

RT_{v2}
**GNSS-aided
inertial
measurement
systems**



User Manual

Covers all RT models

Confidently. Accurately.

Legal Notice

Information furnished is believed to be accurate and reliable. However, Oxford Technical Solutions Limited assumes no responsibility for the consequences of use of such information nor for any infringement of patents or other rights of third parties which may result from its use. No license is granted by implication or otherwise under any patent or patent rights of Oxford Technical Solutions Limited. Specifications mentioned in this publication are subject to change without notice and do not represent a commitment on the part of Oxford Technical Solutions Limited. This publication supersedes and replaces all information previously supplied. Oxford Technical Solutions Limited products are not authorised for use as critical components in life support devices or systems without express written approval of Oxford Technical Solutions Limited.

All brand names are trademarks of their respective holders.

The software is provided by the copyright holders and contributors “as is” and any express or implied warranties, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose are disclaimed. In no event shall the copyright holders or contributors be liable for any direct, indirect, incidental, special, exemplary, or consequential damages (including, but not limited to, procurement of substitute goods or services; loss of use, data, or profits; or business interruption) however caused and on any theory of liability, whether in contract, strict liability, or tort (including negligence or otherwise) arising in any way out of the use of this software, even if advised of the possibility of such damage.

Environmental protection

Waste electrical products should not be disposed of with household waste. Please recycle where facilities exist. Check with your Local Authority or OxTS representative for recycling advice.



Copyright Notice

The software is protected by copyright of Oxford Technical Solutions at oxts.com.

© 2008–2019, Oxford Technical Solutions Ltd.

Unauthorised use, copying or distribution is not permitted.

The software also includes software in binary form from:

Xiph.Org Foundation at xiph.org.

Copyright (c) 2002, Xiph.org Foundation

QNX at qnx.com.

© 1982–2008, QNX Software Systems Ltd. All rights reserved.

Botan at botan.randombit.net.

Copyright (C) 1999–2013,2014,2015,2016 Jack Lloyd

2001 Peter J Jones

2004–2007 Justin Karneges

2004 Vaclav Ovsik

2005 Matthew Gregan

2005–2006 Matt Johnston

2006 Luca Piccarreta

2007 Yves Jerschow

2007,2008 FlexSecure GmbH

2007,2008 Technische Universitat Darmstadt

2007,2008,2010,2014 Falko Strenzke

2007,2008 Martin Doering

2007 Manuel Hartl

2007 Christoph Ludwig

2007 Patrick Sona

2008 Copyright Projet SECRET, INRIA, Rocquencourt

2008 Bhaskar Biswas and Nicolas Sendrier

2008 Google Inc.

2010 Olivier de Gaalon

2012 Vojtech Kral

2012,2014 Markus Wanner

2013 Joel Low

2014 cryptosource GmbH

2014 Andrew Moon

2015 Daniel Seither (Kullo GmbH)

2015 Simon Warta (Kullo GmbH)

2015 Matej Kenda (TopIT d.o.o.)

2015 RenÅ© Korthaus

2015 Daniel Neus

2015 Uri Blumenthal

All rights reserved.

TI at software-dl.ti.com.
Copyright (c) 2002–2015, Texas Instruments Incorporated
All rights reserved.

Any redistribution of the software must reproduce the above copyright notices, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution.

None of the names of the Xiph.org Foundation, QNX, Botan, or Texas Instruments Incorporated, nor the names of their contributors may be used to endorse or promote this product or products using this software without specific prior written permission.

Revision

Document Revision: 190130 (*See Revision History for detailed information*).

Contact Details

Oxford Technical Solutions Limited
77 Heyford Park
Upper Heyford
Oxfordshire
OX25 5HD
United Kingdom

Tel: +44 (0) 1869 814 253

Web: <http://www.oxts.com>

Email: support@oxts.com

Warranty

Oxford Technical Solutions Limited warrants its products to be free of defects in materials and workmanship, subject to the conditions set forth below, for a period of one year from the Date of Sale.

‘Date of Sale’ shall mean the date of the Oxford Technical Solutions Limited invoice issued on delivery of the product. The responsibility of Oxford Technical Solutions Limited 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 Oxford Technical Solutions Limited personnel or by personnel expressly authorised by Oxford Technical Solutions Limited for this purpose.

In no event will Oxford Technical Solutions Limited be liable for any indirect, incidental, special or consequential damages whether through tort, contract or otherwise. This warranty is expressly in lieu of all other warranties, expressed or implied, including without limitation the implied warranties of merchantability or fitness for a particular purpose. The foregoing states the entire liability of Oxford Technical Solutions Limited with respect to the products herein.

Table of contents

Introduction	10
Easy operation	11
Self-correcting	11
Interchangeable	11
Advanced processing	11
Related documents	12
RT product family	13
Single antenna	13
Dual antenna	13
GLONASS	14
250 Hz	14
Satellite differential corrections	14
Scope of delivery	16
RT2000 system components	16
RT3000 system components	17
RT4000 system components	18
Specification	20
Common specifications	24
Notes on specifications	24
Heading accuracy	25
Environmental protection	25
GNSS antenna operating temperature	25
Safety information	25
Export control classification number	25
Conformance notices	27
Regulator testing standards	27
Software installation	29
Hardware installation	31
RT orientation and alignment	31

Antenna placement and orientation	31
Operation	33
Front panel layout	33
LED definitions	35
Co-ordinate frame conventions	37
IMU frame	37
OxTS NED navigation frame	39
ISO 8855 ENU earth-fixed system	39
OxTS horizontal frame	40
ISO 8855 intermediate system	41
OxTS Vehicle frame	42
ISO 8855 vehicle system	43
Ethernet configuration	43
Connection details	45
Dual antenna systems	46
Multipath effects on dual antenna systems	48
Inputs and outputs	49
Digital inputs and outputs	49
1PPS output	50
Event input	50
Wheel speed input	51
Wheel speed output	51
IMU sync output pulse	51
Reverse polarity protection	51
Configuring the RT	53
Overview	53
Selecting the operating language	54
Navigating through NAVconfig	54
Product selection	54
Reading configuration	55
GNSS Selection	57
Orientation	57
Get improved settings	59
Primary antenna	61
Secondary antenna	63
Advanced slip	64

Options	66
Vehicle starts	67
Vibration	67
GNSS environment	68
Differential correction	68
SBAS	70
DGNSS service	70
CAN	71
Heading lock	77
Garage mode	78
Initialisation speed	78
Displace output	78
Distance output	79
Analogue output	79
Acceleration filter	80
Wheel speed input	81
Local co-ordinates	83
Serial 1 output	84
Ethernet output	86
Steering robot IP	88
Output smoothing	88
Slip points	89
GNSS control	90
Surface tilt	92
Coordinate system	93
Advanced	94
Committing the configuration to the RT	95
Saving the configuration and finishing	96
Setting up the base station	97
Using the RT-Base S	97
Initialisation process	98
Real-time outputs	98
Warm-up period	99
Post-processing data	103
Laboratory testing	104
Accelerometer test procedure	104
Gyro test procedure	104
Testing the internal GNSS and other circuitry	106

Using the orientation measurements	107
Operating principles	108
Internal components	108
Strapdown navigator	109
Kalman filter	110
CAN messages and signals	112
Termination resistor	112
CAN-DB file	112
CAN bus messages	112
Table heading definitions	114
Signals	115
Revision history	131
Drawing list	132

Introduction

The RT family of inertial navigation system (INS) devices, are instruments for making precision measurements of motion in real-time.

There are three divisions within the RT family; RT2000s, RT3000s and RT4000s—and each division contains a number of different models. The difference between the divisions is described in more detail in the “RT product family” section on page 13.

From June 2014, all products in the RT family—except RT2500s, will be built to a new specification called v2. These v2 devices can achieve 1 cm RTK accuracy in both real-time and post-process, instead of the 2 cm accuracy of previous models. While the existing model names have been kept for continuity, a v2 suffix denotes devices built to the new specification. The only significant change is for customers using a DGNSS subscription service, as v2 devices only support TerraStar, not OmniSTAR.

To obtain high-precision measurements, the RT uses mathematical algorithms developed for use in fighter aircraft navigation systems. An inertial sensor block with three accelerometers and three gyros (angular rate sensors) is used to compute all the outputs. A WGS 84 modelled strapdown navigator algorithm compensates for earth curvature, rotation and Coriolis accelerations, while measurements from high-grade kinematic GNSS receivers update the position and velocity navigated by the inertial sensors. This innovative approach gives the RT several distinct advantages over systems that only use GNSS:

- The RT has a high (100 Hz or 250 Hz) update rate and a wide bandwidth.
- The outputs are available with very low, 3.5 ms latency.
- All outputs remain available continuously during GNSS blackouts when, for example, the vehicle drives under a bridge.
- The RT recognises jumps in GNSS position and ignores them.
- The position and velocity measurements the GNSS makes are smoothed to reduce the high-frequency noise.
- The RT makes many measurements GNSS cannot, for example acceleration, angular rate, heading, pitch and roll.

An RT system processes data in real-time. The real-time results are output via an RS232 serial port, over 10/100 Base-T Ethernet using a UDP broadcast and on CAN bus. Outputs are time-stamped and refer to GPS time; a 1PPS timing sync can be used to give very 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 unit, downloaded using “ftp”, processed on a PC and viewed using the customer’s software.

Easy operation

There is minimal configuration required to use the system. The configuration can be saved to the RT so it can operate autonomously without user intervention. A lot of work has been put into the initialisation of the inertial algorithms so the RT can reliably start to navigate in the vast majority of situations.

The single unit contains inertial sensors, GNSS receiver, data storage and CPU. One or two antennas need to be mounted outside the vehicle where they have a clear view of the sky. A 10–25 V dc power supply can be obtained from most vehicles. A laptop computer allows real-time viewing of the results.

Self-correcting

Unlike conventional inertial navigation systems, the RT uses GNSS to correct all its measurements. GNSS makes measurements of position, velocity and (for dual antenna systems) heading. Using these measurements, the RT is able to keep other quantities, such as roll and pitch accurate. Tight coupling of the GNSS and inertial measurements means the raw GNSS data can also be used. There is no drift from the RT in any of the measurements while GNSS is present.

Interchangeable

All RT products have identical output capabilities and are interchangeable. The serial port, Ethernet and CAN bus are the same on all the systems including the data formats. The connectors on the RT2000 products are different but can usually be interfaced.

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

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; all of which can be downloaded from the support website (<https://support.oxts.com>).

Table 1. Supplementary manuals

Manual	Description
NAVdisplay Manual	NAVdisplay can be used to view INS measurements on a PC in real-time or by replaying existing data files. It provides a useful method of checking the status of your INS
NAVgraph Manual	NAVgraph is used to plot, analyse and export measurement data once processed
NCOM Manual	NCOM is a propriety format developed by OxTS that is used in our products. The NCOM manual provides information about decoding and using the NCOM format
NCOM C Code Drivers	This ZIP file contains a collection of C functions that can be used to decode the binary protocols from the INS
NMEA 0183 Description	NMEA description manual for the NMEA outputs found on our INS products
NAVsolve Manual	NAVsolve can download data from an INS and process it using a number different technologies to extract the best possible accuracy. DGNSS corrections can also be applied
RT-Base S	Explains how to set-up and use the RT-Base S base station to achieve RTK integer operation mode
RT Quick-start guide	Short guide to quickly set-up and start using an RT.

RT product family

The RT product family is split into three divisions—all based on similar technology, and within each division, there are a number of models serving different accuracy requirements.

The RT family is split into the following divisions:

- **RT2000s**
Fitted with lower-cost GNSS receivers. Available in single and dual antenna models and can be GLONASS enabled. 100 Hz and 250 Hz versions.
- **RT3000s**
Survey grade GNSS receivers provide high-precision position and velocity measurements even in high multipath environments. Can be GLONASS enabled. Single and dual antenna models are available. Update rates up to 100 Hz.
- **RT4000s**
These products are identical to the RT3000 series, but have an update rate of up to 250 Hz.

The models contained within each division are listed in the “Specification” section on page 20.

Single antenna

An advanced algorithm in the RT software means most road vehicle customers are able to use a single antenna system. The Heading lock and Advanced slip features allow RT devices to maintain an accurate heading while stationary and while driving with low vehicle dynamics.

Dual antenna

Dual antenna systems provide high accuracy heading information and almost constant heading performance under all conditions. Single antenna systems can experience reduced heading accuracy on aircraft, boats or in low speed land vehicles.

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 after five 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.

GLONASS

GLONASS capability adds the ability to utilise the Russian satellite constellation GLONASS as well as the American constellation GPS. This means an extra 24 satellites are available for the RT to lock on to and obtain position and velocity updates from.

In open sky conditions, the addition of GLONASS capability is of little benefit as the GPS signals 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, GPS and GLONASS 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.

Note: at this time, gx/ix processing does not support GLONASS. To take full advantage of GLONASS capability, standard processing must be used.

250 Hz

1. All product divisions have the option of coming with a 250 Hz version of the inertial measurement unit (IMU). The IMUs used in 100 Hz and 250 Hz products are essentially the same, both with a fundamental sampling frequency of 1000 Hz. The difference is the 3D filter used to integrate the accelerations and angular rates has a smaller time step in the 250 Hz models, allowing a higher update rate.
2. However, because of the smaller time step, measurements that depend on angular acceleration are typically noisier on the 250 Hz products. The noise can be managed by filtering the data to limit the bandwidth.

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 subscription service. RT systems that have TerraStar capability include the necessary hardware to receive corrections. It is necessary to pay a license fee to activate

these corrections. Capable RT system will use the TERRASTAR-D service which can provide better than 10 cm position accuracy. TerraStar is available on all continents. Marine versions also exist.

For more information, see TerraStar's web site: <http://www.terrestar.net/>.

Scope of delivery

RT products are supplied complete with cables, GNSS antennas, software and manuals. As standard, magnetic mount antennas are provided but other antenna types are available; please enquire for more details.

RT2000 system components

Table 2 lists all items that are delivered with each RT2000 model.

Table 2. Summary of RT2000 system components

Description	RT2500 RT2500-250	RT2502 RT2502-250	RT2002 RT2002G RT2002-250 RT2002G-250
RT2000 system unit	✓	✓	✓
Power cable 77C0002B	✓	✓	✓
GNSS antenna AT575-70	✓	× 2	
GNSS antenna G5Ant-2AMNS1			✓
5 m GNSS antenna cable			✓
Radio modem cable 14C0062B			✓
Ethernet cable (cross-over)	✓	✓	✓
USB memory stick with software	✓	✓	✓
User manual	✓	✓	✓
Calibration certificate	✓	✓	✓

The RT2000 product requires the correct differential corrections in order to work to full specification. Differential corrections can be supplied by an RT-Base, GPS-Base, NTRIP or other suitable differential correction source.

In addition to the components supplied, the user will require a laptop computer or other logging system.

RT3000 system components

Table 3 lists all the items that are delivered with each RT3000 model.

Table 3. Summary of RT3000 system components

Description	RT3100	RT3102	RT3100G	RT3102G	RT3002 RT3002G	RT3003 RT3003G
RT3000 system unit	✓	✓	✓	✓	✓	✓
User cable (14C0038B)	✓	✓	✓	✓	✓	✓
GNSS antenna AT575-70	✓	× 2				
GNSS antenna G5Ant-2AMNS1			✓	× 2	✓	× 2
5 m GNSS antenna cable			✓	× 2	✓	× 2
USB memory stick (manual & software)	✓	✓	✓	✓	✓	✓
Ethernet cable	✓	✓	✓	✓	✓	✓
Ethernet crossover coupler	✓	✓	✓	✓	✓	✓
User manual	✓	✓	✓	✓	✓	✓
Calibration certificate	✓	✓	✓	✓	✓	✓

The RT3000 products require the correct differential corrections in order to work to their full specification. Differential corrections can be supplied by an RT-Base S, GPS-Base, NTRIP or other suitable differential correction source.

In addition to the components supplied the user will require a laptop computer or alternative logging system.

RT4000 system components

Table 4 lists all the items that are delivered with each RT4000 model.

Table 4. Summary of RT4000 system components

Description	RT4100	RT4102	RT4100G	RT4102G	RT4002 RT4002G	RT4003 RT4003G
RT4000 system unit	✓	✓	✓	✓	✓	✓
User cable (14C0038B)	✓	✓	✓	✓	✓	✓
GNSS antenna AT575-70	✓	× 2				
GNSS antenna G5Ant-2AMNS1			✓	× 2	✓	× 2
GNSS antenna cable (5 m)			✓	× 2	✓	× 2
USB memory stick (manual & software)	✓	✓	✓	✓	✓	✓
Ethernet cable	✓	✓	✓	✓	✓	✓
Ethernet crossover coupler	✓	✓	✓	✓	✓	✓
User manual	✓	✓	✓	✓	✓	✓
Calibration certificate	✓	✓	✓	✓	✓	✓

The RT4000 products require the correct differential corrections in order to work to their full specification. Differential corrections can be supplied by an RT-Base, GPS-Base, NTRIP or other suitable differential correction source.

In addition to the components supplied the user will also require a laptop computer or alternative logging system.

Figure 1. Typical RT system and cables in transit case.



Specification

Specifications for RT products can be found in Table 5, Table 6, and Table 7. These specifications are listed for operation of the system under the following conditions:

- After a warm-up period of 15 minutes' continuous operation.
- 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 distance from the RT measurement point to the primary GNSS antenna must be known by the system to a precision of five millimetres or better. The vibration of the system relative to the vehicle cannot allow this to change by more than five millimetres. The system will estimate this value itself in dynamic conditions.
- For dual antenna systems, the system must know the relative orientation of the two antennas to 0.05° or better. The system will estimate this value itself under dynamic conditions.
- For single antenna systems, the heading accuracy is only achieved under dynamic conditions. Under benign conditions, such as motorway driving, the performance will degrade. The performance is undefined when stationary for prolonged periods of time.

Optionally, extended measurement ranges covering 30 g acceleration and 300°/s angular rate may be requested. The specification using the extended measurement range sensors can be marginally worse than those listed here.

Table 5. RT2000 performance specification

Parameter	RT2500 / RT2500– 250	RT2502 / RT2502–250	RT2002 v2/ RT2002–250 v2	RT2002G v2 / RT2002G–250 v2
Positioning	GPS L1	GPS L1	GPS L1, L2	GPS L1, L2 GLONASS L1, L2

Position accuracy ¹	3.0 m CEP SPS 2.0 m CEP SBAS 0.5 m CEP DGPS	3.0 m CEP SPS 2.0 m CEP SBAS 0.5 m CEP DGPS	1.5 m CEP SPS 0.6 m CEP SBAS 0.4 m CEP DGPS 0.1 m CEP PPP 0.2 m 1 σ L1 0.01 m 1 σ L1/L2	1.5 m CEP SPS 0.6 m CEP SBAS 0.4 m CEP DGPS 0.1 m CEP PPP 0.2 m 1 σ L1 0.01 m 1 σ L1/L2
Velocity accuracy	0.1 km/h RMS	0.1 km/h RMS	0.1 km/h RMS	0.1 km/h RMS
Roll/pitch	0.05° 1 σ	0.05° 1 σ	0.05° 1 σ	0.05° 1 σ
Heading	0.2° 1 σ	0.15° 1 σ ²	0.1° 1 σ	0.1° 1 σ
Acceleration				
– Bias stability	5 μ g	5 μ g	5 μ g	5 μ g
– Linearity	0.01% 1 σ	0.01% 1 σ	0.01%	0.01%
– Scale factor	0.1% 1 σ	0.1% 1 σ	0.1% 1 σ	0.1% 1 σ
– Range	100 m/s ²	100 m/s ²	100 m/s ²	100 m/s ²
Angular rate				
– Bias	0.01°/s 1 σ	0.01°/s 1 σ	0.01°/s 1 σ	0.01°/s 1 σ
– Scale factor	0.1% 1 σ	0.1% 1 σ	0.1% 1 σ	0.1% 1 σ
– Range	100°/s	100°/s	100°/s	100°/s
Track (at 50 km/h)	0.15° 1 σ	0.15° 1 σ	0.1° 1 σ	0.1° 1 σ
Slip angle (at 50 km/h)	0.3° 1 σ	0.25° 1 σ	0.2° 1 σ	0.2° 1 σ
Lateral velocity	0.5% 1 σ	0.4% 1 σ	0.2% 1 σ	0.2% 1 σ
Update rate	100 Hz / 250 Hz	100 Hz / 250 Hz	100 Hz / 250 Hz	100 Hz / 250 Hz
Input voltage ³	10–25 V dc	10–25 V dc	10–25 V dc	10–25 V dc
Power consumption	15 W	15 W	15 W	15 W
Dimensions	234 × 120 × 76 mm	234 × 120 × 76 mm	234 × 120 × 76 mm	234 × 120 × 76 mm
Mass	2.3 kg	2.3 kg	2.4 kg	2.4 kg
Dual antenna	No	Yes	No	No

¹ To achieve specification, relevant differential corrections from a base station, NTRIP or TerraStar subscription are required. The RTK accuracies are based on v2 products.

² With two-meter antenna separation. Wider separation will improve accuracy (supports up to five-meter separation).

³ 10-18 V dc voltage levels apply to units with the 14P0019 front panel fitted which was used in manufacture prior to June 2014.

Table 6. RT3000 / RT4000 v2 single antenna performance specification

Parameter	RT3100 v2/ RT4100 v2	RT3100G v2 / RT4100G v2	RT3002 v2 / RT4002 v2	RT3002G v2 / RT4002G v2
Positioning	GPS L1	GPS L1 GLONASS L1	GPS L1, L2	GPS L1, L2 GLONASS L1, L2
Position accuracy ¹	1.8 m CEP SPS 0.6 m CEP SBAS 0.4 m CEP DGPS	1.8 m CEP SPS 0.6 m CEP SBAS 0.4 m CEP DGPS	1.5 m CEP SPS 0.6 m CEP SBAS 0.4 m CEP DGPS 0.1 m CEP PPP 0.2 m 1 σ L1 0.01 m 1 σ L1/L2	1.5 m CEP SPS 0.6 m CEP SBAS 0.4 m CEP DGPS 0.1 m CEP PPP 0.2 m 1 σ L1 0.01 m 1 σ L1/L2
Velocity accuracy	0.1 km/h RMS	0.1 km/h RMS	0.05 km/h RMS	0.05 km/h RMS
Roll/pitch	0.05° 1 σ	0.05° 1 σ	0.03° 1 σ	0.03° 1 σ
Heading	0.1° 1 σ	0.1° 1 σ	0.1° 1 σ	0.1° 1 σ
Acceleration				
– Bias stability	5 μ g 1 σ	5 μ g 1 σ	5 μ g 1 σ	5 μ g 1 σ
– Linearity	0.01% 1 σ	0.01% 1 σ	0.01% 1 σ	0.01% 1 σ
– Scale factor	0.1% 1 σ	0.1% 1 σ	0.1% 1 σ	0.1% 1 σ
– Range	100 m/s ²	100 m/s ²	100 m/s ²	100 m/s ²
Angular rate				
– Bias	0.01°/s 1 σ	0.01°/s 1 σ	0.01°/s 1 σ	0.01°/s 1 σ
– Scale factor	0.1% 1 σ	0.1% 1 σ	0.1% 1 σ	0.1% 1 σ
– Range	100°/s	100°/s	100°/s	100°/s
Track (at 50 km/h)	0.1° 1 σ	0.1° 1 σ	0.07° 1 σ	0.07° 1 σ
Slip angle (at 50 km/h)	0.2° 1 σ	0.2° 1 σ	0.15° 1 σ	0.15° 1 σ
Lateral velocity	0.2% 1 σ	0.2% 1 σ	0.2% 1 σ	0.2% 1 σ
Update rate	100 Hz / 250 Hz	100 Hz / 250 Hz	100 Hz / 250 Hz	100 Hz / 250 Hz
Input voltage ²	10–25 V dc	10–25 V dc	10–25 V dc	10–25 V dc
Power consumption	15 W	15 W	15 W	15 W
Dimensions	234 × 120 × 80 mm	234 × 120 × 80 mm	234 × 120 × 80 mm	234 × 120 × 80 mm
Mass	2.2 kg	2.2 kg	2.2 kg	2.2 kg

¹ To achieve specification, relevant differential corrections from a base station, NTRIP or TerraStar subscription are required. The RTK accuracies are based on v2 products.

² 10-18 V dc voltage levels apply to units with the 14P009 front panel fitted, which was used prior to December 2011.

Table 7. RT3000 / RT4000 v2 dual antenna performance specification

Product	RT3102 v2/ RT4102 v2	RT3102G v2/ RT4102G v2	RT3003 v2 / RT4003 v2	RT3003G v2 / RT4003G v2
Positioning	GPS L1	GPS L1 GLONASS L1	GPS L1, L2	GPS L1, L2 GLONASS L1, L2
Position accuracy ¹	1.8 m CEP SPS 0.6 m CEP SBAS 0.4 m CEP DGPS	1.8 m CEP SPS 0.6 m CEP SBAS 0.4 m CEP DGPS	1.5 m CEP SPS 0.6 m CEP SBAS 0.4 m CEP DGPS 0.1 m CEP PPP 0.2 m 1σ L1 0.01 m 1σ L1/L2	1.5 m CEP SPS 0.6 m CEP SBAS 0.4 m CEP DGPS 0.1 m CEP PPP 0.2 m 1σ L1 0.01 m 1σ L1/L2
Velocity accuracy	0.1 km/h RMS	0.1 km/h RMS	0.05 km/h RMS	0.05 km/h RMS
Acceleration				
– Bias stability	5 μg 1σ	5 μg 1σ	5 μg 1σ	5 μg 1σ
– Linearity	0.01% 1σ	0.01% 1σ	0.01% 1σ	0.01% 1σ
– Scale factor	0.1% 1σ	0.1% 1σ	0.1% 1σ	0.1% 1σ
– Range	100 m/s ²	100 m/s ²	100 m/s ²	100 m/s ²
Roll/pitch	0.05° 1σ	0.05° 1σ	0.03° 1σ	0.03° 1σ
Heading ²	0.05° RMS	0.05° RMS	0.05° RMS	0.05° RMS
Angular rate				
– Bias	0.01°/s 1σ	0.01°/s 1σ	0.01°/s 1σ	0.01°/s 1σ
– Scale factor	0.1% 1σ	0.1% 1σ	0.1% 1σ	0.1% 1σ
– Range	100°/s	100°/s	100°/s	100°/s
Track (at 50 km/h)	0.1° 1σ	0.1° 1σ	0.07° 1σ	0.07° 1σ
Slip angle (at 50 km/h)	0.2° 1σ	0.2° 1σ	0.15° 1σ	0.15° 1σ
Lateral velocity	0.2% 1σ	0.2% 1σ	0.2% 1σ	0.2% 1σ
Update rate	100 Hz / 250 Hz	100 Hz / 250 Hz	100 Hz / 250 Hz	100 Hz / 250 Hz
Input voltage ³	10–25 V dc	10–25 V dc	10–25 V dc	10–25 V dc
Power consumption	20 W	20 W	20 W	20 W

Dimensions	234 × 120 × 80 mm	234 × 120 × 80 mm	234 × 120 × 80 mm	234 × 120 × 80 mm
Mass	2.4 kg	2.4 kg	2.4 kg	2.4 kg

¹ To achieve specification, relevant differential corrections from a base station, NTRIP or TerraStar subscription are required. The RTK accuracies are based on v2 products.

² Accuracy is achieved using a four metre antenna separation (supports up to five metre separation).

³ 10–18 V dc voltage levels apply to units with the 14P009 front panel fitted which was used in manufacture prior to December 2011.

Common specifications

Table 8. RT common specifications

Parameter	Specification
Calculation latency	3.5 ms
Operating temperature ¹	-10 to 50 °C
Vibration	0.1 g ² /Hz 5–500 Hz
Shock survival	100 g, 11 ms
Internal storage	2 GB

¹ The operating temperature range for the antenna is much wider since it can be mounted outside the vehicle. See specification below.

Notes on specifications

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

For the TerraStar service, at least 30 minutes of open-sky condition may be required before full accuracy is achieved. This service can easily achieve this accuracy in airborne applications.

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.

The accuracy of the product will depend on the operating mode of the GNSS. For example, an RT3002 operating without differential corrections enabled will have the specifications of the RT3100.

Heading accuracy

The heading accuracy that can be achieved by the dual antenna system in the RTs in Table 7 is $0.2^\circ 1\sigma$ per metre of separation in ideal, open sky conditions. The system can provide these accuracies in static and dynamic conditions. A four metre separation is required to reach the accuracy listed in Table 7. The maximum recommended separation is five metre, at which it may be possible to achieve better than accuracy than that listed in Table 7 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 6 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.

Environmental protection

The RT3000 and RT4000 products are rated to IP65. To achieve IP65 it is necessary to have connectors fitted to both TNC antenna connectors and to use self-amalgamating tape over the TNC connectors.

The RT2000 products have no environmental protection rating.

GNSS antenna operating temperature

The GNSS antennas have a much wider operating temperature range, from -55°C to 85°C , allowing them to be used on the outside of vehicles.

Safety information

RT2000 products have been tested to safety standard EN60950-1:2006 and A11:2009. These safety standards will only apply when the RT2000 is used with the cables supplied or with the RT-UPS.

Please note: if the equipment is used in a manner not specified by OXTS, the protection provided by the equipment may be impaired.

Export control classification number

Export control regulations change, and so the classification number of the RT may also change. The information presented here was correct when the manual was published. RT products can fall under two different export control categories depending on the type of accelerometer fitted internally. The type of accelerometer does not affect the

specification of the product, only the export control classification number (ECCN). Table 9 lists the ECCN for the products.

Table 9. ECCN for RT products

Product	Serial number	ECCN
RT2000	1–1422	7A003d
RT2000	>=1423	Either 7A003d or 7A103a1, see invoice or delivery note or contact support at OxTS. Some products will have codes that relate to export control on their labels. EXCT-1—7A003d EXCT-2—7A103a1
RT3000, RT4000	1–799	7A003d
RT3000, RT4000	>=800	7A103a1 or 7A003d, see invoice or delivery note or contact support at OxTS.

Conformance notices

The RT complies with the radiated emission limits for 47 CFR 15.109:2010 class A of Part 15 subpart B of the FCC rules, and with the emission and immunity limits for class A of EN 55022. 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 RT 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 L1 GPS frequency (1575 MHz) or L2 1228 MHz.

The RT conforms to the requirements for CE.

Regulator testing standards







- RT2000 products
 - 47 CFR 15.109:2010 class A (radiated emissions).
 - EN 300 440-1:2010-08, test methods 8.3.2 (conducted emissions) and 8.3.3 (radiated emissions).
 - EN 55022 class A according to standard EN 301 489-1:2008 (conducted emissions).
 - EN 6100-4-3 criterion A according to standard EN 301 489-1:2008 (radiated immunity).
 - ISO 7637-2 criterion B, 12 V according to standard EN 301 489-1:2008 (vehicular transients and surges immunity). Older RT systems do not conform to this standard, contact OXTS for further details.
- RT3000/4000 products
 - 47 CFR 15.109:2010 class A (radiated emissions).

- EN 61000-4 criterion A according to standard EN 301 489-1:2008 (-2:2009 electrostatic discharge), (-3:2006+A2:2010 radiated immunity), (-4:2012 electrical fast transients), (-5:2006 voltage surge) and (-6:2009 conducted radio frequency immunity).
- EN 55022:2010 class A according to standard EN 301 489-1:2008 (Radiated electromagnetic emissions) and (conducted emissions).
- EN 55011:2009+A1:2010 class A according to standard EN 301 489-1:2008 (Radiated electromagnetic emissions).

Software installation

Included with every RT is a USB memory stick containing the software package NAVsuite. This package contains a number of programs required to take full advantage of the RT's capabilities. Table 10 lists the contents of NAVsuite.

Table 10. NAVsuite components

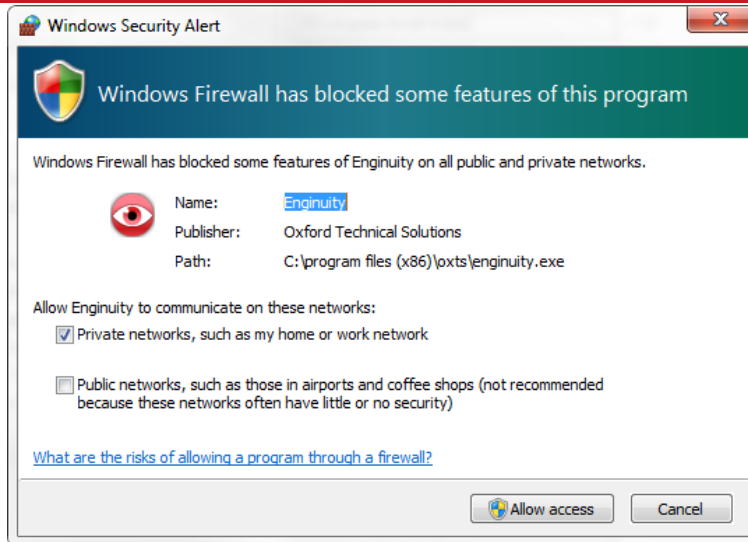
Icon	Software	Description
	NAVdisplay	Used to view real-time data from OxTS products via Ethernet or a serial port. It can also be used to transmit special commands and replay logged data.
	NAVconfig	Used to create, send, and receive configurations from OxTS products. As configurations vary between products there is no manual for NAVconfig. The options relevant to the RT products are covered in this manual on page 49.
	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	This folder contains PDF versions of relevant OxTS manuals. Other manuals can be downloaded from the OxTS website, http://www.oxts.com/support/manuals/ .

To install NAVsuite, insert the USB memory 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

It is essential to install the RT rigidly in the vehicle. The RT should not be able to move or rotate compared to either GNSS antenna, otherwise the performance will be reduced. In most circumstances the RT should be mounted directly to the chassis of the vehicle. If the vehicle experiences high shocks, then vibration mounts may be required.

The RT is compatible with the RT-Strut product from OxTS to provide a quick and secure vehicle mounting solution.

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

RT orientation and alignment

The orientation of the RT in the vehicle is normally specified using three consecutive rotations that rotate the RT to the vehicle's co-ordinate frame. The order of the rotations is heading (z -axis rotation), then pitch (y -axis rotation), then roll (x -axis rotation). The RT co-ordinate conventions are detailed on page 37. It is important to get the order of the rotations correct.

In the default configuration the RT expects its y -axis to be pointing right and its z -axis pointing down relative to the host vehicle. There are times however when installing an RT in the default configuration is not possible, for example when using the RT-Strut. The RT can be mounted at any angle in the vehicle as long as the configuration is described to the RT using NAVconfig. This allows the outputs to be rotated based on the settings entered to transform the measurements to the vehicle frame.

For ease of use it is best to try and mount the RT so its axes are aligned with the vehicle axes. This saves the offsets having to be measured by the user. If the system must be mounted misaligned with the vehicle and the user cannot accurately measure the angle offsets, the RT has some functions to measure these offsets itself. The heading offset can be measured if the vehicle has a non-steered axle. The Advanced slip and Get settings utilities should be used for this (see pages 64 and 59 respectively). Roll and pitch offsets can be measured using the Surface tilt utility in NAVdisplay.

Antenna placement and orientation

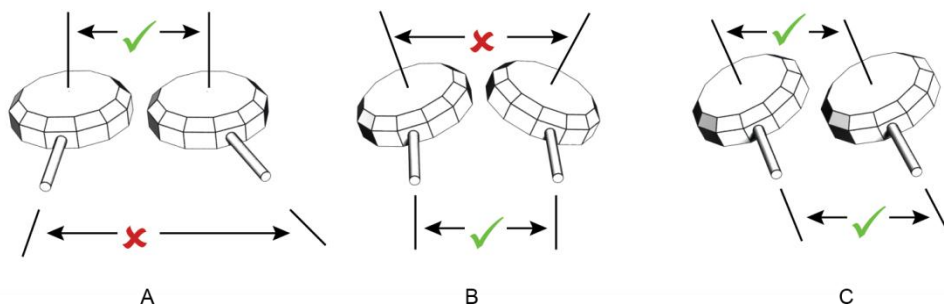
For optimal performance it is essential for the GNSS antenna(s) to be mounted where they have a clear, uninterrupted view of the sky and on a suitable ground plane, such as the roof of a vehicle. For good multipath rejection the antennas must be mounted on a metal surface using the magnetic mounts provided; no additional gap may be used.

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 3. 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. In the default configuration the primary antenna should be at the front of the vehicle and the secondary antenna should be at the rear.

Figure 3. 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 best to mount the two antennas on the top of the vehicle. Although it is possible to mount one on the roof and one on the bonnet (hood), in reality the multipath reflections from the windscreen will degrade the performance of the system.

Multipath affects dual antenna systems on stationary vehicles more than moving vehicles and it can lead to heading errors of more than 0.5° RMS if the antennas are mounted poorly.

It is critical to have the RT mounted securely in the vehicle. If the angle of the RT 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 the testing. (If the RT is shock mounted then the RT mounting will change by more than 0.05° ; this is acceptable, but the hysteresis of the mounting may not exceed 0.05°).

For both single and dual antenna systems it is essential that the supplied GNSS antenna cables are used and not extended, shortened or replaced. This is even more critical for dual antenna systems and the two antenna cables must be of the same specification. Do not, for example, use a 5 m antenna cable for one antenna and a 15 m antenna cable for the other. Do not extend the cable, even using special GNSS signal repeaters that are designed to accurately repeat the GNSS signal. Cable length options are available in 5 m and 15 m lengths.

Operation

The front panel label and LEDs convey some basic information that aid configuration and troubleshooting. Once power is applied, the RT requires no further input from the user to start logging and outputting data.

This section covers some basic information required for operation of the RT.

Front panel layout

Figure 4 and Figure 5 show the layouts of the RT front panels. Table 11 lists the parts of the RT2000 front panel labelled in Figure 4 and Table 12 lists the parts of the RT3000/RT4000 labelled in Figure 5. For single antenna models, the secondary antenna connector is not connected internally.

Figure 4. RT2000 front panel layout

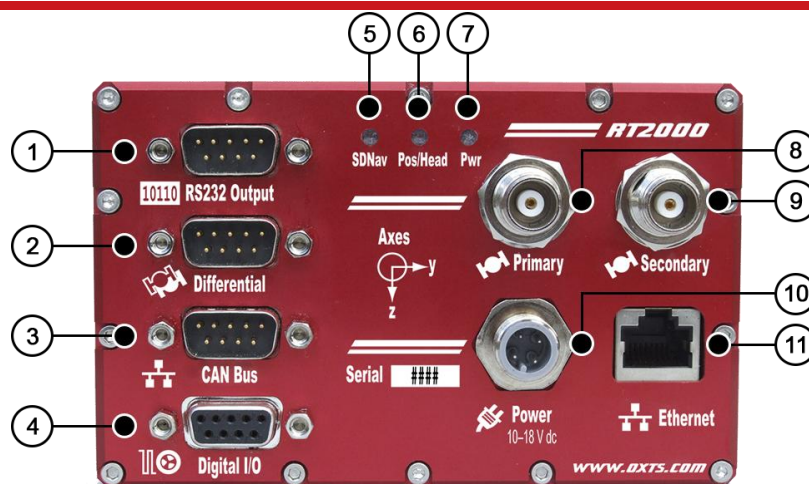


Table 11. RT2000 front panel descriptions

Label no.	Description
1	RS232 serial port
2	Radio port
3	CAN port
4	Digital I/O port
5	SDNav LED
6	Pos/Head LED
7	Pwr LED

8	Primary antenna connector
9	Secondary antenna connector
10	M12 power connector
11	Ethernet port

Figure 5. RT3000/RT4000 front panel layout



Table 12. RT3000/RT4000 front panel descriptions

Label no.	Description
1	SDNav LED
2	Position LED (single antenna systems) Heading LED (dual antenna systems)
3	GPS LED
4	Power LED
5	Primary antenna connector
6	User cable main connector
7	Secondary antenna connector

LED definitions

The front panel of the RTs has some LEDs that give an indication of the internal state of the system and are designed to provide enough feedback so that a laptop does not need to be connected. They can be used for some simple operational checks on the system.

Table 13 and Table 14 give a description of each LED on the RTs. Table 15 to Table 19 list the precise meanings of the states of each LED.

Table 13. RT2000 LED descriptions

Name	Description
SDNav	Strapdown navigator state
Pos/Head	Position solution (single antenna) or heading solution (dual antenna) from GNSS
Pwr	Power and communication

Table 14. RT3000/RT4000 LED descriptions

Name	Description
SDNav	Strapdown navigator state
Position	Position solution (only on single antenna systems)
Heading	GNSS heading solution (only on dual antenna systems)
GPS	Self-test
Power	Power and communication

Table 15. SDNav LED states

Colour	Description
Off	The operating system has not yet booted and the program is not yet running. This occurs at start-up.
Red-green flash	The RT is asleep. Contact OxTS support for further information.
Red flash	The operating system has booted and the program is running. 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 (the 1PPS output will now be valid). The strapdown navigator is ready to initialise. If the vehicle is travelling faster than the value set for “Initialisation speed” during configuration, then the strapdown navigator will initialise and the system will become active. On dual antenna systems the system will initialise once the GNSS receiver has determined heading, even if the vehicle is stationary or moving slowly.
Orange	The strapdown navigator has initialised and data is being output, but the system is not real-time yet. It takes 10 s for the system to become real-time after start up.
Green	The strapdown navigator is running and the system is real-time.

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

Table 16. Pos/Head (single antenna systems) or Position LED states

Colour	Description
Off	The GNSS receiver is not sending data.
Red flash	(Start-up only). The GNSS receiver is sending data to the RT. This is an operational check for the GNSS receiver.
Red	The GNSS receiver has a standard position solution (SPS).
Orange	The GNSS receiver has a differential solution (DGPS) or a kinematic floating position solution (20 cm accuracy).
Green	The GNSS receiver has a kinematic integer position solution (1 cm accuracy).

Table 17. Pos/Head (dual antenna systems) or Heading LED states

Colour	Description
Off	GNSS receiver fault (valid only after start-up).
Red flash	GNSS receiver is active, but has been unable to determine heading.
Red	The GNSS 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 18. GPS LED states

Colour	Description
Green flash	The GNSS receiver is functioning normally.
Other	The GNSS receiver has failed. Contact OxTS for further information.

Table 19. Power or Pwr LED states

Colour	Description
Off	There is no power to the system or the system power supply has failed.
Green	The 5 V power supply for the system is active.
Orange	The system is outputting data on connector J2.

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 6), 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.

When making measurements required in the configuration files, measurements should be made between the point of interest and the measurement origin shown in Figure 6. The axes and measurement origin point are the same for all RT models.

Figure 6. IMU co-ordinate frame and measurement origin

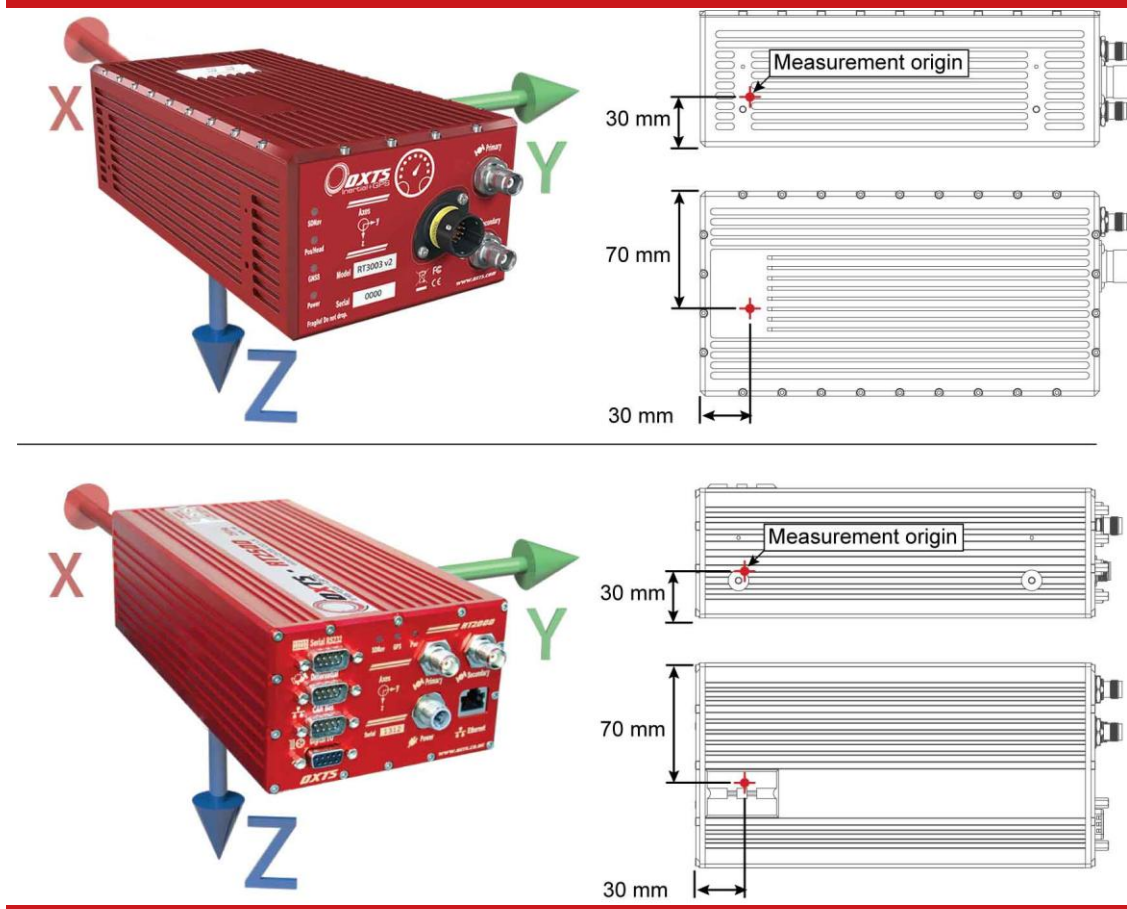


Table 20 lists the directions that the axes should point for zero heading, pitch and roll outputs when the default mounting orientation is used.

Table 20. Direction of axes for zero heading, pitch and roll outputs

Axis	Direction	Vehicle axis
X	North	Forward
Y	East	Right
Z	Down	Down

Once installed, if the RT axes and the vehicle axes are not the same as those listed in Table 20, they can be aligned by reconfiguring the RT for a different mounting orientation using the NAVconfig software.

If the RT-Strut is being used to mount the RT in the vehicle then NAVconfig will have to be used to configure the orientation or the RT will not work correctly. Page 57 gives more information on configuring the orientation of the RT in a vehicle.

OxTS NED navigation frame

Table 21. OxTS NED navigation frame definition

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.

Figure 7. OxTS NED navigation frame definition



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.

ISO 8855 ENU earth-fixed system

Table 22. ISO 8855 ENU earth-fixed system

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.

Figure 8. 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.

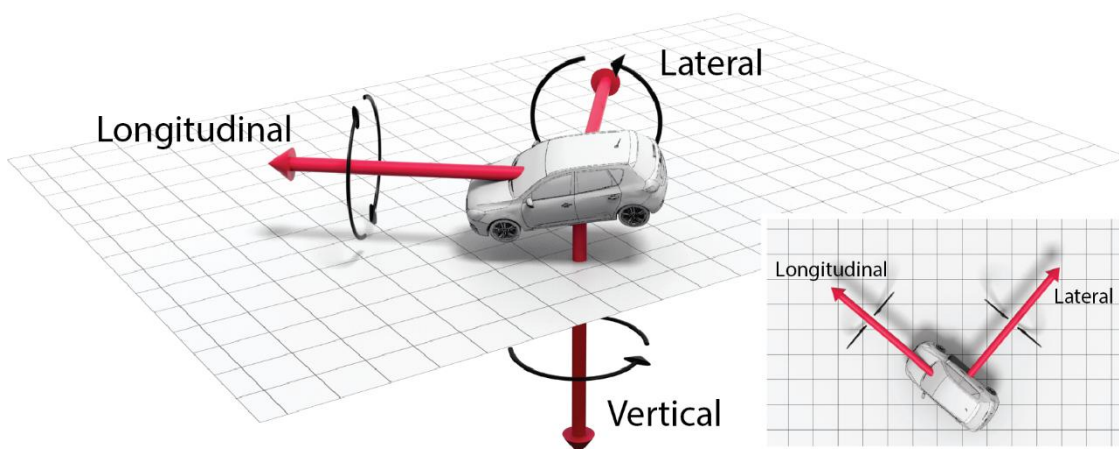
OxTS horizontal frame

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 23 and shown in Figure 9.

Table 23. OxTS Horizontal frame definition

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.

Figure 9. OxTS horizontal frame definition

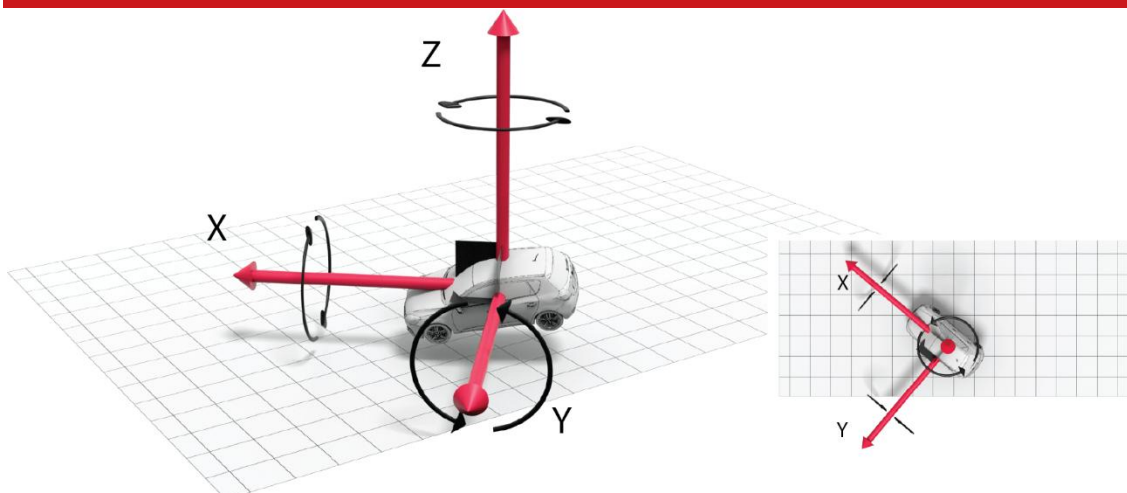


The OxTS horizontal frame is attached to the vehicle. The longitudinal and lateral axes remain parallel to a horizontal plane. The Longitudinal axis is also parallel to the vehicle’s heading when viewed from above.

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 24. ISO 8855 intermediate system and shown in Figure 10.

Figure 10. 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.

Table 24. ISO 8855 intermediate system

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

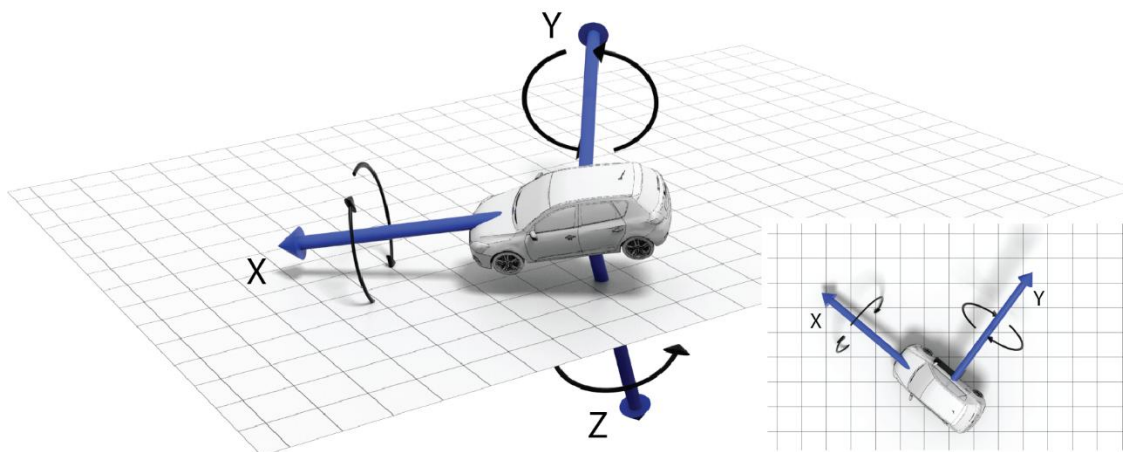
OxTS Vehicle frame

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 25 and shown in Figure 11.

Table 25. Vehicle frame definition

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

Figure 11. 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

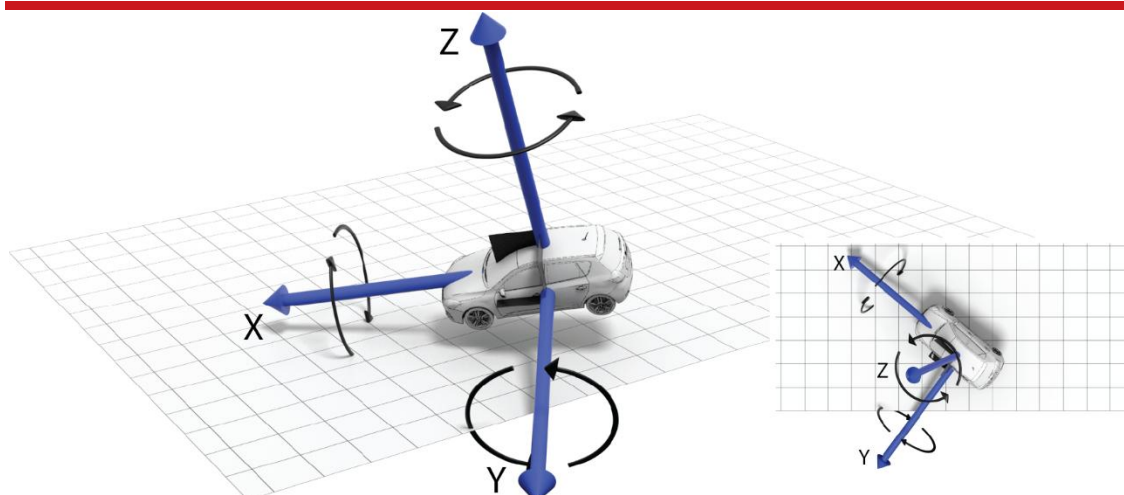
ISO 8855 vehicle system

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 26 and shown in Figure 12.

Table 26. ISO 8855 vehicle system

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

Figure 12. 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'.

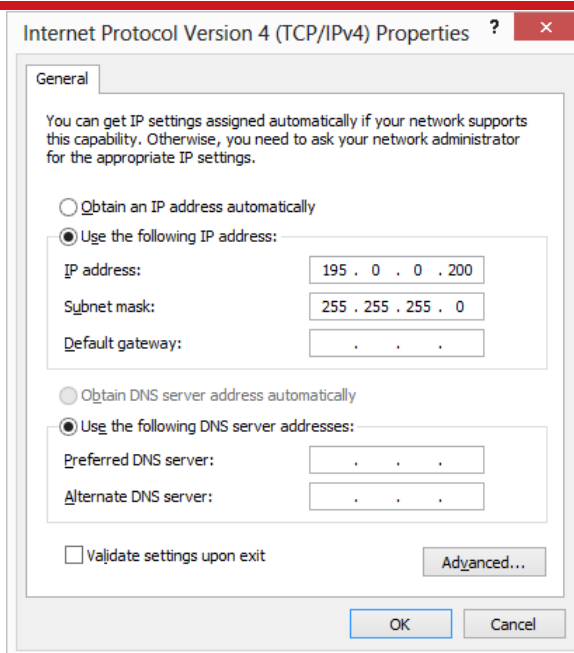
The RT outputs its data over Ethernet using a UDP broadcast. The use of a UDP broadcast allows everyone on the network to receive the data sent by the RT. The data rate of the UDP broadcast is 100 Hz or 250 Hz depending on the RT model.

In order to communicate via Ethernet, each RT is configured with a static IP address that is shown on the delivery note. If the delivery note is unavailable, the default IP address normally takes the form 195.0.0.*sn*, where *sn* is the last two digits of the RT's serial number. The serial number can be found on the front panel of the RT or on the delivery note.

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):

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 13), select **Use the following IP address** and enter the IP address and subnet mask to use.
7. Click **OK** when finished.

Figure 13. Configuring the computer's IP address

Once the computer is configured the IP address of a 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

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 RT2000 uses a standard Ethernet port. This can be connected to a hub using a *straight* cable or to a laptop directly using a *cross-over* cable.

The RT3000 or RT4000 can also 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 27. Note that this is not the normal configuration sold and it may be necessary to modify an existing coupler to suit.

Table 27. In-line coupler connections

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	–

A typical in-line coupler is shown in Figure 14.

Figure 14. 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.

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.

4. 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.

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.

5. 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.
6. 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.

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.

7. 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.

To avoid the Kalman filter from getting things wrong it is possible to drive a calibration run, then use the **Get settings** utility within NAVconfig (see page 59 for more information). 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.

In an ideal environment, with no surrounding building, trees, road signs or other reflective surfaces, the only multipath received is from the vehicle’s roof. The antennas supplied with the RT are designed to minimise multipath from the vehicle’s roof when the roof is made of metal. For use on non-metallic roofs a different type of antenna is required.

When stationary the heading from the RT will show some error, the size of the error depends on the multipath in the environment. Table 28 lists the errors to be expected when stationary with a 1 m base-line.

Table 28. Typical heading error for when stationary in different environments

Environment	Typical error (3σ)
Complete open-sky	0.6° (0.2° 1σ)
Near trees, buildings	1°
Next to trees, buildings	2°

Typical figures using a 1 m base-line. For accuracy specification of 0.1° RMS a 2 m separation is required. Using a 2 m base-line can halve the figures shown here.

Inputs and outputs

RT3000s and RT4000s have one main connector for their inputs and outputs (label 6 on Figure 5, page 34). The J1 connector of the 14C0038B user cable connects to this and connectors J2–J7 provide connections for the inputs and outputs. See the user cable drawing located at the back of this manual for more details on the connectors and pin assignments. The main connector is keyed so the user cable must be correctly aligned for it to connect.

All connections to RT2000s are marked on the front panel, shown in Figure 4 on page 33. The pin outs are the same as the equivalent connectors J2–J7 on the 14C0038B user cable. See the user cable drawing located at the back of this manual for more details on the connectors and pin assignments.

The system can output data on the serial port, over Ethernet and over CAN bus. The standard serial output of the RT is a proprietary binary format, referred to as NCOM. OxTS offers C and C++ code that will interpret the packet. This can be used freely in users' programs to interpret the output of the RT. More information about NCOM can be found in the NCOM description manual.

It is also possible to output a standard NMEA string from the RT to mimic the output of standard GNSS receivers.

OxTS offers a service to tailor the serial output format to the customer's specification. Contact Oxford Technical Solutions for details of this service

Digital inputs and outputs

Table 29 describes each of the signals on the digital I/O connector. A more detailed explanation of each signal can be found below.

Table 29. Digital I/O signals

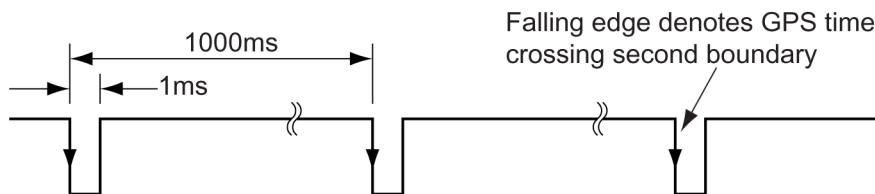
Pin	Function	Description
1	Digital 1	1PPS output from GNSS receiver
2	Digital 2	Event input
3	Digital 3	Wheel speed input (from tachometer on a single wheel)
4	Digital 4	Wheel speed output simulation
5	Digital 5	IMU sync output pulse (100 or 250 Hz)
6	Digital Ground	Digital ground
7	Digital Ground	Digital ground
8	Digital Ground	Digital ground

1PPS output

The 1PPS output is a pulse from the GNSS receiver. 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.

On RT2500 and RT2502 products the 1PPS is only output when the GNSS has a valid position measurement. With RT2002, RT3000 and RT4000 products the 1PPS will always be output.

Figure 15. 1PPS waveform



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. Older models have no protection on this output (protection circuitry would disturb the accuracy of the timing). New models (post-September 2013) have limited protection.

Event input

The event input can be used to time events, like the shutter of a camera or a brake switch. The event input has a pull-up resistor so it can be used with a switch or as a CMOS input. The input sees less than 0.8 V as low and more than 2.4 V as high. There is no protection on this input (protection circuitry would disturb the accuracy of the timing). Keep the input in the range of 0 V to 5 V.

By default the maximum event rate is 1 Hz for 100 Hz products and 4 Hz for 250 Hz products. This can be increased to 50 Hz by selecting one or both the **Output on falling edge of trigger** and **Output on rising edge of trigger** check boxes on the Ethernet Output window. This is accessed from the Options page in NAVconfig (see “Ethernet output” on page 86 of this manual).

Trigger information can be found in status message 24 and 43 (output over NCOM and CAN) for the low-rate triggers. The fast trigger information can only be output over NCOM.

Wheel speed input

The wheel speed input accepts TTL pulses from an encoder on a single wheel. An encoder from a gearbox should not be used, and simulated TTL pulses (e.g. from the CAN bus) should not be used. The timing of the wheel speed input pulses is critical and nothing should cause any delay in the wheel speed input pulses.

The wheel speed input requires less than 0.8 V for a low pulse and more than 2.4 V for a high pulse. Limited protection is provided on this port, however the input voltage should not exceed 12 V.

The wheel that is used should not steer the vehicle. The RT will assume this wheel travels straight.

Wheel speed output

The wheel speed output generates pulses in the same way as a wheel encoder would. The configuration software can change the number of pulses per metre of travel. The output has 0.8 V or less for a low and 2.4 V or more for a high. There is no protection on this output, no more than 10 mA should be used on this output.

IMU sync output pulse

The IMU (inertial measurement unit) sync output pulse is a 100 Hz or 250 Hz output pulse synchronised to the IMU sample time. The output has a duty cycle of approximately 50% and the falling edge is synchronised to the sample time of the data from the IMU.

The IMU is already synchronised to GPS time so one of the pulses each second will line up with the 1PPS output. This allows other systems to sample based on the timing of the RT.

Reverse polarity protection

The RT products have limited reverse polarity protection. Reversing the polarity on the power inputs for short periods of time is unlikely to damage the product.

Causing a short circuit through the RT will damage the product. A short-circuit will be created if the polarity is reversed and another connector has ground connected. In this condition the ground input of the power supply will be connected to the positive power supply; this causes a high current to flow through the circuits in the RT and it will damage several internal components.

RT2000 products have had a formal safety test (see specifications). The safety certificate only applies if the cables supplied are used or if the RT2000 is used with an RT-UPS. If the fuse in the plug needs to be replaced, then it should be replaced with the Littelfuse model specified in Table 30. If a different connector is fitted to the cable then an

appropriate five amp, fast-blow fuse should be fitted and the safety specification will no longer apply.

RT3000 and RT4000 products have not had a formal safety test. If the fuse in the plug needs to be replaced, then it should be replaced with the Littelfuse model given in Table 30 below. If an alternative connector is fitted to the cable then an appropriate five amp, fast-blow fuse should be fitted.

Table 30. Replacement fuse

Parameter	Specification
Manufacturer	Littelfuse
Part Number	0214005
Description	5 A torpedo type fuse
Dimensions	25 × Ø 6 mm
Voltage Rating	36 V

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 for the first time. 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 on your computer configured correctly in order to communicate with the RT and change the settings. See the section “Ethernet configuration” on page 43 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.

In particular, 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 return to the default configuration rather than using parameters that have been tuned for a different vehicle.

Selecting the operating language

The NAVconfig software can operate in several languages. To change the language, select a language from the menu at the bottom of the page. The language can be changed at any time without affecting the current configuration.

NAVconfig uses the regional settings of the computer to choose whether numbers are represented in the English or European format (dot or comma for the decimal separator). The selected language does not change the format used for numbers.

Navigating through NAVconfig

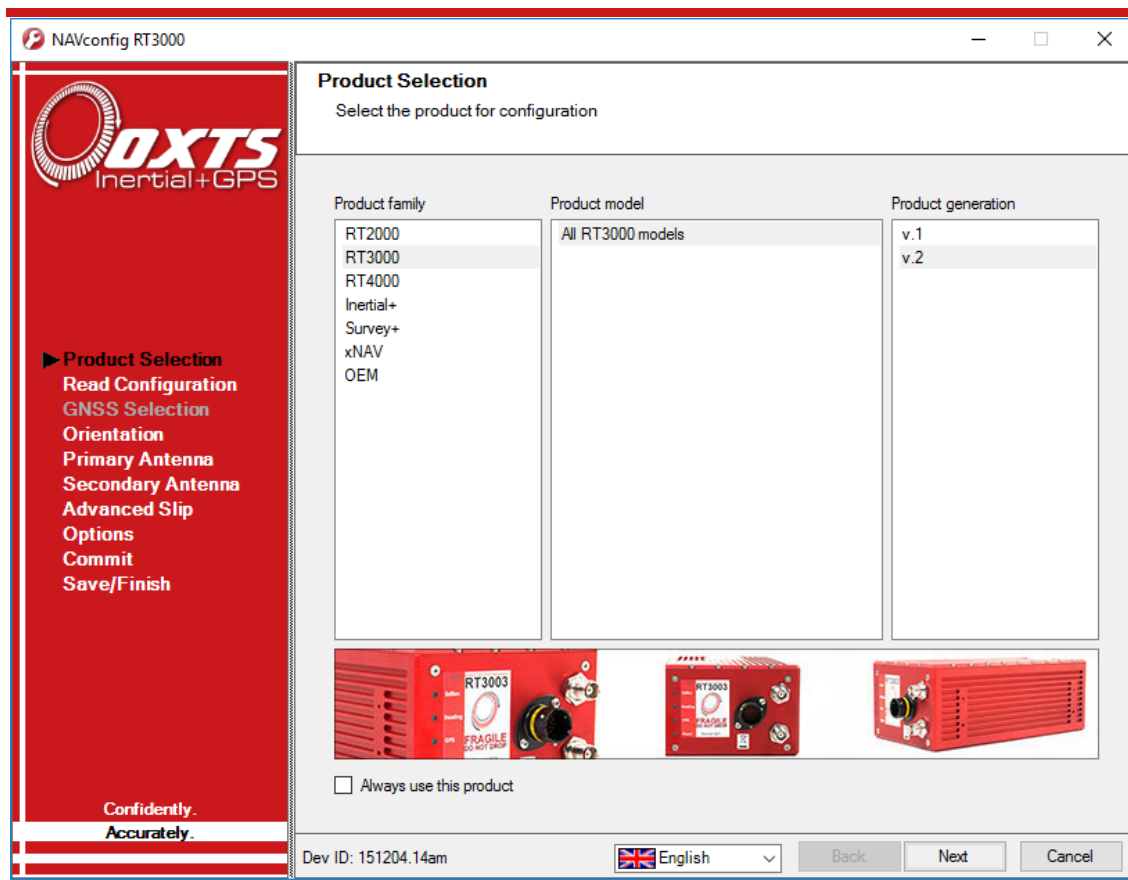
To make the process of creating a configuration easier, NAVconfig allows you navigate to different sections by simply clicking the section name in the left-hand sidebar. You can also move forwards and backwards through the different sections using the Back and Next buttons.

Measurements are always displayed in metric units in NAVconfig. However, when entering measurements alternate units can be used as long as they are specified, e.g. 10" or 10 in. NAVconfig will then convert and display these in metric units.

Product selection

NAVconfig is a universal tool that is used to configure many different devices, so the first step in most configurations is to choose the product that will be configured, as shown in Figure 16.

Figure 16. NAVconfig Product Selection page



It is important to ensure the correct Product family, Product model and Product generation is selected as the options and configuration pages shown in NAVconfig differ between products. Any pages that are not available will be displayed as grey in the sidebar.

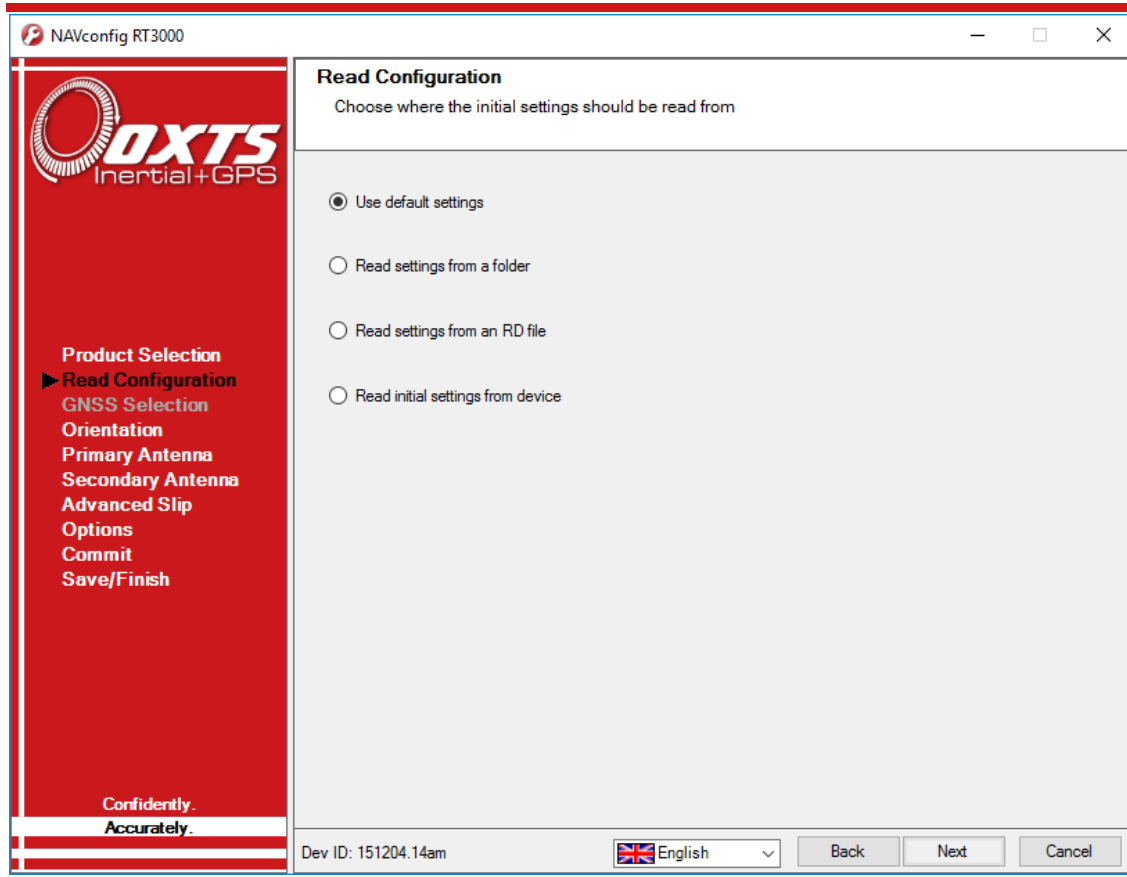
The product model and generation can be found on the connector panel of your product.

If you only own one type of OxTS product, the Product Selection page can be skipped in the future by clicking the **Always use this product** checkbox. If a different product needs configuring, the selection page can be returned to by clicking **Product Selection** in the sidebar.

Reading configuration

The Read Configuration page tells NAVconfig where to read the initial configuration from (see Figure 17).

Figure 17. NAVconfig Read Configuration page



Use default settings: NAVconfig loads the default settings the RT was delivered with.

Note: choosing Use default settings overwrites any advance settings that may have been sent with prior configurations. To maintain those advanced settings, the **Read initial settings from device** option must be used.

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 an 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 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. Select this option and enter the correct IP address of your RT, or select it from the drop-down list. The list will show

all systems that are connected to the network, so if more than one system is connected ensure you select the correct system. Note: the list will not function correctly if NAVdisplay or other software is using the RT UDP port unless the OxTS UDP Server is running.

GNSS Selection

This page does not apply to RT devices and will remain unavailable.

Orientation

The Orientation page 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.

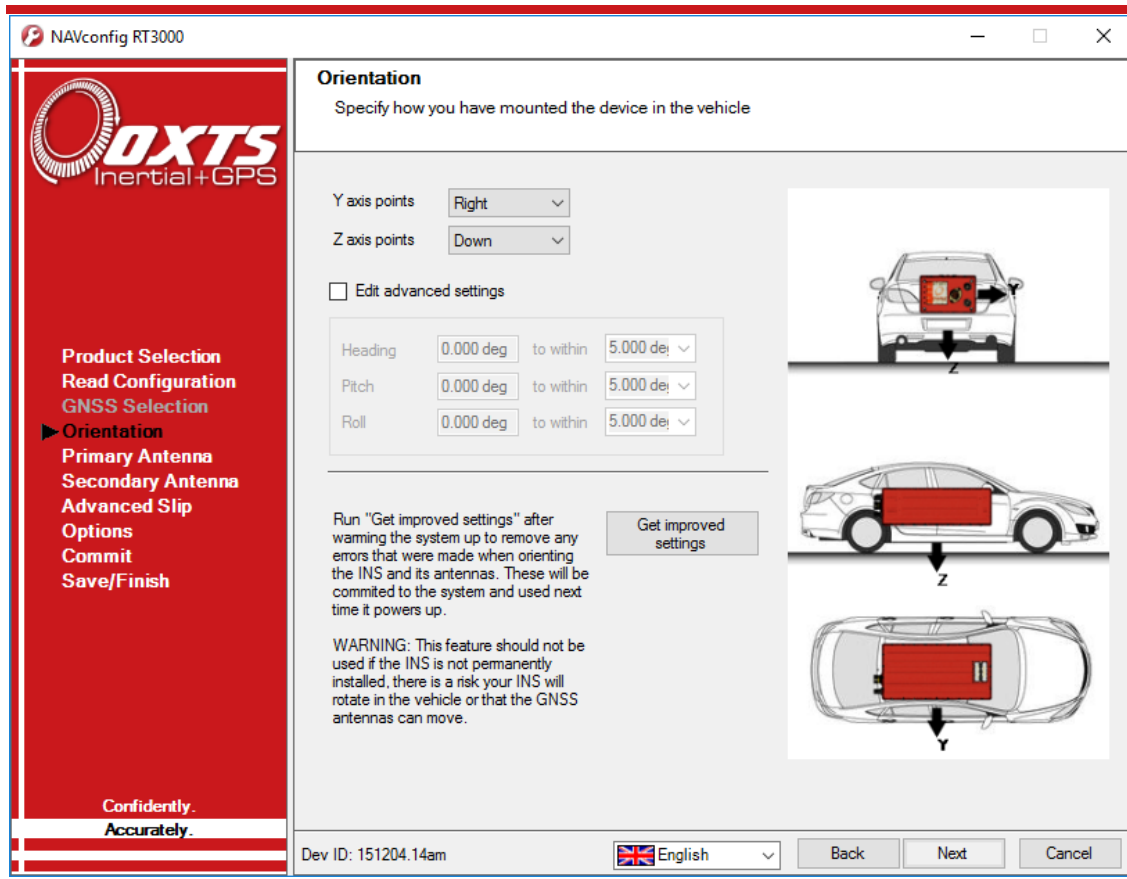
When using an RT-Strut, the orientation will need to be changed. Figure 18 shows an RT mounted on an RT-Strut in a vehicle. In this configuration, the y -axis points left and the z -axis points forwards. Other configurations are possible with the RT-Strut.

Figure 18. An RT device mounted on our RT-Strut system



Use the **Y axis points** and the **Z axis points** box to specify which way the RT's axes point in the vehicle. Figure 6 on page 38 shows the RT axes directions. The Orientation page of the configuration wizard, shown in Figure 19, 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 19. NAVconfig Orientation page



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 (see Vehicle starts, page 67) is used, then the pitch and roll orientations must also be correct.

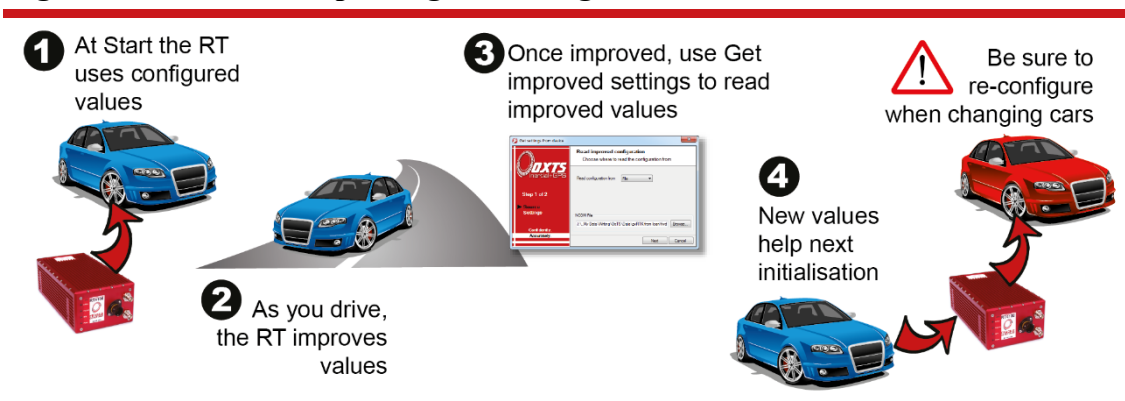
To make small adjustments, select the **Edit advanced settings** checkbox to enable the rotations for editing. This allows any slip angle, pitch or roll offsets to be zeroed.

Get improved settings

The **Get improved settings** button provides the ability to read the configuration settings from a warmed up system. While the RT is running it tries to improve some of its configured parameters. This option is useful if a calibration run has been done and the Kalman filter's values are known to be good.

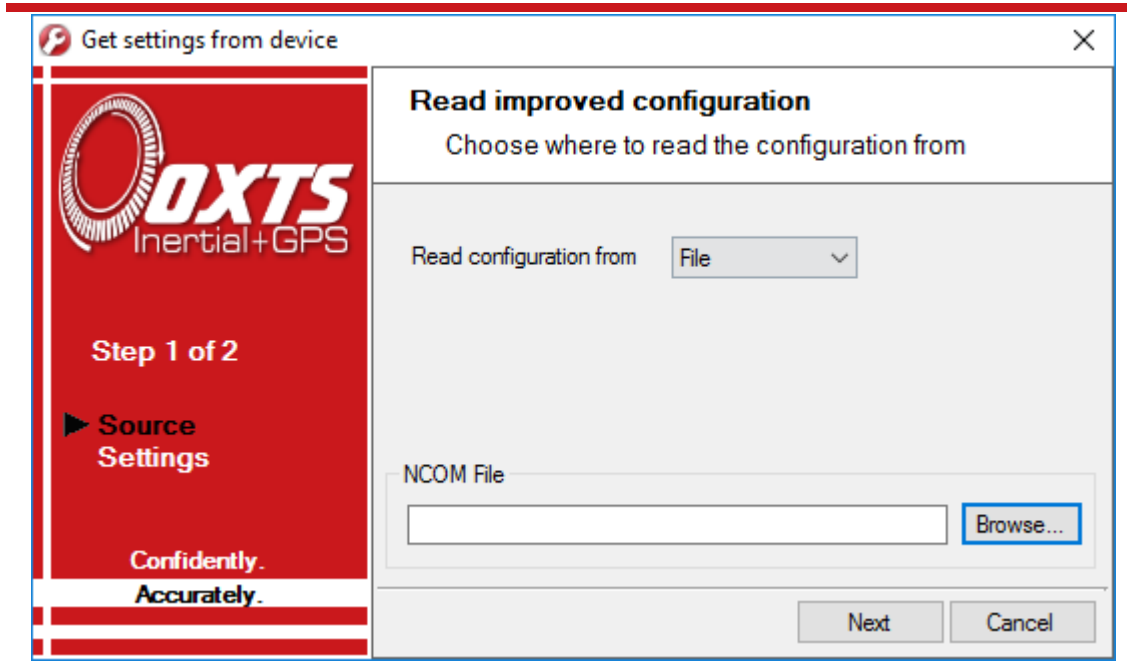
In particular the RT will try to improve the GNSS antenna position, the orientation of the dual antennas, the yaw orientation of the RT in the vehicle and, if one is being used, the wheel speed calibration values. In applications where the RT is permanently installed in a vehicle it can be beneficial to import these improved values into the RT's configuration file to be used next time. It can make the results more consistent. Figure 20 shows this process diagrammatically. This feature should not be used if there is a risk the RT will rotate in the vehicle or that the GNSS antennas can move—even by a few millimetres.

Figure 20. Process of improving RT settings



To read the improved values from the RT, click the **Get improved settings** button on the Orientation page. This will open the Get settings from device window, as shown in Figure 21.

Figure 21. Source selection for Get improved settings



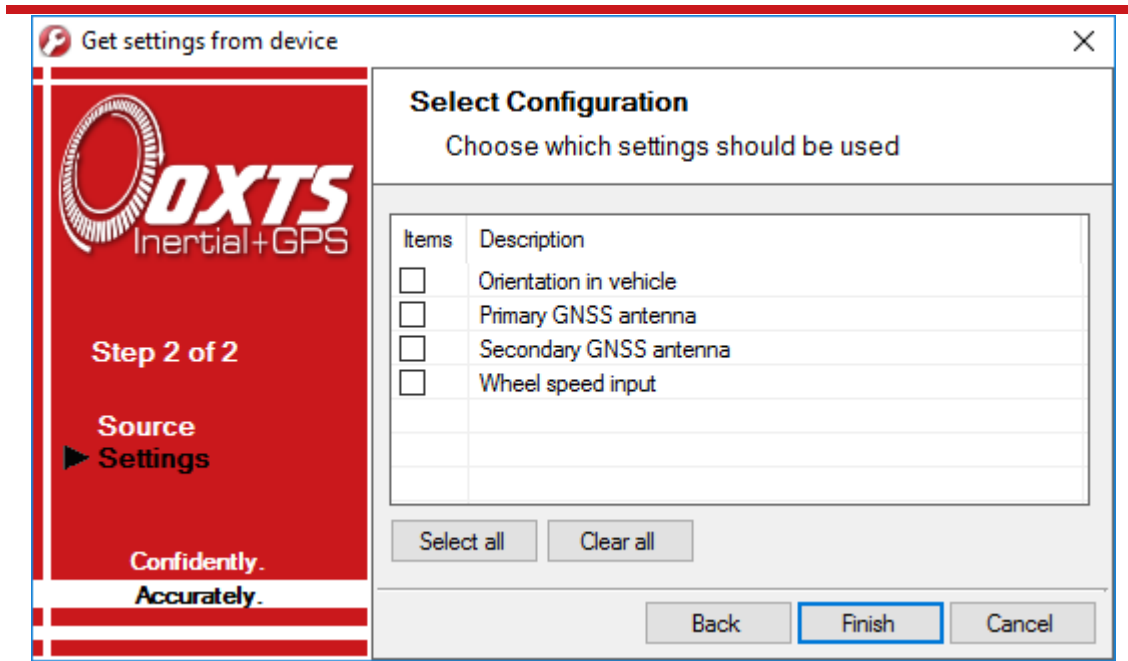
In the **Read configuration from** box, select the source for the improved settings. The options are:

- Read configuration from **File**. If an NCOM file has been saved to disk, or processed using the NAVsolve, then this file can be read and the settings extracted from it. Use this setting if you have an NCOM file. Click **Browse...** and select the NCOM file you wish to read the configuration from. Do not use an NCOM file that has been combined from forward and backwards processing of the inertial data.
- Read configuration from **Ethernet**. This will get the information that the RT is currently using and apply it next time the RT starts. Use this setting if the RT is running, has initialised and has warmed up. Select the correct IP address of the RT to read the configuration from in the drop-down list. Note: the list will not function correctly if NAVdisplay or other software is using the RT UDP port unless the OxTS UDP Server is running

Once the source has been selected, click **Next** and the software will find which settings can be obtained from the source. Settings that cannot be obtained will be shown in grey; this may be because the RT is not calculating these values at present. Figure 22 shows the Settings page with the parameters available to improve in the configuration.

You may update several parameters at once. Select the settings you want to be updated and uncheck the ones that you do not want to update.

Figure 22. Select which settings to update with Get improved settings

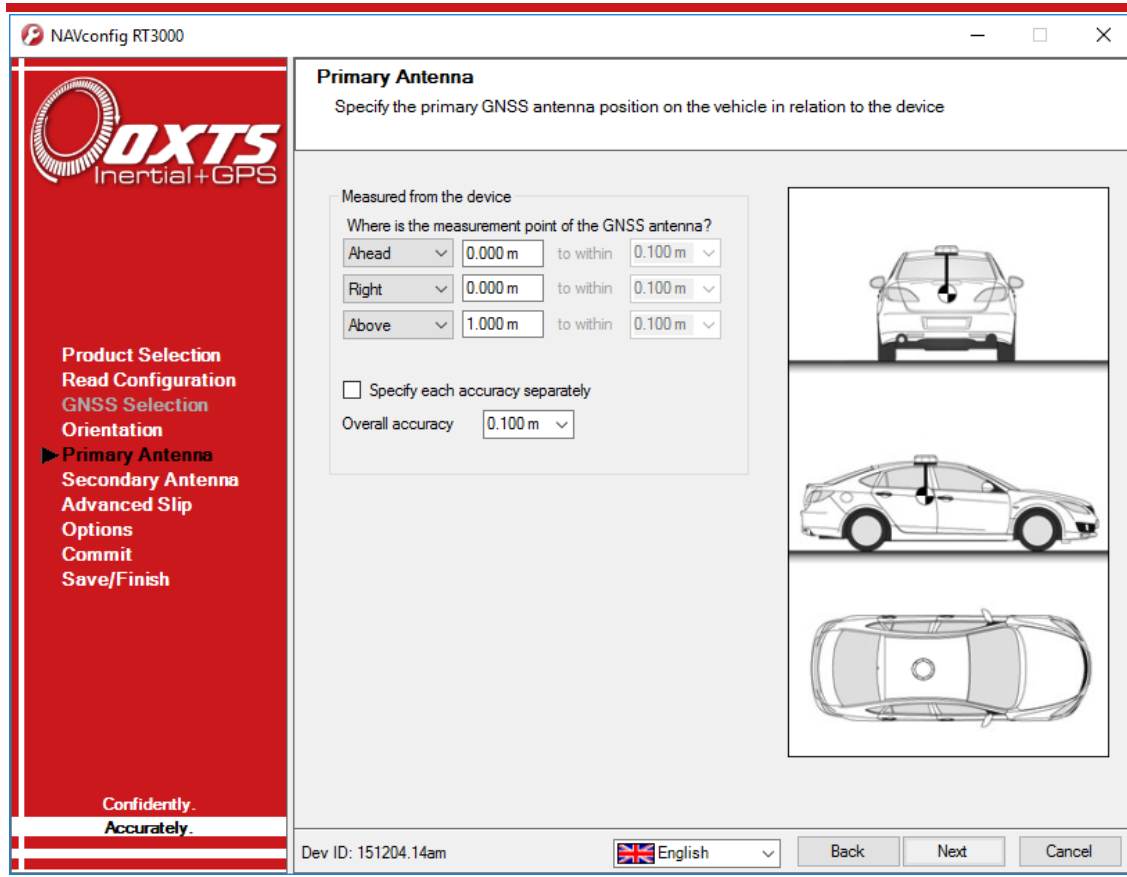


If **Orientation in vehicle** is selected, the improvement to orientation should only be applied if the change in the orientation is small (less than 5°). If the change in orientation is large then it is likely that the original configuration was wrong or has not been loaded into NAVconfig. You are very likely to get poor results if the orientation is changed by a large amount.

Primary antenna

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 23 shows the Primary Antenna page.

Figure 23. NAVconfig Primary Antenna page



It is necessary to tell the RT the distance between its measurement origin (shown in Figure 6) and the GNSS antenna’s measurement point. This should be entered in the vehicle’s co-ordinate frame.

The accuracy of the measurements should also be specified, and care should be taken here. It is very easy to measure within 1 cm or better in a straight line, but it is much harder to measure within 1 cm through a car roof. This is compounded if the RT is slightly misaligned in the vehicle. Any alignment errors should be included in the accuracy you believe you can measure to.

Telling the RT you have measured the distances within 5 mm may lead the RT to believe its results are better than they really are. You may be impressed by the accuracy the RT reports, but in reality it will not be that accurate. It is better to overestimate the accuracy (i.e. tell the RT a worse value) than to underestimate it.

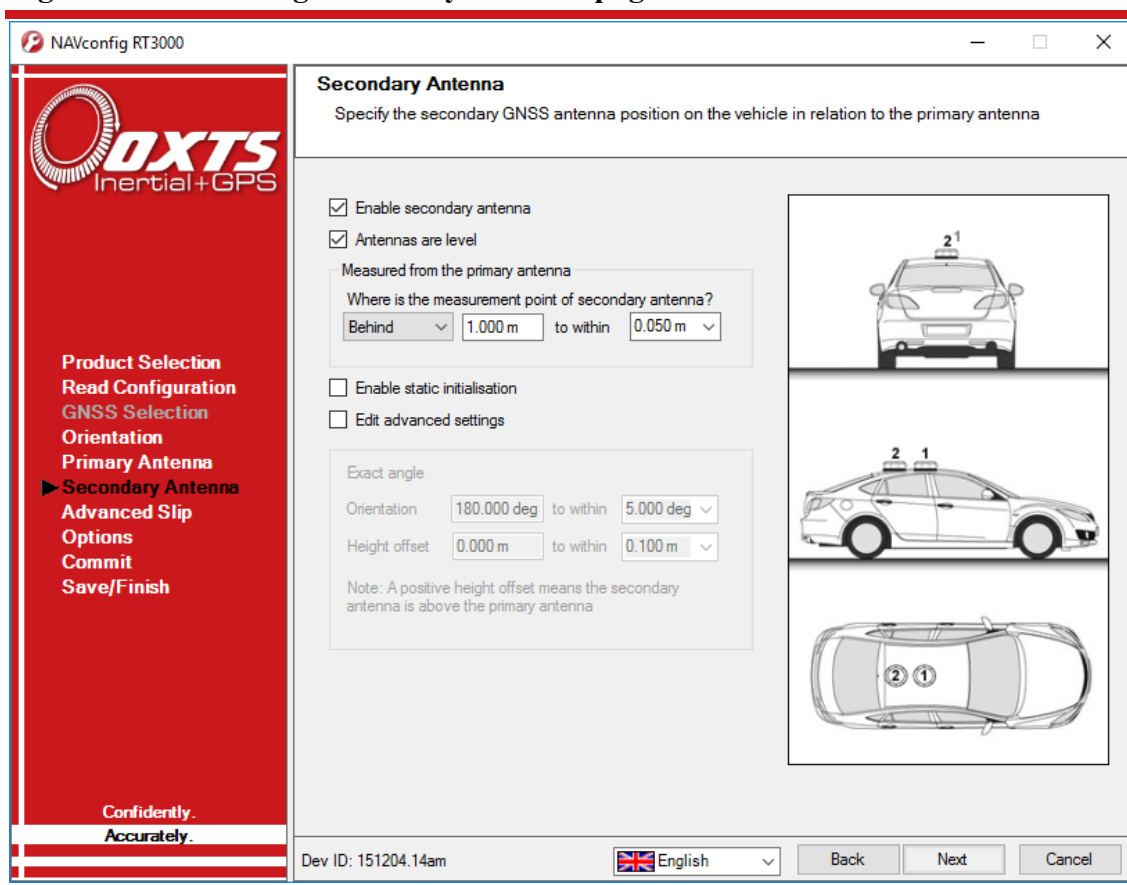
The RT will try to improve the position of the primary GNSS antenna during use. To use the values the RT has estimated use the **Get improved settings** utility on the Orientation page. More information about Get improved settings is provided on page 59.

Secondary antenna

If your system has dual antennas, click the **Enable secondary antenna** checkbox on the Secondary Antenna page (Figure 24) 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 drop-down list. The illustrations will change according to the settings you choose to help visualise the configuration of the antennas.

Figure 24. NAVconfig Secondary Antenna page



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, giving an accuracy of up to 0.05° in both static and dynamic conditions

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.

If you can guarantee the antennas are level (always within 15° of horizontal) during static initialisation then the following advanced command can also speed up static initialisation and make it more reliable:

```
-gps_pitch15.0
```

This is a “pitch constraint” (or “tilt constraint”). Enter this text into the **Advanced** window on the Options page. It will tell the ambiguity resolution algorithm to only search within 15° of the horizontal. Note that this is the angle between the antennas and it is independent of the height offset entered in to the software.

The RT will improve the estimate of the secondary antenna orientation settings. Use the **Get improved settings** utility to use the improved values. More information on Get improved settings is provided on page 59.

Advanced slip

The Advanced slip 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.

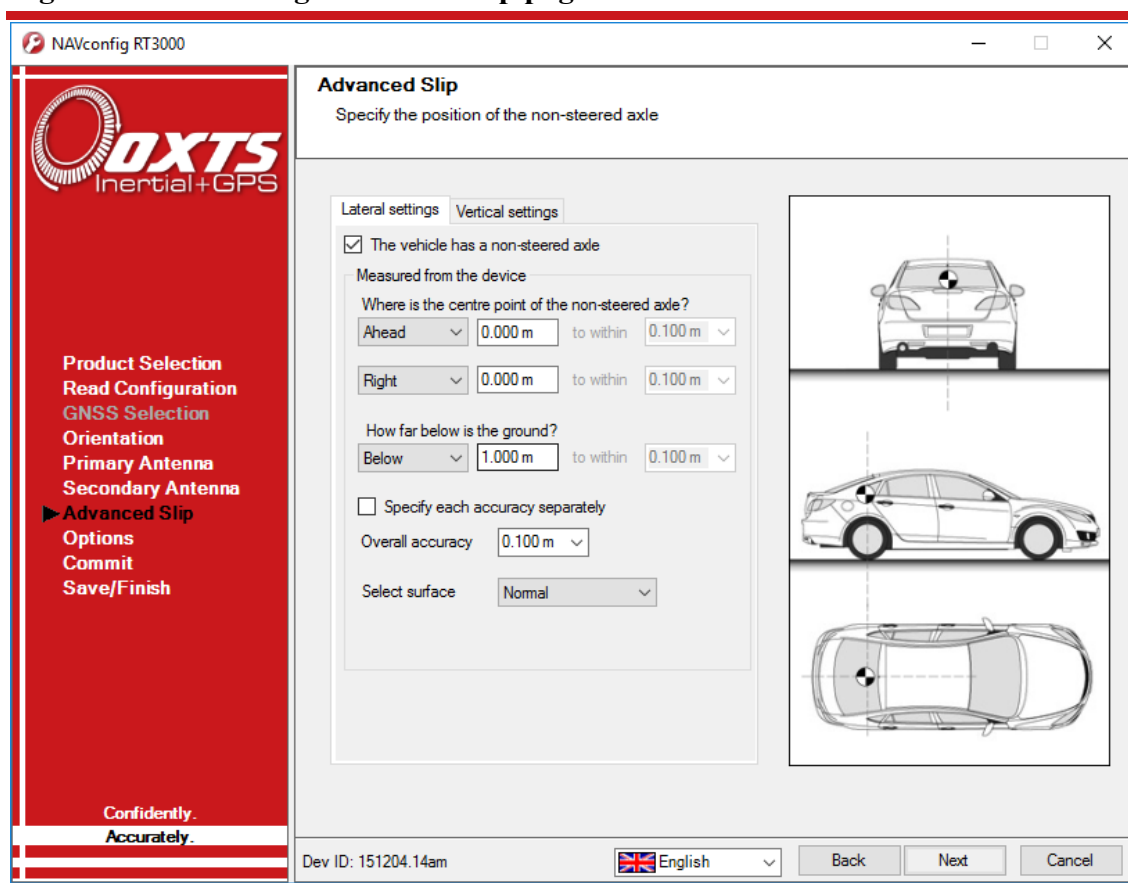
This feature must be disabled for airborne and marine systems where the lateral velocity can be significant. This feature is also not suitable for land vehicles that use all wheels to steer, i.e. no fixed wheels. The vertical settings should not be used if the vehicle can perform wheelies.

The Advanced 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 (see “Wheel speed input” on page 81) the drift of the RT when GNSS is not available is drastically reduced.

Figure 25 shows the Advanced Slip page of NAVconfig.

Figure 25. NAVconfig Advanced Slip page



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 26. Vehicles with all wheels steering cannot use this feature reliably, although minor steering of the rear wheels does not significantly affect the results.

Figure 26. Measurement point for Advanced 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 drop-down lists and enter the distances.

Typically the measurements would all be 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 accuracy fields to select or specify the accuracy of the measurements.

The Advanced slip feature also requires some knowledge of the road surface. Select one of the predefined options from the drop-down list, Normal or Low friction (ice).

For the **Vertical settings**, 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 drop-down lists.

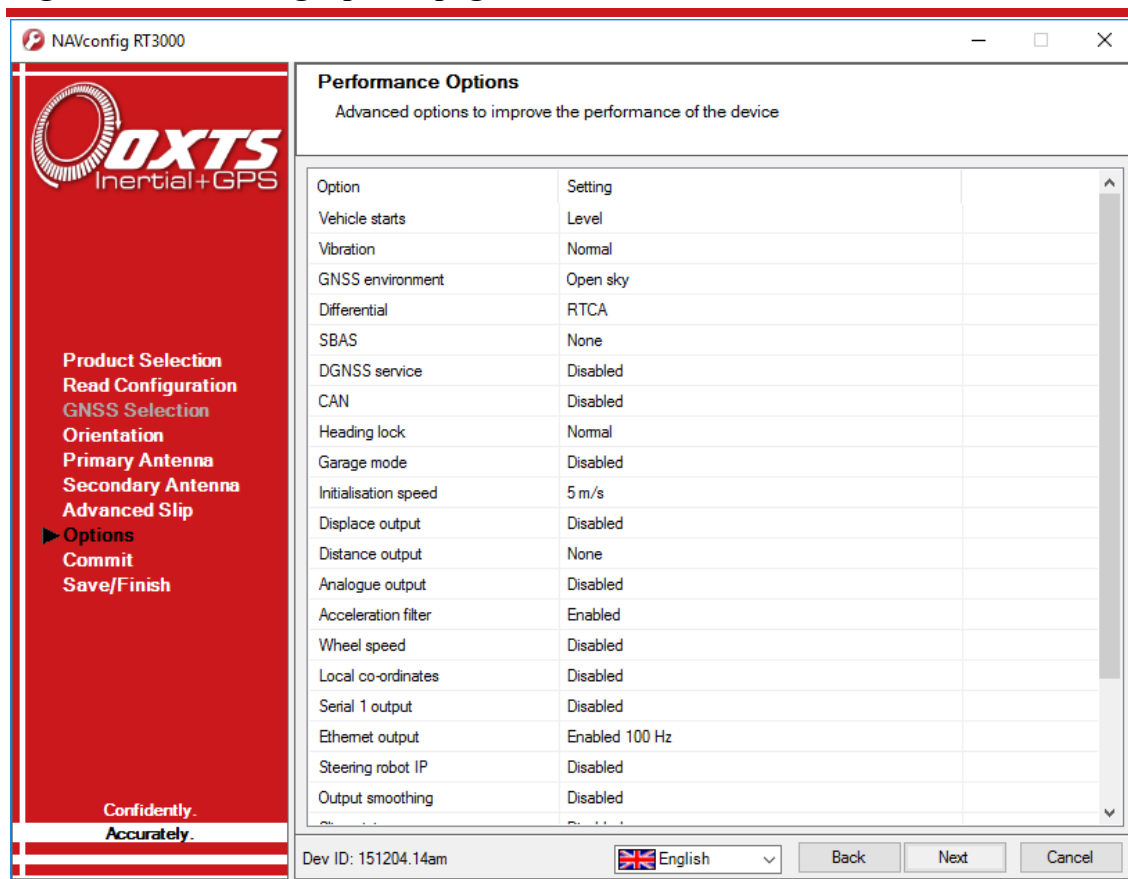
When using Advanced slip, the RT can estimate the slip angle offset of the RT compared to the vehicle. After the RT is initialised and warmed-up, use the **Get improved settings** utility to automatically read the RT's slip angle offset estimate. This ensures a slip angle of zero is measured when driving straight on a level track. See page 59 for more information on Get improved settings.

Options

The Options page includes some important settings for getting the best results from your RT system. Figure 27 shows the Options page of the configuration wizard.

To adjust the settings, click the default value in the Setting column to activate the cell. A description on each option and how to adjust it is found below. Clicking in either column header will sort the Options in ascending or descending alphabetical order.

Figure 27. NAVconfig Options page



Vehicle starts

Adjustment: select a predefined value from the drop-down 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.

Vibration

Adjustment: select a predefined value from the drop-down 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).

GNSS environment

Adjustment: select a predefined value from the drop down list.

If the system is used predominantly in open-sky, then the **Open sky** 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-sky setting is used, the RT will not report accuracies that meet its specifications.

Differential correction

Adjustment: click ... button to open properties window.

An RT can be configured to use several different differential correction message types on connector J3. Figure 28 shows the Differential corrections properties window and Table 31 gives details on the correction types available.

Figure 28. NAVconfig Differential corrections properties window

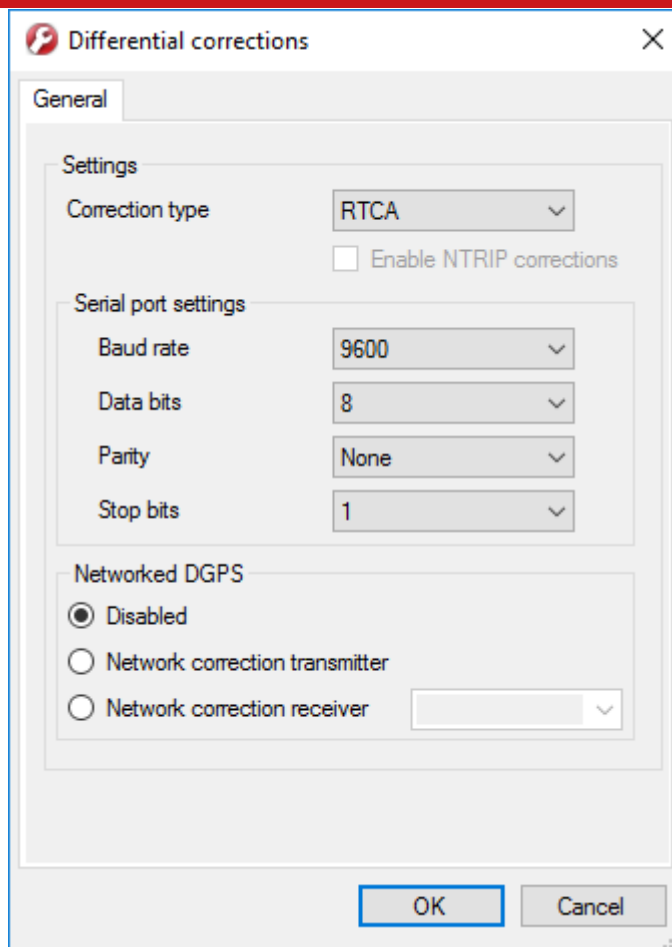


Table 31. NAVconfig differential correction types

Correction type	Description
RTCA	RTCA is the standard adopted for aircraft. It was the first open standard to use 1 cm corrections. The RT-Base S and GPS-Base products use RTCA.
RTCM	RTCM is the most common open standard used for differential corrections. Old implementations of RTCM did not support 1 cm corrections, which is why OxTS uses RTCA by default. New versions of the RT products support 1 cm corrections over RTCM.
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

Select the **Correction type** you wish to use from the box and then select the **Baud rate**. 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** boxes should be set to match the incoming signal.

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

The **Networked DGPS** 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 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

Adjustment: select a predefined value from the drop-down list.

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.

DGNSS service

Adjustment: click ... button to open properties window.

Select either **Automatic** or **Manual** from the **corrections** drop-down list in the properties window to enable corrections.

When manual is used, the correct satellite should be selected for the region where you are operating.

Several satellites have been pre-programmed into the software. In the future more satellites may exist, or their properties may change. In this case it is necessary to select **Use advanced settings** to set the satellite's **Frequency** and **Baud rate**.

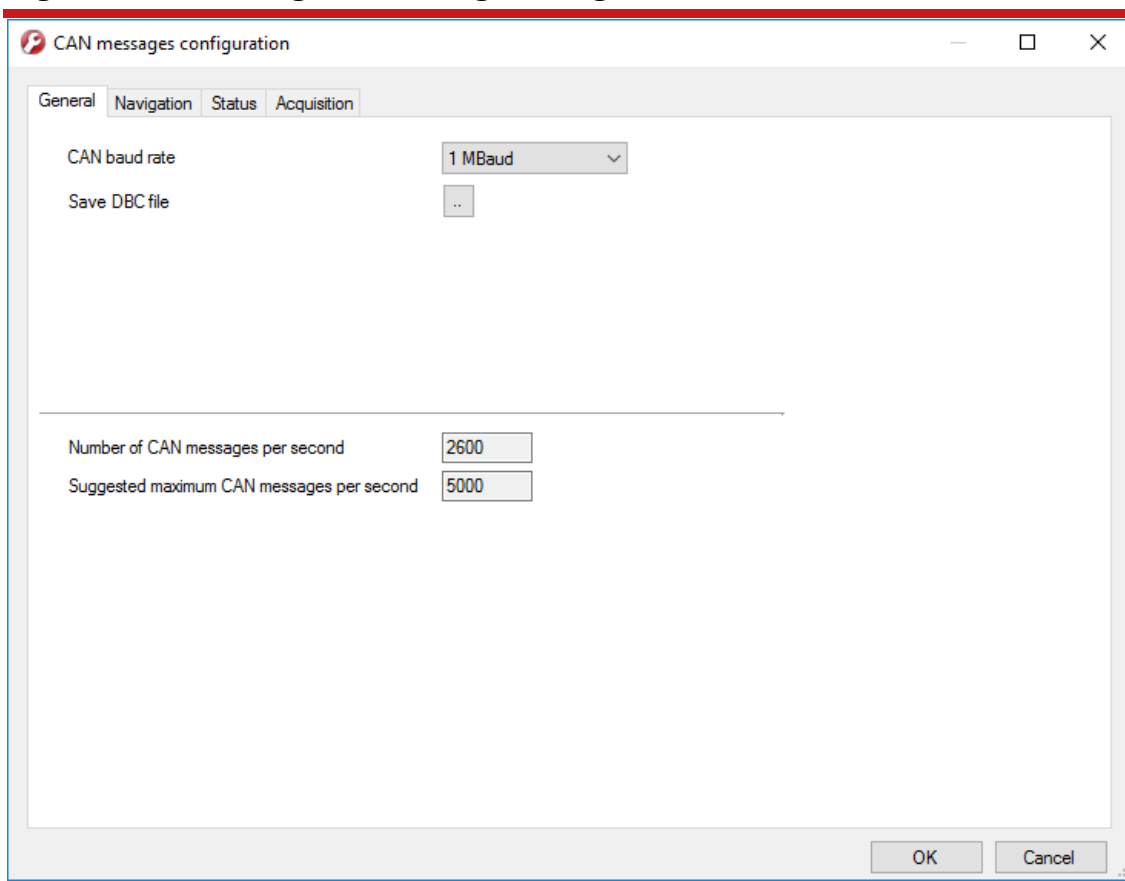
CAN

Adjustment: click ... button to open properties window.

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.

By default, CAN communication is disabled. It is enabled by selecting an option from the drop-down list for **CAN baud rate** on the **General** tab of the properties window, shown in Figure 29.

Figure 29. NAVconfig CAN messages configuration window - General



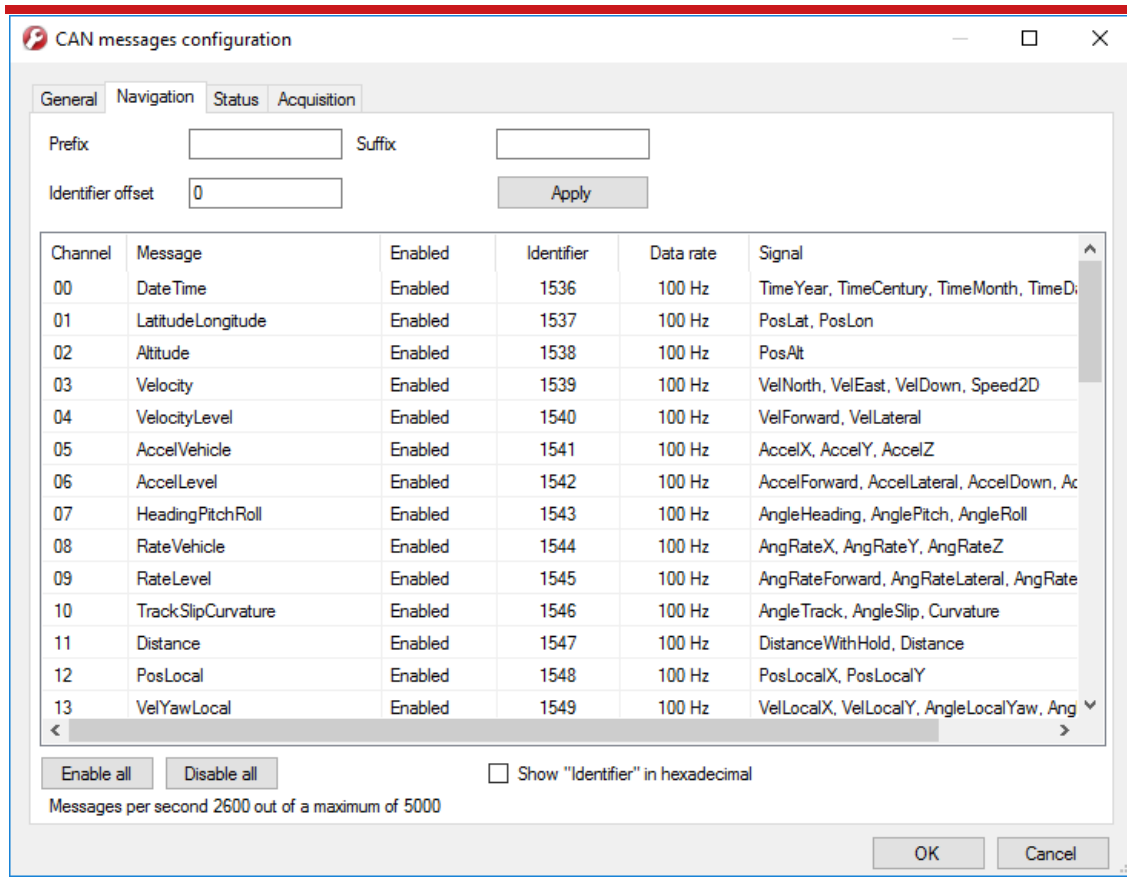
Depending on the baud rate selected, the suggested maximum CAN messages per second will change. A warning message will appear if the combined rate of all current navigation and status messages will overload the CAN bus at the selected baud rate. Disabling or

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 Save 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 from Table 37 onwards on page 106. 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 is not sufficient to describe the decoding process.

The **Navigation** tab (Figure 30) 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 30. NAVconfig CAN messages configuration window - Navigation



The **Prefix** and **Postfix** boxes can be used to quickly add alpha-numeric strings to the beginning or end of all message names. By clearing the prefix or postfix, and then clicking the Apply button, the original message name will be restored.

The **Identifier offset** box allows users to quickly apply a blanket offset to all CAN IDs. This is useful when IDs conflict with other equipment. 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 a “h”. To remove the offset, type 0 in the identifier offset box and click Apply.

Each message can be enabled/disabled by clicking in the appropriate cell and selecting from the drop-down 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’ be appended.

The **Data rate** can be set using the drop-down 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 **Enable all** button quickly enables all messages. The **Disable all** button disables all messages.

On RT4000 systems the default set of CAN messages may overload the CAN bus (depending on how many slip points are used and whether local co-ordinates are configured). It may be necessary to reduce the number of messages that are output on an RT4000 system.

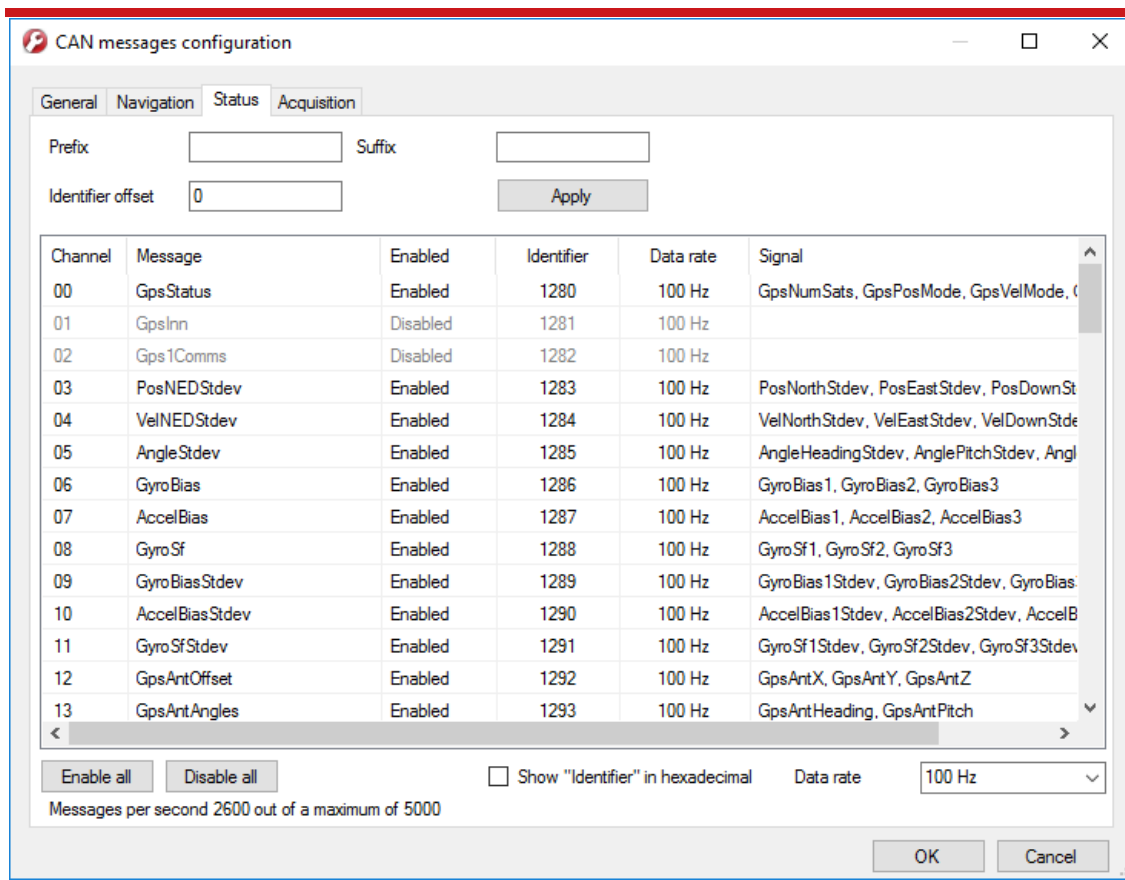
The **Status** tab (Figure 31) lists all status messages, which are sent one after another in a repeating loop. Although 80 messages are shown in the list, 100 are actually used internally. If the data rate is set to 100 Hz, a status message will be sent every 10 ms. Some messages are transmitted more 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 **Postfix** boxes can be used to quickly add alpha-numeric strings to the beginning or end of all status message names. By clearing the prefix or postfix, and then clicking the Apply button, the original name will be restored.

The **Identifier offset** box allows users to quickly apply a blanket offset to identifiers. This is useful when IDs conflict with other equipment. 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 a “h”. To remove the offset, type 0 in the identifier offset box and click Apply.

The **Select all** button quickly enables all status messages. The **Clear all** button disables all status messages. Messages shown in grey are not included in the CAN DBC file.

Figure 31. NAVconfig CAN messages configuration window - Status

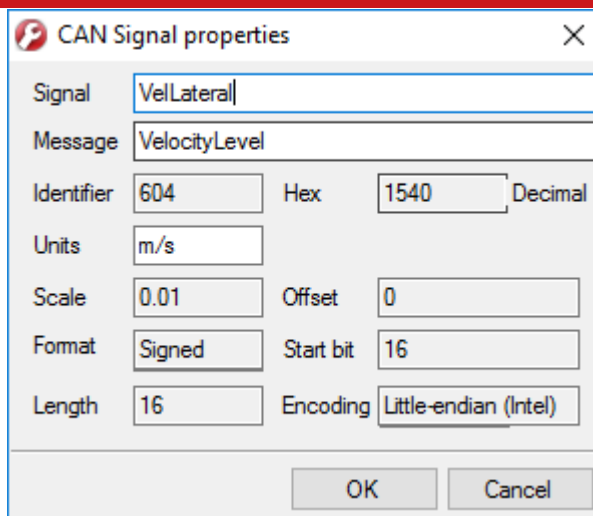


The **Acquisition tab** (Figure 32) is where incoming CAN signals are defined. These signals can be viewed in real-time along with the RT’s native data using NAVdisplay, or at a later time using NAVgraph.

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 RT’s update speed of 100 Hz or 250 Hz. This is not adjustable.

Extra CAN messages (those on the grey background) do not need deleting from the list but will not be logged. To move a message up into the top 12 area for logging, right-click on messages above and delete them from the list. To remove individual signals from a message, right-click on the signal in the right-hand window to bring up the delete option.

Figure 33. NAVconfig CAN signal properties window



Heading lock

Adjustment: select a predefined value from the drop down list.

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

Table 32. NAVconfig 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.

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

Adjustment: select a predefined value from the drop-down list.

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.

Initialisation speed

Adjustment: select a predefined value from the drop-down list, or type in a value.

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.

Displace output

Adjustment: click ... button to open properties window.

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 in the properties window 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 drop-down lists.

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.

Distance output

Adjustment: select a predefined value from the drop-down list or type in a value.

It is possible to configure the RT to simulate the output of a wheel speed encoder. This will be in the form of TTL pulses—each pulse representing a distance travelled. Using the Distance output option the scaling of this output can be configured, in pulses per metre (ppm) travelled.

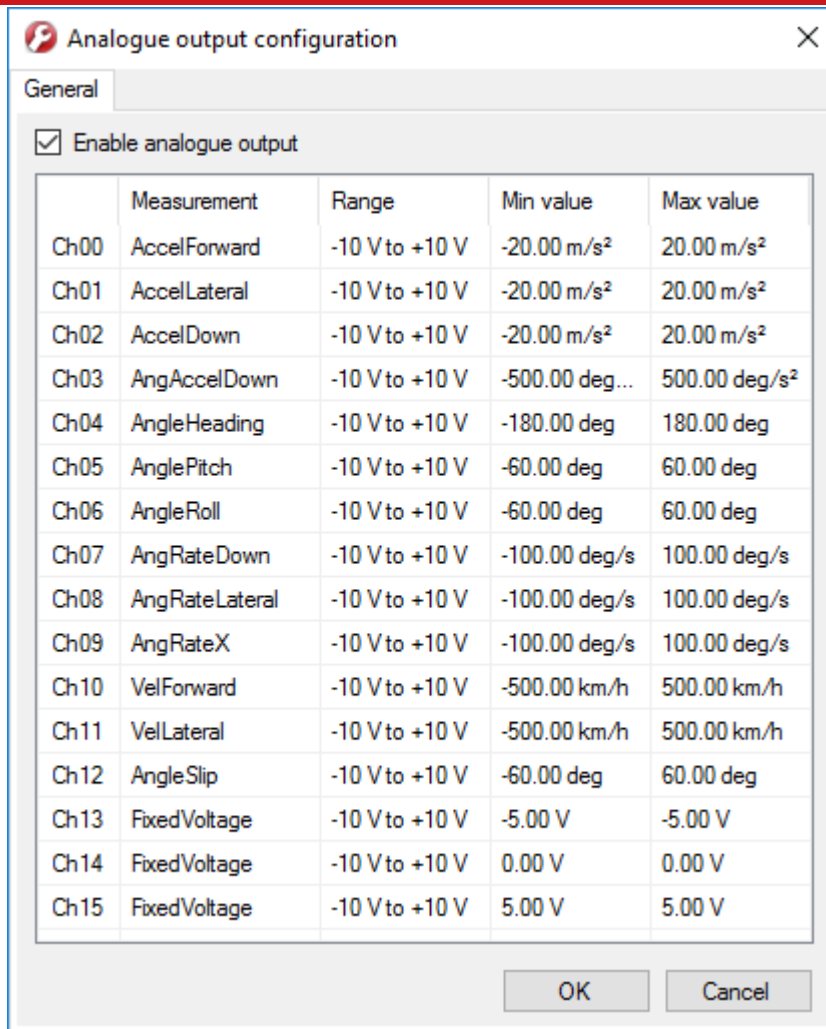
Analogue output

Adjustment: click ... button to open properties window.

The Analogue output 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.

Figure 34. NAVconfig Analogue outputs configuration window



Acceleration filter

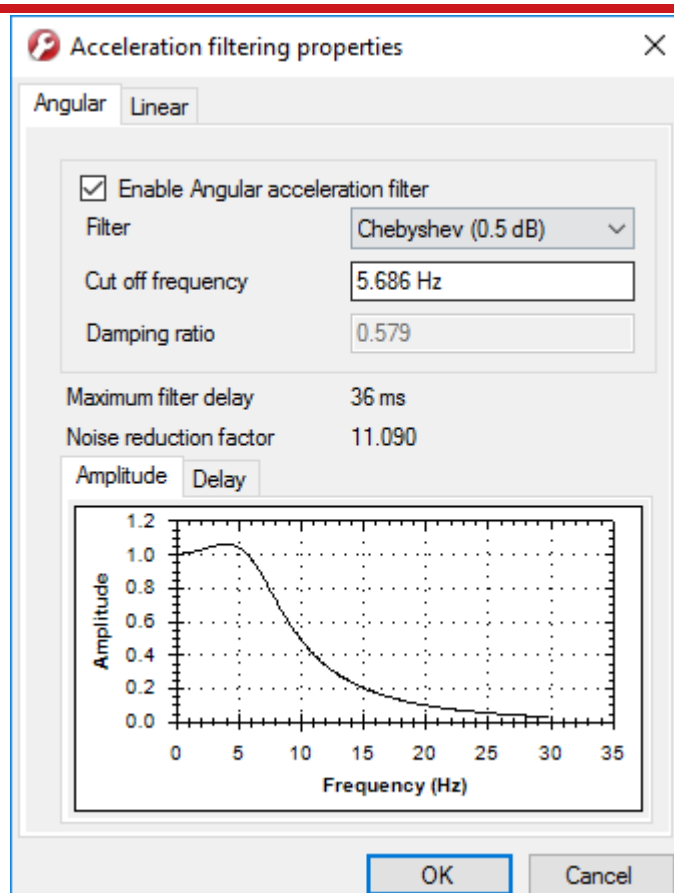
Adjustment: click ... button to open properties window.

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 filtering properties window (Figure 35).

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 35. NAVconfig acceleration filter properties window



Wheel speed input

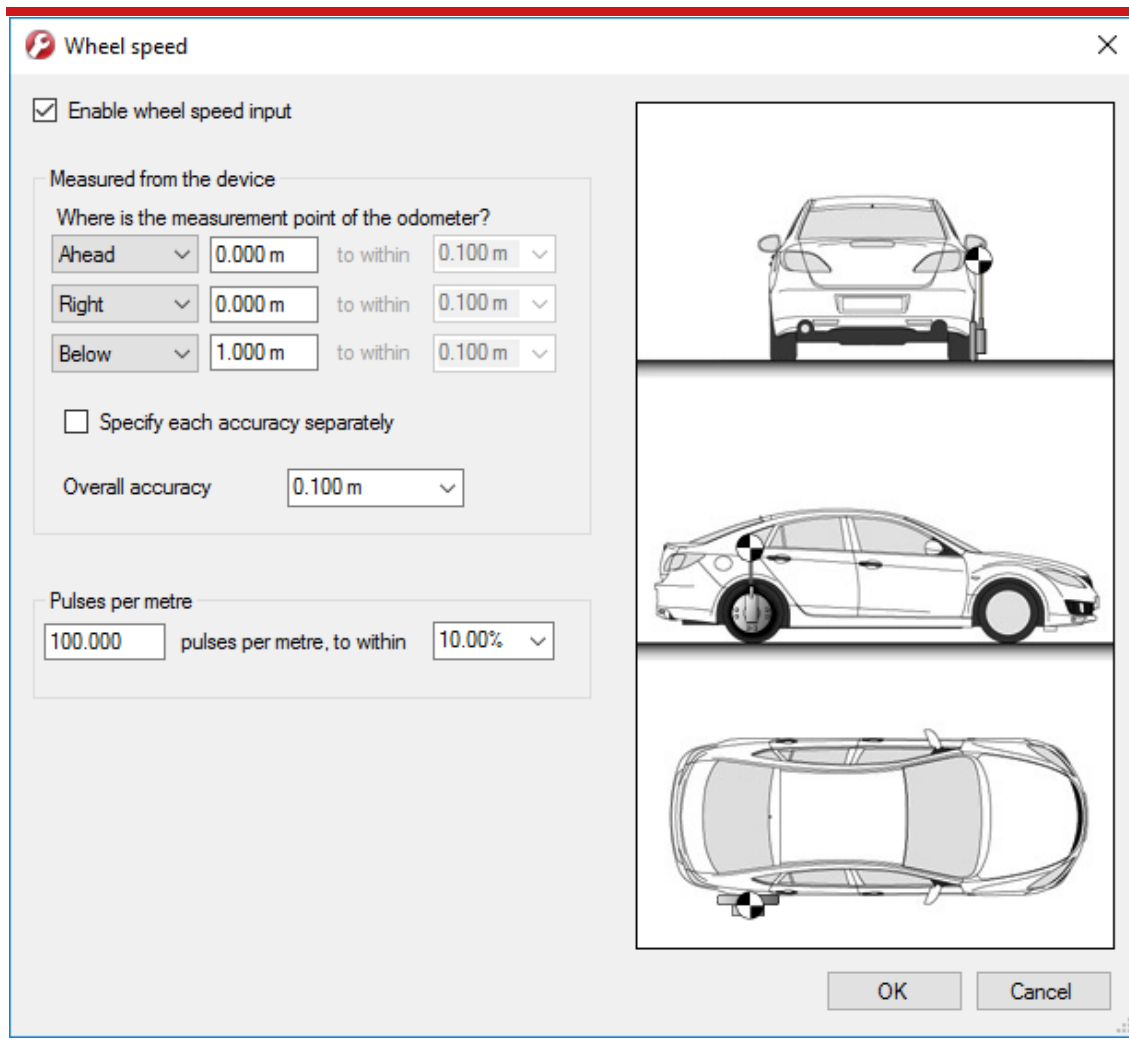
Adjustment: click ... button to open properties window.

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 Advanced slip feature (page 64) at the same time as wheel speed corrections.

As with the Advanced 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 36 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 36. NAVconfig wheel speed configuration window



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 drop-down 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

window will change depending on the settings you choose, to help visualise the position of the RT in relation the wheel speed.

Ideally the measurements would be 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 as the same for all measurements using **Overall accuracy** or it can be specified for each individual measurement by clicking the **Specify each accuracy separately** checkbox. In either case, choose a predefined value from the drop-down list or type in a value.

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 **Get improved settings** utility (see page 59 for details) 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.

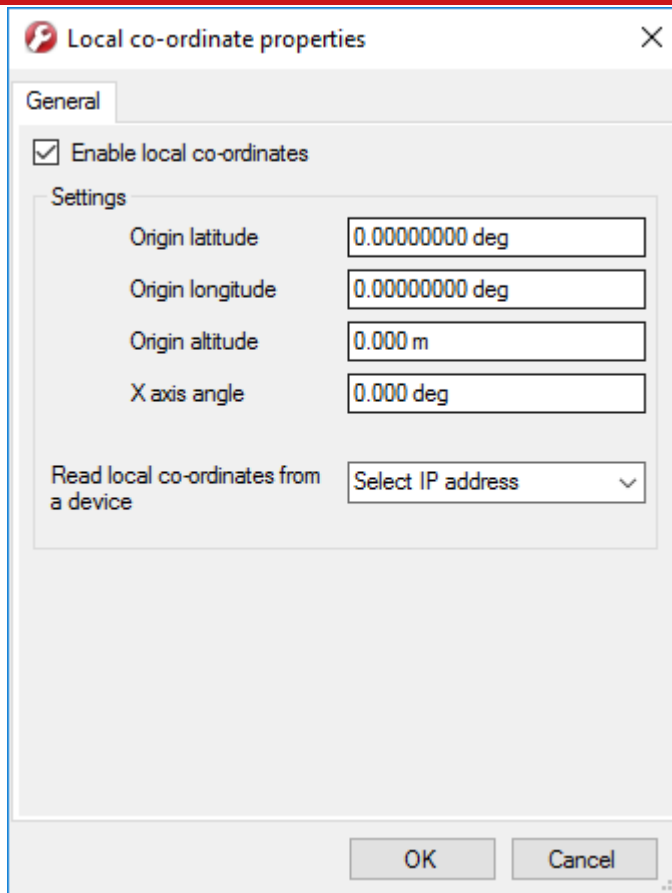
For best results, a front wheel drive vehicle should be used with the wheel speed on a rear wheel. The wheel speed pulses from driven wheels are less accurate.

Local co-ordinates

Adjustment: click ... button to open properties window.

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 in to 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 37. NAVconfig local co-ordinate properties window

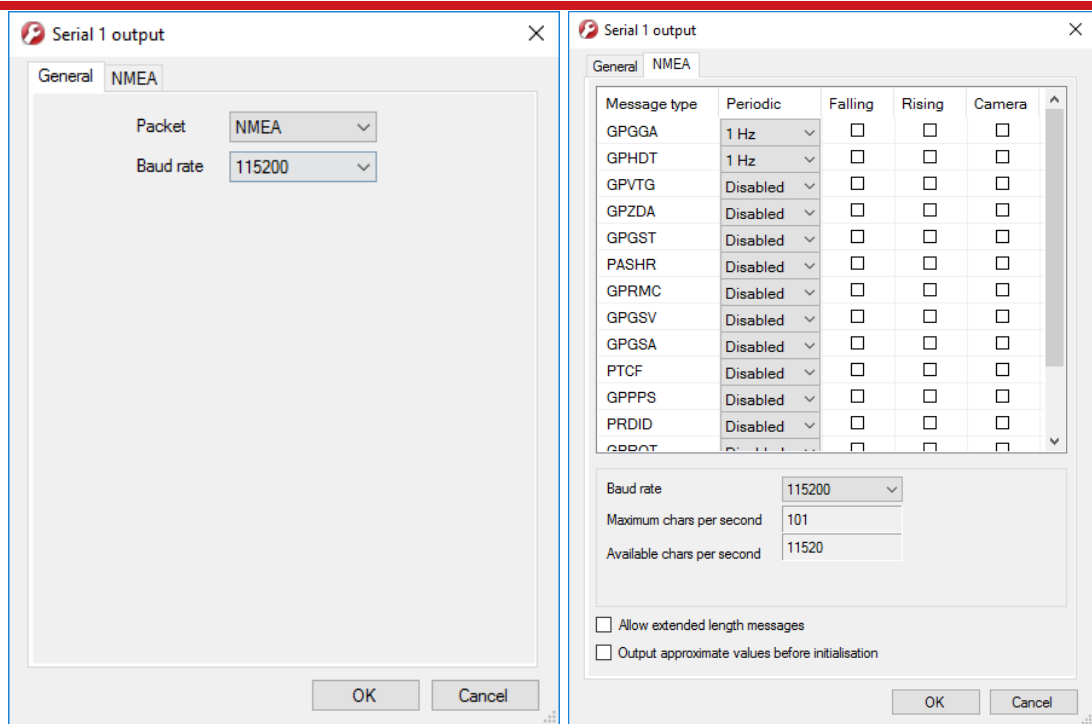


Serial 1 output

Adjustment: click ... button to open properties window.

The serial output ports can be configured for different message types. Figure 38 shows the properties windows for the Serial 1 output.

Figure 38. NAVconfig serial 1 output properties window



Note: NMEA tab only appears when NMEA is selected from the Packet drop-down list.

Select the message type to output from the **Packet** drop-down list and select the baud rate and data rate to output at. Table 33 gives details of the different messages.

Table 33. Serial output options

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 100 Hz or 125 Hz (for 250 Hz systems; RS232 does not support 250 Hz). 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.
IPAQ+	NCOM output at a reduced rate and polled. Windows Mobile 5 on IPAQs crashes if the RT is sending data when the IPAQ is turned on. Using IPAQ+ the IPAQ will poll the RT; the RT will not send data while the IPAQ is off, preventing the turn-on crash of the IPAQ.

NMEA	The NMEA outputs conform to the National Marine Electronics Association Standard (NMEA 0183 version 3.01). The NMEA sentences available are GPGGA, GPHTD, 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.
MCOM	Used for marine applications. Identical to NCOM output but with the addition of heave measurements.
TSS1	TSS1 format outputting acceleration, heave, roll and pitch.
TSSHHRP	TSSHHRP format.
EM3000	Suitable for use with Simrad EM3000 multibeam sounders.
EM1000	Suitable for use with Simrad EM1000 multibeam sounders.

If the NMEA packet type is selected, the **NMEA** tab will appear in the properties window (see Figure 38). In this tab the NMEA messages to output on the serial port of the RT are selected by choosing the data rate for each message type from the drop-down lists and clicking the checkbox for when to generate the message.

NMEA messages can be generated on the falling or rising edge of the event input. Check the falling or rising edge checkbox to instruct the RT to compute the sentence when the event occurs. The RT can also output NMEA messages when the distance output has a falling edge. The camera output replaces distance output when the distance output is set to less than 1 ppm (contact support@oxts.com for information on how to do this). These messages use interpolation to compute the values at the exact time of the event and 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.

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 certain extended NMEA sentences to be output. Please see the NMEA 0183 Description manual for more details.

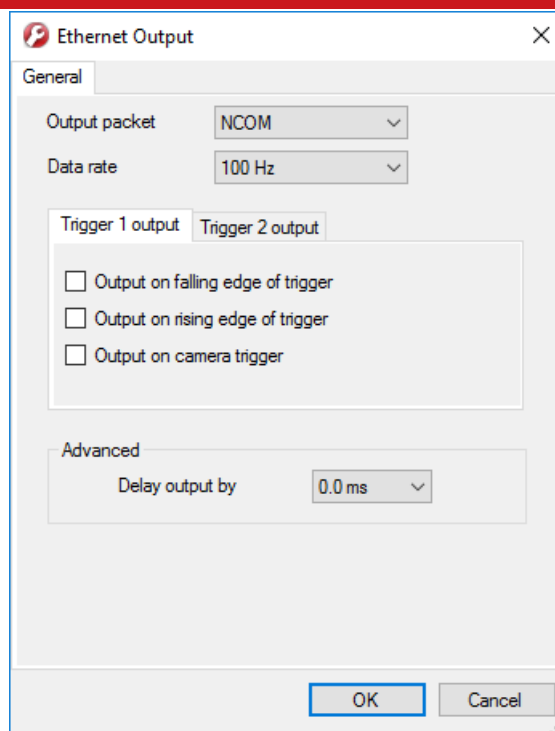
Selecting **Output approximate values before initialisation** forces output of the raw GNSS measurements before the RT is initialised. Note that there will be a jump (from the antenna to the inertial measurement unit) when initialisation occurs.

Ethernet output

Adjustment: click ... button to open properties window.

The Ethernet output of the RT can be configured for different data rates and delays. Figure 39 shows the Ethernet Output window.

Figure 39. NAVconfig Ethernet output properties window



The Ethernet Output can either output NCOM or MCOM, or be disabled by using the **Output Packet** drop-down list. When NCOM or MCOM is selected, the **Data rate** can be selected by using the drop-down list.

The RT can output Ethernet messages when an event (rising or falling edge) is input on the event input pin. It can also output Ethernet messages when the distance output is configured in camera output mode. This mode is enabled automatically by selecting a distance output of less than 1 ppm—contact support@oxts.com for details. These messages 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 if the events have a rate higher than 1 Hz, otherwise the output cannot communicate all of the events and some will be lost.

The output delay in **Advanced** should only be used with the RT-Range when there are multiple targets. It will delay the Ethernet broadcast from the RT by a number of milliseconds so the wireless LAN in the RT-Range can transmit each RT's messages at different time slots. The timing is not guaranteed when using this option and it should not be used in other applications.

Steering robot IP

Adjustment: select a predefined value from the drop down list, or type in a value.

The default address (195.0.0.100) is listed in the drop-down 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.

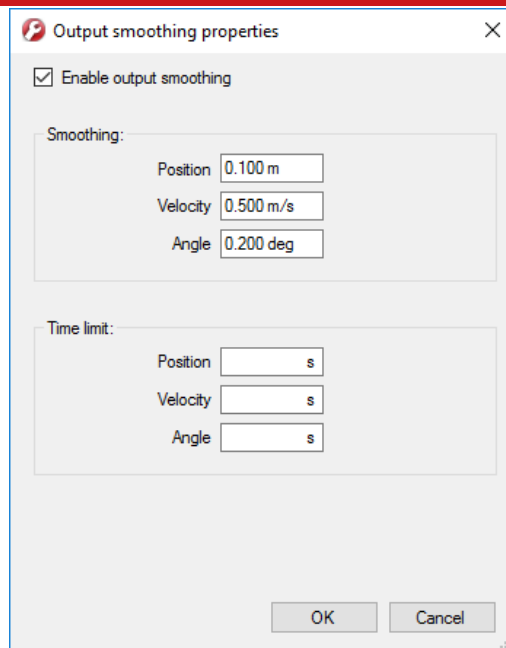
Output smoothing

Adjustment: click ... button to open properties window.

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 40 shows the Output smoothing window. Click the checkbox to enable output smoothing and unlock the properties for editing.

Figure 40. 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

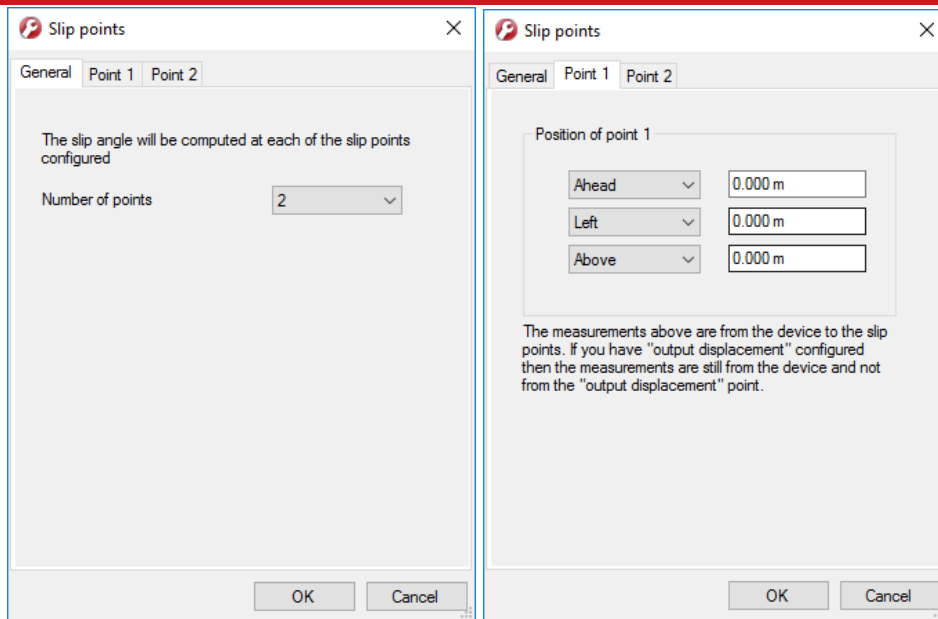
Adjustment: click ... button to open properties window.

The RT can output the slip angle measurements at additional points (maximum of eight points) on the CAN bus, see Table 40 for the CAN message ID of the slip points. Figure 41 shows the properties windows for slip point configuration.

On the **General** tab select the additional **Number of points** from the drop-down list. A number of additional tabs corresponding to the number of points selected will appear. Click on the **Point 1** and subsequent tabs to configure the position of each additional slip point. 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 41. NAVconfig Slip points properties window



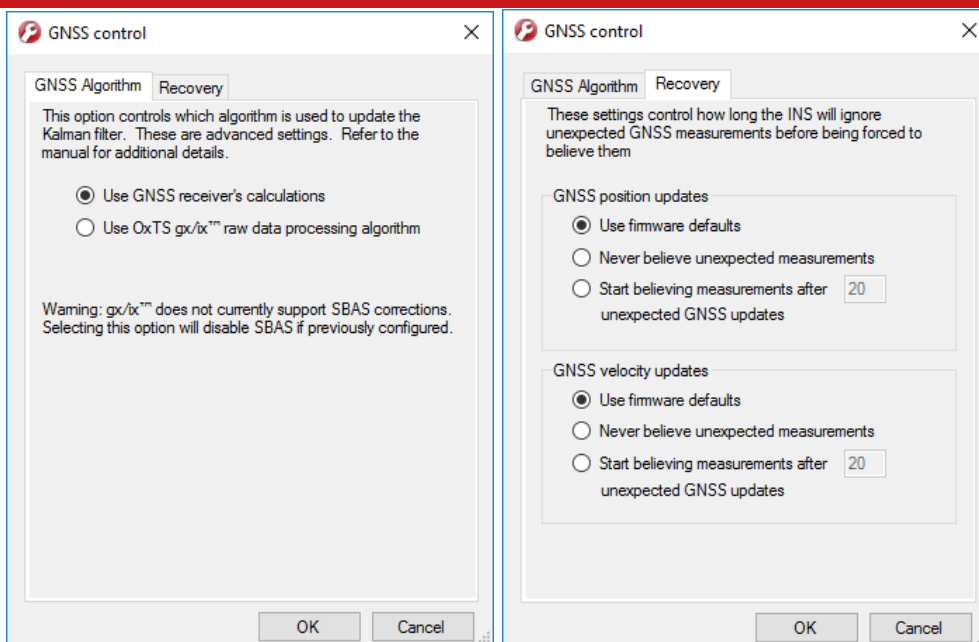
GNSS control

Adjustment: click ... button to open properties window.

The GNSS control option 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 42 shows both tabs in the GNSS control properties window.

Figure 42. NAVconfig GNSS control properties window



The **GNSS algorithm** tab gives a choice of two algorithms for computing the GNSS measurements. The default option is to use the algorithm provided by the GNSS receiver. Using this algorithm the RT will accept position and velocity from the GNSS and use it to update the Kalman filter.

The gx/ix raw data processing algorithm 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. Gx/ix mode is recommended to achieve the highest accuracy in environments where RTK lock may be difficult to maintain.

Note: gx/ix processing is a new technology and is still being developed and improved. As such there are some limitations to its compatibility. Table 34 details the current compatibilities of gx/ix mode.

Table 34. gx/ix compatibility

GNSS mode	Real-time	Post-process
SPS	✓	✓
SBAS	x	x
DGPS	✓	✓
RTK	x	✓

GLONASS

x

x

Note: only RTCM V3 format differential corrections are supported in gx/ix mode.

The **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.

The RT families have different GNSS receivers in which have different update rates for position and velocity. Table 35 shows the update rates of the RTs.

Table 35. GNSS update rates

Product family	Position	Velocity
RT2000	2 Hz	4 Hz
RT3000	2 Hz	10 Hz
RT4000	2 Hz	10 Hz

This means for example, that if you wish an RT3000 to start believing both position and velocity GNSS measurements after 30 s, the device it should be configured to start believing measurements after 60 position updates and 300 velocity updates.

Surface tilt

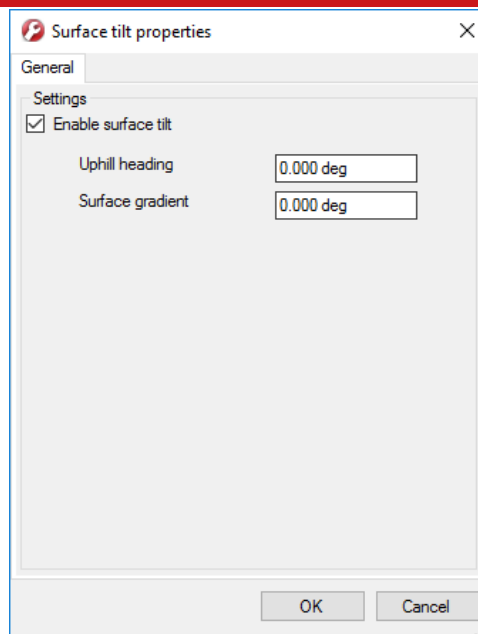
Adjustment: click ... button to open properties window.

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. Figure 43 shows the Surface tilt properties window.

Figure 43. NAVconfig Surface tilt properties window



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.

Coordinate system


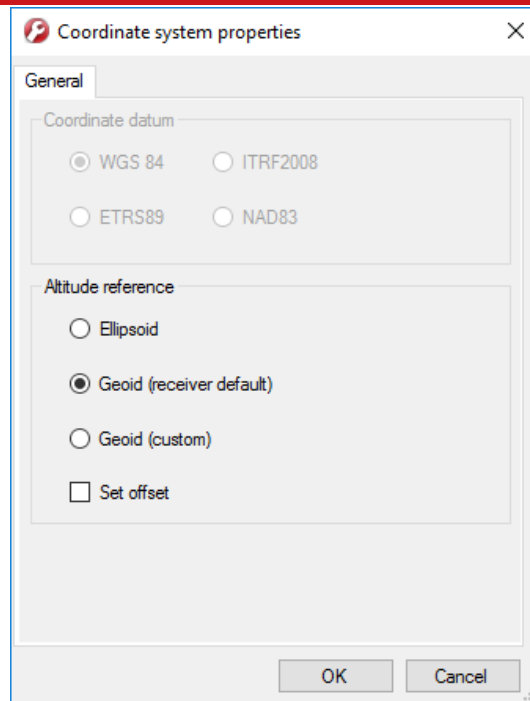
The RT can output position relative to different coordinate frames. Click the  button to open the properties window, shown in Figure 44.

Figure 44. NAVconfig coordinate system properties window



From the **Coordinate datum** section 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.

Advanced

Adjustment: click ... button to open settings window.

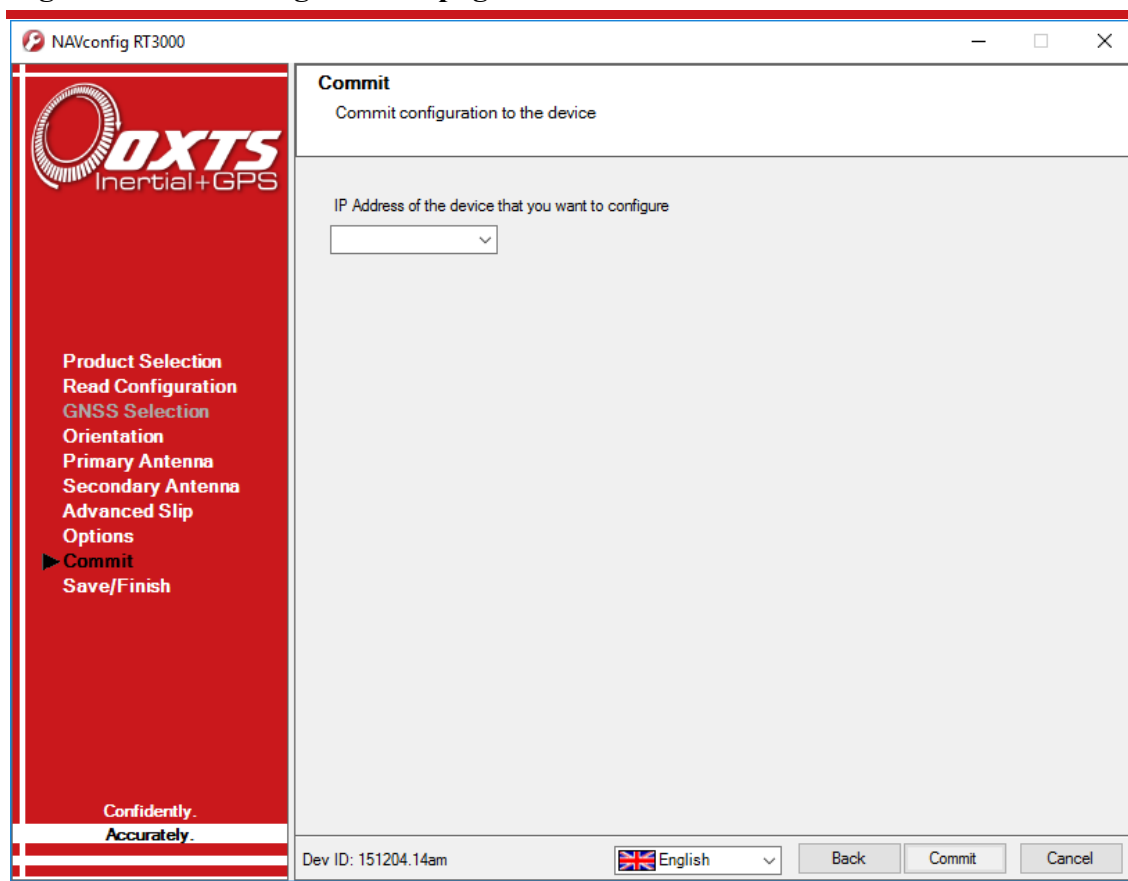
The Advanced option is used to set special commands for the RT. This should only be done with special instructions from OXTS.

Committing the configuration to the RT

Changes to the RT settings must be sent using Ethernet. It is necessary to configure your computer's Ethernet settings so it is on the same network as the RT. The section "Ethernet configuration" on page 43 gives details on how to do this.

Figure 45 shows the Commit page.

Figure 45. NAVconfig Commit page



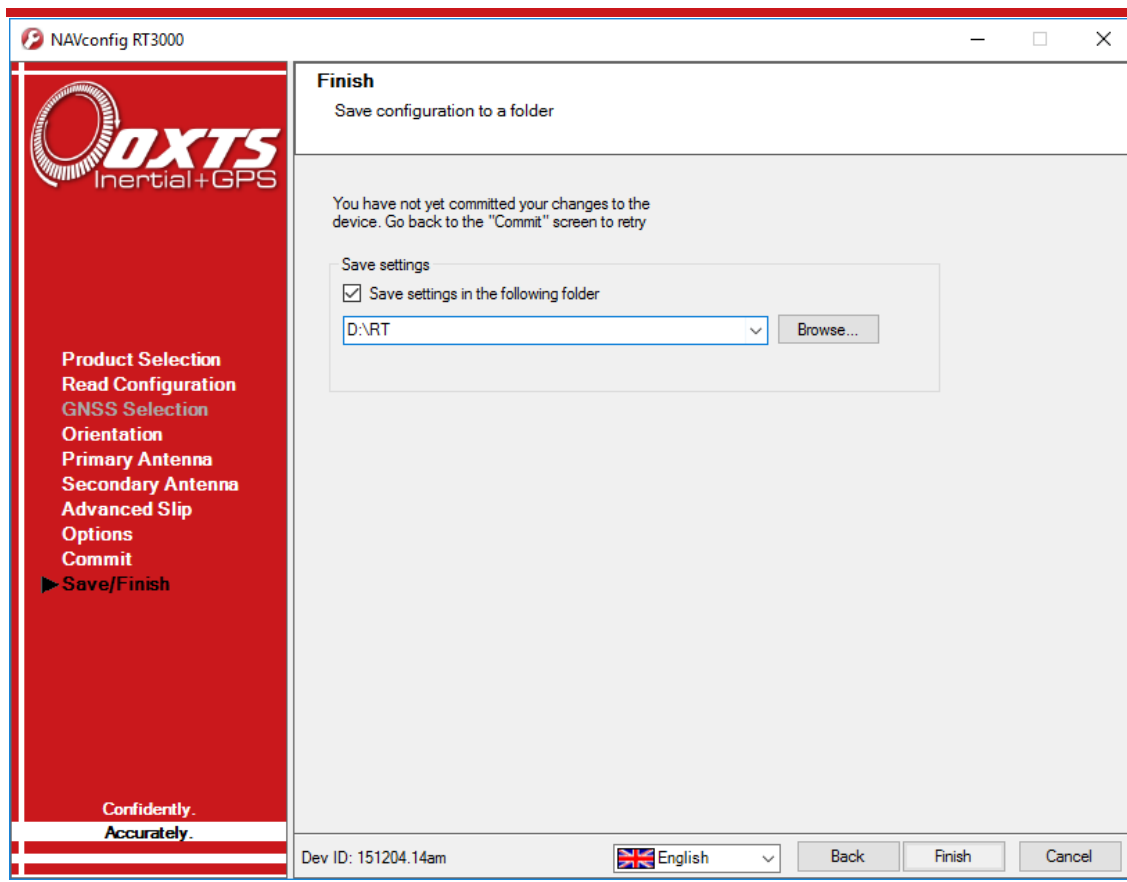
Enter the IP address of the RT you want to configure or select it from the drop-down list. The drop-down box will list all systems currently connected to the computer's network so ensure to select the correct system if there are multiple listed. The list will not function correctly if NAVdisplay or other software is using the RT UDP port unless the OXTS UDP server is running.

Press **Commit** to save the configuration in the RT. This will automatically reset the RT so the changes take effect. It will be necessary to initialise and warm-up the RT again after the changes have been applied.

Saving the configuration and finishing

Before finishing it is possible to save a copy of the configuration in a folder on the computer. This can then be loaded next time. The Save/Finish page also confirms if the settings have been committed successfully or not. Figure 46 shows the Save/Finish page.

Figure 46. NAVconfig Save/Finish page



To save a copy of the configuration in a local folder check the **Save settings in the following folder** box and use **Browse...** to select a folder. The configuration has a number of files associated with it so it is recommended to create a new folder. Click **Finish** to save the configuration to the selected folder and close NAVconfig.

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 36.

Table 36. Quantities required for initialisation

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.

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 SDNav 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 15 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:

3. 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).
4. 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. These are plotted in the example below.

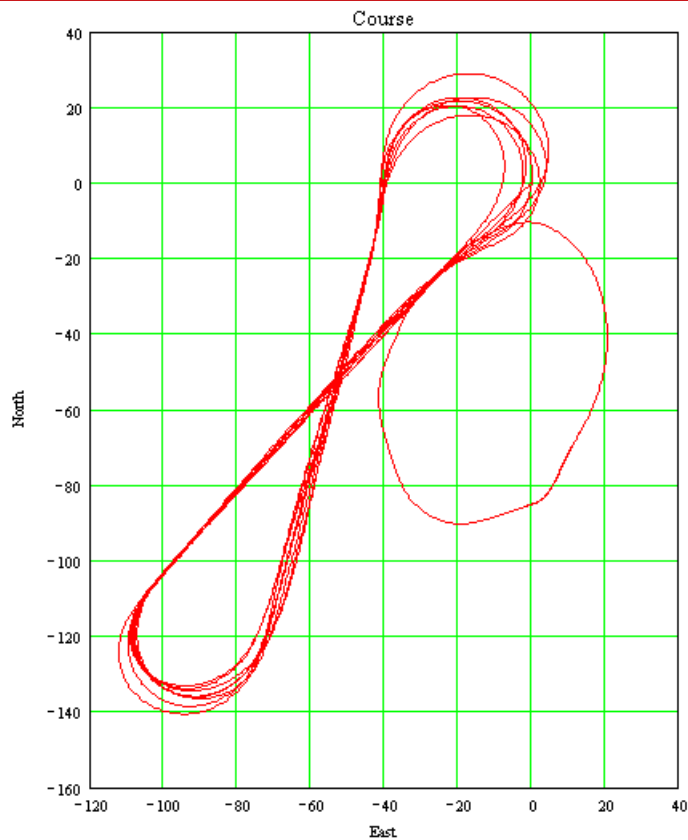
The warm-up period is a concern to some customers but it is often very simple to overcome. Below is an example of a good warm-up procedure that did not involve a lot of work for the user. In this example the key features are:

- The RT3003 was configured well—the GNSS antenna position, Advanced slip options and dual-antenna separation were measured accurately in advance.
- The RT3003 was turned on as soon as possible. In this case it took us 15 minutes to get all the other equipment sorted out. The RT was stationary for most of this period—which is not a problem.
- Although in this example the RT3003 was receiving corrections from a base station while stationary, it is not necessary. The base station should be working before the dynamic driving starts so the RT3003 can use the best information to self-calibrate (if a base station is not being use this does not apply).
- There are 6 minutes during which the car was driven in figures of eight. From the graphs you can see the RT3003 is accurate almost after the first figure of eight, after that the improvement is very small.

The trick is to turn the RT on early, do not reconfigure it (which resets it) or cycle the power.

Figure 47 shows the route driven and Figure 48 shows the accuracy estimated by the Kalman filter for various output parameters during the first 25 minutes. The quality of initialisation would have been the same if the stationary period was 10 minutes, followed by 5 minutes of driving. The time on the graphs is the time from initialisation. In this example the RT3003 was initialised 25 s after starting up; the quality of initialisation would be the same if it had been not been initialised for the first 10 minutes, then initialised and driven for 5 minutes.

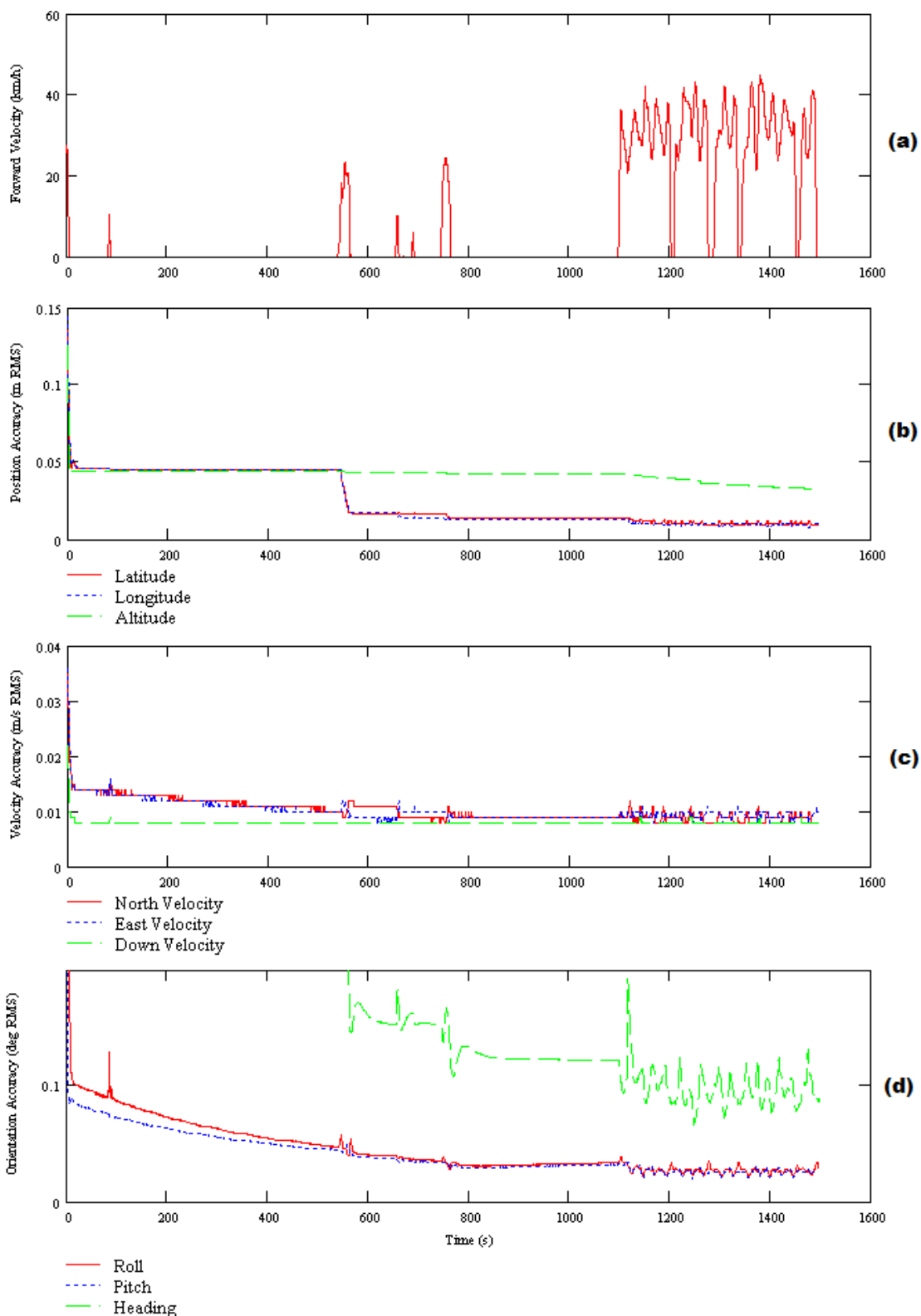
Figure 47. Example warm-up driving route



At the start there is just a small amount of motion to get the RT3003 initialised. During this time the Kalman filter cannot improve the position accuracy because the position of the GNSS antenna is not known accurately and cannot be estimated without motion. The accuracy of the velocity, roll and pitch steadily improves as the Kalman filter places more and more weight on the inertial sensors. At this point the heading accuracy is worse than the scale of the graph ((d) in Figure 48); the heading is not accurate and the dual antenna system cannot measure the angle of the GNSS antennas compared to the inertial sensors, so the dual antenna cannot provide accurate information.

Just after 500 s the RT3003 is driven (it is the small loop on the east side in Figure 47, not the figures of eight). This small amount of driving is sufficient for the Kalman filter to gain confidence in the antenna position and to improve the alignment of the two GNSS antennas compared to the inertial sensors. After this period the position accuracy is better than 1 cm and the heading is better than 0.2° .

Figure 48. Example warm-up accuracy estimates



(a) Forward velocity. (b) Position accuracies. (c) Velocity accuracies. (d) Orientation accuracies.

You can see the RT3003 is nearly at specification after just this small amount of driving. However, experience tells us the Kalman filter will continue to make some improvements (not obvious) during the first few figures of eight. The main part of the motion occurs after 1100 s when the car was driven in a figure of eight for 6 minutes.

These are fairly large figures of eight driven at relatively low speeds. Notice the brake stops in the velocity graph ((a) in Figure 48) where the speed falls to zero. These are important parts of the warm-up—so as many states in the Kalman filter as possible can be updated.

Notice how close to the specification the RT3003 is even without the figure of eight manoeuvres. A proper warm-up is recommended in order to achieve the highest level of accuracy. However the effect is small and only significant when you need the full performance of the RT.

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, which can be used to reprocess the data. NAVsolve 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.

Laboratory testing

There are several checks that can be performed in the laboratory to ensure the system is working correctly. The most fragile items in the system are the accelerometers, the other items are not subject to shock and do not need to be tested as thoroughly.

Accelerometer test procedure

To check the accelerometers are working correctly, follow this procedure.

1. Connect power and a laptop to the system.
2. Commit a default setting to the RT using NAVconfig, then run NAVdisplay.
3. Click the **Calibration** button, then select the **Navigation** tab and ensure the *x*, *y*, and *z* accelerations (values 19 to 21) are within specification when the RT is placed on a level surface in the orientations according to Table 37.

Table 37. Acceleration measurement specifications

Orientation			Acceleration measurement
<i>x</i>	<i>y</i>	<i>z</i>	
Flat	Flat	Down	<i>z</i> -acceleration between -9.7 and -9.9 m/s ²
Flat	Flat	Up	<i>z</i> -acceleration between 9.7 and 9.9 m/s ²
Down	Flat	Flat	<i>x</i> -acceleration between -9.7 and -9.9 m/s ²
Up	Flat	Flat	<i>x</i> -acceleration between 9.7 and 9.9 m/s ²
Flat	Down	Flat	<i>y</i> -acceleration between -9.7 and -9.9 m/s ²
Flat	Up	Flat	<i>y</i> -acceleration between 9.7 and 9.9 m/s ²

This test is sufficient to ensure the accelerometers have not been damaged.

Gyro test procedure

To check that the gyros (angular rate sensors) are working correctly, follow this procedure:

1. Connect power and a laptop to the system.
2. Commit a default setting to the RT using NAVconfig, then run NAVdisplay.
3. Click the **Calibration** button, then select the **Navigation** tab and scroll to view the x , y , and z angular rates (values 30 to 32).
4. Rotate the RT according to Table 38 and check the angular rate measurements occur.
5. With the unit stationary, check all the angular rates are within $\pm 5^\circ/\text{s}$. (In general they will be within $\pm 0.5^\circ/\text{s}$, but the algorithm in the RT will work to specification with biases up to $\pm 5^\circ/\text{s}$).

Table 38. Angular rate measurement specifications

Orientation			Angular rate measurement
x	y	z	
+ve	Zero	Zero	The x -axis should indicate positive rotation, others are small.
-ve	Zero	Zero	The x -axis should indicate negative rotation, others are small.
Zero	+ve	Zero	The y -axis should indicate positive rotation, others are small.
Zero	-ve	Zero	The y -axis should indicate negative rotation, others are small.
Zero	Zero	+ve	The z -axis should indicate positive rotation, others are small.
Zero	Zero	-ve	The z -axis should indicate negative rotation, others are small.

It is hard to do a more exhaustive test using the angular rate sensors without specialised software and equipment. For further calibration testing it is necessary to return the unit to OxTS.

Note that the RT is capable of correcting the error in the angular rate sensors *very* accurately. It is not necessary to have very small values for the angular rates when stationary since they will be estimated during the initialisation process and warm-up period. This estimation process allows the RT to go for long periods without requiring recalibration.

Testing the internal GNSS and other circuitry

To check all the internal circuits in the RT are working correctly and the navigation computer has booted correctly, use the following procedure:

1. Connect power to the system, connect the system to a laptop computer and run the visual display software (NAVdisplay).
2. Use Table 39, below, to check the status fields are changing.

Table 39. Status field checks

Field	Increment rate
IMU packets	100 per second or 250 per second, depending on product model.
IMU chars skipped	Not changing (but not necessarily zero).
GPS packets	Between 2 and 20 per second (depending on system).
GPS chars skipped	Not changing (but not necessarily zero).
GPS2 packets ¹	Between 2 and 20 per second (depending on system).
GPS2 char skipped ¹	Not changing (but not necessarily zero).

¹The GPS2 related fields will only increase for dual antenna systems.

These checks will ensure the signals from the GNSS and from the inertial sensors are being correctly received at the navigation computer.

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.

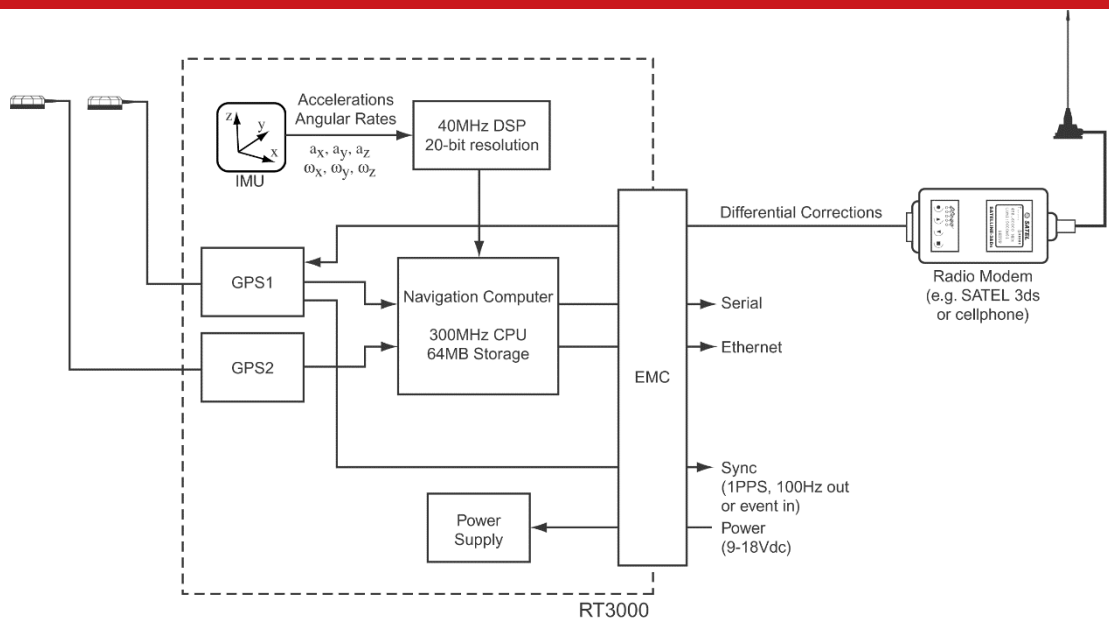
Operating principles

This short section gives some background information on the components in the RT and how they work together to give the outputs. A short overview of the algorithm is given and some explanation of how the software works. The section is provided as ‘interesting information’ and is not required for normal operation.

Internal components

Figure 49 gives a schematic view of the components in the RT system.

Figure 49. Schematic showing the internal components of the RT



The schematic shows the layout for a dual antenna system, the second GNSS (GNSS2) and the second antenna are not fitted on single antenna systems.

The accelerations and angular rates are measured in the inertial measurement unit. The accelerometers are all mounted at 90° to each other so they can measure each direction independently. The three angular rate sensors are mounted in the same three directions as the accelerometers. A powerful, 40 MHz floating point DSP controls the ADC and, through advanced signal processing, gives a resolution of 20-bits. Digital anti-aliasing filters and coning/sculling motion compensation algorithms are run on the DSP. Calibration of the accelerometers and angular rate sensors also takes place in the DSP; this includes very high-precision alignment matrices that ensure that the direction of the acceleration and angular rate measurements is accurate to better than 0.01°.

The sampling process in the inertial measurement unit is synchronised to GPS time so the 100 Hz or 250 Hz measurements from the RT are synchronised to GPS.

The navigation computer is a Pentium class processor that runs the navigation algorithms (more on this below). Information from the DSP and the two GNSS receivers is fed into the navigation computer. The navigation computer runs a real-time operating system (QNX) so outputs are made in a deterministic amount of time. The outputs from the navigation computer are available over Serial RS232, UDP broadcast on Ethernet or CAN bus.

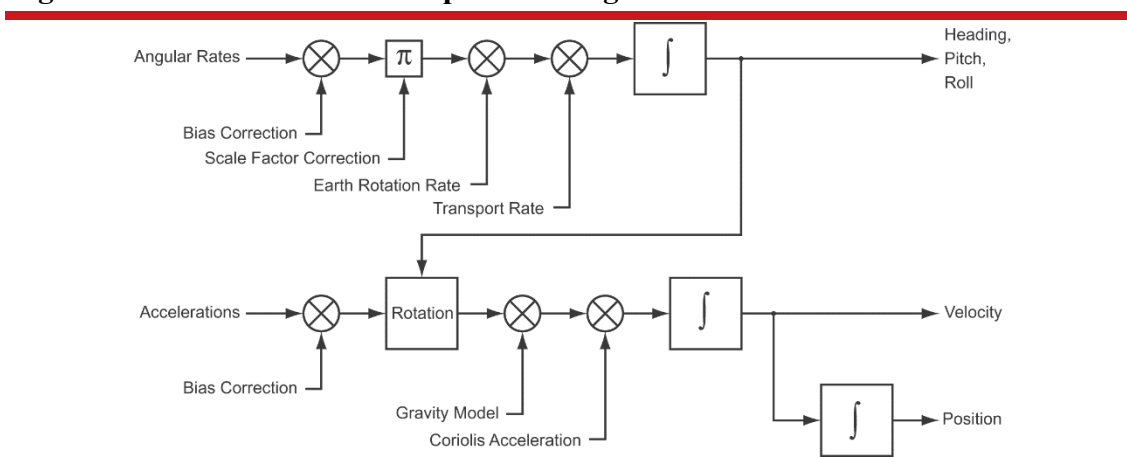
On RT3000 and RT4000, and some RT2000 products differential corrections can be supplied directly to the GNSS receiver to improve the positioning accuracy. The differential corrections can be supplied via radio modem from a base station, via cell phone from a base station or from a separate differential source, such as TerraStar or US Coastguard.

Strapdown navigator

The outputs of the system are derived directly from the strapdown navigator. The role of the strapdown navigator is to convert the measurements from the accelerometers and angular rate sensors to position. Velocity and orientation are also tracked and output by the strapdown navigator.

Figure 50 shows a basic overview of the strapdown navigator. Much of the detail has been left out and only the key elements are shown here.

Figure 50. Schematic of the strapdown navigator



People familiar with inertial navigation systems will note that ‘angular rates’ and ‘accelerations’ are labelled as the inputs. In reality the DSP in the RT converts these to ‘change in angle’ and ‘change in velocity’ to avoid problems of coning and sculling.

Some other rotations are also missed in the diagram. The RT does not use a wander angle, so it will not operate correctly on the North and South poles.

The angular rates have their bias and scale factor corrections (from the Kalman filter) applied. Earth rotation rate is also subtracted to avoid the 0.25° per minute rotation of the earth. The transport rate is also corrected; this is the rate that gravity rotates by due to the vehicle moving across the earth's surface and it is proportional to horizontal speed. Finally the angular rates are integrated to give heading, pitch and roll angles. These are represented internally using a quaternion (so the RT can work at any angle and does not have any singularities).

The accelerations have their bias corrections (from the Kalman filter) applied. Then they are rotated to give accelerations in the earth's co-ordinate frame (north, east down). Gravity is subtracted and Coriolis acceleration effects removed. The accelerations are integrated to give velocity. This is integrated to give position.

The strapdown navigator uses a WGS 84 model of the earth, the same as GPS uses. This is an elliptical model of the earth rather than a spherical one. The position outputs are in degrees latitude, degrees longitude and altitude. The altitude is the distance from the model's earth sea level.

The Kalman filter used in the RT is able to apply corrections to several places in the strapdown navigator, including position, velocity, heading, pitch, roll, angular rate bias and scale factor and acceleration bias.

Kalman filter

Kalman filters can be used to merge several measurements of a quantity and therefore give a better overall measurement. This is the case with position and velocity in the RT; the Kalman filter is used to improve the position measurement made from two sources, inertial sensors and GNSS.

Using a model of how one measurement affects another, the Kalman filter is able to estimate states where it has no direct measurement.

Consider a lift (or elevator) in a building. We might make measurements of acceleration and we might know what our position is when we pass a floor; these are the two measurements our system makes. A Kalman filter could be used to measure velocity in this situation even though no sensor measures velocity directly. The Kalman filter could also be used to measure the bias (or offset) of the accelerometer, thereby improving the system by providing on-line calibration. The bias of the accelerometer might mean the system always believes the lift arrives early at each floor; by changing the bias on the accelerometer the measurement of lift position can be made to correlate with the floor sensor more accurately.

The same principles are used in the RT. Position and velocity are compensated directly, but other measurements like accelerometer bias, have no direct measurements. The Kalman filter *tunes* these so the GNSS measurements and the inertial measurements match each other as closely as possible.

The Kalman filter in the RT has 24 states. These are position error (north, east, down); velocity error (north, east, down); heading error; pitch error; roll error; gyro bias (x, y, z); gyro scale factor (x, y, z); accelerometer bias (x, y, z); GNSS antenna position (x, y, z); GNSS antennas orientation (heading, pitch) and vehicle mounting angle (for advanced slip).

The errors are applied smoothly to the states. For example, if the Kalman filter wants to correct a position error of five centimetres in the north direction then this is applied slowly, rather than jumping directly to the new position. This helps applications that use the RT for control since any differential terms in the control algorithm do not have large step changes in them.

CAN messages and signals

In the default configuration the CAN bus uses identifiers 500h to 5FFh for RT status information; 600h to 60Fh for navigation information; 610h to 613h for RT-ANA messages and 620h to 623h for the additional slip points.

Using the configuration software it is possible to change the default message identifiers.

Only one status message is output per cycle (100 Hz or 250 Hz output rate) you do not get each status message at the specified rate.

All values from the RT are encoded in little-endian format (Intel-style).

Termination resistor

The CAN bus output does not include a termination resistor. It is essential to include a 120 Ω resistor at each end of your CAN bus—otherwise the CAN bus will not work.

CAN-DB file

NAVconfig can output a CAN DBC file that contains all the measurements the RT is configured to output. See the CAN option in NAVconfig (page 70).

CAN bus messages

Table 40 lists all the messages the RT outputs on the CAN bus and the identifiers that are used for each message. The signals in each message are listed in the tables that follow.

Table 40. CAN bus messages

Default identifier (hex)	Message name	Data contents	See table
1536 (600h)	DateTime	Date and time	Table 41
1537 (601h)	LatitudeLongitude	Latitude and longitude	Table 42
1538 (602h)	Altitude	Altitude	Table 43
1539 (603h)	Velocity	OxTS NED frame velocity	Table 44
1540 (604h)	VelocityLevel	OxTS horizontal frame velocity	Table 45
1541 (605h)	AccelVehicle	OxTS output frame IMU acceleration	Table 46
1542 (606h)	AccelLevel	OxTS horizontal frame IMU acceleration	Table 47
1543 (607h)	HeadingPitchRoll	OxTS orientation	Table 48

1544 (608h)	RateVehicle	OxTS output frame IMU angular rate	Table 49
1545 (609h)	RateLevel	OxTS horizontal frame IMU angular rate	Table 50
1546 (60Ah)	TrackSlipCurvature	Track, slip and curvature	Table 51
1547 (60Bh)	Distance	Distance	Table 52
1548 (60Ch)	PosLocal	Position in local co-ordinates	Table 53
1549 (60Dh)	VelYawLocal	Velocity and yaw angle in local co-ordinates	Table 54
1550 (60Eh)	AngAccelVehicle	OxTS output frame IMU angular acceleration	Table 55
1551 (60Fh)	AngAccelLevel	OxTS horizontal frame IMU angular acceleration	Table 56
1552...1555 (610h...613h)		Reserved for RT-ANA signals	
1568 (620h)	TrackSlipCurvaturePoint1	Measurement point 1 track, slip and curvature	Table 57
1569 (621h)	TrackSlipCurvaturePoint2	Measurement point 2 track, slip and curvature	Table 58
1570 (622h)	TrackSlipCurvaturePoint3	Measurement point 3 track, slip and curvature	Table 59
1571 (623h)	TrackSlipCurvaturePoint4	Measurement point 4 track, slip and curvature	Table 60
1572 (624h)	HeadingPitchRollFromSurf	Level surface orientation	Table 61
1573 (625h)	TrackSlipCurvaturePoint5	Measurement point 5 track, slip and curvature	Table 62
1574 (626h)	TrackSlipCurvaturePoint6	Measurement point 6 track, slip and curvature	Table 63
1575 (627h)	TrackSlipCurvaturePoint7	Measurement point 7 track, slip and curvature	Table 64
1576 (628h)	TrackSlipCurvaturePoint8	Measurement point 8 track, slip and curvature	Table 65
1577 (629h)	ApproxLatitudeLongitude	Approximate latitude and longitude	Table 66
1578 (62Ah)	ApproxAltitude	Approximate altitude	Table 67
1579 (62Bh)	ApproxVelocity	Approximate OxTS NED frame velocity	Table 68
1580 (62Ch)	Reserved		
1581 (62Dh)	FallingTrigger	Trigger 1 falling edge	Table 69
1582 (62Eh)	RisingTrigger	Trigger 1 rising edge	Table 70
1583 (62Fh)	PosLocalNE	Northing and easting in local co-ordinates	Table 71
1584 (630h)	MilliTime	Absolute GPS time	Table 72
1585 (631h)	Reserved		
1586 (632h)	Reserved		

1587 (633h)	IsoOrientation	ISO 8855 orientation	Table 73
1588 (634h)	IsoVsVelocity	ISO 8855 vehicle system velocity	Table 74
1589 (635h)	IsoVsAcceleration	ISO 8855 vehicle system acceleration	Table 75
1590 (636h)	IsoVsAngularVelocity	ISO 8855 vehicle system angular velocity	Table 76
1591 (637h)	IsoVsAngularAcceleration	ISO 8855 vehicle system angular acceleration	Table 77
1592 (638h)	IsoIsVelocity	ISO 8855 intermediate system velocity	Table 78
1593 (639h)	IsoIsAcceleration	ISO 8855 intermediate system acceleration	Table 79
1594 (63Ah)	IsoIsAngularVelocity	ISO 8855 intermediate system angular velocity	Table 80
1595 (63Bh)	IsoIsAngularAcceleration	ISO 8855 intermediate system angular acceleration	Table 81
1596 (63Ch)	IsoEfsVelocity	ISO 8855 earth-fixed system velocity	Table 82
1597 (63Dh)	IsoEfsAcceleration	ISO 8855 earth-fixed system acceleration	Table 83

The status information in NCOM is output over the CAN bus on Identifiers 500h to 5FFh. The offset from 500h is the same as the *Channel* number in the NCOM message definition. The bytes 0 to 7 are the same in the CAN message as in the NCOM packet.

Table heading definitions

The fields in the tables have the following meanings.

Offset (bits). This is the offset into the message where the signal starts. To compute the offset in bytes divide the value by 8.

Length (bits). This is the length of the signal in bits. To compute the length of the signal in bytes, divide the value by 8.

Type. This specifies either an unsigned value (U) or a signed value (S).

Units. This is the units for the signal.

Factor. This is the factor that the integer unit should be multiplied by to get the signal into the units given in the table.

Offset. This is the value of the signal when the integer value in the CAN message is zero. It is zero for all the RT signals and can usually be discarded.

Signals

The following tables describe the signals in each of the messages.

Table 41. Identifier 600h (1536), DateTime

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	8	U	Year	1	0	Year within century (e.g. '16' during year 2016)	TimeYear
8	8	U	Year	100	0	Century (e.g. '20' during 2016)	TimeCentury
16	8	U	Month	1	0	Month	TimeMonth
24	8	U	Day	1	0	Day	TimeDay
32	8	U	s	0.01	0	Hundredths of current second	TimeHSecond
40	8	U	s	1	0	Seconds	TimeSecond
48	8	U	Min	1	0	Minutes	TimeMinute
56	8	U	Hour	1	0	Hours	TimeHour

Note: time is always reported as GPS time. Currently this is 16 s different from UTC.

Table 42. Identifier 601h (1537), LatitudeLongitude

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	32	S	°	1e-7	0	Latitude	PosLat
32	32	S	°	1e-7	0	Longitude	PosLon

Table 43. Identifier 602h (1538), Altitude

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	32	S	m	0.001	0	Altitude	Altitude

By default the altitude is output relative to mean sea level, not WGS 84. The datum can be changed using NAVconfig.

Table 44. Identifier 603h (1539), Velocity

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	S	m/s	0.01	0	OxTS NED frame north velocity	VelNorth
16	16	S	m/s	0.01	0	OxTS NED frame east velocity	VelEast
32	16	S	m/s	0.01	0	OxTS NED frame vertical (down) velocity	VelDown
48	16	U	m/s	0.01	0	Horizontal speed	Speed2D

The horizontal speed is the vector addition of north and east velocities. For forward speed (which can go negative) see message 604h.

Table 45. Identifier 604h (1540), VelocityLevel

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	S	m/s	0.01	0	OxTS horizontal frame longitudinal (forward) velocity	VelForward
16	16	S	m/s	0.01	0	OxTS horizontal frame lateral (right) velocity	VelLateral

The forward velocity can go negative when driving backwards.

Table 46. Identifier 605h (1541), AccelVehicle

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	S	m/s ²	0.01	0	OxTS output frame longitudinal (forward) IMU acceleration	AccelX
16	16	S	m/s ²	0.01	0	OxTS output frame lateral (right) IMU acceleration	AccelY
32	16	S	m/s ²	0.01	0	OxTS output frame vertical (down) IMU acceleration	AccelZ

Table 47. Identifier 606h (1542), AccelLevel

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	S	m/s ²	0.01	0	OxTS horizontal frame longitudinal (forward) IMU acceleration	AccelForward
16	16	S	m/s ²	0.01	0	OxTS horizontal frame lateral (right) IMU acceleration	AccelLateral
32	16	S	m/s ²	0.01	0	OxTS horizontal frame vertical (down) IMU acceleration	AccelDown
48	16	S	m/s ²	0.01	0	Slip rate	AccelSlip

Table 48. Identifier 607h (1543), HeadingPitchRoll

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	U	°	0.01	0	Heading angle	AngleHeading
16	16	S	°	0.01	0	Pitch angle	AnglePitch
32	16	S	°	0.01	0	Roll angle	AngleRoll

Note: the range of the heading angle is 0 to 359.99 The range of the pitch angle is ±90° and the range of the roll angle is ±180°.

Table 49. Identifier 608h (1544), RateVehicle

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	S	%s	0.01	0	OxTS output frame longitudinal (forward) IMU angular rate	AngRateX
16	16	S	%s	0.01	0	OxTS output frame lateral (right) IMU angular rate	AngRateY
32	16	S	%s	0.01	0	OxTS output frame vertical (down) IMU angular rate	AngRateZ

Table 50. Identifier 609h (1545), RateLevel

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	S	%s	0.01	0	OxTS horizontal frame longitudinal (forward) IMU angular rate	AngRateForward
16	16	S	%s	0.01	0	OxTS horizontal frame lateral (right) IMU angular rate	AngRateLateral
32	16	S	%s	0.01	0	OxTS horizontal frame vertical (down) IMU angular rate	AngRateDown

See message 608h for roll angular rate. The definition of roll rate used in this manual is consistent with the Euler angles used to output roll, pitch and heading; therefore the roll angular rate is the same as the pitched *x*-angular rate or the body *x*-angular rate. The forward angular rate is the rotation about the axis which is horizontal.

Table 51. Identifier 60Ah (1546), TrackSlipCurvature

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	U	°	0.01	0	Track angle	AngleTrack
16	16	S	°	0.01	0	Slip angle	AngleSlip
32	16	S	1/m	0.0001	0	Curvature	Curvature

Note that the slip angle will be close to 180° when driving backwards.

Table 52. Identifier 60Bh (1547), Distance

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	32	U	m	0.001	0	Horizontal distance with hold	DistanceWithHold
32	32	U	m	0.001	0	Horizontal distance without hold	Distance

Note: Distance with hold will not increase when the RT measures a speed less than 0.2 m/s whereas the Distance field will drift by the noise of the RT when stationary. The distances start from zero when the RT-CAN unit is powered up.

Table 53. Identifier 60Ch (1548), PosLocal

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	32	S	m	0.0001	0	Distance from origin along x-axis	PosLocalX
32	32	S	m	0.0001	0	Distance from origin along y-axis	PosLocalY

Note: The origin is set using the local co-ordinates option in NAVconfig. The convention used for the local co-ordinates uses a right-handed set with the z-axis up.

Table 54. Identifier 60Dh (1549), VelYawLocal

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	S	m/s	0.01	0	Velocity along the x-axis	VelLocalX
16	16	S	m/s	0.01	0	Velocity along the y-axis	VelLocalY
32	16	S	°	0.01	0	Yaw angle	AngleLocalYaw
48	16	S	°	0.01	0	Track angle in local co-ordinates	AngleLocalTrack

Note: The convention used for the local co-ordinates uses a right-handed set with the z-axis up.

Table 55. Identifier 60Eh (1550), AngAccelVehicle

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	S	°/s ²	0.1	0	OxTS output frame longitudinal (forward) IMU angular acceleration	AngAccelX
16	16	S	°/s ²	0.1	0	OxTS output frame lateral (right) IMU angular acceleration	AngAccelY
32	16	S	°/s ²	0.1	0	OxTS output frame vertical (down) IMU angular acceleration	AngAccelZ

Table 56. Identifier 60Fh (1551), AngAccelLevel

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	S	°/s ²	0.1	0	OxTS horizontal frame longitudinal (forward) IMU angular acceleration	AngAccelForward
16	16	S	°/s ²	0.1	0	OxTS horizontal frame lateral (right) IMU angular acceleration	AngAccelLateral
32	16	S	°/s ²	0.1	0	OxTS horizontal frame vertical (down) IMU angular acceleration	AngAccelDown

Table 57. Identifier 620h (1568), TrackSlipCurvaturePoint1

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	U	°	0.01	0	Measurement point 1 track angle	AngleTrackPoint1
16	16	S	°	0.01	0	Measurement point 1 slip angle	AngleSlipPoint1
32	16	S	1/m	0.0001	0	Measurement point 1 curvature	CurvaturePoint1

Note that the slip angle of point 1 will be close to 180° when driving backwards.

Table 58. Identifier 621h (1569), TrackSlipCurvaturePoint2

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	U	°	0.01	0	Measurement point 2 track angle	AngleTrackPoint2
16	16	S	°	0.01	0	Measurement point 2 slip angle	AngleSlipPoint2
32	16	S	1/m	0.0001	0	Measurement point 2 curvature	CurvaturePoint2

Note that the slip angle of point 2 will be close to 180° when driving backwards.

Table 59. Identifier 622h (1570), TrackSlipCurvaturePoint3

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	U	°	0.01	0	Measurement point 3 track angle	AngleTrackPoint3
16	16	S	°	0.01	0	Measurement point 3 slip angle	AngleSlipPoint3
32	16	S	1/m	0.0001	0	Measurement point 3 curvature	CurvaturePoint3

Note that the slip angle of point 3 will be close to 180° when driving backwards.

Table 60. Identifier 623h (1571), TrackSlipCurvaturePoint4

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	U	°	0.01	0	Measurement point 4 track angle	AngleTrackPoint4
16	16	S	°	0.01	0	Measurement point 4 slip angle	AngleSlipPoint4
32	16	S	1/m	0.0001	0	Measurement point 4 curvature	CurvaturePoint4

Note that the slip angle of point 4 will be close to 180° when driving backwards.

Table 61. Identifier 624h (1572), HeadingPitchRollFromSurf

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	U	°	0.01	0	Heading relative to the road surface	AngleHeadingFromSurf
16	16	S	°	0.01	0	Pitch relative to the road surface	AnglePitchFromSurf
32	16	S	°	0.01	0	Roll relative to the road surface	AngleRollFromSurf

Note: the range of heading is 0 to 360°; the range of pitch is ±90°; the range of roll is ±180°. The road surface angle needs to be defined in order for these measurements to be active.

Table 62. Identifier 625h (1573), TrackSlipCurvaturePoint5

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	U	°	0.01	0	Measurement point 5 track angle	AngleTrackPoint5
16	16	S	°	0.01	0	Measurement point 5 slip angle	AngleSlipPoint5
32	16	S	1/m	0.0001	0	Measurement point 5 curvature	CurvaturePoint5

Note that the slip angle of point 5 will be close to 180° when driving backwards.

Table 63. Identifier 626h (1574), TrackSlipCurvaturePoint6

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	U	°	0.01	0	Measurement point 6 track angle	AngleTrackPoint6
16	16	S	°	0.01	0	Measurement point 6 slip angle	AngleSlipPoint6
32	16	S	1/m	0.0001	0	Measurement point 6 curvature	CurvaturePoint6

Note that the slip angle of point 6 will be close to 180° when driving backwards.

Table 64. Identifier 627h (1575), TrackSlipCurvaturePoint7

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	U	°	0.01	0	Measurement point 7 track angle	AngleTrackPoint7
16	16	S	°	0.01	0	Measurement point 7 slip angle	AngleSlipPoint7
32	16	S	1/m	0.0001	0	Measurement point 7 curvature	CurvaturePoint7

Note that the slip angle of point 7 will be close to 180° when driving backwards.

Table 65. Identifier 628h (1576), TrackSlipCurvaturePoint8

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	U	°	0.01	0	Measurement point 8 track angle	AngleTrackPoint8
16	16	S	°	0.01	0	Measurement point 8 slip angle	AngleSlipPoint8
32	16	S	1/m	0.0001	0	Measurement point 8 curvature	CurvaturePoint8

Note that the slip angle of point 8 will be close to 180° when driving backwards.

Table 66. Identifier 629h (1577), ApproxLatitudeLongitude

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	32	S	degrees	1e-7	0	Approximate latitude	ApproxPosLat
32	32	S	degrees	1e-7	0	Approximate longitude	ApproxPosLon

Before initialisation the approximate latitude and longitude message will have the GNSS measurement of latitude and longitude (at the GNSS antenna location). After initialisation it will contain the same latitude and longitude as message 601h.

Table 67. Identifier 62Ah (1578), ApproxAltitude

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	32	S	m	0.001	0	Approximate altitude	ApproxPosAlt

By default, the altitude is output relative to mean sea level, not WGS 84. See altitude in the NCOM description for information on how to change this. Before initialisation the approximate altitude message will have the GNSS measurement of altitude (at the GNSS antenna location). After initialisation it will contain the same altitude as message 602h.

Table 68. Identifier 62Bh (1579), ApproxVelocity

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	S	m/s	0.01	0	Approximate OxTS NED frame north velocity	ApproxVelNorth
16	16	S	m/s	0.01	0	Approximate OxTS NED frame east velocity	ApproxVelEast
32	16	S	m/s	0.01	0	Approximate OxTS NED frame vertical (down) velocity	ApproxVelDown
48	16	U	m/s	0.01	0	Approximate horizontal speed	ApproxSpeed2D

Before initialisation the approximate velocity message will have the GNSS measurement of velocity (at the GNSS antenna location). After initialisation it will contain the same altitude as message 603h.

Table 69. Identifier 62Dh (1581), FallingTrigger

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	8	U		1	0	TTL signal level (0 low, 1 high, 255 unknown)	SignalLevelFalling
8	8	U		1	0	Trigger count, increments with each new trigger	TriggerCountFalling
16	16	U	s	0.0002	0	Time since last trigger	TriggerTimeFalling
32	32	U	m	0.001	0	Distance with hold since last trigger	TriggerDistanceFalling

Table 70. Identifier 62Eh (1582), RisingTrigger

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	8	U		1	0	TTL signal level (0 low, 1 high, 255 unknown)	SignalLevelRising

8	8	U		1	0	Trigger count, increments with each new trigger	TriggerCountRising
16	16	U	s	0.0002	0	Time since last trigger	TriggerTimeRising
32	32	U	m	0.001	0	Distance with hold since last trigger	TriggerDistanceRising

Table 71. Identifier 62Fh (1583), PosLocalNE

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	32	S	m	0.0001	0	Northing	PosLocalNorth
32	32	S	m	0.0001	0	Easting	PosLocalEast

Table 72. Identifier 630h (1584), MilliTime

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	48	S	ms	1	0	Milliseconds since the start of GPS time	MilliTime
0	48	S	s	0.001	0	Seconds since the start of GPS time	MilliTimeSeconds
48	8	S	s	1	0	GPS UTC offset	UtcOffset

Note: MilliTime and MilliTimeSeconds both refer to the same bits on the CAN bus—however they are decoded twice with a different scale in the DBC file. MilliTime needs to be stored as a signed 64-bit integer value as the current value already exceeds the limits of a 32-bit integer, however this is not supported by all CAN software. To overcome that problem MilliTimeSeconds can be stored as a 32-bit double-precision value, however limitations in the double-precision format mean there may be an error of up to 5 ms and the resulting decimal numbers may contain rounding errors. Where possible MilliTime should be used, otherwise use MilliTimeSeconds with care.

Table 73. Identifier 633h (1587), IsoOrientation

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	S	°	0.01	0	ISO 8855 yaw angle	IsoYawAngle

16	16	S	°	0.01	0	ISO 8855 pitch angle	IsoPitchAngle
32	16	S	°	0.01	0	ISO 8855 roll angle	IsoRollAngle

Table 74. Identifier 634h (1588), IsoVsVelocity

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	S	m/s	0.01	0	ISO 8855 vehicle system longitudinal (forward) velocity	IsoVsLongitudinalVelocity
16	16	S	m/s	0.01	0	ISO 8855 vehicle system lateral (left) velocity	IsoVsLateralVelocity
32	16	S	m/s	0.01	0	ISO 8855 vehicle system vertical (up) velocity	IsoVsVerticalVelocity

Table 75. Identifier 635h (1589), IsoVsAcceleration

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	S	m/s ²	0.01	0	ISO 8855 vehicle system longitudinal (forward) acceleration	IsoVsLongitudinalAcceleration
16	16	S	m/s ²	0.01	0	ISO 8855 vehicle system lateral (left) acceleration	IsoVsLateralAcceleration
32	16	S	m/s ²	0.01	0	ISO 8855 vehicle system vertical (up) acceleration	IsoVsVerticalAcceleration

Table 76. Identifier 636h (1590), IsoVsAngularVelocity

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	S	°/s	0.01	0	ISO 8855 vehicle system roll (longitudinal angular) velocity	IsoVsRollVelocity
16	16	S	°/s	0.01	0	ISO 8855 vehicle system pitch (lateral angular) velocity	IsoVsPitchVelocity
32	16	S	°/s	0.01	0	ISO 8855 vehicle system yaw (vertical angular) velocity	IsoVsYawVelocity

Table 77. Identifier 637h (1591), IsoVsAngularAcceleration

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	S	°/s ²	0.1	0	ISO 8855 vehicle system roll (longitudinal angular) acceleration	IsoVsRollAcceleration
16	16	S	°/s ²	0.1	0	ISO 8855 vehicle system pitch (lateral angular) acceleration	IsoVsPitchAcceleration
32	16	S	°/s ²	0.1	0	ISO 8855 vehicle system yaw (vertical angular) acceleration	IsoVsYawAcceleration

Table 78. Identifier 638h (1592), IsoIsVelocity

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	S	m/s	0.01	0	ISO 8855 intermediate system longitudinal (forward) velocity	IsoIsLongitudinalVelocity

16	16	S	m/s	0.01	0	ISO 8855 intermediate system lateral (left) velocity	IsoIsLateralVelocity
32	16	S	m/s	0.01	0	ISO 8855 intermediate system vertical (up) velocity	IsoIsVerticalVelocity

Table 79. Identifier 639h (1593), IsoIsAcceleration

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	S	m/s ²	0.01	0	ISO 8855 intermediate system longitudinal (forward) acceleration	IsoIsLongitudinalAcceleration
16	16	S	m/s ²	0.01	0	ISO 8855 intermediate system lateral (left) acceleration	IsoIsLateralAcceleration
32	16	S	m/s ²	0.01	0	ISO 8855 intermediate system vertical (up) acceleration	IsoIsVerticalAcceleration

Table 80. Identifier 63Ah (1594), IsoIsAngularVelocity

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	S	°/s	0.01	0	ISO 8855 intermediate system roll (longitudinal angular) velocity	IsoIsRollVelocity

16	16	S	°/s	0.01	0	ISO 8855 intermediate system pitch (lateral angular) velocity	IsoIsPitchVelocity
32	16	S	°/s	0.01	0	ISO 8855 intermediate system yaw (vertical angular) velocity	IsoIsYawVelocity

Table 81. Identifier 63Bh (1595), IsoIsAngularAcceleration

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	S	°/s ²	0.1	0	ISO 8855 intermediate system roll (longitudinal angular) acceleration	IsoIsRollAcceleration
16	16	S	°/s ²	0.1	0	ISO 8855 intermediate system pitch (lateral angular) acceleration	IsoIsPitchAcceleration
32	16	S	°/s ²	0.1	0	ISO 8855 intermediate system yaw (vertical angular) acceleration	IsoIsYawAcceleration

Table 82. Identifier 63Ch (1596), IsoEfsVelocity

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	S	m/s	0.01	0	ISO 8855 earth-fixed system east velocity	IsoEfsEastVelocity

16	16	S	m/s	0.01	0	ISO 8855 earth-fixed system north velocity	IsoEfsNorthVelocity
32	16	S	m/s	0.01	0	ISO 8855 earth-fixed system vertical (up) velocity	IsoEfsVerticalVelocity

Table 83. Identifier 63Dh (1597), IsoEfsAcceleration

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description	Signal name
0	16	S	m/s ²	0.01	0	ISO 8855 earth-fixed system east acceleration	IsoEfsEastAcceleration
16	16	S	m/s ²	0.01	0	ISO 8855 earth-fixed system north acceleration	IsoEfsNorthAcceleration
32	16	S	m/s ²	0.01	0	ISO 8855 earth-fixed system vertical (up) acceleration	IsoEfsVerticalAcceleration

Revision history

Table 84. Revision history

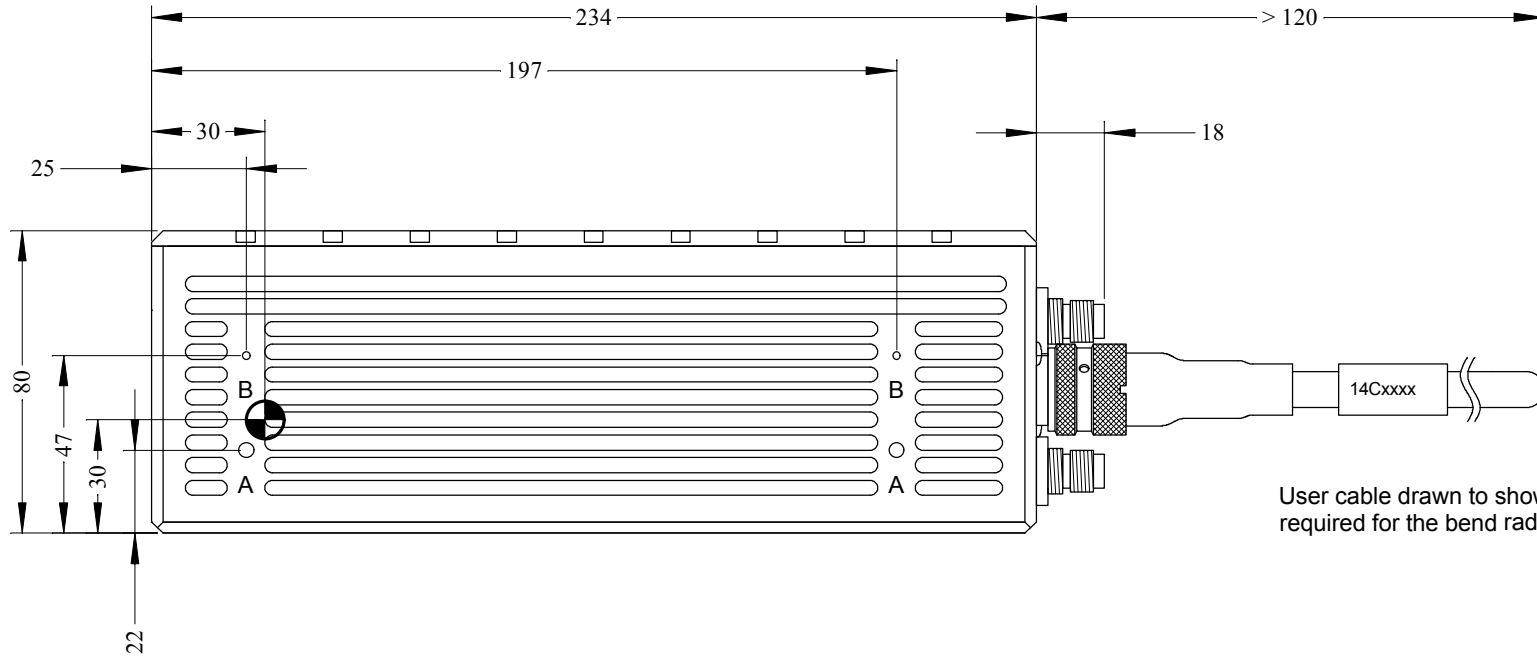
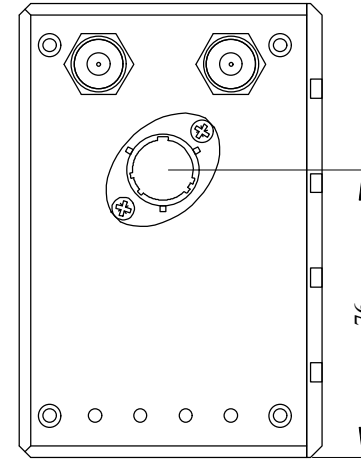
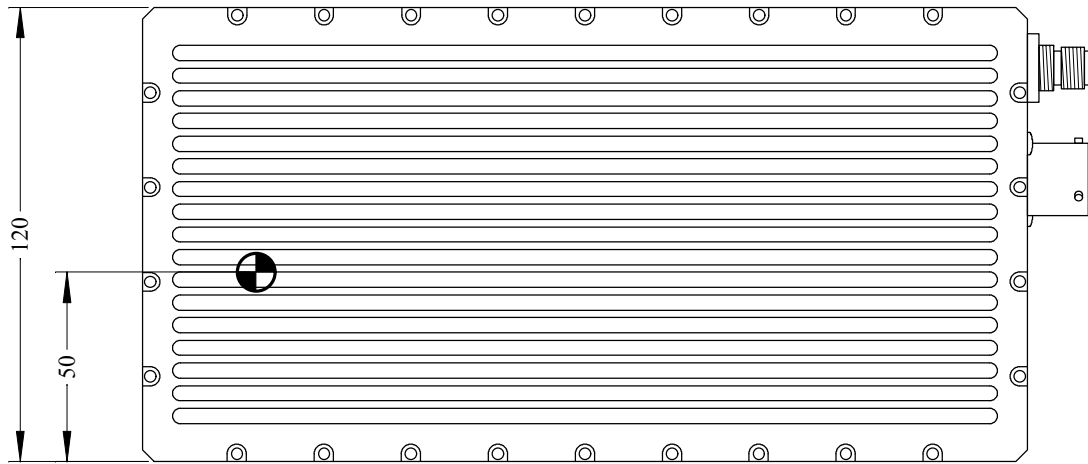
Revision	Comments
071120	Merged RT2000, RT3000 and RT4000 manuals.
080121	Heading Lock changes. Surface Attitude CAN IDs.
080303	Improved RT2500 specification. Heading Lock “Loose” changed to “Normal”.
080804	Surface tilt added to RT Config. Specification changes for “1 σ ”. Clarified positioning modes and accuracies.
090630	Added power cable drawing, updated all drawings. 50 Hz trigger described. Added fields for GNSS position mode. Added description of sign conventions. Recommended PC IP address described. Ethernet Output options described. Other small changes.
100125	Added MGC0M1 protocol. Clarifications to rotation order and dual-antenna section
100312	Added RT2002. Updated for latest software. Added CAN message descriptions for additional slip points and approximate outputs. Separated some specifications in to a separate table. Improved warm-up description.
100624	Added RT2004 product.
101124	Updated for RT Config software changes. Triggered NMEA outputs. PTCF output. Camera output on Ethernet. Clarified power output on RT2000 differential connector. Added information about GNSS pitch constraint for improving static initialisation. Altitude datum options. Other minor corrections.
110505	Added the recommended fuse information; added GNSS antenna drawings.
111115	Updated CE/FCC statement for new internal design. Added linear acceleration filter. Added gx processing. Added software disclaimer. ECCN revision.
130221	Updated RT2000 specifications. Updated for RT Config software changes. Added CAN acquisition section. Updated screenshots for new GUI. Aligned document style. Updated user cable part number.
131024	Updated screenshots to NAVconfig. Removed obsolete products. Updated RT’s input voltage. Altered document structure.
140325	Minor revisions.
140501	PPP Service changes, specification updates and other minor revisions.
140611	NAVconfig updates and new images and text for v2 2nd Generation.
141117	Specification and regulator testing changes. Other minor revisions.
150312	Added vertical advanced slip and coordinate frame configuration options.
150620	Updated screenshots, added networked corrections, and CAN prefix. Other minor corrections.
160105	New CAN definitions added, new frames of reference.
170124	Minor updates.
180221	WEEE update

Drawing list

Table 85 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 Oxford Technical Solutions.

Table 85. List of available drawings

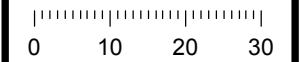
Drawing	Description
14A0029x	RT2000 system outer dimension drawing
14A0007x	RT3000 / RT4000 system outer dimension drawing
14C0038B	RT3000 / RT4000 user interface cable
77C0002B	RT2000 power cable
GPS-600	GPS antenna
AT575-70B	GNSS antenna
110-00012-601	G5-Ant-2AMNS1 antenna
110-00148-601	G5Ant-42AT1 antenna
110-00149-601	G3Ant-42AT1 antenna
110-00150-601	G5Ant-52AT1 antenna



User cable drawn to show space required for the bend radius.

Confidential Information

The information in this document is confidential and must not be published or disclosed either wholly or in part to other parties or used to build the described components without the prior written consent of Oxford Technical Solutions.



Print Size: A4

Scale: 1:2 (Half)

Units: mm

Tolerances: X.X - 0.1

Projection: 3rd Angle

Material: HE30 Alu

Finish: Anodised

Notes:

- A – M4 x 10 Tapped Hole
- B – 2mm dia x 3 hole

Date: 24/10/13

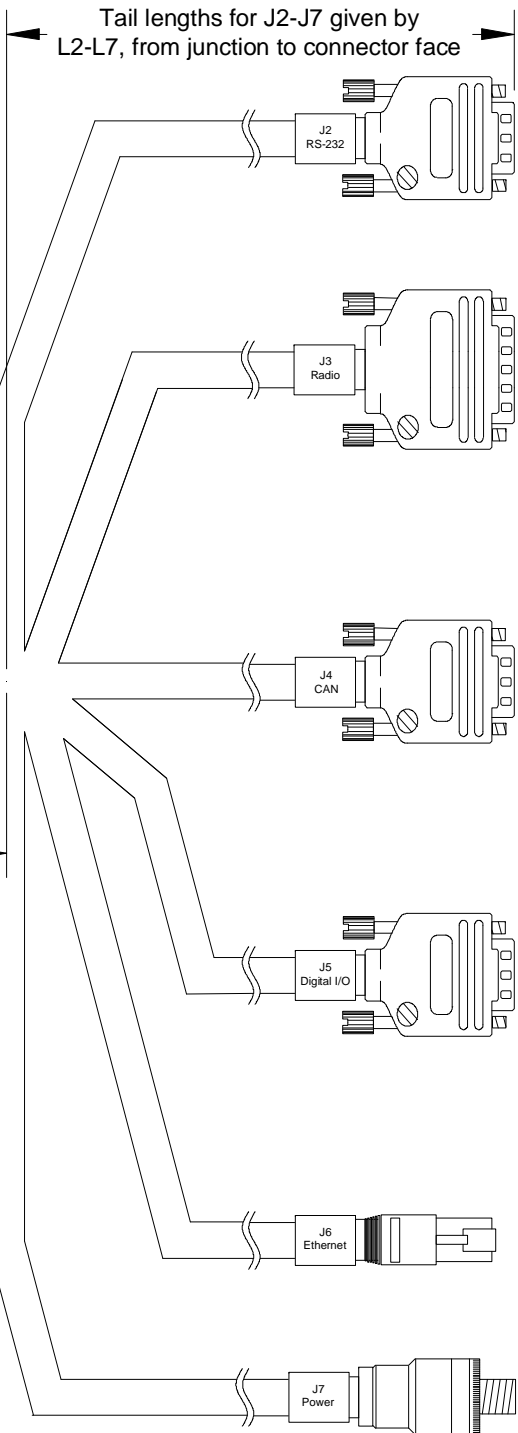
Part #: 14A0007A

Document:
 RT3000/RT4000 out
 dimensions

Sheet: 1 of 1

Connector/Boot Details

J1	Deutsch AS612-35SA	Hellerman 154-42-G
J2	9-Way Male D-type and shell	FEC 1342694
J3	DGPS Option: 9-Way Male D-type and shell	FEC 1342694
J3	Radio Option: 15-Way Male D-type and shell	FEC 1342696
J4	9-Way Male D-type and shell	FEC 1342694
J5	9-Way Female D-type and shell	FEC 1342695
J6	See notes	
J7	4-Way M12 Male Cable Assy D-type Plug Crimp Contacts	FEC 1889386 FEC 1560032
	D-type Socket Crimp Contacts	FEC 1560034



Pin	Function	Conn
2	Nav Data RS232 RX	J1-4
3	Nav Data RS232 TX	J1-3
5	RS232 Common	J1-12

Radio		
Pin	Function	Conn
1	+Supply	J3-14
7	RS232 Common	J1-16
8	Supply Return	J7-3
9	Radio Data RX	J1-7
11	Radio Data TX	J1-6
14	+Supply	J7-1
15	+Supply	J7-1

DGPS Alternative		
Pin	Function	Conn
2	GPS Data RS232 RX	J1-7
3	GPS Data RS232 TX	J1-6
5	RS232 Common	J1-16
Sleeved and made safe		J7-1
Sleeved and made safe		J7-3

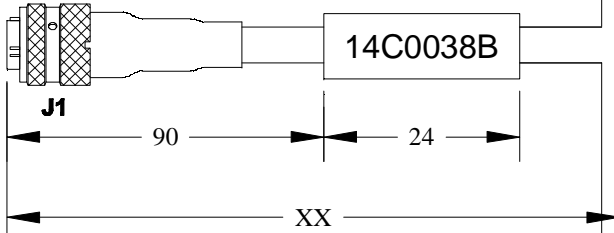
CAN		
Pin	Function	Conn
2	CAN -	J1-10
3	CAN Ground	J1-17
6	CAN Ground	J4-3
7	CAN +	J1-9

Digital I/O		
Pin	Function	Conn
1	Digital 1	J1-11
2	Digital 2	J1-8
3	Digital 3	J1-15
4	Digital 4	J1-19
5	Digital 5	J1-5
6	Digital Ground	J1-18
7	Digital Ground	J1-18
8	Digital Ground	J1-18
9	Digital Ground	J1-18

See manual for details of the signals on Digital 1 to Digital 5

Pin	Function	Conn
1	Ethernet (ETX +)	J1-20
2	Ethernet (ETX -)	J1-13
3	Ethernet (ERX +)	J1-21
6	Ethernet (ERX -)	J1-14

Pin	Colour	Function	Conn
1	Brown	+Supply (10-25 Volts DC)	J1-1
2	White	Sleeved and made safe	
3	Blue	Supply Return	J1-2
4	Black	Sleeved and made safe	



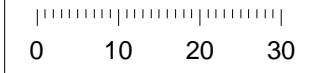
Length XX is denoted in the part ordered by the final digits of the part number in centimetres. 40cm is the default length if not specified.

For example 14C0038x-100 specifies a cable length of 100cm. (x is the revision)

Tail Lengths	
L2	300mm
L3	300mm
L4	300mm
L5	300mm
L6	300mm
L7	300mm

Confidential Information

The information in this document is confidential and must not be disclosed to other parties or used to build the described components without the written permission of Oxford Technical Solutions.



Print Size: A4
Scale: Not to scale
Units: mm
Tolerances: 5mm

Projection: N/A

Notes:
J6 is a RJ45 UTP patch lead which is cut to length and terminated at J1.

Wire Types:
J7-1, J7-3 16/0.2
All others 7/0.2
J1-13 & J1-20 Twisted pair
J1-14 & J1-21 Twisted pair

Cables outers braided and connected to J1-22, J1 shell and J7 shell (through cable assembly braiding).

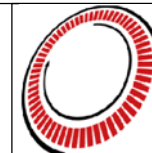
Please populate all unused pins with empty crimps.

Ensure that the cable legend text precisely matches that given in diagram.

Date: 05/10/11
Part #: 14C0038B
Document: RT3000 User Cable
Sheet: 1 of 1

Connector/Boot Details

J1	9 Way D-type Female	RS 473-896
	9 Way D-type Backshell	RS 322-9850
J2	15 Way D-type Male	RS 473-903
	15 Way D-type Backshell	RS 322-9866



Oxford Technical Solutions
 77 Heyford Park
 Upper Heyford
 Oxfordshire
 OX25 5HD
 www.oxts.com

© Copyright Oxford Technical Solutions,2013

Confidential Information

The information in this document is confidential and must not be disclosed to other parties or used to build the described components without the written permission of Oxford Technical Solutions.



Print Size: A4

Scale: N/A

Units: mm

Tolerances: 5mm

Projection: N/A

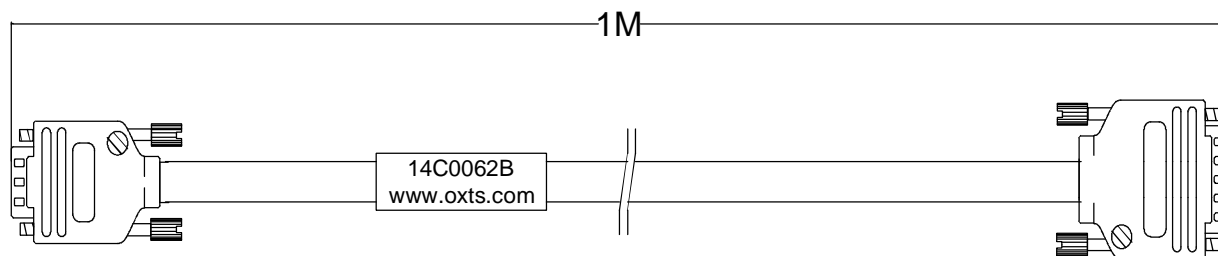
Notes:

Cable RS 660-7067 4 Core Unscreened 16/0.2 or similar

Cable Ident to show both part number and www.oxts.com

Cable Ident to positioned at the center of the cable

All part numbers for guide only suitable alternatives may be used



J1 Pin	Colour	Function	J2 Conn
2	Yellow	RxD	9
3	Blue	TxD	11
5	Green	Ground	7+8
9	Red	Supply +	1+14+15

Cable Lengths:

All 1M

Edit History:

140818 Reissued

Date: 140828

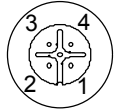
MRP Part #: 100-00054-301

Drawing #: 14C0062B

Cable Name:

Radio Modem Cable for Split IMU

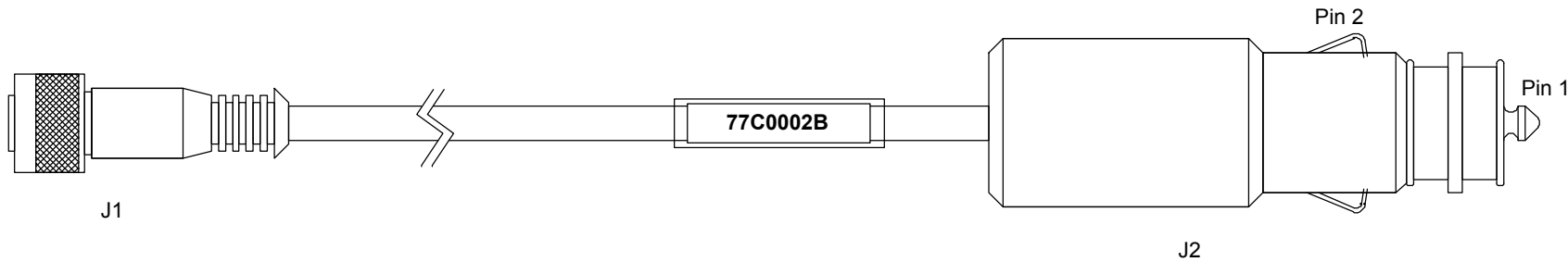
Sheet: 1 of 1



View from front
of socket

Pin Definitions

- J1-1 (Brown) Positive 12V Power supply (9–18V d.c.)
- J1-2 (White) Positive 12V Power/Charger supply (11–18V d.c.)
- J1-3 (Blue) 0V/GND
- J1-4 (Black) 0V/GND



Parts

- RS291-5881 M12 4w 5m PVC straight Connector
- FEC 658-376 Car Cigarette Lighter Plug
- RS399-524 Yellow Heat Shrink 6.4mm
- RS399-934 Clear Heat Shrink 6.4mm

(Alternative Part: RS 266-0250
Car Cigarette Lighter Plug - 8A fused)

Fuse

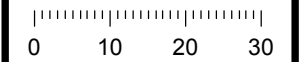
Littelfuse Part Number 0214005 (5A Torpedo Type Fuse, 25 x 6mm, 36V)

Connections

- J1-1 (Brown) – J2-1
- J1-2 (White) – J2-1
- J1-3 (Blue) – J2-2
- J1-4 (Black) – J2-2

Confidential Information

The information in this document is confidential and must not be published or disclosed either wholly or in part to other parties or used to build the described components without the prior written consent of Oxford Technical Solutions.



Print Size: A4

Scale: 1:1

Units: mm

Tolerances: 1mm

Projection: N/A

Notes:

10/04/02
Alternative Part Number added

Date: 05/05/11

Part #: 77C0002B

Document:
RT2000 Power Cable

Sheet: 1 of 1



Oxford Technical Solutions

77 Heyford Park
Upper Heyford
Oxfordshire
OX25 5HD
www.oxts.co.uk

© Copyright Oxford Technical Solutions, 2009

Confidential Information

The information in this document is confidential and must not be published or disclosed either wholly or in part to other parties or used to build the described components without the prior written consent of Oxford Technical Solutions.



Print Size: A4

Scale: 1:1

Units: mm

Tolerances: 1mm

Projection: 3rd Angle

Notes:

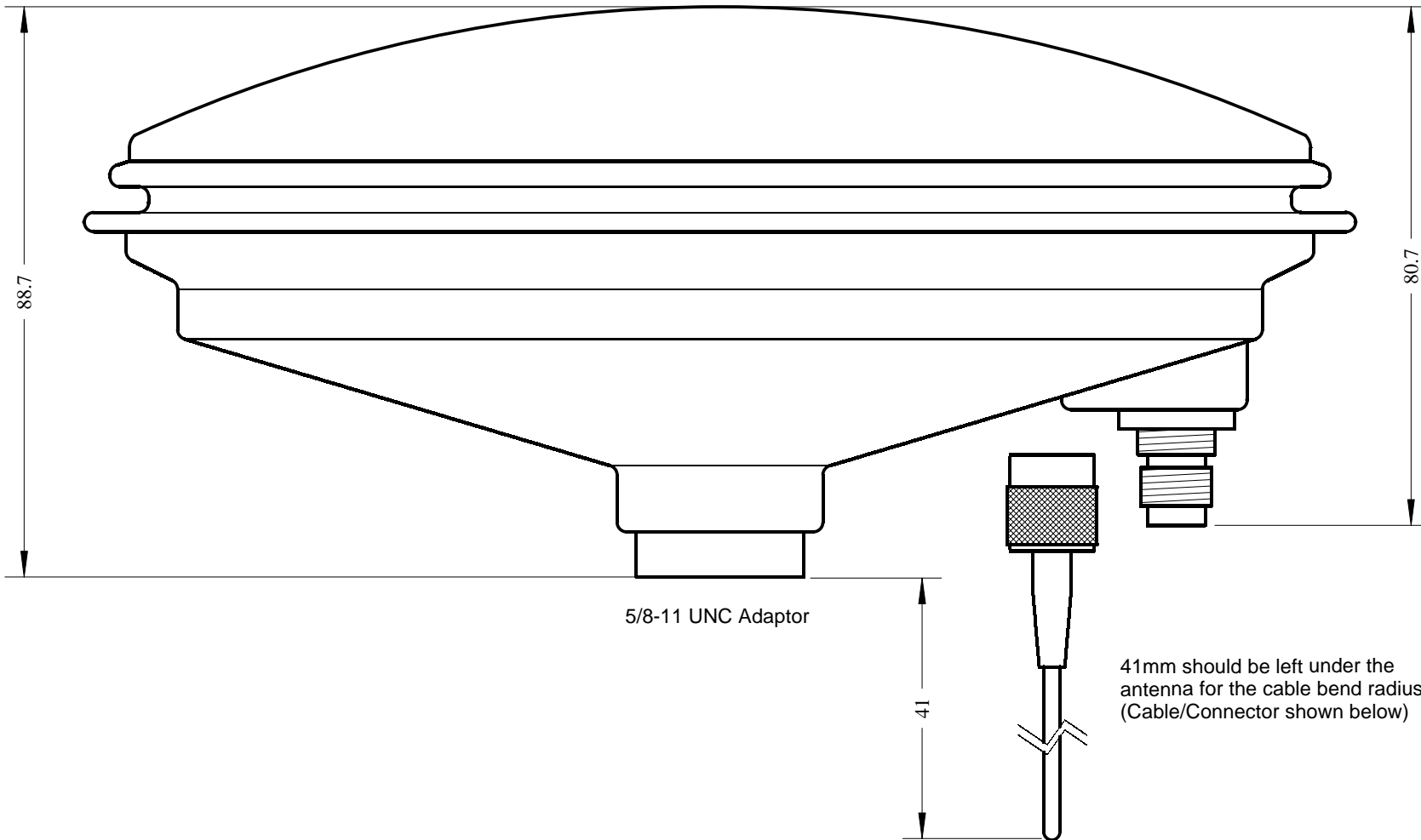
- L1 Ant. - Blue Rim
- L1/L2 Ant. - Black Rim

Date: 23/07/09

Part #: GPS-600

Document:
Novatel GPS Antenna

Sheet: 1 of 1





Oxford Technical Solutions

77 Heyford Park
Upper Heyford
Oxfordshire
OX25 5HD
www.oxts.co.uk

© Copyright Oxford Technical Solutions, 2009

Confidential Information

The information in this document is confidential and must not be published or disclosed either wholly or in part to other parties or used to build the described components without the prior written consent of Oxford Technical Solutions.



Print Size: A4

Scale: 1:1

Units: mm

Tolerances: 1mm

Projection: 3rd Angle

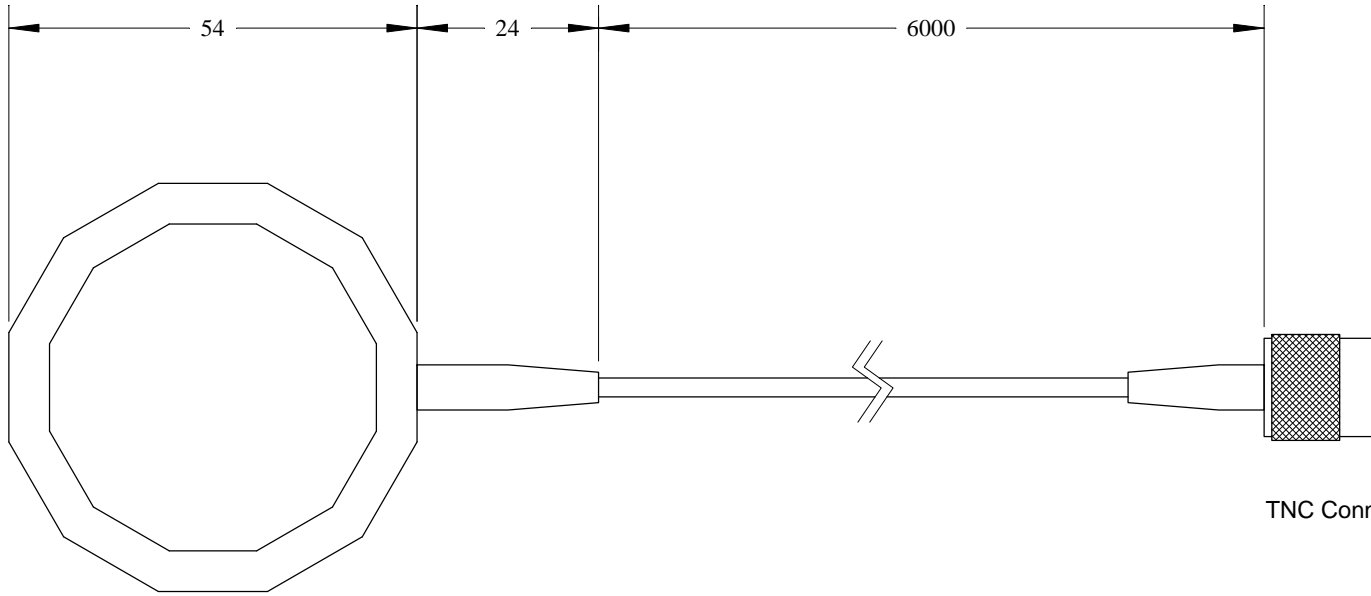
Notes:

Date: 23/07/09

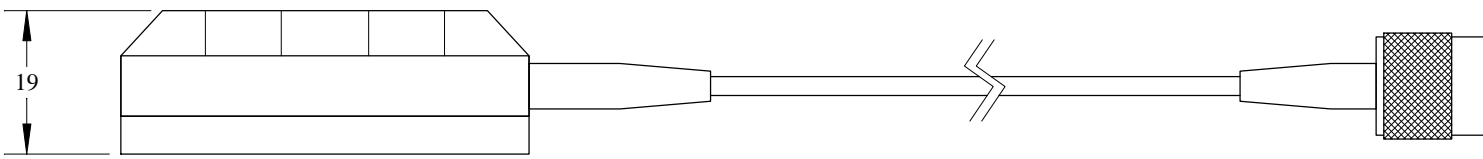
Part #: 201-990146-789

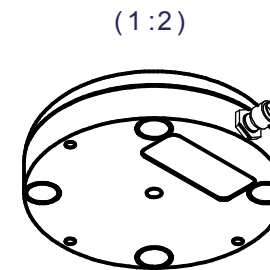
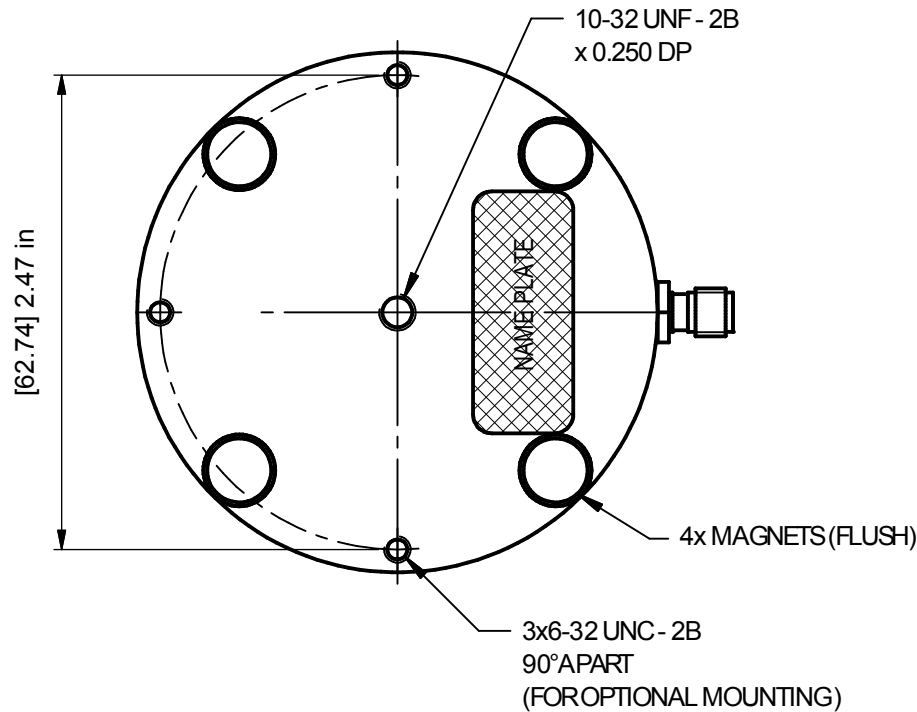
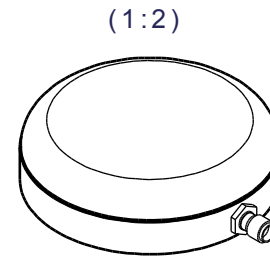
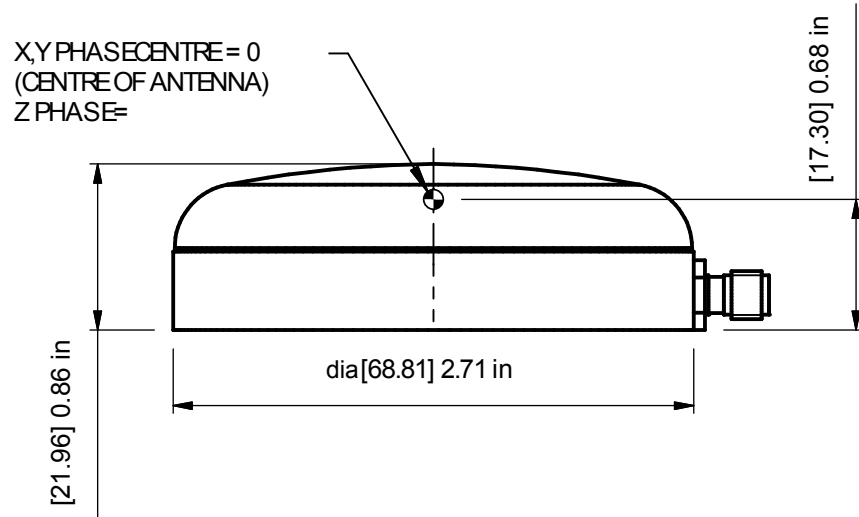
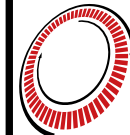
Document:
Magnetic GPS Antenna

Sheet: 1 of 1



TNC Connector





Confidential Information

The information in this document is confidential and must not be published or disclosed either wholly or in part to other parties or used to build the described components without the prior written consent of Oxford Technical Solutions.



Print Size: A4

Scale: 1:1

Units: mm

Tolerances: 1mm

Projection: 3rd Angle

Notes:

- GPS/GLONASS Antenna
- SMA Connector
- magnetic
- 2 cm
- Omnistar

Date: 06/05/11

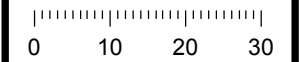
Part #: 110-00012-601

Document:
G5Ant-2AMNS1

Sheet: 1 of 1

Confidential Information

The information in this document is confidential and must not be published or disclosed either wholly or in part to other parties or used to build the described components without the prior written consent of Oxford Technical Solutions.



Print Size: A4

Scale: 1:2

Units: mm

Tolerances: 1mm

Projection: 3rd Angle

Notes:

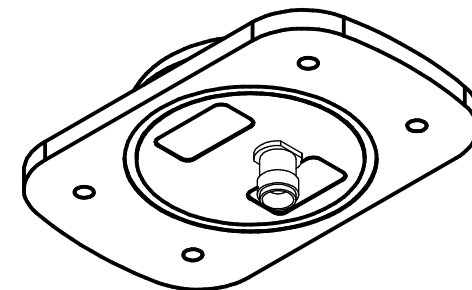
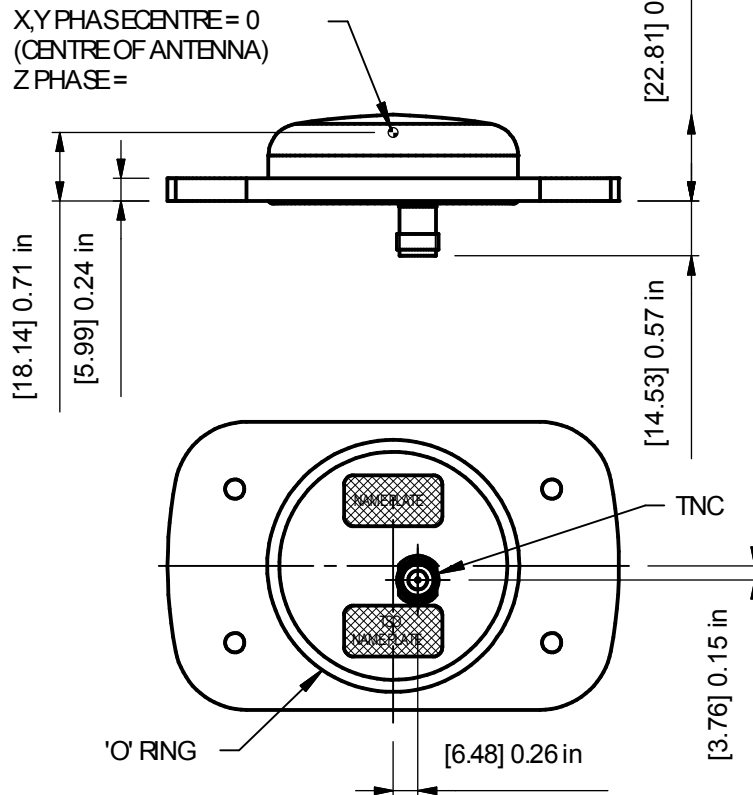
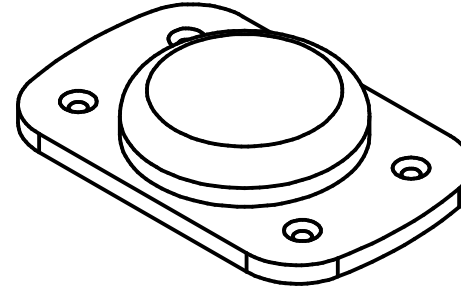
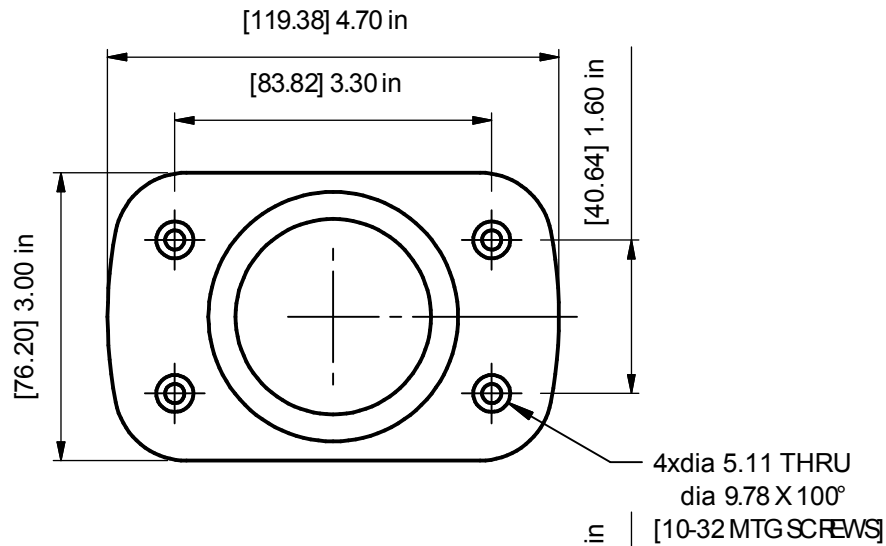
- * L1/L2/L5 GPS/GLO.
- * OmniSTAR
- * Precision carrier phase
- * Suitable for 2 cm products
- * Typically for aircraft
- * TNC Connector
- * ARINC Form Factor
- * Must be mounted on a metal surface for optimum performance
- 5V, 35dB Gain
- Weight 227g

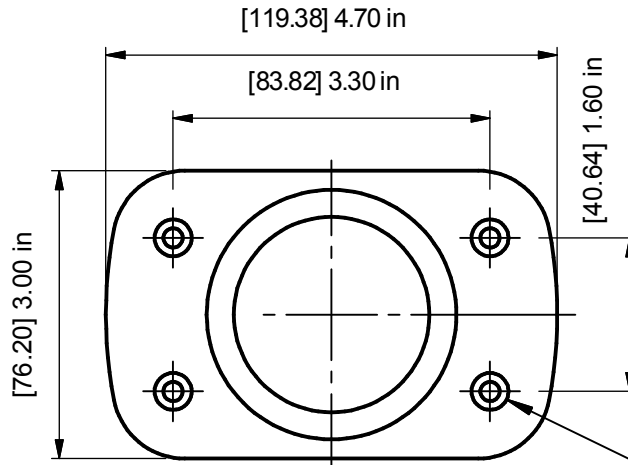
Date: 06/05/11

Part #: 110-00148-601

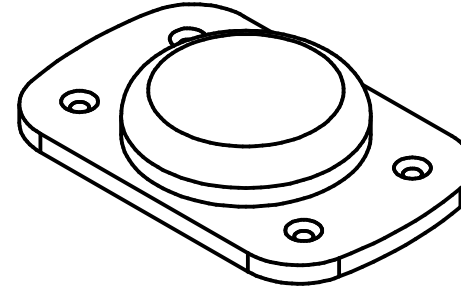
Document:
G5Ant-42AT1

Sheet: 1 of 1

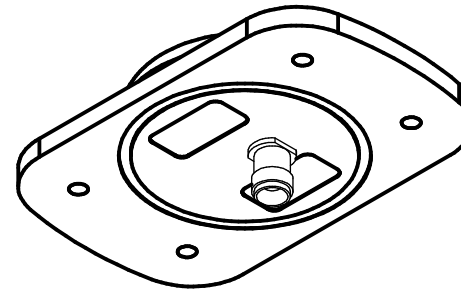
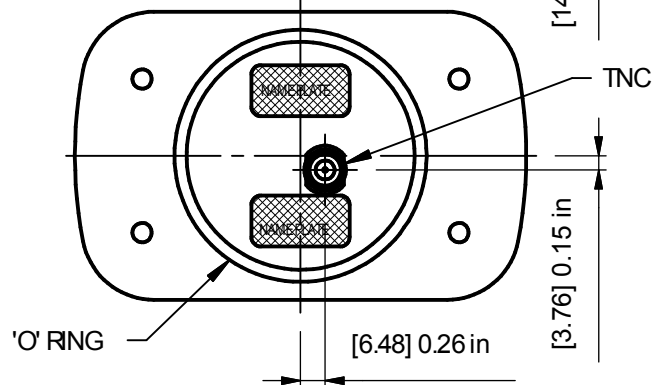
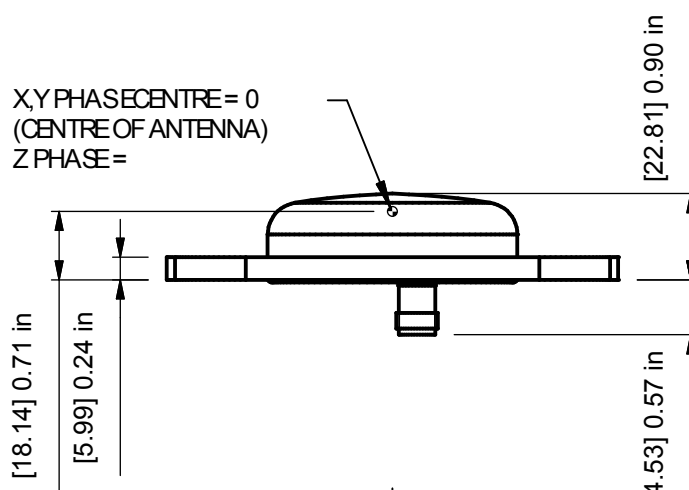




4xdia 5.11 THRU
 dia 9.78 X 100°
 [10-32 MTG SCREWS]

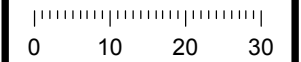


X,Y PHASE CENTRE = 0
 (CENTRE OF ANTENNA)
 Z PHASE =



Confidential Information

The information in this document is confidential and must not be published or disclosed either wholly or in part to other parties or used to build the described components without the prior written consent of Oxford Technical Solutions.



Print Size: A4

Scale: 1:2

Units: mm

Tolerances: 1mm

Projection: 3rd Angle

Notes:

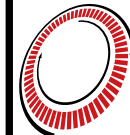
- * L1 GPS/GLONASS
- * Suitable for up to 20 cm precision
- * TNC Connector
- * Typically for aircraft
- * Must be mounted on a metal surface for optimum performance
- * 5V, 35dB Gain
- * Weight 227g

Date: 06/05/11

Part #: 110-00149-601

Document:
 G3Ant-42AT1

Sheet: 1 of 1



Confidential Information

The information in this document is confidential and must not be published or disclosed either wholly or in part to other parties or used to build the described components without the prior written consent of Oxford Technical Solutions.



Print Size: A4

Scale: 1:2

Units: mm

Tolerances: 1mm

Projection: 3rd Angle

Notes:

- * L1/L2/L5 GPS /GLO.
- * OmniSTAR
- * Precision carrier phase
- * Suitable for 2 cm products
- * TNC Connector
- * Mount on survey poles
UNC 5/8"-11 Thread
Alternative mounting
4x 6-32 UNC-2B
5V, 35dB Gain
Weight 250g

Date: 06/05/11

Part #: 110-00150-601

Document:
G5Ant-52AT1

Sheet: 1 of 1

