INTRODUCTORY PRESENTATION

FEBRUARY 2023

X-Spatial®

KEY TO A SUSTAINABLE AIRPORT DIGITAL TWIN

Presentation Overview

- x-Spatial Introduction
- What is an Airport Digital Twin
- Use Cases, components
- Examples of leveraging DT & integration with other airport data
- Case Study
  - Using LiDAR to create a 3D DT at Charlotte Douglas International Airport
- Sustaining DT - Updating the master LiDAR model
- Q & A

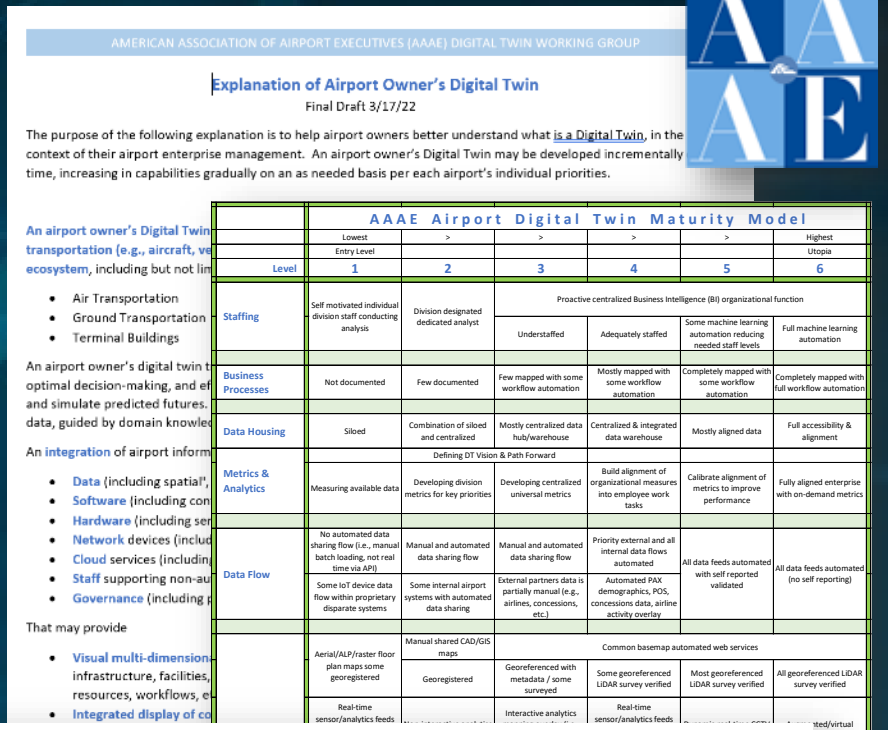
Introductions

- Founding member of Airports Digital Twin Consortium (https://airportdigitaltwin.org/)
- x-Spatial was formed in 2006 to better focus our application development for our clients
- Formally the application development division of Kelar Corporation (established in 1982)
- Our current focus are airports, assisting them with managing their assets as well as financial information (lease & concession mgmt.) leveraging GIS
- We have over 25 years of direct experience of application development including CAD / GIS / IT in an airport environment, at major European & US airports

What is an Airport Digital Twin

AAAE Digital Twin Working Group

- Roadmap for Airport Owners
  - Definition / Explanation
  - Top Use Cases / Examples
  - System Architecture
  - Implementation Approach
  - Governance to Sustain
  - Industry Resources



AMERICAN ASSOCIATION OF AIRPORT EXECUTIVES (AAAE) DIGITAL TWIN WORKING GROUP

Explanation of Airport Owner's Digital Twin

Final Draft 3/17/22

The purpose of the following explanation is to help airport owners better understand what is a Digital Twin, in the context of their airport enterprise management. An airport owner's Digital Twin may be developed incrementally time, increasing in capabilities gradually on an as needed basis per each airport's individual priorities.

An airport owner's Digital Twin transportation (e.g., aircraft, ve ecosystem, including but not lin

- Air Transportation
- Ground Transportation
- Terminal Buildings

An airport owner's digital twin t optimal decision-making, and ef and simulate predicted futures. data, guided by domain knowled

An integration of airport inform

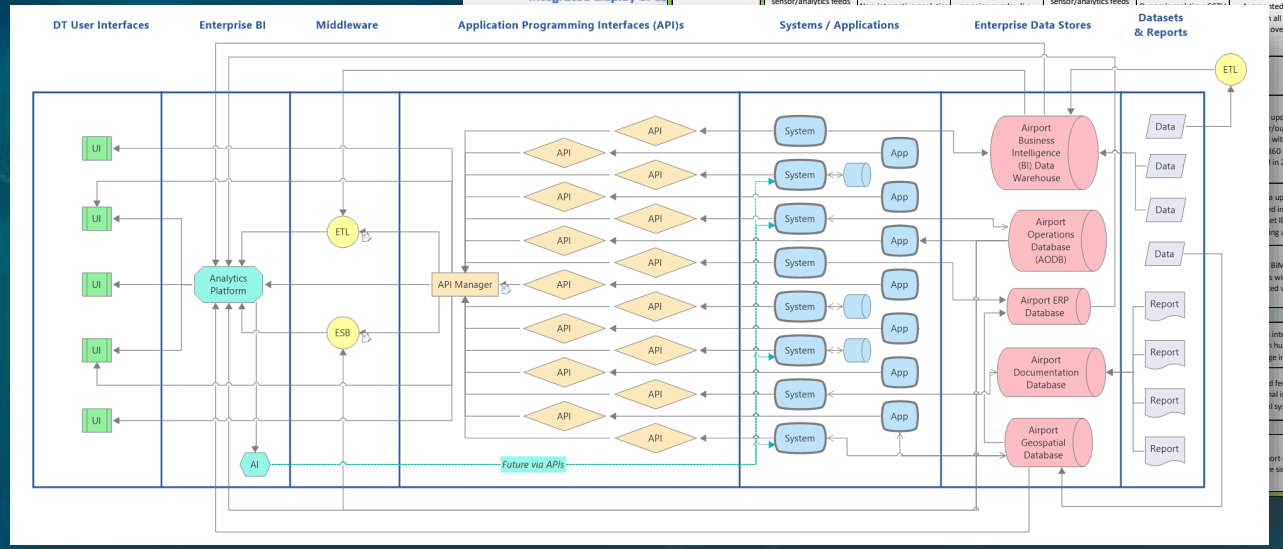
- Data (including spatial*,
- Software (including con
- Hardware (including ser
- Network devices (includ
- Cloud services (including
- Staff supporting non-au
- Governance (including p

That may provide

- Visual multi-dimension infrastructure, facilities, resources, workflows, e
- Integrated display of co

AAAE Airport Digital Twin Maturity Model

	Lowest / Entry Level	>	>	>	>	Highest / Utopia
Level	1	2	3	4	5	6
Staffing	Self motivated individual division staff conducting analysis	Division designated dedicated analyst	Proactive centralized Business Intelligence (BI) organizational function			
			Understaffed	Adequately staffed	Some machine learning automation reducing needed staff levels	Full machine learning automation
Business Processes	Not documented	Few documented	Few mapped with some workflow automation	Mostly mapped with some workflow automation	Completely mapped with some workflow automation	Completely mapped with full workflow automation
Data Housing	Siloed	Combination of siloed and centralized	Mostly centralized data hub/warehouse	Centralized & integrated data warehouse	Mostly aligned data	Full accessibility & alignment
Metrics & Analytics	Defining DT Vision & Path Forward					
	Measuring available data	Developing division metrics for key priorities	Developing centralized universal metrics	Build alignment of organizational measures into employee work tasks	Calibrate alignment of metrics to improve performance	Fully aligned enterprise with on-demand metrics
Data Flow	No automated data sharing flow (i.e., manual batch loading, not real time via API)	Manual and automated data sharing flow	Manual and automated data sharing flow	Priority external and all internal data flows automated	All data feeds automated with self reported validated	All data feeds automated (no self reporting)
	Some IoT device data flow within proprietary disparate systems	Some internal airport systems with automated data sharing	External partners data is partially manual (e.g., airlines, concessions, etc.)	Automated PAX demographics, POS, concessions data, airline activity overlay		
	Aerial/ALP/raster floor plan maps some georegistered	Manual shared CAD/GIS maps	Common basemap automated web services			
		Georegistered	Georeferenced with metadata / some surveyed	Some georeferenced LiDAR survey verified	Most georeferenced LiDAR survey verified	All georeferenced LiDAR survey verified
	Real-time sensor/analytics feeds		Interactive analytics	Real-time sensor/analytics feeds		



What's an Airport Digital Twin

An airport owner's Digital Twin is a virtual digital representation of the airport's real-world assets, intermodal transportation (e.g., aircraft, vehicles, passengers, cargo), and processes which may span the entire aerodrome ecosystem, including but not limited to:

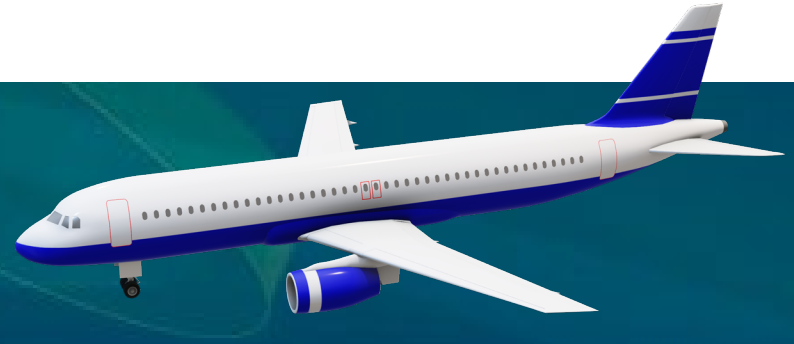
- Air Transportation
- Ground Transportation
- Terminal Buildings
- Other Buildings
- Infrastructure
- Properties & Environment

An airport owner's digital twin transforms the airport business enterprise by accelerating holistic understanding, optimal decision-making, and effective action. It uses real-time and historical data to represent the past and present and simulate predicted futures. It is motivated by outcomes, tailored to use cases, powered by integration, built on data, guided by domain knowledge, and implemented in IT/OT systems.[i]

Source:

AAAE Airport Owner's Digital Twin Working Group Roadmap

(based on Digital Twin Consortium's Definition)



What's an Airport Digital Twin cont'

An **integration** of airport information systems (including processes, data, and technologies)

- **Data** (including spatial[ii], non-spatial, real-time, historic, forecast, and simulated)
- **Software** (including configurable COTS solutions, data maintenance, and business intelligence & analytics)
- **Hardware** (including servers, desktops, laptops, tablets, smartphones, and sensors)
- **Network** devices (including switches, routers, and hotspots)
- **Cloud** services (including software, data, databases, and infrastructure "as a service")
- **Staff** supporting non-automated data updates (such as airport configuration changes)
- **Governance** (including policies, standards, compliance, processes, and procedures)

That may provide

- **Visual multi-dimensional representation** of the airport's ecosystem including its airspace, surroundings, infrastructure, facilities, assets, systems, flux (e.g., aircraft, vehicles, passengers, meeter greeters), staff resources, workflows, etc.
- **Integrated display of correlated information** from multiple systems/sources (aka business intelligence) in the form of analytic graphs, tables, and maps
- **Temporal analysis** of past, current, real-time, forecast, and/or simulated data

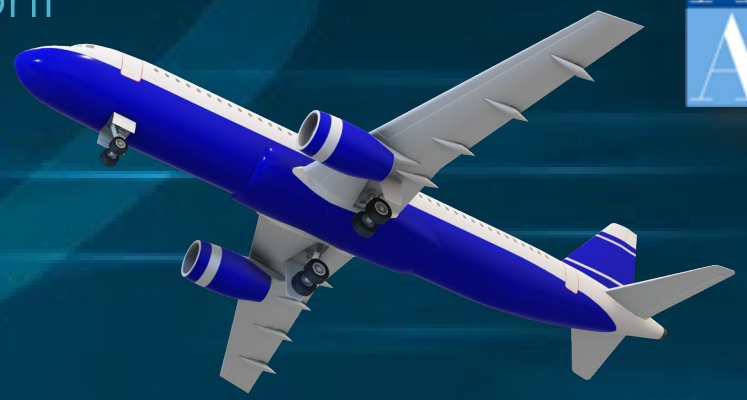
What's an Airport Digital Twin cont'

To enable

- **Efficient collection, access, correlation, and understanding of quality**[iii] **data** from multiple airport systems/sources to support faster and more confident decisions to improve airport:
  - Level of Service
  - Safety & Security
  - Operations & Maintenance
  - Planning & Development
  - Costs & Revenue
  - Compliance & Risk Management
- **Autonomous** operations and decision making

Source: AAAE Airport Owner's Digital Twin Working Group Roadmap

What's an Airport Digital Twin cont'



In support of all airport management disciplines

- Planning & Environmental
- Engineering & Construction
- Facilities & Asset Maintenance
- Operations (Landside, Terminal, Airside, Security, Fire, Police)
- Property Leasing & Concessions
- Business Development
- Public & Governmental Affairs
- Information Technology & Communications
- Finance & Procurement
- Legal & Administration

Addressing informational needs of various airport stakeholders

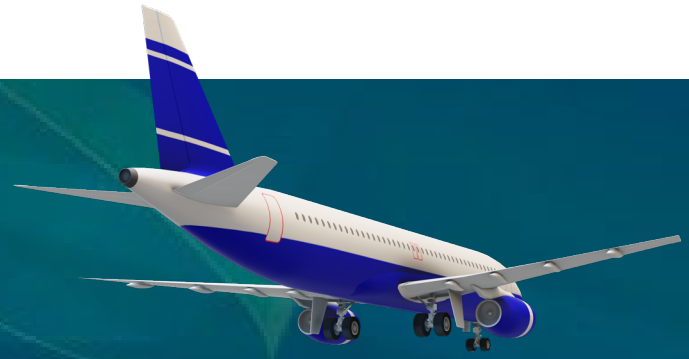
- Board members
- Management
- Staff
- Vendors / Consultants / Contractors / Service providers
- Tenants
- Passengers
- Meeters & Greeters
- Governing agencies (e.g., local, state, federal)
- Surrounding Community

Source: AAAE Airport Owner's Digital Twin Working Group Roadmap

What's an Airport Digital Twin

An airport owner's digital twin is

- NOT a single system, but rather an integration of systems/data,
  which are assembled into a Digital Twin head-end system
- NOT replacing existing airport systems, but rather expanding their utility;
  some existing systems may become obsolete or consolidated as a result of a Digital Twin
- NOT the Architectural-Engineering-Construction (AEC) Digital Twin used to design-build-activate new facilities;
  however, the AEC's Digital Twin data may be leveraged by the airport owner's Digital Twin
- NOT a Building Information Modeling (BIM) nor a Geospatial Information System (GIS),
  although BIM and GIS are parts of a digital twin



Source: AAAE Airport Owner's Digital Twin Working Group Roadmap

Use Cases & Components

Airport DT Business Needs

- Internet of Things (IoT) with analytics have become common place (e.g., **CCTV cameras, sensors, alarms, elevators, escalators, etc**.)
- Different IoT types overlayed on disparate system maps/floorplans **need to be updated more efficiently with constant airport changes**
- **Need to correlate interdependencies** of various IoT types across large and complex airport facilities that are constantly evolving
- **Need** various IoTs with analytics **on same "page"** via shared up-to-date airport maps/floorplans

Airports Digital Twin Consortium™ Proprietary

Top Use Cases

- Landside Arrivals
- Shuttle Bus Frequency
- Security Checkpoints
- Digital Content
- APM Frequency
- Concessions
- Connecting Flights/PAX Loads
- Terminal Resources
- Terminal Energy Management
- Terminal Cleaning
- Predictive Maintenance
- Work Scheduling
- Airfield Safety
- PAX Safety & Health
- Emergency Situational Awareness

Path to Achieving Airport Digital Twin

Maturity Model

- Staffing
- Business Processes
- Data Housing
- Metrics & Analytics
- Data Flow
- Spatial Correlation
- Systems Integration
- Predictive Simulation

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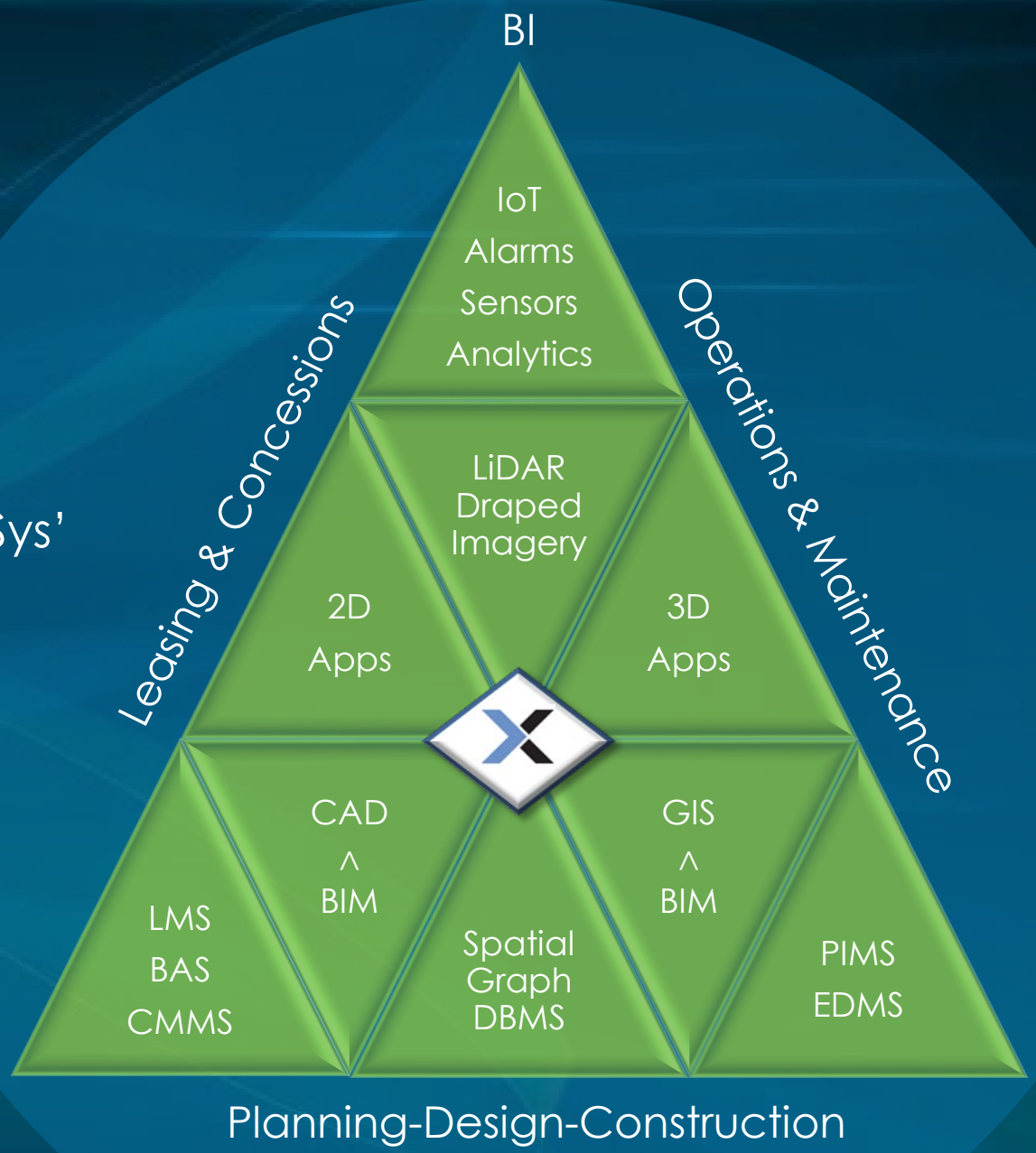
	Aerial/ALP/raster floor	Manual shared CAD/GIS maps	Common basemap automated web services			

Source: AAAE Digital Twin Working Group

Airport DT Components

- BAS – Building Automation System
- BI – Business Intelligence
- BIM – Building Information Modeling
- CAD – Computer Aided Design
- CMMS – Computerized Maintenance Mgm't Sys'
- DBMS – Database Mgm't System
- EDMS – Electronic Doc's Mgm't System
- GIS – Geospatial Information System
- IoT – Internet of Things
- LiDAR – Light Detection and Ranging
- LMS – Lease Management System
- PIMS – Project Info' Mgm't System



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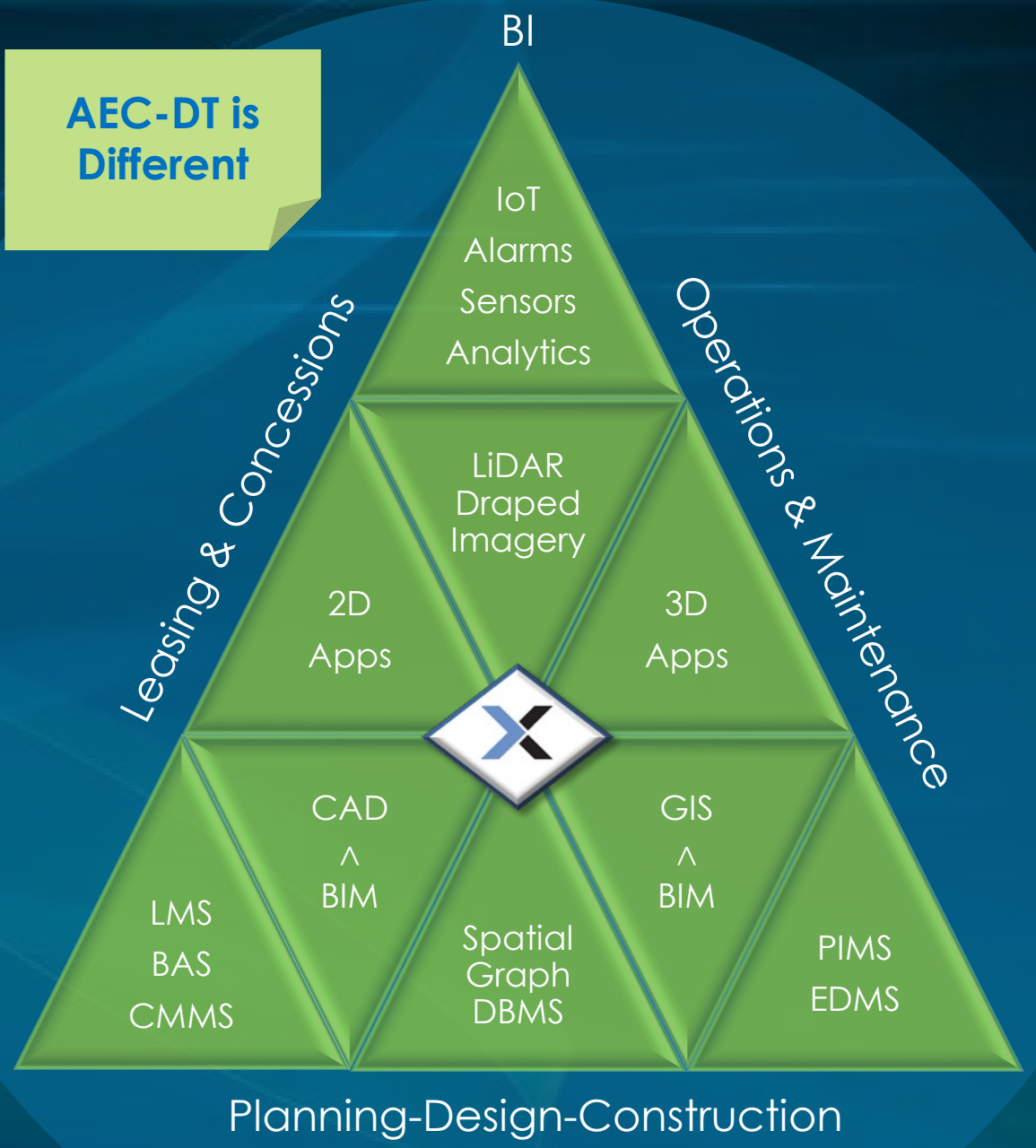
Holistic DT Stakeholders on Airport Owner-Side ---------->

- Planning & Environmental
- Engineering & Construction
- Operations & Security
- Facilities Maintenance
- IT Systems & Infrastructure
- Leasing & Concessions (Revenues)
- Finance & Procurement
- Legal & Administration

AEC-DT is Different



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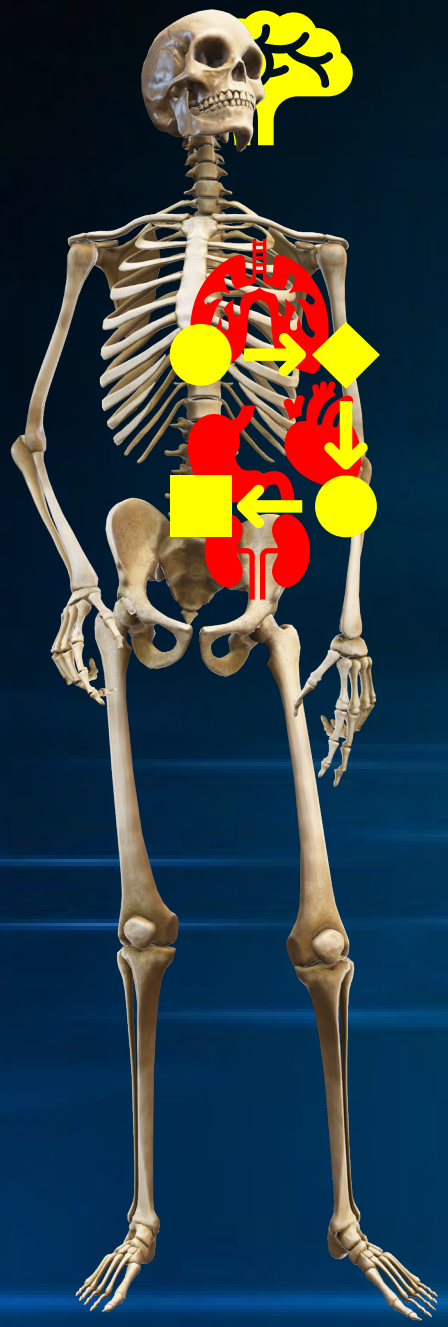


DT Foundation

"Skeleton"

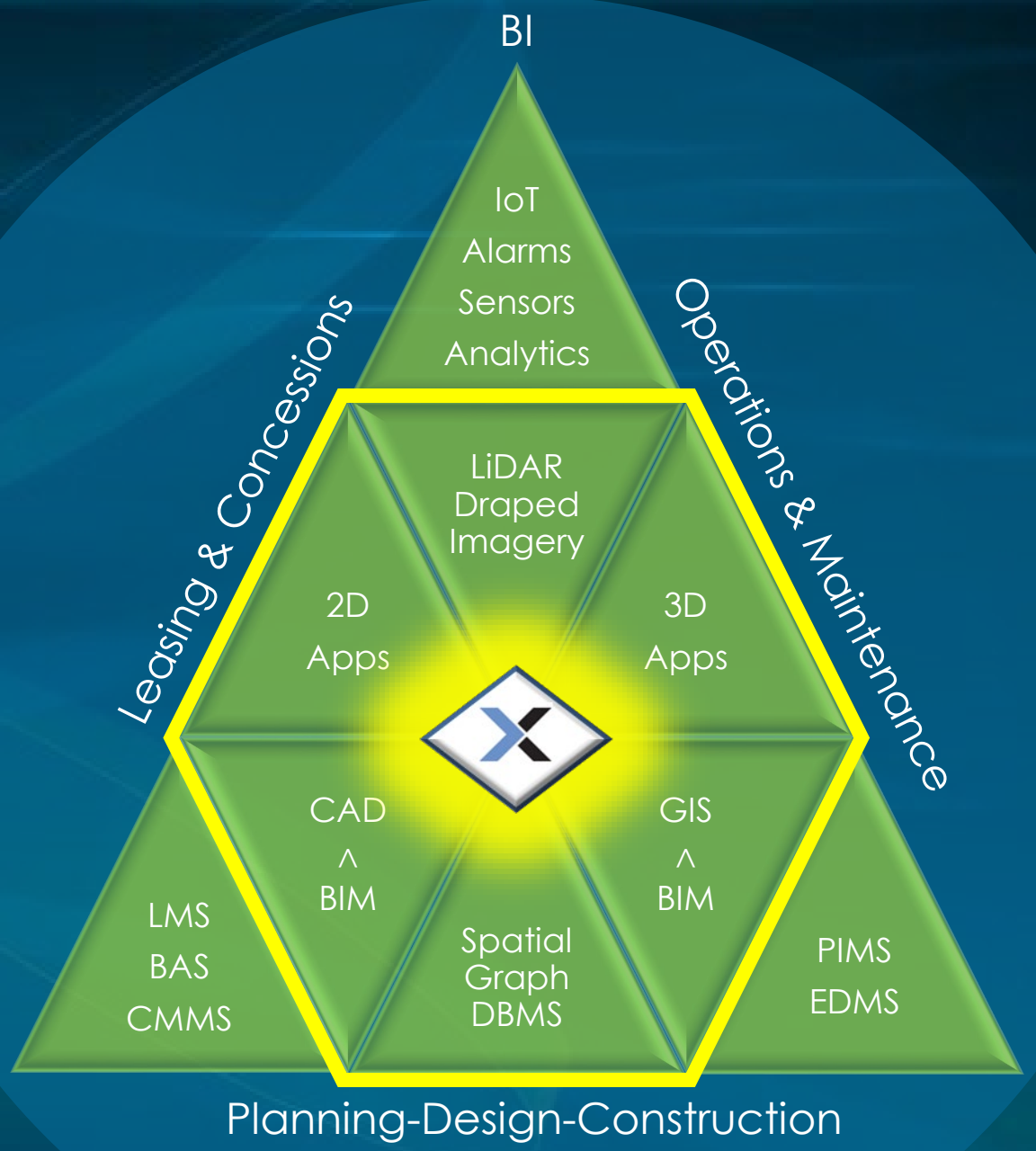
correlates DT components together

via common denominator

Spatial Database

key

to achieving DT



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DT & integration with other airport data

Spatial Data is Common Denominator

Enabling Spatial Correlation for Digital Twin

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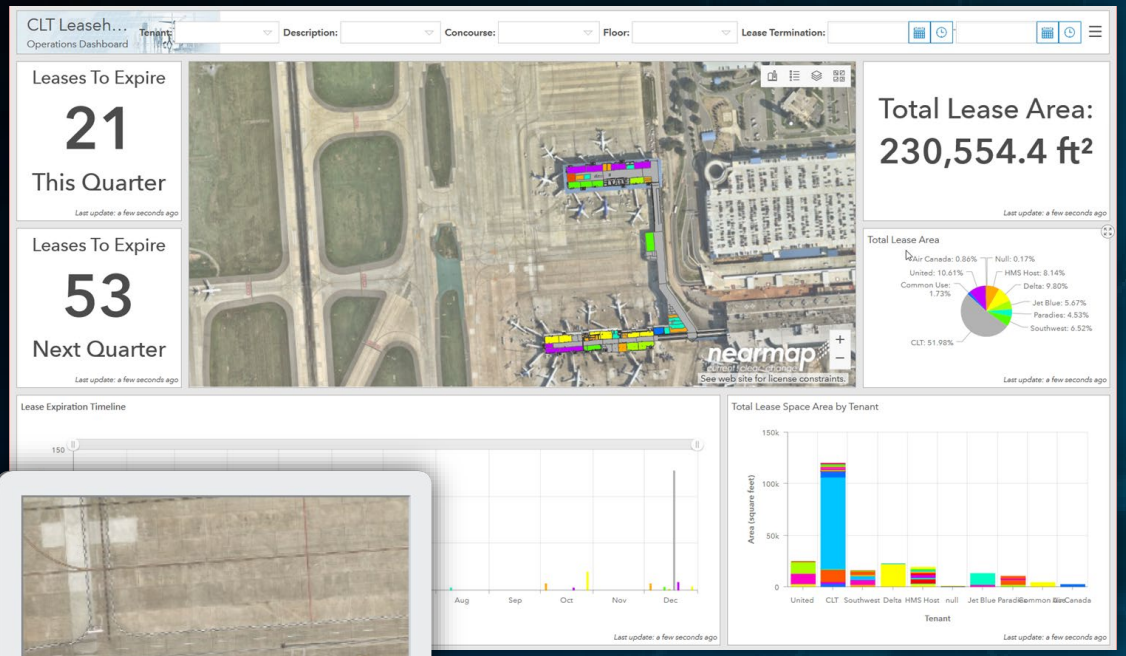
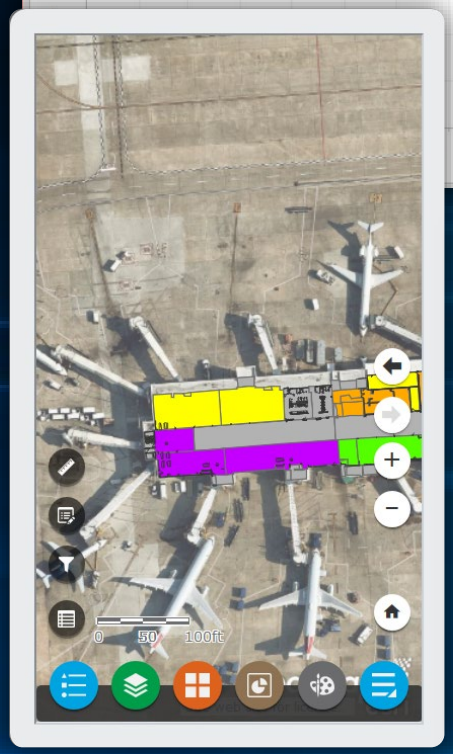
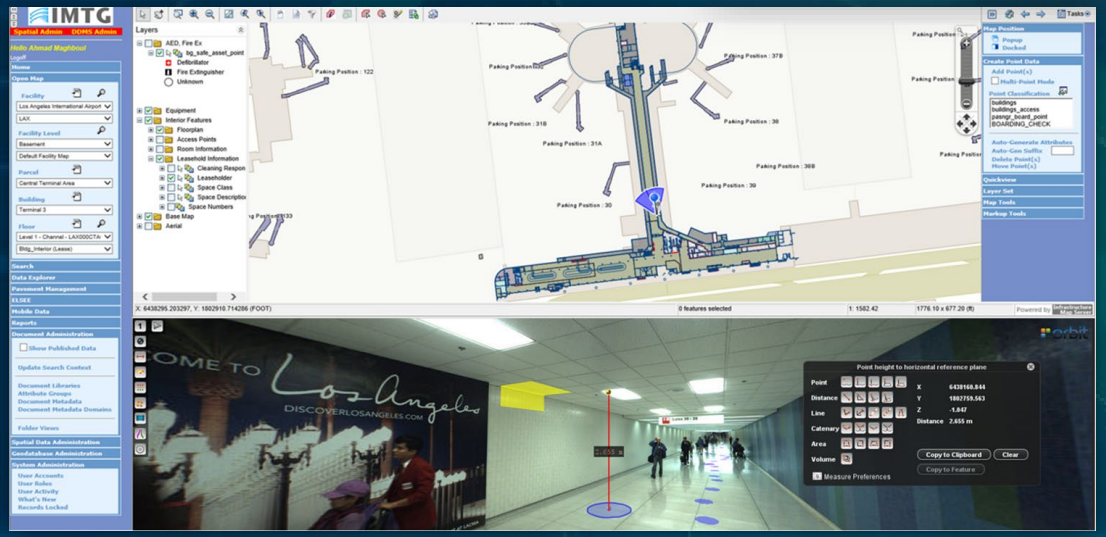
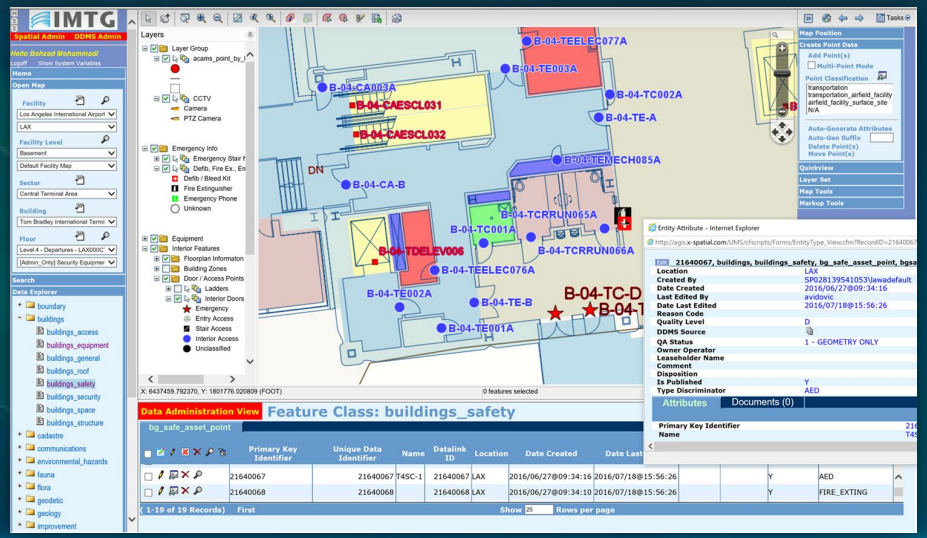
Spatial Correlation









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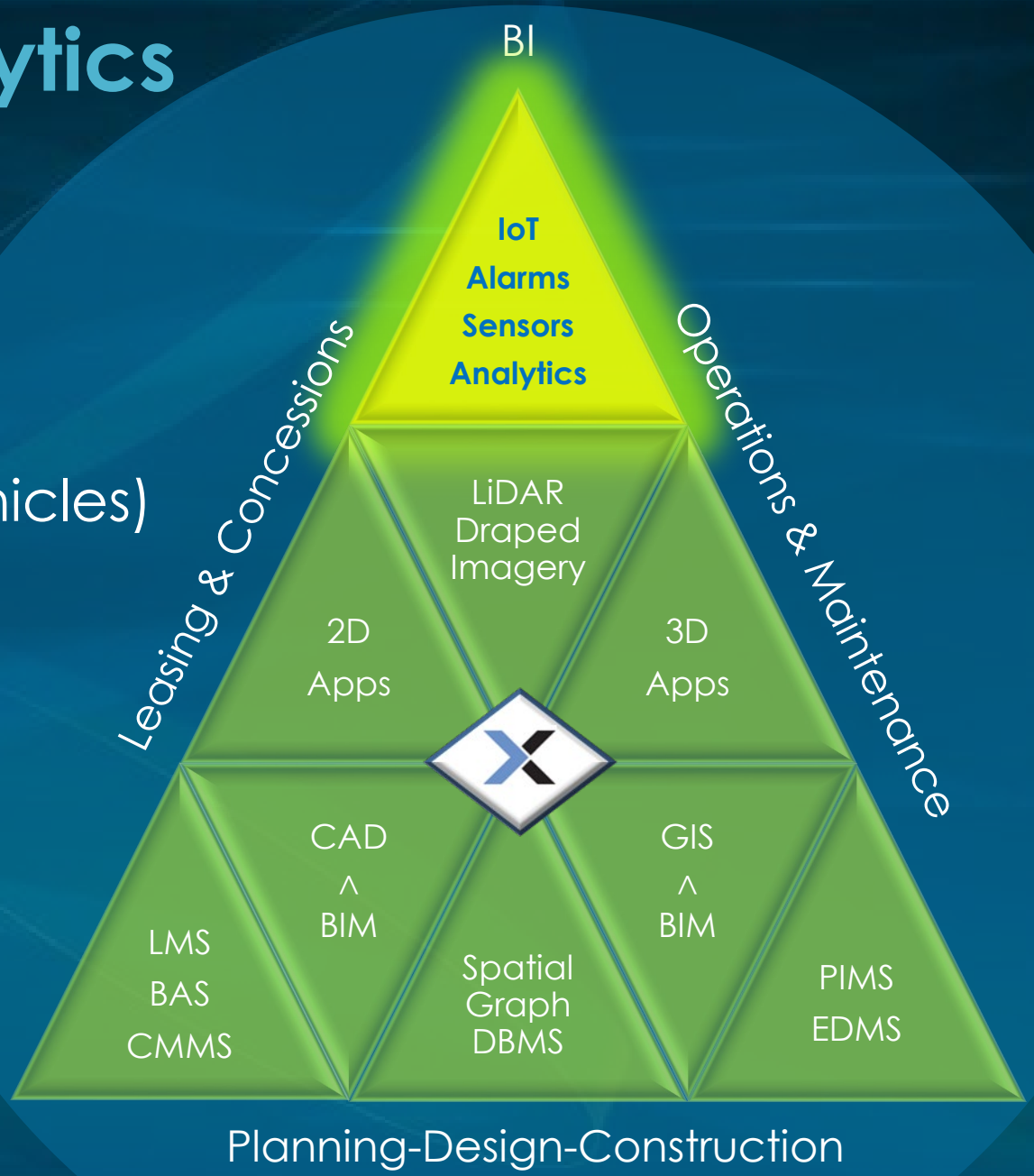
Examples of DT Data Fusion

- ALP & Floor Plans
- 3D LiDAR with Draped Imagery Outdoors & Indoors
- Airspace / AOA Traffic & NOTAMS
- Aircraft Gate Turn-Around Status
- On-Airport Roadways / Curbs
- Parking Garages / Lots Status
- People Movers Status
- Elevators / Escalators Status
- Ticket Counters Status
- Security Checkpoints Status
- PAX Congestion / Queues
- Bathrooms Status
- Alarms / Sensors / CCTV
- Incidents / Complaints
- Inspections / Issues / Weather
- Projects, Work Orders, Outages…

IoT Alarms - Sensors - Analytics

- Roadway Traffic
- Curb to Gate PAX Flux
- Security Checkpoint Wait Times
- AOA Movements (e.g., aircraft, vehicles)
- Aircraft Gate Turnaround
- Access Control Alarms
- Fire Alarms
- Restrooms Level of Service
- Trash-bins capacity
- etc…



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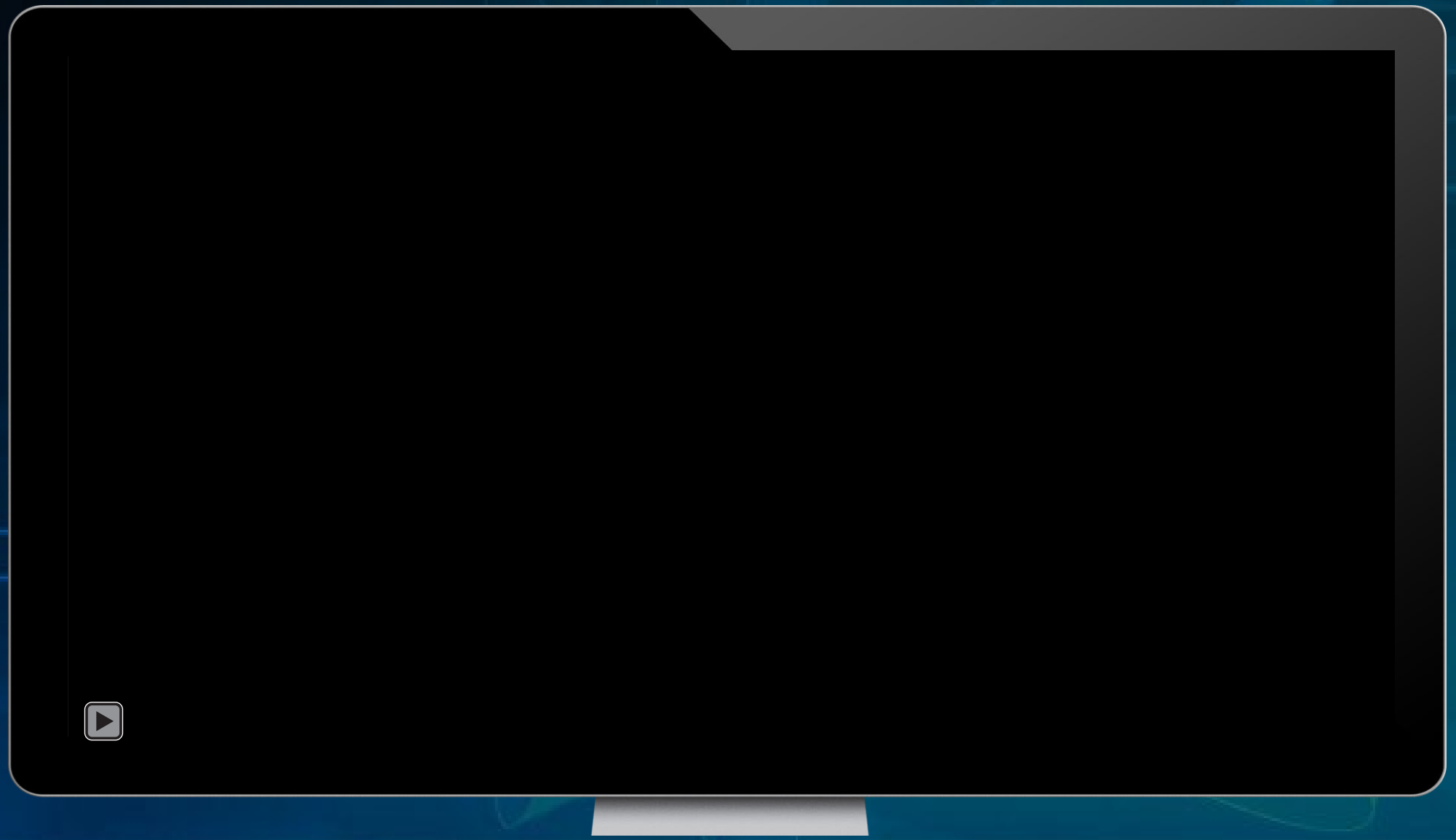
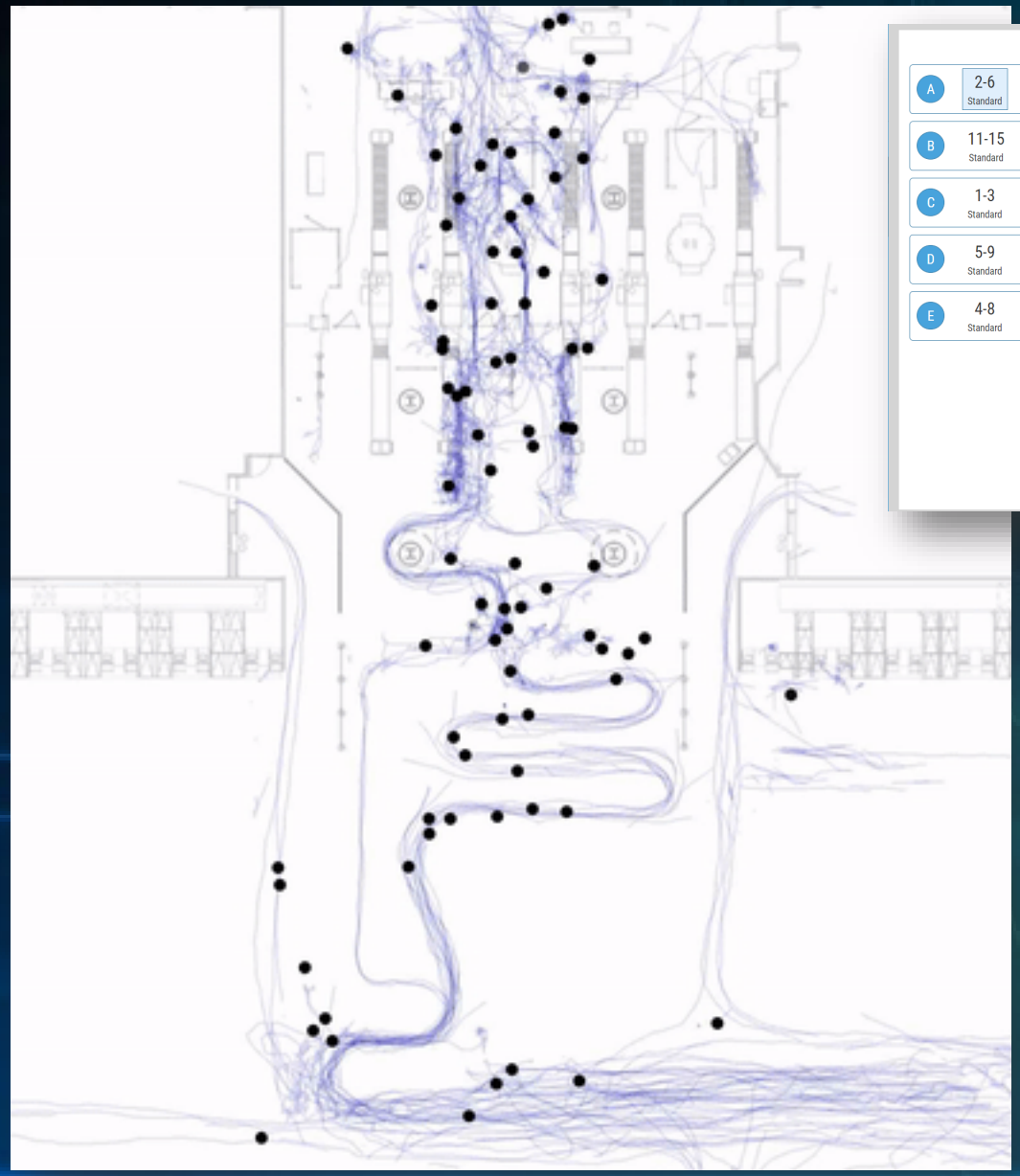
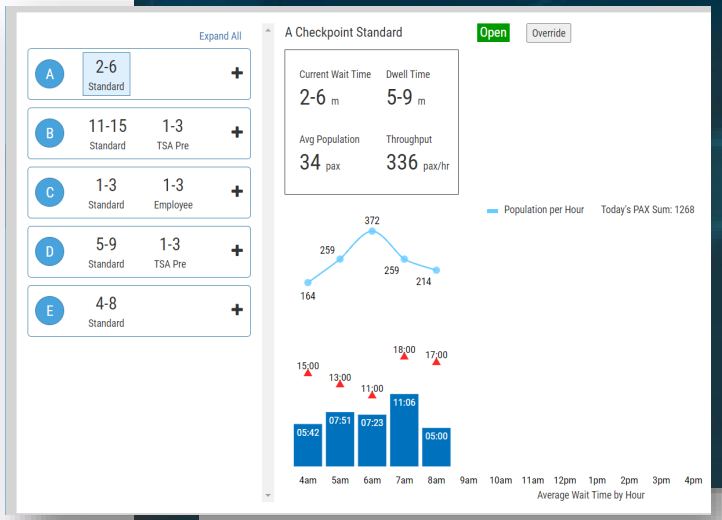
Leveraging CCTV Machine Vision & Analytics



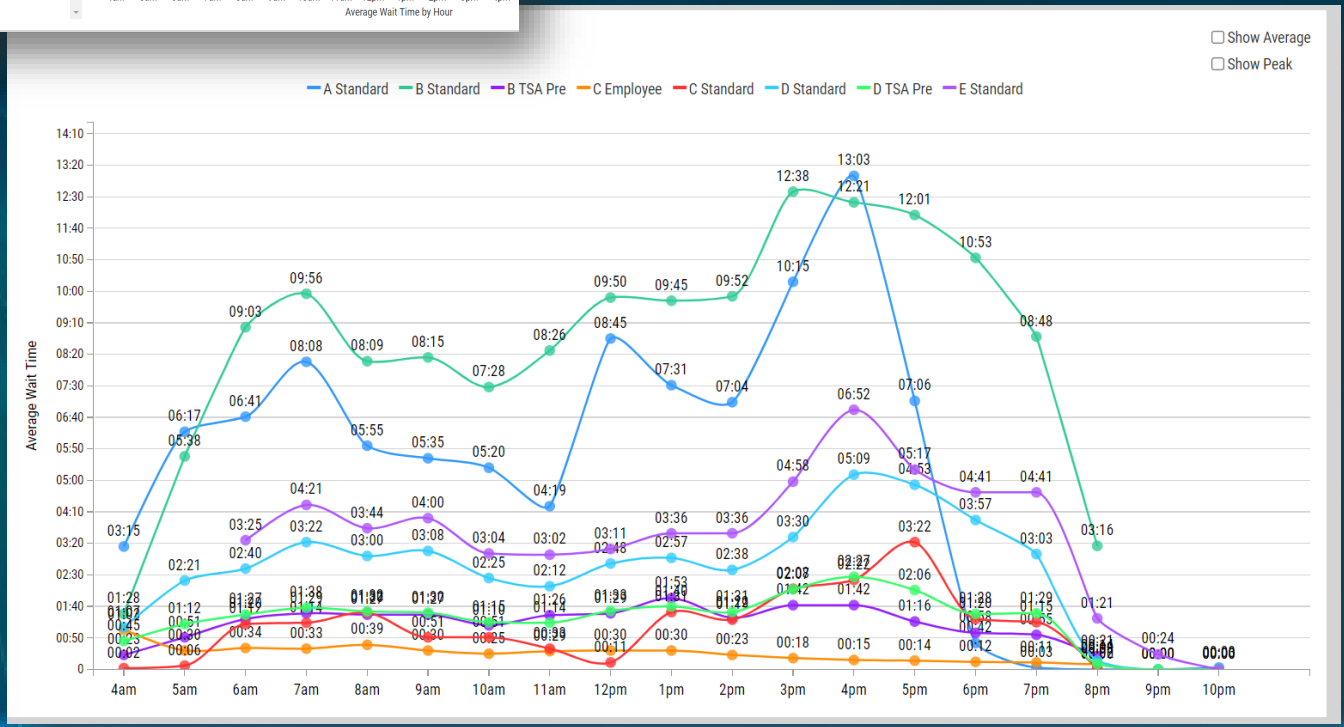
Courtesy
of Intell Act

Leveraging PAX Movement Sensors & Analytics



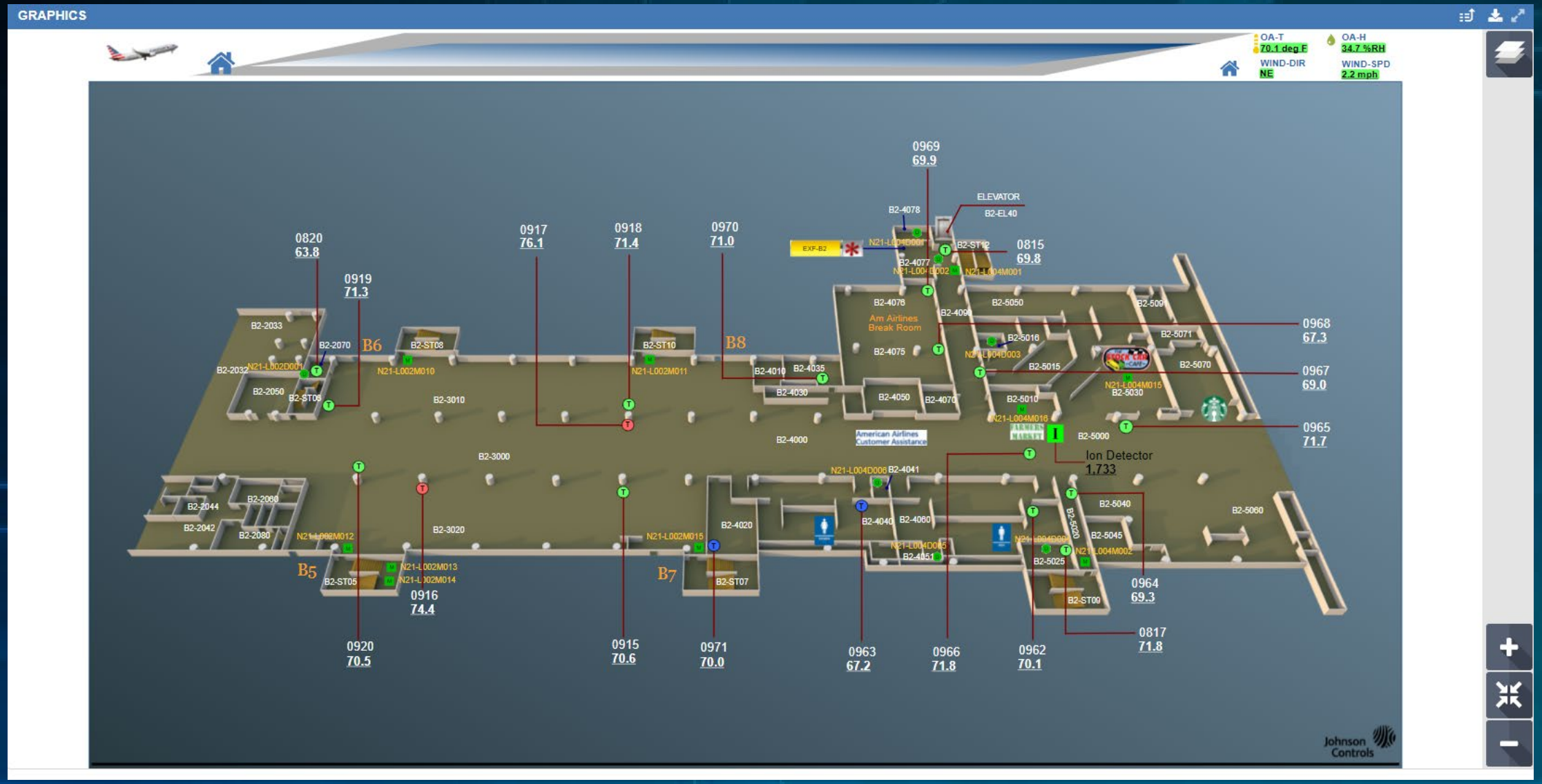


Courtesy of CLT & Skyfii (Crowdvision)



Leveraging Building Sensors & Alarms

Courtesy of CLT & Johnson Controls (Metasys)



Real-Time Sensor Overlay

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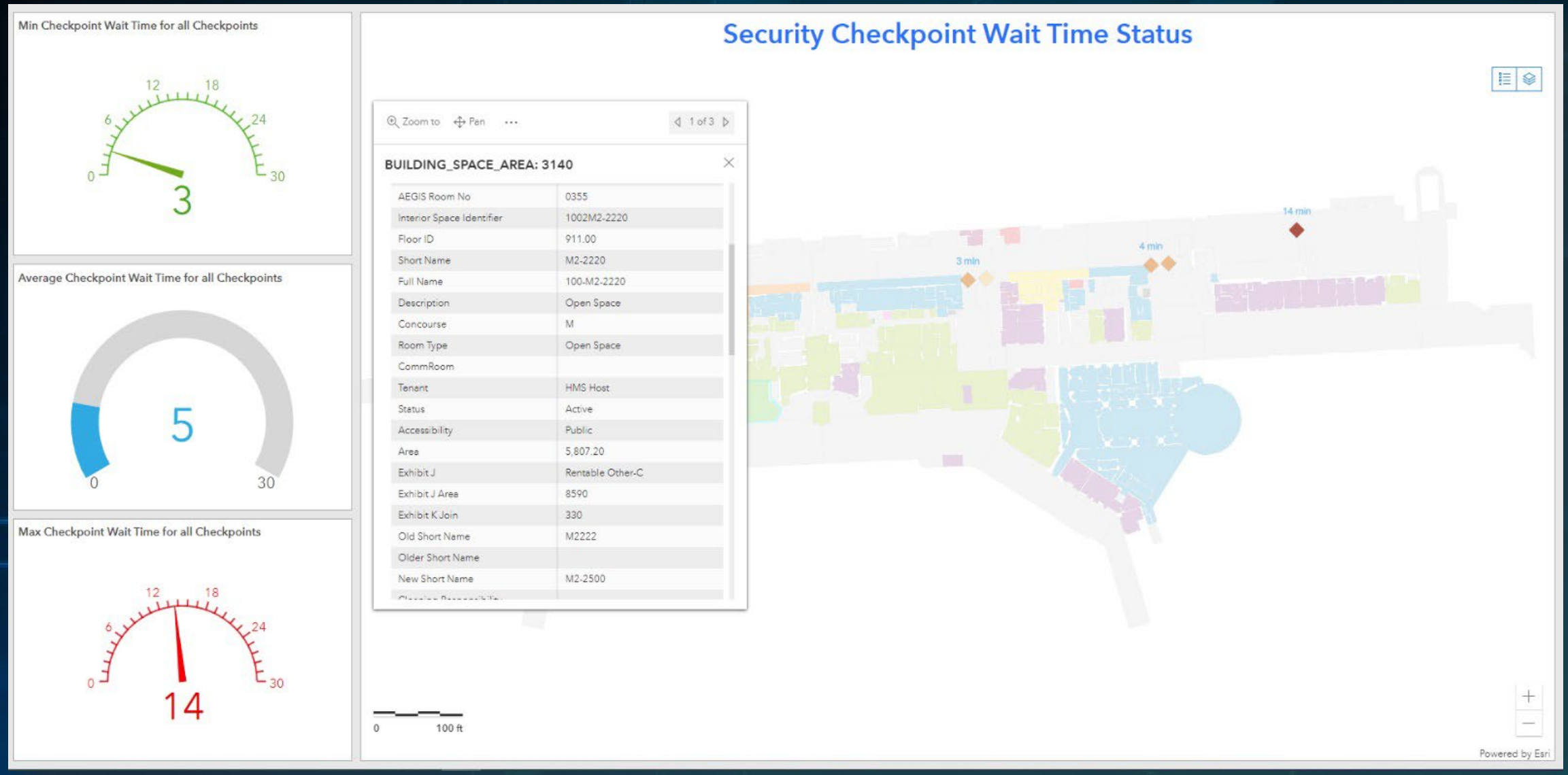
Real-Time Sensor Overlay



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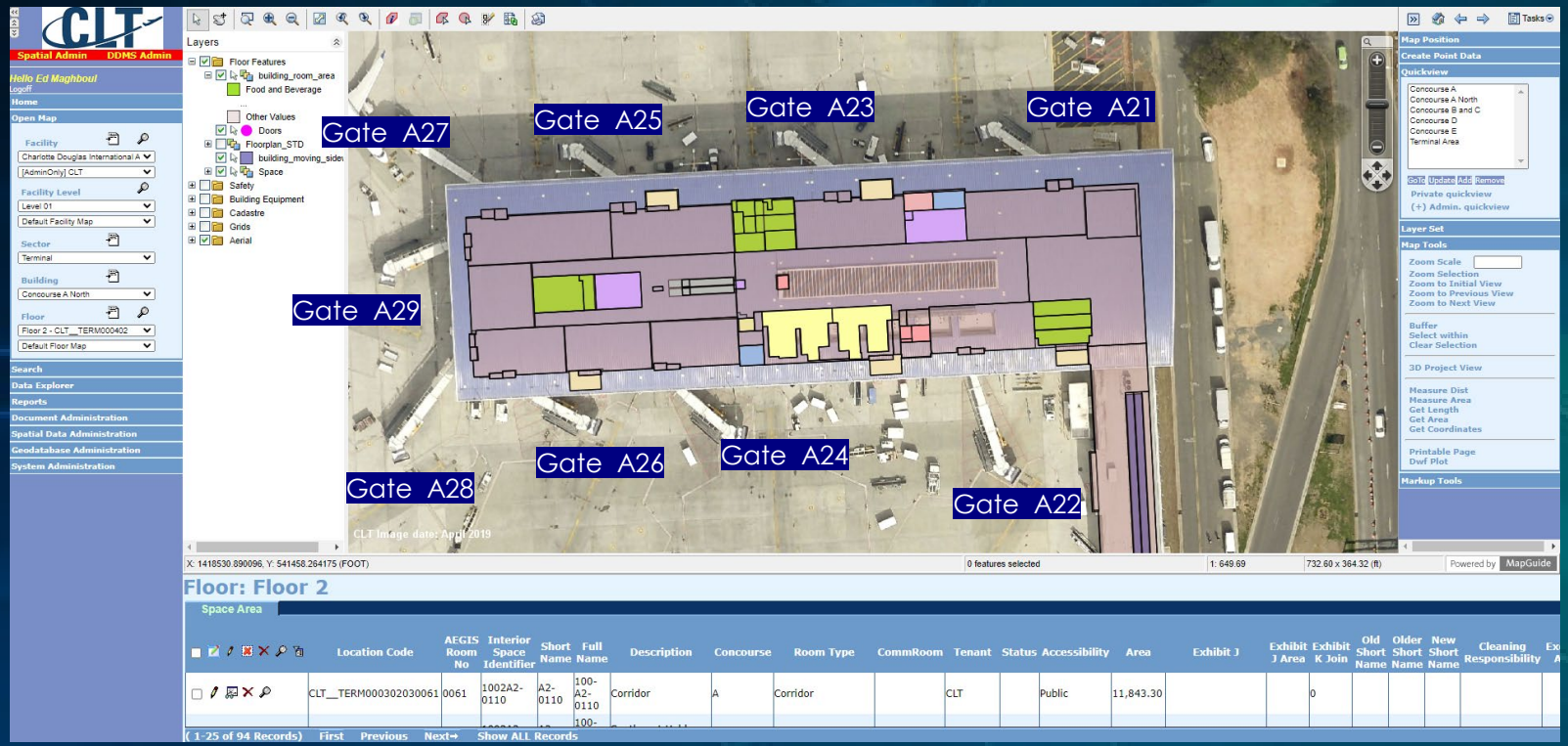
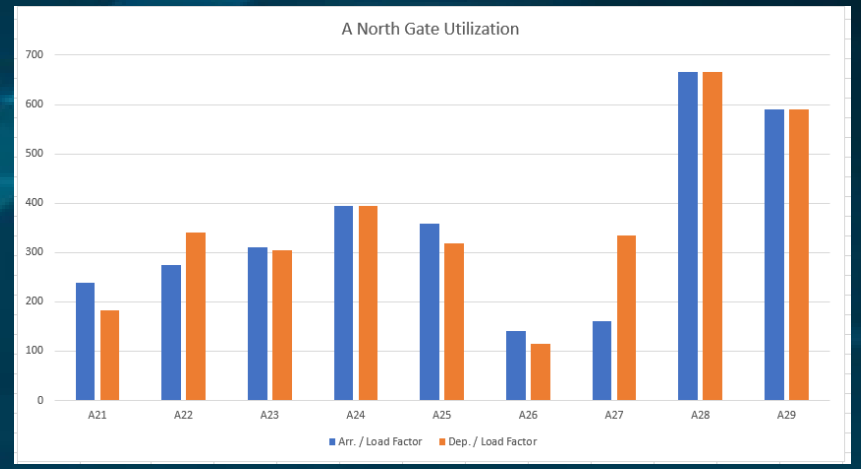
AODB Integration – Passenger flow modeling

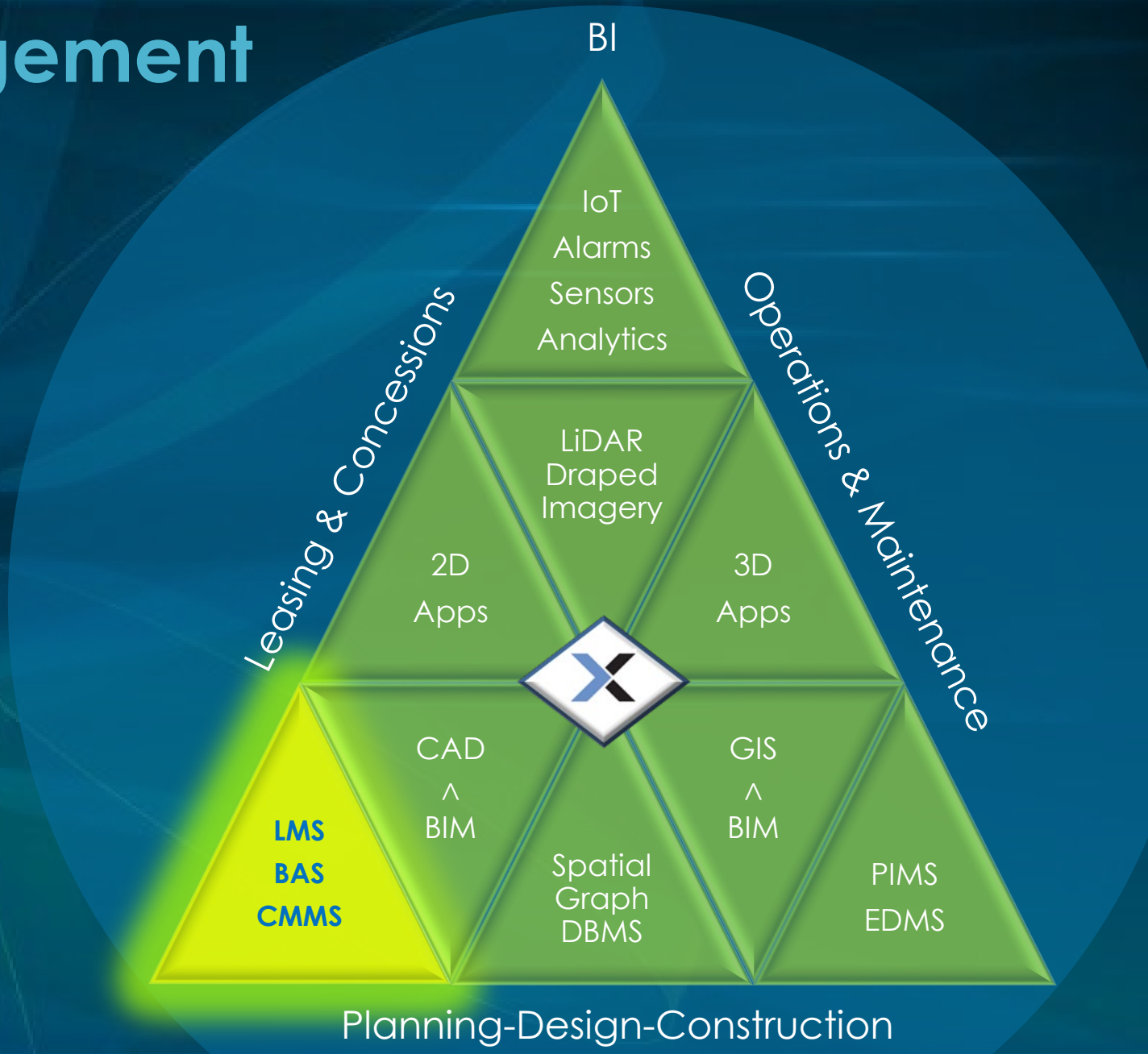




A North		
Number of gates	9	
Arrival		
Total Available Seats		3914
Load Factor		80%
Number of passengers		3131
Departure		
Total Available Seats		4056
Load Factor		80%
Number of passengers		3245

Enterprise Asset Management

- Leases & Concessions
- Building Automation
  - SCADA (HVAC/Electrical)
    - HVAC
    - Electrical & Lighting
  - People Movers
    - Escalators
    - Elevators
    - Moving Sidewalks
    - APMS
  - Jet Bridges
- Work Orders
- Condition Assessments



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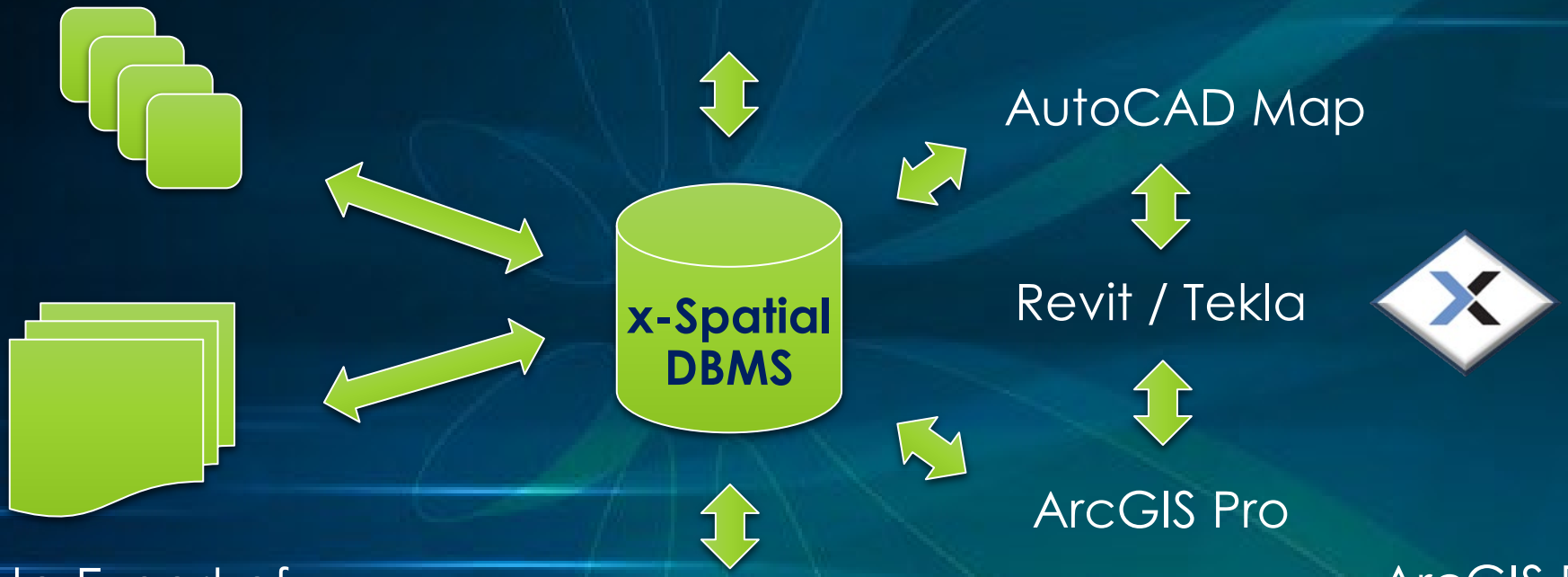
x-Spatial DBMS Interoperability

Digital Twin

x-Spatial Apps

Web & Mobile User Interfaces



x-Spatial is the "Glue" between Autodesk + esri

Auto-Export of Standardized CAD-GIS Files (e.g., NCS, ANSI)

Seamless Export of Geodatabase Supporting 3rd Party Products & Apps

- ArcGIS Portal / Online
- ArcGIS Dashboards
- Maximo / Infor / Cityworks
- Simplify i3
- etc…

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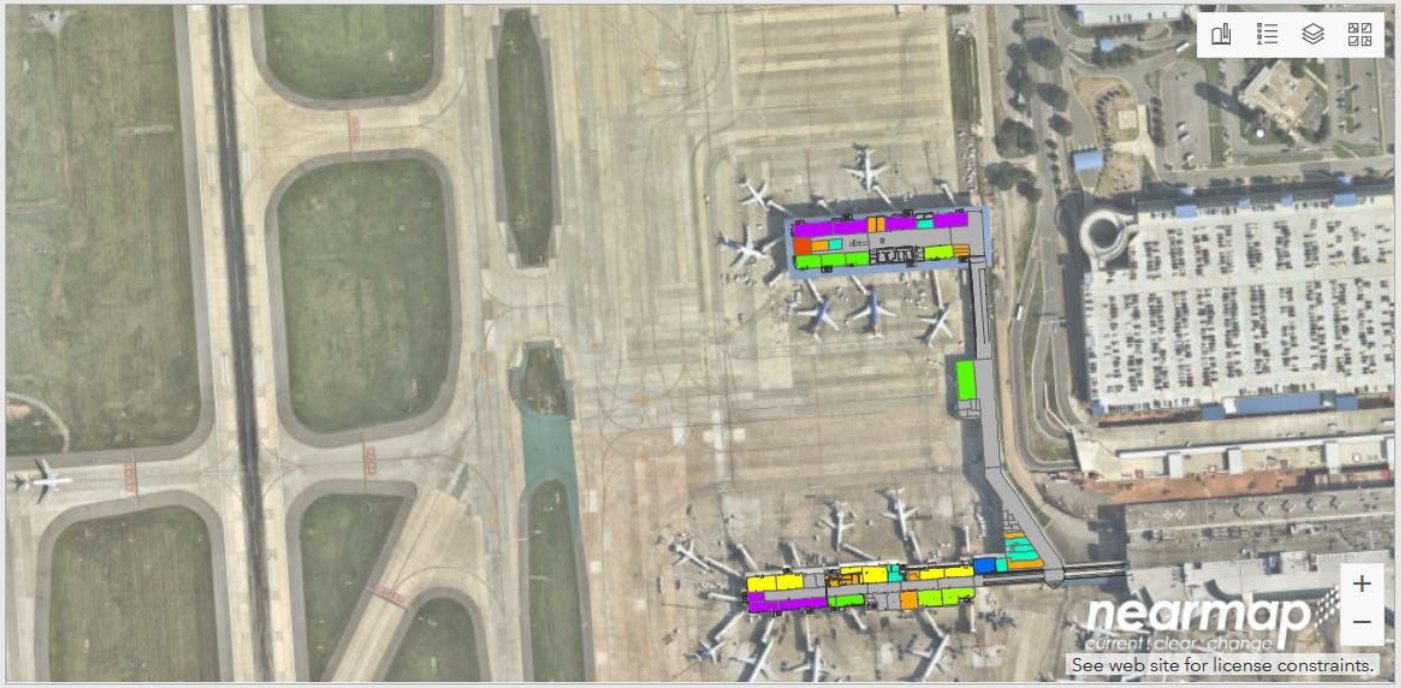
Analytics Dashboards

CLT Leaseh…
Operations Dashboard

Tenant: | Description: | Concourse: | Floor: | Lease Termination:

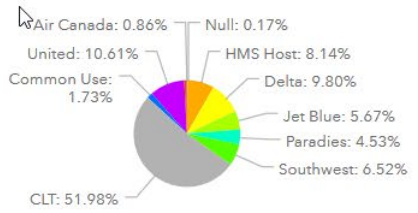
Leases To Expire
21
This Quarter
Last update: a few seconds ago

Leases To Expire
53
Next Quarter
Last update: a few seconds ago



Total Lease Area:
230,554.4 ft²
Last update: a few seconds ago

Total Lease Area



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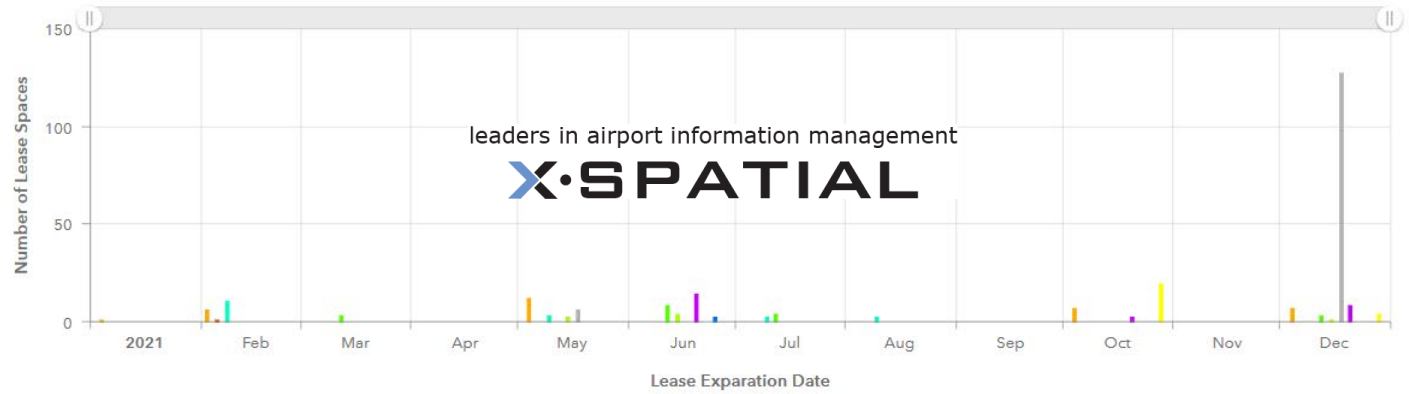
Lease Expiration Timeline



leaders in airport information management
X·SPATIAL

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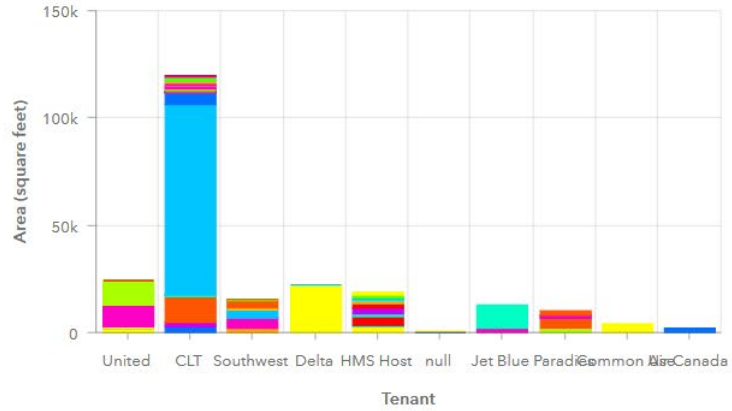
Total Lease Space Area by Tenant



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Space & Lease Mgm't ArcGIS Dashboard

Rooms at CLT Operations Das...
X-Spatial

Tenant: | Description: | Concourse: | Expire:

Total Room Area:
230,554.4 ft²

Last update: a minute ago

Leases to Expire

This Quarter:

21

Next Quarter: 53

Last update: a minute ago

1/4 | Year

Map Legend

FloorPlan

Rooms

- <Null>
- Air Canada
- CLT
- Common Use
- Delta

Lease Exparation Timeline

Last update: a minute ago

leaders in airport information management

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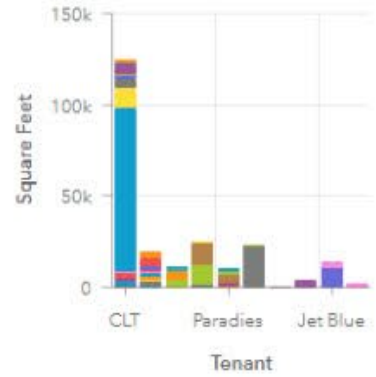
Area by Tenant and Room Description



Last update: a minute ago

Bar | Pie

ArcGIS On-Line Web Lease Management

leaders in airport information management
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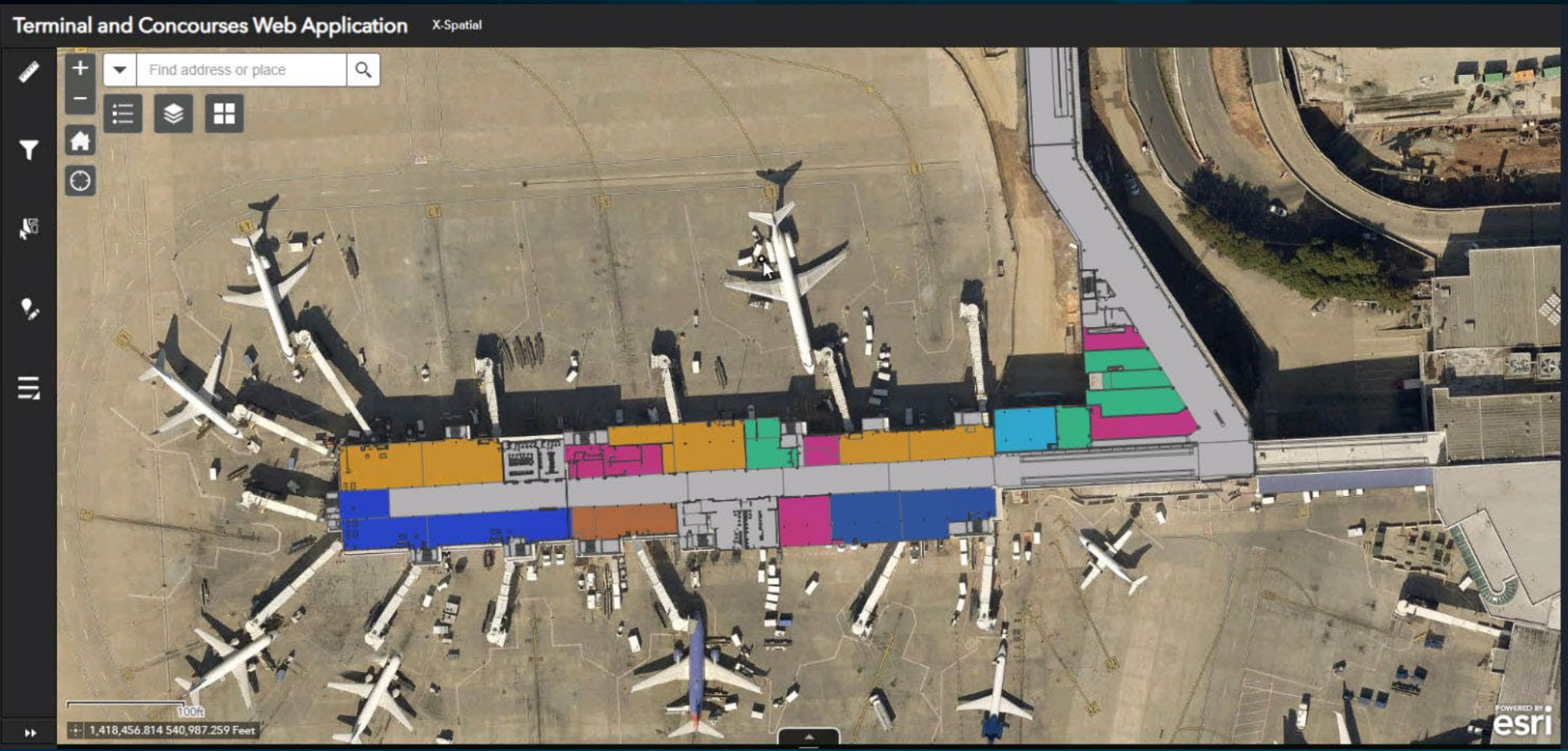

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ArcGIS On-Line Web Lease Management

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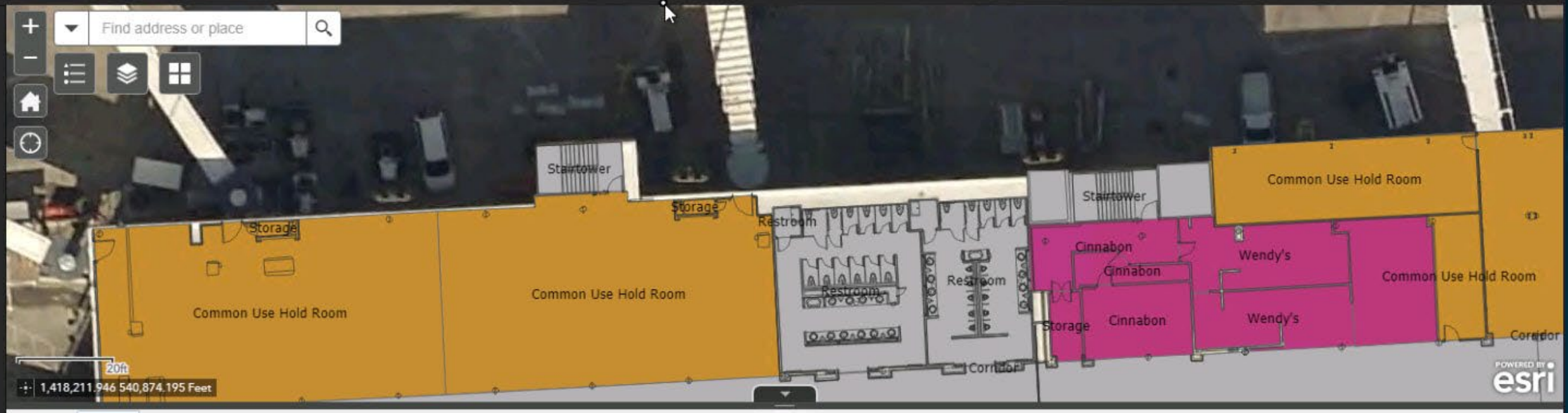
Terminal and Concourses Web Application X-Spatial



FloorPlan | Rooms

Options | Filter by map extent | Zoom to | Clear selection | Refresh

LeaseTermination	Tenant	Description	OBJECTID_1	A_LOC_ID	Location Code	AEGIS Room No	Interior Space Identifier	Short Name	Full Name	Concourse	Room Type	CommRoom	Status	Access
December 31, 2021	CLT	Mechanical Chase	96	CLT__TERM00030	CLT__TERM00030	2.000000	1002A2-MC07	A2-MC07	100-A2-MC07	A	Mechanical Chase	A1483	Active	Private
October 1, 2021	HMS Host	Common Use Hold Room	104	CLT__TERM00030	CLT__TERM00030	10.000000	1002A2-0420	A2-0420	100-A2-0420	A	Hold Room	A1483	Active	Private

48 features 0 selected

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ArcGIS On-Line Web Lease Management

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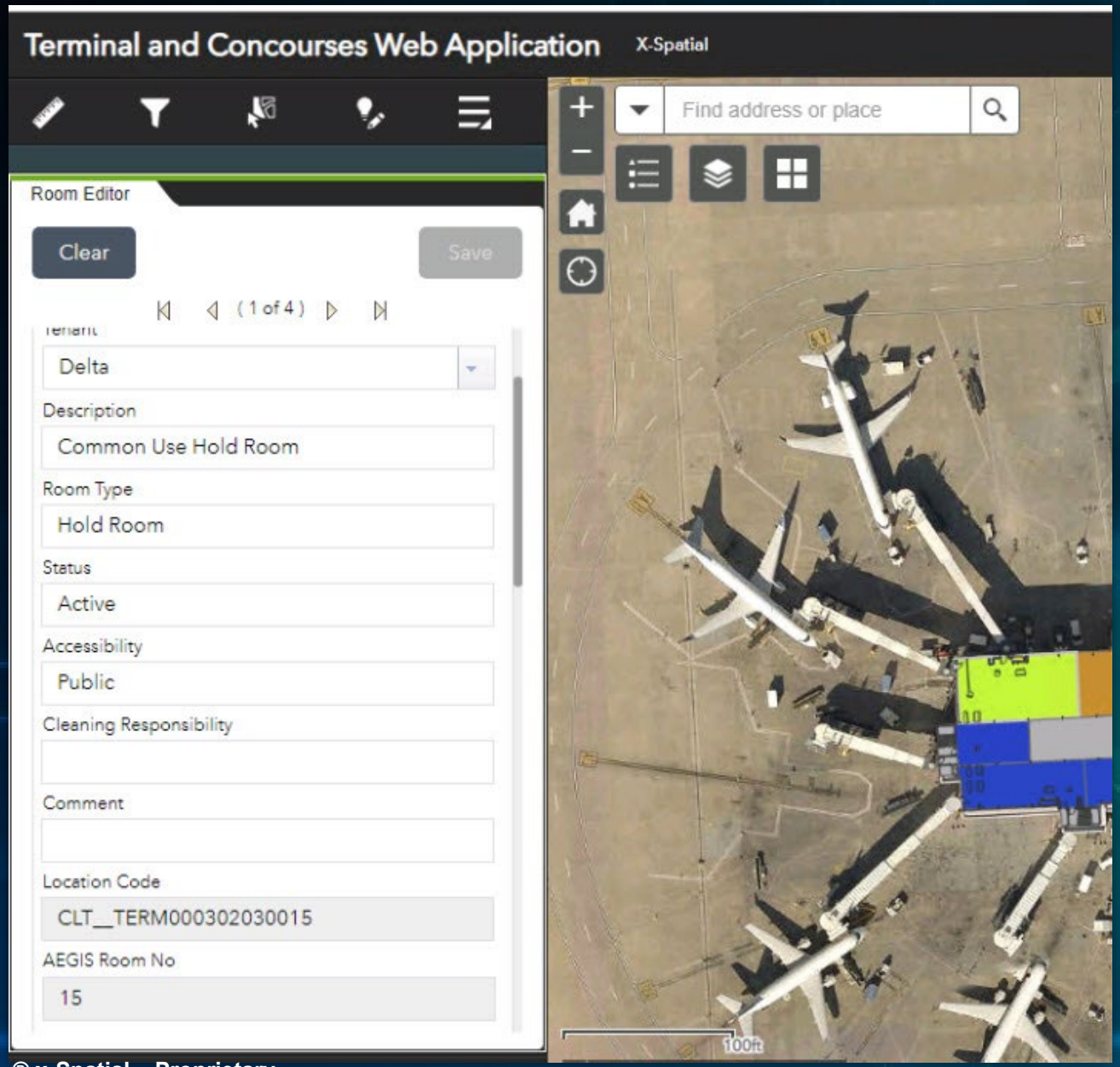

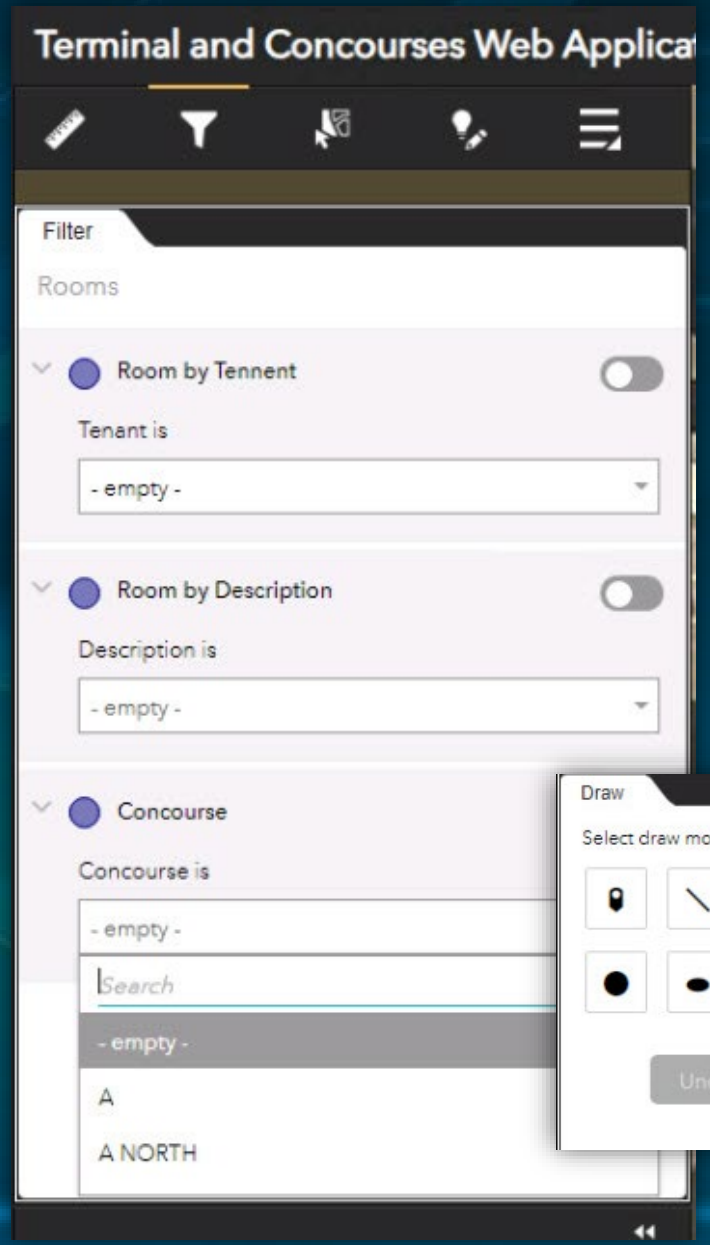

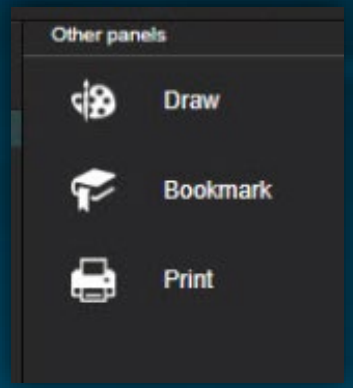

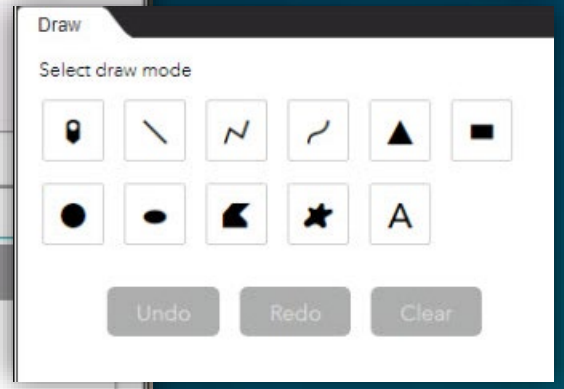

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Lease Exhibit Print/Output via Web App

leaders in airport information management
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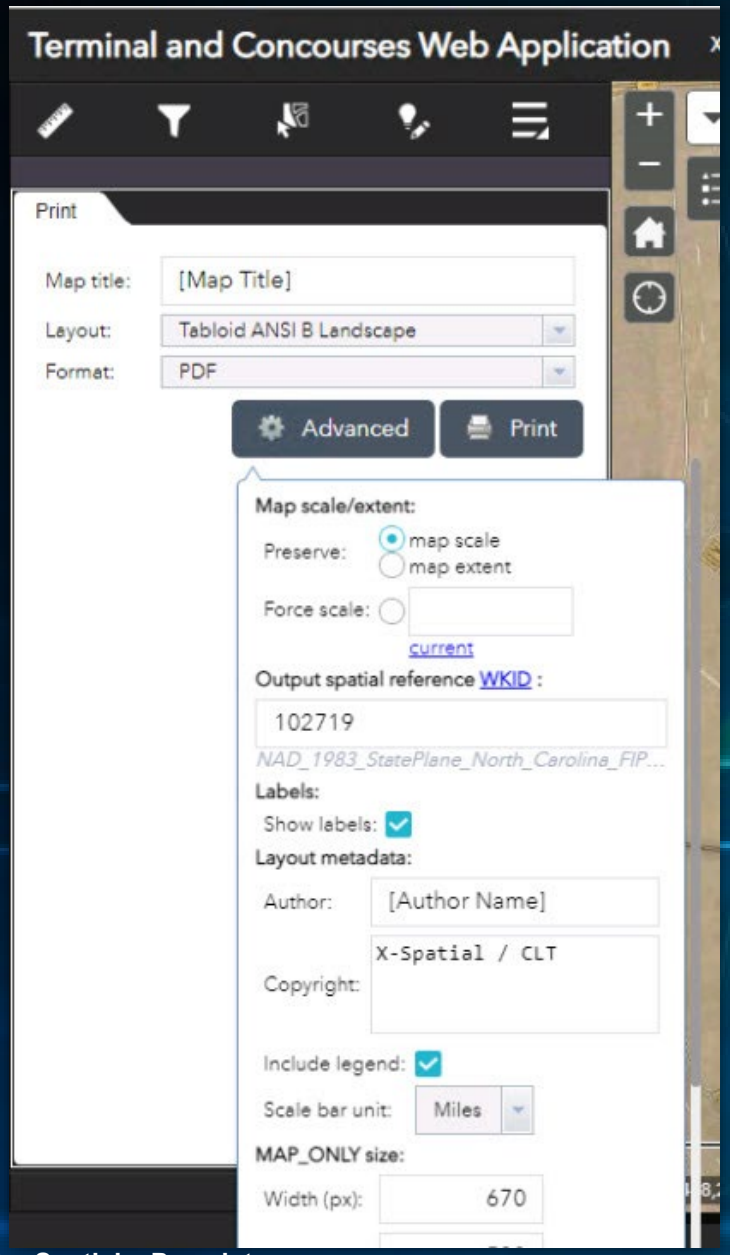

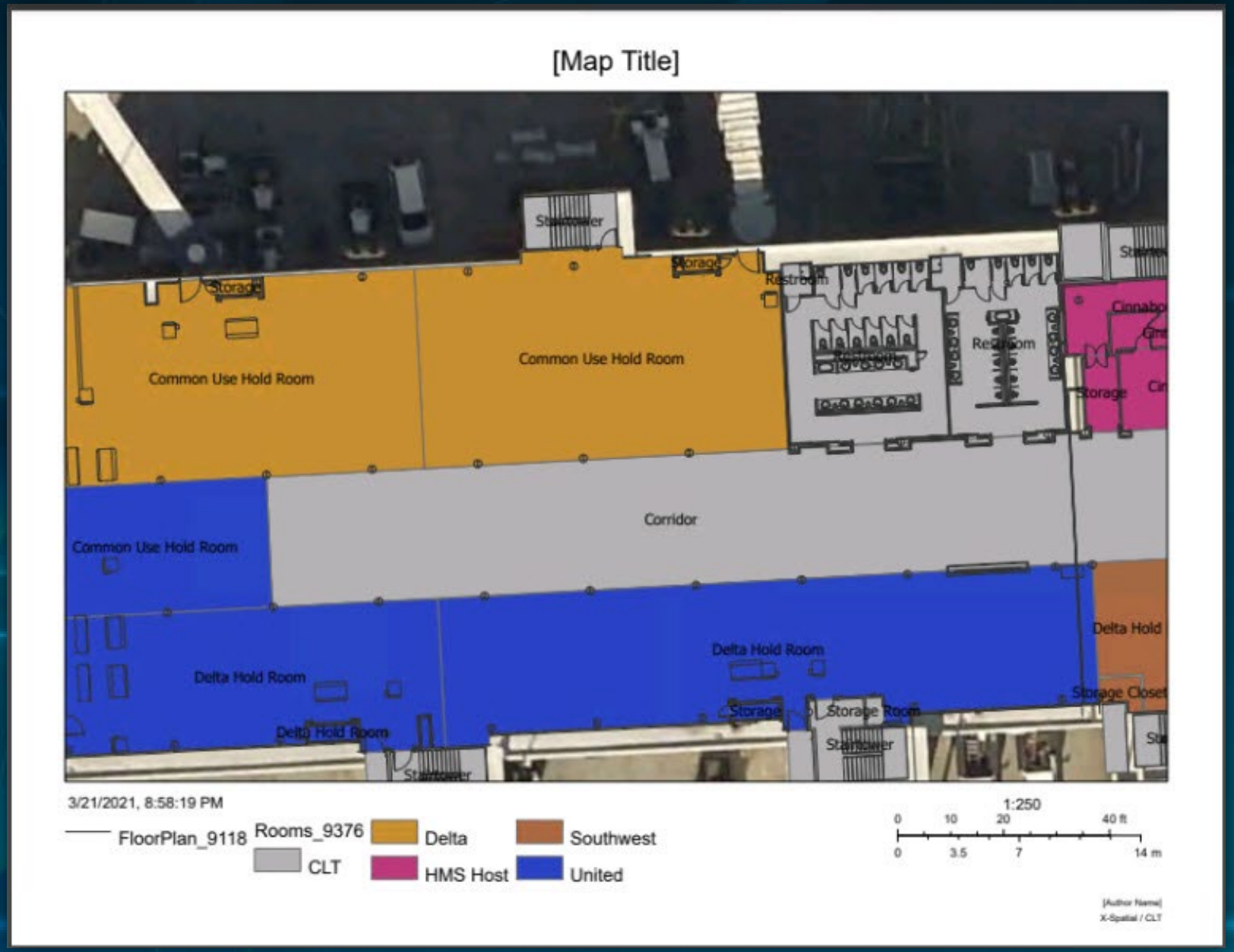

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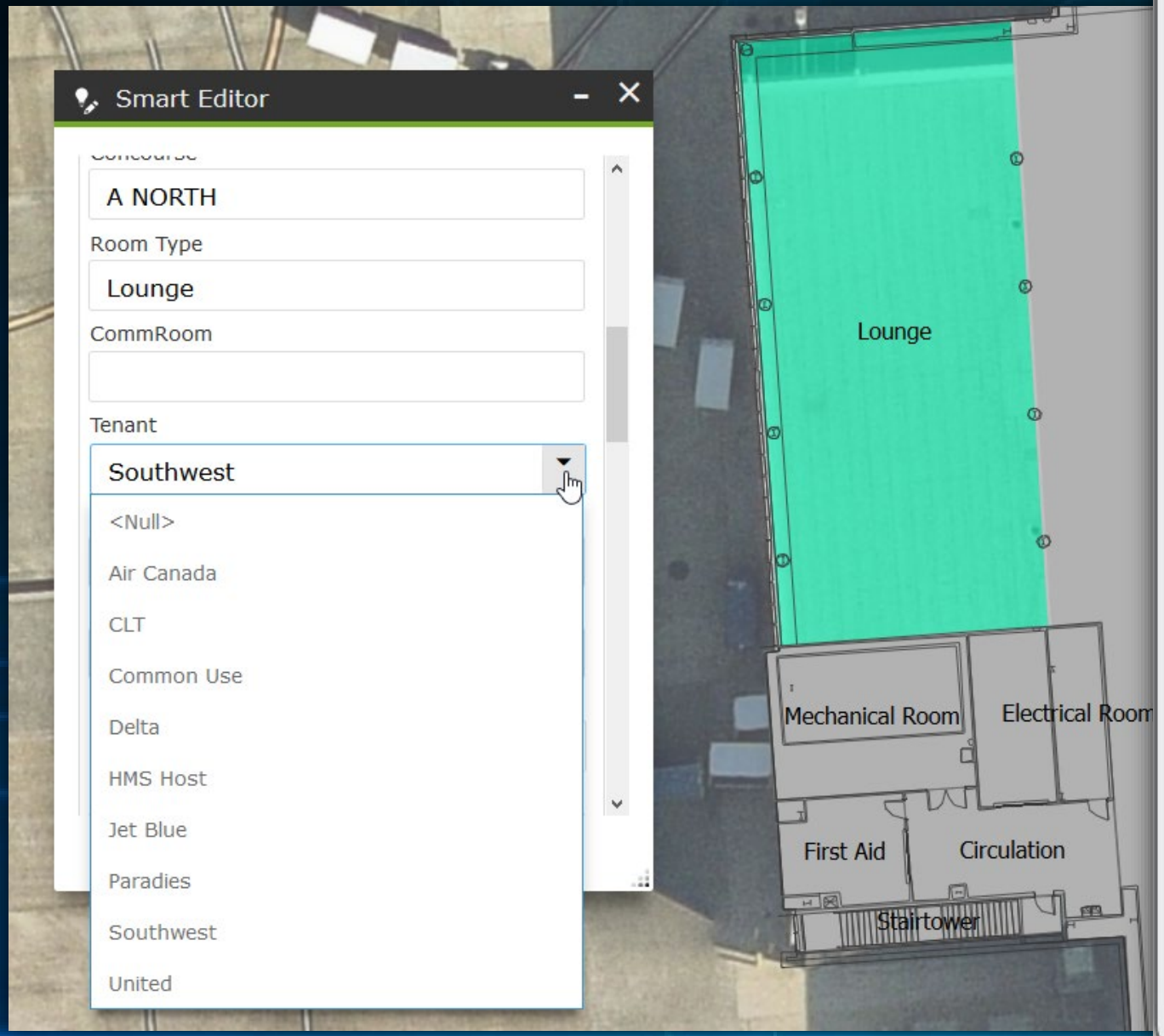
Mobile View & Edit



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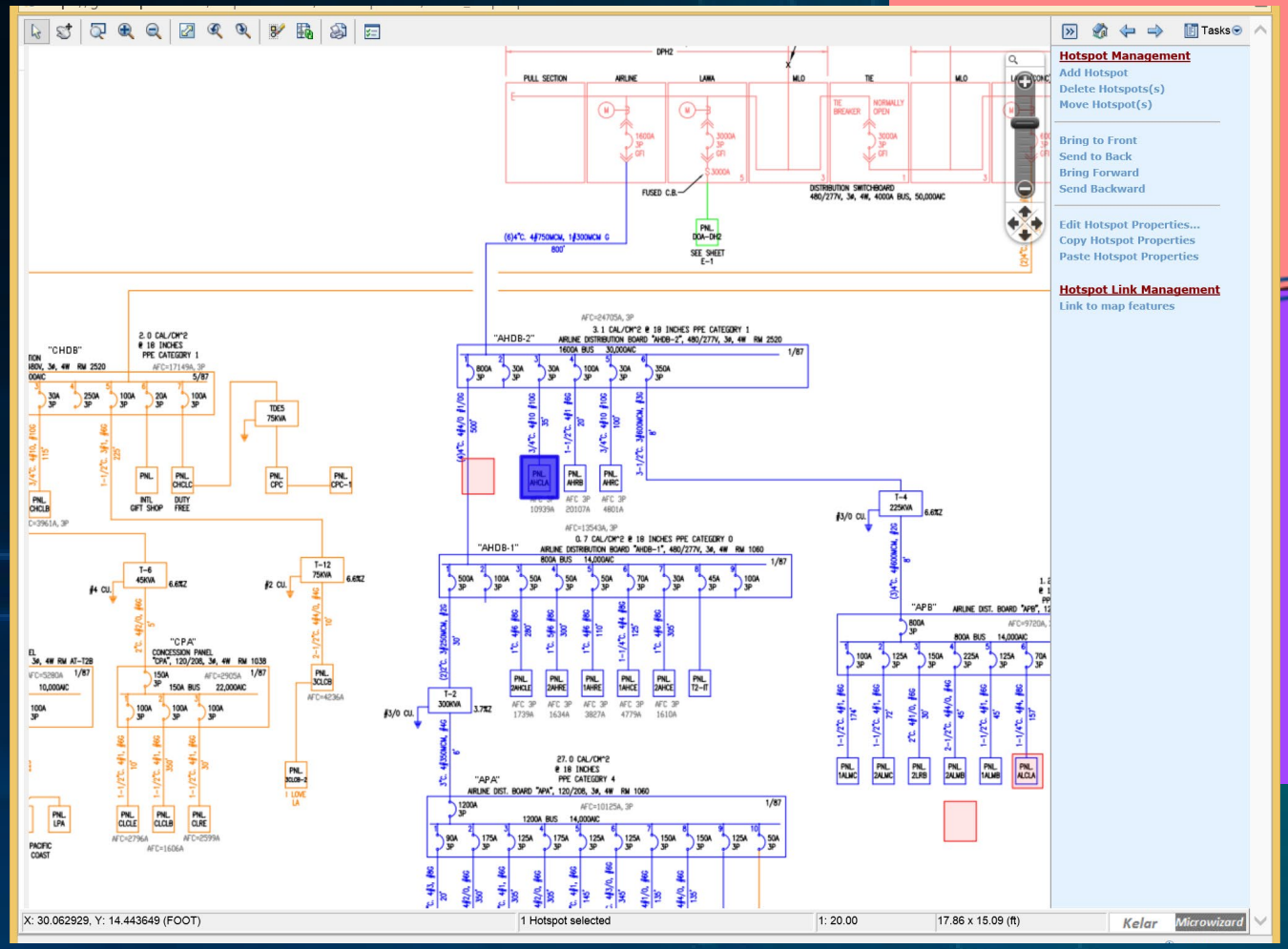
Asset Linked Drawings & Documents

Mapped Electrical Panels with 2-Way Hyperlinked One-Line Diagrams



1

Datalink ID: 11954082
Entity Type Name: electrical_panel_area
Type Discriminator: NORMAL_PWR
DDMS Source: 2021515
Comment: AHCLA
Panel Name: AHCLA
Related Documents (first 20):
: 2021511_AHCLA_1. T2 Equip Assessment Report 2009-11-01 342.pdf
Hyperlinked Drawings:
20060029A-11-E03 - Panel AHCLA (4)
20060029A-12-E04 - Panel Sch AHDB - AHCLA (3)

2

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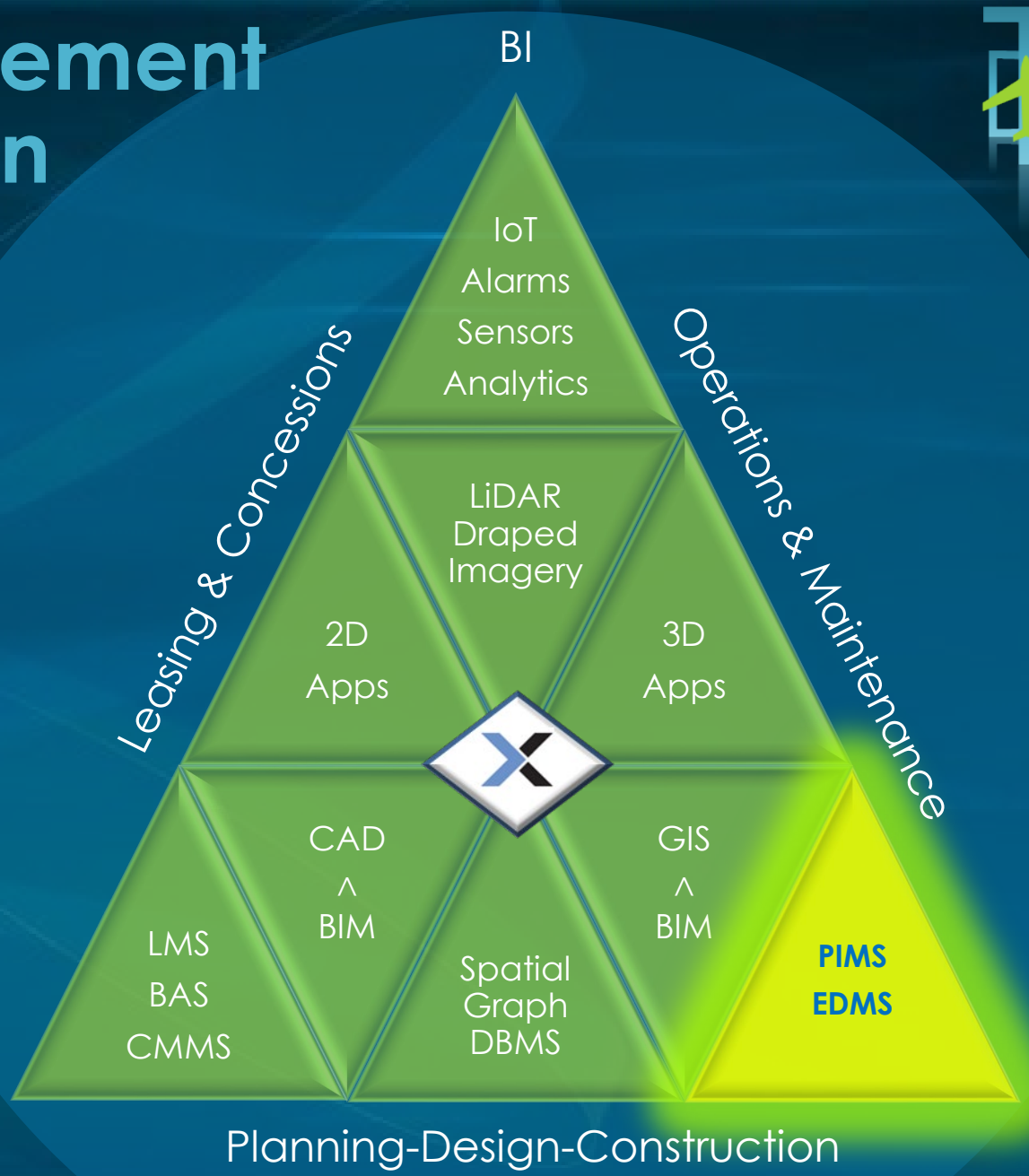
Project Information Management & Electronic Documentation

- ALP Change Requests / 7460s
- Construction/O&M Logistics
  Outage Coordination
- Construction Photos
- LiDAR Scans & Survey Data
- ORAT
- As-Builts / O&M Manuals
- etc…



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Integrated BIM Deliverables

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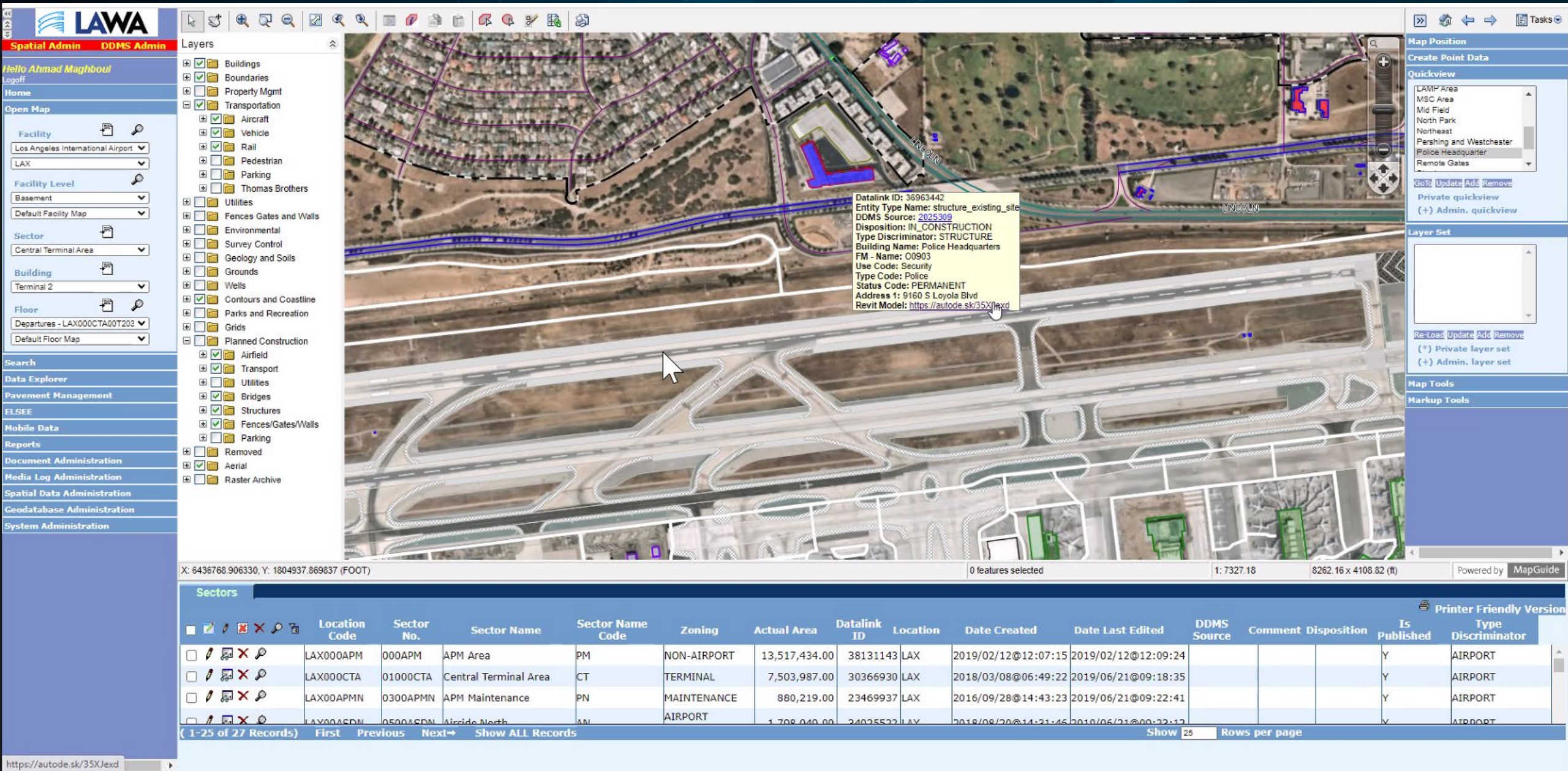

Web-enabled BIM Viewing

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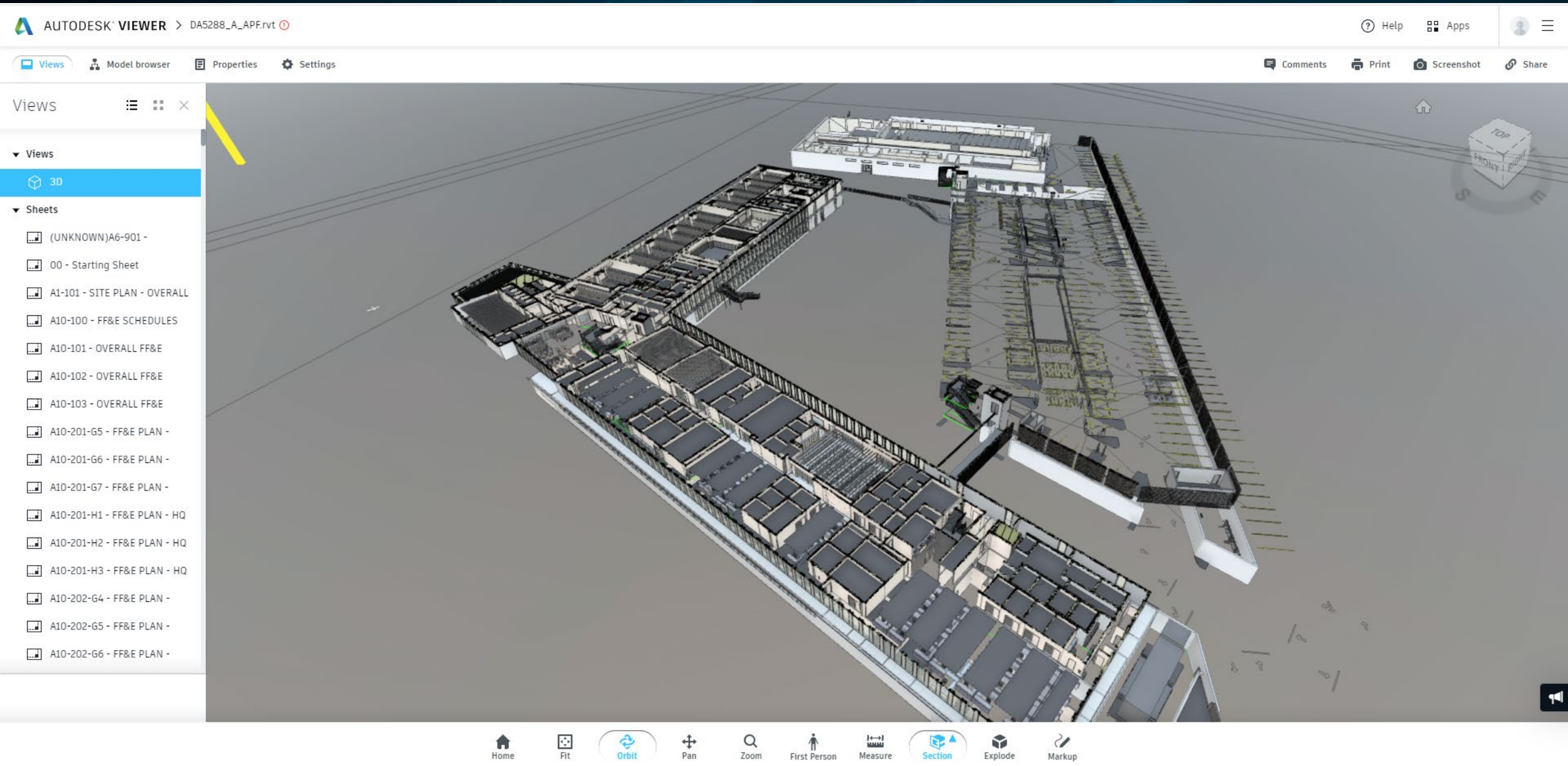

Web-enabled BIM Viewing

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BIM Exported Drawing Sheet Viewing

X·SPATIAL

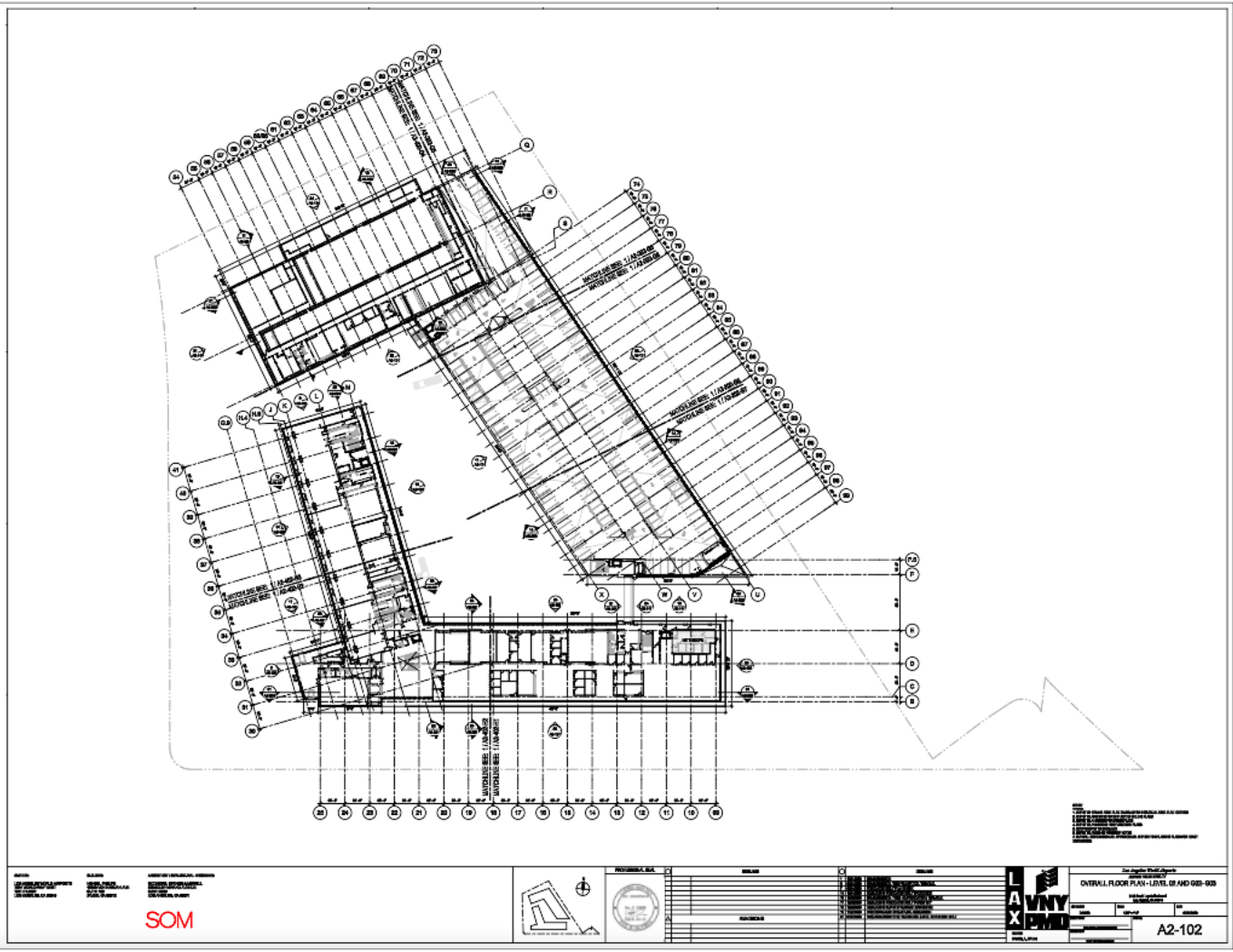
AUTODESK VIEWER > DA5288_A_APF.rvt

Help Apps

Views Properties Settings Comments Print Screenshot Share

Views

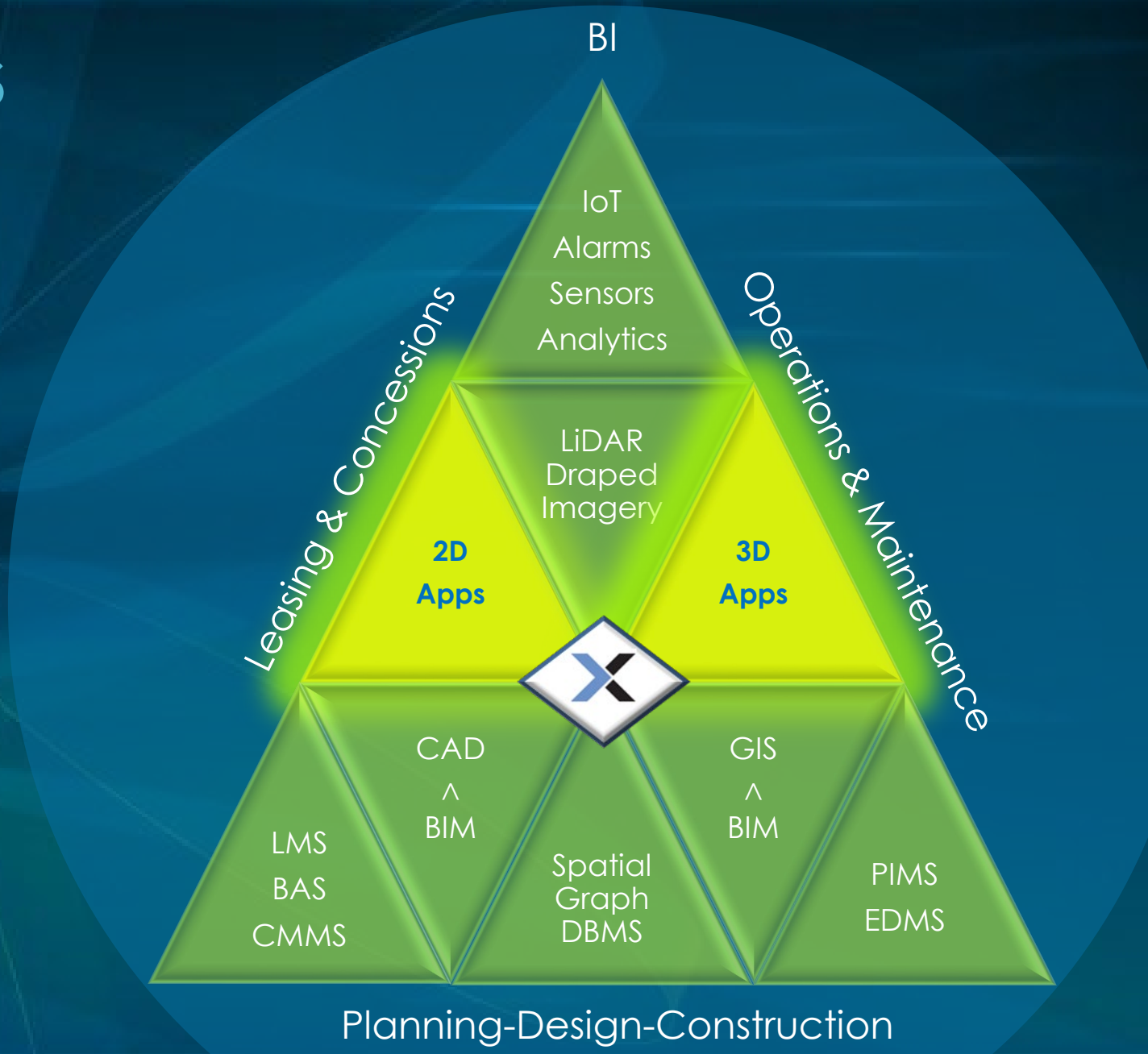
- A2-044 - ENCLOSURE TYPE
- A2-045 - ENCLOSURE TYPE
- A2-051 - OPEN GARAGE
- A2-061 - HQ BUILDING AREA
- A2-062 - GARAGE AREA
- A2-063 - HQ BUILDING AREA
- A2-064 - GARAGE AREA
- A2-065 - HQ BUILDING AREA
- A2-066 - GARAGE AREA
- A2-067 - HQ BUILDING AREA
- A2-068 - GARAGE AREA
- A2-101 - OVERALL FLOOR
- A2-102 - OVERALL FLOOR
- A2-103 - OVERALL FLOOR
- A2-104 - OVERALL FLOOR
- A2-201-G4 - FLOOR PLAN -
- A2-201-G5 - FLOOR PLAN -
- A2-201-G6 - FLOOR PLAN -
- A2-201-G7 - FLOOR PLAN -
- A2-201-H1 - FLOOR PLAN - HQ
- A2-201-H2 - FLOOR PLAN - HQ
- A2-201-H3 - FLOOR PLAN -



Home Fit Pan Zoom Measure Markup

2D & 3D Applications

- Most map-based applications used by airport owner are 2D; easier to understand
- 3D mostly used by airport owner for:
  - Height constraints analysis related to airspace
  - Line of site analysis for ATCT and CCTV camera placement
  - Subsurface utilities depth analysis



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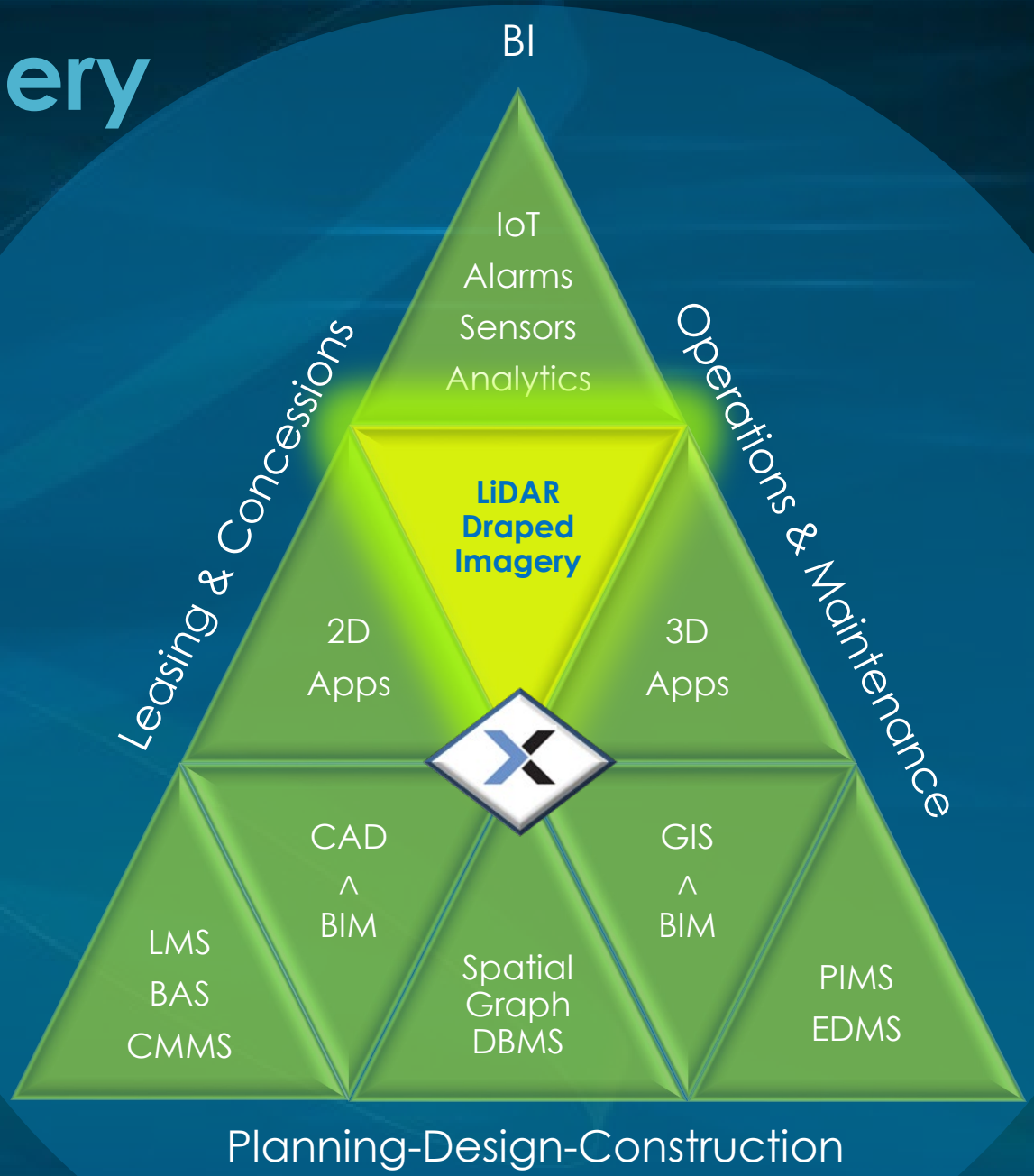
LiDAR with Draped Imagery

- 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



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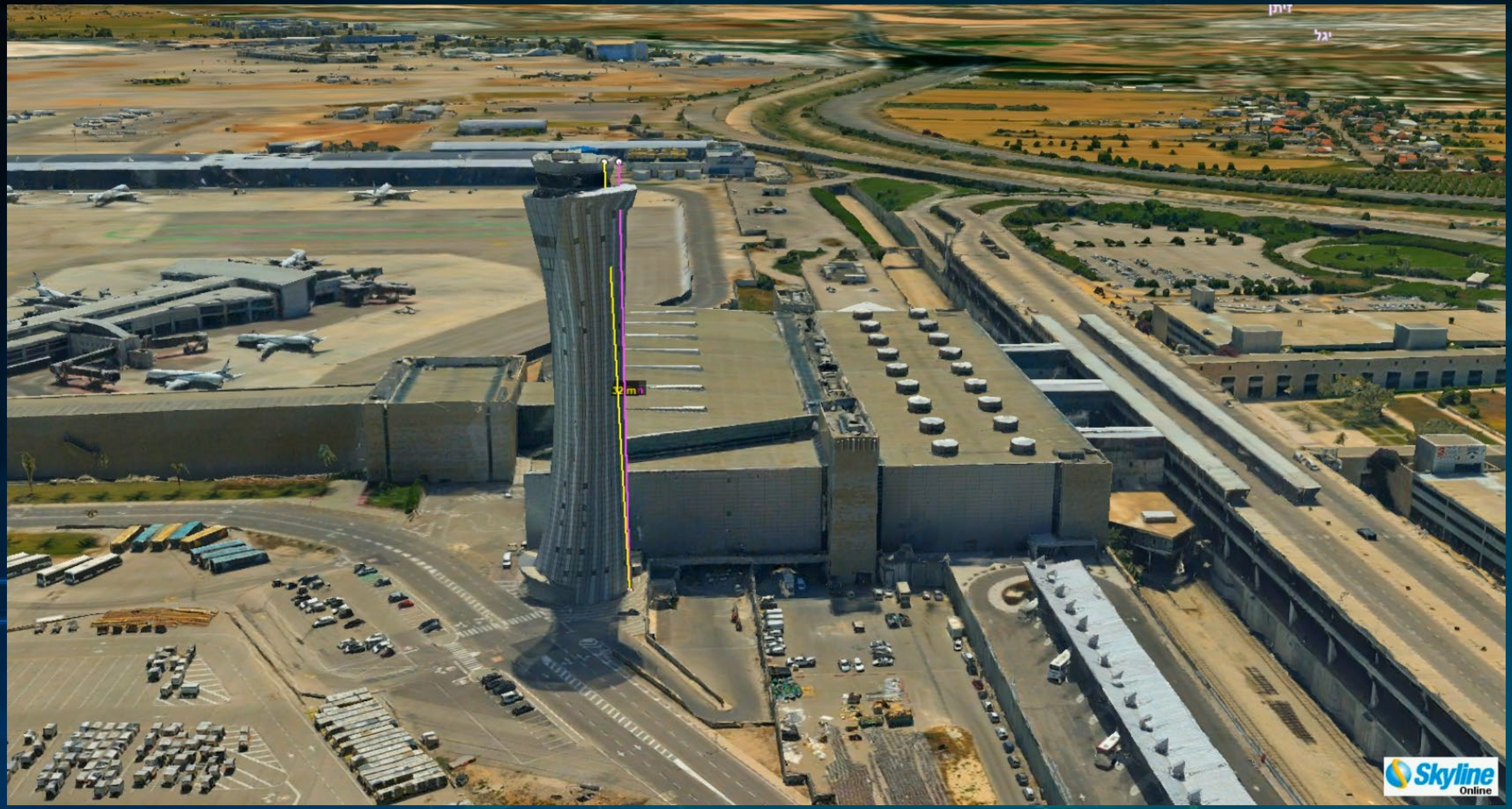


3D Aerial Imagery Leveraging LiDAR & PhotoMesh

Courtesy of Skyline Software Systems

3D LiDAR with Draped Imagery

X·SPATIAL

Charlotte Douglas International Airport
LiDAR Scanning Project

Business Drivers

Create accurate, up-to-date floor plans drawings

- Leasing purposes
- Integration with other systems (sensors, other location-dependent systems, etc.)

Create a digital twin of the Terminal and Concourses

- Asset management (location, extraction, etc.)
  - Signage / HVAC / Fire Extinguishers, etc.
- Door/room renumbering
- Space usage
- Situational awareness
- Wayfinding

Project Overview

- Approximately 1.8 million SQFT of the terminal area scanned in 7 Days
- 5.16 TB of data (LiDAR & 360d images) delivered
- Over 67000 360d images
- 299 1cm Color LAS files edited & combined to create 17 distinct floors
- 17 CAD floor plans

Mission Planning

Mission planning was based on the framework established in CLT's Guideline for indoor scanning document.

- The scanning routes for the terminal and concourses were created based on levels, regions and rooms.
- Other considerations for planning included flight ops, inaccessible or out-of-service elevators, secured area's escort requirements, etc.

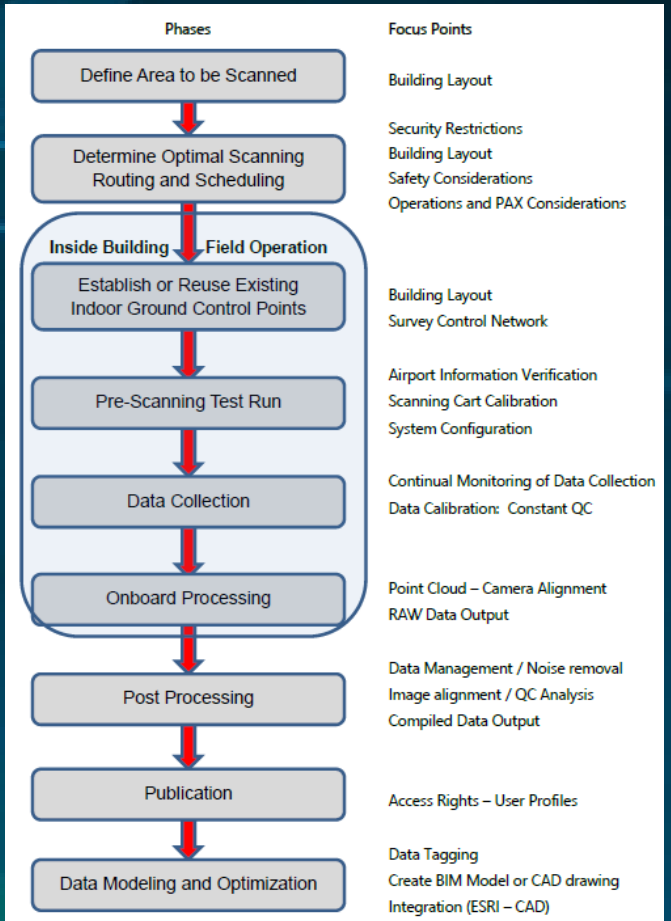
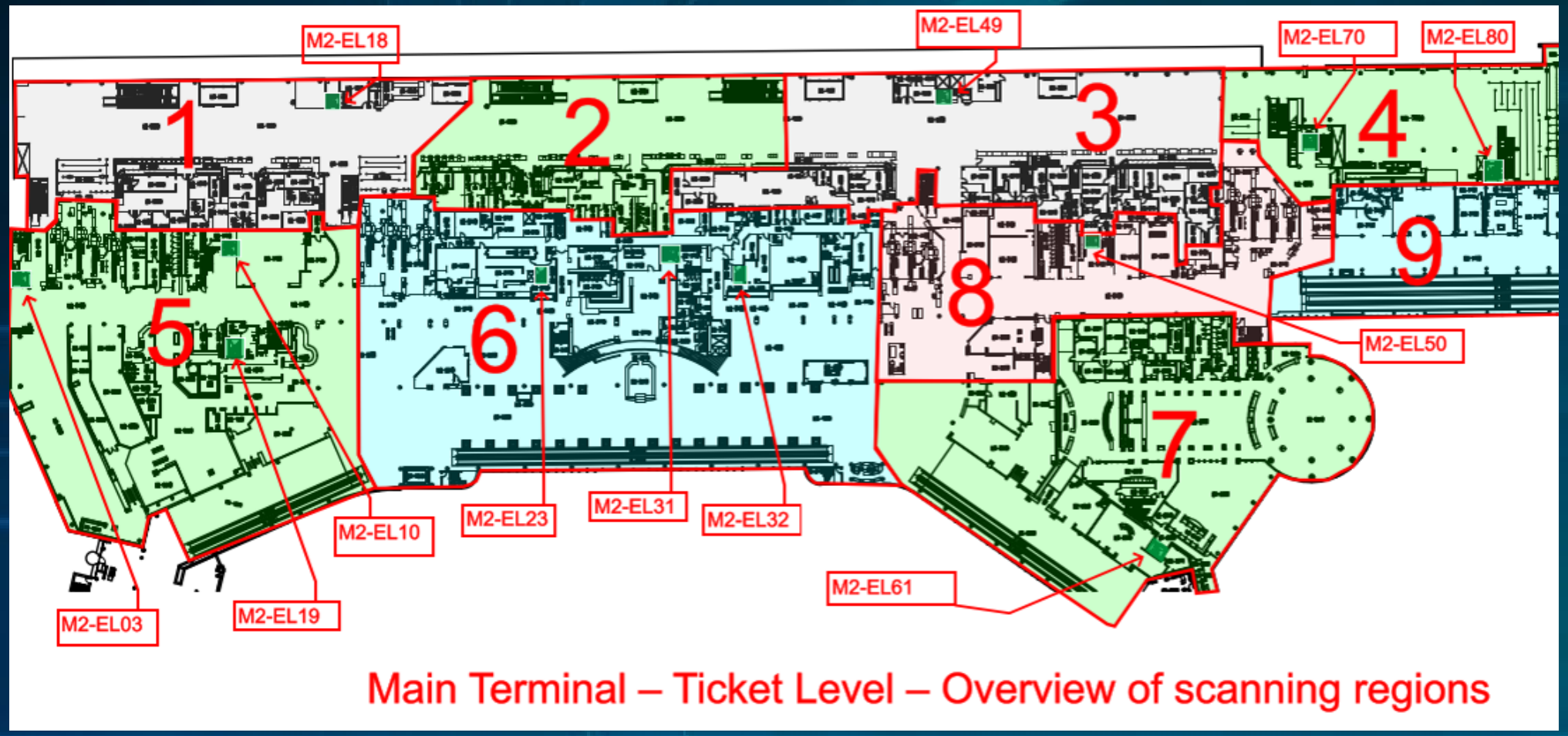


Figure 2: Scanning Survey - Planning and Execution Framework

Mission Planning

Scanning regions were created and elevators were marked to assist in more efficient routing

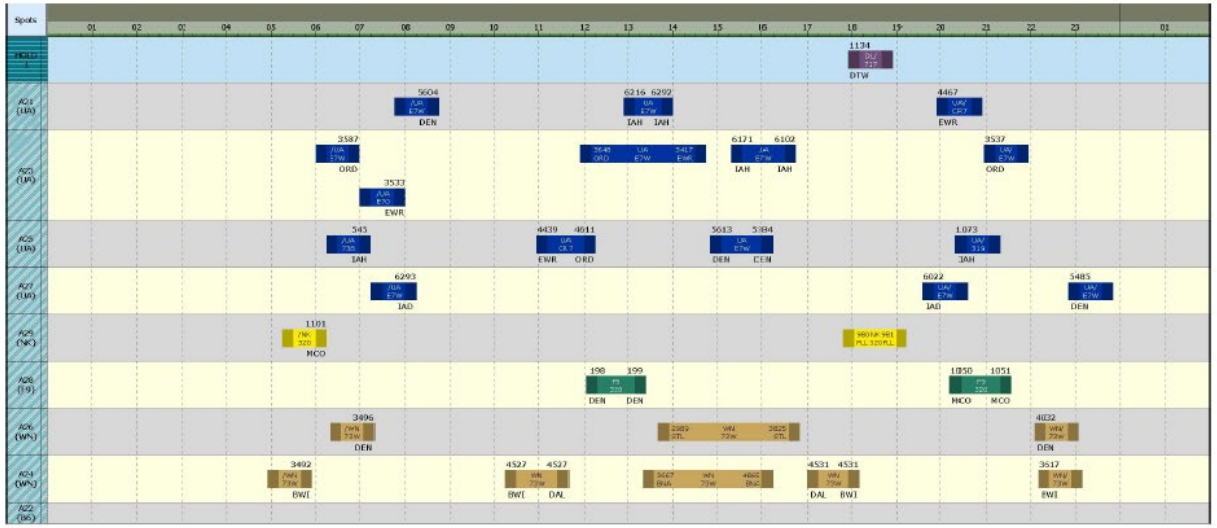


Mission Planning

- A detailed schedule for scanning was created based on the number of rooms within each level and region
- A report was also created to inform the scanning crew of issues that need to be addressed and spaces to avoid
- Aircraft operations per concourse was one of the key drivers for mission planning to avoid a high number of passengers, which affects the quality and increases the post-processing of LiDAR data

Building	Level	Region	Rooms	Time @ 60 rooms per hour	Sunday		Monday			
					10-14am	14-20pm	06-12am	12-18pm	18-24pm	00
				60						
Terminal	Basement	Region 1	132	2.20						
		Region 2								
		Region 3	6	0.50	0.50					
	Ramp	Region 1	239	3.98	Together with Ticket region 4					
		Region 2								
		Region 3								
		Region 4								
		Region 5								
		Region 6								
	Ticket	Region 1	480	8.00	8.00					
		Region 2								
		Region 3								
		Region 4								
		Region 5								
		Region 6								
		Region 7								
		Region 8								
		Region 9								
	Office	Region 1	259	4.32						
		Region 2								
		Region 3								
		Region 4								
		Region 5								
	Tower 01	Region 1	21	0.35						
		Region 2								

Scanning planning



Aircraft Operations: day-overview Concourse A

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	

A typical report showing potential scanning issues for a building/level/region

Survey

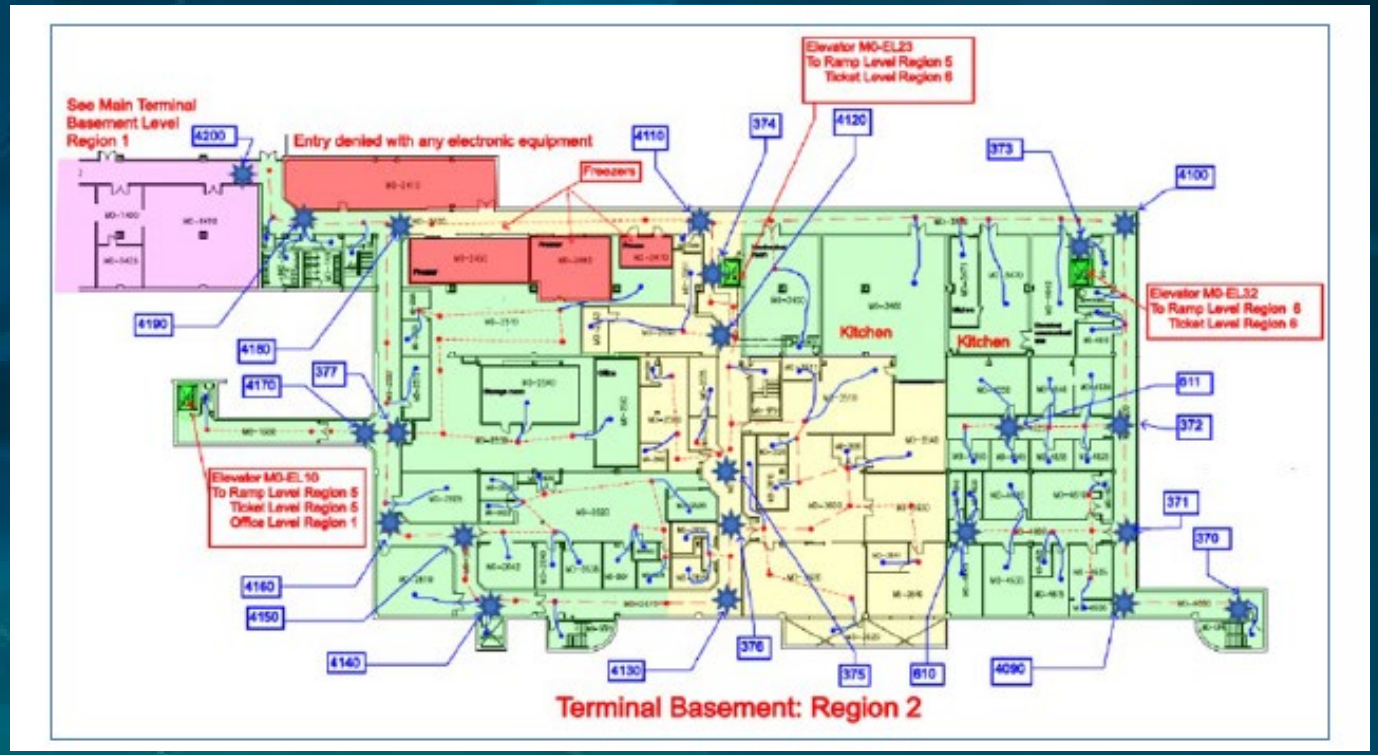
Survey Control Network and Supplemental Indoor Ground Control Points are keys for sustainability & updating the master LiDAR model

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

Supplemental Indoor-Ground-Control-Points (IGCP)

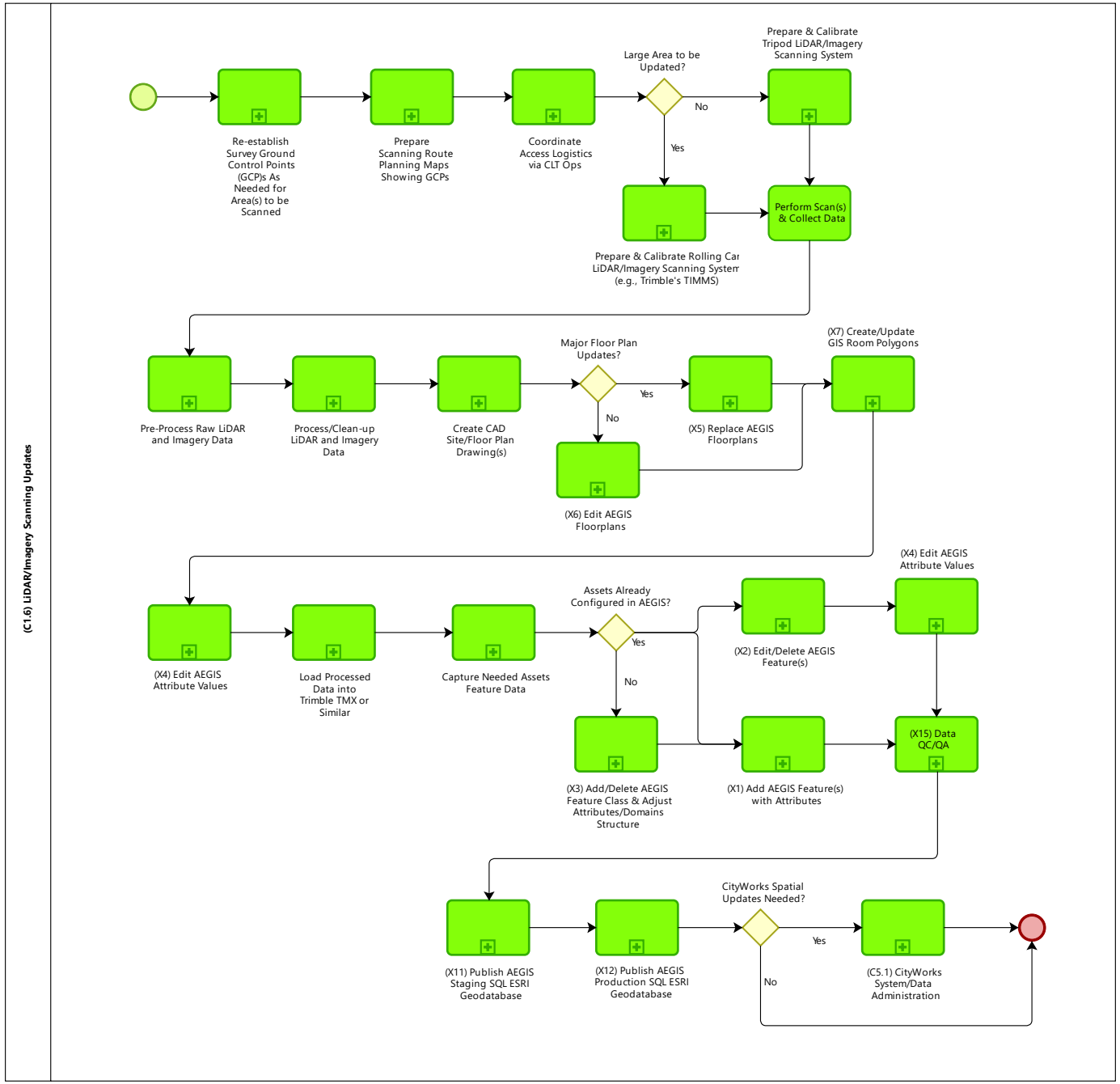
- CLT Terminals and Buildings are environments where the accuracy, integrity, continuity and consequent suitable availability of GNSS signals cannot be assured.

- Supplemental Indoor-Ground-Control-Points are densification or extension of the survey control network that are required for future scanning projects.



LiDAR Data Update Process

Incremental update of master model (sustainability)is the key benefit of creation of IGCP's.



Survey

The survey deliverables included;

- CAD drawings
- Survey report including photographs of IGCP
- Excel file identifying IGCP point #, type, location, etc.

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	1,898,526,089	0.02	0.02	0.02	Terminal	Ramp	5	PK NAIL SET IN CONCRETE
265	1,521,997,874	-8,094,510,121	1,898,594,361	0.02	0.02	0.02	Concourse B	Ramp	1	PK NAIL SET IN CONCRETE
266	1,521,928,509	-8,094,503,908	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	1,521,918,137	-8,094,508,384	1,899,158,039	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	1,521,850,998	-8,094,549,329	1,898,842,269	0.02	0.02	0.02	Concourse B	Ramp	4	PK NAIL SET IN CONCRETE
278	1,521,837,984	-8,094,507,941	1,898,836,608	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	1,898,845,974	0.02	0.02	0.02	Concourse B	Ramp	4	PK NAIL SET IN CONCRETE
282	1,521,800,513	-8,094,561,017	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	1,522,027,196	-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	-8,094,303,062	189,881,331	0.02	0.02	0.02	Terminal	Ramp	6	PK NAIL SET IN CONCRETE
293	1,522,001,748	-8,094,276,570	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

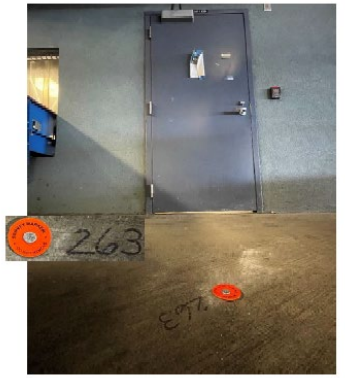
PK Nail set in concrete

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

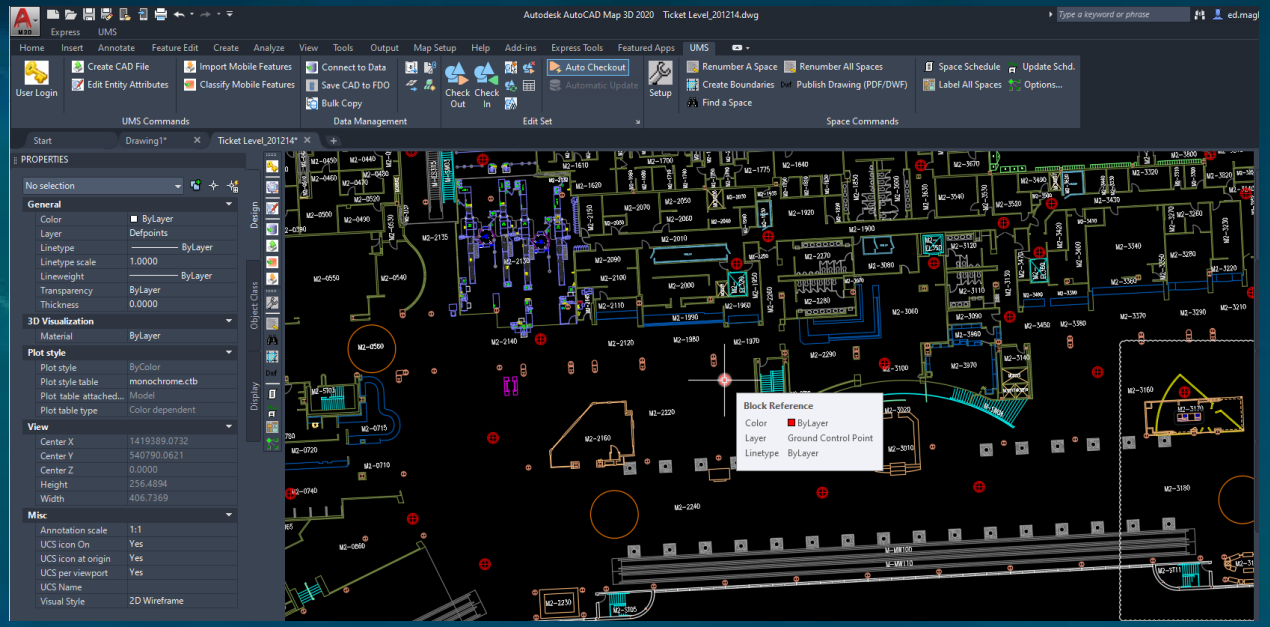
wood.

NC State Plane 1983
Northing 540783.02
Easting 1419119.00
Elevation 723.48

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



Sample GCP Report



AutoCAD floor plan with marked IGCP's

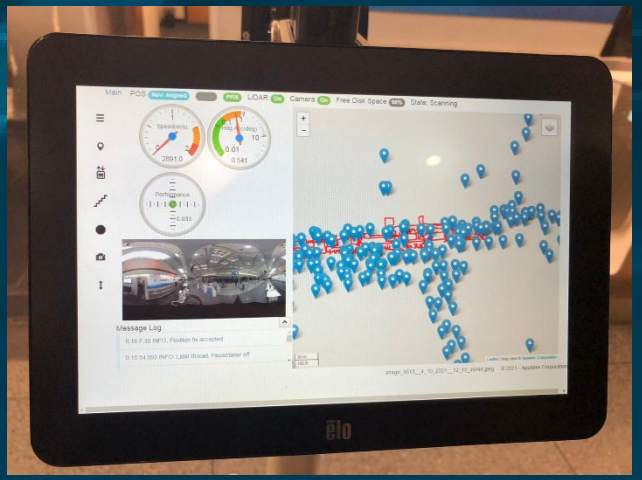
Scanning

Mission overview

FLOOR	AREA	REGION	SCAN MISSION	HDPics numbering	Total
03_Ticket	Terminal	1	1	0000-3754	3,755
03_Ticket	Terminal	2			
03_Ticket	Terminal	3			
03_Ticket	Terminal	4			
03_Ticket	Terminal	8	2	0000-1176	1,177
03_Ticket	Terminal	9			
03_Ticket	Terminal	5	3	0000-3322	3,323
03_Ticket	Terminal	7			
04_Office	Terminal	1	4	0000-3264	3,265
04_Office	Terminal	2			
04_Office	Terminal	3			
03_Ticket	Concourse C	All	5	2034-4624	2,591
02_Ramp	Terminal	3		4839-6394	1,556
03_Ticket	Terminal	6		0000-2033	2,034
03_Ticket	Concourse A	All	6	2056-4390	2,335
04_Office	Concourse D	All		0000-0661	662
04_Office	Terminal	5		1065-1707	643
03_Ticket	Concourse A North	All	7	0000-2791	2,792
04_Office	Concourse A North	All		2798-3548	751
03_Ticket	Concourse B	All		4003-6644	2,642
00_Basement	Terminal	1	8	0626-3839	3,214
00_Basement	Terminal	2			
00_Basement	Terminal	3		0013-0327	314
02_Ramp	Concourse A North	2	9	0000-3825	3,826
02_Ramp	Concourse A North	3			
02_Ramp	Concourse A North	4			
02_Ramp	Concourse A North	1	10	0001-0593	593
02_Ramp	Terminal	1		0733-2378	1,646
02_Ramp	Terminal	2			
03_Ticket	Concourse D	Time Restrictions	11	0001-0636	636
02_Ramp	Terminal	5		0974-4626	3,653
02_Ramp	Terminal	6			
03_Ticket	Concourse D	All	12	0000-1435	1,428
02_Ramp	Concourse A	All	13	0000-3428	3,429
02_Ramp	Concourse B	All		3429-7915	4,487
02_Ramp	Concourse C	All	14	0000-4235	4,236
02_Ramp	Concourse E	All	15	0000-8256	8,257
03_Ticket	Concourse E	All		8390-8689	300
03_Ticket	Concourse C	Missing Rooms	16	0485-0662	178
03_Ticket	Concourse D	Missing Rooms		0000-0235	236
02_Ramp	Terminal	1 - Missing Rooms		1191-1218	28
03_Ticket	Terminal	6 - Missing Rooms		0976-1128	153
					64,140

Mission Planning

Trimble Indoor Mobile Mapping System (TIMMS)



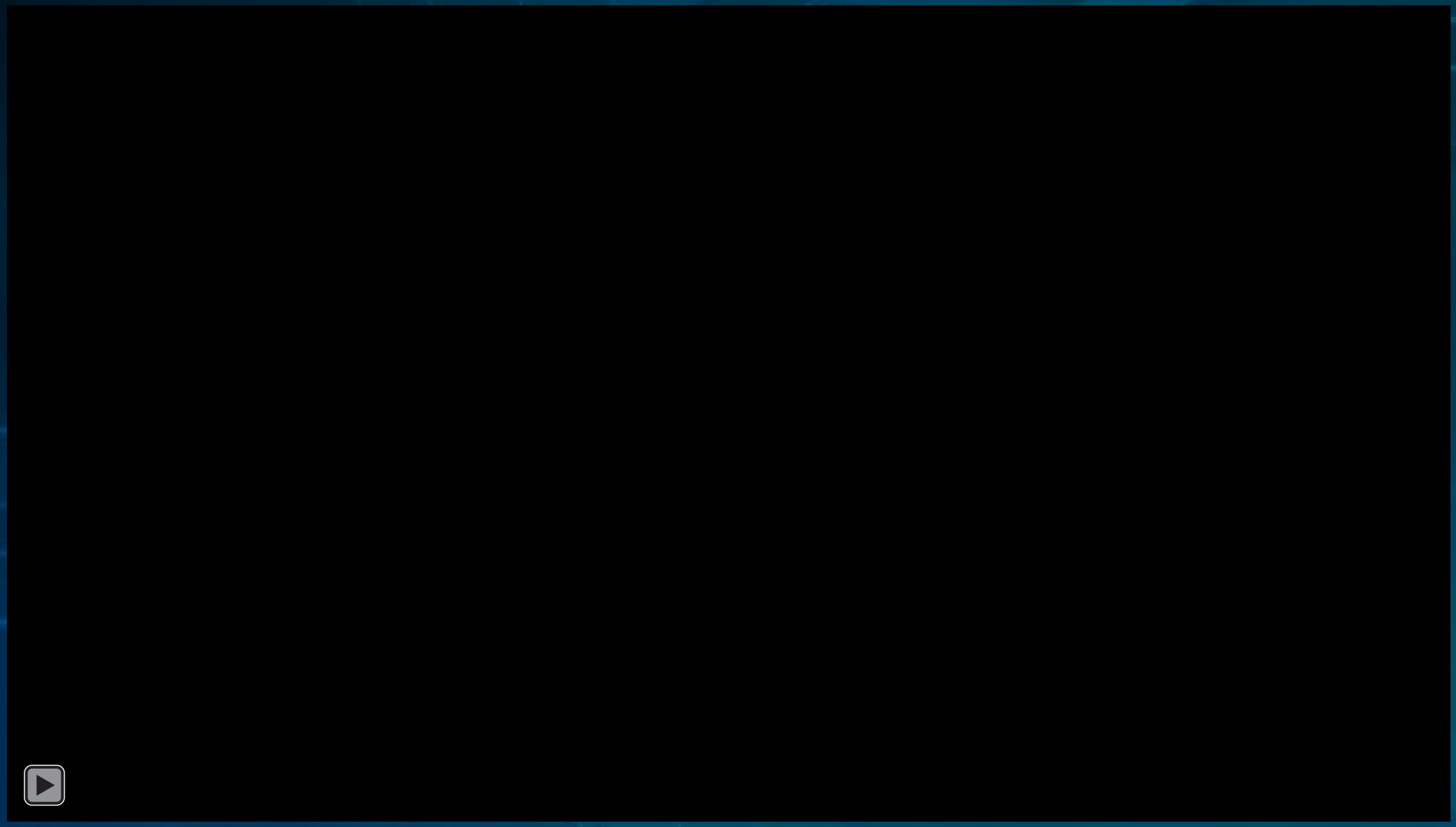
TIMMS interface showing scanned path and 360° image capture locations

Scanning - Interior

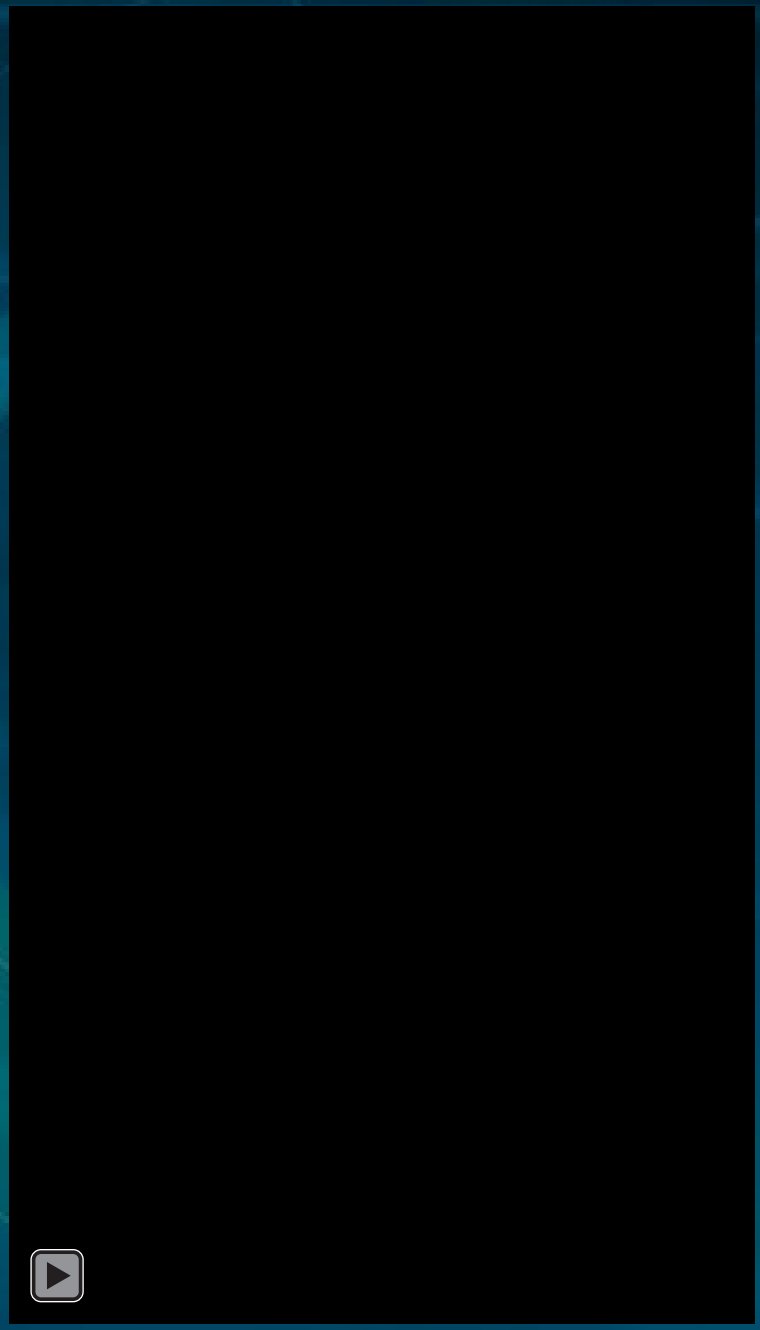
Scanning - Exterior

Scanning - Obstacles

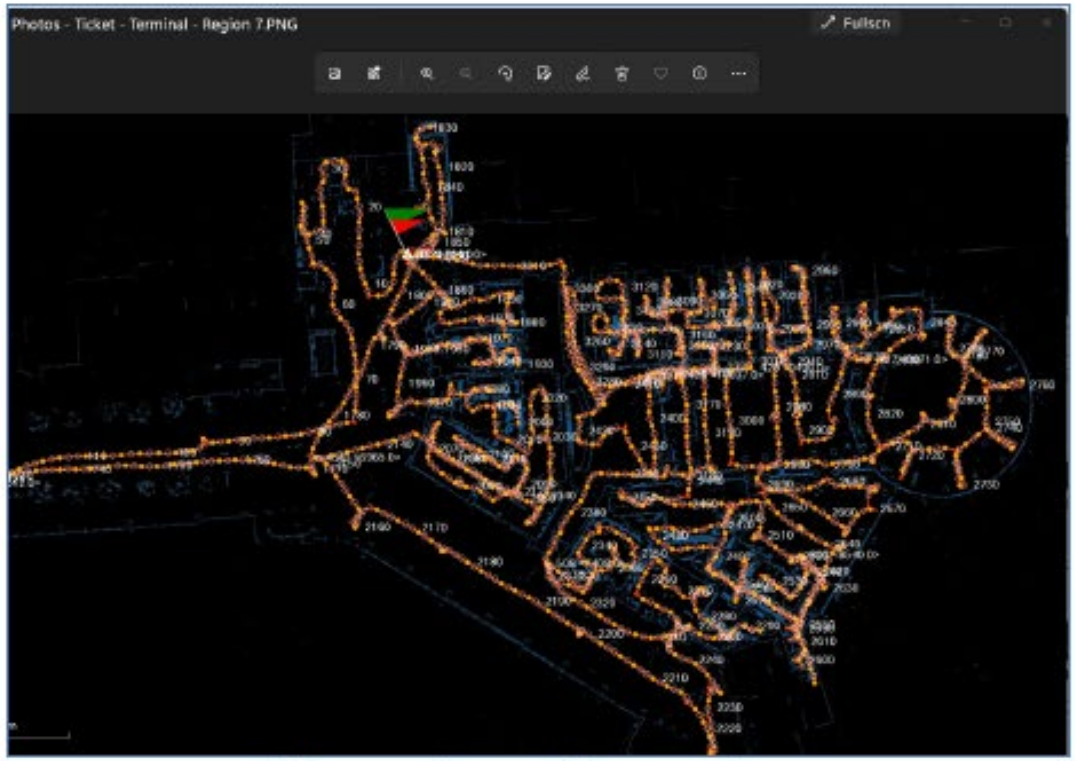
Scanning – Mechanical Rooms



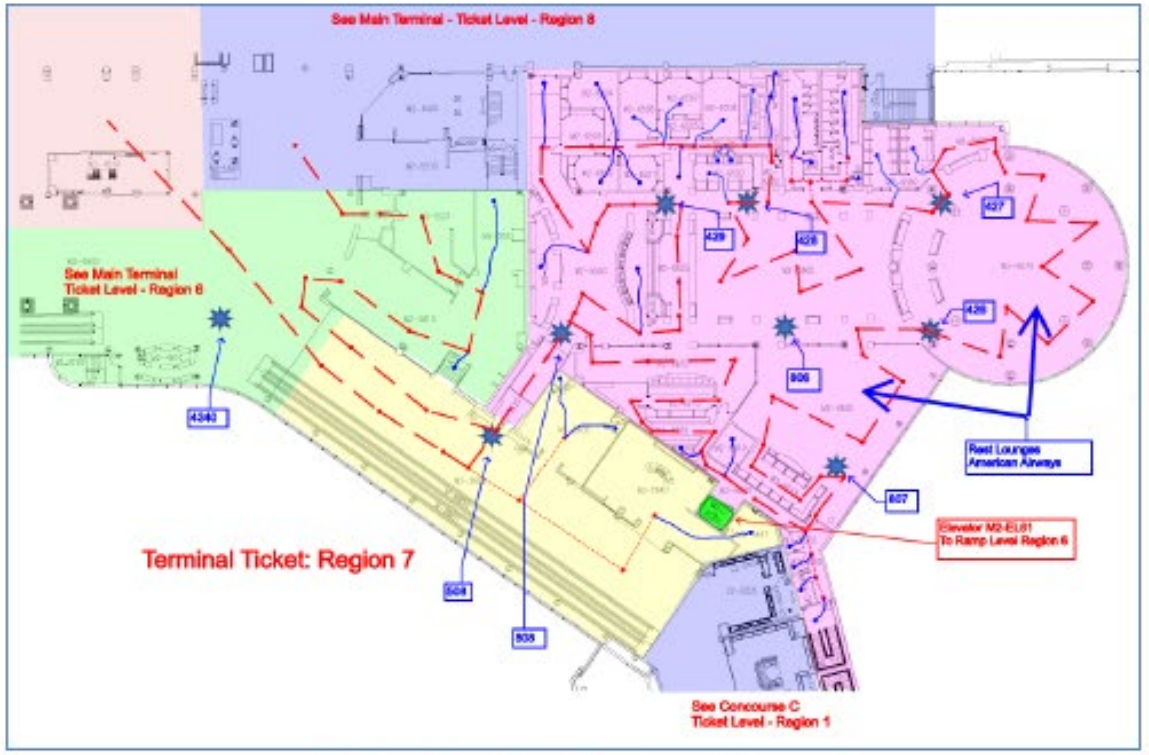
Scanning - Obstacles



Scanning – Planned vs. Actual



The actual route of the scanning cart



Planned route of the scanning cart

Deliverables and Post-processing

Spherical 360° imagery

- RAW images (JPEG images): both high definition and
- standard, along with supporting files, for each part of the scanning project

area_ftUS_eo_tmx_txt - Notepad

Photo Id	Time	Easting(ft US)	Northing(ft US)	Ellipsoid Height(ft US)	Omega TMX (deg)	Phi TMX (deg)	Kappa TMX (deg)	Lat(deg)	Long(deg)
0	1345.281475	1419643.748	540855.3964	652.7318728	-0.32010944	-0.40921302	78.91644238	35.22049185	-80.94334001
1	1357.158426	1419643.995	540857.9095	652.7175253	0.27124428	1.25154558	-68.07630695	35.22049876	-80.94333935
2	1358.360435	1419640.825	540855.2285	652.7323736	-0.0794022	0.50438841	-34.05860338	35.22049123	-80.94334979
3	1359.36045	1419639.824	540851.6097	652.7341944	-0.01360591	0.52136716	-20.82352698	35.22048123	-80.9433529
4	1360.260515	1419639.656	540848.3113	652.7072782	-0.4273756	0.18950391	-23.29680671	35.22047216	-80.94335325
5	1361.256681	1419639.575	540845.0312	652.7072659	-0.81728277	0.8106318	-36.38993227	35.22046315	-80.9433533
6	1363.255742	1419638.64	540841.9939	652.7638652	-0.27558998	0.71075723	-54.79493598	35.22045475	-80.94335673
7	1364.758661	1419636.919	540839.3265	652.7759	0.35428949	0.69178166	-84.93396334	35.22044733	-80.94336182
8	1365.962786	1419633.962	540838.2415	652.7718848	0.0763524	0.01490632	-105.9656952	35.22044419	-80.94337165
9	1374.762192	1419629.035	540838.9741	652.7509061	0.82965247	-0.54059313	-179.7036767	35.22044594	-80.94338819
10	1376.459356	1419627.945	540842.2703	652.7200144	0.64815648	-0.12229076	-176.8422136	35.22045494	-80.94339206

Image locations .txt file

Point Cloud files

- Color georeferenced point cloud in ASPRS LAS format: (The American Society for Photogrammetry & Remote Sensing – LASer format)
- Mono georeferenced point cloud

Name	Date modified	Type	Size
L1_TICKET_color_001_m_to_sft.las	6/15/2021 9:56 PM	AutoCAD Layer State	557,166 KB
L1_TICKET_color_002_m_to_sft.las	6/16/2021 1:43 AM	AutoCAD Layer State	404,197 KB
L1_TICKET_color_003_m_to_sft.las	6/15/2021 10:01 PM	AutoCAD Layer State	426,380 KB
L1_TICKET_color_004_m_to_sft.las	6/16/2021 1:43 AM	AutoCAD Layer State	901,901 KB
L1_TICKET_color_005_m_to_sft.las	6/15/2021 10:12 PM	AutoCAD Layer State	854,251 KB
L1_TICKET_color_006_m_to_sft.las	6/16/2021 12:41 A...	AutoCAD Layer State	870,687 KB
L1_TICKET_color_007_m_to_sft.las	6/16/2021 1:43 AM	AutoCAD Layer State	717,726 KB

Color full: Contains every point from the point cloud data

Name	Date modified	Type	Size
L1_TICKET_refl_001_m_to_sft.las	5/16/2021 9:33 PM	AutoCAD Layer State	520,370 KB
L1_TICKET_refl_002_m_to_sft.las	5/16/2021 9:33 PM	AutoCAD Layer State	360,200 KB
L1_TICKET_refl_003_m_to_sft.las	5/16/2021 9:33 PM	AutoCAD Layer State	376,137 KB
L1_TICKET_refl_004_m_to_sft.las	5/16/2021 9:33 PM	AutoCAD Layer State	766,964 KB
L1_TICKET_refl_005_m_to_sft.las	5/16/2021 9:33 PM	AutoCAD Layer State	727,640 KB
L1_TICKET_refl_006_m_to_sft.las	5/16/2021 9:33 PM	AutoCAD Layer State	739,781 KB
L1_TICKET_refl_007_m_to_sft.las	5/16/2021 9:33 PM	AutoCAD Layer State	614,559 KB

monocolor full: Contains every point from the point cloud data

Deliverables and Post-processing

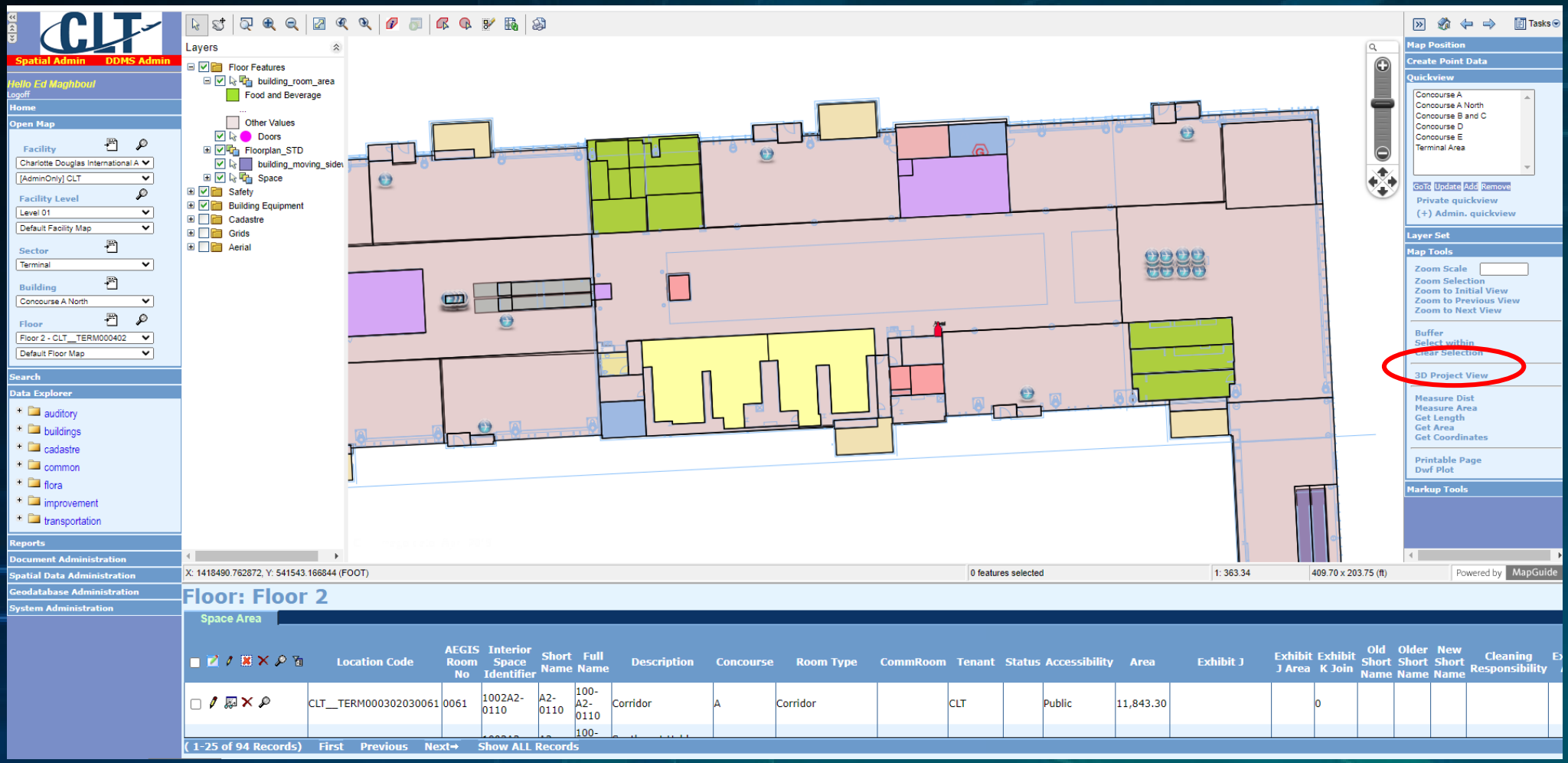
Cleaned and combined 1cm Point Cloud files

- Combining the several mission files to create one file per building floor
- Removing excess noise from the point cloud
- Publishing the point cloud and imagery to be used for future feature extraction

Example of six scanning crew continually moving within the range of the scanning cart and creating numerous ghost images

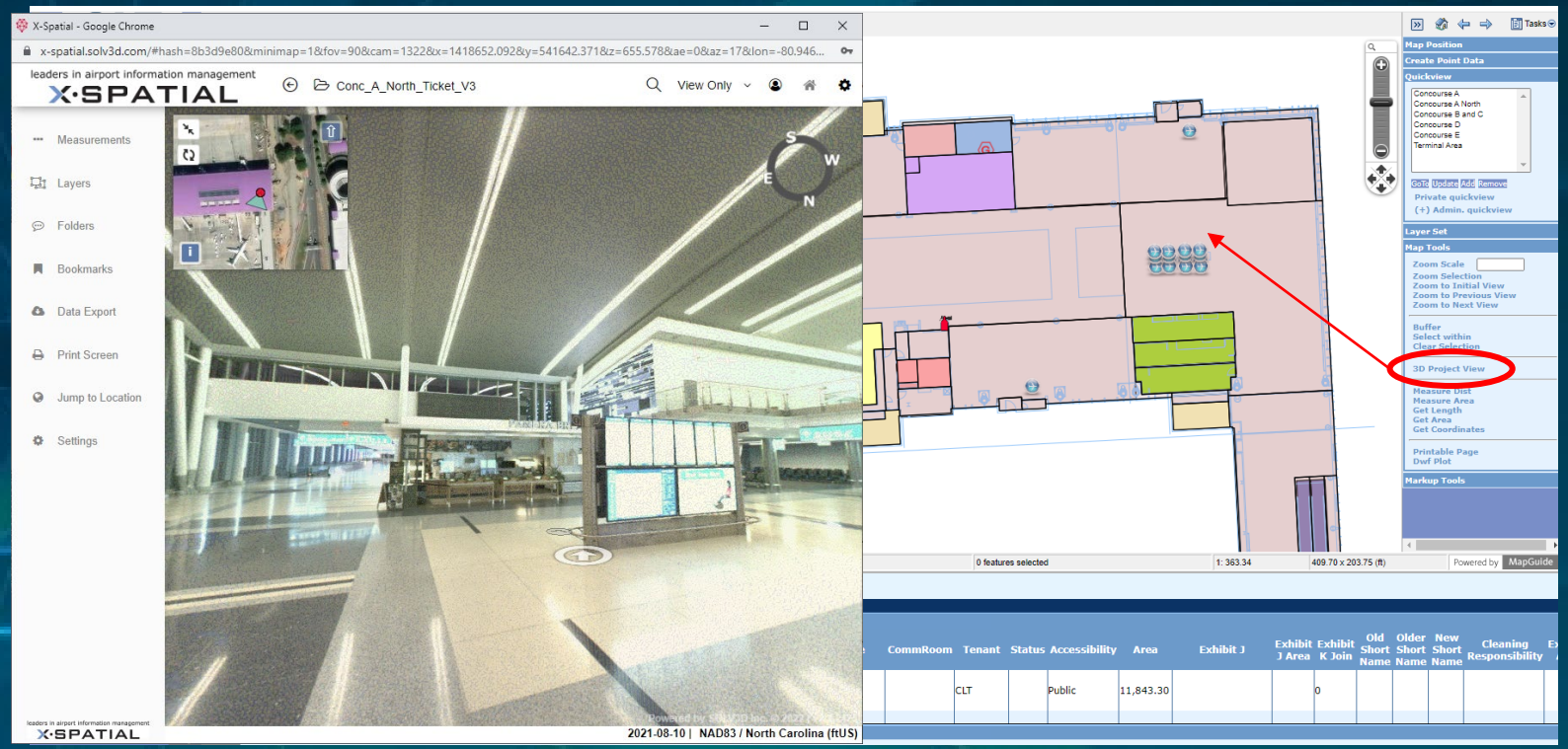
FLOOR	AREA	REGION	SCAN MISSION	Pics Name	USR Frame Date is?	HDPics	Total	area_ftUS_eo_tmx.txt	Color LAS Files
02_Ramp	Concourse A	All	13	ladybug_panoramic_M13_000000 to _M13_003428	22 May 2021	0-3428	3,429	0-3428	1m - 16m
03_Ticket	Concourse A	All	6	ladybug_panoramic_M06_002056 to _M06_004390	18 May 2021	2056-4390	2,335	2056-4390	1m - 11m
02_Ramp	Concourse A North	1	10	ladybug_panoramic_M10_000001 to _M10_000593	20 May 2021	1-593	593	1-593	1m - 2m
02_Ramp	Concourse A North	2	9	ladybug_panoramic_M09_000000 to _M09_003825	20 May 2021	0-3825	3,826	0-3825	1m - 16m
02_Ramp	Concourse A North	3							
02_Ramp	Concourse A North	4							
03_Ticket	Concourse A North	All	7	ladybug_panoramic_M07_000000 to _M07_002791	18 May 2021	0-2791	2,792	0-2791	1m - 12m
04_Office	Concourse A North	All	7	ladybug_panoramic_M07_002798 to _M07_003548	19 May 2021	2798-3548	751	2798-3548	1m - 4m

LiDAR + 360° Image Integration with GIS



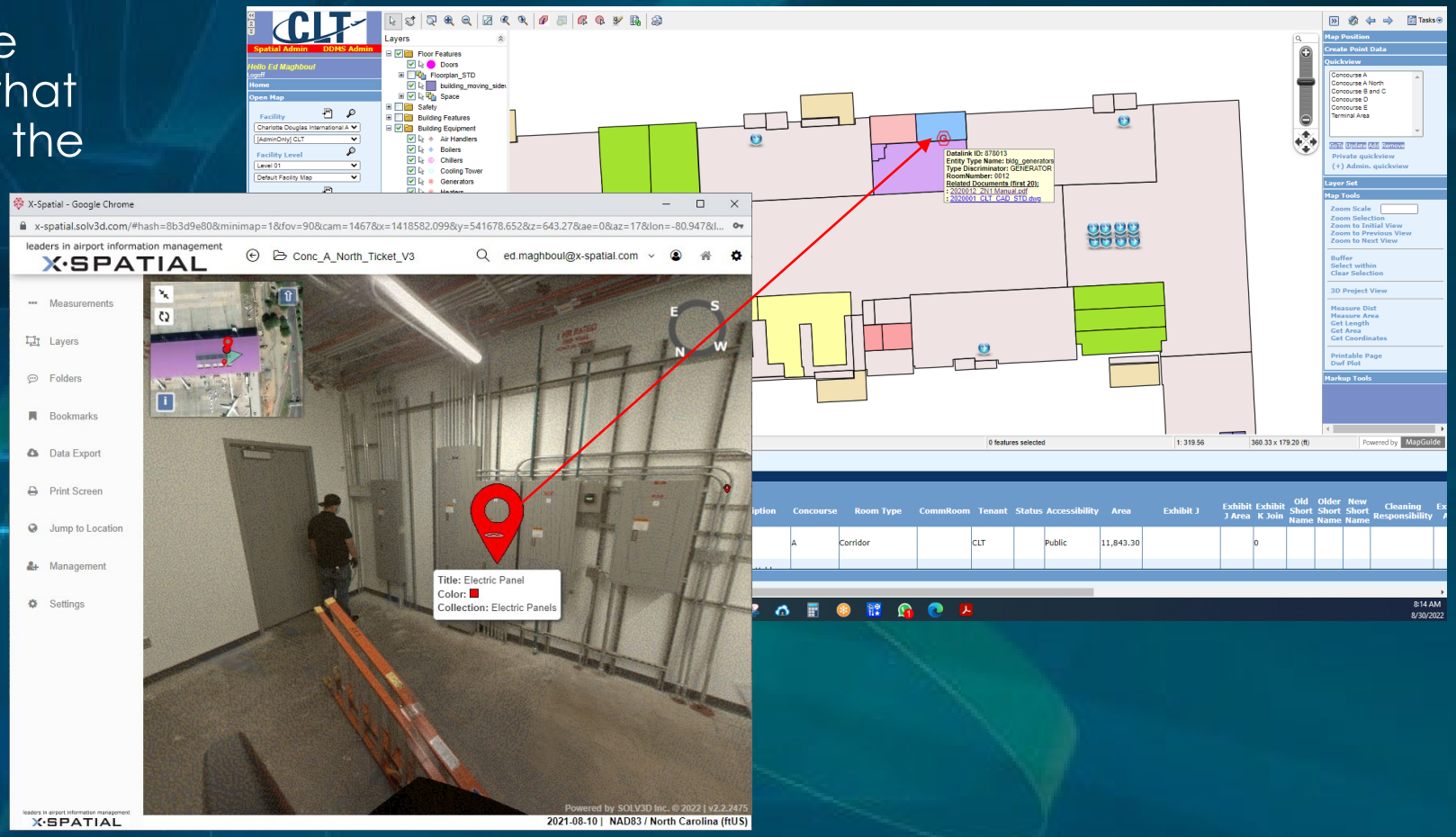
LiDAR + 360° Image Integration with GIS

- 3D AEGIS functions launches a window showing a 360° panoramic image of that location draped over the point cloud
- Image viewer allows
  - Virtual walkthrough
  - Measurement
  - Asset tagging
  - Feature Extraction



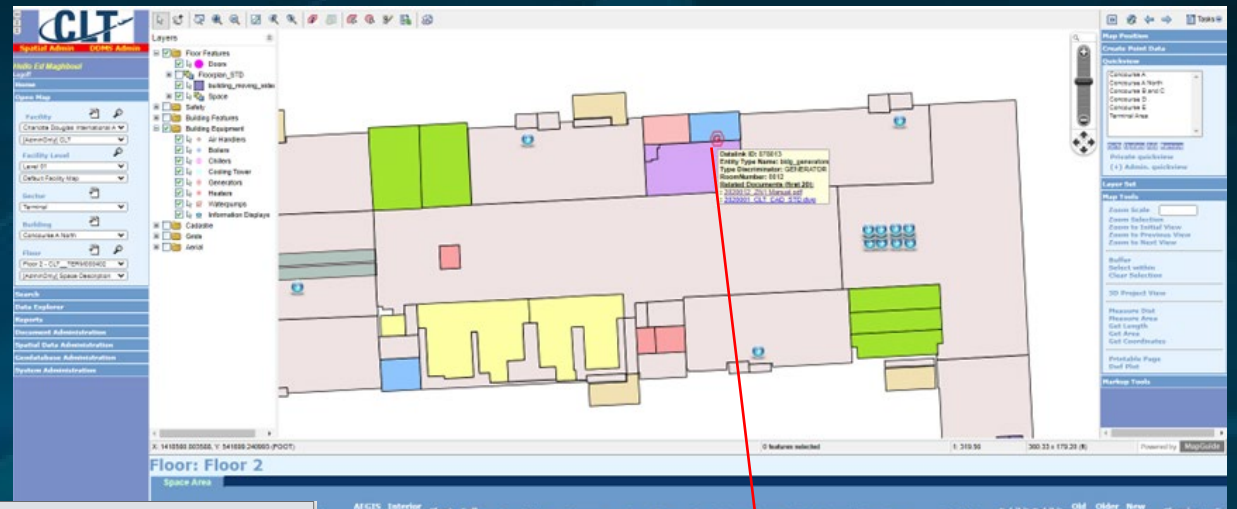
LiDAR + 360° Image Integration with GIS

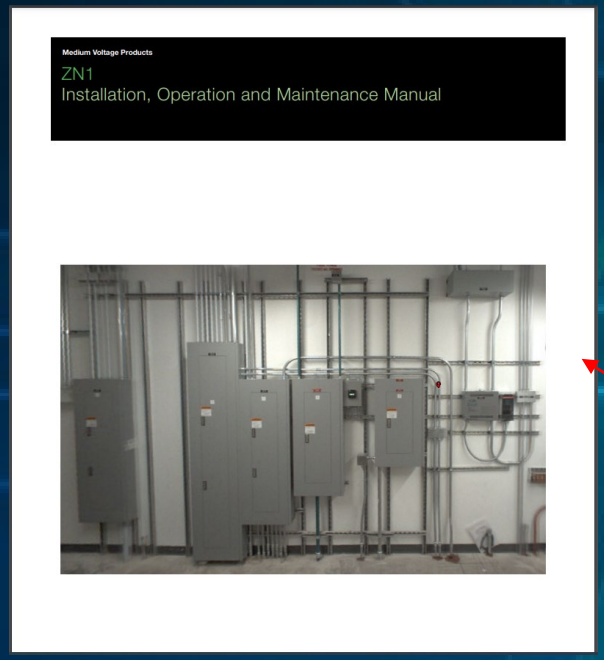
New tools have been developed which allow tagging of an asset in the 360° image, transferring that point to AEGIS and using the provided AEGIS tools to classify the asset



Asset Tagging

Once the asset has been classified and recorded in the dB, users can proceed to attach documents and edit its attributes





Entity Attribute - Google Chrome

Not secure | airports.x-spatial.com/UMSCLT/cfscripts/forms/EntityType_view.cfm?RecordID=878013...

878013, buildings, buildings_equipment, bldg_generators, bgutgen

Location	CLT
Created By	ed
Date Created	2022/02/10@10:06:10
Last Edited By	ed
Date Last Edited	2022/02/11@09:49:35
Asset ID	90001
Quality Level	A
DDMS Source	
Comment	
Disposition	
Is Published	N
Type Discriminator	GENERATOR

Attributes | Documents (2)

Bar Code No.	Project Title	Sheet No	Sheet Title	Alias	Document Type	Document Subtype	File Name
2020001	CAD Standard Drawing						
2020012	ABB Elec panel				Manual		

Entity Attribute - Google Chrome

Not secure | airports.x-spatial.com/UMSCLT/cfscripts/forms/EntityType_view.cfm?RecordID=878013...

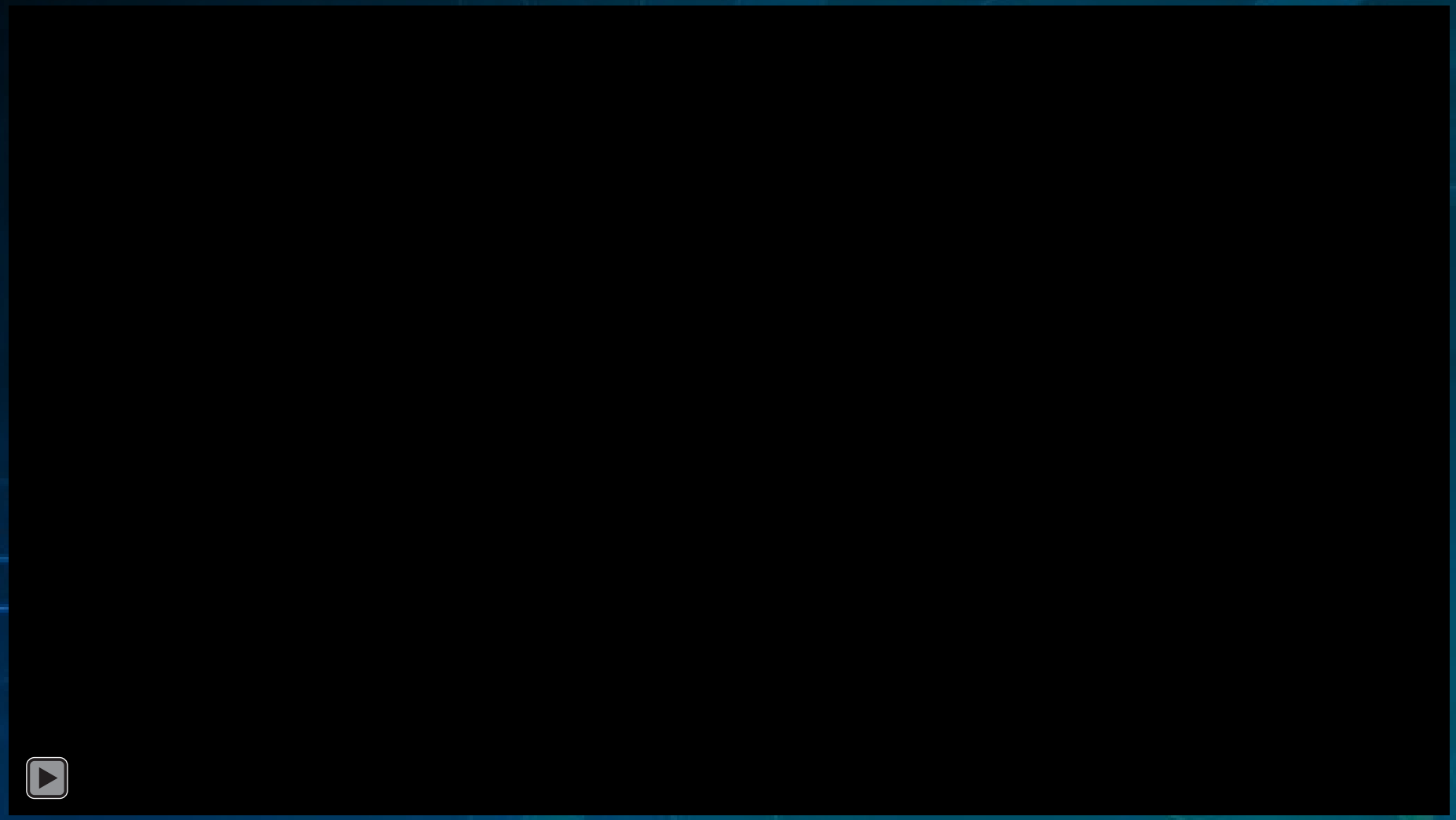
878013, buildings, buildings_equipment, bldg_generators, bgutgen

Location	CLT
Created By	ed
Date Created	2022/02/10@10:06:10
Last Edited By	ed
Date Last Edited	2022/02/11@09:49:35
Asset ID	90001
Quality Level	A
DDMS Source	
Comment	
Disposition	
Is Published	N
Type Discriminator	GENERATOR

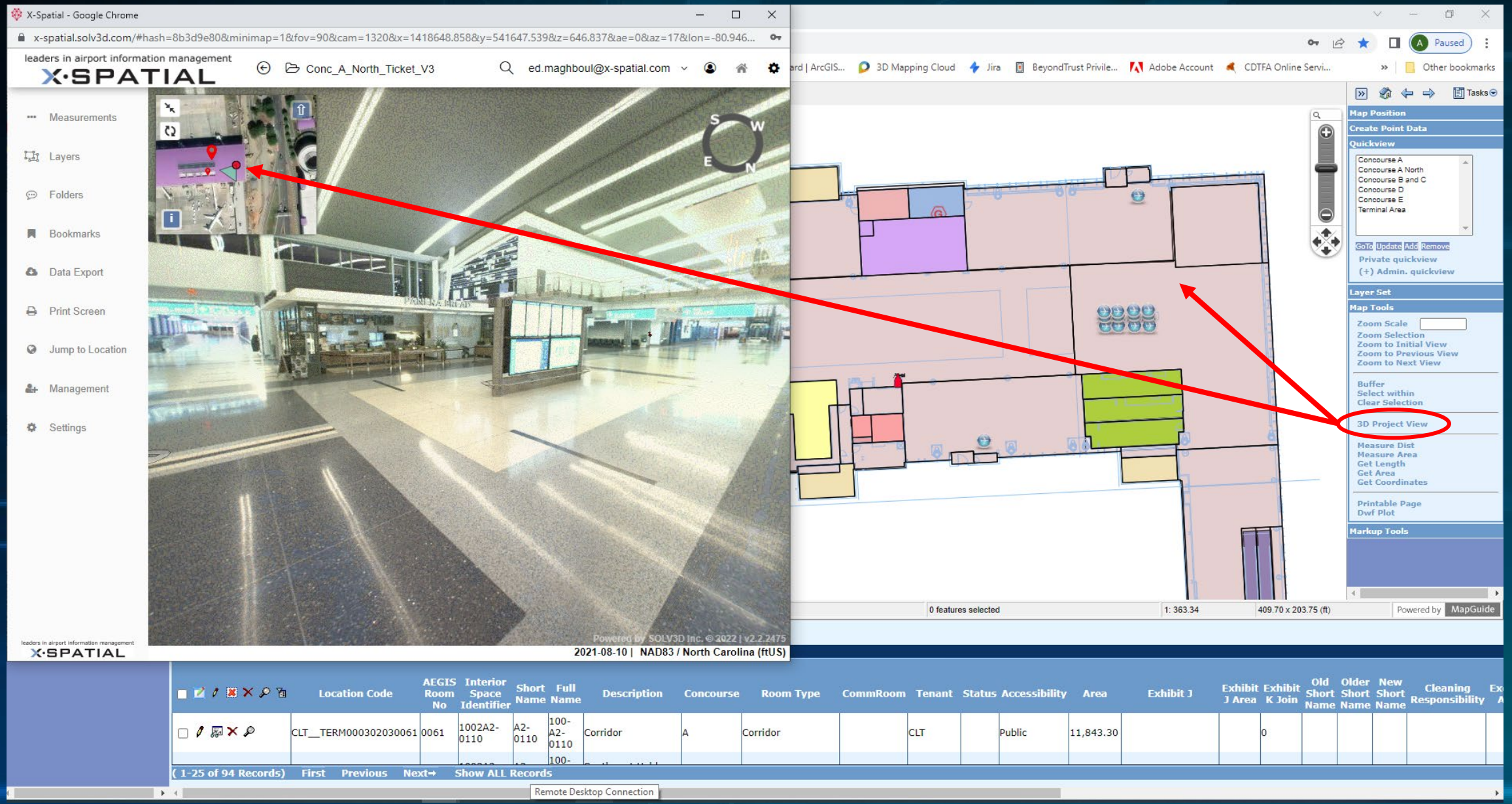
Attributes | Documents (2)

ID	
RoomNumber	0012
BuildingNumber	
Location	Conc A North
Model	ABB ZN1
Serial	
KW	
Age	
Manufactre_Date	06/2017
Notes	
Fuel_Tank_Types	
Fuel_Tank_Size	
Floor	
Status	ACTIVE
Verified?	YES
MaintainedBy	CLT

LiDAR + 360° Image Integration with GIS

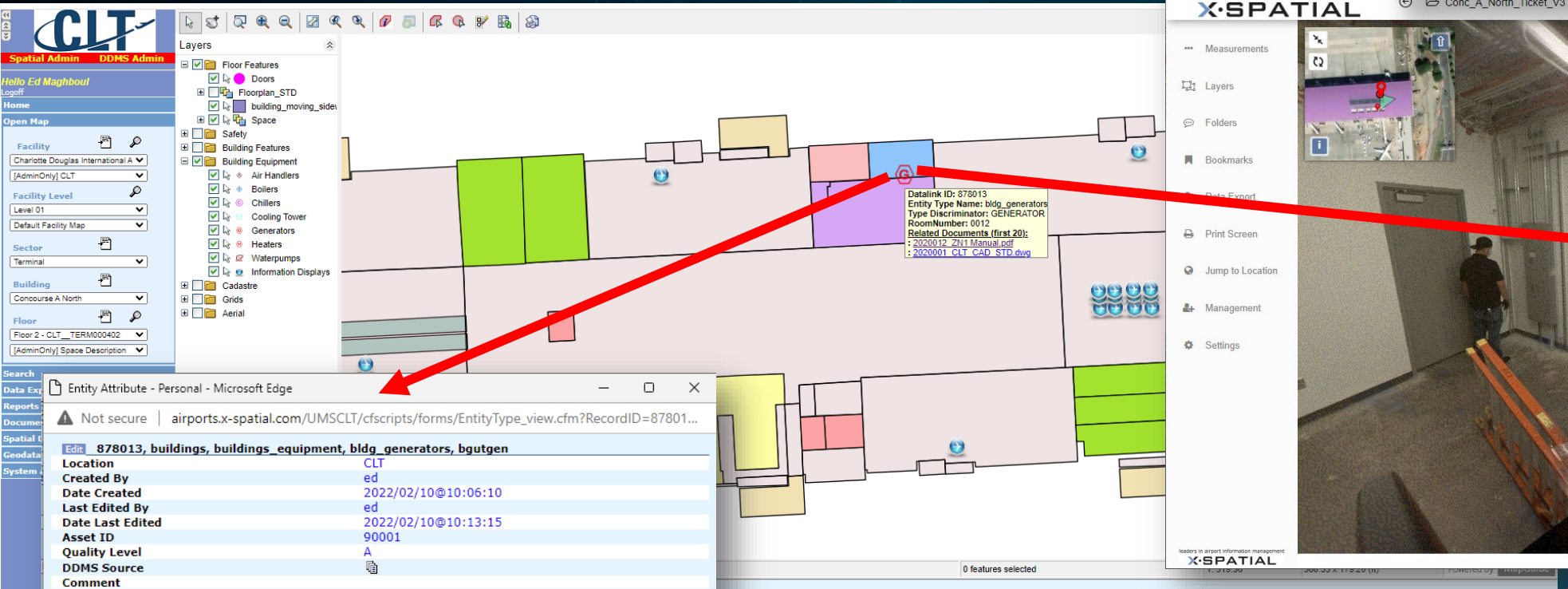


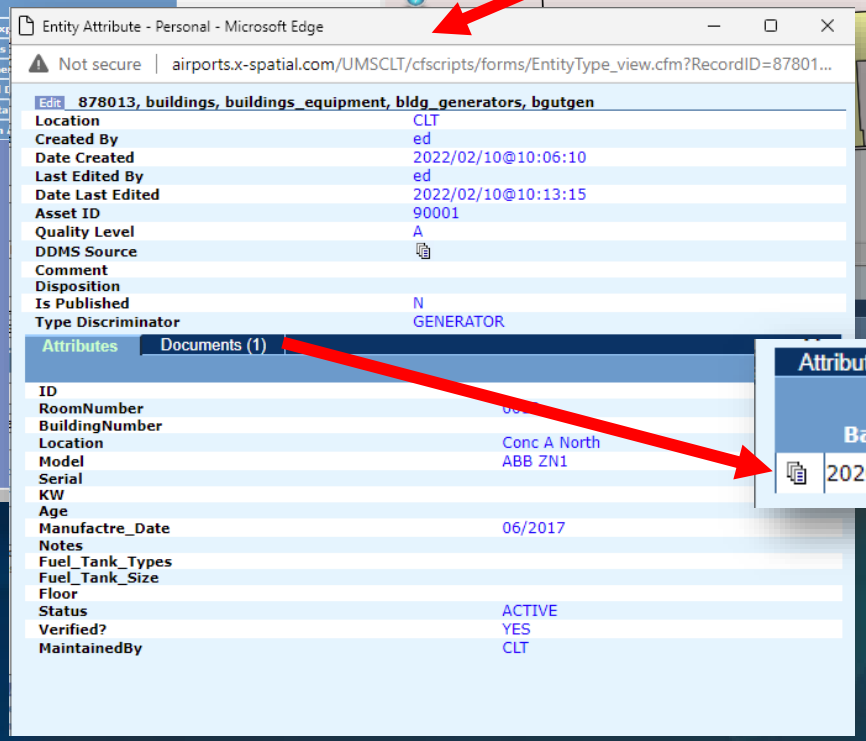
Integrated with GIS

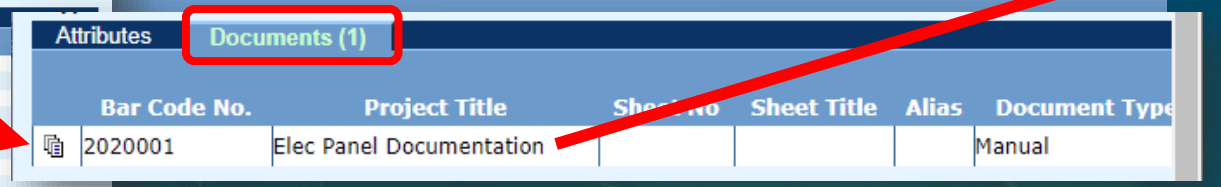


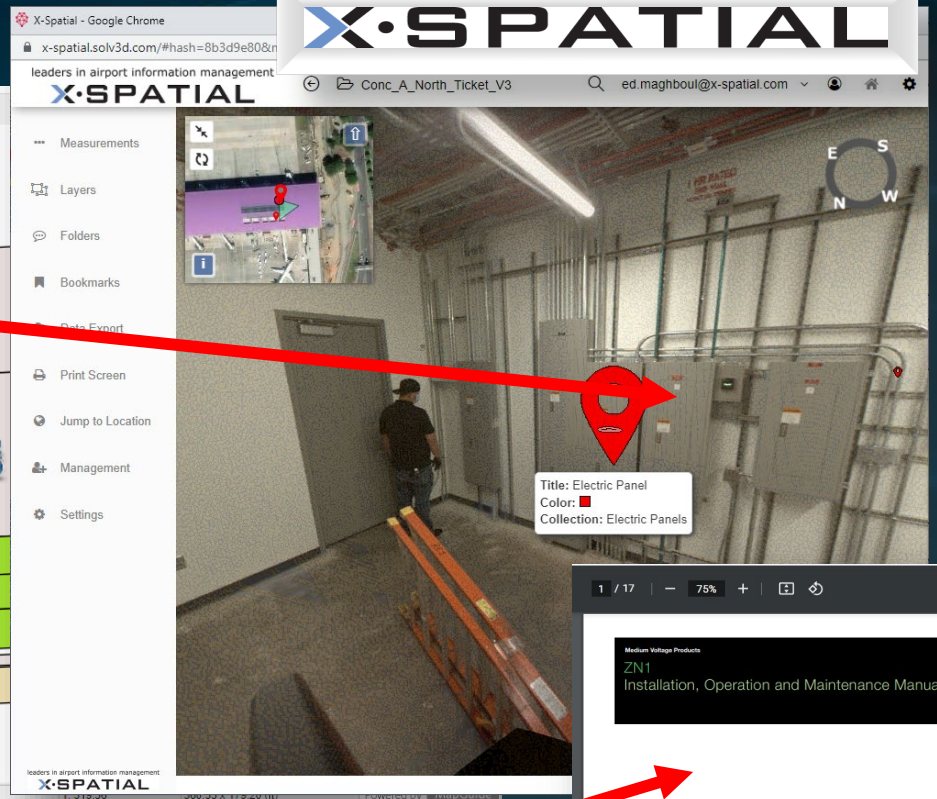
3D LiDAR with Draped Imagery

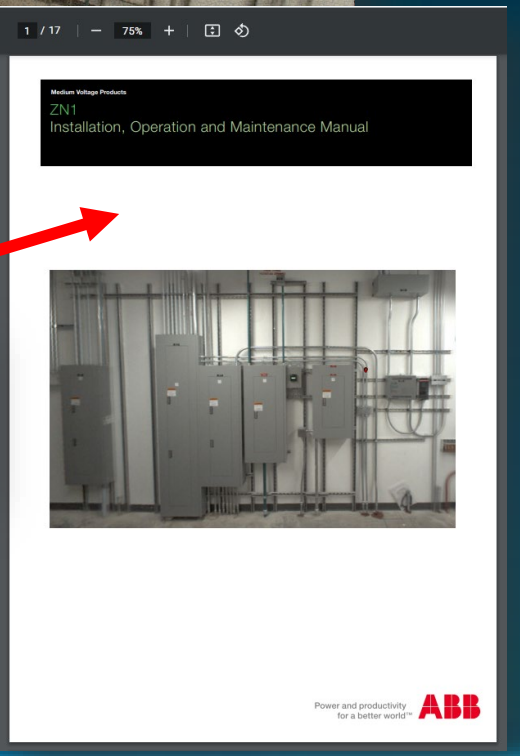
Multi-Dimensional Data





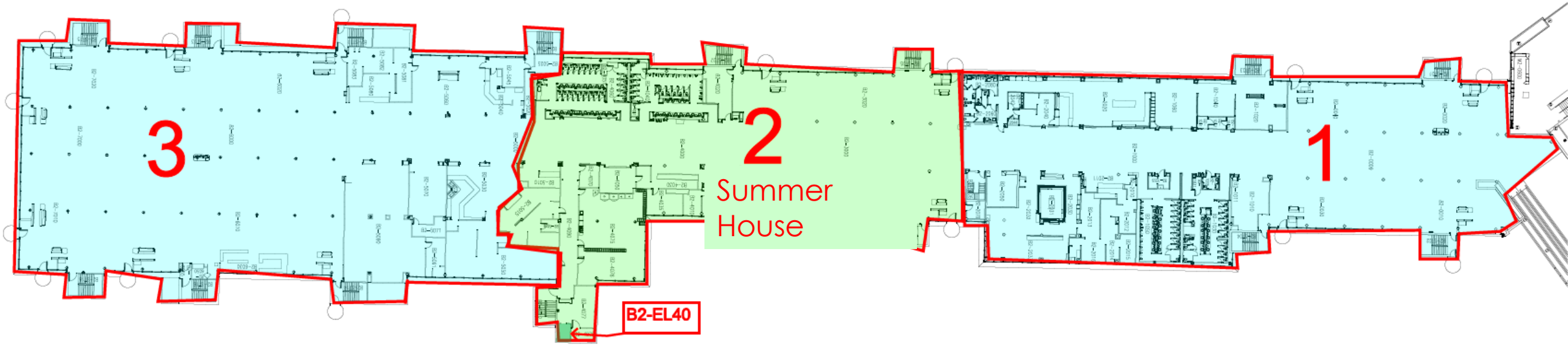




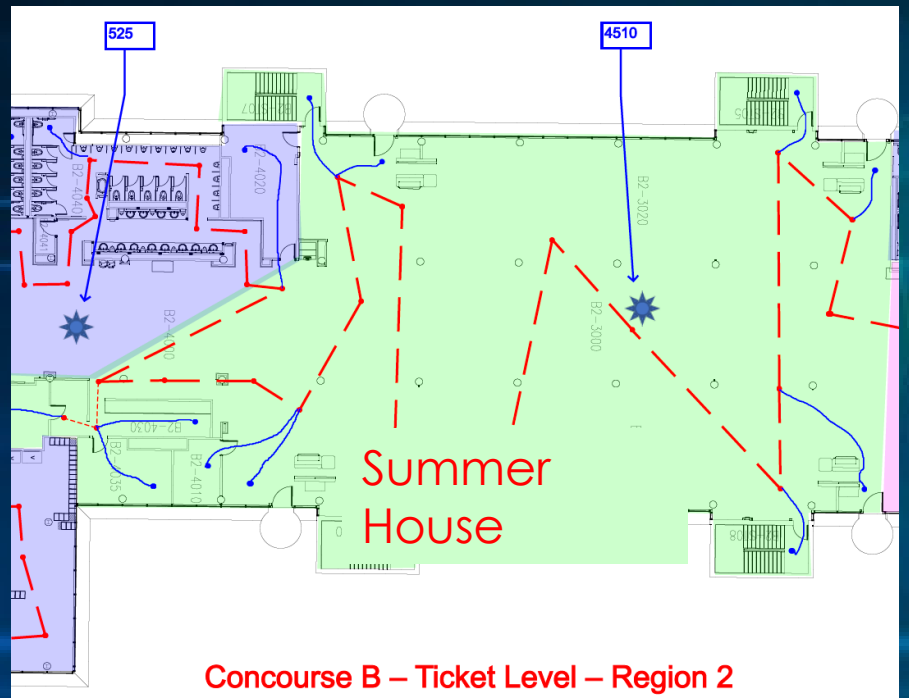


In-door Imagery Draped over LiDAR
Integrated with GIS

Rescanning a renovated region / Updating the master LiDAR model



Concourse B – Ticket Level – Overview of scanning regions



Concourse B – Ticket Level – Region 2

Name	4510
Concourse	B
Level	TICKET
Description	TARGET WITH PINK TAG NE CORNER BLUE TILE @ MIDLINE GATES B5 AND B7

NC State Plane 1983

Northing	540337.95
Easting	1419070.96
Elevation	735.48

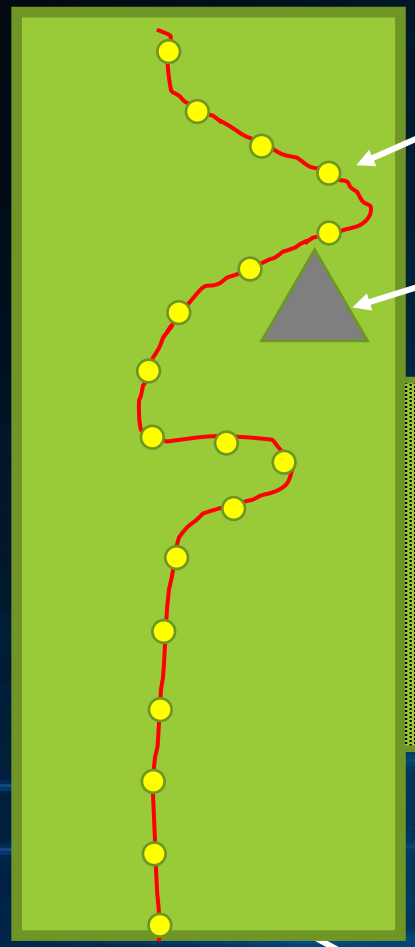
WGS 1984

Longitude	80° 56' 42.8052" W
Latitude	35° 13' 08.5441" N
Ellipsoid H	635.14

Nearest IGCP

Example showing a similar type of concession project as the summer house

Original (master scan)
2020



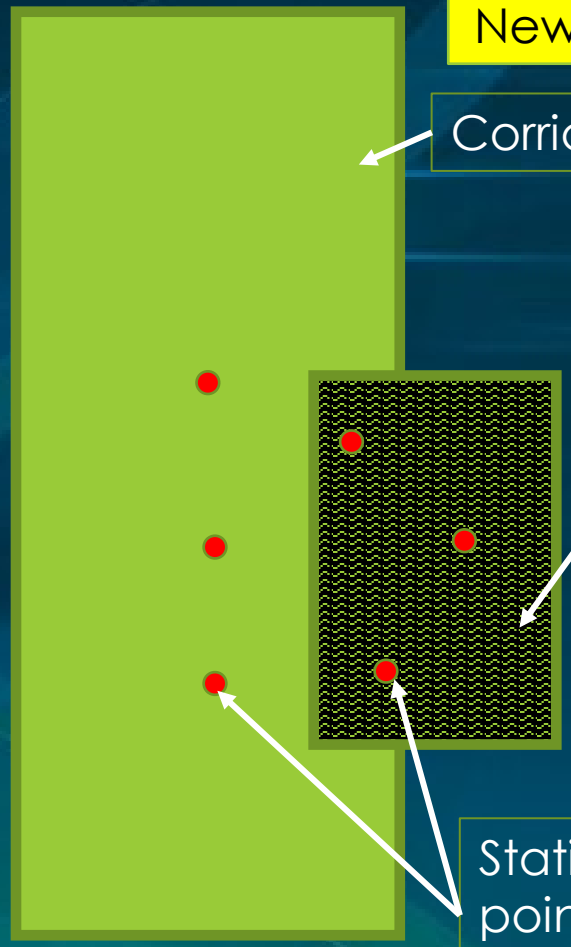
Corridor

Feature

Not included in scanning mission
(Area under construction)

Mobile scanner route:
360° images taken at 1-meter intervals (2020)

New Scan 2022



Corridor

Concession

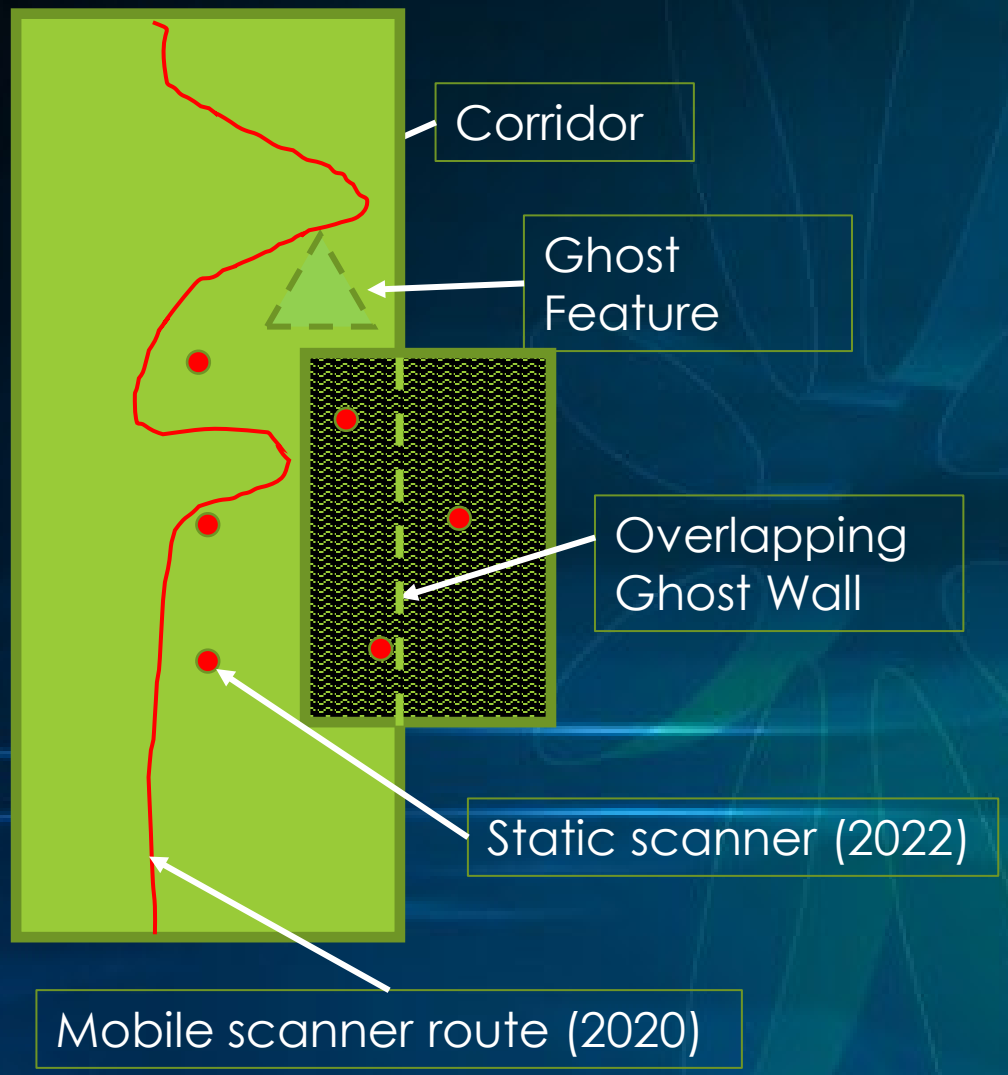
Static scanner location points
Point cloud and Imagery

Note:

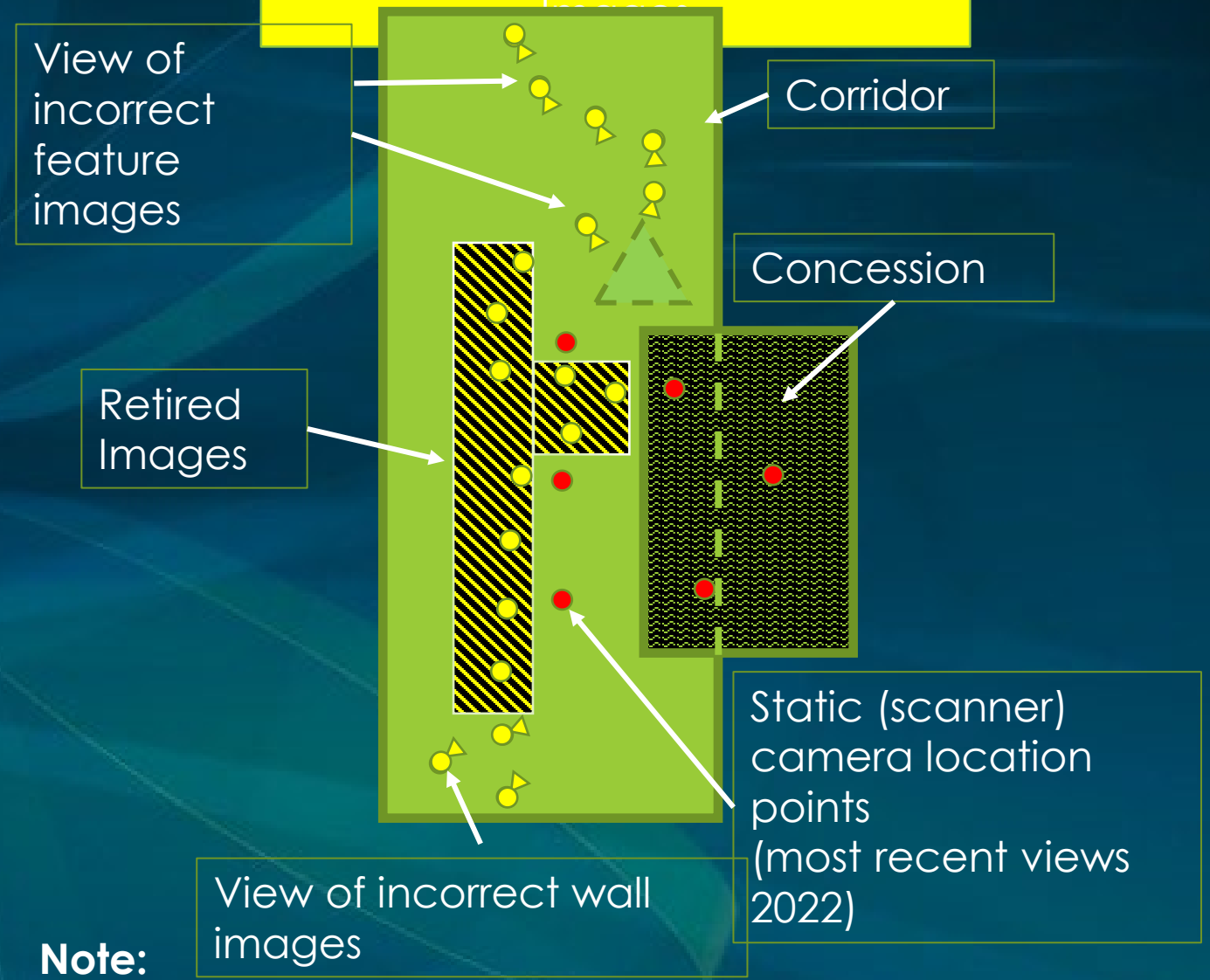
- There need to be more camera location points (in the corridor) to cover all viewpoints of the changes.
- Point cloud requires: Noise removal and Image alignment Solv3D and/or Recap

Example showing a similar type of concession project as the summer house

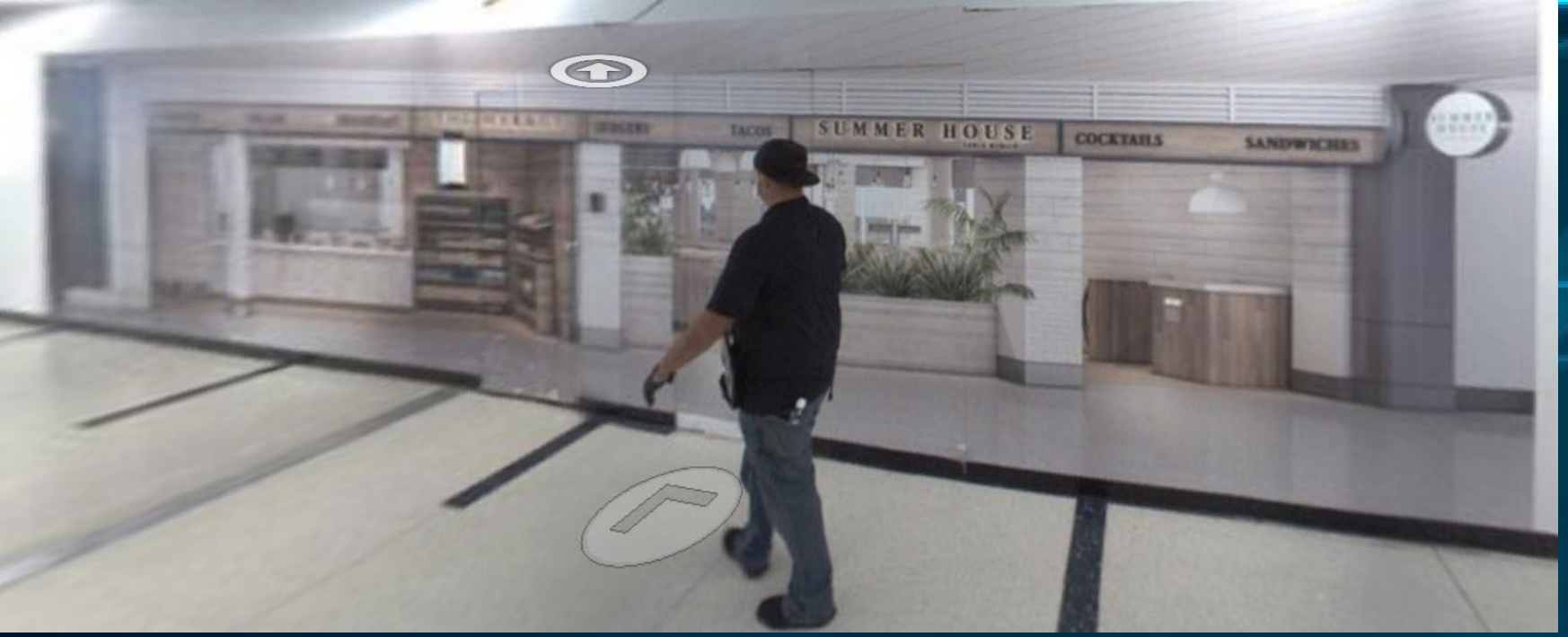
Combined 2020 and 2022 point clouds



Combined 2020 and 2022



Note:
There are insufficient camera location points (in the corridor) to cover all viewpoints of the changes



Retired photo (date: 2020)

New photo (date: 2022)

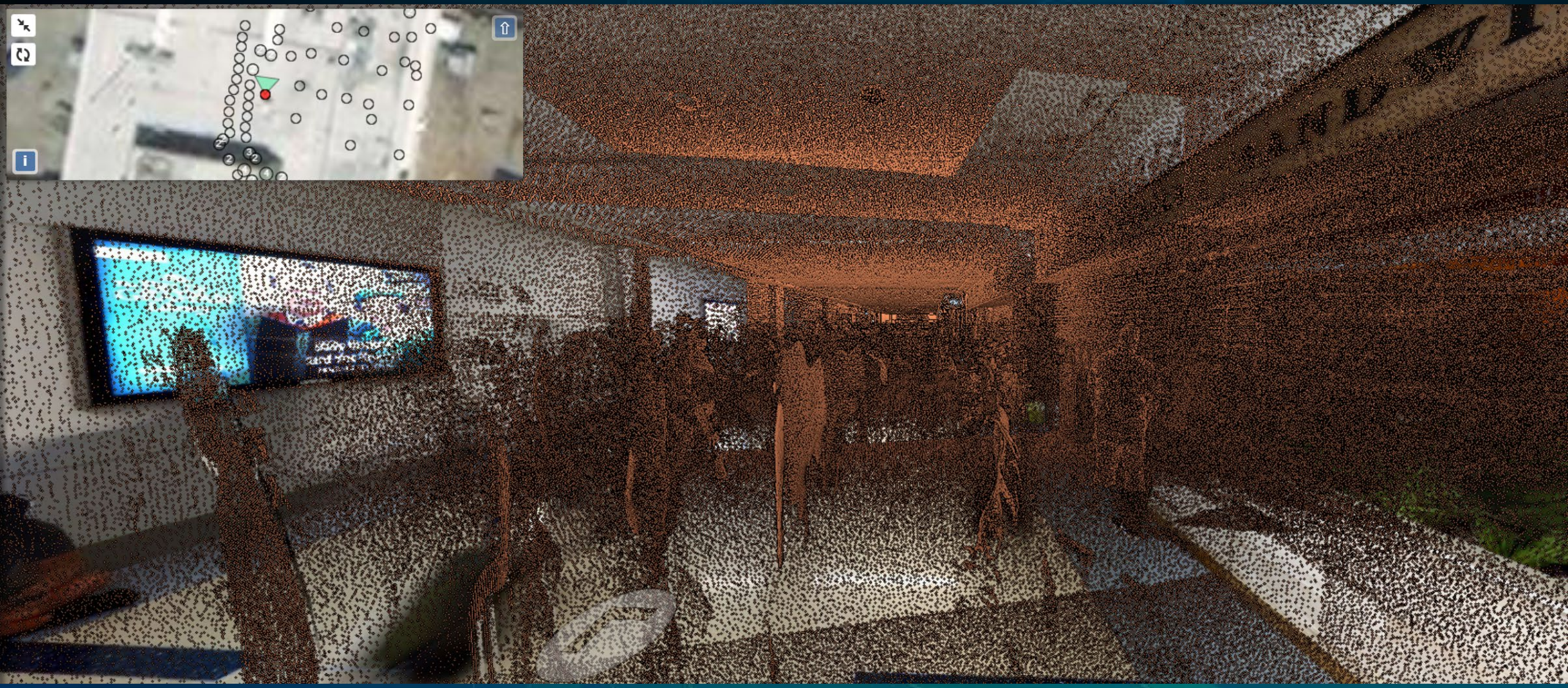
Filename	X	Y	Z	Roll	Pitch	Yaw
ladybug_panoramic_M07_004152.jpg	1419094.471	540450.8661	646.309739	-1.05849	-1.35918	35.25035
ladybug_panoramic_M07_004153.jpg	1419093.388	540447.3813	646.313961	-1.68237	-0.41526	28.27305
ladybug_panoramic_M07_004154.jpg	1419092.843	540444.0938	646.27646	-1.76848	-0.36329	29.02638
ladybug_panoramic_M07_004155.jpg	1419092.277	540440.6363	646.257501	-1.83061	-0.34345	28.48124
ladybug_panoramic_M07_004156.jpg	1419091.837	540437.2924	646.227028	-1.71551	-0.77253	31.89983
ladybug_panoramic_M07_004157.jpg	1419091.153	540434.0392	646.204083	-1.97468	-0.90033	34.74238
ladybug_panoramic_M07_004158.jpg	1419090.148	540430.6169	646.179002	-1.73937	-0.57001	35.57959
ladybug_panoramic_M07_004159.jpg	1419089.078	540427.1928	646.165955	-0.98452	-0.59861	29.06799
ladybug_panoramic_M07_004160.jpg	1419088.559	540423.4911	646.17601	-1.41168	-1.02094	23.51646
ladybug_panoramic_M07_004161.jpg	1419088.328	540420.0427	646.185581	-1.6911	-0.97708	20.67407
ladybug_panoramic_M07_004162.jpg	1419088.618	540416.74	646.171334	-0.98237	-0.60995	41.9955
ladybug_panoramic_M07_004163.jpg	1419087.825	540413.4159	646.19573	-0.56149	0.96447	111.76797
ladybug_panoramic_M07_004164.jpg	1419083.979	540413.1044	646.206249	1.76133	0.27515	222.96599
ladybug_panoramic_M07_004165.jpg	1419085.465	540416.4304	646.187232	-0.42544	-1.26066	358.31142
ladybug_panoramic_M07_004166.jpg	1419086.519	540413.1996	646.198019	-0.60503	-1.70661	2.40749
ladybug_panoramic_M07_004167.jpg	1419087.481	540409.861	646.208657	-0.82502	-1.47147	354.30188
ladybug_panoramic_M07_004168.jpg	1419089.227	540406.9977	646.186128	-1.22512	-1.26614	16.13291
ladybug_panoramic_M07_004169.jpg	1419089.107	540404.0314	646.185487	1.40665	-1.34052	295.7288
ladybug_panoramic_M07_004170.jpg	1419092.119	540403.3136	646.193997	-0.10998	1.24217	108.37726

Scanner position 2020 photos.

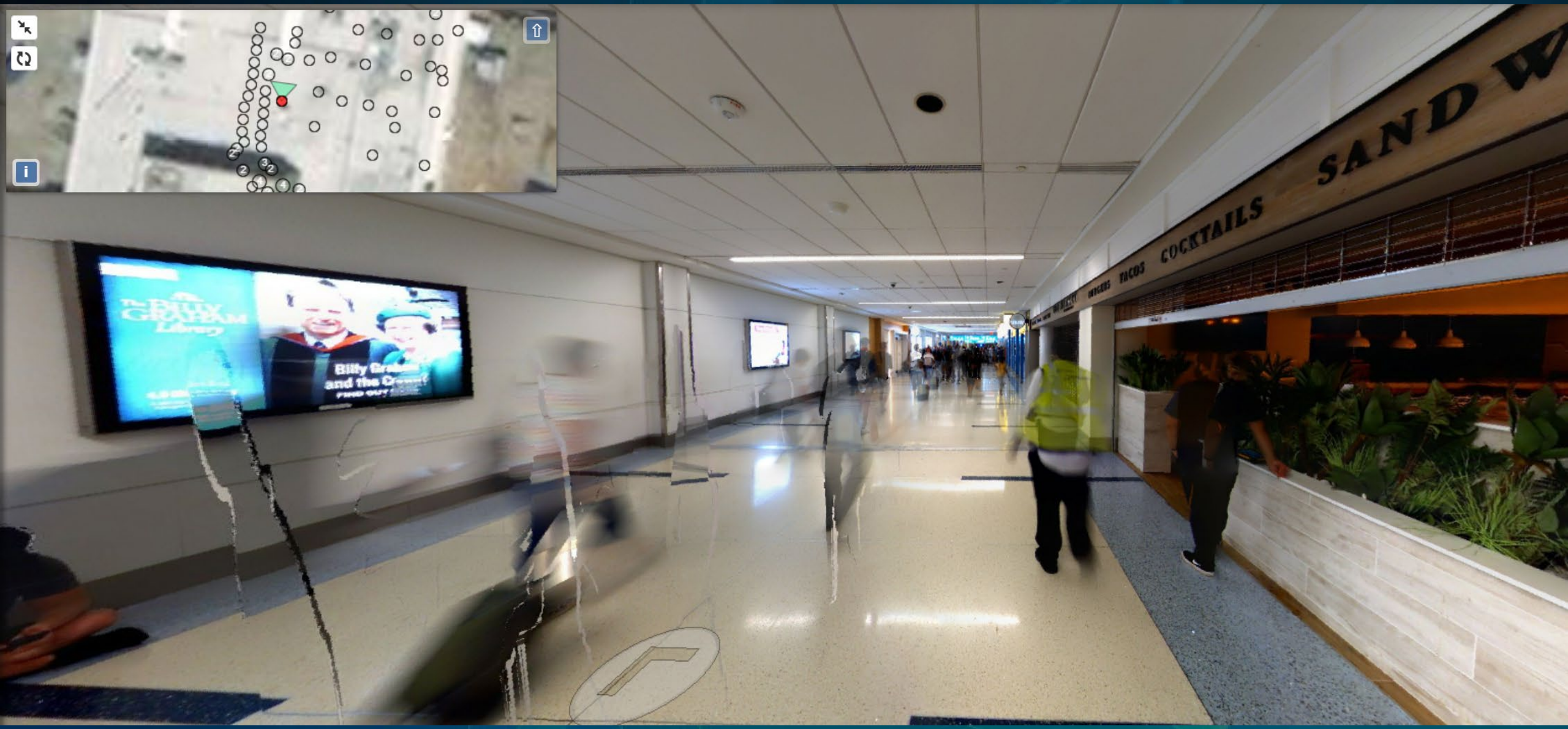
Filename	X	Y	Z	Roll	Pitch	Yaw
SummerHouseExportXspatial_48	1419073.8	540344.5994	741.1200072	-0.0194	0.08093	17.80163
SummerHouseExportXspatial_47	1419086.035	540352.5427	741.1493807	0.19099	0.24862	-139.81399
SummerHouseExportXspatial_46	1419095.606	540401.1732	741.1465497	-0.3166	0.0054	-77.37746
SummerHouseExportXspatial_45	1419089.012	540374.2901	741.1334785	0.53212	-0.14121	-121.08866
SummerHouseExportXspatial_44	1419094.533	540409.3928	741.0879978	0.3512	0.07719	-136.65786
SummerHouseExportXspatial_43	1419100.162	540428.8373	741.0507545	-1.70914	0.45345	-125.88256
SummerHouseExportXspatial_42	1419108.729	540440.937	741.153359	-0.43209	-0.5792	127.22978
SummerHouseExportXspatial_41	1419153.751	540448.7748	741.4572646	-0.37343	2.04586	-31.06913
SummerHouseExportXspatial_40	1419123.566	540449.6413	741.304119	-6.99929	-5.32167	-58.47966
SummerHouseExportXspatial_39	1419132.284	540448.2211	741.2847409	-3.80676	-4.61394	-80.97263
SummerHouseExportXspatial_38	1419141.873	540446.44	741.2671414	-0.10152	-6.90209	-118.22638
SummerHouseExportXspatial_37	1419111.381	540431.3276	741.382945	-1.58427	-0.6767	15.54796
SummerHouseExportXspatial_36	1419109.943	540421.1119	741.0266678	-1.98454	-0.20591	-57.25499
SummerHouseExportXspatial_35	1419115.106	540441.5415	741.5770861	-0.86377	1.32012	-79.71418
SummerHouseExportXspatial_34	1419125.563	540439.2543	741.5127879	0.52606	2.34132	-48.64062
SummerHouseExportXspatial_33	1419137.657	540435.753	741.2018534	-1.83804	-0.93063	-72.51612
SummerHouseExportXspatial_32	1419118.269	540428.624	741.0411466	-1.55056	0.92828	-25.17691
SummerHouseExportXspatial_31	1419126.196	540427.1094	741.093536	-0.68196	-1.25976	-123.17655
SummerHouseExportXspatial_30	1419133.31	540425.2834	741.2167071	-0.84445	-0.89227	-48.83357
SummerHouseExportXspatial_29	1419134.183	540420.1471	741.1460811	-0.68308	1.55542	-172.40829
SummerHouseExportXspatial_28	1419127.234	540412.1553	741.0677353	-1.37422	-0.31479	87.84318
SummerHouseExportXspatial_27	1419124.898	540398.3701	741.0999109	-1.00777	0.86011	134.16706

Scanner position 2022 photos.

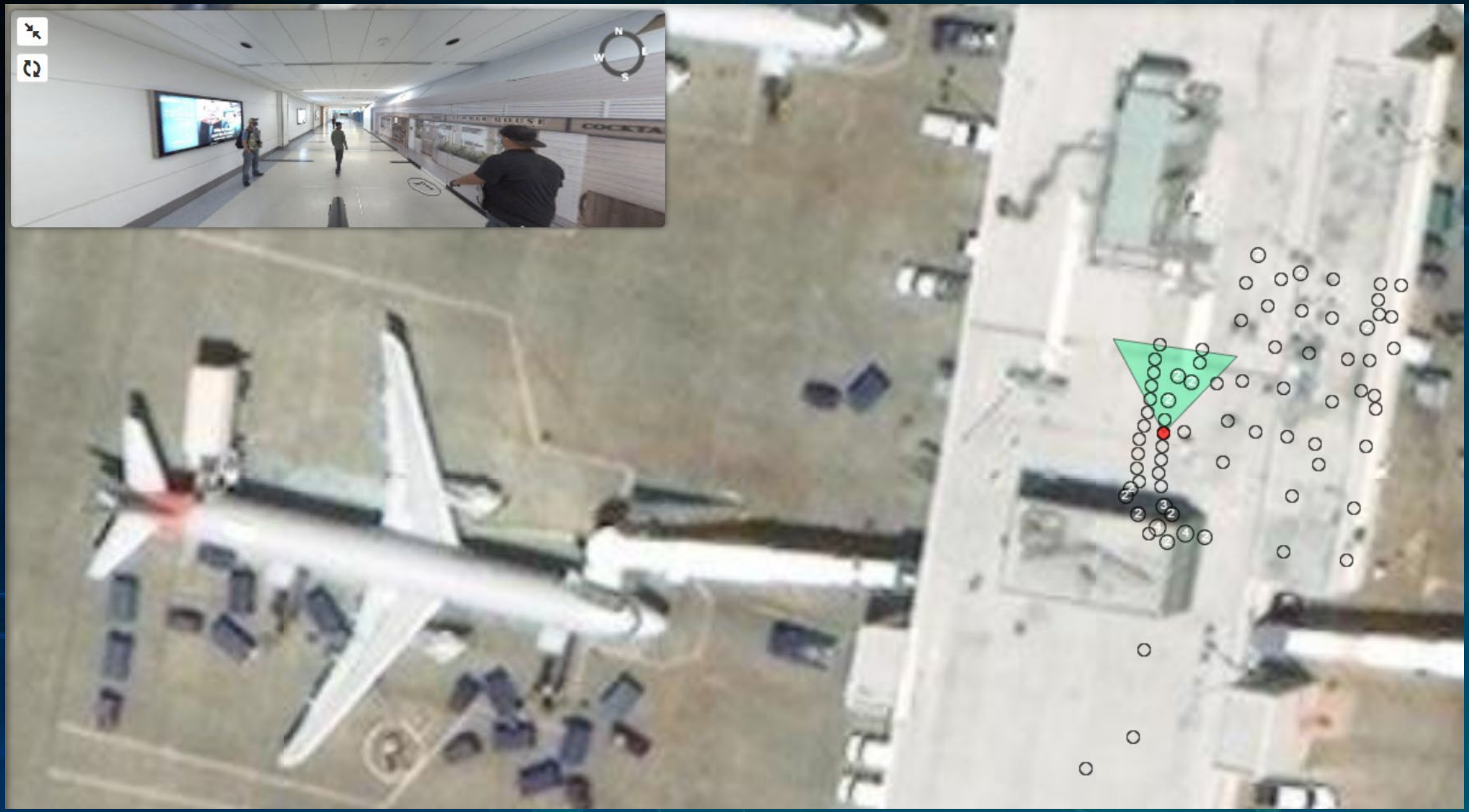
Combined Scanner (TIMMS and TMX) images 2020 and Summerhouse Mission 2022



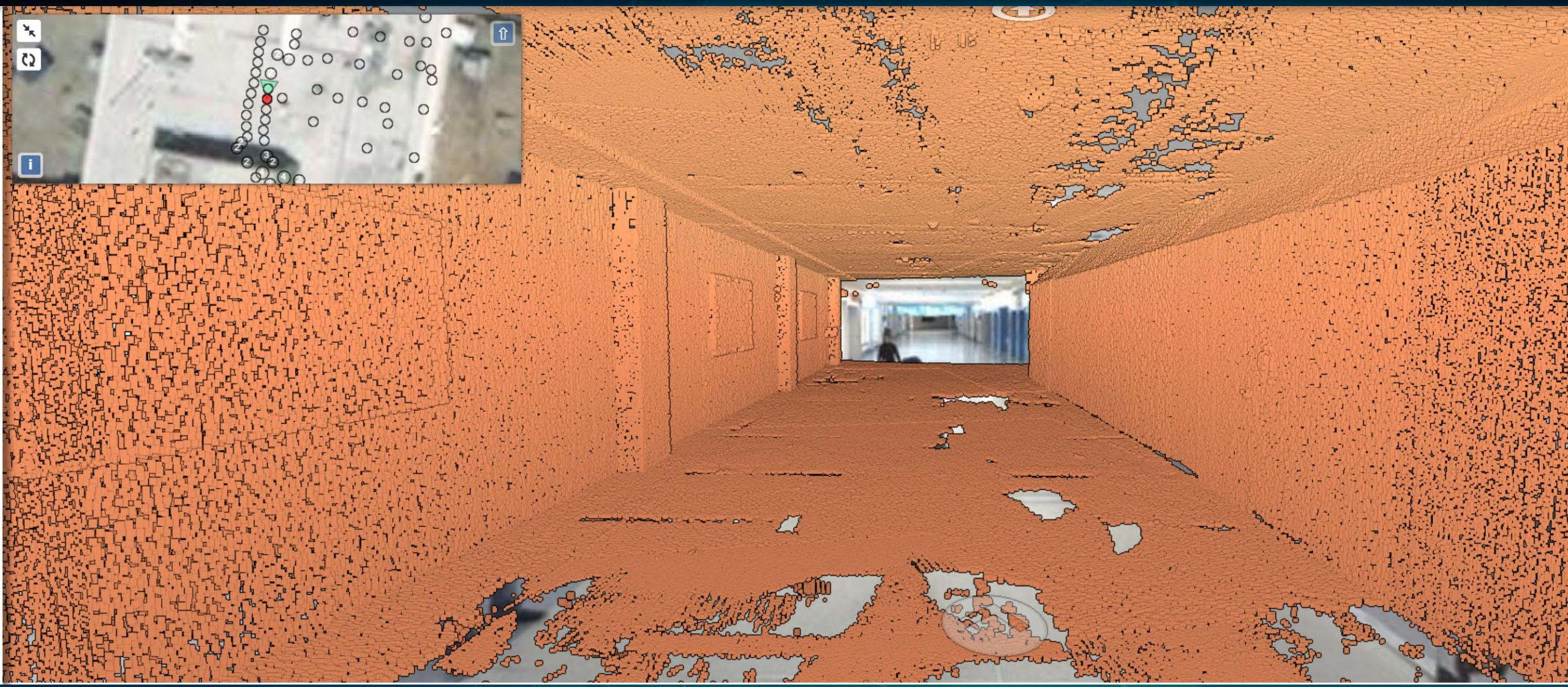
New Static scanner (X7) Point cloud requires: Noise removal and Image alignment



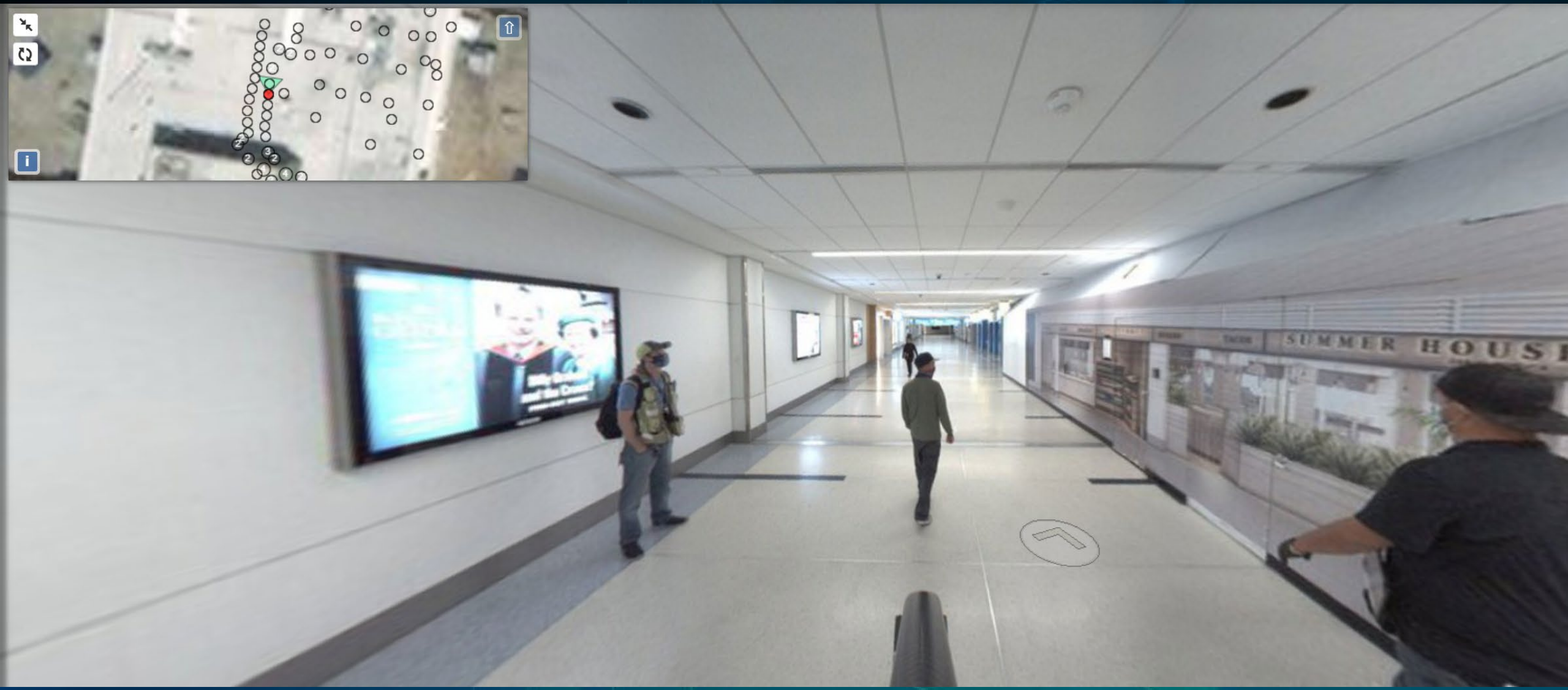
New Static scanner (X7) images showing passenger crowd movements and ghosts images that cannot be removed



Combined Scanner (TIMMS and X7) images 2020 and Summerhouse Mission 2022



TIMMS scanner Mission 7 (sliced): Noise removed and images aligned



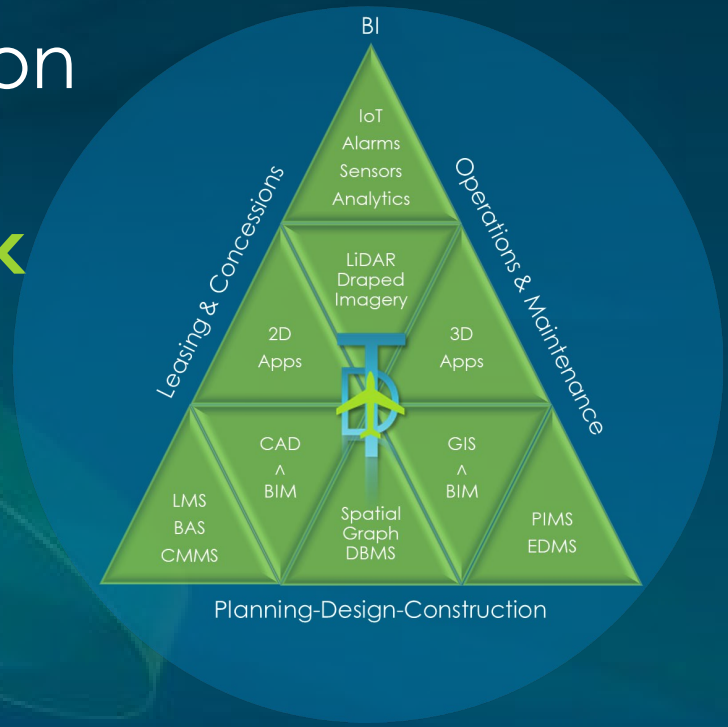
TIMMS photo to be retired: Mission 7 2020

Keys to Sustaining Airport Digital Twin

- Keep it Simple & Sustainable **(KISS) Principle**
- Leverage **IoT sensors with APIs to automate overlay** of real-time (and historical) data
- **Update spatial "skeleton"** with new and/or relocated IoT sensors, assets, etc...; **leverage simple GIS symbolized point features in 2D/3D**
- Leverage **LiDAR draped imagery** with **semi-automated/robotic scanning platforms**

Takeaways

- Airport Owner's Digital Twin (DT) is not a single software solution; it's an **integration of systems, data, and processes**
- DT is **not replacing existing airport systems**, but rather expand their utility via DT integration
- DT **requires sustainable geospatial framework**
- Airport **CIP builds and renovates** assets physically and should **also virtually via DT**



Q / A

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