388	1,899,327,813	0.02	0.02	0.02	Concourse C	Ramp	1	PK NAIL SET IN CONCRETE
296	1,521,947,413	-8,094,256,903	189,877,399	0.02	0.02	0.02	Concourse C	Ramp	1	PK NAIL SET IN CONCRETE
297	1,521,927,551	-8,094,249,977	1,898,809,347	0.02	0.02	0.02	Concourse C	Ramp	2	PK NAIL SET IN CONCRETE

PK Nail set in concrete



Terminal Basement: Region 2

Post-Processing: Enhancing Data Accuracy and Alignment:

POSPac® Mobile Mapping Suite

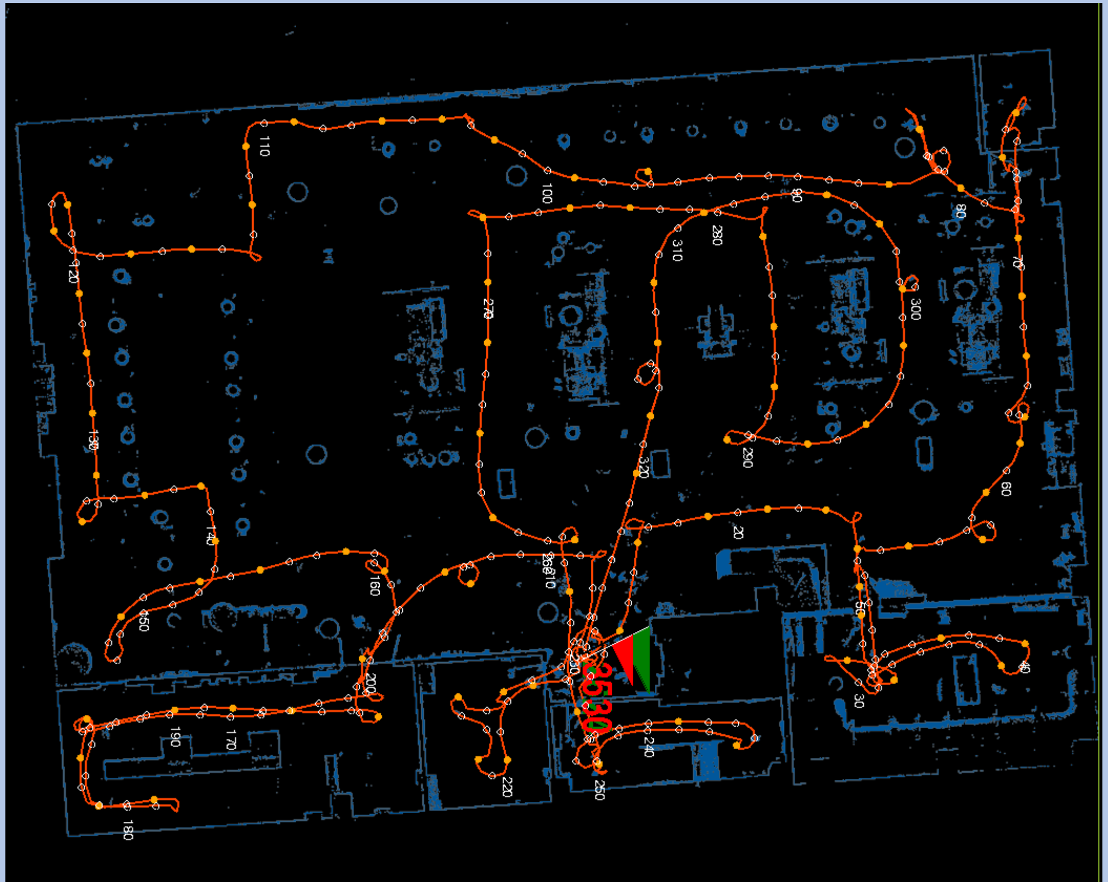
Data Alignment and Calibration:
Synchronizes and correctly orientates data from multiple missions for accurate alignment.

Georeferencing and Trajectory Estimation:
Computes the accurate trajectory of the TIMMS Trolley, creating an SBET (Smoothed Best Estimated Traject) for mapping to real-world coordinates.

Point Cloud Registration:
Aligns and combines individual point clouds into a seamless, georeferenced 3D model.

Quality Control:
Identifies data errors and discrepancies to ensure data quality.

Error Correction:
Corrects errors in the data, such as sensor drift or misalignments, using Indoor Ground Control Points.



Harmonization Software

Optimizing the point cloud, format conversion, cleaning, Integration, and publishing
Solv3D Engine

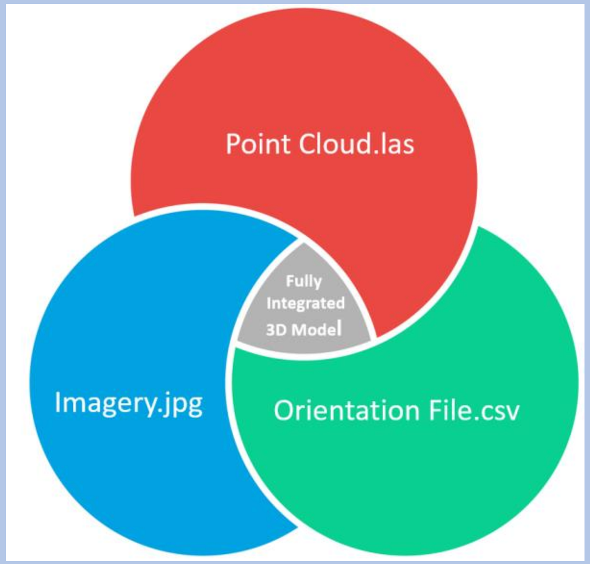
Flexibility: Easily adapt to evolving scanning technologies and equipment.

Future-Proofing: Stay prepared for emerging standards and innovations in scanning.

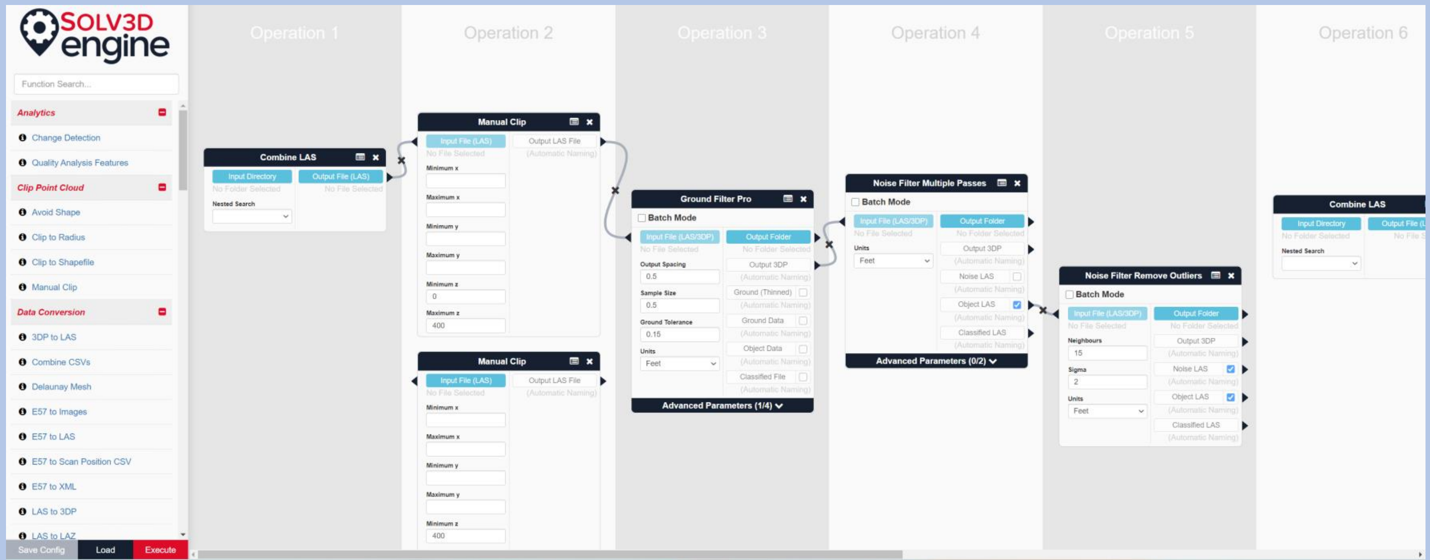
Efficiency: Streamline data processing and reduce costs.

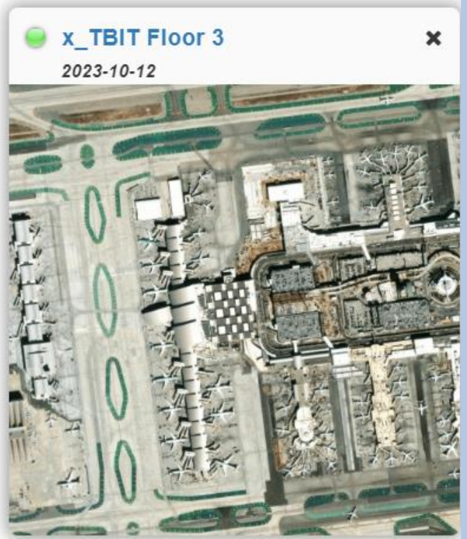
Accuracy: Ensure precise alignment and consistency in data.

Data Integration: Seamlessly combine data from different scanning methods.



Integration of Point Cloud, Imagery, and Orientation Files





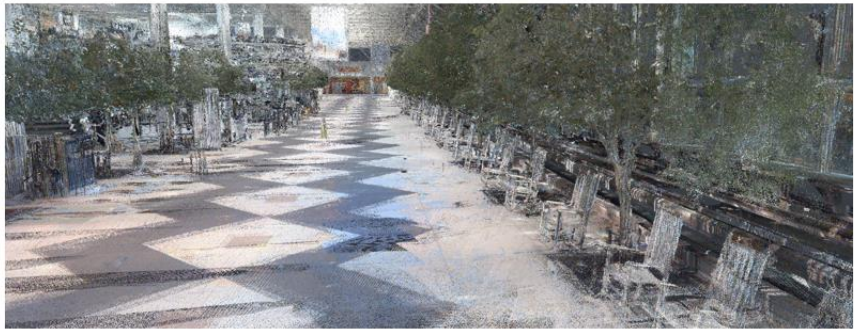
Standards and Guidelines

Construction and surveying standards, including Caltrans, CAD, BIM, and GIS, are universally recognized and used to ensure consistency and interoperability.

Outdoor Mobile and Static terrestrial laser scanning (MTLS) combines LiDAR technology with Global Navigation Satellite Systems (GNSS) and is covered in the Caltrans standards.

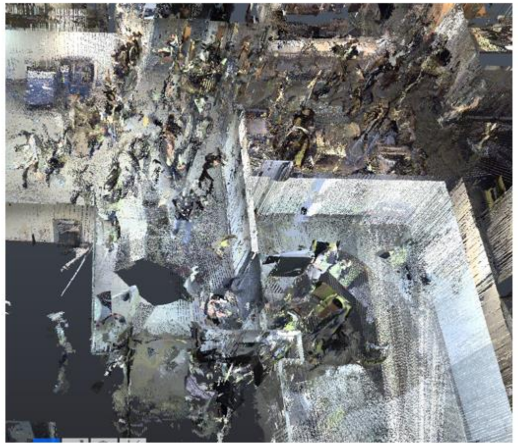
Indoor LiDAR scanning There are **no National or International standards or well-established guidelines** for indoor LiDAR and photogrammetry data collection or derived end products.

Guideline to Indoor Ground Control Points, Mobile Indoor Laser Scanning and 360° Imagery at Charlotte Douglas International Airport (CLT)



Maximizing Data Quality and Efficiency for Indoor Scanning at CLT

Scanning Survey at CLT Review and Lessons Learned



Optimizing Data Capture and Efficiency for Future Projects

Temporal Scanning Guidelines Maintaining CLT's Master Point Cloud Model in a Dynamic Airport Environment

A Comprehensive Guide to Efficient Data Capture, Processing, and Publication in CLT's Ever-Changing Terminal and Concourses

Initial Scanning Missions

Laying the foundations for all future reality capture scans

An Overview of Initial Reality Capture Missions for CLT:

- Terminal and five Concourses Covered
- Conducted 16 Scanning Missions
- Processed 299 1cm Color LAS Files
- Completed 1.8 Million SQFT Scanned in Just 7 Days
- Delivered a Total of 5.16 TB of Data (Including LiDAR and 360-degree Images)
- Captured a Collection of 67,000 High-Quality 360-degree Images
- Generated 17 comprehensive CAD Floor Plans

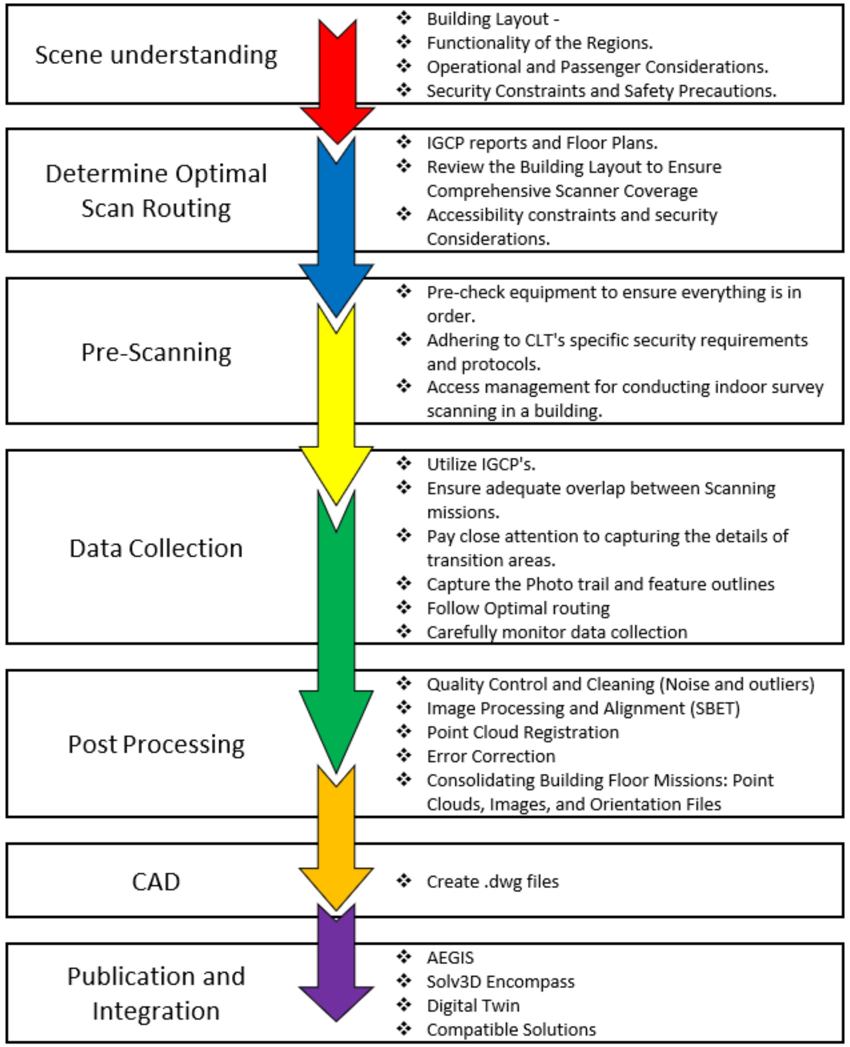
Mission Planning

A Comprehensive Approach

Mission planning follows the framework outlined in CLT's Indoor Scanning Guidelines.

Due to the Terminal and Concourse size and complexity, we subdivided the optimal scanning routes into levels and regions.

Additional planning considerations involved flight operations, accessibility challenges such as out-of-service elevators, and the escort requirements for secure areas.

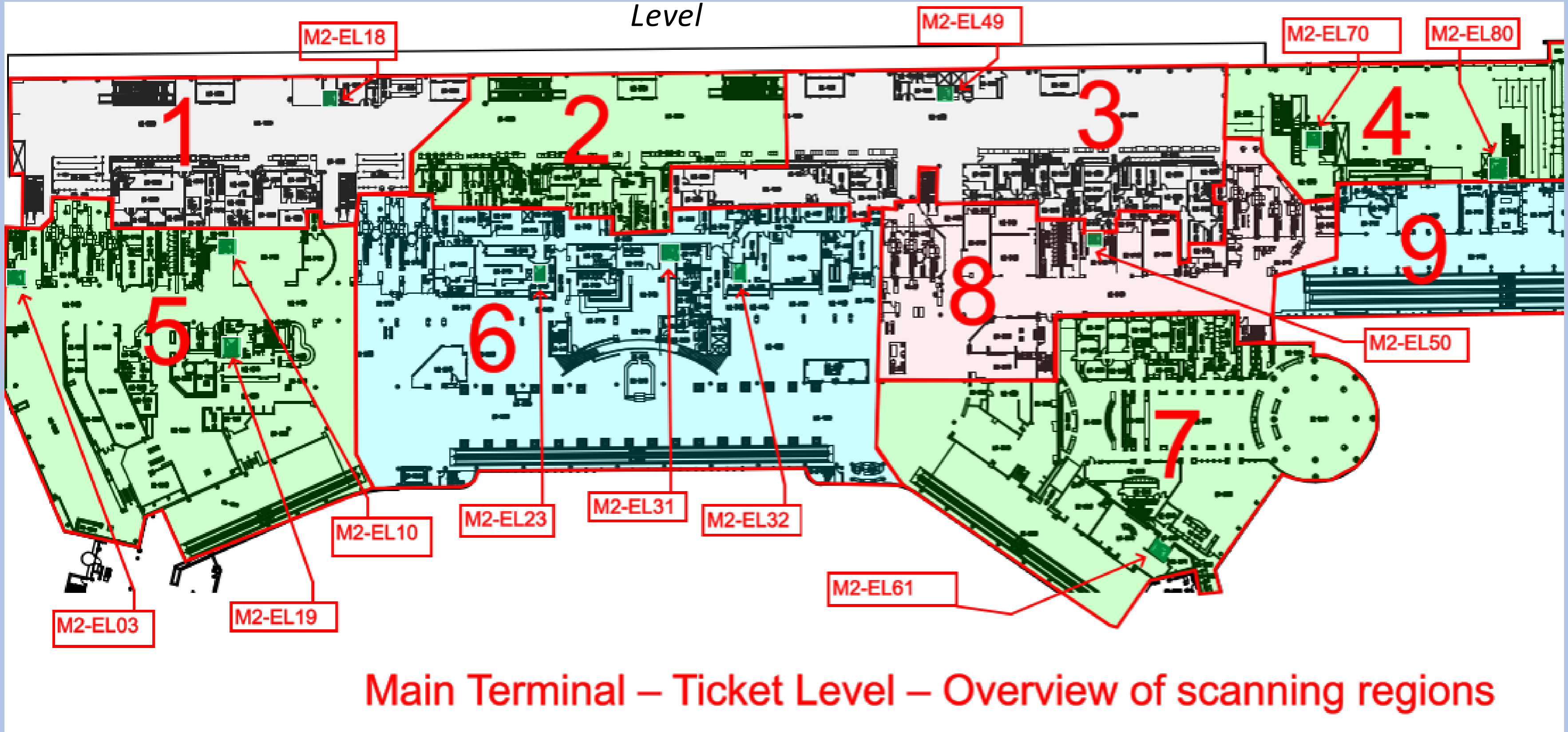


Mission Planning and Execution

Scene Understanding: Building Floor-Delineated Regions.

Strategic Scanning Regions: Regions are designed considering IGCP placements, accessibility constraints, and security factors, shaping the composition of each scanning mission, which consists of several regions.

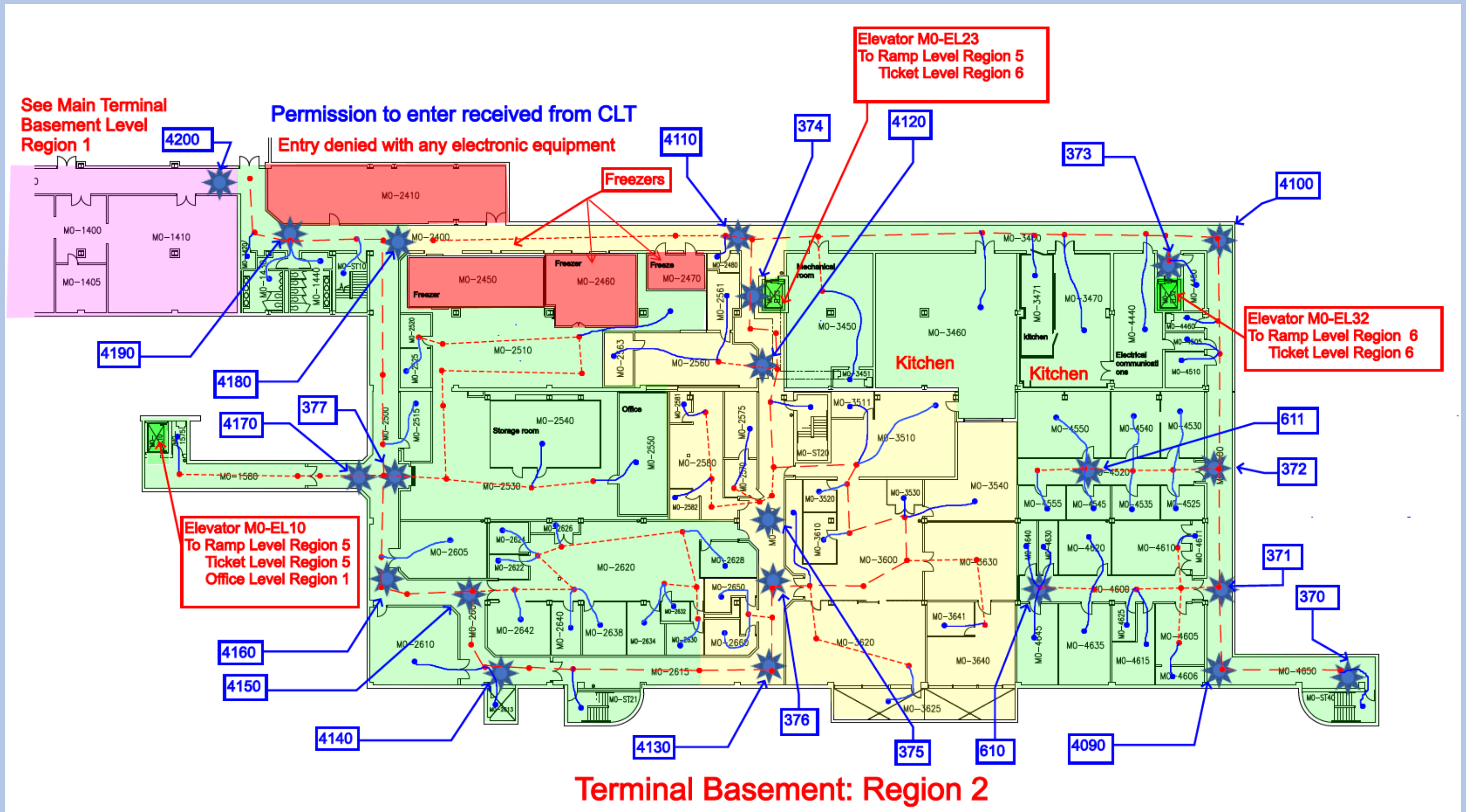
Overview of Scanning regions: Main Terminal - Ticket Level



Optimal Scanning Routes:

- Optimal scanning routes are determined primarily by the interconnection of spaces and the most efficient pathways.
- Color coding the area improves the visualization of the scanning trolley's route.
- The number of IGCPs in the basement exceeds what's necessary for the scanning trolley but is crucial for establishing the required IGCPs by providing line-of-sight points.

Terminal Basement Level Region 2



Mission Planning: Schedule, Communication, and Aircraft Operations

- We created a comprehensive scanning schedule based on region size (ft^2) and the room count in each level and region.
- We generated a report to inform the scanning crew of issues requiring attention and areas to avoid.
- Aircraft operations per concourse played a significant role in mission planning, aimed at minimizing passenger disruptions, ensuring data quality, and reducing LiDAR data post-processing.

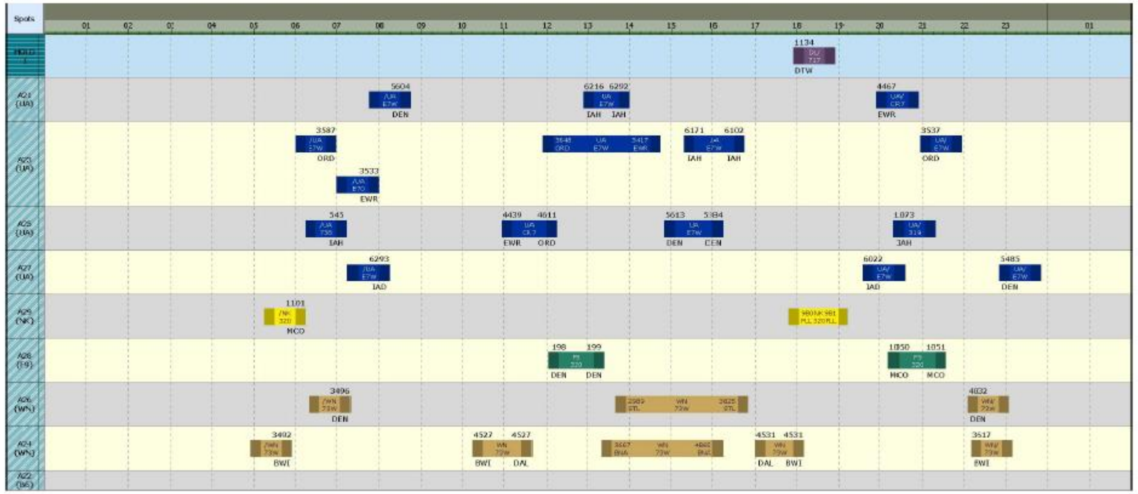
Scanning planning

Building	Level	Region	Area	Rooms	Estimated Time Required	Sunday (18-19, 19-20, 20-21, 21-22, 22-23, 23-24, 24-01, 01-02, 02-03, 03-04, 04-05, 05-06)	Monday (18-19, 19-20, 20-21, 21-22, 22-23, 23-24, 24-01, 01-02, 02-03, 03-04, 04-05, 05-06)
					30,000 ft²	9,854 ft²	0 ft²
Terminal	Basement	Region 1 Region 2	65,013 ft²	130	2.17		
		Region 3	9,854 ft²	6	0.33	Together with Ticket region 4 9,854 ft²	
	Ramp	Region 1 Region 2 Region 3 Region 4 Region 5 Region 6	278,541 ft²	249	8.75	Region 4: Part of FIS renovation project: 16,055 ft²	After 01:00 262,486 ft 249 rooms
	Ticket	Region 1 Region 2 Region 3 Region 4 Region 5 Region 6 Region 7 Region 8 Region 9	288,627 ft²	501	9.62	After 21:00 288 627 ft² 601 rooms	
	Office	Region 1 Region 2 Region 3 Region 4	60,000 ft²	268	2.47		After 19:00 60,000ft² 268 rooms
		Region 5	14,000 ft²				

A standard report on scanning challenges for a building/level/region.

Building	Level	Region	Scanning times	Comments	Comments
Terminal	Office	Region 1	After 19:00	Includes a Mechanical room, roof access only: out-of-scope	ELEV. M3-EL10 inactive last visit
		Region 2			ELEV. M3-EL31 is out-of-service
		Region 3		Includes a Mechanical room, roof access only: out-of-scope	
		Region 4		Mechanical rooms, roof access only: out-of-scope	
		Region 5		TSA Offices – Access via Elevator M2-EL80 on ticket level	Escort required for TSA offices
	Tower 01	Region 1	N/A	No access Covid 19 restrictions	
		Region 2	N/A	Mechanical room, roof access only: out-of-scope	
	Tower 02	Region 1	N/A	No access Covid 19 restrictions	

Aircraft Operations: day-overview Concourse A



Data Collection

Scanning across diverse functional zones.

CLT Data Capture involved completing 16 missions, each with designated scanning routes.

Scanner Initialization for Airport Data Capture

Trimble Indoor Mobile Mapping Solution (TIMMS)

The wheels of the TIMMS Trolley are also crucial.

Precision Movement: The wheels enable the scanning cart to move precisely along its intended path.

Data Consistency: Consistency in wheel movement helps maintain a uniform scanning pattern.

Data Quality: The quality of the scanning data, including point clouds and imagery, depends on the stability and smoothness of the cart's movement.

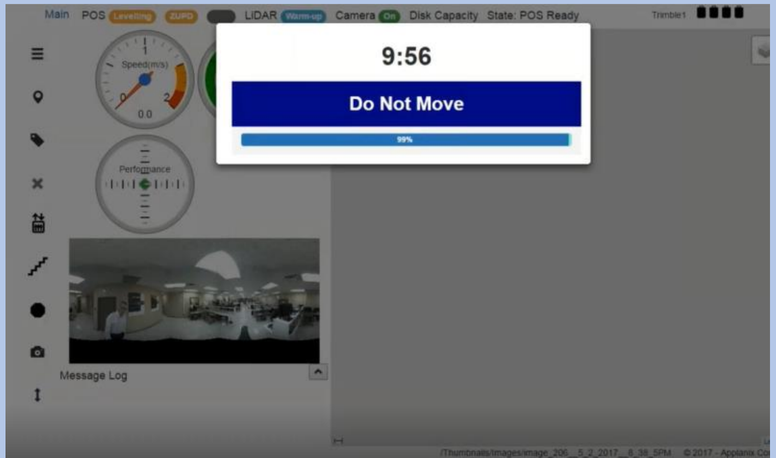
Georeferencing: Accurate wheel movement is essential for georeferencing the scanning data.

Efficiency: Smooth and reliable wheel movement contributes to the efficiency of the scanning process.

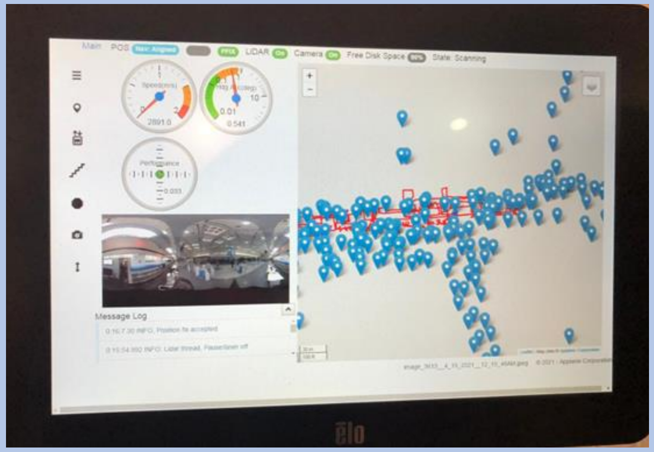
Each turn of the wheel triggers the camera to take a 360°
If the wheels stop turning, the LiDAR stops registering.

Aligning TIMMS to an IGCP

20-minute Heading initialization
Automatically orients itself to true north.

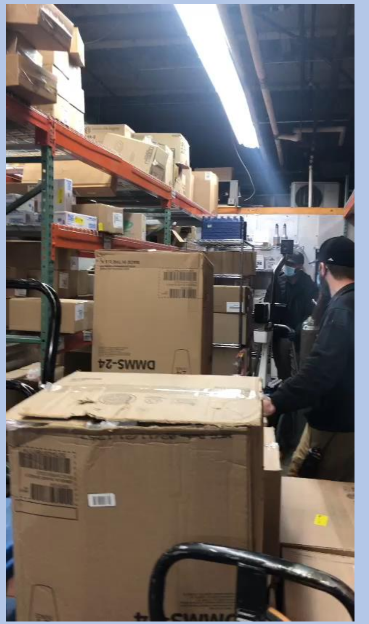


Monitoring the Trolley progress



To complete the scanning, 16 missions were required.

FLOOR	AREA	REGION	SCAN MISSIO	HD Pics	a
02_Ramp	Concourse A	All	13	3,429	
03_Ticket	Concourse A	All	6	2,335	
02_Ramp	Concourse A North	1	10	593	
02_Ramp	Concourse A North	2			
02_Ramp	Concourse A North	3	9	3,826	
02_Ramp	Concourse A North	4			
03_Ticket	Concourse A North	All	7	2,792	
04_Office	Concourse A North	All	7	751	
02_Ramp	Concourse B	All	13	4,487	
03_Ticket	Concourse B	All	7	2,642	
02_Ramp	Concourse C	All	14	4,236	
03_Ticket	Concourse C	All	5	2,591	
03_Ticket	Concourse C	Missing Rooms	16	178	
03_Ticket	Concourse D	All	12	1,428	
03_Ticket	Concourse D	Missing Rooms	16	236	
03_Ticket	Concourse D	Time Restrictions	11	636	
04_Office	Concourse D	All	6	662	
02_Ramp	Concourse E	All	15	8,257	
03_Ticket	Concourse E	All	15	300	
00_Basement	Terminal	1		3,214	
00_Basement	Terminal	2	8		
00_Basement	Terminal	3		315	
02_Ramp	Terminal	1	10	1,646	
02_Ramp	Terminal	2			
02_Ramp	Terminal	3	5	1,556	
02_Ramp	Terminal	5	11	3,653	
02_Ramp	Terminal	6			
02_Ramp	Terminal	1 - Missing Rooms	16	28	
03_Ticket	Terminal	1			
03_Ticket	Terminal	2			
03_Ticket	Terminal	3	1	3,755	
03_Ticket	Terminal	4			
03_Ticket	Terminal	5	3	3,323	
03_Ticket	Terminal	6	5	2,034	
03_Ticket	Terminal	7	3	3,323	
03_Ticket	Terminal	8	2	1,177	
03_Ticket	Terminal	9			
03_Ticket	Terminal	6 - Missing Rooms	16	153	
04_Office	Terminal	1			
04_Office	Terminal	2	4	3,265	
04_Office	Terminal	3			
04_Office	Terminal	5	6	643	
				67,464	



Within the airport, a diverse range of scanning regions and sub-regions, each representing different functional zones with unique characteristics and nuances requiring distinct scanning approaches.

Total walking distance during scanning: 67.5 kilometers (approximately 42 miles)
Average nightly distance: 10 kilometers (about 4.2 miles) or (13000 steps)

Actual Scanning Routes:

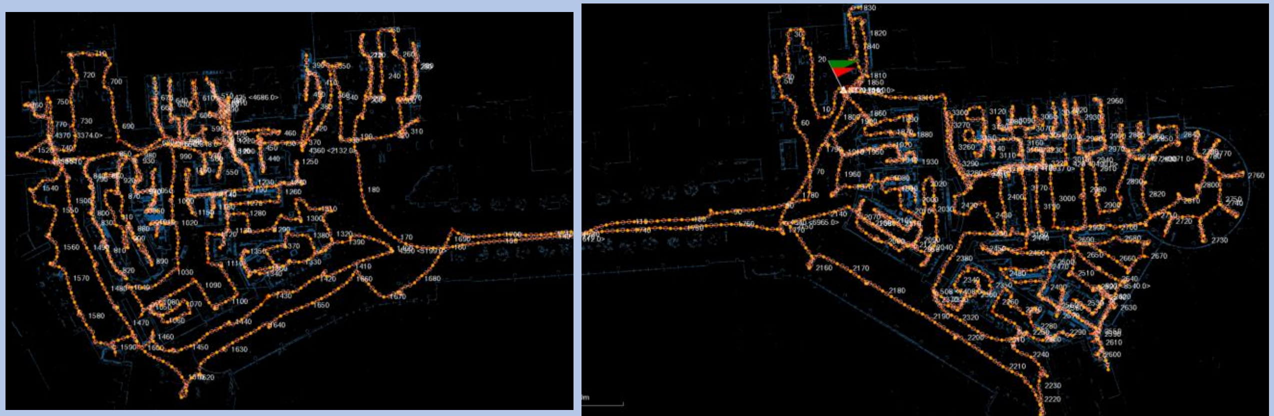
The scanning Trolley's actual route must account for passenger densities, discrepancies between reality and CAD drawings, and unforeseen factors such as locked doors.

While establishing a photo trail to track the scanning Trolley's route, precise real-world coordinates are recorded for each photo location. A photo is automatically captured at each full turn of the scanning Trolley's wheels, which equals one meter.

Additionally, the scanning Trolley processes a thin slice of the point cloud, displaying point cloud data between 3 and 6 feet above the floor level.

Progress reporting: Sliced point cloud and photo's locations

Photo Trail of Mission 3 – Covering Regions 5, 6 (partially) and 7



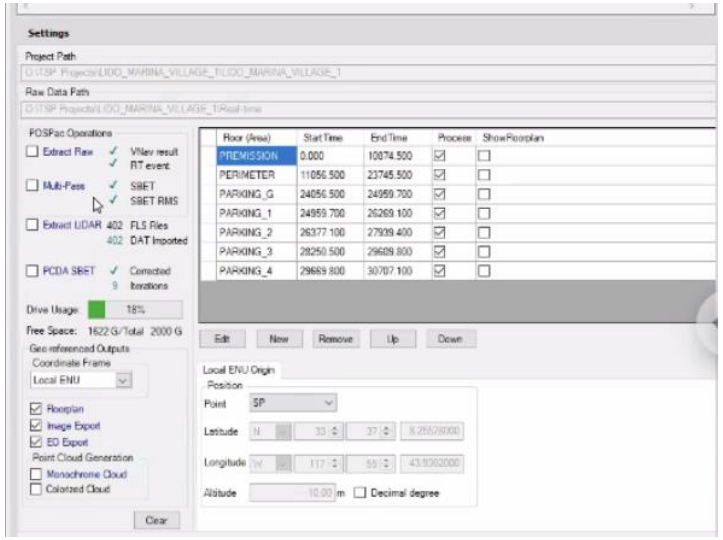
Post Processing

Enhancing Data Accuracy
Optimizing cleaning and Integration

POSPac® Mobile Mapping Suite

Post-Processing Software:

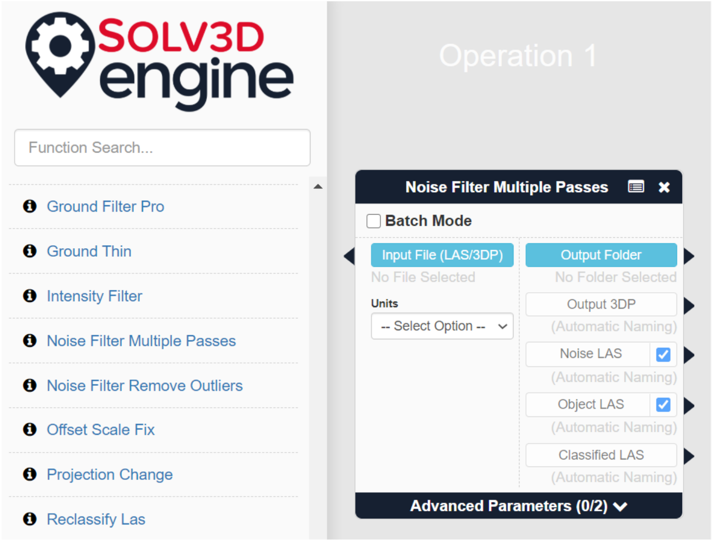
Enhancing Data Accuracy and Alignment:



Solv3D Engine

Harmonization Software

Optimizing the point cloud, format conversion, cleaning, and Integration



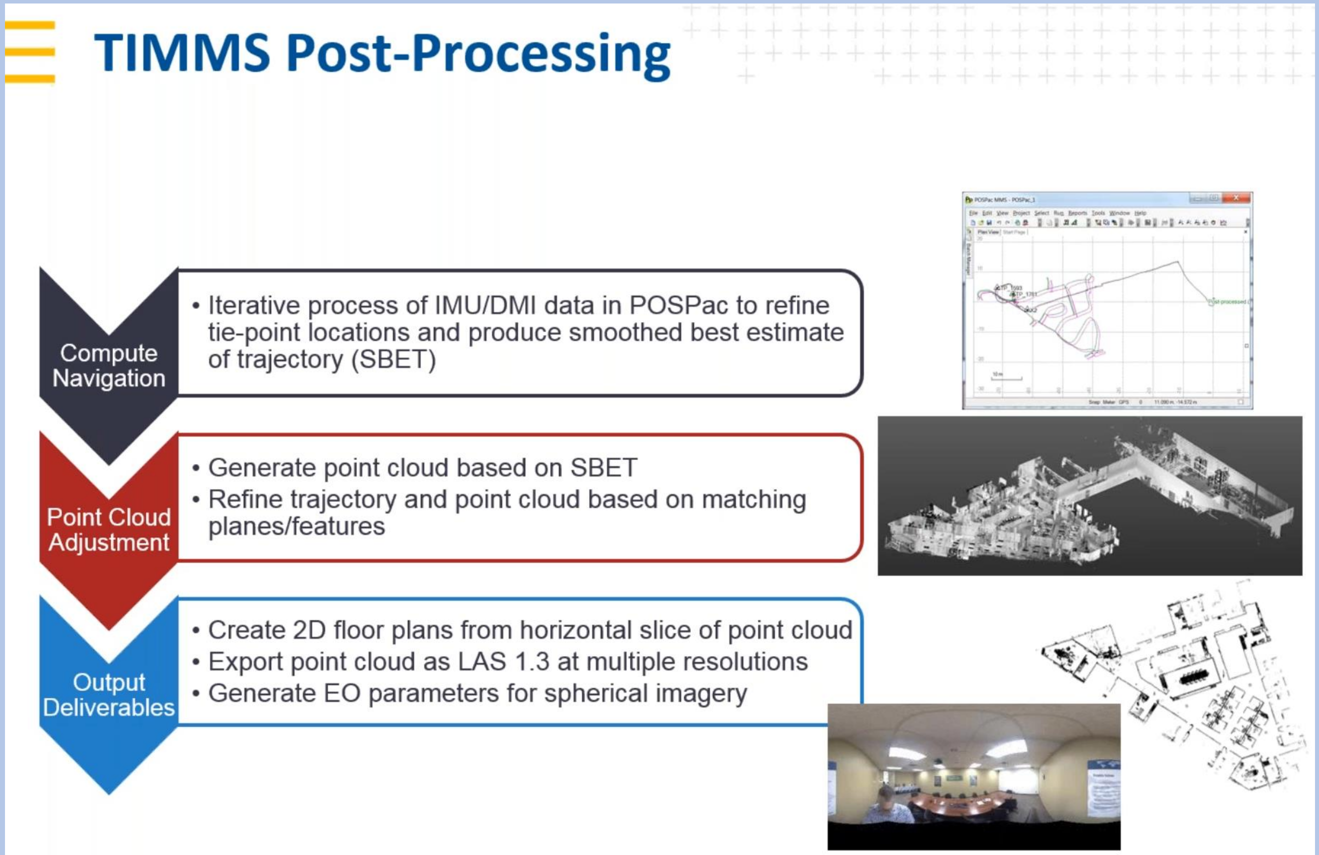
POSPac® Mobile Mapping Suite

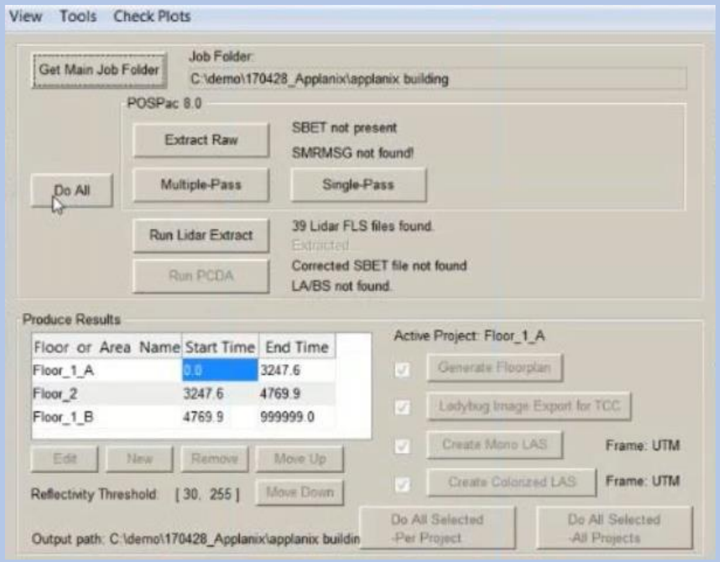
Processing

After configuring the settings, the processing occurs automatically.

Processing time matches collection time 1:1, meaning that one hour of data collection requires one hour of processing.

Enhanced: Georeferencing is applied to all point clouds and imagery.



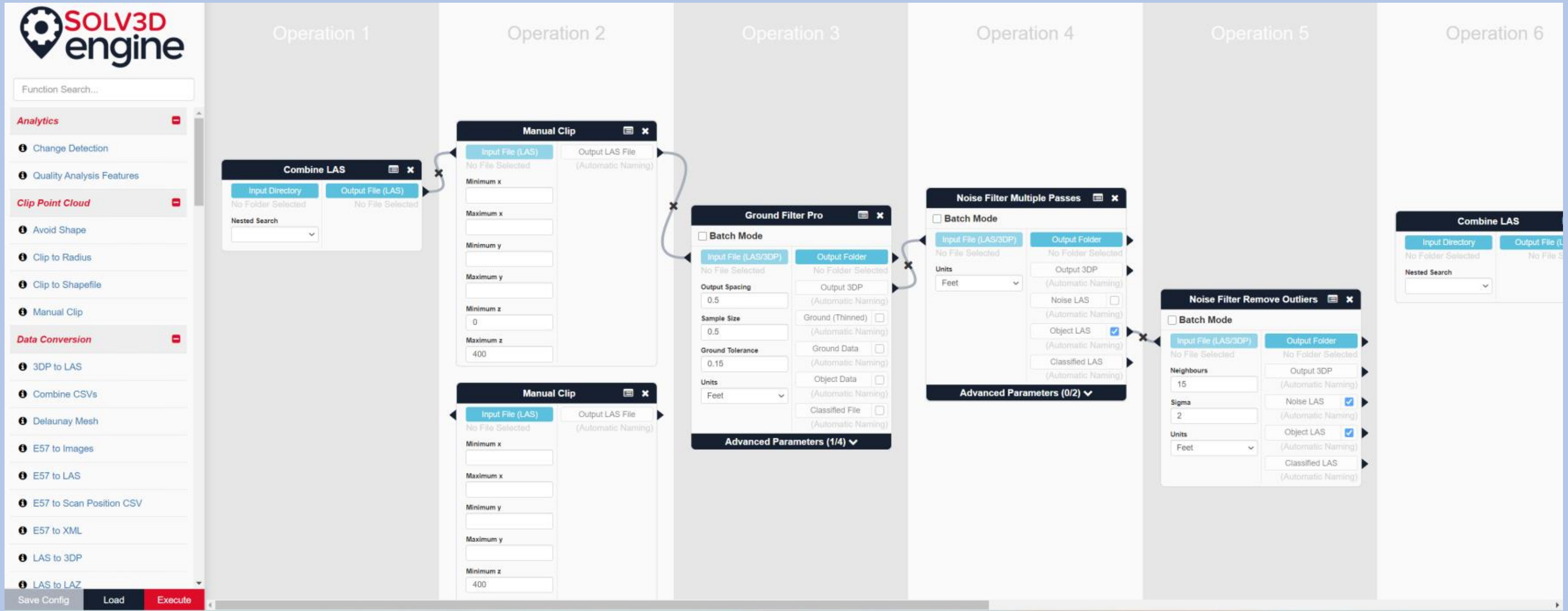


Solv3D Engine

Optimizing the point cloud, format conversion, cleaning, and Integration.

Example of a workflow

- **Combining Point Cloud:** Combine “.LAS” files from multiple Missions
- **Manual Clip:** Clip the ceiling from a building floor to enable Noise Filtering.
- **Ground Filter Pro:** Classify the input LAS or 3DP file into ground and not ground and thin the data as specified by the user
- **Noise Filter Multiple Passes:** Filters the noise from a LAS file and outputs the cleaned scene to LAS.
  (Requires Ground Filter Pro to be active)
- **Noise Filter Remove Outliers:** A statistical outlier noise filter. All noise is classified to a value of “7.”



Solv3D Engine

Optimizing the point cloud, format conversion, cleaning, and Integration.

Surgical Removal of Ghosts:

If the ghost removal workflow fails to detect and eliminate ghosts due to factors like excessive movement or their proximity to doors, walls, or stationary features, surgical removal becomes necessary.

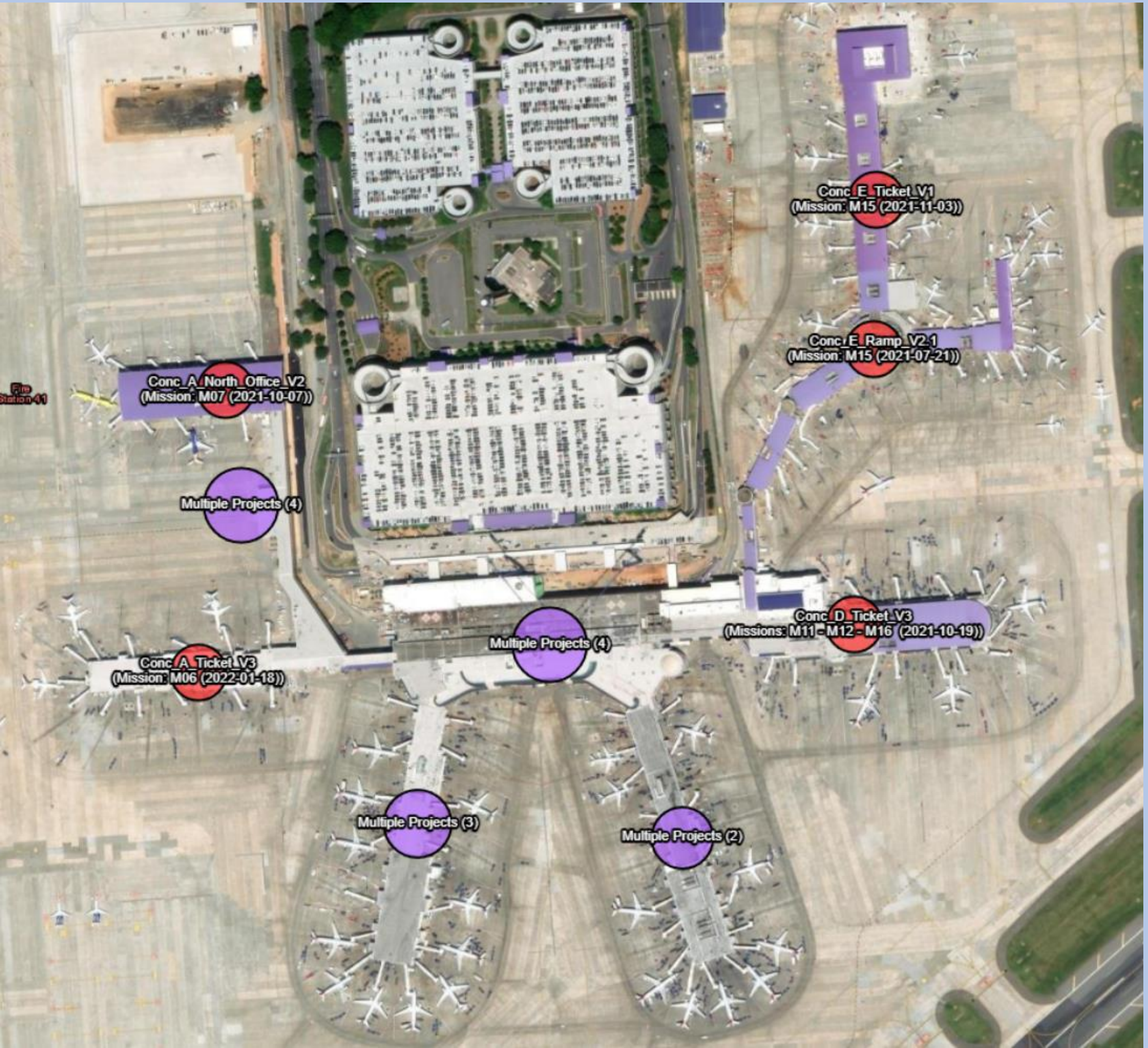
An example where six scanning crew members constantly move within the scanning trolley's range, resulting in numerous ghost images.

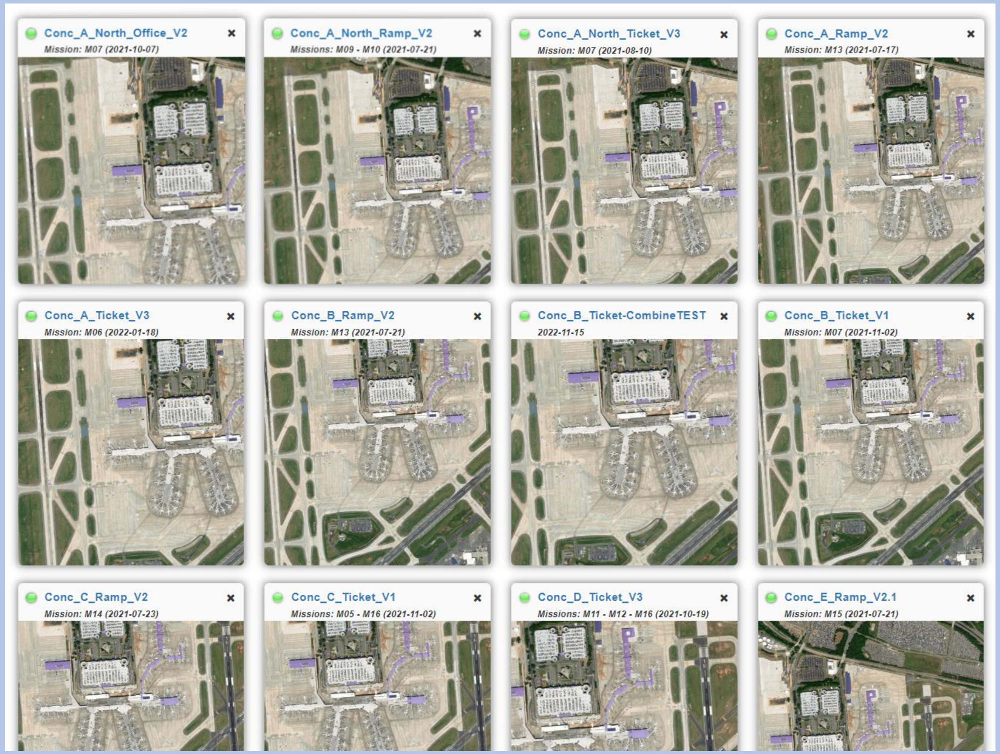
Publication and Integration

Maximizing Data Usage

Solv3D Encompass

Data consolidation, visualization, and collaboration

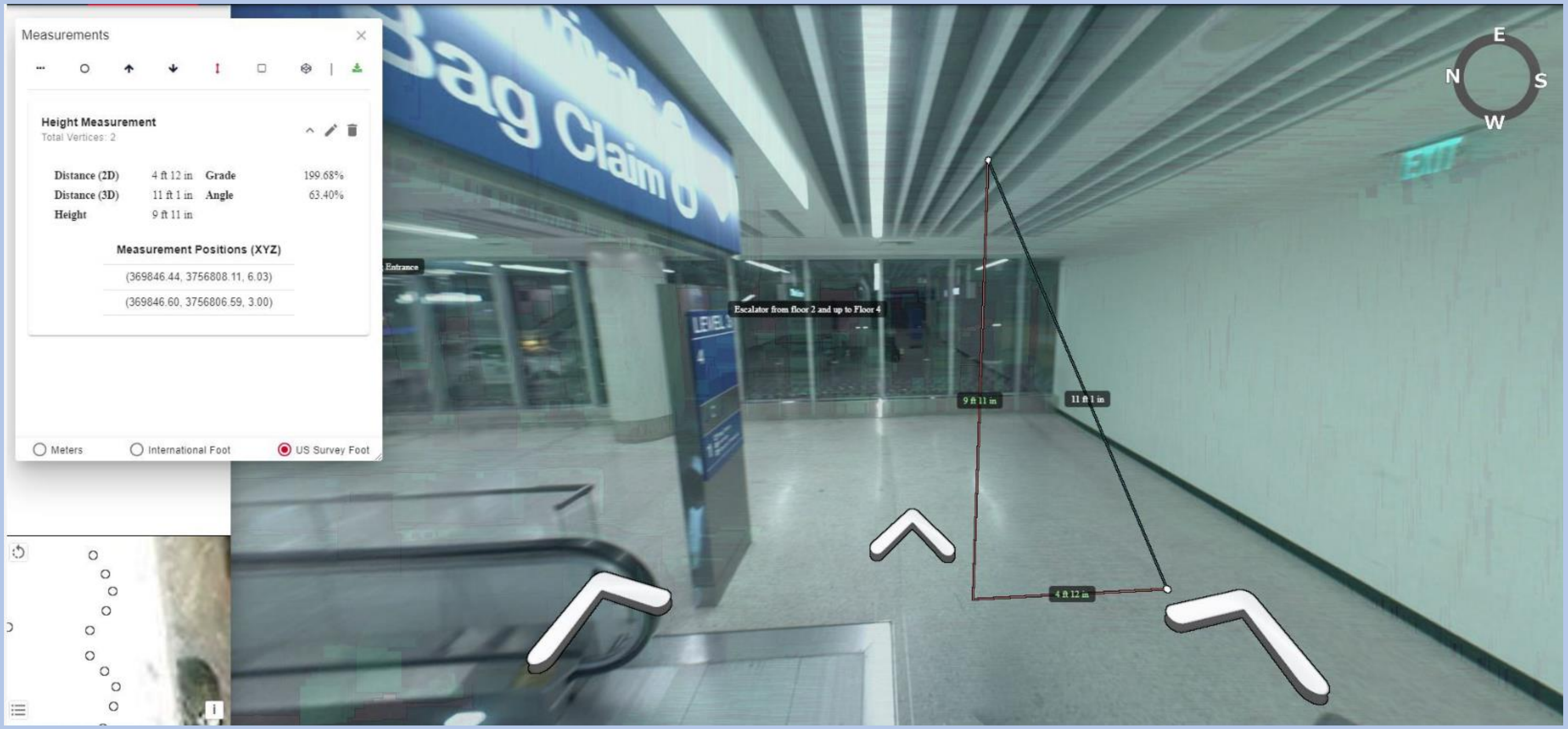




Solv3D Encompass

Data consolidation, visualization, and collaboration

Publication and Measurement Tools

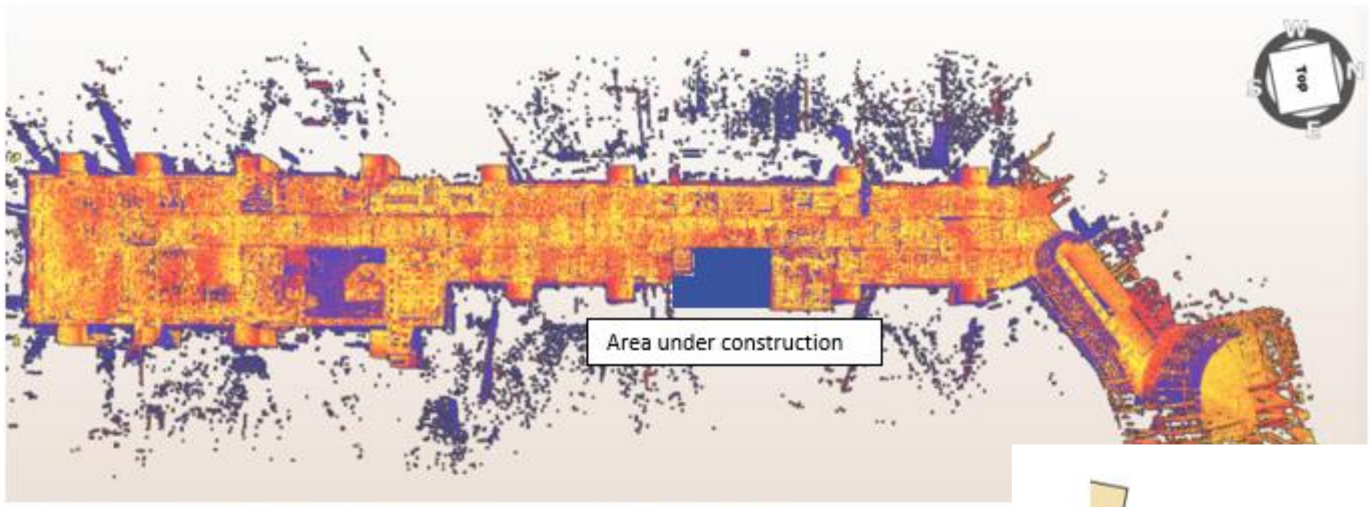


Temporal Scanning

Quality 3D master Model is Vital

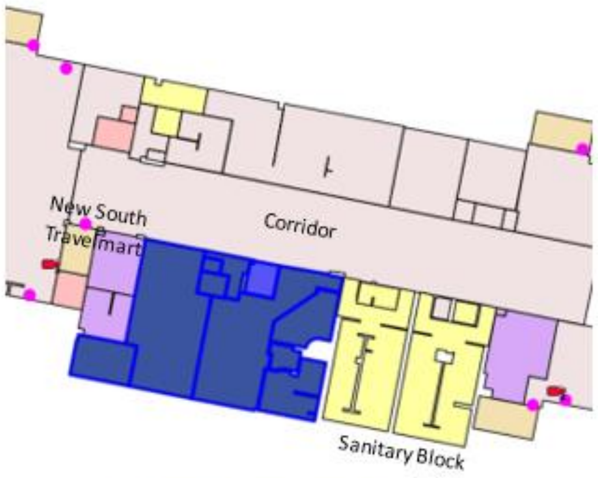
The situation when the master 3D model was created.

The renovation of the Summerhouse in Concourse B showcases several challenges related to redundant data during a scanning mission.



The Master Model Point Cloud of the Concourse B Ticket Level

Summerhouse location.



Summerhouse location

The area marked in blue signifies the location scheduled for the Sumer House Renovation

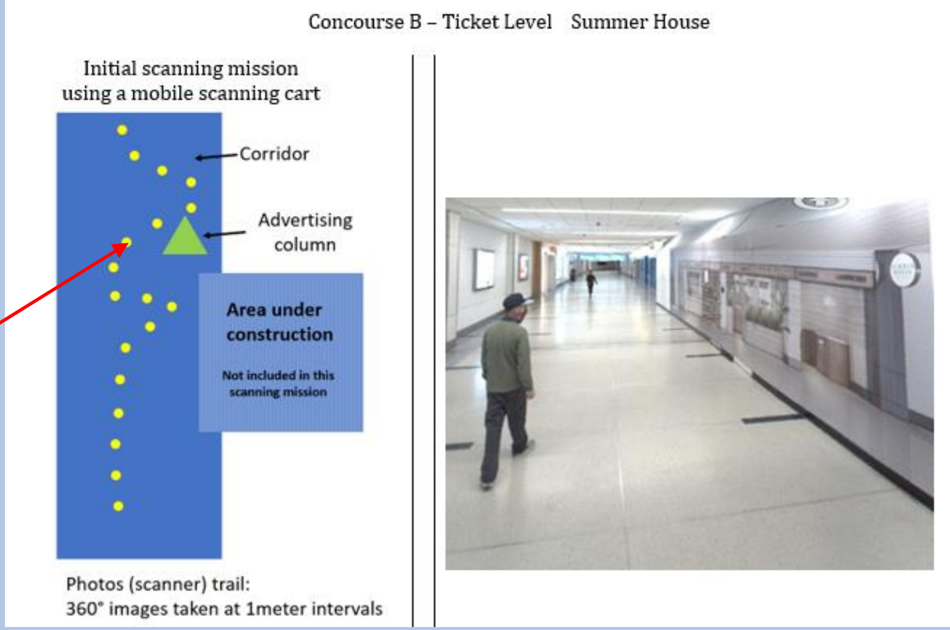
As-Is and Redundant Imagery

Refurbished Retail area

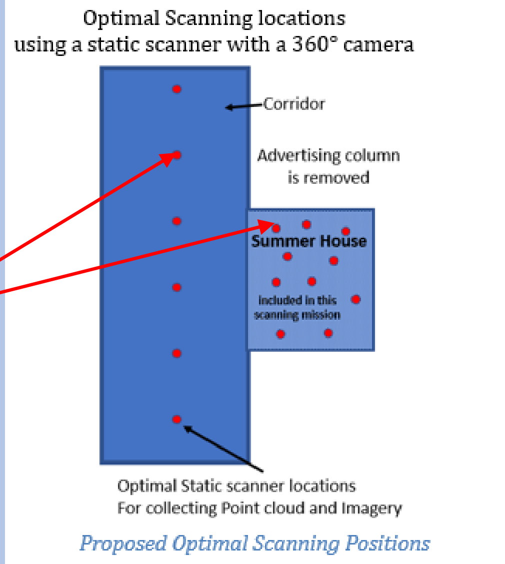
Retail Advertisement – Currently in the Master 3D model

A new scan is necessary to update the master 3D model.

Master 3D Model
Optimal routing of the mobile scanner during the 2020 mobile trolley scanning project.



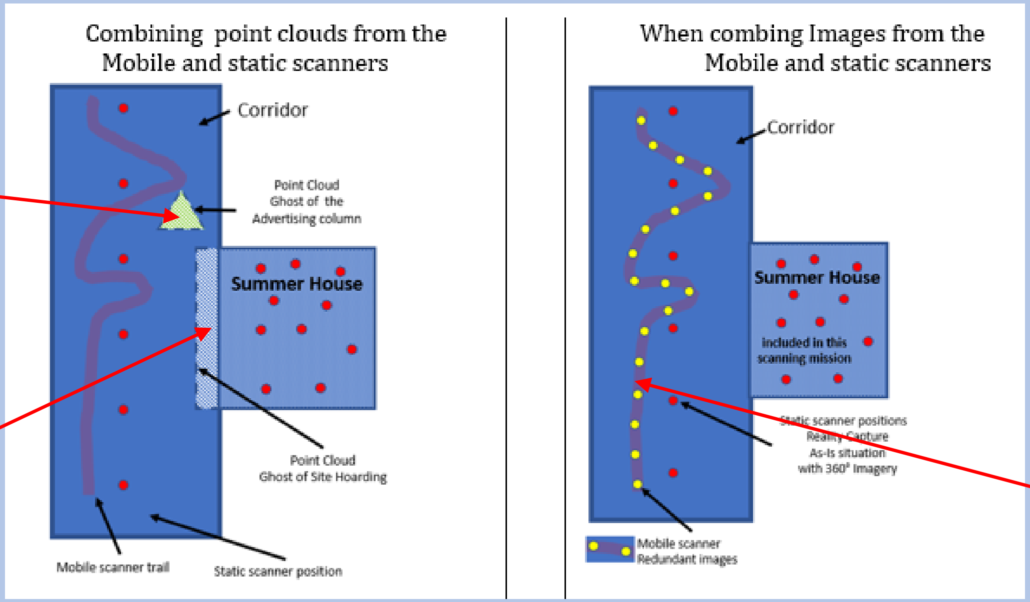
Temporal Scan:
Determine the Optimal Scan Positions Using a Trimble X7 Static Scanner.



Ghost Point Cloud Data and Superfluous Imagery.

Ghost of the Advertising Column

Ghost of the Site Hoarding

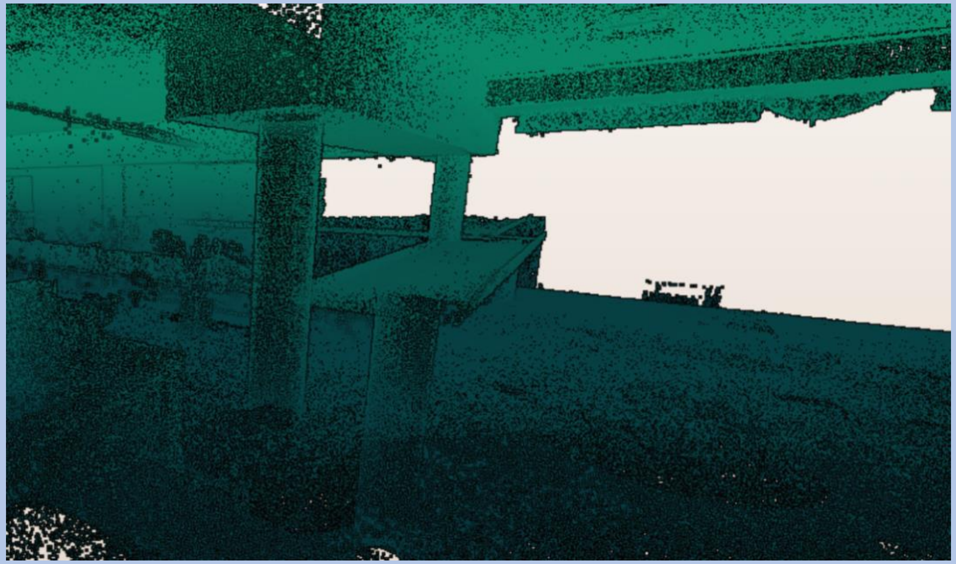


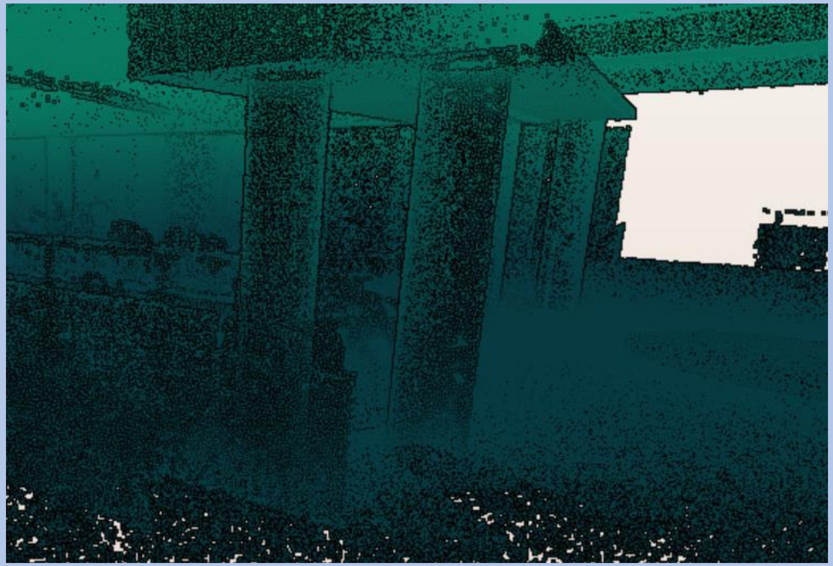
Redundant Imagery in the Master 3D Data Model 3D

Ghost point cloud data and superfluous imagery when using the Trimble x7 scanner

MinuteSuites: Alignment Issues of Temporal Mission with the 3D Master Model

2022_M02_MinuteSuites_Initial Alignment within Clipped ConcD_Ticket Scan
XYZ are all out of alignment





MinuteSuites: Aligned Point Cloud Overlayed onto Master 3D Model

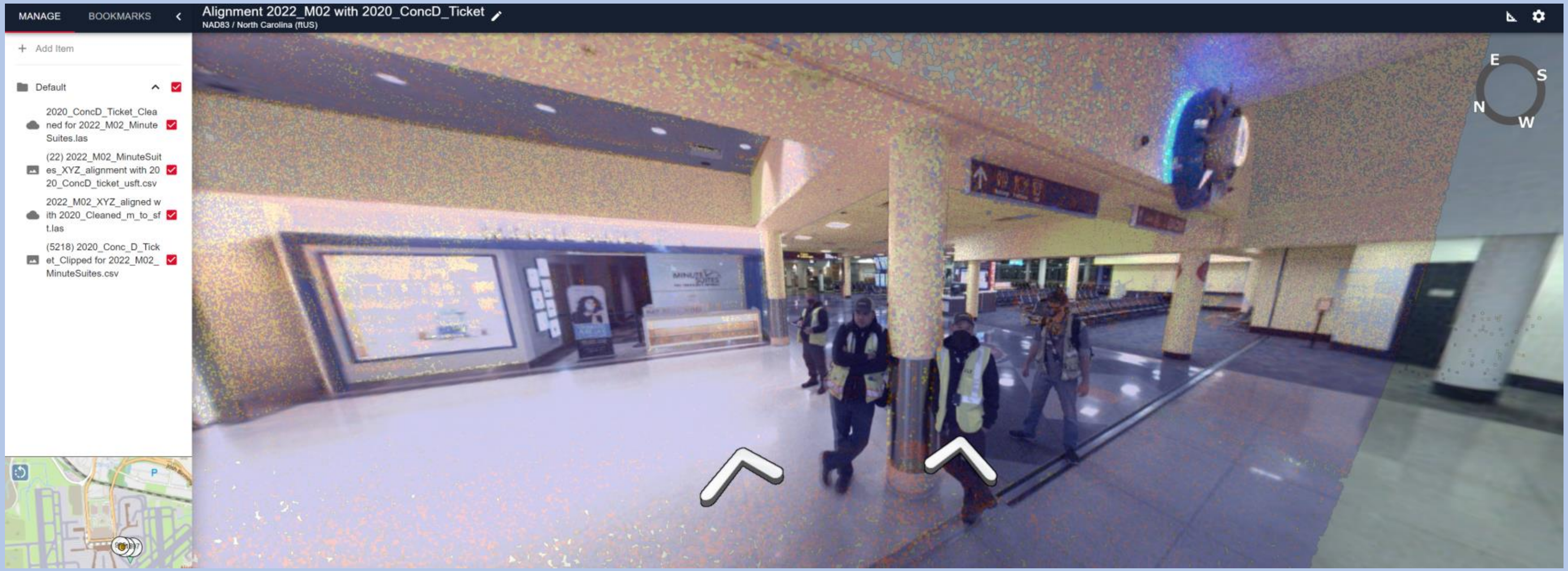
Following the Temporal Scanning Guidelines
2022_M02 Z aligned with 2020 ConcD_Ticket

MinuteSuites: Image Overlay of Mission file onto Master 3D Model Point Cloud

2022_M02 XYZ images are not aligned with the unified point cloud

MinuteSuites: Full alignment

Following the Temporal Scanning Guidelines
Images and point-cloud from missions 2020_ConcD_Ticket and 2022_M02_Minute Suites are fully aligned



Takeaways

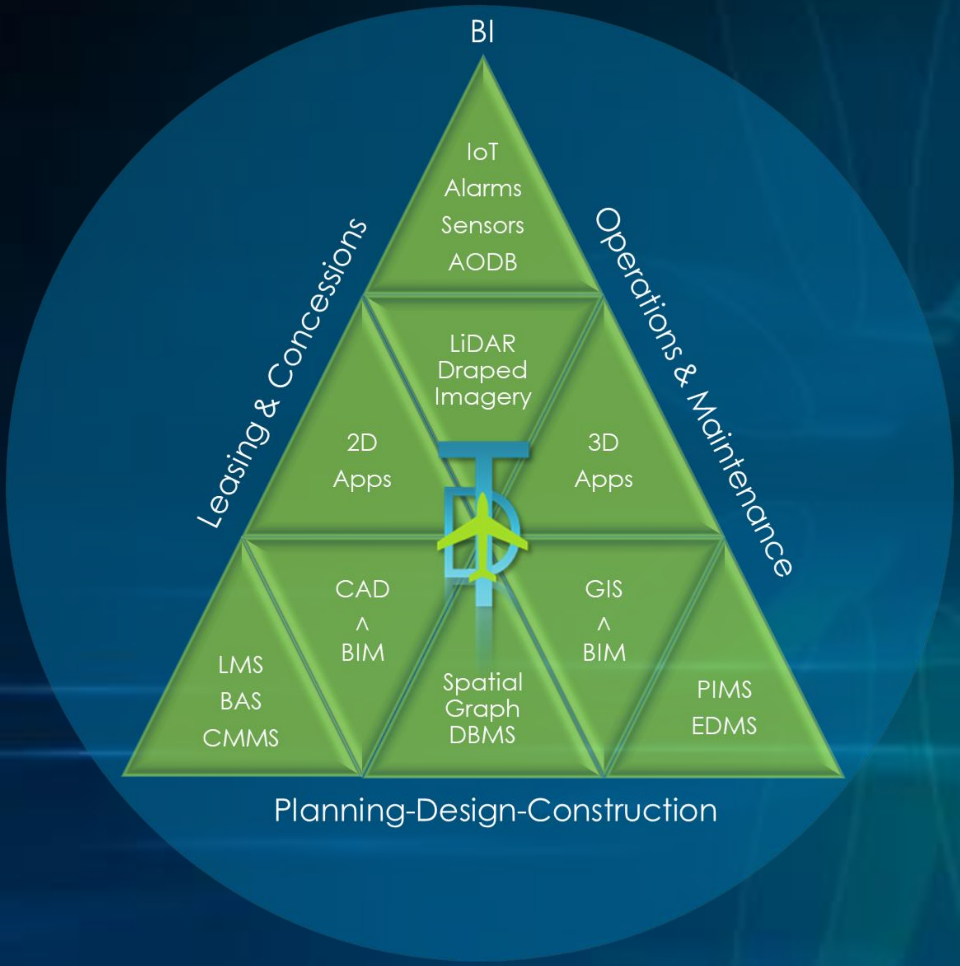
Q&A

Sustaining an accurate up-to-date 3D master model, leveraging LiDAR with draped imagery, requires:

- Appropriate scanner selection
- Use of permanent Indoor Ground Control Points (IGCPs)
- Post-processing software of the scanned data
- Harmonizing software for optimizing the point cloud, format conversion, cleaning, and publishing
- Indoor scanning and temporal indoor scanning guidelines

X·SPATIAL Trimble. Applanix SOLV3D

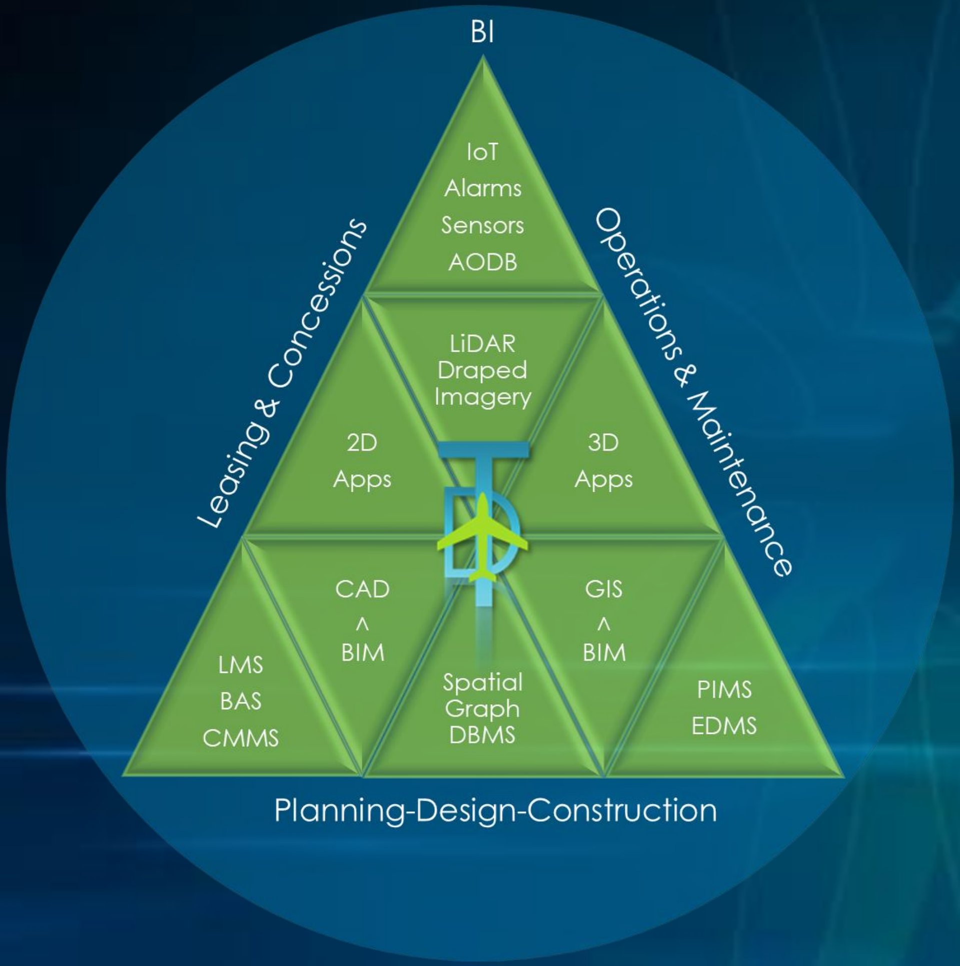
Webinar Series



1. Jul 19: **BIM Processing**
2. Jul 26: **Information Integration**
3. Aug 2: **Enabling Integrated SMS**
4. Aug 9: **Holistic Business Intelligence**
5. Sep 27: **Roadmap for Airport Owners**
6. Oct 18: **LiDAR with Draped Imagery**

AirportDigitalTwin.org

Webinar Series



6. Oct 18: **LiDAR with Draped Imagery**
7. Nov 15: **FME Middleware to Sustain Airport Digital Twins**
8. Dec 20: **Video Analytics Middleware**
9. Jan 17: **Deep Dive into Airport BIM Best Practices & Standards**
10. Feb 21: **Geospatial Integrated Predictive Modeling**
11. Mar 20: **TBD**

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Thank You

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INTEGRATED SOLUTION PLATFORM

Simplify i3

Airport Digital Twin Transformation Platform by EPIC Engineering & Consulting Group

Learn more

AEGIS

Airport Enterprise Geospatial Information System by x-Spatial

Learn more

BIM

Building Information Modeling Standardization Harvesting and Integration by PDBM/x-Spatial

Learn more

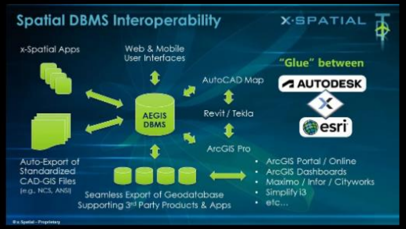
Welcome About Us Q&A Solution Webinars

AEGIS

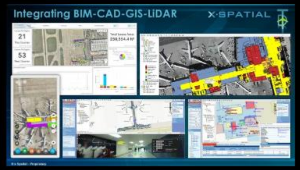
Our Airport Digital Twin solution leverages x-Spatial's Airport Enterprise Geospatial Information System (AEGIS) as the "common denominator" component, providing the spatial skeleton supporting the correlation of various airport data.

AEGIS includes an airport specific spatial Database Management System (DBMS), integrating both Autodesk and Esri data structures and functionality. The AEGIS DBMS se

+ Show More



AIRPORT DIGITAL TWIN ENABLING CAPABILITIES

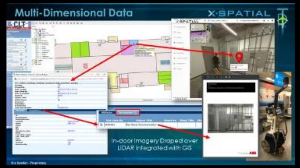


Spatial Integration Platform

The x-Spatial AEGIS backbone of our Airport Digital Twin solution, leverages stat-of-the-art technologies from Autodesk, Esri, Trimble, SOLV3D, Oracle, and Microsoft to integrate BIM, CAD, GIS, and LiDAR with draped imagery.

Integrating BIM deliverables

AEGIS enables the best of both worlds -- Autodesk and Esri. It integrates Autodesk Revit BIM models, delivered for airport AEC projects, with our overall digital twin solution spanning the entire airport campus. AEGIS enables data edits from both AutoCAD and ArcGIS Pro. It also serves spatial data for analysis to both Autodesk and Esri tools and applications.

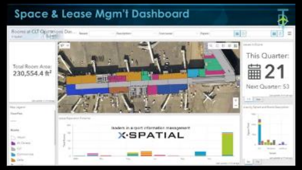


Integrating Multi-Dimensional Data

The x-Spatial AEGIS platform allows integration of mutli-dimensional data types, including 2D and 3D interconnected facility views, with embedded asset attribute data, as well as asset documentation.

Integrating Business Analytics Spatially

Airport Business Intelligence (BI) requires correlation of various disparate analytics data. The most effective means for correlating multiple such datasets for airport use cases is via spatial dashboarding. x-Spatial leverages the power of Esri's ArcGIS spatial analytics, as shown in this example involving lease management data.



Integrated Signage Data

The AEGIS system supports integration of various types of airport signage data spanning the airfield per FAA requirements, terminal indoor signage, and outdoor signage covering the remaining airport campus including roadways, wayfinding, buildings, etc.

Integrated Pavement Condition Data

AEGIS includes airport pavement management functionality for both