Spatial Dual Reference Manual

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1 Revision History

Version	Date	Changes
2.15	14/11/2023	Updated firmware changelog, section 2 Updated software changelog, section 11.1 Remove wire colours for pre-terminated breakout and USB cables Updated Advanced Navigation Packet 195 Updated Disclaimer
2.14	20/02/2023	Updated software changelog, section 11.1 Updated software installation information to include Java 11 requirement, section 11.3 Added instructions to run Manager on MacOS, section 11.3
2.13	17/10/2022	Updated software changelog, section 11.1 Added note that Spatial Dual Manager only works on systems with x64 architecture, sections 6.2 and 9.1 Added note about External Data packet acknowledgements, section 13.4 Reworded 1PPS Output, section 12.4.1 Added additional specifics to ANPP Input and ANPP Output, sections 12.4.10 and 12.4.11 Added more context to Geoid Height Packet, section 13.9.35 Updated External Time Packet to show it is Read only, section 13.7 Added External Depth Packet, section 13.9.34 Added raw satellite Ephemeris packet, section 13.9.42
2.12	09/03/2022	Added Device ID table, section 13.8.4.1 Updated hardware changelog, section 3 Updated software changelog, section 11.1 Updated Log Converter Tool image and description, section 11.9.4 Added logging command line information, section 11.6 Updated GNSS Configuration Packet, section 13.10.14 Updated connector pin-out, section 8.10 Added pin location image, section 8.10 Updated list of accessories, section 7.4 Added RS422 evaluation cable information, section 8.11.2 Clarified geoid, ellipsoid and orthometric heights, section 5.7 Added reference to RS422 evaluation cable to evaluation kit content section, section 6.1
2.11	25/10/2021	Updated firmware changelog, section 2 Updated moving base details, section 12.4.44
2.10	31/03/2021	Updated firmware changelog, section 2
2.9	22/01/2021	Updated part numbers and ordering, section 7 Updated base station packet, section 13.9.48 Updated software manager changelog section 11.1 Added GNSS firmware update section 11.9.3

Version	Date	Changes
2.8	22/09/2020	Updated firmware changelog, section 2
2.7	09/09/2020	Updated firmware changelog, section 2 Added zero angular velocity input GPIO function, section 12.4.47 Added Mavlink output GPIO function, section 12.4.47 Added base station packet, section 13.9.48 Added zero angular velocity packet, section 13.9.48 Added sensor temperatures packet, section 13.9.50 Added GNSS configuration packet, section 13.10.14
2.6	04/06/2019	Updated firmware changelog section 2 Updated mechanical drawings, section 8.1 Updated and corrected hardware changelog, section 3 Corrected raw GNSS packet units, section 13.9.10 Updated packet summary, section 13.7 Updated post processing packet information, section 13.9.40 Updated GNSS receiver models, section 13.9.45.2 Updated dynamic pin functions table, section 12.4 Updated GPIO configuration packet, section 13.10.8 Added pressure depth transducer deprecated input function 12.4.17 Added Teledyne DVL input function 12.4.22 Added Tritech USBL input function 12.4.23 Added Linkquest DVL input function 12.4.24 Added Linkquest USBL input functionality 12.4.25 Added reverse alignment input functions 12.4.45 Added zero angular velocity input function 12.4.47 Added moving base corrections output function 12.4.44 Clarified port baud rates in sections 8.6 , 12.1 , 12.3 and 13.10.3 Updated wheel speed sensor section 12.4.30 Updated external body velocity packet section 13.9.28 Updated external pitot pressure packet section 13.9.37
2.5	18/09/2017	Updated firmware changelog, section 2 Updated hardware changelog, section 3 Updated navigation specifications, section 8.2 Updated NMEA GPIO output, section 12.4.7 Added Nortek DVL binary format, section 12.4.26 Updated Auxiliary RS232 Transmit functions, section 13.10.8.3 Updated Auxiliary RS232 Receive functions, section 13.10.8.4 Updated GPIO output configuration packet, section 13.10.12
2.4	23/03/2017	Updated firmware changelog, section 2 Updated hardware changelog, section 3 Added Galileo license to part numbers, section 7.3 Added raw satellite data information, section 10.13 Added post processing information, section 10.14 Updated Spatial Dual Manager changelog, section 11.1 Updated antenna flag in system status, section 13.9.1.1 Updated satellite frequencies, section 13.9.41.1

Version	Date	Changes
2.3	12/04/2016	Updated firmware changelog, section 2 Updated hardware changelog, section 3 Updated images in foundation knowledge, section 5 Updated sensor specifications with more detail, section 8.4 Added antenna offset diagrams, section 9.5 Updated Spatial Dual Manager changelog, section 11.1
2.2	14/04/2015	Updated firmware changelog, section 2 Added part numbers and ordering options, section 7 Updated Spatial Dual evaluation cable harness, section 8.11 Updated serial number, section 8.13 Added network RTK corrections, section 10.12.1 Updated Spatial Dual Manager changelog, section 11.1 Added gimbal encoder phase a function, section 12.4.40 Added gimbal encoder phase b function, section 12.4.41 Added odometer direction forward low, section 12.4.42 Added odometer direction forward high, section 12.4.43 Added packet timing, section 13.6 Corrected packet summary table, section 13.7 Updated raw GNSS status, section 13.9.10.1 Name of wind estimation packet changed to wind packet and it is also now read/write, section 13.9.38 Updated GNSS receiver information packet, section 13.9.45 Added RTK software license accuracy, section 13.9.45.4 Added gimbal state packet, section 13.9.46 Added automotive packet, section 13.9.47 Updated vehicle types, section 13.10.6.1 Corrected length of GPIO output packet, section 13.10.12 Heave offsets packet changed name to reference point offsets packet, format remains the same, section 13.10.11 Added user data packet, section 13.10.15 Added GPIO input configuration packet, section 13.10.16 Fixed a document heading spacing issue
2.1	10/09/2014	Corrected incomplete paragraph in power supply, section 9.4 Fixed error in raw GNSS packet, section 13.9.10 Fixed error in local magnetic field packet, section 13.9.31 Fixed error in baud rates packet, section 13.10.3
2.0	21/08/2014	Added hardware changelog, section 3 Updated connector pin-out, section 8.10 Updated Spatial Dual evaluation cable, section 8.11 Updated serial number information, section 8.13 Updated power supply, section 9.4 Updated GNSS antennas, section 9.5 Added GNSS antenna cables, section 9.6 Updated OBDII Odometer photo, section 9.7.2 Updated Omnistar information, section 10.11 Updated Spatial Manager changelog, section 11.1 Updated linux troubleshooting, section 11.4.3

Version	Date	Changes
		Added communications dialogue, section 11.7.8 Added GNSS receiver dialogue, section 11.7.9 Updated all configuration screenshots, section 11.8 NMEA Output is now GPIO Output, section 11.8.11 Corrected error with dual antenna packet, section 13.10.13 Changed Raw GNSS packet, section 13.9.10.1 NMEA configuration packet has changed to GPIO output configuration packet, section 13.10.12 Added new stunt plane vehicle profile, section 13.10.6.1 Added GNSS receiver information packet, section 13.9.45 Added external odometer packet, section Error: Reference source not found Added external air data packet, section 13.9.44 Added serial port pass through packet, section 13.8.7 Added serial port pass through function, section 12.4.38
1.2	28/02/2014	Added firmware changelog, section 2 Added antenna survey mount assembly, section 6.3 Added evaluation cable harness, section 8.11 Updated antenna installation, section 9.5 Removed underwater navigation section Added Omnistar operation, section 10.11 Added RTK operation, section 10.12 Added Spatial Dual Manager, section 11 Added TSS1 output, section 12.4.35 Added Simrad 1000 output, section 12.4.36 Added Simrad 3000 output, section 12.4.37 Added Dual antenna configuration packet, section 13.10.13
1.1	29/07/2013	Added evaluation kit information, section 6 Added heading accuracy specifications, section 8.3 Updated odometer installation, section 9.7 Updated magnetics installation, section 9.8 Updated heading source, section 10.4 Added event 1 input, section 12.4.33 Added event 2 input, section 12.4.34 Added GNSS receiver passthrough, section 12.4.39 Updated filter status, section 13.9.1.2
1.0	08/05/2013	Initial Release

Table 1: Revision history

2 Firmware Changelog

Version	Date	Changes
3.7		Added support for Trimble firmware v5.53. **This is now the recommended firmware version for BD982 and BD992 devices** Fixed inverse reporting of Automatic Dual Antenna offsets when antenna configuration was Left/Right or Right/Left Fixed 8mm RTK accuracy showing incorrectly Fixed incorrect Omnistar/RTX expiry date in ANPP GNSS Receiver Information packets Fixed timestamp occasionally jumping backwards in NMEA0183 packets Fixed incompatibility with Spatial Dual hardware versions <= 1.3 Improved reliability of time calculations Added support for new Trimble Omnistar satellite names and frequencies, eg OCSAT, EMSAT, etc Fixed Time Filter initialisation issue when receiving 1PPS and Raw GNSS packet in the GPIO or Aux port Increased magnetometer sample rate to 100 Hz on the devices that use MMC5983MA magnetometer
3.6	31/08/2021	Add support for v2.2 hardware Added support for Trimble BD992 v5.5 firmware Fix Packet 80 output not working Added $GPGSV NMEA output
3.5	25/03/2021	Fix intermittent factory restore not working Filter improvements result in higher accuracy navigation and orientation. Better dead reckoning Fix to factory calibration algorithms that could result in higher startup biases than normal on some units
3.42	17/03/2021	Fix Packet 60 remaining on after configuring packet rate to 0 Hz.
3.31	24/02/2021	Regression fix from v3.3 where satellites data would not be displayed when using older Trimble firmware
3.3	22/09/2020	Bug fix for issue where GNSS failure could appear intermittently with older hardware
3.22	10/09/2020	Bug fix for issue where Trimble RTX satellite was not set correctly
3.2	09/09/2020	Increased NMEA output precision Fixed issue with receiver not reporting RTK license Algorithm improvements result in increased accuracy World magnetic model updated to 2020 edition Added Mavlink output option Added Galileo E6 frequency support Added GNSS receiver configuration Added the ability to update the Trimble receiver firmware using Spatial Dual Manager
3.0	23/12/2019	Improvements to heading integrity monitoring

		Updated Omnistar satellite frequencies World magnetic model updated to 2019 edition
2.9	28/08/2019	Support for Novatel HEADING2 messages Improvements to sensor factory calibration
2.8	12/07/2019	Improvements to odometer online scaling algorithm
2.7	31/05/2019	Fixed regression with integrity monitoring introduced in version 2.6
2.6	07/05/2019	Improvements to INS performance in urban canyons Improvements to odometer aided navigation Added support for u-blox Z9P protocol changes World magnetic model updated to WMM2015v2 Added zero angular velocity GPIO input Improvements to water height estimation algorithm Online odometer scaling now adjusts for up to 5% scaling error Added moving base corrections output (CMR format) function for some devices
2.5	18/09/2017	Bug fix for false indication of cycle slips in packet 60 Added NMEA messages GPGSV, PFEC,GPAtt and PFEC,GPHve New integrity monitoring algorithms provide better error rejection, significant performance improvements in multipath environments Improved odometer error rejection
2.41	24/03/2017	Support for hardware version 2.0 Significantly improved dead reckoning performance for automotive, marine and fixed wing aircraft.
2.4	16/03/2017	Addition of new frequencies in raw satellite data. Bug fix for overflow of raw satellite data on systems with BeiDou enabled. Changes to packet 60 output rate now applied immediately. Bug fix for QZSS satellite numbering.
2.31	01/07/2016	Bug fix for magnetometer and pressure false failure indications after saving configuration. 1PPS input and 1PPS output timing improvements. Packet timing improvements (lower jitter and better aligned to UTC time). Maximum baud rate increased to 2M baud for RS232. New multipath mitigation algorithm significantly improves performance in poor signal areas.
2.2	05/04/2016	Performance improvements Added support for NMEA messages GPROT and GPHEV Added support for raw GNSS packet input Bug fix for NMEA mode character indicating incorrectly Bug fix for raw satellite data packet update rate not saving correctly Support for hardware version 1.4
2.1	14/04/2015	Enhanced odometer hot start dead reckoning performance

		Bug fix with serial port passthrough incorrect port ID New tightly coupled heave filter operating at 1000Hz Improved hot start performance and functionality New algorithm for use inside gimbals (requires encoder) More robust time acceptance from external sources NMEA time is now perfectly aligned to the millisecond Support for offsetting reference position of output data Improved handling of leap second change during operation Virtual odometer distance filter added Slip filter added Bug fix for differential corrections being sent to GNSS receiver before initialised causing issues Updated world magnetic model to 2015 version Improved reversing detection filter Added gimbal state and configuration packets Added automotive packet Added race car vehicle profile
2.0	21/08/2014	Support added for new hardware version 1.3 Significant filter performance improvements under high dynamics Improved filter performance under dead reckoning Improved performance in urban canyon conditions where a GNSS fix is rarely available Improvements to car and fixed wing plane vehicle profiles Improvements to delay compensation filter Fixed bug that could cause temporary GNSS failure after long periods Raw GNSS packet updated to new format GPIO output configuration packet updated Support for external odometer packet added Support for external air data packet added Wind estimation filter improvements Added stunt plane vehicle profile Added support for serial port passthrough Support for GNSS receiver information packet added GPIO data output now up to 50Hz
1.2	10/03/2014	Update internal AN RTOS to v4.0 Improved heading performance in multipath conditions Added TSS1 output support Added Simrad 1000 output support Added Simrad 3000 output support Added Dual antenna configuration packet support
1.1	17/10/2013	Post-processing improvements
1.0	08/05/2013	Initial release

Table 2: Firmware changelog

3 Hardware Changelog

Version	Date	Changes
2.2	23/07/2021	Updated Magnetometers Updated IMU
2.1	03/01/2019	Updated internal GNSS receiver to BD992
2.0	25/03/2017	Updated internal disciplined TCXO for significantly improved timing holdover. Updated magnetometer offers improved performance. Improved protection on RS232/RS422 signal lines against high voltage damage
1.4	04/12/2015	Minor internal improvements No noticeable changes for customers
1.3	21/08/2014	Power supply is now galvanically isolated Pin 1 changed from ground to signal ground Pin 9 changed from unused to power ground GPIO pins now automatically switch from TTL levels to RS232 levels when operating as data functions Slew rate control on RS232 automatically changes based upon baud rate setting Evaluation kit now comes with RG-58/U Low Loss cables
1.2	25/08/2013	Minor internal improvements No noticeable changes for customers
1.0	08/05/2013	Initial release

Table 3: Hardware changelog

4 Introduction

Spatial Dual is a miniature GNSS/INS & AHRS system that provides accurate position, velocity, acceleration and orientation under the most demanding conditions. It combines temperature calibrated accelerometers, gyroscopes, magnetometers and a pressure sensor with a dual antenna RTK GNSS receiver. These are coupled in a sophisticated fusion algorithm to deliver accurate and reliable navigation and orientation.

Spatial Dual can provide amazing results but it does need to be set up properly and operated with an awareness of its limitations. Please read through this manual carefully to ensure success within your application.

The Spatial Dual Manager software is downloadable from the software section. It allows Spatial Dual to be easily configured and tested. It is referenced throughout this manual.

Note: Spatial Dual Manager is only available for systems with x64 architecture.

If you have any questions please contact support@advancednavigation.com.au.

5 Foundation Knowledge

This chapter is a learning reference that briefly covers knowledge essential to understanding Spatial Dual and the following chapters. It explains the concepts in simple terms so that people unfamiliar with the technology may understand it.

5.1 GNSS

GNSS stands for global navigation satellite system. A GNSS consists of a number of satellites in space that broadcast navigation signals. These navigation signals can be picked up by a GNSS receiver on the earth to determine that receiver's position and velocity. For a long time the only operational GNSS was the United States GPS. However the Russian GLONASS is now fully operational with similar performance to GPS. The Chinese BeiDou is in the process of becoming operational and the European Union's GALILEO should be operational within ten years.

GNSS is excellent for navigational purposes and provides fairly accurate position (2.5 metres) and velocity (0.03 metres/second). The main drawback of GNSS is that the receiver must have a clear signal from at least 4 satellites to function. GNSS satellite signals are very weak and struggle to penetrate through buildings and other objects obstructing view of the sky. GNSS can also occasionally drop out due to disturbances in the upper atmosphere.

5.2 INS

INS stands for inertial navigation system. An inertial navigation system can provide position and velocity similar to GNSS but with some big differences. The principle of inertial navigation is the measurement of acceleration. This acceleration is then integrated into velocity. The velocity is then integrated into position. Due to noise in the measurement and the compounding of that noise through the integration, inertial navigation has an error that increases exponentially over time. Inertial navigation systems have a very low relative error over short time periods but over long time periods the error can increase dramatically.

5.3 GNSS/INS

By combining GNSS and INS together in a mathematical algorithm, it is possible to take advantage of the benefits of GNSS long-term accuracy and INS short-term accuracy. This provides an overall enhanced position and velocity solution that can withstand short GNSS drop outs.

5.4 AHRS

AHRS stands for attitude and heading reference system. An AHRS uses accelerometers, gyroscopes and magnetometers combined in a mathematical algorithm to provide orientation. Orientation consists of the three body angles roll, pitch and heading.

5.5 The Sensor Co-ordinate Frame

Inertial sensors have 3 different axes: X, Y and Z and these determine the directions around which angles and accelerations are measured. It is very important to align the axes correctly in installation otherwise the system won't work correctly. These axes are marked on the top of the device as shown in Illustration 1 below with the X axis pointing in the direction of the connectors, the Z axis pointing down through the base of the unit and the Y axis pointing off to the right.

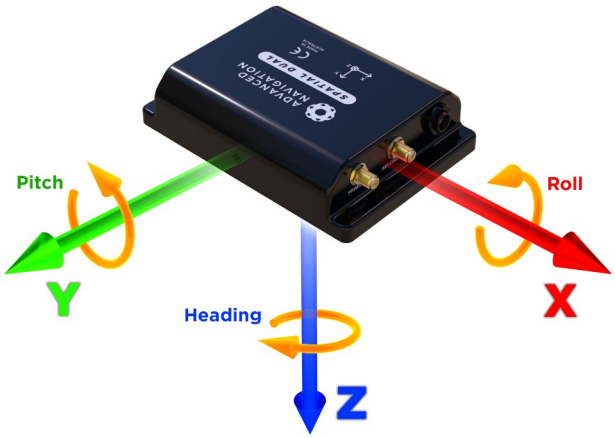


Illustration 1: Spatial Dual axes

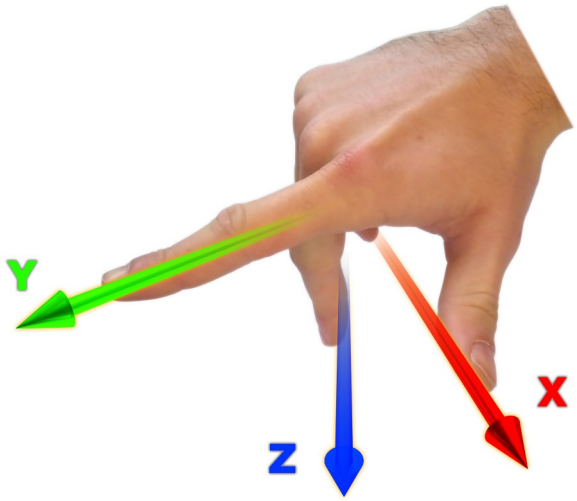


Illustration 2: First right hand rule

When installed in an application the X axis should be aligned such that it points forwards and the Z axis aligned so that it points down when level. A good way to remember the sensor axes is the right hand rule, which is visualised in Illustration 2. You take your right hand and extend your thumb, index and middle. Your thumb then denotes the X axis, your index denotes the Y axis and your middle denotes the Z axis.

5.6 Roll, Pitch and Heading

Orientation can be described by the three angles roll, pitch and heading, these are known as the Euler angles. The rotation axes of roll, pitch and heading are shown visually in Illustration 1. The arrow indicates the positive rotation direction.

Roll is the angle around the X axis and is zero when the unit is level. Pitch is the angle around the Y axis and is zero when the unit is level. Heading is the angle around the Z axis and is zero when the positive X axis is pointing to true north.

5.6.1 Second Right Hand Rule

The two right hand rules are often the best way to memorise the sensor axes and directions of positive rotation. The first right hand rule gives the positive axis directions and is described in section 5.5. The second right hand rule shown in Illustration 3 provides the direction of positive rotation. To use it, point your thumb in the positive direction of that axis, then the direction that your fingers curl over is the positive rotation on that axis.

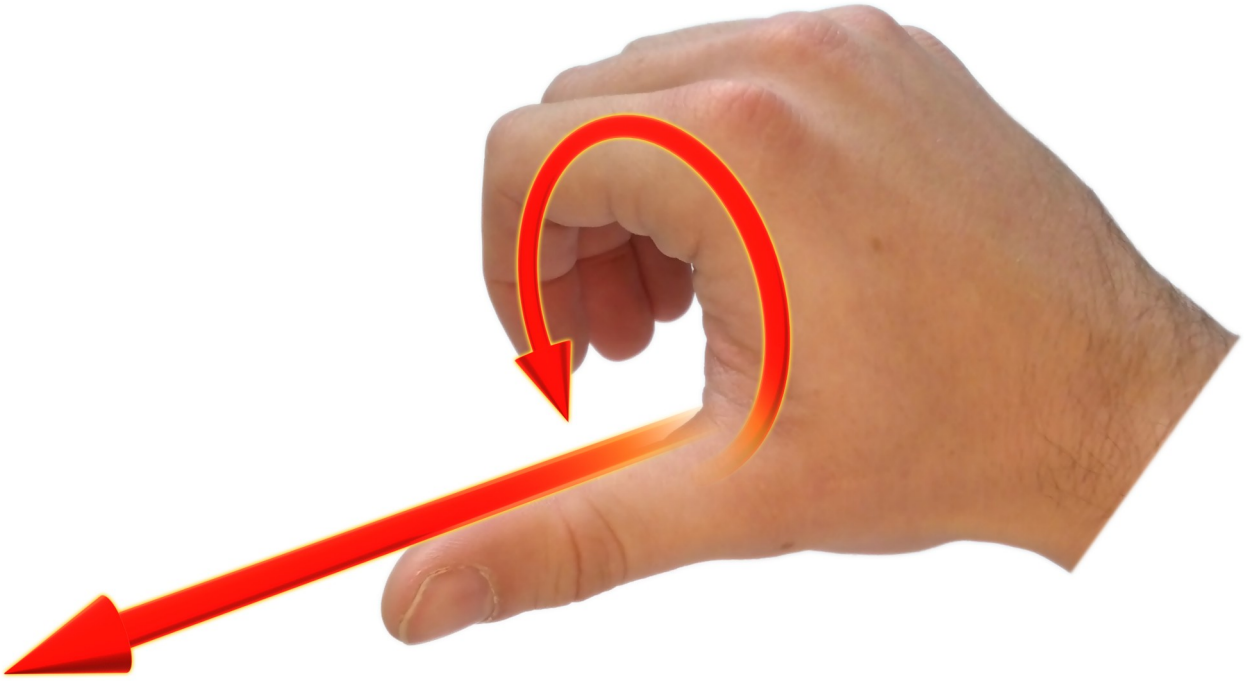


Illustration 3: Second right hand rule

5.6.2 Rotation Order

When multiple axes are rotated, to imagine the final orientation the three rotations must be performed in the order heading first, then pitch and then roll. To deduce the final orientation the unit should first be considered level with the X axis pointing north and the Z axis pointing down. Heading is applied first, then pitch is applied and finally roll is applied to give the final orientation. This can be hard for some people to grasp at first and is often best learned experimentally by rotating Spatial Dual with your hand whilst watching the orientation plot in real time on the computer.

5.7 Geodetic Co-ordinate System

The geodetic co-ordinate system is the most popular way of describing an absolute position on the Earth. It is made up of the angles latitude and longitude combined with a height relative to the ellipsoid.

5.7.1 Longitude and Latitude

Latitude is the angle that specifies the north to south position of a point on the Earth's surface, reported as ± 90°. Longitude is the angle that specifies the east to west position of a point on the Earth's surface, reported as ± 180°. The line of zero latitude is the equator and the line of zero longitude is the prime meridian. Illustration 4 shows how latitude and longitude angles are used to describe a position on the surface of the Earth.

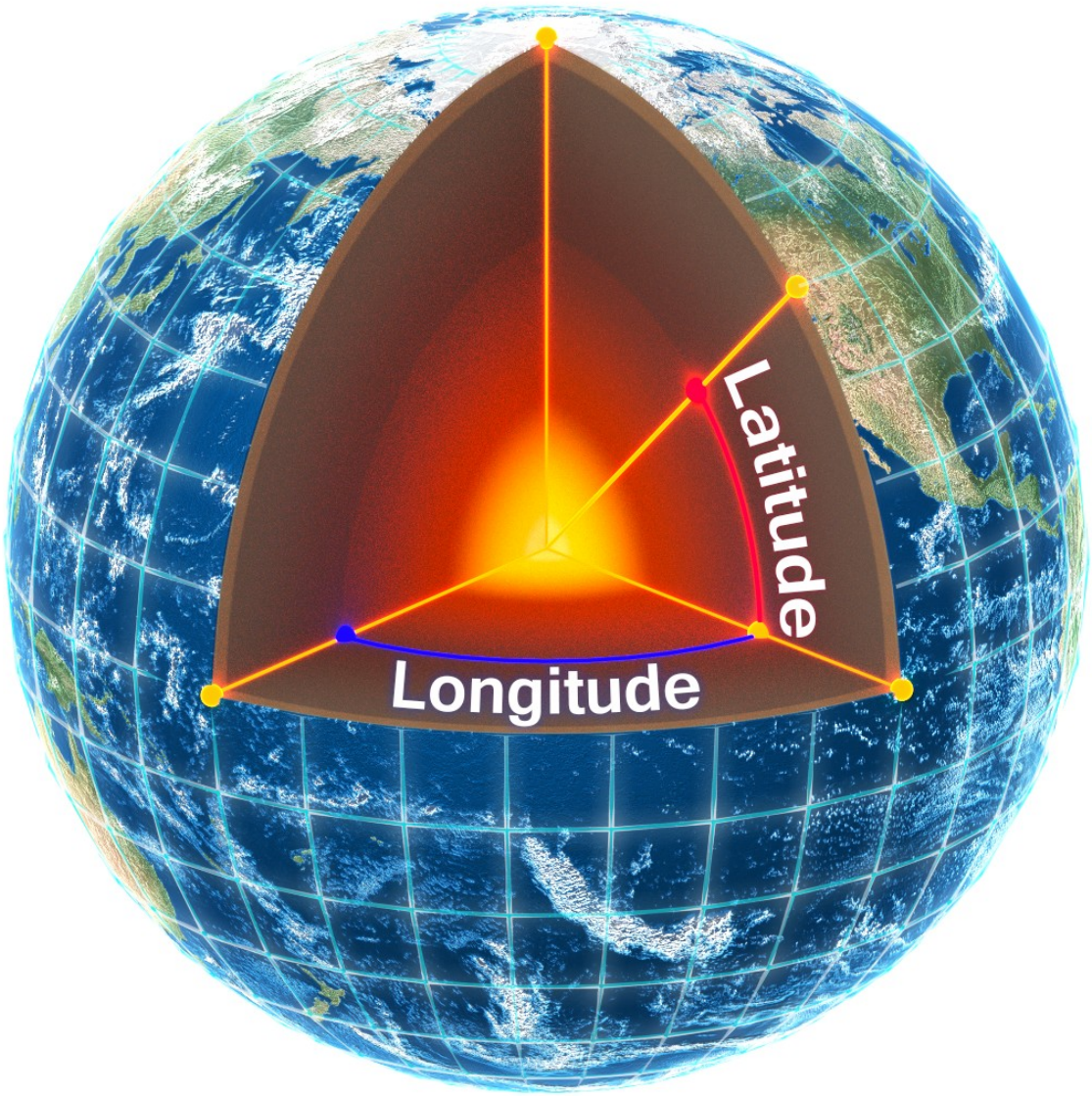


Illustration 4: Latitude and longitude represented visually to describe a position

Illustration 5 below shows latitude and longitude on a map of the world, represented with a standard Mercator projection.

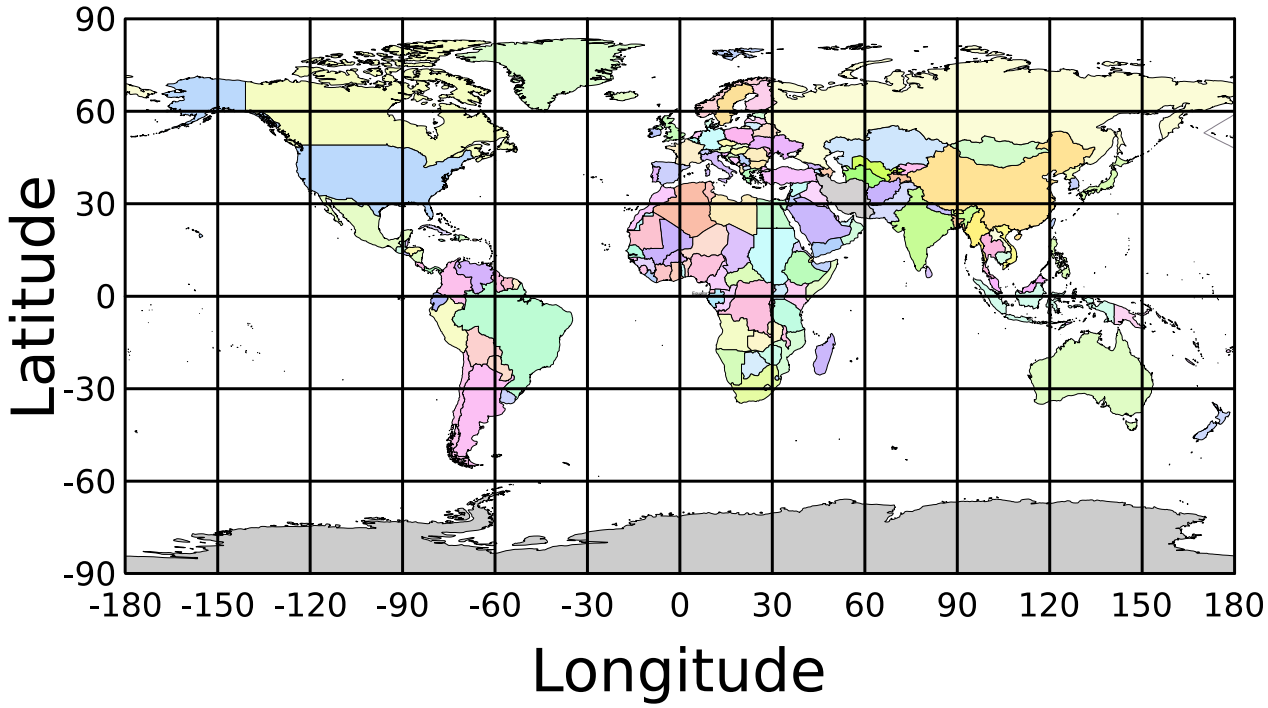


Illustration 5: World map showing latitudes and longitudes

Latitude and longitude give the 2D point on the surface of the Earth. These are combined with height to give the 3D position on the Earth.

5.7.2 Height

Any height data output by Advanced Navigation devices is the height referenced the WGS84 reference ellipsoid. The WGS84 reference ellipsoid is a smooth mathematical model that approximates the form of the surface of the earth. The ellipsoid height (as used by GNSS) is not referenced to mean sea level; the height from the EGM96 geoid (orthometric height) approximates the height above mean sea level (MSL).

See Illustration 6 below for a visual representation of geoid height, ellipsoid height and orthometric height (height above mean sea level).

Note:

- Ellipsoid height refers to the height of a point of interest referenced to the WGS84 reference ellipsoid
- Geoid height refers to the height of the EGM96 geoid referenced to the WGS84 reference ellipsoid at a point of interest
- Orthometric height is the height at a point of interest referenced to the EGM96 geoid.

All heights can be either positive or negative dependant upon direction from the reference surface.

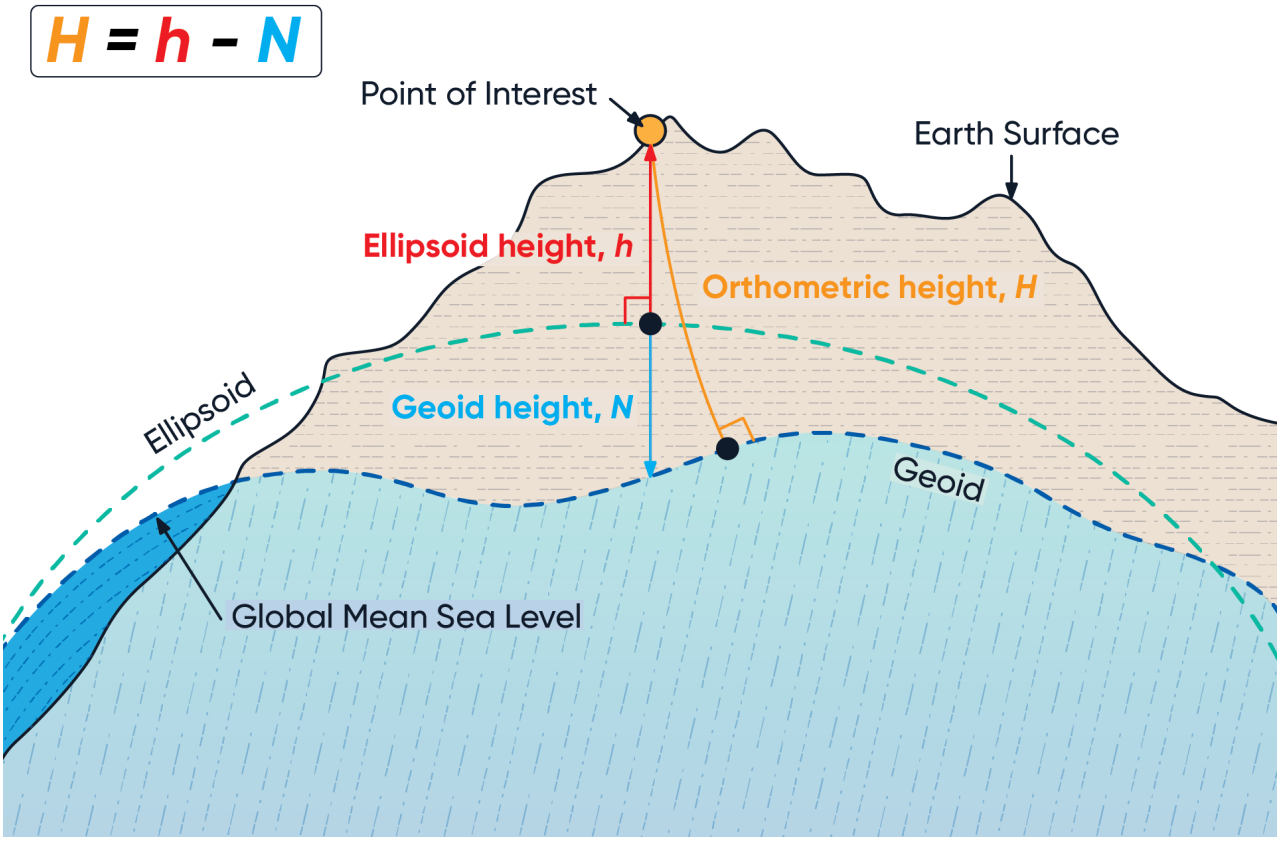


Illustration 6: Orthometric, ellipsoid and geoid height diagram

The value required to convert the WGS84 ellipsoid height to orthometric height can be found in the geoid height packet, see section 13.9.35 .

5.8 NED Co-ordinate Frame

The NED (North East Down) co-ordinate frame is used to express velocities and relative positions. The origin of the co-ordinate frame can be considered the current position. From that origin, the north axis points true north and parallel to the line of latitude at that point. The east axis points perpendicular to the north axis and parallel to the line of longitude at that point. The down axis points directly down towards the centre of the Earth. See Illustration 7 for a graphical representation of the NED co-ordinate frame at a position on the Earth.

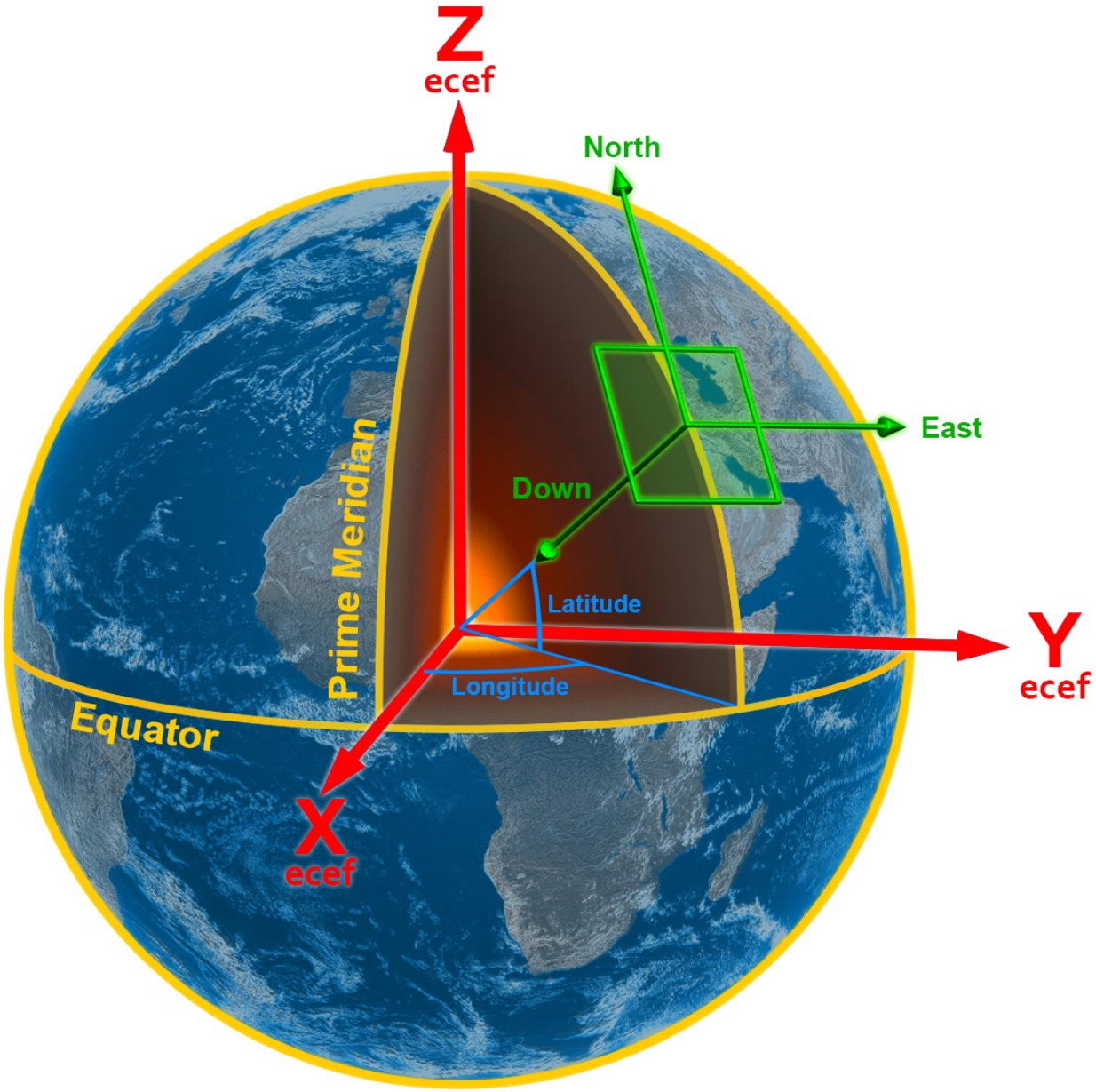


Illustration 7: Graphic showing geodetic, NED and ECEF co-ordinates

5.9 ECEF Co-ordinate Frame

The ECEF (Earth-centred earth-fixed) co-ordinate frame is a Cartesian co-ordinate frame used to represent absolute positions on the Earth. It's origin is at the centre of the Earth. ECEF is an alternative to the geodetic co-ordinate frame. It is represented by the three axes X, Y and Z which are presented graphically in Illustration 7. ECEF positions can be retrieved from Advanced Navigation products however the geodetic system is used as the default.

6 Evaluation Kit

Spatial Dual is supplied in an evaluation kit that contains everything required to get started operating the system right away. The evaluation kit is supplied in a rugged transport case to protect the equipment during shipping.

Illustration 8: Spatial Dual Evaluation Kit rugged transport case

Illustration 9: Spatial Dual Evaluation Kit contents

6.1 Evaluation Kit Contents

1. 1 x Spatial Dual GNSS/INS
2. 2 x Antcom G5Ant-53A4T1 L1/L2/L5 GNSS antennas with 5/8”-11 survey mounts
3. 2 x 4 metre RG58/U antenna cables
4. 1 x 2 metre interface cable harness, see section 8.11.1 for the RS232 evaluation kit cable, and section 8.11.2 for the RS422 cable.
5. 1 x 1 metre FTDI USB to RS232 / RS422 (switchable) adaptor cable
6. 1 x 100-240 volt AC to 24 volt DC power supply

6.2 Quick Start

1. Position the two GNSS antennas in a level orientation with a clear view of the sky. The primary antenna should be positioned directly forwards of the secondary antenna with separation of at least 0.5 metres.
2. Connect the coaxial cables between the antennas and Spatial Dual.
3. Plug the interface cable into Spatial Dual.
4. Plug the USB to RS232 cable into the interface cable and your computer.
5. Plug the power supply into the interface cable and then into the wall socket.
6. Download the Spatial Dual Manager software from the Advanced Navigation website.
7. Java 11 is required to run Spatial Dual Manager. Adoptium JRE 11 is the recommended Java installer to be used on all platforms. Install the latest version of Java 11 from

Adoptium, selecting the correct operating system and architecture for your computer.

8. Click the connect button in Spatial Dual Manager.
9. The various windows in Spatial Dual Manager can be used to view the real time data.
10. The dual antenna heading will take a short time to initialise. The progress can be monitored in the status view.
11. To view the data logs, click disconnect in Spatial Dual Manager. In the tools menu, select log converter and press convert. The *.anpp binary log file will be converted to CSV files that can be opened with popular data processing programs such as Matlab or Microsoft Excel. The log files can be found in the same folder as the Spatial Dual Manager software.

6.3 Antenna Survey Mount Assembly

The Antcom G5Ant-53A4T1 antennas included in the evaluation kit can either be mounted to a panel or mounted to a standard 5/8”-11 survey mount thread with the optional survey mount kit included in the evaluation kit. Please see Illustration 10 below for assembly of antenna with the survey mount kit.

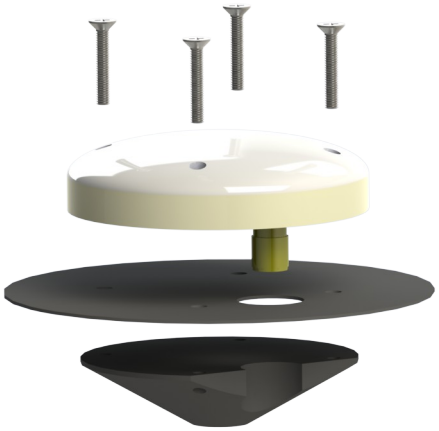


Illustration 10: Antenna survey mount exploded view

7 Part Numbers and Ordering Options

7.1 Evaluation Kit

Part Number	Description	Notes
SPATIAL-DUAL-EK	Spatial Dual Evaluation Kit	Spatial Dual evaluation kit Includes items listed in section 6.1 L1/L2/L5 GPS, GLONASS, Omnistar, Trimble RTX and SBAS Raw satellite data output supported 0.3m float RTK supported License required for fixed RTK, BeiDou and Galileo
SPATIAL-DUAL-EK-422	Spatial Dual Evaluation Kit (RS422 option)	Spatial Dual evaluation kit (RS422) RS422 instead of RS232 No auxiliary serial port Includes items listed in section 6.1 L1/L2/L5 GPS, GLONASS, Omnistar, Trimble RTX and SBAS Raw satellite data output supported 0.3m float RTK supported License required for fixed RTK, BeiDou and Galileo

Table 4: Evaluation kit part numbers

7.2 Standalone Unit

Part Number	Description	Notes
SPATIAL-DUAL	Spatial Dual Unit	Spatial Dual Unit L1/L2/L5 GPS, GLONASS, Omnistar, Trimble RTX and SBAS Raw satellite data output supported 0.3m float RTK supported License required for fixed RTK, BeiDou and Galileo No cables included
SPATIAL-DUAL-422	Spatial Dual Unit (RS422 option)	Spatial Dual Unit (RS422) RS422 instead of RS232 No auxiliary serial port L1/L2/L5 GPS, GLONASS, Omnistar, Trimble RTX and SBAS Raw satellite data output supported 0.3m float RTK supported License required for fixed RTK, BeiDou and Galileo No cables included

Table 5: Standalone unit part numbers

7.3 Internal GNSS Receiver License Upgrades

These license upgrades can either be ordered with the unit or purchased later and installed in the field using Spatial Dual Manager.

Part Number	Description	Notes
SD-BEI-UPG	Spatial Dual BeiDou Upgrade	BeiDou B1/B2 support for Spatial Dual
SD-GAL-UPG	Spatial Dual Galileo Upgrade	Galileo E1/E5 support for Spatial Dual
SD-LIC-10CM	Spatial Dual 0.1m RTK Upgrade	Upgrade from 0.3m to 0.1m RTK position accuracy
SD-LIC-8MM	Spatial Dual 0.008m RTK Upgrade	Upgrade from 0.3m to 0.008m RTK position accuracy

Table 6: Internal GNSS receiver license upgrade part numbers

7.4 Accessories

Part Number	Description	Notes
A503-SDC20740-2M	ODU plug with 2m cable (unterminated)	Spatial Dual ODU plug with 2m of unterminated cable, see section 8.10
A503-SDC20753	ODU to D9 connectors and DC socket	Spatial Dual ODU plug with 2m of cable to industry standard D9 connectors and DC socket, see section 8.11.1
A503-SDC20755	ODU to D9 connectors and DC socket (RS422)	Spatial ODU plug with 2m of cable to industry standard D9 connectors and DC socket, see section 8.11.2
CABLE-FTDI	USB to RS232 / RS422 cable 1 m	FTDI USB to RS232 / RS422 (selectable) 1 metre cable
SUPPLY-24V	24V DC Power Supply	100-240V AC Mains to 24V DC Power Supply (DC jack) Includes 2-pin plug types A/C/G/I
CAR12VPWR	Car auxiliary power outlet supply	Car cigarette lighter to DC jack power supply
BF046WS130621-06	SMA to TNC 4m cable	4 metre RG-58A/U antenna cable with SMA and TNC connectors
G5ANT-53A4T1	Antcom GNSS Antenna	Antcom G5 L1/L2/L5 GNSS antenna with survey mount
VSP6337L	VeroStar GNSS Antenna	VeroStar GNSS Antenna - L1/L2/L5 plus L-band, pole mount, TNC Female Connector

Part Number	Description	Notes
OBDII-ODOMETER	OBDII Odometer	OBDII Odometer Interface See section 9.7.2
AD-UNIT-LS (Low Speed) AD-UNIT (Standard) AD-UNIT-HS (High Speed)	Air Data Unit	Air data unit provides pitot and static air data aiding for Spatial Dual in fixed wing aircraft
MOUNT-SUCT	Suction Cup Antenna Mount	Suction cup 5/8” GNSS antenna survey mount for easy installation of GNSS antenna on vehicles
ILU	Interface and Logging Unit	Interface and logging unit provides an ethernet interface to Spatial with built in logging, time server and more ports

Table 7: Accessories part numbers

8 Specifications

8.1 Mechanical Drawings

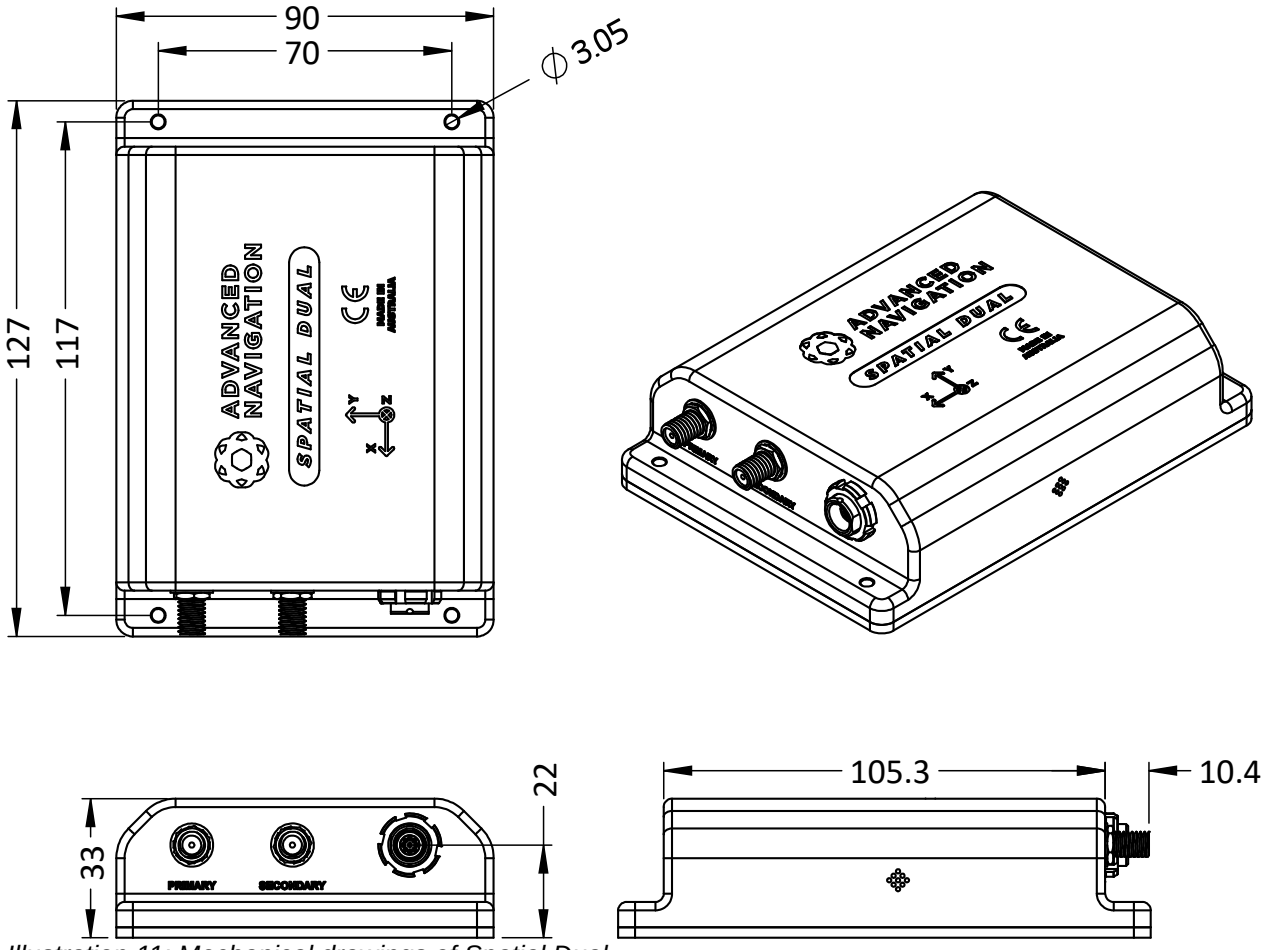


Illustration 11: Mechanical drawings of Spatial Dual

8.2 Navigation Specifications

Parameter	Value
Horizontal Position Accuracy	1.2 m
Vertical Position Accuracy	2.0 m
Horizontal Position Accuracy (SBAS)	0.5 m
Vertical Position Accuracy (SBAS)	0.8 m
Horizontal Position Accuracy (RTK or Kinematica Post Processing)	0.008 m
Vertical Position Accuracy (RTK or Kinematica Post Processing)	0.015 m
Velocity Accuracy	0.007 m/s
Roll & Pitch Accuracy	0.1 °
Heading Accuracy	0.1 °
Roll & Pitch Accuracy (Kinematica Post Processing)	0.03 °
Heading Accuracy (Kinematica Post Processing)	0.06 °
Slip Accuracy	0.1 °
Heave Accuracy	5 % or 0.05 m
Orientation Range	Unlimited
Hot Start Time	500 ms
Internal Filter Rate	1000 Hz
Output Data Rate	Up to 1000 Hz

Table 8: Navigation specifications

8.3 Heading Accuracy

Antenna Separation	Accuracy
0.5 m	0.16 °
1 m	0.1 °
2 m	0.07 °
5 m	0.05 °
10 m	0.02 °

Table 9: Heading accuracy

8.4 Sensor Specifications

Parameter	Accelerometers	Gyroscopes	Magnetometers	Pressure
Range (dynamic)	±2 g ±4 g ±16 g	±250 °/s ±500 °/s ±2000 °/s	±2 G ±4 G ±8 G	10 to 120 KPa
Bias Instability	20 µg	3 °/hr	-	10 Pa
Initial Bias	< 5 mg	< 0.2 °/s	-	< 100 Pa
Initial Scaling Error	< 0.06 %	< 0.04 %	< 0.07 %	-
Scale Factor Stability	< 0.06 %	< 0.05 %	< 0.09 %	-
Non-linearity	< 0.05 %	< 0.05 %	< 0.08 %	-
Cross-axis Alignment Error	< 0.05 °	< 0.05 °	0.05 °	-
Noise Density	150 ug/√Hz	0.005 °/s/√Hz	210 uG/√Hz	0.56 Pa/√Hz
Bandwidth	400 Hz	400 Hz	110 Hz	50 Hz

Table 10: Sensor specifications

8.5 GNSS Specifications

Parameter	Value
Supported Navigation Systems	GPS L1, L2, L5 GLONASS L1, L2 GALILEO E1, E5 BeiDou B1, B2
Supported SBAS Systems	WAAS EGNOS MSAS GAGAN QZSS Omnistar HP/XP/G2
Update Rate	20 Hz
Hot Start First Fix	3 s
Cold Start First Fix	30 s
Horizontal Position Accuracy	1.2 m
Horizontal Position Accuracy (with SBAS)	0.5 m
Horizontal Position Accuracy (with RTK)	0.008 m
Velocity Accuracy	0.007 m/s
Timing Accuracy	20 ns
Acceleration Limit	11 g

Table 11: GNSS Specifications

8.6 Communication Specifications

Parameter	Value
Interface	RS232 (RS422 optional)
Primary and Auxiliary Port Speed	2400 to 2 M baud
GPIO Port Speed	2400 to 250 K baud
Protocol	AN Packet Protocol
Peripheral Interface	2x GPIO and 1x Auxiliary RS232
GPIO Level	5V or RS232

Table 12: Communication specifications

8.7 Hardware Specifications

Parameter	Value
Operating Voltage	9 to 36 V
Input Protection	-40 to 100 V
Power Consumption	220 mA @ 12 V (typical)
Hot Start Battery Capacity	> 24 hrs
Hot Start Battery Charge Time	30 mins
Hot Start Battery Endurance	> 10 years
Operating Temperature	-40 °C to 85 °C
Environmental Sealing	IP67 MIL-STD-810G
Shock Limit	75 g
Dimensions	90 x 127 x 33 mm
Weight	285 grams

Table 13: Hardware specifications

8.8 Electrical Specifications

Parameter	Minimum	Typical	Maximum
Power Supply			
Input Supply Voltage	9 V		36 V
Input Protection Range	-40 V		100 V
RS232			
Tx Voltage Low		-5.4 V	-5 V
Tx Voltage High	5 V	5.4 V	
Tx Short Circuit Current			±60 mA
Rx Threshold Low	0.8 V	1.3 V	
Rx Threshold High		1.7 V	2.5 V
GPIO			
Output Voltage Low	0 V		0.3 V
Output Voltage High	4.8 V		5 V
Input Voltage	-20 V		20 V
Input Threshold Low			1.5 V
Input Threshold High	3.5 V		
Output Current			5 mA
GNSS Antenna			
Active Antenna Supply Voltage	4.8 V		5 V
Antenna Supply Current			100 mA

Table 14: Electrical specifications

8.9 Power Consumption

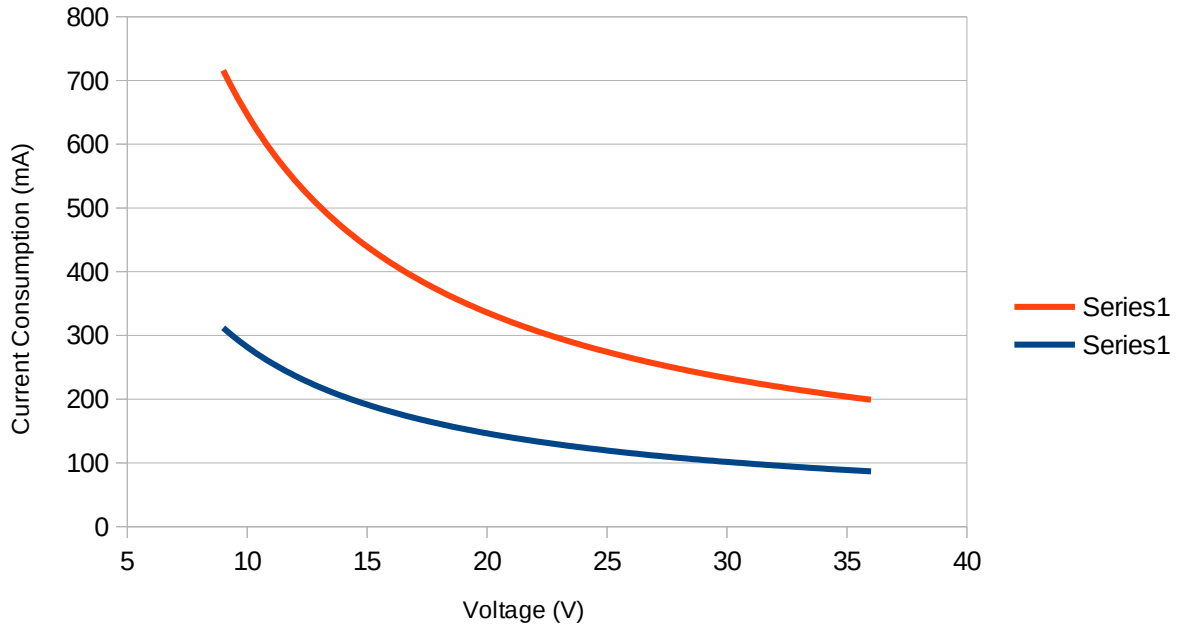


Illustration 12: Maximum and typical current consumption across operating voltage

8.10 Connector Pin-out

Power supply and signal connections are made through a ODU Mini-Snap Series B 9 pin connector (part number S30B0S-P09MCC0-5000). The connector provides a reliable and rugged connection to the Spatial Dual under demanding conditions and is rated to IP68 in the mated condition. Advanced Navigation stocks 2 metre unterminated ODU cables that are shielded and have external TPE insulation. Each individual wire is colour coded, FEP coated 28AWG wire, labelled with the ODU pin number on the unterminated end. Custom cable lengths can be ordered by request.

Illustration 13: ODU B series mating plug for Spatial Dual

See Illustration 14 for ODU connector pin locations and Table 15 for each pin function. Illustration 15 shows the perspective used for the pin location diagram.

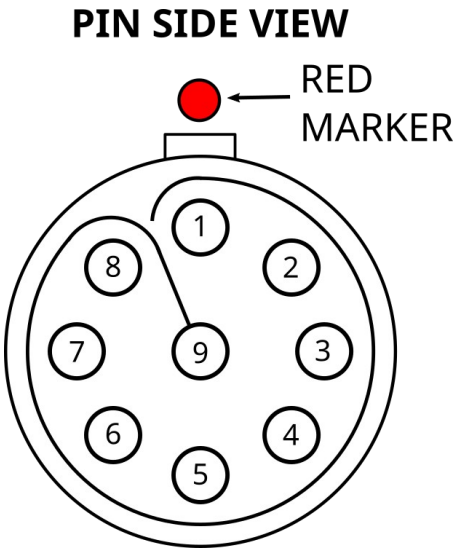


Illustration 14: ODU B series pin locations

Illustration 15: Pin-out view perspective

Pin	Colour	Function (RS232 version)	Function (RS422 version)
1	Black	Ground	Ground
2	Brown	Power Supply	Power Supply
3	White	GPIO 1	GPIO 1
4	Green	GPIO 2	GPIO 2
5	Red	Primary RS232 Transmit	RS422 Transmit +
6	Orange	Primary RS232 Receive	RS422 Receive +
7	Yellow	Auxiliary RS232 Transmit	RS422 Transmit −
8	Blue	Auxiliary RS232 Receive	RS422 Receive −
9	Pink	Ground	Ground

Table 15: Pin allocation table

8.11 Spatial Dual Evaluation Cable Harnesses

Advanced Navigation supplies pre-terminated breakout cables in the evaluation kits for access to all of Spatial Dual's pins. There are two breakout cables – one for the RS232 unit and one for the RS422 unit. All external signal and power connections are provided with 2m of cable. The breakout cables are an optional extra and are not supplied as standard with the evaluation kit.

8.11.1 RS232 Evaluation Cable (A503-SDC20753)

The RS232 interface cable is provided with industry standard 9 pin DSUB connectors for each of the two RS232 communication channels and GPIO pins. Please note that this cable is only applicable to the RS232 version of Spatial (part number SPATIAL-DUAL).

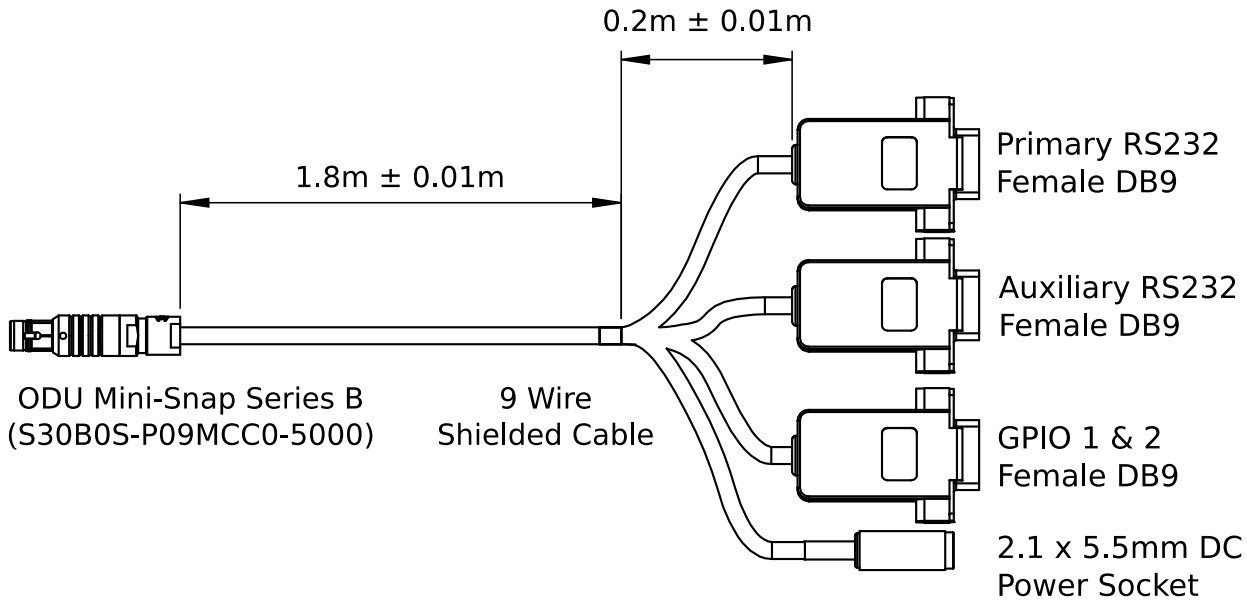


Illustration 16: RS232 evaluation cable diagram

Pin	Function	Primary	Auxiliary	GPIO	Power
1	Ground	5	5	5	
2	Power				Tip
3	GPIO 1			2	
4	GPIO 2			3	
5	Primary RS232 Tx	2			
6	Primary RS232 Rx	3			
7	Auxiliary RS232 Tx		2		
8	Auxiliary RS232 Rx		3		
9	Ground				Ring

Table 16: RS232 evaluation cable connector pin-out

8.11.2 RS422 Evaluation Cable (A503-SDC20755)

The RS422 interface cable is provided with an industry standard 9 pin DSUB connector for the RS422 communication channel and GPIO pins.

Please note that this cable is only applicable to the RS422 version of Spatial Dual (part number SPATIAL-DUAL-422)

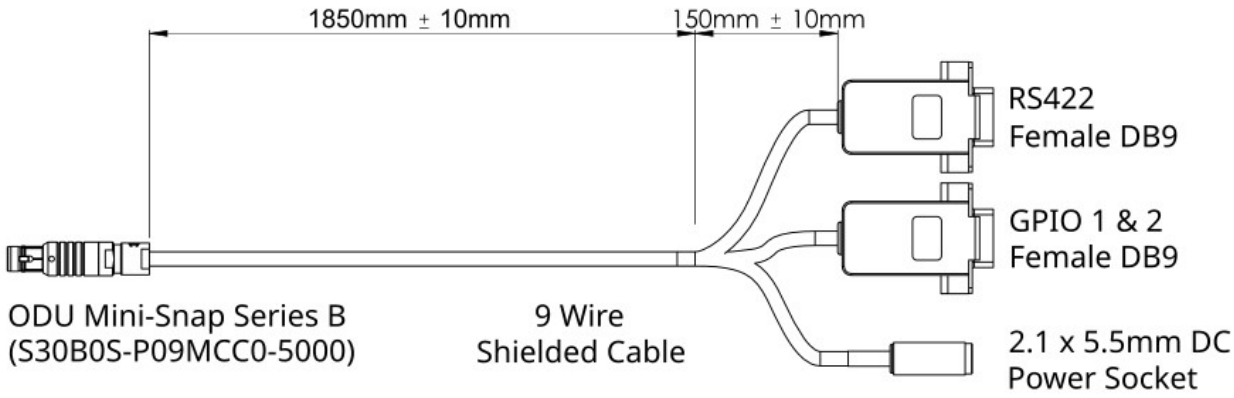


Illustration 17: RS422 evaluation cable diagram

Pin	Function	RS422	GPIO	Power
1	Ground	5	5	
2	Power			Tip
3	GPIO 1		2	
4	GPIO 2		3	
5	RS422 Tx +	2		
6	RS422 Rx +	3		
7	RS422 Tx −	8		
8	RS422 Rx −	7		
9	Ground			Ring

Table 17: RS422 evaluation cable connector pin-out

8.12 Sensor Calibration

Spatial Dual's sensors are calibrated for bias, sensitivity, misalignment, cross-axis sensitivity, non-linearity and gyroscope linear acceleration sensitivity across the full operating temperature range and for each of the three sensor ranges.

8.13 Serial Number

The serial number can be inspected by using the device information dialogue in the Spatial Dual Manager software, see section 11.7.1. The primary serial number label is located inside the enclosure and is accessible only by Advanced Navigation technicians. The secondary serial number label is located on the outside rear of the enclosure with the serial number encoded in a 2D data matrix bar code to assist customers in tracking their units. The external label also contains the hardware version and build date. Applications are available for most smart-phones that can scan the 2D data matrix bar code to display the serial number.

Illustration 18: Spatial Dual external serial number label

9 Installation

9.1 Installation Checklist

1. Securely mount the unit to the vehicle following the guidelines in section 9.2.
2. Mount the two GNSS antennas following the guidelines in section 9.5 and then connect the antenna cables between the antennas and the Spatial Dual unit. If the two antennas are not installed in the standard configuration of primary front and secondary rear, the offset will need to be entered into the Dual Antenna dialogue in Spatial Dual Manager.
3. Connect the connector cable to Spatial Dual and then connect a suitable power supply as specified in section 9.4. A suitable power supply is included in the evaluation kit.
4. Connect the USB converter cable to the primary port and a computer, open the Spatial Dual Manager software and click connect.

   Note: Spatial Dual Manager is only available for systems with x64 architecture.
5. If the unit is mounted in an alignment other than the standard alignment of X pointing forward and Z pointing down, this alignment offset will need to be entered into the Alignment Configuration dialogue in Spatial Dual Manager. Please see section 9.2.1 for more details.
6. Accurately measure the primary GNSS antenna offset from the centre of the Spatial Dual unit to the central base of the antenna in the body co-ordinate frame (X positive forward and Z positive down) and enter these values into the Alignment Configuration dialogue in Spatial Dual Manager. Please see section 9.5 for more details. Please note that the body axes are always X positive forward and Z positive down irrespective of any alignment offset entered in the previous step.
7. Enter the vehicle type in the Filter Options dialogue in Spatial Dual Manager.
8. The system is now ready for use.

9.2 Position and Alignment

When installing Spatial Dual into a vehicle, correct positioning and alignment are essential to achieve good performance. There are a number of goals in selecting a mounting site in your application, these are:

1. Spatial Dual should be mounted in an area that is not going to exceed it's temperature range.
2. Spatial Dual should be mounted away from high levels of vibration where possible.
3. Spatial Dual should be mounted within several metres of the GNSS antennas where possible.
4. If atmospheric altitude is going to be used, the two vents on the sides of Spatial Dual should not be obstructed.
5. Spatial Dual should be mounted close to the centre of gravity of the vehicle where possible.
6. For best performance during GNSS outages, Spatial Dual should be mounted at least 10cm away from sources of dynamic magnetic interference i.e. high current wiring, large motors.

9.2.1 Alignment

The easiest way to align Spatial Dual is by installing it with the sensor axes aligned with the vehicle axes. This means that the X axis points forward towards the front of the vehicle and the Z axis points down towards the ground.

If aligning Spatial Dual with the vehicle axes is not possible or not optimal, it may be mounted in a different alignment and the alignment offset should be configured using Spatial Dual Manager, see section 11.8.5. For easy alignment, the set zero orientation button in the Spatial Dual Manager alignment dialogue can be used to set the current orientation as the level alignment, see section 11.8.5. Please note that this will only correct for roll and pitch offsets. Any heading offset will need to be entered manually and saved after using this function.

9.3 Mounting Plate

Spatial Dual's mounting plate and hole guide is shown below in Illustration 19. The holes are designed for M3 cap screws.

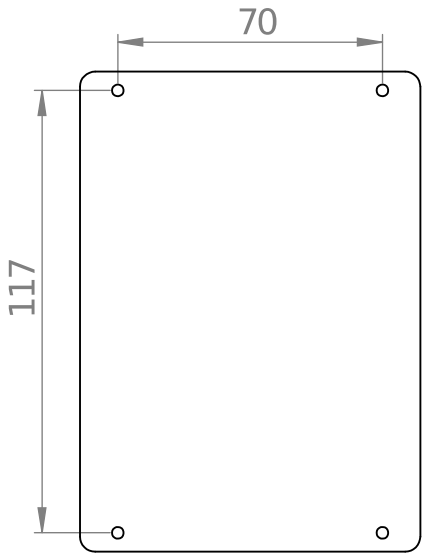


Illustration 19: Spatial Dual mounting plate

9.4 Power Supply

A high level of power supply filtering has been built into Spatial Dual, however it is still recommended that the power supply be free of significant noise. Spatial Dual contains a fully isolated power supply and has separate grounds for power and signal to ensure that power supply noise does not corrupt communications or cause ground loops with other equipment. When wiring the system, the signal ground should be routed with the primary RS232, auxiliary RS232 and GPIO pins. The power ground should be routed with the power supply to the power source.

A power supply should be selected that can provide at least the maximum current calculated from the graph in Illustration 12.

Spatial Dual contains an active protection circuit on the power supply input that protects the unit from under-voltage, over-voltage and reverse polarity events. The protection circuit shuts off power

and automatically recovers the unit to full operation once the fault is removed. Take care when running the unit close to its under-voltage lockout of 8.5 V because small voltage drops can engage the under-voltage shutdown and potentially oscillate between the on and off state. It is recommended that the unit is always run at 9.5 V or more to avoid issues associated with this.

9.5 GNSS Antennas

The GNSS antennas should be installed level with a clear unobstructed view of the sky and close to the Spatial Dual unit where possible. The antennas should be mounted away from any RF emitters. It is important to have a ground plane (flat conductive surface such as a piece of plate aluminium) under the antenna with a minimum radius of 60mm. Correct antenna positioning is very important for Spatial Dual's heading to function correctly.

The primary antenna position offset should be configured in the Spatial unit by using the alignment dialogue in Spatial Dual Manager, see section 11.8.5. The antenna offset is measured from the centre of the Spatial Dual unit to the central base (ARP) of the antenna in the body frame. It is very important to set the antenna offset accurately as Spatial Dual corrects for lever arm velocities. Incorrect GNSS antenna offset will lead to performance degradation under turning and angular rotations.The antenna offset is measured from the centre of the Spatial unit to the centre of the antenna in the body frame (X forward, Z down). Please note that as Z is positive down, mounting the antenna above the Spatial unit will result in a negative Z offset.

An example installation with axes marked is shown below in Illustration 20 and Illustration 21. In this installation there would be a positive X antenna offset value, a positive Y antenna offset value and a negative Z offset value.

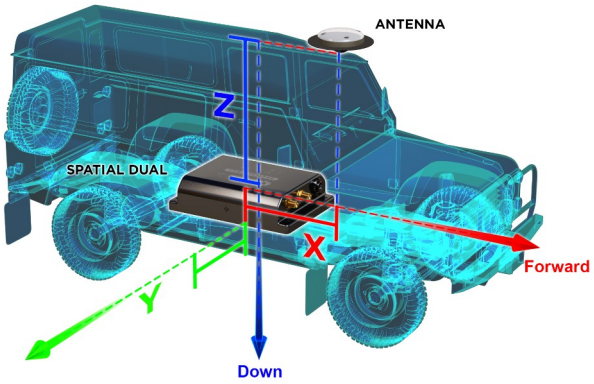


Illustration 20: Spatial Dual antennna offset isometric view

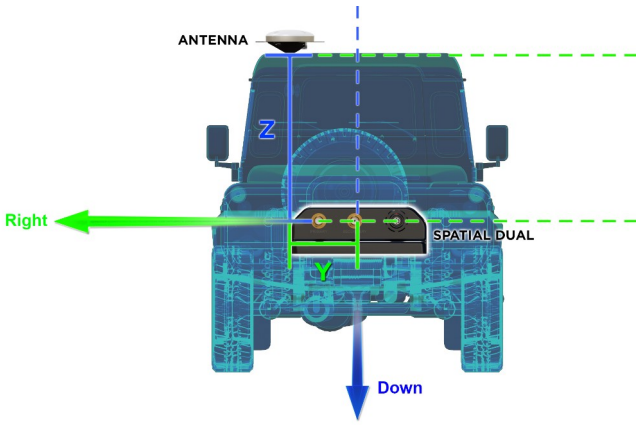


Illustration 21: Spatial Dual antenna offset front view

The secondary antenna should be mounted directly behind the primary antenna with as much separation as possible. The higher the separation the better the orientation accuracy. See Illustration 22 for example mounting on a car. If it is impractical to mount the secondary antenna directly behind the primary antenna, it can be mounted in another position. In this case the secondary antenna offset must be accurately measured and entered using the secondary antenna configuration dialogue in Spatial Dual Manager, see section 11.8.13.

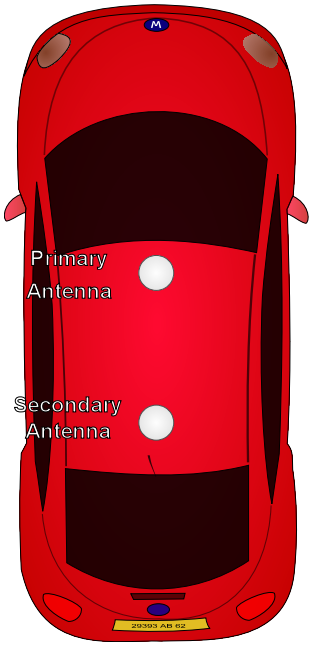


Illustration 22: Spatial Dual example antenna placement

The standard antenna supplied in the Spatial Dual evaluation kit is the Antcom G5Ant-53A4T1. It is an L1/L2/L5 RTK antenna that supports GPS, GLONASS, BeiDou, Galileo, Omnistar and SBAS. It is environmentally sealed to the IP68 standard.

If you are sourcing your own antenna, please note the following antenna guidelines:

- The antenna should be capable of receiving both L1 and L2. Heading performance will be significantly degraded with an L1 only antenna.
- The antenna needs to have an accurate phase centre to be RTK capable. This is required for the dual antenna heading to function correctly. Low performance (low cost) antennas are typically not able to achieve good heading performance.
- The antenna should have an LNA gain of at least 35dB.
- The antenna should support both GPS and GLONASS.
- The antenna should be environmentally sealed, including connectors.

If you are sourcing your own antenna cables it is important to ensure that the antenna has enough gain to support the loss over the cable. Spatial Dual requires a minimum of 33dB of gain at the connector. With the standard 4 metre RG-58 antenna cables supplied by Advanced Navigation, the

minimum antenna gain is 36.5dB.

9.6 GNSS Antenna Cables

The antenna cables should be routed away from powerful RF emitters, high current wiring, high temperatures and any rotating or reciprocating machinery. It is very important not to bend the antenna cable beyond it's maximum bend radius. It is recommended to use wide cable ties and be careful not to do them up too tight. Advanced Navigation recommends using either RG58 low loss or LMR240 coaxial cable combined with high quality connectors. LMR300 and LMR400 can also be used to minimise loss for very long antenna cables.

Cable Type	Minimum Bend Radius	Signal Loss
RG-58/U Low Loss	20 mm	~0.92 dB/m
LMR240	20 mm	~0.33 dB/m
LMR300	22.2 mm	~0.26 dB/m
LMR400	25.4 mm	~0.17 dB/m

Table 18: GNSS antenna co-axial cable properties

9.7 Odometer

On ground vehicles, the use of an odometer input can greatly improve Spatial Dual's navigation and orientation solution during GNSS outages. With a high resolution wheel encoder Spatial Dual can be used to navigate indoors with GNSS disabled altogether.

There are several different options for odometer installation which are listed below.

9.7.1 Factory VSS Signal

Most road cars since 1980 contain a VSS (vehicle speed sensor) signal that can be wired directly into one of Spatial Dual's GPIO pins. The vehicle should be taken to an automotive electrician to perform the work.

To setup the odometer, the appropriate GPIO pin should be set to odometer input using Spatial Dual Manager. The odometer pulse length must then be set either manually or automatically, please see section 10.8 for more information.

For more information on the GPIO signals and their requirements please see section 12.4.3.

9.7.2 OBDII Odometer Interface

For applications where it is undesirable to modify the vehicle or the system needs to be used with multiple vehicles, the OBDII odometer interface may be a better solution. OBDII is a vehicle diagnostic port standard and most vehicles from the mid 1990s onwards contain an OBDII port in the drivers side foot well. Advanced Navigation produces an OBDII odometer interface that plugs into this OBDII port and feeds Spatial Dual with odometer data over the Auxiliary RS232 port, please see Illustration 23. These units are priced at approximately AUD 500. Please contact Advanced Navigation sales for more information.

Illustration 23: Advanced Navigation OBDII Odometer

9.7.3 Aftermarket Wheel Speed Sensor

Applications requiring very high performance are recommended to use a high precision aftermarket wheel speed sensor. Advanced Navigation recommends aftermarket wheel speed sensors from Kistler, Pegasem or GMH Engineering.

Illustration 24: Aftermarket wheel speed sensor

9.7.4 Radar Speed Sensor

For applications requiring high performance in harsh conditions where aftermarket wheel speed sensors are not feasible, a radar speed sensor is recommended. Advanced Navigation recommends radar speed sensors from Stalker or GMH Engineering.

Illustration 25: Radar speed sensor

9.8 Magnetics

Spatial Dual contains magnetometers which it uses to determine when the heading is stationary to reduce drift when dual antenna heading is not available. For best heading performance through extended GNSS outages, it is recommended to mount Spatial Dual at least 10cm away from dynamic magnetic interference sources. Dynamic magnetic interference sources include electric motors, high current wiring and moving masses of steel. Magnetic interference will not cause heading errors with Spatial Dual but mounting the unit in an area free of dynamic magnetic interference will help reduce heading drift during periods where dual antenna heading is not available.

9.9 Vibration

Spatial Dual is able to tolerate a high level of vibration compared to other inertial systems. This is due to a unique gyroscope design and a special filtering algorithm. There is however a limit to the amount of vibration that Spatial Dual can tolerate and large levels of vibration can cause Spatial Dual's accuracy to degrade.

When mounting Spatial Dual to a platform with vibration there are several options. It is recommended to first try mounting Spatial Dual and see whether it can tolerate the vibrations. The raw sensor view in the Spatial Dual Manager software can give you a good idea of how bad the vibrations are, see section 11.7.4. If the vibrations are causing the sensors to go over range you will need to increase the sensors range, see section 10.5.

If Spatial Dual is unable to tolerate the vibrations there are several options:

1. Try to find a mounting point with less vibration.
2. Spatial Dual can be mounted with a small flat piece of rubber.
3. Spatial Dual can be mounted to a plate which is then mounted to the platform through vibration isolation mounts.

10 Operation

10.1 Initialisation

There are four different levels of initialisation on Spatial Dual. These are orientation, navigation, heading and time. The initialisation can be monitored by inspecting the status view in Spatial Dual Manager, see section 11.7.2.

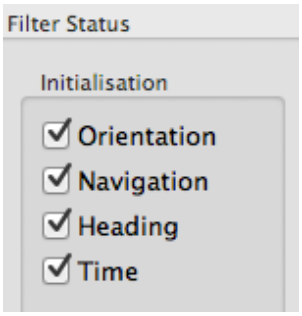


Illustration 26: The four initialisation levels

After all four levels of initialisation, Spatial Dual's filter takes several minutes to achieve it's full accuracy. It is recommended to wait two minutes after initialisation for applications requiring high accuracy.

10.1.1 Orientation Initialisation

Orientation initialisation occurs automatically upon power on and typically completes within several seconds. Once orientation initialisation is complete, the roll, pitch and angular velocity values will be valid.

When Spatial Dual starts up, it assumes that it can be in any orientation. To determine it's orientation it uses the accelerometers to detect the gravity vector. Whilst this is occurring, if there are random accelerations present, these can cause an incorrect orientation to be detected. To prevent this, Spatial Dual monitors the accelerometers and gyroscopes and restarts the orientation detection if there are sudden movements. It is however still possible under some circumstances for it to miss minor movements and start with a small orientation error. In this scenario Spatial Dual will progressively correct the orientation error over a period of several seconds.

10.1.2 Navigation Initialisation

Navigation initialisation completes once the system has determined a starting position. The most common method of navigation initialisation is for the system to get a 3D GNSS fix. If the system is hot starting it will remember it's position from when it was switched off and use this as the starting position. The other possibility for navigation initialisation is an external position source, see section 12.2 for more information. In a situation where a GNSS fix is not available to initialise navigation, it can be initialised manually by entering a position into the manual initialisation dialogue in Spatial Dual Manager, see section 11.8.12.

Once navigation initialisation is complete, the position, velocity and acceleration values will be valid.

10.1.3 Heading Initialisation

Heading initialisation completes once the system has determined a heading. The conditions required to determine a heading depend upon the heading source being used, see section 10.4. The default heading source is dual antenna heading and this will initialise the heading within several minutes of power on assuming both antennas are connected with a clear unobstructed view of the sky. The system can be stationary or moving during this initialisation. If the system is hot starting it will remember it's heading from when it was switched off and use this as the starting heading until another source becomes available.

Until the heading has been initialised, the system will not be able to navigate without a GNSS fix and the roll and pitch values will not be able to reach full accuracy.

10.1.4 Time Initialisation

Time initialisation completes once the system has determined time accurately. This occurs as soon as the GNSS receiver obtains it's first fix. It is also possible to provide an external source of time, see section 12.2 for more information on external time sources.

Until the time has initialised the values of unix time and formatted time that Spatial Dual outputs will not be valid and may change.

10.2 Hot Start

Spatial Dual is the first GNSS/INS on the market with hot start functionality. This allows Spatial Dual to start inertial navigation within 500 milliseconds and obtain a GNSS fix in as little as 3 seconds. Spatial Dual's hot start is always on and fully automatic.

A next generation backup battery system within Spatial Dual provides the hot start ability for more than 24 hours without power. When Spatial Dual hot starts it assumes that it is in the same state it was when it lost power and begins navigating from that position. The hot start also provides ephemeris, almanac and time information to the GNSS receiver which allows it to achieve a fix far more quickly than it otherwise would. When the GNSS achieves it's first fix, if this position deviates from the hot start position, Spatial Dual will jump to the new position without causing any side effects to the filter.

Whilst Spatial Dual is without power it keeps track of the time accurately to within 1 second so that the time is immediately valid on a hot start.

Spatial Dual's hot start is of particular benefit to vehicle tracking and robotics applications. The primary benefits are immunity and fast recovery from power failure as well as fast startup time.

10.3 Time

Spatial Dual was designed to provide a highly accurate time reference. When a GNSS fix is available Spatial Dual's time is accurate to within 50 nanoseconds. When a GNSS fix is lost, Spatial Dual's time accuracy typically remains within 10 microseconds over extended time periods. When Spatial Dual hot starts the time accuracy is typically within 1 second immediately on startup and corrected to within 50 nanoseconds as soon as a GNSS fix is achieved. To synchronise with Spatial Dual's high accuracy time, both the packet protocol and a 1PPS line must be used.

10.4 Heading Source

There are three different heading sources available for Spatial Dual. The heading sources can be configured using the filter options dialogue in Spatial Dual Manager. It is possible to use multiple heading sources and this can often provide performance benefits.

10.4.1 Dual Antenna Heading

This is the default heading source and provides very accurate heading while GNSS is available. Dual antenna heading only works when there is a good GNSS fix available. It requires a clear view of the sky with minimal nearby sources of interference or multipath.

10.4.2 Velocity Heading

Velocity heading works by deriving heading from the direction of velocity and acceleration. Velocity heading works well with cars, boats, fixed wing aircraft and other vehicles that don't move sideways. Velocity heading does not work with helicopters and other 3D vehicles. Velocity heading can only be measured when the vehicle travels at a horizontal speed of over 1.15 metres/second with a GNSS fix. It is recommended not to use velocity heading with Spatial Dual unless there is problems achieving a dual antenna heading fix.

10.4.3 External Heading

This can be used if there is some other way to derive heading that is external to Spatial Dual. Examples include north seeking gyroscopes, reference markers and SLAM systems. The heading must be fed into Spatial Dual using the External Heading Packet or through NMEA into a GPIO pin.

10.5 Sensors Range

Spatial Dual supports dynamic ranging on it's sensors. Each of the three sensors have three different range levels. At lower ranges the sensor performance is better, but at higher ranges Spatial Dual can be used in more extreme dynamics. The goal is to choose the lowest range that your application won't exceed.

Sensor over range events can be detected in the filter status, see section 13.9.1.2. In Spatial Dual manager the status indicator will go orange indicating that a sensor has gone over range. When a sensor goes over range this causes the filter to become inaccurate and in some cases it can cause the filter to reset.

By default Spatial Dual comes configured in the lowest sensor ranges. In this configuration it is possible to send the gyroscopes over range by quickly rotating the unit in your hand. It is recommended to watch what happens in Spatial Dual Manager when you do this.

The sensor range can be set using the sensors range dialogue in Spatial Dual Manager, see section 11.8.2.

10.6 Data Anti Aliasing

Internally Spatial Dual's filters update at 1000 Hz. When Spatial Dual outputs data, most applications require the data at a much lower rate (typically < 100 Hz). This causes a problem for time based data such as velocities and accelerations where aliasing will occur at the lower rate. To prevent this problem, if the output rate is lower than 1000 Hz, Spatial Dual will low pass filter the

values of the time dependent data between packets to prevent aliasing. This is only the case when a packet is set up to output at a certain rate. If the packet is simply requested no anti aliasing will occur. Additionally there is no anti aliasing for non time dependent fields such as position.

10.7 Vehicle Profiles

Spatial Dual supports a number of different vehicle profiles. These vehicle profiles impose constraints upon the filter that can increase performance. If your application matches one of the available vehicle profiles, it is recommended to select it for use in the filter options dialogue in Spatial Dual Manager, see section 11.8.3. For a list of the different vehicle profiles please see section 13.10.6.1. Please note that if the wrong vehicle profile is selected it can cause a significant decrease in performance.

10.8 Odometer Pulse Length

For Spatial Dual to use a wheel speed sensor or odometer input, it must know the pulse length of the signal. The pulse length is the distance in metres between low to high transitions of the signal. The odometer pulse length can either be entered manually or automatically calibrated by Spatial Dual. To enter the pulse length manually, please use the odometer configuration dialogue in Spatial Dual Manager. To automatically calibrate the odometer pulse length please use the procedure listed below in section 10.8.1. By default the odometer will automatically calibrate itself.

10.8.1 Odometer Automatic Pulse Length Calibration Procedure

1. Ensure that the signal is connected correctly and that the GPIO pin is configured as an odometer input using the GPIO configuration dialogue in Spatial Dual Manager, see section 11.8.8.
2. Open Spatial Dual Manager, connect to Spatial Dual and open the odometer configuration dialogue. In the odometer configuration dialogue tick the automatic pulse length calibration check box and press the write button, see section 11.8.8.
3. Wait until Spatial Dual has a continuous GNSS fix and then drive 1000 metres over flat terrain with as little turning as possible.
4. If Spatial Dual loses a GNSS fix for any extended period of time during the calibration, the distance travelled will be reset. The distance travelled can be checked in the odometer configuration dialogue to ensure that it has passed 1000m.
5. Once 1000 metres has been driven, check that the automatic pulse length check box has become un-ticked and the pulse length value has changed. This indicates a successfully completed calibration.

10.9 Reversing Detection

Reversing detection is an algorithm that can detect when the vehicle is travelling in reverse. Knowledge of reverse motion is important when using velocity heading or odometer input to provide correct results. If Spatial is fitted to a vehicle that does not reverse or doesn't use velocity heading or odometer, this function should be disabled. Reversing detection is enabled by default and it can be disabled using the filter configuration dialogue in Spatial Dual Manager, see section 11.8.3.

10.10 Motion Analysis

Motion analysis is an artificial intelligence algorithm that associates patterns in high frequency inertial data with the speed of the vehicle. After power on it takes some time to match patterns with speed before it will become active. Motion analysis only activates when dead reckoning and is most effective when the vehicle is near stationary. Motion analysis does not work in all situations and it's primary benefit is in ground vehicles. It should be enabled in any car application. When active it can be recognised by 2Hz steps in velocity data. Motion analysis is disabled by default and can be enabled using the filter configuration dialogue in Spatial Dual Manager, see section 11.8.3.

10.11 Omnistar

Spatial Dual's internal GNSS receiver supports the Omnistar corrections service. The Omnistar corrections service allows Spatial Dual to achieve higher positional accuracy than standard GNSS, see section 8.2. Omnistar is a satellite based service and the corrections are received using the same GNSS antenna used for positioning, this means that there is no additional infrastructure equipment required to use Omnistar. Omnistar is a paid subscription service with a yearly fee. Please contact your local Omnistar representative for pricing information. The current Omnistar subscription can be viewed in the GNSS Receiver Information dialogue in Spatial Manager.

10.12 RTK

Spatial Dual's internal GNSS receiver supports RTK GNSS which uses correction data from a base station to provide significantly higher positional accuracy than standard GNSS. RTK requires additional infrastructure equipment to receive corrections and is not practical for all applications. There are three different options for receiving RTK corrections. For applications where Spatial Dual can be connected to a computer that has access to the internet, network RTK corrections are recommended, see section 10.12.1. For applications that are unable to access the internet we recommend base station radio modem RTK corrections, see section 10.12.2.

10.12.1 Network RTK Corrections

Spatial Dual Manager has a built in NTRIP client that can connect to a network RTK service to provide RTK corrections to Spatial Dual. Please see section 11.9.5. This requires that the computer running Spatial Dual Manager is connected to the internet. It also requires a valid subscription with a local network RTK service. Typically these services will offer a free trial period. Please contact support@advancednavigation.com.au for assistance in getting set up for network RTK corrections.

10.12.2 Base station radio modem RTK corrections

Illustration 27: Trimble R4 base station

Illustration 28: Trimble TDL 450L radio modem

Base station radio modem RTK corrections require two additional pieces of hardware, these are the base station and the radio modem receiver. The base station is setup at a fixed location and transmits corrections to the radio modem receiver that is connected to the mobile Spatial Dual unit. The radio modem receiver and Spatial Dual unit must remain within range of the base station to receive these corrections, typically this range is approximately 50km. Advanced Navigation recommends contacting a local surveying company for assistance setting up a base station.

10.13 Raw Satellite Data

Spatial Dual supports outputting raw satellite data. This raw satellite data can be used by post-processing programs to achieve high accuracy kinematic positioning.

The maximum output rate for raw satellite data is 20Hz and it can be enabled by turning on the Raw Satellite Data Packet (ID 60) in the packet rates dialogue in Spatial Dual Manager, see Illustration 29. This packet will be automatically converted to RINEX v3.02 by Spatial Dual Managers log converter utility.

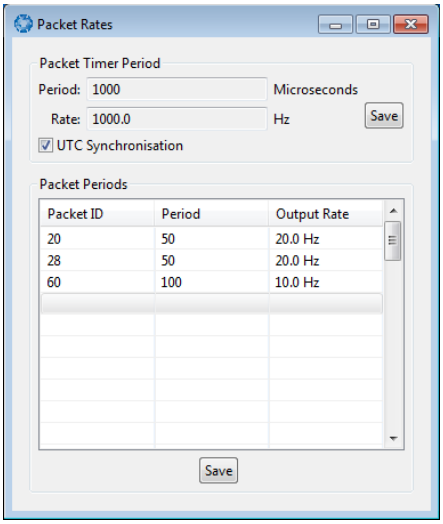


Illustration 29: Enabling packet 60

10.14 Post Processing

Spatial Dual can be used with Advanced Navigation's post processing platform Kinematica to achieve high accuracy kinematic positioning of 8mm and significantly improved dead reckoning performance.

To configure Spatial Dual for use with Kinematica please follow the steps below.

1. Connect to your device using Spatial Dual Manager.
2. Ensure your GNSS offset and any alignment offset has been entered as per the installation checklist in section 9.1.
3. Open the Baud Rates dialogue under the Configuration menu and set the primary port baud rate to 1,000,000. See Illustration 30. If you are using Windows ensure you have adjusted the latency settings for the serial port as detailed in section 11.4.2.
4. Open the Packet Rates dialogue under the Configuration menu and set up the packets as shown in Illustration 30.

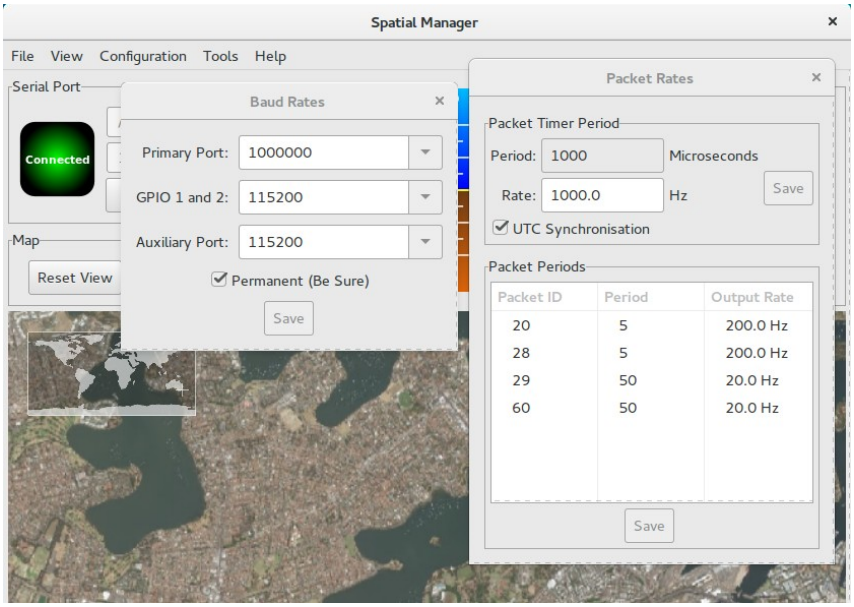


Illustration 30: Spatial Dual post processing configuration

For more information on using Kinematica, please see the Kinematica Reference Manual available for download from the Advanced Navigation website.

10.15 Vents

Spatial Dual contains a sophisticated venting system that allows it to measure air pressure whilst keeping water out. There are two sets of vent holes on either side of the enclosure. It is very important that these remain clean and clear of debris. Should debris get into the vents they should be rinsed with fresh water. Foreign bodies should never be poked into the vent holes, this will break the environmental seal and void the warranty on the unit.

10.16 RAIM

RAIM stands for receiver autonomous integrity monitoring. It allows a GNSS receiver to detect and exclude both faulty and fraudulent satellite signals. Spatial Dual's internal GNSS is equipped with RAIM and it is enabled by default.

10.17 Heave

Spatial Dual can provide vertical heave position at four different points on a ship. Spatial Dual's heave filter is always on and fully automatic. After power on, Spatial Dual requires approximately 5 minutes for it's heave filter to converge upon an accurate solution. Heave works without a GNSS fix, however best heave performance is achieved when Spatial Dual has a GNSS fix.

By default Spatial Dual provides heave from the point at which the Spatial Dual unit is mounted, however it can provide heave at four different offset points on the ship. To set the heave offsets use the heave configuration dialogue in Spatial Dual Manager.

10.18 Environmental Exposure

Whilst Spatial Dual is environmentally protected, there are clearly defined limits to this protection that must be adhered to for reliable operation.

Spatial Dual is only protected when it's connector is mated and two IP67 SMA GNSS antennas are attached to it. When any of these three connections are not finger tightly closed the unit offers no environmental protection.

Spanners or tools should never be used to tighten the connectors. They should only ever be finger tight.

10.18.1 Temperature

Spatial Dual should not be subjected to temperature's outside of it's operating range. If the temperature rises above 90 degrees Celsius, Spatial Dual will automatically shut off power to it's sensors and GNSS in an attempt to prevent damage, this will also send the filters into reset. Subjecting Spatial Dual to temperature's outside of the storage range can effect the factory sensor calibration which will cause a permanent performance degradation.

10.18.2 Water

Spatial Dual is water-proof to the IP67 standard which means that it can be submersed in water to a depth of up to 1 metre only. Submersion to depths beyond 1 metre can cause water entry and destruction of the internal electronics.

10.18.3 Salt

Spatial Dual is made from marine grade aluminium which gives it reasonably good salt water corrosion resistance. However Spatial Dual cannot tolerate extended periods of time in salt water environments. After any contact with salt water environments, Spatial Dual should be thoroughly rinsed with fresh water.

10.18.4 Dirt and Dust

Spatial Dual is completely sealed against dirt and dust entry. It is important to note that this is only the case when the connectors are mated. When un-mating the connectors if the Spatial Dual unit is dirty or dusty, the dirt should be rinsed off with fresh water first and then dried off. This is to prevent dirt or dust entering the connectors which can cause them to fail.

10.18.5 PH Level

Environments with a high or low PH level can cause the Spatial Dual enclosure to corrode. If Spatial Dual comes into contact with these environments it should be rinsed in fresh water as soon as possible. It is not recommended to operate Spatial Dual in non neutral PH environments.

10.18.6 Shocks

Spatial Dual can tolerate shocks to 2000g, however continuous shocks of this severity are likely to cause premature failure. Shocks above 2000g can effect the factory sensor calibration and degrade performance. Normally shocks to Spatial Dual when mounted in a vehicle are fine. Even a high speed car crash is likely to reach a peak of only 50g. Shocks directly to Spatial Dual's

enclosure can more easily go over the limit however so care should be taken when handling the unit prior to mounting.

11 Spatial Dual Manager

Spatial Dual Manager is a software tool provided by Advanced Navigation for logging, testing, display and configuration of Spatial Dual. It is designed to be simple and easy to use.

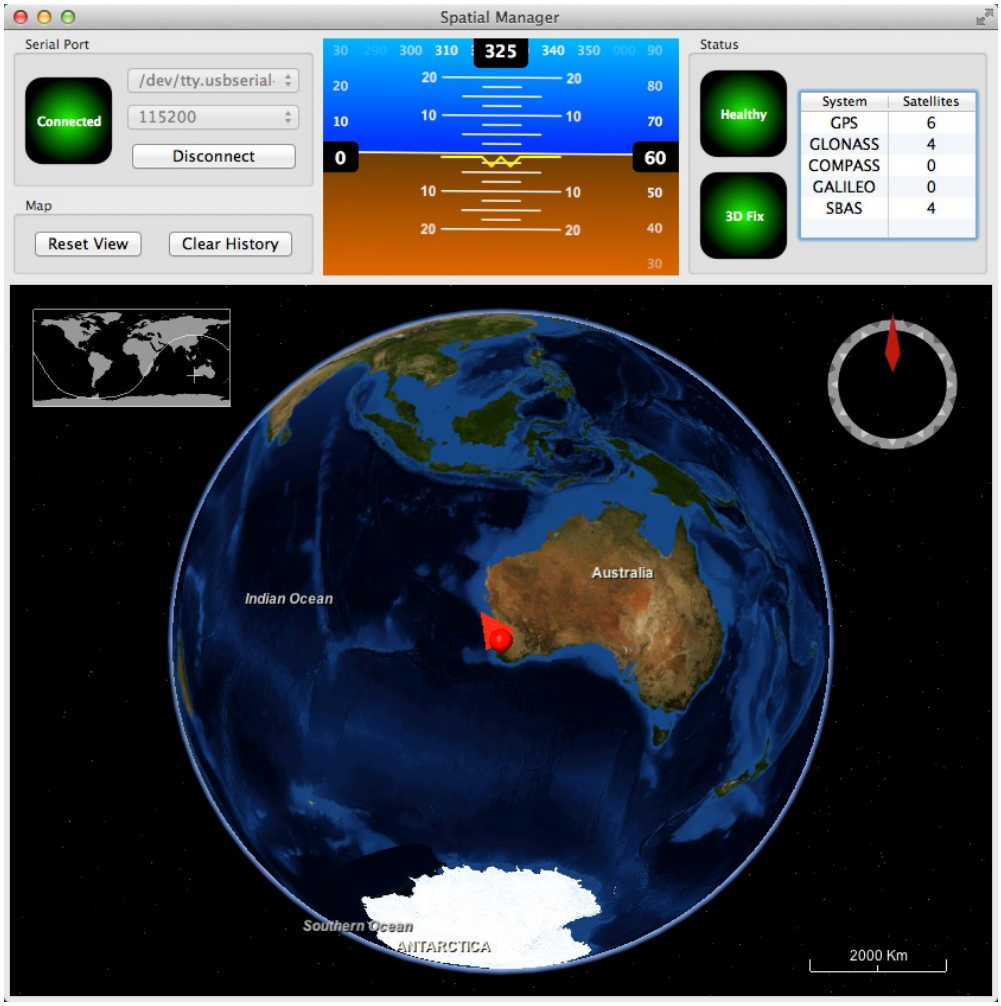


Illustration 31: Screenshot of Spatial Dual Manager

11.1 Software Changelog

Version	Date	Changes
7.2	10/11/2023	Clear map history on reconnection Fix incorrect timezone text displayed in terminal.csv Updated leap-seconds list URL Add automatically log configuration at the start of a new log Added elevation to the gimbal state packet Added support for NavIC satellite system Fixed indicators behaviour on disconnect In satellites window, only populate azimuth and elevation fields in the table view when the values have been determined. Increased NTRIP client timeout Show COCOM status of Trimble BD9xx receivers in the licence field Update support for Trimble BD9xx RTX frequencies as of 30 Sep 2022 Updated support for Mac silicon with latest macOS Removed 3D model display for better cross platform compatibility.
7.0	13/02/2023	Updated from JDK8 to JDK11. **JRE11/JDK11 required to run this release** Refresh Port Mode information on reconnection Refresh Packet Rates information on reconnection Improved reliability of firmware update Fixed issue with NTRIP client streaming from some servers When the NTRIP sourcetable says authentication type is any of '', 'B', 'N', then use Basic Authentication. This is to workaround NTRIP servers that incorrectly populate the authentication field. Overwrite/clear existing packet rates on import of configuration Added support for ARM (aarch64) processors with 64-bit OS Updated Seastar frequencies for Trimble receivers Updated RTX frequencies for Trimble receivers Added support for Apple M1 processors and improved MacOS support Various UI improvements
6.2	10/10/2022	Allowed copying version numbers etc from Device Information and GNSS Receiver Information dialog boxes. Clicking on the field will copy it to the clipboard. Renamed position error to position standard deviation in position page of view menu Support NTRIP Casters that request Username & Password to retrieve Source Table. BaseStation.csv output "Fix Type" column now split into "Base Fix Type" and "Rover Fix Type" Renamed Log Conversion menu item Added Settings menu item
6.1	18/02/2022	Device information updated automatically after a firmware update Add ability to control log file location

		Improve display of Trimble receiver options Included software version number in title Improved NTRIP server reconnection GNSS receiver information is updated after applying a receiver option Improve export configuration reliability Improved Log files saved by default in the directory from where the application is launched Improved NTRIP mountpoint selection. Added handling of non-standard NTRIP server responses Force the device to exit bootloader mode if a firmware update is not in progress Add EMSAT, OCSAT, IOSAT, etc and corresponding default freqs to the Omnistar GNSS Configuration list Added ability to set custom L Band satellite frequency and baud Updated source of map tiles
5.6	09/09/2020	Updated raw sensors dialogue to include all temperatures Updated network connection functionality to improve usability More information on the GNSS Receiver Information page Fixed bug with communications statistics dialogue cutting off numbers Added zero angular velocity update GPIO function Added Mavlink output GPIO function Added GNSS Receiver Update dialogue
4.6	18/09/2017	Added new GPIO functions to GPIO configuration Added new NMEA messages to GPIO output configuration Update to 3D mapping fixes issues with map data not loading
4.5	17/03/2017	Fix for incorrect leap second in RINEX files since 01/01/2017. More signals output in RINEX files.
4.4	12/04/2016	Extended NTRIP support for older versions Log converter now outputs a KML file for Google Earth with detailed information as well as the GPX file Added serial port passthrough tool Secondary antenna raw satellite data is now converted to RINEX as well as the primary antenna
4.3	17/08/2015	Spatial Manager now requests all configuration upon connection Spatial Manager converts any configuration packets found in ANPP log files into text Bug fix for NTRIP invalid connection
4.2	10/04/2015	Added network connection capability, section 11.9.6 Added NTRIP client, section 11.9.5 Two new satellite views in satellites dialogue, section 11.7.3 Added gimbal configuration dialogue, section 11.8.14 Heave offsets changed to reference point offsets, section 11.8.10 Fixed issue with locales that use commas instead of decimal

		points in floating point numbers
4.0	21/08/2014	Improvements to the 3D map Support for more graphics cards Status display now shows when heading not initialised Communications dialogue added, section 11.7.8 GNSS receiver dialogue added, section 11.7.9 Configuration dialogues now auto update
3.2	28/02/2014	Improvements to the 3D map Support for bluetooth serial ports Orientation standard deviation graph added Latitude and longitude shown in position dialogue Dual antenna configuration dialogue added
3.1	15/10/2013	Added 3D model dialogue Added configuration export dialogue, section 11.8.1
3.0	13/09/2013	Initial Release

Table 19: Spatial manager software changelog

11.2 System Requirements

Spatial Dual Manager is only available for systems with x64 and ARM architectures.

The software includes a 3D mapping display which requires a modern 3D graphics card and up to date drivers to run. If your machine does not meet the graphics requirements the mapping view will only show space without a globe.

When Spatial Dual is running at very high output rates e.g. 1000 Hz, Spatial Dual Manager can consume significant system resources handling the large quantity of data.

11.3 Installation

The latest version of Spatial Dual Manager can be downloaded from the Spatial Dual product page of the Advanced Navigation website. Installation notes are as follows:

- Java 11 is required to run Spatial Dual Manager. Adoptium JRE 11 is the recommended Java installer to be used on all platforms. Install the latest version of Java 11 from Adoptium, selecting the correct operating system and architecture for your computer.
- Spatial Dual Manager does not need to be installed and on a Windows system it can be run from any directory by simply double clicking on it. To open the program on some systems it may be necessary to right click and select open with → Java Runtime Environment.
- On MacOS systems it may be necessary to run the application from a terminal window:

  java –jar XstartOnFirstThread SpatialDualManager-7.x.jar
- On Linux systems it may be necessary to run the application from a terminal window:

  java –jar SpatialDualManager-7.x.jar

The Spatial Dual evaluation kit makes use of an FTDI USB to RS232 device. The drivers are normally installed automatically, if not they are available from http://www.ftdichip.com/Drivers/VCP.htm.

11.4 Troubleshooting

Please contact support@advancednavigation.com.au if you are having issues.

11.4.1 All Platforms

If the globe does not appear in the 3D map area, this indicates that either your graphics card is not powerful enough or your graphics card driver is out of date.

11.4.2 Windows

There is a well known problem with USB serial devices under Windows known as “crazy mouse”. The problem occurs when the system mistakenly installs the USB serial device as a mouse. Unfortunately Microsoft has not fixed this problem in over 15 years, so it probably won't be fixed. If you experience this problem, often a restart will resolve it. Otherwise there is a tool available at http://www.stentec.com/anonftp/pub/wingps/pnpblockersetup.exe that can fix the issue.

If the serial port does not show up when you plug in your Spatial Dual USB device, you may need to install the drivers from http://www.ftdichip.com/Drivers/VCP.htm.

If you experience a blue screen of death whilst using Spatial Dual Manager, this is typically a problem associated with older FTDI drivers. To resolve the problem, install the latest drivers from http://www.ftdichip.com/Drivers/VCP.htm.

When operating Spatial Dual at a very high data rate, data can be lost due to the latency of the FTDI driver. To resolve this problem the latency of the driver should be reduced by going to control panel → system → device manager → ports and right click on the USB serial port, then click properties. In the properties window click the port settings tab and then the advanced button. You then need to change the latency timer setting to 1ms. Please see the screenshot in Illustration 32.

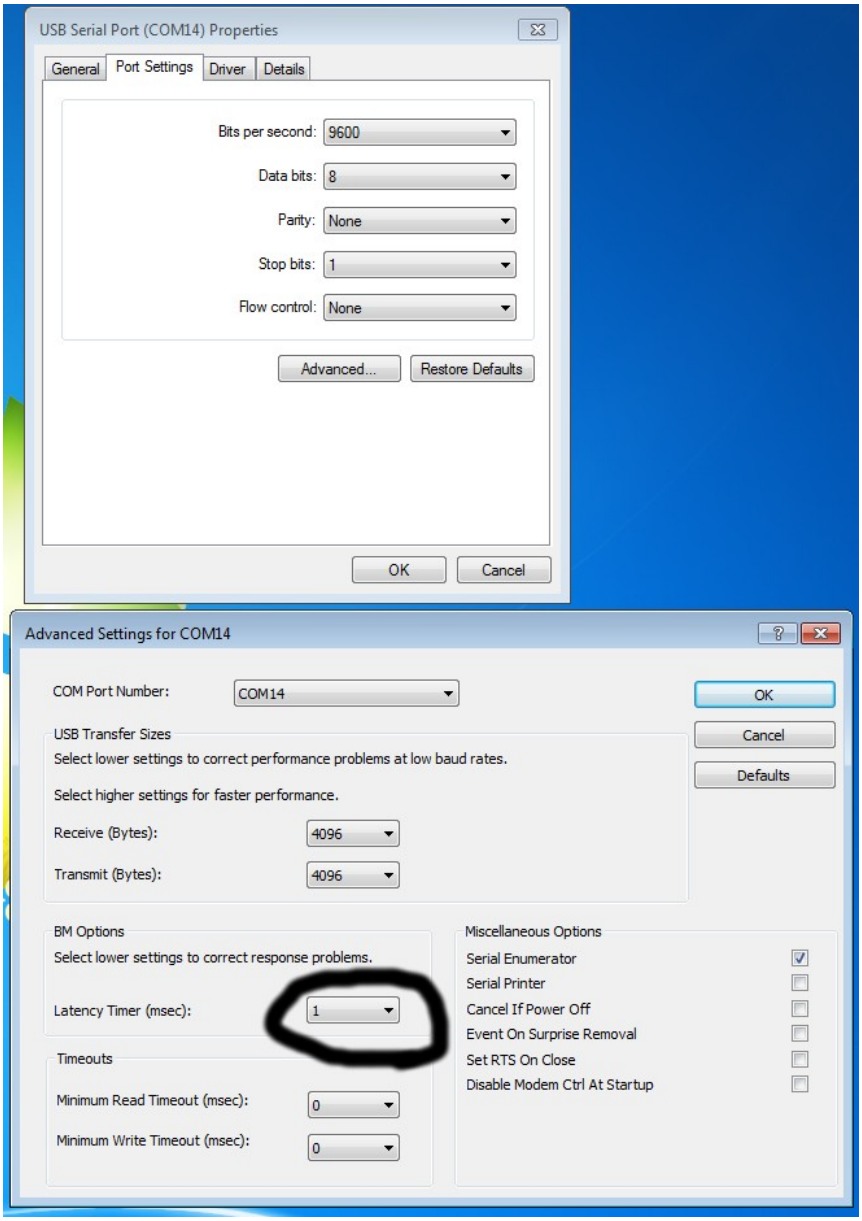


Illustration 32: Screenshot of latency timer setting

11.4.3 Linux

If serial ports do not show up, the typical cause is permissions. The user should add themselves to the dialout group with the command sudo adduser username dialout.

Compiz causes issues with the 3D mapping. If you are experiencing problems it is recommended to turn off compiz.

Modemmanager can also sometimes cause problems on Linux installations. If you are not using a modem, it is recommended to remove modemmanager with the command sudo apt-get remove modemmanager.

11.5 Main View

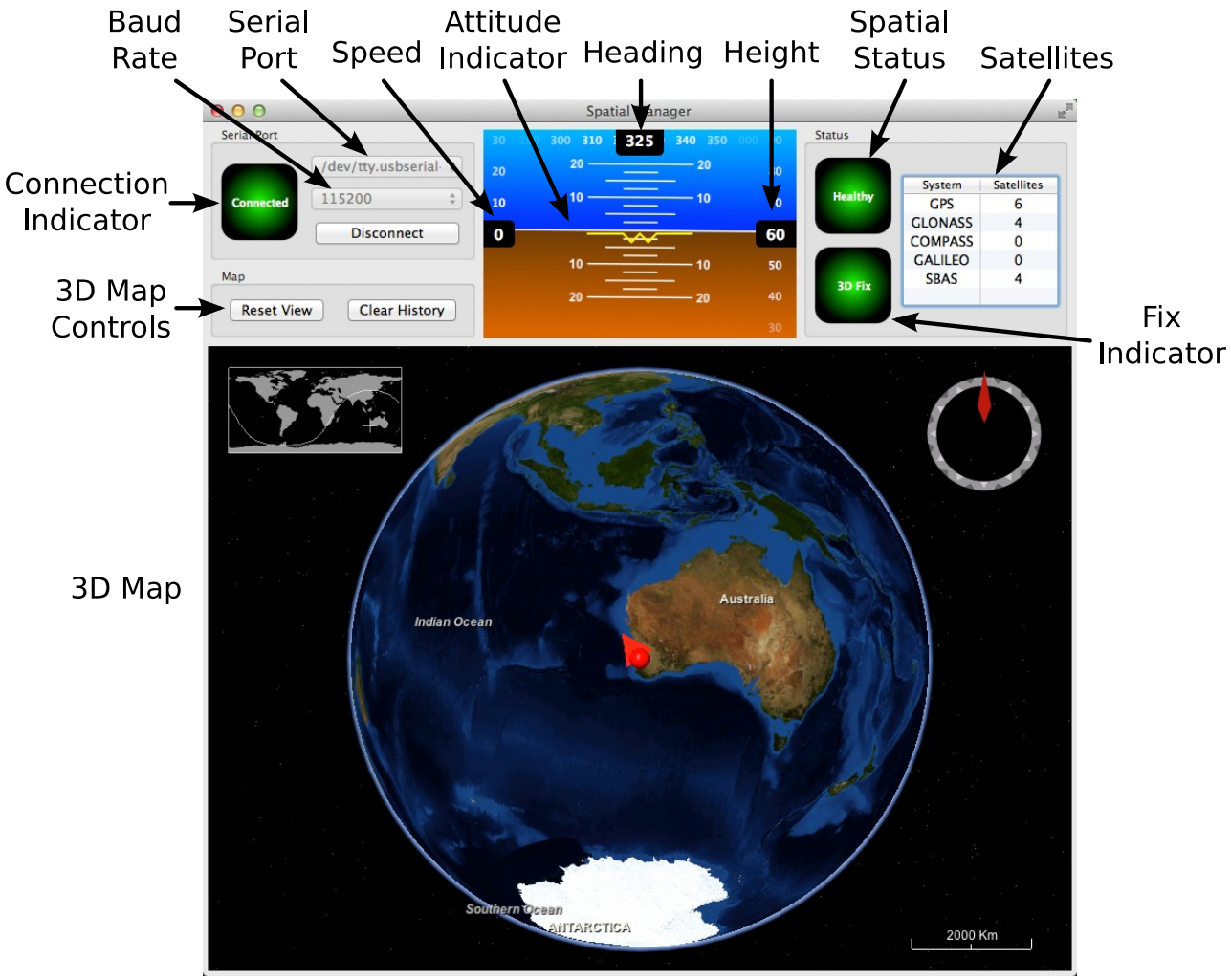


Illustration 33: Screenshot of Spatial Dual Manager main view

11.5.1 Serial Port

The serial port dialogue is used to connect to Spatial Dual. You should select a serial port and baud rate and click connect. The default baud rate of Spatial Dual is 115200. The connection indicator displays whether there is communication with a Spatial Dual unit.

11.5.2 Attitude Indicator

The aircraft style attitude indicator shows roll and pitch through a virtual horizon. Around the sides heading, speed and height are shown. All units are SI (metric) and degrees.

11.5.3 Status Indicator

The status indicator section contains a Spatial Dual status indicator, a fix indicator and a satellites table.

11.5.3.1 Spatial Status Indicator

This indicator shows any problems with Spatial Dual. Before a GNSS fix is achieved it will show the status “Filter not initialised”. Once the filter has initialised it should show “Healthy”. Clicking on the indicator will show the detailed status flags.

11.5.3.2 Fix Indicator

This shows the status of the GNSS fix. Under normal operating conditions it should show either “3D Fix” or “SBAS Fix”. When satellite visibility is poor it may show either “2D Fix” or “No Fix”.

11.5.3.3 Satellites Table

The satellites table shows the number of active satellites being used in the current GNSS solution. More detailed information can be found in the satellites view.

11.5.4 3D Map

The 3D map shows Spatial Dual's position on the Earth as well as a red trail of position history. When the filter initialises the map will automatically reset the view to Spatial Dual's location. To move the camera click and drag on the map. To zoom in and out use the scroll wheel. To change the camera view right click and drag or shift click and drag.

11.5.5 3D Map Controls

11.5.5.1 Reset View

This resets the map view to Spatial Dual's current position.

11.5.5.2 Clear History

This clears the current position history, this is the red trail shown on the map.

11.6 Logging

Spatial Dual Manager features a fully automatic logging system. Every time the serial port connect button is clicked Spatial Dual Manager starts a new log file in either the current directory or the user's home directory. The log file is given the file name SpatialLog_date_time.anpp and contains all of the raw data received from Spatial Dual in the AN packet protocol. The log files are closed when the serial port is disconnected.

Logging can be disabled via command line -n,--logdisable, and log file location can be set via command line -l,--logpath <Path of output logfile>.

To convert these log files into easily accessible formats, the log converter dialogue in the tools menu can be used, see section 11.9.4. The log converter dialogue creates a folder and generates files in the CSV (comma separated values) format that can be easily opened with Microsoft Excel, Matlab, libreoffice and most other data analysis programs. It also creates a GPX file of position that is designed to be opened with Google Earth.

SpatialLog_13-02-11_11-30-52	Today 1:02 PM	--	Folder
EulerOrientation.csv	Today 1:02 PM	40 KB	comm...values
EulerStandardDeviation.csv	Today 1:02 PM	39 KB	comm...values
GoogleEarth.kml	Today 1:02 PM	78 KB	Googl...ument
RawSensors.csv	Today 1:02 PM	101 KB	comm...values
Satellites.csv	Today 1:02 PM	8 KB	comm...values
State.csv	Today 1:02 PM	753 KB	comm...values
Status.csv	Today 1:02 PM	57 KB	comm...values
SpatialLog_13-02-11_11-30-52.anpp	Today 11:32 AM	264 KB	Document

Illustration 34: Screenshot showing log file and log conversion folder

11.7 Views

The views menu contains a number of different options for viewing data from Spatial Dual.

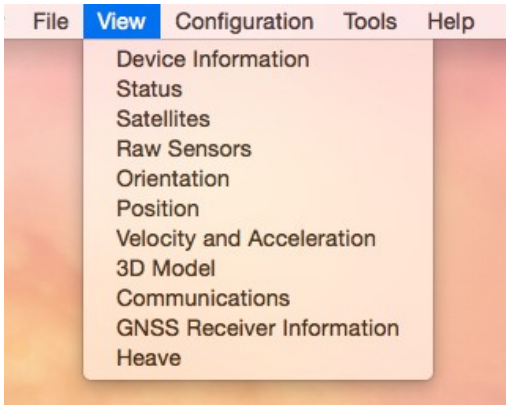


Illustration 35: Screenshot of Spatial Dual Manager views menu

11.7.1 Device Information

Device information is useful during technical support and for tracking your serial number, firmware and hardware version.

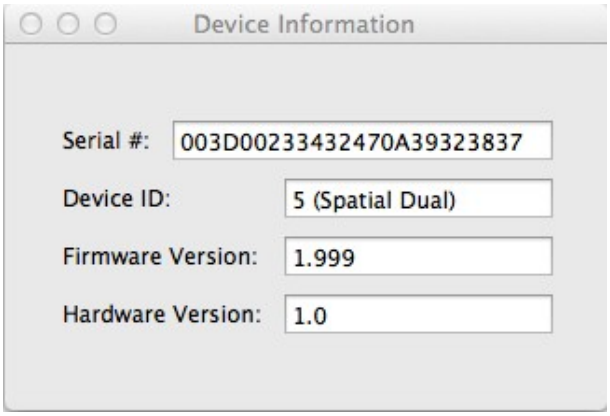


Illustration 36: Screenshot of Spatial Dual Manager device information dialogue

11.7.2 Status

Status shows Spatial Dual's complete status as contained in the system state packet detailed in section 13.9.1.1.

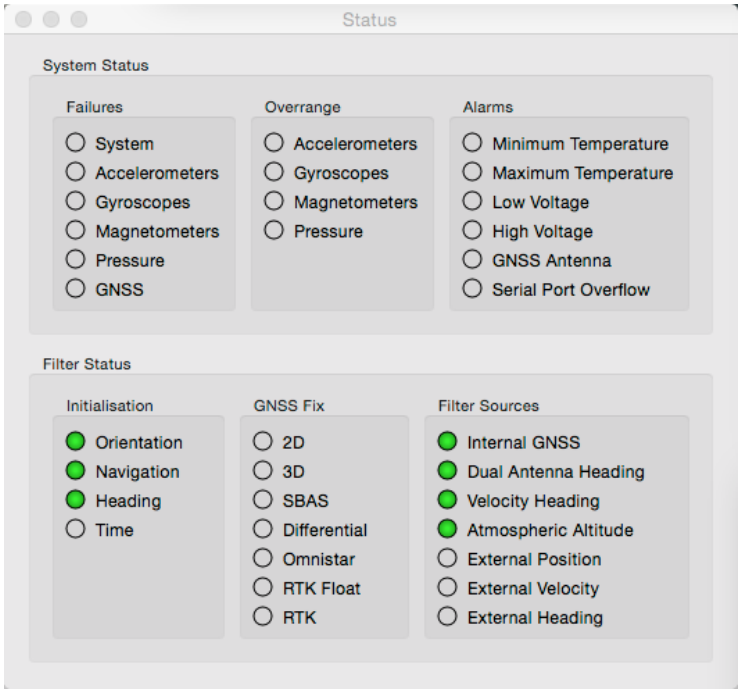
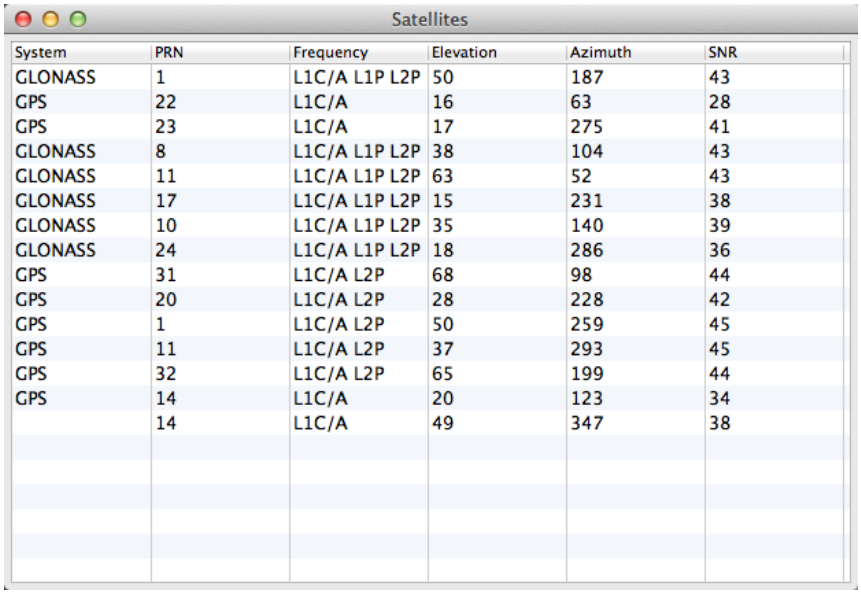


Illustration 37: Screenshot of Spatial Dual Manager status dialogue

11.7.3 Satellites

Satellites shows detailed information on the satellites that Spatial Dual's GNSS receiver is tracking.



System	PRN	Frequency	Elevation	Azimuth	SNR
GLONASS	1	L1C/A L1P L2P	50	187	43
GPS	22	L1C/A	16	63	28
GPS	23	L1C/A	17	275	41
GLONASS	8	L1C/A L1P L2P	38	104	43
GLONASS	11	L1C/A L1P L2P	63	52	43
GLONASS	17	L1C/A L1P L2P	15	231	38
GLONASS	10	L1C/A L1P L2P	35	140	39
GLONASS	24	L1C/A L1P L2P	18	286	36
GPS	31	L1C/A L2P	68	98	44
GPS	20	L1C/A L2P	28	228	42
GPS	1	L1C/A L2P	50	259	45
GPS	11	L1C/A L2P	37	293	45
GPS	32	L1C/A L2P	65	199	44
GPS	14	L1C/A	20	123	34
	14	L1C/A	49	347	38

Illustration 38: Screenshot of Spatial Dual Manager satellites dialogue

11.7.4 Raw Sensors

Raw sensors shows the temperature calibrated raw sensor values.

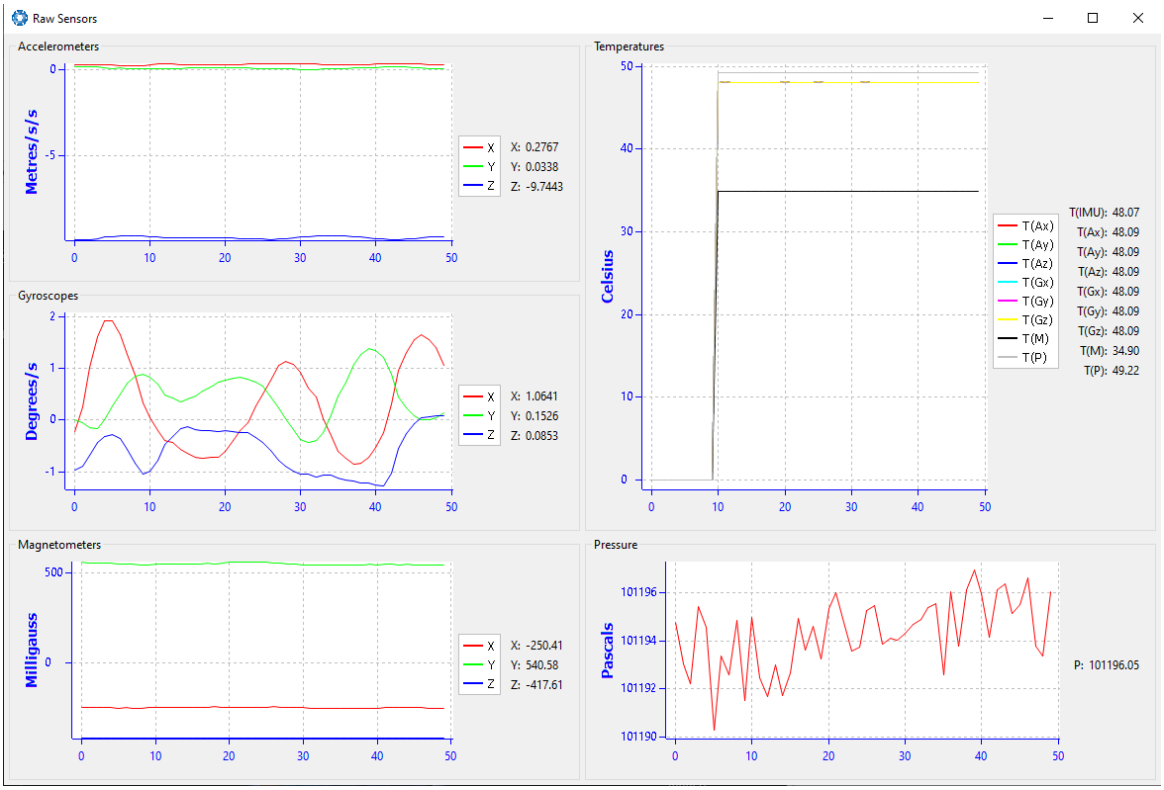


Illustration 39: Screenshot of Spatial Dual Manager raw sensors dialogue

11.7.5 Orientation

Orientation shows Spatial Dual's orientation and angular velocity.

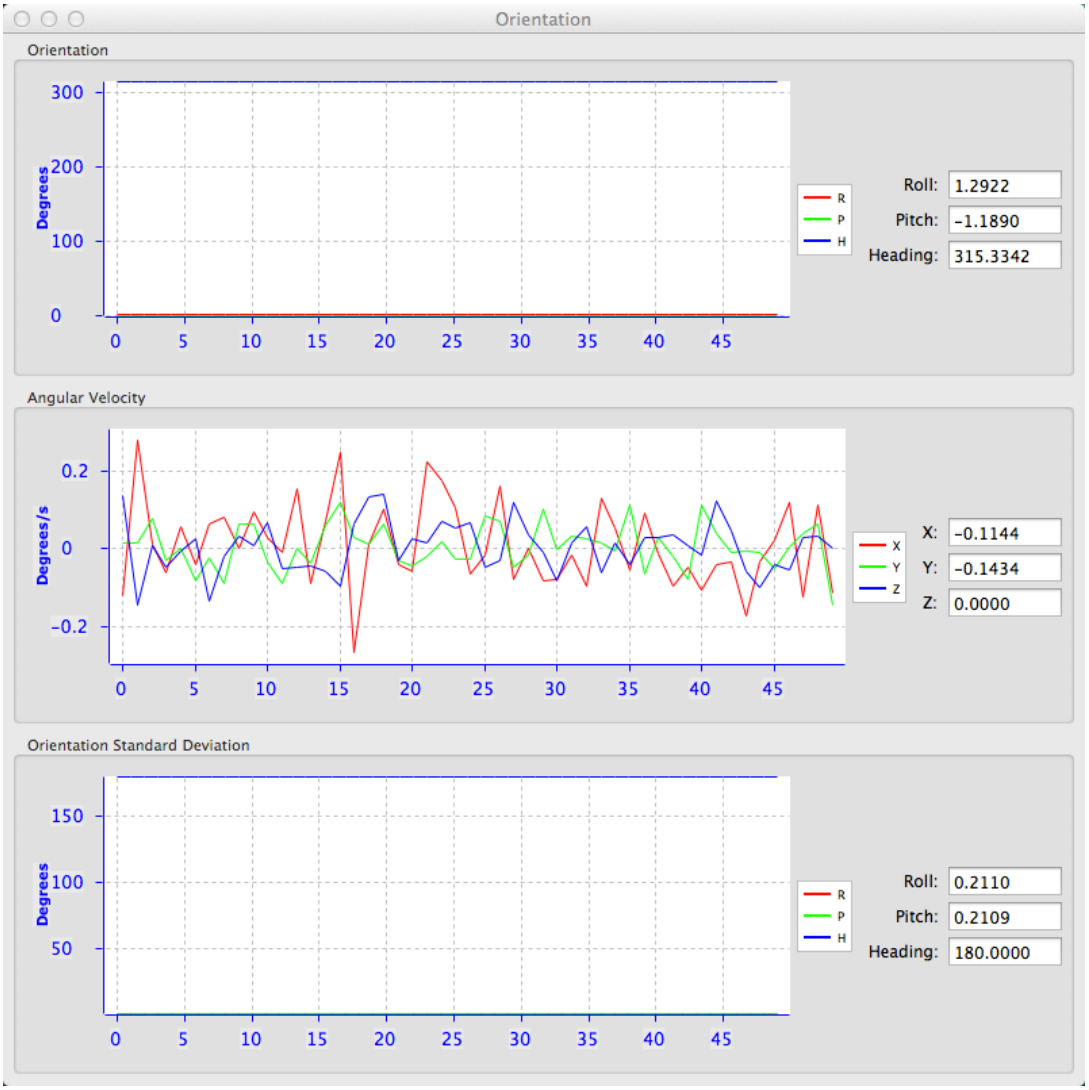


Illustration 40: Screenshot of Spatial Dual Manager orientation dialogue

11.7.6 Position

Position shows Spatial Dual's position and position error. Latitude and longitude are converted to North and East metres from a reference point that can be reset.

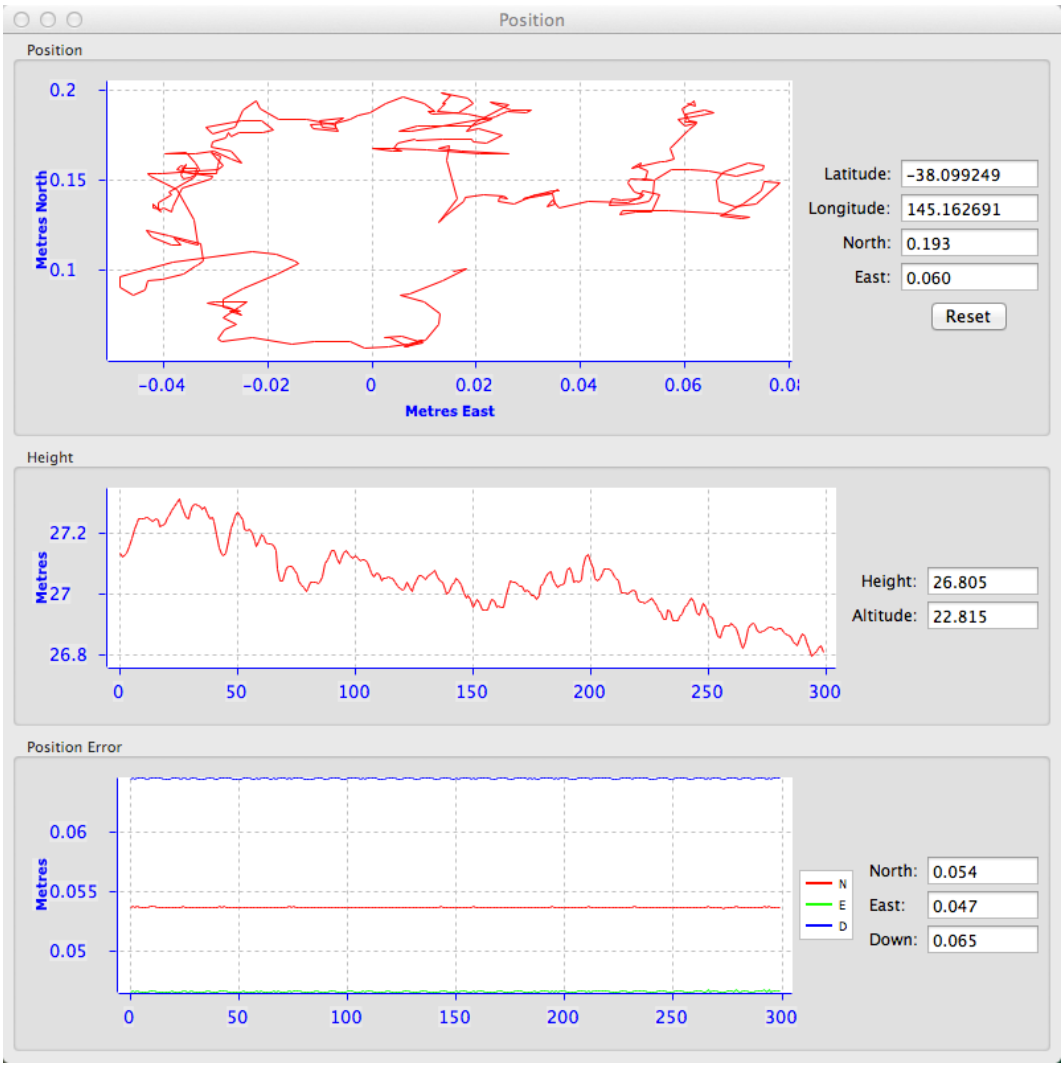


Illustration 41: Screenshot of Spatial Dual Manager position dialogue

11.7.7 Velocity and Acceleration

Velocity and Acceleration show Spatial Dual's velocity, acceleration and g-force.

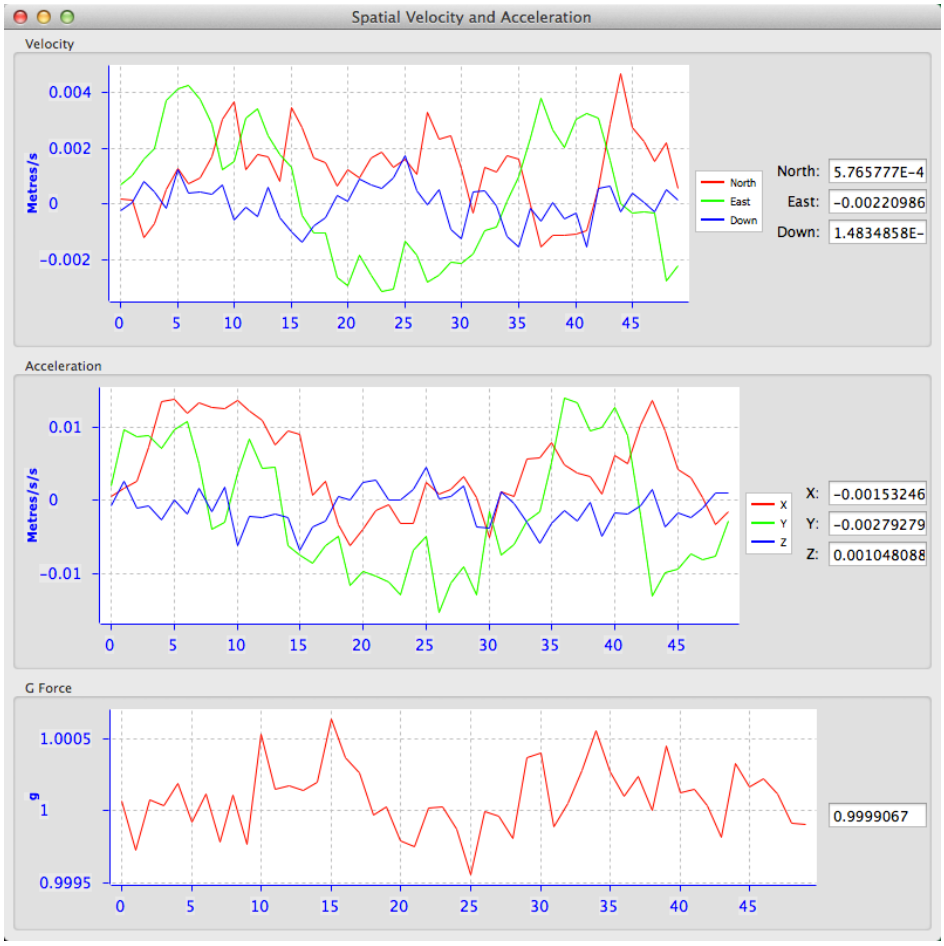


Illustration 42: Screenshot of Spatial Dual Manager velocity and acceleration dialogue

11.7.8 Communications

This dialogue shows statistics on the data packets received from Spatial Dual and can be useful in diagnosing signal integrity problems.

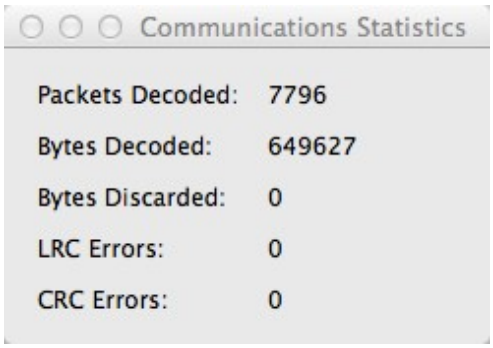


Illustration 43: Screenshot of Spatial Dual Manager communications statistics dialogue

11.7.9 GNSS Receiver Information

This dialogue shows information on the internal GNSS receiver contained inside of Spatial Dual.

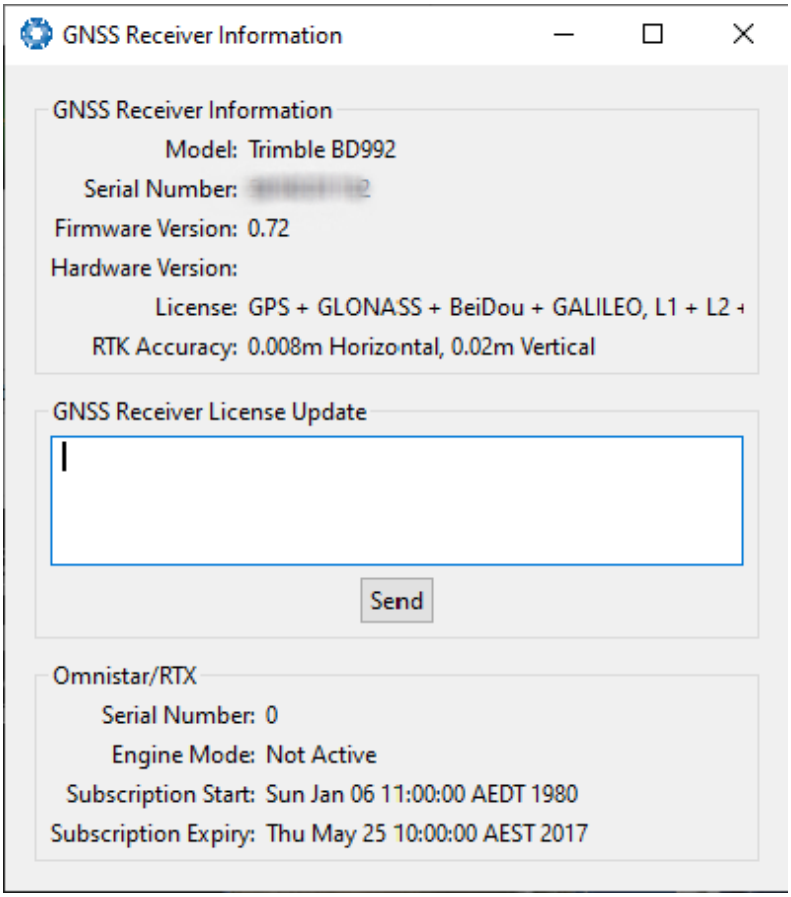


Illustration 44: Screenshot of Spatial Dual Manager GNSS receiver information dialogue

11.7.10 Heave

For the heave dialogue to function the heave packet (ID 58) must be set to output periodically using the Packet Rates dialogue.

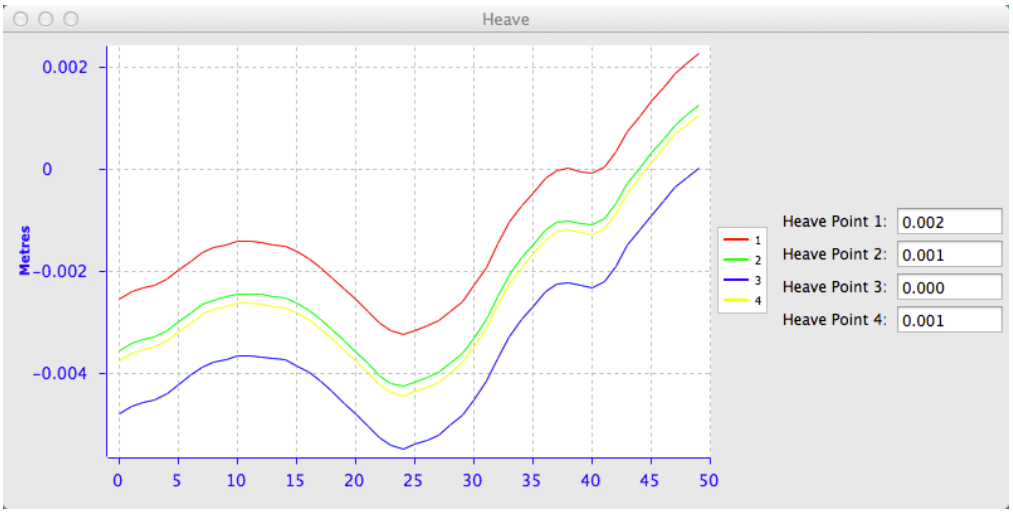
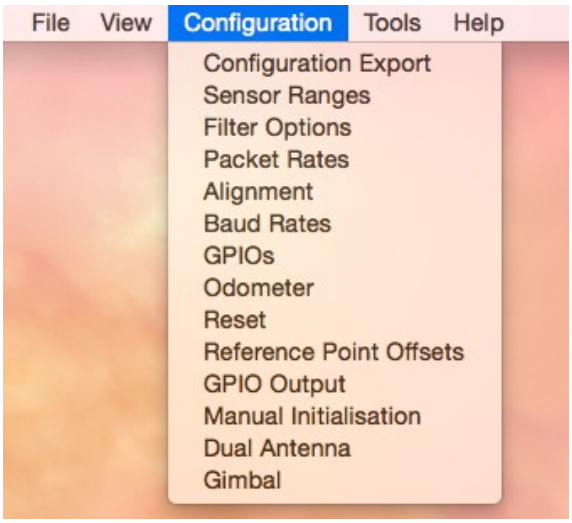


Illustration 45: Screenshot of Spatial Dual Manager heave dialogue

11.8 Configuration

The configuration menu contains a number of dialogues for the configuration of Spatial Dual.



11.8.1 Configuration Export

The configuration export dialogue can be used to export all Spatial Dual settings to a file. This file can be imported at a later date or on other units. This is useful to restore a unit to preset configuration at a later date or for batch configuration of multiple units.

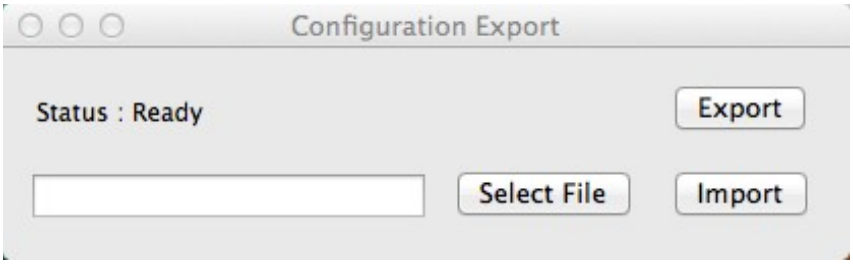


Illustration 46: Screenshot of Spatial Dual Manager configuration export dialogue

11.8.2 Sensor Ranges

The sensor ranges dialogue is used to set the dynamic range of the sensors. If you are experiencing over-range events during operation this dialogue should be used to increase the range of the offending sensor. The lowest ranges give the best performance so it is preferable not to use the highest range by default.

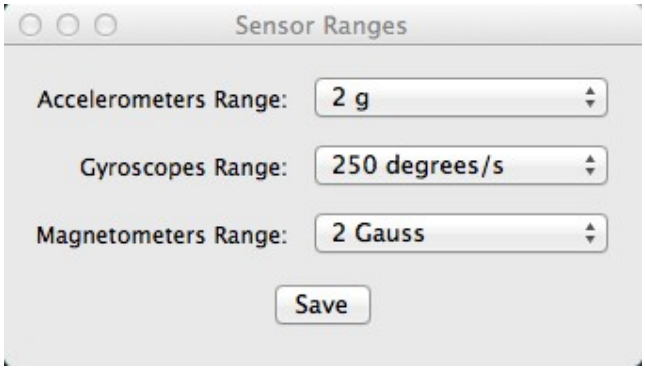


Illustration 47: Screenshot of Spatial Dual Manager sensor ranges dialog

11.8.3 Filter Options

For most applications the default filter options should be used and only the vehicle profile set. If in doubt please contact support@advancednavigation.com.au.

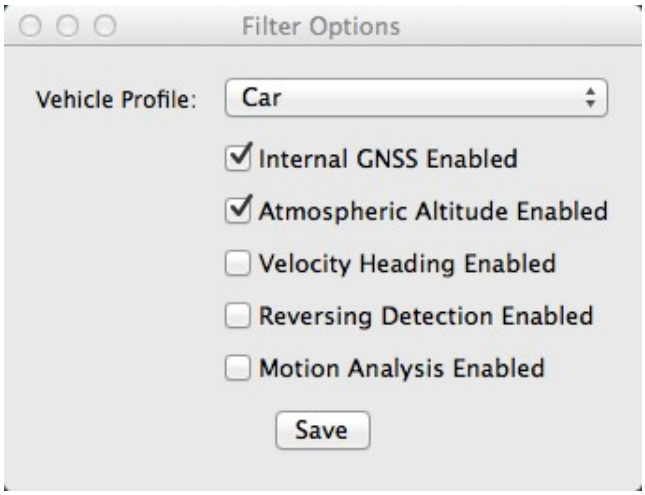


Illustration 48: Screenshot of Spatial Dual Manager filter options dialogue

11.8.4 Packet Rates

The packet rates dialogue allows the user to specify which packets output on a periodic basis and at what rate. The default packets enabled are the System State Packet (ID 20) and the Raw Sensors Packet (ID 28) at 20Hz and these typically provide all the data that a user will require. These two packets need to be enabled for the data graphs to update in Spatial Dual Manager. Other state packets can be enabled as required. Please see the Packet Summary table in section 13.7 for a list of all packets.

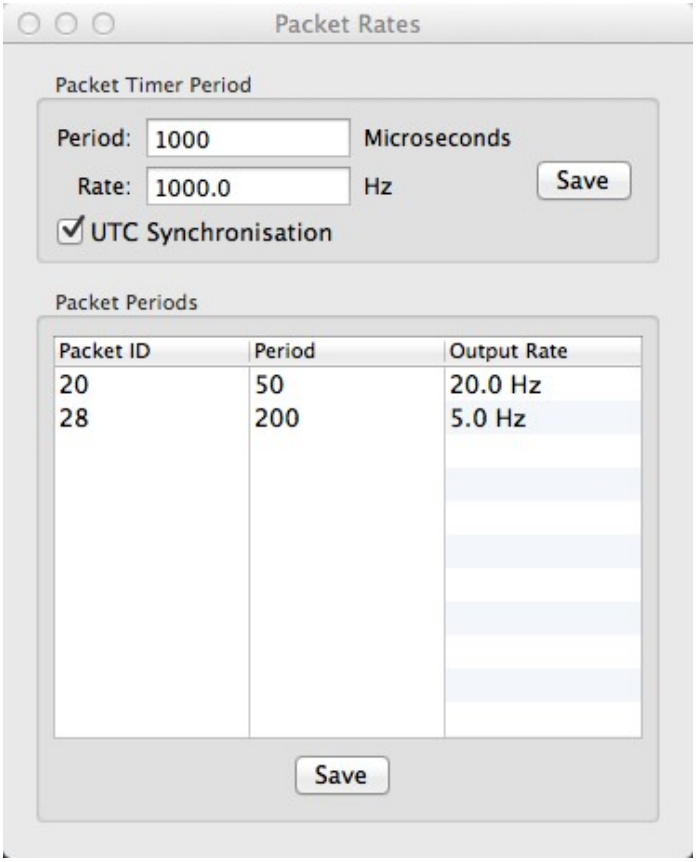


Illustration 49: Screenshot of Spatial Dual Manager packet rates dialogue

11.8.5 Alignment Configuration

The alignment configuration dialogue is used to set the alignment offsets of the system installation. It is important to set the values in this dialogue correctly for accurate results. For most applications only the GNSS antenna offset values need to be entered and the rest of the values can be left at their factory defaults of zero.

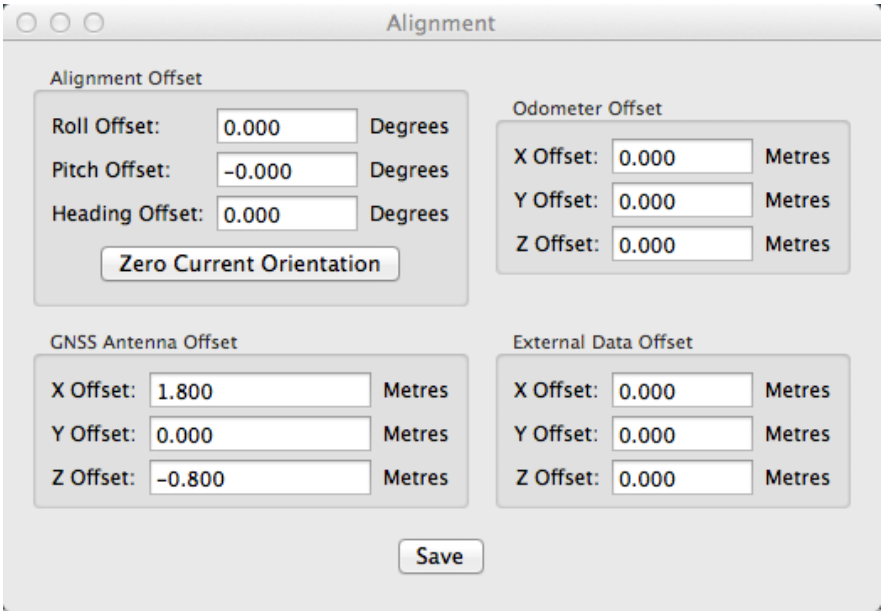


Illustration 50: Screenshot of Spatial Dual Manager alignment configuration dialogue

11.8.5.1 Alignment Offset

If Spatial Dual is installed into the vehicle with the X axis pointing forwards and the Z axis pointing down, then no alignment offset is required and the roll, pitch and heading offset values can remain at the factory defaults of zero.

If the unit is installed in a different orientation then the roll, pitch and heading offset must be entered. For example if the unit is installed on its side with the X axis pointing up and the Z axis pointing forwards and no change to the Y axis, then this would result in a pitch offset of +90 degrees with roll and heading remaining zero.

If there is a small misalignment due to mechanical mounting error this can be compensated for by setting the vehicle stationary on a level surface and pressing the zero current orientation button. Please note that this will only correct for roll and pitch offsets, the heading offset must be entered manually and saved before using this function.

All the other offsets will be measured in the realigned body co-ordinate frame (X positive forward, Z positive down) after being corrected for any alignment offset entered.

11.8.5.2 GNSS Antenna Offset

The GNSS antenna offset is measured from the centre of the Spatial Dual unit to the centre of the antenna in the body co-ordinate frame (X positive forward, Z positive down).

11.8.5.3 Odometer Offset

The odometer offset is measured from the centre of the Spatial Dual unit to the point at which the vehicle's tyre makes contact with the road in the body co-ordinate frame (X positive forward, Z positive down).

11.8.5.4 External Data Offset

These values are only required for speciality applications operating with external sources of data. Please contact support@advancednavigation.com.au for assistance with these values.

11.8.6 Baud Rates

When changing baud rates, some Microsoft Windows machines are unable to function at the higher baud rates. It is recommended to test the baud rate first with the permanent box unticked. This way, if it is not possible to communicate at the higher baud rate, a power cycle can be used to revert to the previous baud rate.

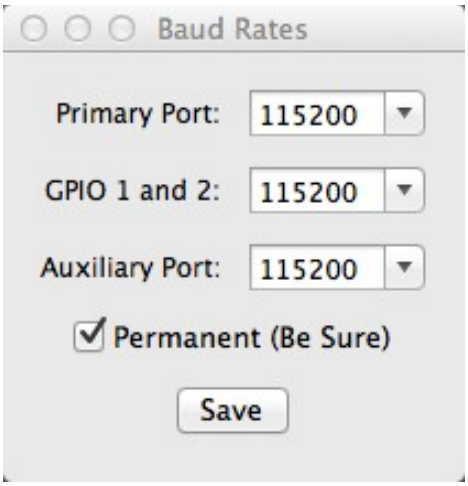


Illustration 51: Screenshot of Spatial Dual Manager baud rates dialogue

11.8.7 GPIO Configuration

This dialogue allows the user to select the function of the GPIO pins and Auxiliary RS232. These functions change dynamically and are effective immediately upon pressing save. Please note that GPIO pins function at RS232 levels for data functions and 0 to 5 volt levels for all other functions. The internal hardware automatically reconfigures based upon the selected function.

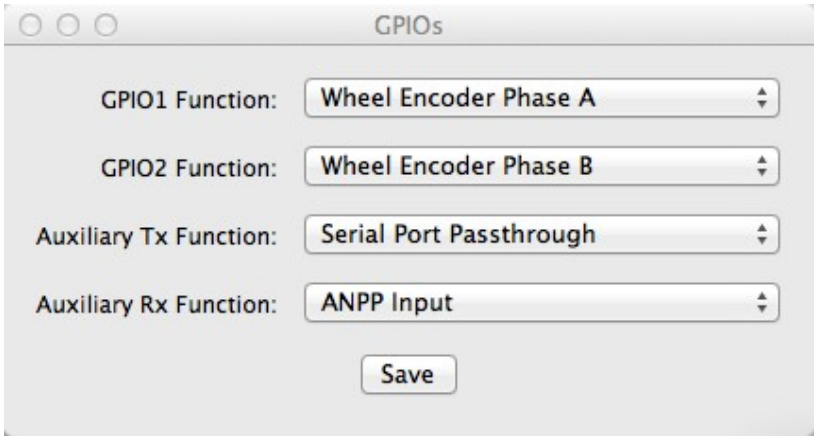


Illustration 52: Screenshot of Spatial Dual Manager GPIO configuration dialogue

11.8.8 Odometer

The odometer dialogue allows the user to configure the odometer pulse length and view the real time odometer data to verify correct operation.

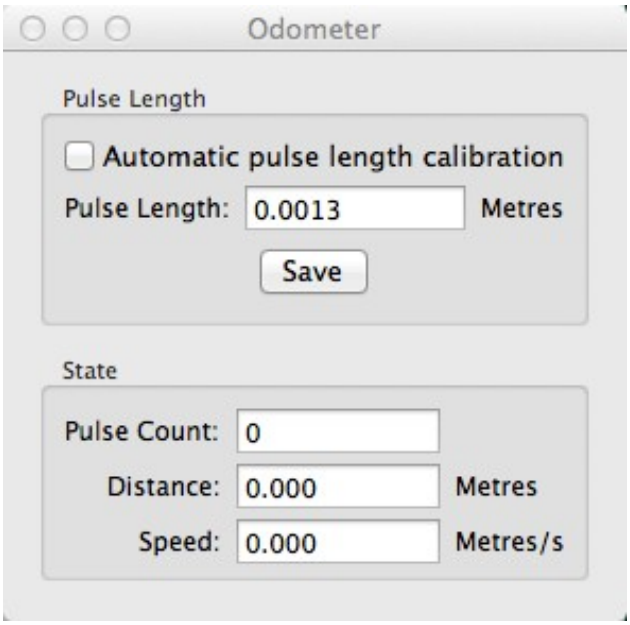


Illustration 53: Screenshot of Spatial Dual Manager odometer configuration dialogue

11.8.9 Reset

The Reset button causes the system to perform a power cycle. No configuration settings or state data are lost. The Cold Start button clears all filters, and connections are reset and must re-established. No configuration settings are lost. The Factory Reset button resets all settings back to their factory defaults, including state data and all configuration settings. It also erases the hot start data so that the system is forced to perform a cold start.

Illustration 54: Screenshot of Spatial Dual Manager reset dialogue

11.8.10 Reference Position Offsets

The reference point offsets dialogue allows the user to adjust the point of measurement away from its default position at the centre of the Spatial Dual unit. The primary reference point offset applies to data from all ANPP packets as well as all peripheral output such as NMEA and heave point 1. The heave points 2 to 4 allow the user to offset reference points for the heave values 2 to 4 in the Heave Packet.

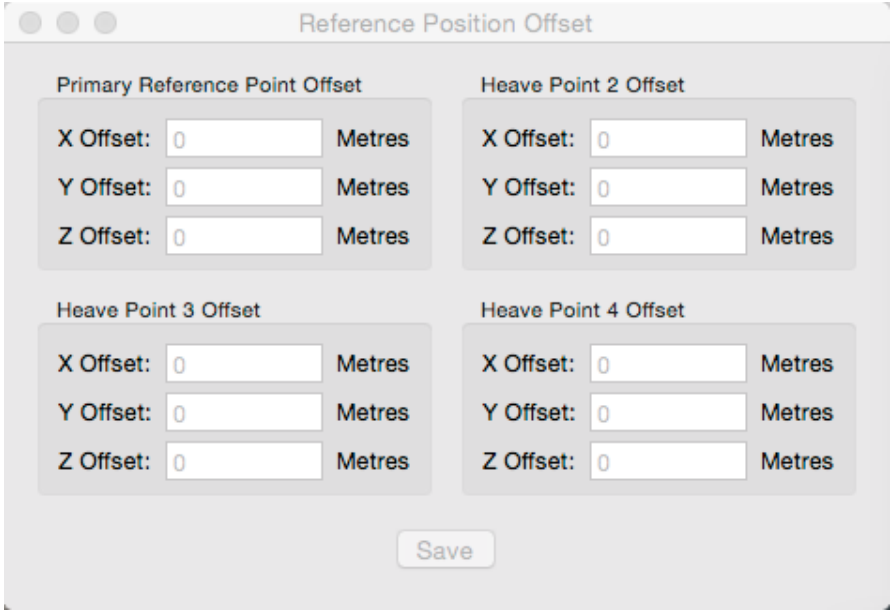


Illustration 55: Screenshot of Spatial Dual Manager reference position offsets dialogue

11.8.11 GPIO Output

The GPIO output configuration dialogue allows the user to configure the output rates for the GPIO and Auxiliary RS232 data functions NMEA, TSS and PASHR.

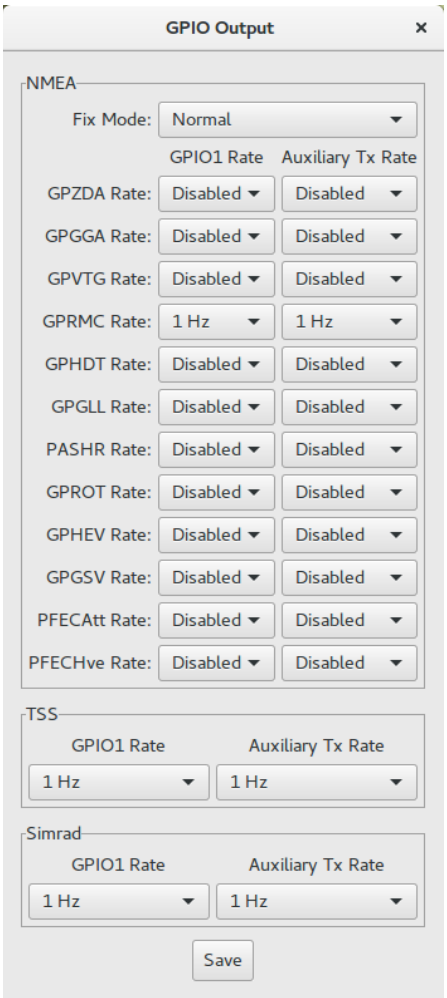


Illustration 56: Screenshot of Spatial Dual Manager GPIO output dialogue

11.8.12 Manual Initialisation

This dialogue can be used to manually initialise Spatial Dual when a GNSS fix is not available. Setting the position will initialise the navigation filter. Setting the heading will initialise the heading.

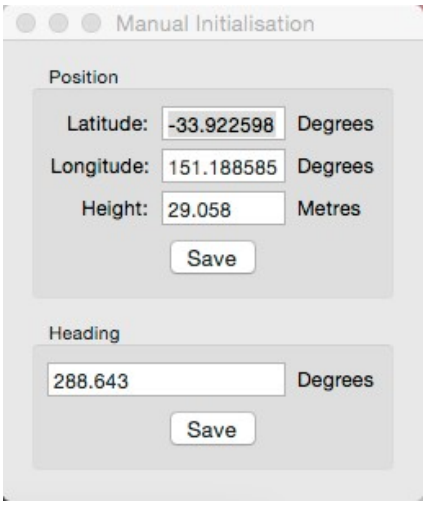


Illustration 57: Screenshot of Spatial Dual Manager position configuration dialogue

11.8.13 Dual Antenna

The dual antenna configuration dialogue is only used if the antennas are not installed in their default positions of primary front and secondary rear.

The recommended installation is with the primary antenna to the front and the secondary antenna directly to the rear along the same axis, in which case the values in this dialogue can be left at their factory defaults.

If it is not practical to mount the antennas in the recommended alignment, the alternate alignment must be entered into this dialogue. It is recommended to try and use one of the automatic offsets where possible, where the antennas must be installed in one of four different automatic offset orientations aligned on an axis.

If it is not possible to use one of the automatic offsets, the antennas can be installed in any configuration and a manual offset should be entered. The manual offset is measured from the central base of the secondary antenna to the central base of the primary antenna in the body co-ordinate frame (X positive forward, Z positive down). If using a manual offset, please be careful to measure the offset accurately, as even small offset errors can result in relatively large heading errors e.g. 2 cm error = 1.15 degrees heading error with a 1 metre separation.

When using an automatic offset, the manual offset values are ignored and when using a manual offset, the automatic offset selection is ignored. When using automatic offset the manual offset values will show the distance that Spatial Dual has automatically measured.

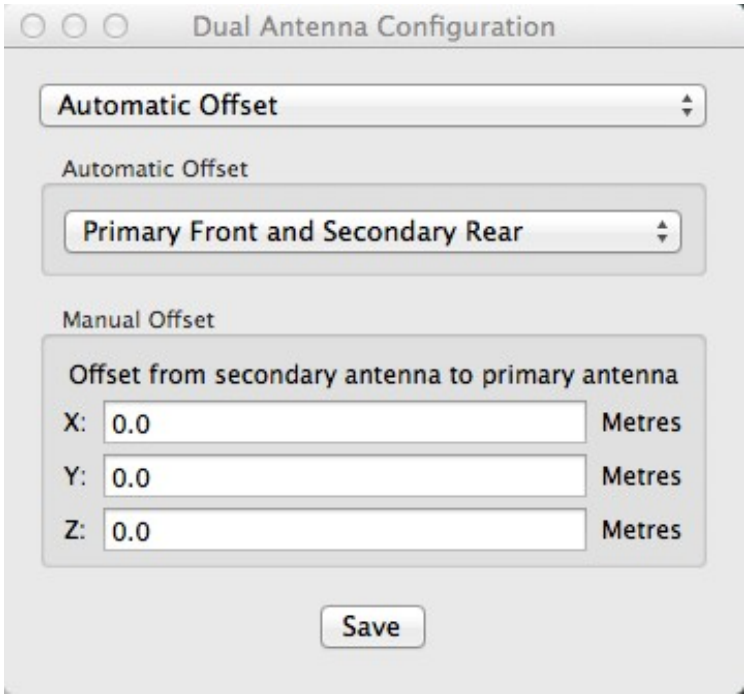


Illustration 58: Screenshot of Spatial Dual Manager dual antenna configuration dialogue

11.8.14 Gimbal

The gimbal configuration dialogue is only used in speciality gimbal applications. Please contact support@advancednavigation.com.au for more information on using Spatial Dual inside a gimbal.

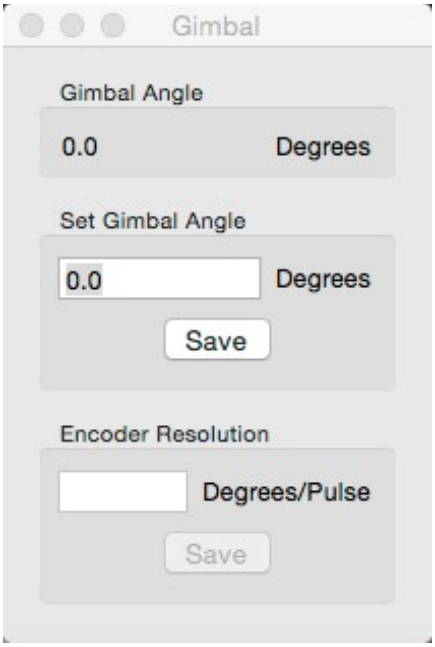


Illustration 59: Screenshot of Spatial Dual Manager gimbal dialogue

11.9 Tools

The tools menu contains tools for performing procedures with Spatial Dual.

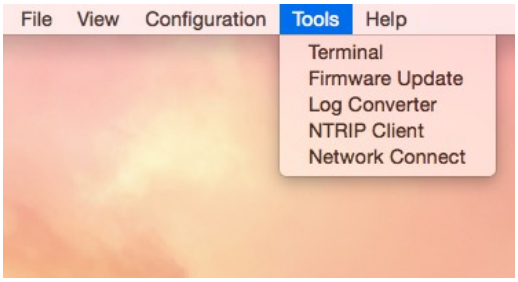


Illustration 60: Screenshot of Spatial Dual Manager tools menu

11.9.1 Terminal

The terminal is only used during specialised technical support with Advanced Navigation engineers.

11.9.2 Firmware Update

The firmware update dialogue is used to update Spatial Dual's firmware. Advanced Navigation firmware files have the extension .anfw. The dialogue shows the version number of the firmware file along with the date and time it was generated by engineering.

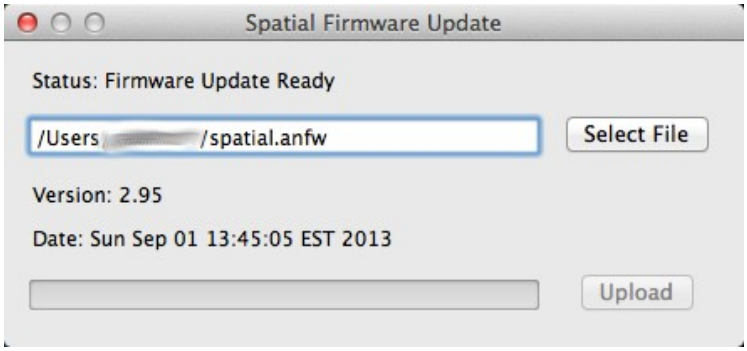


Illustration 61: Screenshot of Spatial Dual Manager firmware update dialogue

11.9.3 GNSS Firmware Update

The GNSS Firmware Update dialogue is used to update the Trimble GNSS receiver firmware. Check the receiver type as show in section 11.7.9.

The latest Trimble firmware can be found under ‘Support’ at:

- BD992: https://www.trimble.com/Precision-GNSS/BD992-Board.aspx
- BD982: https://www.trimble.com/Precision-GNSS/BD982-Board.aspx

Note: Firmware can take up to **1 hour** to load on to the device. Ensure that the computer has sufficient charge and will not go to sleep during this time.

Once connected to the Spatial Dual device, Select ‘Tools’, ‘GNSS Firmware Update’.

Select "Update" to select the file to flash to the GNSS Receiver

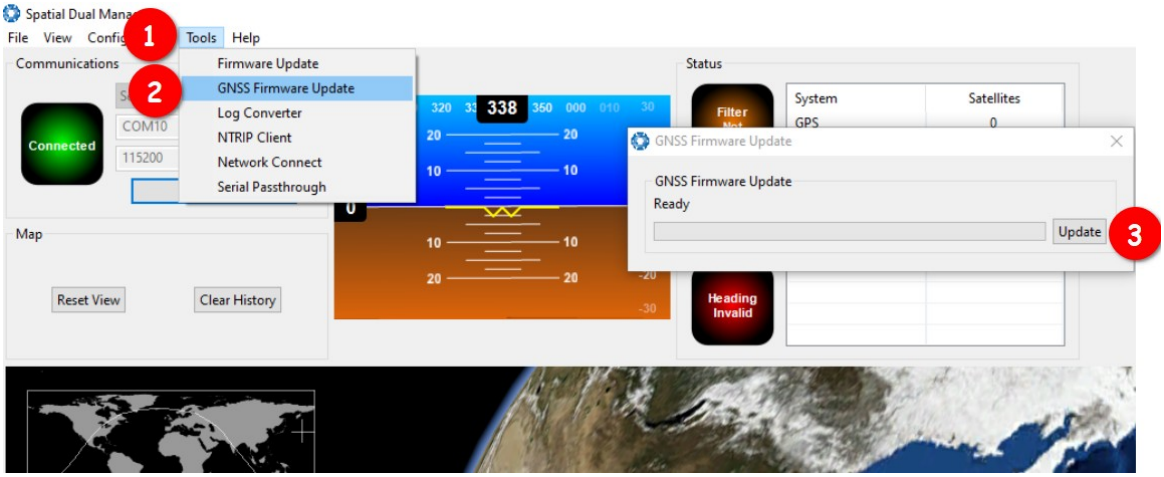


Illustration 62: Screenshot of Spatial Dual Manager GNSS firmware update dialogue

Note: Take care selecting the file, as once you double click, or select Open, the firmware will begin to immediately upload to the device.

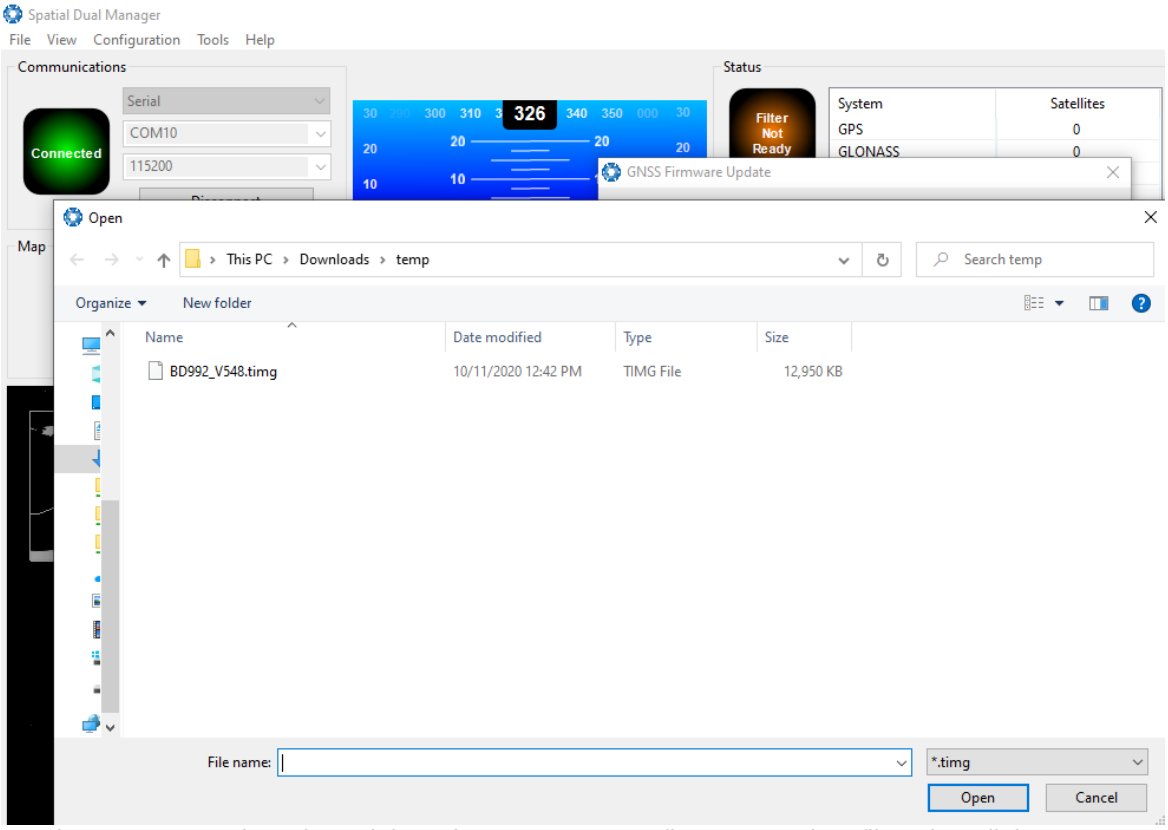


Illustration 63: Screenshot of Spatial Dual Manager GNSS firmware update file select dialogue

Due to the duration of the upload process, the progress dialogue may show 0% for quite some time. Do not prematurely click Cancel thinking that the process has frozen, this is likely not the case.

Note: Firmware can take up to 1 hours to load onto the device.

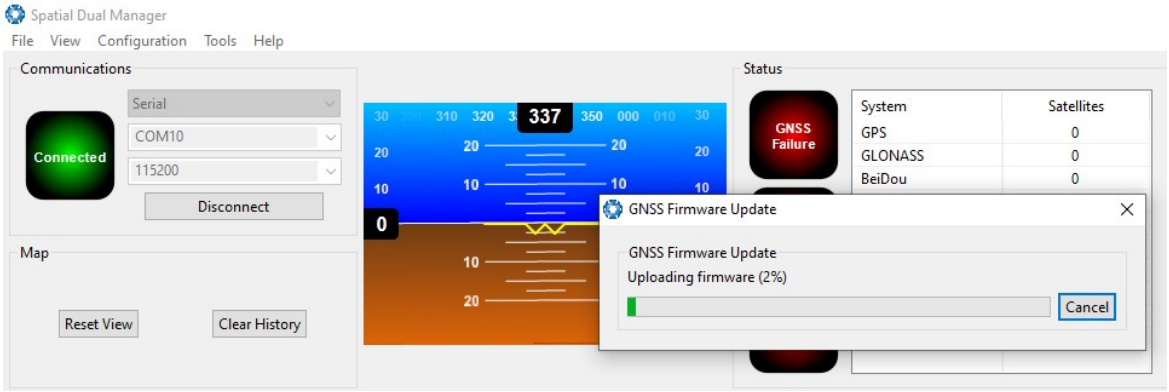


Illustration 64: Screenshot of Spatial Dual Manager firmware update dialogue

If you choose to Cancel the process it will take a short while to complete. At the end of the process it will report 'Error 2' as shown in illustration 65. This is normal and signifies that the operation is complete. The dialogue can either be closed, or a new firmware selected for upload.

Illustration 65: Screenshot of Spatial Dual Manager firmware post Cancel dialogue

11.9.4 Log Converter

This tool allows the user to convert Spatial Dual log files into various standard formats that are readable by many programs, as well as set a user configurable log path. The offset is used to project the exported position to a point other than the centre of the Spatial Dual unit. For most users these values should be left at zero.

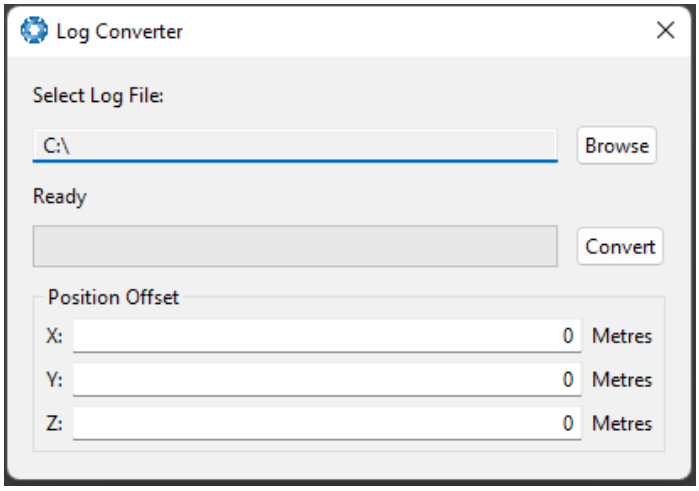


Illustration 66: Screenshot of Spatial Dual Manager Log Converter dialogue

To configure the Log path, navigate to *Settings* under the File menu

Illustration 67: Settings menu for configuring log path

11.9.5 NTRIP Client

The NTRIP client can be used to connect to a network DGPS or RTK service to stream correction data to Spatial Dual for DGPS or RTK. The NTRIP client requires an internet connection to function. Please contact support@advancednavigation.com.au for guidance on getting set up with network DGPS or RTK.

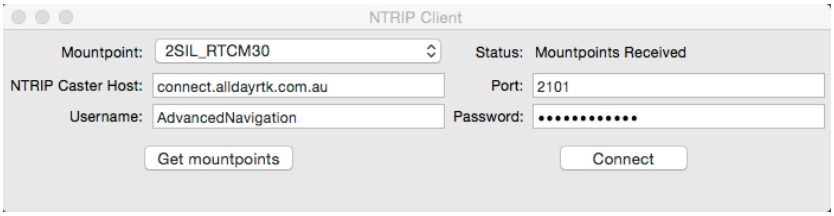


Illustration 68: Screenshot of Spatial Dual Manager NTRIP client dialogue

11.9.6 Network Connect

The network connect dialogue allows Spatial Dual Manager to make a connection to Spatial Dual over a TCP/IP network rather than the default serial port connection. This allows Spatial Dual to be used with ethernet to serial converters. Advanced Navigation recommends Lantronix ethernet to serial converters.

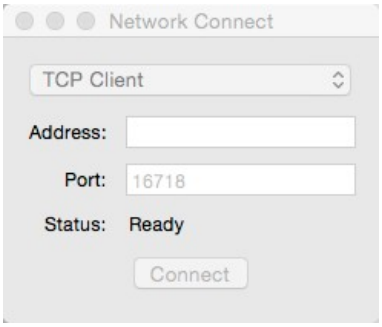


Illustration 69: Screenshot of Spatial Dual Manager network connect dialogue

12 Interfacing

12.1 Communication

Communication with Spatial Dual is over an RS232 interface (or RS422 if you have that model) in the Advanced Navigation Packet Protocol (ANPP). The format is fixed at 1 start bit, 8 data bits, 1 stop bit and no parity. See section 13 for details on the protocol.

Model	Primary Port	Auxiliary Port	GPIO Port
Spatial Dual RS232	Yes	Yes	Yes
Spatial Dual RS422	Yes	No	Yes

Table 20: I/O ports available

12.1.1 Baud Rate

The default baud rate of Spatial Dual is 115200. The primary port baud rate can be set anywhere from 2400 to 2000000 baud and can be modified using the Spatial Dual Manager software or the Baud Rates packet, see section 13.10.3. It is important to select a baud rate that is capable of carrying the amount of data that Spatial Dual is configured to output. See Packet Rates in section 13.5 for more details on the data output calculation. The data rate in bytes per second can be calculated by dividing the baud rate by 10. For example if the baud rate is 115200, then the data rate is 11520 bytes per second.

12.2 External Data

External sources of position, velocity and/or heading can be integrated into Spatial Dual's filter solution. The data can be sent to Spatial Dual in the ANPP format over the main RS232 port or through the GPIO pins or auxiliary RS232 in a number of different formats. If using the ANPP, please use Table 21 below to find the relevant section. If using the GPIO pins or auxiliary RS232, please see section 12.3.

Packet	Section
External Position and Velocity	13.9.25
External Position	13.9.26
External Velocity	13.9.27
External Body Velocity	13.9.28
External Heading	13.9.29
External Time	13.9.33
External Depth	13.9.34
External Pitot Pressure	13.9.37
External Odometer	13.9.43
External Air Data	13.9.44

Table 21: ANPP External Data Reference

12.3 GPIO Pins and Auxiliary RS232

The RS232 model of Spatial Dual contains two general purpose input output (GPIO) pins and an auxiliary RS232 port on the main connector. The RS422 model of Spatial Dual does not have the auxiliary port. These pins are multi function and can be used to extend Spatial Dual with additional peripherals, sensors and data formats. Both GPIO pins have digital input, digital output, frequency input and frequency output functionality.

For for both models, GPIO1 can also function as an RS232 serial transmit line and GPIO2 can function as an RS232 serial receive line. The GPIO serial baud rate can be configured anywhere from 2400 to 250 K baud. The auxiliary serial baud rate can be configured anywhere from 2400 to 2 M baud. Changes to these baud rates can be made by using the Baud Rates dialog box in Spatial Dual Manager (see section 11.8.6) or the Baud Rates Packet (see section 13.10.3).

The available GPIO pin functions and auxiliary RS232 functions are listed below in section 12.4 . The function of a GPIO pin or the auxiliary RS232 can be changed at any time using the GPIO Configuration dialog box in Spatial Dual Manager (see section 11.8.7) or the GPIO Configuration Packet (see section 13.10.8). GPIO 1 and GPIO 2 function at 0 – 5 volt levels for digital input, digital output, frequency input and frequency output, but when a serial data function is selected that GPIO pin automatically switches to RS232 level.

12.4 Dynamic Pin Functions

Function	Type	GPIOs	Auxiliary RS232
Inactive	Tristate	All	All
1PPS Output	Digital Output	All	Transmit
GNSS Fix Output	Digital Output	All	Transmit
Odometer Input	Frequency Input	All	Receive
Zero Velocity Input	Digital Input	All	Receive

Function	Type	GPIOs	Auxiliary RS232
Pitot Tube Input	Frequency Input	All	Receive
NMEA Input	Serial Receive	2	Receive
NMEA Output	Serial Transmit	1	Transmit
Novatel GNSS Input	Serial Receive	2	Receive
Topcon GNSS Input	Serial Receive	2	Receive
ANPP Input	Serial Receive	2	Receive
ANPP Output	Serial Transmit	1	Transmit
Disable GNSS	Digital Input	All	Receive
Disable Pressure	Digital Input	All	Receive
Set Zero Orientation Alignment	Digital Input	All	Receive
System State Packet Trigger	Digital Input	All	Receive
Raw Sensors Packet Trigger	Digital Input	All	Receive
Pressure Depth Transducer	Frequency Input	All	Receive
RTCM Differential GNSS Corrections Input	Serial Receive	2	Receive
Trimble GNSS Input	Serial Receive	2	Receive
u-blox GNSS Input	Serial Receive	2	Receive
Hemisphere GNSS Input	Serial Receive	2	Receive
Teledyne DVL Input	Serial Receive	2	Receive
Tritech USBL Input	Serial Receive	2	Receive
Linkquest DVL Input	Serial Receive	2	Receive
Linkquest USBL Input	Serial Receive	2	Receive
Nortek DVL Input	Serial Receive	2	Receive
Left Wheel Speed Sensor	Frequency Input	All	Receive
Right Wheel Speed Sensor	Frequency Input	All	Receive
1PPS Input	Digital Input	All	Receive
Wheel Speed Sensor	Frequency Input	All	Receive
Wheel Encoder Phase A	Frequency Input	All	
Wheel Encoder Phase B	Frequency Input	All	
Event 1 Input	Digital Input	All	Receive
Event 2 Input	Digital Input	All	Receive
TSS1 Output	Serial Transmit	1	Transmit
Simrad 1000 Output	Serial Transmit	1	Transmit
Simrad 3000 Output	Serial Transmit	1	Transmit

Function	Type	GPIOs	Auxiliary RS232
Serial Port Passthrough	Serial	All	All
GNSS Receiver Passthrough	Serial	All	All
Gimbal Encoder Phase A	Frequency Input	All	
Gimbal Encoder Phase B	Frequency Input	All	
Odometer Direction, Forward Low	Digital Input	All	Receive
Odometer Direction, Forward High	Digital Input	All	Receive
Moving Base Corrections Output	Serial Transmit	1	Transmit
Reverse Alignment, Forward Low	Digital Input	All	Receive
Reverse Alignment, Forward High	Digital Input	All	Receive
Zero Angular Velocity Input	Digital Input	All	Receive
Mavlink Output	Serial Transmit	1	Transmit

Table 22: GPIO pin and auxiliary RS232 functions

12.4.1 1PPS Output

In this function, the pin pulses for 50 milliseconds to signal the precise second. The 1PPS line starts pulsing approximately 100 milliseconds after power up and always fires irrespective of whether Spatial Dual has accurate time or not. It is important to note that when Spatial Dual acquires time corrections from it's GNSS receiver, the 1PPS signal may fire at an interval of less than 1 second. This typically only occurs the first time the GNSS receiver obtains a fix after startup. The time initialised status flag can be used to determine whether the time and 1PPS line is accurate or not.

1PPS Source	Voltage Level	Trigger
Auxiliary	-5v to 5v	Falling Edge
GPIO	0 to 5v	Rising Edge

Table 23: 1PPS Specifications

12.4.2 GNSS Fix Output

In this function, the pin is low when there is no GNSS fix or a 2D fix and high when there is a 3D, SBAS, Differential or RTK GNSS fix.

12.4.3 Odometer Input

This function is designed for low resolution vehicle speed sensors and odometers. It expects a normally low input with a high state for the trigger. If the pulse length is more than 0.1 metres this odometer input function should be used, if it is less than 0.1 metres the wheel speed sensor function should be used. Please contact Advanced Navigation support for help integrating with your speed sensor.

Parameter	Value
Trigger	Low → High
Maximum Frequency	600Khz
Maximum Pulse Rate	4294967 pulses/metre

Table 24: Odometer Specifications

12.4.4 Zero Velocity Input

When using this function, a high state indicates to Spatial Dual that it is stationary. The low state indicates that the vehicle is not stationary. Use of this function can significantly improve drift performance when a GNSS signal is not available.

12.4.5 Pitot Tube Input

This function is designed for fixed wing aircraft to enhance navigation through the use of a pitot tube to measure airspeed. It requires a differential pressure sensor that has a frequency output such as the Kavlico P992 (frequency output option) or the Paroscientific series 5300. Please contact Advanced Navigation support for help integrating with a pitot tube.

12.4.6 NMEA Input

This function accepts external data in the NMEA format. Advanced Navigation recommends against using NMEA where possible due to the inefficiency, inaccuracy and poor error checking of the format. All NMEA messages received must have a valid checksum. Supported messages are listed below. The recommended combination of messages are GPGGA, GPVTG and GPZDA with optional messages GPGSV and GPGSA.

Message ID	Description
GPGGA GNGGA	3D position
GPGLL GNGLL	2D position
GPRMC GNRMC	2D position, 2D velocity and coarse time
GPVTG GNVTG	2D velocity
GPHDT GNHDT HEHDT	Heading
GPGSV GNGSV	Satellites
GPGSA GNGSA	Dilution of Position
GPZDA GNZDA	Time

Table 25: Supported NMEA messages

12.4.7 NMEA Output

This function outputs a configurable combination of the NMEA messages GPZDA, GPGGA, GPVTG, GPRMC, GPHDT, PASHR, GPROT, GPHEV, GPGSV, PFECGPAtt, and PFECGPHve at up to 50 Hz. The messages output and the output rate can be configured using the NMEA output configuration dialogue in Spatial Dual Manager or the GPIO Output Configuration Packet. An example output is shown below.

$GPZDA,031644.460,07,05,2013,00,00*52

$GPGGA,031644.460,3352.3501851,S,15112.2355488,E,6,00,1.4,150.0,M,0.0,M,,*7E

$GPVTG,089.19,T,089.19,M,000.00,N,000.00,K,E*27

$GPRMC,031644.460,A,3352.3501851,S,15112.2355488,E,0.0,89.2,070513,12.5,W,E*02

$GPHDT,89.2,T*06

$PASHR,031644.460,089.19,T,-00.01,-00.47,-00.00,,,,0,0*2E

12.4.8 Novatel GNSS Input

This function is designed for interfacing Spatial Dual with a Novatel GNSS receiver. It accepts data in the Novatel binary format and requires messages BESTPOS and BESTVEL at rates higher than 1 Hz (20Hz recommended). The message BESTSATS is optional to display detailed satellite information. The message HEADING is also supported for ALIGN capable receivers.

12.4.9 Topcon GNSS Input

This function is designed for interfacing Spatial Dual with a Topcon GNSS receiver. It accepts data

in the GRIL TPS binary format and expects messages PG and VG at rates higher than 1 Hz.

12.4.10 ANPP Input

This function accepts data in the ANPP format as specified in section 13. This function is for ANPP peripheral devices or external aiding data input only. The external aiding data packets that can be input are listed in Table 21.

12.4.11 ANPP Output

This function outputs data in the ANPP format as specified in section 13. For packets to be sent out they must be requested through another GPIO functioning as ANPP input. This function is for ANPP peripheral devices only. It cannot be used as an alternative to the primary port. This function is also used when connecting two Spatial units together, for example when using a USBL.

12.4.12 Disable GNSS

This function accepts a digital input with a low state enabling the GNSS and a high state disabling the GNSS.

12.4.13 Disable Pressure

This function accepts a digital input with a low state enabling the atmospheric pressure sensor and a high state disabling the atmospheric pressure sensor.

12.4.14 Set Zero Orientation Alignment

This function accepts a digital input. The input is normally low and a transition from low to high causes Spatial Dual to set it's alignment so that the current orientation is zero. Due to the risk of exhausting the flash cycles, the change is not permanent and will disappear on reset. To make it permanent the Installation Alignment Packet must be read and then sent back to Spatial Dual with the permanent flag set. This function requires de-bouncing if attached to a switch.

12.4.15 System State Packet Trigger

This function accepts a digital input. The input is normally low and a transition from low to high causes Spatial Dual to send the system state packet. This function requires de-bouncing if attached to a switch.

12.4.16 Raw Sensors Packet Trigger

This function accepts a digital input. The input is normally low and a transition from low to high causes Spatial Dual to send the raw sensors packet. This function requires de-bouncing if attached to a switch.

12.4.17 Pressure Depth Transducer

This function is designed for interfacing with a legacy pressure depth transducer. These are no longer available and the function is now deprecated.

12.4.18 RTCM Differential GNSS Corrections Input

This function accepts RTCM v2, RTCM v3 or CMR differential GNSS corrections. This allows for Differential GNSS or RTK with Spatial Dual's internal GNSS receiver.

12.4.19 Trimble GNSS Input

This function is designed for interfacing Spatial Dual with an external Trimble GNSS receiver. It accepts data in the Trimble binary format GSOF and expects packet 0x40 with records 1, 2, 8, and 12 at rates higher than 1Hz (20Hz recommended) and optional records 9 and 34 at 1 to 2Hz.

12.4.20 u-blox GNSS Input

This function is designed for interfacing Spatial Dual with a u-blox GNSS receiver. It accepts data in the u-blox binary format and expects message NAV-PVT at rates higher than 1Hz.

12.4.21 Hemisphere GNSS Input

This function is designed for interfacing Spatial Dual with a Hemisphere GNSS receiver. It accepts data in the Hemisphere binary format and expects message Bin1 at rates higher than 1Hz. For Hemisphere receivers that provide heading using two antennas, NMEA should be used instead as the binary format does not allow for transmission of heading information.

12.4.22 Teledyne DVL Input

This function accepts DVL data from a Teledyne DVL. For assistance with configuration please contact support@advancednavigation.com.au.

12.4.23 Tritech USBL Input

This function accepts USBL data from a Tritech USBL. For assistance with configuration please contact support@advancednavigation.com.au.

12.4.24 Linkquest DVL Input

This function accepts DVL data from a Linkquest DVL. For assistance with configuration please contact support@advancednavigation.com.au.

12.4.25 Linkquest USBL Input

This function accepts USBL data from a Linkquest USBL. For assistance with configuration please contact support@advancednavigation.com.au.

12.4.26 Nortek DVL Input

This function accepts DVL data in the Nortek DVL binary format. It accepts the packets 0x1B (DVL Bottom Track) and 0x1D (DVL Water Track). The recommended update rate is 8Hz.

12.4.27 Left Wheel Speed Sensor

This function is designed for the left wheel of a vehicle with dual wheel speed sensors.

12.4.28 Right Wheel Speed Sensor

This function is designed for the right wheel of a vehicle with dual wheel speed sensors.

12.4.29 1PPS Input

This function is designed to allow external GNSS receivers to synchronise time with Spatial Dual. It triggers on a transition from low to high.

12.4.30 Wheel Speed Sensor

This function is designed for high resolution vehicle speed sensors and wheel speed sensors. It expects a normally low input with a high state for the trigger. If the pulse length is more than 0.1 metres the odometer input function should be used, if it is less than 0.1 metres the wheel speed sensor function should be used. Please contact Advanced Navigation support for help integrating with your speed sensor.

Parameter	Value
Trigger	Low → High
Maximum Frequency	40 MHz
Maximum Pulse Rate	4,294,967,295 pulses/metre

Table 26: Wheel Speed Sensor Specifications

12.4.31 Wheel Encoder Phase A

This function is designed for rotary incremental quadrature encoders. It should be used in combination with Wheel Encoder Phase B.

12.4.32 Wheel Encoder Phase B

This function is designed for rotary incremental quadrature encoders. It should be used in combination with Wheel Encoder Phase A.

12.4.33 Event 1 Input

This function is designed to allow external events to be recorded inside Spatial Dual's output. The event is recorded in the filter status, see section 13.9.1.2, and resets after the next packet is output. The event triggers on a transition from low to high.

12.4.34 Event 2 Input

This function is designed to allow external events to be recorded inside Spatial Dual's output. The event is recorded in the filter status, see section 13.9.1.2, and resets after the next packet is output. The event triggers on a transition from low to high.

12.4.35 TSS1 Output

This function outputs the TSS1 format at a user configurable rate up to 50 Hz. The output rate can be configured using the GPIO output configuration dialogue in Spatial Dual Manager, see section 11.8.11.

12.4.36 Simrad 1000 Output

This function outputs the Simrad 1000 format at a user configurable rate up to 50 Hz. The output rate can be configured using the GPIO output configuration dialogue in Spatial Dual Manager, see section 11.8.11.

12.4.37 Simrad 3000 Output

This function outputs the Simrad 3000 format at a user configurable rate up to 50 Hz. The output rate can be configured using the GPIO output configuration dialogue in Spatial Dual Manager, see section 11.8.11.

12.4.38 Serial Port Passthrough

This function allows passthrough communication through either GPIO 1 and 2 or the Auxiliary RS232. To transmit data use the Serial Port Pass-through Packet. When data is received it will be sent back using the same Serial Port Pass-through Packet.

12.4.39 GNSS Receiver Passthrough

This function allows for pass through connection to the internal GNSS receiver. This is useful for firmware updates of the internal GNSS receiver.

12.4.40 Gimbal Encoder Phase A

This function is designed for interfacing with a rotary incremental quadrature encoder to measure the azimuth angle of a gimbal that Spatial Dual is installed in. It should be used in combination with Gimbal Encoder Phase B.

12.4.41 Gimbal Encoder Phase B

This function is designed for interfacing with a rotary incremental quadrature encoder to measure the azimuth angle of a gimbal that Spatial Dual is installed in. It should be used in combination with Gimbal Encoder Phase A.

12.4.42 Odometer Direction, Forward Low

This function is designed to take a reversing indication input for direction with an odometer or wheel encoder. It should be used in combination with Odometer Input or Wheel Speed Sensor.

12.4.43 Odometer Direction, Forward High

This function is designed to take a reversing indication input for direction with an odometer or wheel encoder. It should be used in combination with Odometer Input or Wheel Speed Sensor.

12.4.44 Moving Base Corrections Output

Certain configurations of your device can act as an RTK base station and output the corrections data. The moving base corrections output requires either a 10 cm or 8 mm RTK licence. The output data is in the ANPP format. For assistance with configuration please contact support@advancednavigation.com.au.

12.4.45 Reverse Alignment, Forward Low

This function is designed to reverse the alignment settings for vehicles that can have two vehicle forward directions, such as locomotives.

12.4.46 Reverse Alignment, Forward High

This function is designed to reverse the alignment settings for vehicles that can have two vehicle forward directions, such as locomotives.

12.4.47 Zero Angular Velocity Input

In this function, a high state indicates to Spatial Dual that the vehicle is not rotating. The low state indicates that the vehicle could be rotating. Use of this function can significantly improve heading drift performance when a GNSS signal is not available.

12.4.48 Mavlink Output

This function outputs the Mavlink GPS_INPUT message at 50Hz. This can be connected to a telemetry or GPS port on PX4 or Ardupilot autopilot to provide high accuracy position, velocity and heading. GPS1 needs to be set to MAVLINK format and magnetometers disabled.

13 Advanced Navigation Packet Protocol

The Advanced Navigation Packet Protocol (ANPP) is a binary protocol designed with high error checking, high efficiency and safe design practices. It has a well defined specification and is very flexible. It is used across all existing and future Advanced Navigation products.

13.1 Data Types

The following data types are used in the packet protocol. All data types in the protocol are little endian byte ordering.

Abbreviation	Bytes	Also known as
u8	1	unsigned char, unsigned byte, uint8_t
s8	1	char, byte, int8_t
u16	2	unsigned short, uint16_t
s16	2	short, int16_t
u32	4	unsigned int, unsigned long, uint32_t
s32	4	int, long, int32_t
u64	8	unsigned long long, uint64_t
s64	8	long long, int64_t
fp32	4	float
fp64	8	double

Table 27: Data type abbreviations used in the ANPP

13.2 Packet Structure

The ANPP packet structure is shown in Table 28 and the header format is shown in Table 29. Example code can be downloaded from the software section.

Header				
Header LRC	Packet ID	Packet Length	CRC16	Packet Data

Table 28: ANPP Packet Structure

ANPP Header Format				
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Header LRC, see section 13.2.1
2	1	u8	1	Packet ID, see section 13.2.2
3	2	u8	1	Packet Length, see section 13.2.3
4	3	u16	2	CRC16, see section 13.2.4

Table 29: ANPP header format

13.2.1 Header LRC

The header LRC (Longitudinal Redundancy Check) provides error checking on the packet header. It also allows the decoder to find the start of a packet by scanning for a valid LRC. The LRC can be found using the following:

LRC = ((packet_id + packet_length + crc[0] + crc[1])^0xFF) + 1

13.2.2 Packet ID

The packet ID is used to distinguish the contents of the packet. Packet IDs range from 0 to 255.

Within this range there are three different sub-ranges, these are system packets, state packets and configuration packets.

System packets have packet IDs in the range 0 to 19. These packets are implemented the same by every device using ANPP.

State packets are packets that contain data that changes with time, i.e. temperature. State packets can be set to output at a certain rate. State packets are packet IDs in the range 20 to 179.

Configuration packets are used for reading and writing device configuration. Configuration packets are packet IDs in the range 180 to 255.

13.2.3 Packet Length

The packet length denotes the length of the packet data, i.e. from byte index 5 onwards inclusive. Packet length has a range of 0 – 255.

13.2.4 CRC

The CRC is a CRC16-CCITT. The starting value is 0xFFFF. The CRC covers only the packet data.

13.3 Packet Requests

Any of the state and configuration packets can be requested at any time using the request packet. See section 13.8.2.

13.4 Packet Acknowledgement

When configuration packets are sent to Spatial Dual, it will reply with an acknowledgement packet that indicates whether the configuration change was successful or not. For details on the acknowledgement packet, see section 13.8.1.

External data packets will also generate negative acknowledgement packets if there is a problem with the packet. Positive acknowledgements will not be sent.

13.5 Packet Rates

The packet rates can be configured either using Spatial Dual Manager or through the Packets Period Packet. By default Spatial Dual is configured to output the System State Packet at 50Hz. When configuring packet rates it is essential to ensure the baud rate is capable of handling the data throughput. This can be calculated using the rate and packet size. The packet size is the packet length add five to account for the packet overhead. For example to output the system state packet at 50Hz the calculation would be:

Data throughput = (100 (packet length) + 5 (fixed packet overhead)) * 50 (rate)

Data throughput = 5250 bytes per second

Minimum baud rate = data throughput x 11 = 57750 Baud

Closest standard baud rate = 115200 Baud

When multiple packets are set to output at the same rate, the order the packets output is from lowest ID to highest ID.

13.6 Packet Timing

Packets are output in order of packet ID from lowest ID to highest ID and all packets that are output in one sequence have their data matched to the same time of validity. The time of validity can be found in either the System State Packet, the Unix Time Packet or the Formatted Time Packet. For example if the Unix Time Packet, Status Packet and NED Velocity Packet packet were all set to output at 10 Hz, at each 0.1 second period the three packets would output consecutively by order of packet ID with all data synchronised between them and the Unix Time Packet providing the time of validity for the other two packets.

13.7 Packet Summary

Packet ID	Length	R/W	Name
System Packets			
0	4	R	Acknowledge Packet
1	Varies	W	Request Packet
2	1	R/W	Boot Mode Packet
3	24	R	Device Information Packet
4	4	W	Restore Factory Settings Packet
5	4	W	Reset Packet
10	Varies	R/W	Serial Port Pass-through Packet

Packet ID	Length	R/W	Name
State Packets			
20	100	R	System State Packet
21	8	R	Unix Time Packet
22	14	R	Formatted Time Packet
23	4	R	Status Packet
24	12	R	Position Standard Deviation Packet
25	12	R	Velocity Standard Deviation Packet
26	12	R	Euler Orientation Standard Deviation Packet
27	16	R	Quaternion Orientation Standard Deviation Packet
28	48	R	Raw Sensors Packet
29	74	R/W	Raw GNSS Packet
30	13	R	Satellites Packet
31	Varies	R	Detailed Satellites Packet
32	24	R	Geodetic Position Packet
33	24	R	ECEF Position Packet
34	25	R	UTM Position Packet
35	12	R	NED Velocity Packet
36	12	R	Body Velocity Packet
37	12	R	Acceleration Packet
38	16	R	Body Acceleration Packet
39	12	R	Euler Orientation Packet
40	16	R	Quaternion Orientation Packet
41	36	R	DCM Orientation Packet
42	12	R	Angular Velocity Packet
43	12	R	Angular Acceleration Packet
44	60	R/W	External Position & Velocity Packet
45	36	R/W	External Position Packet
46	24	R/W	External Velocity Packet
47	24	R/W	External Body Velocity Packet
48	8	R/W	External Heading Packet
49	8	R	Running Time Packet
50	12	R	Local Magnetic Field Packet
51	20	R	Odometer State Packet
52	8	R	External Time Packet

Packet ID	Length	R/W	Name
53	8	R/W	External Depth Packet
54	4	R	Geoid Height Packet
55	Varies	W	RTCM Corrections Packet
56	8	R/W	External Pitot Pressure Packet
57	12	R/W	Wind Packet
58	16	R	Heave Packet
59	-	R	Post Processing Packet
60	Varies	R	Raw Satellite Data Packet
61	Varies	R	Raw Satellite Ephemeris Packet
67	13	W	Error: Reference source not found
68	25	R/W	External Air Data Packet
69	48	R	GNSS Receiver Information Packet
72	8	R/W	Gimbal State Packet
73	24	R	Automotive Packet
80	45	R	Base Station Packet
83	8	W	Zero Angular Velocity Packet
85	32	R	Sensor Temperatures Packet
Configuration Packets			
180	4	R/W	Packet Timer Period Packet
181	Varies	R/W	Packets Period Packet
182	17	R/W	Baud Rates Packet
184	4	R/W	Sensor Ranges Packet
185	73	R/W	Installation Alignment Packet
186	17	R/W	Filter Options Packet
187	-	R/W	Advanced Filter Parameters Packet
188	13	R/W	GPIO Configuration Packet
192	8	R/W	Odometer Configuration Packet
193	5	W	Set Zero Orientation Alignment Packet
194	49	R/W	Reference Point Offsets Packet
195	33	R/W	GPIO Output Configuration Packet
196	17	R/W	Dual Antenna Configuration Packet
197	85	R/W	GNSS Configuration Packet
198	64	R/W	User Data Packet
199	65	R/W	GPIO Input Configuration Packet

Table 30: Packet summary

13.8 System Packets

13.8.1 Acknowledge Packet

Acknowledgement Packet				
Packet ID				0
Length				4
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Packet ID being acknowledged
2	1	u16	2	CRC of packet being acknowledged
3	3	u8	1	Acknowledge Result, see section 13.8.1.1

Table 31: Acknowledge packet

13.8.1.1 Acknowledge Result

Value	Description
0	Acknowledge success
1	Acknowledge failure, CRC error
2	Acknowledge failure, packet size incorrect
3	Acknowledge failure, values outside of valid ranges
4	Acknowledge failure, system flash memory failure
5	Acknowledge failure, system not ready
6	Acknowledge failure, unknown packet

Table 32: Acknowledge result

13.8.2 Request Packet

Request Packet				
Packet ID				1
Length				1 x number of packets requested
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Packet ID requested
+				Field 1 repeats for additional packet requests

Table 33: Request packet

13.8.3 Boot Mode Packet

Boot Mode Packet				
Packet ID				2
Length				1
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Boot mode, see section 13.8.3.1

Table 34: Boot mode packet

13.8.3.1 Boot Mode Types

Value	Description
0	Bootloader
1	Main Program

Table 35: Boot mode types

13.8.4 Device Information Packet

Device Information Packet				
Packet ID				3
Length				24
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Software version
2	4	u32	4	Device ID, see section 13.8.4.1
3	8	u32	4	Hardware revision
4	12	u32	4	Serial number part 1
5	16	u32	4	Serial number part 2
6	20	u32	4	Serial number part 3

Table 36: Device information packet

13.8.4.1 Device ID

Bit	Description
1	Spatial
4	Spatial FOG
5	Spatial Dual
11	Orientus >v3
13	Air Data Unit
14	Subsonus
16	Spatial FOG Dual
17	Motus
19	GNSS Compass
21	Subsonus Tag
22	Poseidon
26	Certus
27	Aries
28	Boreas D90

Table 37: Device ID

13.8.5 Restore Factory Settings Packet

Restore Factory Settings Packet				
Packet ID				4
Length				4
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Verification sequence (set to 0x85429E1C)

Table 38: Restore factory settings packet

13.8.6 Reset Packet

Reset Packet				
Packet ID				5
Length				4
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Verification sequence, see section 13.8.6.1

Table 39: Reset packet

13.8.6.1 Verification Sequence Values

Value	Description
0x21057A7E	Standard hot start reset
0x9A5D38B7	Cold start reset

Table 40: Verification sequence values

13.8.7 Serial Port Pass-through Packet

Serial Port Pass-through Packet				
Packet ID				10
Length				Variable, up to 255 bytes
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Pass-through Route, see section 13.8.7.1
2	1			Pass-through data

Table 41: Serial port pass-through packet

13.8.7.1 Pass-through Routes

Value	Description
1	GPIO 1 and 2
2	Auxiliary RS232

Table 42: Pass-through routes

13.9 State Packets

Spatial Dual supports a large number of packets providing extensive functionality. However for the majority of users the easiest approach is to configure Spatial Dual using the Spatial Dual Manager software and then support only the single system state packet shown below in section 13.9.1. Advanced functionality can be added as required through the other packets.

13.9.1 System State Packet

System State Packet				
Packet ID				20
Length				100
Field #	Bytes Offset	Data Type	Size	Description
1	0	u16	2	System status, see section 13.9.1.1
2	2	u16	2	Filter status, see section 13.9.1.2
3	4	u32	4	Unix time stamp (seconds), see section 13.9.1.4
4	8	u32	4	Microseconds, see section 13.9.1.5
5	12	fp64	8	Latitude (rad)
6	20	fp64	8	Longitude (rad)
7	28	fp64	8	Height (m)
8	36	fp32	4	Velocity north (m/s)
9	40	fp32	4	Velocity east (m/s)
10	44	fp32	4	Velocity down (m/s)
11	48	fp32	4	Body acceleration X (m/s/s)
12	52	fp32	4	Body acceleration Y (m/s/s)
13	56	fp32	4	Body acceleration Z (m/s/s)
14	60	fp32	4	G force (g)
15	64	fp32	4	Roll (radians)
16	68	fp32	4	Pitch (radians)
17	72	fp32	4	Heading (radians)
18	76	fp32	4	Angular velocity X (rad/s)
19	80	fp32	4	Angular velocity Y (rad/s)
20	84	fp32	4	Angular velocity Z (rad/s)
21	88	fp32	4	Latitude standard deviation (m)
22	92	fp32	4	Longitude standard deviation (m)
23	96	fp32	4	Height standard deviation (m)

Table 43: System state packet

13.9.1.1 System Status

This field contains 16 bits that indicate problems with the system. These are boolean fields with a zero indicating false and one indicating true.

Bit	Description
0	System Failure
1	Accelerometer Sensor Failure
2	Gyroscope Sensor Failure
3	Magnetometer Sensor Failure
4	Pressure Sensor Failure
5	GNSS Failure
6	Accelerometer Over Range
7	Gyroscope Over Range
8	Magnetometer Over Range
9	Pressure Over Range
10	Minimum Temperature Alarm
11	Maximum Temperature Alarm
12	Low Voltage Alarm
13	High Voltage Alarm
14	GNSS Antenna Short Circuit
15	Data Output Overflow Alarm

Table 44: System status

13.9.1.2 Filter Status

This field contains 16 bits that indicate the status of the filters. These are boolean fields with a zero indicating false and one indicating true.

Bit	Description
0	Orientation Filter Initialised
1	Navigation Filter Initialised
2	Heading Initialised
3	UTC Time Initialised
4	GNSS Fix Status, see section 13.9.1.3
5	
6	
7	Event 1 Occurred
8	Event 2 Occurred
9	Internal GNSS Enabled
10	Dual Antenna Heading Active
11	Velocity Heading Enabled
12	Atmospheric Altitude Enabled
13	External Position Active
14	External Velocity Active
15	External Heading Active

Table 45: Filter Status

13.9.1.3 GNSS Fix Status

Value	Bit 6	Bit 5	Bit 4	Description
0	0	0	0	No GNSS fix
1	0	0	1	2D GNSS fix
2	0	1	0	3D GNSS fix
3	0	1	1	SBAS GNSS fix
4	1	0	0	Differential GNSS fix
5	1	0	1	Omnistar/Starfire GNSS fix
6	1	1	0	RTK Float GNSS fix
7	1	1	1	RTK Fixed GNSS fix

Table 46: GNSS fix status

13.9.1.4 Unix Time Seconds

This field provides UTC time in seconds since January 1, 1970, including leap seconds.

13.9.1.5 Microseconds

This field provides the sub-second component of time. It is represented as microseconds since the last second. Minimum value is 0 and maximum value is 999999.

13.9.2 Unix Time Packet

Unix Time Packet				
Packet ID				21
Length				8
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Unix time stamp (seconds), see section 13.9.1.4
2	4	u32	4	Microseconds, see section 13.9.1.5

Table 47: Unix time packet

13.9.3 Formatted Time Packet

Formatted Time Packet				
Packet ID				22
Length				14
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Microseconds
2	4	u16	2	Year
3	6	u16	2	Year day, 0 - 365
4	8	u8	1	Month, 0 - 11
5	9	u8	1	Month Day, 1 - 31
6	10	u8	1	Week Day, 0 – 6 (0 = Sunday)
7	11	u8	1	Hour, 0 - 23
8	12	u8	1	Minute, 0 - 59
9	13	u8	1	Second, 0 - 59

Table 48: Formatted time packet

13.9.4 Status Packet

Status Packet				
Packet ID				23
Length				4
Field #	Bytes Offset	Data Type	Size	Description
1	0	u16	2	System status, see section 13.9.1.1
2	2	u16	2	Filter status, see section 13.9.1.2

Table 49: Status packet

13.9.5 Position Standard Deviation Packet

Position Standard Deviation Packet				
Packet ID				24
Length				12
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Latitude standard deviation (m)
2	4	fp32	4	Longitude standard deviation (m)
3	8	fp32	4	Height standard deviation (m)

Table 50: Position standard deviation packet

13.9.6 Velocity Standard Deviation Packet

Velocity Standard Deviation Packet				
Packet ID				25
Length				12
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Velocity north standard deviation (m/s)
2	4	fp32	4	Velocity east standard deviation (m/s)
3	8	fp32	4	Velocity down standard deviation (m/s)

Table 51: Velocity standard deviation packet

13.9.7 Euler Orientation Standard Deviation Packet

Euler Orientation Standard Deviation Packet				
Packet ID				26
Length				12
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Roll standard deviation (rad)
2	4	fp32	4	Pitch standard deviation(rad)
3	8	fp32	4	Heading standard deviation(rad)

Table 52: Euler orientation standard deviation packet

13.9.8 Quaternion Orientation Standard Deviation Packet

Quaternion Orientation Standard Deviation Packet				
Packet ID				27
Length				16
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Q0 standard deviation
2	4	fp32	4	Q1 standard deviation
3	8	fp32	4	Q2 standard deviation
4	12	fp32	4	Q3 standard deviation

Table 53: Quaternion orientation standard deviation packet

13.9.9 Raw Sensors Packet

Raw Sensors Packet				
Packet ID				28
Length				48
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Accelerometer X (m/s/s)
2	4	fp32	4	Accelerometer Y (m/s/s)
3	8	fp32	4	Accelerometer Z (m/s/s)
4	12	fp32	4	Gyroscope X (rad/s)
5	16	fp32	4	Gyroscope Y (rad/s)
6	20	fp32	4	Gyroscope Z (rad/s)
7	24	fp32	4	Magnetometer X (mG)

8	28	fp32	4	Magnetometer Y (mG)
9	32	fp32	4	Magnetometer Z (mG)
10	36	fp32	4	IMU Temperature (deg C)
11	40	fp32	4	Pressure (Pascals)
12	44	fp32	4	Pressure Temperature (deg C)

Table 54: Raw sensors packet

13.9.10 Raw GNSS Packet

This packet represents the raw data as it is received from the GNSS receiver. The position is not corrected for antenna position offset and the velocity is not compensated for the antenna lever arm offset. The INS position and velocity that are in the other packets are corrected for antenna position offset and lever arm.

Raw GNSS Packet				
Packet ID				29
Length				74
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Unix time stamp (seconds)
2	4	u32	4	Microseconds
3	8	fp64	8	Latitude (rad)
4	16	fp64	8	Longitude (rad)
5	24	fp64	8	Height (m)
6	32	fp32	4	Velocity north (m/s)
7	36	fp32	4	Velocity east (m/s)
8	40	fp32	4	Velocity down (m/s)
9	44	fp32	4	Latitude standard deviation (m)
10	48	fp32	4	Longitude standard deviation (m)
11	52	fp32	4	Height standard deviation (m)
12	56	fp32	4	Tilt (rad)
13	60	fp32	4	Heading (rad)
14	64	fp32	4	Tilt standard deviation (rad)
15	68	fp32	4	Heading standard deviation (rad)
16	72	u16	2	Status, see section 13.9.10.1

Table 55: Raw GNSS packet

13.9.10.1 Raw GNSS Status

Bit	Description
0	GNSS Fix Status, see section 13.9.1.3
1	
2	
3	Doppler velocity valid
4	Time valid
5	External GNSS
6	Tilt valid
7	Heading valid
8	Floating ambiguity heading
9-15	Reserved (set to zero)

Table 56: Raw GNSS status

13.9.11 Satellites Packet

Satellites Packet				
Packet ID				30
Length				13
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	HDOP
2	4	fp32	4	VDOP
3	8	u8	1	GPS satellites
4	9	u8	1	GLONASS satellites
5	10	u8	1	BeiDou satellites
6	11	u8	1	GALILEO satellites
7	12	u8	1	SBAS satellites

Table 57: Satellites packet

13.9.12 Detailed Satellites Packet

Detailed Satellites Packet				
Packet ID				31
Length				7 x number of satellites
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Satellite system, see section 13.9.12.1
2	1	u8	1	Satellite number (PRN)
3	2	s8	1	Satellite frequencies, see section 13.9.12.2
4	3	u8	1	Elevation (deg)
5	4	u16	2	Azimuth (deg)
6	6	u8	1	SNR
+				Fields 1-6 repeat for additional satellites

Table 58: Detailed satellites packet

13.9.12.1 Satellite Systems

Value	System
0	Unknown
1	GPS
2	GLONASS
3	BeiDou
4	GALILEO
5	SBAS
6	QZSS
7	Starfire
8	Omnistar
9	IMES

Table 59: Satellite systems

13.9.12.2 Satellite Frequencies

Bit	Description
0	L1 C/A
1	L1 C
2	L1 P
3	L1 M

4	L2 C
5	L2 P
6	L2 M
7	L5

Table 60: Satellite frequencies

13.9.13 Geodetic Position Packet

Geodetic Position Packet				
Packet ID				32
Length				24
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp64	8	Latitude (rad)
2	8	fp64	8	Longitude (rad)
3	16	fp64	8	Height (m)

Table 61: Geodetic position packet

13.9.14 ECEF Position Packet

ECEF Position Packet				
Packet ID				33
Length				24
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp64	8	ECEF X (m)
2	8	fp64	8	ECEF Y (m)
3	16	fp64	8	ECEF Z (m)

Table 62: ECEF position packet

13.9.15 UTM Position Packet

UTM Position Packet				
Packet ID				34
Length				26
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp64	8	Northing (m)
2	8	fp64	8	Easting (m)

3	16	fp64	8	Height (m)
4	24	u8	1	Zone number
5	25	s8	1	Zone character

Table 63: UTM position packet

13.9.16 NED Velocity Packet

NED Velocity Packet				
Packet ID				35
Length				12
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Velocity north (m/s)
2	4	fp32	4	Velocity east (m/s)
3	8	fp32	4	Velocity down (m/s)

Table 64: NED velocity packet

13.9.17 Body Velocity Packet

Body Velocity Packet				
Packet ID				36
Length				12
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Velocity X (m/s)
2	4	fp32	4	Velocity Y (m/s)
3	8	fp32	4	Velocity Z (m/s)

Table 65: Body velocity packet

13.9.18 Acceleration Packet

This packet includes the acceleration due to gravity.

Acceleration Packet				
Packet ID				37
Length				12
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Acceleration X (m/s/s)
2	4	fp32	4	Acceleration Y (m/s/s)
3	8	fp32	4	Acceleration Z (m/s/s)

Table 66: Acceleration packet

13.9.19 Body Acceleration Packet

This packet does not include the acceleration due to gravity.

Body Acceleration Packet				
Packet ID				38
Length				16
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Body acceleration X (m/s/s)
2	4	fp32	4	Body acceleration Y (m/s/s)
3	8	fp32	4	Body acceleration Z (m/s/s)
4	12	fp32	4	G force (g)

Table 67: Body acceleration packet

13.9.20 Euler Orientation Packet

Euler Orientation Packet				
Packet ID				39
Length				12
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Roll (rad)
2	4	fp32	4	Pitch (rad)
3	8	fp32	4	Heading (rad)

Table 68: Euler orientation packet

13.9.21 Quaternion Orientation Packet

Quaternion Orientation Packet				
Packet ID				40
Length				16
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	QS
2	4	fp32	4	QX
3	8	fp32	4	QY
4	12	fp32	4	QZ

Table 69: Quaternion orientation packet

13.9.22 DCM Orientation Packet

DCM Orientation Packet				
Packet ID				41
Length				36
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	DCM[0][0]
2	4	fp32	4	DCM[0][1]
3	8	fp32	4	DCM[0][2]
4	12	fp32	4	DCM[1][0]
5	16	fp32	4	DCM[1][1]
6	20	fp32	4	DCM[1][2]
7	24	fp32	4	DCM[2][0]
8	28	fp32	4	DCM[2][1]
9	32	fp32	4	DCM[2][2]

Table 70: DCM orientation packet

13.9.23 Angular Velocity Packet

Angular Velocity Packet				
Packet ID				42
Length				12
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Angular velocity X (rad/s)
2	4	fp32	4	Angular velocity Y (rad/s)
3	8	fp32	4	Angular velocity Z (rad/s)

Table 71: Angular velocity packet

13.9.24 Angular Acceleration Packet

Angular Acceleration Packet				
Packet ID				43
Length				12
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Angular acceleration X (rad/s/s)
2	4	fp32	4	Angular acceleration Y (rad/s/s)
3	8	fp32	4	Angular acceleration Z (rad/s/s)

Table 72: Angular acceleration packet

13.9.25 External Position & Velocity Packet

External Position & Velocity Packet				
Packet ID				44
Length				60
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp64	8	Latitude (rad)
2	8	fp64	8	Longitude (rad)
3	16	fp64	8	Height (m)
4	24	fp32	4	Velocity north (m/s)
5	28	fp32	4	Velocity east (m/s)
6	32	fp32	4	Velocity down (m/s)
7	36	fp32	4	Latitude standard deviation (m)
8	40	fp32	4	Longitude standard deviation (m)

9	44	fp32	4	Height standard deviation (m)
10	48	fp32	4	Velocity north standard deviation (m/s)
11	52	fp32	4	Velocity east standard deviation (m/s)
12	56	fp32	4	Velocity down standard deviation (m/s)

Table 73: External position & velocity packet

13.9.26 External Position Packet

External Position Packet				
Packet ID				45
Length				36
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp64	8	Latitude (rad)
2	8	fp64	8	Longitude (rad)
3	16	fp64	8	Height (m)
4	24	fp32	4	Latitude standard deviation (m)
5	28	fp32	4	Longitude standard deviation (m)
6	32	fp32	4	Height standard deviation (m)

Table 74: External position packet

13.9.27 External Velocity Packet

External Velocity Packet				
Packet ID				46
Length				24
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Velocity north (m/s)
2	4	fp32	4	Velocity east (m/s)
3	8	fp32	4	Velocity down (m/s)
4	12	fp32	4	Velocity north standard deviation (m/s)
5	16	fp32	4	Velocity east standard deviation (m/s)
6	20	fp32	4	Velocity down standard deviation (m/s)

Table 75: External velocity packet

13.9.28 External Body Velocity Packet

This packet has been defined to support a single velocity standard deviation for all three axes, or, different values for all three axes. Please ensure you modify the packet length in the packet header accordingly, depending on which format you are using.

External Body Velocity Packet				
Packet ID				47
Length				16 or 24
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Velocity X (m/s)
2	4	fp32	4	Velocity Y (m/s)
3	8	fp32	4	Velocity Z (m/s)
4	12	fp32	4	Velocity X standard deviation (m/s)
5	12	fp32	4	OPTIONAL: Velocity standard deviation Y (m/s)
6	12	fp32	4	OPTIONAL: Velocity standard deviation Z (m/s)

Table 76: External body velocity packet

13.9.29 External Heading Packet

External Heading Packet				
Packet ID				48
Length				8
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Heading (rad)
2	4	fp32	4	Heading standard deviation (rad)

Table 77: External heading packet

13.9.30 Running Time Packet

Running Time Packet				
Packet ID				49
Length				8
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Running time seconds
2	4	u32	4	Microseconds

Table 78: Running time packet

13.9.31 Local Magnetic Field Packet

Local Magnetic Field Packet				
Packet ID				50
Length				12
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Local magnetic field X (mG)
2	4	fp32	4	Local magnetic field Y (mG)
3	8	fp32	4	Local magnetic field Z (mG)

Table 79: Local magnetic field packet

13.9.32 Odometer State Packet

Odometer State Packet				
Packet ID				51
Length				20
Field #	Bytes Offset	Data Type	Size	Description
1	0	s32	4	Odometer pulse count
2	4	fp32	4	Odometer distance (m)
3	8	fp32	4	Odometer speed (m/s)
4	12	fp32	4	Odometer slip (m)
5	16	u8	1	Odometer active
6	17		3	Reserved

Table 80: Odometer state packet

13.9.33 External Time Packet

External Time Packet				
Packet ID				52
Length				8
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Unix time seconds, see section 13.9.1.4
2	4	u32	4	Microseconds, see section 13.9.1.5

Table 81: External time packet

13.9.34 External Depth Packet

External Depth Packet				
Packet ID				53
Length				8
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Depth (m)
2	4	u32	4	Depth standard deviation (m)

Table 82: External depth packet

13.9.35 Geoid Height Packet

This packet provides the offset at the current location between the WGS84 ellipsoid and the EGM96 geoid model. This can be used to determine the current height above mean sea level and also depth through the following equations:

Height Above Mean Sea Level = WGS84 Height – Geoid Height

Depth = Geoid Height – WGS84 Height

WGS84 Height is the height at the current location in the System State packet.

Geoid Height Packet				
Packet ID				54
Length				4
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Geoid height (m)

Table 83: Geoid height packet

13.9.36 RTCM Corrections Packet

This packet is used to encapsulate RTCM v2, RTCM v3 or CMR correction data to be sent to Spatial Dual's internal GNSS receiver for differential or RTK GNSS functionality.

RTCM Corrections Packet				
Packet ID				55
Length				Variable, up to 255 bytes
Field #	Bytes Offset	Data Type	Size	Description
1	0			RTCM corrections data

Table 84: RTCM corrections packet

13.9.37 External Pitot Pressure Packet

This packet is no longer supported. The External Air Data packet # 69 should be used see section 13.9.44 .

13.9.38 Wind Packet

This packet provides Spatial Dual's current 2D wind velocity. These values are only valid when external air data is provided to Spatial Dual. This can be either through the External Pitot Pressure Packet, the External Air Data Packet or when a pitot tube is interfaced to one of the GPIO pins. When this packet is written to the device, it disables the wind estimation filter and the wind values provided are used statically.

Wind Packet				
Packet ID				57
Length				12
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Wind velocity north (m/s)
2	4	fp32	4	Wind velocity east (m/s)
3	8	fp32	4	Wind velocity standard deviation (m/s)

Table 85: Wind packet

13.9.39 Heave Packet

Heave Packet				
Packet ID				58
Length				16
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Heave point 1 (m)
2	4	fp32	4	Heave point 2 (m)
3	8	fp32	4	Heave point 3 (m)
4	12	fp32	4	Heave point 4 (m)

Table 86: Heave packet

13.9.40 Post Processing Packet

No longer supported. If you need an IMR file please contact Advanced Navigation support for required settings.

13.9.41 Raw Satellite Data Packet

Spatial Dual Manager will automatically convert this packet to RINEX 3.02 format.

Raw Satellite Data Packet				
Packet ID				60
Length				16 + Satellites * (6 + Frequencies * 26)
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Unix time (seconds)
2	4	u32	4	Nanoseconds
3	8	s32	4	Receiver clock offset (nanoseconds)
4	12	u8	1	Receiver number
5	13	u8	1	Packet number
6	14	u8	1	Total packets
7	15	u8	1	Number of satellites
For each satellite				
8	16	u8	1	Satellite system, see section 13.9.12.1
9	17	u8	1	PRN or satellite number
10	18	u8	1	Elevation (degrees)
11	19	u16	2	Azimuth (degrees)
12	21	u8	1	Number of frequencies
For each frequency of each satellite				
13	22	u8	1	Satellite frequency, see section 13.9.41.1
14	23	u8	1	Tracking status, see 13.9.41.2
15	24	fp64	8	Carrier phase (cycles)
16	32	fp64	8	Pseudo range (m)
17	40	fp32	4	Doppler frequency (Hz)
18	44	fp32	4	Signal to noise ratio (dB-Hz)

Table 87: Raw satellite data packet

13.9.41.1 Satellite Frequencies

Value	GPS	GLONASS	Galileo	BeiDou	SBAS	QZSS
0	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
1	L1 C/A	G1 C/A	E1 OS	B1	L1 C/A	L1 C/A
2	L1 C		E1 PRS			L1 C
3	L1 P	G1 P				L1 SAIF
4	L1 M					
5	L2 C	G2 C/A	E6 CS	B2		L2 C
6	L2 P	G2 P	E6 PRS			LEX
7	L2 M					
8	L5	G3	E5 a	B3	L5	L5
9			E5 b			
10			E5 a+b			

Table 88: Satellite frequencies

13.9.41.2 Tracking Status

Bit	Description
0	Carrier phase valid
1	Carrier phase cycle slip detected
2	Carrier phase half-cycle ambiguity
3	Pseudo range valid
4	Doppler valid
5	SNR valid
6-7	Reserved (set to zero)

Table 89: Tracking status

13.9.42 Raw Satellite Ephemeris Packet

Spatial Dual Manager will automatically convert this packet to RINEX 3.02 format.

Raw Satellite Ephemeris Packet				
Packet ID				61
Length				Varies
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Unix time seconds
3	4	u8	1	Satellite system, see section 13.9.12.1
4	5	u8	1	Satellite number (PRN)
For GPS Satellites (132 bytes)				
5	6	u32	4	Time of ephemeris (Toe) (s)
6	10	u16	2	Issue of Data Clock [IODC] (s)
7	12	u16	2	Issue of Data Ephemeris [IODE] (s)
8	14	fp32	4	Satellite Clock Bias [af0] (s)
9	18	fp32	4	Satellite Clock Drift [af1] (s/s)
10	22	fp32	4	Satellite Clock Drift Rate [af2] (s/s/s)
11	26	fp32	4	Crs (m)
12	30	fp32	4	Delta N (rad/s)
13	34	fp64	8	M0 (rad)
14	42	fp32	4	Cuc (rad)
15	46	fp64	8	Eccentricity [e]
16	54	fp32	4	Cus (rad)
17	58	fp64	8	√A (√m)
18	66	fp32	4	Cic (rad)
19	70	fp64	8	OMEGA0 (rad)
20	78	fp32	4	Cis (rad)
21	82	fp64	8	i0 (rad)
22	90	fp32	4	Crc (m)
23	94	fp64	8	Omega (rad)
24	102	fp64	8	Omega dot (rad/s)
25	110	fp64	8	IDOT (rad/s)
26	118	fp32	4	TGD (s)
27	122	u16	2	Ephemeris week number
28	124	u32	4	Transmission time (s)
29	128	u16	2	User range accuracy (m)
30	130	u16	2	GPS Flags,

For GLONASS satellites (94 bytes)				
5	6	fp32	4	Satellite clock bias (s)
6	10	fp32	4	Satellite frequency bias [gamma]
7	14	fp64	8	Satellite position X (m)
8	22	fp64	8	Satellite position Y (m)
9	30	fp64	8	Satellite position Z (m)
10	38	fp64	8	Satellite velocity X (m/s)
11	46	fp64	8	Satellite velocity Y (m/s)
12	54	fp64	8	Satellite velocity Z (m/s)
13	62	fp64	8	Satellite acceleration X (m/s/s)
14	70	fp64	8	Satellite acceleration Y (m/s/s)
15	78	fp64	8	Satellite acceleration Z (m/s/s)
16	86	u32	4	Message frame start time (s)
17	90	u8	1	Age of operational information [E] (days)
18	91	s8	1	Frequency slot number
19	92	u8	1	Satellite Health
20	93	u8	1	Reserved

Table 90: Raw satellite Ephemeris packet

13.9.42.1 GPS Flags

Bit	Description
0	Data flag for L2 P-code
1-2	Codes on L2 channel
3	Anti-spoof flag
4-9	Satellite health
10	Fit interval flag
11	URA bad
12-14	Satellite block type

Table 91: GPS Flags

13.9.43 External Odometer Packet

External Odometer Packet				
Packet ID				67
Length				13
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Estimated delay (s)
2	4	fp32	4	Speed (m/s)
3	8	fp32	4	Reserved (set to zero)
4	12	u8	1	Odometer flags, see section 13.9.43.1

Table 92: External odometer packet

13.9.43.1 Odometer flags

Bit	Description
0	Reversing detection supported
1-7	Reserved (set to zero)

Table 93: Odometer flags

13.9.44 External Air Data Packet

External Air Data Packet				
Packet ID				68
Length				25
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Barometric altitude delay (s)
2	4	fp32	4	Airspeed delay (s)
2	8	fp32	4	Barometric altitude (m)
3	12	fp32	4	Airspeed (m/s)
4	16	fp32	4	Barometric altitude standard deviation (m)
5	20	fp32	4	Airspeed standard deviation (m/s)
6	24	u8	1	Flags, see section 13.9.44.1

Table 94: External air data packet

13.9.44.1 External Air Data Flags

Bit	Description
0	Barometric altitude set and valid
1	Airspeed set and valid
2	Barometric altitude reference reset

Table 95: External air data flags

13.9.44.2 Notes

Barometric altitude does not need to be referenced to any co-ordinate frame or QNH. If the barometric altitude reference is changed during operation, the barometric altitude reference reset flag should be set for the next packet.

13.9.45 GNSS Receiver Information Packet

GNSS Receiver Information Packet				
Packet ID				69
Length				48
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	GNSS manufacturer ID, see section 13.9.45.1
2	1	u8	1	GNSS receiver model, see section 13.9.45.2
3	2	s8[10]	10	GNSS serial number in ASCII character string
4	12	u32	4	Firmware version
5	16	u32[3]	12	Software license code
6	28	u32	4	Omnistar serial number
7	32	u32	4	Omnistar subscription start unix time
8	36	u32	4	Omnistar subscription expiry unix time
9	40	u8	1	Omnistar engine mode, see section 13.9.45.3
10	41	u8	1	RTK software license accuracy, see section 13.9.45.4
11	42		6	Reserved (set to zero)

Table 96: GNSS receiver information packet

13.9.45.1 GNSS Manufacturer IDs

For Spatial Dual the GNSS Manufacturer ID will always be 1 (Trimble).

Value	Description
0	GNSS Manufacturer Unknown
1	Trimble

Table 97: GNSS manufacturer IDs

13.9.45.2 GNSS Receiver Models

For Spatial Dual the GNSS receiver model will always be 3 or 7 (Trimble BD982 or BD992).

Value	Description
0	GNSS Receiver Model Unknown
1	Trimble BD920
2	Trimble BD930
3	Trimble BD982
4	Trimble MB-One
5	Trimble MB-Two
6	Trimble BD940
7	Trimble BD992

Table 98: GNSS receiver models

13.9.45.3 Omnistar Engine Modes

Value	Description
0	Omnistar engine not active
1	HP
2	XP
3	G2
4	HP+G2
5	HP+XP

Table 99: Omnistar engine modes

13.9.45.4 RTK Software License Accuracy

Value	Description
0	RTK accuracy unknown
1	0.3m horizontal, 0.3m vertical
2	0.1m horizontal, 0.1m vertical
3	0.1m horizontal, 0.02m vertical
4	0.008m horizontal, 0.1m vertical

5	0.008m horizontal, 0.02m vertical

Table 100: RTK software license accuracies

13.9.46 Gimbal State Packet

Gimbal State Packet				
Packet ID				72
Length				8
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Current angle (rad)
2	4		4	Reserved (set to zero)

Table 101: Gimbal state packet

13.9.47 Automotive Packet

Automotive Packet				
Packet ID				73
Length				24
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Virtual odometer distance (m)
2	4	fp32	4	Slip Angle (rad)
3	8	fp32	4	Velocity X (m/s)
4	12	fp32	4	Velocity Y (m/s)
5	16	fp32	4	Distance standard deviation (m)
6	20		4	Reserved (set to zero)

Table 102: Automotive packet

13.9.48 Base Station Packet

Base Station Packet				
Packet ID				80
Length				45
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Unix time stamp (seconds)
2	4	u32	4	Microseconds
3	8	fp64	8	Latitude (rad)

4	16	fp64	8	Longitude (rad)
5	24	fp64	8	Height (m)
6	32	fp32	4	Vector to Base North (m)
7	36	fp32	4	Vector to Base East (m)
8	40	fp32	4	Vector to Base Down (m)
9	44	u8	1	Status flags, see section 13.9.48.1

Table 103: Base station packet

13.9.48.1 Base Station Status Flags

Bit	Description
0	Base GNSS Fix Status, see section 13.9.1.3
1	
2	
3	Rover GNSS Fix Status, see section 13.9.1.3
4	
5	

Table 104: Base station status flags

13.9.49 Zero Angular Velocity Packet

Zero Angular Velocity Packet				
Packet ID				83
Length				8
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Duration, see section 13.9.49.1
2	4		4	Reserved (set to zero)

Table 105: Zero angular velocity packet

13.9.49.1 Duration

Duration is the duration that the unit has been stationary for about the heading axis. The minimum value is 0.1 seconds and the maximum value is 2 seconds.

13.9.50 Sensor Temperatures Packet

Sensor Temperatures Packet	
Packet ID	85
Length	32

Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Accelerometer X temperature (C)
2	4	fp32	4	Accelerometer Y temperature (C)
3	8	fp32	4	Accelerometer Z temperature (C)
4	12	fp32	4	Gyroscope X temperature (C)
5	16	fp32	4	Gyroscope Y temperature (C)
6	20	fp32	4	Gyroscope Z temperature (C)
7	24	fp32	4	Magnetometers temperature (C)
8	28	fp32	4	Pressure temperature (C)

Table 106: Sensor temperatures packet

13.10 Configuration Packets

Configuration packets can be both read from and written to the device. On many of the configuration packets the first byte is a permanent flag. A zero in this field indicates that the settings will be lost on reset, a one indicates that they will be permanent (i.e. stored in flash).

13.10.1 Packet Timer Period Packet

Packet Timer Period Packet				
Packet ID				180
Length				4
Field #	**Bytes Offset**	**Data Type**	**Size**	**Description**
1	0	u8	1	Permanent
2	1	u8	1	UTC synchronisation, see section 13.10.1.1
3	2	u16	2	Packet timer period, see section 13.10.1.2

Table 107: Packet timer period packet

13.10.1.1 UTC Synchronisation

This is a boolean value that determines whether or not the packet timer is synchronised with UTC time, with zero for disabled and one for enabled. For UTC Synchronisation to be enabled the packet timer period must multiply into 1000000 evenly. For example if the packet timer period is 10000 (10 ms), 1000000/10000 = 100 which is valid for UTC synchronisation. If the packet timer period is 15000 (15 ms), 1000000/15000 = 66.6666 which is not valid for UTC synchronisation. To get the rate use the following.

Packet Timer Rate = 1000000/(Packet Timer Period) Hz

13.10.1.2 Packet Timer Period

This is a value in microseconds that sets the master packet timer period. The minimum value is 1000 (1 ms) or 1000 Hz and the maximum value is 65535 (65.535 ms) or 15.30 Hz.

13.10.2 Packets Period Packet

Packets Period Packet				
Packet ID				181
Length				2 + (5 x number of packet periods)
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u8	1	Clear existing packet periods, see section 13.10.2.1
3	2	u8	1	Packet ID
4	3	u32	4	Packet period, see section 13.10.2.2
+				Fields 3-4 repeat for additional packet periods

Table 108: Packets period packet

13.10.2.1 Clear Existing Packets

This is a boolean field, when set to one it deletes any existing packet rates. When set to zero existing packet rates remain. Only one packet rate can exist per packet ID, so new packet rates will overwrite existing packet rates for the same packet ID.

13.10.2.2 Packet Period

This indicates the period in units of the packet timer period. The packet rate can be calculated as follows.

Packet Rate = 1000000/(Packet Period x Packet Timer Period) Hz

For example if the packet timer period is set to 1000 (1 ms). Setting packet ID 20 with a packet period of 50 will give the following.

Packet 20 Rate = 1000000/(50 x 1000)

Packet 20 Rate = 20 Hz

13.10.3 Baud Rates Packet

Baud Rates Packet				
Packet ID				182
Length				17
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u32	4	Primary RS232 and RS422 baud rate (2400 to 2000000)
3	5	u32	4	GPIO 1 & 2 baud rate (2400 to 250000)
4	9	u32	4	Auxiliary RS232 Baud Rate (2400 to 2000000)
5	13		4	Reserved (set to zero)

Table 109: Baud rates packet

13.10.4 Sensor Ranges Packet

Sensor Ranges Packet				
Packet ID				184
Length				4
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u8	1	Accelerometers range, see section 13.10.4.1
3	2	u8	1	Gyroscopes range, see section 13.10.4.2
4	3	u8	1	Magnetometers range, see section 13.10.4.3

Table 110: Sensor ranges packet

13.10.4.1 Accelerometers Range

Value	Description
0	2 g (19.62 m/s/s)
1	4 g (39.24 m/s/s)
2	16 g (156.96 m/s/s)

Table 111: Accelerometers range

13.10.4.2 Gyroscopes Range

Value	Description
0	250 degrees/second
1	500 degrees/second

2	2000 degrees/second

Table 112: Gyroscopes range

13.10.4.3 Magnetometers Range

Value	Description
0	2 Gauss
1	4 Gauss
2	8 Gauss

Table 113: Magnetometers range

13.10.5 Installation Alignment Packet

Installation Alignment Packet				
Packet ID				185
Length				73
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	fp32	4	Alignment DCM[0][0]
3	5	fp32	4	Alignment DCM[0][1]
4	9	fp32	4	Alignment DCM[0][2]
5	13	fp32	4	Alignment DCM[1][0]
6	17	fp32	4	Alignment DCM[1][1]
7	21	fp32	4	Alignment DCM[1][2]
8	25	fp32	4	Alignment DCM[2][0]
9	29	fp32	4	Alignment DCM[2][1]
10	33	fp32	4	Alignment DCM[2][2]
11	37	fp32	4	GNSS antenna offset X (m)
12	41	fp32	4	GNSS antenna offset Y (m)
13	45	fp32	4	GNSS antenna offset Z (m)
14	49	fp32	4	Odometer offset X (m)
15	53	fp32	4	Odometer offset Y (m)
16	57	fp32	4	Odometer offset Z (m)
17	61	fp32	4	External data offset X (m)
18	65	fp32	4	External data offset Y (m)
19	69	fp32	4	External data offset Z (m)

Table 114: Installation alignment packet

13.10.5.1 Alignment DCM

The alignment DCM (direction cosine matrix) is used to represent an alignment offset of Spatial Dual from it's standard alignment. A DCM is used rather than euler angles for accuracy reasons. To convert euler angles to DCM please use the formula below with angles in radians.

DCM[0][0] = cos(heading) * cos(pitch)

DCM[0][1] = sin(heading) * cos(pitch)

DCM[0][2] = -sin(pitch)

DCM[1][0] = -sin(heading) * cos(roll) + cos(heading) * sin(pitch) * sin(roll)

DCM[1][1] = cos(heading) * cos(roll) + sin(heading) * sin(pitch) * sin(roll)

DCM[1][2] = cos(pitch) * sin(roll)

DCM[2][0] = sin(heading) * sin(roll) + cos(heading) * sin(pitch) * cos(roll)

DCM[2][1] = -cos(heading) * sin(roll) + sin(heading) * sin(pitch) * cos(roll)

DCM[2][2] = cos(pitch) * cos(roll)

13.10.6 Filter Options Packet

Filter Options Packet				
Packet ID				186
Length				17
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u8	1	Vehicle type, see section 13.10.6.1
3	2	u8	1	Internal GNSS enabled (boolean)
4	3	u8	1	Reserved (set to zero)
5	4	u8	1	Atmospheric altitude enabled (boolean)
6	5	u8	1	Velocity heading enabled (boolean)
7	6	u8	1	Reversing detection enabled (boolean)
8	7	u8	1	Motion analysis enabled (boolean)
9	8		9	Reserved (set to zero)

Table 115: Filter options packet

13.10.6.1 Vehicle Types

Value	Description
0	Unconstrained
1	Bicycle or Motorcycle
2	Car
3	Hovercraft
4	Submarine
5	3D Underwater Vehicle
6	Fixed Wing Plane
7	3D Aircraft
8	Human
9	Boat
10	Large Ship

11	Stationary
12	Stunt Plane
13	Race Car

Table 116: Vehicle types

13.10.7 Advanced Filter Parameters Packet

Please contact Advanced Navigation support.

13.10.8 GPIO Configuration Packet

GPIO Configuration Packet				
Packet ID				188
Length				13
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u8	1	GPIO1 function, see section 13.10.8.1
3	2	u8	1	GPIO2 function, see section 13.10.8.2
4	3	u8	1	Auxiliary RS232 transmit function, see section 13.10.8.3
5	4	u8	1	Auxiliary RS232 receive function, see section 13.10.8.4
6	5		8	Reserved (set to zero)

Table 117: GPIO configuration packet

13.10.8.1 GPIO1 Functions

Value	Description
0	Inactive
1	1PPS Output
2	GNSS Fix Output
3	Odometer Input
4	Zero Velocity Input
5	Pitot Tube Input
7	NMEA Output
12	ANPP Output
14	Disable GNSS
15	Disable Pressure
16	Set Zero Orientation Alignment

17	System State Packet Trigger
18	Raw Sensors Packet Trigger
26	Pressure Depth Transducer
27	Left Wheel Speed Sensor
28	Right Wheel Speed Sensor
29	1PPS Input
30	Wheel Speed Sensor
31	Wheel Encoder Phase A
32	Wheel Encoder Phase B
33	Event 1 Input
34	Event 2 Input
38	GNSS Receiver Passthrough
39	TSS1 Output
40	Simrad 1000 Output
41	Simrad 3000 Output
42	Serial Port Passthrough
43	Gimbal Encoder Phase A
44	Gimbal Encoder Phase B
45	Odometer Direction, Forward Low
46	Odometer Direction, Forward High
52	Moving Base Corrections Output
53	Reverse Alignment, Forward Low
54	Reverse Alignment, Forward High
55	Zero Angular Velocity Input
56	Mavlink Output

Table 118: GPIO1 functions

13.10.8.2 GPIO2 Functions

Value	Description
0	Inactive
1	1PPS Output
2	GNSS Fix Output
3	Odometer Input
4	Zero Velocity Input
5	Pitot Tube Input

6	NMEA Input
8	Novatel GNSS Input
9	Topcon GNSS Input
11	Error: Reference source not found
14	Disable GNSS
15	Disable Pressure
16	Set Zero Orientation Alignment
17	System State Packet Trigger
18	Raw Sensors Packet Trigger
19	RTCM Differential GNSS Corrections Input
20	Trimble GNSS Input
21	u-blox GNSS Input
22	Hemisphere GNSS Input
23	Teledyne DVL Input
24	Tritech USBL Input
25	Linkquest DVL Input
26	Pressure Depth Transducer
27	Left Wheel Speed Sensor
28	Right Wheel Speed Sensor
29	1PPS Input
30	Wheel Speed Sensor
31	Wheel Encoder Phase A
32	Wheel Encoder Phase B
33	Event 1 Input
34	Event 2 Input
35	Linkquest USBL Input
38	GNSS Receiver Passthrough
42	Serial Port Passthrough
43	Gimbal Encoder Phase A
44	Gimbal Encoder Phase B
45	Odometer Direction, Forward Low
46	Odometer Direction, Forward High
51	Nortek DVL Input
53	Reverse Alignment, Forward Low
54	Reverse Alignment, Forward High

55	Zero Angular Velocity Input

Table 119: GPIO2 functions

13.10.8.3 Auxiliary RS232 Transmit Functions

Value	Description
0	Inactive
1	1PPS Output
2	GNSS Fix Output
7	NMEA Output
12	ANPP Output
38	GNSS Receiver Passthrough
39	TSS1 Output
40	Simrad 1000 Output
41	Simrad 3000 Output
42	Serial Port Passthrough
52	Moving Base Corrections Output
56	Mavlink Output

Table 120: Auxiliary RS232 transmit functions

13.10.8.4 Auxiliary RS232 Receive Functions

Value	Description
0	Inactive
3	Odometer Input
4	Zero Velocity Input
5	Pitot Tube Input
6	NMEA Input
8	Novatel GNSS Input
9	Topcon GNSS Input
11	Error: Reference source not found
14	Disable GNSS
15	Disable Pressure
16	Set Zero Orientation Alignment
17	System State Packet Trigger
18	Raw Sensors Packet Trigger
19	RTCM Differential GNSS Corrections Input

20	Trimble GNSS Input
21	u-blox GNSS Input
22	Hemisphere GNSS Input
23	Teledyne DVL Input
24	Tritech USBL Input
25	Linkquest DVL Input
26	Pressure Depth Transducer
27	Left Wheel Speed Sensor
28	Right Wheel Speed Sensor
29	1PPS Input
30	Wheel Speed Sensor
33	Event 1 Input
34	Event 2 Input
35	Linkquest USBL Input
38	GNSS Receiver Passthrough
42	Serial Port Passthrough
45	Odometer Direction, Forward Low
46	Odometer Direction, Forward High
51	Nortek DVL Input
53	Reverse Alignment, Forward Low
54	Reverse Alignment, Forward High
55	Zero Angular Velocity Input

Table 121: Auxiliary RS232 receive functions

13.10.9 Odometer Configuration Packet

Odometer Configuration Packet				
Packet ID				192
Length				8
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u8	1	Automatic pulse measurement active
3	2		2	Reserved (set to zero)
4	4	fp32	4	Pulse length (m)

Table 122: Odometer configuration packet

13.10.10 Set Zero Orientation Alignment Packet

This packet was modified as of firmware version 2.1 for code safety certification. Previously it was 1 byte long with no verification sequence.

Set Zero Orientation Alignment Packet				
Packet ID				193
Length				5
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u32	4	Verification sequence (set to 0x9A4E8055)

Table 123: Set zero orientation alignment packet

13.10.11 Reference Point Offsets Packet

The reference point offsets packet can be used to adjust the measurement point that all data is referenced to. By default all the values of this packet are zero and the measurement point that all data is referenced to is the centre of the Spatial Dual unit. The primary reference point offset can be used to adjust the measurement point to a different location on the vehicle. The primary reference point offset applies to all data output including NMEA etc as well as heave point 1. The other heave point offsets apply only to heave points 2-4 in the Heave Packet.

Reference Point Offsets Packet				
Packet ID				194
Length				49
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	fp32	4	Primary reference point offset X (m)
3	5	fp32	4	Primary reference point offset Y (m)
4	9	fp32	4	Primary reference point offset Z (m)
5	13	fp32	4	Heave point 2 offset X (m)
6	17	fp32	4	Heave point 2 offset Y (m)
7	21	fp32	4	Heave point 2 offset Z (m)
8	25	fp32	4	Heave point 3 offset X (m)
9	29	fp32	4	Heave point 3 offset Y (m)
10	33	fp32	4	Heave point 3 offset Z (m)
11	37	fp32	4	Heave point 4 offset X (m)
12	41	fp32	4	Heave point 4 offset Y (m)
13	45	fp32	4	Heave point 4 offset Z (m)

Table 124: Reference point offsets packet

13.10.12 GPIO Output Configuration Packet

GPIO Output Configuration Packet				
Packet ID				195
Length				33
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u8	1	NMEA fix behaviour, see section 13.10.12.1
3	2	u16	2	GPZDA Rates, see section 13.10.12.2
4	4	u16	2	GPGGA Rates, see section 13.10.12.2
5	6	u16	2	GPVTG Rates, see section 13.10.12.2
6	8	u16	2	GPRMC Rates, see section 13.10.12.2
7	10	u16	2	GPHDT Rates, see section 13.10.12.2
8	12	u16	2	GPGLL Rates, see section 13.10.12.2
9	14	u16	2	PASHR Rates, see section 13.10.12.2
10	16	u16	2	TSS1 Rates, see section 13.10.12.2
11	18	u16	2	Simrad Rates, see section 13.10.12.2
12	20	u16	2	GPROT Rates, see section 13.10.12.2
13	22	u16	2	GPHEV Rates, see section 13.10.12.2
14	24	u16	2	GPGSV Rates, see section 13.10.12.2
15	26	u16	2	PFECAtt Rates, see section 13.10.12.2
16	28	u16	2	PFECHve Rates, see section 13.10.12.2
17	30	u16	2	GPGST Rates, see section 13.10.12.2
18	32		1	Reserved (set to zero)

Table 125: GPIO output configuration packet

13.10.12.1 NMEA Fix Behaviour

Value	Description
0	Normal
1	Always indicate 3D fix when the navigation filter is initialised

Table 126: NMEA fix behaviour

13.10.12.2 GPIO Output Rates

Bit	Description
0-3	GPIO 1 rate, see 13.10.12.3
4-7	Auxiliary RS232 Tx rate, see 13.10.12.3
8-15	Reserved (set to zero)

Table 127: GPIO output rates

13.10.12.3 GPIO Output Rates Index

Value	Bit 3	Bit 2	Bit 1	Bit 0	Description
0	0	0	0	0	Disabled
1	0	0	0	1	0.1 Hz
2	0	0	1	0	0.2 Hz
3	0	0	1	1	0.5 Hz
4	0	1	0	0	1 Hz
5	0	1	0	1	2 Hz
6	0	1	1	0	5 Hz
7	0	1	1	1	10 Hz
8	1	0	0	0	25 Hz
9	1	0	0	1	50 Hz

Table 128: GPIO output rates index

13.10.13 Dual Antenna Configuration Packet

By default the system uses automatic offset with primary front and secondary rear. If entering a manual offset, the automatic offset orientation type is ignored and can be set to zero. Likewise when using an automatic offset, the manual offset values are ignored and can be set to zero. When operating with an automatic offset the manual offset values will be populated with the automatically calculated offset values.

Dual Antenna Configuration Packet				
Packet ID				196
Length				17
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u16	2	Offset type, see section 13.10.13.1
3	3	u8	1	Automatic offset orientation, see section 13.10.13.2
4	4	u8	1	Reserved (set to zero)
5	5	fp32	4	Manual offset X (m)
6	9	fp32	4	Manual offset Y (m)
7	13	fp32	4	Manual offset Z (m)

Table 129: Dual antenna configuration packet

13.10.13.1 Offset Types

Value	Description
0	Manual offset
1	Automatic offset

Table 130: Offset types

13.10.13.2 Automatic Offset Orientations

Value	Description
0	Primary front and secondary rear
1	Primary rear and secondary front
2	Primary right and secondary left
3	Primary left and secondary right

Table 131: Automatic offset orientations

13.10.14 GNSS Configuration Packet

GNSS Configuration Packet				
Packet ID				197
Length				85
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u64	8	GNSS frequencies. This is a bitfield where each bit describes whether a particular frequency is enabled. For a list of the fields that are currently available, section 13.10.14.1
3	9	fp32	4	PDOP threshold - the Position Dilution of Precision to achieve a fix
4	13	fp32	4	TDOP threshold - The Time dilution of Precision to achieve a fix
5	17	u8	1	Elevation mask (degrees) - Minimum elevation of the satellite that will be used when calculating fix
6	18	u8	1	SNR Mask (dB) - Signal-to-noise (SNR) ratio of a satellite signal to allow it to be used when calculating a fix
7	19	u8	1	SBAS corrections enabled
8	20	u8	1	L band modes, section 13.10.14.2
9	21	u32	4	L band frequency (Hz)
10	25	u32	4	L band baud rate
11	29	u32	4	Primary antenna type
12	33	u32	4	Secondary Antenna type
13	37	u8	1	Band Satellite IDs – this refers to the satellite name, section 13.10.14.3
14	38	u8	47	Reserved

Table 132: GNSS configuration packet

13.10.14.1 GNSS Frequency Bitfields

Each GNSS frequency is a field that contains 8 bits that indicate whether a particular frequency is enabled for a constellation. These are boolean fields with a zero indicating false and a one indicating true. The table below provides a description of each bit, which is a combination of a constellation name and its frequency.

Bit	Description
0	GPS L1CA
1	GPS L1C
2	GPS L1P
3	GPS L2C
4	GPS L2P
5	GPS L2M
6	GPS L5
7	GLONASS G1CA
8	GLONASS G1P
9	GLONASS L1OC
10	GLONASS L1SC
11	GLONASS G2CA
12	GLONASS G2P
13	GLONASS L2OC
14	GLONASS L2SC
15	GLONASS L3OC
16	GLONASS L3SC
17	BEIDOU B1
18	BEIDOU B2
19	BEIDOU B3
20	GALILEO E1
20	GALILEO E5A
22	GALILEO E5B
23	GALILEO E5AB
24	GALILEO E6
25	QZSS L1CA
25	QZSS L1SAIF
26	QZSS L1C
27	QZSS L2C
28	QZSS L5
29	QZSS LEX
30	SBAS L1CA

Table 133: GNSS configuration packet

13.10.14.2 L Band Modes

L Band Mode	L Band Mode Name
0	Disabled
2	Omnistar Auto
3	Omnistar HP
4	Omnistar XP
5	Omnistar VBS
8	Omnistar G2
9	Omnistar HP+G2
10	Omnistar HP+XP
11	Trimble RTX
13	Omnistar L1 On
14	Omnistar G4 Only
15	Omnistar G2+ Only
16	Omnistar G4+ Only

Table 134: L Band Modes

13.10.14.3 L Band Satellite IDs

L Band Satellite ID	Satellite Name
110	Auto
20	RTXIO
21	RTXAE
22	RTXEN
23	RTXNA
27	RTXWN
28	RTXAP
30	RTXSA
31	RTXCN
3	IOR
5	POR
8	AORET
9	ESAT
10	AORE
11	AORW
12	ASAT
14	AUSAT
24	MSVCN
25	MSVEN
26	MSVWN

Table 135: L Band Satellite IDs

13.10.15 User Data Packet

This packet is for storage of users data. The data itself is not used by Spatial Dual.

User Data Packet				
Packet ID				198
Length				64
Field #	Bytes Offset	Data Type	Size	Description
1	0		64	User Data

Table 136: User data packet

13.10.16 GPIO Input Configuration Packet

GPIO Input Configuration Packet				
Packet ID				199
Length				65
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	fp32	4	Gimbal radians per encoder tick
3	2		60	Reserved (set to zero)

Table 137: GPIO input configuration packet

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