

Survey+

**GNSS-aided
inertial
measurement
systems**



User Manual

**Covers Survey+ v3
models**

The inertial experts.

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Contact Details

Oxford Technical Solutions Limited
Park Farm Business Centre
Middleton Stoney
Oxfordshire
OX25 4AL
United Kingdom

Tel: +44 (0) 1869 814 253
Fax: +44 (0) 1869 251 764

Web: <http://www.oxts.com>
Email: support@oxts.com

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Introduction

The Survey+ inertial navigation system (INS) device is an instrument for making precision measurements of motion in real time.

From September 2019 the Survey+ became v3 with new functionality. v2 devices are now end of life and include: Survey+ v2 and Survey+L1 v2.

To obtain high-precision measurements, the Survey+ 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 Survey+ several distinct advantages over systems that only use GNSS:

- The Survey+ has a high (100 Hz 200 Hz or 250 Hz) update rate and a wide bandwidth.
- The outputs are available with low, 3.5 ms latency.
- All outputs remain available continuously during GNSS blackouts when, for example, the vehicle drives under a bridge.
- The Survey+ 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 Survey+ makes many measurements GNSS cannot, for example acceleration, angular rate, heading, pitch and roll.

A Survey+ system processes data in real time. The real-time results are output via an RS232 serial port, or over 10/100 Base-T Ethernet using a UDP broadcast. Outputs are time-stamped and refer to GPS time; a 1PPS timing sync can be used to give accurate timing synchronisation between systems. The inertial measurements are synchronised to the GPS clock.

Internal data logging enables the data to be reprocessed post-mission. Data can be collected in the unit, downloaded using “ftp” protocol, processed on a PC and viewed using the NAVsolve.

Easy operation

There is minimal configuration required to use the system. The configuration can be saved to the Survey+ so it can operate autonomously without user intervention. A lot of work has been put into the initialisation of the inertial algorithms so the Survey+ 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 10–50 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 Survey+ uses GNSS to correct all its measurements. GNSS makes measurements of position, velocity and (for dual antenna systems) heading. Using these measurements, the Survey+ is able to keep other measurements, 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 Survey+ in any of the measurements while GNSS is present.

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 Survey+ systems, but it is beyond its scope to provide details on service or repair. Contact OxTS support or your local representative for customer service-related inquiries.

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

Table 1. Supplementary manuals

Manual	Description
NAVdisplay Manual	For viewing real-time information from an RT. https://support.oxts.com/hc/en-us/articles/115002433285-NAVdisplay-Online-manual
NAVgraph Manual	For plotting and exporting captured data. https://support.oxts.com/hc/en-us/articles/115002433465-NAVgraph-Online-manual
NCOM Manual	For decoding and using the NCOM format. www.oxts.com/Downloads/Support/NCOM Manual and Code Drivers/ncomman.pdf
NCOM C Code Drivers	A collection of C functions that can be used to decode the binary protocols from the RT. www.oxts.com/Downloads/Support/NCOM Manual and Code Drivers/ncomrx.zip
NMEA 0183 Description	NMEA description manual for the NMEA outputs. www.oxts.com/Downloads/Support/NMEA/nmeaman.pdf
NAVsolve Manual	Explains how to use our post-processing application. https://support.oxts.com/hc/en-us/articles/360000225449-NAVsolve-manual

Survey+ product family

Survey+ (v3)

Survey-grade GNSS receivers provide high-precision position and velocity measurements even in high multipath environments. GPS & GLONASS enabled as standard on primary and secondary receivers. Can be BeiDou enabled. The Survey+ with RTK support is dual antenna. 100 Hz is the standard output rate. 200 Hz and 250 Hz options are available.

The options contained within each device type are listed in the “Specification” section on page 15.

Single antenna

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

Single antenna systems can experience reduced heading accuracy on aircraft, boats or in low-speed land vehicles.

Dual antenna

Dual antenna systems provide high accuracy heading information and almost constant heading performance under all conditions.

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 Survey+ allows relock to occur after five seconds of a sky-obstruction – unlike GNSS-only systems which can take several minutes; in this time the Survey+’s heading will not have significantly degraded. The fast relock time is made possible because the Survey+’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 Survey+ 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 Survey+ 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.

BeiDou

BeiDou capability adds the ability to utilise the Chinese satellite constellation BeiDou as well as the American constellation GPS and Russian constellation GLONASS. This means an extra 34 satellites are available for the Survey+ to lock on to and obtain position and velocity updates from. BeiDou is not compatible with the gx/ix™ tight coupling algorithms.

200/250 Hz

1. All Survey+ have the option of coming with a 200/250 Hz output of the inertial measurement unit (IMU). The IMUs used in 100 Hz 200 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 200/250 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. Survey+ systems that have TerraStar capability include the necessary hardware to receive corrections. It is necessary to pay a licence fee to activate these corrections. Capable Survey+ systems 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 website: <http://www.terrastar.net>.

Scope of delivery

Survey+ products are supplied complete with, software, standard cables, a tape measure, and a quick start guide. The user will have specified at the point of ordering which user cable and antennas (including antenna cables) they need for their application.

Survey+ system components

Table 2 lists all items that are delivered with each standard Survey+ model.

Table 2. Summary of Survey+ system components

Description	RT500 and RT3000
Survey+unit	✓
Power cable 77C0002B	✓
User cable	Specify at point of ordering
Aux user cable	Specify at point of ordering
GNSS antennas	Specify at point of ordering
Ethernet cable (cross-over)	✓
USB stick with manual and software	✓
Tape measure	✓
Quick start guide	✓

The Survey+ product is RTK capable and 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

Specification

Specifications for Survey+ products can be found in Table 3 and Table 4. 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 Survey+ 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 $300^\circ/\text{s}$ angular rate may be requested. The specification using the extended measurement range sensors can be marginally worse than those listed here.

Table 3. Survey+ specifications

Parameter	Survey+ v3 (Dual Antenna)
Positioning	GPS L1, L2 GLONASS L1, L2 BeiDou L1, L2 ¹
Position accuracy ²	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
Roll/pitch	0.03° 1 σ
Heading	0.1° 1 σ ³
Acceleration	
– Bias stability	5 μ g 1 σ
– Linearity	0.01%
– Scale factor	0.1% 1 σ
– Range	100 m/s ²
Angular rate	
– Bias	0.01°/s 1 σ
– Scale factor	0.1% 1 σ
– Range	100°/s
Lateral velocity	0.2% 1 σ
Update rate	100 Hz / 250 Hz
Input voltage ⁴	10–48 V dc
Power consumption	14 W
Dimensions	184 × 120 × 71 mm
Mass	1.5 kg

¹ Optional upgrade.

² To achieve specification, relevant differential corrections from a base station, NTRIP or TerraStar subscription are required. The RTK accuracies are based on v2 products.

³ With two-meter antenna separation. Wider separation will improve accuracy (supports up to five-meter separation).

⁴ Voltage range of connected devices such as radio modems must be considered.

Common specifications

Table 4. Survey+ 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	32 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 Survey+ products will require appropriate differential corrections where applicable, either from a base station or with a TerraStar licence. Alternatively, a RINEX file can be downloaded post-mission and used to post-process the data to full accuracy.

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

The accuracy of the product will depend on the operating mode of the GNSS.

Heading accuracy

The heading accuracy that can be achieved by the dual antenna system in the Survey+’s in Table 3 is 0.2° 1 σ 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 3. The maximum recommended separation is five metres, at which it may be possible to achieve better accuracy than that listed if the structure is rigid, including temperature variation.

For single antenna systems, the heading is calculated from the inertial measurements. The accuracies listed in Table 3 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 Survey+ 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.

Export control classification number

Export control regulations change, and so the classification number of the Survey+ may also change. The information presented here was correct when the manual was published. Survey+ 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 5 lists the ECCN for the products.

Table 5. ECCN for Survey+ products

Product	ECCN
Survey+ 10G	7A103a1
Survey+ 30G	7A003d

Conformance notices

The Survey+ 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 Survey+ 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 Survey+ conforms to the requirements for CE.

Regulator testing standards








Survey+ 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 Survey+ is a USB stick containing the software package NAVsuite. This package contains several programs required to take full advantage of the Survey+'s capabilities. Table 6 lists the contents of NAVsuite.

Table 6. 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.
	NAVstart	A menu from which you can navigate between OxTS applications. This opens automatically when you are connected to a unit.
	NAVconfig	Used to create, send, and receive configurations from OxTS products. As configurations vary between products there is no manual for NAVconfig.
	NAVsolve	Used to download raw data files from the Survey+ 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.

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

The first time some OxTS applications are run, a firewall warning message similar to that shown in Figure 1 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 1. 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 Survey+ rigidly in the vehicle. The Survey+ should not be able to move or rotate compared to either GNSS antenna, otherwise the performance will be reduced. In most circumstances the Survey+ should be mounted directly to the chassis of the vehicle. If the vehicle experiences high shocks, then vibration mounts may be required.

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

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

Survey+ orientation and alignment

The orientation of the Survey+ in the vehicle is normally specified using three consecutive rotations that rotate the Survey+ 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 Survey+ co-ordinate conventions are detailed on page 28. It is important to get the order of the rotations correct.

In the default configuration the Survey+ 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 Survey+ in the default configuration is not possible, for example when using the RT-Strut. The Survey+ can be mounted at any angle in the vehicle as long as the configuration is described to the Survey+ 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 Survey+ 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 Survey+ has some functions to measure these offsets itself. The heading offset can be measured if the vehicle has a non-steered axle. The Improve Configuration wizard in NAVconfig should be used for this (see pages 84 to 89 respectively).

Antenna placement and orientation

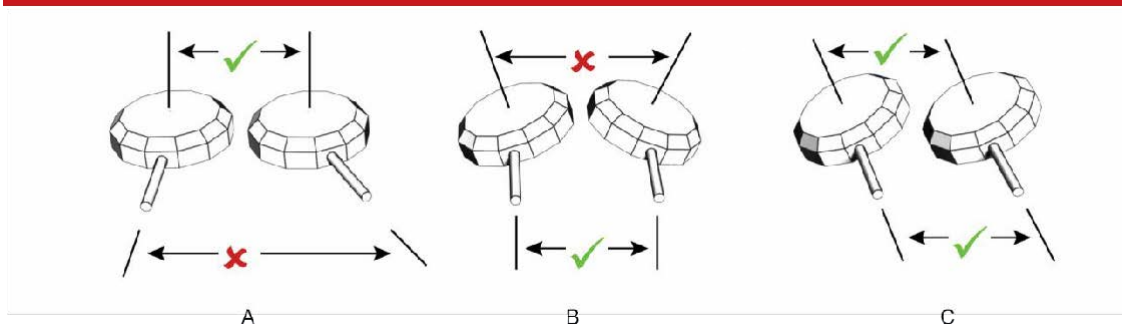
For optimal performance it is essential for the GNSS antenna(s) to be mounted where they have a clear, uninterrupted view of the sky and on a suitable ground plane, such as the roof of a vehicle. For good multipath rejection the antennas must be mounted on a metal surface using the magnetic mounts provided; 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 2. 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 2. 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), 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 Survey+ mounted securely in the vehicle. If the angle of the Survey+ 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 Survey+ is shock mounted then the Survey+ 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 top label and LEDs convey some basic information that aids configuration and troubleshooting. Once power is applied, the Survey+ requires no further input from the user to start logging and outputting data.

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

Front panel layout

Figure 3 shows the layout of the Survey+ front panel. Table 7 lists the parts of the front panel labelled in Figure 3.

Figure 3. Survey+ front panel layout



Table 7. Survey+ v3 front panel descriptions

Label no.	Description
1	Power LED
2	Status LED
3	GNSS LED
4	User cable main connector
5	Second user cable connector
6	Primary GNSS antenna connector
7	Secondary GNSS antenna connector
8	WI-Fi antenna connector

LED definitions

The LEDs on the connector panel provide information about the current system state, but it is not possible for the LEDs to communicate everything the product is capable of measuring.

Instead, they provide a snapshot of the current status and are useful for at-a-glance checks without the need for a portable PC. The tables below describe the behaviour of each LED.

Table 8. GNSS 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 9. Status 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 Survey+ 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 seconds for the system to become real-time after start up
Green	The strapdown navigator is running and the system is real-time ^a

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

Table 10. Power (PWR) states

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

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 Survey+ (shown in Figure 4), 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 4. The axes and measurement origin point are the same for all Survey+ models.

Figure 4. IMU co-ordinate frame and measurement origin

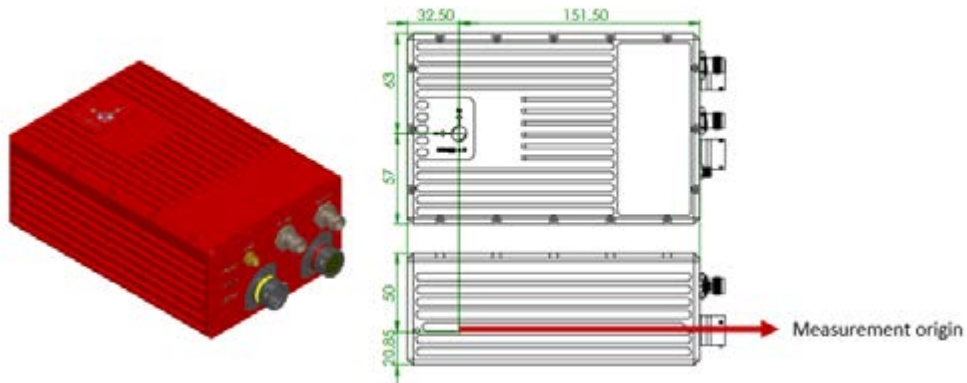


Table 11 lists the directions that the axes should point for zero heading, pitch and roll outputs when the default mounting orientation is used.

Table 11. Direction of axes for zero heading, pitch and roll outputs

Axis	Direction	Vehicle axis
<i>X</i>	North	Forward
<i>Y</i>	East	Right
<i>Z</i>	Down	Down

Once installed, if the Survey+ axes and the vehicle axes are not the same as those listed in Table 12, they can be aligned by reconfiguring the Survey+ for a different mounting orientation using the NAVconfig software.

If the RT-Strut is being used to mount the Survey+ in the vehicle then NAVconfig will have to be used to configure the orientation or the Survey+ will not work correctly. Page 52 gives more information on configuring the orientation of the Survey+ in a vehicle.

OxTS NED navigation frame

Table 12. 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 5. 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 13. 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 6. 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.

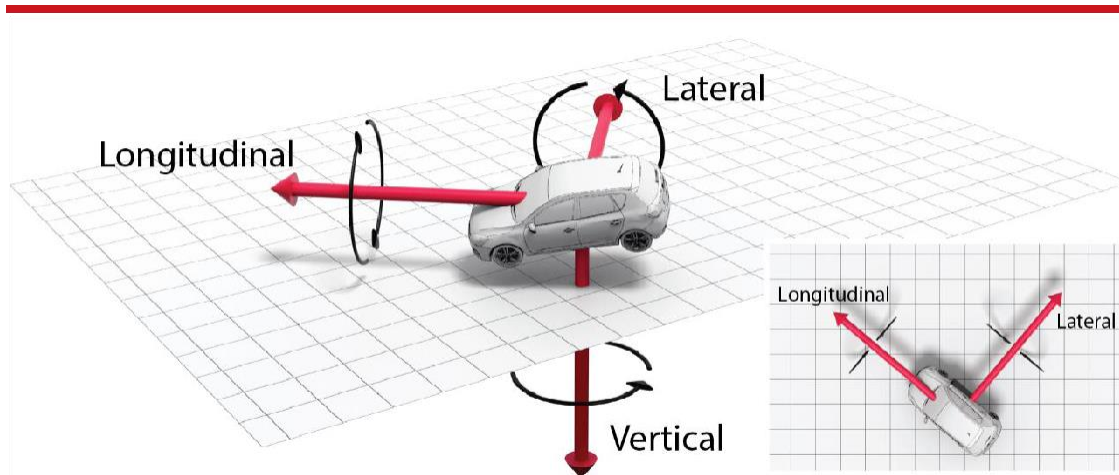
OxTS horizontal frame

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 14 and shown in Figure 7.

Table 14. 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 7. OxTS horizontal frame definition

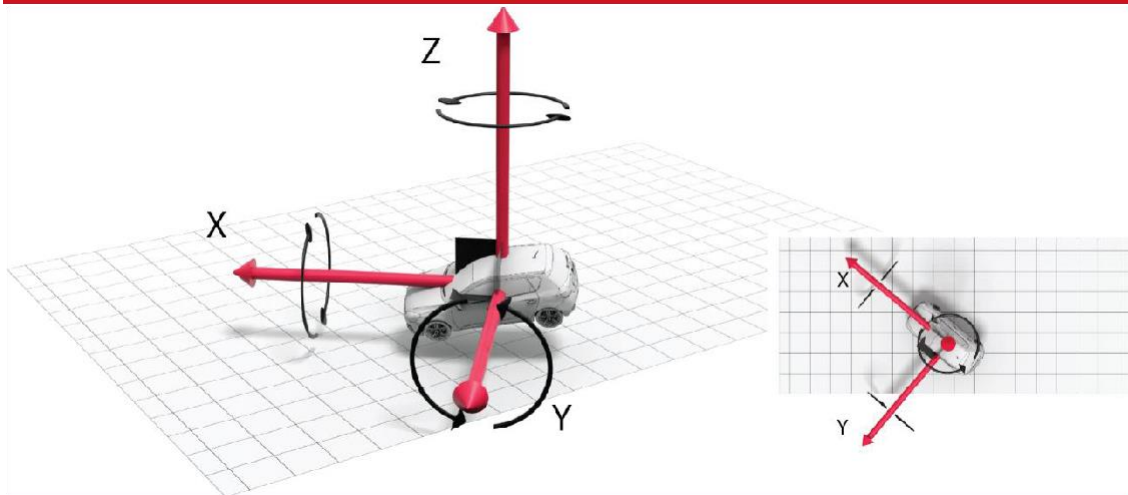


The OxTS horizontal frame is attached to the vehicle. The longitudinal and lateral axes remain parallel to a horizontal plane. The longitudinal axis is also parallel to the vehicle's heading when viewed from above.

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 15. ISO 8855 intermediate system and shown in Figure 8.

Figure 8. 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 15. 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.

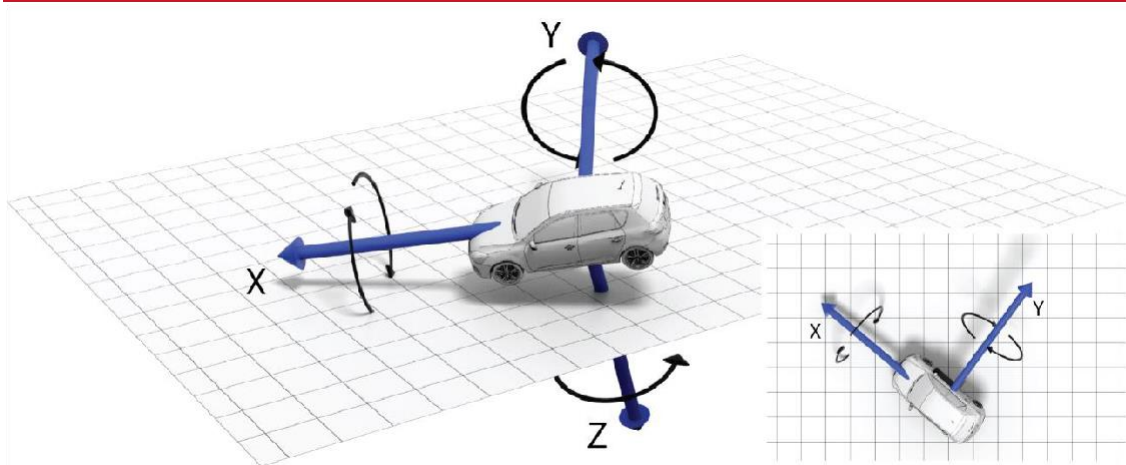
OxTS vehicle frame

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 16 and shown in Figure 9.

Table 16. 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 9. Vehicle frame definition



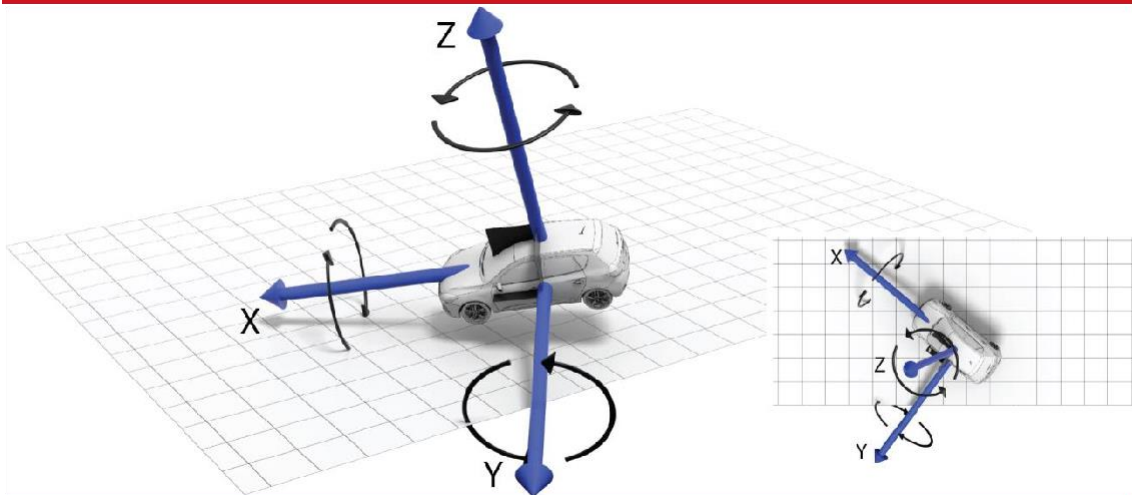
The OxTS vehicle frame is attached to the vehicle and rotates with it in all three axes. The X -axis remains parallel to the vehicle's heading, while the Y -axis points to the right and is perpendicular to the vehicle's vertical plane of symmetry

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 17 and shown in Figure 10.

Table 17. 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 10. 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 Survey+ for unrestricted data transmission it is necessary to use the Ethernet connection. The Survey+ v3 also supports Wi-Fi data transmission and the setup of WiFi is covered later in this manual. The operating system at the heart of the Survey+ 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 Survey+. The default username and password are both "user".

The Survey+ 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 by default the same rate as the IMU.

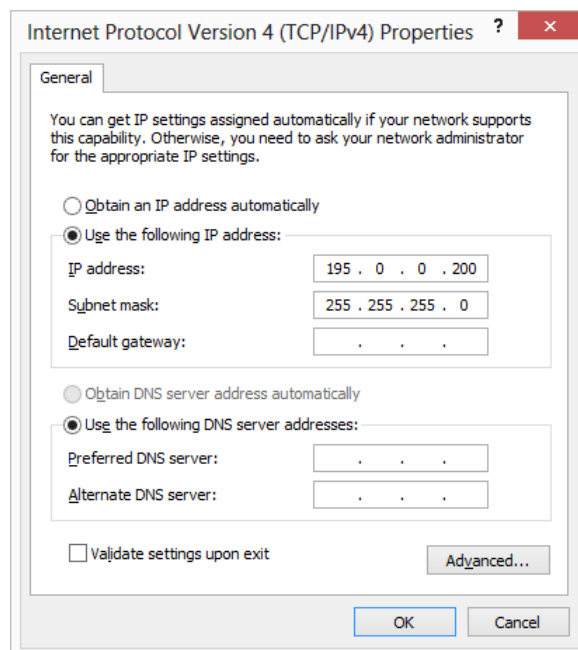
In order to communicate via Ethernet each Survey+ is configured with a static IP address that is shown on the delivery note. If the delivery note is unavailable, the default IP address normally takes the form 195.0.0.*sn*, where *sn* is the last two digits of the Survey+'s serial number. The serial number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

The IP address of the computer being used to communicate with the Survey+ 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 Survey+ by default.

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

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

Figure 11. Configuring the computer's IP address for Ethernet data transmission



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

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

Connection details for Ethernet configuration

The RJ-45 connector on the 14C00121x 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 Survey+ can be connected directly to an Ethernet card in a computer. To do this a crossed in-line coupler must be used. The connections in the crossed coupler are given in Table 18. Note that this is not the normal configuration sold and it may be necessary to modify an existing coupler to suit.

Table 18. 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 12.

Figure 12. In-line RJ-45 coupler



Wi-Fi configuration

The Survey+ can be configured via a Wi-Fi connection using the Wi-Fi access point inside the Survey+ itself. Like Ethernet, the use of FTP via a Wi-Fi connection 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 Survey+. The default username and password are both “user”.

The Survey+ outputs its data over Wi-Fi using a UDP broadcast. The use of a UDP broadcast allows everyone on the network to receive the data sent by the RT. The default data rate of the UDP broadcast is the rate that the IMU is outputting at (100/200/250 Hz).

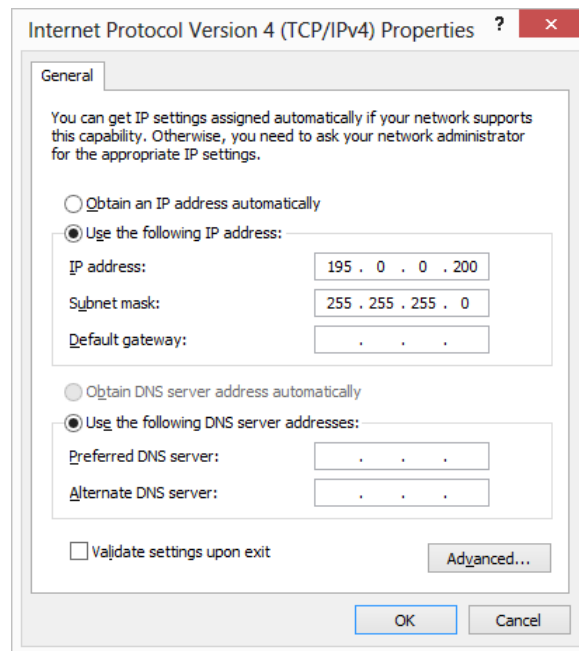
In order to communicate via Wi-Fi, each Survey+ is configured with a static IP address that is shown on the delivery note. If the delivery note is unavailable, the default IP address normally takes the form 195.0.0.*sn*, where *sn* is the last two digits of the RT’s serial number. The serial number can be found on the front panel of the Survey+ or on the delivery note. This IP address will differ from the Ethernet output.

The IP address of the computer being used to communicate with the Survey+ 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 Survey+ by default.

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

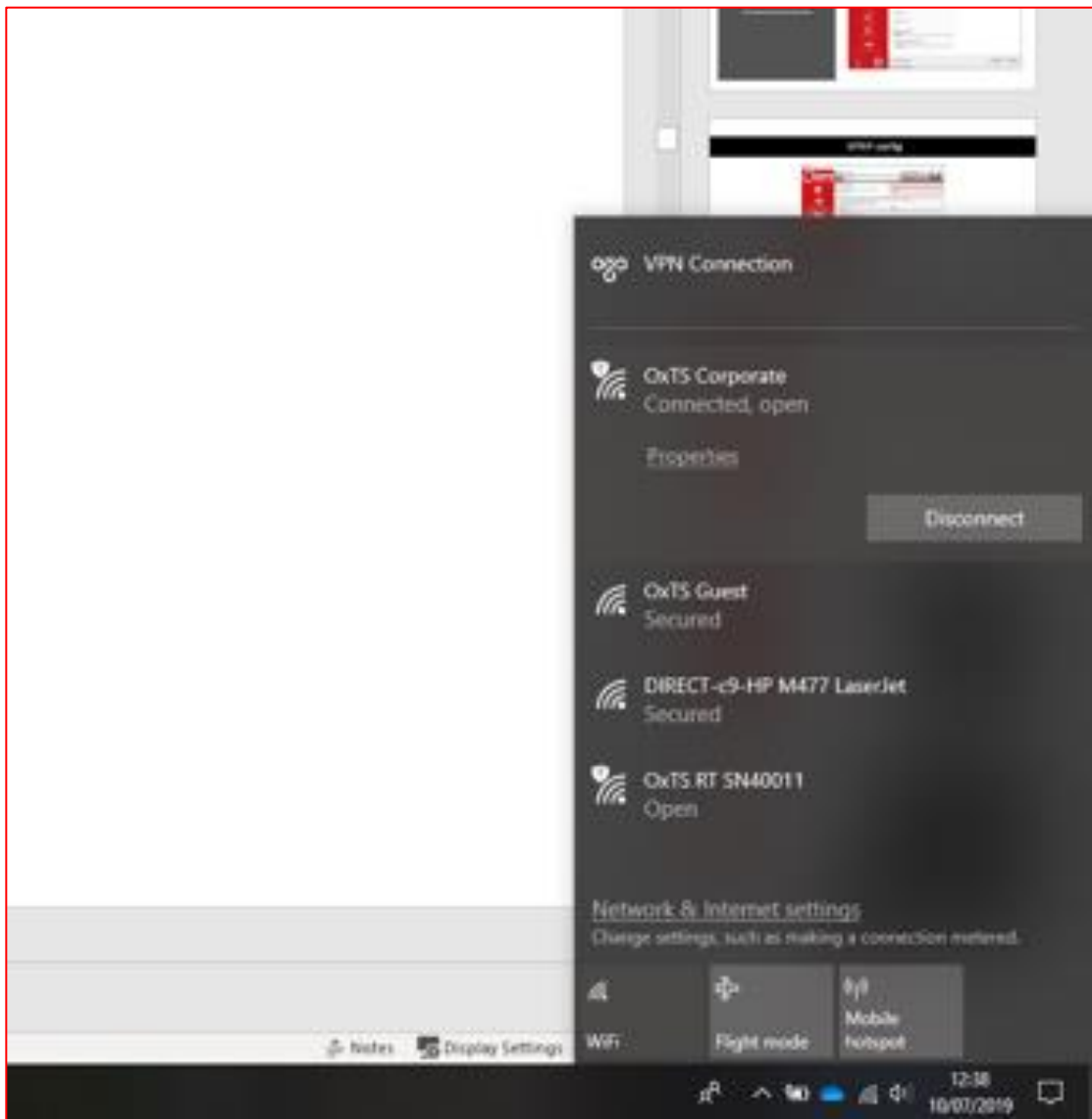
1. Open the ‘Control Panel’ from the Start menu.
2. In category view, select ‘Network and Internet’ and then ‘Network and Sharing Centre’.
3. Select ‘Change adapter settings’ in the side panel.
4. Right-click the WLAN option and select ‘Properties’.
5. In the window that opens, navigate the list to find **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 for Ethernet data transmission



Once you are on the same IP range as the Survey+ you can connect to the it via Wi-Fi. Via your PC's network settings you should be able to select the 'Survey+' as a Wi-Fi network'. The Survey+ that you wish to connect to can be identified by its serial number. See Fig 14 below.

Figure 14. Connect to Wi-Fi on the Survey+.



Wi-Fi settings are configured using NAVconfig and this process is explained later in this manual.

Dual antenna systems

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

1. To use the measurements properly the Survey+ needs to know the angle of the GNSS antennas compared to the angle of the Survey+. This is very difficult to measure accurately without specialised equipment; therefore the Survey+ needs to measure this itself as part of the warm-up process.
2. The Survey+ 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 Survey+.
3. When the vehicle drives forward and reaches the initialisation speed, the Survey+ assumes that the vehicle heading and course over ground are similar and initialises heading to course over ground angle.

If the Survey+ 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 Survey+ 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 Survey+ will solve the RTK Integer “dual antenna attitude mode” using the inertial heading.

If the antenna angle is offset from the Survey+ by a significant amount then the RTK Integer solution that is solved will be incorrect. For a 2 m antenna separation the Survey+ 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 Survey+ 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 vector angle between the primary and secondary antenna. The default value used in the configuration software (5°) is not accurate enough so that the Survey+ 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 dual antenna vector angle. The accuracy of this angle is available 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 than operating with single antenna.

To avoid the Kalman filter from getting things wrong it is possible to drive a calibration run, then use the Improve configuration wizard within NAVconfig (see page 84 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 Survey+ is permanently mounted in a vehicle and the antennas are bolted on. Any movement of either the Survey+ or the antennas will invalidate the optimisation in the Kalman filter states.

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 Survey+ works by comparing the carrier-phase measurements of the two antennas from common GNSS satellites. 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 buildings, trees, road signs or other reflective surfaces, the only multipath received is from the vehicle's roof. The antennas supplied with the Survey+ 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 Survey+ will show some error; the size of the error depends on the multipath in the environment. Table 19 lists the errors to be expected when stationary with a 1 m base-line.

Table 19. 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

Survey+ has two front panel connectors for their inputs and outputs. The J1 connector of the 14C00121 user cable (primary) connects to the primary front panel connector and connectors J2–J7 provide connections for the inputs and outputs. The J1 connector on the Aux user cable (secondary) connects to the secondary connector provides three additional inputs and outputs. See the user cable drawings located at the back of this manual for more details on the connectors and pin assignments. The main connectors are keyed so the user cable must be correctly aligned for it to connect.

The system can output data on the serial port and Ethernet. The standard serial output of the Survey+ 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 decode the output of the Survey+. More information about NCOM can be found in the NCOM description manual.

It is also possible to output a standard NMEA string from the Survey+ 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 20 describes each of the signals on the digital I/O connector J5 of the 14C00121 user cable. A more detailed explanation of each signal can be found below.

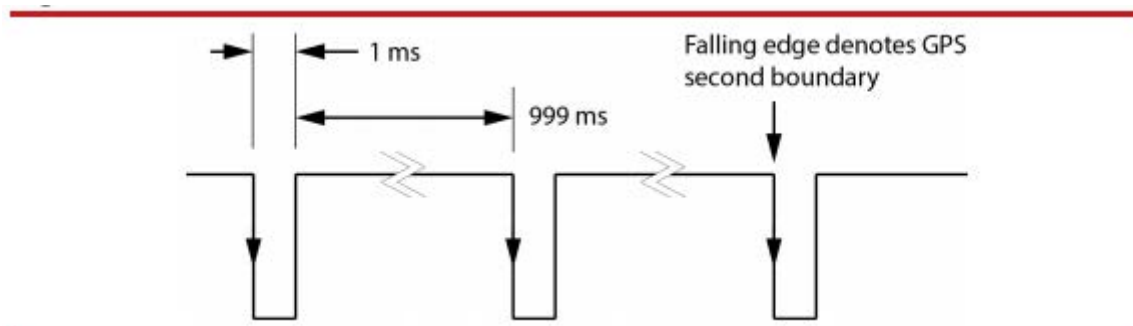
Table 20. Digital I/O signals

Pin#	Name (function)	Description
J5-1	Digital 1 (1PPS output)	Pulsed output from primary GNSS receiver, synchronised with the transition of GPS seconds
J5-2	Digital 2 (Trigger 1)	User-selectable I/O (input/distance output/IMU sync output)
J5-3	Digital 3 (Wheel speed 1A)	Input for Hall-effect wheel speed sensor. When connecting a quadrature sensor, this input is the A-channel
J5-4	Digital 4 (Trigger 2)	User-selectable I/O (input/distance output/IMU sync output)
J5-5	Digital 5 (Wheel speed 1B)	When connecting a quadrature wheel speed sensor, this input is for the B-channel
J5-6	Digital ground	
J5-7	Digital ground	
J5-8	Digital ground	
J5-9	Digital ground	

1PPS output

The 1PPS (J5-1) output is a pulse generated by the GNSS receiver. The output is active even when the GNSS receiver has no valid position measurement. The falling edge of the pulse is the exact transition from one second to the next in GPS time. The pulse is low for 1 ms, then high for 999 ms and repeats every second. The output is a low-voltage CMOS output, with 0.8 V or less representing a low and 2.4 V or more representing a high. No more than 10 mA should be drawn from this output.

Figure 15. 1PPS waveform



Trigger 1 and 2

Trigger 1 (J5-2) and Trigger 2 (J5-4) can be used to generate events within the Survey+ for purposes of identifying external events, or to output a time/distance-based signal for the purpose of driving external events. Both Triggers are independently configurable in the Options page of NAVconfig.

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

Input signal characteristics:

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

The default maximum detection rate for input signals is 1 Hz for 100 Hz products and 4 Hz for 250 Hz products. The detection rate for both products increases to 50 Hz when Output on falling edge of trigger or Output on rising edge of trigger is selected in the Ethernet Output option in NAVconfig.

Trigger information is contained within status message 24 and 43 (output over NCOM) for the low-rate triggers (1 Hz). The fast trigger information (50 Hz) can only be output over NCOM.

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

Output signal characteristics:

- 0 V and 5 V output
- low ≤ 0.8 V
- high ≥ 2.4 V

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

To enter camera mode, configure a trigger as an output, and set the distance to less than one pulse per metre. A signal will be generated according to the specifications above at the

distance interval defined by the PPM settings. At the same moment the trigger signal is output, a position measurement will be internally generated and logged alongside the regular measurement data. To generate a real-time message in relation to the camera trigger, it is necessary to select the 'Output on camera trigger option' on the Ethernet configuration window.

Wheel speed input

The wheel speed 1A input (J5-3) 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. converted from the vehicle CAN bus) should not be used either. The timing of the wheel speed input pulses is critical and nothing should cause any delay to them.

The Survey+ also accepts signals from quadrature wheel speed sensors. When using quadrature sensors, connect one channel from the quadrature sensor to wheel speed 1A, and the other to wheel speed 1B input (J5-5). The odometer input should be configured as per a normal wheel speed sensor – the RT1003 will automatically detect the use of the quadrature sensor.

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.

Wheel speed input signal characteristics:

- 0 V to 12 V
- low < 0.8 V
- high > 2.4 V

The wheel that is used should not steer the vehicle. The Survey+ will assume the wheel travels straight.

IMU sync output pulse

The IMU (inertial measurement unit) sync output pulse is a 100 Hz 200 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 file 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 Survey+.

Configuring the Survey+

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

It is only possible to change the Survey+ configuration using Ethernet or WiFi. It is necessary to have the Ethernet and Wi-Fi adaptor settings on your computer configured correctly in order to communicate with the Survey+ and change the settings. See the sections “Ethernet configuration” and “WiFi configuration” on page 33 for more information.

Overview

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

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

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

Survey+ products can calculate the position of the GNSS antenna. This works well when using a base station to achieve 1 cm accuracy, but is not possible 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 Survey+ 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 Survey+, then use them next time you start the system. If you move the Survey+ from one vehicle to another it is essential you create a new configuration rather than using parameters that have been tuned for a different vehicle.

Working through NAVconfig

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

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

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

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

NAVconfig Home section in NAVconfig

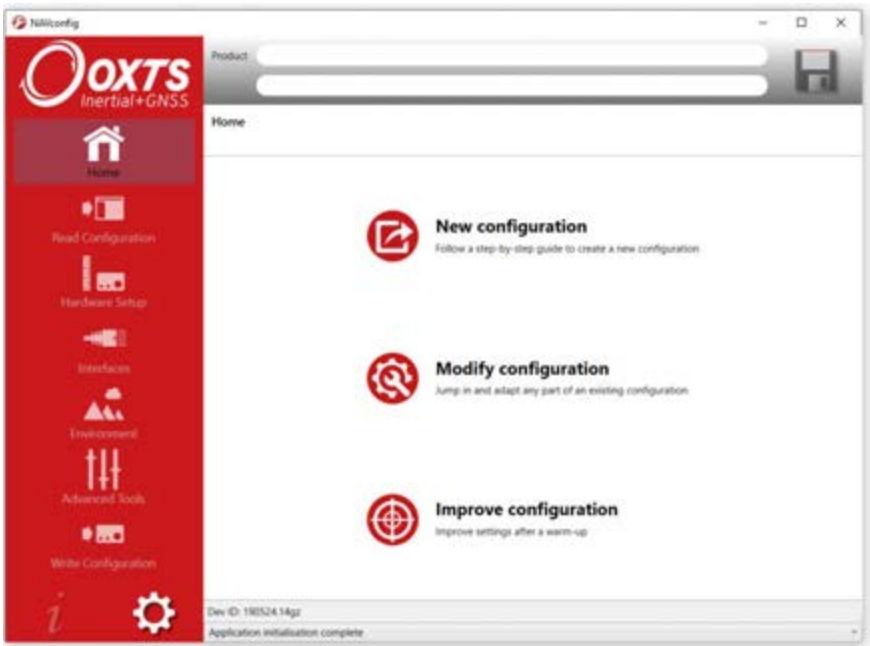
NAVconfig is a universal tool that is used to configure many different devices. The first step is to choose whether you are starting a new configuration, modifying an existing configuration or improving a configuration after a device warm-up.

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

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

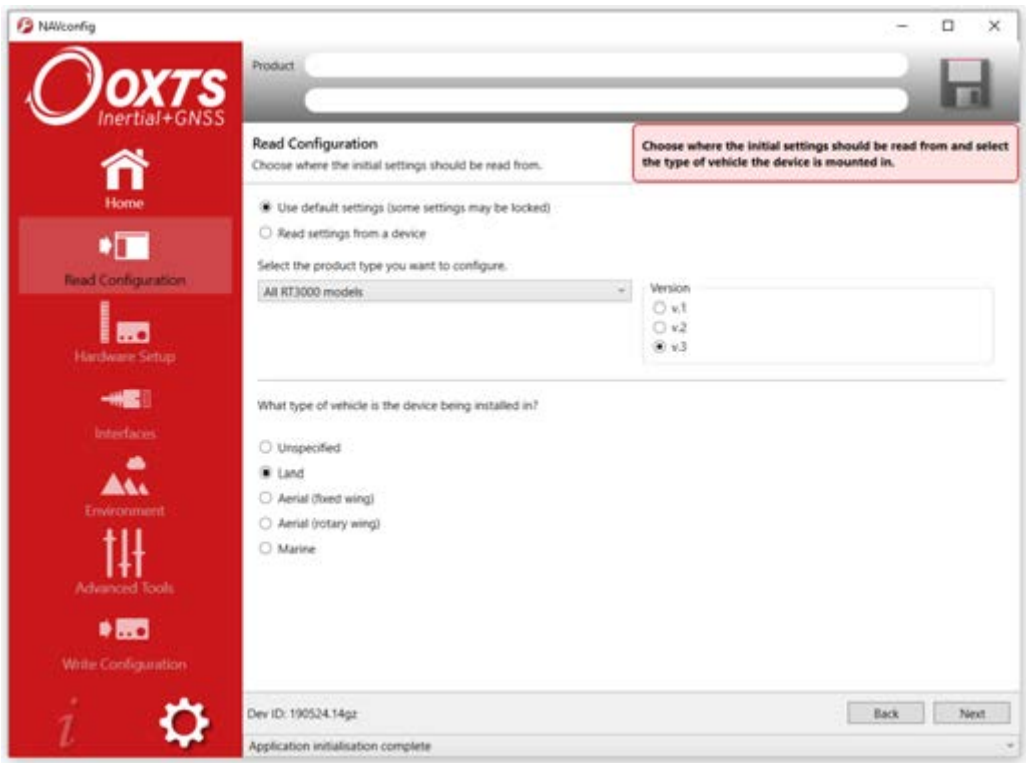
Selecting “Improve configuration” sets up a different workflow within NAVconfig for users who have completed a device warm-up and want to apply improved settings to the device and recommit these settings. Pages 84 to 89 outline the steps for Improve configuration wizard.

Figure 16. NAVconfig Home section



Start/Read Configuration section in NAVconfig

Figure 17. NAVconfig Start/Read Configuration section



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

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

Read Configuration section

The Read Configuration choice tells NAVconfig where to read the initial configuration from (see Figure 18).

Figure 18. NAVconfig Read Configuration section



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

‘Read settings from a raw data (RD) file:’ The Survey+ 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 Survey+ is connected to the computer via Ethernet or WiFi it is possible to read the initial settings directly from the Survey+. The settings loaded are the settings that were last committed to the Survey+ using NAVconfig or the factory default settings applied at manufacture stage. Select this option and enter the correct IP address of your Survey+ or select it from the dropdown list.

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

Hardware Setup section in NAVconfig

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

IMU orientation tab

The IMU orientation tab is used to define the vehicle co-ordinate frame relative to the Survey+’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 Survey+, if the outputs are not properly rotated to the vehicle frame then the measurements will appear incorrect.

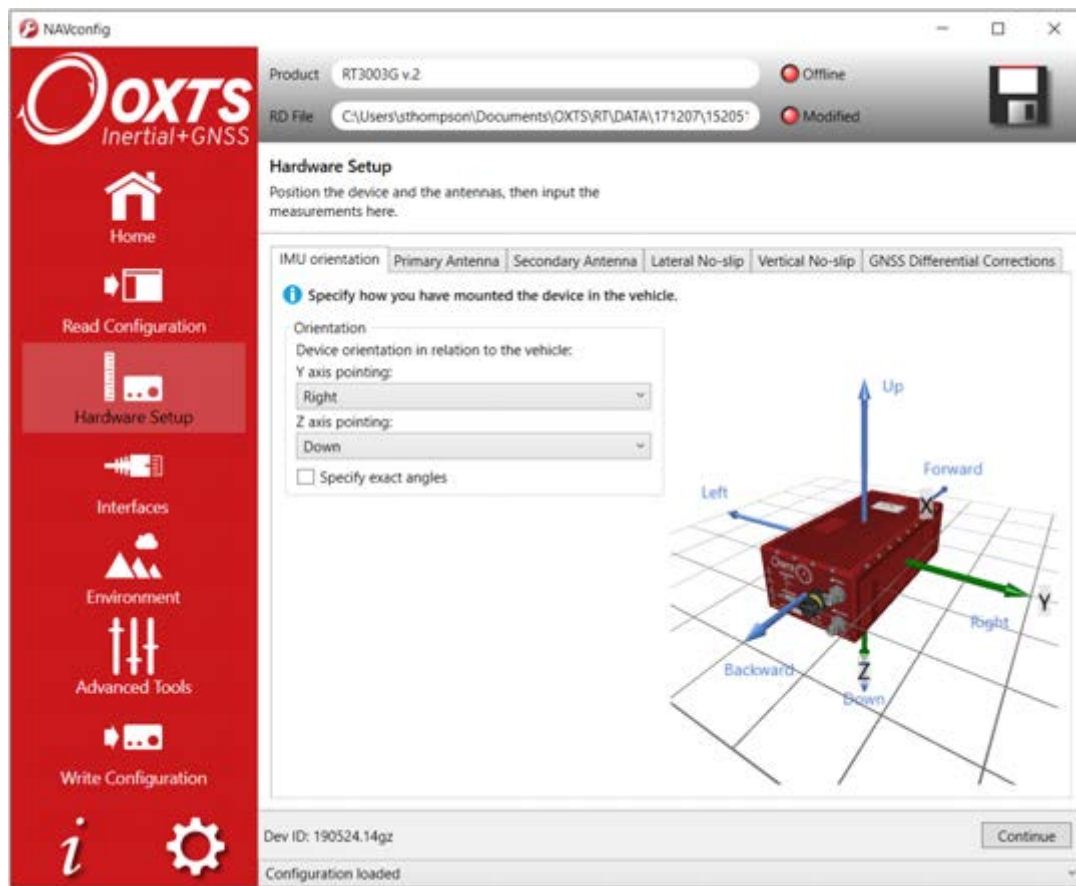
When using an RT-Strut, the orientation will need to be changed. Figure 19 shows an Survey+ mounted on an RT-Strut in a vehicle. In this configuration, the y-axis points left and the z-axis points forwards. Other configurations are possible with the RT-Strut.

Figure 19. A Survey+ device mounted on OxTS RT-Strut



Use the **Y axis points** and the **Z axis points** box to specify which way the Survey+'s axes point in the vehicle. Figure 5 on page 28 shows the Survey+ axes' directions. The Orientation page of the configuration wizard, shown in Figure 20, also has illustrations to visualise the orientation of the Survey+ 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 20. NAVconfig IMU orientation tab in the Hardware Setup section



For correct initialisation, it is necessary to get the heading orientation correct. The Survey+ 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 Survey+ then it will not initialise correctly when the vehicle drives forwards.

If the vehicle level option (see "Vehicle starts") is used, then the pitch and roll orientations must also be correct.

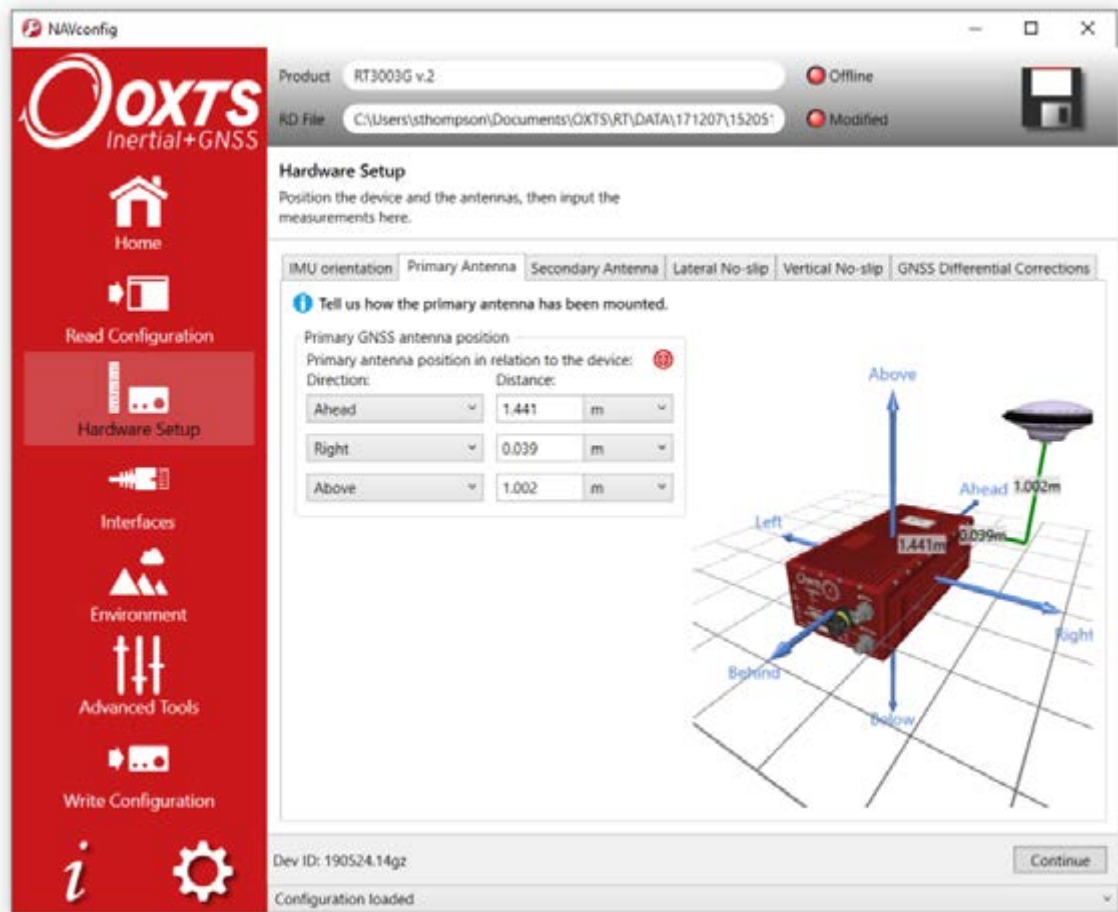
To make small adjustments, select the 'Specify exact angles' checkbox to enable the rotations for editing. This allows any slip angle, pitch or roll offsets to be zeroed.

Primary antenna tab

The Survey+ can calculate the position of the primary antenna itself. However, this takes time and better results can be achieved sooner if the user use differential corrections from a base-station because the GNSS updates received by the antenna will be 1cm accurate, allowing for quicker optimisation. Getting these measurements wrong is one of the main reasons for poor results from the Survey+, 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 21 shows the Primary Antenna page.

Figure 21. NAVconfig Primary Antenna tab



It is necessary to tell the Survey+ the distance between its measurement origin (shown in Figure 5) and the GNSS antenna's measurement point. This should be entered in the vehicle's co-ordinate frame.

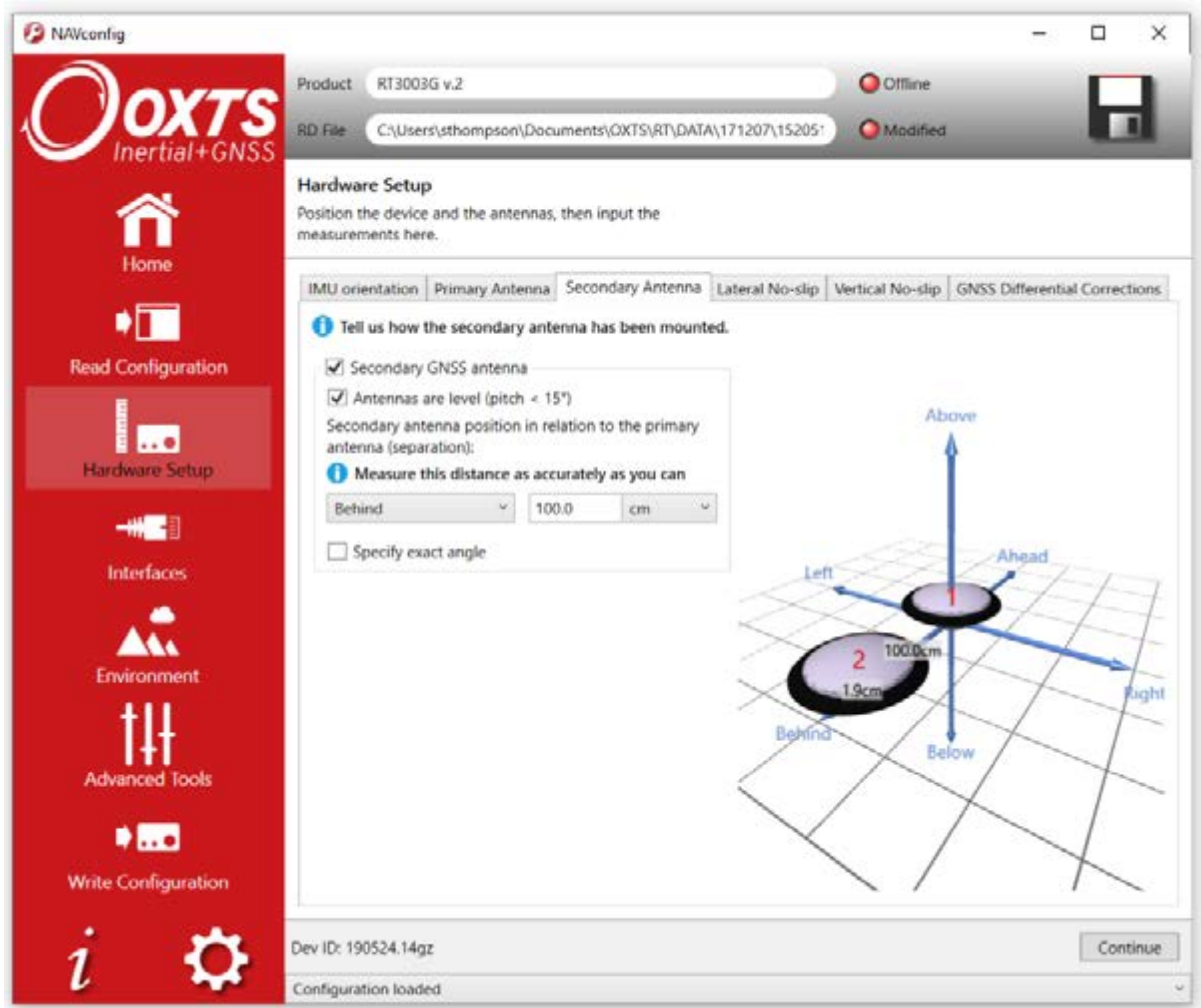
The Survey+ will try to improve the position of the primary GNSS antenna during use. To use the values the Survey+ has estimated use the "Improve configuration" wizard after your warm-up on the Home page of NAVconfig.

Secondary Antenna tab

If your system has two antennas, click the ‘Secondary GNSS antenna’ checkbox on the Secondary Antenna page (Figure 22) to allow the configuration to be entered. If it is not enabled, the Survey+ will ignore the secondary antenna and will not use it to compute a heading solution.

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

Figure 22. NAVconfig Secondary Antenna tab in the Hardware Setup section



The Survey+ 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 Survey+ 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 Survey+ running before moving (for example in autonomous vehicles). Static initialisation is 99% reliable in open sky, but the reliability decreases in environments with high multipath. Static initialisation is also faster when the antenna separation is smaller. This can be configured in the Environment section.

The Survey+ will improve the estimate of the secondary antenna orientation settings. Use the “Improve configuration” option to use the improved values. More information on Improved Configuration is provided on page 84.

Lateral No-slip and Vertical No-slip tabs

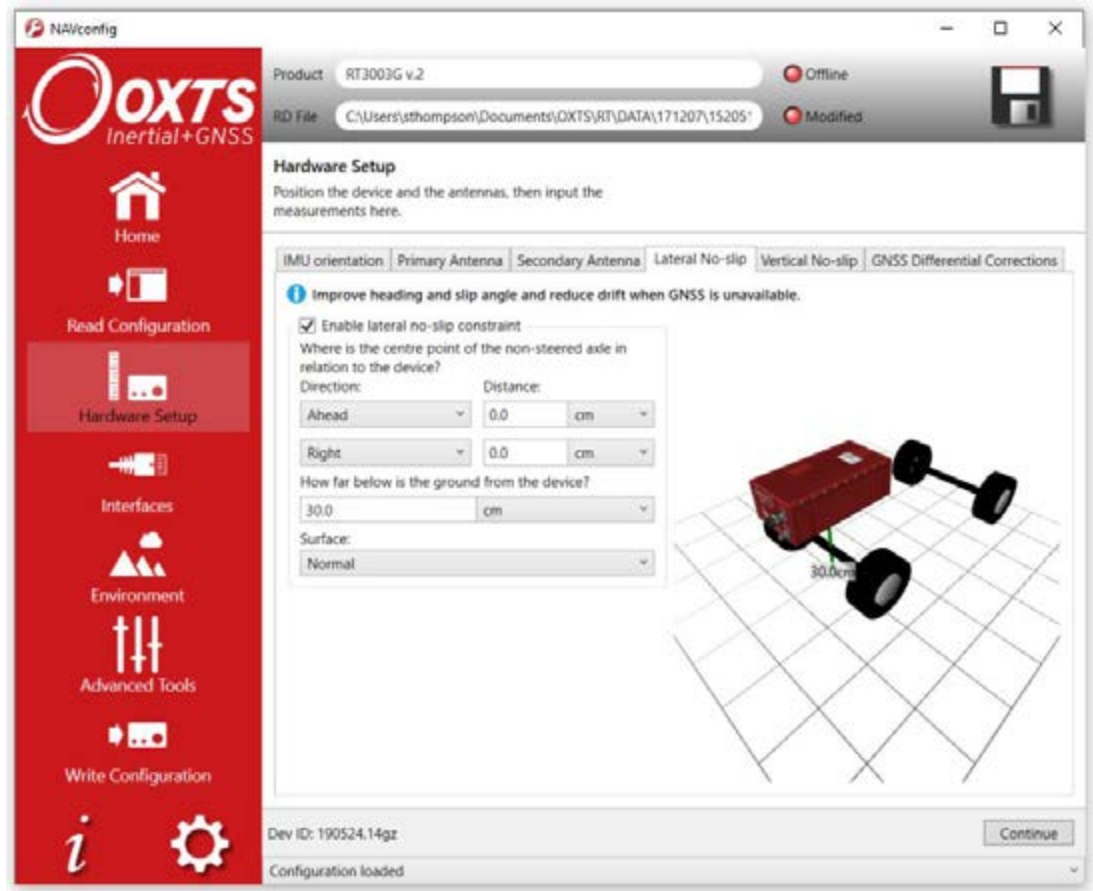
This feature uses characteristics of land vehicle motion to improve heading and slip angle and to reduce drift. Specifying the position of the non-steered wheels makes a huge difference to the lateral drift performance of the Survey+ when GNSS is not available.

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

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

Figure 23 shows the Lateral No-Slip tab.

Figure 23. NAVconfig Lateral No-slip tab in the Hardware setup section



For the Lateral settings, the system needs to know the position of the non-steered axle (rear wheels on a front-wheel steering vehicle and vice versa). A position at road height, mid-way between the rear wheels should be used as shown in Figure 24. Vehicles with all wheels steering cannot use this feature reliably, although minor steering of the rear wheels does not significantly affect the results.

Figure 24. Measurement point for Lateral No-slip



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

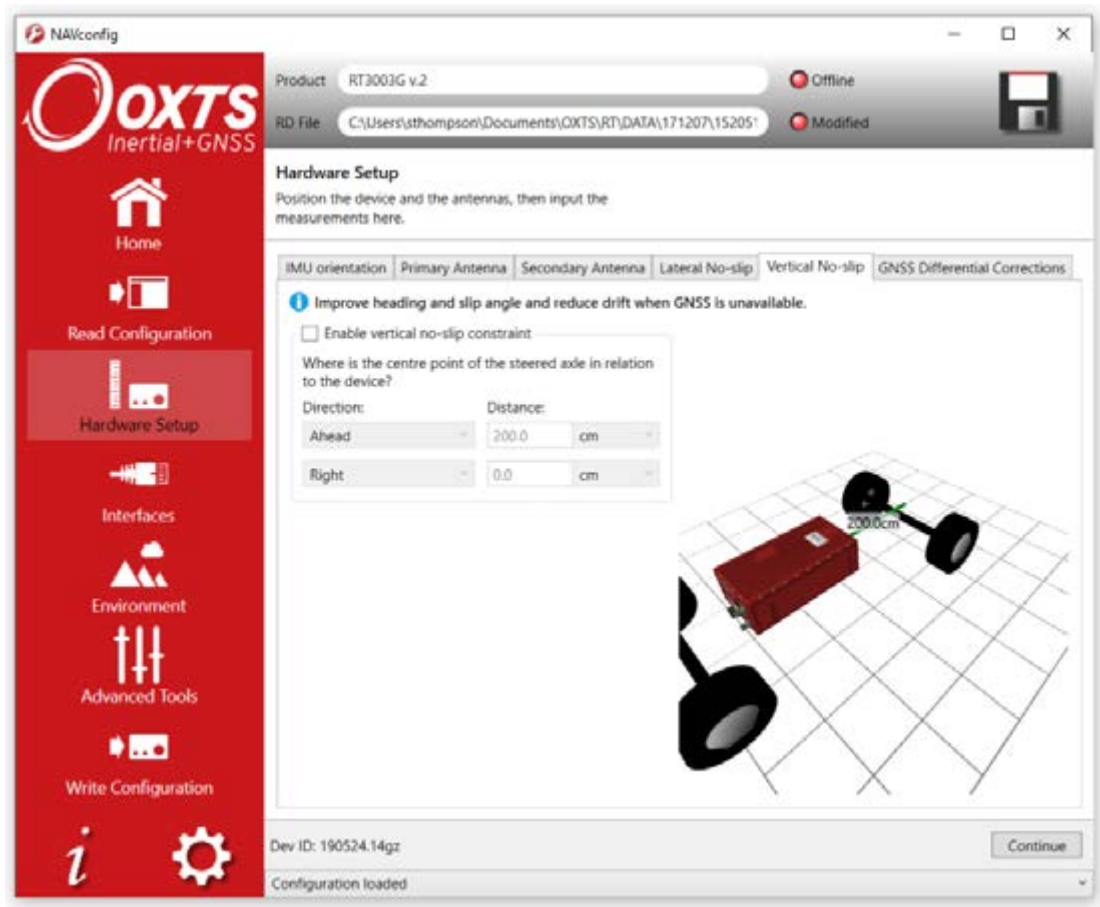
The measurements are made to an accuracy of 10 cm. Selecting an accuracy better than 10 cm does not improve results. Using an accuracy figure worse than 20 cm will increase the drift of the Survey+. Use the **Accuracies** tab in the Advanced Tools section to specify measurement accuracies individually.

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

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

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

Figure 25. NAVconfig Lateral No-slip tab in the hardware Setup section



When using No-Slip features, the Survey+ can estimate the slip angle offset of the Survey+ compared to the vehicle. After the Survey+ is initialised and warmed-up, use the Improve configuration option from the NAVconfig Home section to automatically read the Survey+'s slip angle offset estimate. This ensures a slip angle of zero is measured when driving straight on a level track. See pages 84 to 89 for steps on the Improve configuration wizard.

GNSS Differential Corrections tab

An Survey+ can be configured to use several different differential correction message types on connector J3. Figure 26 shows the Differential corrections properties window and Table 21 gives details on the correction types available.

Figure 26. NAVconfig Differential corrections tab in the Hardware Setup section

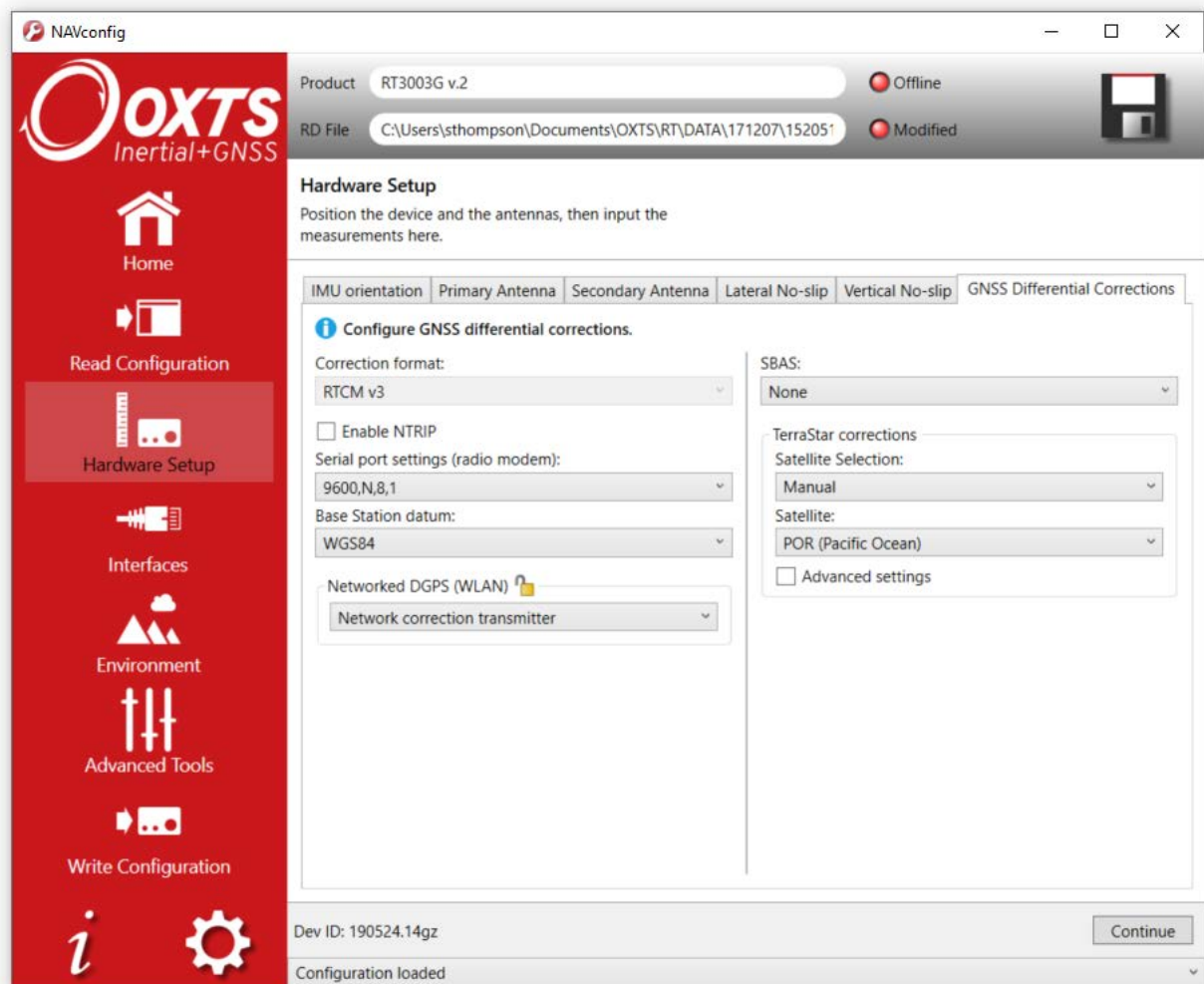


Table 21. NAVconfig Differential Correction formats

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.
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.
CM	This is a standard adopted by Trimble. The Survey+ products support both CMR and CMR+ formats.
Advanced.	This option is reserved

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

NTRIP

When selected, the “Enable NTRIP corrections” check box configures the Survey+ for RTCMv3 corrections and sends an NMEA GGA message out from J3 back to the NTRIP server.

Networked DGPS (WLAN)

The **Networked DGPS (WLAN)** controls allow an Survey+ to be configured to broadcast or receive differential corrections over WiFi. When **Network correction transmitter** is selected, a Survey+ will broadcast differential corrections it is receiving via a radio modem from an OXTS base station, using a WLAN device. Other OXTS devices that are on the network as the broadcasting Survey+, 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 Survey+’s need DGPS corrections as only one pair of radio modems needs to be used.

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

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

SBAS

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

TerraStar corrections

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

Interfaces section in NAVconfig

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

Ethernet tab

The Ethernet settings include configuring the Ethernet data output rate, packet type and Triggers for the Survey+.

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

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

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

Wi-Fi tab

In the Wi-Fi setting you can configure the system to either be an Access Point or to connect to an existing network.

Access Point

To configure the Wi-Fi as an Access Point, click on the option and the field to configure the Network details and router details will become available to edit.

The Network name (SSID) will be by default OxTS Survey+ SN[serial number]. This can be changed to another name but cannot contain any of the following characters: [<], [>], [&], ['] and ["]. It is possible to add a password to the network created. To enable this, select what security protocol to use, WPA or WPA2, and then enter the Passphrase.

For the router, the Gateway and Subnet mask can be changed if using a different IP range or to prevent IP clashes.

Connect to existing Network

To Configure the Wi-Fi to connect to an existing WLAN, you will need to have the Wi-Fi already enabled and have the Access Point disabled. If the Wi-Fi is not enabled, the Survey+ will not be able to see what network it could connect to. If the Access Point is enabled, the Survey+ will not connect to an existing network.

Under “*Wireless networks in range of device*”, you can choose which network you wish to connect the Survey+ to and drag the network to the box on the right. If the network is secured, a text box will be available to enter a password. This will contain the networks that the Survey+ will connect to when they are in range.

Warning:

A network containing the following characters, [<], [>], [&], ['] and ["], will not be seen correctly and the Survey+ will not be able to connect to the device. These characters cannot be used in the SSID of the Survey+.

If using an iPhone to hotspot, please be aware if the phone is called "[name]'s iPhone" as this has the non-usable [']. To change the name of the hotspot, go to "Settings" > "General" > "About" and select "Name".

Serial 1 Output tab

The serial port can be configured to output different types of message (see Table 22).

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

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

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

Table 22. Serial outputs

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 RT1003. NCOM data is transmitted at up to 125 Hz over serial. The format is described in the NCOM Description Manual. Software drivers exist for decoding the NCOM data
IPAQ	NCOM output at a reduced rate. The baud rate of the serial port is set to 19200 and the update rate is 25 Hz. It is used because the IPAQ cannot manage to receive the data reliably above 25 Hz
IPAQ+	NCOM output at a reduced rate and polled. Windows Mobile 5 on IPAQs crashes if the inMOTIONx is sending data when the IPAQ is turned on. Using IPAQ+ the IPAQ will poll the RT1003; the RT1003 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, GPHDT, GPVTG, GPZDA, GPGST, PASHR, GPRMC, GPGSV, GPGSA, PTCF, GPPPS, PRDID, GPROT, GPGGK, and GPUTC. The NMEA 0183 description manual gives details of the fields output in the NMEA sentences
Javad I+RTK	A special set of messages output in GREIS format to be used with Javad receivers. For assistance please contact OxTS for support
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

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

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

PPS / Triggers tab

PPS will output 1 pulse per second synchronised to GPS time, providing a highly accurate time pulse for synchronising external devices.

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

NAVconfig Environment section

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

Initialisation

Static initialisation is disabled by default.

If static initialisation has not been enabled, the Survey+ 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. In contrast, some faster vehicles will achieve much higher speeds and will have an unstable heading at lower speeds e.g. Formula 1 cars, so a higher initialisation speed should be set here.

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

Vehicle starts

Select a predefined value from the dropdown list.

If you know the vehicle will be level when starting (to within about 5°) select 'Level'. This saves about 40 s during the initialisation process since the Survey+ 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 Survey+ can only start if the vehicle is level and the **Level** option has been specified.

GNSS environment

Select a predefined value from the dropdown list.

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

Unless the open-skies setting is used, the Survey+ will not report accuracies that meet its specifications due to the Kalman filter reducing its expected tolerances to accommodate the harsher environment.

Vibration levels

Select a predefined value from the dropdown list.

The Normal vibration level is adequate for most circumstances. The Survey+ 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/Very High** vibration setting should be used include those where vibration mounts have been used, or where the Survey+ and the antenna are mounted on different sprung parts of the vehicle (e.g. the cab/chassis of a truck).

Heading lock

The heading of single antenna systems can drift when the Survey+ remains stationary for long periods of time. To solve this, the Survey+ includes an option to lock the heading to a fixed value when stationary. This option should not be used if the vehicle can turn on the spot (i.e. with no forward velocity). With heading lock enabled the Survey+ can remain stationary for indefinite periods of time without free drift on the heading output. For vehicle testing with a single antenna 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 but should be used with caution as something as simple as turning the steering wheel while stationary can result in 1° of heading change.

Table 23 gives a more detailed description on each of the heading lock options.

Table 23. 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

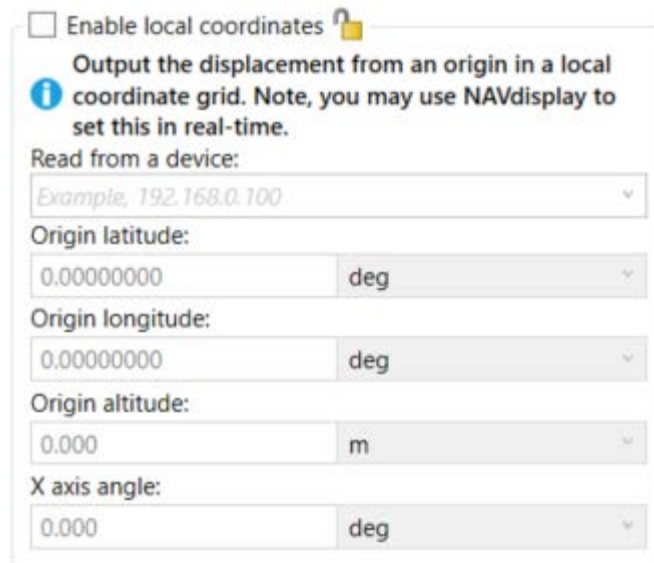
The Garage mode option is used to stabilise the Survey+’s outputs when GNSS is not available. For example, GNSS can be blocked when the vehicle returns to the garage to have some modifications. Without Garage mode enabled, the Survey+ may drift too far and may not be able to recover.

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

Enable local coordinates

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

Figure 27. NAVconfig Enable local co-ordinates in the Environment section

Advanced Tools section

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

Displace Output tab

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

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

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

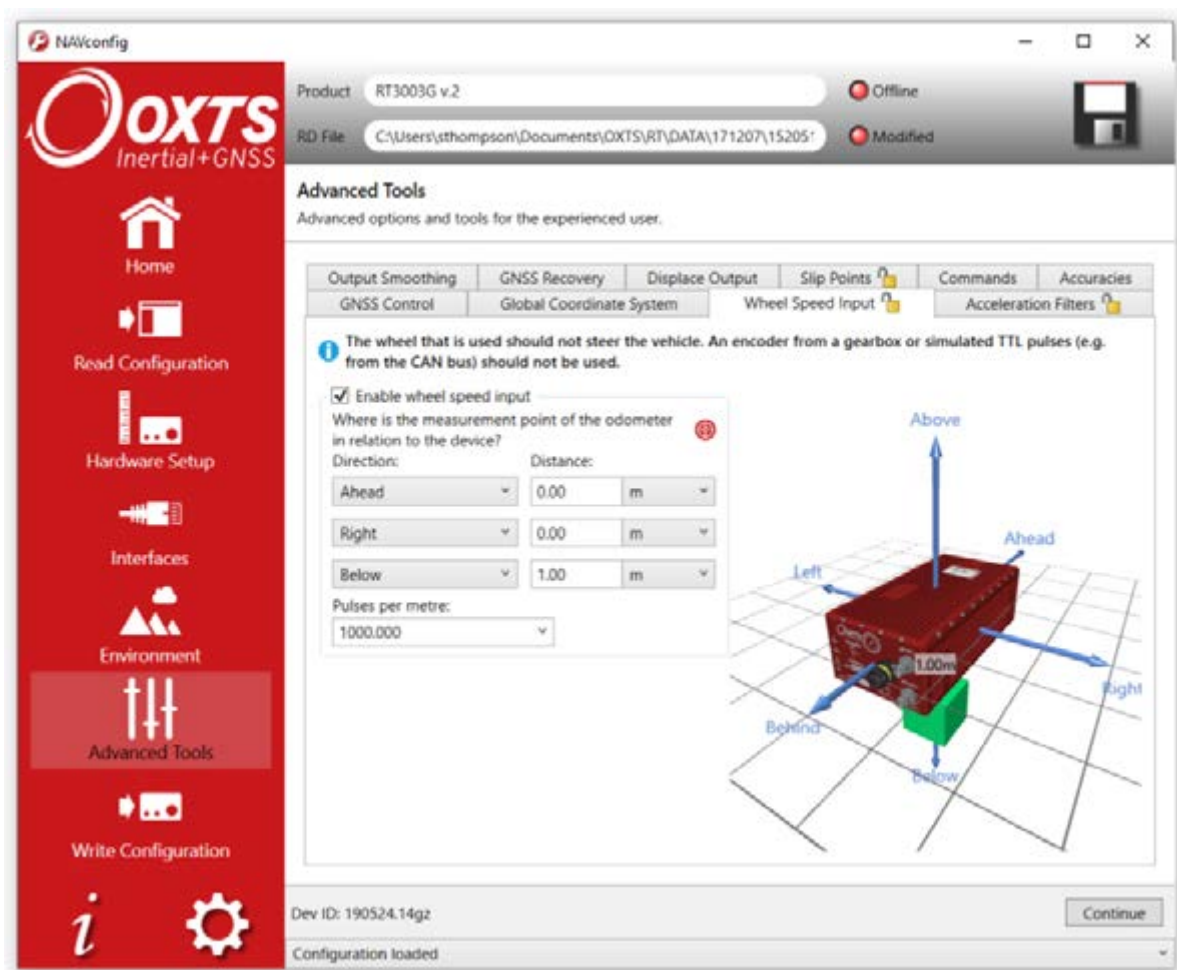
Wheel Speed Input

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

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

Figure 28 shows the wheel speed configuration window. To enable the wheel speed input, ensure the checkbox is checked. If this option is disabled, the Survey+ will ignore corrections from the wheel speed even if it is connected.

Figure 28. NAVconfig Wheel Speed Input tab in the Advanced Tools section



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

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

Enter the pulses per metre of the wheel speed. A value that is accurate to 10% is sufficient unless you know the figure more accurately. The Survey+ will improve this scaling factor itself when GNSS is available as it is a state monitored by the Kalman Filter. The **Improved settings** utility (see page 84 for details) can be used to apply a more accurate value calculated by the Survey+ from a calibration run. If this option is used, then the Survey+ 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 Survey+ 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.

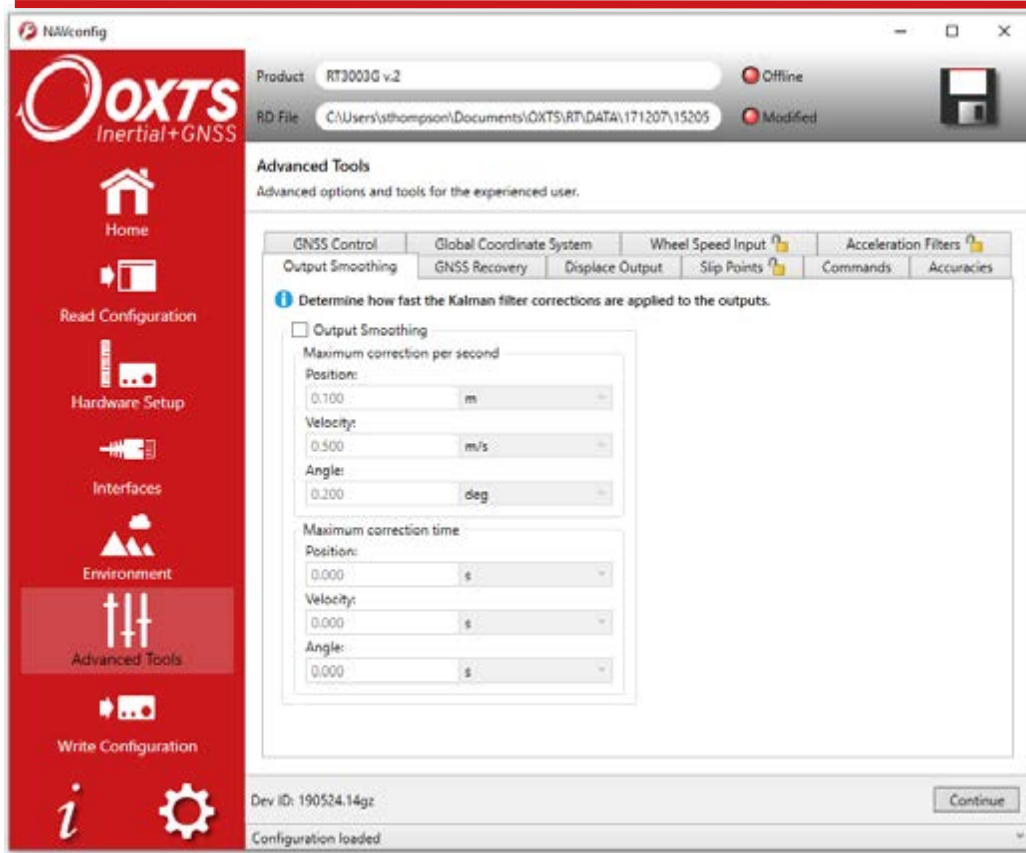
For best results, a front wheel drive vehicle should be used with the wheel speed on a rear wheel. The wheel speed pulses from driven wheels are less accurate.

Output smoothing tab

When the Kalman filter in the Survey+ 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 29 shows the Output smoothing tab in the Advanced Tools section within NAVconfig. Click the checkbox to enable output smoothing and unlock the properties for editing.

Figure 29. 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 Survey+ 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 Survey+ 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 Survey+ 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.

GNSS control tab

The GNSS control tab contains advanced options that control how the GNSS information is managed in the Survey+. 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 30 shows both tabs in the GNSS control properties window.

Figure 30. NAVconfig GNSS Control tab in Advanced Tools within NAVconfig



The **GNSS Control** tab gives a choice of three algorithms for computing the GNSS measurements. The default option is to use the algorithm provided by the GNSS receiver. Using this algorithm, the Survey+ will accept precalculated position and velocity updates from the GNSS and use it to update the Kalman filter.

The gx/ix™ raw data processing algorithm is OxTS' tight coupling engine. It 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.

There is also a third option to use a mix of the two algorithms in order to gain the benefit from each mode in real time.

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 24 details the current compatibilities of gx/ix™ mode.

Table 24. gx/ix™ compatibility

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

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

GNSS Recovery tab

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

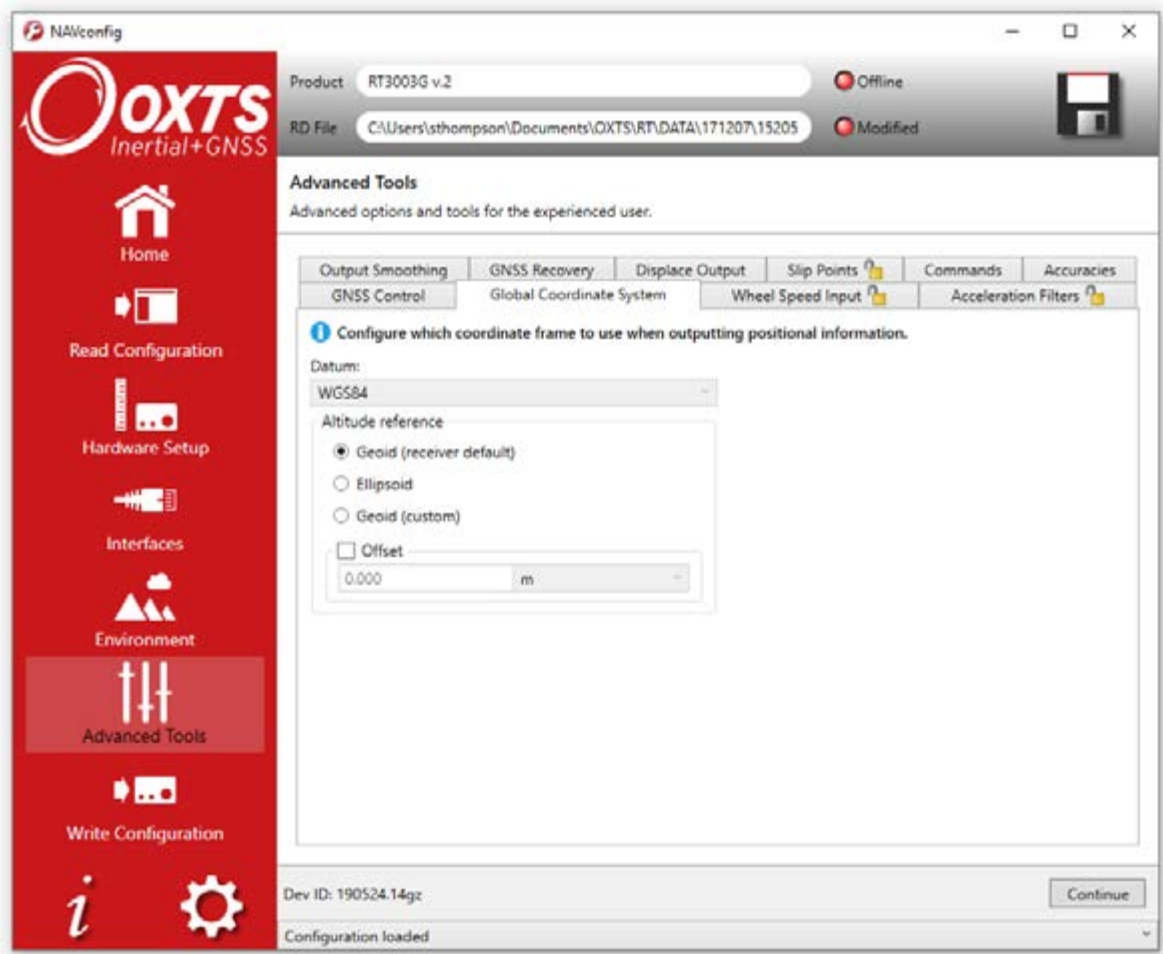
In the default state the Survey+ will reject up to 20 GNSS measurements before it forces the GNSS to be accepted. However, in high multipath environments, and when wheel speed is used, it may be desirable to reject more GNSS measurements. Select the 'Start believing

measurements after' option and enter the number of GNSS measurements to reject before the system starts believing it again.

Global Coordinate System tab

The Survey+ can output position relative to different coordinate frames. You can change the coordinate frame settings in the Global Coordinate System tab within Advanced Tools in NAVconfig, shown in Figure 31.

Figure 31. NAVconfig Global Coordinate System properties window



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

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

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

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

Accuracies tab

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

Commands tab

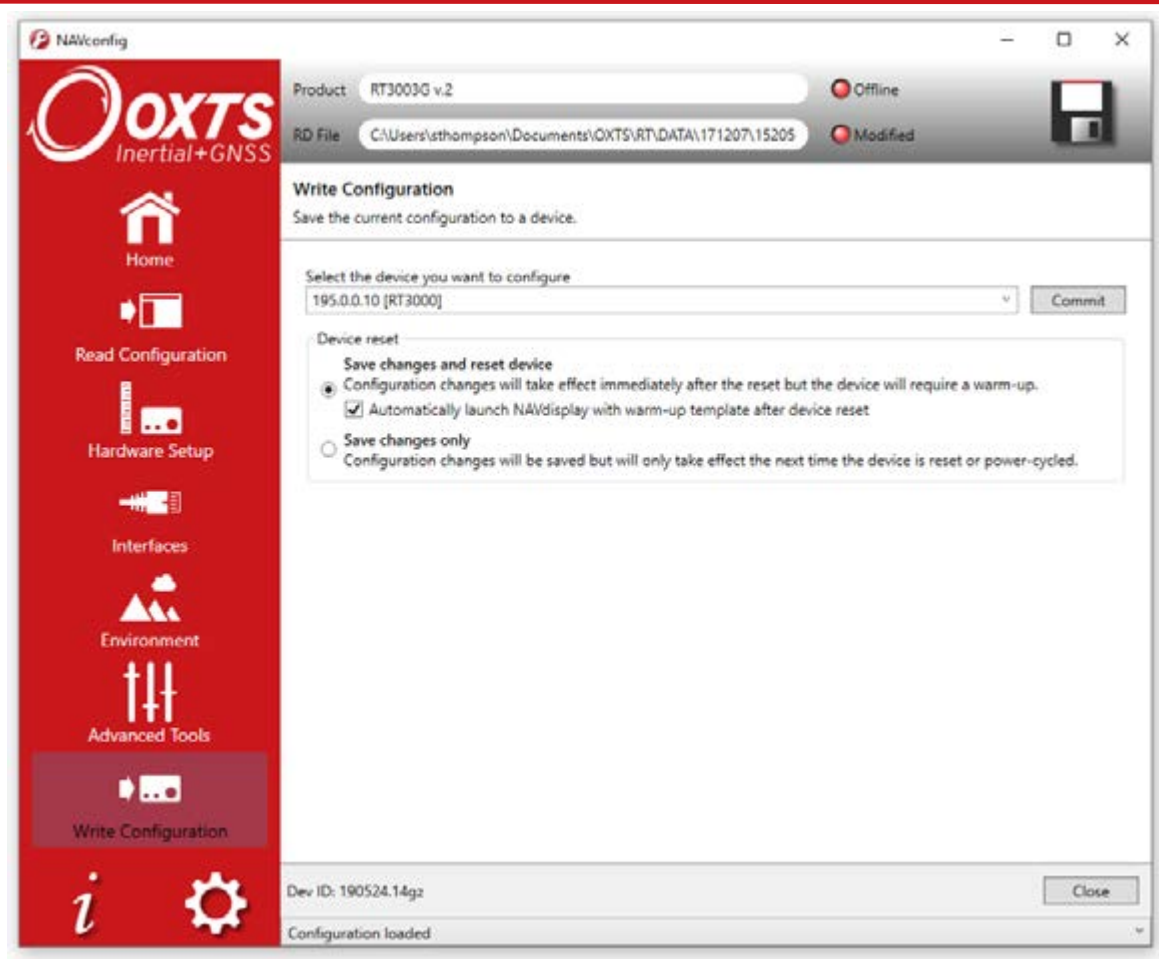
Using the Commands tab you can enter device-specific commands that apply specific features or perform actions onto the Survey+. The OXTS technical support team often use these and can provide you with a list of useful commands if you request them at support@oxts.com.

The Write Configuration section of NAVconfig

Changes to the Survey+ settings must be sent using Ethernet or Wi-Fi. It is necessary to configure your computer's LAN and WLAN settings, so it is on the same network as the Survey+. The section "Ethernet and Wi-Fi configuration" gives details on how to do this.

Figure 32 shows the Write Configuration page.

Figure 32. NAVconfig Write Configuration page



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

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

Setting up the base station

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

The base station is a separate GNSS receiver that monitors signals from the GNSS satellites. Using its knowledge of position it works out the errors in each satellite's signal. It also measures the carrier-phase of the signal for kinematic corrections. The carrier-phase observations and the satellite signal errors are sent from the base station GNSS to the Survey+ 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 Survey+. In order to relate the Survey+ 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 Survey+ user cable supplied. This cable supplies power to the radio modem as well as sending the differential corrections to the Survey+.

Initialisation process

Before the Survey+ can start to output all the navigation measurements, it needs to initialise itself. In order to initialise, the Survey+ needs all the measurements listed in Table 25.

Table 25. 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 Survey+ 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:

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

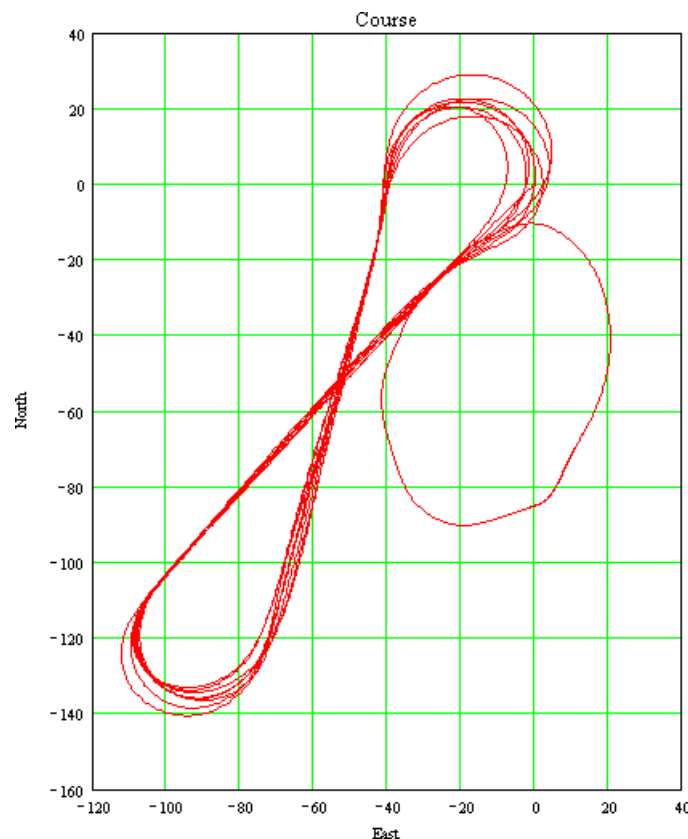
During this period it is necessary to drive the vehicle or the errors will not be estimated and the specification will not be reached. The NCOM output message includes status information that can be used to identify when the required specification has been met. These are plotted in the example below.

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 Survey+ was configured well – the GNSS antenna position, Advanced slip options and dual-antenna separation were measured accurately in advance.
- The Survey+ was turned on as soon as possible. In this case it took us 15 minutes to get all the other equipment sorted out. The Survey+ was stationary for most of this period – which is not a problem.
- Although in this example the Survey+ 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 Survey+ 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 Survey+ is accurate almost after the first figure of eight; after that the improvement is very small.

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

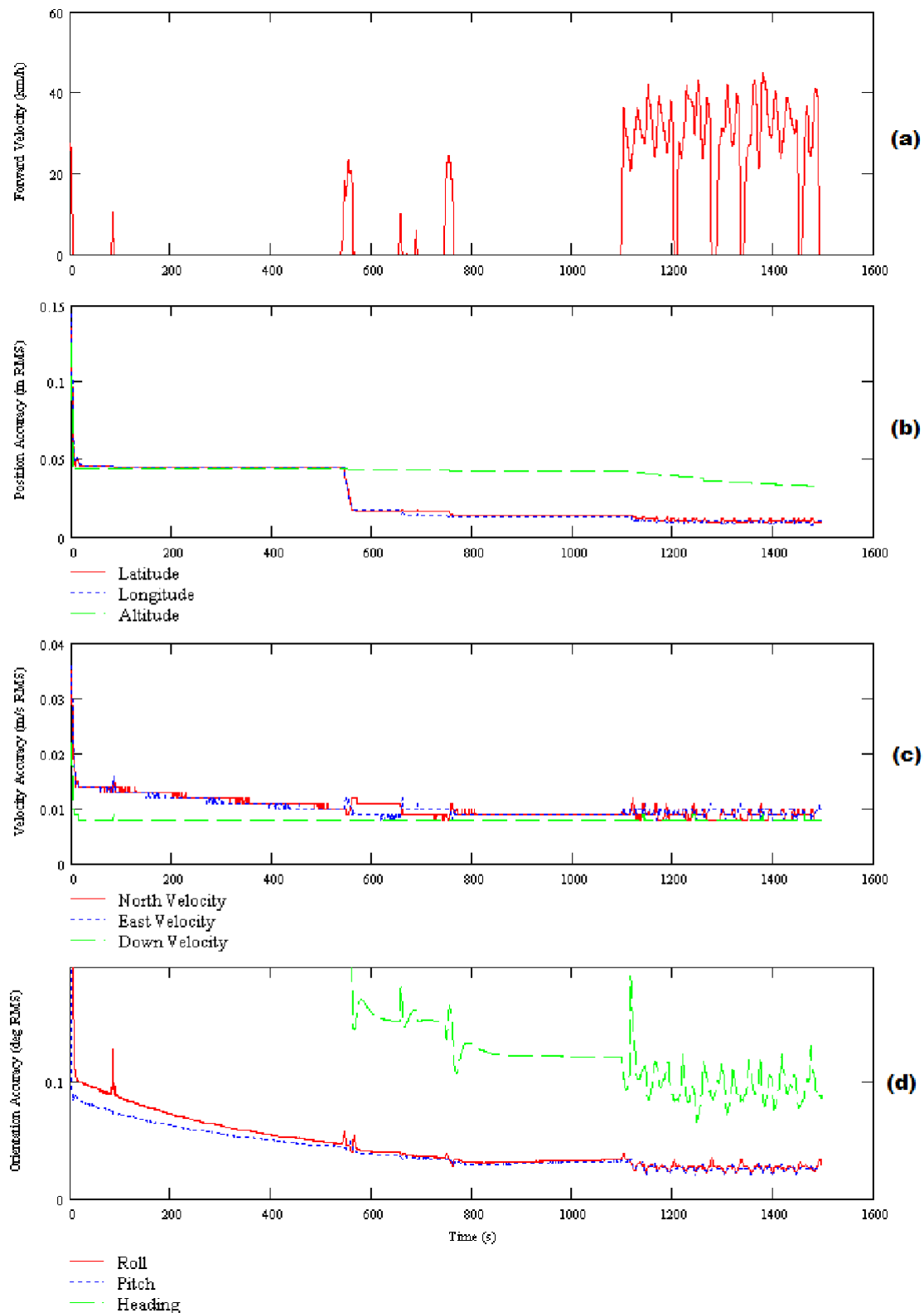
Figure 33 shows the route driven and Figure 33 shows the accuracy estimated by the Kalman filter for various output parameters during the first 25 minutes. The quality of initialisation would have been the same if the stationary period was 10 minutes, followed by 5 minutes of driving. The time on the graphs is the time from initialisation. In this example the Survey+ 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 33. Example warm-up driving route

At the start there is just a small amount of motion to get the Survey+ 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 34); 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 Survey+ is driven (it is the small loop on the east side in Figure 33, 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 34. Example warm-up accuracy estimates



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

You can see the Survey+ 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 34) 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 Survey+ 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 Survey+.

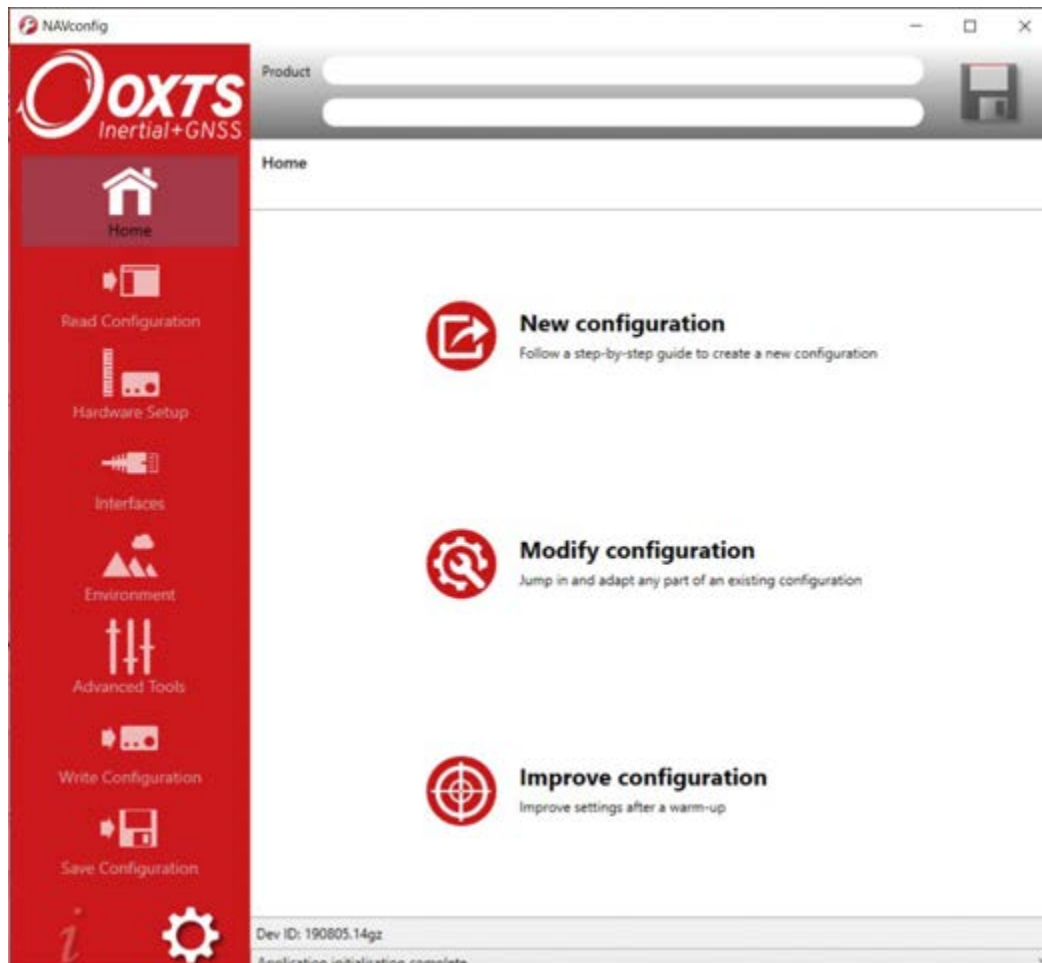
Improving the configuration after a warm-up

Committing the configuration to the Survey+

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

To commit improved settings to the Survey+, first open NAVconfig and select ‘Improve configuration’. Figure 35 shows this option on the NAVconfig home section.

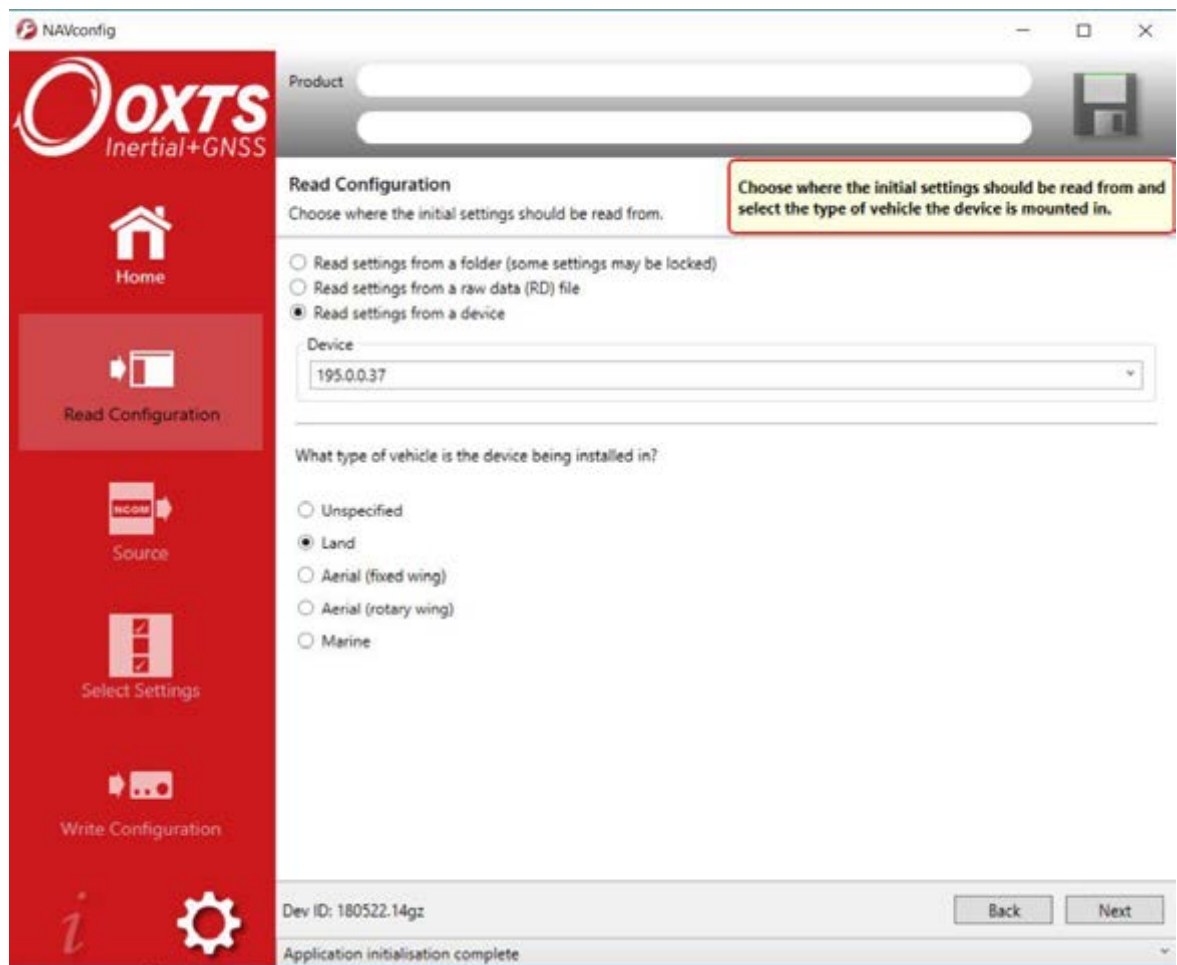
Figure 35. NAVconfig home page – select Improve configuration



Read configuration section in NAVconfig improved configuration wizard

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

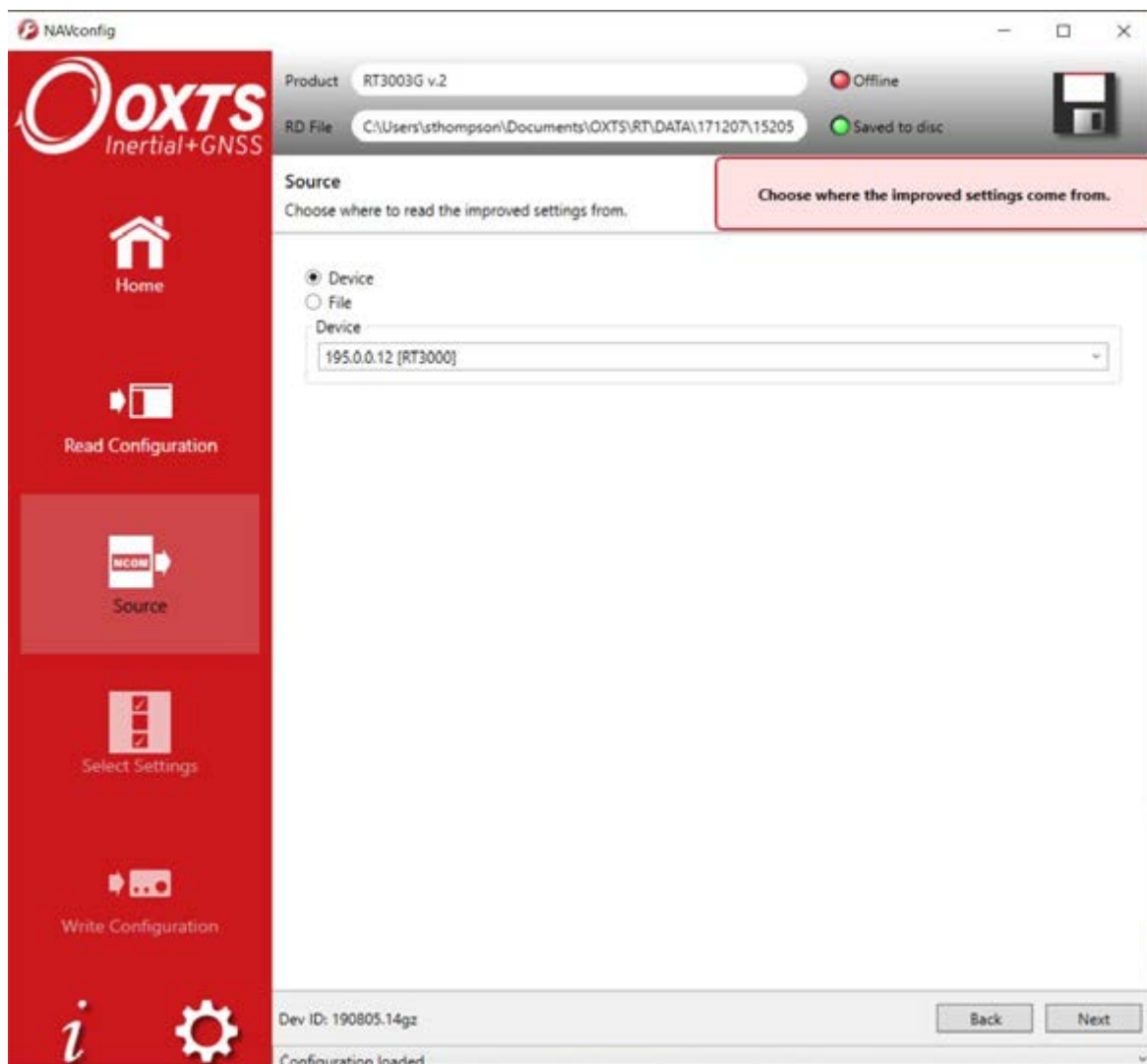
Figure 36. Choose where to read configuration from



Click 'Next' to continue.

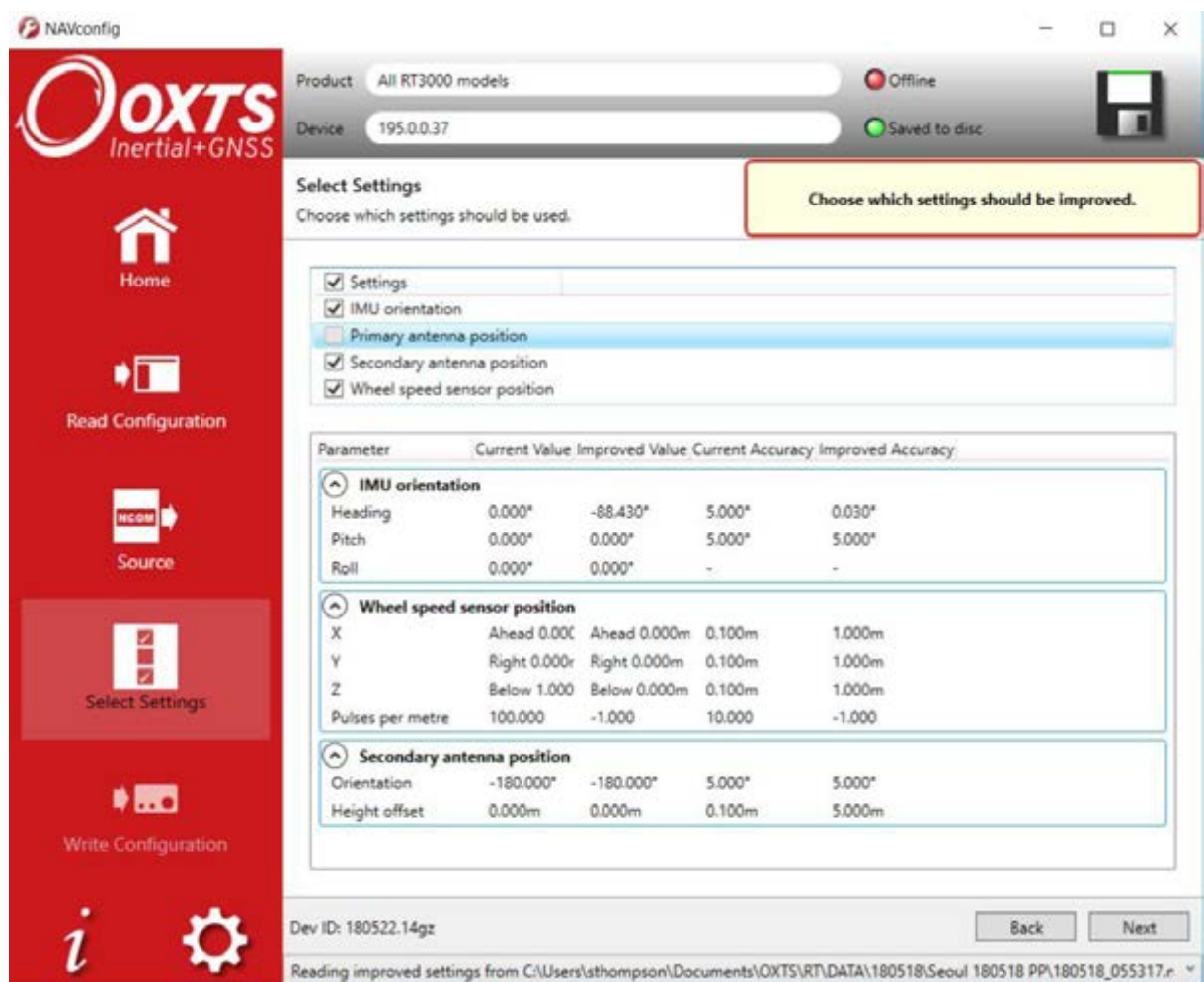
Confirm whether the improved data should be read from: The Device, or a File. Click 'Next' to continue.

Figure 37. Confirm if configuration should be read from device or logged file



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

Figure 38. Choose which settings to optimise



NAVconfig

Product: All RT3000 models

Device: 195.0.0.37

Offline

Saved to disc

Select Settings

Choose which settings should be used.

Choose which settings should be improved.

☒ Settings

☒ IMU orientation

☐ Primary antenna position

☒ Secondary antenna position

☒ Wheel speed sensor position

Parameter	Current Value	Improved Value	Current Accuracy	Improved Accuracy
IMU orientation				
Heading	0.000°	-88.430°	5.000°	0.030°
Pitch	0.000°	0.000°	5.000°	5.000°
Roll	0.000°	0.000°	-	-
Wheel speed sensor position				
X	Ahead 0.000	Ahead 0.000m	0.100m	1.000m
Y	Right 0.000r	Right 0.000m	0.100m	1.000m
Z	Below 1.000	Below 0.000m	0.100m	1.000m
Pulses per metre	100.000	-1.000	10.000	-1.000
Secondary antenna position				
Orientation	-180.000°	-180.000°	5.000°	5.000°
Height offset	0.000m	0.000m	0.100m	5.000m

Dev ID: 180522.14gz

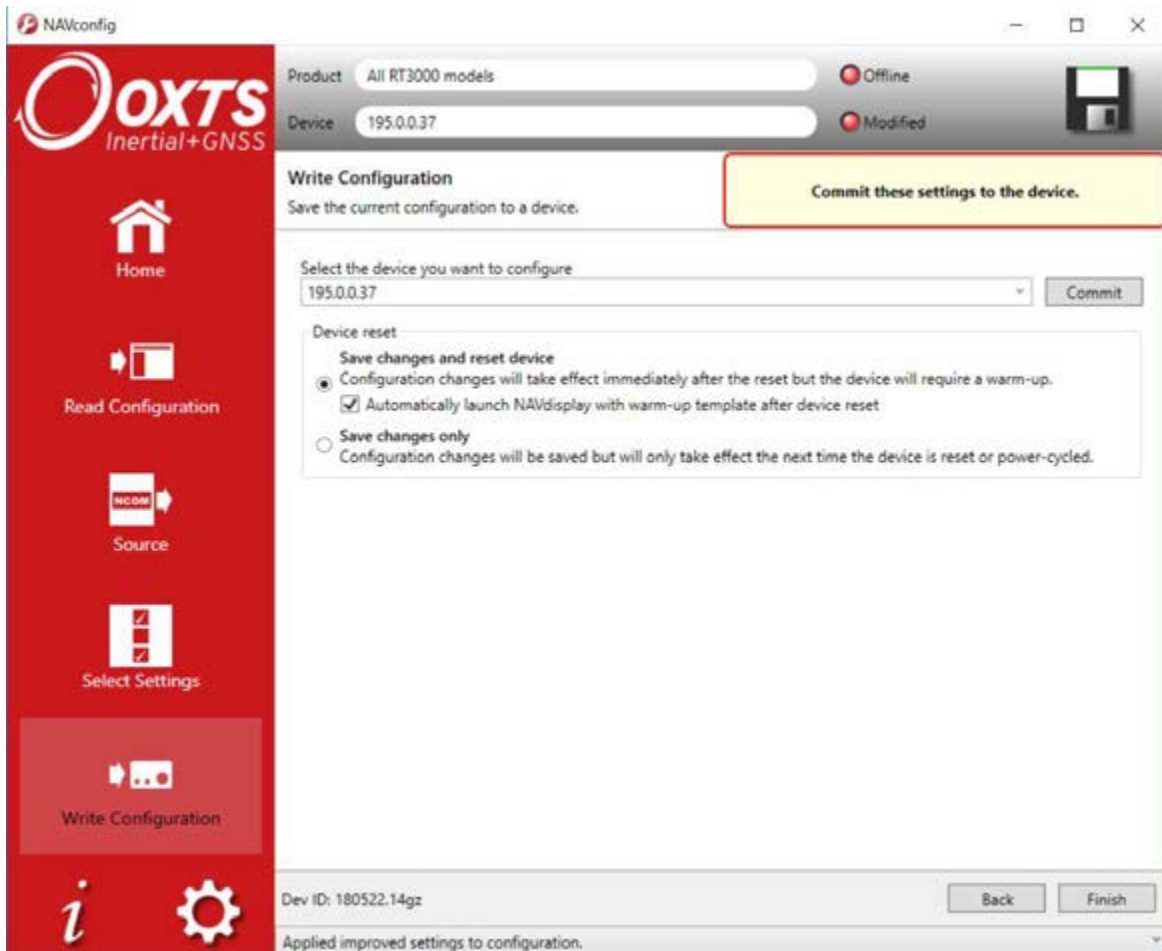
Back Next

Reading improved settings from C:\Users\stthompson\Documents\OXTS\RT\DATA\180518\Seoul 180518 PP\180518_055317.r

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

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

Figure 39. Choose to commit and reset, or just commit



Post-processing data

Data stored on the Survey+ 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 Survey+ includes the NAVsolve software which can be used to reprocess the data. The NAVsolve Wizard also gives the user the ability to change the NCOM binary output format to text.

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

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 Survey+ 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 Survey+ is placed on a level surface in the orientations according to Table 26.

Table 26. Acceleration measurement specifications

Orientation			Acceleration measurement
x	y	z	
Flat	Flat	Down	z -acceleration between -9.7 and -9.9 m/s ²
Flat	Flat	Up	z -acceleration between 9.7 and 9.9 m/s ²
Down	Flat	Flat	x -acceleration between -9.7 and -9.9 m/s ²
Up	Flat	Flat	x -acceleration between 9.7 and 9.9 m/s ²
Flat	Down	Flat	y -acceleration between -9.7 and -9.9 m/s ²
Flat	Up	Flat	y -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 Survey+ 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 Survey+ according to Table 27 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 Survey+ will work to specification with biases up to $\pm 5^\circ/\text{s}$.)

Table 27. Angular rate measurement specifications

Orientation			Angular rate
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 Survey+ 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 Survey+ to go for long periods without requiring recalibration.

Testing the internal GNSS and other circuitry

To check all the internal circuits in the Survey+ 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 28, below, to check the status fields are changing.

Table 28. 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 Survey+.

The Survey+ 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 Survey+ 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.

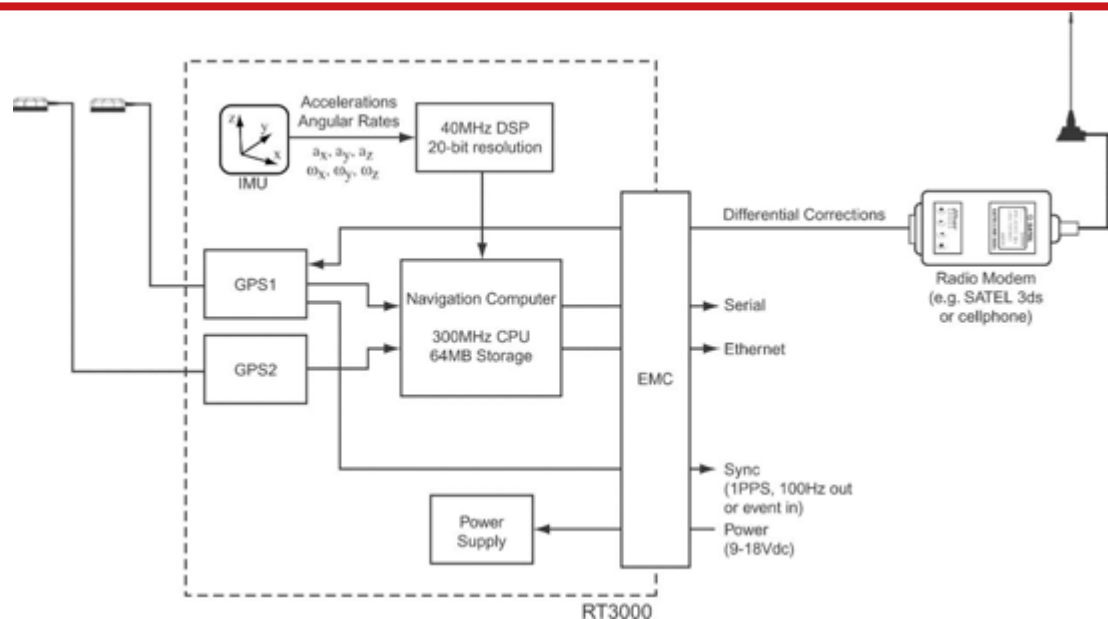
Operating principles

This short section gives some background information on the components in the Survey+ 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 40 gives a schematic view of the components in the Survey+ system.

Figure 40. Schematic showing the internal components of the Survey+



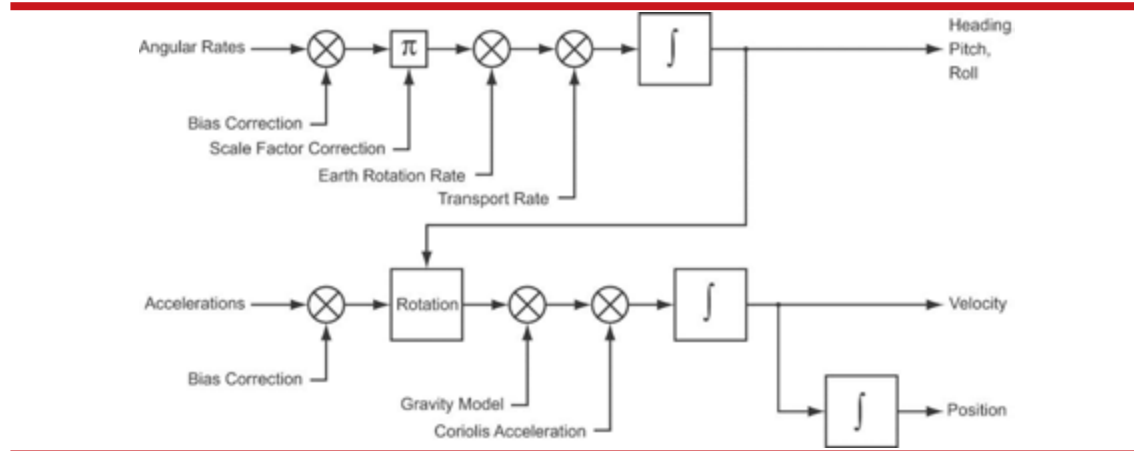
The schematic shows the layout for a dual antenna system.

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 41 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 41. 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 Survey+ 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 Survey+ 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 Survey+ 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 Survey+ 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 Survey+; 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 Survey+. 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 Survey+ has 25 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 two vehicle mounting angles (for advanced slip and vertical 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 Survey+ for control since any differential terms in the control algorithm do not have large step changes in them.

Revision history

Table 29. Revision history

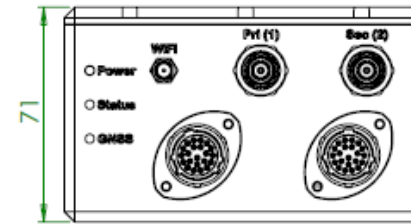
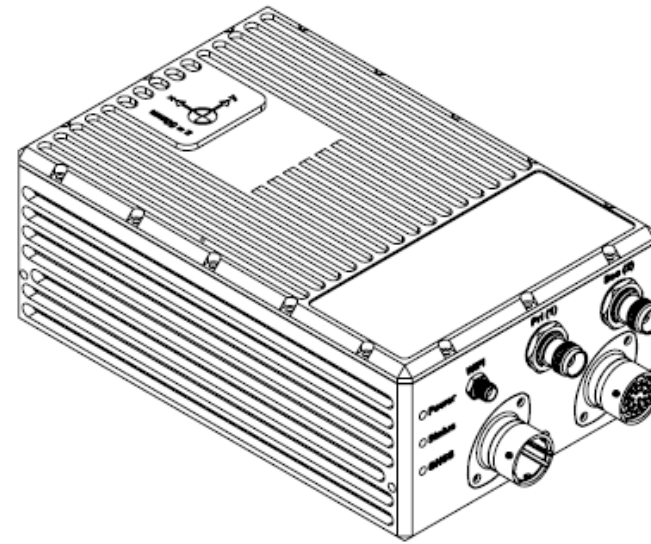
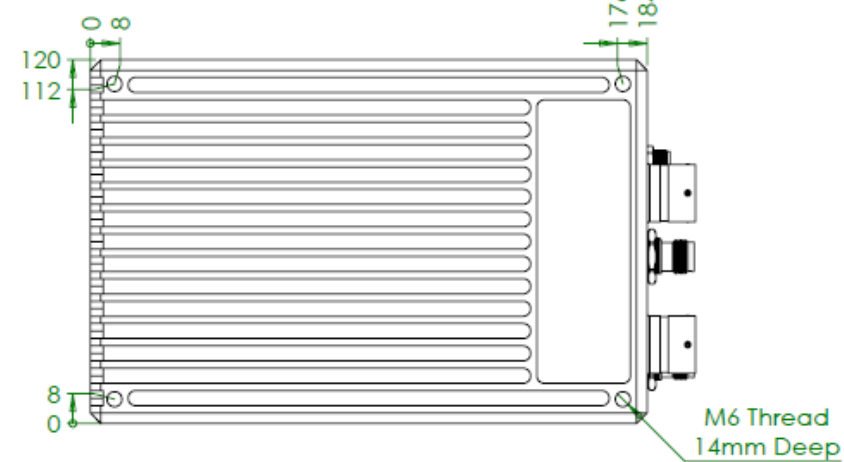
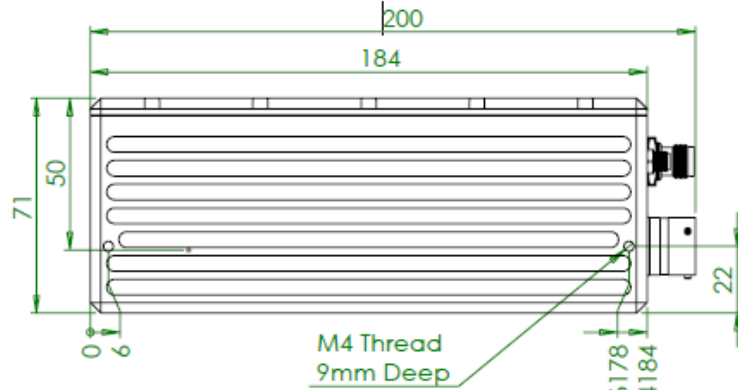
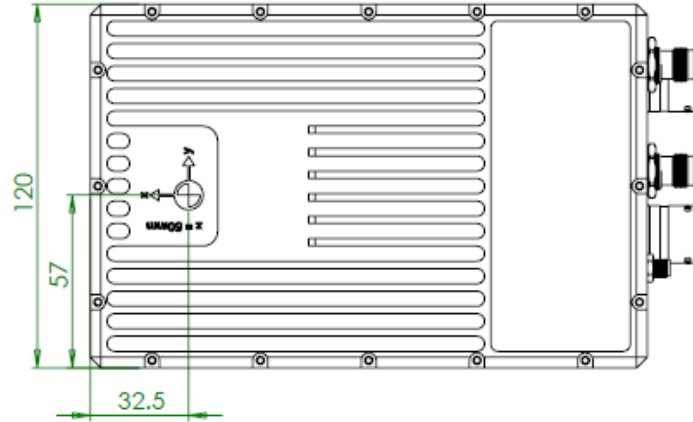
Revision	Comments
190902	Original Survey+v3 manual


Drawing list

Table 30 lists the available drawings that describe components of the Survey+ 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 30. List of available drawings

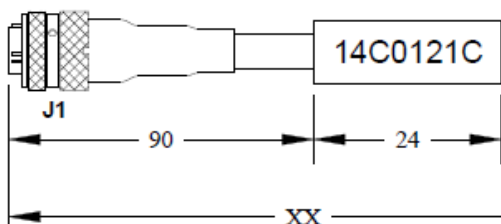
Drawing	Description
14A0085	RT500, RT3000 system outer dimensions drawing
14C0038D	RT500, RT3000 primary user cable
14C0213D	RT500, RT3000 Aux user cable
14C0062B	RT2000 radio cable modem
77C0002B	RT500, RT3000 power cable



THIRD ANGLE PROJECTION NOT TO SCALE		DRAWING NO: 14A0085	REV: A SHEET 1 OF 1
		TITLE: Survey+v3 drawing	
DRAWN BY	sbedford	<div>Oxford Technical Solutions 77 Heyford Park Upper Heyford Oxfordshire OX25 5HD www.oxts.co.uk</div> 	
DATE	13/08/2019		
MATERIAL			
WEIGHT	1.5kg		
A3			

Connector/Boot Details

J1	Deutsch AS612-35SA	Hellerman 154-42-G
J2	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 plug	HARTING 21033291401
	D-type Plug Crimp Contacts	FEC 1560032
	D-type Socket Crimp Contacts	FEC 1560034
	Radio Option	
F1	Radial Leaded Fuse, BOURNS	MF-RX185/72-0



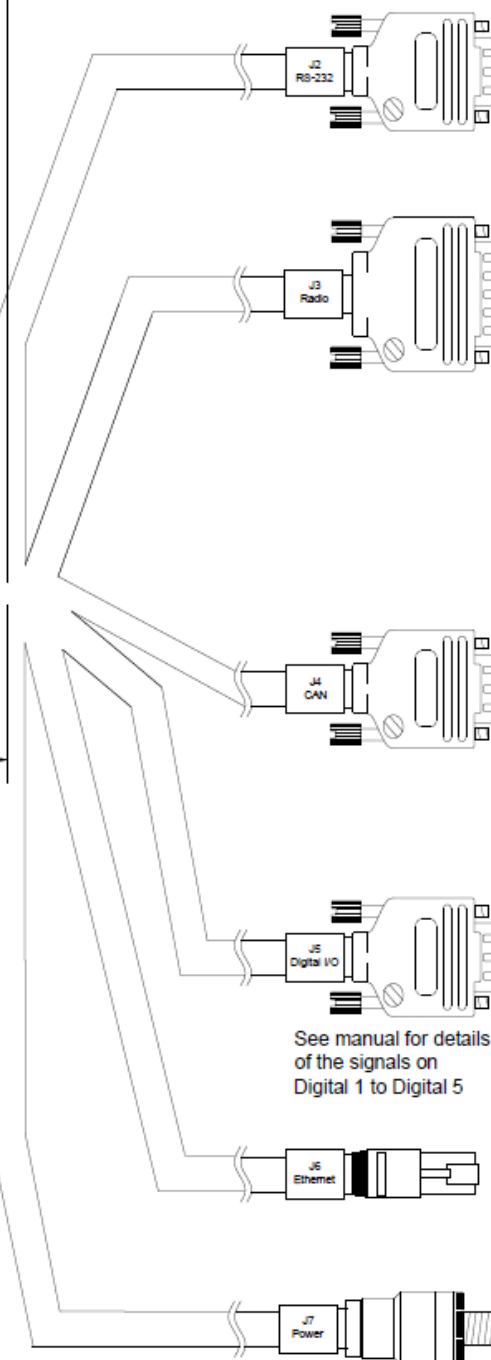
Length XX is denoted in the part ordered by the final digits of the part number in centimetres. 40cm is the default length if not specified.

For example 14C0121x-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

Tail lengths for J2-J7 given by
L2-L7, from junction to connector face



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_fused	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_fused	J3-15
15	+Supply_fused	F1-1

Fuse F1 (Radio Option)

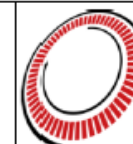
Pin	Function	Conn
1	+Supply_fused	J3-15
2	+Supply	J7-1

Aux RS232		
Pin	Function	Conn
2	Aux RS232 RX	J1-10
3	Aux RS232 TX	J1-9
5	Aux RS232 Common	J1-17

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

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	J1-1
2	White	Sleeved and made safe	
3	Blue	Supply Return	J1-2
4	Black	Sleeved and made safe	



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

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0	10	20	30
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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

All cables outers fully braided (no gaps) and connected to J1-22, J1 shell rear anodising plating removed and J7 shell (through cable assembly braiding). All gaps in shielding due to wiring joints to be shielded (electrically connected and mechanically entirely encompassing to all shielding)

Please populate all unused pins with empty crimps.

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

Radio Option
Fuse F1 is fitted inside the case of J3. Heat shrink sleeve over all connections and made safe. A second layer of heat shrink is to be added over the whole fuse and attaching wires assembly

Date: 28/08/19

Part #: 14C0121C

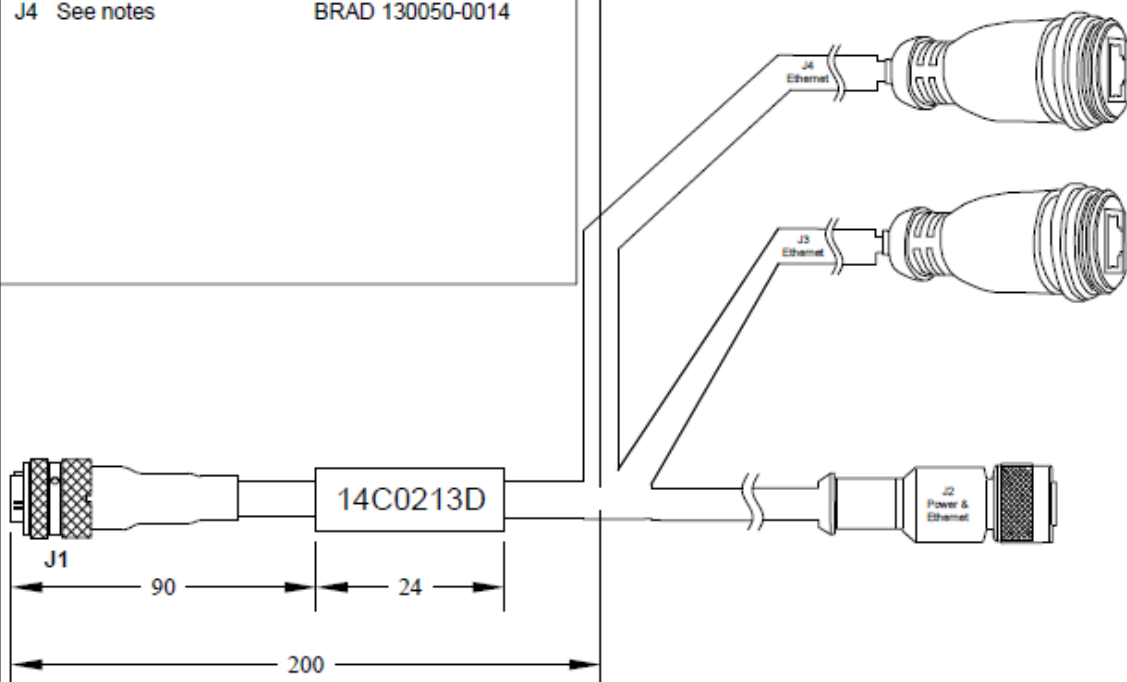
Document:
Survey + User Cable

Sheet: 1 of 1

Connector/Boot Details

J1	Deutsch AS612-35PN	TE AS612-35PN
J2	See notes	Harting 21033292801
J3	See notes	BRAD 130050-0014
J4	See notes	BRAD 130050-0014

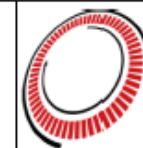
Tail lengths for J2-J4 given by
L2-L4, from junction to connector face



Pin	Function	Conn
1	Ethernet (ETX +)	J1-7
2	Ethernet (ETX -)	J1-6
3	Ethernet (ERX +)	J1-5
6	Ethernet (ERX -)	J1-17

Pin	Function	Conn
1	Ethernet (ETX +)	J1-15
2	Ethernet (ETX -)	J1-2
3	Ethernet (ERX +)	J1-21
6	Ethernet (ERX -)	J1-1

Pin	Function	Conn
1	Tx+	J1-14
2	Tx-	J1-20
3	Rx+	J1-13
4	Power Supply +	J1-11
5	Power Supply +	J1-11
6	Rx-	J1-12
7	Power Supply -	J1-10
8	Power Supply -	J1-10



Oxford Technical Solutions

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Upper Heyford
Oxfordshire
OX25 5HD
www.oxts.com

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0	10	20	30
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Print Size: A4

Scale: Not to scale

Units: mm

Tolerances: 5mm

Projection: N/A

Notes:

All cables outer sheath black and fully shielded. No gaps in shielding for any part of the cable

J2 is a shielded M12 8 Pole Female screened cable consisting of 2 individual foil screened pairs (Twisted pairs between: J2 Pins 1<->2, 3<->6), wired to and terminated at J1 for the ethernet and the two power connections for PoE which can be a single wire terminated at J2 or a 4 pair ethernet cable can be used with 1 twisted pair being used for each power line and terminated at J1.

J3 and J4 are shielded RJ45 socketed leads wired to and terminated at J1.

Wire Types to J1 if extending required

Pins 11, 10 Strands x Strand Size: 16/0.2 or both lines of a 7/0.2 twisted pairs.

Twisted pairs between: Pins 14<->20, 13<->12 Strands x Strand Size: 7/0.2, 2<->15, 1<->21, 7<->17, 5<->6 (from lead assemblies)

ALL cables outers fully braided and connected to J1-22 and J1, J2, J3 and J4 shells (through cable assembly braiding).

All gaps in shielding due to wiring joints to be shielded (electrically connected and mechanically entirely encompassing to all shielding)

J1 AS612 connector, plating removed from rear, screen completely surrounding and securely fixed to it.

Please populate all unused pins with empty crimps.

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

Legends to be black text on yellow

Tail Lengths

L2	400mm
L3	400mm
L4	400mm

Date: 15/07/19

Part #: 14C0213D

Document:
Aux user cable

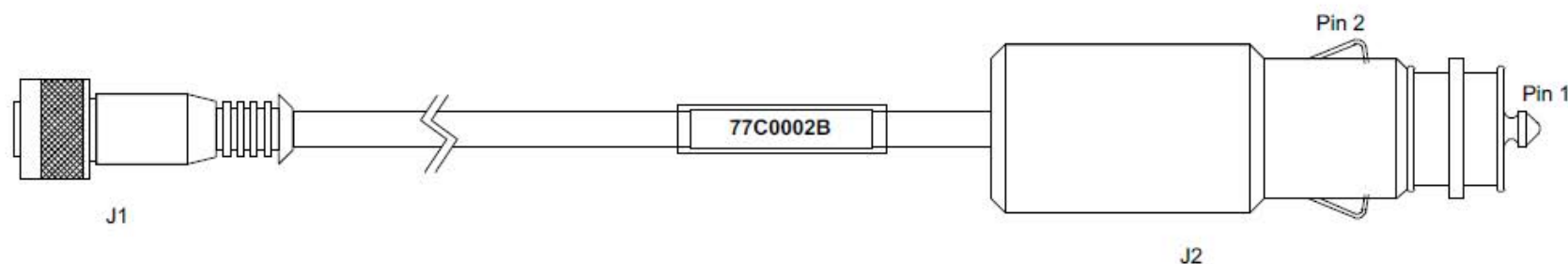
Sheet: 1 of 1



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

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0 10 20 30

Print Size: A4

Scale: 1:1

Units: mm

Tolerances: 1mm

Projection: N/A

Notes:

10/04/02
 Alternative Part Number added

22/05/15
 Fit 5A fuse in Cigar Plug

Date: 22/05/15

Part #: 77C0002B

Document:
 MicroSAT Power Cable

Sheet: 1 of 1