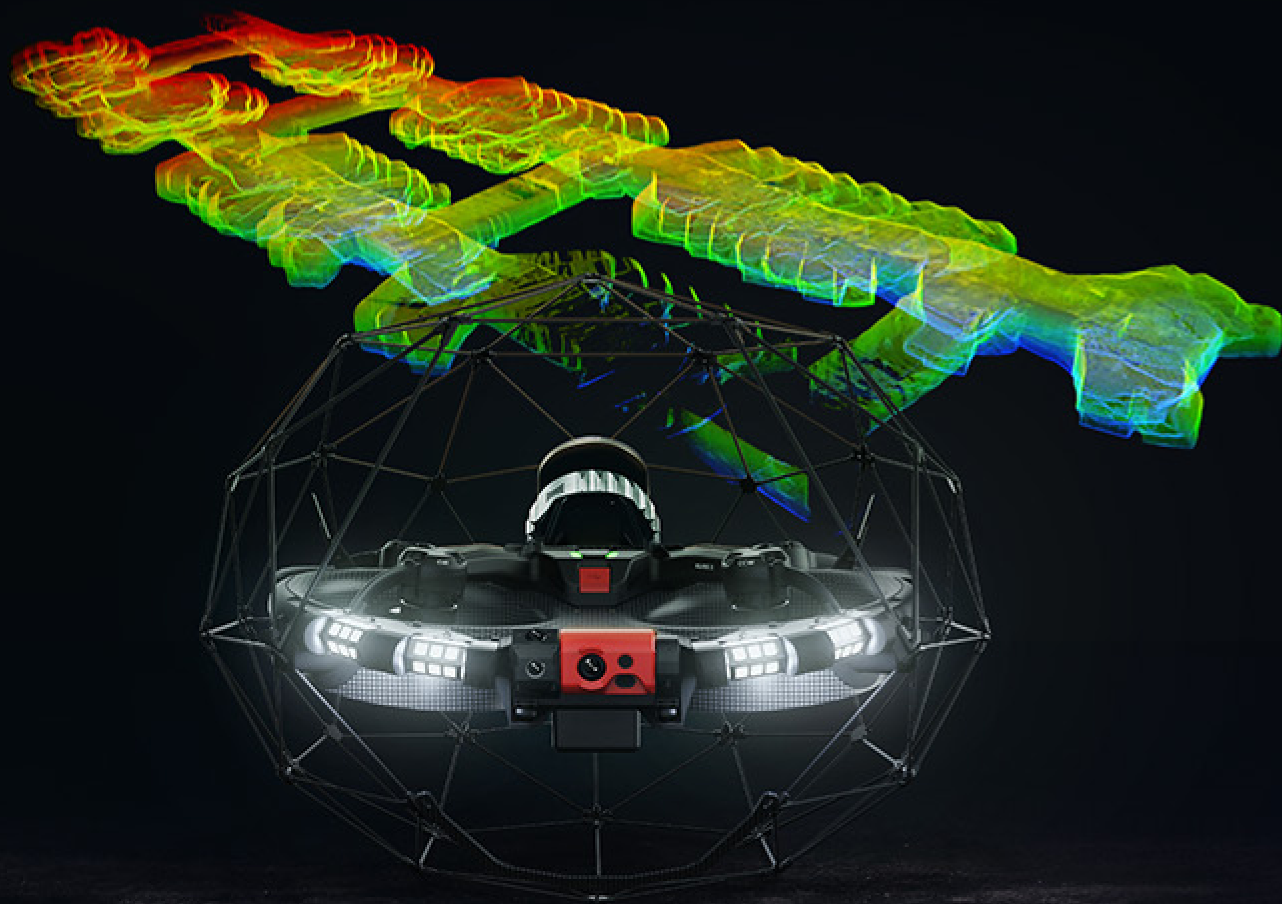
FLYABILITY



Assessing the Global Accuracy of the Elios 3 Surveying Payload

An in-depth accuracy report analyzing test results of the Surveying Payload in various environments to determine its level of global accuracy.

Since its release, the Elios 3 has become a key instrument in the surveyor's toolbox for capturing LiDAR data in areas where it was previously impossible to do so. With the growing need for better and more efficient data capture, sectors like mining, construction, and infrastructure management have turned to the Elios 3 to conduct safer inspections and surveys with greater data coverage.

The accuracy of the Elios 3's LiDAR scans is augmented by the Surveying Package, a combination of hardware and software that is designed to produce highly accurate results. The Surveying Package is made up of the Elios 3's Rev 7 LiDAR, FARO Connect software, and georeferencing targets that all combine to generate LiDAR point clouds that are accurate to within 0.1% drift factor with a precision of +/- 6mm one sigma.

Over the course of this whitepaper, we will define how we measure the accuracy of the Elios 3 and its Surveying Payload, as well as present concrete examples of different environments the drone has been deployed in and the results achieved. In its conclusion, you should have a comprehensive understanding of the level of accuracy possible with the Elios 3 Surveying Package.

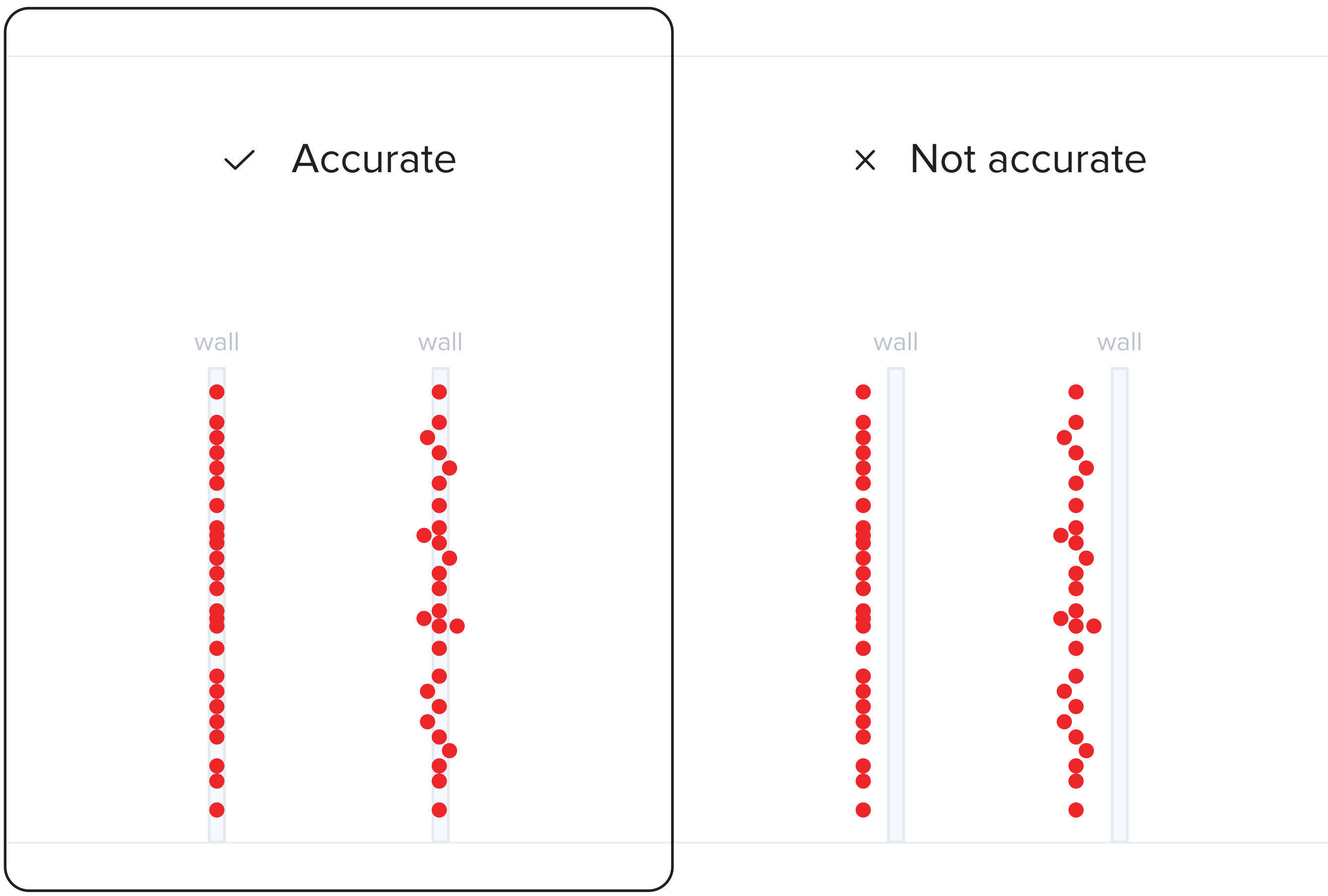
IMPORTANT IMPORTANT

Please note that the reported accuracy levels were obtained using the FARO Connect [2025.01] software release. To achieve similar results, users should ensure they are running FARO Connect [2025.01] or a more recent version.

1.0 Defining Accuracy and Precision

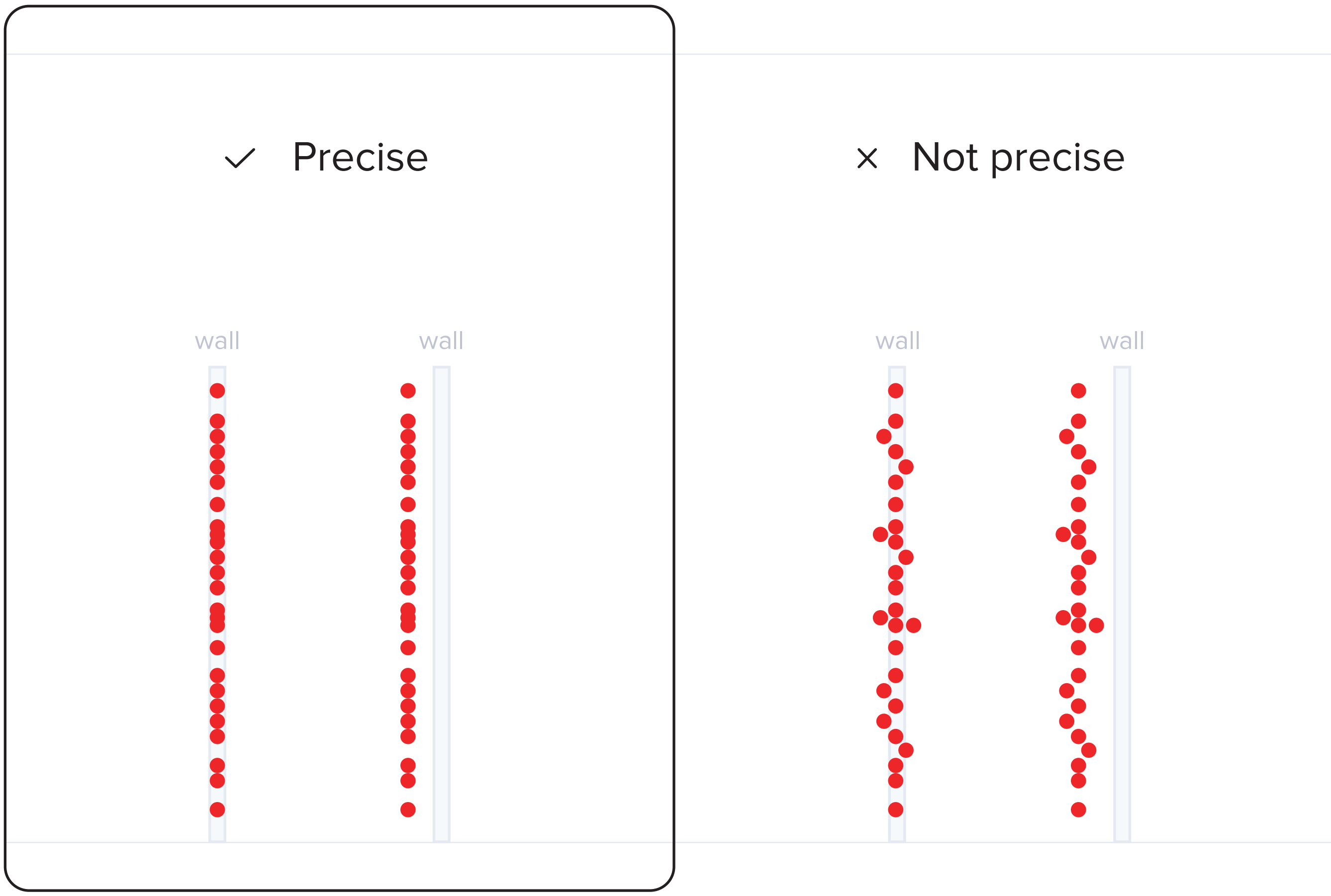
In this paper, we will assess the accuracy of the Elios 3's Surveying Package, including FARO Connect. Before we begin the analysis, it is important to differentiate between accuracy and precision.

Accuracy refers to the geographical precision of a tool. This measures how closely the LiDAR measurements match real-world values. For example, imagine that you are scanning a wall. If your LiDAR point cloud (a digital version of the wall) produces measurements and distances that match the real-world wall, then the accuracy is high. We measure accuracy in terms of distance errors, (i.e. centimeters or inches). This accuracy measurement is crucial for applications that require measurements as close to reality as possible.



In the high-accuracy versions on the left, you can see that the points match the location of the wall.

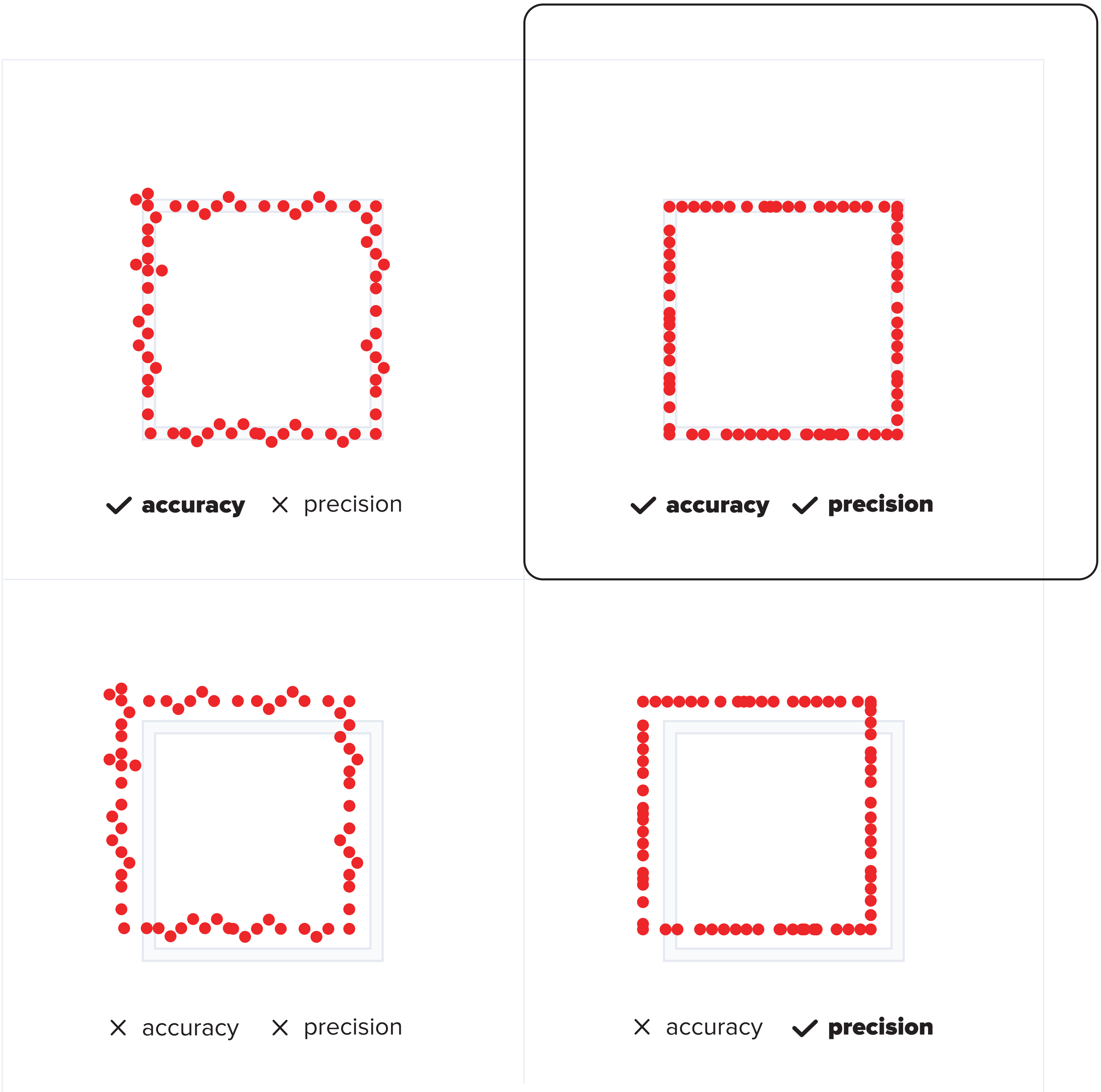
On the other hand, precision refers to the replicable nature of a measurement. How consistently can it make a measurement, and how true-to-reality is that measurement? A ruler can measure 30 cm very precisely every time because its measurement is clearly defined. When it comes to LiDAR for drones, precision is defined by the thickness of the point cloud. In the example of scanning a wall, the point cloud for a precise laser scan will be very thin, matching the wall. If there are lots of scattered points (called "noise"), then that point cloud is not very precise.



A precise point cloud, as shown on the left, has little "noise" - the points closely match the shape of the real-world object

So, to understand the relationship between accuracy and precision, you can refer to these 4 diagrams of a square below. When there is high accuracy (the points match the location of the wall) but precision is low (there is noise in the point cloud), you have the top left version, which loosely matches the real structure of the square. Alternatively, when the accuracy and precision are both close to reality, you can see that there is little noise in the point cloud, and the points all closely follow the outline of the square.

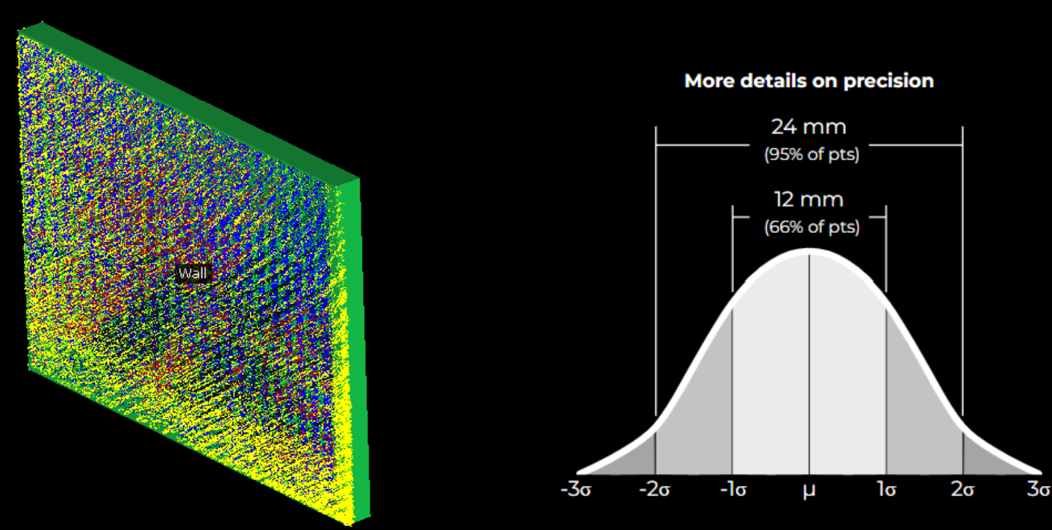
Accuracy vs Precision



2.0 The Accuracy and Precision of the Surveying Payload

The LiDAR payload carried by the Elios 3 is the Ouster OS0 128 Rev 7. This version was launched in 2023 and has greater accuracy and precision than previous iterations. The LiDAR sensor is part of the overall Surveying Package, which includes FARO Connect, a leading LiDAR processing program, and retroreflective targets for georeferencing. FARO released an update to Connect in 2025 (Version 2025.01), which enhances convergence and accuracy - we will explain this during the testing section of this paper.

As part of our accuracy assessment for this paper, we plotted points captured with the Elios 3 on a bell curve, looking at the standard deviation. This is used to quantify the level of noise or uncertainty of a LiDAR measurement on a planar surface. A higher standard deviation indicates greater variability in the point cloud, and thus lower precision. We have found that the precision of the Rev 7 payload is accurate to +/- 6 mm at 1 sigma and +/- 12mm at 2 sigma. This means that 66% of the points measured are accurate to within 6 mm. 95% of the points are accurate to within 12 mm (2 sigma). This means that almost all of the points in a point cloud are, on average, as accurate as 6mm, and thus the Rev 7 payload is precise to within 1 centimeter of reality.



On the left, there is a wall that we scanned to get the points used for the standard deviation calculation. As you can see in the bell curve, 66% of points with the Surveying payload fall +/- 6mm of reality

Global Accuracy Testing and Results for the Surveying Payload

The way we test accuracy and precision in a point cloud is by determining the level of drift. Drift is a key metric used to express the accuracy of a mapping system. The term is used in 3D modeling to describe the cumulative decrease in accuracy over the duration of a capture. Accuracy cannot easily be expressed in absolute values unless you have a clear system of reference. This is why surveyors use ground control points or GNSS to tether their point clouds to real-world coordinate systems or reference points. Without GNSS or ground control points (GCPs), the absolute error of a point cloud typically expands as the asset/area being surveyed increases in size.

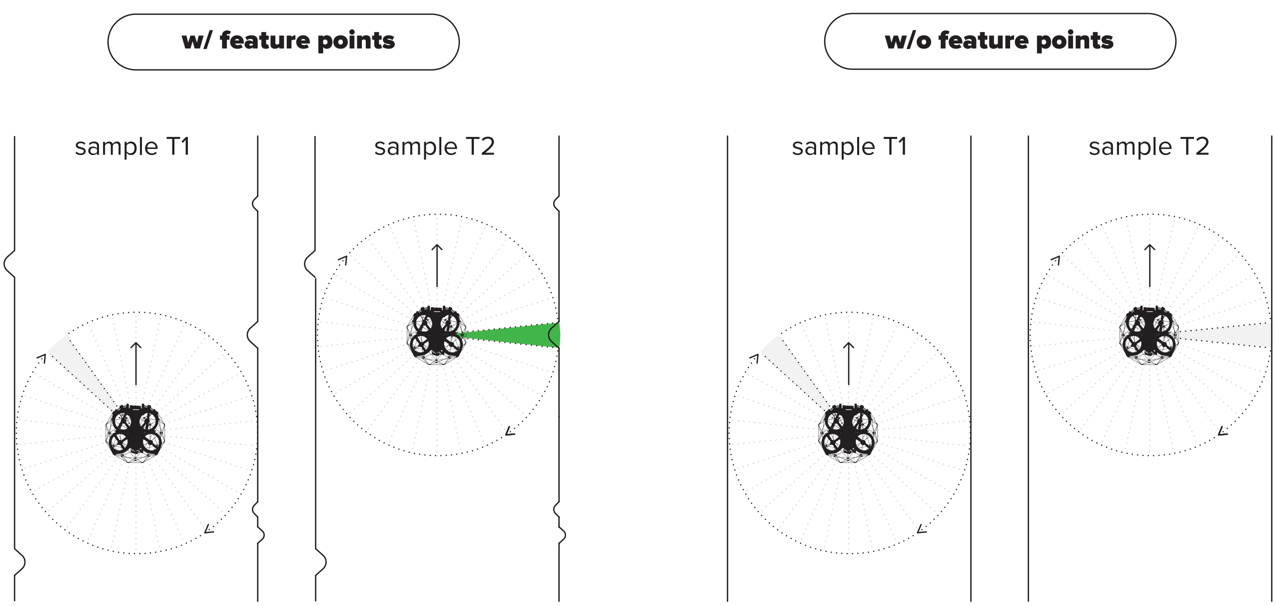
To explain this with numbers, you can expect the error on a 30-meter (98-foot) measurement to be smaller than the error on a 300-meter (984-foot) distance measurement. This is because a mobile scanner moving through the space will accumulate errors on top of previous errors. This accumulation of errors over distance is what we call drift, and represents a percentage of the traveled distance during data collection - for example, a 1% drift on a 300-meter distance corresponds to a 3-meter error compared to reality.

Understanding factors that can affect global accuracy

Global accuracy is impacted by the size and characteristics of the area being surveyed, as well as surveying method.

When it comes to surveying complex, confined spaces where the Elios 3 is at work, there can be additional challenges (and factors that increase the drift) if an environment has little variation, which is also known as being homogenous. This is typical in assets like pipes, chimneys, and tunnels. They can be incredibly complex to survey due to the homogenous nature of the space. This is because LiDAR relies on detecting and measuring features on surfaces, such as corners, edges, or texture variations, to create 3D point clouds. When an environment is symmetrical, there are fewer feature points, making it more difficult for the LiDAR to identify and track reference points for accurate measurements. This paper will assess the changes in overall accuracy in environments that are progressively more challenging.

It should also be noted that the method of data collection affects the quality of results. For example, flying the drone too fast can limit successful data capture, while slowly and carefully avoiding collisions optimizes data collection. Further details on this are available via Flyability and FARO's training resources.



When there are fewer geometric features, as in highly symmetrical environments, it is harder for the LiDAR to detect key features of reference that enable it to correctly interpret its surroundings, causing it to accumulate drift

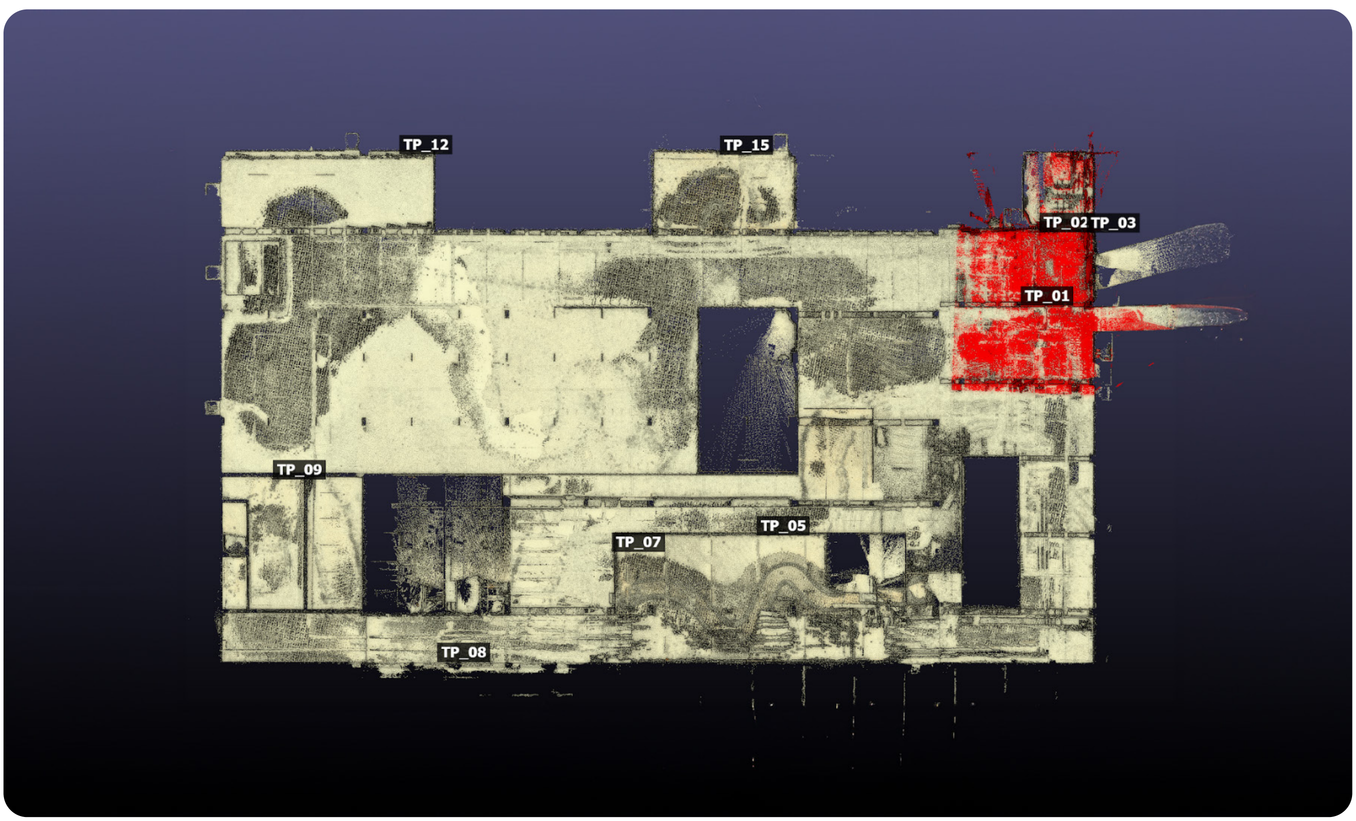
Bearing all of these factors in mind, we tested the Elios 3's Surveying Payload in several environments with varying degrees of symmetry to assess how it handles these scenarios.

3.0 Defining the Workflow for the Elios 3 and FARO Connect Accuracy Assessments

In this section of the whitepaper, we assess how the Elios 3 and FARO Connect perform in environments of varying complexity. Each test features an explanation of the environment and an overview of the process from data collection to processing, along with the results. Where possible, we offer comparisons with the original LiDAR payload, the Rev 6.2, to express the difference in results between the Surveying Payload and the standard LiDAR sensor.

3.1 Accuracy in Structured Environments

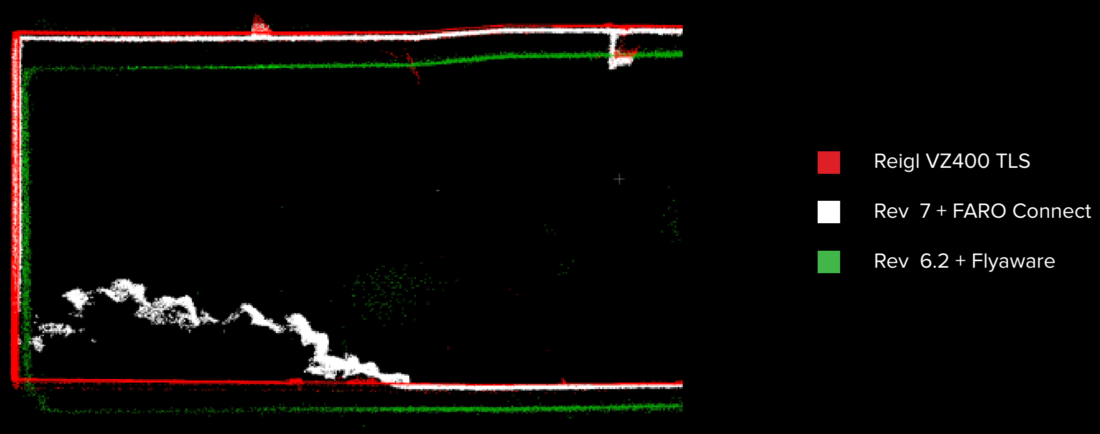
Structured environments are ones with little to no symmetry, as well as feature points - such as buildings, stockpiles, and containment areas. They also have a diameter or distance between walls that is over 2 meters wide (6.5 feet).



In our test, the Flyability team flew around the basement of a factory. We used data from a Terrestrial Laser Scanner (Reigl VZ400) to scan the entire area to produce a highly accurate and precise ground truth model of the test environment. From this scan, we identified a 15x15 meter section that we used as the take-off and landing area. We would use this area to align multiple point clouds through a processing setting called Iterative Closest Point (ICP). We conducted multiple flights with the Elios 3 standard configuration (Rev 6.2) and the Elios 3 Surveying payload (Rev 7). Each Elios 3 flight was aligned to the ICP area, and the computer transformation was then applied to each Elios point cloud so that each flight was registered to the 15x15 meter ICP location. The reference centroids from the TLS data were recorded and compared to the registered Elios 3 detected target centroids from each flight, with the new transformations applied.

		Survey pachage: FARO Connect + rev7		FlyAware + rev6.2	
Target	**Distance from take-off**	**XYZ Drift**	**XY Drift**	**XYZ Drift**	**XY Drift**
TP_05	45	0.15%	0.08%		
TP_06	58	0.19%	0.17%		
TP_07	50	0.14%	0.13%		
TP_08	68	0.19%	0.19%	0.40%	0.39%
TP_09	88	0.09%	0.07%		
TP_10	73	0.25%	0.21%	0.76%	0.45%
TP_12	57	0.13%	0.08%	0.46%	0.13%
TP_15	30	0.14%	0.09%		
	Averages	**0.16%**	**0.13%**	**0.54%**	**0.32%**

The results, as shown in this table, demonstrated significant improvements in the Surveying payload. The previous LiDAR payload (the Rev 6.2) had 0.5% drift when flown in this environment. The new Rev 7 model is 4X more accurate, with 4X less drift. The drift reduced to just 0.16%, showing a high degree of accuracy across the entire space (this is the global accuracy).



This vertical cross-section through the floor and ceiling of the basement shows the Rev 7 and FARO Connect results closely matching the TLS point cloud (in red) compared to the Rev 6.2 results, shown in green.

3.2 Accuracy in Nominally Symmetrical Environments

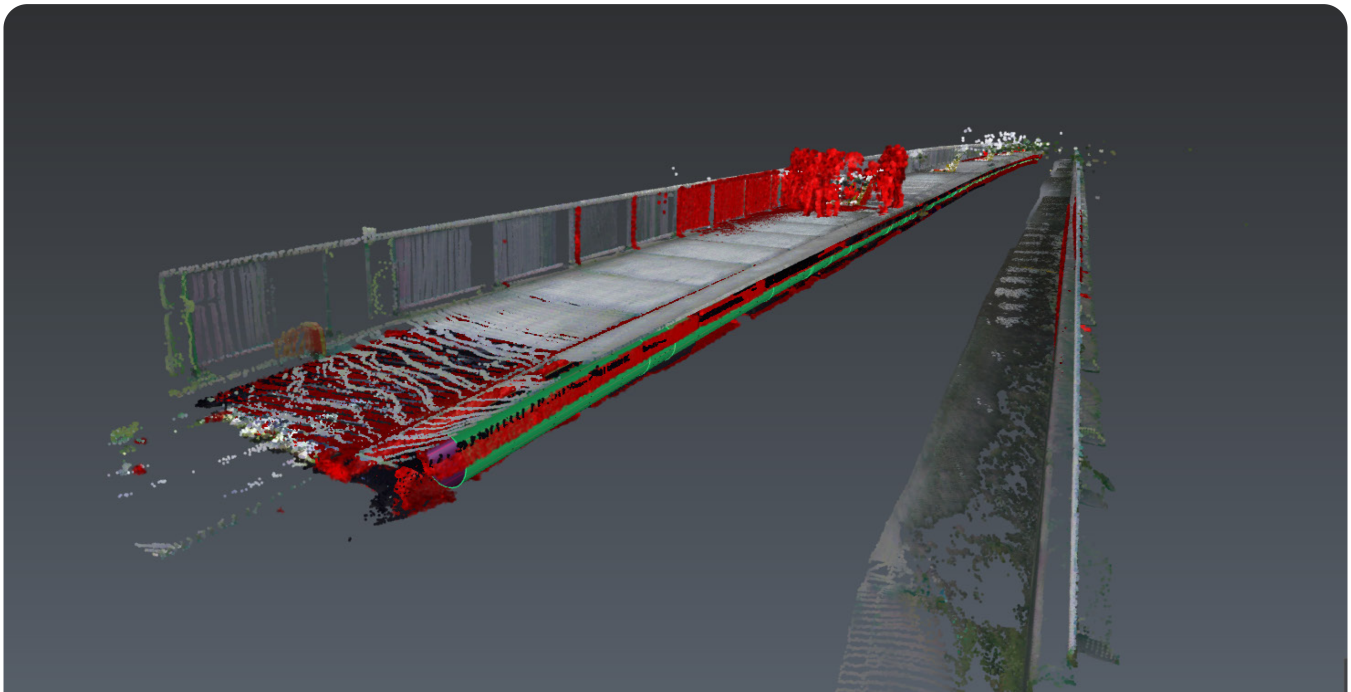
The next tests took place in a nominally symmetrical environment. These environments have more than 1.5 - 2 meters of width and height and have regular geometric features or clear bends at intervals of max 30-50 meters.

In this case, we assessed the Elios 3's performance in 2 different locations. The first was a bridge and the second was a 200 meter sewer tunnel.

The variety of geometric features in this bridge section meant that drift was reduced

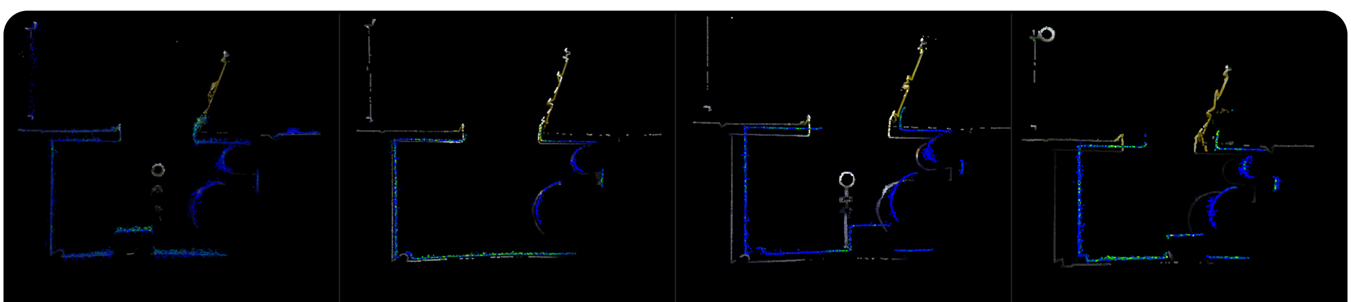
Nominally Symmetrical Test 1: Bridge

The first test took place in a section of a bridge, where various features helped the LiDAR scan reduce drift. These features included pipes, racks, and an electrical conduit, along with the overall structure being over 2 meters in diameter. After collecting and processing the data, our team found that there is a 5-10-times improvement in drift for the new Rev 7 payload compared to the original Rev 6.2 payload. This highlights just how critical geometric features are in reducing overall drift for 3D digitalization.



Ground truth data and Elios 3 data ICP'd at the take-off location and drift calculated at 4 defined intervals.

Overall, the accuracy of the Rev 7 LiDAR payload in this nominally symmetrical environment was found to be excellent with a drift factor limited to just 0.3-0.4% in various sections of the tunnel, resulting in an 80 %+ convergence success rate.

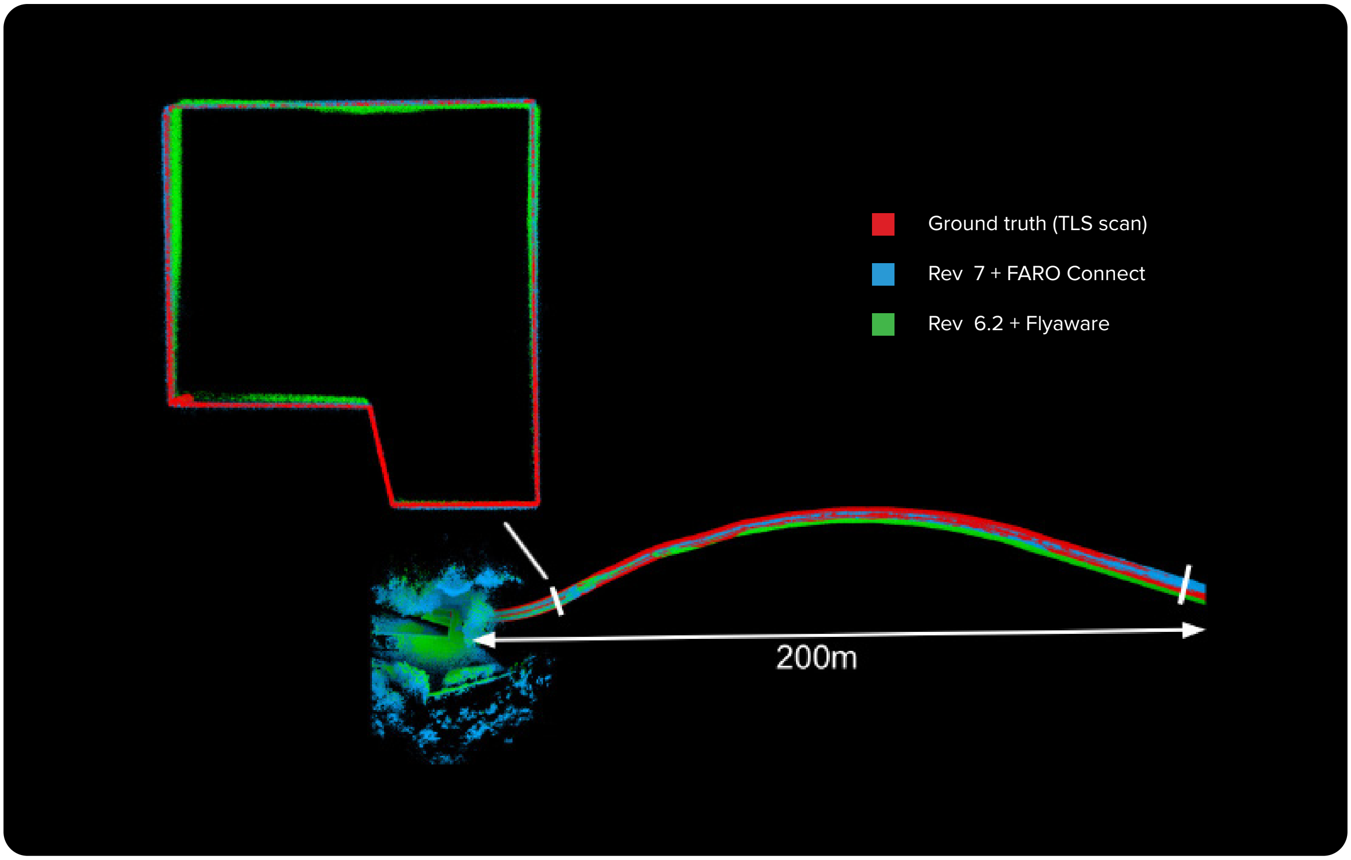


Section 1	**Section 2**	**Section 3**	**Section 4**
0m Takeoff ICP	Manhole 20m	Manhole 60m	Manhole 100m

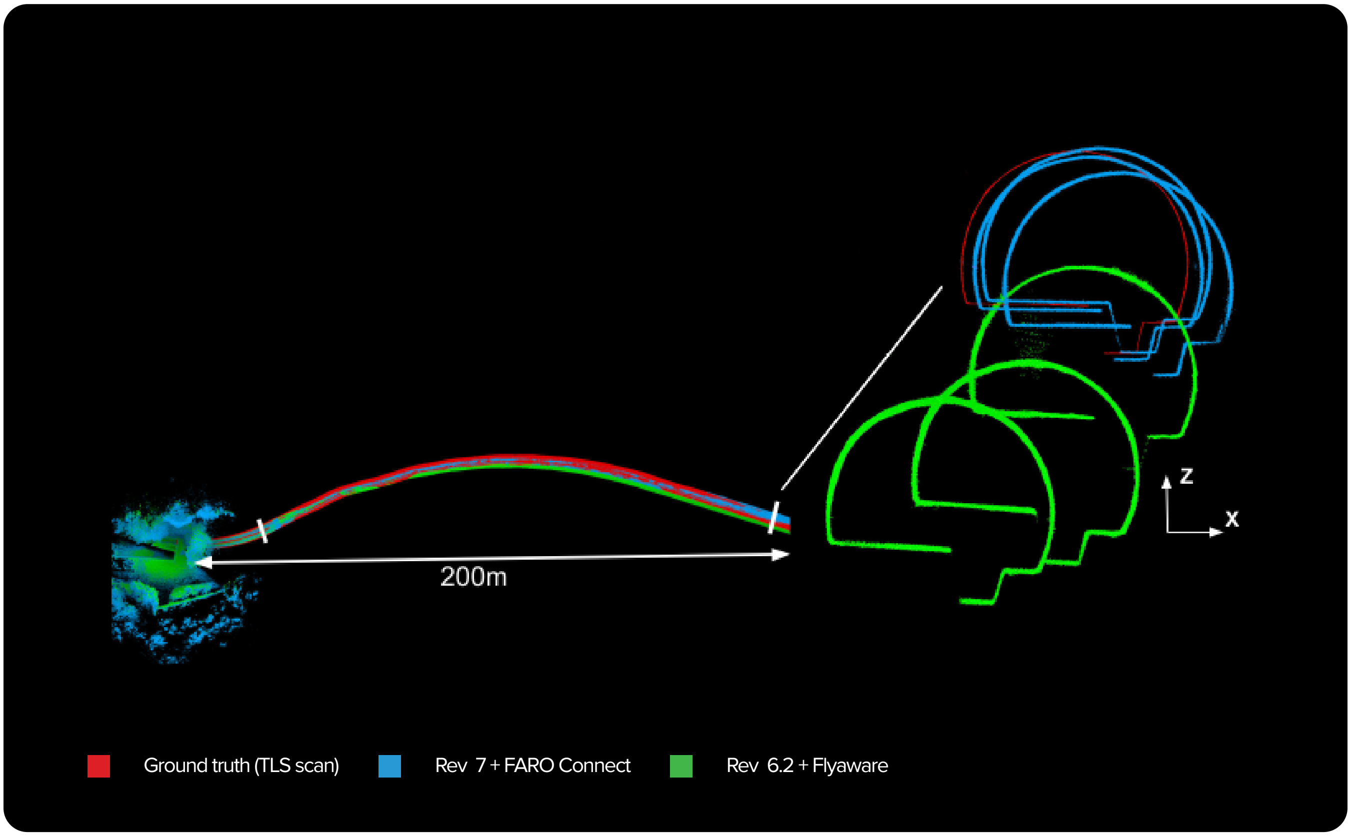
Here you can see cross sections at various points along the bridge with distance measurements included.

Nominally Symmetrical Test 2: Sewer Tunnel

The second accuracy test took place in the sewer tunnel. In this case, 3 scans were conducted with the Rev 7 LiDAR payload and processed with FARO Connect. The data sets were aligned in their respective projects with the ICP method using points around the entrance that had been ground-truth captured with a TLS, along with survey targets every 25 meters inside the tunnel.



This cross-section (above) from the beginning of the tunnel shows colored point clouds from the LiDAR Surveying Payload (Rev 7), the Terrestrial Laser Scanner as a control dataset, and the Rev 6.2. This was the area used to align the different point clouds with the ICP settings in FARO Connect.



This is the sewer cross-section (above) at the end of the flight. As you can see, the green Rev 6.2 has significantly more drift, reaching 1.4%, compared to the Surveying Payload Rev 7 and FARO Connect, which only have 0.19% drift.

Overall, the average 0.39% difference from reality by the Rev 7 payload highlights the improved robustness of the payload in symmetrical environments. Its global accuracy in this project was 5-8 times better than the standard LiDAR payload.

The clear superiority of the Rev 7 in these environments thus makes it the preferred payload for surveying environments with nominal symmetry, providing a high level of accuracy and precision.

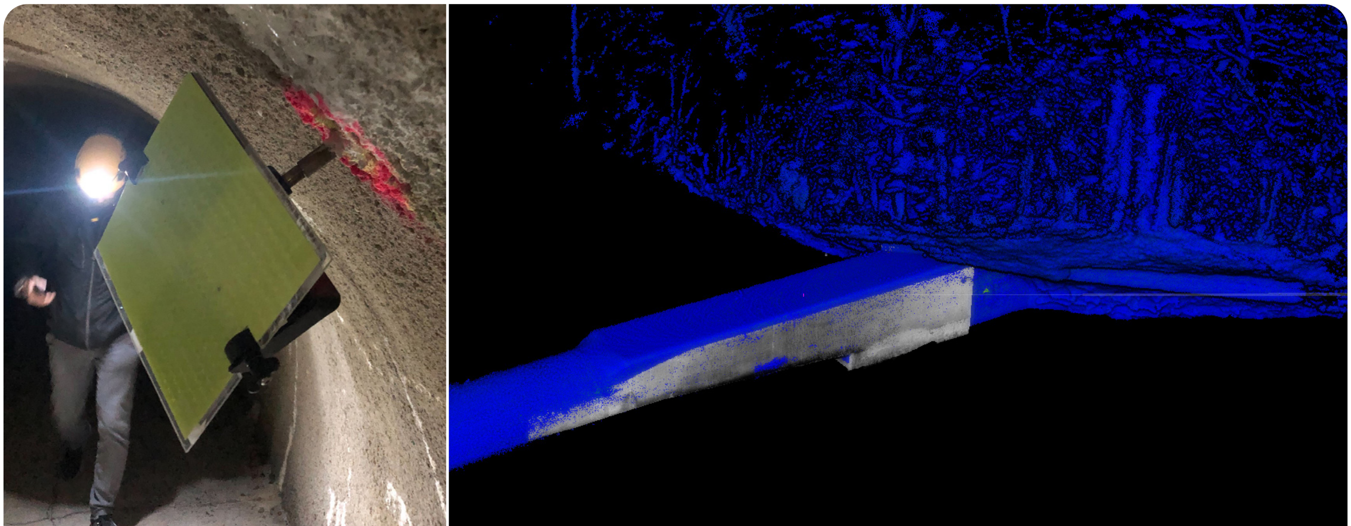
3.3 Accuracy in Challenging Symmetrical Environments

Next, the Surveying Payload was tested in increasingly challenging environments. We defined a challenging symmetrical environment as one with light geometric features or texture in prolonged straight areas (greater than 50 - 80 meters), as well as a diameter greater than 2 meters. Examples of environments with these features, either horizontal or vertical, could include tunnels, stacks, and shafts.

This tunnel has few clear geometric features to help reduce drift in a LiDAR scan

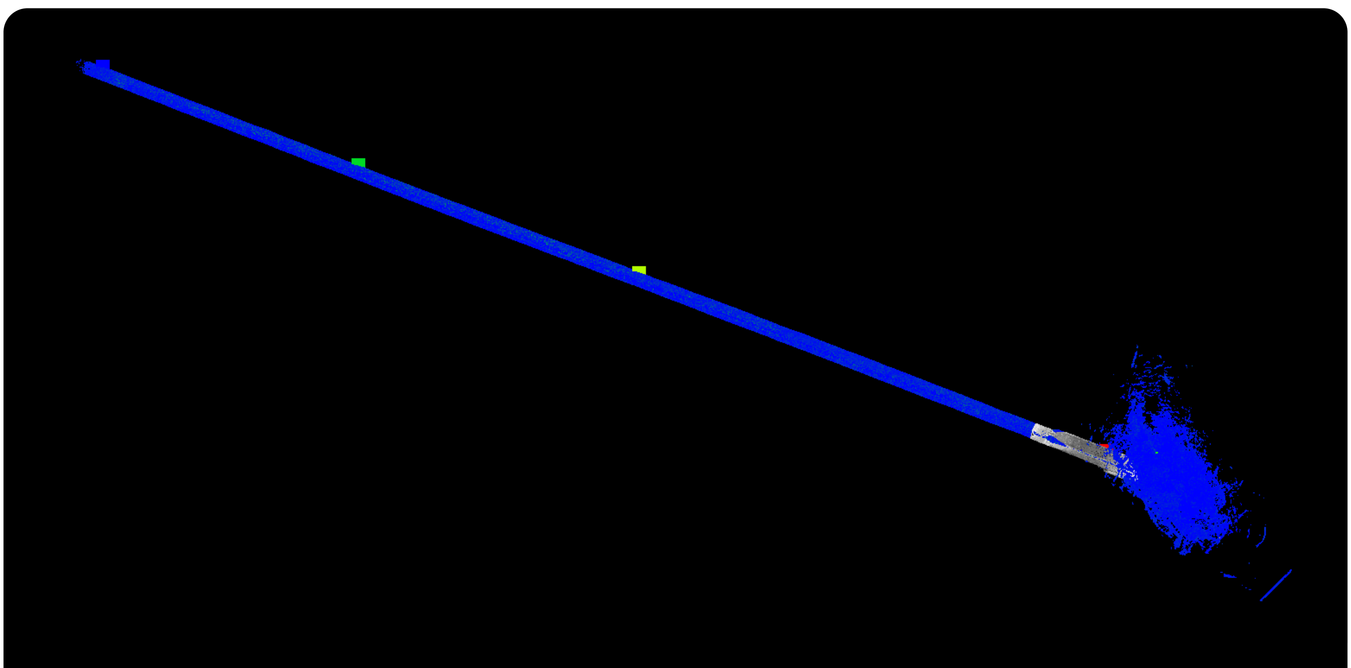
In this testing environment, the Rev 7 payload was flown in a sewer with a greater than 2-meter diameter. The only geometric features were walkways, a gully, and shotcrete with textured surfaces.

All flight data was compared to high-accuracy TLS ground truth data, which was ICP'd at the entrance to the sewer section. 4 reflective targets were placed at defined intervals in the tunnel and georeferenced with a total station. The drift between the target's absolute positions and the computed positions from FARO Connect was analyzed.



4 targets were mounted in the sewer and Elios data ICP'd to ground truth.

All 3 scans captured in this test were successfully converged and showed an average drift of 0.5 - 1% across various sections of the tunnel.



Over 250m of tunnel, just 0.63% drift was found

SLAM Strength 1 - Tunnel Environment: Table of Results

	Norm	Drift XYZ (%)	Norm xy(m)	Drift XY (%)
Target 1	0.061	0.02%	0.061	0.02%
Target 2	1.337	1.24%	1.337	1.24%
Target 3	3.512	1.92%	3.511	1.92%
Target 4	4.538	1.84%	4.528	1.84%
		0.63%		**0.62%**

This table showcases the drift percentages at each target, showing how we find an overall result of 0.63%. The lowest row shows the average offset measurement from the targets in the ground truth to the processed SLAM data on the drone.

In environments with very few geometric features that make drift more likely, the Rev 7 payload is still achieving improved results compared to Rev 6.2, thanks to the improved LiDAR capabilities as well as processing with FARO Connect.

3.4 Accuracy in Very Challenging Symmetrical Environments

For a final test, the Rev 7 Surveying Payload was used to scan another symmetrical environment. It was considered to be very challenging because the diameter was less than 2 meters and less than 1.2m in height, along with having a very smooth, symmetrical shape. The total lack of geometric features or textures in straight sections alongside rapidly flowing water adds to the difficulty of this surveying environment.

A diameter of less than 2 meters and a smooth, symmetrical structure makes this space more challenging for LiDAR scans.

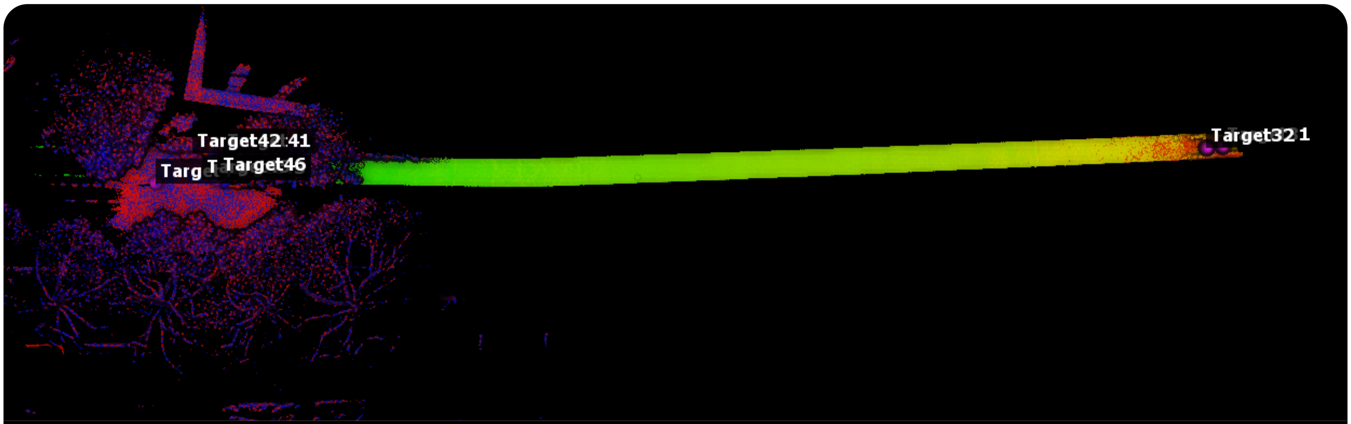
The freshwater tunnel changed in geometric size from a box section to a curved roof; however the width and height remained the same. The flowing water was clean, but there were lots of surface ripples. The flight was conducted at approximately 1m per second speed in assist mode to try and maintain a clear flight without the drone bumping into the tunnel surfaces.

Survey targets were placed on the surface, and two targets were inside the manhole. All targets were georeferenced with an RTK GNSS with high accuracy.

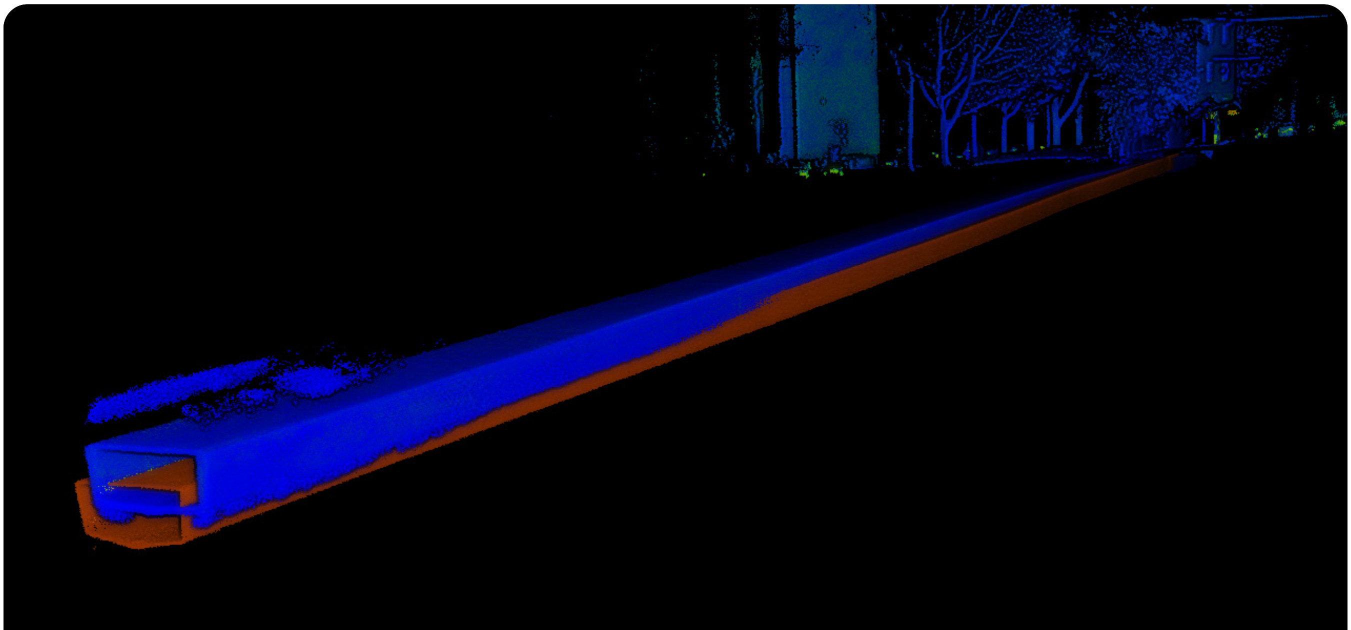
The target positions on site are placed at different angles as georeferencing points

The flight was georeferenced using 5 targets adjacent to the first manhole (called Manhole A). 2 targets were placed in the next upstream access point (called Manhole B), 102m away for reference analysis of the drift factor. The targets at the first manhole A act as an ICP, and the drift factor was analyzed based on changes from Manhole A->B.

The Surveying Payload and FARO Connect were still capable of acceptably accurate results, with a drift of 2-5 %. The exact analysis was 4.1% drift over 102m of tunnel.



Top down view of the water tunnel process with targets at the start and inside the next manhole



Here, the Rev 7 data processed in FARO is shown in blue, compared to the Rev 7 and Flyaware in brown. There is 4-5% or more drift when comparing the FARO optimized processing and Flyaware with no global optimization.

With greater geometrical features in a similar environment and also less flowing water, it may be possible to reduce the drift. However, considering the challenges of this location, the Surveying Payload's Rev 7 handled the survey very well.

Conclusion: Summary of Findings & Analysis

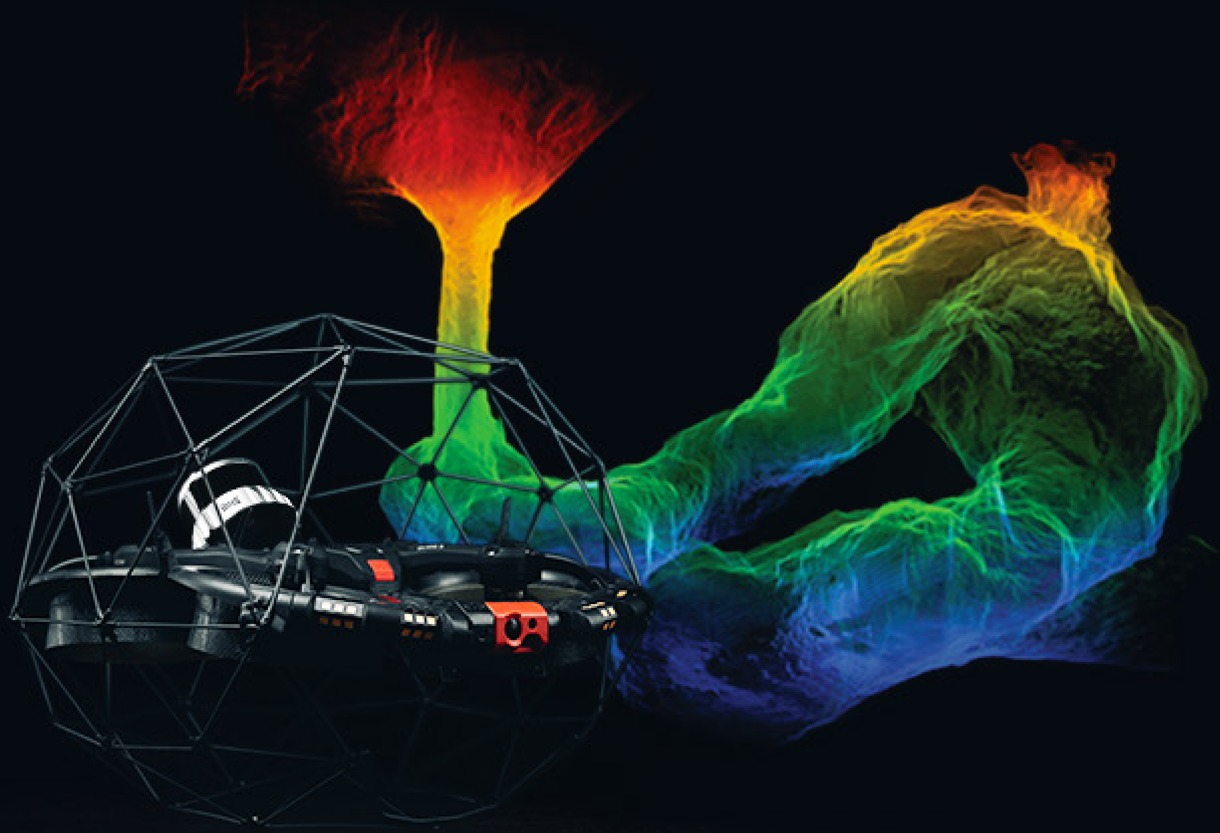
This table summarizes the findings of these accuracy tests, with comparisons between the standard Elios 3 6.2 Rev data and the Elios 3 Surveying Payload with FARO Connect.

		Configuration **Elios 3 & FlyAware**	Configuration **Elios 3 Surveying Payload and FARO Connect**
Structured environments	• Buildings, stockpiles, and containment areas • Little to no symmetry • Geometric features • Diameter/distance between walls >2m (6.5 feet)	**1x** 0.5-1% drift	**5-10x improvement** ~0.1-0.2%
Nominal symmetric environments	• Tunnels, stacks, shafts • Diameter >2m (6.5 feet) • Regular geometric features	**1x** ~2% drift	**5-10x** ~0.25-0.5%
Challenging symmetrical environments	• Tunnels, stacks, shafts • Diameter >2m (6.5 feet) • Light geometric features and/or texture and/or and clear bends after 30-50 meters of smooth sections	**1x** 2-5% drift	**4-5x** 0.5-1% (80%+ success rate)
Very challenging symmetrical environments	• Tunnels, pipes, stacks, shafts • Diameter <2m (6.5 feet) • Light geometric features and/or texture and/or bends after 20 to 30 meters of smooth sections	**1x** 5+% drift	**1-2x** 2-5% (50-80% success rate)

The Rev 7 Surveying payload has achieved stunning results even in complex surveying environments. In combination with FARO Connect, it is capable of achieving sub-centimeter accuracy over large survey areas.

These results will appeal to surveyors and inspectors working not only in wastewater management but also in mining and manufacturing industries such as cement, alongside industry-standardizing bodies.

With overall precision to within +/- 6mm and replicable accuracy results, the Surveying Payload for the Elios 3 is the ideal solution for those looking to gather data in complex and potentially hazardous environments - be they confined spaces or larger structures - that need an extra level of accuracy.



Still wonder which payload is right for you?

If you have any questions or if you would like to get more information on the capabilities of the Elios 3 Surveying Payload, get in touch with our team! We can advise on your choice and help you select the best option for your specific needs.

Flyability now offers a specialized training course for sewer inspections, including georeferencing training. Learn more on our website.