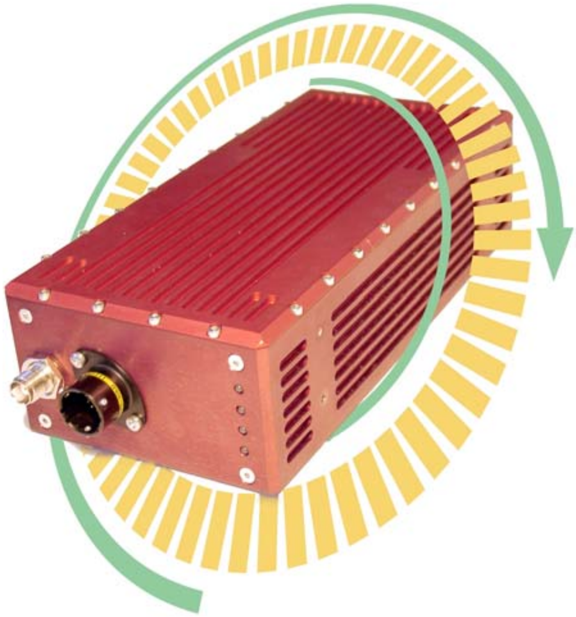
RT3000

Inertial and GPS Measurement System



User Manual

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Revision

Document Revision: 030728 *(See Revision History for detailed information).*

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Introduction

The RT3000 family of Inertial and GPS Navigation Systems from Oxford Technical Solutions are instruments for making precision measurements of motion in real-time.

The RT3000 uses mathematical algorithms developed for use in fighter aircraft navigation systems. An inertial sensor block with three accelerometers and three gyros (angular rate sensors) is used to compute all the outputs. A WGS-84 modelled Strapdown Navigator Algorithm compensates for earth curvature, rotation and Coriolis accelerations while measurements from high-grade kinematic GPS receivers update the position and velocity navigated by the inertial sensors.

This innovative approach gives the RT3000 several distinct advantages over systems that use GPS alone:

- The RT3000 has a high, 100Hz update rate and a wide bandwidth.
- The outputs are available with very low, 3.9ms latency.
- All outputs remain available continuously during GPS blackouts when, for example, the vehicle drives under a bridge.
- The RT3000 recognises jumps in the GPS position and ignores them.
- The position and velocity measurements that the GPS makes are smoothed to reduce the high-frequency noise.
- The RT3000 makes many measurements that GPS cannot make, for example acceleration, angular rate, heading, pitch, roll, etc.

The standard RT3000 system processes the data in real-time. The real-time results are output via an RS232 serial port, over 100 Base-T Ethernet using a UDP broadcast and, optionally, on CAN bus. Outputs are time-stamped and refer to GPS time; a 1PPS timing sync can be used to give very accurate timing synchronisation between systems. The inertial measurements are synchronised to the GPS clock.

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

Installation and operation of the RT3000 could not be simpler. A single unit contains the inertial sensors, GPS receiver, data storage and CPU. One or two antennas need to be mounted outside the vehicle where they have a clear view of the sky. 9 to 18Vd.c. power can be obtained from most vehicles’ power supplies. A laptop computer allows real-time viewing of the results.

Taking the time to thoroughly read and understand the manual will inevitably lead to achieving the best results with the RT3000 system. A little time spent now will save you considerable time later.

RT3000 Family Variants

The RT3000 product family includes several different products based on the same technology. Each product has been selected to serve a different accuracy requirement or operating condition. The family is split between single antenna systems and dual-antenna systems.

Single Antenna Models

It is only possible for a single antenna RT3000 product to provide accurate heading when the vehicle is accelerating. When stationary (or moving at constant speed in a straight line) the heading will drift. Single antenna variants can remain stationary for about 60 minutes before their heading output will have drifted too far for them to recover, after that it will be necessary to restart the system.

For vehicles that are dynamic (e.g. racing cars) the heading performance of a single antenna model is the same as that of a dual antenna model. The single antenna models are simpler to use since only one antenna and less configuration is required. For many road vehicles the performance of the single-antenna systems are sufficient.

The single antenna models are as follows:

- RT3100 – Differential GPS with positioning accuracy to0.4m CEP using a suitable differential source.
- RT3020 – L1 Kinematic GPS with positioning accuracy to 20cm RMS.
- RT3002 – L1/L2 Kinematic GPS with positioning accuracy to 2cm RMS.

The lower specification systems can be upgraded to a higher specification through a GPS receiver software upgrade and use of the correct base-station. The Single Antenna models can also be upgraded to dual-antenna (unless the small box option has been specified, in which case the second GPS card does not fit).

Dual Antenna Models

With a dual antenna RT3000 product the system uses the difference in position between the two antennas to keep heading accurate, even when stationary. The vehicle can remain stationary, or have low-vehicle dynamics and still maintain accurate heading.

Dual antenna systems are recommended for road vehicle testing on low-friction surfaces (e.g. ice), rail-track vehicles, aerial survey and marine use (ships, survey vessels). GPS-only dual-antenna systems require open-sky environments to operate because they can take several minutes to acquire heading lock. Advanced processing in the RT3000 allows relock to occur after 5s of a sky-obstruction; in this time the RT3000's heading will not have significantly decreased. The fast relock time is made possible because the RT3000's own heading is used resolve the ambiguities in the GPS measurements, resolution of these ambiguities is what normally takes several minutes. The heading software in the RT3000 enables significantly better performance and coverage compared to GPS-only solutions.

The dual antenna models are as follows:

- RT3102 – Differential GPS with position accuracy to 0.4m using a suitable differential source.
- RT3022 – L1 Kinematic GPS with position accuracy to 20cm RMS.
- RT3003 – L1/L2 Kinematic GPS with position accuracy to 2cm RMS.

The lower specification systems can be upgraded to a higher specification through a GPS receiver software upgrade and use of the correct base-station.

Satellite Differential Corrections

To improve the positioning accuracy of the standard GPS two satellite based differential correction services are available. These are WAAS (or EGNOS) and OmniStar.

WAAS/EGNOS is a free service mainly directed at aircraft. It provides an accuracy of about 1m CEP. It is currently in test mode and the corrections are not guaranteed.

OmniStar is a subscription service. The RT3000 systems that have OmniStar capability include the necessary hardware to receive the OmniStar corrections. In addition to this it is necessary to pay OmniStar a license fee to activate the corrections. OmniStar provides two levels of correction. These are VBS (Virtual Base Station) and HP (High Performance).

For more information on OmniStar see the OmniStar web site, www.omnistar.com.

Scope of Delivery

Table 1, below, lists all the items that are delivered with each RT3000 model.

Table 1. Summary of the RT3000 System Components

Qty	Description	RT3100	RT3020	RT3002	RT3102	RT3022	RT3003	RT3060	RT3050	RT3040
Vehicle Components										
1	RT3000 System Unit	✓	✓	✓	✓	✓	✓	✓	✓	✓
1	User Cable[1]	✓	✓	✓	✓	✓	✓	✓	✓	✓
1	GPS Antenna AT575-70B	✓	✓		x2	x2		✓		
1	GPS Antenna AT2775-12			✓			x2			
1	GPS-600-LB Antenna								✓	✓
1	5m TNC-SMA Cable			✓			x2		✓	✓
1	Null Modem Serial Cable	✓	✓	✓	✓	✓	✓	✓	✓	✓
Base Station Components[2]										
1	Base Station GPS Receiver		✓	✓		✓	✓			
1	15m Antenna Cable		✓	✓		✓	✓			
1	GPS-600 L1 Antenna		✓			✓				
1	GPS-600 L1/L2 Antenna			✓			✓			
1	Null Modem Serial Cable		✓	✓		✓	✓			
1	Base-Station Power Cable		✓	✓		✓	✓			
Accessories										
1	CD-ROM with Manual and Software	✓	✓	✓	✓	✓	✓	✓	✓	✓
1	RT3000 User Manual	✓	✓	✓	✓	✓	✓	✓	✓	✓

Note 1: Several different user cables are available. A different cable may be chosen by the customer. Custom cables are also made. See drawings at the end of the manual for cable specifications.

Note 2: The Base Station is an optional extra and must be purchased separately or as part of a bundle. New systems can be supplied with an optional RT-Base unit, which is covered by a separate manual.

In addition to the components supplied the user will require a laptop computer and, for systems that include a base-station, radio modems. For line of sight operation within a 2km range the optional SATEL radio modems can be purchased.

Figure 1. Typical RT3000 system in transit case.

Note that the antenna style has changed since this picture was taken.

Warranty

Oxford Technical Solutions Limited warrants the RT3000 products to be free of defects in materials and workmanship, subject to the conditions ser forth below, for a period of one year from the Date of Sale.

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

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

Specification

The specification of the products is listed in Table 2, Table 3 and Table 4. These specifications are listed for operation of the system under the following conditions:

- After a warm-up period of 15 minutes continuous operation.
- Open sky environment, free from cover by trees, bridges, buildings or other obstructions. The vehicle must have remained in open sky for at least 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 system to the GPS (primary) antenna must be known by the system to a precision of 5mm or better. The vibration of the system relative to the vehicle cannot allow this to change by more than 5mm. The system will estimate this value itself in dynamic conditions.
- For dual-antenna systems the relative orientation of the two antennas must be known to the system to 0.05° or better. The system will estimate this value itself under dynamic conditions.
- For single antenna systems the heading accuracy is only achieved under dynamic conditions. Under benign conditions, such as motorway driving, the performance will degrade. The performance is undefined when stationary for prolonged periods of time.

Optionally extended measurement ranges covering 30G 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 2. Performance Specification for the RT3000 Single Antenna Systems

Product	RT3002	RT3020	RT3100
Positioning	L1/L2 Kinematic	L1 Kinematic	Stand Alone / DGPS
Position Accuracy	2cm 1σ open sky	20cm 1σ open sky	1.8m CEP Stand Alone 0.4m CEP DGPS
Velocity Accuracy	0.05 km/h RMS	0.08 km/h RMS	0.1 km/h RMS
Acceleration – Bias – Linearity – Scale Factor – Range	 10 mm/s² 1σ 0.01% 0.1% 1σ 100 m/s²	 10 mm/s² 1σ 0.01% 0.1% 1σ 100 m/s²	 10 mm/s² 1σ 0.01% 0.1% 1σ 100 m/s²
Roll/Pitch	0.03° 1σ	0.04° 1σ	0.06° 1σ
Heading	0.1° 1σ (dynamic)	0.1° 1σ (dynamic)	0.2° 1σ (dynamic)
Angular Rate – Bias – Scale Factor – Range	 0.01°/s 1σ 0.1% 1σ 100°/s	 0.01°/s 1σ 0.1% 1σ 100°/s	 0.01°/s 1σ 0.1% 1σ 100°/s
Track (at 50km/h)	0.07° RMS	0.1° RMS	0.2° RMS
Slip Angle (at 50 km/h)	0.15° RMS	0.15° RMS	0.25° RMS
Lateral Velocity	0.2%	0.2%	0.4%
Update Rate	100 Hz	100 Hz	100 Hz
Calculation Latency	3.9 ms	3.9 ms	3.9 ms
Power	9-18 V d.c. 15W	9-18 V d.c. 15W	9-18 V d.c. 15W
Dimensions	234 x 120 x 80 mm	234 x 120 x 80 mm	234 x 120 x 80 mm
Weight	2.2 kg	2.2 kg	2.2 kg
Operating Temperature	–10 to 50°C	–10 to 50°C	–10 to 50°C
Vibration	0.1 g²/Hz 5-500 Hz	0.1 g²/Hz 5-500 Hz	0.1 g²/Hz 5-500 Hz
Shock Survival	100G, 2ms ½ sine	100G, 2ms ½ sine	100G, 2ms ½ sine
Base Station Included	Yes	Yes	No
Internal Storage	512 MB	512 MB	512 MB
Twin Antenna	No	No	No
Upgradeable GPS	Yes (to dual antenna)	Yes	Yes

Note: The single antenna units may be supplied in a smaller box, with a single antenna port. The dimensions are 243 x 108 x 68mm and the weight is 2.1kg. This box does not allow the single antenna system to be easily upgraded to dual antenna.

Table 3. Performance Specification for the RT3000 Differential Systems

Product	RT3040	RT3050	RT3060
Positioning	OmniStar HP	OmniStar VBS	WAAS
Position Accuracy	10cm CEP[1]	50cm CEP	1m CEP
Velocity Accuracy	0.07 km/h RMS	0.08 km/h RMS	0.1 km/h RMS
Acceleration – Bias – Linearity – Scale Factor – Range	 10 mm/s² 1σ 0.01% 0.1% 1σ 100 m/s²	 10 mm/s² 1σ 0.01% 0.1% 1σ 100 m/s²	 10 mm/s² 1σ 0.01% 0.1% 1σ 100 m/s²
Roll/Pitch	0.03° 1σ	0.04° 1σ	0.05° 1σ
Heading	0.1° 1σ (dynamic)	0.1° 1σ (dynamic)	0.2° 1σ (dynamic)
Angular Rate – Bias – Scale Factor – Range	 0.01°/s 1σ 0.1% 1σ 100°/s	 0.01°/s 1σ 0.1% 1σ 100°/s	 0.01°/s 1σ 0.1% 1σ 100°/s
Track (at 50km/h)	0.08° RMS	0.1° RMS	0.2° RMS
Slip Angle (at 50 km/h)	0.15° RMS	0.15° RMS	0.25° RMS
Lateral Velocity	0.2%	0.2%	0.4%
Update Rate	100 Hz	100 Hz	100 Hz
Calculation Latency	3.9 ms	3.9 ms	3.9 ms
Power	9-18 V d.c. 20W	9-18 V d.c. 20W	9-18 V d.c. 20W
Dimensions	234 x 120 x 80 mm	234 x 120 x 80 mm	234 x 120 x 80 mm
Weight	2.3 kg	2.3 kg	2.3 kg
Operating Temperature	–10 to 50°C	–10 to 50°C	–10 to 50°C
Vibration	0.1 g²/Hz 5-500 Hz	0.1 g²/Hz 5-500 Hz	0.1 g²/Hz 5-500 Hz
Shock Survival	100G, 2ms ½ sine	100G, 2ms ½ sine	100G, 2ms ½ sine
Base Station Included	Yes	Yes	No
Internal Storage	512 MB	512 MB	512 MB
Twin Antenna	No	No	No
Upgradeable GPS	No	Yes	Yes

Note 1: For OmniStar HP continuous sky may be required for a long period of time (30 minutes or more) before the accuracy achieves 10cm. The OmniStar HP service can achieve this in complete open-sky and airborne applications.

Table 4. Performance Specification for the RT3000 Dual Antenna Systems

Product	RT3003	RT3022	RT3102
Positioning	L1/L2 Kinematic	L1 Kinematic	Stand Alone / DGPS
Position Accuracy	2cm 1σ open sky	20cm 1σ open sky	1.8m CEP Stand Alone 0.4m CEP DGPS
Velocity Accuracy	0.05 km/h RMS	0.08 km/h RMS	0.1 km/h RMS
Acceleration – Bias – Linearity – Scale Factor – Range	 10 mm/s² 1σ 0.01% 0.1% 1σ 100 m/s²	 10 mm/s² 1σ 0.01% 0.1% 1σ 100 m/s²	 10 mm/s² 1σ 0.01% 0.1% 1σ 100 m/s²
Roll/Pitch	0.03° 1σ	0.04° 1σ	0.06° 1σ
Heading	0.1° 1σ	0.1° 1σ	0.1° 1σ
Angular Rate – Bias – Scale Factor – Range	 0.01°/s 1σ 0.1% 1σ 100°/s	 0.01°/s 1σ 0.1% 1σ 100°/s	 0.01°/s 1σ 0.1% 1σ 100°/s
Track (at 50km/h)	0.07° RMS	0.1° RMS	0.2° RMS
Slip Angle (at 50 km/h)	0.15° RMS	0.15° RMS	0.25° RMS
Lateral Velocity	0.2%	0.2%	0.4%
Update Rate	100 Hz	100 Hz	100 Hz
Calculation Latency	3.9 ms	3.9 ms	3.9 ms
Power	9-18 V d.c. 20W	9-18 V d.c. 20W	9-18 V d.c. 20W
Dimensions	234 x 120 x 80 mm	234 x 120 x 80 mm	234 x 120 x 80 mm
Weight	2.4 kg	2.4 kg	2.4 kg
Operating Temperature	–10 to 50°C	–10 to 50°C	–10 to 50°C
Vibration	0.1 g²/Hz 5-500 Hz	0.1 g²/Hz 5-500 Hz	0.1 g²/Hz 5-500 Hz
Shock Survival	100G, 2ms ½ sine	100G, 2ms ½ sine	100G, 2ms ½ sine
Base Station Included	Yes	Yes	No
Internal Storage	512 MB	512 MB	512 MB
Twin Antenna	Yes	Yes	Yes
Upgradeable GPS	No	Yes	Yes

Environmental Protection

The RT3000 is 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.

Quick Guide to Operation

The basic operation of the RT3000 products is simple. The following steps should be taken to operate the units.

1. Fit the RT3000 system to the vehicle with the cable connections facing the rear of the vehicle. The LEDs should be to the left and the antenna connections to the right for normal, level operation.

2. Connect the User Cable (14C0009A) to the RT3000.

Figure 2. RT3000 System in vehicle

3. Connect the GPS Cable to the RT3000. For quick operation of dual antenna models connect to the primary (top) antenna connection and do not use the secondary antenna. Refer to the section on the secondary antenna for additional information on using the secondary antenna.

4. Connect the GPS Cable to the GPS antenna.

5. Secure the GPS antenna on the top of the vehicle where it has a clear view of the sky and is not obstructed at any angle by masts, aerials or other high objects. For best results before configuration of the RT3000 system try to keep the antenna roughly above the RT3000 system. (The RT3000 system will be delivered expecting the antenna to be 1m above the RT3000 unit with no X- or Y-axis displacement; it will assume that these measurements are accurate to about 1m).

6. Use the Null Modem Cable to connect J2 of the User Cable (14C0009A) to a serial port on a laptop computer. Run the program ENGINUITY.EXE (it can be run directly from the CD).

7. Apply power to the RT3000. The bottom LED will turn green to show that power has been applied. Wait for the top LED to flash red – this will happen when the operating system has booted and will take about 30 seconds. Wait for the top LED to turn permanently red – this will happen when the GPS receiver has found sufficient satellites to provide valid time, position and velocity and will take between 60 seconds and 20 minutes from power-on. (It is very rare for the GPS to take 20 minutes to find satellites, the typical lock time is less than 90 seconds, though if the unit has just been shipped from another part of the world then lock-time will increase).

8. Accelerate gently on a forward direction. The system will initialise and start to output data once the speed of the vehicle exceeds about 5 m/s (10 km/h). The top LED will turn orange (when real-time data is not yet available) and then turn green (after 10 seconds when the outputs are real-time and the latency is to specification).

The RT3000 is now operating. Fully specification will not be achieved within the first 15 minutes of operation. During this time dynamic vehicle manoeuvres will help the system achieve full specification.

Initialisation Process

Before the RT3000 can start to output all the navigation measurements it needs to initialise itself. Before it can initialise itself it needs to have all the measurements listed in Table 5, below.

Table 5. Quantities required for Initialisation

Quantity	Description
Time	Measured by internal GPS
Position	Measured by internal GPS
Velocity	Measured by internal GPS
Heading	Approximated to Course over Ground when the vehicle moves with large error. (Some Dual-Antenna systems can initialise when stationary)
Roll, Pitch	Vehicle Level option: Assumed zero with a large error Otherwise: Estimated over first 40s of motion with large error.

The system will start when it has estimates of all of these quantities. Course over Ground will be used to as the initial Heading when the system exceeds 5m/s (18kmh, about 11mph). If the system is mounted level in the vehicle then the Vehicle Level option will enable the system to start immediately. Otherwise the system requires about 40s to find approximate values for Roll and Pitch.

For the initialisation process to work correctly, the system 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 second behind so that the information from the GPS can be compared to the information from the inertial sensors. After initialisation the system has to "catch-up" this one second lag. It takes 10 seconds to do this, during the first 10 seconds the system cannot output data in real-time, the delay decays to the specified latency linearly over this 10 second period.

The user can identify that the outputs are not real-time because the Strapdown Navigator State LED is orange. When the system is running it real-time this LED is green.

Warm Up Period

During the first 15 minutes of operation the system will not conform to the 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, otherwise the errors will not be estimated and the specification will not be reached. The NCOM output message (and the CAN outputs) includes status information that can be used to identify when the required specification has been met.

System Outputs

The system can output data on two serial ports and over Ethernet; if the CAN bus option is selected then the second serial output is replaced by the CAN bus output. The outputs are available on the standard cables as follows:

Table 6. Output Connector functions

Connector	Function
J2	RS232 Serial Output, normally NCOM
J4	RS232 Serial Output, normally NCOM Optionally CAN bus output
J6	10T or 100T Ethernet

The standard serial output of the RT3000 is a proprietary binary format, referred to as NCOM, this is described in detail at the end of the manual. Oxford Technical Solutions offers C and C++ code that will interpret the packet. This can be used freely in user's programs to interpret the output of the RT3000. For those who wish to interpret the packet directly, the format is provided here.

It is also possible to have a standard NMEA output from the RT3000 to mimic the output of GPS standard receivers.

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

Co-ordinate Frame Conventions

The RT3000 uses a co-ordinate frame that is popular with most navigation systems. Figure 3, below, shows how the axes relate to the RT3000 box.

Figure 3. RT3000 Co-ordinate Frame Definition

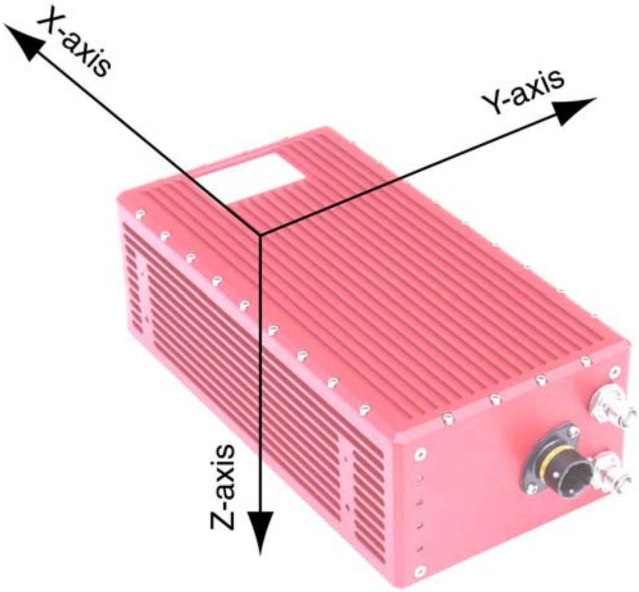


Table 7, below, lists the directions that the axes should point for zero heading, pitch and roll outputs when the default mounting orientation is used.

Table 7. 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 RT3000 and the Vehicle Axes are not the same as those listed in Table 7, above, then they can be aligned by reconfiguring the RT3000 for a different mounting orientation. See section *Changing the RT3000's Configuration*, below.

LED Definitions

The front panel of the RT3000 has four LEDs. These give an indication of the internal state of the system. They can also be used for some simple operational checks on the system. The definitions of the LEDs are given in Table 8, below.

Table 8. LED Descriptions

LED	Position	Description
1	Top	Strapdown Navigator State
2	Top-Middle	Single Antenna: Position Solution Dual Antenna: GPS Heading Solution
3	Bottom-Middle	OEM4 GPS: Self-test
4	Bottom	Power/Comms

Strapdown Navigator LED States

The Strapdown Navigator LED shows the state of the Strapdown Navigator in the system. Table 9, below, gives the states of this LED.

Table 9. Strapdown Navigator 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 Flash	The operating system has booted and the program is running. The GPS receiver has not yet output a valid time, position and velocity.
Red	The GPS 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 5 m/s then the Strapdown Navigator will initialise and the system will become active. On dual-antenna systems the system will initialise once the GPS receiver has determined heading, even if the vehicle is stationary or moving slowly.
Yellow	The Strapdown Navigator has initialised and data is being output, but the system is not real-time yet. It takes 10 seconds for the system to become real-time after startup.
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.

Position Solution (Single Antenna only)

The Position Solution LED shows what type of GPS solution is currently being used by the Kalman filter to update the Strapdown Navigator. Table 10, below, gives the states of this LED.

Table 10. Position Solution LED States

Colour	Description
Off	The GPS receiver does not have a valid position.
Red Flash	(Start-up only). The GPS receiver is sending data to the main processor. This is an operational check for the GPS receiver.
Red	The GPS receiver has a standard position solution (SA) or a differential solution (DGPS).
Yellow	The GPS receiver has a kinematic floating position solution (20cm accuracy).
Green	The GPS receiver has a kinematic integer position solution (2cm accuracy).

GPS Heading Solution (Dual Antenna only)

The GPS Heading Solution LED indicates the state of the dual antenna receiver. Table 11, below, defines the states of this LED.

Table 11. States of the GPS Attitude LED

Colour	Description
Off	GPS receiver fault. (Valid only after start-up).
Red Flicker	GPS receiver is active, but has been unable to determine heading.
Red	Integer uncalibrated heading lock.
Yellow	The receiver has a floating (poor) calibrated heading lock.
Green	The receiver has an integer (good) calibrated heading lock.

Self-Test LED

The Self-Test LED gives Novatel information about a failed GPS card. During normal operation this LED will flash Green.

Power/Comms LED

The Power/Comms LED shows the state of the internal 5V power-supply and the state of the TX line of the J2 connector. Table 12, below, gives the states of this LED.

Table 12. Power/Comms LED States

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

Fitting the Secondary Antenna

For best performance of the dual-antenna systems it is necessary to fit the secondary antenna to the system. The system is *very* sensitive to incorrect fitting and operation of the secondary antenna and these instructions should be followed carefully otherwise it is unlikely that the system will operate correctly.

Before fitting the secondary antenna bear the following information in mind:

1. In the default configuration the primary antenna should be at the front of the vehicle's roof and the secondary antenna should be at the rear.

2. The antenna separation must be correct to 3mm or better.

3. It is essential to orientate the antennas the same way. Always have the cable exiting from each antenna in the same direction. See Figure 4, below.

Figure 4. Dual-Antenna Orientations

4. For good multipath rejection the antennas must be mounted on a metal surface using the magnetic mounts provided; no additional gap may be used. Multipath affects stationary vehicle more than moving vehicles and it can lead to heading errors of 0.5 degrees RMS if the antennas are mounted poorly on the vehicle.

5. For both single antenna systems and dual antenna systems it is essential that the supplied GPS 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 5m antenna cable for one antenna and a 15m-antenna cable for the other. Do not extend the cable, even using special GPS signal repeaters that are designed to accurately repeat the GPS signal. Cable length options are available in 5m, 15m and 30m lengths.

6. Mount both antennas where they have a clear, unobstructed view of the whole sky from all angles.

7. It is critical to have the RT3000 mounted securely in the vehicle. If the angle of the RT3000 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 degrees

of mounting angle change throughout the testing. (If the RT3000 is shock mounted then the RT3000 mounting will change by more than 0.05 degrees; this is acceptable, but the hysteresis of the mounting may not exceed 0.05 degrees).

When shipped the antenna separation is set to 1000mm exactly. It is possible to change the antenna separation distance, either for ease of use or to change the performance (a larger distance will improve performance). Contact Oxford Technical Solutions for details on how to change the antenna separation.

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 GPS receiver cannot track the satellite signal as accurately.

The dual-antenna system in the RT3000 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 GPS receivers must measure the relative position to about 3mm. 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 RT3000 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 (for example, the GPS-600 supplied with the base-station). This type of antenna can be supplied as an option.

When stationary the heading from the RT3000 will show some drift, the size of the drift depends on the multipath in the environment. Table 13, below, lists the drift you can expect when stationary with a 1m base-line.

Table 13. Typical Heading Drift for when Stationary in different Environments

Environment	Typical Drift
Complete Open-Sky	0.3 degrees max (0.1 degrees 1σ)
Near Trees, Buildings	0.7 degrees
Next to Trees, Buildings	2 degrees

Typical figures using a 1m base-line.

Setting-up the Base Station

For correct operation of the higher accuracy systems it is necessary to use a base-station GPS receiver. Refer to Table 1, above, to see if the system includes a base-station. All of the systems can be successfully used without a base-station, however, the specification will only be met if a base-station is used.

The base-station is a separate GPS receiver that monitors the signals from the GPS satellites. Using its knowledge of position it works out the errors in each satellite's signal. It also measures the carrier-phase of the signal for kinematic corrections. The carrier-phase observations and the satellite signal errors are sent from the base-station GPS to the RT3000 via a radio modem (not provided).

The position of the base-station GPS antenna can either be determined by the base-station GPS receiver or can be surveyed in by a chartered surveyor. If the base-station GPS receiver determines its own position, through position averaging, then any error in the base-station receiver will also result in error at the RT3000. In order to relate the RT3000 signals to maps, or other items on the world, it is necessary to have a surveyor measure the position of the GPS antenna and then tell the base-station GPS receiver what position to use.

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

Using the RT-Base

The RT-Base system is a self-contained GPS, Radio Modem and Battery all in an IP65-rated 'Peli' case. For instructions on how to use the RT-Base see the RT-Base User Guide.

The RT-Base is supplied with a SATEL radio modem. This should be connected to the Radio connector of the RT3000 User Cable supplied (normally 14C0021A). This cable supplies power to the Radio Modem as well as sending the differential corrections to the RT3000.

Using the Novatel Power-Pak

For base-stations supplied as a Novatel Power-Pak (now superseded by the RT-Base) the following instructions apply.

You are advised to look at the Novatel Millennium GPSCard *Command Descriptions Manual* for more details on how the base-station operates. The manual includes a lot of information on base-stations and covers the topic in more detail than is described here.

Recently the type of base-station supplied has changed. The new base-station receivers use an OEM4 GPS card from Novatel, whereas the original ones use an OEM3 card. Please follow the instructions specific to your card where marked in the text.

To set up a base-station the following steps must be followed.

1. Place the base-station GPS receiver at a suitable location. The receiver should be inside in a dry environment and it will require a 12V (9-36V) d.c. power supply.

2. Place the GPS antenna where it has a clear view of the whole sky. It is very important for the base-station GPS to have full view of the whole sky; any satellite it cannot receive cannot be used by the RT3000, even if the RT3000 can see the satellite. It is also important to place the GPS antenna in a low multipath environment.

3. Connect the GPS antenna to the base-station GPS receiver using the GPS antenna cable provided.

4. Connect COM1 of the base-station GPS receiver to a laptop computer

5. Run Novatel's GPSoln32 (OEM3 model) software or GPSolution4 (OEM4). (This software is included on the RT3000 Software CD in the OEM3/OEM4 directory. It will need to be installed on the computer.)

6. Open a connection to the GPS receiver. Any baud rate can be used as the software will search for the correct baud rate. Open a Command Console window and an ASCII Logs window. The best baud rate to use for connecting to the base-station is the default, 9600.

7. If the base-station GPS receiver is determining its own position use the `POSAVE` command to average the position and then store it. For example, to average the position for 0.1 hours (6 minutes) type:

   `POSAVE 0.1↵` (OEM3 or OEM4 receiver)

   If the base-station antenna position is known then use the `FIX POSITION` command to enter the exact position of the antenna. For example, to fix the position of the GPS antenna at 51.3455323 degrees north latitude, 114.289534 degrees west longitude and 1201.123 metres above the geoid reference type:

   `POS FIX 51.3455323 -114.289534 1201.123↵` (OEM3)

   `FIX POSITION 51.3455323 -114.289534 1201.123↵` (OEM4)

   Refer to the Novatel Millennium GPS Card *Commands Description Manual* for more details on these commands.

8. Once the base-station has fixed its position, this position can be saved to non-volatile memory and used automatically next time the GPS receiver is turned on. To do this type:

   `SAVECONFIG↵`

9. While the base-station is averaging its position connect COM2 of the base-station GPS to the radio modems. The communications settings of the radio modem will have to match the communication settings of the GPS receiver, listed below.

Note: If the base-station antenna is moved then it is necessary to re-average the position or to re-enter the new surveyed co-ordinates. Once the base-station has had its position fixed the valid position light will be on, even when there are no valid satellites (i.e. at start-up before it has correctly acquired the satellites and before it is transmitting valid corrections).

Changing the RT3000's Configuration

The default parameters that the RT3000 is shipped with will work for most applications. To get the best results from your RT3000 it is necessary to change the configuration to suit the way you have installed the RT3000 in your vehicle.

The program `RT3000Cfg.EXE` can be used to do this. This section describes how to use `RT3000Cfg` and gives additional explanations on the meanings of some of the terms used.

It is only possible to change the RT3000's configuration using Ethernet. It is necessary to have the Ethernet on your computer configured correctly in order to communicate with the RT3000 and change the settings.

Overview

In order to give the best possible performance, the RT3000 needs to know the following things:

- The orientation that the RT3000 is mounted at in the vehicle
- The position of the Primary GPS antenna compared to the RT3000
- The orientation of the Dual-antennas compared to the RT3000
- Some environment parameters

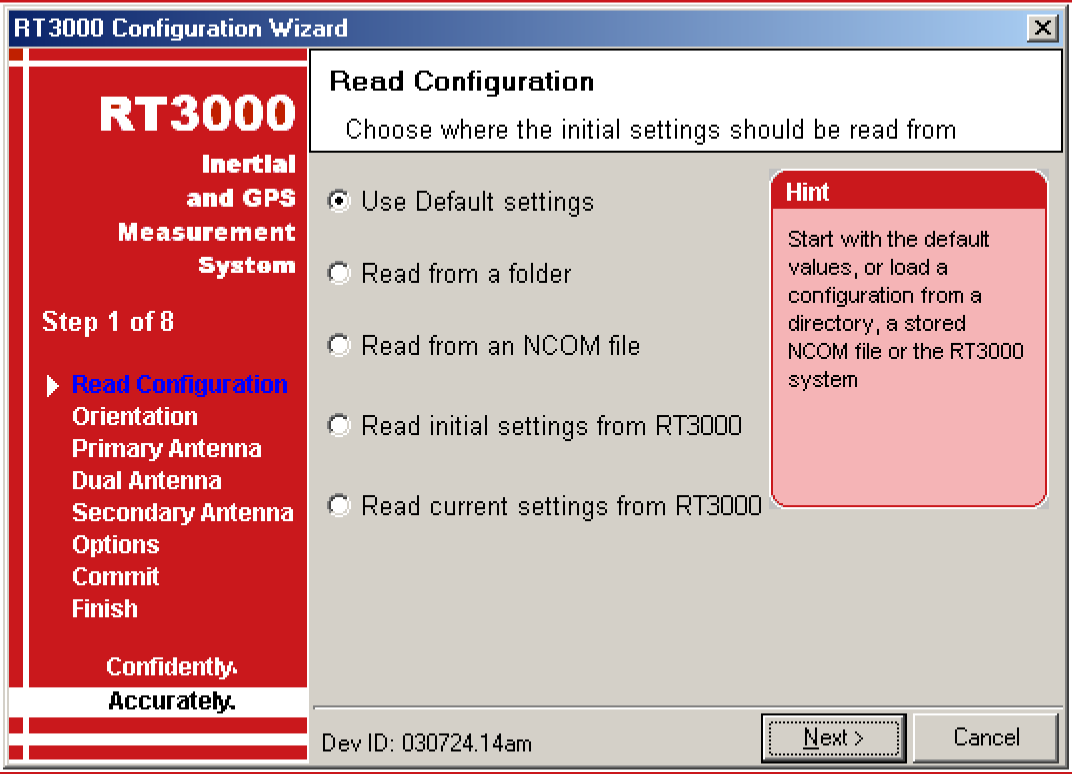
Many of these parameters the RT3000 can figure out by itself, but this takes time. Measuring the parameters yourself and configuring the RT3000 shortens the time before full specification can be met.

If the RT3000 has been running for some time, it will have improved the measurements that you have made. It is possible to read these improved measurements into `RT3000Cfg`, commit them to the RT3000 and then use them next time you start the system. If you move the RT3000 from one vehicle to another it is essential that you return to the default configuration rather than using a set of parameters that have been *tuned* for a different vehicle.

Reading the Initial Configuration

The first page of `RT3000Cfg` gives several options for reading the configuration from different places. Figure 5, below, shows `RT3000Cfg` just after it is started.

Figure 5. `RT3000Cfg` Initial Screen



Default Settings. To use the default settings select this radio button. The following pages will contain the default settings that the RT3000 was delivered with.

Read 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 radio button. A group box will appear and the folder can be selected.

Read from an NCOM File. If the RT3000 has been running for some time then it will have improved the configuration parameters. If the NCOM file was logged to disk then the improved parameters can be read from this NCOM file. Select this radio button and choose the file in the group box that appears.

Read Initial Settings from RT3000. If the RT3000 is connected to the computer via Ethernet then it is possible to read the initial settings directly from the RT3000. The initial settings are the settings that the RT3000 starts up with, before it makes any improvements. Select this radio button and enter the correct IP address of your RT3000.

Read Current Settings from RT3000. If the RT3000 has been running for some time then it will have improved the configuration parameters. `RT3000Cfg` can pick up the improved settings from a serial (COMM) port that is transmitting NCOM or from the UDP Ethernet broadcasts.

Orientation of the RT3000 in the vehicle

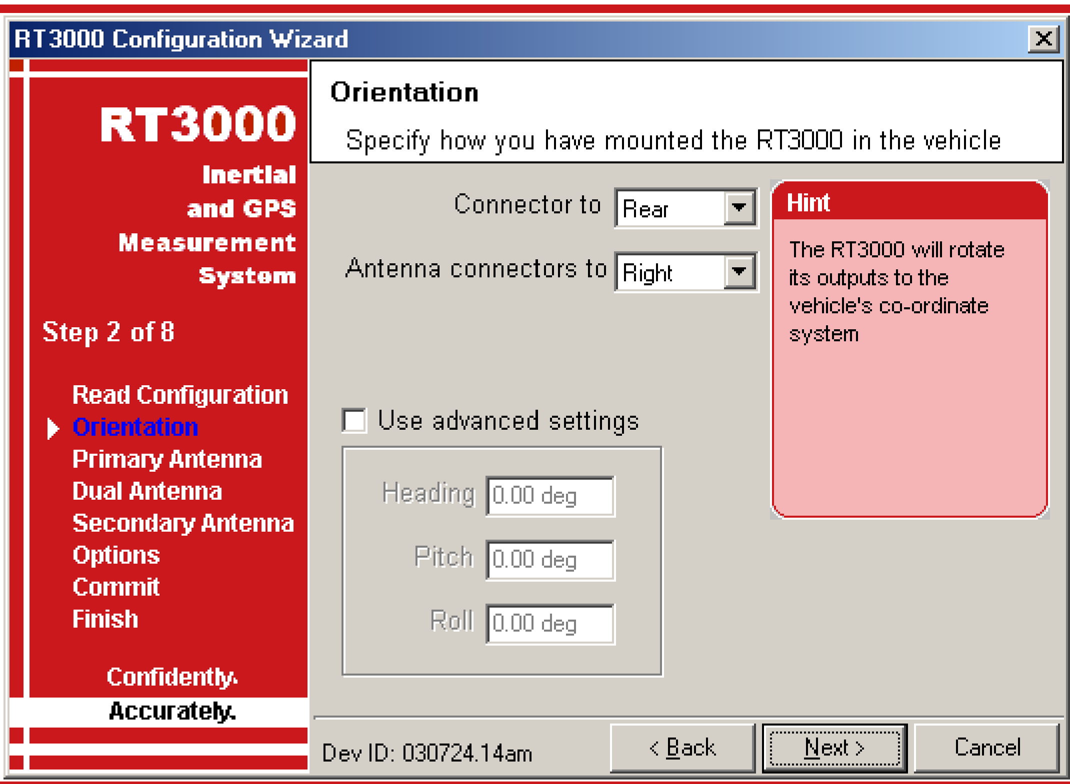
The RT3000 can be mounted at any angle in the vehicle. The outputs can be rotated so that the measurements can be referenced to the vehicle co-ordinate frame. For correct initialisation it is also necessary to get the heading orientation correct. If the 'vehicle level' option is used then the pitch and roll orientations must also be correct.

The RT3000 gets its initial heading by assuming that the lateral velocity or slip angle is small. If the definition of the vehicle's X-axis (forward direction) is incorrect in the RT3000 then it will not initialise correctly when the vehicle drives forwards.

The orientation of the RT3000 in the vehicle is normally specified using three consecutive rotations that rotate the RT3000 to the vehicle's co-ordinate frame. The RT3000 co-ordinate conventions are listed in Figure 3, above and Table 7, above.

Figure 6, below, shows the orientation screen of `RT3000Cfg`.

Figure 6. `RT3000Cfg` Orientation Screen



To make it simpler to configure the RT3000's orientation in the vehicle `RT3000Cfg` asks the user to define the direction that the main connector points in the vehicle. After that stand facing the main connector and enter the direction that the antenna connectors are compared to the main connector.

In the list there is no option for the main connector facing upwards or downwards. It is necessary to use the advanced settings to configure the unit to be mounted this way.

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

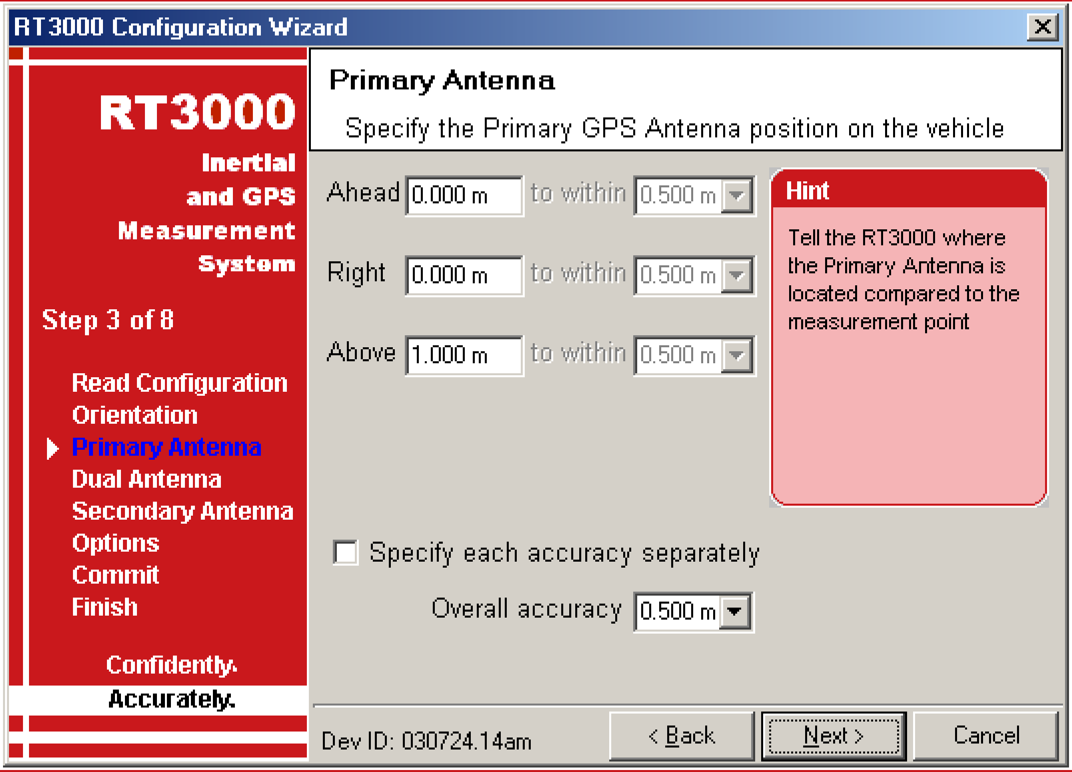
Although it is possible to mount the RT3000 in any orientation, Dual antenna systems do not perform as well when mounted with the main connector pointing upward or downward. There is a singularity in the GPS Antenna Orientation estimates when the mounting pitch angle is at 90 degrees. To avoid this, Dual antenna systems should not be mounted with pitch close to 90 degrees. Single antenna systems are not affected.

Specifying the Position of the Primary Antenna

The RT3000 is able to measure 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 incorrect is one of the main reasons for poor results from the RT3000, so it is important to be careful with the measurements.

Figure 7, below, shows the Primary Antenna screen.

Figure 7. **`RT3000Cfg`** **Primary Antenna Screen**



It is necessary to tell the RT3000 the distance from the measurement point (shown on diagram 14A0007*x* at the end of this manual) to the GPS antenna measurement point. This should be entered in the vehicle's co-ordinate frame (note that the software deliberately uses a left-handed co-ordinate frame here because it is conceptually easier).

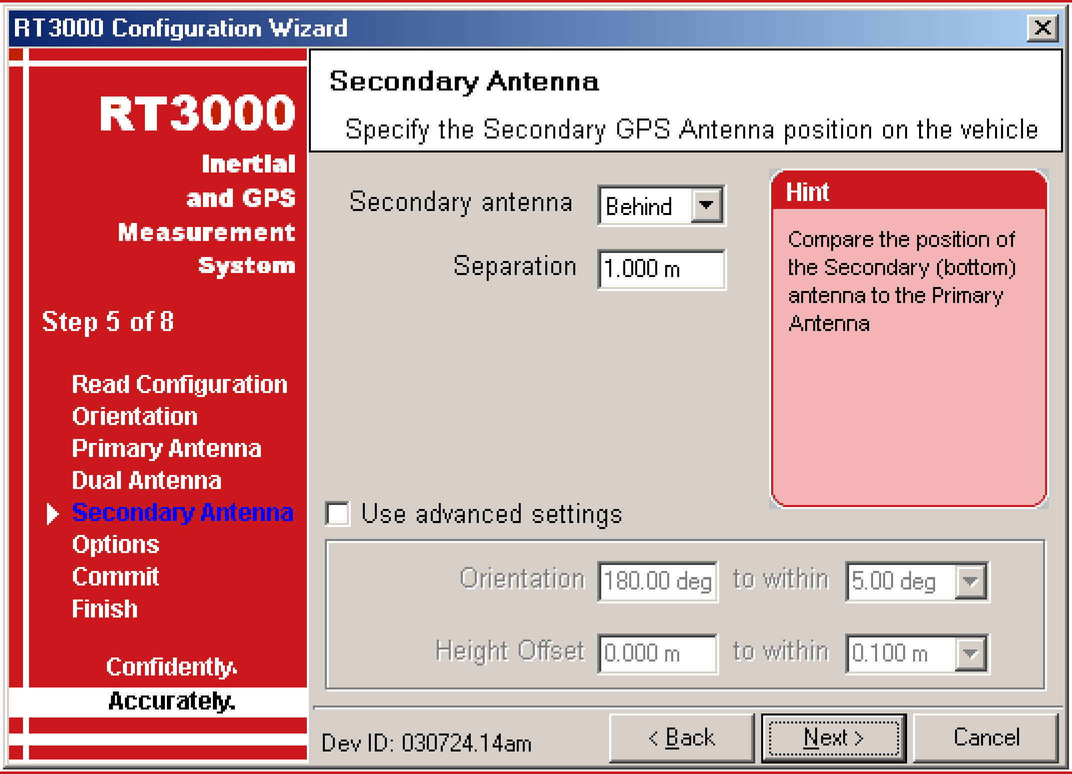
The accuracy of the measurements should also me specified. Care should be taken here because it is very easy to measure distance to 1cm or better in a straight line. It is much harder to measure to 1cm through a car roof and it is much harder to measure to 1cm if the RT3000 is slightly misaligned in the vehicle. Any alignment errors should be included in the accuracy that you believe you can measure to.

Telling the RT3000 that you have measured the distances to 1mm may lead the RT3000 to believe its results are better than they really are. You may be impressed by the accuracy that the RT3000 reports, but in reality it will not be that accurate. It is better to overestimate the accuracy than to underestimate it.

Specifying the Orientation of the Secondary Antenna

If your system has two antennas then it is necessary to tell the RT3000 the orientation of the two-antenna system compared to the vehicle. It is critical to tell the RT3000 the exact distance between the two antennas (to 5mm or better).

Figure 8. `RT3000Cfg` Secondary Antenna Screen



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 of the bonnet (hood), in reality the multi-path reflections from the windscreen will degrade the performance of the system.

If the antennas are mounted at significantly different heights or if the mounting angle is not directly along a car axis (forward or right) then use the advanced settings.

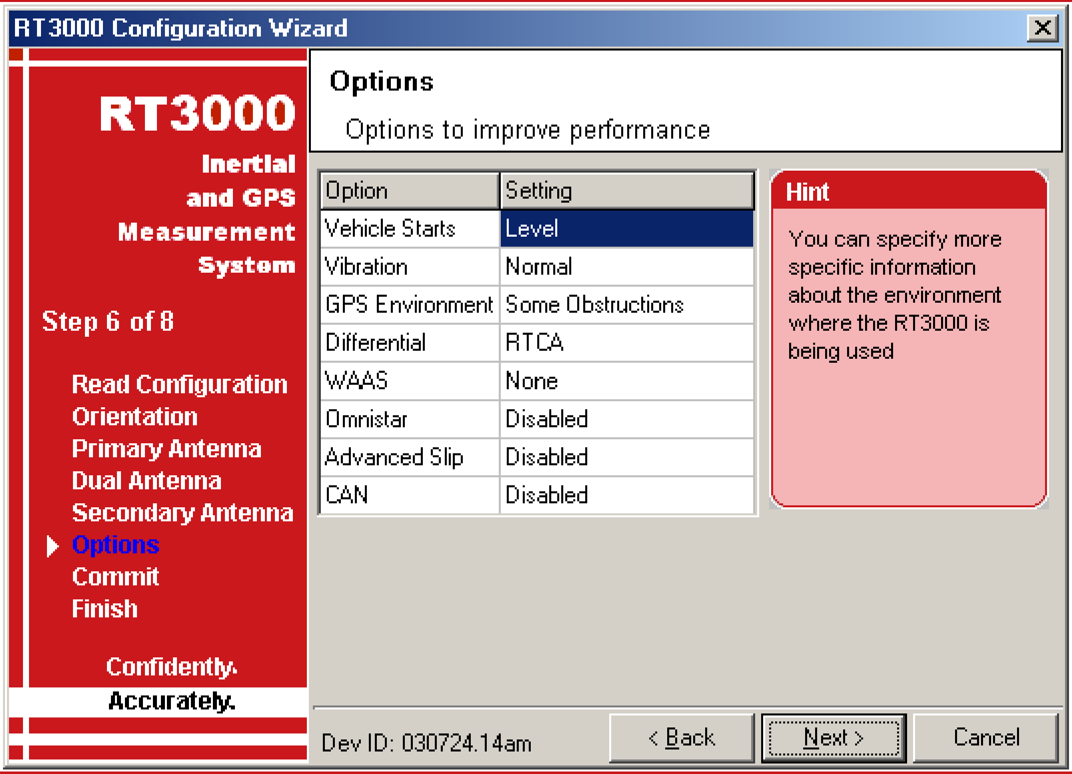
Getting the angle wrong by more than 3 degrees can lead the RT3000 to lock on to the wrong heading solution. The performance will degrade or be erratic if this happens.

The RT3000 does not estimate the distance between the two antennas. It is essential to get this right yourself, otherwise the system will not work correctly and the performance will be erratic.

Setting the Correct Options

The options screen gives some settings that should be changed if you are experiencing trouble. Figure 9, below, shows the Options screen.

Figure 9. `RT3000Cfg` Options Screen



If you know that the vehicle will be level when starting (to within about 5 degrees) then the *Level* option can be used. This saves about 40 seconds during the initialisation process since the RT3000 does not have to take the time to compute an initial roll and an initial pitch. In high vibration environments the *Not Level* option may not work and so the RT3000 can only start if the vehicle is level and the *Level* option has been specified.

The *Normal* vibration level is adequate for most circumstances. The RT3000 is very tolerant of vibration and has been used successfully in environments with more than 2g RMS using the Normal setting. If the velocity innovations are very high and many GPS packets are being dropped then this setting can be changed.

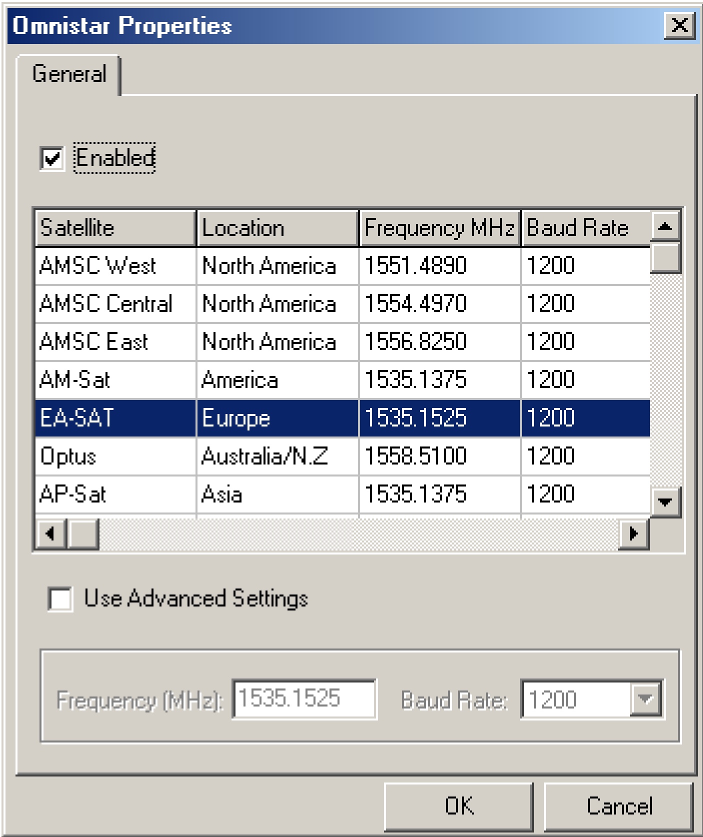
If the system is used predominantly in open-sky then the *open-sky* setting should be used. In environments with a lot of GPS multi-path the other two settings can be used. This will allow less accurate GPS measurements to update the system.

The RT3000 can be configured to use several different Differential correction message types on connector J3. The RT-Base transmits RTCA messages. RTCM (RTCM-104) or CMR (Trimble) can also be selected or the port can be disabled. The Advanced option should not be used except in specialised applications. The corrections are always received at 9600 baud.

For WAAS enabled systems the GPS receiver can be set up to receive corrections in North America or Europe. Because WAAS (North America) and EGNOS (Europe) are in test mode they can sometimes be unreliable; the corrections can be disabled by selecting *None*. For systems that do not have WAAS capability this setting has no effect and is ignored.

For OmniStar Enabled Systems the correct satellite should be selected for the region where you are operating. The correct satellite must be selected before OmniStar can send a new license. For systems that do not have OmniStar capability this setting has no effect and is ignored.

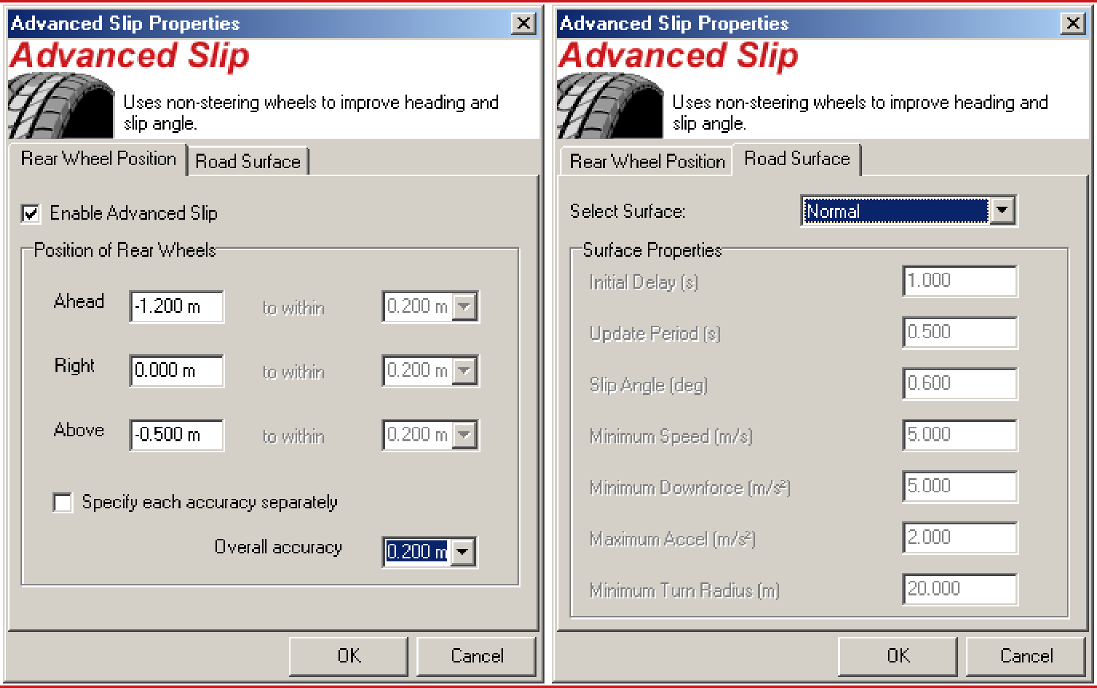
Figure 10. `RT3000Cfg` OmniStar Properties



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 use the *Advanced Settings* to set the Satellite's Frequency and Baud Rate.

The Advanced Slip feature uses characteristics of land vehicle motion to improve heading and slip angle. This feature **must** be disabled for airborne and marine systems where the lateral velocity can be significant. The Advanced Slip feature applies heading correction when the land vehicle is not slipping; when the car is slipping the lateral acceleration is usually large enough so that the normal heading corrections provide excellent results.

Figure 11. `RT3000Cfg` Advanced Slip Properties



For the Advanced Slip feature to work correctly the system needs to know the position of the rear-wheels on a vehicle with front-wheel steering. (Vehicles with rear-wheel steering should use the front wheels; vehicles with all wheels steering cannot use this feature reliably). 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.

The Advanced Slip feature also requires some knowledge of the road surface. Three pre-defined options are given, *Normal, Low Friction (Ice)* and *High Friction*. The *Other* feature should not be used.

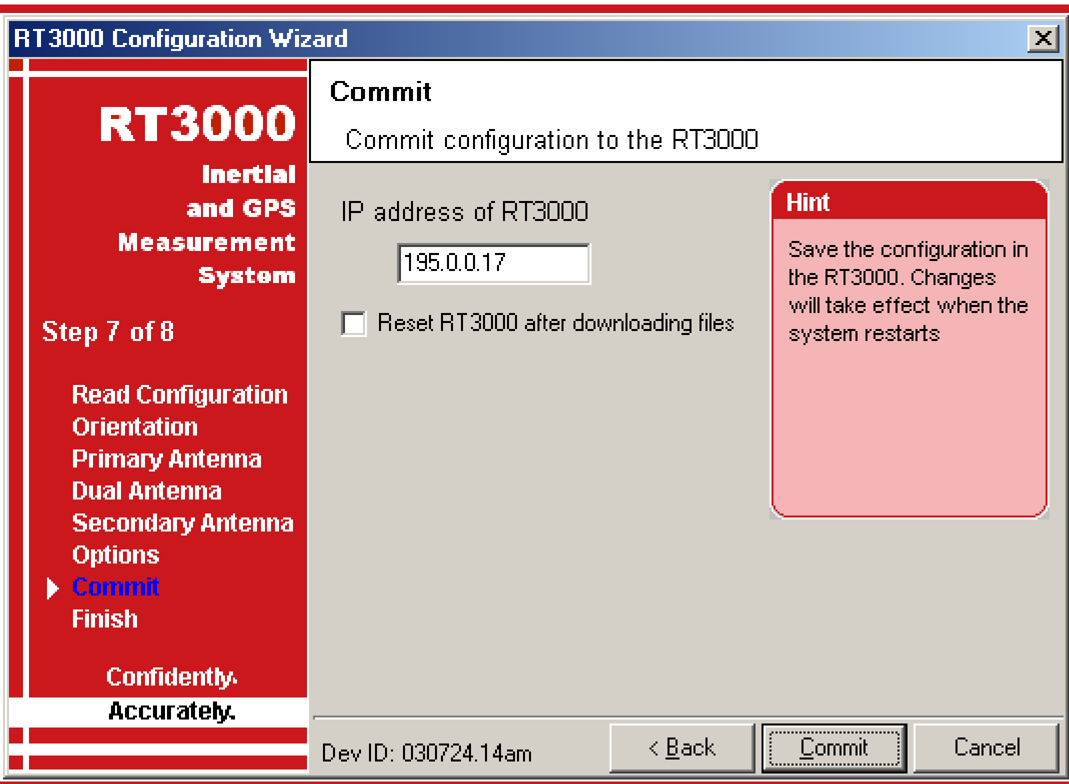
The CAN bus can be enabled or disabled. In systems without the CAN option this should be set to *Disabled*.

Committing the Configuration to the RT3000

The changes to the RT3000 settings must be performed using Ethernet. It is necessary to configure your computer's Ethernet settings so it is on the same network as the RT3000. If necessary, ask you system administrator to help.

Figure 12, below, shows the Commit screen.

Figure 12. `RT3000Cfg` Commit Screen



Enter the IP address of the RT3000 that you want to configure. The IP address is usually 195.0.0.*x* where *x* is the serial number of the RT3000.

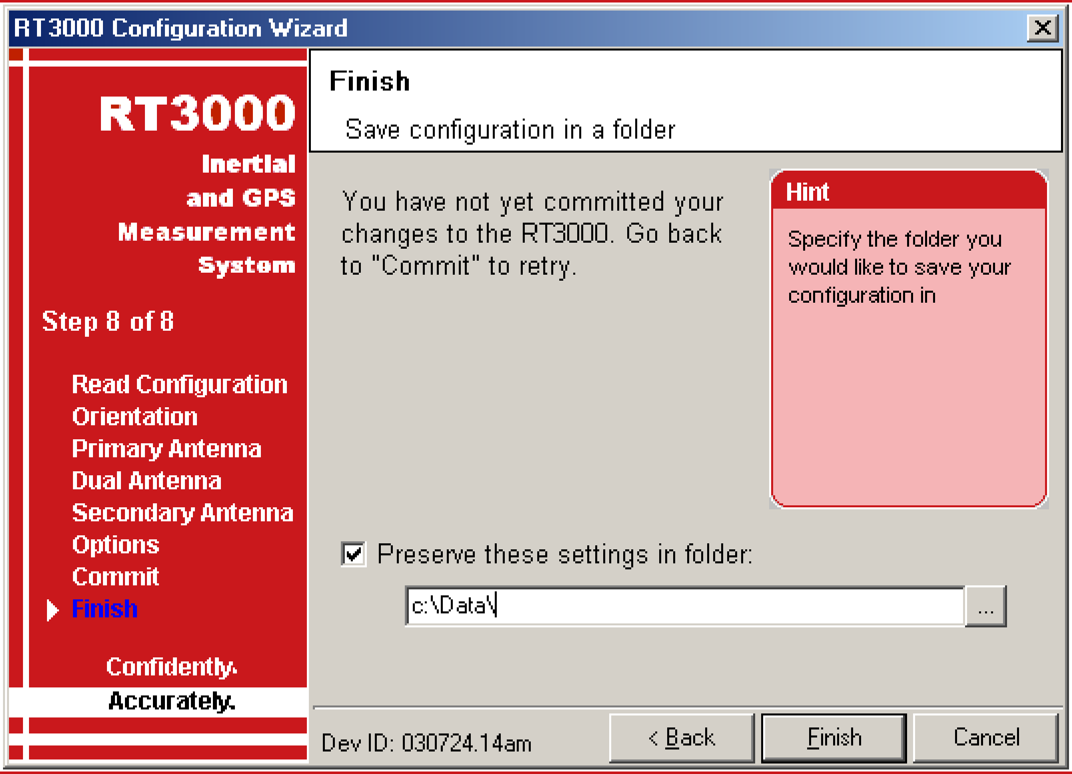
The changes to the configuration do not take effect until after the RT3000 is reset (or next power on). To reset the RT3000 after downloading check the *Reset RT3000 after downloading files* check box.

Press *Commit* to save the configuration on the RT3000.

Saving a copy of the settings locally

Before finishing it is possible to save a copy of the settings in a folder on your computer. This can then be reloaded next time. The Finish screen also lets you know if the settings have been committed successfully to the RT3000 or not. Figure 13, below, shows the Finish screen.

Figure 13. `RT3000Cfg` Finish Screen



To save a copy of the settings in a local folder check the *Preserve these settings in folder* check box and enter the folder name.

Ethernet Configuration

To obtain maximum use of the RT3000 it is necessary to use the Ethernet connection. The operating system at the heart of the RT3000 product 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 uploaded 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 RT3000.

The RT3000 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 RT3000.

It is advisable to use the RT3000 on its own private network. This will help avoid loss of data through collisions on the network. Due to processing restrictions in the unit and collisions on the network it is advisable not to use the FTP services while the unit is being used to process data. The FTP server has a very low priority and will be slow while the RT3000 is running (i.e. while the top LED is green).

The settings of the RT3000's Ethernet adapter are given in Table 14, below.

Table 14. RT3000 Ethernet Settings

Setting	Value
IP Address	195.0.0.*x* where *x* is the serial number.
Subnet Mask	255.255.255.0
FTP User	"user"
FTP User Password	"user"

For details on the output packet format of the UDP broadcast, contact Oxford Technical Solutions.

Connection Details

The RJ-45 connector on the 14C0009*x* User Interface Cable is designed to be connected directly to a network hub. To extend the cable it is necessary to use an "In-Line Coupler". This is two RJ-45 sockets wired together in a straight-through configuration. Following the "In-Line Coupler" a normal, straight UDP Cat 5e cable can be used to connect the coupler to the hub.

The RT3000 can also be connected directly to an Ethernet card in a computer. To do this a "Crossed In-Line Coupler" must be used. The connections in the crossed coupler are given in Table 15, below. Note that this is not the normal configuration sold and it may be necessary to modify an existing coupler to suit.

Table 15. In-Line Coupler Connections

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

A typical In-Line Coupler is shown in Figure 14, below.

Figure 14. In-Line RJ-45 Coupler

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. If there is a `mobile.vat` file in your system to convert from the RT3000 co-ordinate frame to the vehicle's co-ordinate frame then it needs to be removed and the system needs to be restarted.

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

3. Orient the RT3000 in the following ways and check that the accelerations measurements are within the specifications shown in Table 16, below.

Table 16. Acceleration Measurement Specifications

Orientation			Acceleration Measurement
X	Y	Z	
Flat	Flat	Down	Z-Acceleration between –9.7 and –9.9m/s²
Flat	Flat	Up	Z-Acceleration between 9.7 and 9.9m/s²
Down	Flat	Flat	X-Acceleration between –9.7 and –9.9m/s²
Up	Flat	Flat	X-Acceleration between 9.7 and 9.9m/s²
Flat	Down	Flat	Y-Acceleration between –9.7 and –9.9m/s²
Flat	Up	Flat	Y-Acceleration between 9.7 and 9.9m/s²

This test is sufficient to ensure that the accelerometers have not been damaged. Typically a damaged accelerometer will read full scale (about 100m/s² or –100m/s²) or will not change its value.

Gyro Test Procedure

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

1. If there is a `mobile.vat` file in your system to convert from the RT3000 co-ordinate frame to the vehicle's co-ordinate frame then it needs to be removed and the system needs to be restarted.

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

3. Rotate the RT3000 according to Table 17, below, 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 RT3000 will work to specification with biases up to ±5°/s).

Table 17. 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 Oxford Technical Solutions.

Note that the RT3000 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 RT3000 to go for long periods without requiring recalibration.

Testing the Internal GPS and other Circuitry

To check that all the internal circuits in the RT3000 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 (`ENGINUTIY.EXE`).

2. Use Table 18, below, to check that the status fields are changing.

Table 18. Status Field Checks

Field	Increment Rate
IMU Packets	100 per second
IMU Chars Skipped	Not changing (but not necessarily zero)
GPS Packets	Between 2 and 20 per second (depending on system)
GPS Chars Skipped	Not changing (but not necessarily zero)
GPS2 Packets	Between 2 and 20 per second (only for dual-GPS systems)
GPS2 Char Skipped	Not changing (but not necessarily zero)

These checks will ensure that the signals from the GPS and from the Inertial Sensors are being correctly received at the navigation computer.

Deriving further Measurements

The RT3000 outputs are complete for all aspects of vehicle motion apart from angular acceleration. There are instances when other outputs will be required, or when the same output is required in a different measurement co-ordinate frame. For example, you may wish to compute the following parameters:

1. compute velocity at a point remote from the RT3000 measurement point;
2. compute the slip angle of the vehicle;
3. compute the lateral acceleration perpendicular to gravity (so that vehicle roll does not affect the measurements);
4. plot position on a flat metric grid

Many of these outputs are computed using the RT-CAN unit or using the software provided. The equations are provided here to help understanding and to make it easier for engineers who need to write their own interpreters for the RT3000 output.

Before computing the additional outputs, you should have a clear understanding of the definitions of heading, pitch and roll. The RT3000 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 RT3000 has rules to avoid problems when operating close to the singularities; if you regenerate the rotation matrices given below then they will be correct.

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

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

$$V_n = C_{bn} \cdot V_b$$

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

where:

> ψ is the heading angle;
> θ is the pitch angle and
> φ is the roll angle.

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

Computing a Velocity at a remote point

You can use the outputs of the RT3000 to compute the velocity at any other point on the vehicle (assuming that the vehicle is rigid). Velocity measurements from the RT3000 are expressed in the navigation co-ordinate frame, whereas the remote point is expressed in the body co-ordinate frame. The following formula relates the outputs of the RT3000 to a velocity at a remote point:

$$V2_n = V_n + C_{bn} \cdot (\omega_b \times \rho_b)$$

where:

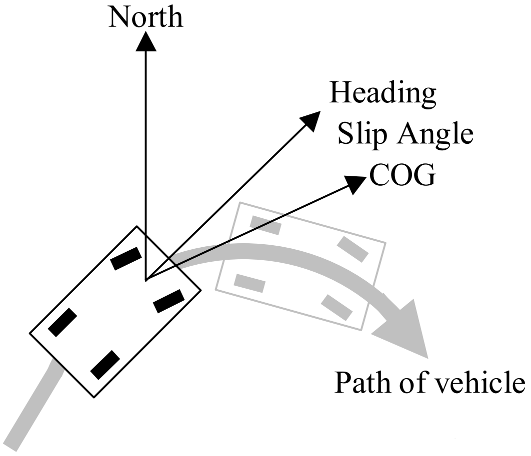
> $V2_n$ is the velocity at the remote point;
> V_n is the velocity at the RT3000;
> C_{bn} is the rotation matrix above;
> ω_b is the angular rate vector in the body co-ordinate frame and
> ρ_b is the distance from the RT3000 to the remote point expressed in the body co-ordinate frame.

The operator between ω_b and ρ_b is the cross-product operator.

Computing the Slip Angle

The Slip Angle, or Yaw angle is the difference between the Heading and the direction of travel over the ground.

Figure 15. Relationship between Heading, Slip Angle and COG



In Figure 15, above, the Heading angle is the angle that the vehicle is *pointing* compared to North. The *Course over Ground* is the direction that the vehicle is going *over the ground*; this angle varies depending on the position in the car and it depends on whether the car is slipping across the surface of the road or not. The *Course over Ground* direction is also known as *Track*, *Track over Ground*, *Vector* or *Vector Velocity*.

The *Slip Angle* is the difference between the *Heading* and the *Course over Ground*.

To compute the Slip Angle it is necessary to compute the Track angle first. The track angle can be computed *only when speed is non-zero* using the four quadrant arc-tan function (usually called atan2):

$$\text{Track} = \text{atan2}\left(V_e, V_n\right) \cdot \frac{180}{\pi}$$

The Slip Angle is then:

$$\text{Slip} = \text{Heading} - \text{Track}$$

You should test the slip angle to make sure it is in the correct range (±180°). If not you will get large spikes in your data (for example, if heading is 0.1° and Course over Ground is 359.8° then you need to add 360° to your result).

Computing Forward and Lateral Velocities

Speed is the total rate of travel in any given direction. It can be expressed as a horizontal speed or a 3D speed. Forward Velocity is usually very close to speed, except when the vehicle skids. The Lateral Velocity is usually very close to zero, except when the vehicle skids.

The Forward and Lateral Velocities can be found by rotating the velocities in the navigation co-ordinate frame to be in the direction of the vehicle (using the heading angle). The rotation required to compute the Forward and Lateral Velocities are:

$$V_L = C_{Ln} \cdot V_n = \begin{bmatrix} \cos(\psi) & \sin(\psi) & 0 \\ -\sin(\psi) & \cos(\psi) & 0 \\ 0 & 0 & 1 \end{bmatrix} \cdot V_n$$

where:

V_L is the vector containing the Forward and Lateral Velocities (and Down Velocity);

C_{Ln} is the rotation matrix from the navigation co-ordinate frame to a level co-ordinate frame where the X-axis is aligned to the heading of the vehicle and

V_n is the velocity in the navigation co-ordinate frame.

Computing the Forward, Lateral and Down Accelerations

When the vehicle rolls, the Y-Acceleration measured in the body co-ordinate frame contains a component of gravity because the Y-direction is no longer at right angles to gravity. A roll angle as small as 1° gives a Y-acceleration of 0.171m/s² just from the coupling of gravity. The RT3000 can measure acceleration to 10mm/s² and has a resolution of about 0.1mm/s² at 100Hz (nearly 2000 times better than the gravity caused by a 1° rotation).

To compute the accelerations in a level co-ordinate frame (where gravity does not affect the acceleration measurements) use the following rotation:

$$A_L = C_{Lb} \cdot A_b = \begin{bmatrix} \cos(\theta) & 0 & \sin(\theta) \\ 0 & 1 & 0 \\ -\sin(\theta) & 0 & \cos(\theta) \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\phi) & -\sin(\phi) \\ 0 & \sin(\phi) & \cos(\phi) \end{bmatrix} \cdot A_b$$

where:

A_L is the vector containing the Forward, Lateral and Down accelerations;

C_{Lb} is the rotation from the body co-ordinate frame to the level co-ordinate frame and

A_b is the vector of accelerations on the body co-ordinate frame.

Using a Flat Metric Grid

Because the earth is elliptical it is not possible to have distance in metres that make sense on the whole globe. Over a small, local area (for example, 10km) the effects of earth curvature can be ignored and a local, square grid can be used.

When working on a local grid the measurements for position will be expressed as Northings and Eastings (i.e. the number of metres North of an origin and the number of metres east of an origin). It is necessary to choose an origin where the Northings and Eastings are zero, we will call this the *base latitude* and the *base longitude*. Then we can compute the Northings and Eastings using the following equations:

$$\text{Northings} = (\text{Latitude} - \text{Base\_Latitude}) \cdot \left(6378137 \cdot \frac{\pi}{180}\right)$$

$$\text{Eastings} = (\text{Longitude} - \text{Base\_Longitude}) \cdot \left(6378137 \cdot \frac{\pi}{180}\right) \cdot \cos\left(\text{Base\_Latitude} \cdot \frac{\pi}{180}\right)$$

In each of these equations the Latitude, Longitude, Base Latitude and Base Longitude are all expressed in degrees. The Northings and Eastings are measured in metres.

Computing Performance Metrics

There are several methods of monitoring the performance from the RT3000. For each state a Kalman filter has there is a corresponding accuracy. In the RT3000 there are accuracies for all of the Kalman filter states. These are available in the NCOM output format.

The most useful quantities that measure performance of the system are the Position accuracies, the Velocity accuracies, the Heading, Pitch and Roll accuracy. Since these are 9 separate measurements, it is often useful to group them into fewer values that can be monitored.

Position Accuracy. In general it is best to monitor the *horizontal position accuracy*. This can be computed from the *North Position Accuracy* and the *East Position Accuracy* fields in the Status Information of the NCOM output. Use the formula:

$$\text{HorizontalPositionAccuracy} = \sqrt{\frac{\text{PosAccNorth}^2 + \text{PosAccEast}^2}{2}}$$

Velocity Accuracy. Similar to Position Accuracy, in general it is more useful to monitor the *horizontal velocity accuracy*. This can be computed from the *North Velocity Accuracy* and the *East Velocity Accuracy* fields in the Status Information of the NCOM output. Use the formulae:

$$\text{HorizontalVelocityAccuracy} = \sqrt{\frac{\text{VelAccNorth}^2 + \text{VelAccEast}^2}{2}}$$

$$\text{VelocityAccuracy} = \sqrt{\frac{\text{VelAccNorth}^2 + \text{VelAccEast}^2 + \text{VelAccDown}^2}{3}}$$

Orientation Accuracy. Since the Heading specification and the Pitch/Roll specifications are not the same, it is best to monitor the Orientation accuracy as a combined Pitch/Roll (attitude) accuracy and a separate Heading accuracy. To combine the Pitch/Roll accuracy use the formula:

$$\text{AttitudeAccuracy} = \sqrt{\frac{\text{PitchAcc}^2 + \text{RollAcc}^2}{2}}$$

The Heading accuracy is output directly by the RT3000.

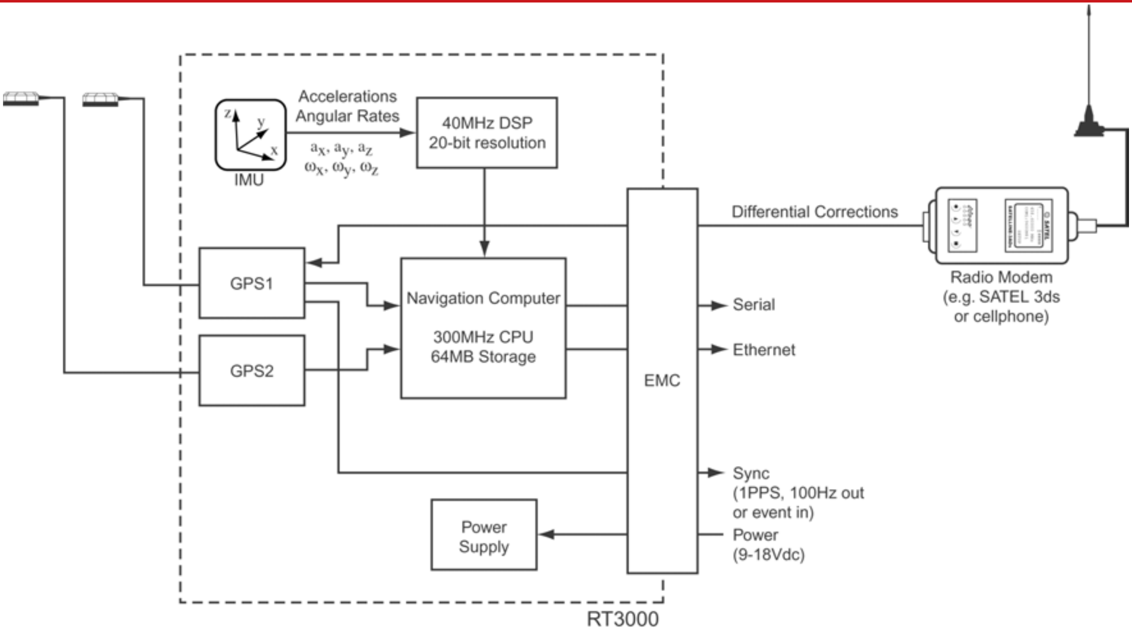
Operating Principles

This short section gives some background information on the components in the RT3000 and how they work together to give the outputs. A short overview of the algorithm is given and some explanation of how the software works. The section is provided as 'interesting information' and is not required for normal operation.

Internal Components

Figure 16, below, gives a schematic view of the components in the RT3000 system.

Figure 16. Schematic showing the internal components of the RT3000



The schematic shows the layout for a dual-antenna system, the second GPS (GPS2) and the second antenna are not fitted on single antenna systems.

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

The sampling process in the Inertial Measurement Unit is synchronised to GPS time so that the 100Hz measurements from the RT3000 are synchronised to GPS.

The Navigation Computer is a 300MHz CPU Pentium class processor that runs the navigation algorithms (more on this below). Information from the DSP and the two GPS receivers is fed into the Navigation Computer. The Navigation Computer runs a real-time operating system (QNX) so that the outputs are made in a deterministic amount of time. The outputs from the Navigation Computer are available over Serial RS232 or as a UDP broadcast on Ethernet.

The Sync pin on the output of the RT3000 is normally configured as a 1PPS output (directly from the GPS card). It may also be configured as a 100Hz sampling output or as an event input. As an event input the RT3000 is able to time when the input becomes closed-circuit. An internal pull-up resistor keeps the voltage high and the Sync pin can be connected directly to a brake switch or a camera shutter trigger. Accurate timing in the RT3000 can measure this event with 1µs resolution. No more than one event per second should be made.

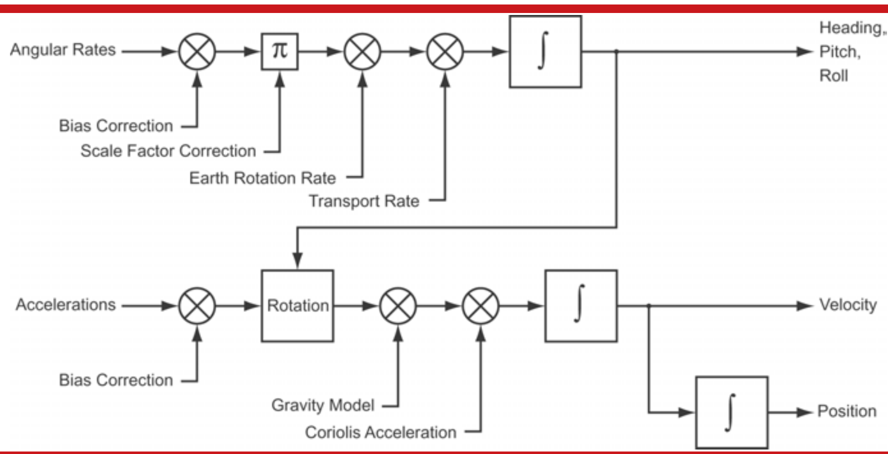
Differential corrections can be supplied directly to the GPS receiver to improve the positioning accuracy. The differential corrections can be supplied via radio modems from a base-station, via cell phones from a base-station or from a separate differential source, such as OmniStar or US Coast Guard.

Strapdown Navigator

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

Figure 17, below, shows a basic overview of the Strapdown Navigator. Much of the detail has been left out and only the key elements are shown here.

Figure 17. Schematic of the Strapdown Navigator



(People familiar with Inertial Navigation Systems will note that 'Angular Rates' and 'Accelerations' are labelled as the inputs. In reality the DSP in the RT3000 converts these to 'Change in Angle' and 'Change in Velocity' to avoid problems of coning and sculling. Some other rotations are also missed in the diagram. The RT3000 does not use a wander angle, so it will not operate correctly on the North and South poles.)

The Angular Rates have their bias and scale factor corrections (from the Kalman Filter) applied. Earth Rotation Rate is also subtracted to avoid the 0.25 degrees per minute rotation of the earth. The Transport Rate is also corrected; this is the rate that gravity rotates by due to the vehicle moving across the earth's surface and it is proportional to horizontal speed. Finally the Angular Rates are integrated to give Heading, Pitch and Roll angles. These are represented internally using a Quaternion (so the RT3000 can work at any angle and does not have any singularities).

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

The Strapdown Navigator uses a WGS-84 model of the earth, the same as GPS uses. This is an elliptical model of the earth rather than a spherical one. The position outputs are in degrees Latitude, degrees Longitude and Altitude. The Altitude is the distance from the model's earth sea level.

The Kalman filter used in the RT3000 is able to apply corrections to several places in the Strapdown Navigator, including Position, Velocity, Heading, Pitch, Roll, Angular Rate Bias and Scale factor and Acceleration Bias.

Kalman Filter

Kalman Filters can be used to merge several measurements of a quantity and therefore give a better overall measurement. This is the case with Position and Velocity in the RT3000; the Kalman filter is used to improve the Position measurement made from two sources, inertial sensors and GPS.

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

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

The same principles are used in the RT3000. Position and Velocity are compensated directly, but other measurements like accelerometer bias, have no direct measurements. The Kalman filter *tunes* these so that the GPS measurements and the inertial measurements match each other as closely as possible.

The Kalman filter in the RT3000 has 23 states. These are position error (north, east, down); velocity error (north, east, down); heading error; pitch error; roll error; gyro bias (X, Y, Z); gyro scale factor (X, Y, Z); accelerometer bias (X, Y, Z); GPS antenna position (X, Y, Z) and GPS antennas orientation (heading, pitch).

The errors are applied smoothly to the states. For example, if the Kalman filter wants to correct a position error of 5cm in the north direction then this is applied slowly, rather than jumping directly to the new position. This helps applications that use the RT3000 for control since any differential terms in the control algorithm do not have large step changes in them.

NCOM Packet Format

The NCOM packet format is a 72 byte packet, transmitted at 115,200 baud rate with 8 data bits, 1 stop bit and no parity. It has an optional low-latency format where the output can be derived after the first 22 characters have been received (1.9ms additional latency). More convenient processing of the data can be achieved after 62 characters have been received (5.3ms additional latency). Full functionality requires multiple packets to be received since low data rate information is divided up and sent in 8 bytes tagged on to the end of each packet.

To save space, many of the data packets are sent as 24-bit signed integer words; 16-bit precision does not provide the range/precision required for many of the quantities whereas 32-bit precision makes the packet much longer than required. All words are sent in little-endian format (meaning "little-end first" or "LSB first"), which is compatible with Intel microprocessors.

The packet is also transmitted over Ethernet as a 72-byte UDP broadcast. The port number is 17. Ethernet provides the lowest latency output from the system since the transmission speed is nearly 1000 times faster than the serial communications.

Table 19. Word Length Definitions

Terminology	Data Length
Byte (UByte)	8-bit integer (unsigned)
Short (UShort)	16-bit integer (unsigned)
Word (UWord)	24-bit integer (unsigned)
Long (ULong)	32-bit integer (unsigned)
Float	32-bit IEEE float
Double	64-bit IEEE float

Note: If a 'U' precedes the value then it is unsigned, otherwise it is signed using 2's complement.

The definition of the packet is given in Table 20, Table 21 and Table 22, below.

Note that, to reduce the latency, the SYNC character, listed as the first character of the packet, is transmitted at the end of the previous cycle. On the communication link there will be a pause between the transmission of the SYNC and the next character. It is not advised to use this pause to synchronise the packet even though the operating system should guarantee the transmission timing of the packet.

Table 20. NCOM Packet Definition – Batch 1.

Byte	Quantity	Notes
0	Sync	Always E7h
1 2	Time Time	Time is transmitted as milliseconds into the minute in GPS time. Range is 0 to 59,999 ms. The packets are always transmitted at 100Hz, use this quantity to verify that a packet has not been dropped.
3 4 5	Acceleration X LSB Acceleration X Acceleration X MSB	Acceleration X is the *vehicle body-frame* acceleration in the x-direction (i.e. after the *IMU to Vehicle Attitude* matrix has been applied). It is a signed word in units of 10^{-4} m/s².
6 7 8	Acceleration Y LSB Acceleration Y Acceleration Y MSB	Acceleration Y is the *vehicle body-frame* acceleration in the y-direction (i.e. after the *IMU to Vehicle Attitude* matrix has been applied). It is a signed word in units of 10^{-4} m/s².
9 10 11	Acceleration Z LSB Acceleration Z Acceleration Z MSB	Acceleration Z is the *vehicle body-frame* acceleration in the z-direction (i.e. after the *IMU to Vehicle Attitude* matrix has been applied). It is a signed word in units of 10^{-4} m/s².
12 13 14	Angular Rate X LSB Angular Rate X Angular Rate X MSB	Angular Rate X is the *vehicle body-frame* angular rate in the x-direction (i.e. after the *IMU to Vehicle Attitude* matrix has been applied). It is a signed word in units of 10^{-5} radians/s.
15 16 17	Angular Rate Y LSB Angular Rate Y Angular Rate Y MSB	Angular Rate Y is the *vehicle body-frame* angular rate in the y-direction (i.e. after the *IMU to Vehicle Attitude* matrix has been applied). It is a signed word in units of 10^{-5} radians/s.
18 19 20	Angular Rate Z LSB Angular Rate Z Angular Rate Z MSB	Angular Rate Z is the *vehicle body-frame* angular rate in the z-direction (i.e. after the *IMU to Vehicle Attitude* matrix has been applied). It is a signed word in units of 10^{-5} radians/s.
21	Nav. Status	See Table 1, below.
22	Checksum 1	This checksum allows the software to verify the integrity of the packet so far. For a low-latency output the accelerations and angular rates can be used to quickly update the previous solution. Contact Oxford Technical Solutions for source code to perform this function.

Table 21. NCOM Packet Definition – Batch 2.

Byte	Quantity	Notes
23	Latitude (Byte 0)	The Latitude of the IMU. It is a double in units of radians.
24	Latitude (Byte 1)	
25	Latitude (Byte 2)	
26	Latitude (Byte 3)	
27	Latitude (Byte 4)	
28	Latitude (Byte 5)	
29	Latitude (Byte 6)	
30	Latitude (Byte 7)	
31	Longitude (Byte 0)	Longitude of the IMU. It is a double in units of radians.
32	Longitude (Byte 1)	
33	Longitude (Byte 2)	
34	Longitude (Byte 3)	
35	Longitude (Byte 4)	
36	Longitude (Byte 5)	
37	Longitude (Byte 6)	
38	Longitude (Byte 7)	
39	Altitude (Byte 0)	Altitude of the IMU. It is a float in units of metres
40	Altitude (Byte 1)	
41	Altitude (Byte 2)	
42	Altitude (Byte 3)	
43	North Velocity (LSB)	North Velocity in units of 10^{-4} m/s.
44	North Velocity	
45	North Velocity (MSB)	
46	East Velocity (LSB)	East Velocity in units of 10^{-4} m/s.
47	East Velocity	
48	East Velocity (MSB)	
49	Down Velocity (LSB)	Down Velocity in units of 10^{-4} m/s.
50	Down Velocity	
51	Down Velocity (MSB)	
52	Heading (LSB)	Heading in units of 10^{-6} radians. Range $\pm\pi$.
53	Heading	
54	Heading (MSB)	

Byte	Quantity	Notes
55	Pitch (LSB)	Heading in units of 10^{-6} radians. Range ±π/2.
56	Pitch	
57	Pitch (MSB)	
58	Roll (LSB)	Heading in units of 10^{-6} radians. Range ±π.
59	Roll	
60	Roll (MSB)	
61	Checksum 2	This checksum allows the software to verify the integrity of the packet so far. For a medium-latency output the full navigation solution is available. Only low-rate information is transmitted next.

Table 22. NCOM Packet Definition – Batch 3.

Byte	Quantity	Notes
62	Channel	The channel number determines what information is sent in Bytes 0 to 7 below.
63	Byte 0	
64	Byte 1	
65	Byte 2	
66	Byte 3	
67	Byte 4	
68	Byte 5	
69	Byte 6	
70	Byte 7	
71	Checksum 3	This is the final checksum that verifies the packet.

See the section on Status Information for the information included in Batch 3.

Table 23. NCOM Navigation Status – Byte 21

Value	Description
0	All quantities in the packet are invalid.
1	Raw IMU measurements. These are output at roughly 10Hz intervals before the system is initialised. They are useful for checking the communication link and for verifying the operation of the accelerometers and angular rate sensors in the laboratory. In this mode *only* the accelerations and angular rates are valid, they are not calibrated or to any specification. The information in the other fields is invalid.
2	Initialising. When GPS time becomes available the system starts the initialisation process. The strapdown navigator and kalman filter are allocated, but do not yet run. Angular Rates and Accelerations during this time are output 1s in arrears. There will be a 1s pause at the start of initialisation where no output will be made (while the system fills the buffers). The system has to run 1s in arrears at this time in order to synchronise the GPS data with the inertial data and perform the initialisation checks. During the Initialising mode the Time, Acceleration and Angular Rate fields will be valid.
3	Locking. The system will move to the locking mode if: b. The velocity exceeds 5 m/s or c. The dual-antenna GPS locks a suitable heading solution. In locking mode the system runs in arrears but catches up by 0.1s every 1s; locking mode lasts 10s. During locking mode the outputs are not real-time.
4	Locked. In Locked mode the system is outputting real-time data with the specified latency guaranteed. All fields are valid.
5 – 255	Reserved

Status Information

Batch 3 of the NCOM packet transmits the Status information on the RT3000. There is a lot of internally used information in the Status Information, but some of this information is useful customers.

The Status Information is transmitted at a low rate. Each cycle a different set of 8-bytes are transmitted. The *Channel* field defines which set of information is included in the 8-bytes.

Some of the Status fields have special bits or values that denote ‘invalid’. The invalid values or the validity bits are noted in the tables.

Table 24. NCOM Packet Definition – Batch 3.

Channel	Information	See
0	Full Time, Number of Satellites, Position Mode, Velocity Mode, Dual-Antenna Mode	Table 25
1	Kalman Filter Innovations	Table 26
2	Internal Information about GPS1	–
3	Position Accuracy	Table 28
4	Velocity Accuracy	Table 29
5	Orientation Accuracy	Table 30
6	Gyro Bias	Table 31
7	Accelerometer Bias	Table 32
8	Gyro Scale Factor	Table 33
9	Gyro Bias Accuracy	–
10	Accelerometer Bias Accuracy	–
11	Gyro Scale Factor Accuracy	–
12	Position estimate of the Primary GPS antenna	Table 34
13	Orientation estimate of Dual-Antenna systems	Table 35
14	Accuracy of Position of the Primary GPS antenna	Table 36
15	Accuracy of the Orientation of Dual-antenna systems	Table 37
16	RT3000 to Vehicle Rotation (from initial setting defined by user)	Table 38
17	Internal Information about GPS2	–
18	Internal Information about Inertial Measurement Unit	–
19	Software version running on RT3000	Table 39
20	Age of Differential Corrections	Table 40
21	Disk Space, Size of current internal log file	Table 41
22	Internal Information on timing of real-time processing	–
23	System Up Time, Number of consecutive GPS rejections	–
24	Reserved	–
25	Reserved	–
26	Reserved	–
27	Internal Information about Dual-Antenna Ambiguity Searches	–
28	Internal Information about Dual-Antenna Ambiguity Searches	–
29	Details on the initial settings	–
30-255	Reserved for future use	–

Note: Channels with no corresponding table are not described in this manual. Contact Oxford Technical Solutions if you require specific information on these channels.

Table 25. Status Information, Channel 0

Bytes	Format	Definition	Invalid When
0–3	Long	Time in minutes since GPS began (midnight 06/01/1980)	Value < 1000
4	UChar	Number of GPS satellites tracked by the Primary GPS receiver	Value = 255
5	UChar	Position Mode of Primary GPS	Value = 255
6	UChar	Velocity Mode of Primary GPS	Value = 255
7	UChar	Orientation Mode of Dual-Antenna Systems	Value = 255

Note: For the definitions of Position Mode, Velocity Mode and Orientation Mode see below.

Table 26. Definitions of Position Mode, Velocity Mode and Orientation Mode

Value	Definition
0	None. The GPS is not able to make this measurement
1	Search. The GPS system is solving ambiguities and searching for a valid solution
2	Doppler. The GPS measurement is based on a Doppler Measurement
3	Stand-Alone. The GPS measurement has no additional external corrections
4	Differential. The GPS measurement used code-phase differential corrections
5	RTK Float. The GPS measurement used L1 Carrier-phase differential corrections to give a floating ambiguity solution.
6	RTK Integer. The GPS measurement used L1/L2 Carrier-phase differential corrections to give an integer ambiguity solution
7 – 255	Reserved or Invalid.

Table 27. Status Information, Channel 1

Bytes	Format	Definition	Valid When
0	Char	Bits 1 to 7: Position X Innovation	Bit 0 = 1
1	Char	Bits 1 to 7: Position Y Innovation	Bit 0 = 1
2	Char	Bits 1 to 7: Position Z Innovation	Bit 0 = 1
3	Char	Bits 1 to 7: Velocity X Innovation	Bit 0 = 1
4	Char	Bits 1 to 7: Velocity Y Innovation	Bit 0 = 1
5	Char	Bits 1 to 7: Velocity Z Innovation	Bit 0 = 1
6	Char	Bits 1 to 7: Orientation Pitch Innovation	Bit 0 = 1
7	Char	Bits 1 to 7: Orientation Heading Innovation	Bit 0 = 1

Note: The innovations are always expressed as a proportion of the current accuracy. Units are 0.1 σ. As a general rule, innovations below 1.0σ are good; innovations above 1.0σ are poor. Usually it is best to filter the square of the innovations and display the square root of the filtered value.

Note 2: If the Orientation Pitch Innovation and/or the Orientation Heading Innovation are always much higher than 1.0σ then it is likely that the system or the antennas have changed orientation in the vehicle. (Or the environment is too poor to use the dual-antenna system).

Table 28. Status Information, Channel 3

Bytes	Format	Definition	Valid When
0 – 1	Short	North Position Accuracy	Age < 150
2 – 3	Short	East Position Accuracy	Age < 150
4 – 5	Short	Down Position Accuracy	Age < 150
6	UChar	Age	
7		Reserved	

Note: The units of the Position Accuraccies are 1mm.

Table 29. Status Information, Channel 4

Bytes	Format	Definition	Valid When
0 – 1	Short	North Velocity Accuracy	Age < 150
2 – 3	Short	East Velocity Accuracy	Age < 150
4 – 5	Short	Down Velocity Accuracy	Age < 150
6	UChar	Age	
7		Reserved	

Note: The units of the Velocity Accuracies are 1mm/s.

Table 30. Status Information, Channel 5

Bytes	Format	Definition	Valid When
0 – 1	Short	Heading Accuracy	Age < 150
2 – 3	Short	Pitch Accuracy	Age < 150
4 – 5	Short	Roll Accuracy	Age < 150
6	UChar	Age	
7		Reserved	

Note: The units of the Orientation Accuracies are 1e-5 radians.

Table 31. Status Information, Channel 6

Bytes	Format	Definition	Valid When
0 – 1	Short	Gyro Bias X	Age < 150
2 – 3	Short	Gyro Bias Y	Age < 150
4 – 5	Short	Gyro Bias Z	Age < 150
6	UChar	Age	
7		Reserved	

Note: The units of the Gyro Biases are 5e-6 radians.

Table 32. Status Information, Channel 7

Bytes	Format	Definition	Valid When
0 – 1	Short	Accelerometer Bias X	Age < 150
2 – 3	Short	Accelerometer Bias Y	Age < 150
4 – 5	Short	Accelerometer Bias Z	Age < 150
6	UChar	Age	
7		Reserved	

Note: The units of the Accelerometer Biases are 0.1mm/s².

Table 33. Status Information, Channel 8

Bytes	Format	Definition	Valid When
0 – 1	Short	Gyro Scale Factor X	Age < 150
2 – 3	Short	Gyro Scale Factor Y	Age < 150
4 – 5	Short	Gyro Scale Factor Z	Age < 150
6	UChar	Age	
7		Reserved	

Note: The units of the Gyro Scale Factors are 1ppm (0.0001%).

Table 34. Status Information, Channel 12

Bytes	Format	Definition	Valid When
0 – 1	Short	Distance to Primary GPS Antenna in X direction	Age < 150
2 – 3	Short	Distance to Primary GPS Antenna in Y direction	Age < 150
4 – 5	Short	Distance to Primary GPS Antenna in Z direction	Age < 150
6	UChar	Age	
7		Reserved	

Note: The units of the Distances are 1mm.

Table 35. Status Information, Channel 13

Bytes	Format	Definition	Valid When
0 – 1	Short	Heading Orientation of the GPS Antennas	Age < 150
2 – 3	Short	Pitch Orientation of the GPS Antennas	Age < 150
4 – 5	Short	Distance between the GPS Antennas	Age < 150
6	UChar	Age	
7		Reserved	

Note: The units of the distances are 1mm. The units of the Orientation Angles are 1e-4 radians.

Table 36. Status Information, Channel 14

Bytes	Format	Definition	Valid When
0 – 1	Short	Accuracy of Distance to Primary GPS Antenna in X direction	Age < 150
2 – 3	Short	Accuracy of Distance to Primary GPS Antenna in Y direction	Age < 150
4 – 5	Short	Accuracy of Distance to Primary GPS Antenna in Z direction	Age < 150
6	UChar	Age	
7		Reserved	

Note: The units of the Distance Accuracies are 0.1mm.

Table 37. Status Information, Channel 15

Bytes	Format	Definition	Valid When
0 – 1	Short	Accuracy of Heading Orientation of the GPS Antennas	Age < 150
2 – 3	Short	Accuracy of Pitch Orientation of the GPS Antennas	Age < 150
4 – 5	Short	Accuracy of Distance between the GPS Antennas	Age < 150
6	UChar	Age	
7		Reserved	

Note: The units of the distances are 1mm. The units of the Orientation Angle Accuracies are 1e-4 radians.

Table 38. Status Information, Channel 16

Bytes	Format	Definition	Valid When
0 – 1	Short	Heading of the vehicle in the RT3000 co-ordinate frame.	Byte 6 = 0
2 – 3	Short	Pitch of the vehicle in the RT3000 co-ordinate frame.	Byte 6 = 0
4 – 5	Short	Roll of the vehicle in the RT3000 co-ordinate frame.	Byte 6 = 0
6	UChar	Validity	
7	Char	Bits 1–7 UTC Time Offset	Bit 0 = 1

Note: The units of the Orientation Angles are 1e-4 radians. To compute UTC Time from GPS Time *add* the offset. Currently the offset is –13 seconds. (The offset is always an integer number of seconds. UTC Time slips or gains a second occasionally whereas GPS Time does not).

Table 39. Status Information, Channel 19

Bytes	Format	Definition	Valid When
0 – 7	8 x Char	This is the Software Version or *Development ID* that is running in the RT3000 in ASCII format.	

Table 40. Status Information, Channel 20

Bytes	Format	Definition	Valid When
0 – 1	Short	Age of the Differential Corrections from the Base-Station	
2 – 7		Reserved	

Note: The unit of the Differential Corrections is 0.01 seconds.

Table 41. Status Information, Channel 21

Bytes	Format	Definition	Valid When
0 – 3	Long	Disk Space Remaining on RT3000. Note that the RT3000 always leaves about 20K spare on the disk.	Value > 0
4 – 7	Long	Size of current logged raw data file. When there is insufficient space on the disk no more data will be written.	Value > 0

Note: The values are output in kilobytes.

CAN Messages and Signals

The RT-CAN uses identifiers 500h to 5FFh for RT3000 Status Information and 600h to 60Fh for navigation information.

All values from the RT3000 are encoded in Little-Endian format (Intel-style).

Termination Resistor

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

CAN-DB File

A CAN-DB file is available for download on the Oxford Technical Solutions web site. This file contains definitions for the Status messages as well as the Measurement outputs. Only the Measurement outputs are described here.

CAN Bus Messages

Table 42, below, lists all the messages that the RT3000 puts on the CAN bus and the identifiers that are used for the messages. The signals in each message are listed in the tables that follow.

Table 42. CAN Bus Messages

Identifier (hex)	Data Contents	See Table
500h to 5FFh	Reserved for RT3000 Status Information	See NCOM Status Channel[1]
600h	Date and Time	Table 43
601h	Latitude, Longitude	Table 44
602h	Altitude	Table 45
603h	Velocity (North East Down)	Table 46
604h	Velocity (Forward/Lateral)	Table 47
605h	Accelerations (body X, Y, Z)	Table 48
606h	Accelerations (Forward, Lateral, Down)	Table 49
607h	Heading, Pitch Roll	Table 50
608h	Angular Rates (body X, Y, Z)	Table 51
609h	Angular Rates (Forward, Pitch, Yaw)	Table 52
60Ah	Slip Angle, Track Angle	Table 53
60Bh	Distance	Table 54
60Ch to 60Fh	Reserved for future use	

Note 1: The Status Information in NCOM is output over the CAN bus on Identifiers 500h to 5FFh. The offset from 500h is the same as the *Channel* number in the NCOM message definition. The bytes 0 – 7 are the same in the CAN message as in the NCOM packet.

Table Heading Definitions

The fields in the tables have the following meanings.

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

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

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

Units. This is the units for the signal.

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

Offset. This is the value of the Signal when the integer value in the CAN message is zero. It is zero for all the RT3000 signals and can usually be discarded.

Signals

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

Table 43. Identifier 600h, Date and Time

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	8	U	year	1	0	Year within century (e.g. '2' during year 2002)
8	8	U	year	100	0	Century (e.g. '20' during 2002)
16	8	U	month	1	0	Month
24	8	U	day	1	0	Day
32	8	U	s	0.01	0	Hundredths of a Second
40	8	U	s	1	0	Seconds
48	8	U	min	1	0	Minutes
56	8	U	hour	1	0	Hours

Note: Time is always reported as GPS time. Currently this is 13 seconds different from UTC

Table 44. Identifier 601h, Latitude and Longitude

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	32	S	degrees	1e-7	0	Latitude
32	32	S	degrees	1e-7	0	Longitude

Table 45. Identifier 602h, Altitude

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	32	S	m	0.001	0	Attitude

Table 46. Identifier 603h, Velocity

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	S	m/s	0.01	0	North Velocity
16	16	S	m/s	0.01	0	East Velocity
32	16	S	m/s	0.01	0	Down Velocity
48	16	S	m/s	0.01	0	Horizontal Speed

The Horizontal Speed is the vector addition of North and East Velocities. For Forward Speed (which can go negative) see message 604h.

Table 47. Identifier 604h, Velocity in Vehicle Frame

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	S	m/s	0.01	0	Forward Velocity
16	16	S	m/s	0.01	0	Lateral Velocity (Right positive)

The Forward Speed can go negative when driving backwards.

Table 48. Identifier 605h, Body Accelerations

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	S	m/s²	0.01	0	Body X-Acceleration
16	16	S	m/s²	0.01	0	Body Y-Acceleration
32	16	S	m/s²	0.01	0	Body Z-Acceleration

Table 49. Identifier 606h, Vehicle Accelerations

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	S	m/s²	0.01	0	Forward Accelerations
16	16	S	m/s²	0.01	0	Lateral Acceleration (Right positive)
32	16	S	m/s²	0.01	0	Down Acceleration

Table 50. Identifier 607h, Heading, Pitch, Roll

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	U	degrees	0.01	0	Heading
16	16	S	degrees	0.01	0	Pitch
32	16	S	degrees	0.01	0	Roll

Note: the range of Heading is 0 to 360 degrees; the range of pitch is ±90 degrees; the range of roll is ±180 degrees.

Table 51. Identifier 608h, Body X, Y, Z Angular Rates

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	S	deg/s	0.01	0	Body X-Angular Rate (Roll Angular Rate)
16	16	S	deg/s	0.01	0	Body Y-Angular Rate
32	16	S	deg/s	0.01	0	Body Z-Angular Rate

Table 52. Identifier 609h, Vehicle Angular Rates

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	S	deg/s	0.01	0	Forward Angular Rate
16	16	S	deg/s	0.01	0	Pitch Angular Rate
32	16	S	deg/s	0.01	0	Yaw Angular Rate

See message 608h for Roll Angular Rate. The definition of roll rate used in this manual is consistent with the Euler Angles used to output Roll, Pitch and Heading; therefore the Roll Angular Rate is the same as the pitched X-Angular Rate or the Body X-Angular Rate. The Forward Angular Rate is the rotation about the axis which is horizontal.

Table 53. Identifier 60Ah, Track, Slip Angles

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	16	S	degrees	0.01	0	Track Angle
16	16	S	degress	0.01	0	Slip Angle

Note that the Slip Angle will be close to 180 degrees when driving backwards.

Table 54. Identifier 60Bh, Distance

Offset (bits)	Length (bits)	Type	Units	Factor	Offset	Description
0	32	U	m	0.001	0	Distance with Hold
32	32	U	m	0.001	0	Distance

Note: The "Distance with Hold" will not increase when the RT3000 measures a speed less than 0.2m/s whereas the "Distance" field will drift by the noise of the RT3000 when stationary. The distances start from zero when the RT-CAN unit is powered up.

Revision History

Table 55. Revision History

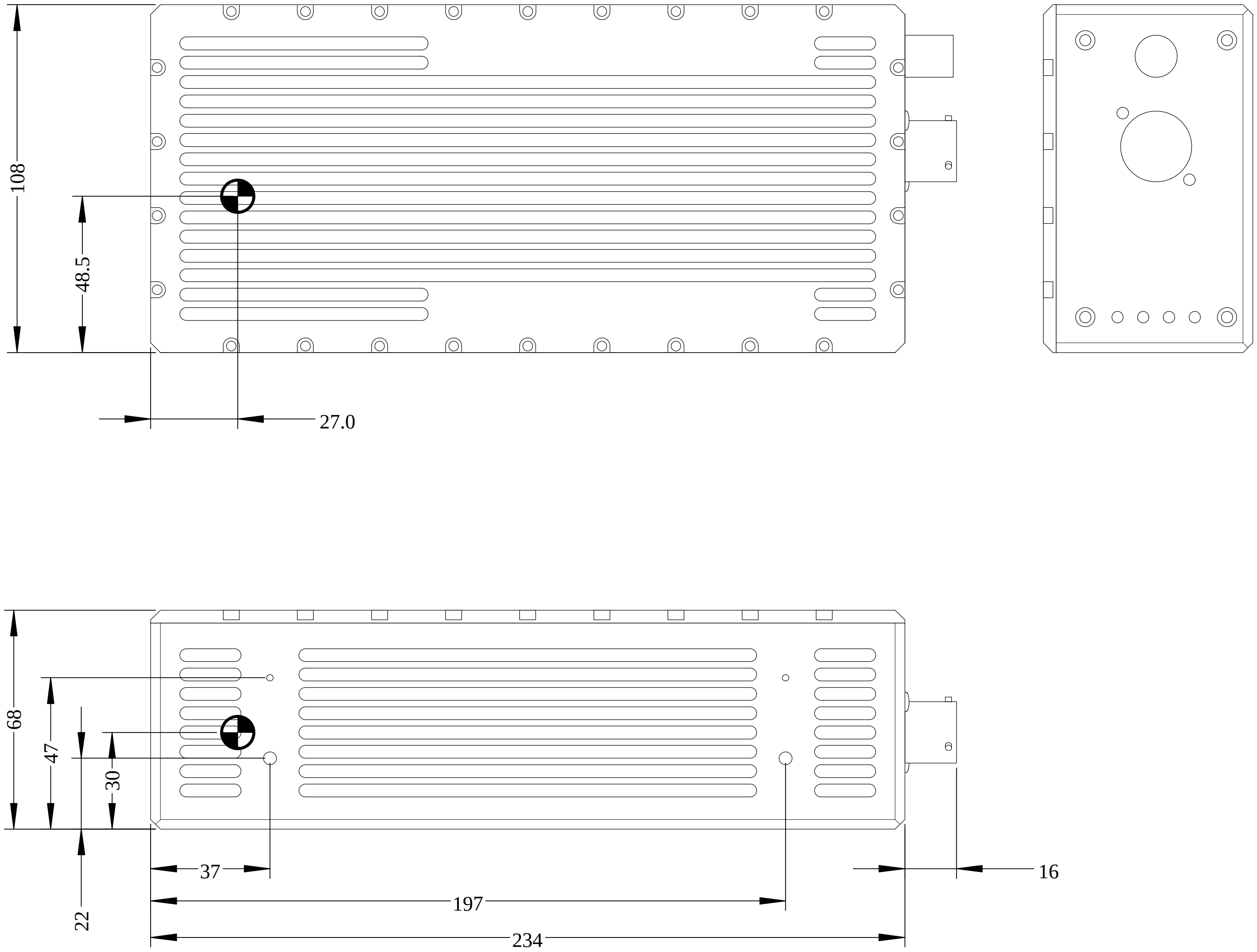
Revision	Comments
011211	Draft.
020225	Draft. Added NCOM description.
020528	Reflects the modification of the system to use RTCA corrections instead of CMR. Upgrade to the specification.
021021	Added information about initialisation, deriving additional outputs. Changed operating temperature specification to 50degC. Added Lab. Test procedures
030131	Specification Changes, Dual-Antenna now simpler, other small changes
030331	Clarified antenna type supplied. Added section on ‘Operating Principles’
030401	Added Status Information, Computing Performance Metrics and `RT300Cfg`.
030407	Corrections. Dual-antenna Multi-path explanation.
030522	Changed small RT3000 dimensions, height increased from 63 to 68mm.
030623	Added RT-Base references.
030728	Added CAN-Inside option; Advanced Slip; OmniStar configuration.

Drawing List

Table 56, below, lists the available drawings that describe components of the RT3000 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 56. List of Available Drawings

Drawing	Description
14A0004*x*	Single Antenna RT3000 System Outer Dimension Drawings. Available as an option for single antenna systems.
14A0007*x*	RT3000 System Outer Dimension Drawing.
14C0009*x*	RT3000 User Interface Cable
14C0016*x*	RT3000 Radio Modem Interface Cable
14C0021*x*	RT3000 User Interface Cable
14C0023*x*	RT3000 User Interface Cable
14C0019*x*	Base-Station Radio Modem/Power Cable
14C0018x	M12 Power Cable
PowerPak-II	Base-Station GPS Receiver
GPS-600	GPS Antenna
AT575-70B	GPS Antenna



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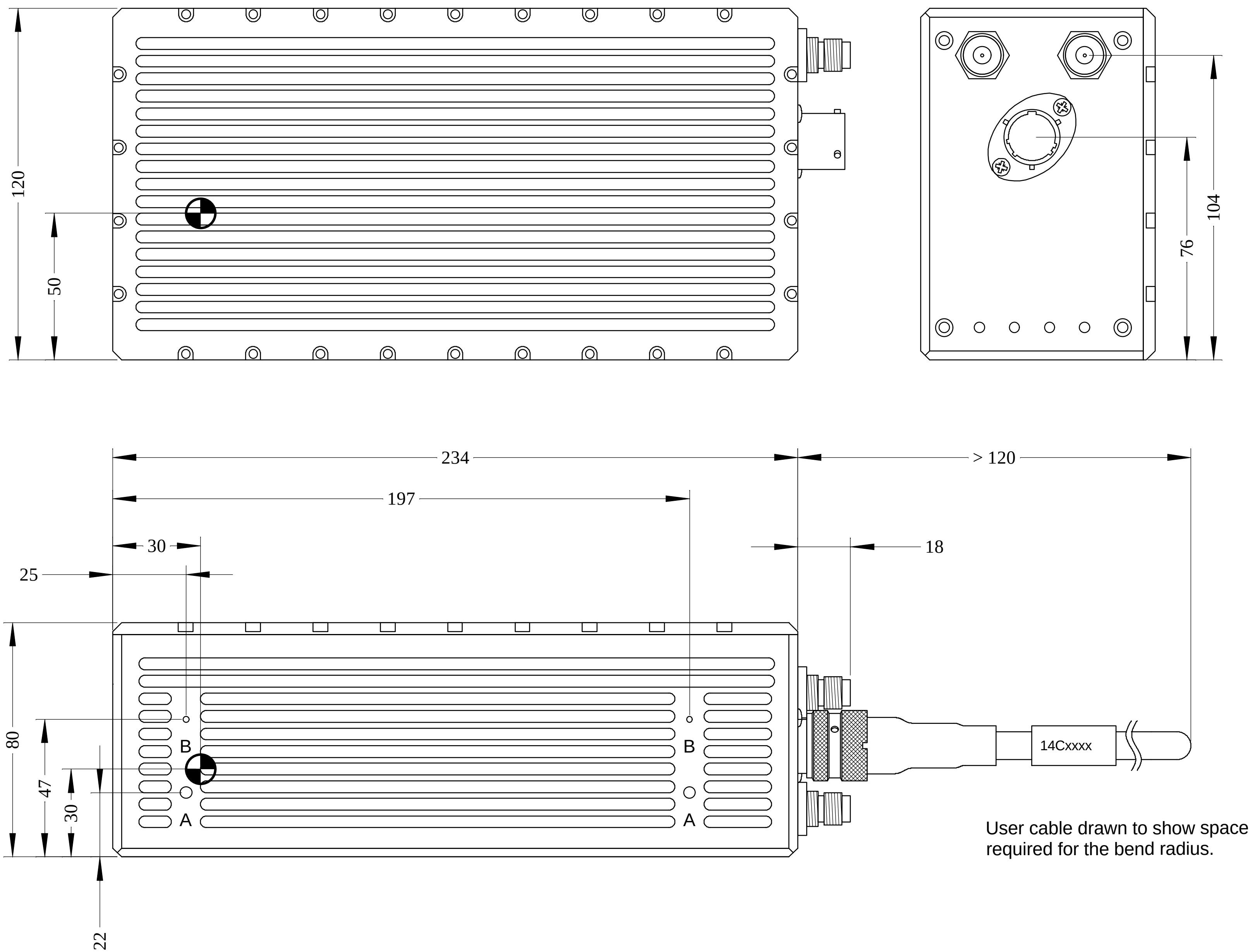
0 10 20 30

Print Size:	A4
Scale:	1:2
Units:	mm
Tolerances:	All 0.1
Material:	HE30
Finish:	Red Anodised
Projection:	3rd Angle
Notes:	

Revision History:

B - Changed Height

Date:	22/05/2003
Part #:	14A0004B
Document:	RT3000 Dimensions
Sheet:	1 of 1



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0 10 20 30

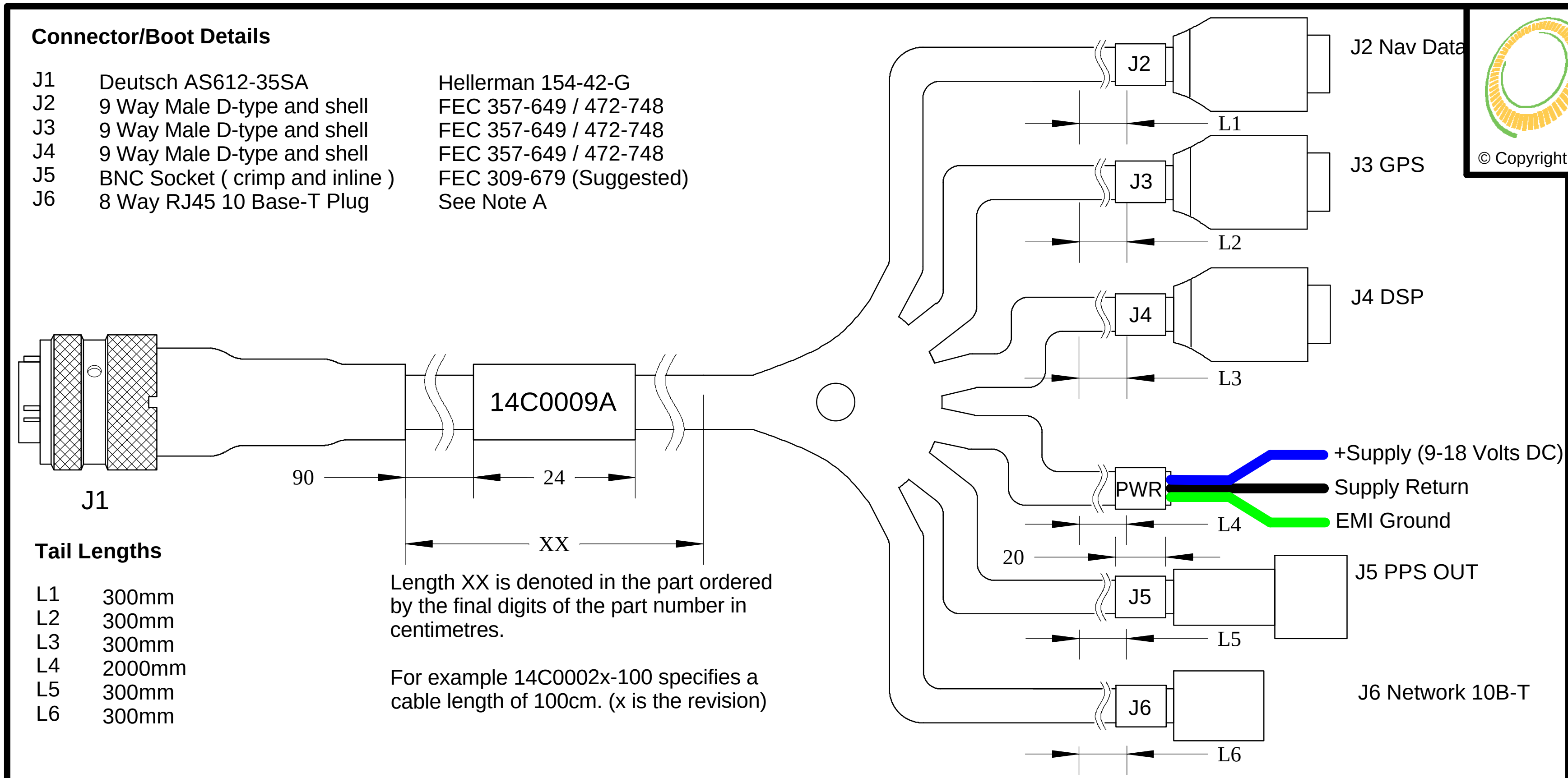
Print Size:	A4
Scale:	1:2 (Half)
Units:	mm
Tolerances:	X.X – 0.1
Projection:	3rd Angle
Material:	HE30 Alu
Finish:	Anodised

Notes:

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

Edit History:

Date:	08/11/01
Part #:	14A0007A
Document:	RT3003 Outer 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 357-649 / 472-748
J3	9 Way Male D-type and shell	FEC 357-649 / 472-748
J4	9 Way Male D-type and shell	FEC 357-649 / 472-748
J5	BNC Socket (crimp and inline)	FEC 309-679 (Suggested)
J6	8 Way RJ45 10 Base-T Plug	See Note A

Tail Lengths

L1	300mm
L2	300mm
L3	300mm
L4	2000mm
L5	300mm
L6	300mm

Length XX is denoted in the part ordered by the final digits of the part number in centimetres.

For example 14C0002x-100 specifies a cable length of 100cm. (x is the revision)

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0 10 20 30

Print Size:	A4
Scale:	Not to scale
Units:	mm
Tolerances:	5mm
Projection:	N/A
Notes:	

Connection/Cable Details

J1		J1	
1	+ Supply (16/02 Blue)	12	J2 - Pin 5 - RS232 Common
2	Supply Return (16/02 Black)	13	J6 - Pin 2
3	J2 - Pin 3 - Nav Data RS232 TX	14	J6 - Pin 6
4	J2 - Pin 2 - Nav Data RS232 RX	15	N/C
5	N/C	16	J3 - Pin 5 - RS232 Common
6	J3 - Pin 3 - GPS Data RS232 TX	17	J4 - Pin 5 - RS232 Common
7	J3 - Pin 2 - GPS Data RS232 RX	18	J5 - PPS out GND (Screen)
8	N/C	19	N/C
9	J4 - Pin 3 - DSP Data RS232 TX	20	J6 - Pin 1
10	J4 - Pin 2 - DSP Data RS232 RX	21	J6 - Pin 3
11	J5 - PPS out (Centre conductor)	22	EMI Ground (Green)

Special Notes

Cable outers braided and connected to EMI Ground.

J1 13-20 Twisted, see NOTE A.
J1 14-21 Twisted, see NOTE A.

NOTE A: J6 is a RJ45 UTP patch lead which is cut to length and terminated at J1, FEC 480-125 will make two assys.

Power cores 1,2 and 22 16/02, All other signals 7/02.

PPS OUT connector to be screened cable, whose screen is isolated from the outer EMI braid. The screen connects to PPS Ground, and the centre conductor connects to PPS Out.

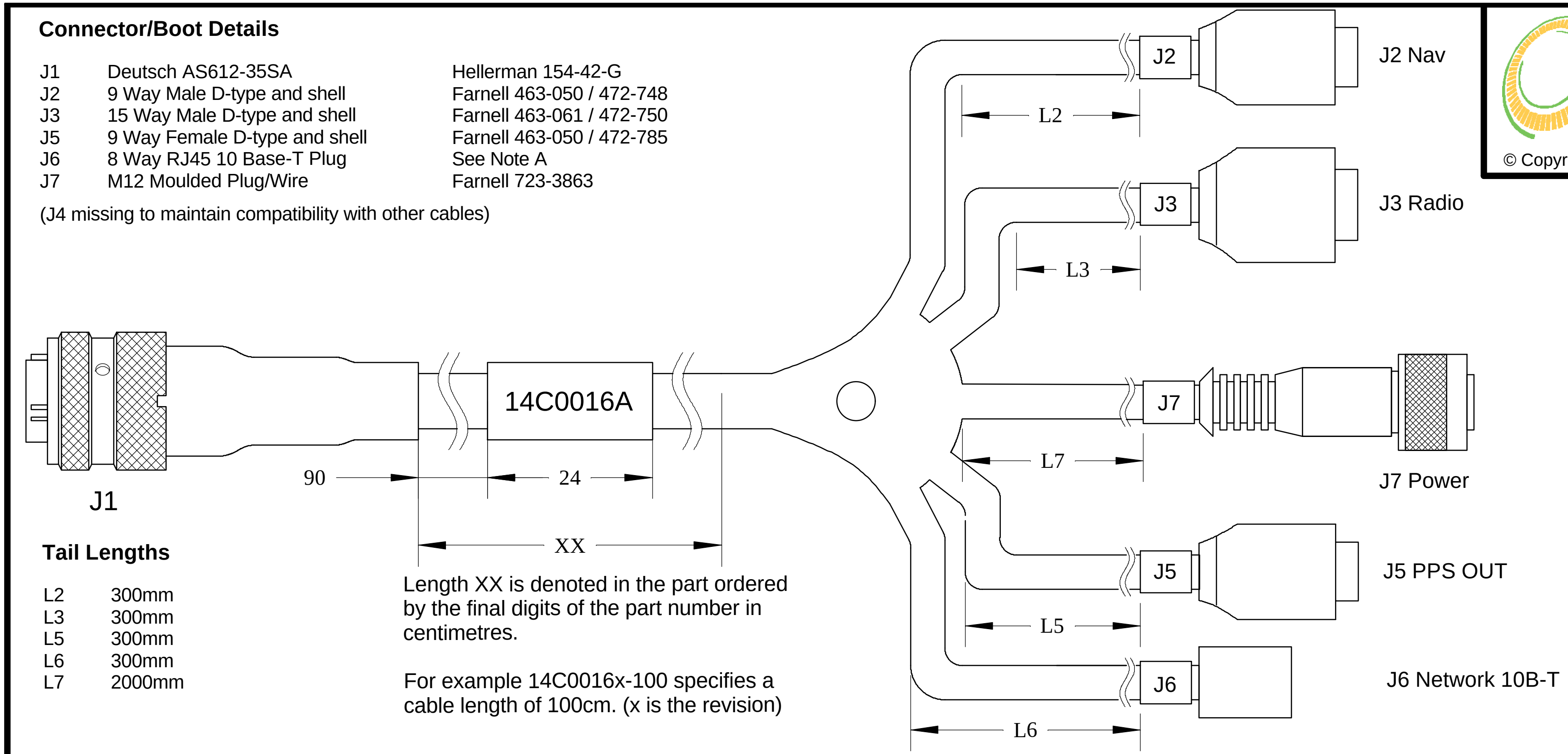
Edit History:

Date:	27/11/00
Part #:	14C0009A
Document:	RT3000 User Cable
Sheet:	1 of 1

Connector/Boot Details

J1	Deutsch AS612-35SA	Hellerman 154-42-G
J2	9 Way Male D-type and shell	Farnell 463-050 / 472-748
J3	15 Way Male D-type and shell	Farnell 463-061 / 472-750
J5	9 Way Female D-type and shell	Farnell 463-050 / 472-785
J6	8 Way RJ45 10 Base-T Plug	See Note A
J7	M12 Moulded Plug/Wire	Farnell 723-3863

(J4 missing to maintain compatibility with other cables)



Tail Lengths

L2	300mm
L3	300mm
L5	300mm
L6	300mm
L7	2000mm

Length XX is denoted in the part ordered by the final digits of the part number in centimetres.

For example 14C0016x-100 specifies a cable length of 100cm. (x is the revision)

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0 10 20 30

Print Size:	A4
Scale:	Not to scale
Units:	mm
Tolerances:	10mm
Projection:	N/A
Notes:	

Connection/Cable Details

Description	Wire	J1	Connections
Power Supply (10 to 18V D.C.)	16/02	1	J7-1 (Brown), J3-14, J3-15, J3-1
Power Return (0v, Ground)	16/02	2	J7-3 (Blue), J3-7, J3-8
Nav Data RS232 TX	7/02	3	J2-3
Nav Data RS232 RX	7/02	4	J2-2
N/C	7/02	5	N/C
GPS Data RS232 TX	7/02	6	J3-11
GPS Data RS232 RX	7/02	7	J3-9
N/C	7/02	8	N/C
DSP Data RS232 TX	7/02	9	N/C
DSP Data RS232 RX	7/02	10	N/C
PPS RS422-A	7/02	11	J5-2
Nav Data RS232 Common	7/02	12	J2-5
Ethernet (ETX-)	7/02	13	J6-2
Ethernet (ERX-)	7/02	14	J6-6
N/C	7/02	15	N/C
GPS Data RS232 Common	7/02	16	J3-7
DSP Data RS232 Common	7/02	17	N/C
PPS RS422 Common	7/02	18	J5-5
PP2 RS422-B	7/02	19	J5-7
Ethernet (ETX+)	7/02	20	J6-1
Ethernet (ERX+)	7/02	21	J6-3
Case/Earth	16/02	22	J7-4 (Black)

Special Notes

All Cable outers braided and connected to EMI Ground apart from J7 where no braid exists)

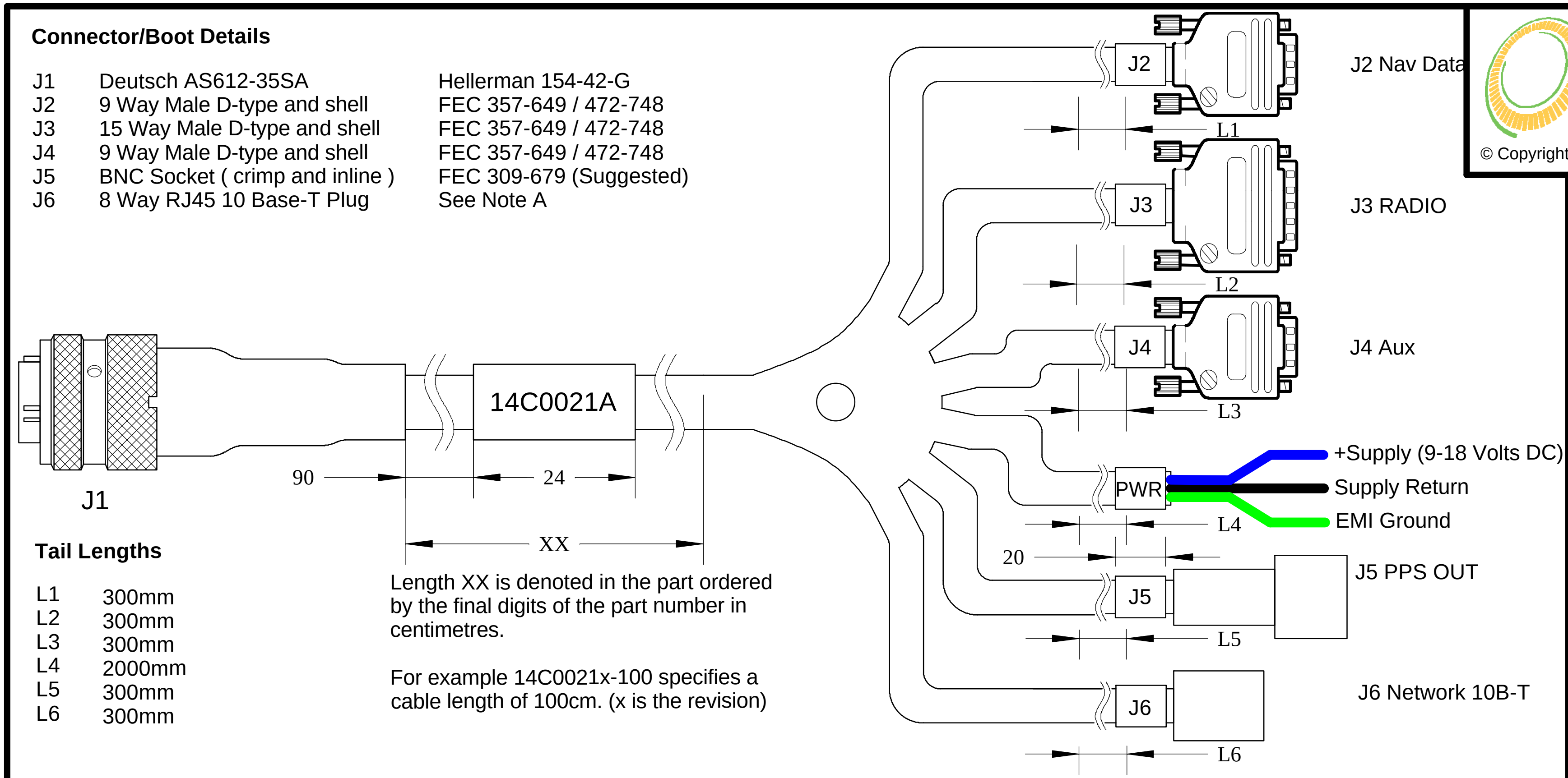
J1 13-20 Twisted, see NOTE A.
J1 14-21 Twisted, see NOTE A.

NOTE A: J6 is a RJ45 UTP patch lead which is cut to length and terminated at J1, FEC 480-125 will make two assys.

Date:	08/11/01
Part #:	14C0016A
Document:	RT3000 User Radio Cable
Sheet:	1 of 1

Connector/Boot Details

J1	Deutsch AS612-35SA	Hellerman 154-42-G
J2	9 Way Male D-type and shell	FEC 357-649 / 472-748
J3	15 Way Male D-type and shell	FEC 357-649 / 472-748
J4	9 Way Male D-type and shell	FEC 357-649 / 472-748
J5	BNC Socket (crimp and inline)	FEC 309-679 (Suggested)
J6	8 Way RJ45 10 Base-T Plug	See Note A



Tail Lengths

L1	300mm
L2	300mm
L3	300mm
L4	2000mm
L5	300mm
L6	300mm

Length XX is denoted in the part ordered by the final digits of the part number in centimetres.

For example 14C0021x-100 specifies a cable length of 100cm. (x is the revision)

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0 10 20 30

Print Size: A4

Scale: Not to scale

Units: mm

Tolerances: 5mm

Projection: N/A

Notes:

NOTE A:
J6 is a RJ45 UTP patch lead which is cut to length and terminated at J1, FEC 480-125 will make two assys.

Connection/Cable Details

Description	J1	Connections
+Supply (Blue) (16/0.2)	1	J3-1,J3-14,J3-15,PWR-Blue
Supply Return (Black) (16/0.2)	2	J3-7,J3-8,PWR-Black
Nav Data RS232 TX	3	J2-3
Nav Data RS232 RX	4	J2-2
N/C	5	N/C
Radio Data RS232 TX	6	J3-11
Radio Data RS232 RX	7	J3-9
N/C	8	N/C
Aux Data RS232 TX	9	J4-3
Aux Data RS232 RX	10	J4-2
PPS out (Centre Conductor)	11	J5-CORE
Nav Data RS232 Common	12	J2-5
Ethernet (ETX-)	13	J6-2
Ethernet (ERX-)	14	J6-6
N/C	15	N/C
Radio Data RS232 Common	16	J3-7
Aux Data RS232 Common	17	J4-5
PPS out GND (Screen)	18	J5-SCREEN
N/C	19	N/C
Ethernet (ETX+)	20	J6-1
Ethernet (ERX+)	21	J6-3
EMI Ground (Green) (16/0.2)	22	PWR-Green

Special Notes

Cable outers braided and connected to EMI Ground.

J1 13-20 Twisted, see NOTE A.
J1 14-21 Twisted, see NOTE A.

Power cores 1,2 and 22 16/02, All other signals 7/02.

PPS OUT connector to be screened cable, whose screen is isolated from the outer EMI braid. The screen connects to PPS Ground, and the centre conductor connects to PPS Out.

Edit History:

Date: 26/04/02

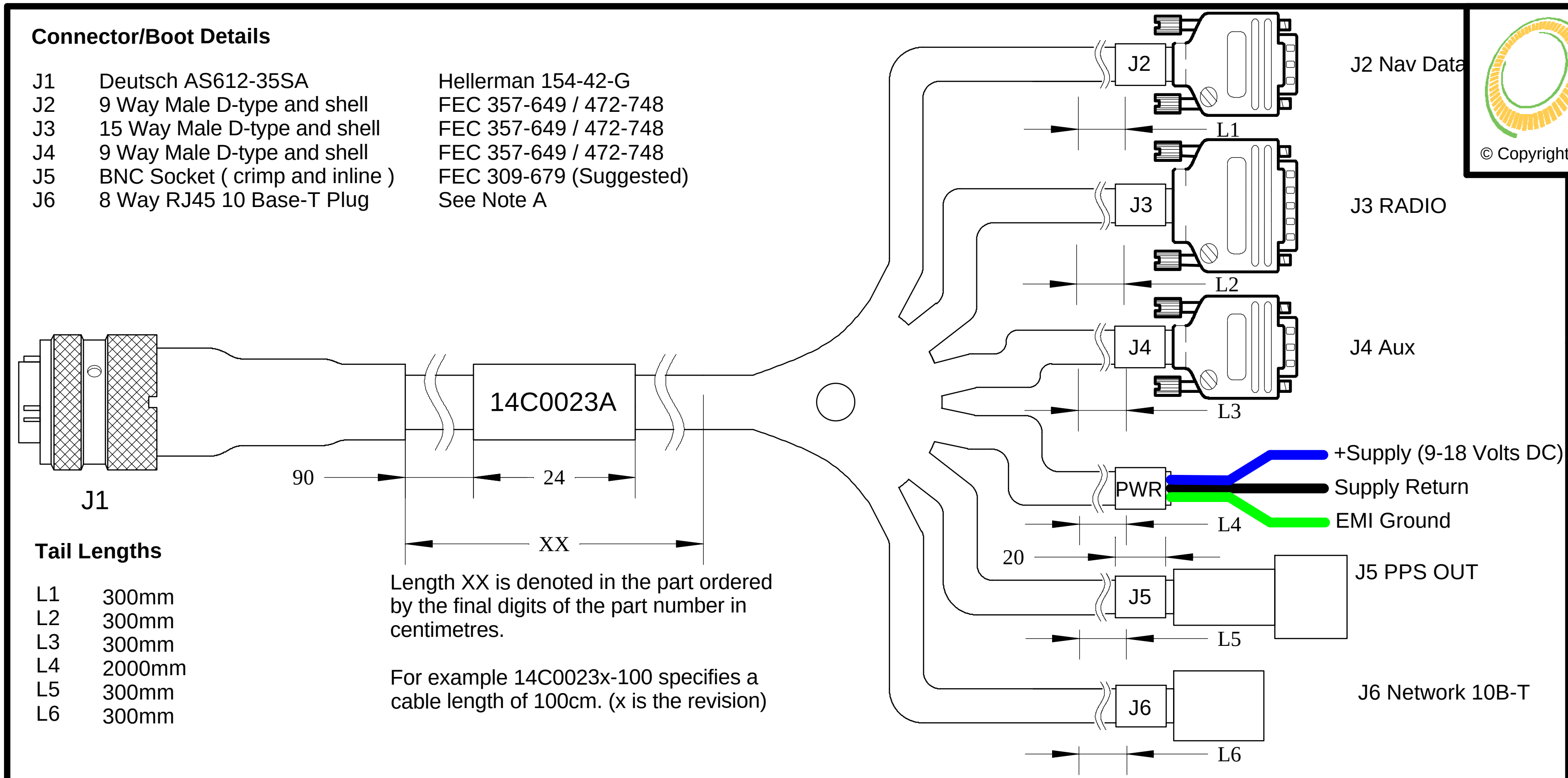
Part #: 14C0021A

Document: RT3000 User Cable

Sheet: 1 of 1

Connector/Boot Details

J1	Deutsch AS612-35SA	Hellerman 154-42-G
J2	9 Way Male D-type and shell	FEC 357-649 / 472-748
J3	15 Way Male D-type and shell	FEC 357-649 / 472-748
J4	9 Way Male D-type and shell	FEC 357-649 / 472-748
J5	BNC Socket (crimp and inline)	FEC 309-679 (Suggested)
J6	8 Way RJ45 10 Base-T Plug	See Note A



Tail Lengths

L1	300mm
L2	300mm
L3	300mm
L4	2000mm
L5	300mm
L6	300mm

Length XX is denoted in the part ordered by the final digits of the part number in centimetres.

For example 14C0023x-100 specifies a cable length of 100cm. (x is the revision)

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0 10 20 30

Print Size:	A4
Scale:	Not to scale
Units:	mm
Tolerances:	5mm
Projection:	N/A

Notes:

NOTE A:
J6 is a RJ45 UTP patch lead which is cut to length and terminated at J1, FEC 480-125 will make two assys.

Connection/Cable Details

Description	J1	Connections
+Supply (Blue) (16/0.2)	1	J3-1,J3-14,J3-15,PWR-Blue
Supply Return (Black) (16/0.2)	2	J3-7,J3-8,PWR-Black
Nav Data RS422 TX+	3	J2-2
Nav Data RS422 RX+	4	J2-7
Nav Data RS422 TX-	5	J2-1
Radio Data RS232 TX	6	J3-11
Radio Data RS232 RX	7	J3-9
N/C	8	N/C
Aux Data RS232 TX	9	J4-3
Aux Data RS232 RX	10	J4-2
PPS out (Centre Conductor)	11	J5-CORE
Nav Data RS422 Common	12	J2-5
Ethernet (ETX-)	13	J6-2
Ethernet (ERX-)	14	J6-6
Nav Data RS422 RX-	15	J2-6
Radio Data RS232 Common	16	J3-7
Aux Data RS232 Common	17	J4-5
PPS out GND (Screen)	18	J5-SCREEN
N/C	19	N/C
Ethernet (ETX+)	20	J6-1
Ethernet (ERX+)	21	J6-3
EMI Ground (Green) (16/0.2)	22	PWR-Green

Special Notes

Cable outers braided and connected to EMI Ground.

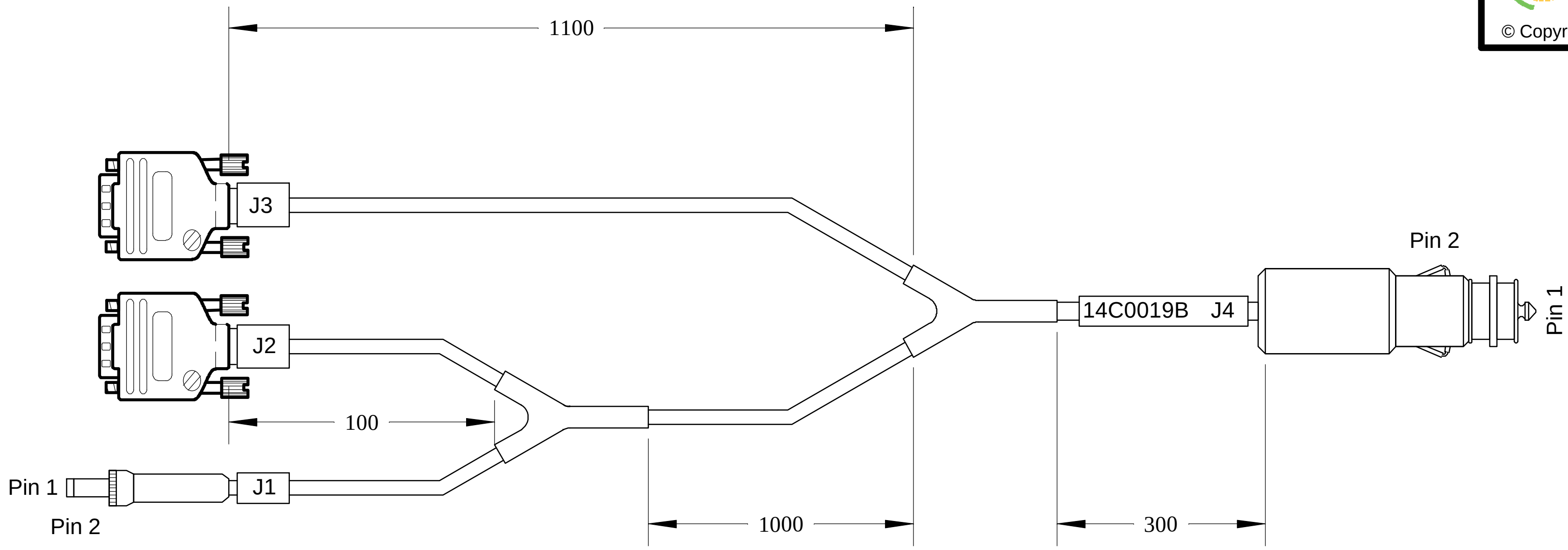
J1 13-20 Twisted, see NOTE A.
J1 14-21 Twisted, see NOTE A.

Power cores 1,2 and 22 16/02, All other signals 7/02.

PPS OUT connector to be screened cable, whose screen is isolated from the outer EMI braid. The screen connects to PPS Ground, and the centre conductor connects to PPS Out.

Edit History:

Date:	02/05/02
Part #:	14C0023A
Document:	RT3000 User Cable
Sheet:	1 of 1



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0 10 20 30

Print Size:	A4
Scale:	1:1
Units:	mm
Tolerances:	10.0
Projection:	3rd Angle
Notes:	

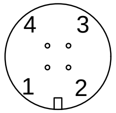
Connections

VS+: J4-1 to J1-1, J3-14, J3-15, J3-1 using blue 16/02 wire
GND: J4-2 to J1-2, J3-7, J3-8, J2-5 using black 16/02 wire
TX: J2-3 to J3-11 using 7/02 wire

Parts

J1	2.1mm Locking Power Jack, 12mm stem	See Note ii)
J2	9-way Female D-type and shell	FEC 472-785/472-748
J3	15-way Male D-type and shell	FEC 463-061/472-750
J4	Cigarette Lighter Socket	FEC 658-376

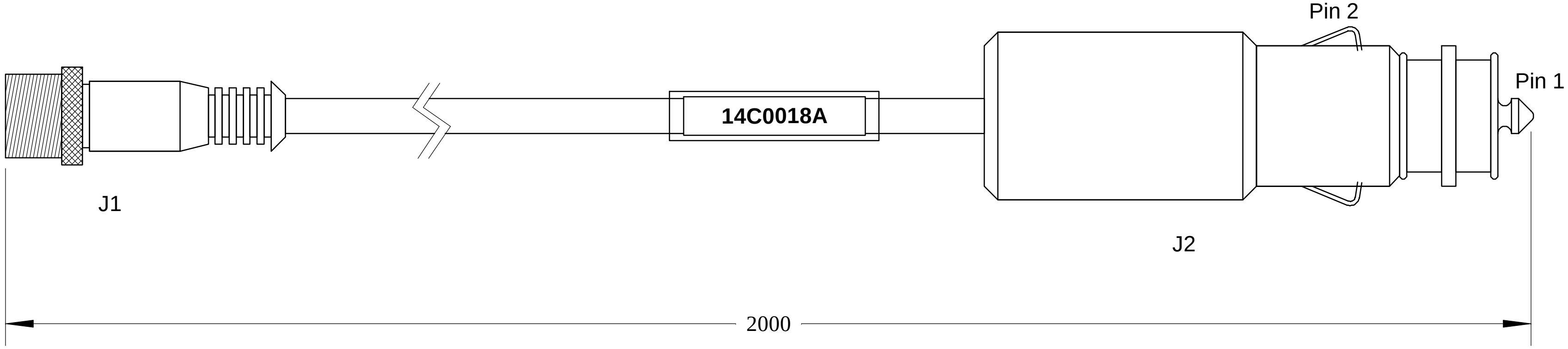
Date:	29/05/02
Part #:	14C0019C
Document:	Radio Modem Base
Sheet:	1 of 1



View from front of plug

Pin Definitions

J1-1 (Brown) Positive 12V Power supply (9–18 d.c.)
J1-2 (White) Not Used
J1-3 (Blue) 0V/GND
J1-4 (Black) Earth/Case



Parts

RS290-6512 M12 4w 2m PUR straight Connector
RS266-0250 Car Cigarette Lighter Plug
RS399-524 Yellow Heat Shrink 6.4mm
RS399-934 Clear Heat Shrink 6.4mm

Connections

J1-1 (Brown) – J2-1
J1-2 (White) – Not Connected
J1-3 (Blue) – J2-2
J1-4 (Black) – J2-2

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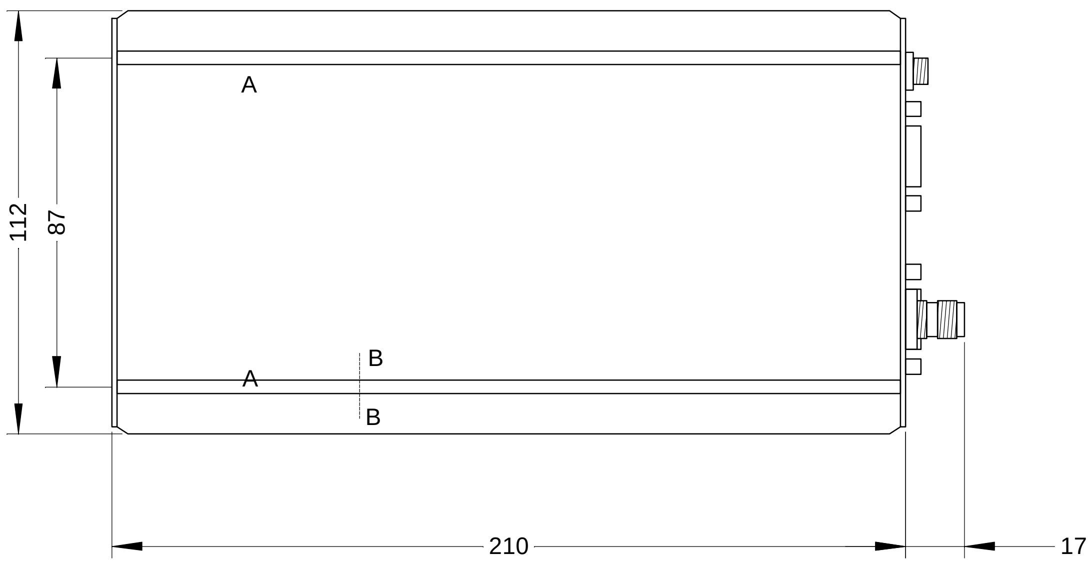
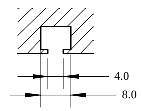
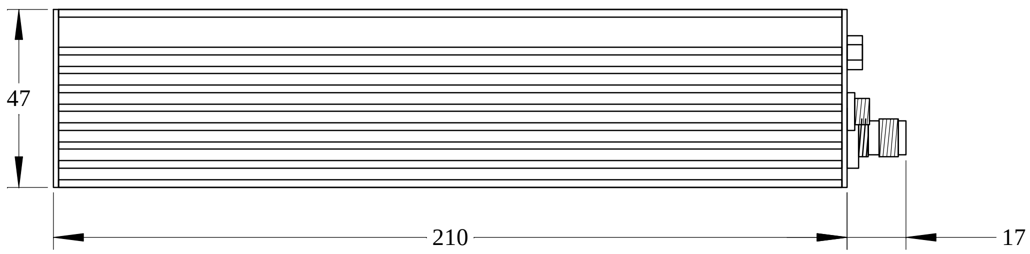
0 10 20 30

Print Size:	A4
Scale:	1:1
Units:	mm
Tolerances:	100mm
Projection:	N/A
Notes:	
Date:	07/12/01
Part #:	14C0018A
Document:	M12 Power Cable
Sheet:	1 of 1



Section through B-B





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

Notes:

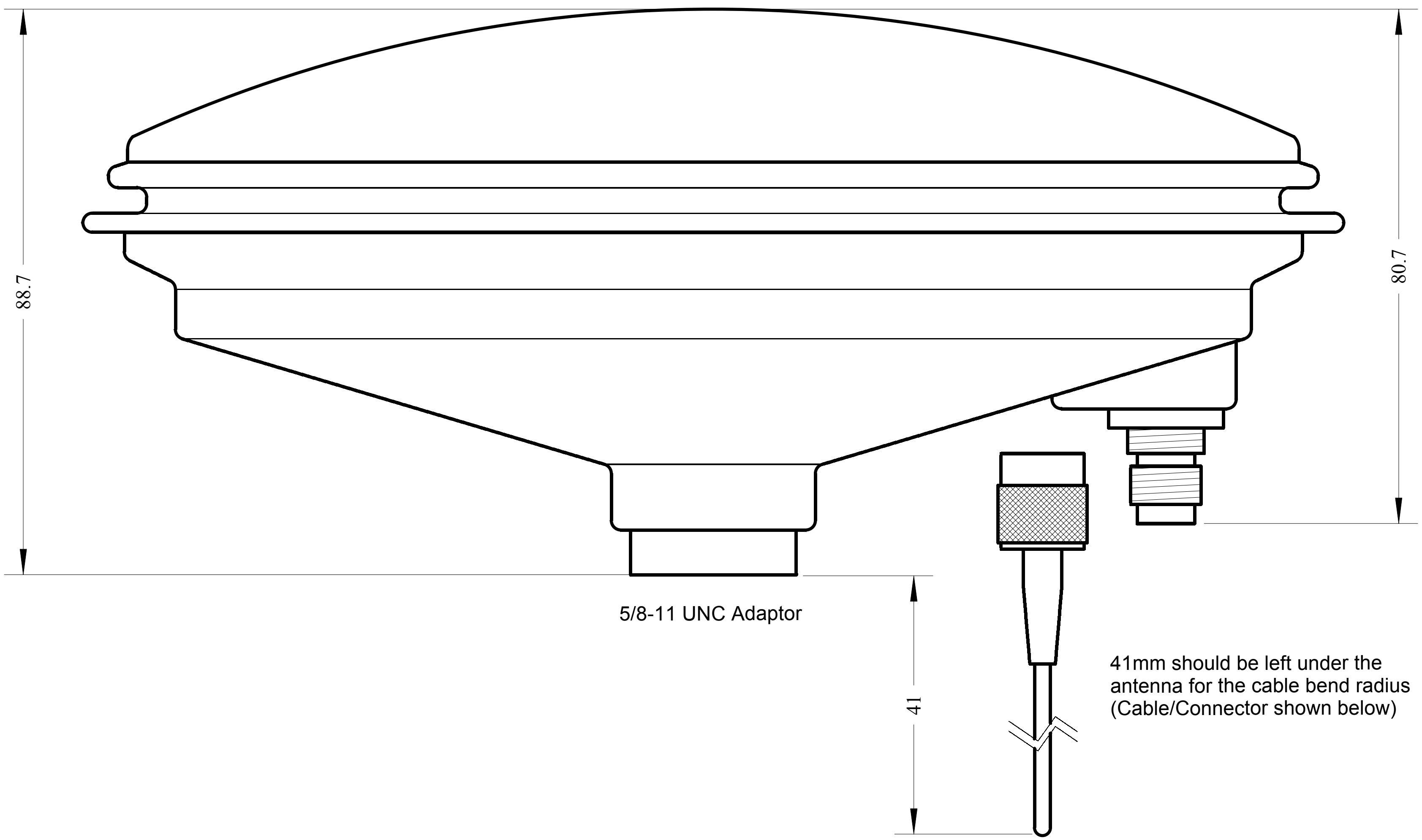
A – Channel for Mounting

Edit History:

Date:	08/11/01
Part #:	N/A

Document:
Novatel Power-Pak-II

Sheet: 1 of 1



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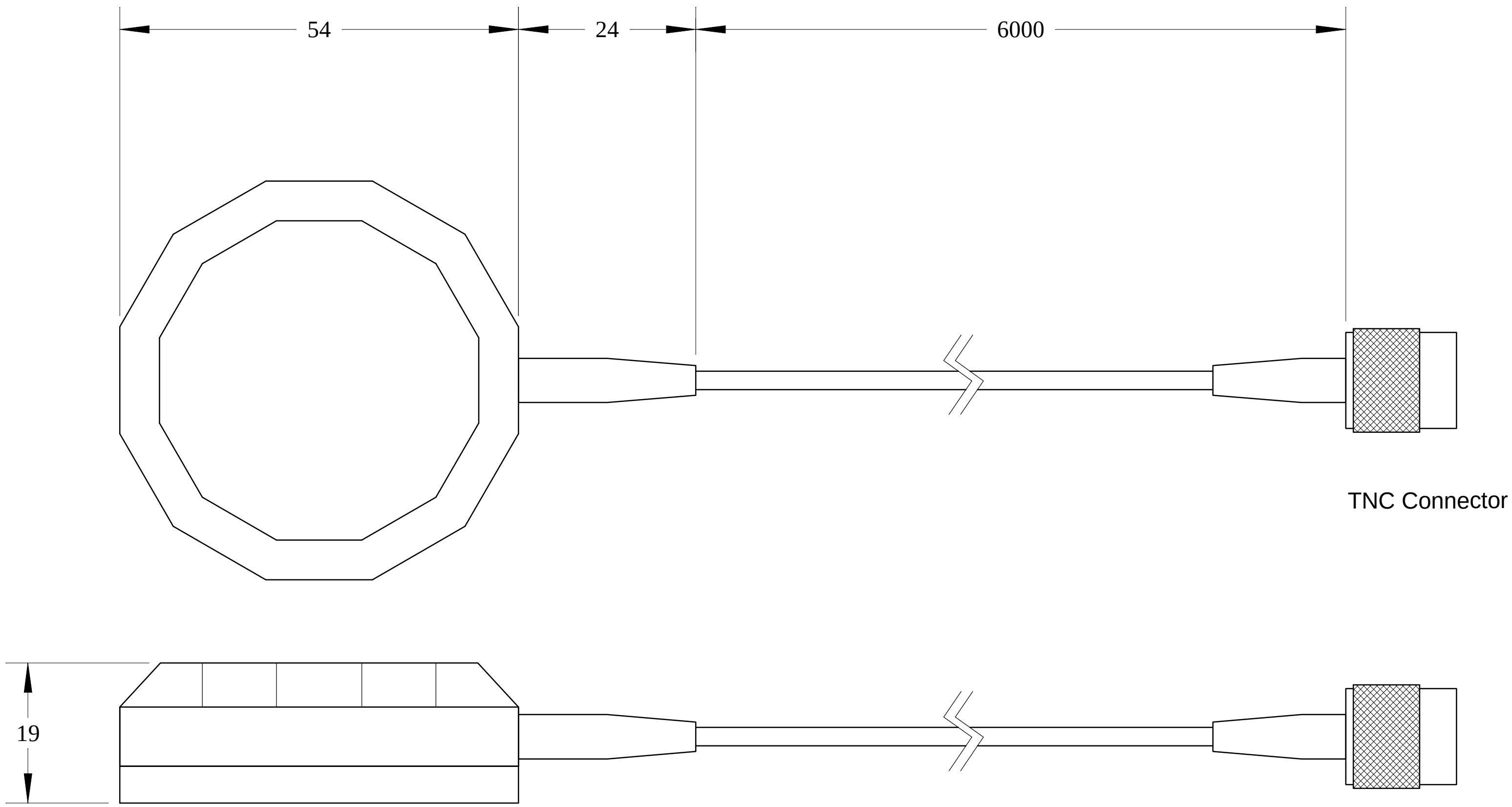
Print Size:	A4
Scale:	1:1
Units:	mm
Tolerances:	1mm
Projection:	3rd Angle

Notes:

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

Date:	08/11/01
Part #:	GPS-600
Document:	Novatel GPS Antenna
Sheet:	1 of 1



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Print Size:	A4
Scale:	1:1
Units:	mm
Tolerances:	1 mm
Projection:	3rd Angle
Notes:	
Date:	21/08/01
Part #:	201-990146-789
Document:	Magnetic GPS Antenna
Sheet:	1 of 1