



Using anyNAV in OxTS Georeferencer

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1. Introduction

Thank you for your interest in the *anyNAV* feature within OxTS Georeferencer.

This document explains everything you need to know to get started with the software application.

OxTS Georeferencer combines navigation and LiDAR data to create accurate, georeferenced 3D pointclouds. The *anyNAV* feature allows the use of any navigation data, from any navigation system, within the software.

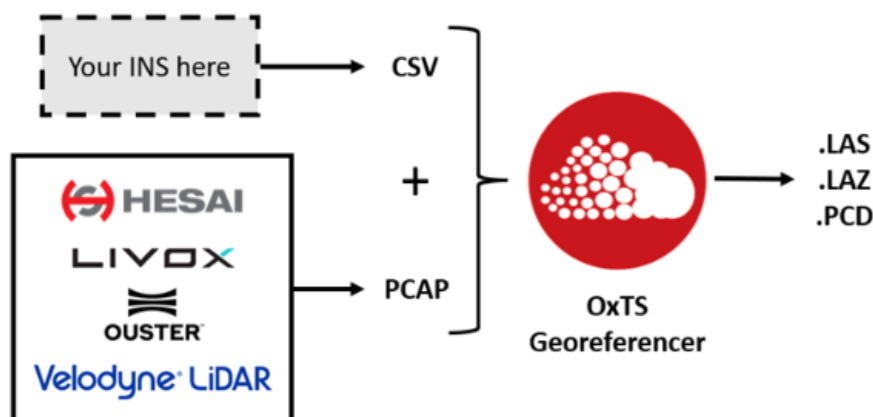


Figure 1: Overview of *anyNAV* feature within OxTS Georeferencer

2. Pre-requisites

This guide assumes that you have a:

1. Device with internet connection and OxTS Georeferencer 2.5 beta installed.
2. Email invitation to register your anyNAV licence
3. Directory on your device containing the following files:
 - a. .pcap file containing LiDAR data from a LiDAR model supported in OxTS Georeferencer.
 - b. .csv file containing INS data. See [Section 5.1](#) for more details.
 - c. .cfg file, with the same name as the .csv file, detailing what parameter each column in the .csv file contains. See [Section 5.7](#) for more details.
4. (Optional) Device with pointcloud viewing software, such as CloudCompare, installed.

3. Overview of workflow

1. Create an OxTS account.
2. Activate your anyNAV licence within OxTS Georeferencer.
3. Conduct a boresight calibration to optimise the INS and LiDAR coordinate frames.
4. Create a georeferenced pointcloud
5. (Optional) View pointcloud in pointcloud viewing software, such as CloudCompare

4. Using the example files supplied by OxTS?

OxTS has put together some example files that you can use to get started with OxTS Georeferencer, if you don't yet have files of your own. They are available to download [here](#).

Below are some specific details related to these files to help you use them.

1. The LiDAR used was a Hesai XT32M2X.
2. The input values for the hardware configuration are as follows:

Position offset (LIP):	X = 0 m	Y = 0 m	Z = 0.145 m
Angular offset (LIR):	Yaw = 90°	Pitch = 0°	Roll = 180°
Angular offset (VAT):	Yaw = 0°	Pitch = -45°	Roll = 0°

3. The location of the boresight calibration targets, in the cluster plot, can be seen here:

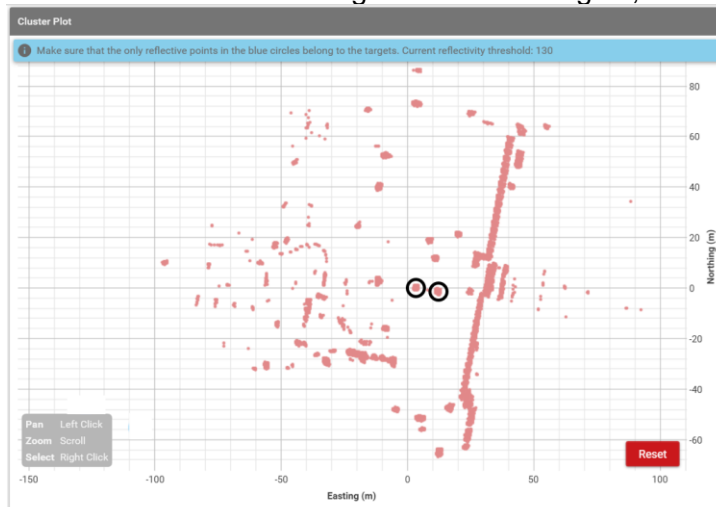


Figure 2: Cluster Plot of OxTS example files with boresight targets highlighted with black circles.

4.1. Create an OxTS account.

You require a licence to use the *anyNAV* feature in OxTS Georeferencer. To obtain your licence, you must register for an account.

You will receive an invitation to create an account via email once OxTS have allocated you a licence. The account creation process requires you to input your first name, last name, email address and the country you are located in. You will also need to create a password.

You will use your email address and the password you create to activate your *anyNAV* licence later.

To create an account with OxTS:

1. Locate the invitation to register your account in your email inbox.
2. Click “View your invitation”



Register your OxTS licence

Hi OxTS Georeferencer user,

OxTS is inviting you to set up your user account to access your organisation's OxTS software licences.

Please click on the button below to accept or decline this invitation.

Completing the registration form will enable you to use your organisation's OxTS software licences.

[View your invitation](#)

Please do not reply to this email message. For any questions, please contact your organisation's licencing administrator.

If your licencing administrator needs further support, they can [contact OxTS](#).

Kind regards,

OxTS

[Click here](#) to visit the OxTS website.

Figure 3: Email invitation to create an OxTS account.

3. Click “Accept” to proceed with your account creation.

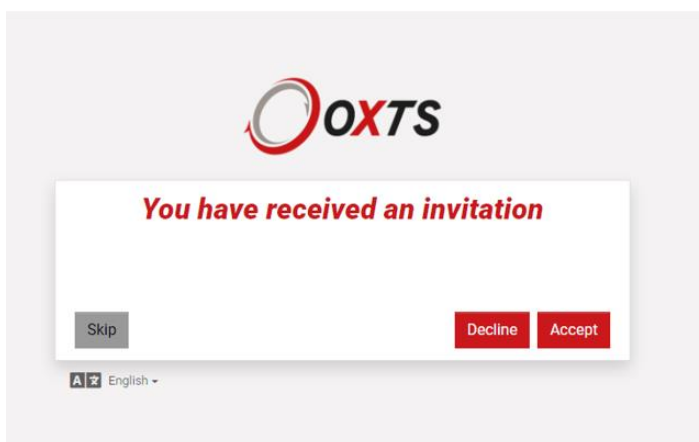


Figure 4: Account creation welcome screen in web browser.

4. Fill in your details in the fields.

OXTS

Create Account

Already have an account? Sign in here

First name ⓘ
First name is required

Last name

Email (user name)
Email is fixed, as the value must match the accepted invitation

Password
A password must have at least 8 characters and at least one of each: lower case letter, upper case letter

Confirm password

Country

☐ I've read and accept the terms and conditions

[Sign in](#) [Sign up](#)

English

Figure 5: "Create Account" screen

5. Click "Sign up".
6. Click "Send validation link".

OXTS

Validate email

A validation link has been sent to your email address. Click the link in the email to validate your email.

If you can't locate the validation link (be sure to check the spam folder), or if the link has expired, you can always request a new validation link.

priya.chevli@gmail [Send validation link](#)

English

Figure 6: "Validate email" screen.

7. Locate the email verification in your email inbox.
8. Click “Confirm your email”.



Email validation

Please click the button below to confirm your email address for your OxTS account.

Confirm your email

Kind regards,

OxTS

[Click here](#) to visit the OxTS website.

www.oxts.com

Figure 7: Validation email

Once you’ve confirmed your email, the screen below will appear and your account has been created.

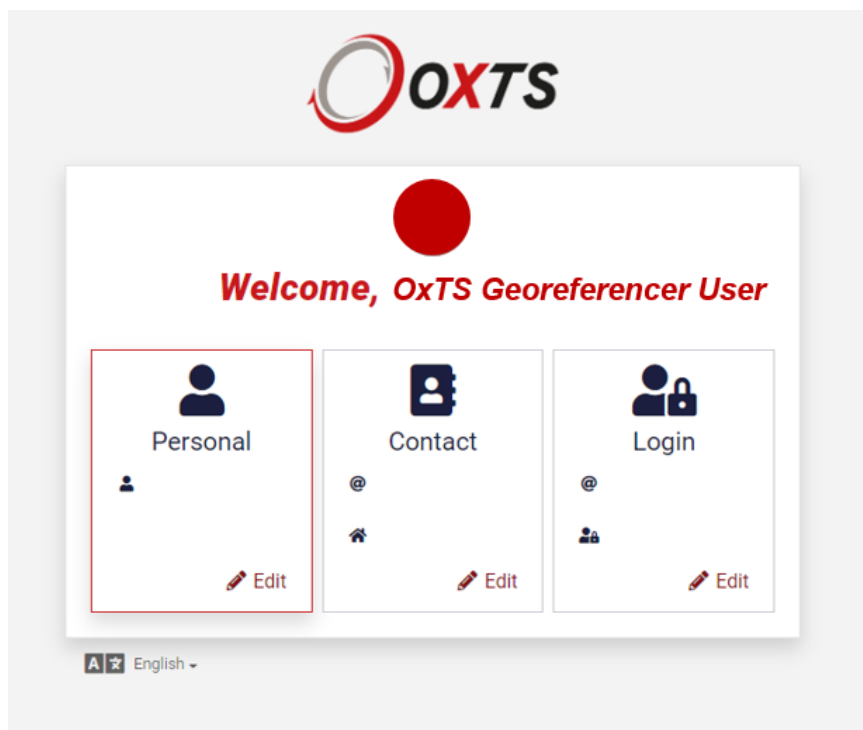


Figure 8: OxTS account portal screen.

4.2. Activate your anyNAV licence.

For an *anyNAV* licence to work, it must be activated. The licence is activated by entering your OxTS account login credentials within OxTS Georeferencer.

The licence should be activated on the device you wish to use for the feature as each *anyNAV* licence can only be activated on a single device.

To activate your *anyNAV* licence:

1. Open the OxTS Georeferencer software.
2. Navigate to the "Licences" tab.
3. Click "Activate a licence"

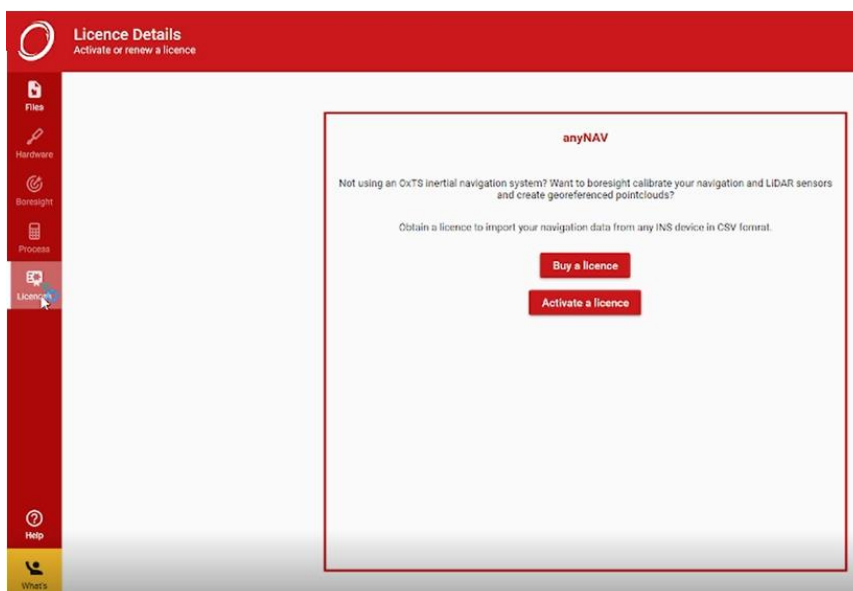


Figure 9: "Licences" tab in OxTS Georeferencer

4. Enter your email address.

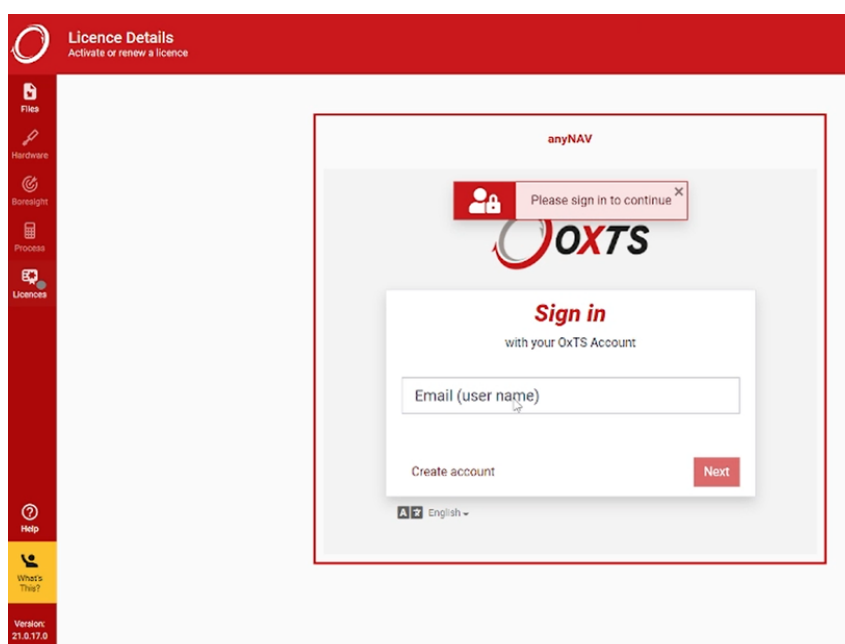


Figure 10: "Enter email" screen.

5. Enter your password.
6. Click “Sign in” to activate your licence.

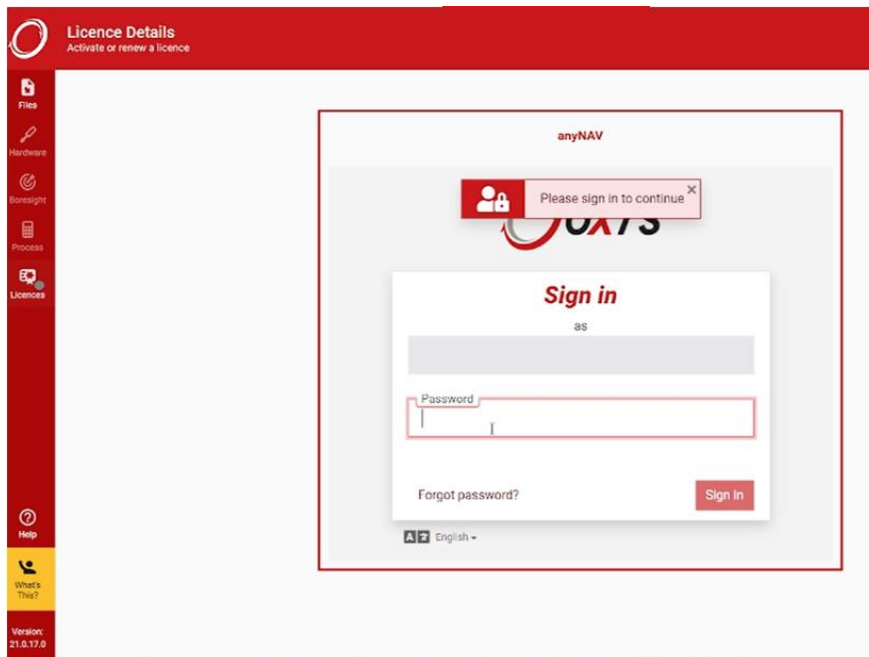


Figure 11: "Enter password" screen.

The status of your licence and its expiry date will appear on the “Licences” tab. One of three statuses will be displayed:

1. Active – this device has a valid *anyNAV* licence that expires in more than 90 days.
2. Expiring – this device has a valid *anyNAV* licence that expires within 90 days.
3. Expired – this device does not have a valid *anyNAV* licence.

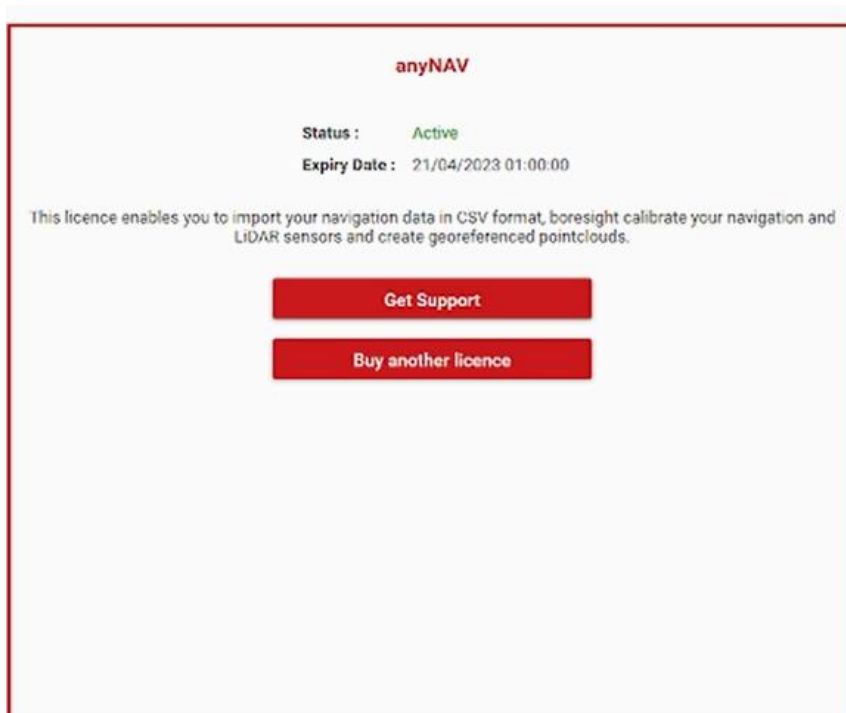


Figure 92: anyNAV licence status screen.

4.3. Conduct a boresight calibration to optimise the INS and LiDAR coordinate frames.

To create clear georeferenced pointclouds – without blurring or double vision - you need to know the exact position and rotation of the LiDAR with respect to the inertial navigation system.

The boresight calibration tool within OxTS Georeferencer calculates the precise angular and linear configuration of the LiDAR and INS with far greater precision than can be achieved manually.

It does this by analysing the LiDAR returns from two boresight targets – flat, four-sided, retroreflective objects with known dimensions (usually 80 cm x 80 cm) – obtained from varying distances and angles.

When unboresighted, errors in the relative rotation and position measurements cause many of the LiDAR returns to fall outside of the known dimensions of the target. The boresight calibration tool adjusts these measurements to those where all returns fit within the flat, 80 cm x 80 cm surface – removing the errors.

[Click here](#) to learn how to collect LiDAR and navigation data for boresight calibration.

This section explains how to use OxTS Georeferencer's boresight calibration tool to optimise the coordinate frames of your LiDAR and INS.

a. Select your working directory.

OxTS Georeferencer will output all files into the working directory that you specify.

To select your preferred output folder:

1. Navigate to the “Files” tab in OxTS Georeferencer
2. Click “Select Output Folder”
3. Navigate to your preferred output folder.
4. Click the folder and click “Select Folder”

The file location you selected will be listed in the ‘Working Directory’ window.



Figure 3: Working Directory window showing selected folder.

b. Input your LiDAR and Navigation files into OxTS Georeferencer

Your LiDAR file will be contained within a .pcap file. Your navigation files will be contained within a .csv file. Click [here](#) for more information on the required contents of the .csv file.

To input these files into OxTS Georeferencer:

1. Click “Select Files”.
2. Navigate to the folder containing your files.
3. Select the .pcap and .csv files.
4. Press “Open”.

The “Input Files” window will be populated with your LiDAR and navigation files. The trajectory detailed in your navigation file will be shown in the ‘INS Route’ window.

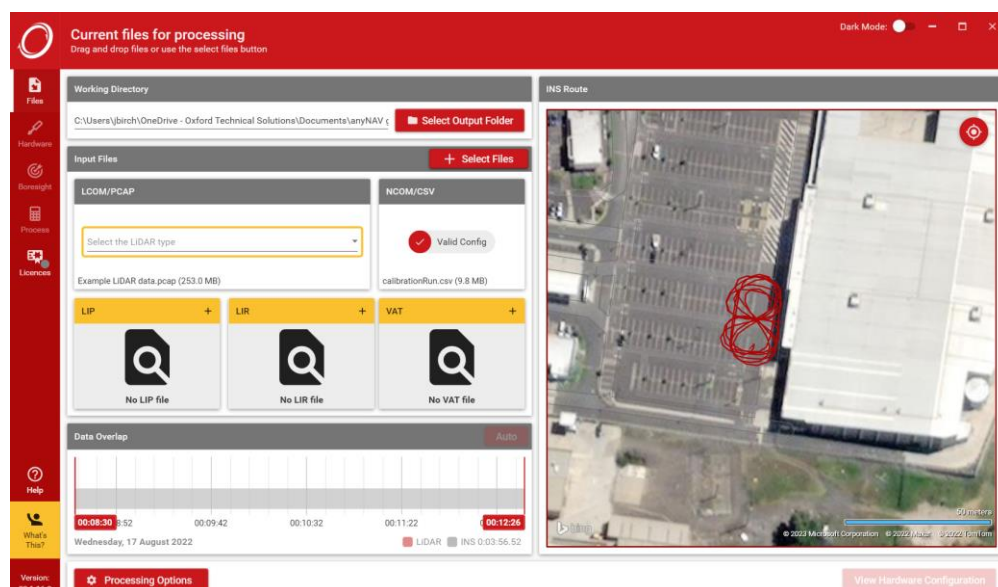


Figure 14: "Files" tab showing .pcap and .csv input and previewing navigation trajectory.

c. Select your LiDAR

To process your .pcap file, OxTS Georeferencer needs to know which of the supported LiDAR you used.

To select your LiDAR:

1. Click “Select the LiDAR type” in the “LCOM/PCAP” window.
2. Scroll the list to navigate to the relevant LiDAR model.
3. Click the relevant LiDAR model.

OxTS Georeferencer will validate when you have selected the correct LiDAR model.

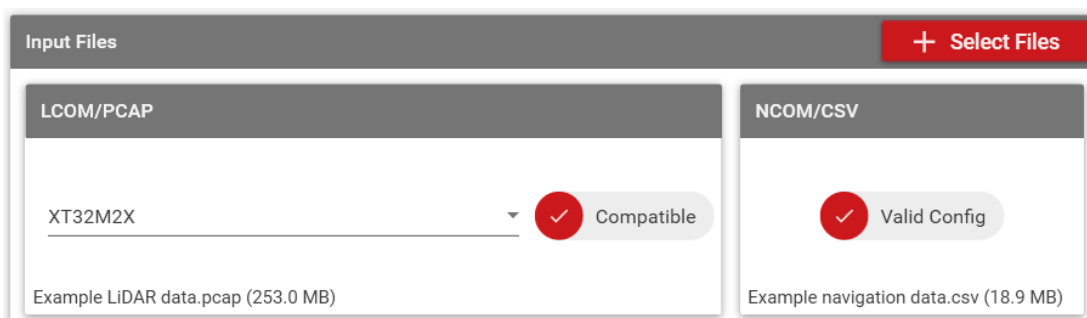


Figure 105: Input Files window validating LiDAR compatibility.

d. Input your approximate hardware configuration.

To optimise your hardware setup, the Boresight Calibration Tool within OXTS Georeferencer requires you to input an approximate configuration. Specifically, the tool needs you to input:

- The relative position of the LiDAR with respect to the navigation system to within 5°.
- The relative orientation of the LiDAR with respect to the navigation system to within 10 cm.
- The relative orientation of the navigation system with respect to the vehicle.

This level of accuracy will enable the tool to identify which points belong to the boresight targets and optimise the measurements.

Please use the vehicle transformation file used by your navigation system as this will ensure the heading, pitch and roll measurements from the CSV are aligned correctly. If you're using an OxTS inertial navigation system, the device automatically optimises the VAT values to a high level of accuracy during data collection.

We recommend that you take pictures of your hardware setup as well as measurements, for reference.

To input your approximate hardware setup:

1. Click the “+” symbol in the LIP, LIR and VAT windows.

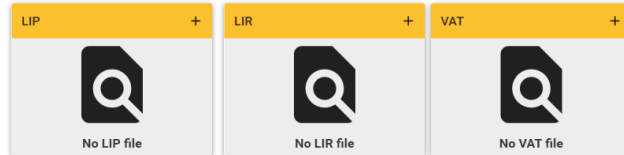


Figure 11: LIP, LIR and VAT windows prior to "+" symbol being clicked.

2. Navigate to the “Hardware” tab.
3. Adjust the LIP, LIR and VAT values to match your measurements using the hardware configuration viewer as a visual validation.
4. Click “Save Changes”.

OXTS Georeferencer will save .lip, .lir and .vat as separate files containing these values in your working directory.

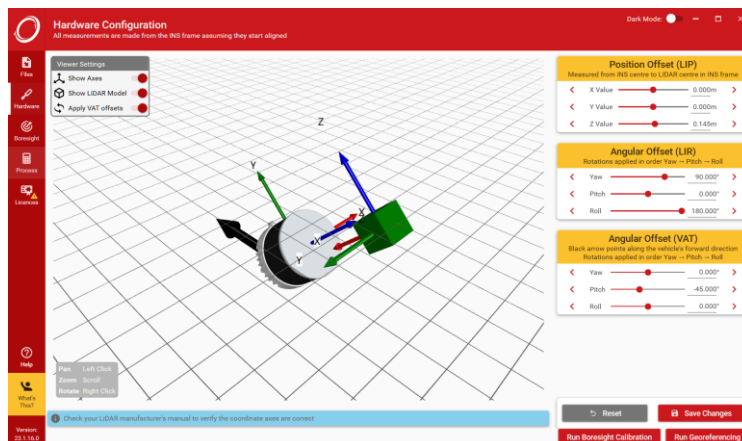


Figure 17: Hardware configuration viewer with LIP, LIR and VAT values adjusted.

e. *Run a Boresight Calibration*

The boresight calibration tool optimises the relative rotation and position measurements between your LiDAR and INS by analysing LiDAR returns from two boresight targets – flat, four-sided, retroreflective objects with known dimensions (OxTS uses 80 cm x 80 cm targets for good portability).

The tool requires you to identify which groups of LiDAR returns are from the boresight targets from a cluster plot – a top down view of all retroreflective objects observed in the environment.

To create a cluster plot:

1. Click “Run Boresight Calibration”
2. Allow OxTS Georeferencer to prepare the cluster plot. Time to completion will be indicated on screen.



Figure 18: Boresight Calibration Tool preparing cluster plot.

To identify the boresight targets within the cluster plot:

1. Click the cluster of points that corresponds to one of the boresight targets.
2. Click the cluster of points that corresponds to the other boresight target.
3. Adjust the search radius to ensure that only points corresponding to a boresight target are contained within the blue circles.
4. Click “Check Target points”
5. Click “Continue Boresight”



Figure 19: Cluster Plot with boresight calibration targets selected and search radius adjusted.

f. Optimise LiDAR-INS Rotations (LIR) and LiDAR-INS Position (LIP) measurements

The boresight calibration tool now has the information it needs to analyse and adjust the relative rotation (LIR) and position (LIP) measurements between the LiDAR and INS to those where all the LiDAR returns fit within the targets' known dimensions – removing the errors.

To begin the analysis and adjustment:

1. Click “Continue Boresight”
2. Allow OxTS Georeferencer to optimise the LIR/LIP values. Time to completion will be indicated on screen

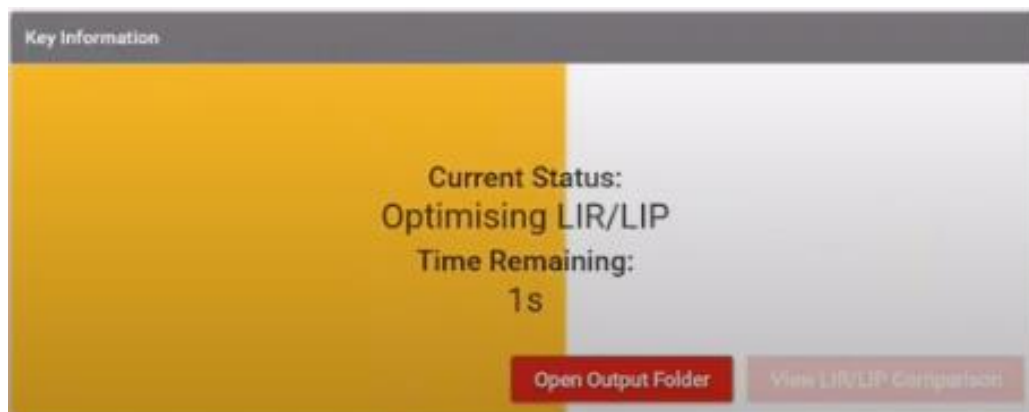


Figure 20: Boresight Calibration Tool optimising LIR/LIP values.

Once complete, the boresight calibration tool will present the adjusted LIR and LIP in an LIR/LIP comparison screen.

For example, the image below shows that the yaw measurement was adjusted by -3.499° , pitch by -1.305° degrees and roll by $+0.656^\circ$. The accuracy of these measurements would not be achievable without this data-driven approach to boresight calibration.

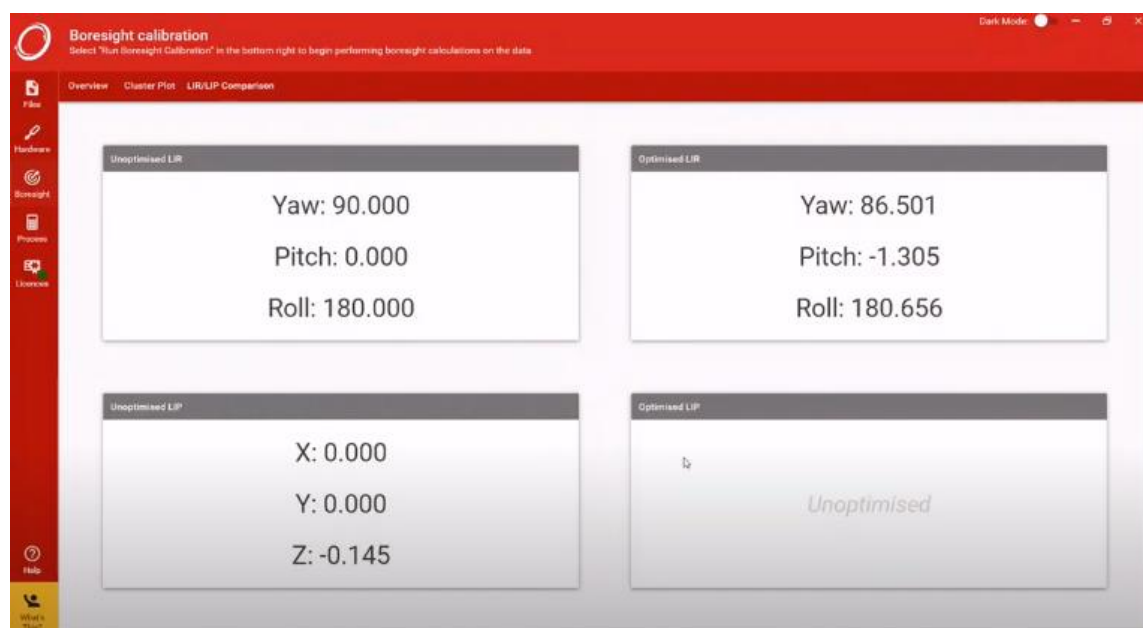


Figure 21: LIR/LIP comparison screen showing LIR and LIP values before and after boresight calibration.

The .lir and .lip files in your working directory will be updated to the adjusted values for future use.

4.4. Create a georeferenced pointcloud

Once you have boresighted .lir and .lip files, you can combine these with your LiDAR data (.pcap), navigation data (.csv) and vehicle-to-INS measurement (.vat), to create an accurate, georeferenced pointcloud (.las, .laz, and/or .pcd).

To create a georeferenced pointcloud:

1. Click “Run Georeferencing” in either the “Files” tab, or “Boresight” tab.
2. Allow OxTS Georeferencer to run the georeferencing processing. Time to completion will be indicated on screen.
3. Click “Open Output Folder” when it becomes visible to view the file in your working directory.



Figure 122: OxTS Georeferencer running Georeferencing processing.

4.5. (Optional) View pointcloud in pointcloud viewing software, such as CloudCompare

OxTS Georeferencer outputs into common pointcloud file types: .las, .laz and .pcd. These files can be opened in third-party pointcloud viewing software.

Below is an example using CloudCompare:



Figure 23: Boresighted pointcloud, created by OxTS Georeferencer, viewed in CloudCompare.

5. Appendix

5.1. CSV File

In order to utilize OxTS Georeferencer with data from a non-OxTS INS, it is required that the following fields be present:

Field	Data Type	Description	Units
Time	Double	The number of seconds elapsed since epoch. Epoch may either be GPS or UTC.	s
Local Coordinate Northing	Double	The offset between the current position and the local coordinate origin, in the north direction.	m
Local Coordinate Easting	Double	The offset between the current position and the local coordinate origin, in the east direction.	m
Local Coordinate Down	Double	The offset between the current position and the local coordinate origin, in the down direction.	m
Latitude	Double	The latitude of the current point.	deg
Longitude	Double	The longitude of the current point.	deg
Altitude	Double	The altitude of the current point.	m
Velocity North	Double	The north component of the navigation frame velocity.	m/s
Velocity East	Double	The east component of the navigation frame velocity.	m/s
Velocity Down	Double	The down component of the navigation frame velocity.	m/s

Roll Angle	Double	The roll angle component of the navigation-frame to vehicle-frame orientation, when applied in the order (Roll, Pitch, Heading).	deg
Pitch Angle	Double	The pitch angle component of the navigation-frame to vehicle-frame orientation, when applied in the order (Roll, Pitch, Heading).	deg
Heading Angle	Double	The heading angle component of the navigation-frame to vehicle-frame orientation, when applied in the order (Roll, Pitch, Heading).	deg
Local Coordinate Northing Accuracy	Double	The accuracy, expressed as a standard deviation, of Local Coordinate Northing measurements.	m
Local Coordinate Easting Accuracy	Double	The accuracy, expressed as a standard deviation, of Local Coordinate Easting measurements.	m
Local Coordinate Down Accuracy	Double	The accuracy, expressed as a standard deviation, of Local Coordinate Down measurements.	m
Roll Angle Accuracy	Double	The accuracy, expressed as a standard deviation, of Roll Angle measurements.	deg
Pitch Angle Accuracy	Double	The accuracy, expressed as a standard deviation, of Pitch Angle measurements.	deg
Heading Angle Accuracy	Double	The accuracy, expressed as a standard deviation, of Heading Angle measurements.	deg

5.2. Vehicle-to-INS Rotation File (VAT)

This file is a text file, comprising three lines, each giving orientation angles (Heading, Pitch, Roll), in degrees, which describes the transformation which takes the X, Y, Z axes of the vehicle frame and transforms into the X, Y, Z axes of the INS/Body frame. While the order of angles in the file is (Heading, Pitch, Roll), the rotations are applied in the order (Roll, Pitch, Heading).

See Section 5.5 for definitions of reference frames and rotation orders.

Example .vat file which specifies a roll of 180 degrees, followed by a pitch of 0 degrees, followed by a heading of -90 degrees:

```
-90  
0  
180
```

5.3. LiDAR-to-IMU Rotation File (LIR)

This file is a text file, comprising four lines. The first three lines give orientation angles (Heading, Pitch, Roll), in degrees, which describes the transformation which takes the X, Y, Z axes of the LiDAR frame and transforms into the X, Y, Z axes of the INS/Body frame. The final line specifies whether the file has been optimized/boresighted (0 = not boresighted, 1 = boresighted). While the order of angles in the file is (Heading, Pitch, Roll), the rotations are applied in the order (Roll, Pitch, Heading).

See Section 5.5 for definitions of reference frames and rotation orders.

Example .lir file which specifies a roll of 180 degrees, followed by a pitch of 0 degrees, followed by a heading of -90 degrees, which is not optimized:

```
-90  
0  
180  
0
```

5.4. LiDAR-to-IMU Offset File (LIP)

This file is a text file, comprising four lines. The first three lines give offsets (X, Y, Z), in metres, which describes the offset between the LiDAR and INS/Body frames. The final line specifies whether the file has been optimized/boresighted (0 = not boresighted, 1 = boresighted).

See Section 5.5 for definitions of reference frames.

Example .lip file which specifies an X offset of 0.10m, a Y offset of -1.0m, and a Z offset of 0.5m, which is optimized:

```
0.1  
-1.0  
0.5  
1
```


5.5. Reference Frames

In OxTS Georeferencer, the following five reference frames are in use:

5.5.1. Local Reference Frame (LRF)

This is a local right-handed reference frame, which is defined as a tangent plane on the world ellipsoid. Its origin lies at a fixed reference latitude, longitude, and altitude. Its principal axes are:

- X (North) is parallel to a line of longitude, pointing towards the (geographic) North Pole.
- Y (East) is parallel to a line of latitude, facing eastwards.
- Z (Down) points towards the centre of the Earth.

5.5.2. Navigation Frame

This is a local right-handed reference frame, which is defined as a tangent plane on the world ellipsoid. Its origin lies at the current INS position. Its principal axes are:

- X (North) is parallel to a line of longitude, pointing towards the (geographic) North Pole.
- Y (East) is parallel to a line of latitude, facing eastwards.
- Z (Down) points towards the centre of the Earth.

5.5.3. Vehicle Frame

This is a local right-handed reference frame, whose origin lies at the current position. Its principal axes are:

- X (Forwards) points along the vehicle's forward direction.
- Y (Right) points along the vehicle's right direction.
- Z (Down) points towards the centre of the Earth.

5.5.4. INS/Body Frame

This is a local right-handed reference frame, whose origin lies at the current position of the INS. Its principal axes are:

- X corresponds to the INS's X (Forward) axis.
- Y corresponds to the INS's Y (Right) axis.
- Z corresponds to the INS's Z (Down) axis.

These axes will vary by INS manufacturer. Care should be taken where the INS's axes are expressed in a different order: for example, NovaTel's SPAN INS expresses its coordinate system in RFU (Right/Forward/Up) order rather than FRU (Forward/Right/Up).

5.5.5. LiDAR Frame

This is a local right-handed reference frame, whose origin lies at the current position of the LiDAR. Its principal axes are:

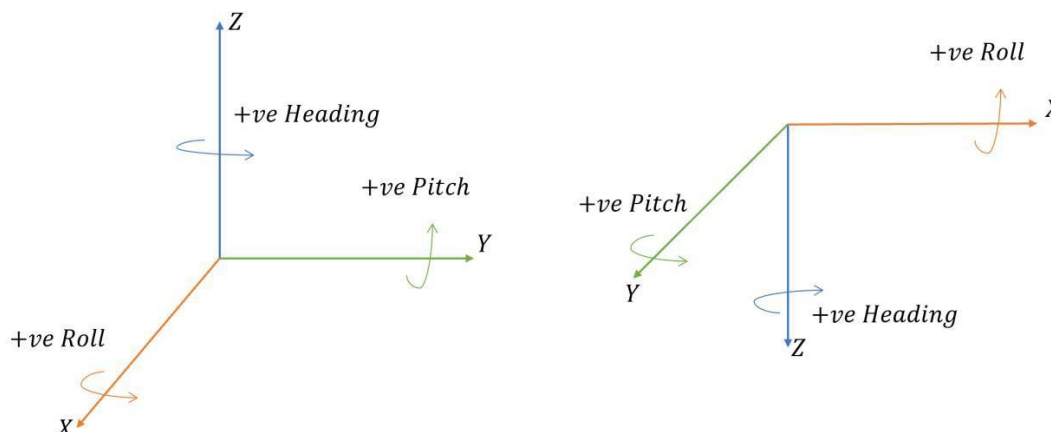
- X corresponds to the LiDARs X axis.
- Y corresponds to the LiDARs Y axis.
- Z corresponds to the LiDARs Z axis.

These axes will vary by LiDAR manufacturer - please refer to the LiDAR's manual for details.

5.6. Rotations

Currently, OxTS Georeferencer only accepts orientation angles (r, p, h) for rotations between frames corresponding to the following series of rotations:

1. A rotation of r degrees, clockwise about the X axis.
2. A rotation of p degrees, clockwise about the new Y axis.
3. A rotation of h degrees, clockwise about the new Z axis.



In this context, "clockwise" describes the direction of rotation when viewed from the origin along the respective axis' positive direction. The following figure describes the direction of each rotation:

In future, functionality may be added to allow rotations to be applied in any order, or in any direction.

5.7. CSV Configuration File Format

The CSV configuration file is a file which shares the same filename as the input CSV file with a change of extension to .cfg - so, for example, if the CSV filename is "C:\SomeFolder\input.csv", then its companion configuration file would have the filename "C:\SomeFolder\input.cfg". It is a file which consists of key-value pairs delimited by the equals "=" character. This tells OxTS Georeferencer which columns of the CSV file correspond to required fields defined in Section 3.1.1.

For example:

```
ins_column_time = 1
ins_column_northing = 2
ins_column_easting = 3
ins_column_down = 4
ins_column_latitude = 6
ins_column_longitude = 7
ins_column_altitude = 8
ins_column_vel_north = 9
ins_column_vel_east = 10
ins_column_vel_down = 11
ins_column_roll = 12
ins_column_pitch = 13
ins_column_heading = 14
ins_column_northing_accu = 15
ins_column_easting_accu = 16
ins_column_down_accu = 17
ins_column_roll_accu = 21
ins_column_pitch_accu = 22
ins_column_heading_accu = 23
ins_north_offset=0.0
ins_east_offset=0.0
ins_down_offset=0.0
ins_time_epoch=utc
```

The following table describes each option:

Option	Data Type	Description
ins_column_time	Int8	The 1-based index of the column representing time.
ins_column_northing	Int8	The 1-based index of the column representing the local coordinate northing.
ins_column_easting	Int8	The 1-based index of the column representing the local coordinate easting.
ins_column_down	Int8	The 1-based index of the column representing the local coordinate down.
ins_column_latitude	Int8	The 1-based index of the column representing the latitude.
ins_column_longitude	Int8	The 1-based index of the column representing the longitude.
ins_column_altitude	Int8	The 1-based index of the column representing the altitude.
ins_column_vel_north	Int8	The 1-based index of the column representing the navigation-frame north component of velocity.
ins_column_vel_east	Int8	The 1-based index of the column representing the navigation-frame east component of velocity.
ins_column_vel_down	Int8	The 1-based index of the column representing the navigation-frame down component of velocity.
ins_column_roll	Int8	The 1-based index of the column representing the vehicle-frame roll angle.
ins_column_pitch	Int8	The 1-based index of the column representing the vehicle-frame pitch angle.
ins_column_heading	Int8	The 1-based index of the column representing the vehicle-frame heading angle.

ins_column_northing_accu	Int8	The 1-based index of the column representing the accuracy of local coordinate northing.
ins_column_easting_accu	Int8	The 1-based index of the column representing the accuracy of local coordinate easting.
ins_column_down_accu	Int8	The 1-based index of the column representing the accuracy of local coordinate down.
ins_column_roll_accu	Int8	The 1-based index of the column representing the vehicle-frame roll angle.
ins_column_pitch_accu	Int8	The 1-based index of the column representing the vehicle-frame pitch angle.
ins_column_heading_accu	Int8	The 1-based index of the column representing the vehicle-frame heading angle.
ins_north_offset	double	Specifies the northing component of a local coordinate origin. In effect, all output northing values in the point cloud will be offset by this value. This value is expressed in metres.
ins_east_offset	double	Specifies the easting component of a local coordinate origin. In effect, all output easting values in the point cloud will be offset by this value. This value is expressed in metres.
ins_down_offset	double	Specifies the down component of a local coordinate origin. In effect, all output down values in the point cloud will be offset by this value. This value is expressed in metres.
ins_time_epoch	string	Specifies the epoch with respect to which the timestamps are expressed. Valid values are "gps" or "utc".

Of note: if the input coordinate system is specified as "LLA (WGS84)", then the following local coordinate options are ignored:

- ins_column_northing
- ins_column_easting
- ins_column_down
- ins_north_offset
- ins_east_offset
- ins_down_offset

Correspondingly, if the input coordinate system is specified as "Local", then the following global coordinate options are ignored:

- ins_column_latitude
- ins_column_longitude
- ins_column_altitude