Survey+ v2

Inertial and GNSS measurement systems

User Manual

Covers Survey+ and Survey+ L1 products

Confidently. Accurately.

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Warranty

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

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

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Scope of delivery

The Survey+ products are supplied with cables, GNSS antenna, software and manual. In the standard configurations, magnetic mount antennas are provided but other antenna types are available, please enquire for more details.

Table 1 lists all the items that are delivered with the Survey+ systems. Figure 1 shows the transit box a Survey+ is shipped in along with the included components.

Table 1. Summary of the Survey+ and Survey+2 system components

Qty Survey+	Qty Survey+2	Description
1	1	Survey+ system unit
1	1	User cable (14C0121A)
1	2	GNSS antenna G5Ant-2AMNS1
1	2	5 m GNSS antenna cable
1	1	Null modem serial cable
1	1	CD-ROM with manual and software
1	1	User manual

The Survey+ products require the correct differential corrections (L1, L2) in order to work to full specification. Differential corrections can be supplied by an RT-Base, GPS-Base, or other suitable differential correction source.

In addition to the components supplied the user will require a laptop to configure the Survey+.

Figure 1. Typical Survey+ transit box

Introduction

The Survey+ series of products from Oxford Technical Solutions are highly accurate inertial navigation systems (INS) for making precision measurements of position and motion in real-time.

Designed for use in survey applications, the Survey+ products are one-box solutions for a complete navigation system. Using complex algorithms to seamlessly blend inertial and GNSS data, the Survey+ produces smooth position and velocity measurements as well as other important measurements such as heading, pitch, and roll.

An inertial sensor block with three accelerometers and three 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, high-rate GNSS receivers update the position and velocity navigated by the inertial sensors.

This innovative approach gives the Survey+ several distinct advantages over systems that use GNSS alone:

- All outputs remain available continuously during GNSS blackouts when, for example, the vehicle drives under a bridge.
- The Survey+ recognises jumps in the GNSS position and ignores them.
- The position and velocity measurements that the GNSS makes are smoothed to reduce the high-frequency noise.
- Pseudo-range and carrier phase measurements from satellites can be used or rejected individually (tight coupling).
- The output measurements can be improved when there are fewer than 4 satellites.
- The Survey+ makes many measurements that GNSS cannot make, for example acceleration, angular rate, heading, pitch, roll, etc.
- The Survey+ takes inputs from an odometer in order to improve the drift rate when no GNSS is available.
- The Survey+ has a high (100 Hz or 250 Hz) update rate and a wide bandwidth.
- The outputs are available with very low, 3.5 ms latency.

The Survey+ system processes the data in real-time. The real-time results are output via RS232 and 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 very accurate timing synchronisation between systems. The measurements are synchronised to the GPS clock.

Easy operation

Installation and operation of the Survey+ could not be simpler. A simple configuration wizard is used to configure the Survey+. 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 that the Survey+ can reliably start to navigate in the vast majority of situations. For example, the Survey+ can initialise during flight without problems.

The Survey+ outputs standard NMEA messages and a 1PPS signal meaning it can integrate with external sensors and provide corrections in real time. The single unit contains the inertial sensors, GNSS receiver, data storage and CPU. All components are ITAR free for maximum flexibility when operating in multiple countries.

Self-correcting

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

Advanced processing

A high raw GNSS data rate coupled with processing forwards and backwards in time means post-processed Survey+ data can achieve highest level accuracy. In poor GNSS environments drift times can be halved by using the combined results of processing once forwards and once backwards in time. OxTS’s 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 less than four satellites in view.

Related documents

This manual contains sufficient information about the installation and operation of the Survey+ system. It is beyond the scope of this manual to provide details on service or repair. Contact OxTS support or your local representative for any customer service related inquiries.

There are separate manuals available for further information on some of the software and communication types mentioned in this manual. Table 2 lists related manuals and where to find them.

Table 2. Supplementary manuals

Manual	Description
NMEA 0183 Description	NMEA description manual for the NMEA outputs. www.oxts.com/Downloads/Support/NMEA/nmeaman.pdf
NCOM Manual and Code Drivers	NCOM description manual. 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 Survey+. www.oxts.com/Downloads/Support/NCOM Manual and Code Drivers/ncomrx.zip
Enginuity Manual	User manual for the real-time display software Enginuity. www.oxts.com/Downloads/Support/Manuals/EnginuityMan.pdf
RT Post-process Manual	User manual for the post-processing software RT Post-process. www.oxts.com/Downloads/Support/Manuals/rtppman.pdf
NAVgraph Manual	User manual for the graphing and display software NAVgraph. www.oxts.com/Downloads/Support/Manuals/NAVgraphman.pdf

Survey+ family divisions

There are two product models in the Survey+ family; the standard Survey+ and the Survey+ L1. The Survey+ models use high-grade dual frequency GNSS receivers while the Survey+ L1 models use single frequency receivers. For each of these models there are a number of different option variations, all based on the same core system but with minor differences to address different applications.

Table 3 lists the current model line-up for the Survey+ family. Table 4 lists the current model line-up for the Survey+ L1 family.

Table 3. Survey+ model options

Product name	Description
Survey+	Base model. Single antenna; 100 Hz; L1, L2 GPS.
Survey+2	Dual antenna; 100 Hz; L1, L2 GPS.
Survey+G	Single antenna; 100 Hz; L1, L2 GPS & GLONASS.
Survey+2G	Dual antenna; 100 Hz; L1, L2 GPS & GLONASS.
Survey+ 250	Single antenna; 250 Hz; L1, L2 GPS.
Survey+2 250	Dual antenna; 250 Hz; L1, L2 GPS.
Survey+G 250	Single antenna; 250 Hz; L1, L2 GPS & GLONASS.
Survey+2G 250	Dual antenna; 250 Hz; L1, L2 GPS & GLONASS.

Table 4. Survey+ L1 model options

Product name	Description
Survey+ L1	Base model. Single antenna; 100 Hz; L1, GPS.
Survey+2 L1	Dual antenna; 100 Hz; L1, GPS.
Survey+G L1	Single antenna; 100 Hz; L1, GPS & GLONASS.
Survey+2G L1	Dual antenna; 100 Hz; L1, GPS & GLONASS.
Survey+ 250 L1	Single antenna; 250 Hz; L1, GPS.
Survey+2 250 L1	Dual antenna; 250 Hz; L1, GPS.
Survey+G 250 L1	Single antenna; 250 Hz; L1, GPS & GLONASS.
Survey+2G 250 L1	Dual antenna; 250 Hz; L1, GPS & GLONASS.

Single antenna

The advanced algorithm in the Survey+ software means that most road vehicle customers are able to use a single antenna system. The Heading lock and Wheel configuration features mean that the Survey+ can maintain accurate heading while stationary and while driving with low vehicle dynamics.

Dual antenna

The dual antenna system gives high accuracy heading information and almost constant heading performance under all conditions. Single antenna systems can have reduced heading accuracy on aircraft, boats or in low speed land vehicles.

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

GNSS-only dual antenna systems require open-sky environments to operate because they can take several minutes to acquire heading lock. Advanced processing in the Survey+2 allows relock to occur after 5 s of a sky-obstruction; in this time the Survey+2's heading will not have significantly degraded. The fast relock time is made possible because the Survey+2'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+2 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+G 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 situations such as road surveying and mobile mapping, 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 2 cm accurate RTK positioning mode at times when GPS-only receivers are not. They are also able to re-establish RTK lock and resolve its ambiguities after an obstruction faster.

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

250 Hz

All product divisions have the option of coming with a 250 Hz version of the inertial measurement unit (IMU). The IMUs used in 100 Hz and 250 Hz products are essentially the same, both with a fundamental sampling frequency of 2500 Hz. The difference is the 3D filter used to integrate the accelerations and angular rates has a smaller time step in the 250 Hz version, allowing a higher update rate.

However, because of the smaller time step, measurements that depend on angular acceleration are typically noisier on the 250 Hz products. The noise can be managed by filtering the data to limit the bandwidth.

Satellite differential corrections

To improve the positioning accuracy of standard GNSS, two satellite-based differential correction services are available to all Survey+ models. These are SBAS and TERRASTAR.

SBAS 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. Other parts of the world are not covered and cannot use this service.

TERRASTAR is a subscription service. Survey+ systems (but not Survey+ L1 systems) include the necessary hardware to receive the TERRASTAR corrections. It is necessary to pay TERRASTAR a license fee to activate the corrections. The Survey+ is capable of using the TERAASTAR-D service, providing better than 10 cm position accuracy. TERRASTAR is available on all continents. Marine versions also exist.

For more information see TERRASTAR’s web site: http://www.terrastar.net/.

Specification

Specifications for the Survey+ can be found in Table 5. 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 5 minutes for full accuracy.
- The vehicle must exhibit some motion behaviour. Accelerations of the unit in different directions are required so that the Kalman filter can estimate the errors in the sensors. Without this estimation some of the specifications degrade.
- The distance from the Survey+ sensor point to the primary GNSS antenna must be known by the system to a precision of 5 mm or better. The vibration of the system relative to the vehicle cannot allow this to change by more than 5 mm. The system can 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 slow and static conditions the performance will degrade.

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

Table 5. Typical performance specification for Survey+ systems

Product	Survey+	Survey+2	Survey+ L1	Survey+2 L1
Positioning	GPS L1, L2 GLONASS L1, L2 (on G models)	GPS L1, L2 GLONASS L1, L2 (on G models)	GPS L1 GLONASS L1 (on G models)	GPS L1 GLONASS L1 (on G models)
Position accuracy (CEP)[1]	1.5 m SPS 0.6 m SBAS 0.4 m DGPS 0.1 m PPP 0.01 m RTK	1.5 m SPS 0.6 m SBAS 0.4 m DGPS 0.1 m PPP 0.01 m RTK	1.8 m SPS 0.6 m SBAS 0.4 m DGPS	1.8 m SPS 0.6 m SBAS 0.4 m DGPS
Velocity accuracy	0.05 km/h RMS	0.05 km/h RMS	0.1 km/h RMS	0.1 km/h RMS
Roll/pitch	0.03° 1σ	0.03° 1σ	0.05° 1σ	0.05° 1σ
Heading	0.1° 1σ	0.05° 1σ	0.1° 1σ	0.05° 1σ
Acceleration – Bias stability – Linearity – Scale factor – Noise – Range	 2 µg 1σ 0.01% 1σ 0.1% 1σ 0.005 m/s/√hr 1σ 10 *g*	 2 µg 1σ 0.01% 1σ 0.1% 1σ 0.005 m/s/√hr 1σ 10 *g*	 2 µg 1σ 0.01% 1σ 0.1% 1σ 0.005 m/s/√hr 1σ 10 *g*	 2 µg 1σ 0.01% 1σ 0.1% 1σ 0.005 m/s/√hr 1σ 10 *g*
Angular rate – Bias stability – Linearity[2] – Scale factor – Noise – Range	 2°/hr 1σ 0.05% 1σ 0.1% 1σ 0.2°/√hr 1σ 100°/s	 2°/hr 1σ 0.05% 1σ 0.1% 1σ 0.2°/√hr 1σ 100°/s	 2°/hr 1σ 0.05% 1σ 0.1% 1σ 0.2°/√hr 1σ 100°/s	 2°/hr 1σ 0.05% 1σ 0.1% 1σ 0.2°/√hr 1σ 100°/s
Heave[3]	10 cm or 10%	10 cm or 10%	10 cm or 10%	10 cm or 10%
Dual antenna	x	✔	x	✔
Update rate	100 Hz / 250 Hz	100 Hz / 250 Hz	100 Hz / 250 Hz	100 Hz / 250 Hz
Input voltage	10–25 V dc	10–25 V dc	10–25 V dc	10–25 V dc
Power consumption	15 W	20 W	15 W	20 W
Dimensions	234×120×80 mm	234×120×80 mm	234×120×80 mm	234×120×80 mm
Mass	2.2 kg	2.4 kg	2.2 kg	2.4 kg
Calculation latency	3.5 ms	3.5 ms	3.5 ms	3.5 ms
Operating temperature[4]	-10° to 50°C	-10° to 50°C	-10° to 50°C	-10° to 50°C
Vibration	0.1 g^2/Hz, 5–500 Hz	0.1 g^2/Hz, 5–500 Hz	0.1 g^2/Hz, 5–500 Hz	0.1 g^2/Hz, 5–500 Hz
Shock survival	100 *g*, 11 ms	100 *g*, 11 ms	100 *g*, 11 ms	100 *g*, 11 ms
Internal storage	2 GB	2 GB	2 GB	2 GB

[1]Valid for open sky conditions.
[2]With SuperCAL adjustment.
[3]Heave output is not available on 250 Hz systems.
[4]Operating temperature range for the antenna is much wider. See specification below.

Heading accuracy

The heading accuracy that can be achieved by the dual antenna system in the Survey+2 models is 0.2° 1σ per metre of separation in ideal, open sky conditions. The maximum recommended separation is 5 m, giving an accuracy of 0.05° 1σ. The dual antenna system can provide these accuracies in static and dynamic conditions.

For single antenna systems, the heading is calculated from the inertial measurements. The accuracy listed in Table 5 is 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.

GNSS antenna operating temperature

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

Export control classification number

Export control regulations change and so the classification number of the Survey+ may also change. The information here relates to the time when the manual was published. The 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).

The current ECCN for the Survey+ products is either 7A103a1 or 7A003d. Please see the invoice or delivery note, or contact OxTS Support to view the ECCN of your Survey+ system.

Conformance notices

The Survey+ complies with the radiated emission limits for 47CFR15.109:2010 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 measures:

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

The Survey+ incorporates a GNSS receiver. Any GNSS receiver will not be able to track satellites in the presence of strong RF radiations within 70 MHz of GNSS frequencies.

The Survey+ conforms to the requirements for CE.

Regulator testing standards

- 47CFR15.109:2010 class A (radiated emissions)
- EN 300 440-1:2008, test methods 8.3.2 (conducted emissions) and 8.3.3 (radiated emissions)
- EN55022 class A according to standard EN 301 489-1:2008 (conducted emissions)
- EN6100-4-3 criterion A according to standard EN 301 489-1:2008 (radiated immunity)
- ISO7637-2 criterion B, 12V according to standard EN 301 489-1:2008 (vehicular transients and surges immunity).

Software installation

Included with every Survey+ is a CD containing the software package NAVsuite. This package contains a number of programs required to take full advantage of the Survey+'s capabilities. Table 6 lists the contents of NAVsuite.

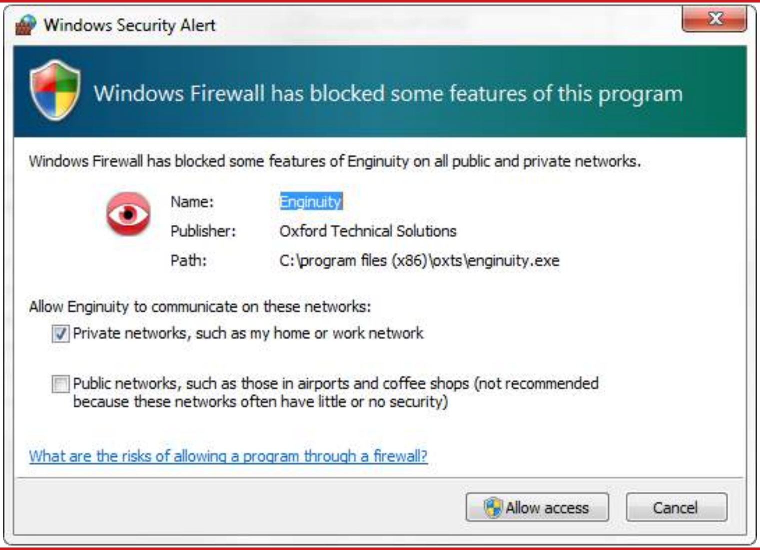
Table 6. NAVsuite components

Icon	Software	Description
	Enginuity	Used to view real-time data from OxTS products via Ethernet or a serial port. It can also be used to transmit special commands and replay logged data.
	NAVconfig	Used to create, send, and receive configurations from OxTS products. As configurations vary between products there is no manual for NAVconfig. The options relevant to the Survey+ products are covered in this manual on page 35.
	RT Post-Process	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.
	Manuals	This folder contains PDF versions of relevant OxTS manuals. Other manuals can be downloaded from the OxTS website, http://www.oxts.com/support/manuals/.

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

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

Figure 2. Windows Firewall warning message



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

Hardware installation

It is essential to install the 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 27. 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 a 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 Wheel configuration and Improve configuration utilities should be used for this (see pages 46 and 41). Roll and pitch offsets can be measured using the Surface tilt utility in Enginuity.

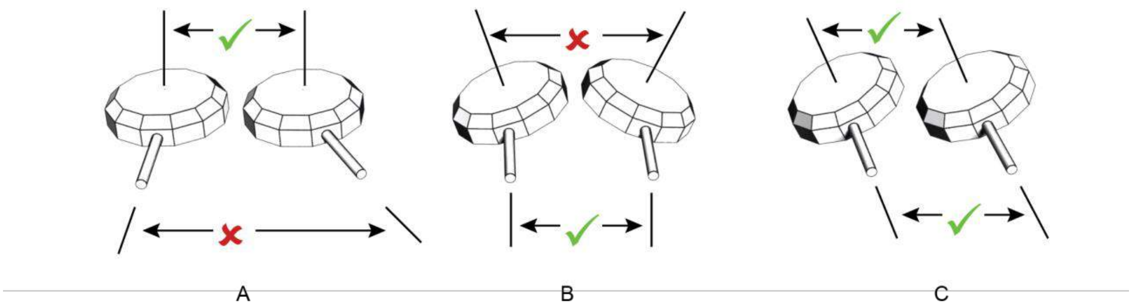
Antenna placement and orientation

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

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

For dual antenna systems, the secondary antenna should be mounted in the same orientation as the primary antenna, as shown in Figure 3. The antenna baseline should also be aligned with one of the vehicle axes where possible, either inline or perpendicular to the vehicle's forward axis. In the default configuration the primary antenna should be at the front of the vehicle and the secondary antenna should be at the rear.

Figure 3. Dual antenna orientations



A) The bases of the antennas are parallel, but the cables exit in different directions. **B)** The cables exit in the same direction but the bases of the antennas are not parallel. **C)** The bases of the antennas are parallel and the cables exit in the same direction. This configuration will achieve the best results.

It is best to mount the two antennas on the top of the vehicle. Although it is possible to mount one on the roof and one on the bonnet (hood), in reality the multipath reflections from the windscreen will degrade the performance of the system. On aircraft it is best to mount the antennas on the main aircraft fuselage if the Survey+ is mounted in the aircraft fuselage itself. If the Survey+ is mounted on a pod under the wings then mounting the antennas on the pod may give the best results.

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+2 mounted securely in the vehicle. If the angle of the Survey+2 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+2 is shock mounted then the Survey+2 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 Survey+ has been designed to be simple and easy to operate. The front panel label and LEDs convey some basic information that aid in configuration and troubleshooting. Once powered, 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 4 shows the layout of the Survey+ front panel. Table 7 lists the parts of the front panel labelled in Figure 4. The layout is the same for all model divisions in the Survey+ family. For single antenna models, the secondary antenna connector is not connected internally.

Figure 4. Survey+ front panel layout

Table 7. Front panel descriptions

Label no.	Description
1	SDNav LED
2	Pos/Head LED
3	GNSS LED
4	Power LED
5	Primary antenna connector
6	User cable main connector
7	Secondary antenna connector

LED definitions

The front panel of the Survey+ has four LEDs. These give an indication of the internal state of the system and are designed to provide enough feedback so that a laptop does not need to be connected. They can be used for some simple operational checks on the system. Table 8 gives a description of each LED and Table 9, Table 10, Table 11, Table 12, and Table 13 list the precise meanings of the states of each LED.

Table 8. LED descriptions

Name	Description
SDNav	Strapdown navigator state
Pos/Head	Position solution (single antenna) or heading solution (dual antenna) from GNSS
GNSS	Self-test
Power	Power/comms

Table 9. SDNav LED states

Colour	Description
Off	The operating system has not yet booted and the program is not yet running. This occurs at start-up.
Red-green flash	The 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 s for the system to become real-time after start up.
Green	The strapdown navigator is running and the system is real-time.

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

Table 10. Pos/Head LED states (single antenna systems)

Colour	Description
Off	The GNSS receiver is not sending data.
Red flash	(Start-up only). The GNSS receiver is sending data to the Survey+. This is an operational check for the GNSS receiver.
Red	The GNSS receiver has a standard position solution (SPS).
Orange	The GNSS receiver has a differential solution (DGPS) or a kinematic floating position solution (20 cm accuracy).
Green	The GNSS receiver has a kinematic integer position solution (2 cm accuracy).

Table 11. Pos/Head LED states (dual antenna systems)

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 12. GNSS LED states

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

Table 13. Power LED states

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

Co-ordinate frame conventions

The Survey+ uses a co-ordinate frame that is popular with most navigation systems. Figure 5 shows how the axes relate to the Survey+ box. All measurements to and from the Survey+ should be made from the measurement origin point shown in Figure 5.

Figure 5. Survey+ co-ordinate frame and measurement origin

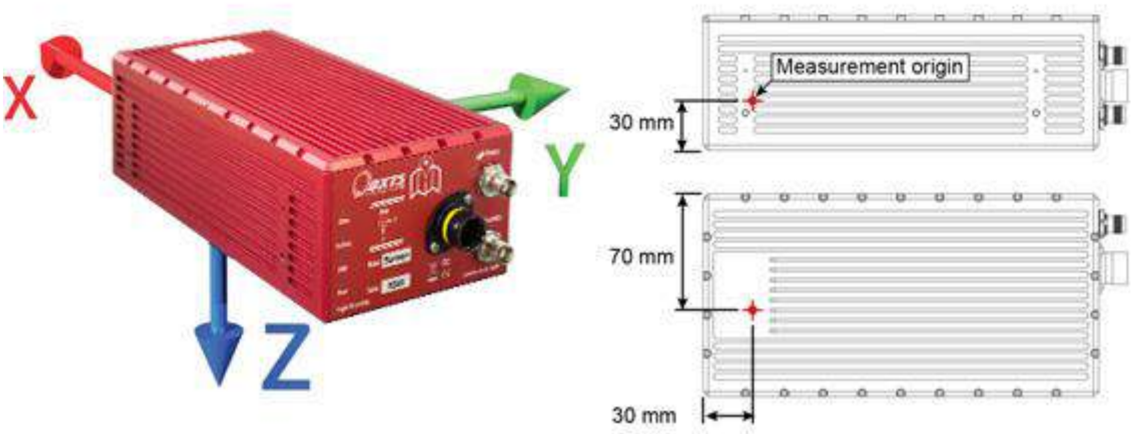


Table 14 lists the directions that the axes should point for zero heading, pitch and roll outputs when the default mounting orientation is used.

Table 14. Direction of axes for zero heading, pitch and roll outputs

Axis	Direction	Vehicle axis
x	North	Forward
y	East	Right
z	Down	Down

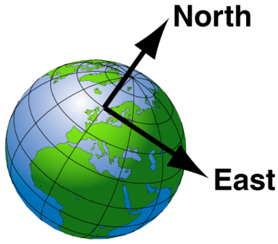
If the axes of the Survey+ and the vehicle axes are not the same as those listed in Table 14, then they can be aligned by reconfiguring the Survey+ for a different mounting orientation using the NAVconfig software.

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 39 gives more information on configuring the orientation of the Survey+ in a vehicle.

Navigation frame

The navigation frame is used by the Survey+ to integrate the acceleration to velocity and to integrate the velocity to position. The definition of the navigation frame is listed in Table 15.

Table 15. Navigation frame definition

Axis	Description	Diagram
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.	

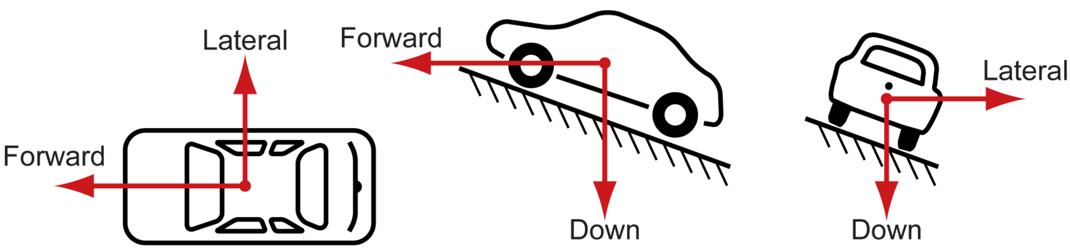
Level frame

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 level frame is listed in Table 16 and shown in Figure 6.

Table 16. Level frame definition

Axis	Description
Forward	This is the forward (f) direction of the car, projected in to the horizontal plane.
Lateral	This is the lateral (l) direction of the car, pointing to the right, projected in to the horizontal plane.
Down	This is the down (d) direction of the car, along the gravity vector.

Figure 6. Level frame definition



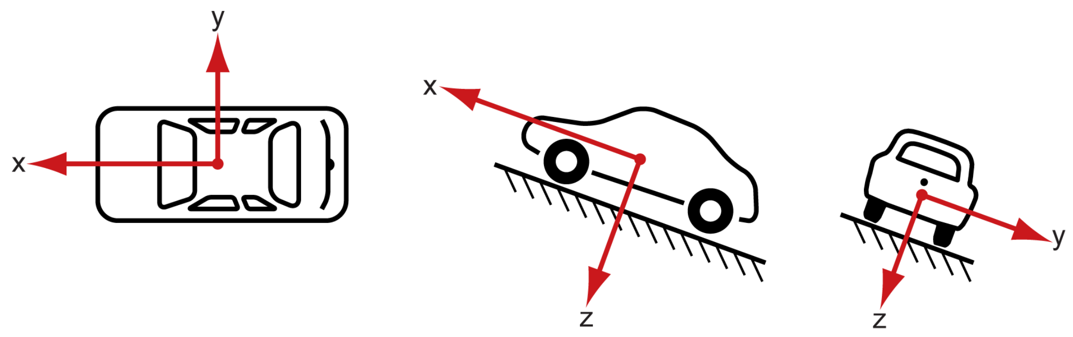
Vehicle frame

The vehicle frame is attached to the body of the vehicle. It is related to the Survey+ through the rotations in the Orientation page of NAVconfig. It can be changed while the Survey+ is running using the Quick Config page of Enginuity. The definitions of the vehicle frame are listed in Table 17 and shown in Figure 7.

Table 17. 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 7. Vehicle frame definition



Ethernet configuration

To configure the Survey+ for unrestricted data transmission it is necessary to use the Ethernet connection. 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 Survey+. The data rate of the UDP broadcast is 100 Hz or 250 Hz.

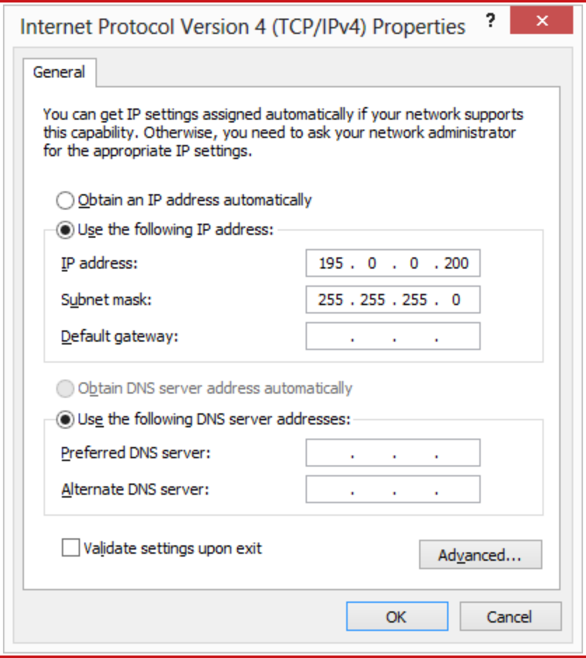
In order to communicate via Ethernet, each Survey+ is configured with a static IP address that is shown on the delivery note. If the delivery note is unavailable, the default IP address normally takes the form 195.0.0.*sn*, where *sn* is the last two digits of the Survey+'s serial number. The serial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

1. Open the **Control Panel** from the Start menu.
2. In category view, select **Network and Internet** and then **Network and Sharing Center**.
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 8), select **Use the following IP address** and enter the IP address and subnet mask to use.
7. Click **OK** when finished.

Figure 8. Configuring the computer's IP address



Once the computer is configured the IP address of a Survey+ can be found by running Enginuity 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 Enginuity 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 Survey+'s.

Dual antenna systems

It is often useful to have an understanding of how the Survey+2 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+2 needs to know the angle of the GNSS antennas compared to the angle of the Survey+2. This is very difficult to measure accurately without specialised equipment, therefore the Survey+2 needs to measure this itself as part of the warm-up process.

2. The Survey+2 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+2

3. When the vehicle drives forward and reaches the initialisation speed, the Survey+2 assumes that the heading and track are similar and initialises heading to track angle.

   If the Survey+2 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+2 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+2 will solve the RTK Integer problem using the inertial heading. There is no need for the Survey+2 to solve the RTK Integer problem by searching.

   If the antenna angle is offset from the Survey+2 by a lot then the RTK Integer solution that is solved will be incorrect. For a 2 m antenna separation the Survey+2 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+2 can start to use the dual antenna solution to improve heading. The level of correction that can be applied depends on how accurately the angle of the secondary antenna is known compared to the inertial sensors.

6. The Kalman filter tries to estimate the angle between the inertial sensors and the secondary antenna. The default value used in the configuration software (5°) is not accurate enough so that the Survey+2 can improve the heading using this value. If you want the vehicle heading to 0.1°, but the angle of the two GNSS antennas is only known to 5°, then the measurements from the antenna are not going to be able to improve the heading of the vehicle.

   Driving a normal warm-up, with stops, starts and turns, helps the Kalman filter improve the accuracy of the secondary antenna angle. The accuracy of this angle is available in the Status tab of the Calibration window in Enginuity. On aircraft or marine vehicles some turns are needed to help the Kalman filter estimate the relative angle of the antennas compared to the Survey+2.

7. In the unlikely event that the RTK Integer solution is incorrect at the start then the Kalman filter can update the secondary antenna orientation incorrectly. If this happens then things start to go wrong. The Kalman filter becomes more convinced that it is correct, so it resolves faster, but it always solves incorrectly. Solving incorrectly makes the situation worse.

   To avoid the Kalman filter from getting things wrong it is possible to drive a calibration run, then use the **Improve configuration** utility within NAVconfig (see page 41 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+2 is permanently mounted in a vehicle and the antennas are bolted on. Any movement of either the Survey+2 or the antennas will upset the algorithms.

Multipath effects on dual antenna systems

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

The dual antenna system in the Survey+2 works by comparing the carrier-phase measurements at the two antennas. This tells the system the relative distance between the two antennas and which way they are pointing (the heading). For the heading to be accurate the GNSS receivers must measure the relative position to about 3 mm. The level of accuracy can only be achieved if there is little or no multipath.

In an ideal environment, with no surrounding building, trees, road signs or other reflective surfaces, the only multipath received is from the vehicle's roof. The antennas supplied with the Survey+2 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+2 will show some error, the size of the error depends on the multipath in the environment. Table 18 lists the errors to be expected when stationary with a 1 m base-line.

Table 18. 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.

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 for the first time.

The program NAVconfig can be used to do this. This section describes how to use NAVconfig and gives additional explanations on the meanings of some of the terms used.

It is only possible to change the Survey+ configuration using Ethernet. It is necessary to have the Ethernet on your computer configured correctly in order to communicate with the Survey+ and change the settings. See the section "Ethernet configuration" on page 30 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 at in the vehicle.
- The position of the primary GNSS antenna compared to the Survey+.
- The orientation of the dual antennas compared to the Survey+.
- The position of the rear wheels (or non-steering wheels) compared to the Survey+.
- The position of the odometer compared to the Survey+.

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.

In particular, Survey+ products can calculate the position of the GNSS antenna. This works well when using a base station to achieve 2 cm accuracy, but can take hours with less accurate positioning modes. It is best to measure the position of the GNSS antenna to an accuracy of 10 cm or better.

If the 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 the system is started. If the Survey+ is moved from one vehicle to another it is essential to return to the default configuration rather than using parameters that have been tuned for a different vehicle.

Selecting the operating language

The NAVconfig software can operate in several languages. To change language, select the language from the drop-down menu at the bottom of the page. The language is "hot-swappable" making it easy and fast to switch between languages.

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

Navigating through NAVconfig

NAVconfig provides a ten-step process to make configuring your product as easy as possible. After completing each step, click the **Next** button at the bottom of the window to proceed to the next step. The **Back** button can be used to return to the previous step at any time. Clicking **Cancel** will bring up a warning asking to confirm you want to close the wizard and lose any changes you have not saved.

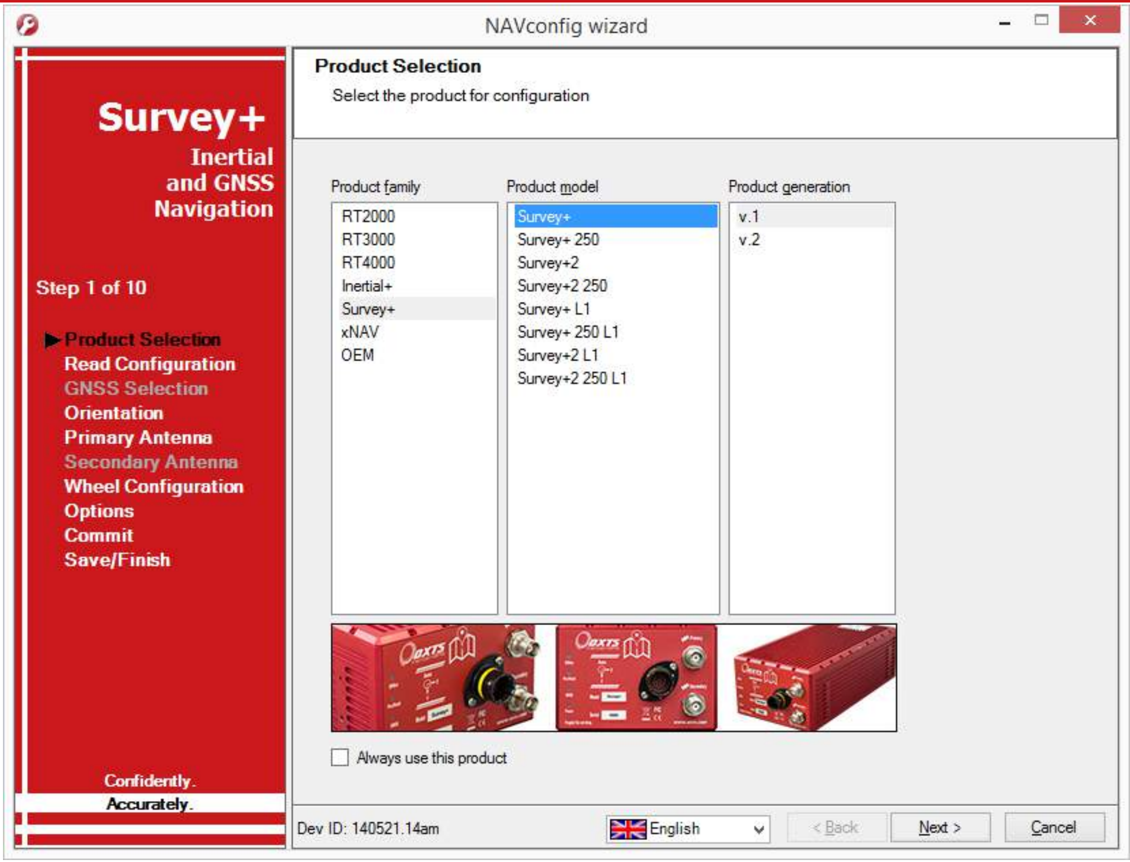
To quickly move between any of the steps, click on the step name in the sidebar to instantly jump to that page.

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

Product selection

The first page of the NAVconfig configuration wizard lets you select the type of product for configuration, see Figure 9.

Figure 9. NAVconfig Product Selection page



The configuration wizard can be run without a system connected so it is necessary to select the correct product for configuration. Some configuration pages are not available with some of the products. These will be displayed as grey in the sidebar.

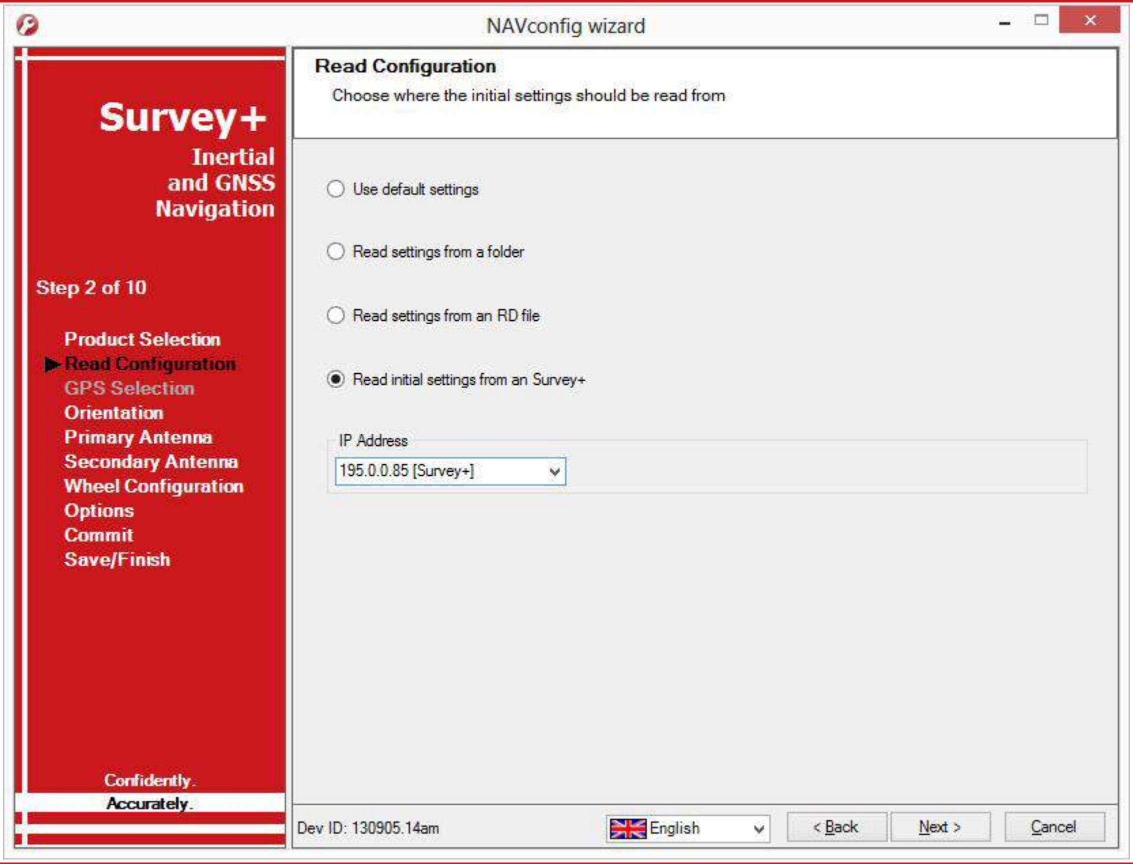
Select "Survey+" from the **Product family** list, then select the correct model for your system from the **Product model** list. There are no "G" models listed as GLONASS capability does not affect anything in the configuration. Just select the closest model type instead. For Survey+ models, the **Product generation** option needs selecting. All systems built after June 2014 are v2 models. These can also be identified by looking on the top of the Survey+ system, if there are axes engraved into the lid above the shockwatch then it is a v2 model. All Survey+ L1 models are v2.

In instances where the same product type will be used each time, the Product Selection page can be skipped in the future by clicking the **Always use this product** checkbox. If a different product needs configuring, the selection page can be returned to by clicking **Product Selection** in the sidebar.

Read configuration

The Read Configuration page gives several options for reading the configuration from different places as shown in Figure 10.

Figure 10. NAVconfig Read Configuration page



Use default settings: This option tells the configuration wizard to use the default settings the Survey+ was delivered with.

Note: choosing Use default settings will overwrite any advanced settings you may have set. To maintain advanced settings the **Read initial settings from a Survey+** option must be used.

Read settings from a folder: It is possible to store a configuration in a folder. The configuration requires 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 specify a folder by clicking the **Browse…** button.

Read settings from an 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 in the configuration wizard. Specify an RD file by selecting this option and clicking the **Browse…** button.

Read initial settings from a Survey+: If the Survey+ is connected to the computer via Ethernet then 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+, before it makes any improvements. Select this option and enter the correct IP address of your Survey+ or select it from the drop-down list. The list will show all systems that are connected to the network, so if more than one system is connected ensure you select the correct system. Note: the list will not function correctly if Enginuity or other software is using the Survey+ UDP port unless the OxTS UDP Server is running.

Orientation

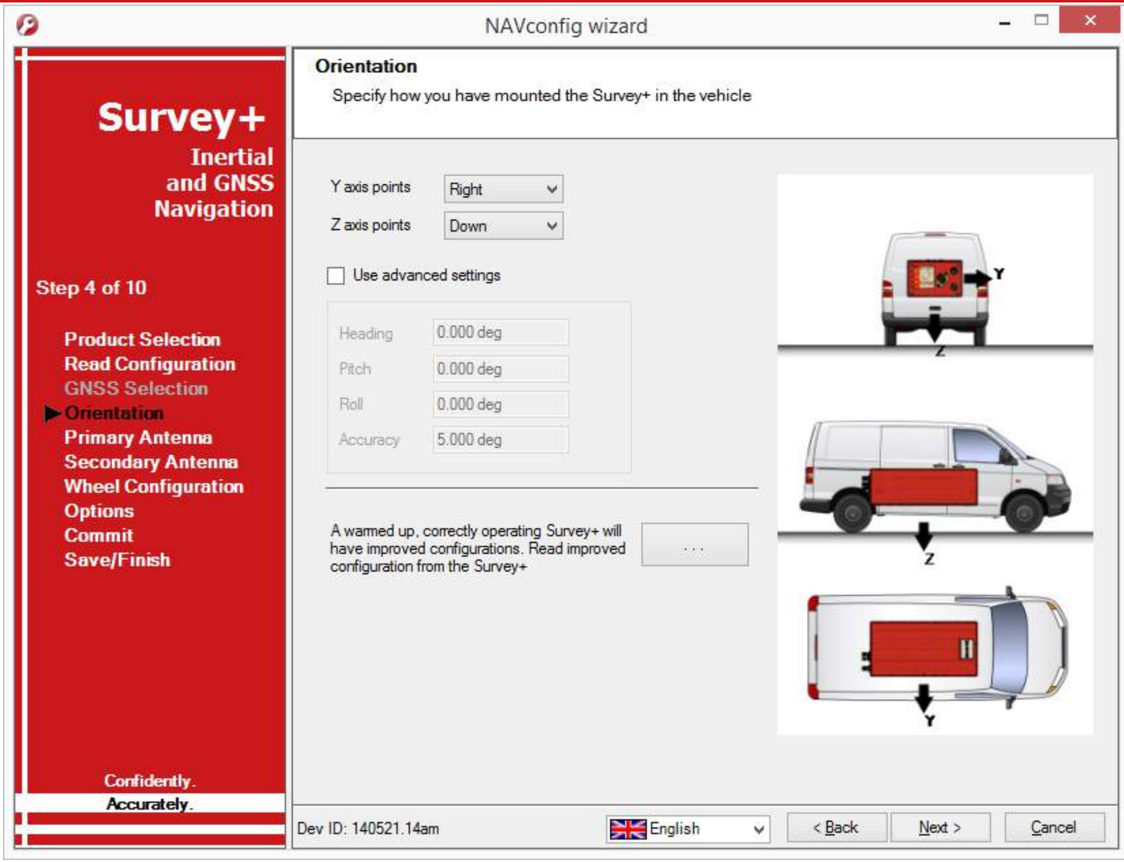
The Orientation page is used to define the vehicle co-ordinate frame relative to the Survey+'s co-ordinate frame. It is important to get the orientation correct as although settings entered on this page do not affect the accuracy of the Survey+, if the outputs are not properly rotated to the vehicle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

When using the RT-Strut the orientation will need to be changed. Figure 11 shows the 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 11. Survey+ mounted on RT-Strut

The front panel label of the Survey+, seen in Figure 4 on page 24, shows the axes and directions relative to the system for easy reference while configuring it. The Orientation page of the configuration wizard, shown in Figure 12, also has illustrations to visualise the orientation of the Survey+ in a vehicle based on the settings input.

Figure 12. NAVconfig Orientation page



To work out the direction that the Survey+ is mounted at, look to see which directions the *y*-axis and the *z*-axis are pointing and select these directions from the drop-down lists. The greyed out advanced settings will change to show the three rotations associated with orientation chosen.

To make small adjustments use the advanced settings. This allows the user to 'zero' any heading, pitch or roll offsets.

For correct initialisation it is also necessary to get the heading orientation correct. The Survey+ gets its initial heading by assuming that 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.

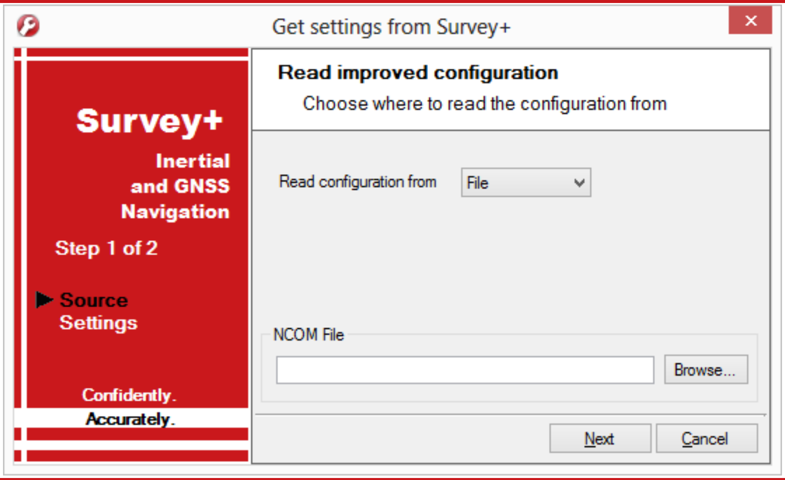
Improve configuration

Also included on the Orientation page is the ability to read the configuration settings from a warmed up system. While the Survey+ is running it tries to improve some of its configured parameters. This option is useful if a calibration run has been done and the Kalman filter's values are known to be good.

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

To read the improved values from the Survey+, click the **…** button on the Orientation page to open the Get settings from Survey+ window, as shown in Figure 13.

Figure 13. Source selection to read improved configuration



Click the drop-down list and choose which source to read the configuration from. The two options are:

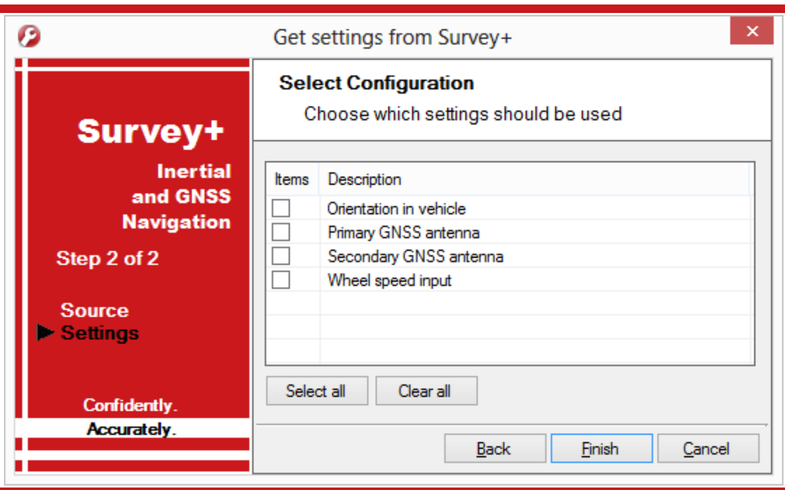
- **Read configuration from file**. If an NCOM file has been saved to disk, or processed using the post-process utility then this file can be read and the settings extracted from it. Use this setting if you have an NCOM file. Click **Browse…** and select the NCOM file you wish to read the configuration from. Do not use an NCOM file that has been combined from forward and backwards processing of the inertial data.

- **Read configuration from Ethernet**. This will get the information that the Survey+ is currently using and apply it next time the Survey+ starts. Use this setting if the Survey+ is running, has initialised and has warmed up. Select the correct IP address of the Survey+ to read the configuration from in the drop-down list. Note: the list will not function correctly if Enginuity or other software is using the Survey+ UDP port unless the OxTS UDP Server is running.

Once the source has been selected, click **Next** and the software will find which settings can be obtained from the source. Settings that cannot be obtained will be shown in grey; this may be because the Survey+ is not calculating these values at present. Figure 14 shows the Settings page with the parameters available to improve in the configuration.

You may update several parameters at once. Select the settings you want to be updated and uncheck the ones that you do not want to update. Click **Finish** to transfer these settings to the configuration wizard.

Figure 14. Select which settings to update for improved configuration



If **Orientation in vehicle** is selected then this has consequences for other measurements that have already been entered into NAVconfig. For example, if the orientation in the vehicle has been changed then it is not clear whether the primary GNSS antenna should be rotated or not. In general NAVconfig will rotate the configurations that the Kalman filter can derive (primary antenna lever-arm and secondary antenna orientation) but it will not change the user measured configurations (wheel config, odometer input).

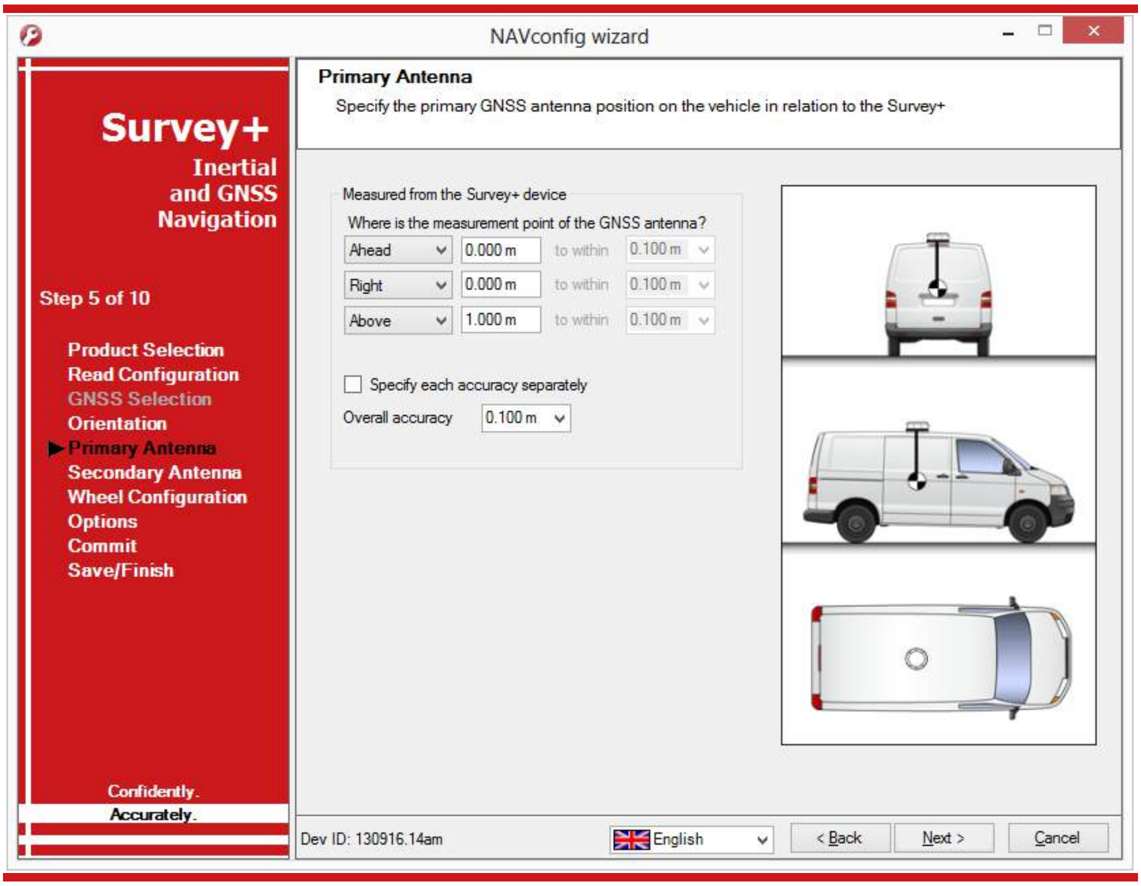
The improvement to orientation should only be applied if the change in the orientation is small (less than 5°). If the change in orientation is large then it is likely that the original configuration was wrong or has not been loaded into NAVconfig. You are very likely to get poor results if the orientation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

Primary antenna position

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 measures the distance accurately. 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 15 shows the Primary Antenna page.

Figure 15. NAVconfig Primary Antenna page



It is necessary to tell the Survey+ the distance between its measurement origin (shown in Figure 5 on page 28) and the GNSS antenna's measurement point. This should be entered in the vehicle's co-ordinate frame.

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

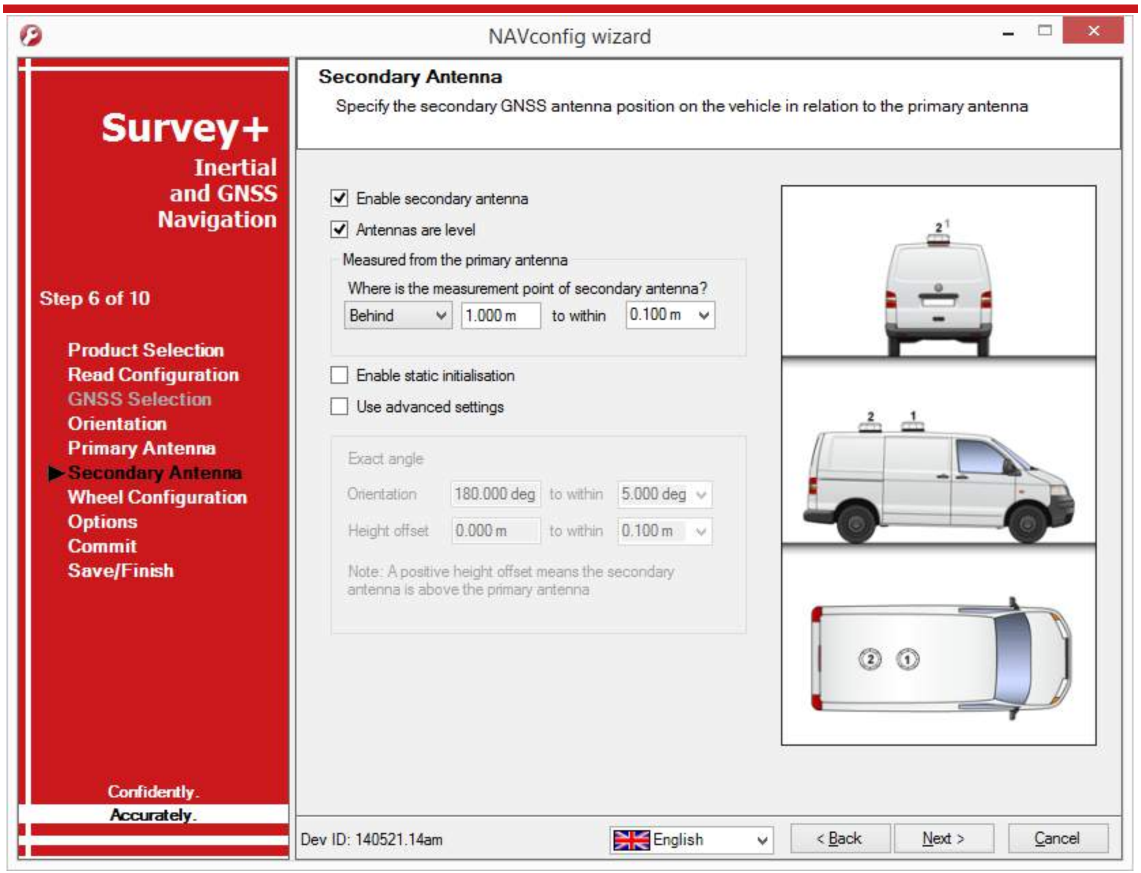
Telling the Survey+ you have measured the distances within 5 mm may lead the Survey+ to believe its results are better than they really are. You may be impressed by the accuracy the Survey+ reports, but in reality it will not be that accurate. It is better to overestimate the accuracy (i.e. tell the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

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** utility on the Orientation page. More information on improving the configuration settings can be found on page 41.

Secondary antenna position

If a Survey+2 option was selected on the Product Selection page, then the Secondary Antenna page (Figure 16) will be available to configure the position of the secondary antenna relative to the primary antenna. Click the **Enable secondary antenna** checkbox to allow the configuration to be entered. If it is not enabled, the Survey+2 will ignore the secondary antenna and will not use it to compute a heading solution.

Figure 16. NAVconfig Secondary Antenna page



By default the **Antennas are level** box is checked. This means the antenna baseline should be within 15° of horizontal. When the antennas are level the separation should be measured to within 5 cm. If the antennas are not level, i.e. mounted with height offsets or on an incline, then the box should be unchecked. In this case, the separation should be measured to within 5 mm.

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

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+2 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 when dynamic initialisation may be difficult. 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 and the **Antennas are level** checkbox is ticked.

The static initialisation algorithms degrade rapidly in non-ideal conditions. They should only be used in open sky environments. Using a shorter separation can improve the accuracy in non-ideal conditions.

Wheel configuration

The Wheel configuration feature uses characteristics of land vehicle motion to improve heading and 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.

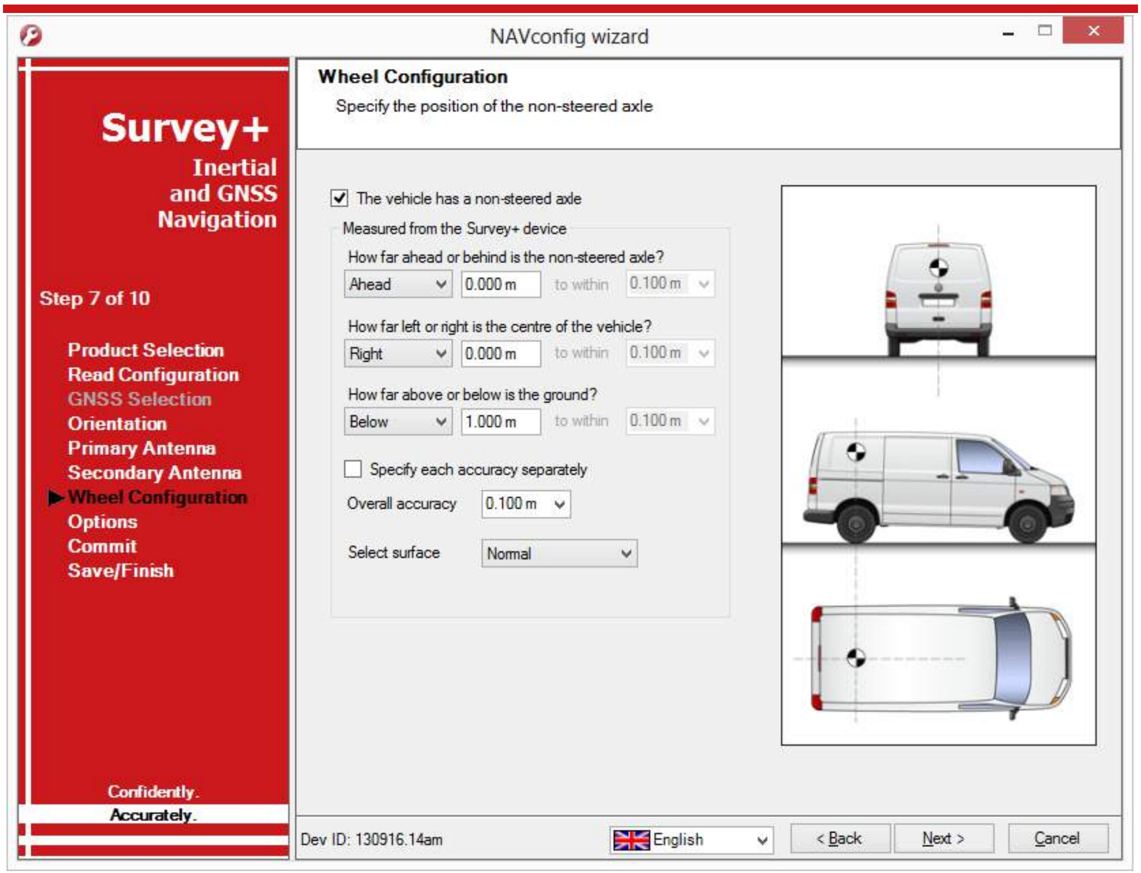
This feature must be disabled for airborne and marine applications where the lateral velocity can be significant. It is also not suitable for land vehicles that have no non-steered wheels.

The Survey+ uses the position of the non-steered wheels to reduce the lateral drift when GNSS is not available and to improve the heading accuracy. The Wheel configuration feature applies heading correction when the 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 an odometer input (see

“Odometer input” on page 51) the drift of the Survey+ when GNSS is not available is drastically reduced.

Figure 17 shows the Wheel Configuration page.

Figure 17. NAVconfig Wheel Configuration page



For the Wheel configuration feature to work correctly, the system needs to know the position of the non-steered axle (rear wheels on a front-wheel steering vehicle and vice versa). Vehicles with all wheels steering cannot use this feature reliably, although minor steering of the rear-wheels does not significantly affect the results. A position at road height, mid-way between the rear wheels should be used, see Figure 18.

Figure 18. Position of road surface at centre of rear wheels

Measure the distances to the non-steered axle position from the Survey+ in each axis in the vehicle co-ordinate frame. Select the direction from the drop-down lists and enter the distances.

Typically the measurements should all be made to an accuracy of 10 cm. Selecting an accuracy better than 10 cm does not improve results. Using an accuracy figure worse than 20 cm will increase the drift of the Survey+. Use the accuracy fields to select or specify the accuracy of the measurements.

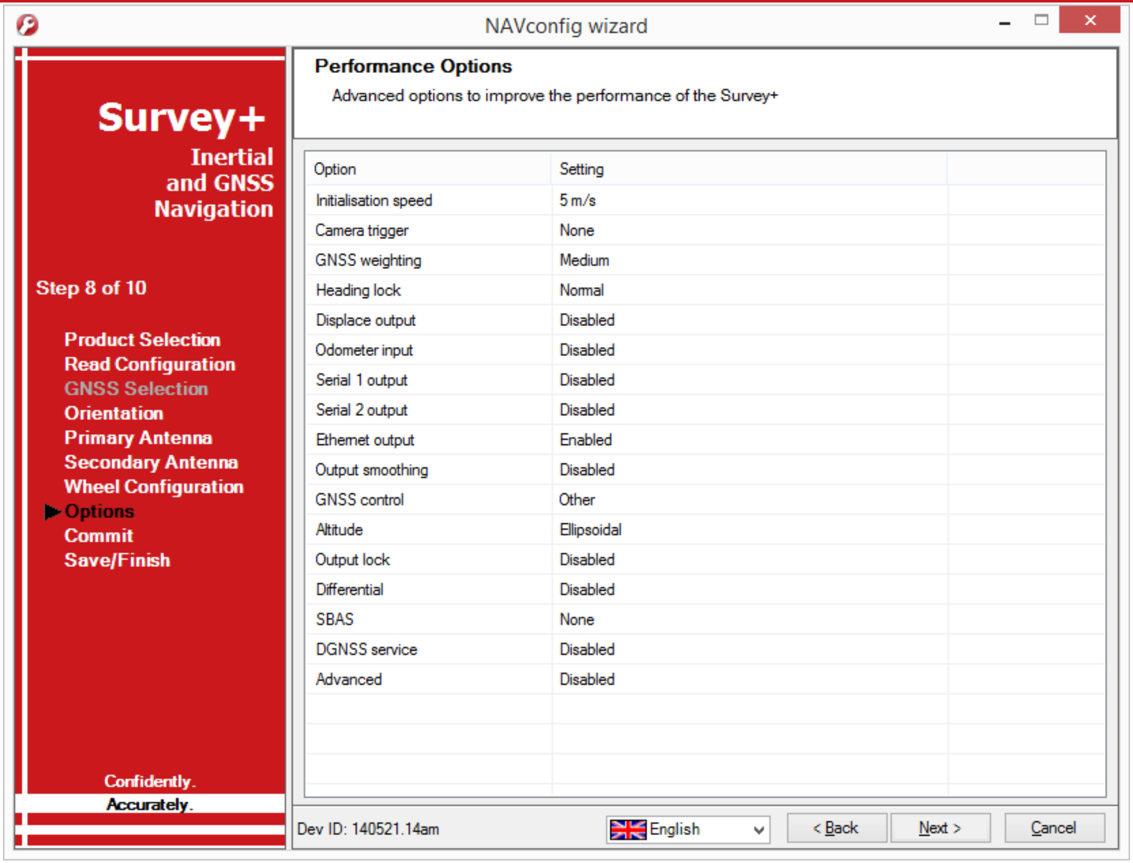
The Wheel configuration feature also requires some knowledge of the road surface. Select one of the predefined options from the drop-down list, Normal or Low friction (ice).

Options

The Options page includes some important settings for getting the best results from your Survey+ system. Figure 19 shows the Options page of the configuration wizard.

To adjust the settings, click the default value in the Setting column to activate the cell. A description on each option and how to adjust it is found below.

Figure 19. NAVconfig Options page



Initialisation speed

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

If static initialisation (see “Secondary antenna position” section) 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 for the Survey+ is 5 m/s. However, some slow vehicles cannot achieve this speed. For these vehicles adjust the initialisation speed to a different value.

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

Camera trigger

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

The Survey+ can generate a regular pulse based on distance; for example, one pulse every 10 m of travel. This can be used to trigger a camera so that a picture can be taken on a regular basis.

Enter the distance between pulses or leave disabled (default).

GNSS weighting

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

The Survey+ can place different emphasis on the GNSS receiver's measurements. The default setting is **Medium**, placing equal weighting on the GNSS receivers and inertial sensors. Selecting **High** will cause the Survey+ to believe the GNSS receivers more and selecting **Low** will make the Survey+ rely more on the inertial sensors.

In urban environments it is better to believe the inertial sensors more whereas in open sky the GNSS receiver should be believed more.

Heading lock

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

The heading of the single antenna Survey+ can drift when it 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 cannot be used if the vehicle can turn on the spot (e.g. on a boat). With heading lock enabled the Survey+ can remain stationary for indefinite periods of time without any problems.

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

Table 19 gives a more detailed description on each of the heading lock options.

Table 19. NAVconfig heading lock options

Heading lock	Description
Normal	This option assumes that 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 that 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 that 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.

Displace output

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

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 in the properties window 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 drop-down lists.

Note that the noise in the acceleration outputs will be much higher when output displacement is used. Typical installations in moving vehicles have angular vibrations of about 2 rads/s²; this equates to 2 m/s² of additional vibration of a 1 m output displacement. It will be necessary to filter the data if Displace output is used.

Odometer input

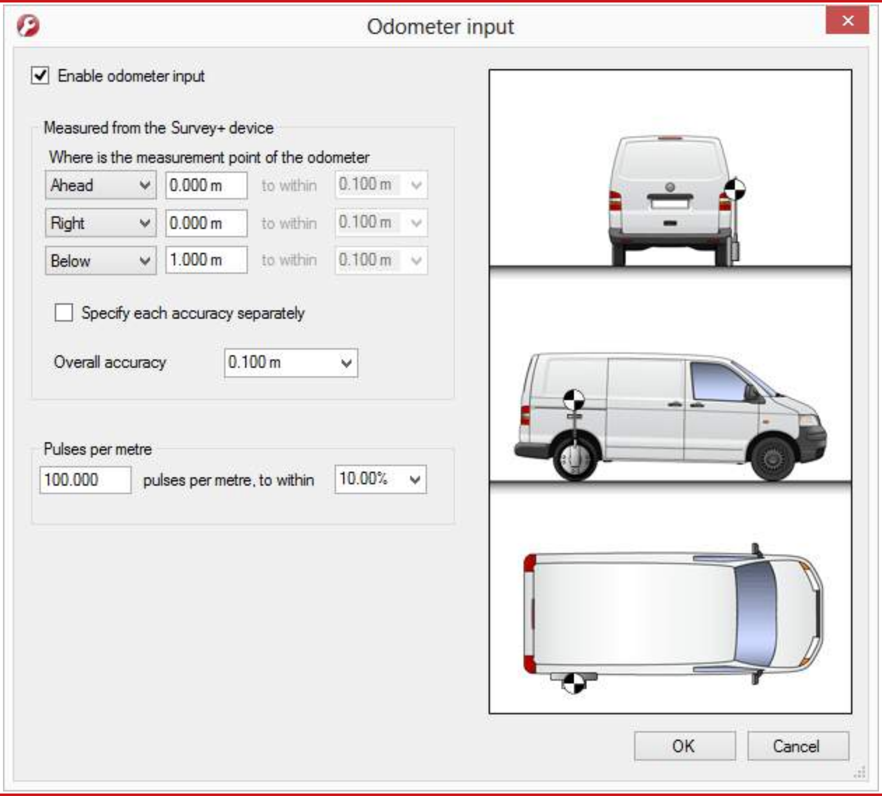
Adjustment: click **…** button to open properties window.

Using an odometer input makes a huge difference to the longitudinal drift performance of the Survey+ when GNSS is not available. It is essential to use the Wheel configuration feature (page 46) at the same time as an odometer input.

As with the Wheel configuration feature, the odometer input can only be used on land vehicles; aircraft and marine vehicles cannot use this option. The odometer 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 20 shows the Odometer input properties window. To enable the odometer input, ensure the checkbox is checked. If this option is disabled, the Survey+ will ignore corrections from the odometer even if it is connected.

Figure 20. NAVconfig Odometer input properties window



The distances from the Survey+ to the measurement point of the odometer in the vehicle co-ordinate frame should be input. The directions can be selected from the drop-down lists. If the odometer is from a prop shaft then the distance should be measured half way between the two wheels. The illustrations in the window will change depending on the settings you choose, to help visualise the position of the Survey+ in relation the odometer.

Ideally the measurements would be made to an accuracy of 10 cm. Using higher precision for the measurement does not improve the results. Using an accuracy figure worse than 20 cm will increase the drift of the Survey+. The accuracy can be specified as the same for all measurements using **Overall accuracy** or it can be specified for each individual measurement by clicking the **Specify each accuracy separately** checkbox. In either case, choose a predefined value from the drop-down list or type in a value.

Enter the pulses per metre of the odometer. A value that is accurate to 10% is sufficient unless the figure is known more accurately. The Survey+ will improve this scaling factor itself when GNSS is available. The **Improve configuration** utility can be used to apply a more accurate value calculated by the 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. See page 41 of this manual for more information on improving the configuration.

The odometer corrections will not be as effective in reducing the drift of the Survey+ if the odometer 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.

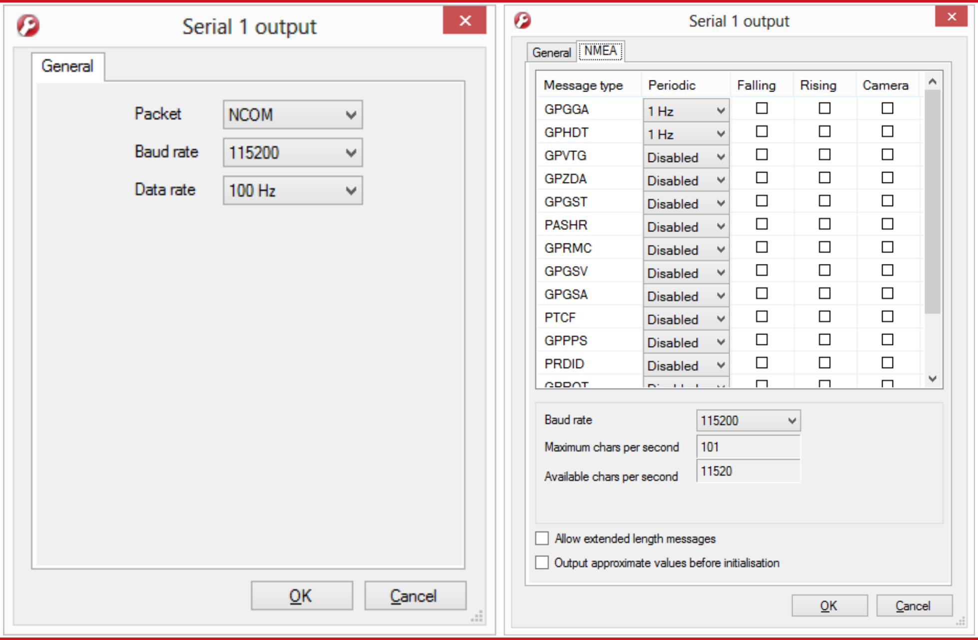
For best results, a front wheel drive vehicle should be used with the odometer on a rear wheel. The odometer pulses from driven wheels are less accurate.

Serial 1 and Serial 2 outputs

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

The Serial 1 and Serial 2 output ports can be configured for different message types. Figure 21 shows the properties windows for the Serial 1 output, which are the same for Serial 2.

Figure 21. NAVconfig Serial output properties windows



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

Select the message type to output from the **Packet** drop-down list and select the baud rate and data rate to output at. Table 20 gives details of the different messages.

Table 20. Serial output options

Option	Description
Disabled	The serial output is disabled. This option can be used to reduce the computational load and ensure that the Kalman filter runs quicker.
NCOM	Normal output of the Survey+. NCOM data is transmitted at up to 100 Hz or 125 Hz (for 250 Hz systems; RS232 does not support 250 Hz). The format is described in the NCOM Description Manual. Software drivers exist for decoding the NCOM data.
IPAQ	NCOM output at a reduced rate. The baud rate of the serial port is set to 19200 and the update rate is 25 Hz. It is used because the IPAQ cannot manage to receive the data reliably above 25 Hz.
IPAQ+	NCOM output at a reduced rate and polled. Windows Mobile 5 on IPAQs crashes if the Survey+ is sending data when the IPAQ is turned on. Using IPAQ+ the IPAQ will poll the Survey+; the Survey+ 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.

If the NMEA packet type is selected, the **NMEA** tab will appear in the properties window (see Figure 21). In this tab the NMEA messages to output on the serial port of the Survey+ are selected by choosing the data rate for each message type from the drop-down lists and clicking the checkbox for when to generate the message.

NMEA messages can be generated by falling or rising voltages on the event inputs. 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 camera trigger. These messages use interpolation to compute the values at the exact time of the event and may be output on the serial port up to 30 ms late and out of order compared to the normal messages. To enable these messages check the appropriate checkbox.

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

Selecting **Allow extended length messages** enables 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.

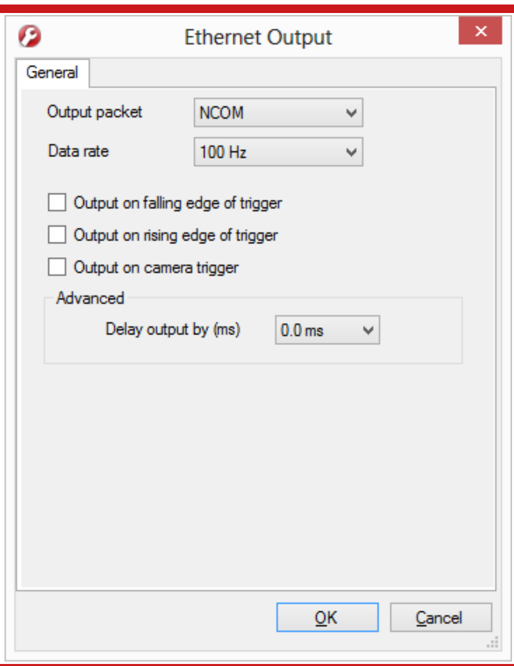
Selecting **Output approximate values before initialisation** forces output of the raw GNSS measurements before the Survey+ is initialised. Currently just the position is output and this is the position of the antenna, not the inertial measurement unit. Note that there will be a jump (from the antenna to the inertial measurement unit) when initialisation occurs.

Ethernet output

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

The Ethernet output of the Survey+ can be configured for different data rates and delays. Figure 22 shows the Ethernet output properties window.

Figure 22. NAVconfig Ethernet output properties window



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

The Survey+ can output Ethernet messages when an event (rising or falling edge) is input on the event input pin. It can also output Ethernet messages from pulses in the camera trigger. These messages are interpolated to the time when the event occurred and may be output up to 30 ms late and out of order compared to the normal messages. It is essential to enable these options if the events have a rate higher than 1 Hz, otherwise the output cannot communicate all of the events and some will be lost.

The **Delay output** option should not be used with the Survey+.

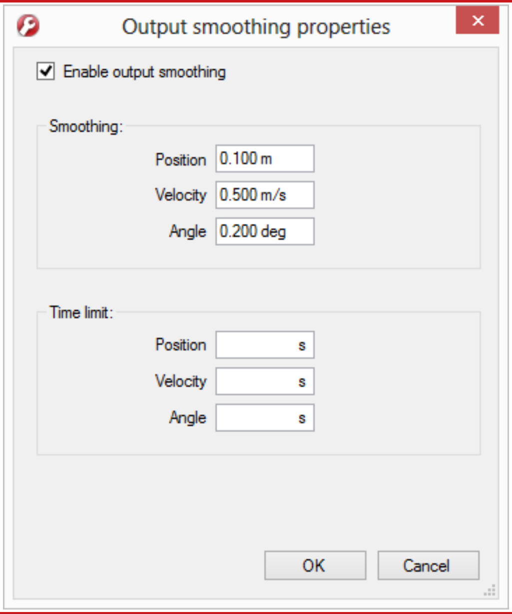
Output smoothing

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

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.

Figure 23 shows the Output smoothing window. Click the checkbox to enable output smoothing and unlock the properties for editing.

Figure 23. 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.

For example, if the position has drifted by 5 m after a period without GNSS and the smoothing is set to 0.05 m then it will take at least 100 s to correct the 5 m drift. If the time limit is set to 20 s then the Survey+ will apply the 5 m correction immediately because the predicted time to correct the position is longer than the time limit.

Care should be taken not to make the smoothing too small. If these parameters are too small 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.

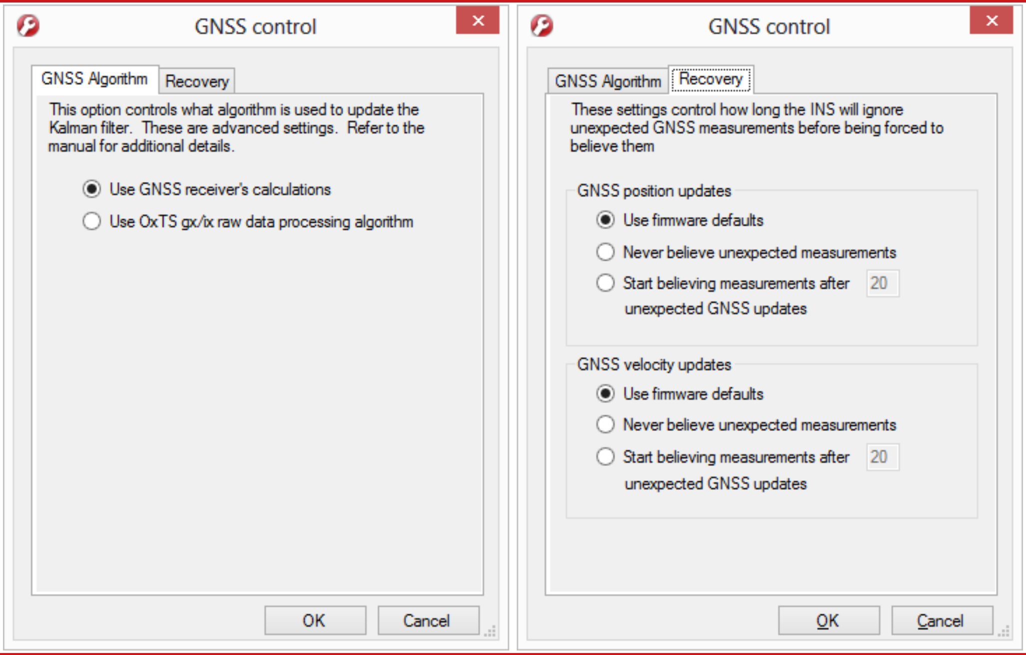
GNSS control

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

The GNSS control option 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 24 shows both tabs in the GNSS control properties window.

Figure 24. NAVconfig GNSS control properties window



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

The gx/ix raw data processing algorithm uses the raw data from the GNSS and custom algorithms to compute position and velocity tailored to the needs of the Kalman filter. It also improves performance in poor GNSS environments using single satellite aiding technology and tightly coupled GNSS and inertial measurements. Gx/ix mode is recommended to achieve the highest accuracy in environments where RTK lock may be difficult to maintain, e.g. urban canyons.

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 21 details the current compatibilities of gx/ix mode.

Table 21. gx/ix compatibility

GNSS mode	Real-time	Post-process
SPS	✔	✔
SBAS	x	x
DGPS	✔	✔
RTK	x	With gxRTK upgrade
GLONASS	x	x

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

The **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 that the Survey+ will reject. Once this limit has passed the Survey+ accepts the GNSS update since it is possible the GNSS is correct and the inertial measurements are not. The GNSS control determines how many updates the Survey+ should ignore 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 or when odometer measurements are used, it may be desirable to reject more GNSS measurements. Select the **Start believing measurements after_** option and enter the number of GNSS measurements to reject before the system starts believing it again.

The Survey+ GNSS receivers update both position and velocity at a rate of 5 Hz. Therefore to ignore updates for 60 s for example, the number to enter to start believing measurements again would be 300.

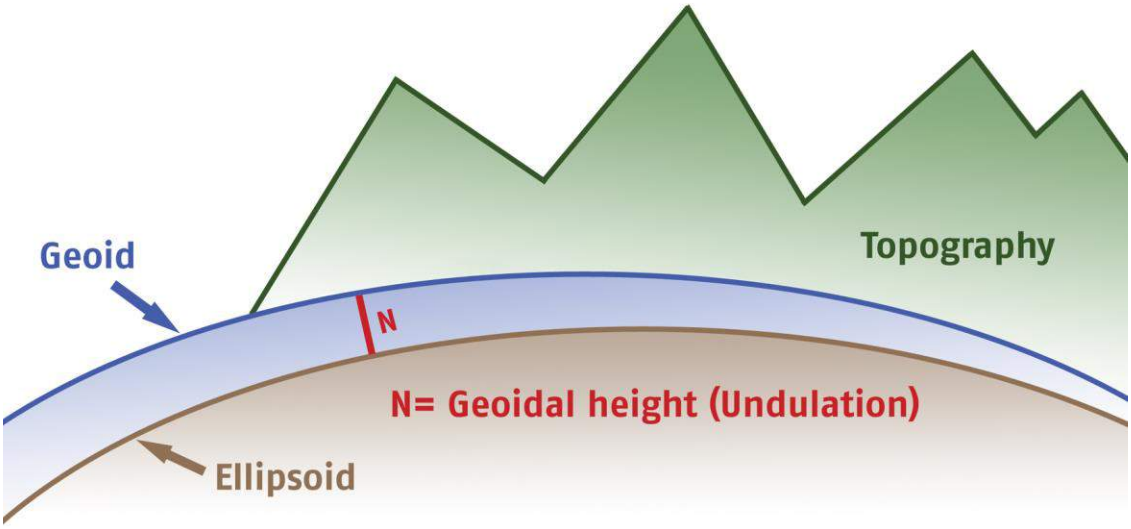
Altitude

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

The Survey+ can output altitude (height) compared to the WGS 84 (ITRF05) ellipsoid or compared to the EGM96 geoid—simply select the relevant option from the list. It can also apply a constant offset to the WGS 84 ellipsoid. This is defined by simply typing a value in the altitude cell.

The difference between geoid and ellipsoid outputs is illustrated in Figure 25.

Figure 25. Difference between geoid and ellipsoid



The earth has a random shape, which is approximately an ellipsoid. The WGS 84 ellipsoid is a "best fit" to the earth's shape. WGS 84 has been updated to ITFR05, which uses the same ellipsoid parameters and the same *x*-axis direction.

Another measure of shape is a geoid; the surface described by a specific value of acceleration due to gravity. This is the shape mean sea level follows. This shape is not uniform and it is normally computed using a lookup table. The lookup table gives a local value of undulation—which is the difference between WGS 84 and the geoid. Marine applications prefer to use the altitude compared to the geoid because it's very close to zero at mean sea level. The ellipsoidal altitude can be different to sea level by up to 50 m.

The value currently being used by the software will be output in the "undulation" field in the NCOM status messages and in the extended NMEA GGA sentences. Other outputs may also include the undulation.

Output lock

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

The output of the Survey+ will continue to change even when the vehicle is stationary. For some video systems this leads to ambiguous results. The position and orientation can be "locked" by the Survey+ automatically when the vehicle becomes stationary.

While the outputs are locked, the Kalman filter continues to run and accumulate errors. When the vehicle moves, the Kalman filter will quickly return to the new solution. The drift rate can be controlled using the Output smoothing option.

Differential correction

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

The Survey+ can be configured to use several different differential correction message types on connector J3. Figure 26 shows the Differential corrections properties window. Table 22 gives details on the different correction types available.

Figure 26. NAVconfig Differential corrections properties window

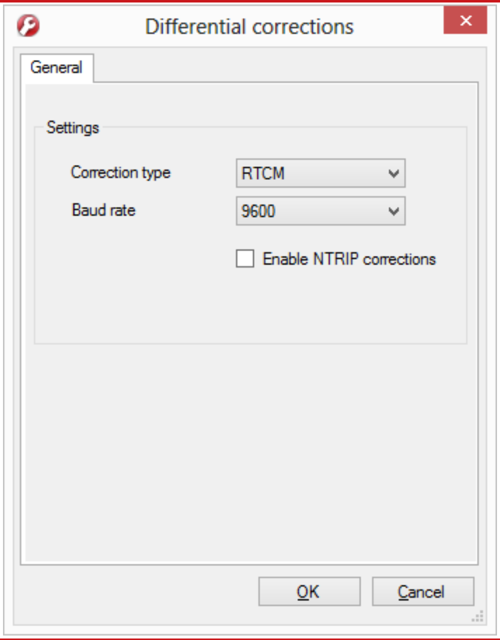


Table 22. NAVconfig differential correction types

Correction type	Description
RTCA	RTCA is the standard adopted for aircraft. It was the first open standard to use 2 cm corrections. The RT-Base and GPS-Base products use RTCA.
RTCM	RTCM is the most common open standard used for differential corrections. Old implementations of RTCM did not support 2 cm corrections, which is why Oxford Technical Solutions uses RTCA by default. New models support 2 cm corrections over RTCM.
RTCM V3	RTCM V3 is the latest version of RTCM. This option gives the best accuracy and should be used if your differential corrections are in Version 3 format.
CMR	This is a standard adopted by Trimble. The Survey+ products support both CMR and CMR+ formats.
Advanced	This option is reserved.

Select the **Correction type** you wish to use from the drop-down list and then select the **Baud rate**. The most common baud rates used for differential corrections are 4800 baud and 9600 baud. The RT-Base and GPS-Base use 9600 baud.

When checked, the NTRIP option sends an NMEA GGA message out from J3 back to the NTRIP server.

SBAS

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

In Europe, North America, and Japan SBAS can be used for differential corrections. These services will improve the position accuracy of the 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.

DGNSS service

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

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

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

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

Advanced

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

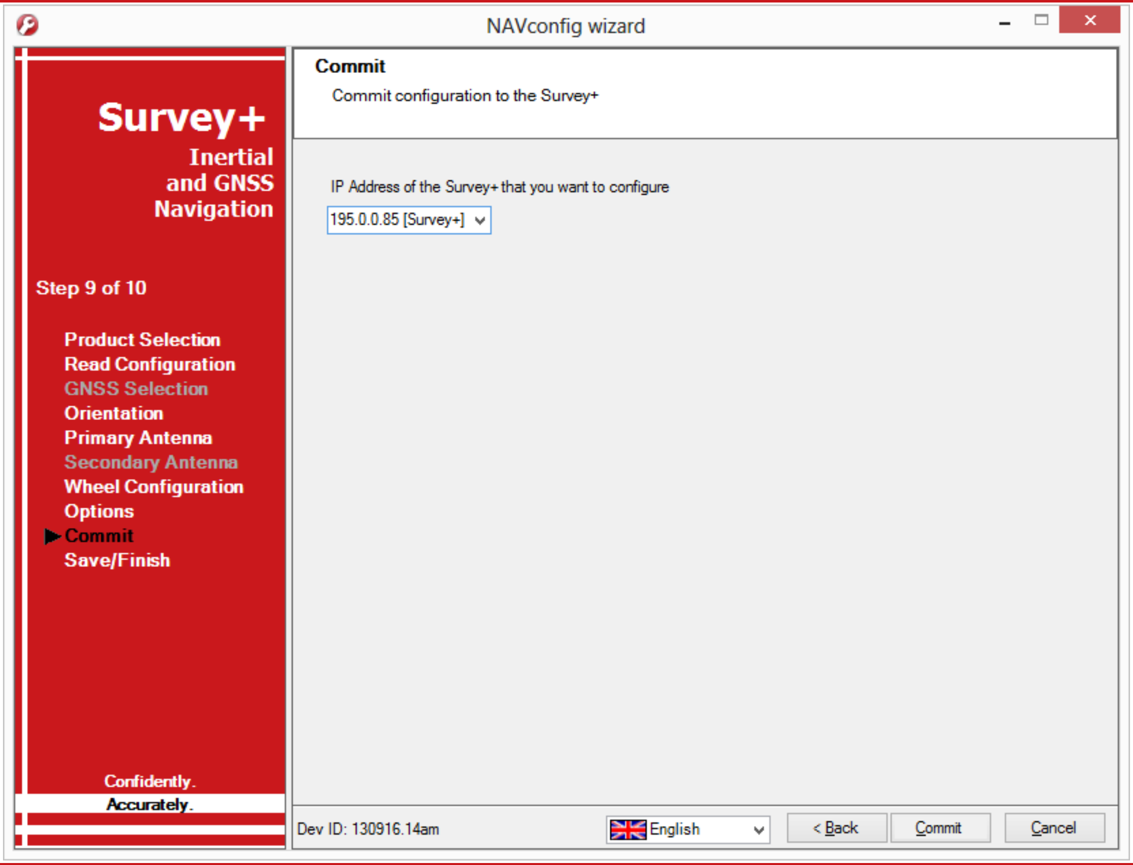
The Advanced option is used to set special commands for the Survey+. This should only be done with special instructions from OxTS.

Committing the configuration to the Survey+

Changes to the Survey+ settings must be sent using Ethernet. It is necessary to configure your computer's Ethernet settings so it is on the same network as the Survey+. The section "Ethernet configuration" on page 30 gives details on how to do this.

Figure 27 shows the Commit page.

Figure 27. NAVconfig Commit page



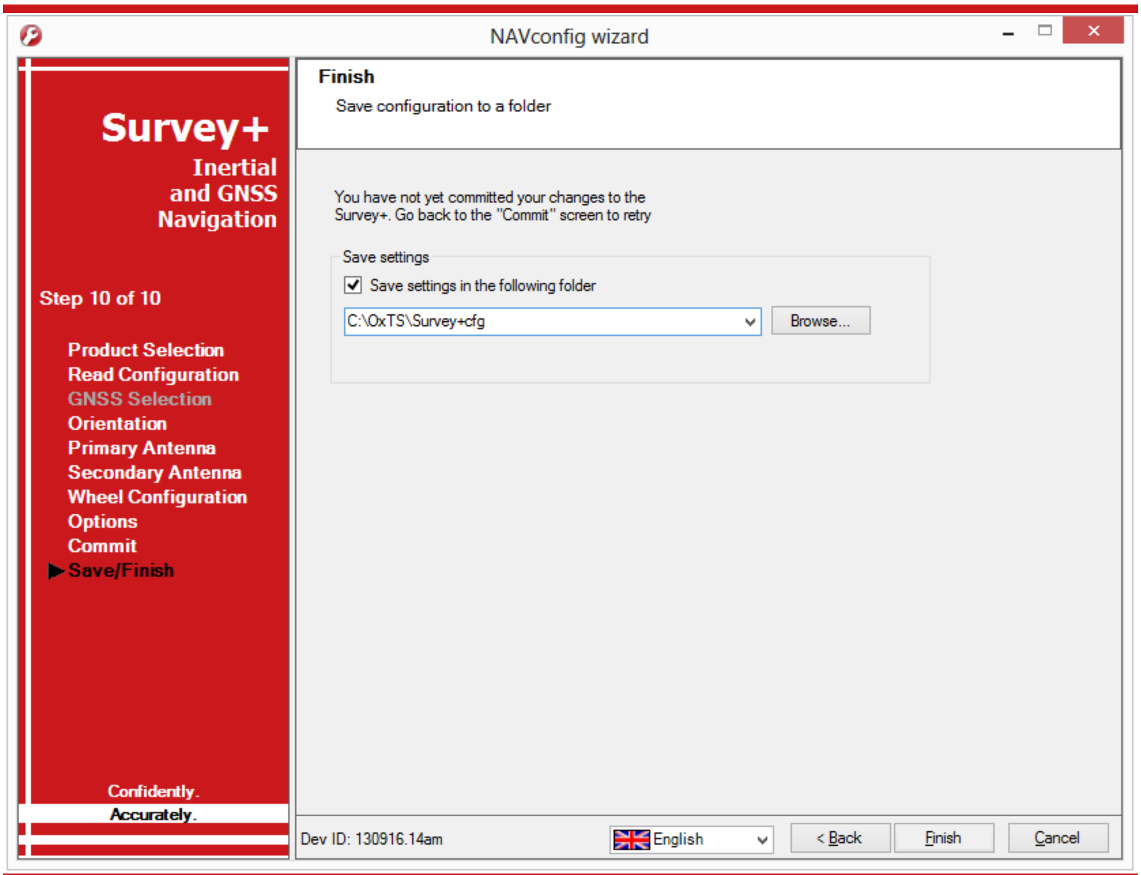
Enter the IP address of the Survey+ that you want to configure or select it from the drop-down list. The drop-down box will list all of the systems that are connected to the computer's network so ensure to select the correct system if there are multiple listed. The list will not work if Enginuity or other software is using the Survey+ UDP port unless the OxTS UDP server is running.

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

Saving the configuration and finishing

Before finishing it is possible to save a copy of the configuration in a folder on your computer. This can then be loaded next time. The Save/Finish page also lets you know if the settings have been committed successfully or not. Figure 28 shows the Save/Finish page.

Figure 28. NAVconfig Save/Finish page



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

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 23.

Table 23. 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	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 unless static initialisation has been selected for a dual antenna system. 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:

1. 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).

2. 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, Wheel configuration 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.

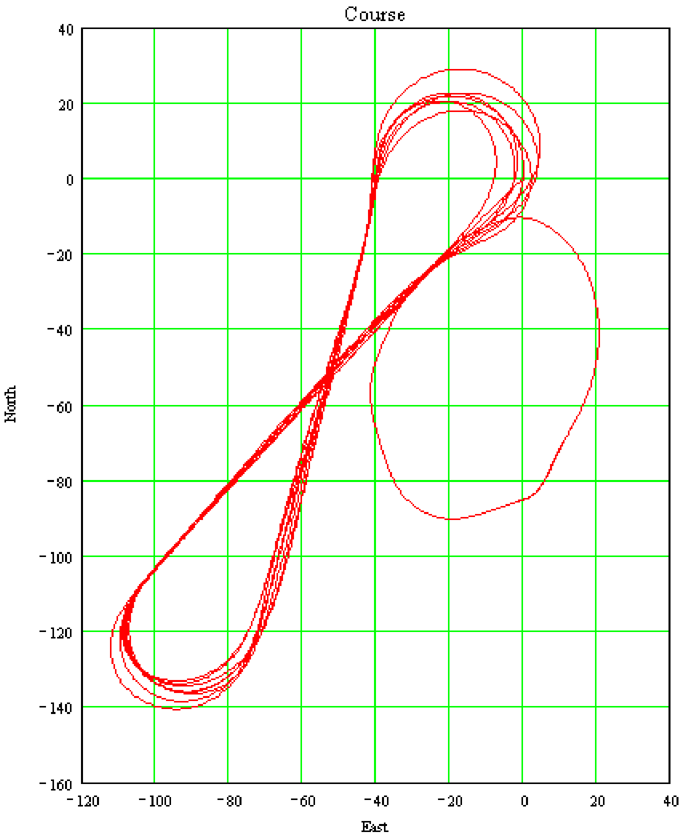
- Although in this example the Survey+ was receiving corrections from a base-station while stationary, it is not necessary. The base-station should be working before the dynamic driving starts so the Survey+ can use the best information to self-calibrate (if a base-station is not being use this does not apply).

- There are 6 minutes during which the vehicle 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 29 shows the route driven and Figure 30 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.

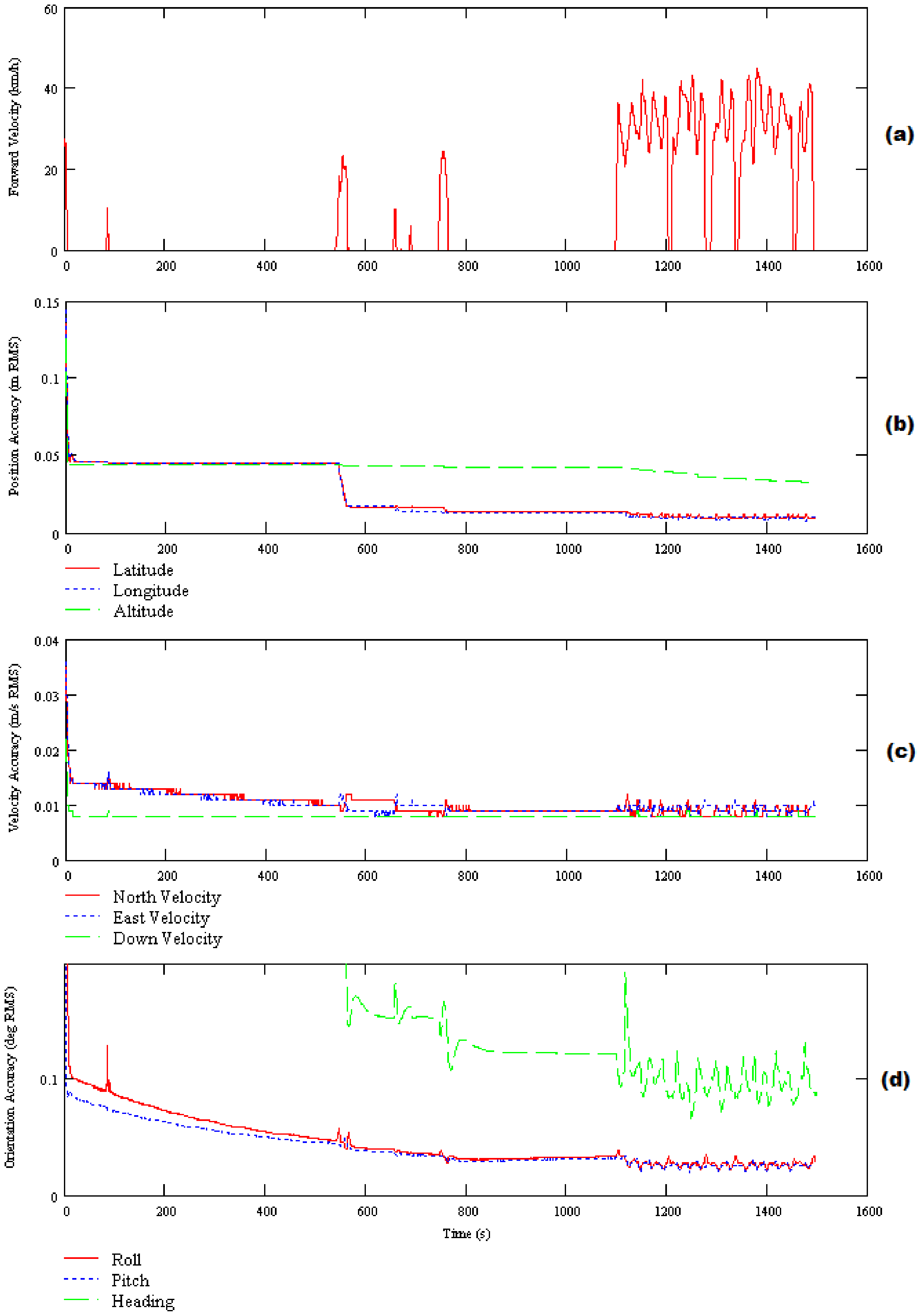
Figure 29. Example warm-up driving route



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 30); 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 29, 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 2 cm and the heading is better than 0.2°.

Figure 30. 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 vehicle 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 30) 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. Warm-up is recommended in order to achieve the highest level of accuracy. In aircraft applications, flying figures of eight will remove a few hundredths of a degree of roll and pitch error—which can be critical for geo-referencing applications. The same is true for marine applications. However the effect is small and only significant when you need the full performance of the Survey+.

Inputs and outputs

The Survey+ has one main connector for its inputs and outputs (label 6 on Figure 4). The J1 connector of the Survey+ user cable connects to this and connectors J2-J7 of the user cable provide connections for the inputs and outputs. The connector on the Survey+ is keyed so the user cable must be correctly aligned for it to connect. The Survey+ user cable drawing located at the back of this manual gives details on each connector and the pin assignments.

Digital inputs and outputs

Table 24 describes each of the signals on the J5 digital I/O connector. A more detailed explanation of each signal can be found below.

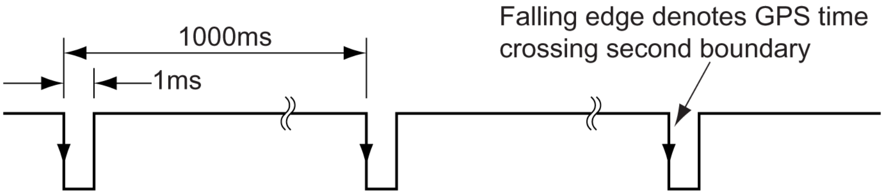
Table 24. J5 pin assignments - digital I/O

Function	Description
Digital 1	1PPS from GNSS receiver
Digital 2	Event input
Digital 3	Odometer input
Digital 4	Camera trigger
Digital 5	IMU sync output pulse (100 or 250 Hz)
Digital Ground	Ground
Digital Ground	Ground
Digital Ground	Reserved
Digital Ground	Reserved

1PPS output

The 1PPS output is a pulse from the GNSS receiver. The falling edge of the pulse is the exact transition from one second to the next in GPS time. The pulse is low for 1 ms then high for 999 ms and repeats every second.

Figure 31. 1PPS waveform



The output is a low-voltage CMOS output, with 0.8 V or less representing a low and 2.4 V or more representing a high. No more than 10 mA should be drawn from this output. Limited protection is provided on this output.

Event input

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

By default the maximum event rate is 1 Hz for 100 Hz products and 4 Hz for 250 Hz products. This can be increased to 50 Hz by selecting one or both the **Output on falling edge of trigger** and **Output on rising edge of trigger** check boxes on the Ethernet output properties window. This is accessed from the Options page of the configuration wizard (see “Ethernet output” on page 56 of this manual).

Trigger information can be found in status message 24 and 43, output over NCOM.

Odometer input

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

The odometer 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 input, however the input voltage should not exceed 12 V.

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

Camera trigger

The camera trigger output generates a pulse for a fixed distance travelled. The configuration software can change the number of metres travelled between pulses. The output has 0.8 V or less for a low and 2.4 V or more for a high. There is no protection on this output, no more than 10 mA should be used on this output.

IMU sync output pulse

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

Reverse polarity protection

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

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

If the fuse in the plug needs to be replaced then it should be replaced with the Littelfuse model given in Table 25. If an alternative connector is fitted to the cable then an appropriate 5 A, fast-blow fuse should be fitted.

Table 25. Replacement fuse

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

Laboratory testing

There are several checks that can be performed in the laboratory to ensure that 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 that 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 Enginuity.
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/s²
Flat	Flat	Up	*z*-acceleration between 9.7 and 9.9 m/s²
Down	Flat	Flat	*x*-acceleration between –9.7 and –9.9 m/s²
Up	Flat	Flat	*x*-acceleration between 9.7 and 9.9 m/s²
Flat	Down	Flat	*y*-acceleration between –9.7 and –9.9 m/s²
Flat	Up	Flat	*y*-acceleration between 9.7 and 9.9 m/s²

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

Gyro test procedure

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

1. Use the default orientation configuration in NAVconfig.

2. Connect power to the system, connect the system to a laptop computer and run the visual display software (Enginuity).

3. Rotate the Survey+ according to Table 27 and check that the angular rate measurements occur.

4. With the unit stationary, check that all the angular rates are within ±5°/s. (In general they will be within ±0.5°/s, but the algorithm in the Survey+ will work to specification with biases up to ±5°/s).

Table 27. Angular rate measurement specifications

Rotation			Angular rate measurement
x	*y*	*z*	
+ve	Zero	Zero	*x*-direction should indicate positive rotation, others are small.
–ve	Zero	Zero	*x*-direction should indicate negative rotation, others are small.
Zero	+ve	Zero	*y*-direction should indicate positive rotation, others are small.
Zero	–ve	Zero	*y*-direction should indicate negative rotation, others are small.
Zero	Zero	+ve	*z*-direction should indicate positive rotation, others are small.
Zero	Zero	–ve	*z*-direction 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 that all the internal circuits in the Survey+ are working correctly and that 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 (Enginuity).
2. Use Table 28 to check that the status fields are changing.

Table 28. Status field checks

Field	Increment rate
IMU packets	100 or 250 per second, depending on product model.
IMU chars skipped	Not changing (but not necessarily zero).
GPS packets	About 20 per second (depending on system).
GPS chars skipped	Not changing (but not necessarily zero).
GPS2 packets[1]	About 5 to 10 per second (depending on system).
GPS2 chars skipped[1]	Not changing (but not necessarily zero).

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

These checks will ensure that the signals from the GNSS receivers 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 $\boldsymbol{V}_{\boldsymbol{n}}$ is vector $\boldsymbol{V}$ measured in the navigation co-ordinate frame and $\boldsymbol{V}_{\boldsymbol{b}}$ is the same vector measured in the body co-ordinate frame the two vectors are related by:

$$\boldsymbol{V}_{\boldsymbol{n}} = \boldsymbol{C}_{\boldsymbol{bn}} \cdot \boldsymbol{V}_{\boldsymbol{b}}$$

$$\boldsymbol{V}_{\boldsymbol{n}} = \begin{bmatrix} \cos(\psi) & -\sin(\psi) & 0 \\ \sin(\psi) & \cos(\psi) & 0 \\ 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} \cos(\theta) & 0 & \sin(\theta) \\ 0 & 1 & 0 \\ -\sin(\theta) & 0 & \cos(\theta) \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\phi) & -\sin(\phi) \\ 0 & \sin(\phi) & \cos(\phi) \end{bmatrix} \cdot \boldsymbol{V}_{\boldsymbol{b}}$$

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.

Revision history

Table 29. Revision history

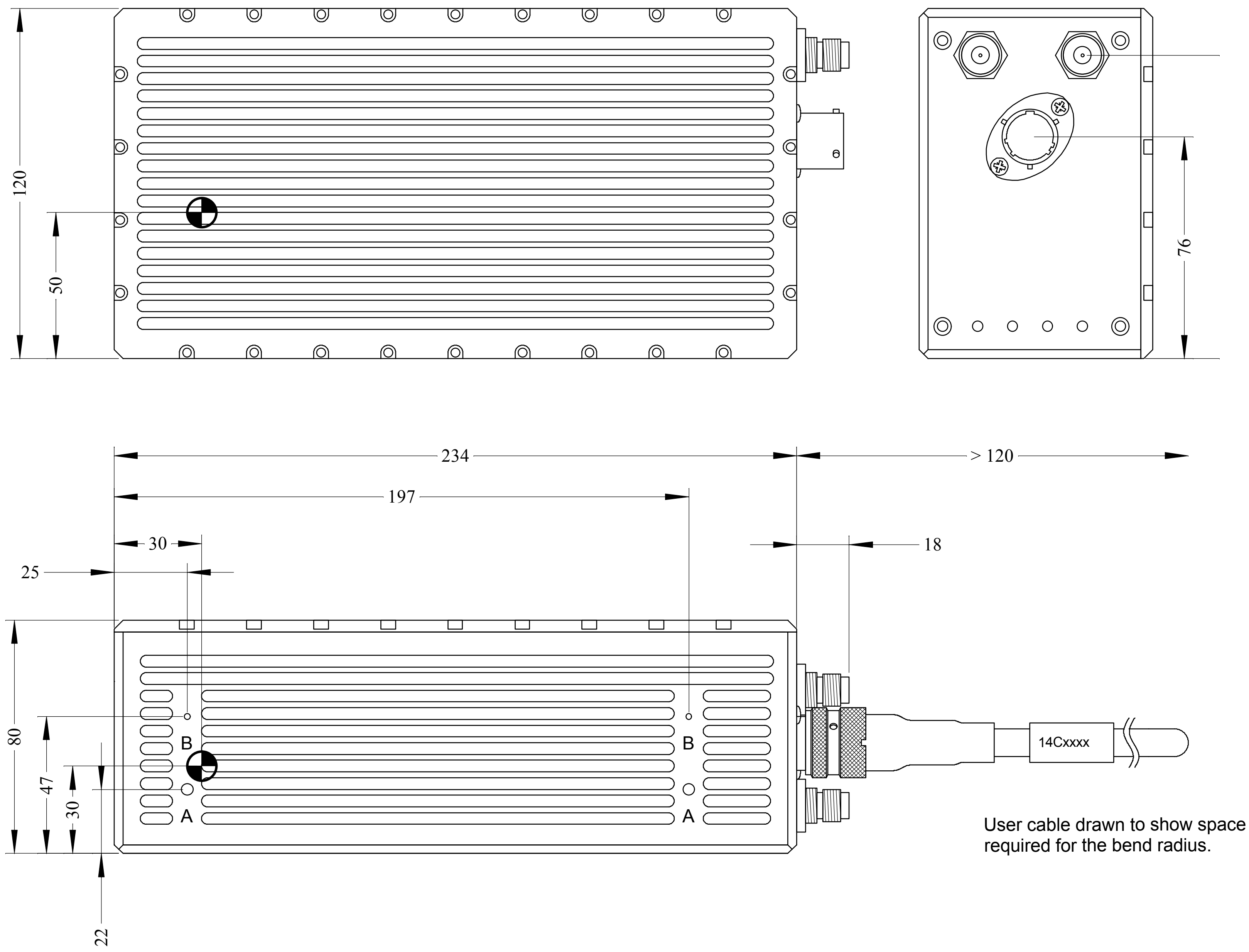
Revision	Comments
131008	Initial version.
140501	Removed OmniSTAR support.
140610	Updated to v2 systems. Added Survey+ L1.

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
14A0007x	Survey+ system outer dimensions
14C0121A	Survey+ user cable
110-00012-601	G5Ant-2AMNS1 GNSS antenna
110-00148-601	G5Ant-42AT1 GNSS antenna
110-00150-601	G5Ant-52AT1 GNSS antenna



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0 10 20 30

Print Size:	A4
Scale:	1:2 (Half)
Units:	mm
Tolerances:	X.X - 0.1
Projection:	3rd Angle
Material:	HE30 Alu
Finish:	Anodised

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

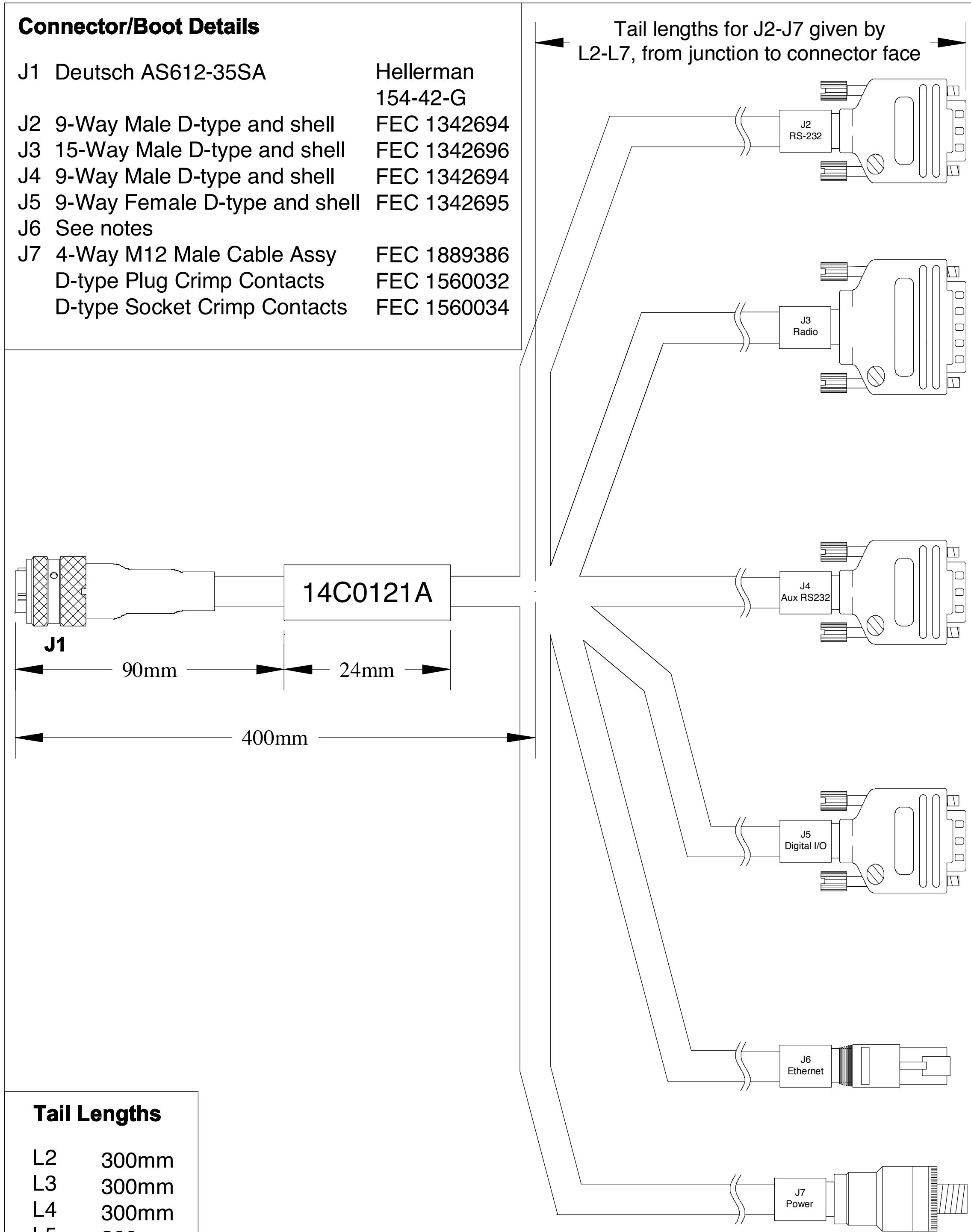
Date:	23/07/09
Part #:	14A0007A

Document:
Survey+ out dimensions

Sheet: 1 of 1

Connector/Boot Details

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



Nav Data RS232

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

Radio

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

Aux RS 232

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

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

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

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

Tail Lengths

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

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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.

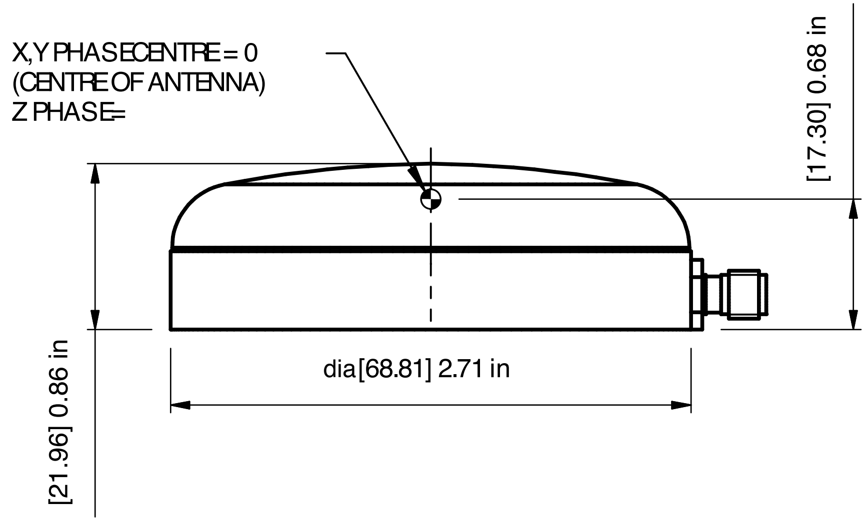
Wire Types:
J7-1, J7-3 16/0.2
All others 7/0.2
J1-13 & J1-20 Twisted pair
J1-14 & J1-21 Twisted pair

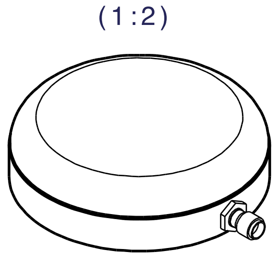
Cables outers braided and connected to J1-22, J1 shell and J7 shell (through cable assembly braiding).

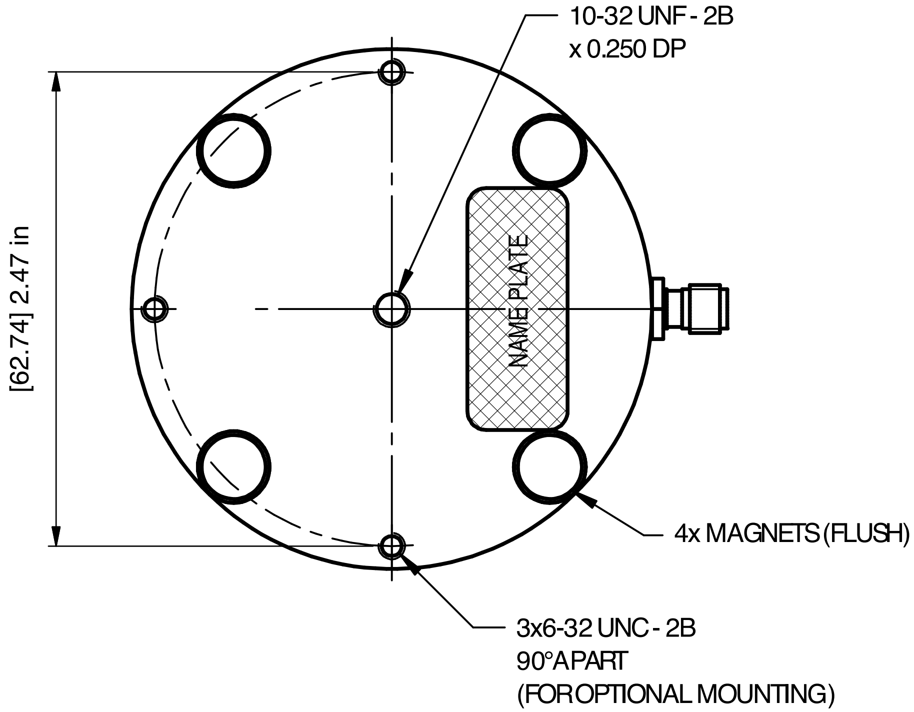
Please populate all unused pins with empty crimps.

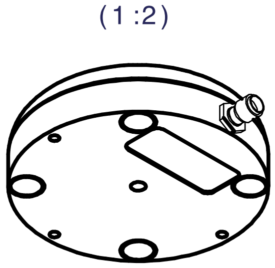
All cable markers in White
Ensure that the cable legend text precisely matches that given in diagram.

Date:	30/08/13
Part #:	14C0121A
Document:	Survey+ User Cable
Sheet:	1 of 1









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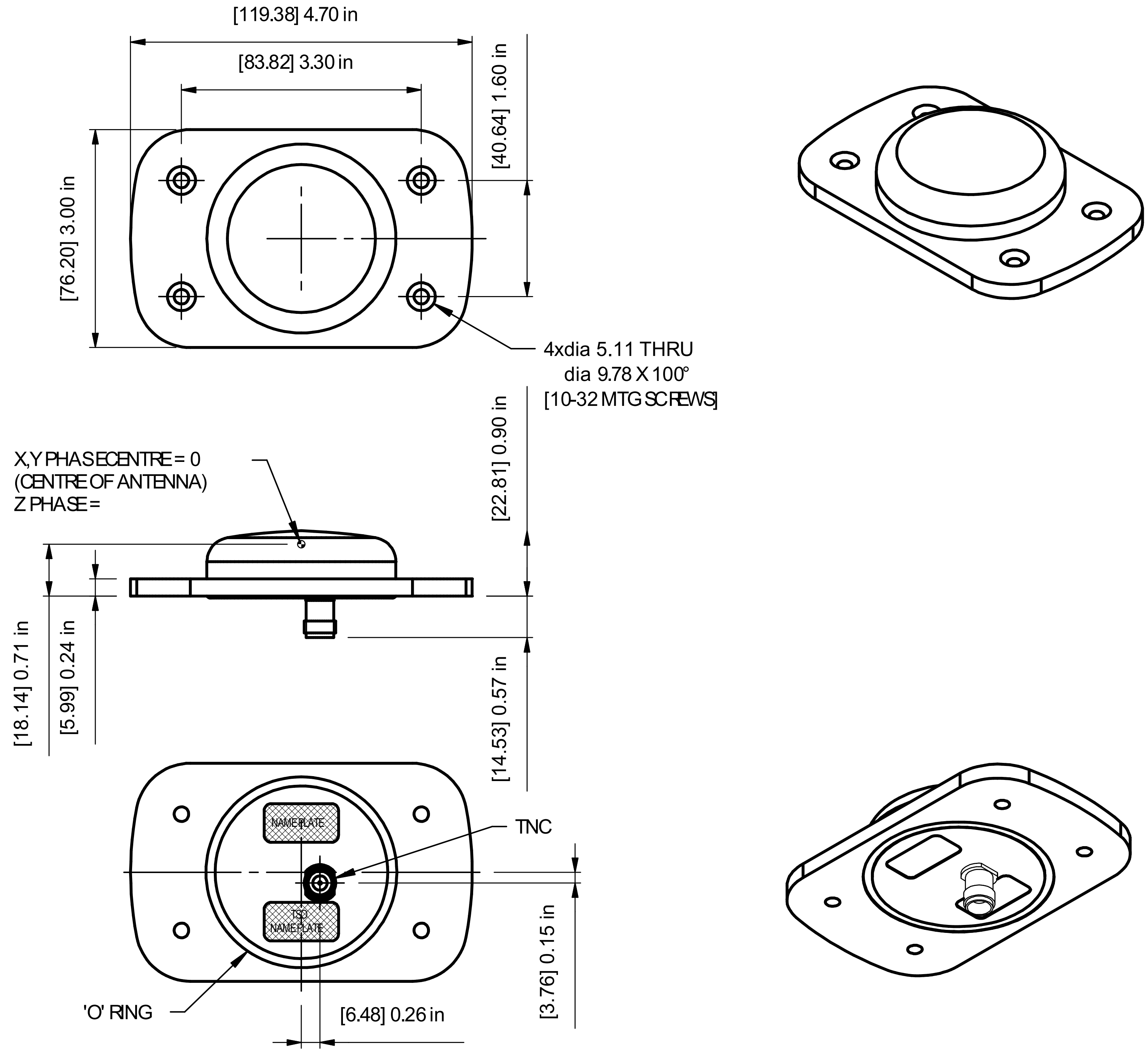
Print Size:	A4
Scale:	1:1
Units:	mm
Tolerances:	1mm
Projection:	3rd Angle

Notes:

GPS/GLONASS Antenna
SMA Connector
magnetic
2cm
OmniStar

Date:	06/05/11
Part #:	110-00012-601
Document:	G5Ant-2AMNS1
Sheet:	1 of 1



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0 10 20 30

Print Size: A4

Scale: 1:2

Units: mm

Tolerances: 1mm

Projection: 3rd Angle

Notes:

* L1/L2/L5 GPS/GLO.
* OmniStar
* Precision carrier phase
* Suitable for 2 cm products
* Typically for aircraft
* TNC Connector
* ARINC Form Factor
* Must be mounted on a metal surface for optimum performance

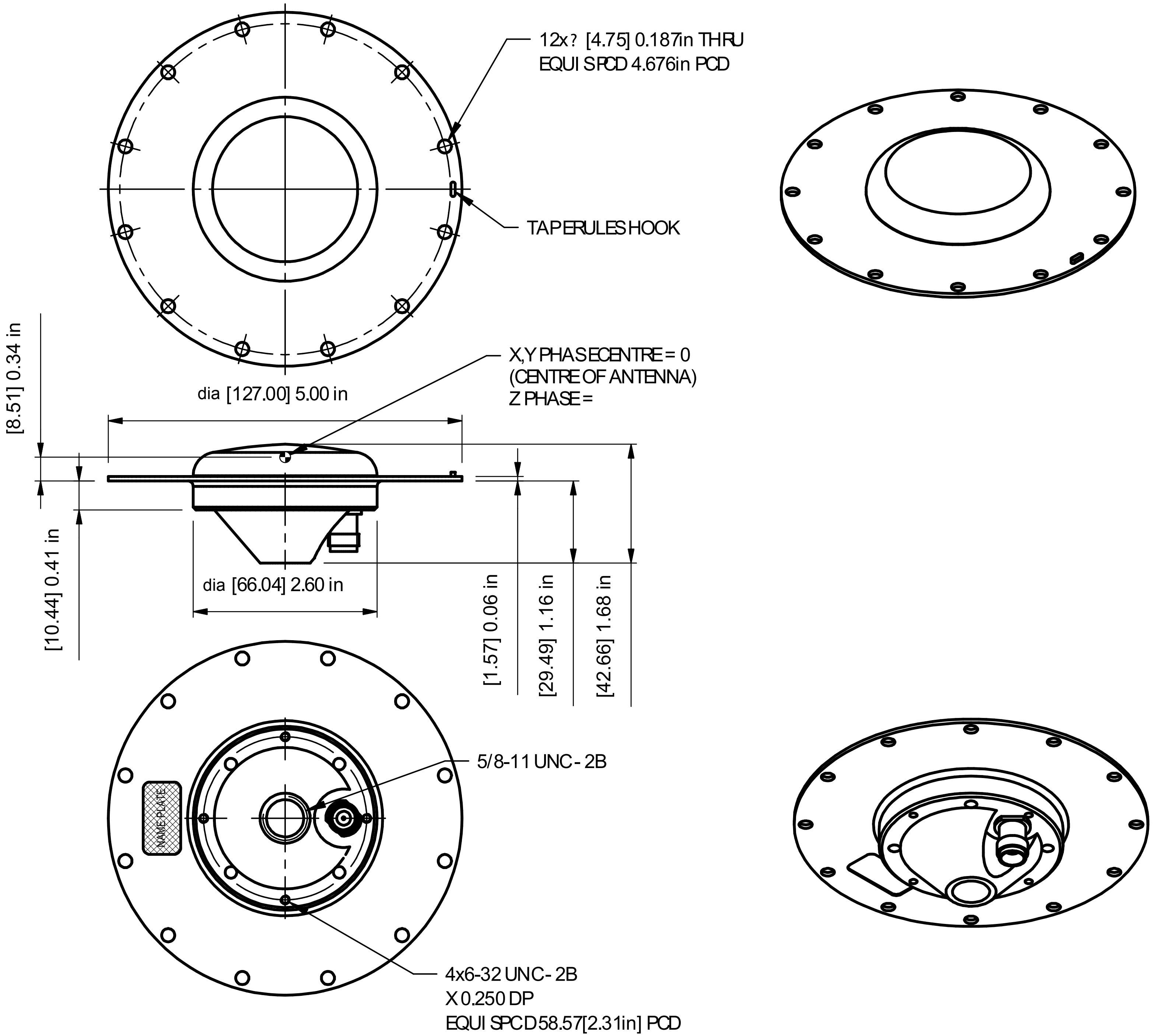
5V, 35dB Gain
Weight 227g

Date: 06/05/11

Part #: 110-00148-601

Document: G5Ant-42AT1

Sheet: 1 of 1



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0 10 20 30

Print Size: A4

Scale: 1:2

Units: mm

Tolerances: 1mm

Projection: 3rd Angle

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

Date: 06/05/11

Part #: 110-00150-601

Document: G5Ant-52AT1

Sheet: 1 of 1