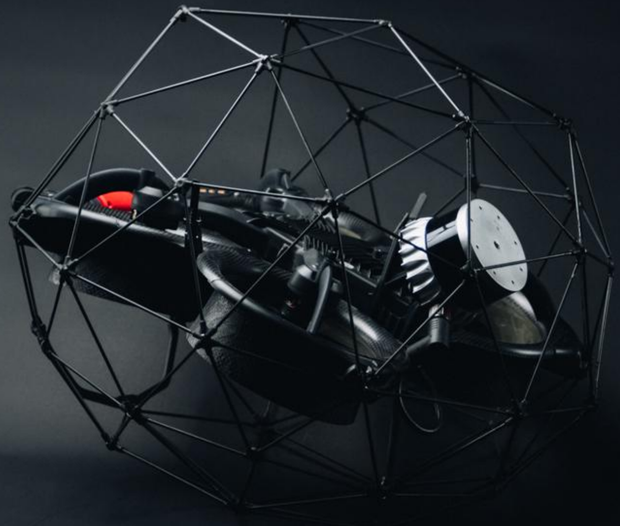

FLYABILITY

SAFE DRONES FOR INACCESSIBLE PLACES

How to Make Survey-Grade 3D Models with the Elios 3 and GeoSLAM Connect

Wednesday, November 9 2022

4 PM - 5 PM CEST / 10:00 AM - 11:00 AM EST

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WEBINAR ENGAGEMENT

Ask questions during the webinar.

AGENDA

1 Introduction

—5 minutes

2 Part 1: How to Make Survey Grade Models with the Elios 3 and GeoSLAM Connect

– 10 minutes

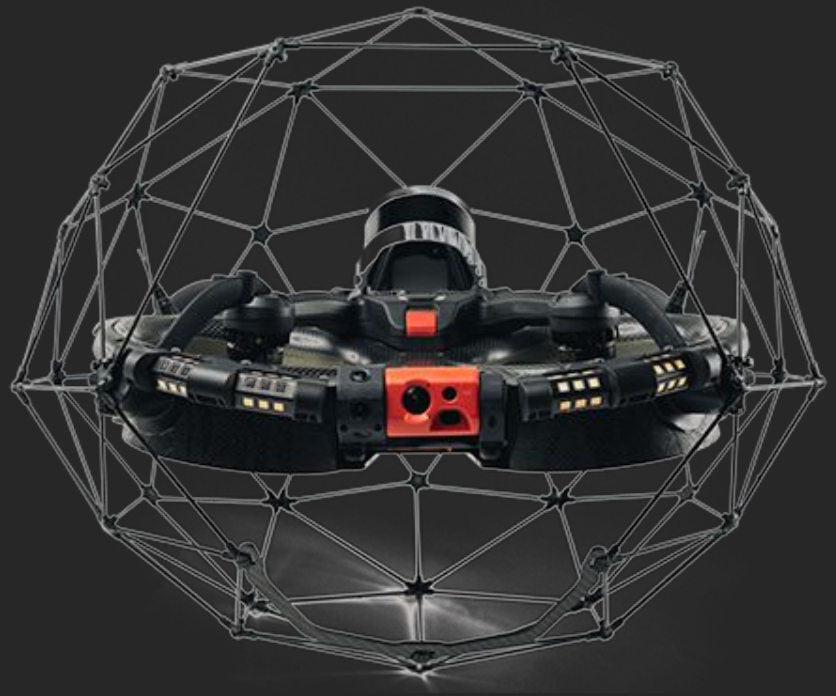
3 Part 2: Elios 3 + GeoSLAM Accuracy and Precision Testing

—20 minutes

4 Part 3: Why Accuracy Matters—Examples from the Field

—10 minutes

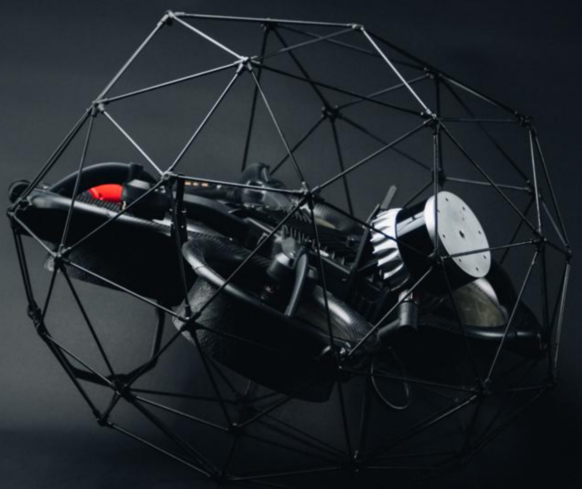
5 Q&A—15 minutes



Part 1:

How to Make Survey Grade Models with the Elios 3 and GeoSLAM Connect

Much more than a flying camera, Elios 3 is a powerful data-harvesting tool.



FlyAware™ SLAM Engine

SLAM-Based Stabilization

3D Live Map

3D reporting

3D Surveying Solution

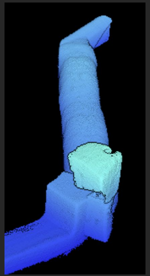
Modular Payload Bay

Collision-Resilient Rugged Design

Close-Up Inspection Dedicated Payload

Extended Air-Time

How to make Survey Grade Models with the Elios 3 and GeoSLAM Connect

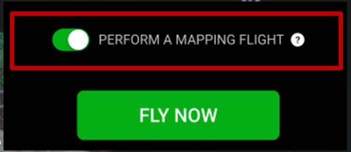


Good flight plan + Mapping flight / GeoSLAM = Survey grade map

"The way you capture your data will have the biggest impact on the success and accuracy of your mapping"

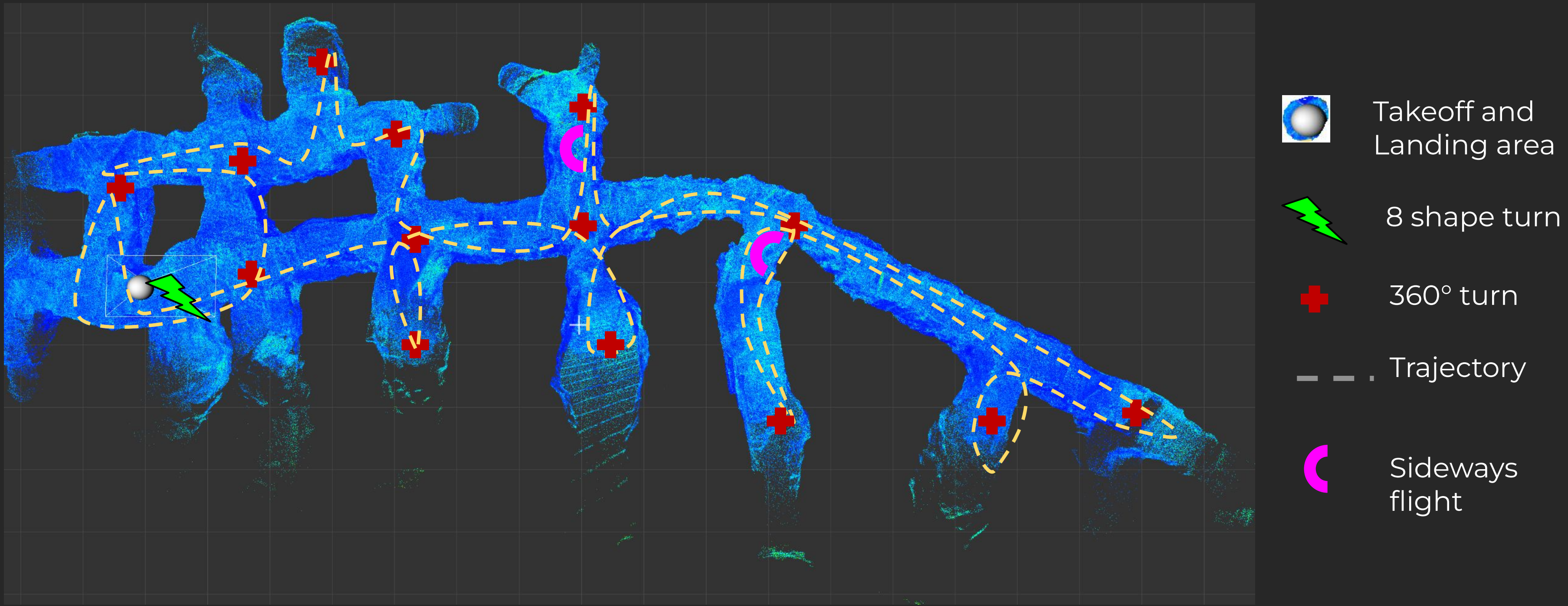
Best practices for mapping flights

1. Define your flight plan in advance (think about the LiDAR coverage)
2. Identify (physically) the take off point
3. In Cockpit, activate the mapping flight slider for the drone calibration
4. Do the arming sequence. The drone must be on the take off point and should not be moved during the countdown
5. Take off and gain altitude 3-6 feet
6. Do an 8 pattern flight turn around your take off place.
7. Start your mapping flight in assist flight mode
8. At each junction do a 360 ° turn* or another 8 pattern turn
9. Pass sideways manholes and small openings.
10. Fly within 1-10 metres of walls and objects
11. Do not stay too long in the same spot
12. Land on your take off point

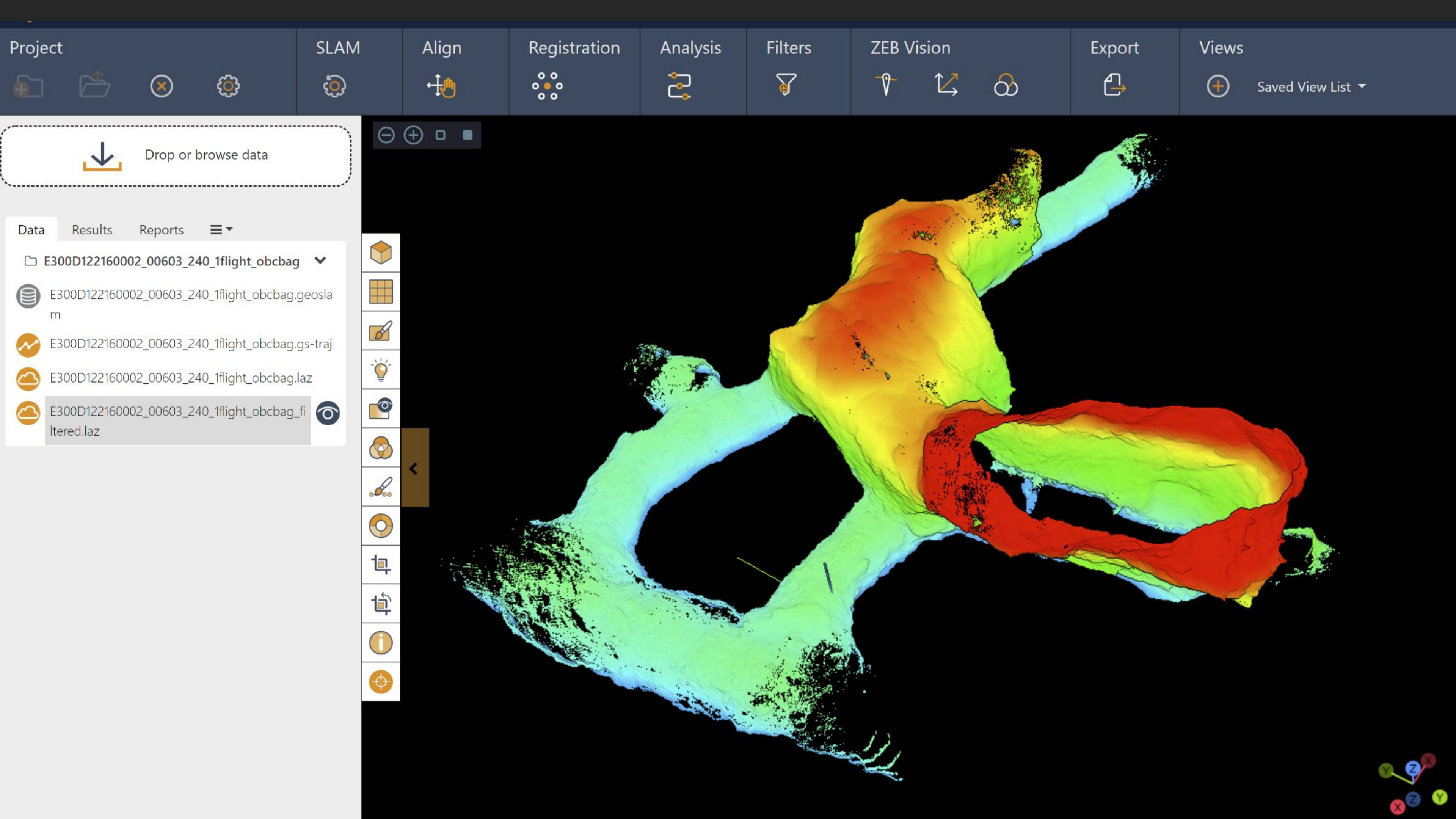


Example of flight trajectory

Length of the flight area: 200 m/ 660 feet. Height of the tunnels: max 20 meters /66 feet



The yellow dots represent a good flight trajectory with many 360° turns and overlapping areas. Due to the size of the tunnels flying at 10m/30 feet would be the right altitude for good mapping here.


Project
SLAM
Align
Registration
Analysis
Filters
ZEB Vision
Export
Views
Saved View List
Drop or browse data
Data
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Reports
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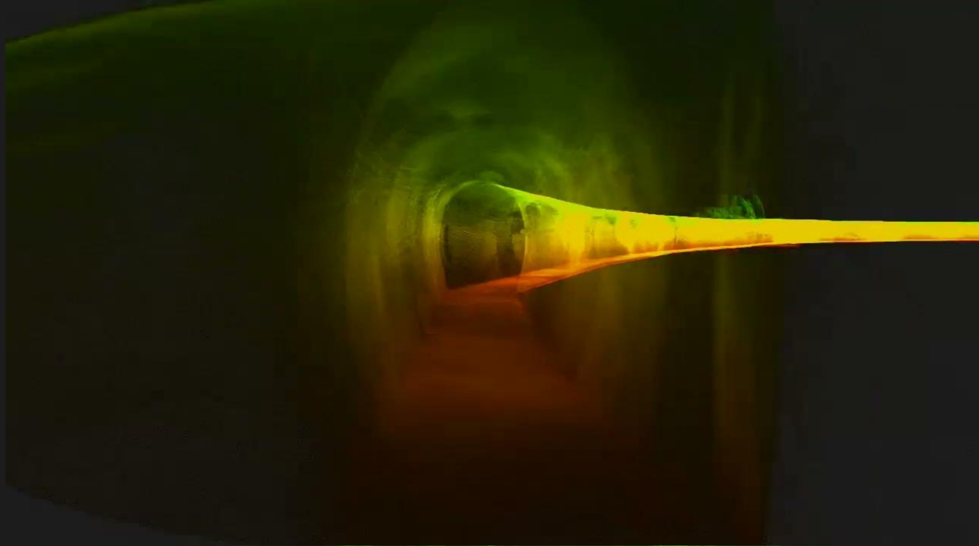
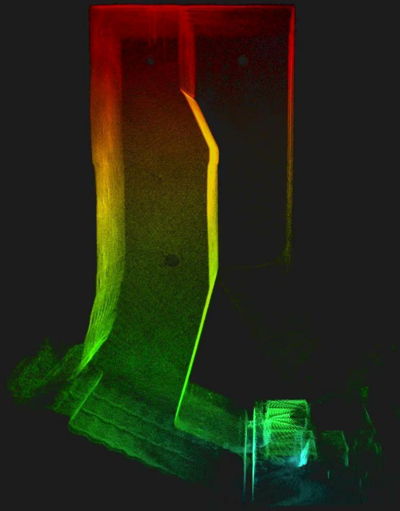
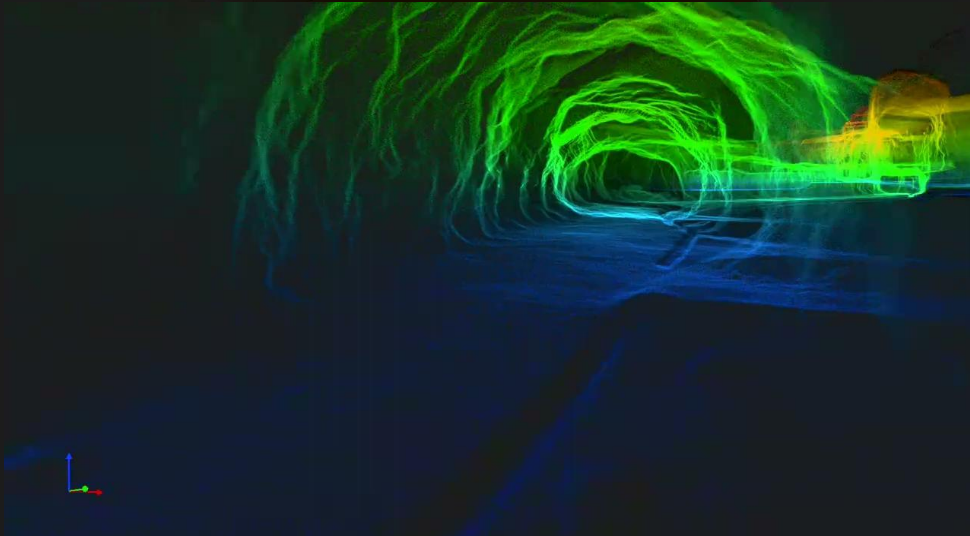
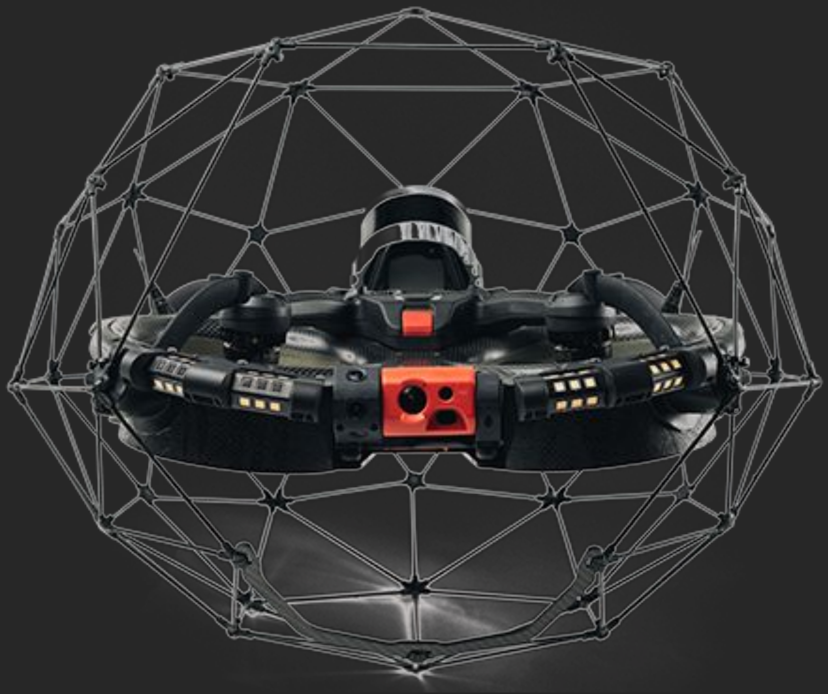






Part 2:

Elios 3 + GeoSLAM Accuracy and Precision Testing

GeoSLAM Introduction

GeoSLAM is the market leader in SLAM technology for both hardware and software, making it easy to capture and connect data from the world around us.

In 2013 GeoSLAM pioneered the first handheld SLAM system, the ZEB-1 and since then has led the way in developing the ZEB range by releasing new mobile laser scanners and SLAM technology.

GeoSLAM technology gives people the power to collect geospatial data from difficult environments, whether they are indoor, outdoors, or underground.

Flyability / GeoSLAM partnership has brought together the Flyabilities expertise of inspecting the inaccessible with GeoSLAM, market leading SLAM algorithm to create a mapping tool for the most challenging environments.

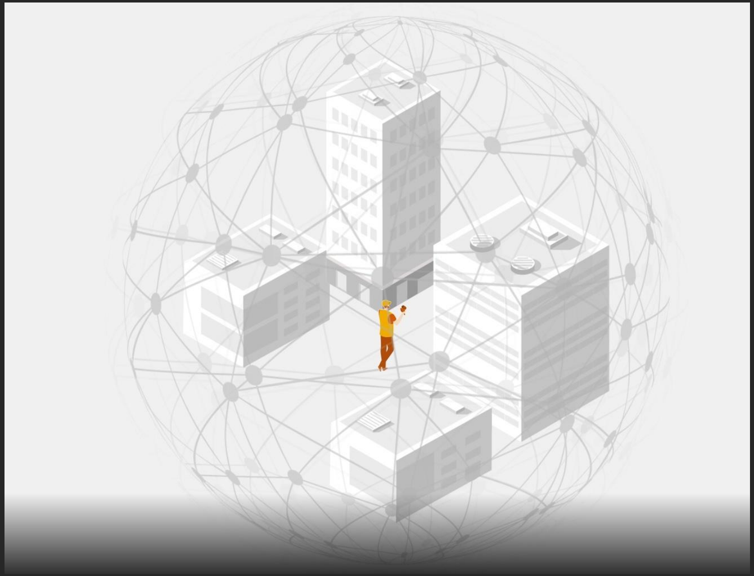
Introduction to SLAM—What is SLAM?

SLAM stands for **Simultaneous Localization and Mapping**

It is the process of mapping an area whilst keeping track of the location of the device within that area without the requirement for GNSS.

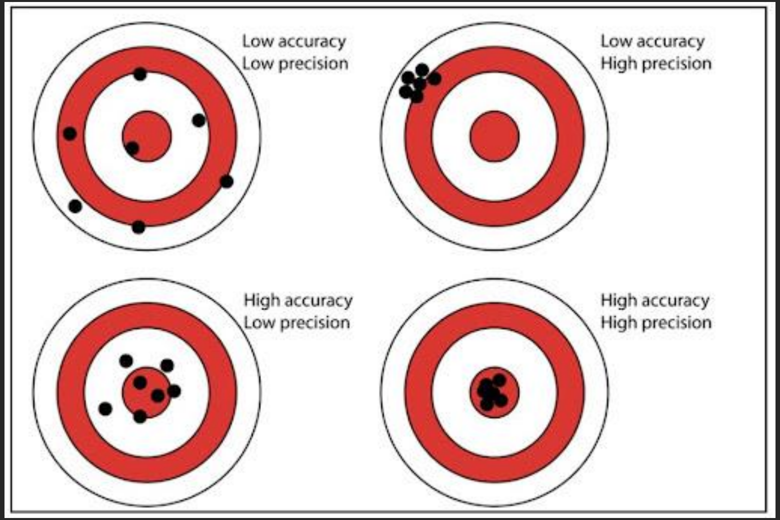
A LiDAR-based SLAM system uses a laser sensor to generate a 3D map of its environment. LiDAR (Light Detection and Ranging) measures the distance to an object by illuminating the object using an active laser “pulse”.

SLAM allows for accurate model creation of large areas in a short period of time by mapping using mobile systems, such as drones or vehicles in comparison to a terrestrial system.



Introduction to SLAM characterization — Key terminology

- **Precision** is defined as the degree to which further measurements show the same result.
- **Accuracy** is most universally defined as the degree of conformity of a measured quantity to its actual (benchmark) value.
    - **Local accuracy** when the object can be viewed from a single position (e.g., the dimensions of a single room).
    - **Global accuracy** where the object cannot be viewed from a single position (e.g., the distance between two rooms).
    - **Georeferenced accuracy** is global accuracy plus inaccuracies caused by the alignment method.
    - **Drift** is the error as a % with respect to the distance measured/travelled. The drift is used to identify the expected error as absolute error grows in the absence of ground control points or GNSS

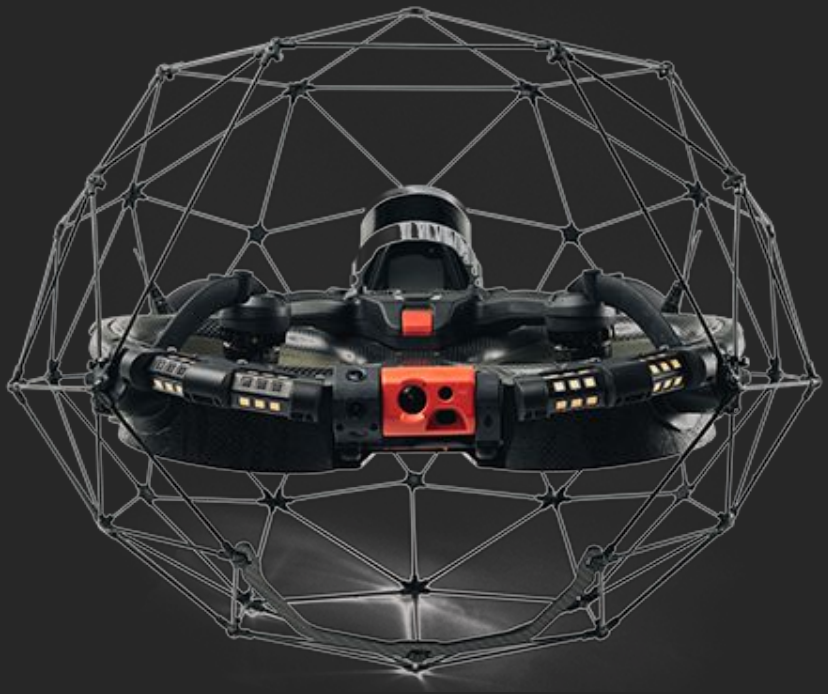


Disclaimer

- The definition of **Survey Grade** depends on the use case and application of both the hardware and software.

- Hence, the Elios 3 with GeoSLAM Connect will meet many requirements for both surveying and mapping the inaccessible, however this does not define that all survey requirements are met with the Elios 3.

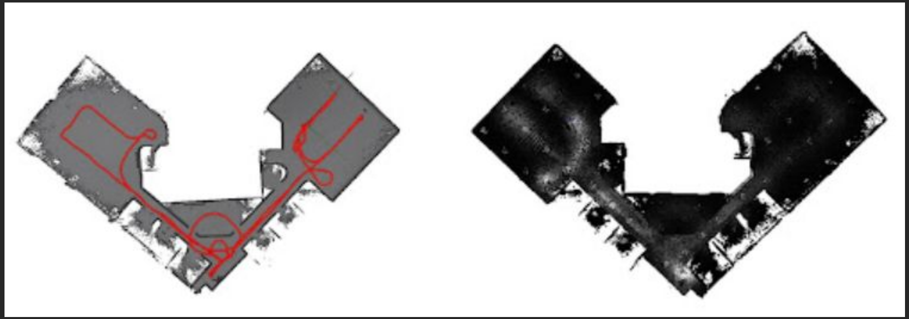
- The rest of the presentation will cover the accuracy and precision of the system and allow you to make an educated decision on whether it fits or not your surveying needs!



—Test 1—

Local Accuracy & System Precision

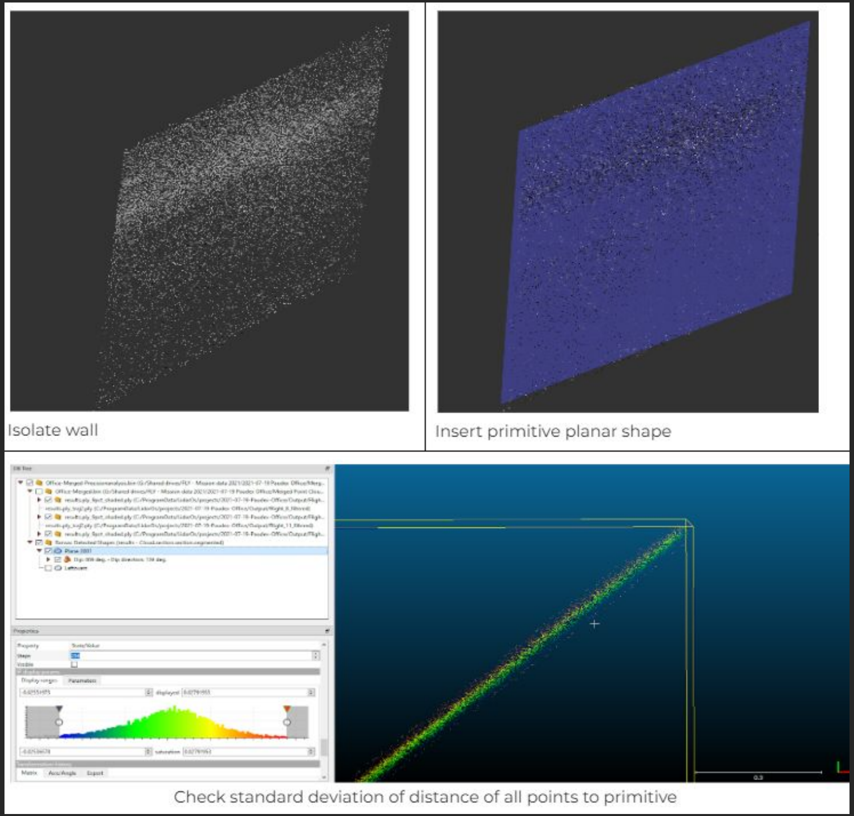
Test 1: Local Accuracy & System Precision



Test Overview

- **Who did the testing**. GeoSLAM 3D mapping experts and members of the Flyability product team.
- **What was tested**. System precision and local accuracy of 3D models made with LiDAR data collected by Flyability's Elios 3 processed with GeoSLAM Connect (standard processing preset, with outlier filter).
- **What tests were conducted**. Local accuracy was tested with a Plane to-Plane analysis. System precision was tested with a Range Noise evaluation.
- **Reference model**. The reference model used for the tests was made with a TLS (Terrestrial Laser Scans) Riegl VZ-400, and the registration process was undertaken using RiScan Pro V2.14.1.

Test 1: Local Accuracy & System Precision



Isolate wall

Insert primitive planar shape

Check standard deviation of distance of all points to primitive

Test Results

- **Test results—precision analysis.** The Mean Standard Deviation between the Elios 3 scan and the reference planes was **8mm** (1-sigma), aka 95% of the points (2-sigma) fall within **+-16mm** of the reference planes.

- **Test results—local accuracy**. The mean Absolute Normal Distance between the Elios 3 and the Reference Model was **8mm** (.31 inches) and all the comparisons fell within +/- 16mm (.63 inches)

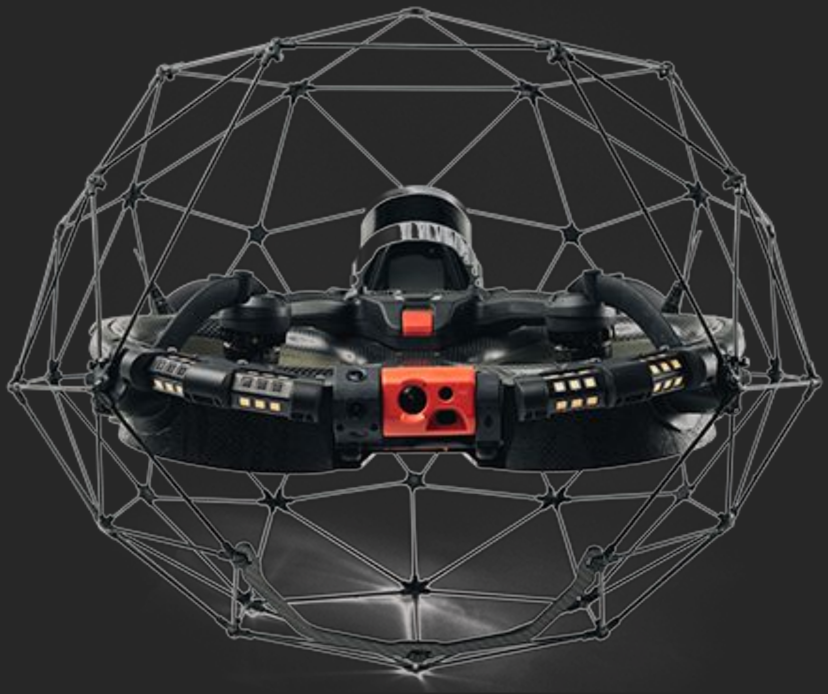
Test 1: Local Accuracy & System Precision

Test results—precision analysis

Name	Standard Deviation
Test 1	7 mm (.28 inches)
Test 2	7 mm (.28 inches)
Test 3	8 mm (.32 inches)
Test 4	6 mm (.24 inches)
Test 5	6 mm (.24 inches)
Test 6	15 mm (.59 inches)
Mean Standard Deviation	**8 mm (.32 inches)**

Test results—local accuracy

Name	Normal Distance
Plane 1	6 mm (.24 inches)
Plane 2	0 mm
Plane 3	-16 mm (-.63 inches)
Plane 4	-10 mm (-.39 inches)
Plane 5	-13 mm (-.51 inches)
Plane 6	-3 mm (-.19 inches)
Mean—Absolute Normal Distance	**8 mm (.32 inches)**



—Test 2—

Global Accuracy & Georeferenced Accuracy

Test 2: Global Accuracy & Georeferenced Accuracy

Test overview

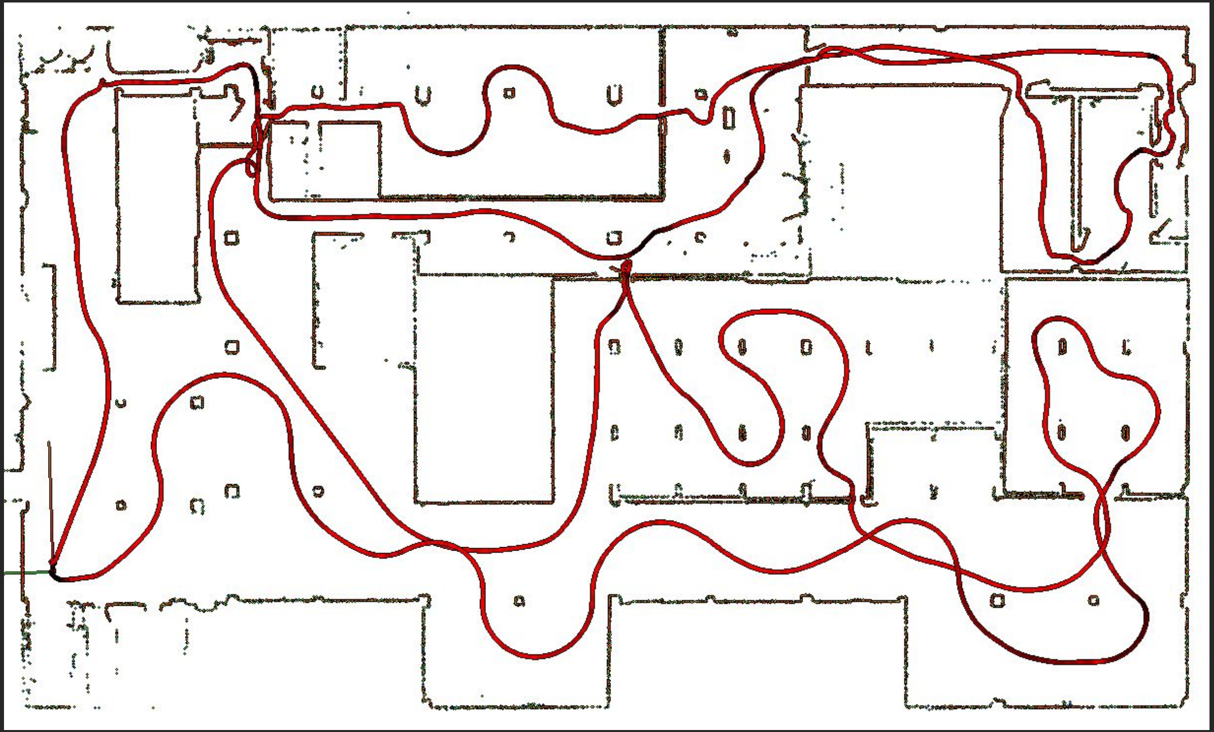
- **Who did the testing.** GeoSLAM 3D mapping experts and members of the Flyability product team.
- **What was tested.** System global accuracy and georeferenced accuracy of 3D models of the LiDAR data collected by Flyability's Elios 3 processed with GeoSLAM Connect.
- **What tests were conducted.** Three scans were captured with Elios 3 of the same large underground facility of 70 meters x 40 meters and processed with GeoSLAM Connect. 15 targets were set-up in the facility and a centroid extraction script was used for accuracy evaluations.
- **Reference Model.** The Reference Model used for the tests was made with a TLS (Terrestrial Laser Scans) Riegl VZ-400, and the registration process was undertaken using RiScan Pro V2.14.1.

Elios 3 + GeoSLAM Global Accuracy

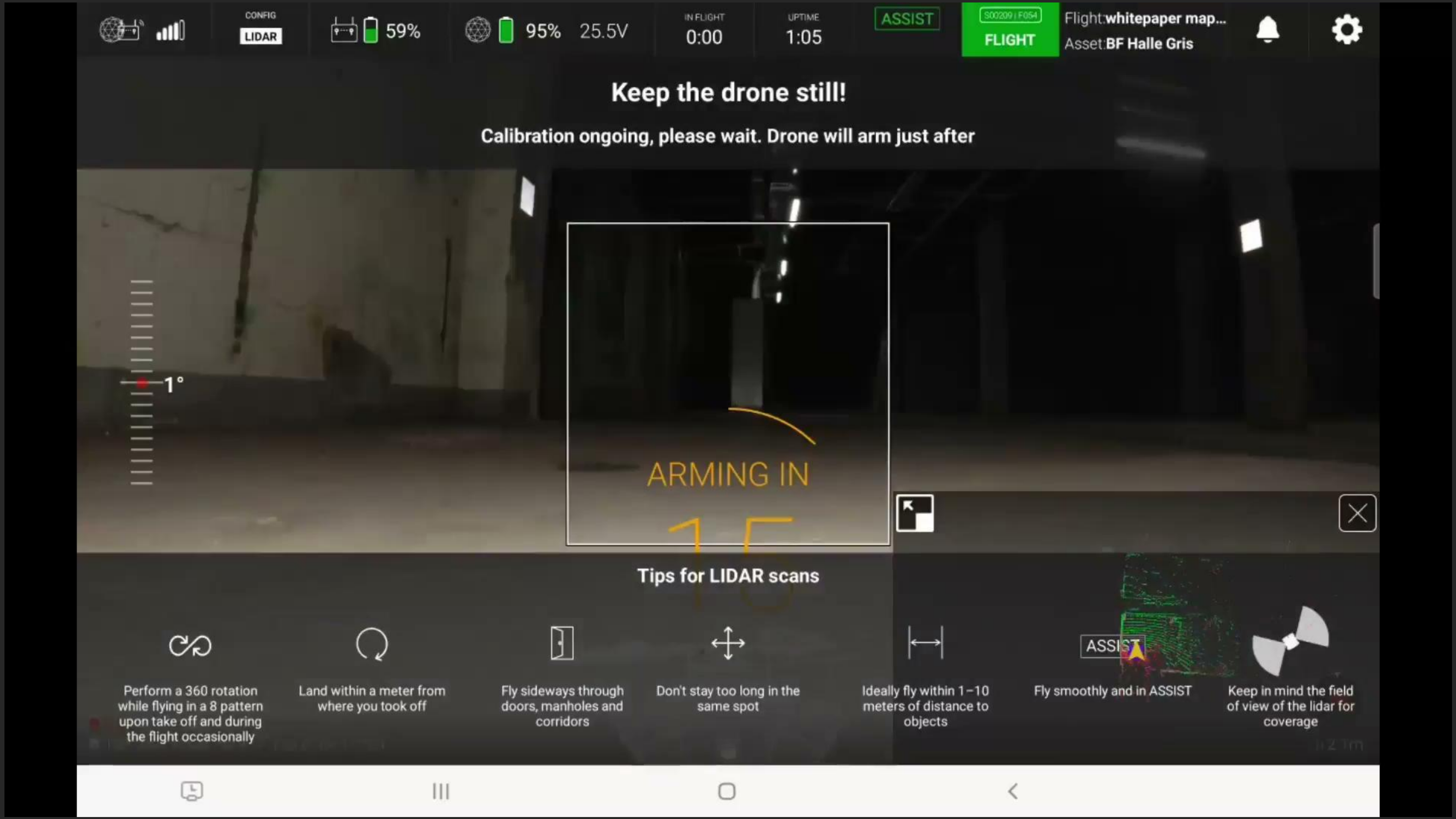
Riegl TLS used for the ground truth (6 hour capture time) and 15x control targets.

Elios 3 + GeoSLAM Global Accuracy

3 scans were captured with Elios 3 (each scan capturing the full asset, in 8.5 minutes of flight)



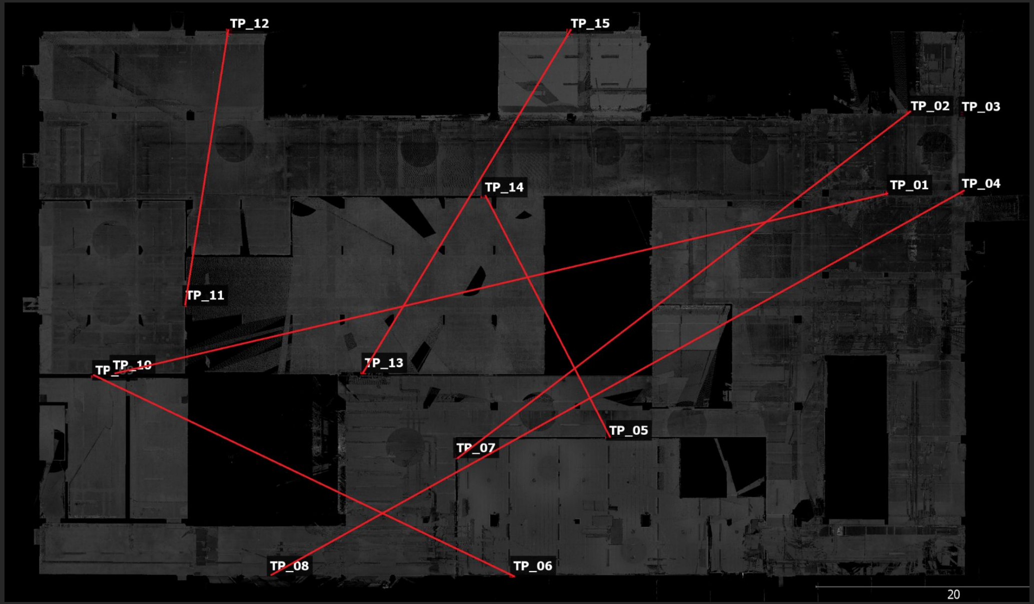
Elios 3 + GeoSLAM Global Accuracy



Elios 3 Point Cloud and TLS Control

Comparison of the Elios 3 data captured in 8 minutes vs Terrestrial Laser Scanner (TLS) data captured in 6 hours.

Elios 3 + GeoSLAM Global Accuracy—Methodology



Assessing Global Accuracy—Distance Measurements

- **Distance measurements**. The distance between pairs of centroids was measured for both the control TLS data and the Elios 3 scans .
- **Find residuals**. Residuals were found between the point pair distance of TLS data and the Elios 3 point pair distances.
- **Find RMSE**. The RMSE of the residuals was calculated for the 3 E3 scans.
- **Find RMSE as a percentage of length**. The RMSE of the residuals as a percentage of distance between centroids was computed.
- **Find the mean error**. Finally, the average of the RMSE (MAE) of the residuals as a percentage of distance between centroids was computed.

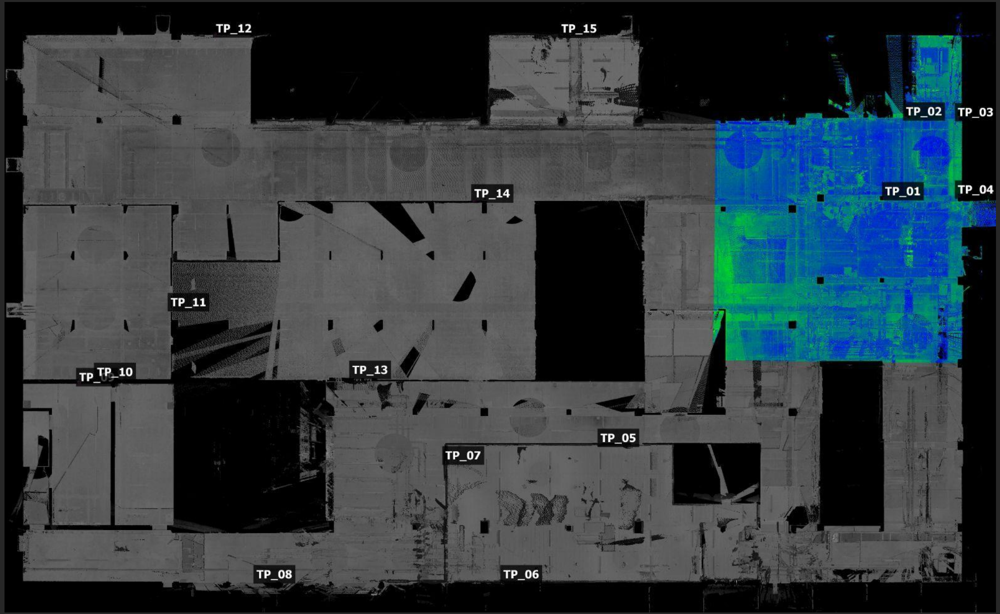
Elios 3 + GeoSLAM Global Accuracy—Results

Residual dXYZ (m)						
Tie Line	Scan 1	Scan 2	Scan 3	RMSE	Length (VZ400)	RMSE % Length
TP01-TP08	0.0005	0.0119	0.0326	0.0200	52.60	0.0381
TP02-TP07	0.0066	0.0071	0.0060	0.0066	41.11	0.0160
TP04-TP08	0.0284	0.0183	0.0164	0.0217	57.15	0.0379
TP05-TP14	0.0351	0.0292	0.0079	0.0268	19.69	0.1359
TP07-TP09	0.0661	0.0496	0.0992	0.0746	26.73	0.2789
TP11-TP12	0.0259	0.0540	0.0571	0.0478	19.88	0.2403
TP14-TP15	0.0558	0.0517	0.0483	0.0520	13.34	0.3898
			RMSE	0.0356	MAE (%)	0.1624

The Global Accuracy distance measurements results showed:

- The RMSE of target-to-target distances in the three scans vs. the reference model was **35mm**.
- The MAE as a percentage of distance (drift) was **0.16%**.

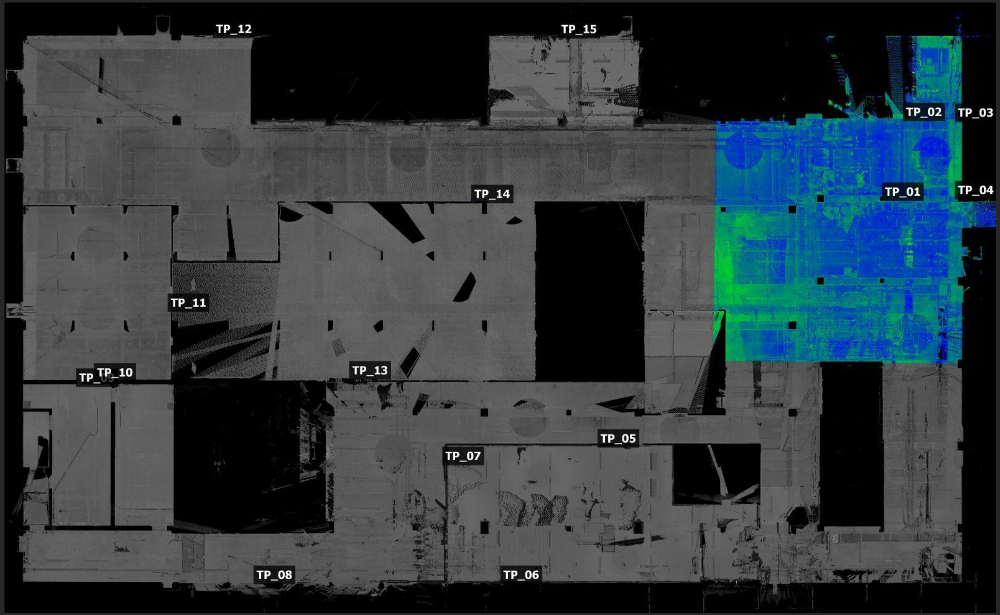
Elios 3 + GeoSLAM Cloud-to-Cloud Georeferenced Accuracy—Methodology



Cloud-to-Cloud Georeferenced Accuracy

- A 15 meter section of the E3 and TLS scans was used to perform cloud-to-cloud registration.
- This alignment was then applied on the entire Elios 3 point cloud.
- The reference centroids from the TLS data were recorded and compared to the aligned Elios 3 centroids.
- The residuals between the reference centroids and the aligned centroids was calculated.
- The RMSE for both dXY and dXYZ for the 3x scans was computed for each reference point.
- The average RMSE values for both dXY and dXYZ were output.

Elios 3 + GeoSLAM Cloud-to-Cloud Georeferenced Accuracy—Results



Cloud-to-Cloud Alignment Results

- Alignment of E3 scan with reference around take-off location

- Average XY drift of each target: **0.1%** (e.g: 10cm on a 100m distance)
- Average XY error (Mean RMSE): **54mm**

- Average XYZ error of each target: **0.2%** (e.g: 20cm on a 100m distance)
- Average XYZ error (Mean RMSE): **110mm**

Only having control in one section of the scan environment causes any inaccuracies in the registration process to propagate throughout the scan and will result in increased inaccuracies compared to using targets or ground control points (GCPs) across the whole scan.

Elios 3 + GeoSLAM Cloud-to-Cloud Georeferenced Accuracy—Results

	dXY					
Target	scan 1	scan 2	scan 3	RMSE		
TP001	0.0213	0.0344	0.0444	0.0347		
TP002	0.0338	0.0154	0.0315	0.0281		
TP003	0.0081	0.0059	0.0060	0.0068		
TP004	0.0195	0.0386	0.0372	0.0329	Distance	Drift
TP005	0.0218	0.0310	0.0617	0.0418	45	0.09%
TP006	0.0182	0.0751	0.0488	0.0528	56	0.09%
TP007	0.0186	0.0214	0.0256	0.0221	50	0.04%
TP008	0.0258	0.0317	0.0373	0.0319	68	0.05%
TP009	0.0666	0.1057	0.1100	0.0961	88	0.11%
TP010	0.0658	0.0969	0.1526	0.1110	73	0.15%
TP011	0.0867	0.0210	0.0560	0.0608	69	0.09%
TP012	0.0541	0.0558	0.0901	0.0687	57	0.12%
TP013	0.0282	0.0385	0.0539	0.0416	50	0.08%
TP014	0.0425	0.0640	0.0591	0.0560	35	0.16%
TP015	0.0159	0.0098	0.0071	0.0115	30	0.04%
			RMSE	**0.0543**	Drift	0.09%
			MAE	**0.0465**		

	dXYZ					
Target	scan 1	scan 2	scan 3	RMSE		
TP001	0.0266	0.0395	0.0488	0.0394		
TP002	0.0526	0.0228	0.0438	0.0416		
TP003	0.0148	0.0191	0.0064	0.0145		
TP004	0.0260	0.0396	0.0396	0.0357	Distance	Drift
TP005	0.0627	0.0460	0.0640	0.0582	45	0.13%
TP006	0.0212	0.0769	0.0490	0.0541	56	0.10%
TP007	0.0393	0.0215	0.0367	0.0335	50	0.07%
TP008	0.1368	0.1256	0.2081	0.1610	68	0.24%
TP009	0.1475	0.2231	0.2247	0.2017	88	0.23%
TP010	0.1825	0.1440	0.2170	0.1836	73	0.25%
TP011	0.1786	0.1172	0.1609	0.1544	69	0.22%
TP012	0.1648	0.1382	0.1975	0.1686	57	0.30%
TP013	0.0951	0.0938	0.1092	0.0996	50	0.20%
TP014	0.0847	0.0736	0.0923	0.0839	35	0.24%
TP015	0.0277	0.0139	0.0433	0.0307	30	0.10%
			RMSE	**0.1104**	Drift	0.19%
			MAE	**0.0907**		

Elios 3 + GeoSLAM GCP's Georeferenced Accuracy—Methodology

GCP Georeferenced Accuracy

- Four targets were chosen around the periphery of the scan—one target each from the NSEW of the dataset.
- The centroids of these four targets from the Elios 3 scans were aligned to the four reference points.
- The dXY and dXYZ residuals between the TLS centroids and the Elios 3 centroids were calculated for all 15x targets.
- The RMSE per target for all the scans was computed.
- RMSE were computed for each scan and an overall average RMSE value for target based alignment accuracy was calculated for both dXY and dXYZ.

Elios 3 + GeoSLAM GCP's Georeferenced Accuracy—Results

GCP Alignment Results

- Average XY error (Mean RMSE): **57mm**
- Average XYZ error (Mean RMSE): **65mm**

Elios 3 + GeoSLAM GCP's Georeferenced Accuracy—Results

	dXY			
Target	scan 1	scan 2	scan 3	RMSE
TP001	0.0742	0.0523	0.0549	0.0612
TP002	0.0959	0.0293	0.0326	0.0609
TP003	0.0757	0.0215	0.0167	0.0465
TP004	0.0612	0.0158	0.0258	0.0394
TP005	0.0392	0.0142	0.0525	0.0387
TP006	0.0307	0.0537	0.0452	0.0442
TP007	0.0194	0.0079	0.0236	0.0182
TP008	0.0163	0.0560	0.0155	0.0348
TP009	0.0447	0.1105	0.1294	0.1016
TP010	0.0608	0.1199	0.1327	0.1091
TP011	0.0578	0.0248	0.0583	0.0495
TP012	0.0056	0.0682	0.0684	0.0559
TP013	0.0227	0.0349	0.0334	0.0308
TP014	0.0583	0.0621	0.0425	0.0550
TP015	0.0598	0.0122	0.0149	0.0363
			RMSE	**0.0573**
			MAE	**0.0521**

	dXYZ			
Target	scan 1	scan 2	scan 3	RMSE
TP001	0.0820	0.0523	0.0562	0.0649
TP002	0.0962	0.0304	0.0460	0.0640
TP003	0.0908	0.0216	0.0185	0.0549
TP004	0.0827	0.0305	0.0280	0.0534
TP005	0.0727	0.0302	0.0599	0.0571
TP006	0.0308	0.0538	0.0454	0.0444
TP007	0.0234	0.0258	0.0299	0.0265
TP008	0.0480	0.0992	0.1391	0.1025
TP009	0.0593	0.1365	0.1392	0.1176
TP010	0.0610	0.1202	0.1333	0.1094
TP011	0.0579	0.0251	0.0598	0.0502
TP012	0.0212	0.0742	0.0685	0.0596
TP013	0.0228	0.0437	0.0357	0.0351
TP014	0.0583	0.0697	0.0454	0.0587
TP015	0.0764	0.0925	0.0570	0.0767
			RMSE	**0.0698**
			MAE	**0.0650**

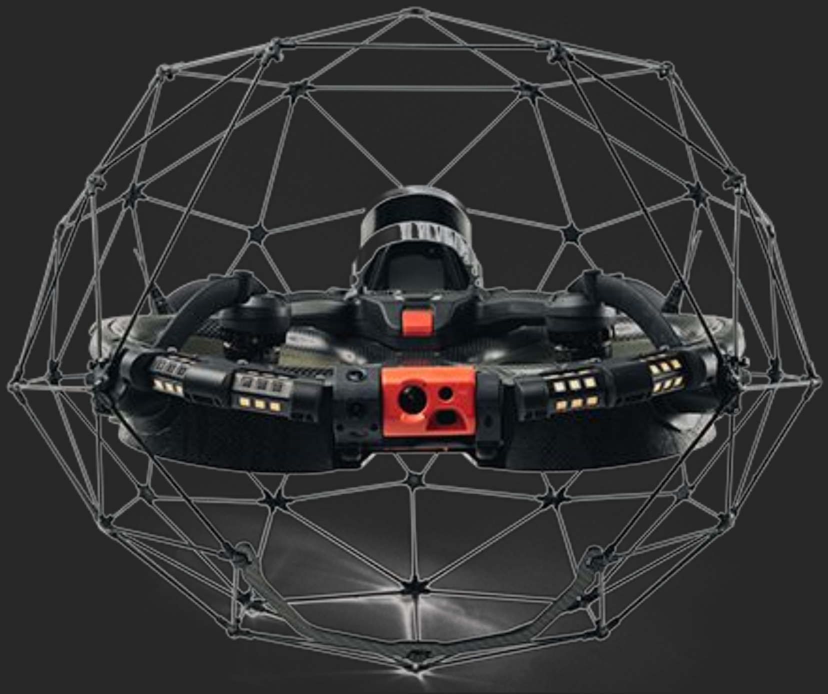
Precision and accuracy summary

Summary findings

- 2-sigma precision: **+-16mm**
- Average global accuracy: **0.16% of distance measured**
- Average global georeferenced accuracy: **0.2% of distance travelled**

Disclaimer

Other assets and other capture techniques or processing options may lead to different results.



Part 3:

Why Accuracy Matters—Examples from the Field

Use case—Ore pass hangup

Industry
Mining

Client need
An ore pass in a mine had a clog (also called a hangup). After two months of exploratory drilling and blasting the clog was still there, and the mine's personnel still didn't know what was causing it. In just one flight, the Elios 3 was able to find the clog and collect LiDAR data for 3D mapping it on GeoSLAM.

Why global accuracy matters in this use case

- Global accuracy allows you to know how far up the ore pass the hangup is located.
- Georeferrenced accuracy at take-off allows you to know where to put explosives if using a global mine model.

Use case—Ore pass hangup

Use case—Decomissioning old power plant

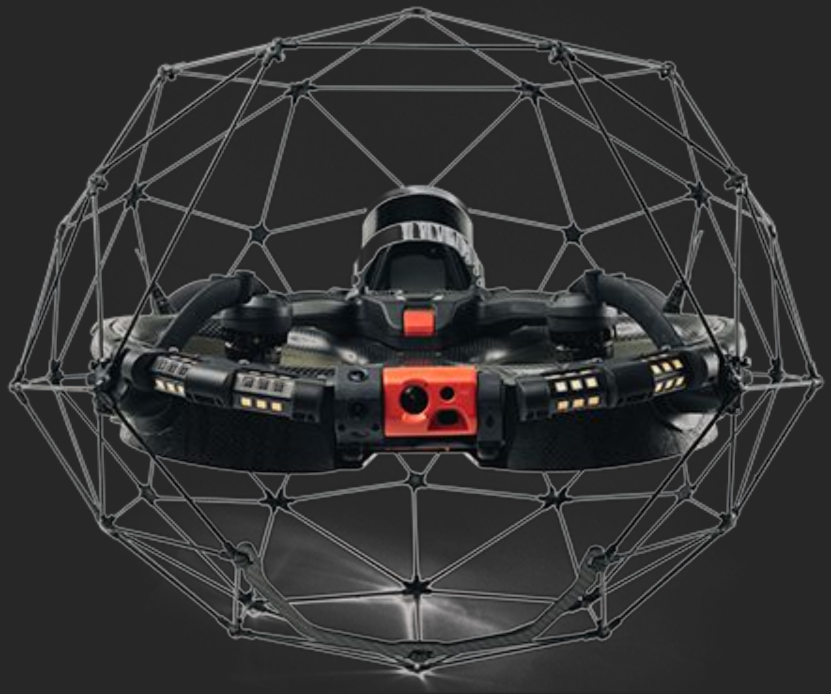
Industry
Power generation

Client need
Power generation company Vattenfall was decommissioning an old power plant in which there were areas that were too dangerous for people to enter. The Elios 3 was able to quickly collect LiDAR data of a staircase in one of these areas, helping personnel plan their decomissioning work.

Why accuracy matters in this use case

- Georeferencing can be done on a few points here.
- It's important to know the accuracy of the rest of the model.

Use case—Decomissioning old power plant



Q&A

Send your follow up questions to:

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