OXTS

RT3000 v4 T DO-160
USER MANUAL

OXTS.COM

Legal notices

Copyright notice

Revision

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“Date of Sale” shall mean the date of the OXTS invoice issued on delivery of the product. The responsibility of OXTS in respect of this warranty is limited solely to product replacement or product repair at an authorised location only. Determination of replacement or repair will be made by OXTS personnel or by personnel expressly authorised by OXTS for this purpose.

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Products should not be used or sold in the development or utilisation of any weapons or life-threatening applications, as well as any life sustaining or security sensitive equipment where a malfunction is expected to lead to bodily harm or significant property damage.

Limitations of liability

The purchaser shall indemnify OXTS from all third-party claims arising from any product use not covered by the parameters of the product datasheet or not approved by OXTS.

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Introduction

Thank you for choosing the RT3000 T DO-160 v4 inertial navigation system. The RT3000 combines dual receiver GNSS and a high-grade multi-core MEMS IMU into one self-contained package for making precision measurements of position and motion in real time. The RT3000 T DO-160 v4 is a variant of the RT3000 v4 family that has some design modifications in order to pass the stringent environmental and EMC tests of the RTCA DO-160G standard for avionics hardware.

This document covers the technical information, hardware set up and configuration steps to enable you to successfully integrate and operate the device.

> Important information is highlighted throughout this manual in these boxes.

Intended use

The RT3000 v4 family of inertial navigation systems are designed to precisely measure position, time, orientation, and dynamics for localisation, georeferencing, and validation applications. The RT3000 T DO-160 v4 in particular has been designed to meet the additional environmental requirements for integration into aircraft such as fixed-wing planes, helicopters, and UAVs.

The RT3000 T DO-160 v4 is capable of logging navigation and localisation data as a passive measurement device, and/or outputting the data in real-time with low latency for use in active systems. If the outputs are used in any way as part of a control system, appropriate steps should be taken by the System Integrator to ensure that the control system as a whole meets the required functional safety standards, with additional independent and redundant sensors and modules. The device is suitable for outdoor use in pollution degree 4 environments.

Related documents

This manual covers the installation and operation of RT systems, but it is beyond its scope to provide details on service or repair. Contact OXTS support or your local representative for customer service-related inquiries.

Additional manuals provide further information on some of the software and communication types mentioned in this manual. Table 1 lists related manuals and where to find them.

Manual	Description
NAVdisplay Manual	For viewing real-time information from an RT. https://www.oxts.com/software/navsuite/documentation/manuals/NAVdisplay_man.pdf
NAVgraph Manual	For plotting and exporting captured data. https://www.oxts.com/software/navsuite/documentation/manuals/NAVgraph_man.pdf
NAVsolve Manual	Explains how to use our post-processing application. https://www.oxts.com/software/navsuite/documentation/manuals/NAVsolve_man.pdf
NCOM Manual	Description of the OXTS NCOM format. https://www.oxts.com/software/navsuite/documentation/manuals/NCOM_man.pdf
NCOM C Decoder	A collection of C functions that can be used to decode the binary protocols from the RT. https://github.com/OxfordTechnicalSolutions/NCOMdecoder
ROS2 driver	Allows an OXTS INS to interact with a wider ROS network. https://github.com/OxfordTechnicalSolutions/oxts_ros2_driver
CAN Interface Manual	Manual describing the CAN format and outputs. https://www.oxts.com/software/navsuite/documentation/manuals/CAN_man.pdf
NMEA 0183 Description	NMEA description manual for the NMEA outputs. https://www.oxts.com/software/navsuite/documentation/manuals/NMEA_man.pdf

Table 1:
Supplementary manuals

Scope of delivery

The standard kits are supplied complete with user cable, an Ethernet cable and crossover, software, a calibration certificate, a tape measure, and a quick start guide. Table 2 lists all items that are delivered with each RT3000 T DO-160 v4.

	Base kit	Evaluation kit
Part number	109-01234	109-01219
RT3000 T DO-160 v4 inertial navigation system	X1	X1
User cable (14C0038) *For evaluation only*[1]		X1
CAN to serial convertor cable (14C0236) *For evaluation only*[1]		X1
Power cable (77C0002) *For evaluation only*[1]		X1
Ethernet cable (cross-over)		X1
USB stick with manuals and software	X1	X1
Tape measure		X1
Calibration certificate	X1	X1
Declaration of Conformity	X1	X1
Quick start guide	X1	X1

Table 2:
Summary of RT3000 T DO-160 V4 scope of delivery
[1]Cables not compliant with DO-160G requirements. Refer to reference cable drawing 99C0044 for instructions on designing a compliant cable.

To achieve full RTK position performance, the INS requires appropriate differential corrections from a base station. Differential corrections can be supplied by an RT-Base S, GPS-Base, NTRIP or other suitable differential correction source such as Terrastar™.

In addition to the components supplied, the user will require a laptop computer.

Conformance notices

The RT3000 T DO-160 v4 complies with all emissions and immunity limits for the standards stated on the Declaration of Conformity. These limits are designed to provide reasonable protection against harmful interference in business, commercial and industrial uses. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following:

+ Re-orient or relocate the receiving antenna.
+ Increase the separation between the equipment and the receiver.

The device incorporates a GNSS receiver. No GNSS receiver will be able to track satellites in the presence of strong RF radiations within 70 MHz of either the GPS frequencies L1 (1575 MHz) or L2 (1228 MHz).

The RT3000 T DO-160 v4 conforms to the requirements for CE.

Regulator testing standards

EMC

+ EN 61326-1:2021 - Electrical equipment for measurement, control and laboratory use.
+ EN 301 489-19 v2.2.1 (2022-09) – Electro Magnetic Compatibility (EMC) standard for radio equipment and services; Part 19: Specific conditions for Receive Only Mobile Earth Stations (ROMES) operating in the 1.5 GHz band providing data communications and GNSS receivers operating in the RNSS band (ROGNSS) providing positioning, navigation, and timing data.

LVD

+ EN 61010-1:2010+A1-2019 - Safety requirements for electrical equipment for measurement, control, and laboratory use.

RED

+ EN 303 413 V1.2.1 (2021-04) - Global Navigation Satellite System (GNSS) receivers. Radio equipment operating in the 1164 MHz to 1300 MHz and 1559 MHz to 1610 MHz frequency bands.

RoHS

+ EN 63000:2018 – Technical documentation for the assessment of electrical and electronics products with respect to the restriction of hazardous substances.

FCC

+ 47 CFR 15.109 – Code of Federal Regulations – Title 47 (Telecommunication): Part 15 (Radio Frequency Devices) – Subpart B (Unintentional Radiators) – Section 15.109.
+ ICES-003 Issue 7 October 2020 – Information Technology Equipment (Including Digital Apparatus) – Limits and Methods of Measurement.

DO-160G test coverage

Test	Category	Parameter
Ground Survival Low Temperature Test, Short-Time Operating Low Temperature Test and Operating Low Temperature Test	Sections 4.5.1 & 4.5.2 Category A4	-40°C
Ground Survival High Temperature Test, Short-Time Operating High Temperature Test and Operating High Temperature Test	Sections 4.5.3 & 4.5.4 Category A4	+85°C (non-operating) +70°C (operating)
Loss of Cooling	Section 4.5.5 Category Z	450 minutes at +45°C
Altitude	Section 4.6.1 Category F2	55,000 ft
Temperature Variation	Section 5 Category C	2°C per minute
Humidity	Section 6 Category B	Severe humidity environment
Waterproofness	Section 10 Category R	Spray proof
Sand and Dust	Section 12 Category S	
Fungus Resistance	Section 13 Category F	
Salt Fog	Section 14 Category S	
Vibration[1]	Section 8 Category R5 curve E/E1	Robust vibration
Operational Shock[1]	Section 7 Category B	6g peak, 11 ms
Crash Safety Shock[1]	Section 7 Category B	20g peak, 11 ms

Table 3:
DO-160G Environmental tests
[1]When mounted according to the guidelines detailed on page 22. Other mounting configurations have not been tested to DO-160G standards.

Test	Category	Parameter
Magnetic Effect	Section 15 Category Z	<0.3 m for deflection
Power Interruption	Section 16.6 Category A	200 ms
Voltage Spike	Section 17 Category B	2X line voltage (56 V peak)
Audio Frequency Conducted Susceptibility[1]	Section 18 Category R	DC supplied from transformer-rectifier
Induced Signal Susceptibility	Section 19 Category ZC	Interference-free operation
Radio Frequency Susceptibility	Section 20 Category R	Conducted and Radiated
Emissions of Radio Frequency Energy[1]	Section 21.4 Category B - Conducted Section 21.5 Category L - Radiated	Interference controlled to tolerable levels.
Lightning Induced Transient Susceptibility[2]	Section 22 Category A1 J1 L1	Pin injection and cable induction
(ESD) Electrostatic Discharge[2]	Section 25 Category A	15 kV

Table 4:
DO-160G EMC tests
[1]When using a suitably constructed cable such as the reference cable described in Appendix C – Drawing list.
[2]Earth/chassis connected on the device and on the braided cable shield.

Hardware description

Overview

The RT3000 T DO-160 v4 is a flagship GNSS-aided inertial navigation system. It combines a dual antenna multi-constellation, multi-frequency RTK GNSS receivers with a tactical-grade multi-core IMU array to provide a highly accurate 3D navigation and dynamics reference solution. Additionally, the system includes 32 GB data storage and an on-board processor running the real-time strapdown navigator and OXTS Kalman filter.

Navigation data is output at a high update rate (up to 250 Hz) and with very low latency (~3 ms). The sensor fusion between inertial data and GNSS measurements ensures all outputs remain available continuously during GNSS blackouts. The device is also able to recognise erroneous GNSS updates and filter them out to maintain a smooth and continuous position output.

Dual antenna

Dual antenna systems provide high accuracy heading information and almost constant heading performance under all conditions. The dual antenna GNSS-compass allows greater heading accuracy with wider antenna baselines and ensures stable heading performance even when stationary and during low dynamics.

For aircraft or marine applications, or road vehicle applications on low-friction surfaces (e.g. ice), a dual antenna system is recommended to maintain high accuracy heading.

Advanced processing in the RT allows relock to occur within seconds of a sky obstruction – unlike GNSS-only systems which can take several minutes; in this time the RT's heading will not have significantly degraded. The fast relock time is made possible because the RT's own heading is used to resolve the ambiguities in the GNSS measurements. Resolution of these ambiguities is what normally takes several minutes.

The heading software in the RT enables significantly better performance and coverage compared to GNSS-only solutions.

Quad constellation

Tracking satellites from GPS, GLONASS, Galileo and BeiDou constellations allows the RT to utilise all the available position satellites.

In open sky conditions, this benefit is smaller as GPS signals alone are unlikely to be interrupted and full accuracy can be achieved almost 100% of the time. However, in open-road testing situations there are likely to be bridges, trees, and tall buildings that can block the view of satellites or cause multipath effect errors. In these situations, quad constellation receivers are able to maintain 1 cm accurate RTK positioning mode at times when GPS-only receivers are not. They are also able to re-establish RTK lock and resolve its ambiguities after an obstruction faster.

Satellite differential corrections

To improve the positioning accuracy of standard GNSS, two satellite-based differential correction services are available. These are SBAS and TerraStar.

Services such as WAAS and EGNOS, are wide-area differential corrections provided for free. They can provide an accuracy of better than 1 m CEP. WAAS is available in North America; EGNOS is available in Europe; MSAS is available in Japan; GAGAN is available in India; SDCM is available in Russia. Other parts of the world are not covered and cannot use this service.

TerraStar is a 3rd party subscription service. The RT3000 T DO-160 v4 includes the necessary hardware to receive the TERRASTAR-C PRO service. For more information, see TerraStar's website: http://www.terrastar.net.

Real-time outputs

The device processes data in real time for high-frequency low-latency outputs. The real-time results are output over 10/100 Base-T Ethernet using a UDP broadcast and on CAN bus. Outputs are time-stamped and refer to GPS time; PTP or a 1PPS timing sync can be used to give accurate timing synchronisation between systems. The inertial measurements are synchronised to the GPS clock.

Internal data logging enables the data to be reprocessed post-mission. Data can be collected in the device, downloaded using File Transfer Protocol (FTP), processed on a PC and viewed using NAVdisplay.

Advanced processing

In poor GNSS environments, drift times can be halved by using the combined results of processing forwards and backwards in time. Our proprietary gx/ix™ processing engine can further improve performance with single satellite aiding algorithms and tight coupling of the inertial and GNSS measurements, meaning position updates even with fewer than four satellites in view.

Specifications

Specifications for RT3000 T DO-160 v4 can be found below.

Parameter	RT3000 T DO-160 v4
GNSS tracking	GPS L1, L2 GLONASS L1, L2 Galileo E1, E5 BeiDou B1, B2 L-Band
Horizontal position accuracy[1]	1.5 m CEP SPS 0.6 m CEP SBAS 0.4 m CEP DGPS 0.03 m CEP PPP[2] 0.01 m 1σ RTK
Altitude accuracy[1]	0.012 m 1σ RTK
Velocity accuracy	0.025 km/h RMS
Roll/pitch accuracy	0.01° 1σ
Heading accuracy[3]	0.04° 1σ
Track angle accuracy (at 50 km/h)	0.04° 1σ
Slip angle accuracy (at 50 km/h)	0.05° 1σ
Update rate	100 / 200 / 250 Hz

Table 5.
RT3000 T DO-160 v4 performance specifications
[1]Typical values, subject to ionospheric/tropospheric conditions, satellite geometry, baseline length, multipath. Requires clear view of the sky and appropriate differential corrections to achieve full specification.
[2]Requires Terrastar-C PRO subscription.
[3]Using dual antenna with 1 m separation baseline. Higher accuracy can be achieved with wider antenna separation.

Accelerometers	RT3000 T DO-160 v4
Full range	±8 *g*
Bias	0.02 m/s^2
In-run bias stability	5 µg
VRW	0.012 m/s/√hr
Scale factor	0.02%
Linearity	0.1%
Axis alignment	<0.01°
Gyros	**Value**
Full range	±490°/s
Bias	0.03°/s
In-run bias stability	0.8°/h
ARW	0.12°/√hr
Scale factor	0.08%
Axis alignment	<0.05°

Table 6:
RT3000 T DO-160 v4 inertial sensor specifications

Parameter	RT3000 T DO-160 v4
Input voltage[1]	10–48 V dc
Power consumption[2]	<10 W
Dimensions	120 × 120 × 71 mm
Mass	850 g
Operating temperature	-40° to 70°C
Environmental protection	IP67
Pollution degree	4 – suitable for outdoor use and wet locations
Vibration	0.1 g/Hz 5-500 Hz
Shock survival	100 *g*, 11 ms
Internal storage	32 GB

Table 7:
RT3000 T DO-160 v4 physical and environmental specifications
[1]Voltage range of connected devices such as radio modems must be considered.
[2]A power supply of at least 18 W is required during the first 10 seconds of booting and will reach a steady state power draw of <10 W after 33 seconds.

Notes on specifications

The performance specifications are listed for operation of the system under the following conditions:

+ A short warm-up period (~3 minutes) during which motion inputs will be used by the navigation system to estimate sensor error characteristics.

- Open-sky environment, free from cover by trees, bridges, buildings, or other obstructions. The vehicle must have remained in open sky for at least five minutes for full accuracy.
- The vehicle must exhibit some motion behaviour. Acceleration of the unit in different directions is required so the Kalman filter can estimate any errors in the sensors. Without this estimation, some of the specifications degrade.
- The system will estimate and improve GNSS antenna lever arm accuracies. For optimal performance the lever arm accuracy should be 5 mm.
- The distance from the INS measurement point to the primary GNSS antenna must be known by the system to a precision of 5 mm or better. The vibration of the system relative to the vehicle cannot allow this to change by more than 5 mm. The system will estimate this value itself in dynamic conditions.
- For single antenna systems, the heading accuracy is only achieved under dynamic conditions. Under benign conditions such as low speeds, the performance will degrade. The performance is undefined when stationary for prolonged periods of time.

To achieve full accuracy in real time, the device will require appropriate differential corrections where applicable, either from a base station or with a TerraStar licence. Alternatively, a RINEX file can be downloaded post-mission and used to post-process the data to full accuracy.

For the TerraStar service, a convergence time is required before full accuracy is achieved. See the Terrastar website for details on convergence times.

The "1σ" specification has been used for parameters where offset cannot be measured by the RT, for example position (the offset of the base station cannot be found by the RT alone). The "RMS" specification was used where the offset is known, for example velocity. For angles and measurements derived from the angles, the "1σ" specification is used because the mounting of the RT compared to the vehicle gives an offset the RT cannot measure.

Heading accuracy

The heading accuracy that can be achieved by the dual antenna system in the RTs in Table 5 is 0.04° 1σ per metre of separation in ideal, open sky conditions. The system can provide these accuracies in static and dynamic conditions. The maximum recommended separation is five metres, at which it may be possible to achieve better accuracy than that listed if the structure is rigid, including temperature variation.

For single antenna systems, the heading is calculated from the inertial measurements. The accuracies listed in Table 5 are achievable under dynamic conditions. Under static conditions the heading accuracy of single antenna systems will degrade.

Non-ideal mounting of the GNSS antennas will reduce the heading accuracy, particularly for dual antenna systems.

Power requirements

The RT3000 T DO-160 v4 has a high in-rush current when it is booted up that lasts for ~30 seconds. A power supply of at least 18 W is required during this boot up, after which it will reach a steady state power draw of 8-10 W. Figure 1 shows a diagram of the typical inrush waveform during power up.

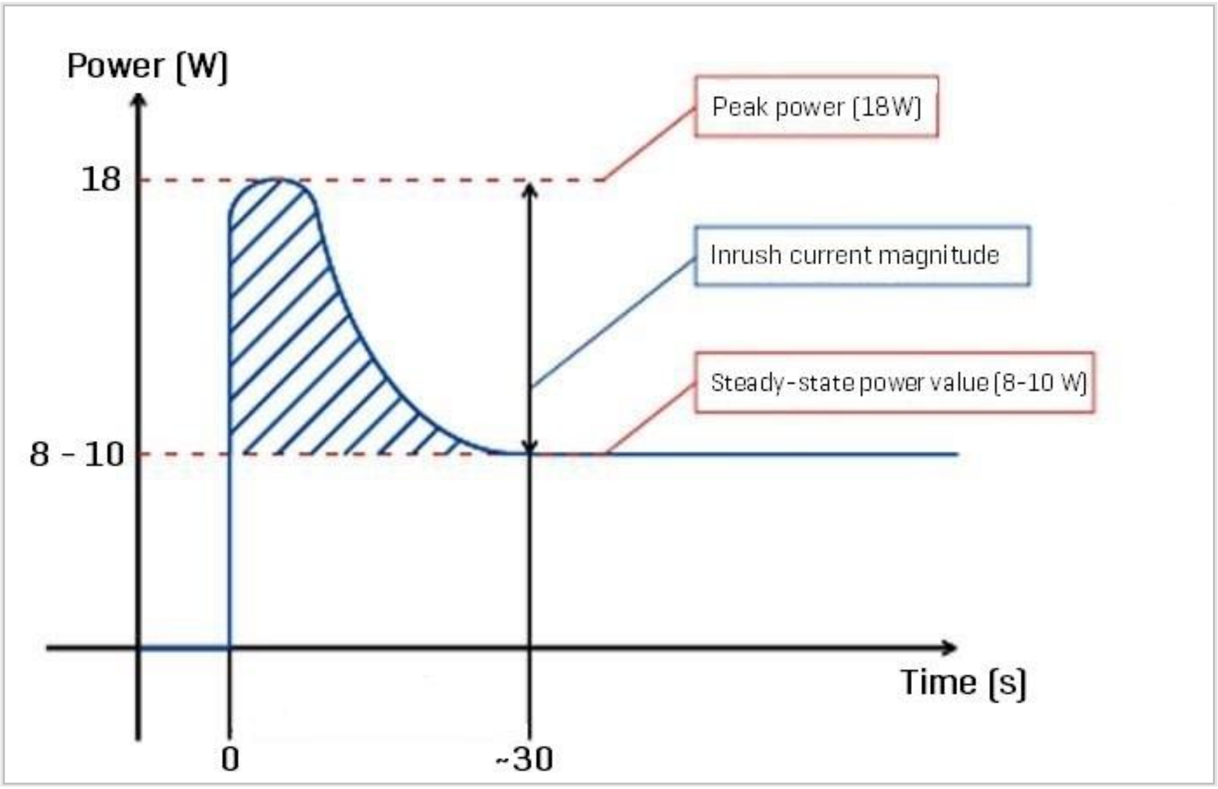


Figure 1:
Power requirements for inrush current

Environmental protection

The RT3000 T DO-160 v4 is rated to IP67. To achieve IP67 it is necessary to have connectors fitted to both TNC antenna connectors and to use self-amalgamating tape over the TNC connectors. The I/O main connector cable needs to be IP67 rated as well.

Export control classification

Export control regulations are subject to change, and so the classification of the device may also change. The information presented here was correct when the manual was published.

The accelerometer and gyro sensors used in the RT3000 T DO-160 v4, as well as the navigation system as a whole, do not fall under the requirements for controlled items on the Export Administration Regulations Commerce Control List (CCL). As such the RT3000 T DO-160 v4 is designated ECCN 7A994 meaning no license is required for export or reexport.

The RT3000 T DO-160 v4 is also classified as “Not Listed” by the Export Control Joint Unit, meaning it is not listed as subject to control in the current UK strategic export control legislation.

Software installation

Included with every RT is a USB stick containing the software package NAVsuite. This package contains several programs required to take full advantage of the RT's capabilities. Table 8 lists the contents of NAVsuite.

Icon	Software	Description
	NAVstart	A menu from which you can navigate between OXTS applications. This opens automatically when you are connected to a unit.
	NAVconfig	Used to create, send, and receive configurations from OXTS products. As configurations vary between products there is no manual for NAVconfig.
	NAVdisplay	Used to view real-time data from OXTS products via Ethernet or a serial port. It can also be used to transmit special commands and replay logged data.
	NAVsolve	Used to download raw data files from the RT and post- process the data. The configuration can be changed and differential corrections can be applied before the data is reprocessed. It can export NCOM, XCOM and CSV file formats.
	NAVgraph	Used to graph NCOM, XCOM and RCOM files created in post-process. It can display graphs, cursor tables and map plots and data can be exported in CSV or KML (Google Earth) format.
	NAVbase	Used to configure and manage RT-Base S and GPS-Base base stations, which can be used to achieve RTK integer level position accuracy.
	Manuals and documents	This folder contains PDF versions of relevant OXTS manuals. Other manuals can be downloaded from the OXTS website.

Table 8.
NAVsuite components

To install NAVsuite, insert the USB stick and run NAVsetup.exe. Follow the onscreen instructions to install the software. By default, the installer creates the program files in C:\Program Files (x86)\OxTS on 64 bit operating systems or C:\Program Files\OxTS on 32 bit operating systems.

The first time some OXTS applications are run, a firewall warning message similar to that shown in Figure 2 may be triggered. This is because the program is attempting to listen for, and communicate with, OXTS devices on the network. The firewall must be configured to allow each program to talk on the network, or programs will not work as intended.

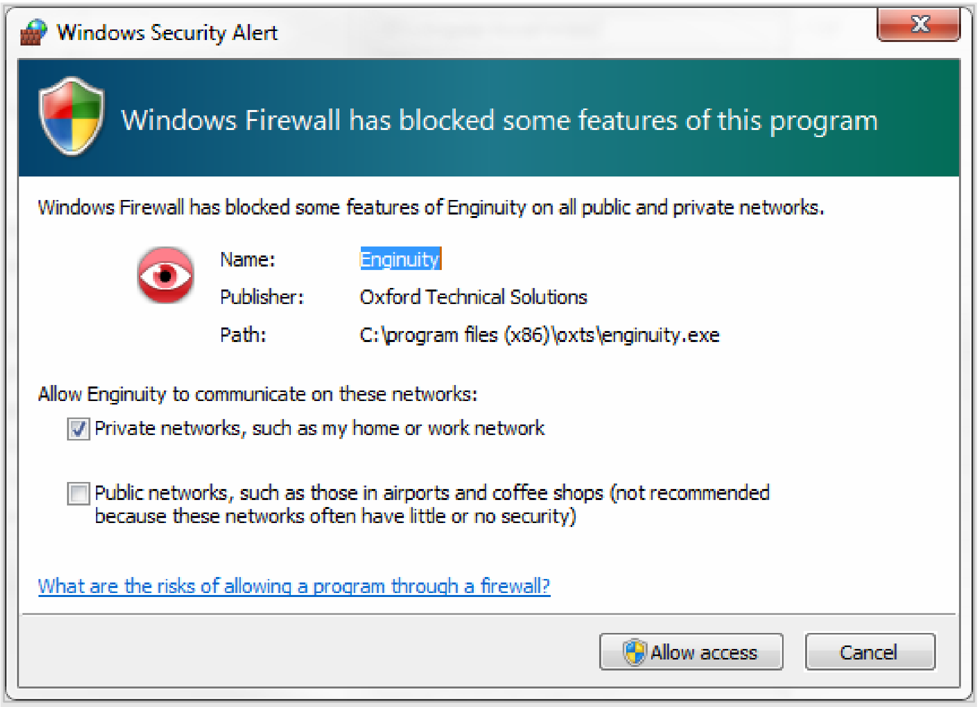


Figure 2:
Windows Firewall warning message

Ensure both Private and Public networks are selected to ensure the software can continue functioning when moving from one type to another.

Hardware installation

Usage guidelines

The RT3000 T DO-160 v4 is suitable for use in harsh environments including outdoors and in wet locations. To ensure safe operation in these conditions, the following considerations should be made.

+ Ensure that all cable connections and ports are properly sealed and waterproof to prevent water ingress and damage to internal components.
+ Maintain adequate creepage and clearance distances between high-voltage and low-voltage components.
+ Properly ground the equipment to prevent static buildup.
+ Regularly inspect the device and its enclosure for signs of wear, corrosion, or damage caused by exposure to wet conditions.

Mounting

It is essential to install the device rigidly in the vehicle. The device should not be able to move or rotate compared to either GNSS antenna, otherwise the performance will be reduced. The device must be mounted directly to the chassis of the vehicle as well as the braided cable shield that is near the I/O; more information about this cable is found in the reference cable drawing in Appendix C – Drawing list. The connection between the enclosure of the unit and the braided cable shield (near the I/O) should have very little resistance between them with the Main I/O user cable connector disconnected. If the vehicle experiences high shocks, then vibration mounts may be required.

Figure 3 shows the mounting points for the RT3000 T DO-160 v4. In order to be compliant with DO-160G vibration and shock standards, the bottom M6 mounting holes must be used. The side threaded holes should be used to earth the device by connecting to the vehicle chassis. Only one needs to be connected.

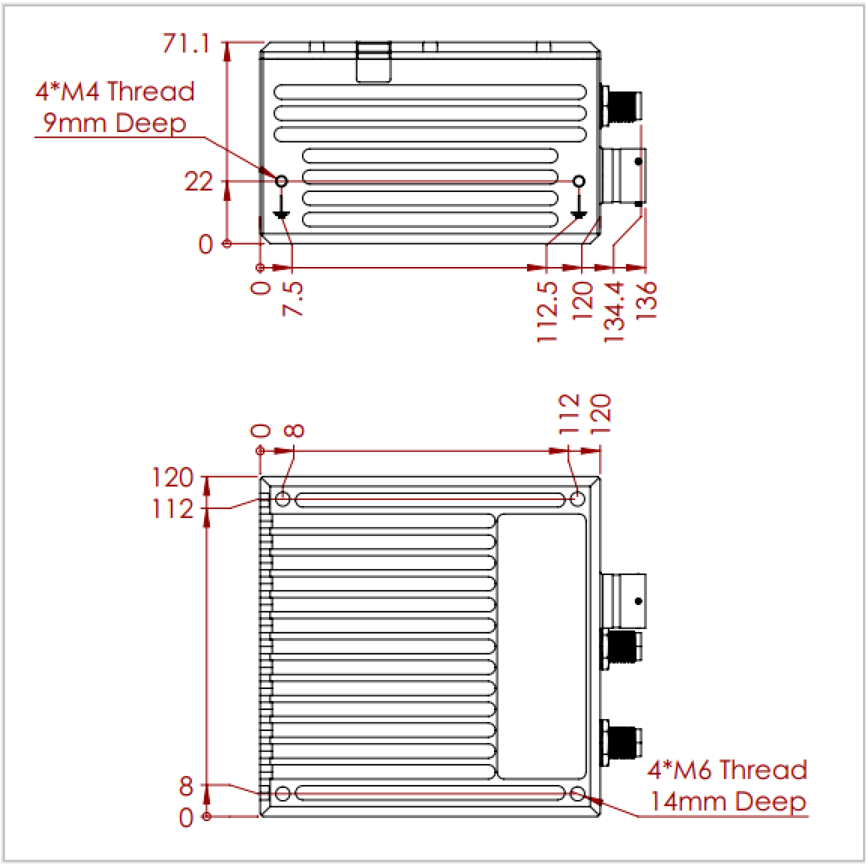


Figure 3:
RT3000 T DO-160 v4 mounting points (mm)

Connections

When mounting the RT3000 T DO-160 v4 please ensure that the enclosure has a good connection to the chassis of the vehicle. If the mounting points in Figure 3 do not have a good connection to the chassis of the vehicle then there are four M4 threaded holes on the side of the device to connect to the chassis of the vehicle using a wire crimped with a lug.

Do not install the device where it is in direct sunlight as, in hot countries, this may cause the case to exceed the maximum temperature specification.

Ensure that the device is not installed near sources of significant heating or cooling as sudden changes in ambient temperature can adversely impact satellite signal tracking.

Orientation and alignment

The orientation of the device in the vehicle is normally specified using three consecutive rotations that rotate the device to the vehicle's co-ordinate frame. The order of the rotations is:

1. Heading (z-axis rotation);
2. then pitch (y-axis rotation);
3. then roll (x-axis rotation).

It is important to get the order of the rotations correct.

The device can be mounted at any angle in the vehicle as long as the orientation is described in the configuration. This allows the outputs to be rotated based on the settings entered to transform the measurements to the vehicle frame.

Antennas

The RT3000 T DO-160 v4 has TNC connectors for the primary and secondary GNSS antennas. Antennas used with the device must at least be capable of tracking the GPS L1 signal for operation and additionally the GPS L2 signal for RTK performance. Antennas capable of tracking L1 and L2 GLONASS signals, E1 and E5b Galileo signals, and B1 and B2 Beidou signals should be used to achieve full specification.

The RT3000 T DO-160 v4 is certified for use with GNSS antennas with a gain of $\leq$ 35 dB.

When using the INS in a dual antenna configuration, it is recommended to use the same type of antenna with the same cable lengths for both the primary and secondary receivers.

Antenna placement and orientation

For optimal performance it is essential for the GNSS antenna(s) to be mounted where they have a clear, uninterrupted view of the sky and on a suitable ground plane (if they do not have one built in), such as the roof of a vehicle. They should be mounted away from any potential sources of interference, such as LiDAR systems.

The antennas cannot be mounted on non-conducting materials or near the edges of conducting materials. If the antennas are to be mounted with no conductor below them, then different antennas must be used. It is recommended to mount the antennas at least 30 cm from any edge where possible.

For dual antenna systems, the secondary antenna should be mounted in the same orientation as the primary antenna, as shown in Figure 4. The antenna baseline should also be aligned with one of the vehicle axes where possible, either inline or perpendicular to the vehicle's forward axis.

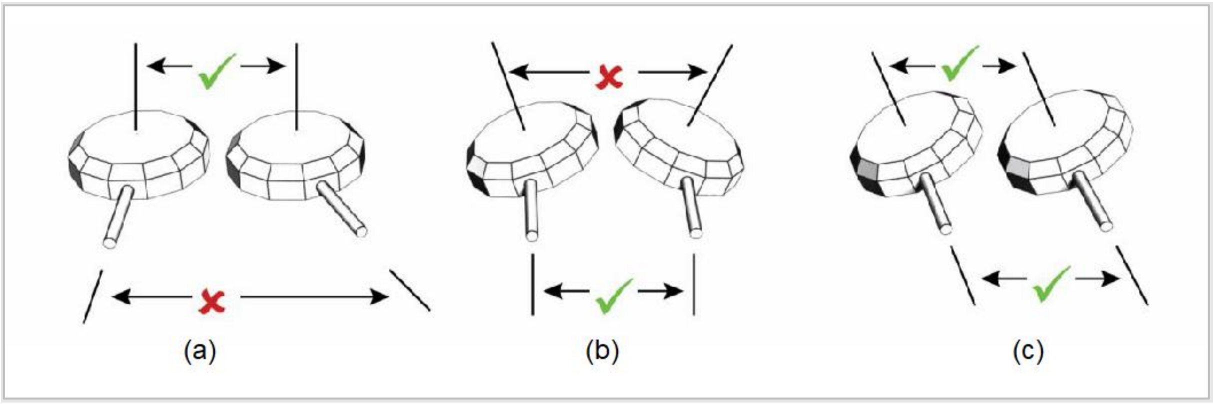


Figure 4:
Dual antenna orientations

a) The bases of the antennas are parallel, but the cables exit in different directions.
b) The cables exit in the same direction but the bases of the antennas are not parallel.
c) The bases of the antennas are parallel and the cables exit in the same direction. This configuration will achieve the best results.

It is critical to have the device mounted securely in the vehicle. If the angle of the device can change relative to the vehicle, then the dual antenna system will not work correctly. This is far more critical for dual antenna systems than for single antenna systems. The user should aim to have no more than 0.05° of mounting angle change throughout operation. (If the device is shock mounted then the mounting will change by more than 0.05°; this is acceptable, but the hysteresis of the mounting may not exceed 0.05°).

Operation

Front panel layout

Figure 5 shows the layout of the RT3000 T DO-160 v4 front panel. Table 9 lists the parts of the front panel labelled in Figure 5.

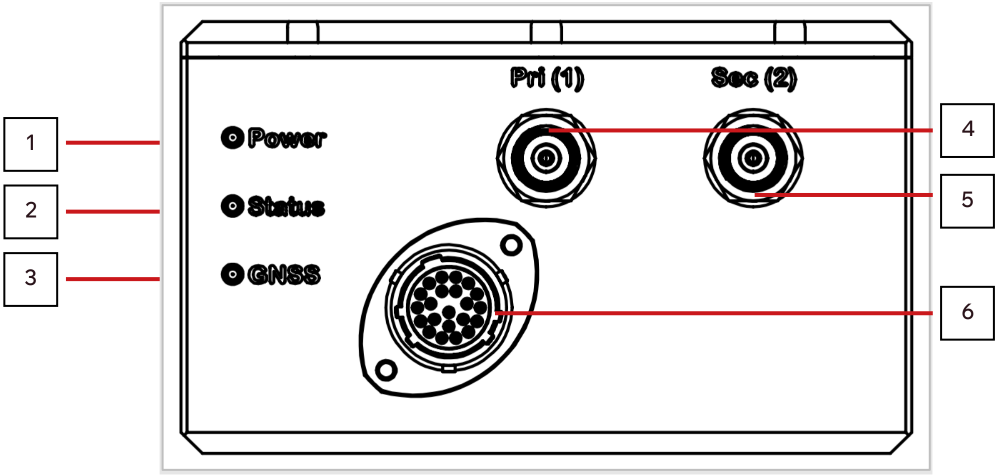


Figure 5:
RT3000 T DO-160 V4 front panel layout

Label Number	Description
1	Power LED
2	Status LED
3	GNSS LED
4	Primary GNSS antenna connector
5	Secondary GNSS antenna connector
6	Main I/O user cable connector

Table 9:
RT3000 T DO-160 V4 front panel descriptions

LED definitions

The LEDs on the connector panel provide information about the current system state, but it is not possible for the LEDs to communicate everything the product is capable of measuring. Instead, they provide a snapshot of the current status and are useful for at-a-glance checks without the need for a portable PC. The tables below describe the behaviour of each LED.

Colour	Description
Off	There is no power to the system or the system power supply has failed.
Green	Power is applied to the system.
Orange (Flashing)	The system is powered and Ethernet traffic is present.

Table 10:
Power LED states

Colour	Description
Off	The operating system has not yet booted. This occurs at start-up.
Red-green flash	The system is asleep. Contact OXTS support for further information.
Red flash	The operating system has booted but the GNSS receiver has not yet output a valid time, position, or velocity.
Red	The GNSS receiver has locked-on to satellites and has adjusted its clock to valid time (1PPS output now valid). The INS is ready to initialise.
Orange	The INS has initialised and data is being output, but the system is not yet real-time (the Kalman filter delay is a few seconds). It takes ~10 seconds for the system to become real-time.
Green	The INS is running and the system is real-time.

Table 11:
Status LED states
In the current versions of the software the strapdown navigator will not leave green and return to any other state. This may change in future releases.

Colour	Description
Off	GNSS receiver fault (valid only after start-up).
Red flash	The GNSS receiver is active but has not yet determined heading.
Red	The GNSS receiver has a differential heading lock.
Orange	The GNSS receiver has a floating (poor) calibrated heading lock.
Green	The GNSS receiver has an integer (good) calibrated heading lock.

Table 12:
GNSS LED states

I/O connectors

The main connector is a male 22-pin Deutsch AS612-35PA connector, marked with a yellow ring. Figure 6 shows the pin layout.

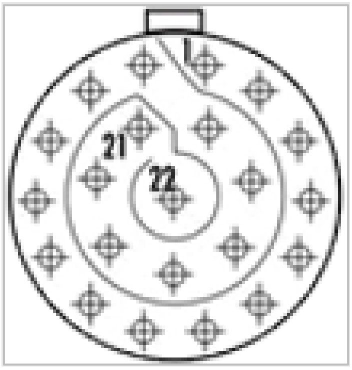


Figure 6:
RT3000 T DO-160 v4 I/O connector pin layout

Table 13 shows the pin descriptions.

Pin #	Function	Description	Notes
1	Supply+	Power supply +	10-48 V DC 10 W
2	Supply-	Power supply -	
3	Not used		
4	Not used		
5	Not used		
6	Not used		
7	Not used		
8	Digital 2	Trigger 1 in/out	
9	CAN+ / RS232 Tx	CAN bus high / serial data transmit (software configurable)	Twisted pair with Pin 10
10	CAN- / RS232 Rx	CAN bus low / serial data receive (software configurable)	Twisted pair with Pin 9
11	Digital 1	PPS	
12	Digital ground	Signal ground	
13	ETX-	Ethernet transmit -	Twisted pair with Pin 20
14	ERX-	Ethernet receive -	Twisted pair with Pin 21
15	Not used		
16	Digital ground	Signal ground	
17	Digital ground	Signal ground	
18	Digital ground	Signal ground	
19	Not used		
20	ETX+	Ethernet transmit +	Twisted pair with Pin 13
21	ERX+	Ethernet receive +	Twisted pair with Pin 14
22	Not used	Not used	

Table 13:
Main connector pin description

User cable

The RT3000 T DO-160 v4 standard kit is supplied with an evaluation cable for indoor laboratory testing and validation purposes only. Figure 7 shows the cable diagram and Table 14 shows the pin descriptions for the interface connectors.

The user cable 14C0038 is not compliant to DO-160G and should not be used in final installations.

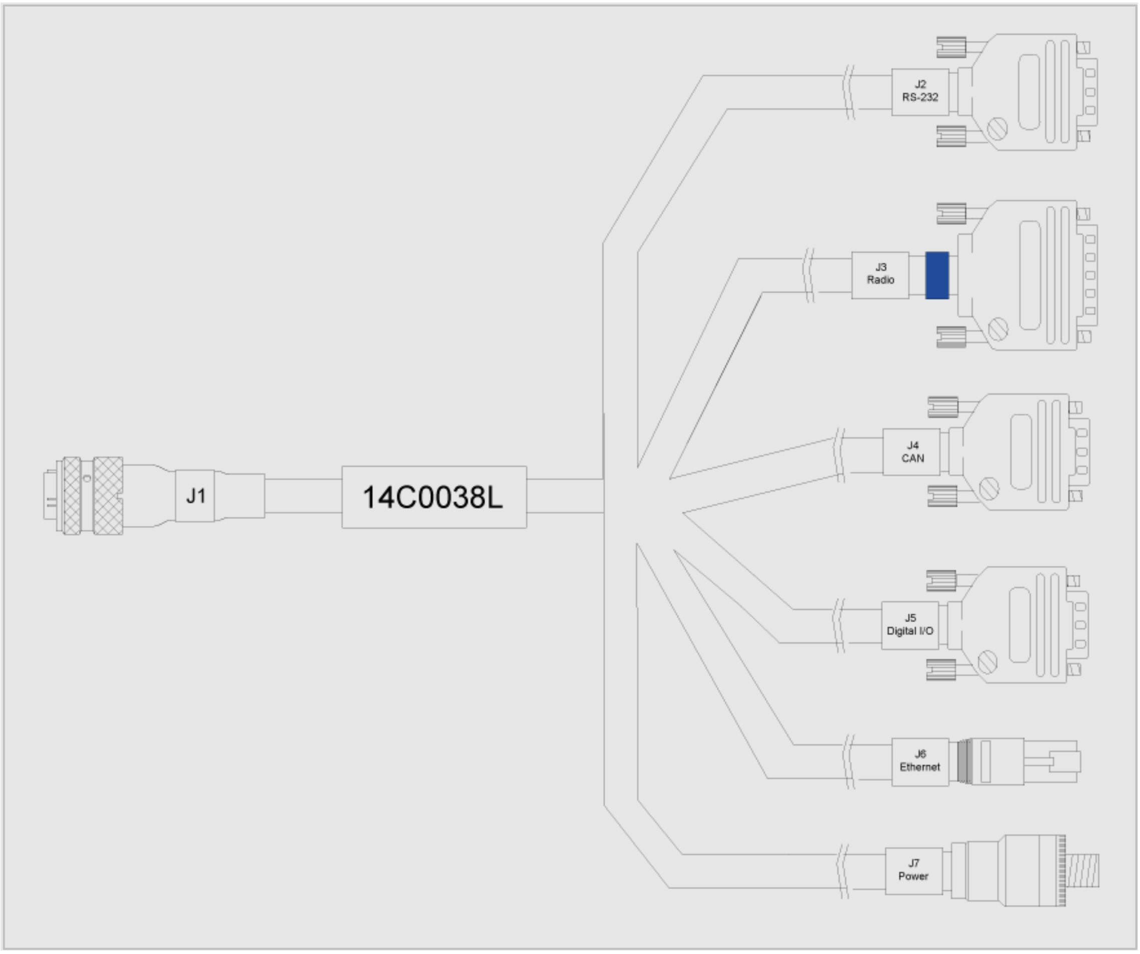


Figure 7:
RT3000 v4 main user cable

Connector	Interface	Connector details	Pin	Function	Terminate to
J2	RS232	9-way male D-type	2	Nav data RS232 Rx	Not used
			3	Nav data RS232 Tx	Not used
			5	RS232 common	Not used
J3	Radio	15-way male D-type	1/14/15	Supply+	Not used
			9	Radio data Rx	Not used
			11	Radio data Tx	Not used
			7	RS232 common	Not used
			8	Supply-	Not used
J4	CAN	9-way male D-type	2	CAN- / RS232 Rx	J1-10
			3	Digital ground	J1-17
			6	Digital ground	J4-3
			7	CAN+ / RS232 Tx	J1-9
J5	Digital I/O	9-way female D-type	1	Digital 1 - PPS	J1-11
			2	Digital 2 – Trigger 1	J1-8
			3	Not used	Not used
			4	Not used	Not used
			5	Not used	Not used
			6	Digital ground	J1-18
			7	Digital ground	J1-18
			8	Digital ground	J1-18
			9	Digital ground	J1-18
J6	Ethernet	RJ45	1	Ethernet transmit +	J1-20
			2	Ethernet transmit -	J1-13
			3	Ethernet receive +	J1-21
			6	Ethernet receive -	J1-14
J7	Power	4-way M12 male plug	1	Supply+	J1-1
			2	Sleeved and made safe	
			3	Supply-	J1-2
			4	Sleeved and made safe	

Table 14:
RT3000 v4 main user cable pin description
See Table **15** for Digital I/O signal details
NOTE: As this user cable intended for use on multiple OXTS products, J2 and J3 will not work with the RT3000 T DO-160 v4. Please be aware that system supply voltage will be output directly on pins 1, 14, and 15 on J3.

Power lines should be correctly terminated and insulated and wired up with a fuse somewhere between the unit and power source before being connected to a power source.

The CAN interface does not include a termination resistor. Appropriate termination must be used, e.g. if used in a single device connection, a 120 Ω terminating resistor must be added between the CAN+ and CAN- pins.

The J1 connector of the 14C0038 user cable connects to the main I/O connector and connectors J4-J7 provide connections for the inputs and outputs. The J1 connector is keyed so the user cable must be correctly aligned for it to connect.

The J4 connector is wired as a CAN interface. If serial output is required and configured in the software, a CAN to serial convertor cable must be used on the J4 connector. Figure 8 shows the 14C0263 CAN to serial convertor cable supplied with the standard kit.

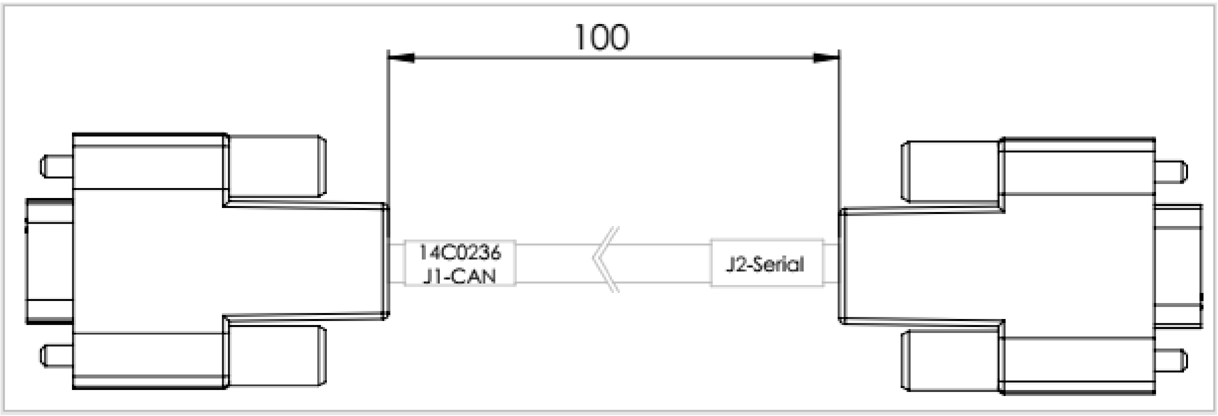


Figure 8:
AN to serial convertor cable

It is up to the installer to construct the cable 99C0044 found in Appendix C – Drawing list for instalment of the RT3000 T DO-160 v4. Please read and understand all notes on the drawing before constructing the cable. It is important to ensure that the enclosure and the braided shield in the cable have a good connection with the J1 connector. When the cable is constructed, please record the colours used in each pin so that wiring the other end of the cable is done more efficiently. Once J1 has been constructed as in the 99C0044 drawing and cable colours have been noted it is now ready to be integrated with your system.

The opposite end of the cable is up to the integrator if they prefer to connect using the appropriate connectors or straight to their interface. It is strongly advised that the integrator has the expertise of stripping, crimping and assembly of the connection. When making any connection directly to any system please ensure that the system has no power and it is safe to connect to the system.

It is the integrator's responsibility to ensure that the cable that is constructed can withstand the environmental conditions that the RT3000 T DO-160 v4 will be subjected to.

Digital inputs and outputs

Table 15 describes each of the signals on the Digital I/O pins. A more detailed explanation of each signal can be found below.

Pin#	Function	Signal	Description
11	Digital 1	1 PPS output	Pulsed output from primary GNSS receiver, synchronised with the transition of GPS seconds
8	Digital 2	Trigger 1	User-selectable I/O (input/distance output/IMU sync output)

Table 15:
Digital I/O signals

1PPS output

The 1PPS output is a pulse generated by the GNSS receiver. The output is active even when the GNSS receiver has no valid position measurement. The falling edge of the pulse is the exact transition from one second to the next in GPS time. The pulse is low for 1 ms, then high for 999 ms and repeats every second. The output is a low-voltage CMOS output, with 0.8 V or less representing a low and 2.4 V or more representing a high. No more than 10 mA should be drawn from this output.

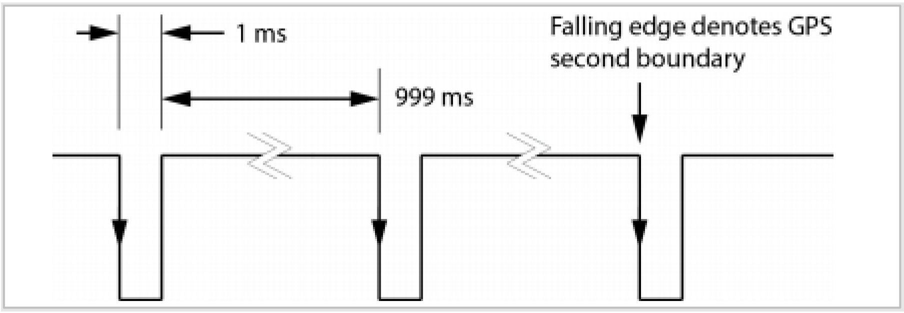


Figure 9:
1PPS waveform

Trigger 1

Trigger 1 can be used to generate events within the device for purposes of identifying external events, or to output a time/distance-based signal for the purpose of driving external events. The trigger is configurable in the Options page of NAVconfig.

In input mode, the trigger waits for a signal from an external device such as a camera or switch. When a signal is detected, a time-stamped measurement is generated by the INS in addition to the normal measurements being generated. The trigger inputs have a pull-up resistor so they can be used with a switch or as a CMOS input.

Input signal characteristics:

+ 0 V and 5 V input
+ low < 0.6 V
+ high > 2.6 V

In output mode, the trigger generates pulses based on distance or in synchronisation with the IMU clock rate. The pulse width of the distance-based signal is 1 ms, whereas the IMU sync signal has a duty cycle of approximately 50%.

Output signal characteristics:

- 0 V and 5 V output
- low <= 0.8 V
- high >= 2.4 V

Camera mode is a software condition that is automatically entered when the PPM distance output is configured as less than 1 PPM. It exists in order to generate time-stamped INS measurements synchronised with distance-based output triggers. The output is called camera mode as it's often used to trigger image recording equipment, which can then be matched to the position measurements at the precise moment of the trigger. Camera mode provides a method of achieving this.

To enter camera mode, configure a trigger as an output, and set the distance to less than one pulse per metre. A signal will be generated according to the specifications above at the distance interval defined by the PPM settings. At the same moment the trigger signal is output, a position measurement will be internally generated and logged alongside the regular measurement data. To generate a real-time message in relation to the camera trigger, it is necessary to select the 'Output on camera trigger option' on the Ethernet configuration window.

IMU sync output pulse

The synchronising edge of the IMU sync pulse is configurable in NAVconfig.

Co-ordinate frame conventions

Measurements made by the INS are available in a number of different reference frames for use in different applications.

IMU frame

The IMU reference frame used by the RT (shown in Figure 10), is popular with navigation systems – where the positive X-axis points forwards, the positive Y-axis points right and the positive Z-axis points down.

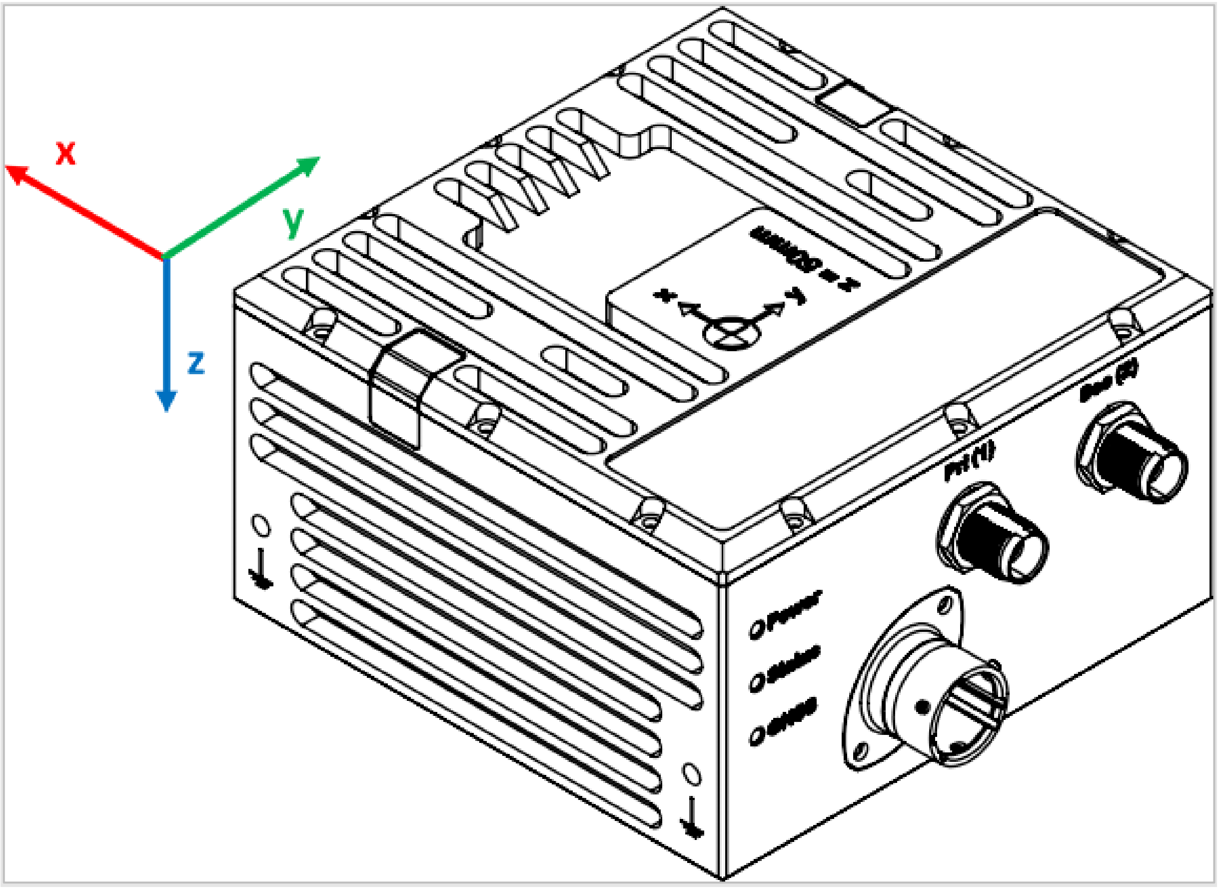


Figure 10:
RT3000 T DO-160 V4 IMU coordinate frame axes

The RT3000 T DO-160 V4 can be mounted in any orientation, it is not necessary for its axes to match those of the host vehicle. The configuration file will specify the transformation from the IMU frame to the vehicle frame.

When making measurements required in the configuration files, measurements should be made between the point of interest and the measurement origin shown in Figure 11.

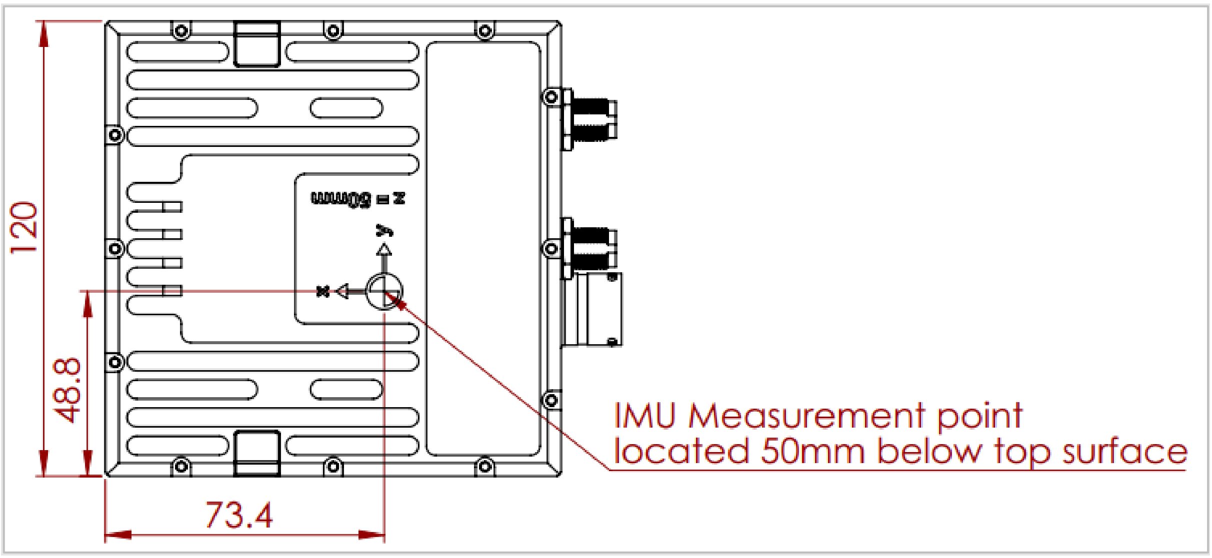


Figure 11:
IMU measurement origin

OXTS NED navigation frame

The OXTS navigation frame is attached to the vehicle but does not rotate with it. The down axis is always aligned to the gravity vector and north always points north.

Axis	Description
North	The north axis (N) is perpendicular to the gravity vector and in the direction of the North Pole along the earth's surface
East	The east axis (E) is perpendicular to gravity, perpendicular to the north axis and is in the east direction
Down	The down axis (D) is along the gravity vector

Table 16:
OXTS NED navigation frame definition

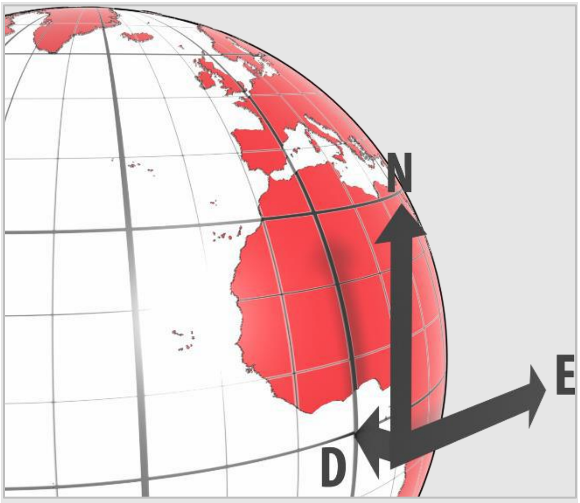


Figure 12:
OXTS NED navigation frame definition

ISO 8855 ENU earth-fixed system

The ISO earth-fixed system is attached to the vehicle but does not rotate with it. The north and east axes are perpendicular to the gravity vector and north always points north.

Axis	Description
East	The east axis (E) is perpendicular to gravity, perpendicular to the north axis and is in the east direction
North	The north axis (N) is perpendicular to the gravity vector and in the direction of the North Pole along the earth's surface
Up	The up axis (U) is co-axial with the gravity vector, and positive in the up direction

Table 17:
ISO 8855 ENU earth-fixed system

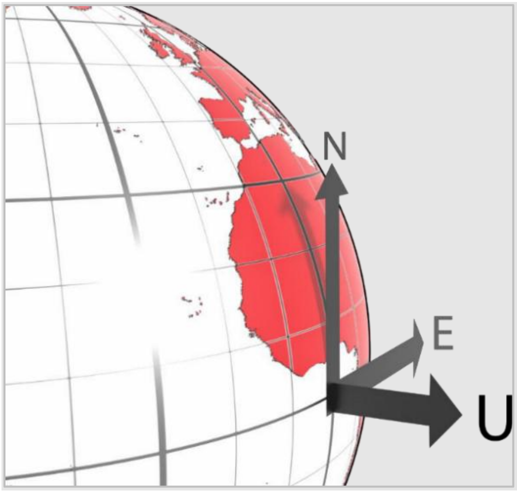


Figure 13:
ISO 8855 ENU earth-fixed system

OXTS horizontal frame

The OXTS horizontal frame (sometimes called the level frame) is attached to the vehicle but does not rotate with the roll and pitch of the vehicle. It rotates by the heading of the vehicle. The definition of the OXTS Horizontal frame is listed in Table 18 and shown in Figure 14.

Axis	Description
Forward	This is the longitudinal (forward) direction of the vehicle, projected in to the horizontal plane
Lateral	This is the lateral direction of the vehicle, pointing to the right, projected in to the horizontal plane
Down	This is the vertical (down) direction of the vehicle, along the gravity vector

Table 18:
OXTS Horizontal frame definition

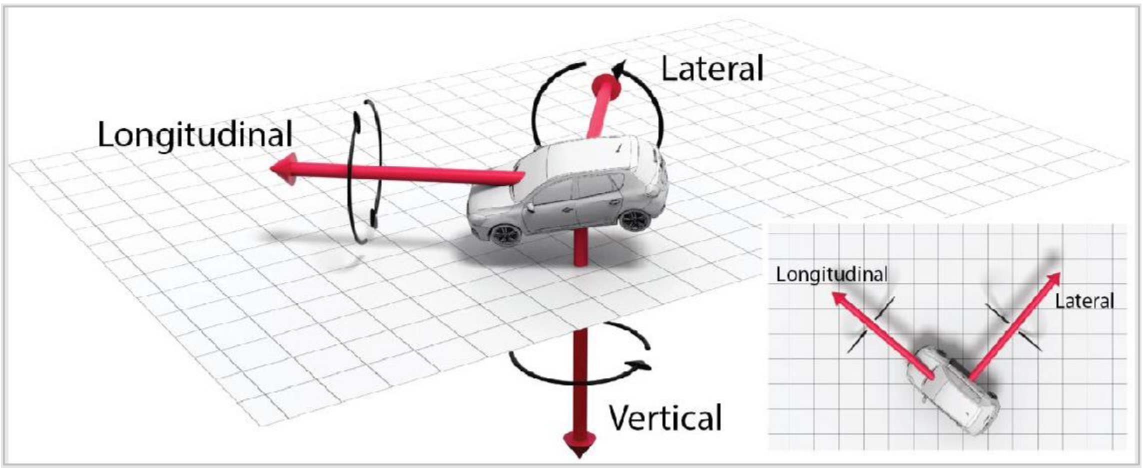


Figure 14:
OXTS horizontal frame definition

The OXTS horizontal frame is attached to the vehicle. The longitudinal and lateral axes remain parallel to a horizontal plane. The longitudinal axis is also parallel to the vehicle's heading when viewed from above.

ISO 8855 intermediate system

The ISO 8855 intermediate system is attached to the vehicle but the X- and Y-axis both remain parallel to the ground plane. The X-axis is also aligned with the vertical projection of the vehicle heading. The definition of the ISO 8855 intermediate system is listed in Table 19. ISO 8855 intermediate system and shown in Figure 15.

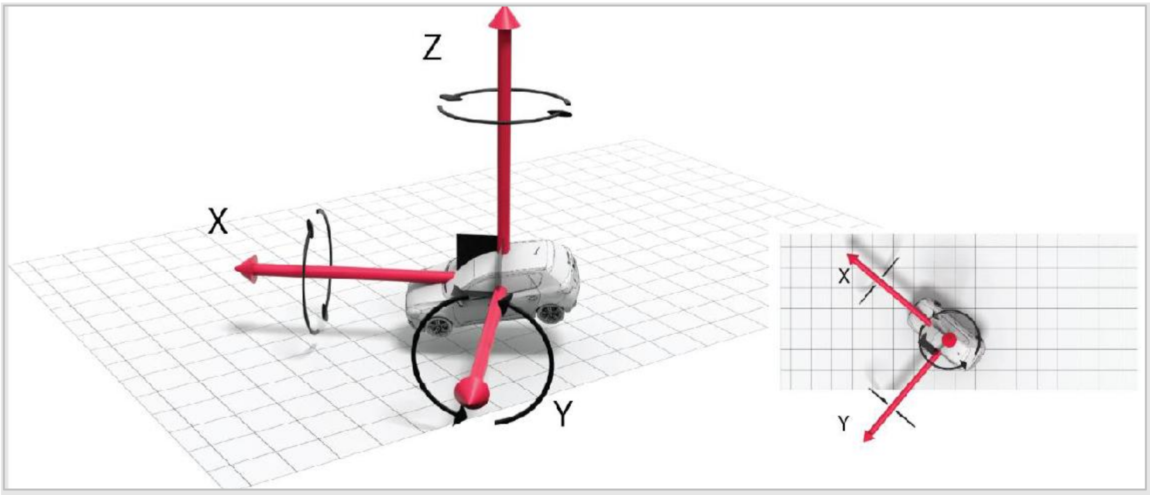


Figure 15:
ISO 8855 intermediate system

The ISO intermediate system is attached to the vehicle. The X- and Y-axes remain parallel to a horizontal plane. The X-axis is also parallel to the vehicle's heading when viewed from above.

Axis	Description
X	This is the forward direction of the vehicle, projected into the horizontal plane
Y	This is the lateral direction of the vehicle, pointing to the left, projected into the horizontal plane
Z	This is the vertical direction of the vehicle, pointing up

Table 19:
ISO 8855 intermediate system

OXTS vehicle frame

The OXTS vehicle frame is attached to the body of the vehicle. It is related to the INS through the rotations in the Orientation page of NAVconfig. It can be changed while the INS is running using the

Quick Config tool of NAVdisplay. The definitions of the vehicle frame are listed in Table 20 and shown in Figure 16.

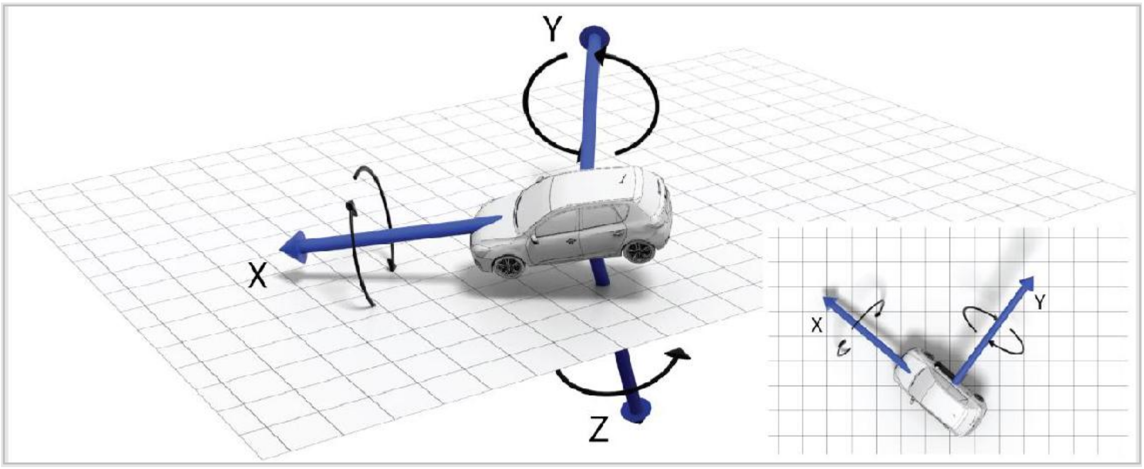


Figure 16:
Vehicle frame definition

Axis	Description
X	This is the forward direction of the vehicle
Y	This is the right direction of the vehicle
Z	This is the down direction of the vehicle

Table 20:
Vehicle frame definition

The OXTS vehicle frame is attached to the vehicle and rotates with it in all three axes. The X-axis remains parallel to the vehicle's heading, while the Y-axis points to the right and is perpendicular to the vehicle's vertical plane of symmetry.

ISO 8855 vehicle system

The ISO 8855 vehicle system is attached to the body of the vehicle. At rest, the X-axis points forwards horizontally and is parallel to the vehicle's longitudinal axis. The Y-axis is perpendicular to the longitudinal axis and points left. The Z-axis is orthogonal to the X- and Y-axes. Definitions are listed in Table 21 and shown in Figure 17.

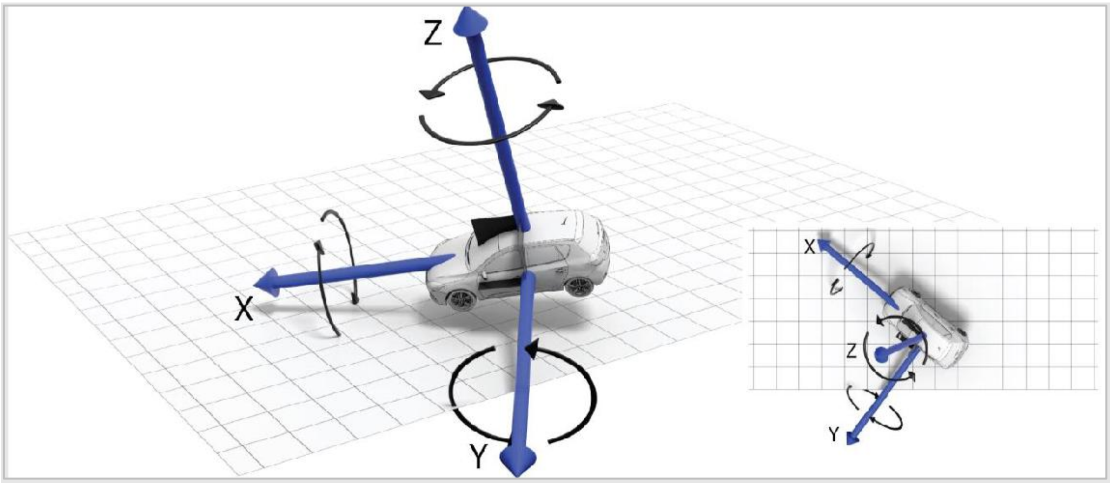


Figure 17:
ISO 8855 vehicle system

Axis	Description
X	This is the forward direction of the vehicle
Y	This is the left direction of the vehicle
Z	This is the up direction of the vehicle

Table 21:
ISO 8855 vehicle system

The ISO vehicle frame is attached to the vehicle and rotates with it in all three axes. The X-axis remains parallel to the vehicle's heading, while the Y-axis points to the left and is perpendicular to the vehicle's vertical plane of symmetry.

Ethernet configuration

To configure the RT for unrestricted data transmission it is necessary to use the Ethernet connection. The operating system at the heart of the RT products allows connection to the unit via FTP. The use of FTP allows the user to manage the data logged to the unit; files can be downloaded for reprocessing and deleted to make space for future files. Configuration files for alternative configurations require FTP to put the configuration files on to the RT. The default username and password are both "user".

The RT outputs its data over Ethernet using a UDP broadcast. The use of a UDP broadcast allows everyone on the network to receive the data sent by the RT. The data rate of the UDP broadcast is 100 Hz, 200 Hz or 250 Hz.

Each RT is configured with a static IP address, to enable communication by ethernet. You can find the unit's IP address by doing the following:

+ Connect your laptop to the unit via ethernet and open:
    - NAVconfig, where the unit should be available to configure
    - NAVdisplay, where you can select the unit to view real time data

The IP address of the computer being used to communicate with the RT may need to be changed so it matches the subnet. For example, 195.0.0.200 should be available since this IP address is never used by the RT by default.

To change the IP address of the computer, follow these steps (applies to Windows Vista/7/8/10/11):

1. Open the ‘Control Panel’ from the Start menu.
2. In category view, select ‘Network and Internet’ and then ‘Network and Sharing Centre’.
3. Select ‘Change adapter settings’ in the side panel.
4. Right-click the Ethernet option and select ‘Properties’.
5. In the window that opens, navigate the list to find Internet Protocol Version 4 (TCP/IPv4). Select it and click ‘Properties’.
6. In the TCP/IPv4 Properties window (Figure 18), select ‘Use the following IP address’ and enter the IP address and subnet mask to use.
7. Click ‘OK’ when finished.

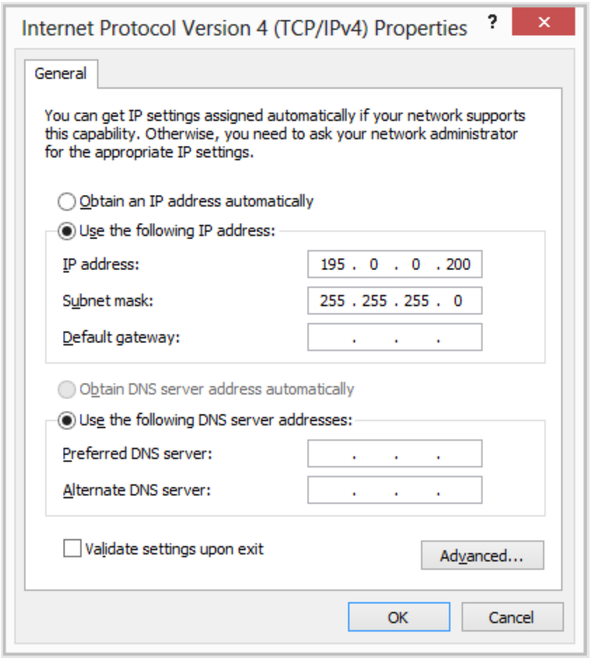


Figure 18:
Configuring the computer’s IP address for Ethernet data transmission

Once the computer is configured the IP address of an RT can be found by running NAVdisplay software; this will display the IP address of any RT connected.

Note that it is possible to change the IP address of RT systems. If the IP address has been changed then NAVdisplay should still be able to identify the address that the RT is using, as long as the PC has a valid IP address and this is not the same as the RT’s.

Connection details for Ethernet configuration

The RJ-45 connector on the 14C0038x user cable is designed to be connected directly to a network hub. To extend the cable it is necessary to use an in-line coupler. This is two RJ-45 sockets wired together in a straight-through configuration. Following the in-line coupler, a normal, straight UDP Cat 5e cable can be used to connect the coupler to the hub.

The RT can be connected directly to an Ethernet card in a computer. To do this a crossed in-line coupler must be used. The connections in the crossed coupler are given in Table 22. Note that this is not the normal configuration sold and it may be necessary to modify an existing coupler to suit.

Socket 1	Straight socket 2	Crossed socket 2
Pin 1	Pin 1	Pin 6
Pin 2	Pin 2	Pin 3
Pin 3	Pin 3	Pin 2
Pin 4	Pin 4	-
Pin 5	Pin 5	-
Pin 6	Pin 6	Pin 1
Pin 7	Pin 7	-
Pin 8	Pin 8	-

Table 22:
In-line coupler connections

A typical in-line coupler is shown in Figure 19.

Figure 19:
In-line RJ-45 coupler

Dual antenna systems

It is often useful to have an understanding of how the RT uses the measurements from the dual antenna system. This can lead to improvements in the results obtained.

1. To use the measurements properly the RT needs to know the angle of the GNSS antennas compared to the angle of the RT. This is very difficult to measure accurately without specialised equipment, therefore the RT needs to measure this itself as part of the warm-up process.
2. The RT will lock on to satellites, but it cannot estimate heading so it cannot start. Either motion or static initialisation can be used to initialise the RT.
3. When the vehicle drives forward and reaches the initialisation speed, the RT assumes that the heading and track are similar and initialises heading to track angle.
4. If the RT is mounted in the vehicle with a large heading offset then the initial value of heading will be incorrect. This can also happen if the RT is initialised in a turn. This can lead to problems later.
5. When the combined accuracy of heading plus the orientation accuracy figure for the secondary antenna is sufficiently accurate then the RT will solve the RTK Integer problem using the inertial heading. There is no need for the RT to solve the RTK Integer problem by searching.

6. If the antenna angle is offset from the RT by a lot then the RTK Integer solution that is solved will be incorrect. For a 2 m antenna separation the RT orientation and the secondary antenna orientation should be known to within 5°. For wider separations the secondary antenna orientation angle needs to be more accurate.
7. Once the RTK Integer solution is available, the RT can start to use the dual antenna solution to improve heading. The level of correction that can be applied depends on how accurately the angle of the secondary antenna is known compared to the inertial sensors.
8. The Kalman filter tries to estimate the angle between the inertial sensors and the secondary antenna. The default value used in the configuration software (5°) is not accurate enough so that the RT can improve the heading using this value. If you want the vehicle heading to 0.1°, but the angle of the two GNSS antennas is only known to 5°, then the measurements from the antenna are not going to be able to improve the heading of the vehicle.
9. Driving a normal warm-up, with stops, starts and turns, helps the Kalman filter improve the accuracy of the secondary antenna angle. The accuracy of this angle is available in the verified in NAVdisplay.
10. In the unlikely event that the RTK Integer solution is incorrect at the start then the Kalman filter can update the secondary antenna orientation incorrectly. If this happens then things start to go wrong. The Kalman filter becomes more convinced that it is correct, so it resolves faster, but it always solves incorrectly. Solving incorrectly makes the situation worse.
11. To avoid the Kalman filter from getting things wrong it is possible to drive a calibration run, then use the Improve configuration wizard within NAVconfig. This tells the Kalman filter it has already estimated the angle of the secondary antenna in the past and it will be much less likely to get it wrong or change it. This step should only be done if the RT is permanently mounted in a vehicle and the antennas are bolted on. Any movement of either the RT or the antennas will upset the algorithms.

Multipath effects on dual antenna systems

Dual antenna systems are very susceptible to the errors caused by multipath. This can be from buildings, trees, roof-bars, etc. Multipath is where the signal from the satellite has a direct path and one or more reflected paths. Because the reflected paths are not the same length as the direct path, the GNSS receiver cannot track the satellite signal as accurately.

The dual antenna system in the RT works by comparing the carrier-phase measurements at the two antennas. This tells the system the relative distance between the two antennas and which way they are pointing (the heading). For the heading to be accurate the GNSS receivers must measure the relative position to about 3 mm. The level of accuracy can only be achieved if there is little or no multipath.

Configuring the RT

To obtain the best results from your RT it will be necessary to configure the RT to suit the installation and application before using it. The program NAVconfig can be used to do this. This section describes how to use NAVconfig and gives additional explanations on the meanings of some of the terms used.

It is only possible to change the RT configuration using Ethernet. It is necessary to have the Ethernet settings on your computer configured correctly in order to communicate with the RT and change the settings. See the sections “Ethernet configuration” on page 40 for more information.

Overview

In order to give the best possible performance, the RT needs to know the following things:

+ The orientation of the RT as it is mounted in the vehicle.
+ The position of the primary GNSS antenna compared to the RT.
+ The orientation of dual antennas (if applicable) compared to the RT.
+ The position of the rear wheels (or non-steering wheels) compared to the RT.
+ Some environment parameters.

The RT can work out many of these parameters by itself, but this takes time. Measuring the parameters yourself and configuring the RT reduces the time taken to achieve full specification.

RT products can calculate the position of the GNSS antenna. This works well when using a base station to achieve 1 cm accuracy, but can take hours with less accurate positioning modes. It is best to measure the position of the GNSS antenna to an accuracy of 10 cm or better.

If the RT has been running for some time, it will have improved the measurements. It is possible to read these improved measurements into NAVconfig, commit them to the RT, then use them next time you start the system. If you move the RT from one vehicle to another it is essential you create a new configuration rather than using parameters that have been tuned for a different vehicle.

Working through NAVconfig

NAVconfig is split into seven sections. Each section contains several tabs with settings that can be applied to the device. The sections are: Home, Ready Configuration, Hardware Setup, Interfaces, Environment, Advanced Tools and Write Configuration.

When a device is connected via Wi-Fi or Ethernet, the product name (including serial number) will be displayed at the top of the application. By clicking on the ‘Save’ icon at the top right of the application you can save your configuration process to a destination on your computer. This can be done at any stage.

NAVconfig supports English and Chinese (simplified) languages. You can switch language in NAVconfig by clicking on the ‘Settings’ button at the bottom left of the window and choosing your preferred language from the options.

If you are connected to a device or editing a configuration file from an RD file then it is possible to view information related to the device in NAVconfig. Click the ‘i’ icon in the bottom left of the window to see a list of features related to your device.

NAVconfig Home section in NAVconfig

NAVconfig is a universal tool that is used to configure many different devices. The first step is to choose whether you are starting a new configuration, modifying an existing configuration or improving a configuration after a device warm-up.

When you select ‘New configuration’ you must then go through each step of the configuration wizard in order before committing a new configuration to the device.

When you select ‘Modify configuration’ you can jump in and edit the configuration, navigating through all the options in any order before committing the changes.

Selecting “Improve configuration” sets up a different workflow within NAVconfig for users who have completed a device warm-up and want to apply improved settings to the device and recommit these settings.

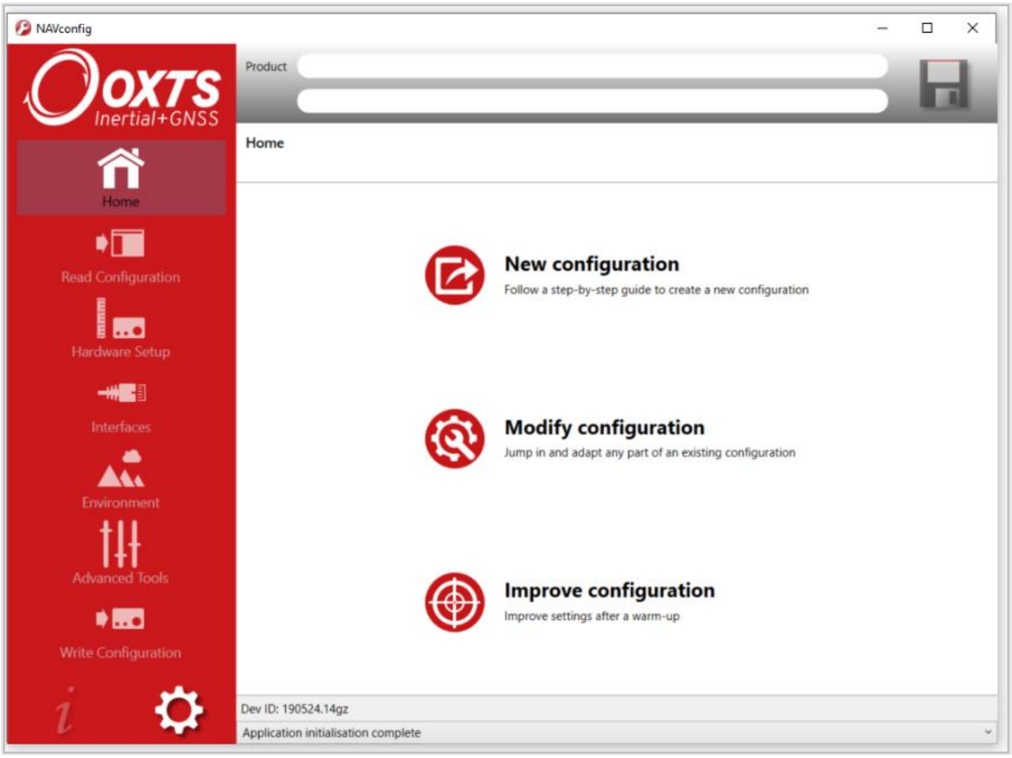


Figure 20:
NAVconfig Home section

Start/Read Configuration section in NAVconfig

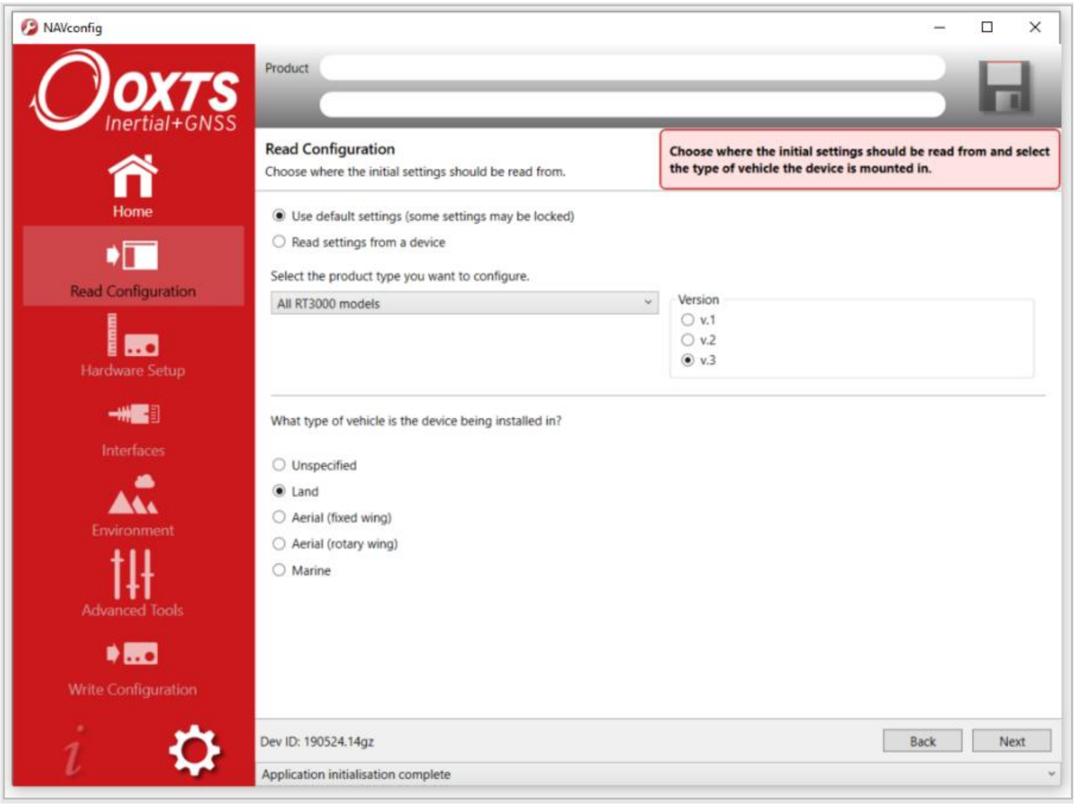


Figure 21:
NAVconfig Start/Read Configuration section

This section becomes available when you choose “New configuration” or “Modify configuration” from the Home section. It is important to ensure the correct Product type and version is selected. The settings available in NAVconfig vary depending on the product type and version chosen.

The product model and generation (version) can be found on the label on your product.

Read Configuration section

The Read Configuration choice tells NAVconfig where to read the initial configuration from (see Figure 22).

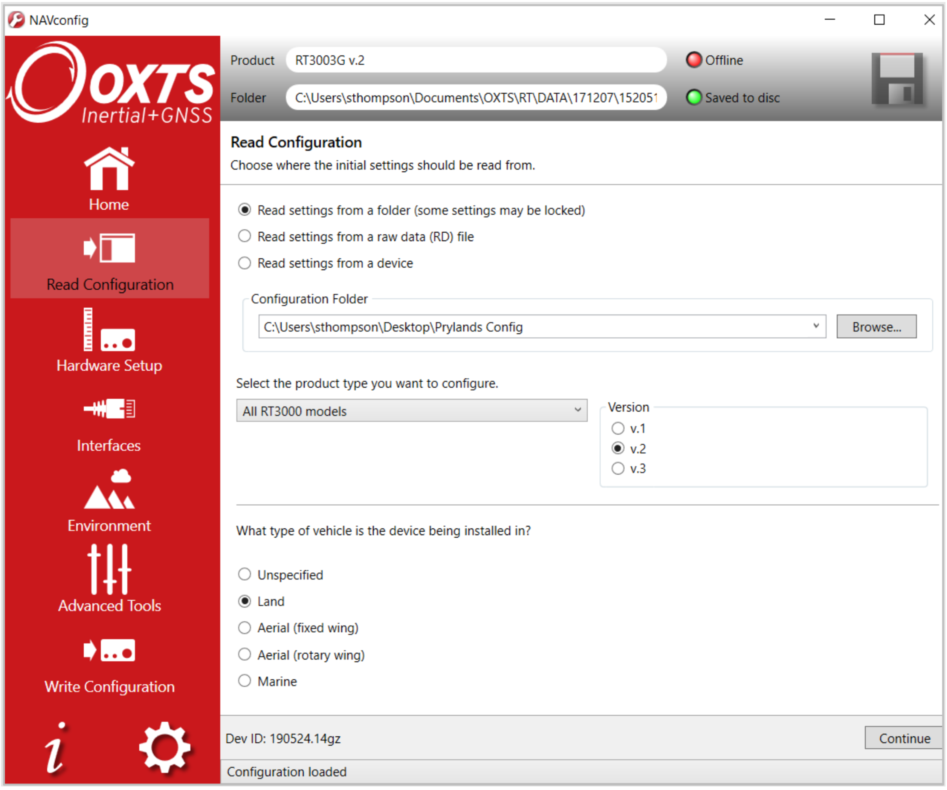


Figure 22::
NAVconfig Read Configuration section

Read settings from a folder: It is possible to store a configuration in a folder. The configuration comprises several files, so it is tidier to keep it in a folder by itself. To read the configuration from a folder, select this option and then specify a folder by clicking the 'Browse…' button.

'Read settings from a raw data (RD) file:' The RT writes the configuration it is using to the internally stored RD file. This option extracts the configuration used and loads it into the configuration wizard. Specify an RD file by clicking the 'Browse'… button.

Read initial settings from device: If the RT is connected to the computer via Ethernet or Wi-Fi it is possible to read the initial settings directly from the RT. The settings loaded are the settings that were last committed to the RT using NAVconfig or the factory default settings applied at manufacture stage. Select this option and enter the correct IP address of your RT or select it from the dropdown list.

You must also specify the type of vehicle that the device is being installed in. This will tailor the settings available to edit in NAVconfig.

Hardware Setup section in NAVconfig

This section contains settings related to the position and orientation of the RT in the vehicle and the GNSS antennas as well as the profile of the vehicle in which the RT is being installed (position of axles). It is broken up into tabs and it is recommended that you work through each tab in order.

IMU orientation tab

The IMU orientation tab is used to define the vehicle co-ordinate frame relative to the RT's co-ordinate frame. It is important to get the orientation correct as although settings entered on this page do not affect the accuracy of the RT, if the outputs are not properly rotated to the vehicle frame then the measurements will appear incorrect.

When using an RT-Strut, the orientation will need to be changed. Figure 23 shows an RT mounted on an RT-Strut in a vehicle. In this configuration, the y-axis points left and the z-axis points forwards. Other configurations are possible with the RT-Strut.

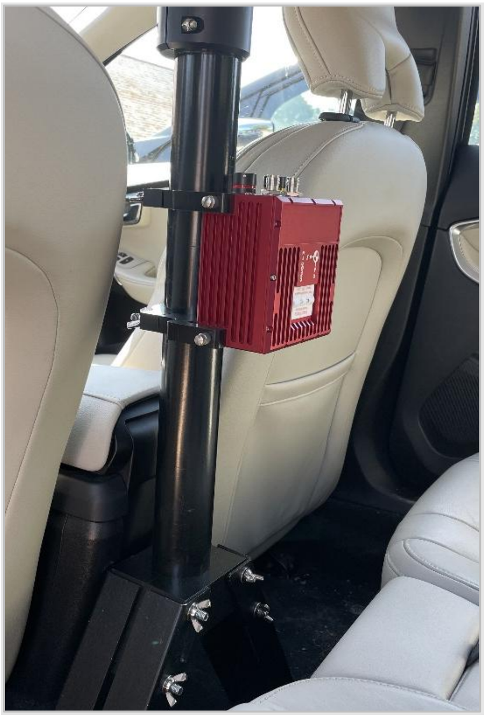


Figure 23:
An RT device mounted on our RT-Strut

Use the Y axis points and the Z axis points box to specify which way the RT's axes point in the vehicle. Figure 11 shows the RT axes' directions. The IMU orientation tab of the configuration wizard, also has illustrations to visualise the orientation of the RT in a vehicle based on the settings input. The advanced settings will change to show the three rotations associated with orientation input, even when unavailable.

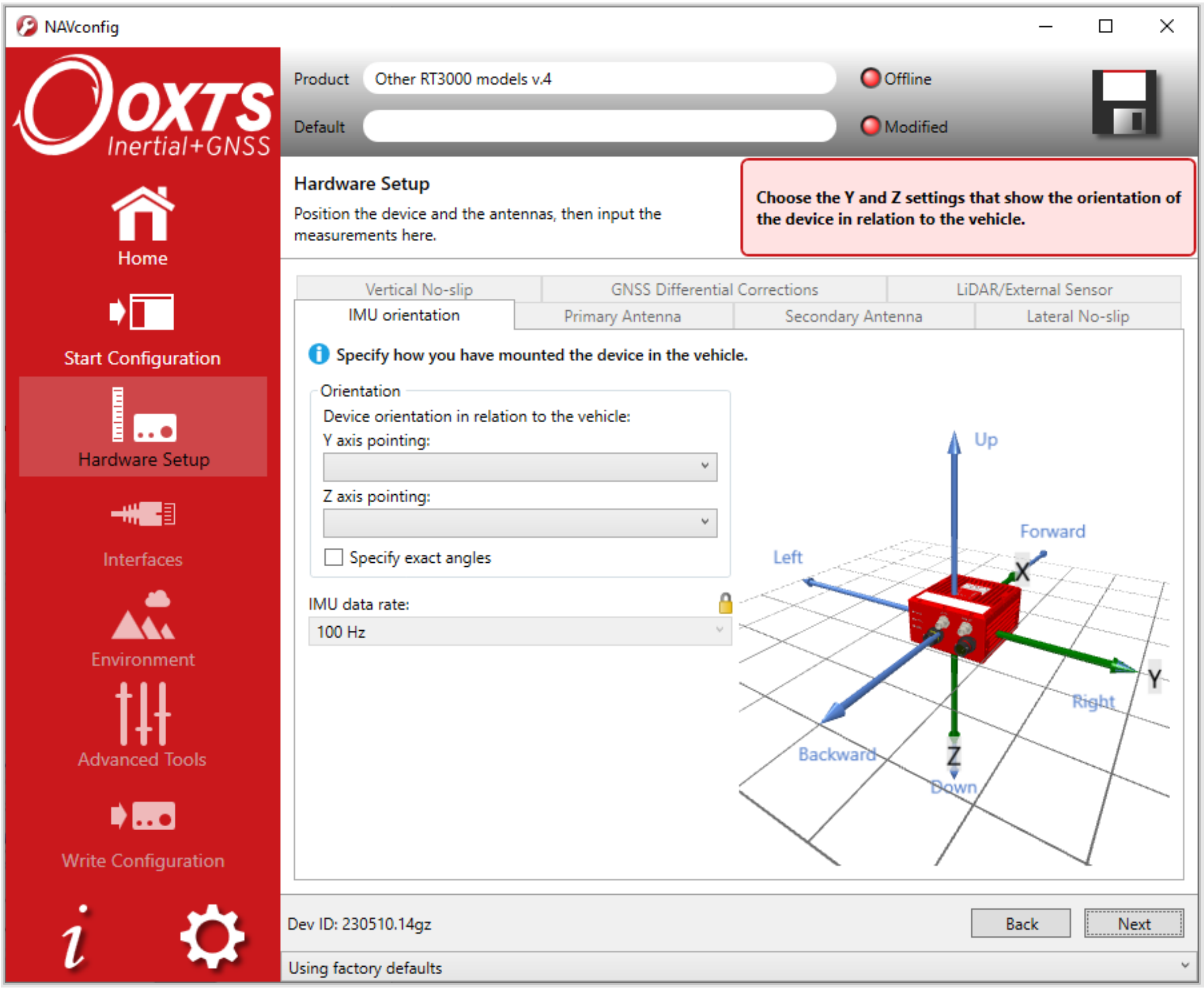


Figure 24:
NAVconfig IMU orientation tab in the Hardware Setup section

For correct initialisation, it is necessary to get the heading orientation correct. The RT gets its initial heading by assuming the vehicle is travelling forwards in a straight line. If the definition of the vehicle's x-axis (forward direction) is incorrect in the RT then it will not initialise correctly when the vehicle drives forwards.

If the vehicle level option is used, then the pitch and roll orientations must also be correct.

To make small adjustments, select the 'Specify exact angles' checkbox to enable the rotations for editing. This allows any slip angle, pitch or roll offsets to be zeroed.

Primary antenna tab

The RT can calculate the position of the primary antenna itself. However, this takes time and better results can be achieved sooner if the user measures the distance accurately. Getting these measurements wrong is one of the main reasons for poor results from the RT, so it is important to be careful. It is recommended to measure the GNSS antenna position to an accuracy of 10 cm or better. Figure 25 shows the Primary Antenna page.

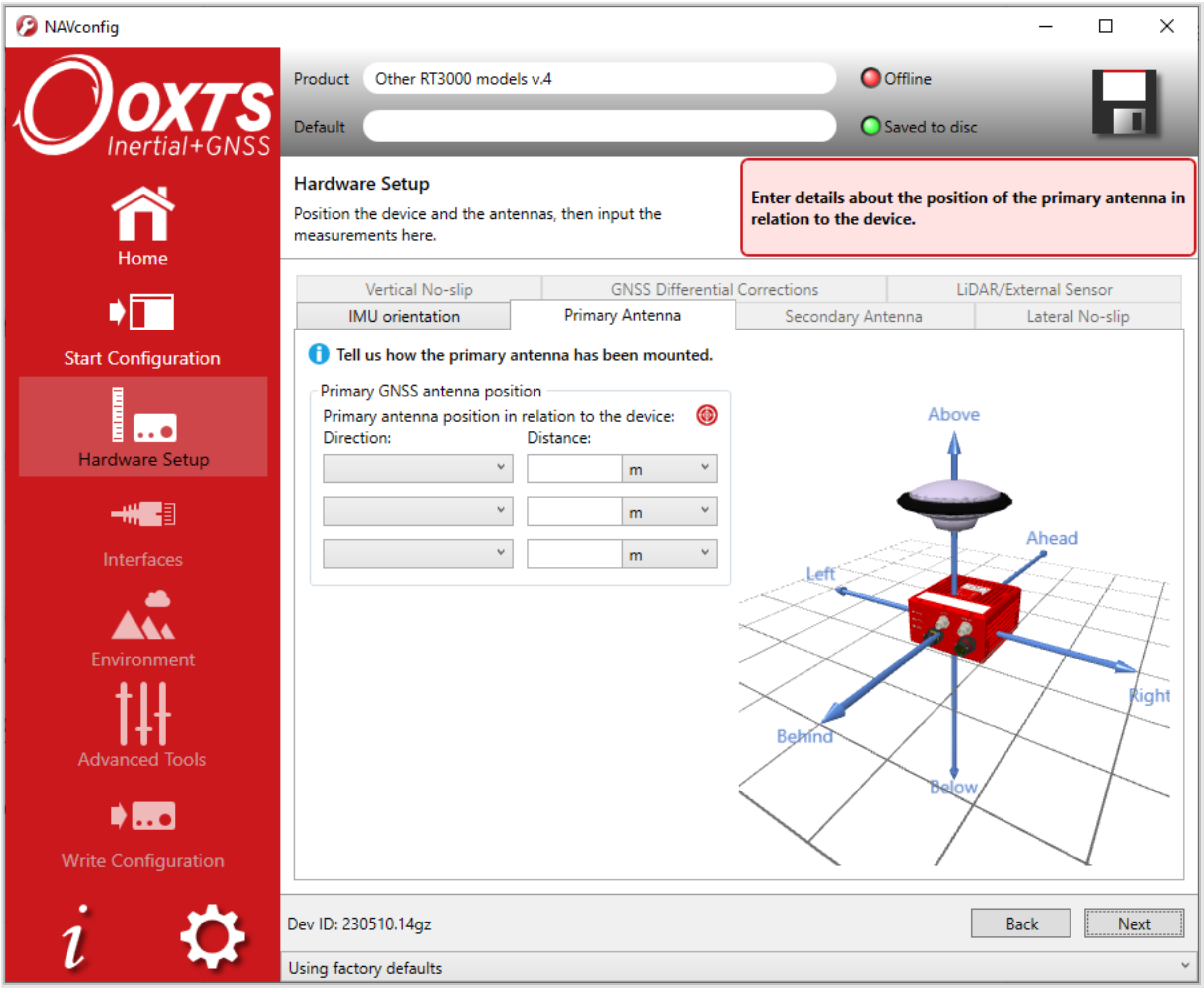


Figure 25:
NAVconfig Primary Antenna tab

It is necessary to tell the RT the distance between its measurement origin (shown in Figure 11) and the GNSS antenna's measurement point. This should be entered in the vehicle's co-ordinate frame.

The RT will try to improve the position of the primary GNSS antenna during use. To use the values the RT has estimated use the "Improve configuration" wizard after your warm-up on the Orientation utility page.

Secondary Antenna tab

If your system has two antennas, click the 'Secondary GNSS antenna' checkbox on the Secondary Antenna page (Figure 26) to allow the configuration to be entered. If it is not enabled, the RT will ignore the secondary antenna and will not use it to compute a heading solution.

Enter the antenna separation and select to position of the secondary antenna relative to the primary antenna from the dropdown list. The illustrations will change according to the settings you choose to help visualise the configuration of the antennas.

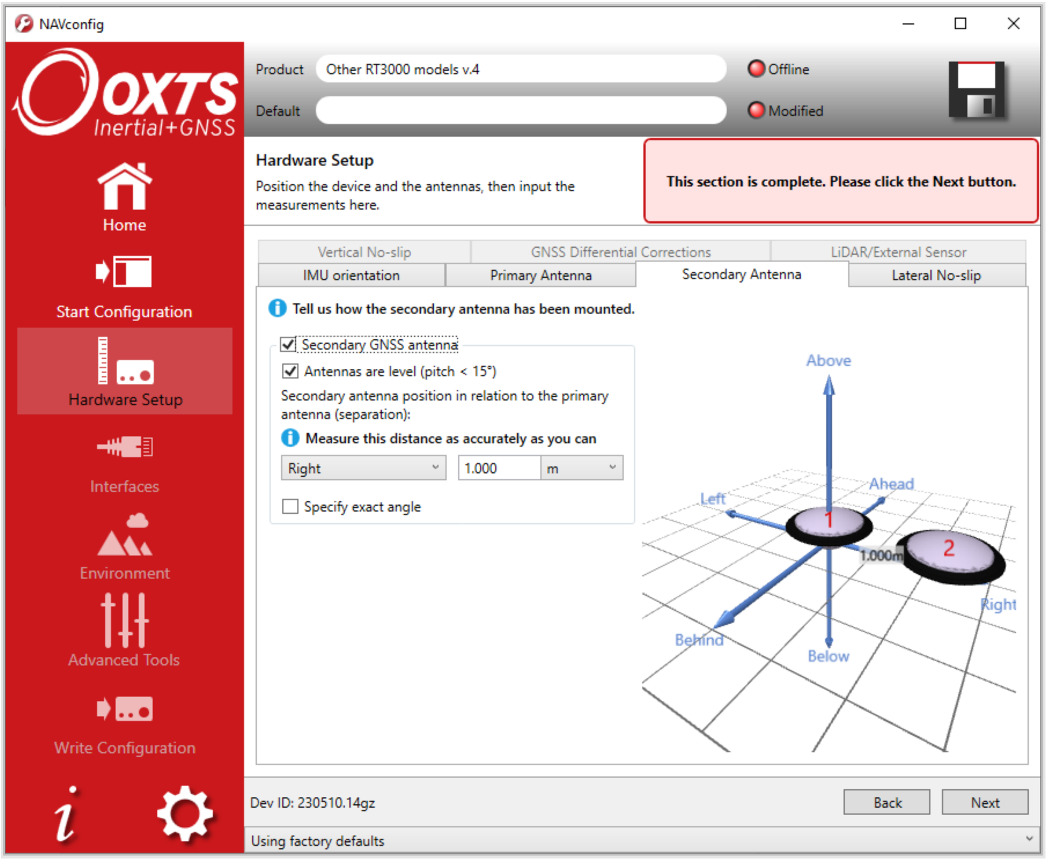


Figure 26:
NAVconfig Secondary Antenna tab in the Hardware Setup section

The RT does not estimate the distance between the two antennas. It is essential to get this right yourself, otherwise the system will not work correctly and the performance will be erratic. The measurement needs to be accurate to 5 mm, preferably better than 3 mm.

A wider separation will increase the dual antenna heading solution accuracy. The maximum recommended separation is 5 m.

If the antennas are mounted at significantly different heights, or if the mounting angle is not directly along a vehicle axis (forward or right), then click the 'Use advanced settings' checkbox to enable advanced settings and specify the orientation and height offset.

Getting the angle wrong by more than 3° can lead the RT to lock on to the wrong heading solution. The performance will degrade or be erratic if this happens. If the angle between the antennas cannot be estimated within a 3° tolerance then contact OXTS support for techniques for identifying the angle of the antennas.

The 'Enable static initialisation' option is useful for slow moving vehicles or where it is essential to start the RT running before moving (for example in autonomous vehicles). Static initialisation is 99% reliable in open sky, but the reliability decreases in environments with high multipath. Static initialisation is also faster when the antenna separation is smaller. This can be configured in the Environment section.

The RT will improve the estimate of the secondary antenna orientation settings. Use the "Improve configuration" option to use the improved values.

Lateral No-slip and Vertical No-slip tabs

This feature uses characteristics of land vehicle motion to improve heading and slip angle and to reduce drift. Specifying the position of the non-steered wheels makes a huge difference to the lateral drift performance of the RT when GNSS is not available.

This feature must be disabled for airborne and marine systems where the lateral velocity can be significant. This feature is also not suitable for land vehicles that use all wheels to steer, i.e. no fixed wheels. The vertical settings should not be used if the vehicle can perform wheelies.

The Lateral No-slip feature applies heading correction when the land vehicle is not slipping. When the vehicle is slipping the lateral acceleration is usually large enough that the normal heading corrections provide excellent results. When combined with a wheel speed input the drift of the RT when GNSS is not available is drastically reduced.

Figure 27 shows the Lateral No-Slip tab.

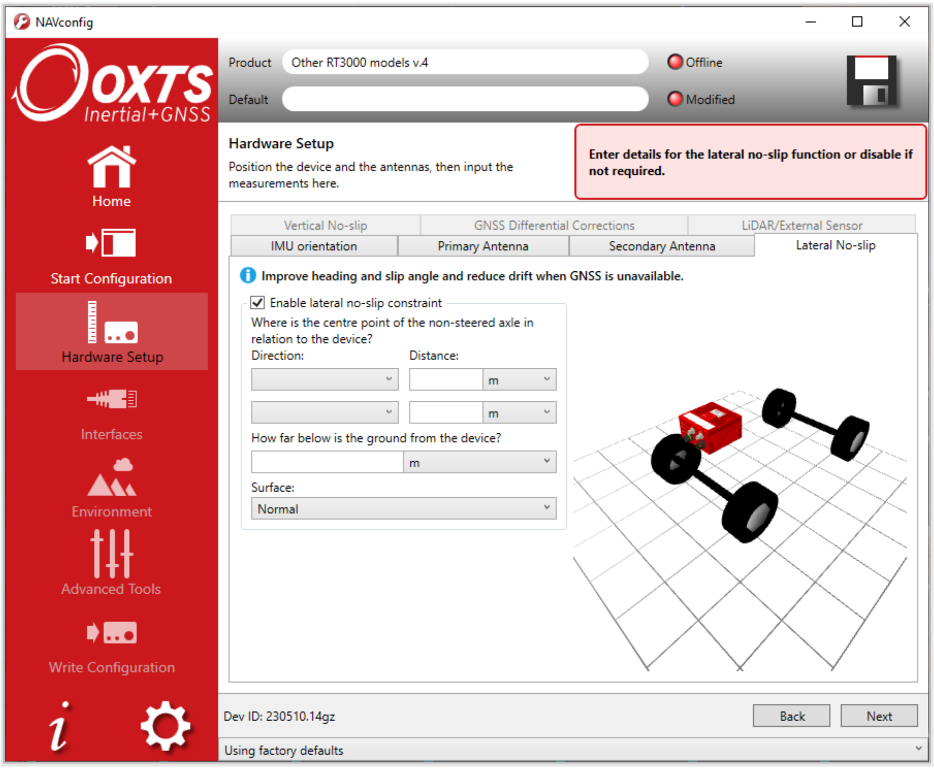


Figure 27:
NAVconfig Lateral No-slip tab in the Hardware setup section

For the Lateral settings, the system needs to know the position of the non-steered axle (rear wheels on a front-wheel steering vehicle and vice versa). A position at road height, mid-way between the rear wheels should be used as shown in Figure 28. Vehicles with all wheels steering cannot use this feature reliably, although minor steering of the rear wheels does not significantly affect the results.

Figure 28:
Measurement point for Lateral No-slip

Measuring from the RT, measure the distances to the non-steered axle position in each axis in the vehicle co-ordinate frame. Select the direction from the dropdown lists and enter the distances.

The measurements are made to an accuracy of 10 cm. Selecting an accuracy better than 10 cm does not improve results. Using an accuracy figure worse than 20 cm will increase the drift of the RT. Use the Accuracies tab in the Advanced Tools section to specify measurement accuracies individually.

The Lateral No-slip feature also requires some knowledge of the road surface. Select one of the predefined options from the dropdown list, Normal or Low friction (ice).

For the Vertical No-Slip, the system needs to know the position of the front axle. A position at road height, mid-way between the wheels should be used, like for the rear axle.

Measure the distances again from the RT and enter them into the cells, selecting the appropriate directions from the dropdown lists.

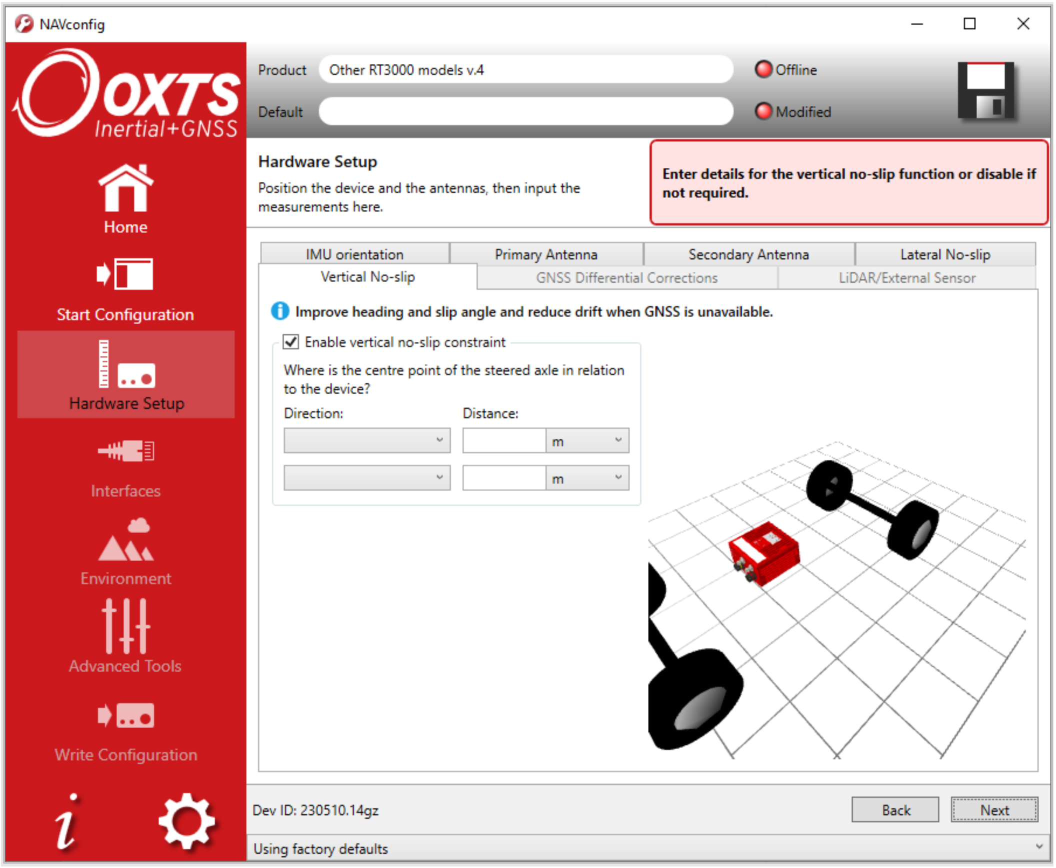


Figure 29:
NAVconfig Lateral No-slip tab in the hardware Setup section

When using No-Slip features, the RT can estimate the slip angle offset of the RT compared to the vehicle. After the RT is initialised and warmed-up, use the Improve configuration option from the NAVconfig Home section to automatically read the RT's slip angle offset estimate. This ensures a slip angle of zero is measured when driving straight on a level track.

GNSS Differential Corrections tab

An RT can be configured to use several different differential correction message types on connector J3. Figure 30 shows the Differential corrections properties window and Table 23 gives details on the correction types available.

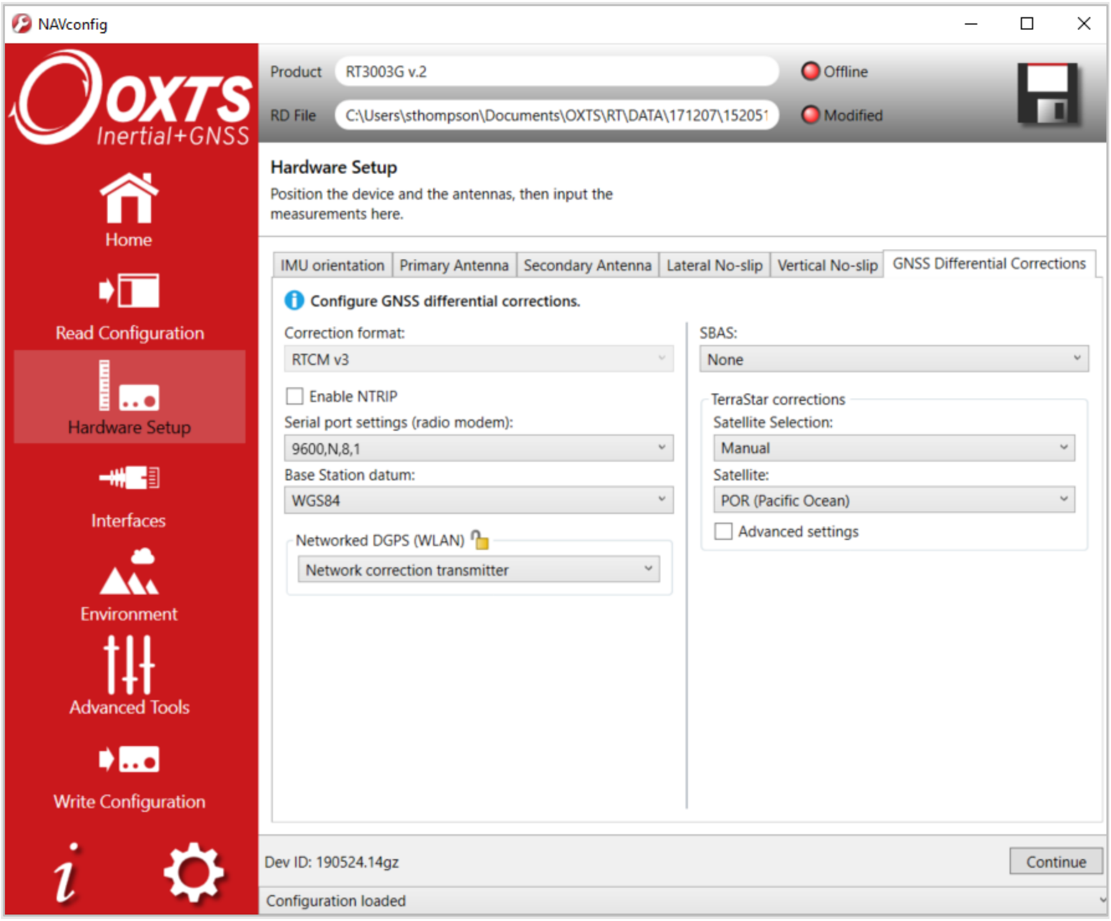


Figure 30:
NAVconfig Differential corrections tab in the Hardware Setup section
Note: SBAS and Terrastar configuration settings are only available on RT3000 T devices.

Correction type	Description
RTCA	RTCA is the standard adopted for aircraft. It was the first open standard to use 1 cm corrections.
RTCM	RTCM is the most common open standard used for differential corrections.
RTCMV3	RTCMV3 is the latest version of RTCM. This option gives the best accuracy and should be used if your differential corrections are in Version 3 format.
CMR	This is a standard adopted by Trimble. The RT products support both CMR and CMR+ formats.
Advanced	This option is reserved

Table 23:
NAVconfig Differential corrections formats

Select the Correction format you wish to use from the box and then select the baud rate from the Serial port settings (radio modem). The most common baud rates used for differential corrections are 4800 baud and 9600 baud. The RT-Base S and GPS-Base use 9600 baud. The values in the Data bits, Parity and Stop bit fields should be set to match the incoming signal.

NTRIP

When selected, the "Enable NTRIP corrections" checkbox box configures the RT for RTCMv3 corrections and sends an NMEA GGA message out from J3 back to the NTRIP server.

The RT3000 T DO-160 v4 includes an internal NTRIP client. Select 'Use Internal Client' to configure the settings of the NTRIP client inside the RT.

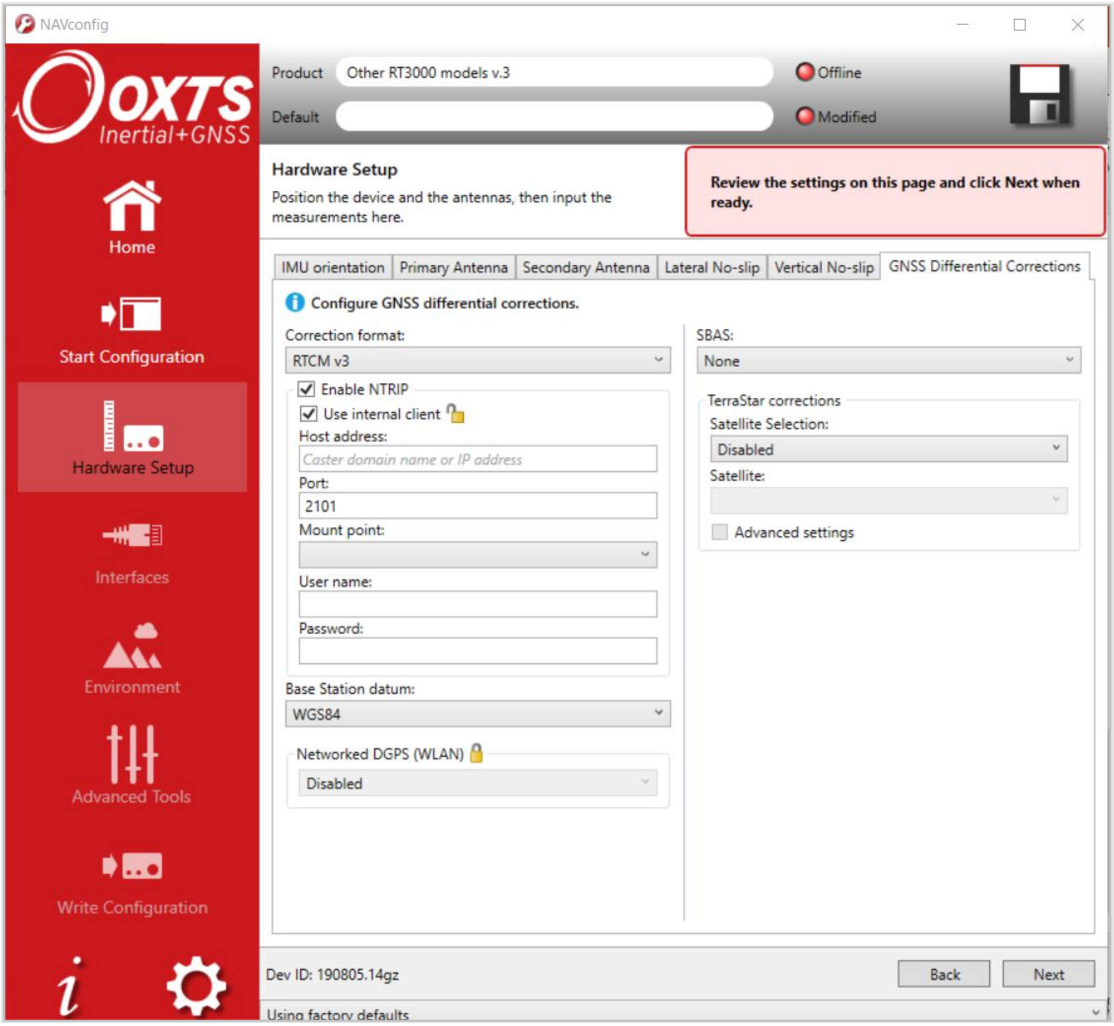


Figure 31:
NTRIP internal client

When the 'Use internal Client' option is selected, several additional settings are provided and need to be configured.

The Host address needs to be entered to receive corrections. This is the domain name or IP address of the caster or service that will be used. This should be provided by the service provider.

The Port is set to 2101 by default. The port should not be changed, or corrections will not be received by the unit.

The Mounting point can be selected from the list available. This list will automatically populate, unless the service provider requires authentication when collecting the information. If the NTRIP service is protected by a login, the list of mounting points will have to be accessed manually and the mounting point typed into the field.

The User name and password for the correction stream need to be inputted for the RT to be able to receive the data from the caster. Please note that this is not the same user name and password as the account held with the service provider.

Networked DGPS (WLAN)

The Networked DGPS (WLAN) controls allow an RT to be configured to broadcast or receive differential corrections over Wi-Fi when connected to an RT-XLAN. When Network correction transmitter is selected, an RT will broadcast differential corrections it is receiving via a radio modem from an OXTS base station, using its RT-XLAN. Other RT devices that are on the network as the broadcasting RT, will then be able to receive the DGPS messages and use them. To do this, the Network correction receiver option should be selected on those devices, and the IP address of the system carrying the radio modem should be selected from the box. Using this system reduces complexity in situations where multiple RTs need DGPS corrections as only one pair of radio modems needs to be used.

Networked DGPS (WLAN) can also use corrections received via NTRIP, rather than a local base station. As before, the RT that is connected to the NTRIP server should be configured with Network correction transmitter selected. Other RTs should be configured with Network correction receiver selected, and the IP address of the system that is configured as the transmitter should be selected in the box.

Regardless of whether DGPS corrections are received via NTRIP or a local base station, only RTCMv3 corrections are currently supported in networked DGPS mode.

SBAS

In Europe, North America, and Japan SBAS can be used for differential corrections. These services will improve the position accuracy of the RT. In North America the SBAS service is known as WAAS, in Europe it is known as EGNOS and in Japan it is known as MSAS. Select the option that is most suitable for the territory you are in.

TerraStar corrections

TerraStar corrections are configured on the GNSS Differential Corrections tab within the Hardware Setup section. You can choose between Manual or Automatic Satellite Selection and if you choose Manual you can select from a list of available options. Using the "Advanced Settings" checkbox you can also change the frequency and baud rate.

Interfaces section in NAVconfig

This section contains options for configuring the interfaces of the RT. Some of these settings are feature code controlled so may not be visible to all users on all devices.

Ethernet tab

The Ethernet settings include configuring the Ethernet data output rate, packet type and Triggers for the RT. You can also enable the Driving Robot interface and input the Driving robot IP if you are using a Driving robot with your RT.

The Ethernet output can either output NCOM or MCOM, or be disabled by using the Output packet dropdown list. When NCOM or MCOM is selected, the data rate can be selected by using the dropdown list.

If a trigger has been configured as an event input, click the 'Output' on falling edge of trigger or Output on rising edge of trigger checkboxes to choose when the extra data packet is generated. If a trigger has been configured as an output trigger, click the 'Output on camera trigger' to generate extra data packets based on the output trigger settings configured earlier. These packets are interpolated to the time when the event occurred and may be output up to 30 ms late and out of order compared to the normal messages.

It is essential to enable these options in order to see trigger information in NCOM, or if the events have a rate higher than 1 Hz otherwise the output cannot communicate all of the events and some will be lost.

For the Driving robot, the default address (195.0.0.100) is listed in the dropdown list but can be changed if required by typing the correct address. When the ABD Steering Robot is enabled, the output smoothing is automatically enabled too.

UCOM

UCOM is enabled in the UCOM tab by checking the "Enable UCOM checkbox". This enables the UCOM measurement stream. Included in this measurement stream will be any Measurement that is individually selected using the checkboxes in this tab. The filter box can be used to search for any specific measurement.

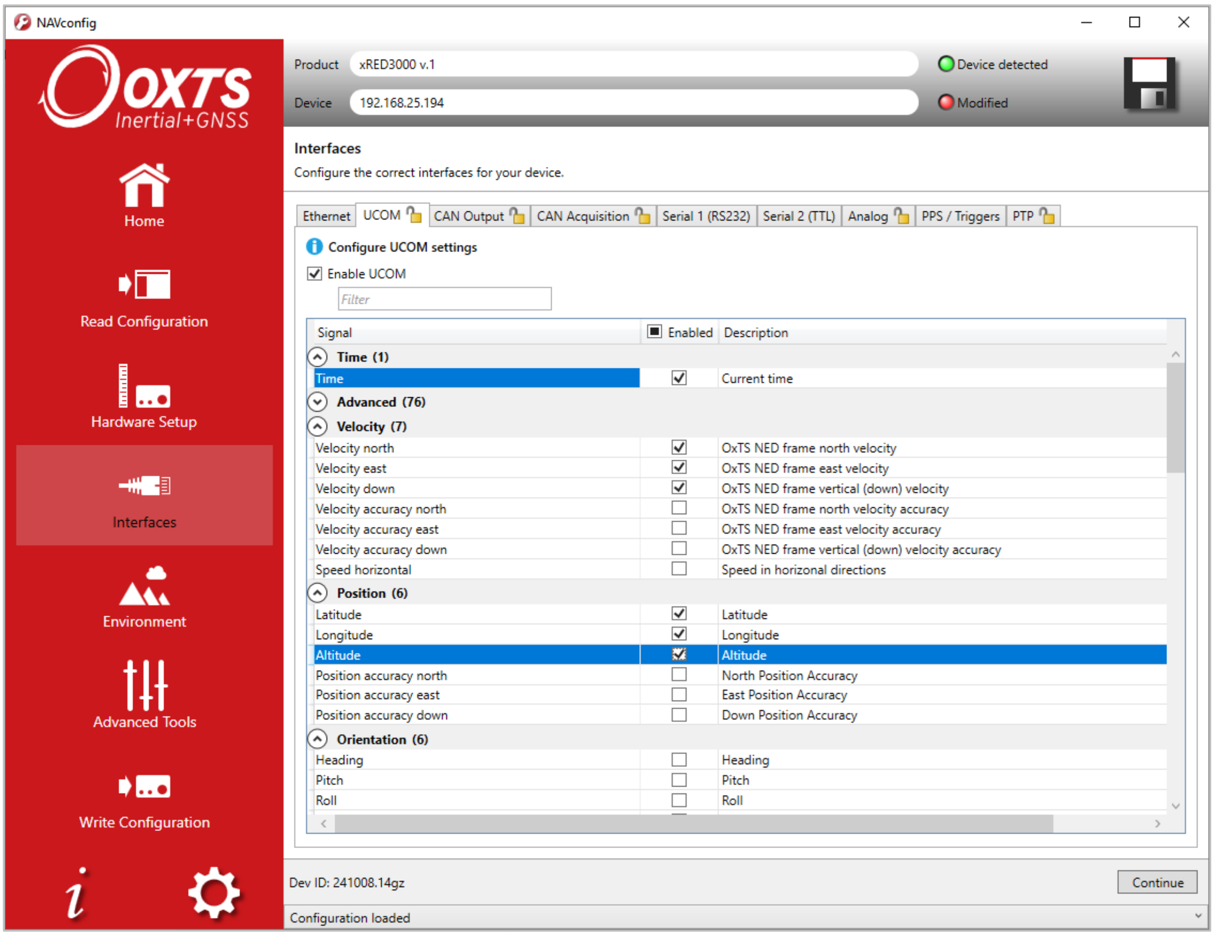


Figure 32:
UCOM configuration

CAN Output tab

RT systems can be configured to send and receive data via a CAN bus. This allows RT data to be sent to external logging devices, and signals from a test vehicle's CAN bus to be logged alongside navigation data inside an RT.

Note: A CAN isolator must be used when connecting the RT directly to a vehicle's CAN bus.

By default, CAN communication is disabled. It is enabled by selecting the Enable CAN interface checkbox (see Figure 33). The default version is CAN 2.0. CAN-FD is also available.

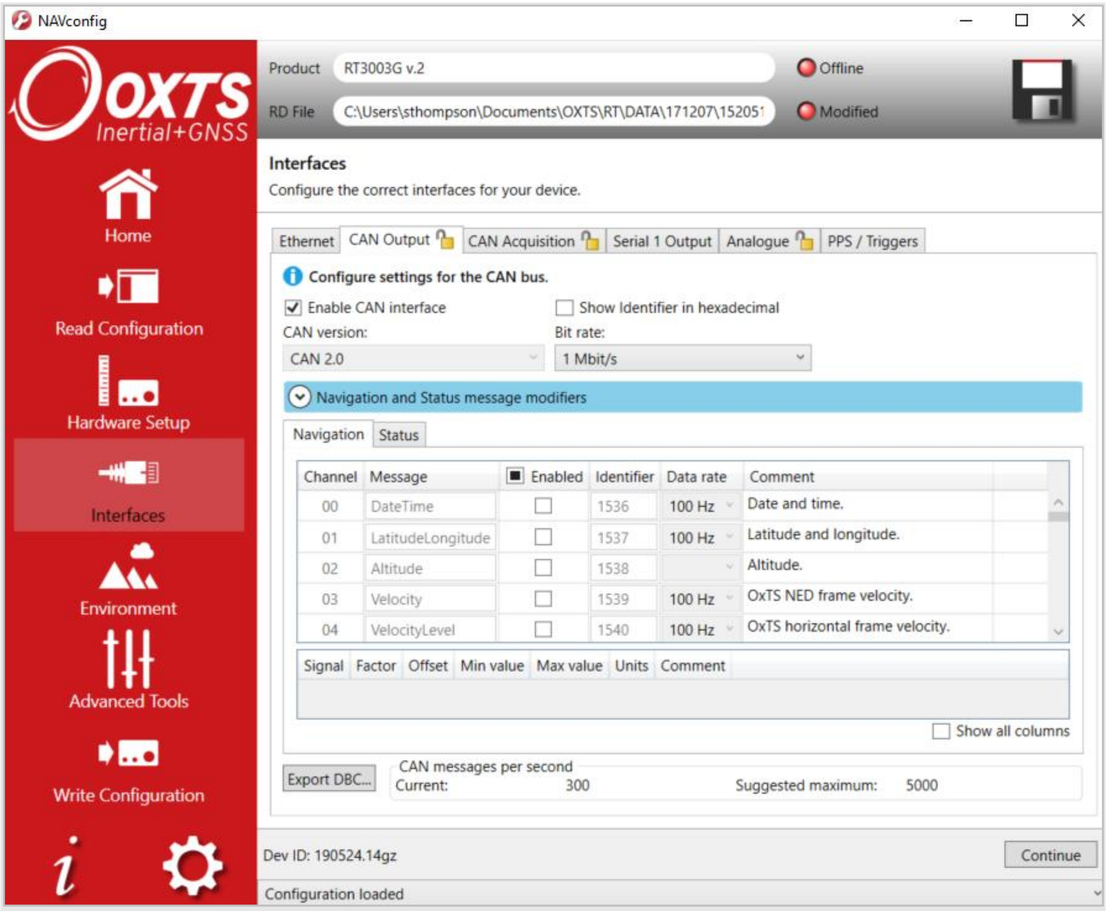


Figure 33:
NAVconfig CAN output configuration tab

You can select individual messages or enable all messages by choosing them from the table displayed.

Depending on the baud rate selected, the suggested maximum CAN messages per second will change. A warning message will appear if the combined rate of all current navigation and status messages will overload the CAN bus at the selected baud rate.

Disabling or reducing the frequency of navigation or status messages will remove the warning and ensure reliable operation of the CAN bus. Increasing the baud also works, but the baud rate must be common to all devices on the bus. When using an RT-ANA, the default baud rate is 1 MBaud.

The Export DBC file button generates a CAN DBC library listing all navigation and status messages that are enabled (not greyed-out). The DBC file does not include channels defined under the acquisition tab. The navigation status message binary format is described in the CAN Interface manual. The status message binary format is the same as the NCOM status message binary format as described in the NCOM Description manual. Those status messages that do not have signals listed against them are not described at the signal level in the DBC file. The binary format of these messages is quite complex and as such the DBC file it not sufficient to describe the decoding process.

The Navigation tab is where navigation-related CAN messages are configured for output. The table can be sorted in ascending or descending order by clicking any column header. This is particularly useful when checking for enabled/disabled messages.

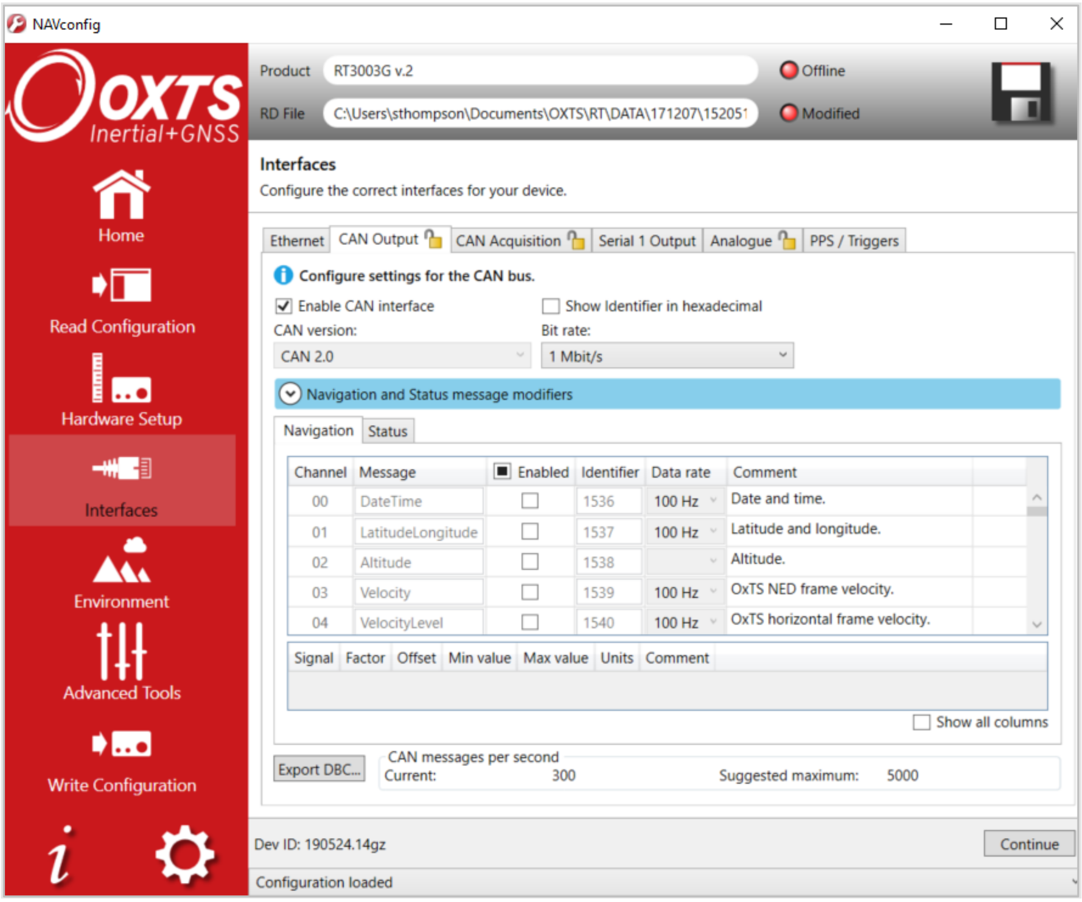


Figure 34:
NAVconfig CAN output configuration tab - Navigation

Each message can be enabled/disabled by clicking in the appropriate cell and selecting from the dropdown menu. The message Identifier is also changed by clicking in the cell. The identifier number should be defined in either hexadecimal or decimal format. Decimal values can be entered as normal. Hexadecimal values should have a letter "h" appended.

The Data rate can be set using the dropdown list that appears after clicking in each data rate cell. When a message's data rate changes or it is enabled or disabled, the caption at the bottom of the window displaying messages per second updates to reflect the new settings.

The Enabled checkbox quickly enables and disables all messages.

The Status tab lists all status messages, which are sent one after another in a repeating loop. Although 80 messages are shown in the list, 100 are actually used internally. If the data rate is set to 100 Hz, a status message will be sent every 10 ms. Some messages are transmitted more frequently than others because they appear in the list more than once. At a data rate of 100 Hz, each message in the Status tab will be transmitted on the CAN bus once per second.

The Prefix and Suffix boxes can be used to quickly add alpha-numeric strings to the beginning and end of all message names, while the Identifier offset box allows users to quickly apply an offset to all CAN

IDs. These tools are useful when IDs conflict with other equipment and changes need to be made to many channels.

Positive and negative integer values can be entered into the Identifier offset box in both decimal and hexadecimal formats. Data entered in hexadecimal format should end with an “h”. To remove the offset, type 0 in the identifier offset box.

The Enabled checkbox quickly enables and disables all status messages.

The Message name, Signal name and Units can be edited in the table. Changes made using NAVconfig are independent of the DBC file, and will not affect it or be saved.

CAN FD (CAN with Flexible Data-Rate) is an extension to the original CAN bus protocol specified in ISO 11898-1. CAN FD was created to accommodate increases in bandwidth requirements within automotive networks. The CAN FD protocol has brought the software closer to “real time” through the minimisation of delays between an instruction and transfer of data (latency) and higher bandwidth.

Enable CAN-FD by selecting it from the CAN version dropdown. Figure 35 displays the options available when configuring the RT for CAN-FD output.

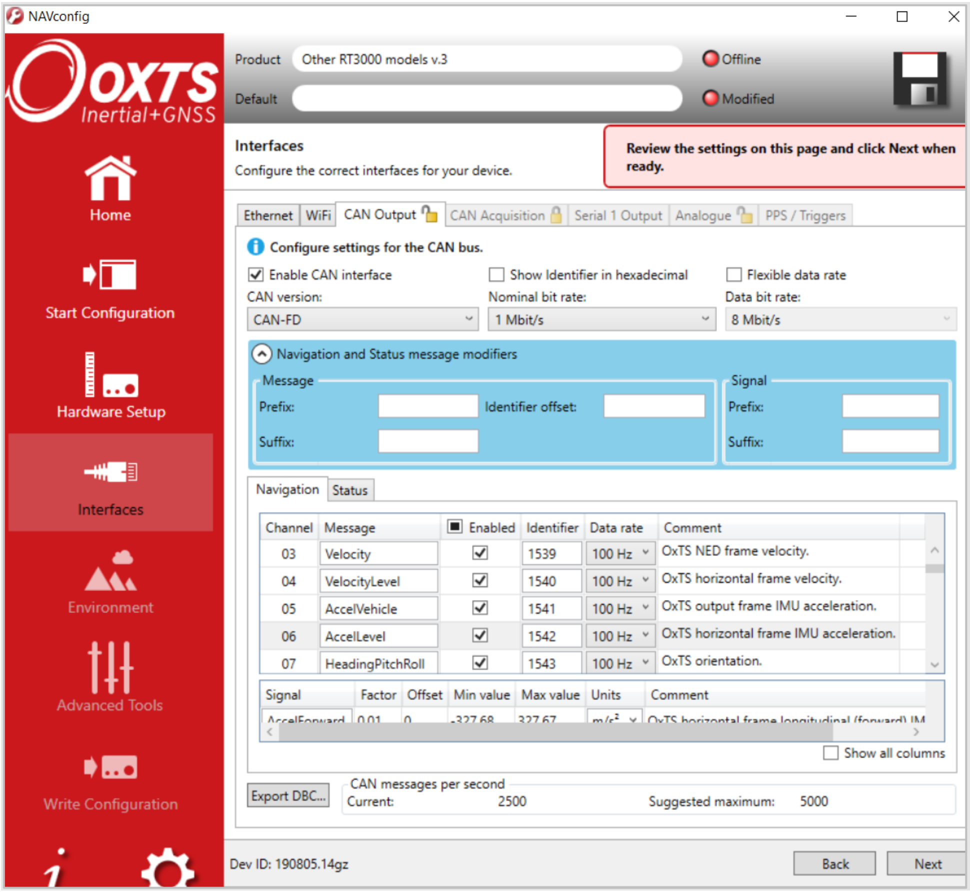


Figure 35:
CAN-FD output configuration

Choose a Nominal bit rate from the dropdown list.

If you want to adjust the Flexible data rate, select the checkbox and then you can choose the Data bit rate from the additional dropdown list and specify the sample points.

CAN Acquisition tab

The CAN Acquisition tab is where incoming CAN signals are defined. These signals can be viewed in real time along with the RT's native data using NAVdisplay, or later using NAVgraph. Aiding data over CAN (such as from a wheel speed or speed over ground sensor) can also be added here.

Note: A CAN isolator must be used when connecting the RT directly to a vehicle's CAN bus.

Channels are added to the acquisition list by clicking on the 'Load DBC file' button and selecting a valid CAN DBC file. The top 12 messages in the list acquisition list are logged at the INS update speed of 100 Hz or 250 Hz. This is not adjustable.

The Message name, Signal name and Units can be edited in the CAN Signal Properties window (Figure 30). This is opened by double-clicking any signal. Changes made using NAVconfig are independent of the DBC file and will not affect it or be saved.

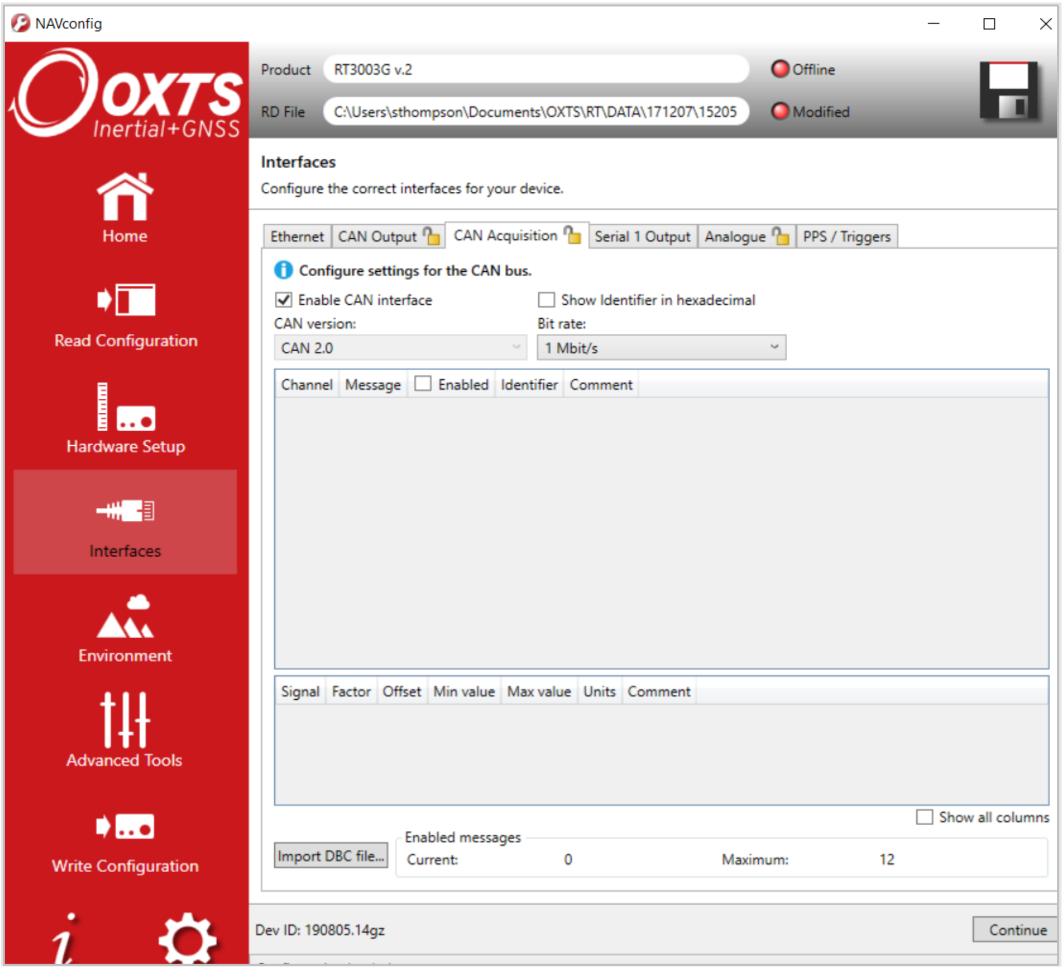


Figure 36:
CAN-Acquisition tab

Serial 1 Output tab

The serial port can be configured to output different types of message (see Table 24).

Select a Packet type and Baud rate. By default, data on the serial port is output using 8-N-1, although odd/even parity and two stop bits are available by using Advanced commands. Please contact support@oxts.com for details on this.

If the NMEA packet type is selected, the NMEA tab will appear in the properties window. In this tab the NMEA messages to output on the serial port are selected by choosing the data rate for each message type from the dropdown lists and clicking the checkbox for when to generate the message.

NMEA messages can also be generated in response to event input triggers. Check the falling or rising edge checkbox to compute the message when the event occurs. The RT can also generate NMEA messages from pulses on the output trigger. These messages use interpolation to compute the values at the exact time of the event but may be output on the serial port up to 30 ms late and out of order compared to the normal messages. To enable these messages check the appropriate checkbox.

Option	Description
Disabled	The serial output is disabled. This option can be used to reduce the computational load and ensure that the Kalman filter runs quicker.
NCOM	Normal output of the RT. NCOM data is transmitted at up to 125 Hz over serial. The format is described in the NCOM Description Manual. Software drivers exist for decoding the NCOM data.
IPAQ	NCOM output at a reduced rate. The baud rate of the serial port is set to 19200 and the update rate is 25 Hz. It is used because the IPAQ cannot manage to receive the data reliably above 25 Hz. (Deprecated)
IPAQ+	NCOM output at a reduced rate and polled. Windows Mobile 5 on IPAQs crashes if the INS is sending data when the IPAQ is turned on. Using IPAQ+ the IPAQ will poll the INS; the INS will not send data while the IPAQ is off, preventing the turn-on crash of the IPAQ. (Deprecated)
NMEA	The NMEA outputs conform to the National Marine Electronics Association Standard (NMEA 0183 version 3.01 The NMEA sentences available are GPGGA, GPHDT, GPVTG, GPZDA, GPGST, PASHR, GPRMC, GPGSV, GPGSA, PTCF, GPPPS, PRDID, GPROT, GPGGK, and GPUTC. The NMEA 0183 description manual gives details of the fields output in the NMEA sentences.
Javad I+RTK	A special set of messages output in GREIS format to be used with Javad receivers. For assistance please contact OXTS for support. (Deprecated)
MCOM	Used for marine applications. Identical to NCOM output but with the addition of heave measurements. (Deprecated)
TSS1	TSS I format outputting acceleration, heave, roll and pitch. (Deprecated)
TSSHHRP	TSSHHRP format. (Deprecated)
EM3000	Suitable for use with Simrad EM3000 multibeam sounders. (Deprecated)
EM1000	Suitable for use with Simrad EM1000 multilkam sounders. (Deprecated)

Table 24:
Serial outputs

Note that it is easy to overload the serial port if there are too many events. The software computes the number of characters that will be output each second and displays this at the bottom of the window. A serial port data overflow warning message will appear if the data rate is too high for the selected baud rate; to fix this it is necessary to lower the data rate of the selected NMEA sentences or increase the baud rate.

Selecting “Allow extended length messages” enables the full GGA and RMC messages to be output, which are longer than the NMEA specification allows. Please see the NMEA 0183 Description manual for more details. Selecting “Output approximate values before initialisation” forces output of the raw GNSS measurements before the RT is initialised. Currently just the position is output and this is the position of the antenna, not the inertial measurement unit. Note that there will be a jump (from the antenna to the inertial measurement unit) when initialisation occurs.

Analogue tab

The Analogue option is used for configuring the RT-ANA companion product. There are 16 channels in the RT-ANA, numbered from 0 to 15. The Measurement, Range, and Min and Max values for all 16 channels can be configured. Click on a specific cell to change the settings.

Note: The CAN bus must be configured correctly for the analogue outputs to work correctly.

PPS / Triggers tab

The output trigger on the digital I/O generates a pulse based on distance. Select the distance interval to generate the pulses on from the dropdown list, or type in a value. The output has 0.8 V or less for a low and 2.4 V or more for a high. The pulse width is 1 ms.

PTP tab

Precision Time Protocol (PTP) is supported according to both the IEEE 1588 standard and the 802.1AS (gPTP) and AUTOSAR profiles of PTPv2. The INS can be configured as either a PTP Grandmaster (synced to GPS time), a PTP slave, taking time from an alternative PTP master clock or as a PTP master taking time from an alternative grandmaster and acting as an intermediate master clock to other time slave devices..

To configure, first select the PTP Mode (PTP, gPTP or gPTP AUTOSAR), from the dropdown and then the System Mode (Master, Slave or MasterSlave).

Note: MasterSlave is not available under the AUTOSAR implementation.

Different time epochs can then be configured by selecting the “Time Epoch” checkbox and then selecting from PTP, GPS, UNIX or UTC from the dropdown list.

If gPTP AUTOSAR is selected, additional message extensions can be added in the Data Id List. If the RT is to be used as a Master clock using the gPTP AUTOSAR mode, additional User data can be provided as a follow up message. Select the length of the User data from the dropdown and choose which Sub-TLVs and CRC flags are required.

gPTP AUTOSAR also supports using standard gPTP compliant messages where the sync and follow up format are supported according to 802.1AS. Select this mode by enabling the message compliance checkbox.

The use of a Cyclic Redundancy Checksum (CRC) can also be enabled via a checkbox.

If the INS is to be used as a time slave in the gPTP AUTOSAR implementation, a static delay can also be applied by typing the value (in nanoseconds) in the relevant box.

NAVconfig Environment section

This section contains settings related to the environment you will be collecting data in, including the device initialisation conditions. This section is not broken down into tabs but contains several selectable options and pre-defined values on one screen.

Initialisation

Static initialisation is disabled by default.

If static initialisation has not been enabled, the RT will need to be initialised by driving forwards in a straight line to initialise the heading to the track angle. The initialisation speed is the speed at which the vehicle must travel to activate the initialisation.

The default initialisation speed is 5 m/s. However, some slow vehicles cannot achieve this speed. For these vehicles adjust the initialisation speed to a different value.

If a speed less than 5 m/s is selected, then care should be taken to make sure that the RT is travelling straight when it initialises.

Initialisation can also be achieved using the Hotstart feature, which uses the last known position and heading at the point at which the device was last reset or powered down. Enable this using the "-hotstart_enable" command (See commands under Advanced Tools). Once the device powers on, the "!hotstart" command can then be used to initialise. This feature can only be used if the time source is set to PTP or IMU.

Vehicle starts

Select a predefined value from the dropdown list.

If you know the vehicle will be level when starting (to within about 5°) select 'Level'. This saves about 40 s during the initialisation process since the RT does not have to take the time to compute an initial roll and an initial pitch. In high vibration environments Not Level may not work and so the RT can only start if the vehicle is level and the Level option has been specified.

GNSS environment

Select a predefined value from the dropdown list.

If the system is used predominantly in open-sky, then the Open skies setting should be used. In environments with a lot of GNSS multipath then Some obstructions or Frequent obstructions can be used depending on the environment. This will allow less accurate GNSS measurements to update the system and it also places more reliance on the inertial sensors compared to the GNSS.

Unless the open-skies setting is used, the RT will not report accuracies that meet its specifications.

Vibration levels

Select a predefined value from the dropdown list.

The Normal vibration level is adequate for most circumstances. The RT is very tolerant of vibration and has been used successfully in environments with more than 2 g RMS using the Normal setting. If the velocity innovations are very high, and many GNSS packets are being dropped, then this setting can be changed.

Typical situations where the High vibration setting should be used include those where vibration mounts have been used, or where the RT and the antenna are mounted on different sprung parts of the vehicle (e.g. the cab/chassis of a truck).

Heading lock

The heading of single antenna systems can drift when the RT remains stationary for long periods of time. To solve this, the RT includes an option to lock the heading to a fixed value when stationary. This option cannot be used if the vehicle can turn on the spot (i.e. with no forward velocity). With heading lock enabled the RT can remain stationary for indefinite periods of time without any problems. For vehicle testing this option is recommended.

There are four settings to choose from. Disabled should be selected if the vehicle can turn on the spot. The default setting Normal is best for most applications as it is least likely to cause problems in the Kalman filter. Tight and Very tight are better when trying to reduce position drift in poor GNSS environments and traffic jams.

Table 25 gives a more detailed description on each of the heading lock options.

Heading lock	Description
Normal	This option assumes the heading of the vehicle does not change by more than 2° while the vehicle is stationary. The heading accuracy recovers quickly when the vehicle moves
Tight	This option assumes the heading of the vehicle does not change by more than 0.5° while the vehicle is stationary. The recovery is fast if the heading of the vehicle does not change but will be slow if the vehicle turns before it moves
Very tight	The option assumes the heading of the vehicle does not change by more than 0.3° while the vehicle is stationary. The recovery is fast if the heading of the vehicle does not change but will be slow if the vehicle turns before it moves. This option can cause problems during the warm-up period if the vehicle remains stationary for a long time and then drives suddenly

Table 25:
NAVconfig heading lock options
Note: The heading of most vehicles does change if the steering wheel is turned while the vehicle is stationary. Junctions and pulling out of parking spaces are common places where drivers turn the steering wheel while not moving.

Garage mode

The Garage mode option is used to stabilise the RT's outputs when GNSS is not available. For example, GNSS can be blocked when the vehicle returns to the garage to have some modifications. Without Garage mode enabled, the RT may drift too far and may not be able to recover.

When Garage mode is active, the RT applies a gentle velocity update and assumes that the vehicle is stationary. This keeps the roll, pitch and velocity within acceptable limits while the RT has no GNSS. With heading lock also enabled, the RT can also keep the heading accurate while stationary.

When using this option, try to keep the vehicle's movement inside the garage to a minimum and exit the garage through the same door the car entered.

Surface tilt

The surface tilt settings are used to compute the roll, pitch (and heading) compared to a flat inclined surface. The roll and pitch from the RT products are measured compared to gravity. Most test tracks are built at an angle so rain water runs off and the track dries faster. As the vehicle drives up the incline, the pitch shows a positive value; as the vehicle drives down the incline the pitch shows a negative value; the value changes with a sinusoidal pattern as you drive round a circle. The roll angle shows a similar effect.

Using the surface tilt option, the roll and pitch compared to the inclined surface can be output as well. The NAVdisplay software contains a tool for working out the surface angles. NAVconfig can be used to configure the surface's angle if it has been measured already. These settings can be input in the Environment section within NAVconfig. Figure 37 shows the Surface tilt properties settings.

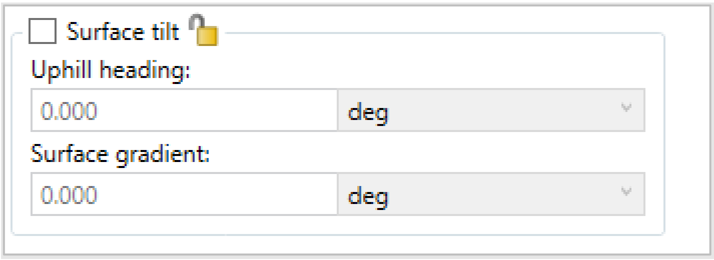


Figure 37:
NAVconfig surface tilt properties in the environment section within NAVconfig

Enter the heading (compared to true north) of the uphill direction and the gradient of the surface.

The RT does not change the roll and pitch outputs because of these settings. Instead there are additional outputs, surface roll, surface pitch and surface heading that are output and the transformation is applied to these outputs. Note that for surfaces with a small gradient the surface heading is almost the same as heading.

Enable local coordinates

The RT can output the displacement from an origin in a local co-ordinate grid. To use this option a "zero" location or origin must be chosen; the latitude, longitude and altitude for the origin must be entered into the RT. If an RT-Base S is available, then these will be shown on the LCD. A rotation can also be specified to rotate the xy directions.

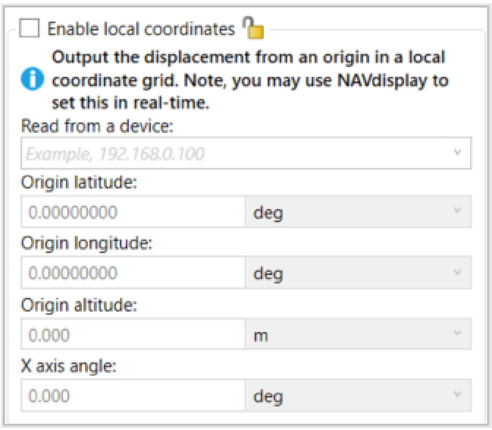


Figure 38:
NAVconfig enable local co-ordinates in the environment section

Advanced Tools section

This section contains several settings for Advanced users. By default, these settings are not switched on so you should navigate through the various tabs to review the settings that apply to your application.

Displace Output tab

The RT can displace or move its outputs to another location in the vehicle. This simulates the RT being mounted at the new location, rather than at its actual location. This function displaces all of the outputs (position, velocity, acceleration) to this new location.

To enable output displacement, click the checkbox and enter the offsets to the new location in the vehicle. The offsets are measured from the RT in the vehicle co-ordinate frame. Select the directions from the dropdown lists and input the distances.

Note that the noise in the acceleration outputs will be much higher when output displacement is used. Typical installations in moving vehicles have angular vibrations of about 2 rad/s^2; this equates to 2 m/s^2 of additional vibration of a 1 m output displacement. It will be necessary to filter the data if output displacement is used.

Acceleration filters tab

The RT is able to filter the linear acceleration and the angular acceleration before they are output. These filters affect the outputs on the CAN bus. On the NCOM output the non-filtered values are output together with the filter characteristics and the NCOM decoders provided by OXTS will implement the chosen filter. The linear acceleration and the angular acceleration can be configured separately.

Due to vibration the accelerations (both linear and angular) are noisy. In particular, angular acceleration is normally filtered when it is used. The RT can filter the acceleration outputs using a second order low-pass filter. The characteristics of the filter can be set and viewed in the Acceleration Filters tab in the Advanced Tools section of NAVconfig.

Designing the right filter is always a compromise between the noise reduction and the filter delay. To help choose the filter, the software will compute the maximum delay over the 0 to 5 Hz interval and the Noise Reduction Factor over the full bandwidth. The Noise Reduction Factor is the ratio of the filtered noise compared to the unfiltered noise assuming the vibration is white (i.e. same amplitude across the frequency spectrum). A graph showing the delay with respect to frequency can also be plotted. The delay is the additional delay of the filter and not the total delay of the acceleration output. The RT has other delays, like calculation delay, too.

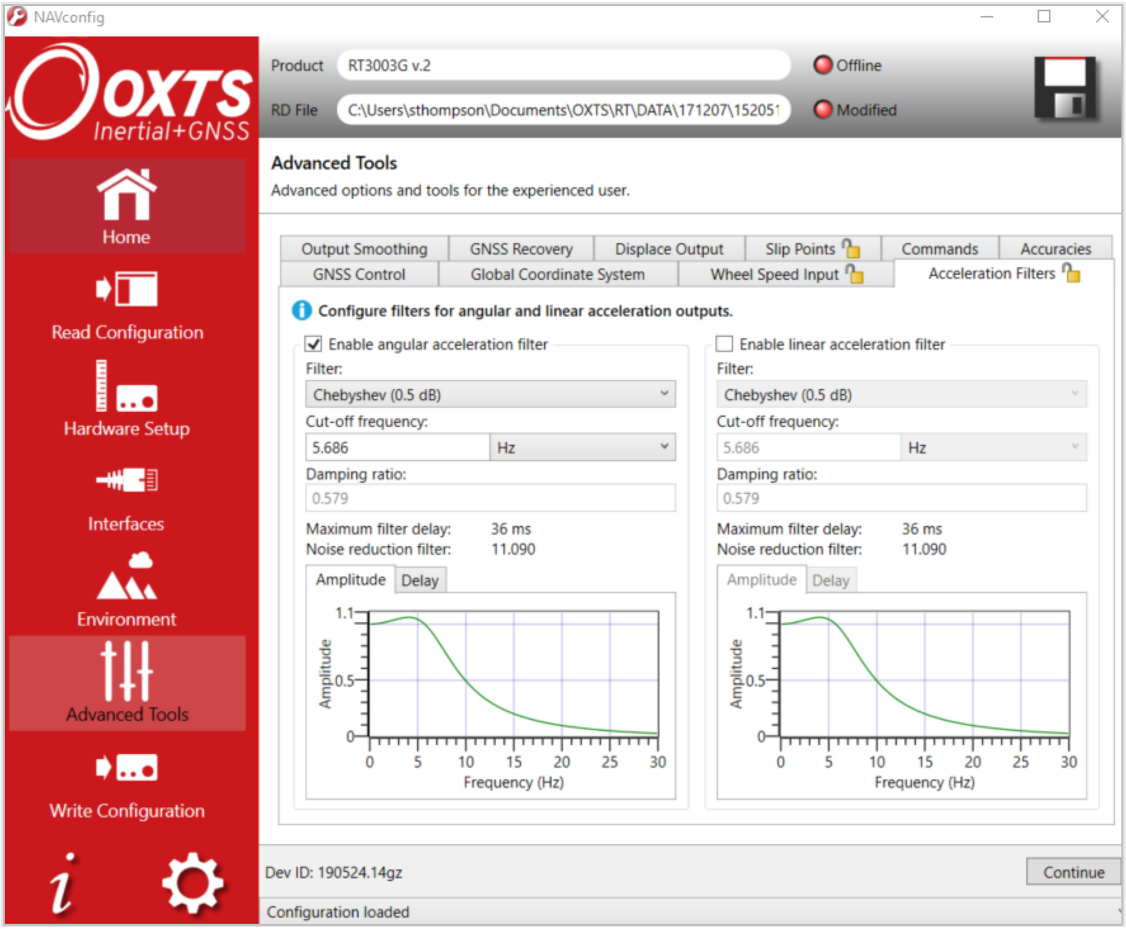


Figure 39:
NAVconfig acceleration filters tab in the advanced tools section

Wheel Speed Input

The RT can be factory configured to include a wheel speed input. This reduces the drift in outputs when GNSS is not available. It is essential to use the Lateral and Vertical No-slip slip features at the same time as wheel speed corrections.

As with the Lateral No-slip feature, the wheel speed input can only be used on land vehicles; aircraft and marine vehicles cannot use this option. The wheel speed must not be used on a steered wheel, it must be used on a wheel that is measuring the forward direction of the vehicle.

Figure 40 shows the wheel speed configuration window. To enable the wheel speed input, ensure the checkbox is checked. If this option is disabled, the RT will ignore corrections from the wheel speed even if it is connected.

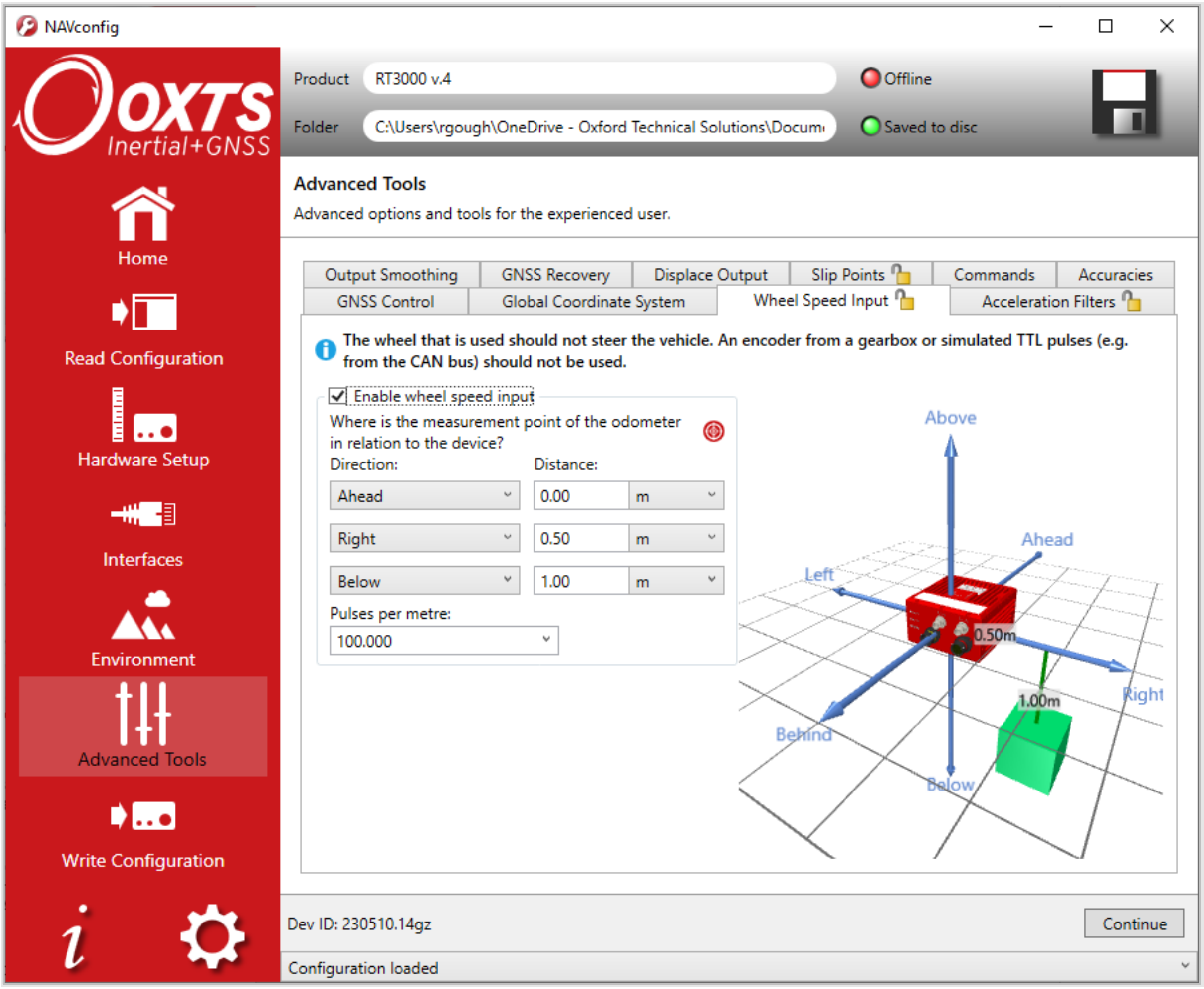


Figure 40:
NAVconfig wheel speed Input tab in the advanced tools section

The distances from the measurement point on the RT to the measurement point of the wheel speed encoder in the vehicle coordinate frame should be input. The directions can be selected from the dropdown lists. If the wheel speed is from a prop shaft then the distance should be measured half way between the two wheels. The illustrations in the image will change depending on the settings you choose, to help visualise the position of the RT in relation the wheel speed sensor.

Measurements by default are made to an accuracy of 10 cm. Using higher precision for the measurement does not improve the results. Using an accuracy figure worse than 20 cm will increase the drift of the RT. The accuracy can be specified exactly in the Accuracies tab in the Advanced Tools section along with other measurements such as antenna position.

Enter the pulses per metre of the wheel speed. A value that is accurate to 10% is sufficient unless you know the figure more accurately. The RT will improve this scaling factor itself when GNSS is available. The Improve Configuration utility can be used to apply a more accurate value calculated by the RT from a calibration run. If this option is used then the RT should be allowed to recalibrate the scaling value occasionally to account for tyre wear.

The wheel speed corrections will not be as effective in reducing the drift of the RT if the wheel speed is measuring two wheels (i.e. after a differential), since the actual position of the wheel is required for accurate navigation. If a post-differential encoder must be used then the accuracy cannot be guaranteed.

For best results, a front wheel drive vehicle should be used with the wheel speed on a rear wheel. The wheel speed pulses from driven wheels are less accurate.

CAN Wheel Speed

In addition to an external wheel-mounted speed sensor, velocity data can also be imported over CAN from a vehicle's CAN bus, an external speed over ground sensor or similar. To use this feature, the CAN acquisition feature must be enabled and the relevant .dbc file loaded in the CAN acquisition tab. Once this is enabled, the relevant CAN channel should be selected. Wheel speed is used by the INS in units of metres per second and so a unit scale is required. To convert km/h to m/s for example, a Unit scale of 0.277778 is used.

For the Kalman filter to correctly interpret the CAN wheel speed data, additional data should be provided:

+ The latency of the measurement should ideally be less than 0.5 seconds. CAN wheel speed data with a latency of more than 1 second is discarded.
+ The real-world scale factor is a measure of the true scale factor error of the sensor and best determined by comparing the CAN wheel speed with the unaided INS output when an Integer-level velocity solution is available.
+ The scaling error is a measure of the noise of the CAN wheel speed sensor given as a decimal. E.g. for a signal with a noise level of 5% it should be 0.05.
+ The absolute error is the zero error of the senso, i.e. any non-zero value given when the system is stationary measured in m/s.

Once this is given, the lever arm to the chosen wheel should be measured and provided in the Lever Arm tab.

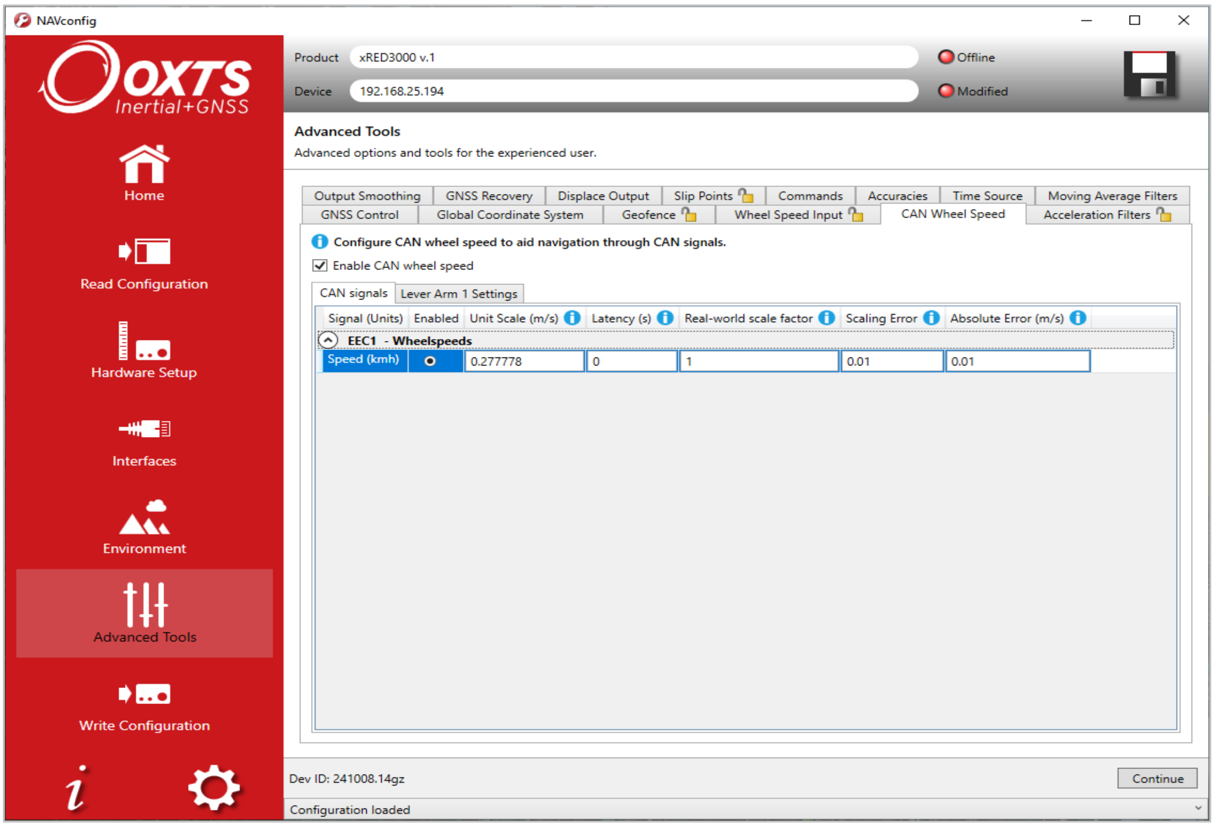


Figure 41:
CAN Wheel Speed Configuration

Output smoothing tab

When the Kalman filter in the RT determines that there is some error to correct, this error is applied smoothly rather than as a jump. The output smoothing controls how fast the correction is applied to the outputs. This option is particularly useful for autonomous vehicles or path-following robots as a rapid change in position can lead to a large change in the steering angle.

Figure 42 shows the Output smoothing tab in the Advanced Tools section within NAVconfig. Click the checkbox to enable output smoothing and unlock the properties for editing.

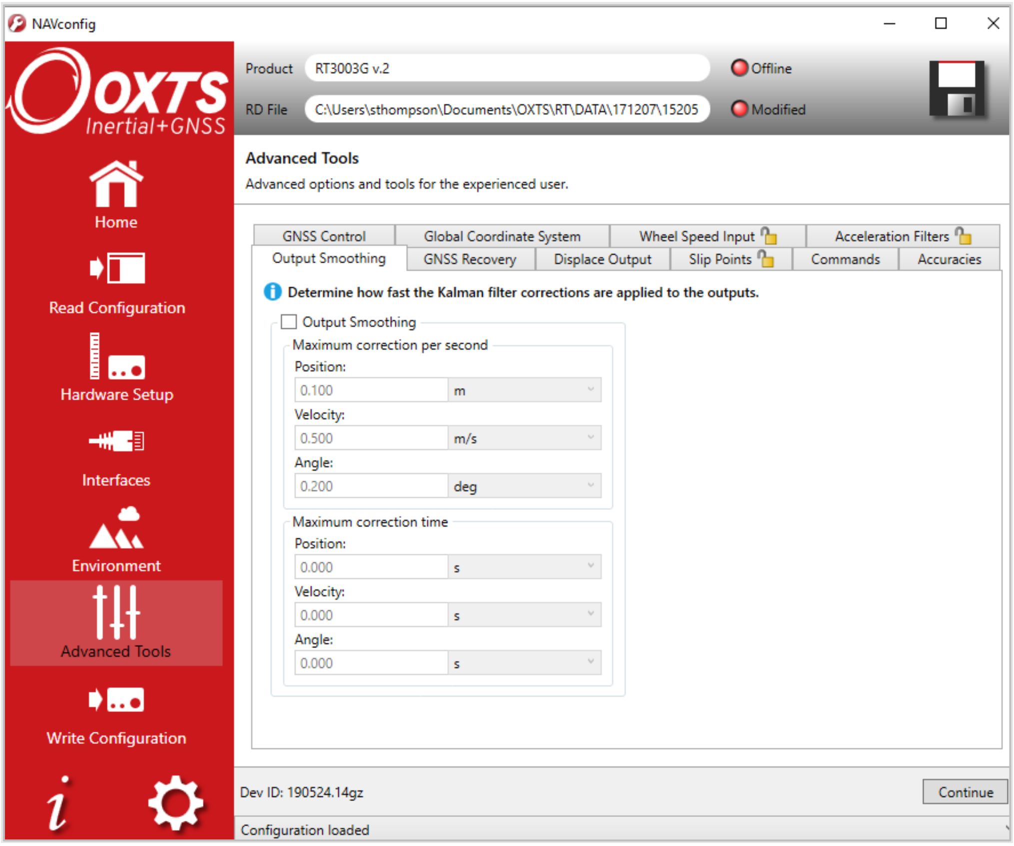


Figure 42:
NAVconfig output smoothing properties window

The smoothing of the position, velocity and orientation corrections can be controlled independently. Enter the maximum correction that can be applied every second. For example, if 0.1 m is entered for the position smoothing then the RT will only correct a position error by a maximum rate of 0.1 m/s.

If a large error is accumulated (for example, if GNSS is not available for a long period of time) then it may take a very long time to apply the correction. Under these circumstances it may be preferable to "jump" the measurement to the correct value quickly. By specifying a time in the Time limit section for the correction, the RT will jump the measurement if it will take too long to correct.

Care should be taken not to make the smoothing too small. If these parameters are inappropriate, then the RT will not be able to make suitable corrections to the outputs and it will not work correctly.

Note: this function is designed to improve the data in real time. When post-processing the data using the forwards-backwards combined option, output smoothing should not be used as it may give unexpected results.

Slip Points tab

The RT can output the slip angle measurements at additional points (maximum of eight points) on the CAN bus; see the CAN Interface manual for the CAN message ID of the slip points. Figure 43 shows the tab for slip point configuration in the Advanced Tools section within NAVconfig.

In the Advanced Tools section within NAVconfig, you can select the number of Slip Points from the Slip Points tab. Select the number of Slip Points you wish to set up and enter the distances and directions from the RT to the Slip Point.

If you have Output displacement enabled, then the measurements are still from the RT and not from the output displacement point.

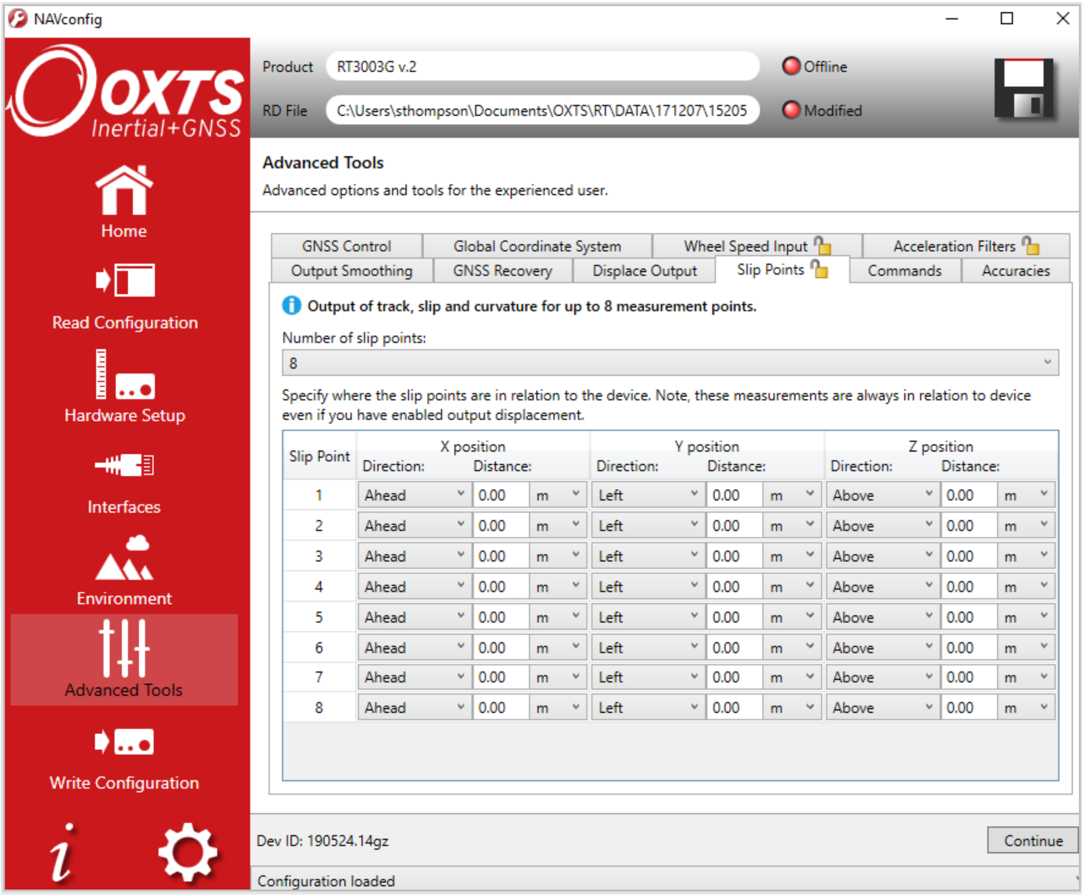


Figure 43:
NAVconfig Slip Points tab

GNSS control tab

The GNSS control tab contains advanced options that control how the GNSS information is managed in the RT. The GNSS Algorithm tab can be used to select the algorithm used for merging the GNSS and the inertial data in the Kalman filter. The Recovery tab can be used to decide how to begin using GNSS measurements if they have been rejected or ignored for a period of time.

Figure 44 shows both tabs in the GNSS control properties window.

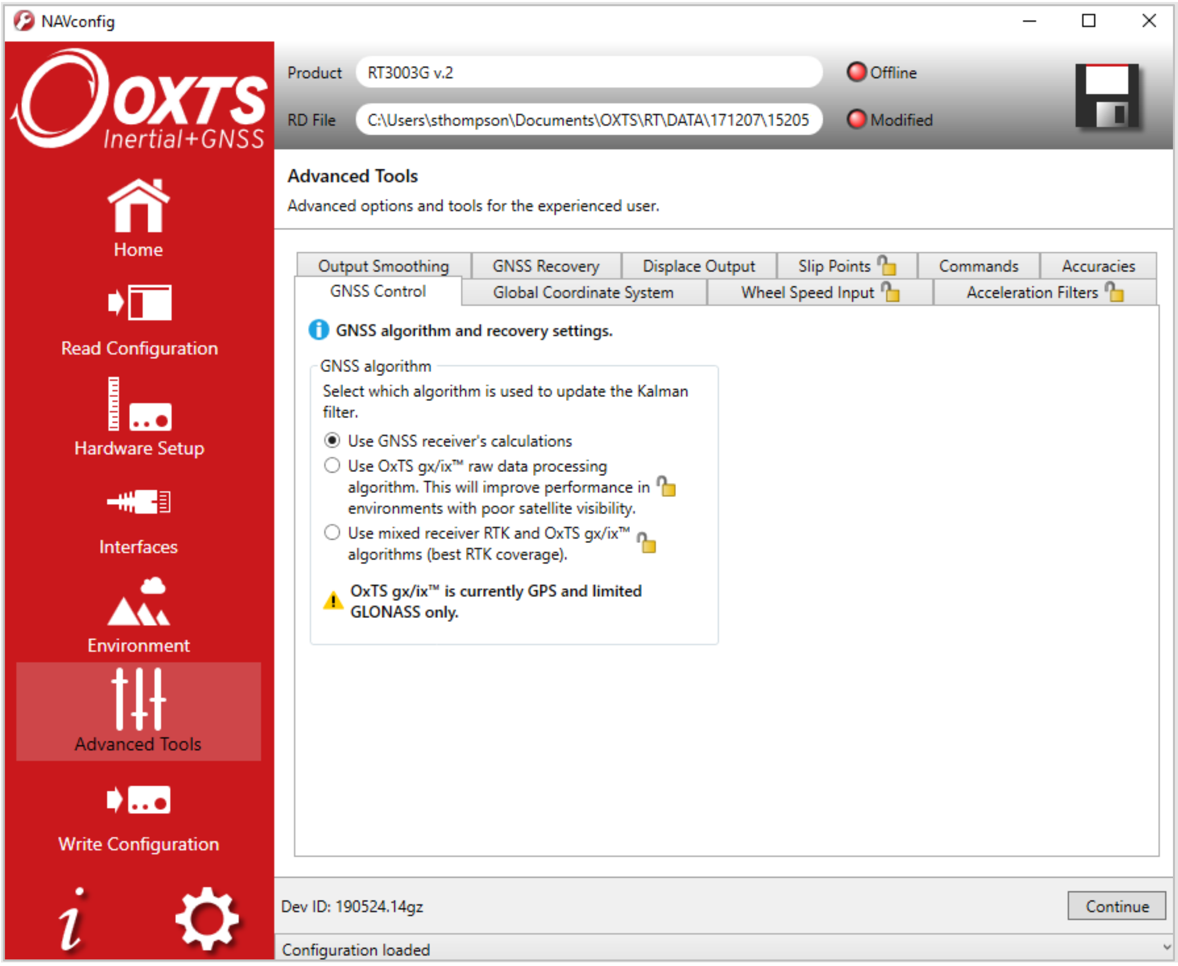


Figure 44:
NAVconfig GNSS Control tab in Advanced Tools within NAVconfig

The GNSS Control tab gives a choice of two algorithms for computing the GNSS measurements.

Use GNSS receiver's calculations – the RT will accept position and velocity from the GNSS receiver and use it to update the Kalman filter.

Use OXTS gx/ix™ raw data processing - uses the raw data from the GNSS and custom algorithms to compute position and velocity tailored to the needs of the Kalman filter. It also improves performance in poor GNSS environments using single satellite aiding technology and tightly coupled GNSS and inertial measurements.

Use mixed receiver and gx/ix algorithms – the system will automatically switch between receiver and gx/ix processing modes in real-time depending on the signal conditions. Typically provides the best performance in mixed environments.

Note: only RTCM V3 format differential corrections are supported in gx/ix™ mode in real-time. RINEX and logged RTCM V3 are supported in post process. For RTK, corrections for GPS are required, corrections for other constellations will be used if provided, GLONASS will be used if it is detected as being compatible. SBAS corrections are not supported in gx/ix.

GNSS Recovery tab

The GNSS Recovery tab controls how the RT will accept or reject GNSS measurements. The RT will automatically reject GNSS updates that it believes are not correct. However, there is a limit on the number of GNSS measurements the RT will reject. Once this limit has passed the RT will accept the GNSS update since it is possible the GNSS is correct and the inertial measurements are not. The GNSS control determines how long the RT should wait before forcing the GNSS to be accepted. Both the velocity and the position can be controlled separately.

In the default state the RT will reject up to 20 GNSS measurements before it forces the GNSS to be accepted. However, in high multipath environments, and when wheel speed is used, it may be desirable to reject more GNSS measurements. Select the 'Start believing measurements after' option and enter the number of GNSS measurements to reject before the system starts believing it again.

Table 26 shows the update rates of the RT.

GNSS processing mode	Position	Velocity
Receiver mode	4 Hz	10 Hz
Gx/ix mode	4 Hz	4 Hz

Table 26:
GNSS update rates

Global Coordinate System tab

The RT can output position relative to different coordinate frames. You can change the coordinate frame settings in the Global Coordinate System tab within Advanced Tools in NAVconfig, shown in Figure 45.

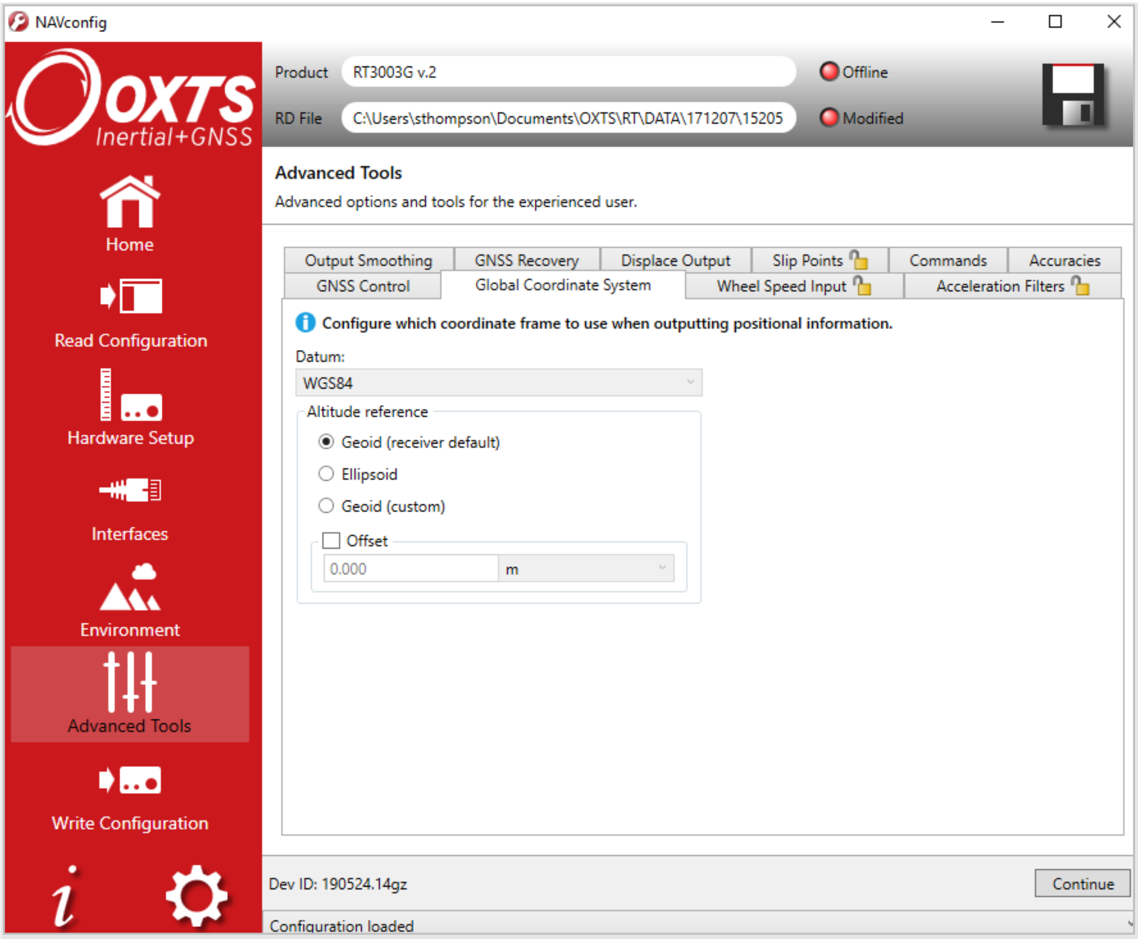


Figure 45:
NAVconfig Global Coordinate System properties window

From the Global Coordinate System tab you can choose which reference datum to output latitude and longitude relative to. The default system and the standard for GPS is the WGS 84 datum.

Note: Currently outputs will only reference datums other than WGS 84 in post- processing. Real-time outputs will still be referenced to WGS 84 even if another option is selected.

The Altitude reference can be compared to either ellipsoidal or geoidal height. If Ellipsoid is selected, the altitude will be output with respect to the reference ellipsoid selected in the coordinate datum section. If Geoid (receiver default) is selected, the altitude will be relative to the geoid used in the GNSS receivers. A Custom geoid file can be used for local variations. To download supported geoid files, go to http://support.oxts.com/local-geoid-files. The UGF file must be saved in C:\Users*username*\Documents\OXTS\Shared\Custom geoid files. Once the file is downloaded and saved in this location, it can be selected from the dropdown box.

A constant offset to the specified altitude reference can be applied by checking the Set offset box typing in a value into the cell.

Accuracies tab

The NAVconfig software uses default accuracies for the measurements made during setup. These include antenna positions, IMU orientation values and measurements for Advanced Slip settings. It is recommended that you stick to these default measurements. However, if you wish to apply specific and more accurate values for measurements then these can be edited in this Accuracies tab. Enter the values directly into the values field.

Commands tab

Using the Commands tab you can enter device-specific commands that apply specific features or perform actions onto the RT. The OXTS technical support team often use these and can provide you with a list of useful commands if you request them at support@oxts.com.

Time Source

The time source is configurable for the following options:

+ Data sets the time used internally by the device and output in the NCOM stream.
+ Data file name sets the time and date used in the labelling of the RD file created by the device
+ IMU steering sets the rate at which the IMU sampling takes place.

For each of the options above, the following time sources are available:

+ GNSS uses the time provided by the internal GNSS receiver. This is the default time source.
+ PTP uses the time from an external master clock. PTP/gPTP slave must be enabled for this time source to be available.
+ User uses a time offset supplied by the user once the unit has been powered on. The following commands can be used to set the offset:
    - !SET TIME TARGET [week] [second]
    - !SET TIME GPS [week] [second]
    - !SET TIME YYYY-MM-DD_HH:MM:SS
+ None (IMU) uses the internal time set by the strapdown navigator. This time is arbitrary and starts from 0 when the unit is powered on.

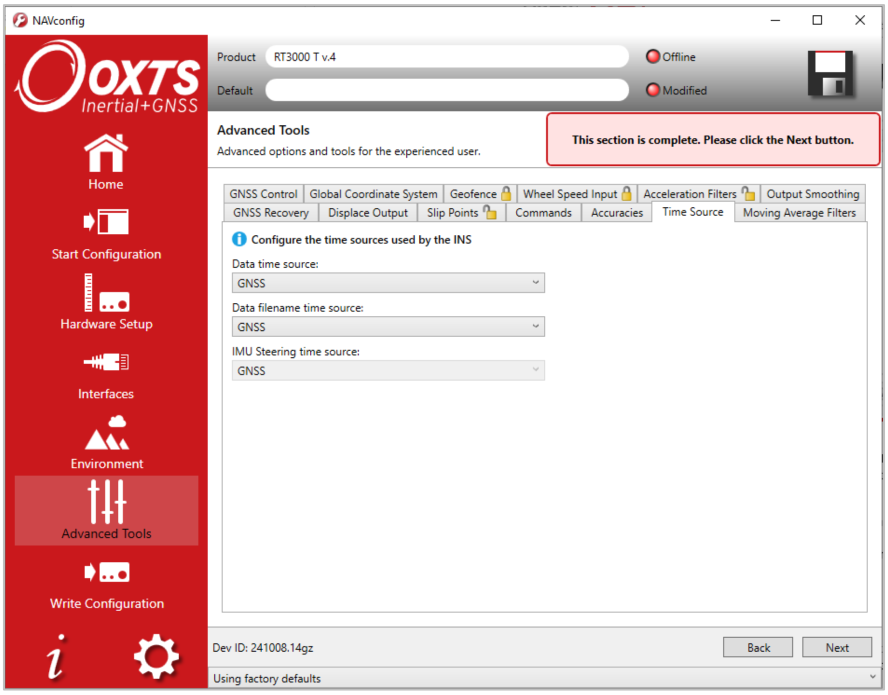


Figure 43:
NAVconfig Time Source Configuration page

The Write Configuration section of NAVconfig

Changes to the RT settings must be sent using Ethernet or Wi-Fi. It is necessary to configure your computer's LAN and WLAN settings, so it is on the same network as the RT.

Figure 46 shows the Write Configuration page.

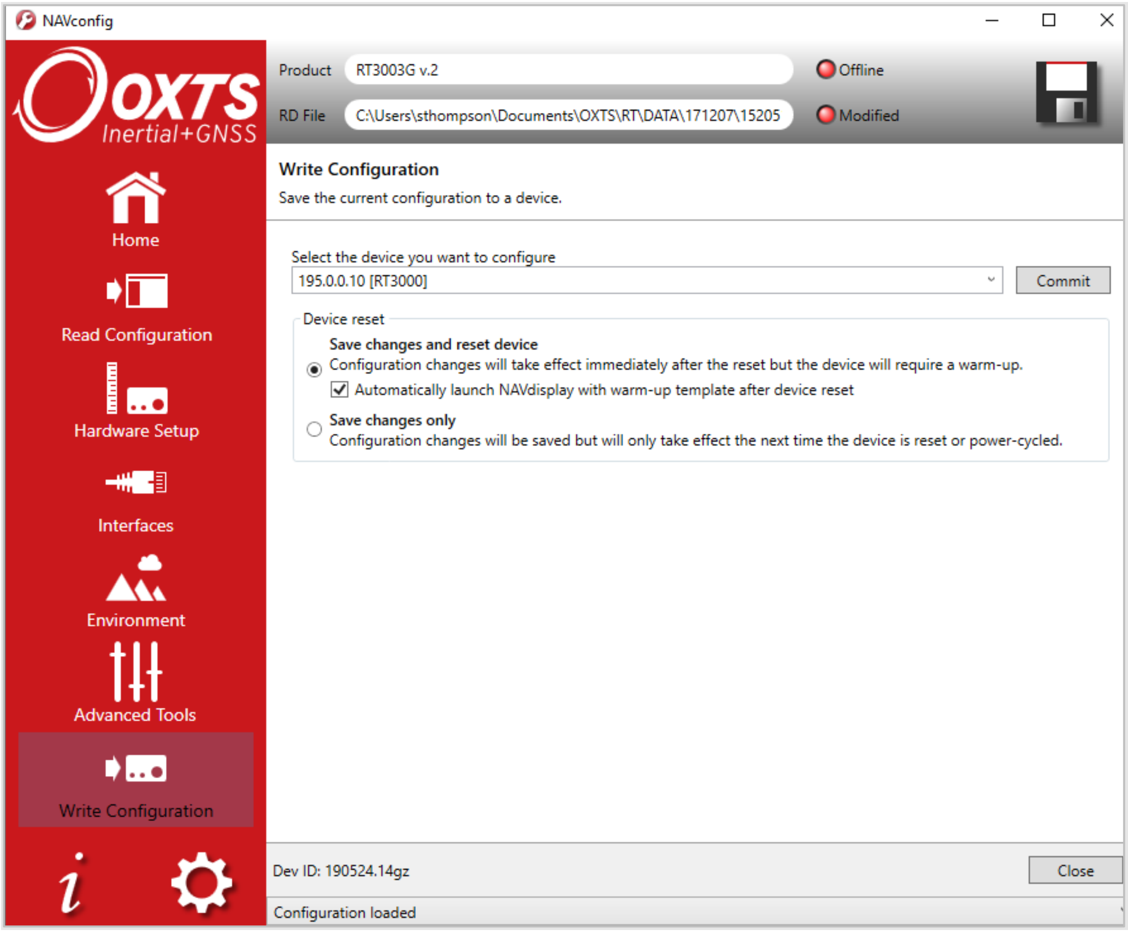


Figure 46:
NAVconfig Write Configuration page

Enter the IP address of the RT you want to configure or select it from the dropdown list. The dropdown box will list all systems currently connected to the computer's network so ensure to select the correct system if there are multiple listed.

Choose whether to commit the configuration changes immediately to the unit or save them until the next time the unit is reset or power cycled.

Setting up the base station

For correct operation of the higher accuracy systems it is necessary to use a base station GNSS receiver. All of the systems can be successfully used without a base station, however, the specification will only be met if a base station is used.

The base station is a separate GNSS receiver that monitors signals from the GNSS satellites. Using its knowledge of position it works out the errors in each satellite's signal. It also measures the carrier-phase of the signal for kinematic corrections. The carrier-phase observations and the satellite signal errors are sent from the base station GNSS to the RT via a radio modem (not provided).

The position of the base station GNSS antenna can either be determined by the base station GNSS receiver or can be surveyed in by a chartered surveyor. If the base station GNSS receiver determines its own position, through position averaging, then any error in the base station receiver will also result in error at the RT. In order to relate the RT signals to maps, or other items on the world, it is necessary to have a surveyor measure the position of the GNSS antenna and then tell the base station GNSS receiver what position to use.

For many applications it is not necessary to survey in the base station antenna since an absolute world-reference is not required. Instead, a local grid can be used.

Using the RT-Base S

The RT-Base S is a self-contained GNSS, radio modem and battery housed in an IP65 rated case. For instructions on how to use the RT-Base S see the “RT-Base S User Guide”.

The RT-Base S is supplied with a radio modem. This should be connected to the radio connector of the RT user cable supplied. This cable supplies power to the radio modem as well as sending the differential corrections to the RT.

Initialisation process

Before the RT can start to output all the navigation measurements, it needs to initialise itself. In order to initialise, the RT needs all the measurements listed in Table 27.

Quantity	Description
Time	Measured by internal GNSS
Position	Measured by internal GNSS
Velocity	Measured by internal GNSS
Heading	Approximated to course over ground (with large error) when the vehicle moves. Dual antenna models have the option for static initialisation which does not require any movement
Roll, pitch	Vehicle Level option: assumed zero with a large error. Otherwise: estimated over first 40 s of motion with large error

Table 27:
Quantities required for initialisation

The system will start when it has estimates of all of these quantities. Course over ground will be used as the initial heading when the system exceeds the value set as the initialisation speed (default of 5 m/s), unless static initialisation has been selected. If the system is mounted level in the vehicle, then the Vehicle Level option will enable the system to start immediately. Otherwise the system takes about 40 s to find approximate values for roll and pitch.

For the initialisation process to work correctly, the RT requires the user to tell it which way it is mounted in the vehicle, otherwise the course over ground will not be close enough to the heading.

Real-time outputs

During the initialisation process the system runs 1 s behind, allowing GNSS information to be compared to information from the inertial sensors. After initialisation the system has to catch-up from this 1 s lag. It takes 10 s to do this. During the first 10 s the system cannot output data in real time, the delay decays to the specified latency linearly over this 10 s period.

The system turns the Status LED orange to show the outputs are not real-time. When the system is running in real time this LED is green.

Warm-up period

During the first few minutes of operation the system will not conform to specification. During this period the Kalman Filter runs a more relaxed model for the sensors. By running a more relaxed model the system is able to:

+ Make better estimates of the errors in the long term (if it does not get these correct then they become more difficult to correct as time goes on).
+ Track the errors in the inertial sensor during their warm-up period (when their errors change more quickly than normal).

During this period it is necessary to drive the vehicle or the errors will not be estimated and the specification will not be reached. The NCOM output message (and CAN outputs) includes status information that can be used to identify when the required specification has been met.

Improving the configuration after a warm-up

Committing the configuration to the RT

After the warm-up process has been completed you can commit the improved settings to the RT using NAVconfig. The RT takes its improved orientation, antenna positions and wheel speed sensor position from values generated in real time during the warm-up and uses them to improve accuracies.

To commit improved settings to the RT, first open NAVconfig and select 'Improve configuration'. Figure 47 shows this option on the NAVconfig home section.

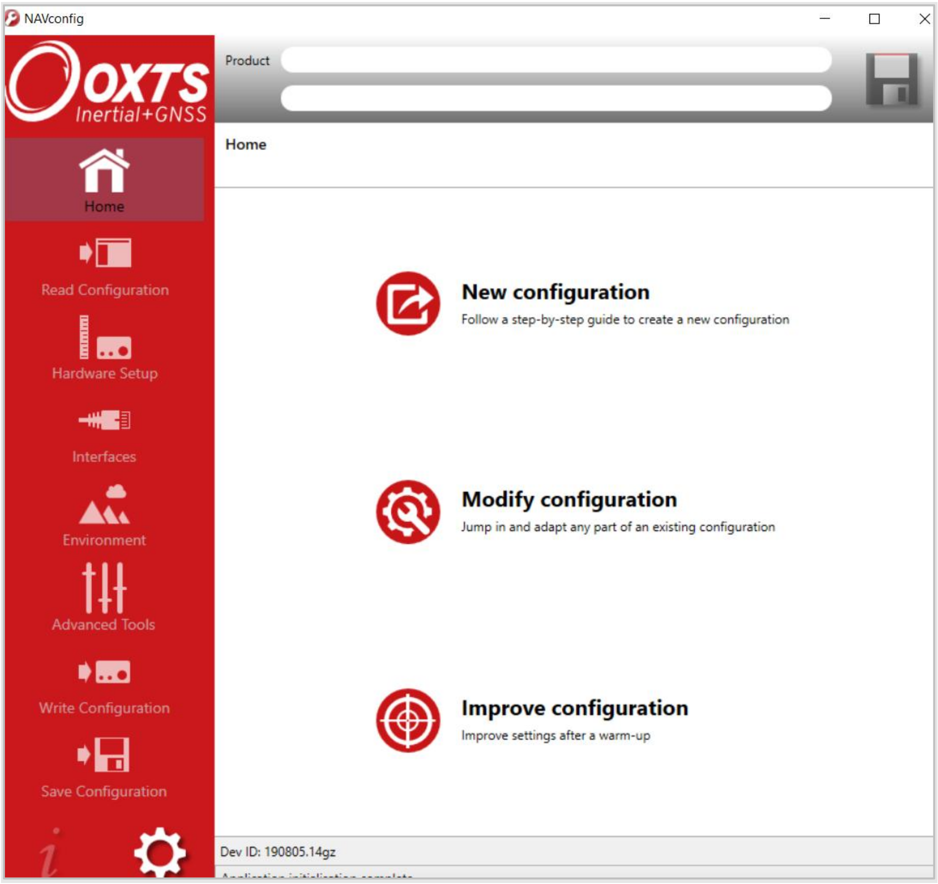


Figure 47:
NAVconfig home section

Read configuration section in NAVconfig improved configuration wizard

If you are connected to a device via Wi-Fi or Ethernet, then select "Read settings from a device" and choose the device from the available list. If the file has been logged to the PC already then you can choose 'Read settings from a data (RD) file' or 'Read settings from a folder' by locating the file or folder on your PC.

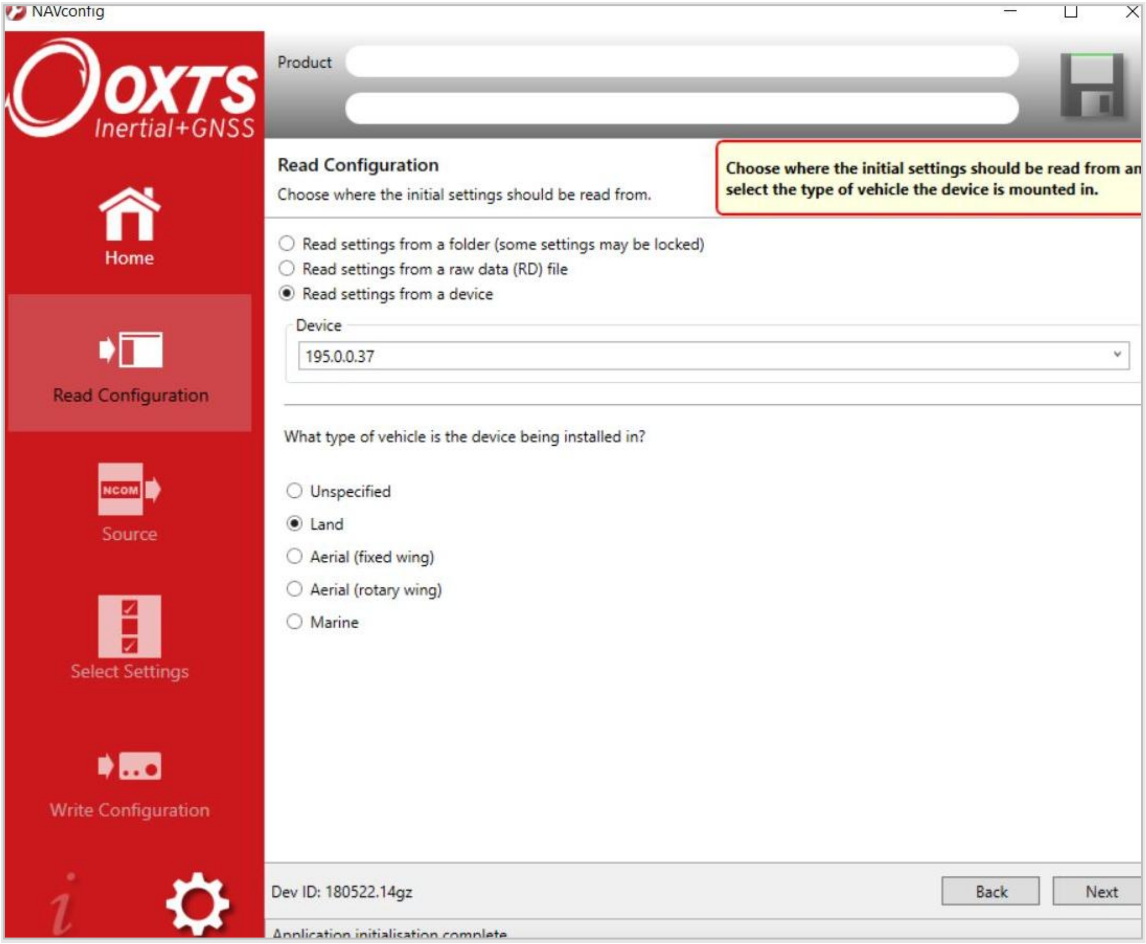


Figure 48:
NAVconfig read configuration

Click 'Next' to continue.

Confirm whether the improved data should be read from: The Device, or a File. Click 'Next' to continue.

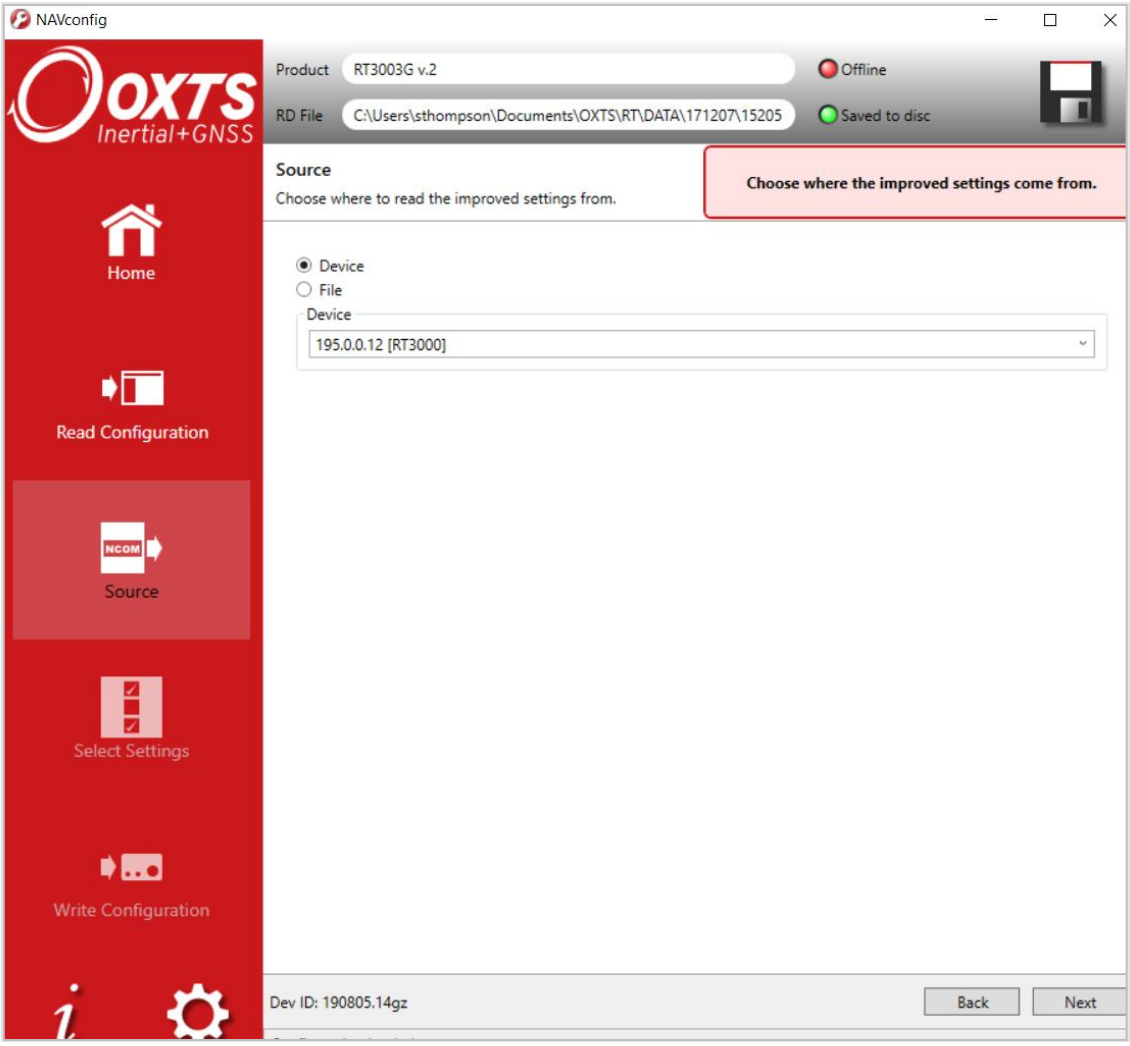


Figure 49:
NAVconfig improve configuration data source

The Select Settings screen will appear. From the list displayed, select the settings that you wish to view. These will be determined according to what is enabled on your device.

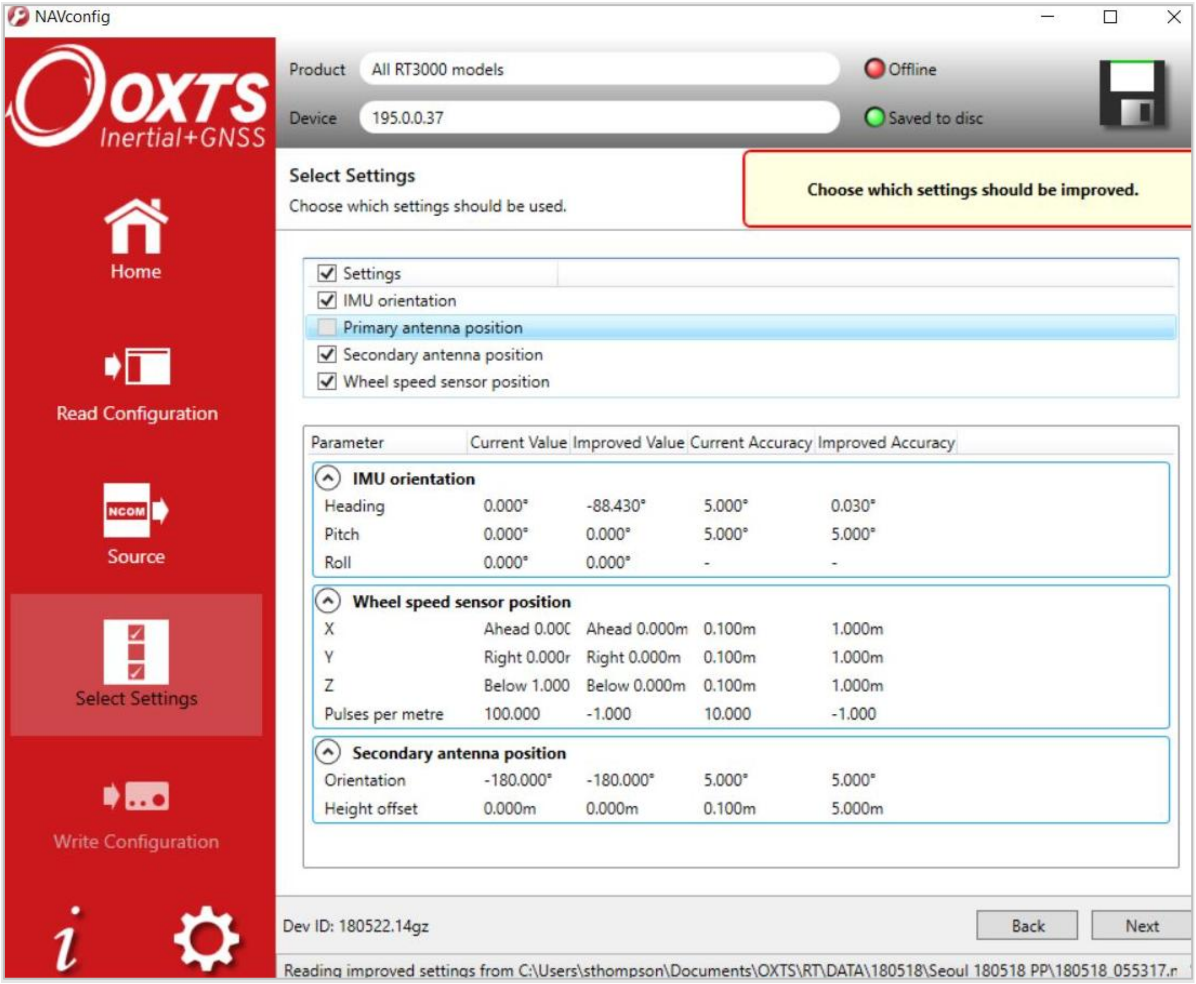


Figure 50:
NAVconfig improve configuration select settings

Select the settings that you wish to improve in the configuration from the options available. By clicking the down arrows, you can expand the settings and view the values that have been improved after the warm-up. It is recommended that you review these before clicking 'Next' to continue.

The final stage of the improved settings wizard is to write the configuration to the device and apply the improved settings with new accuracies. You can choose whether to commit the improved settings to the device after a rest or power cycle (recommended) or to apply them immediately (which does not get saved into the configuration file on the device). For the improved settings to apply to the device in the case where the device will remain in the car for some time, it is recommended that you apply the improved settings and reset the device.

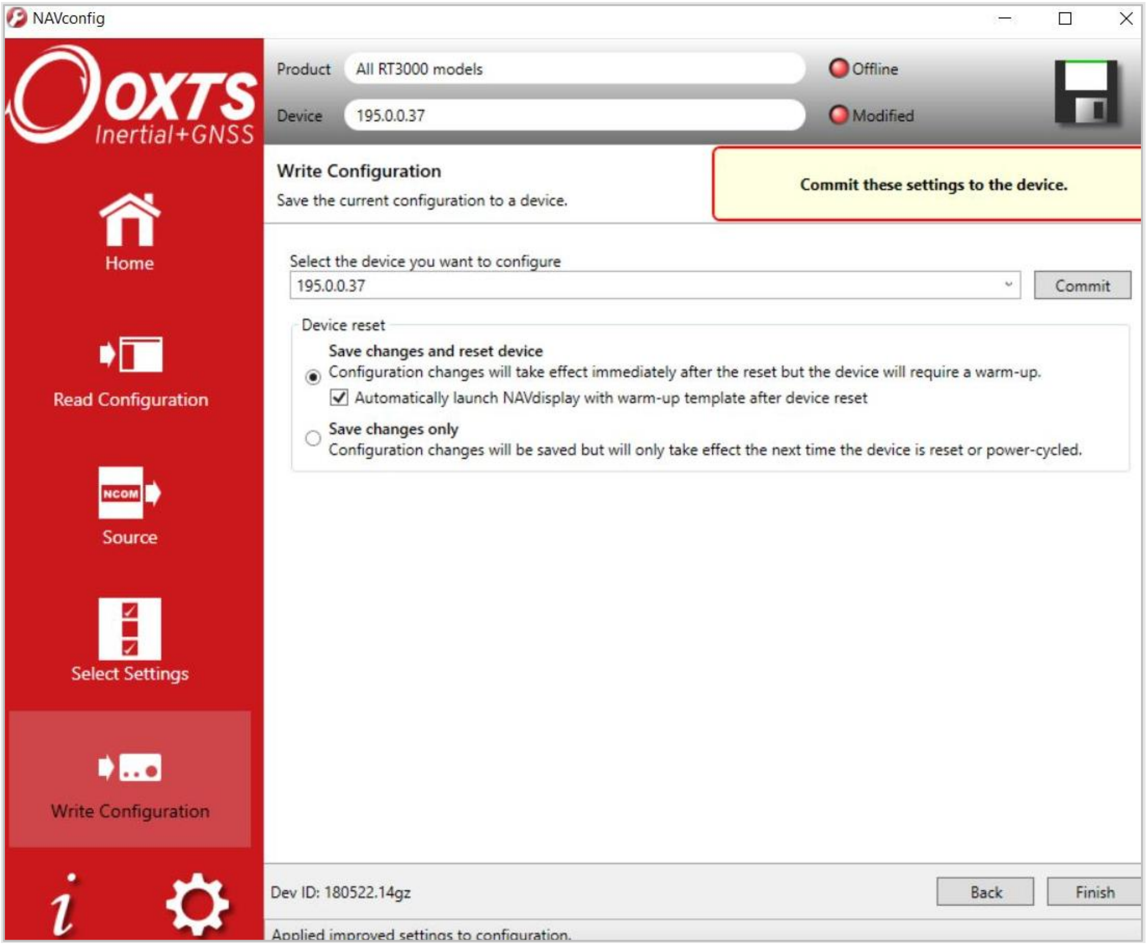


Figure 51:
NAVconfig improve configuration write configuration

Before you write the improved settings to the device, choose whether you want to apply the settings immediately or after a power cycle.

Post-processing data

Data stored on the RT is in a raw, unprocessed format; these files have an RD extension. The advantage of this is it can be reprocessed with different configuration settings. For example, if the configuration was configured incorrectly when running in real time, then the configuration can be changed and the data can be reprocessed post-mission.

The software suite provided with the RT includes the NAVsolve software which can be used to reprocess the data. The NAVsolve Wizard also gives the user the ability to change the NCOM binary output format to text.

A full explanation of NAVsolve is given in the “NAVsolve manual”, which can be downloaded from the OXTS support website.

Appendix A – Ensuring optimal operation

In order to maximise performance and ensure optimal operation, there are a number of areas to consider during installation and operation of the INS. Table 28 lists the topics to pay attention to.

Topic	Consideration
Installation	Antennas installed with same orientation
	Antennas installed clear of obstructions
	Antennas able to see same constellation of satellites
	Antennas and cables routed clear of sources of EMI
	Unit mounted rigidly in vehicle
	Unit and antennas unable to move independently
	Unit mounted away from direct sunlight or sources of high or very low air flow
	Appropriate antivibration mounts used if necessary
	Unit has a stable, uninterrupted power supply
	Appropriate CAN isolation is used
Configuration	Dual antenna set up as per OXTS guidelines
	CAN output configuration below suggested maximum message limit and lowered appropriately for other messages on the CAN bus
	Differential corrections enabled and configured
	Secondary antenna separation distance measured as accurately as possible
	Ethernet output enabled and monitored during vehicle operation
	Vibration levels are set to normal (higher levels will reduce confidence in IMU error models)
	GNSS environment set to Open skies (lower settings will reduce confidence in GNSS error models)
	A good warm up as been performed in RTK and an improved configuration committed to the unit
Pre-drive checks	Ensure all equipment is mounted securely
	Differential corrections are being received and the unit is in RTK position mode
	Position accuracy is being received over ethernet
	All cable connections are secure
Initialisation	Good GNSS conditions for dual antenna static initialisation (open skies, no multipath)
	Able to drive in a straight line and exceed speed threshold for kinematic initialisation

	Care not to exceed initialisation speed while reversing or turning
Vehicle operation	Device status is monitored
	Avoid extended periods in blocked or obstructed GNSS environments without additional aiding sources such as a wheel speed

Table 28:
Optimal operation checks

Appendix B – Using the orientation measurements

This section has been provided to clarify the definitions of heading, pitch and roll that are output by the RT.

The RT uses quaternions internally to avoid the problems of singularities and to minimise numerical drift on the attitude integration. Euler angles are used to output the heading, pitch and roll, and these have singularities at two orientations. The RT has rules to avoid problems when operating close to the singularities; if you regenerate the rotation matrices given below then they will be correct.

The Euler angles output are three consecutive rotations (first heading, then pitch and finally roll) that transform a vector measured in the navigation co-ordinate frame to the body co-ordinate frame. The navigation co-ordinate frame is the orientation on the earth at your current location with axes of north, east and down.

If V_n is vector V measured in the navigation co-ordinate frame and V_b is the same vector measured in the body co-ordinate frame the two vectors are related by:

$V_n = C_{bn} \cdot V_b$

$$V_n = \begin{bmatrix} \cos\psi & \sin\psi & 0 \\ \sin\psi & \cos\psi & 0 \\ 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\phi & -\sin\phi \\ 0 & \sin\phi & \cos\phi \end{bmatrix} \cdot V_b$$

where:

ψ is the heading angle;

θ is the pitch angle; and

ϕ is the roll angle.

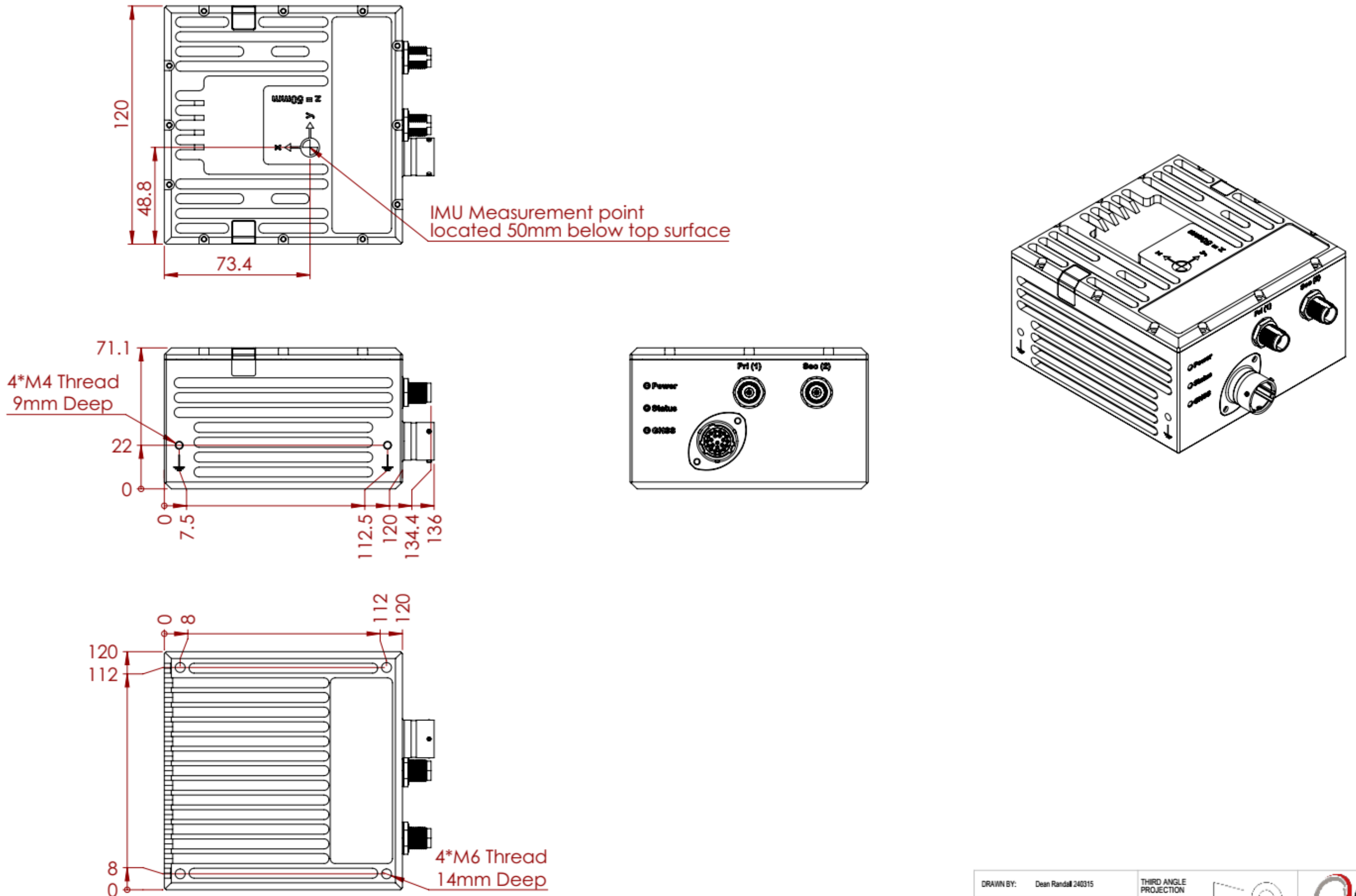
Remember: heading, pitch and roll are usually output in degrees, but the functions *sin* and *cos* require these values in radians.

Appendix C – Drawing list

Table 29 lists the available drawings that describe components of the RT system. Many of these drawings are attached to the back of this manual. Note that the 'x' following a drawing number is the revision code for the part. If you require a drawing, or different revision of a drawing, that is not here then contact OXTS.

Revision	Comments
14A0102	RT3000 T DO-160 V4 outer dimensions
99C0044	RT3000 T DO-160 V4 reference cable
14C0236	CAN to Serial convertor cable

Table 29:
List of available drawings



DRAWN BY:	Dean Randall 240315
CHECKED BY:	Tom Bailey 240316
APPROVED BY:	Andrew Coyle 240319

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THIRD ANGLE PROJECTION
SHEET 1 OF 1
DIMENSIONS: mm

NOT TO SCALE

DRAWING No : 14A0102

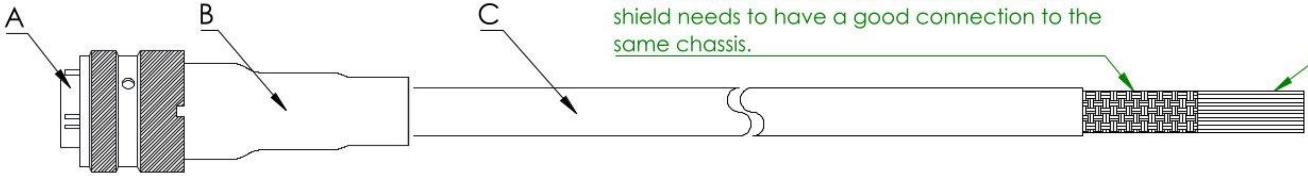
Oxford Technical Solutions Ltd
Park Farm Barns, Middleton Stoney
Oxfordshire, OX25 4AL

TITLE: RT3000 T DO-160 v4 Dimensions

Reference	Part	Model Numbers	Comments
A	Main I/O user cable connector	TE AS612-35PN or Souriau 8STA61235SA	This connector requires a crimping tool, please see datasheet for more information. A good connection between the connector and braided cable shield on the cable is needed. Please see Pictures 1and 2 below.
B	Heatshrink - TE Connectivity	202K111-25/225-CS-2065-0	Please follow datasheet instructions for assembly.
C	Recommended Cable - Alpha wire	6369 SL005	

NOTE:
Braided cable shield needs have a good connection to the same "earth" the unit is mounted to. For example, if the unit is mounted to the chassis of a vehicle this braided cable shield needs to have a good connection to the same chassis.

NOTE:
No connectors or cable length specified. Up to the integrator or client.



Picture 1
Removed paint from the connector to ensure good connection with the braided earth from the cable.

Picture 2
Connection between connector and cable. The braided shield of the cable was pulled over the connector and tied with wire and solder.

Deutsch connector - TE AS612-35PN / 8STA61235SA

Pin Number	Function	Comments
1	PSU +V	10 - 48 V (10 W)
2	PSU -V	
8	Trigger 1	
9	CANH / RS232 Tx	Twisted pair with Pin 10 - CANL / RS232 Rx
10	CANL / RS232 Rx	Twisted pair with Pin 9 - CANH / RS232 Tx
11	PPS	
12	Digital Ground	
13	ETX-	Twisted pair with Pin 20 - ETX+
14	ERX-	Twisted pair with Pin 21 - ERX+
16	Digital Ground	
17	Digital Ground	
18	Digital Ground	
20	ETX+	Twisted pair with Pin 13 - ETX-
21	ERX+	Twisted pair with Pin 14 - ERX-

DATE: 12/03/2024	OXTS Inertial+GNSS Oxford Technical Solutions Ltd Park Farm Barns, Middleton Stoney Oxfordshire, OX25 4AL
DRAWN BY: Dean Randall	
CHECKED BY: Euthymios Kappos	
APPROVED BY: Antony McDermott	
DO160 reference cable	DRAWING No : 99C0044
DIMENSIONS: mm DRAWING NOT TO SCALE SHEET 1 OF 1	DRAWING REVISION: A

Connector	Type	Mfr. Part No.
J1	Socket DB-9 and shell w/ couplings	RS 765-9555
J2	Pin DB-9 w/ couplings	RS 473-880

J1 Pin No.	Signal	Terminate to
1	-	-
2	CAN-	J2.2
3	GND	J2.5
4	-	-
5	-	-
6	GND	J1.3
7	CAN+	J2.3
8	-	-
9	-	-

J2 Pin No.	Signal	Terminate to
1	-	-
2	Rx	J1.2
3	Tx	J1.7
4	-	-
5	GND	J1.3
6	-	-
7	-	-
8	-	-
9	-	-

NOTE:
Please populate all unused pins with empty crimps.

Discard thumb screws from J1 back shell, fit two 8mm screwlocks with spring washer and nut through D-sub mounting holes.

Use UNC4-40 Thread for the D-type connectors.

Cable - 3 cores 7/0.12 (or higher) to be used.

Sleeve all soldered joints.

DATE: 231129	Oxford Technical Solutions Ltd Park Farm Barns, Middleton Stoney Oxfordshire, OX25 4AL
DRAWN BY: Dean Randall	
CHECKED BY: Tom Bailey	
APPROVED BY: Sam Whelan	
TITLE: CAN to Serial	DRAWING No : 14C0236
DIMENSIONS: mm DRAWING NOT TO SCALE SHEET 1 OF 1	DRAWING REVISION: A

Revision history

Revision	Comments
240405	First release
241024	Addition of UCOM and CAN wheel speed sections and added reference to hotstart feature
250507	Manual moved into new formatting

Table 30:
Revision history

Blank for user notes

Connect with us today

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