

Introduction

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Usage in LiDAR applications

In LiDAR applications, GCPs are used for 2 reasons:

- **Determination of the accuracy**: this is performed by comparing the LiDAR point cloud and targets with known coordinates.
- **Global alignment of point cloud**: to improve the precision and the accuracy of the point cloud.

Notes:

- The precision is improved as the misalignment between lines are reduced.
- · Accuracy is improved as the misalignment between the point cloud and GCPs is reduced.

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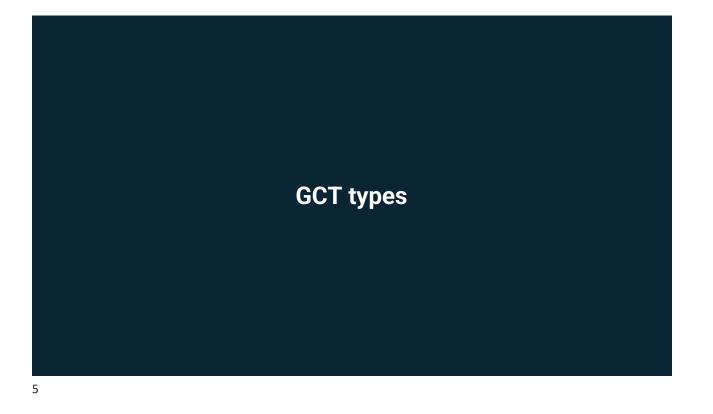
In comparing the Computed GCT Center and the coordinates of the GCP we can assess the deviation from the local point cloud to the GCP at the GCP location: Thus, we can compute the LiDAR point cloud accuracy.

GCP

- Monumented point for which geodesic coordinates are known with a controlled accuracy and precision.
- (may be provided by National Geodetic Authority or made by the user.)

GCT

· Device that defines a unique center



2D Ground Control Target types

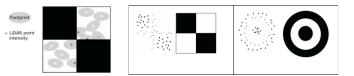
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Classic targets:

- CheckerBoard
- Concentric circle

Limitations:

- the estimation of the center is **dependent of the sampling of low and high intensity** (B&W) points over the target.
- Given the X,Y estimates of the center, the Z value should be estimated by a spatial interpolation in a neighborhood of the estimated center.





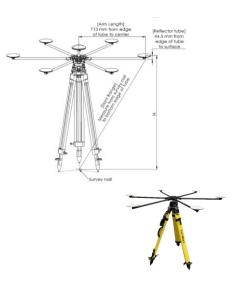
3D GCT (Accuracy Star)

Specs

- Arm length 70cm;
- Reflector diameter 14cm;
- Recommended installation height: at least 1,40m

Installation with GCP

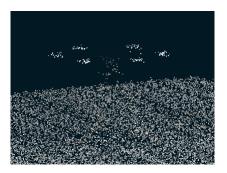
- In placing a GNSS antenna at the center we can make an estimation of the 3D center. This point will play the role of reference coordinates of the GCP.
- Install the Accuracy Star over a survey nail or a monumented GCP by levelling the tripod. The vertical separation between the survey nail and a reference height of the Accuracy Star should be measured accurately (H Offset).

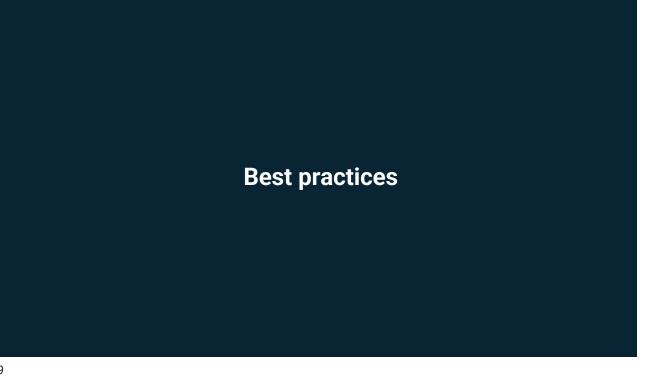


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Advantages of Accuracy Star

- It is accurate since the hexagon geometry enables us to estimate the center from 3 to 6 clusters of points representing the reflectors. Redundancy in the hexagon observation makes the center estimate to be precise and robust.
 - The size and the separation of the reflectors has been optimized to enable a good detection for most UAV LiDAR flight configuration.
- It is **unbiased** since the redundancy of the six reflectors enables us to estimate the center in a robust way.
- The Z component comes from the <u>vertical separation from the</u> <u>ground of the reflectors</u>. It is important to install the Accuracy star at the highest possible elevation from the ground.





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How many GCTs should I use?

It is recommended to deploy at least 3 GCTs to enable a possible rotation-translation transformation

Number of AS	1	2	3+
Translation	Yes	Yes	Yes
Rotation + Translation	No	No	Yes

1 GCT allows validation of the point cloud Accuracy and confirms that the dataset doesn't have major issues. The point cloud cannot be corrected (other than locally) but can be validated that it is within the expected accuracy range of the system

Notes

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Where shoud I install my GCTs

- We recommend installing GCTs at locations where positioning uncertainty is higher, in order to have a conservative estimate of accuracy.
 - Example: for a long corridor survey, GCTs should be installed at the beginning and at the end of the corridor, to measure the effect of IMU heading bias along the corridor, especially if the UAV is flying at low speed.
- Accuracy can be assessed in
 - overlapping areas (intersections between lines)
 - non overlapping area (single line),
 - line by line.

- Discrepancy between different lines can give relevant information on the survey local accuracy and may help the user to understand some sources of errors that may depend on the lines
- If you have multiple flights in an area performed on the same day, you should use the same GCTs for all flights

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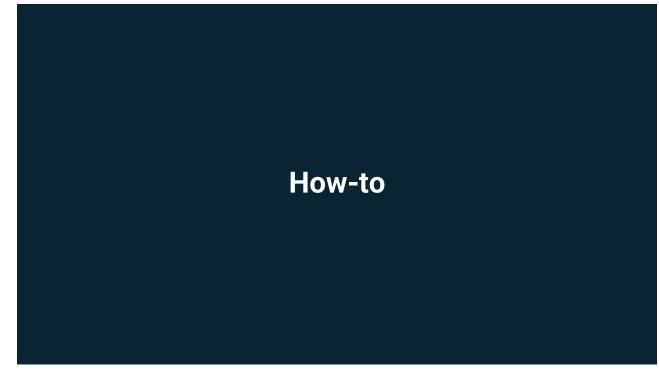
Local versus global accuracy of the survey

- If interested in the global accuracy, accuracy assessment and accuracy enhancement should be performed with some AS distributed over the survey area.
- If interested only in local accuracy, the AS should be placed on the location of interest.



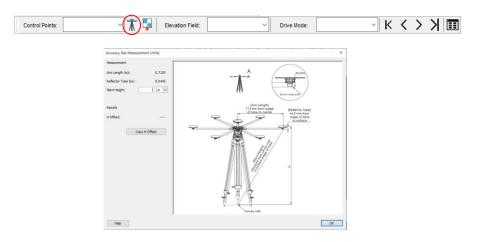
Specific to Accuracy Stars

- For Accuracy Stars, the accuracy assessment is **independent of the nature of the underlying terrain**: An Accuracy Star over a flat/gentle slope area or wet/dry or high/low reflectance will give the same information; It is given by its own reflectors and not by the terrain.
- For Accuracy Stars, the accuracy assessment only depends on the flight conditions:
 - Height, Speed -> parameters affecting point density
 - Motion (long constant heading at low speed, angular rates, etc...)



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Measure Accuracy Stars in the field



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Processing workflow

- 1. Import GCP
- 2. Auto Find
- 3. Solve
- 4. Apply Correction
- 5. Verification

Example

Payload: TV516 Flight Height: 75m Flight Speed : 5 m/s

Step 1. Import Ground Control Points (from txt)

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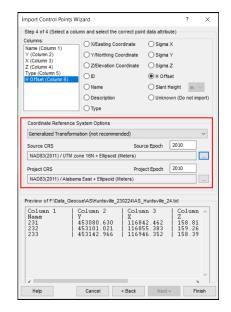
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GCPs can be transformed during import if they are in a different CRS

- Projection/Vertical Change Only
 - Applies no datum transformation
- Transform from ITRF2014 Geographic Coordinates
- Generalized Transformation
 - Applies both datum and epoch transformations

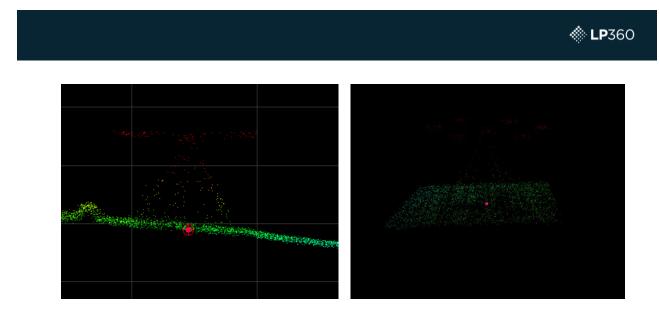


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Step 1. Import Ground Control Points (from shp)

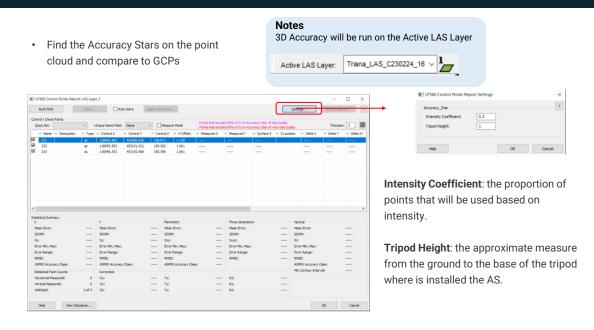
Control Points: AS_Huntsville_242 V	Shape	✓ Drive Mode:	ALL	~ K < > > 🖬 🎞
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- Must be in the same CRS as your LAS
- Must contain an attribute field for the Height Offset, 'HOffset'
- Must contain an attribute field for the target type, 'Type'



Step 2. Auto Find

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- Calculate DX, DY, DXY, DZ, DXYZ
- Calculate statistics
- Generates comments on results of the Auto Find

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1.061	116855.396	453101.045	159.298	Measured	-0.013	-0.024	0.027	-0.036	0.045	Reliable	Results	Very good	
1.051	116946.356	453142.978	158.420	Measured	-0.004	-0.012	0.012	-0.024	0.027	Reliable	Results	Very good	
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Comment (on noise & density)	Ref	flector Identification	on
Reliable ResultsNoise WarningNoise Alert	≥ 5 = 4	Very good	*
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	≤ 2	Very bad	

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Example with GCP transformed from US State Plane to UTM during import

 Results are identical to dataset without transformation

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Step 3. Solve

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- Calculates translation
- Calculates rotation (if at least 3 AS)
- Auto Solve will automatically recalculate if you check/uncheck GCP in the list

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1.061	116855.396	453101.0			-0.013	-0.024	0.027	-0.036	0.045	Reliable		Very good		
1.061	116946.356	453142.9	78 158.42) Measured	-0.004	-0.012	0.012	-0.024	0.027	Reliable	Results	Very good		
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Notes

If the translation is combined to a rotation, the rotation is defined from an origin point (Ox, Oy, Oz). Therefore, the translation is also relative to this origin point.

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Step 4. Apply correction

 Apply correction will apply the translation and rotation on the point cloud and create a new LAS layer.

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1.129	116842.482	45308	0.644	158.845	Measured	-0.020	-0.014	0.025	-0.034	0.042	Reliable Results		Very good		
1.061 1.061	116855.396 116946.356	45310 45314		159.298 158.420	Measured Measured	-0.013 -0.004	-0.024 -0.012	0.027	-0.036 -0.024	0.045 0.027	Reliable Reliable		Very good Very good		
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Step 5. Verification

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Additional workflow

You can also mix Accuracy Stars with checkerboards by manually selecting the checkerboard's planimetric center in the point cloud using Measure Mode.

	Auto Find		Solve	C Ad	n Solve	Apply Corre	chon				9	ttings	Export Rep	ort	
	rol / Check áck Set:	Points	.v .	Inique Name Field:	Name	~ (PM	easure Mode		d 90% of Cilor Acc d 95% of Cilor Acc				Precisio	n: 3	1
	v Name	· Description	- Type	- Control X	* Control Y	- Contr	H Offset		· Measured Y	* Surface Z	and the second designed		+ Delta Y	- Del	ta 1
в	126		SN	116957.875	453140.909	158, 16				158.163	Control				
a i	127		SN	116975.944	453155.460	158.26				158.276	Control				
2	128		SN	117001-887	453158.652	158.20				158.211	Control				
1	130		et	116839.162	453097.825	159.47				159,452	Control	_		_	•
8	131		c2	116875.032	453076.304	157.94	0.000			157.942	Control				
8	132		c3	116954.276	453141.060	158.27	8 0.000			158.285	Control				
8	229		AS	116875.495	453052.682	156.92	4 1.036	116875.450	453052.687	156.932	Measured	0.045	-0.005	0.04	5
8	230		AS	116837.664	453060.834	158.19	0 1.011	116837.651	453060.810	158.177	Measured	0.013	0.024	0.02	7
3	231		AS	116842.462	453080.630	158.81	1 2.155	116842.472	453080.627	157.782	Measured	-0.010	0.003	0.01	0
3	232		AS	116855.383	453101.021	159.26	2 1.055	116855.386	453101.028	159.266	Measured	-0.003	-0.007	0.00	8
8	233		AS	116946.352	453142.966	158.39	6 1.050	116946.347	453142.960	158.404	Measured	0.005	0.006	0.00	8
2	234		AS	116828.425	453133.288	160.31	5 1.045	116828.415	453133.274	160.296	Measured	0.010	0.014	0.01	7
															>
tati X	stical Summ	sary		v			Planimetric		Three dimension			(ertical			
	en Error:		0.010	Mean Error:			Mean Error:	0.019	Mean Error:	ns.		Vertical Mean Error:		0.031	
	OM:		0.007	SDOM:			SDOM:	0.005	SDOM:			SDOM:		0.027	
Sx			0.017	Sy:			Skyt	0.013	Sxyz:			52:		0.165	
	or Min, Ma	ю: [-0.0	10, 0.045]	Error Min, Max:	[-0.007,		Error Min, Max:	[0.008, 0.045]	Error Min, Max:	[0.00		Error Min, Max:	[-0.036,		
	or Range:		0.055	Error Range:			Error Range:	0.037	Error Range:			Error Range:		1.065	
	ISE:		0.020	RMSE:			RMSE:	0.023	RMSE:			RMSE		0.168	
AS	PRS Accur	acy Class:	0.020	ASPRS Accuracy	Class:	0.013	ASPRS Accuracy Class	: 0.020				ASPRS Accuracy C		0.158	
Sta	stistical Poi	nt Counts		Correction								Min Contour Interv	wi:	0.504	
Ho	rizontal Me	asured:	6	Osc			Tx:		Rx:						
Ve	rtical Meas	ured:	38	Oys			Ty:		Ry:						
W	theid:		33 of 39	Oz:		Series V.	Te		Rz:		-				