



Spatial Reference Manual



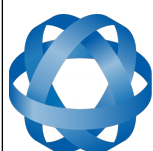


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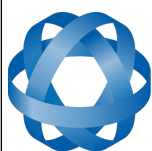
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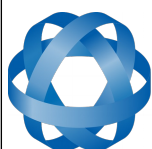


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1 Revision History

Version	Date	Changes
4.1	24/05/2015	Updated firmware changelog, section 2 Updated hardware changelog, section 3 Updated axes image, section 4.5 Added part numbers and ordering information, section 7 Updated optional breakout cable, section 8.11 Updated power consumption graph, section 8.8 Updated 2D magnetic calibration procedure, section 10.6.1 Updated automatic magnetic calibration, section 10.6.3 Added differential GNSS, section 10.13 Updated Spatial Manager changelog, section 11.1 Added gimbal encoder phase a function, section 12.4.34 Added gimbal encoder phase b function, section 12.4.35 Added odometer direction, forward low, section 12.4.36 Added odometer direction, forward high, section 12.4.37 Updated reset packet, section 13.8.6 Updated UTM position packet, section 13.9.15 Added gimbal state packet, section 13.9.42 Added automotive packet, section 13.9.43 Heave offsets packet changed name to reference point offsets packet, format remains the same, section 13.10.14 Added user data packet, section 13.10.16 Added GPIO input configuration packet, section 13.10.17 Fixed a document heading spacing issue
4.0	18/09/2014	Added firmware changelog, section 2 Added hardware changelog, section 3 Updated GNSS specifications for version 3.0 hardware, section 8.4 Updated connector pin-out to include pink wire, section 8.9 Added evaluation kit USB cable, section 8.10 Added optional breakout cable, section 8.11 Added serial number information, section 8.13 Updated GNSS antenna, section 9.5 Updated OBDII Odometer, section 9.6.2 Updated initialisation with more information, section 10.2 Updated hot start for clarity, section 10.3 Updated 2D magnetic calibration procedure for clarity, section 10.6.2.1 Updated 3D magnetic calibration procedure for clarity, section 10.6.2.1 Updated all screenshots in Spatial Manager, section 11 Updated Spatial Manager changelog, section 11.1 Updated Spatial Manager Linux troubleshooting, section 11.4.3 Added Spatial Manager 3D model, section 11.7.8 Added Spatial Manager communications statistics, section



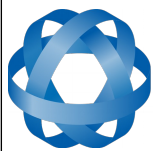
Version	Date	Changes
		<p>Added Spatial Manager GPIO output configuration, section 11.8.11</p> <p>Added Spatial Manager position configuration, section 11.8.12</p> <p>Added serial port pass-through GPIO function, section 12.4.33</p> <p>Added packet timing, section 13.6</p> <p>Added serial port pass-through packet, section 13.8.7</p> <p>Changed raw GNSS packet, section 13.9.10</p> <p>Changed wind estimation packet to wind packet and changed from read only to read/write, section 13.9.38</p> <p>Added external odometer packet, section 13.9.40</p> <p>Added external air data packet, section 13.9.41</p> <p>Added stunt plane vehicle profile, section 13.10.6.1</p> <p>Updated set zero orientation packet, section 13.10.13</p> <p>NMEA output configuration packet changed to GPIO output configuration packet, section 13.10.15</p> <p>Total page numbering in header fixed</p>
3.0	24/09/2013	<p>Manual updated for Spatial v3.0 hardware</p> <p>Updated photo for Spatial v3.0 hardware</p> <p>Added evaluation kit, section 6</p> <p>Updated mechanical drawings, section 8.1</p> <p>Updated navigation specifications, section 8.2</p> <p>Updated sensor specifications, section 8.3</p> <p>Updated communication specifications, section 8.5</p> <p>Updated hardware specifications, section 8.6</p> <p>Updated electrical specifications, section 8.7</p> <p>Updated connector pin-out, section 8.9</p> <p>Updated mounting plate, section 9.3</p> <p>Updated odometer information, section 9.6</p> <p>Added reversing detection, section 10.11</p> <p>Added motion analysis, section 10.12</p> <p>Updated 3D magnetic calibration procedure, section 10.6.2</p> <p>Added automatic magnetic calibration, section 10.6.3</p> <p>Integrated Spatial Manager manual, section 11</p> <p>Added Auxiliary RS232 information, section 12.3</p> <p>Updated NMEA input, section 12.4.6</p> <p>Updated NMEA output, section 12.4.7</p> <p>Added wheel speed sensor function, section 12.4.25</p> <p>Added wheel encoder phase A function, section 12.4.26</p> <p>Added wheel encoder phase B function, section 12.4.27</p> <p>Added event 1 input, section 12.4.28</p> <p>Added event 2 input, section 12.4.29</p> <p>Added TSS1 output, section 12.4.30</p> <p>Added Simrad 1000 output, section 12.4.31</p> <p>Added Simrad 3000 output, section 12.4.32</p>



Version	Date	Changes
		Updated filter status, section 13.9.1.2 Added GNSS fix status, section 13.9.1.3 Updated baud rates packet, section 13.10.3 Updated filter options packet, section 13.10.6 Updated GPIO configuration packet, section 13.10.8 Added NMEA output configuration packet, section 13.10.15
2.7	27/03/2013	Added additional magnetic information, section 10.6 Added 1PPS input, section 12.4.24 Updated detailed satellites packet, section 13.9.12 Corrected geoid height packet, section 13.9.35
2.6	29/01/2013	Added heave information, section 10.16 Added RTCM corrections packet, section 13.9.36 Added external pitot pressure packet, section 13.9.37 Added wind estimation packet, section 13.9.38 Added heave packet, section 13.9.39 Added heave configuration packet, section 13.10.14
2.5	07/12/2012	Added input voltage range to electrical specifications, section 8.7 Added left wheel speed sensor input, section 12.4.22 Added right wheel speed sensor input, section 12.4.23 Added external time packet, section 13.9.33 Added external depth packet, section 13.9.34 Added geoid height packet, section 13.9.35 Updated GPIO functions tables, section 13.10.8
2.3	06/12/2012	Yaw terminology changed to heading for increased clarity Reworded installation magnetics for increased clarity, section 9.7 Reworded initialisation for increased clarity, section 10.2 Reworded operation magnetics for increased clarity, section 10.6 Added vehicle profiles information, section 10.9 Updated NMEA output, section 12.4.7
2.2	19/11/2012	Installation magnetics changed, section 9.7 Heading source added, section 10.5 Disabling magnetometers changed, section 10.6.4 GPIO information updated, section 12.3 Added NMEA input GPGLL support, section 12.4.6 Added NMEA input GPHDT support, section 12.4.6 Added NMEA input HEHDT support, section 12.4.6 Updated NMEA output, section 12.4.7 Added RTCM corrections input, section 12.4.18 Added Trimble GNSS input, section 12.4.19 Added u-blox GNSS input, section 12.4.20 Added Hemisphere GNSS input, section 12.4.21 Updated GPIO functions tables, section 13.10.8

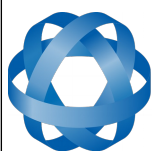


Version	Date	Changes
2.1	30/10/2012	Sensor specifications updated, section 8.3 Fixed error in odometer state packet, section 13.9.32
2.0	18/10/2012	Added information on sensor calibration, section 8.12 Added odometer installation information, section 9.6 Updated filter description to clarify instability, section 10.1 Added hot start information, section 10.3 Added time information, section 10.4 Added odometer pulse length information, section 10.10 Added RAIM information, section 10.15 Updated Odometer input, section 12.4.3 Updated NMEA output, section 12.4.7 Added disable magnetometers GPIO function, section 12.4.12 Added disable GNSS GPIO function, section 12.4.13 Added disable pressure GPIO function, section 12.4.14 Added set zero alignment GPIO function, section 12.4.15 Added system state packet trigger GPIO function, section 12.4.16 Added raw sensors packet trigger GPIO function, section 12.4.17 Updated acknowledge packet, section 13.8.1 Added running time packet, section 13.9.30 Added local magnetic field packet, section 13.9.31 Added odometer state packet, section 13.9.32 Updated installation alignment packet, section 13.10.5 Fixed error in filter options packet, section 13.10.6 Updated GPIO configuration packet, section 13.10.8 Added odometer configuration packet, section 13.10.12 Added set zero orientation alignment packet, section 13.10.13
1.0	16/09/2012	1PPS description updated, section 12.4.1 Corrected reset packet, section 13.8.6 Corrected external body velocity packet, section 13.9.28 Revised alignment packet, section 13.10.5 Grammar and spelling corrections
0.6	31/08/2012	Grammar corrections throughout Spelling corrections throughout Updated 3D magnetic calibration, section 10.6.2
0.5	28/08/2012	Corrected satellite indexes, section 13.9.12.1 Added navigation specifications, section 8.2 Added sensor specifications, section 8.3 Added GNSS specifications, section 8.4 Added communication specifications, section 8.5 Added hardware specifications, section 8.6
0.4	23/08/2012	Clarified anti aliasing, section 10.8 Added external data, section 12.2



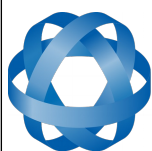
Version	Date	Changes
		Added GPIO information, section 12.3 Added GPIO configuration packet, section 13.10.8
0.3	11/08/2012	Magnetic calibration values packet corrected Incorrect length fixed on several packets Grammar corrections
0.2	08/08/2012	Connector pin allocation table corrected
0.1	31/07/2012	First Draft

Table 1: Revision history



2 Firmware Changelog

Version	Date	Changes
4.1	22/04/2015	Support for hardware version 5.0 added Enhanced odometer hot start dead reckoning performance Overhauled 2D magnetic calibration algorithm offers improved 2D magnetic calibration Overhauled automatic magnetic calibration algorithm now much more robust and enabled by default 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
4.0	18/09/2014	Added support for new hardware version 4.0 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 Raw GNSS packet updated to new format GPIO output configuration packet updated Support for external odometer added Support for external air data added Wind estimation filter improvements Wind packet input support Added stunt plane vehicle profile Added support for serial port passthrough GPIO data output now up to 50Hz
3.1	10/04/2014	Updated internal AN RTOS to v4.0 Added TSS1 output support Added Simrad 1000 output support Added Simrad 3000 output support

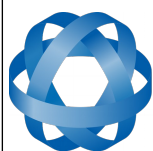


Version	Date	Changes
		Automatic magnetic calibration algorithm disabled due to variation in performance in some applications (new more reliable algorithm will be added in v4.1 as the default magnetic calibration)
3.0	17/09/2013	Added support for new hardware version 3.0 Enhanced odometer algorithms Automatic magnetic calibration algorithm added
2.5	03/05/2013	GNSS receiver firmware update – provides increased performance in high multi-path environments and faster time to first fix in poor satellite visibility
2.4	10/04/2013	Fix for a regression with the gravity model in v2.3 that can reduce accuracy under certain conditions with strong decelerations
2.3	27/03/2013	Added Spatial hardware revision 2.0 support Added experimental post-processing support Issue with RTCM GPIO corrections resolved Detailed satellites packet modified Added 1PPS input GPIO function
2.2	29/01/2013	Added stationary heading drift compensation algorithm to reduce heading drift when no heading correction source is present Added heave filter Added EGM96 geoid model Added dual odometer input support Added Linkquest DVL input support Added pressure depth transducer input support Added external time packet Added external depth packet Added geoid height packet Added RTCM corrections packet Added external pitot pressure packet Added wind estimation packet Added heave packet Added heave offset packet
2.1	11/12/2012	Better reversing detection for velocity heading when magnetometers are disabled Car vehicle profile enhancements 3D underwater vehicle profile enhancements NMEA output GPRMC updated to be v2.3 compliant NMEA output GPHDT added NMEA output changed to 10Hz NMEA input added GPGLL support NMEA input added GPHDT support NMEA input added HEHDT support Added RTCM corrections input support



Version	Date	Changes
		Added Trimble GNSS input support Added u-blox GNSS input support Added Hemisphere GNSS input support Added Teledyne DVL input support Added Tritech USBL input support
2.0	23/10/2012	Enhanced odometer reversing detection Odometer automatic calibration now has stricter conditions and will restart the calibration to prevent erroneous calibrations from succeeding Vibration analysis & suppression filter now enabled as default Enhanced performance in GNSS multipath conditions Lever arm GNSS antenna velocity removal enabled as default Bug fix where time does not get set when only GLONASS satellites are available Bug fix where changing of GPIO1 configuration to 1PPS function was not effective until a restart 3D magnetic calibration is now stricter to ensure that only good calibrations can succeed Hot start data is cleared during a factory restore Added running time packet Added local magnetic field packet Added odometer state packet Changed alignment packet Added odometer configuration packet Added set zero orientation alignment packet Additional acknowledge response types Added disable magnetometers GPIO function Added disable GNSS GPIO function Added disable pressure GPIO function Added set zero alignment GPIO function Added system state packet trigger GPIO function Added raw sensors packet trigger GPIO function Please Note: Some configuration will be reset to factory defaults when upgrading from v1.1 to v2.0 Please use Spatial Manager v2.0 and above with this firmware.
1.1	23/09/2012	INS performance enhancements Odometer enhancements 2D magnetic calibration bug fixed
1.0	06/08/2012	Initial Release

Table 2: Firmware changelog



3 Hardware Changelog

Version	Date	Changes
5.0	01/02/2015	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
4.0	10/08/2014	Internal GNSS receiver changed to the new ublox 8 which provides increased multipath performance
3.0	17/09/2013	New gyroscopes New accelerometers Connector changed to ODU GPIO 3 and GPIO 4 became Auxiliary RS232 Tx and Rx Dimensions increased
2.0	10/01/2013	Minor internal improvements No noticeable changes for customers
1.0	08/05/2013	Initial release

Table 3: Hardware changelog



4 Foundation Knowledge

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

4.1 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.

4.2 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.

4.3 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.

4.4 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.



4.5 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.

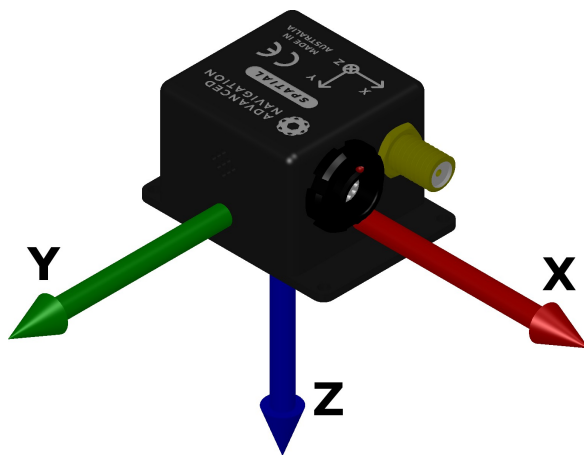


Illustration 1: Spatial axes

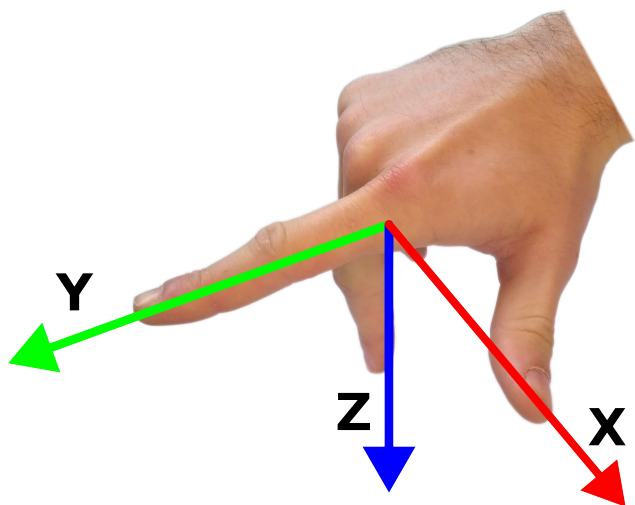


Illustration 2: First right hand rule

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.

4.6 Roll, Pitch and Heading

Orientation can be described by the three angles roll, pitch and heading, these are known as the Euler angles. They are best described visually through the Illustrations below.

4.6.1 Roll

Roll is the angle around the X axis. See Illustration 3 for the positive direction of roll and Illustration 4 for an example of a roll of 90 degrees.

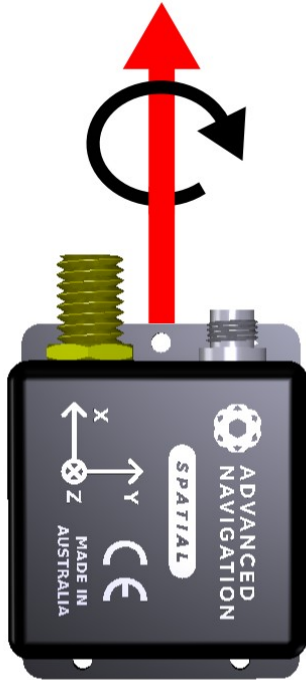


Illustration 3: Spatial with black arrow indicating positive direction of roll



Illustration 4: Spatial after a roll of 90 degrees

4.6.2 Pitch

Pitch is the angle around the Y axis. See Illustration 5 for the positive direction of pitch and Illustration 6 for an example of a pitch of 90 degrees.

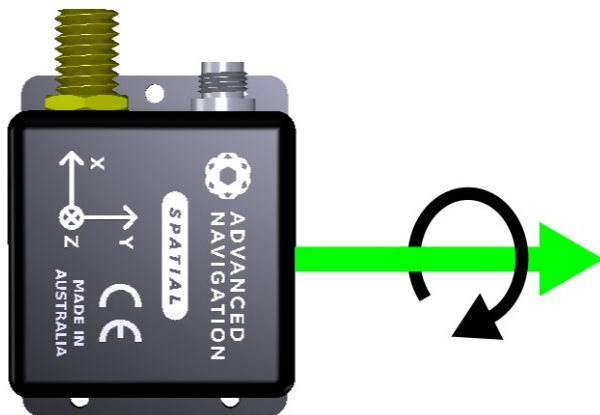


Illustration 5: Spatial with black arrow indicating positive direction of pitch

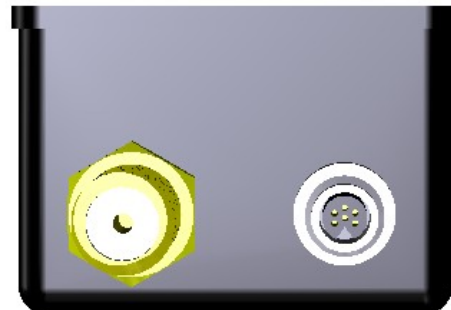


Illustration 6: Spatial after a pitch of 90 degrees



4.6.3 Heading

Heading is the angle around the Z axis. See Illustration 7 for the positive direction of heading and Illustration 8 for an example of a heading change of 90 degrees. 0 degrees heading is when the positive X axis points North and 180 degrees heading is when the positive X axis points South.



Illustration 7: Spatial with black arrow indicating positive direction of heading

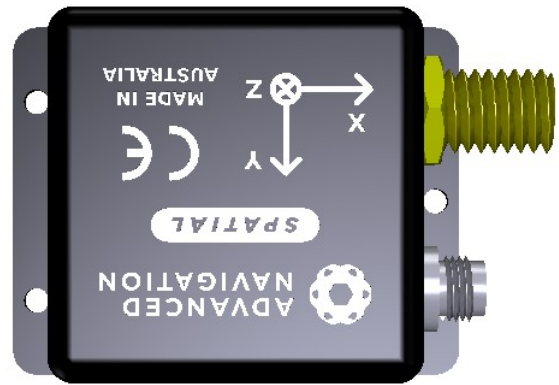


Illustration 8: Spatial after a heading change of 90 degrees

4.6.4 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 4.5. The second right hand rule shown in Illustration 9 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.

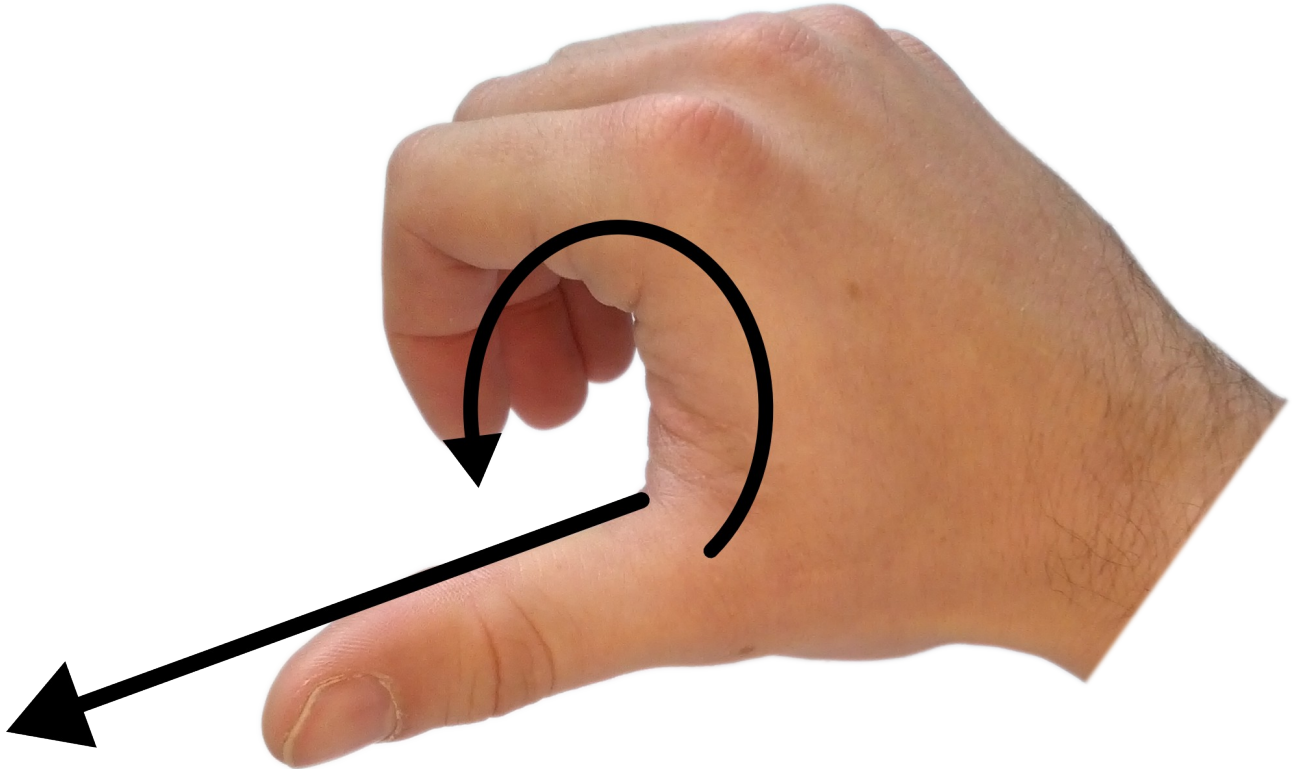


Illustration 9: Second right hand rule

4.6.5 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 with your hand whilst watching the orientation plot in real time on the computer.

4.7 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. Latitude is the angle that specifies the north to south position of a point on the Earth's surface. Longitude is the angle that specifies the east to west position of a point on the Earth's surface. The line of zero latitude is the equator and the line of zero longitude is the prime meridian. Illustration 10 shows how latitude and longitude angles are used to describe a position on the surface of the Earth.

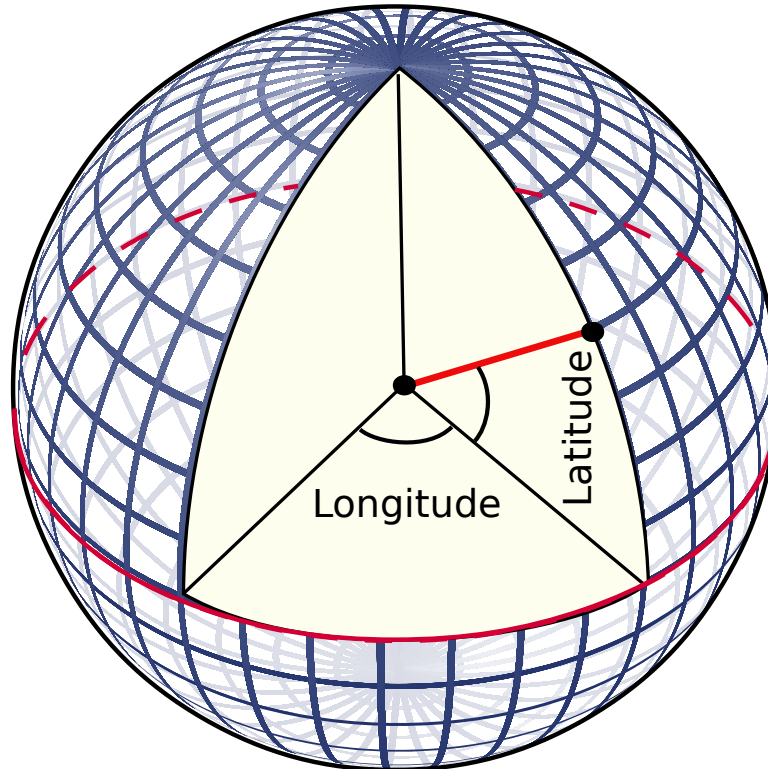


Illustration 10: Latitude and longitude represented visually to describe a position

Illustration 11 below shows latitude and longitude on a map of the world.

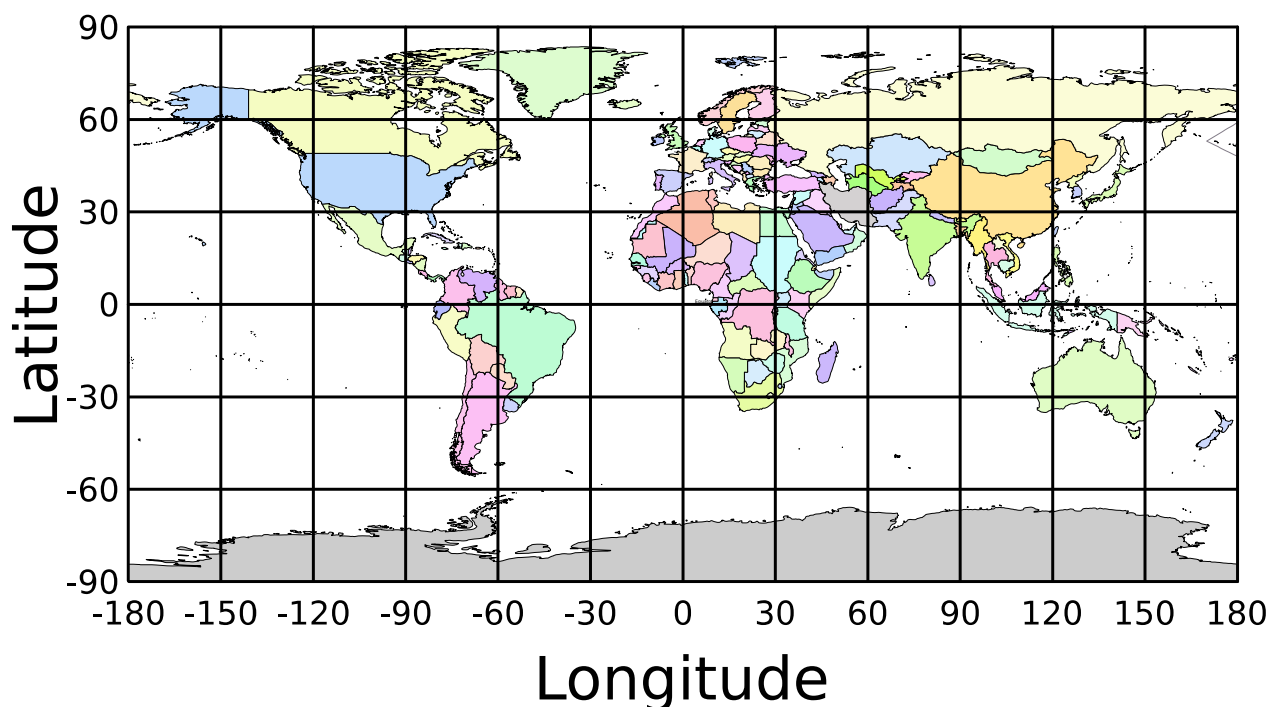
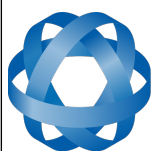


Illustration 11: World map showing latitudes and longitudes

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.

Height is the height above the WGS84 reference ellipsoid. The WGS84 reference ellipsoid is a model used to approximate sea level across the Earth. Therefore the height should be considered approximately relative to sea level. Due to the approximate nature of the WGS84 model, the WGS84 height will not be the same as the actual sea level. For example, in Australia, the WGS84 height at sea level is 9 metres at some points.

4.8 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 12 for a graphical representation of the NED co-ordinate frame at a position on the Earth.

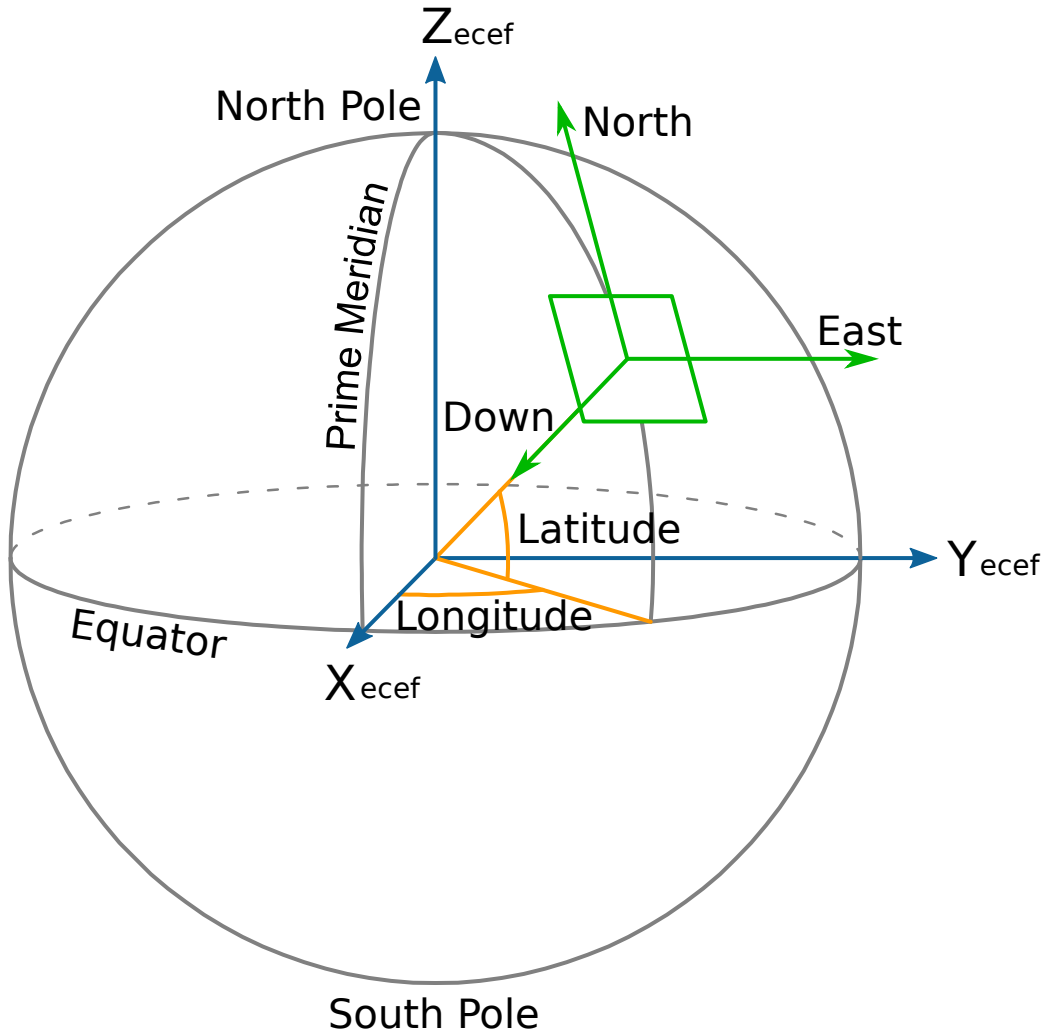


Illustration 12: Graphic showing geodetic, NED and ECEF co-ordinates

4.9 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 12. ECEF positions can be retrieved from Advanced Navigation products however the geodetic system is used as the default.



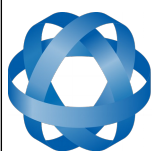
5 Introduction

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

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

The Spatial Manager software is downloadable from the software section of the Advanced Navigation website. It allows Spatial to be easily configured and operated. For more information on Spatial Manager please see section 11.

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



6 Evaluation Kit

Spatial 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 plastic carry case to protect the equipment during shipping.



Illustration 13: Spatial Evaluation Kit

6.1 Evaluation Kit Contents

1. Spatial GNSS/INS
2. Rugged IP67 GPS/GLONASS/GALILEO/BeiDou GNSS antenna
3. Spatial connector to USB interface cable, see section 8.10

6.2 Quick Start

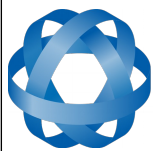
1. Position the GNSS antenna in a level orientation with a clear view of the sky.
2. Connect the coaxial antenna cable to Spatial.
3. Plug the interface cable into Spatial.
4. Plug the USB end of the interface cable into your computer.
5. Download the Spatial Manager software from the Spatial Manager software from the Advanced Navigation website. Java is required to run the software. Java is available from <http://www.java.com> if not already installed.
6. Click the connect button in Spatial Manager.
7. The various windows in Spatial Manager can be used to view the real time data.
8. Once the unit is installed, perform a magnetic calibration. Please see section 10.6.



9. Enter the GNSS antenna position offset into the alignment dialogue in Spatial Manager and press save, see section 11.8.5. The antenna offset is measured from the centre of the Spatial unit to the centre of the antenna in the body co-ordinate frame. Please note that as Z is positive down, if the antenna is above the Spatial unit this will result in a negative Z value.
10. To view the data logs, click disconnect in Spatial 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 Manager software.

6.3 Troubleshooting

1. If you are having trouble opening Spatial Manager, please try reinstalling Java.
2. If you are having problems connecting to Spatial, please try reinstalling the latest FTDI driver from the FTDI website:
<http://www.ftdichip.com/Drivers/VCP.htm>
3. If you are running Spatial at a high update rate under Windows the latency timer will need to be adjusted. To do this please open control panel → system → device manager → ports → right click USB Serial Port → properties → port settings → advanced. In this window change the latency timer to 1 millisecond.



7 Part Numbers and Ordering Options

7.1 Evaluation Kit

Part Number	Description	Notes
SPATIAL-EK	Spatial Evaluation Kit	Spatial evaluation kit Includes items listed in section 6.1

Table 4: Evaluation kit part numbers

7.2 Standalone Unit

Part Number	Description	Notes
SPATIAL	Spatial Unit	Spatial Unit No cables or antennas included
SPATIAL-422	Spatial Unit (RS422)	Spatial Unit With optional RS422 interface instead of standard RS232 interface No cables or antennas included

Table 5: Standalone unit part numbers

7.3 Accessories

Part Number	Description	Notes
A503-SDC20796	ODU plug to FTDI USB cable	Spatial ODU plug with 2m of cable to FTDI RS232 to USB plug, see section 8.10
TW4721	GNSS Antenna	Magnetic mount L1 GNSS Antenna (GPS/GLONASS/BeiDou/Galileo/SBAS)
A503-SDC20740-2M	ODU plug with 2m cable (unterminated)	Spatial ODU plug with 2m of unterminated cable, see section 8.9
A503-SDC20753	ODU to D9 connectors and DC socket	Spatial ODU plug with 2m of cable to industry standard D9 connectors and DC socket, see section 8.11
CABLE-FTDI-DSUB-232	FTDI USB to RS232 Adapter	1 metre FTDI USB to RS232 Adapter
SUPPLY-24V	24V DC Power Supply	100-240V AC Mains (IEC socket) to 24V DC Power Supply (DC jack)
CAR12VPWR	Car cigarette lighter power supply	Car cigarette lighter to DC jack power supply
OBDII-ODOMETER	OBDII Odometer	OBDII Odometer Interface See section 9.6.2
AD-UNIT	Air Data Unit	Air data unit provides pitot and static air data aiding for Spatial in fixed wing aircraft

Table 6: Accessories part numbers



8 Specifications

8.1 Mechanical Drawings

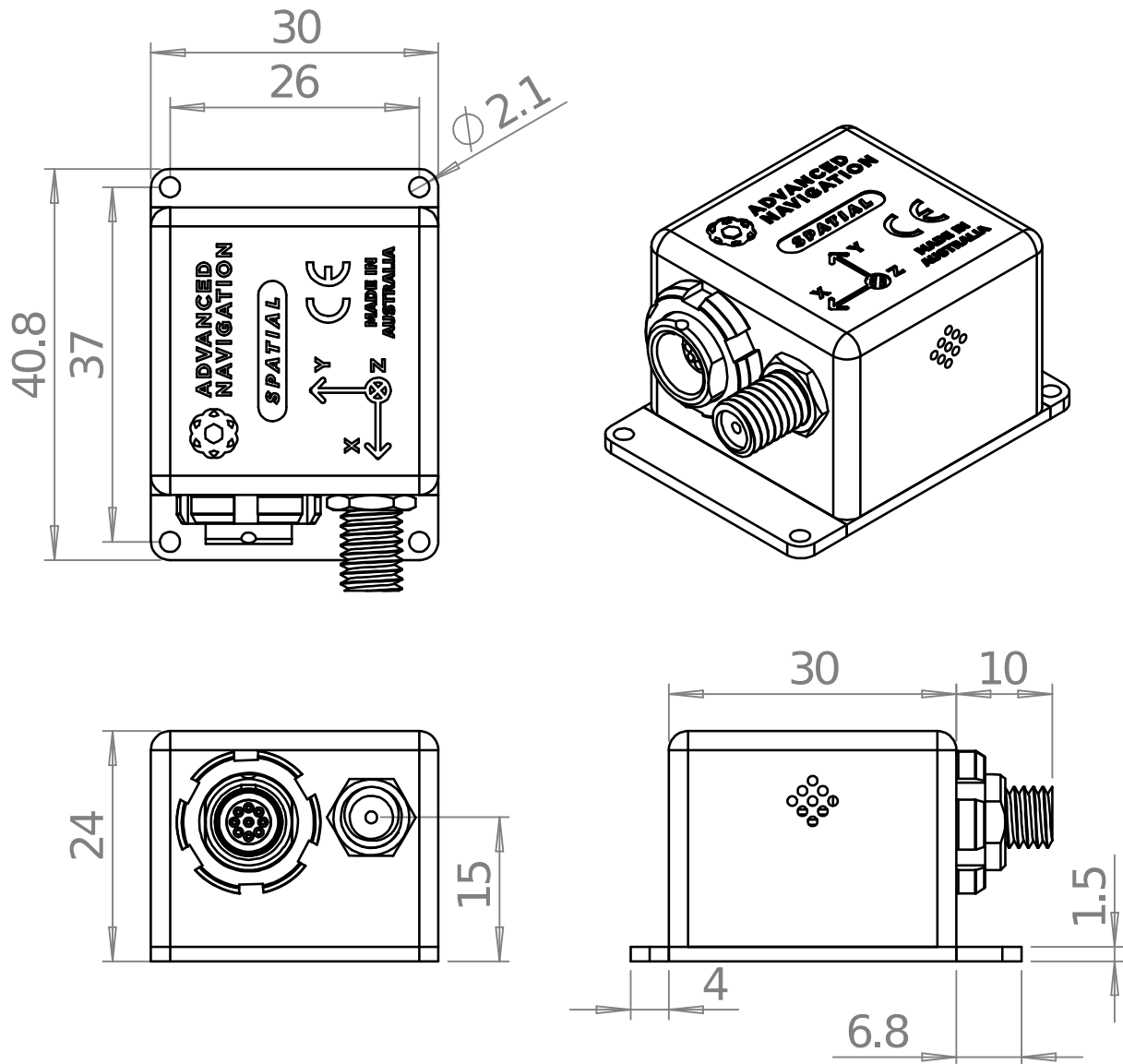
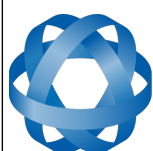


Illustration 14: Mechanical drawings of Spatial

8.2 Navigation Specifications



Parameter	Value
Horizontal Position Accuracy	2.0 m
Vertical Position Accuracy	3.0 m
Horizontal Position Accuracy (with DGNSS)	0.6 m
Vertical Position Accuracy (with DGNSS)	1.0 m
Velocity Accuracy	0.05 m/s
Roll & Pitch Accuracy (Static)	0.1 °
Heading Accuracy (Static)	0.5 °
Roll & Pitch Accuracy (Dynamic)	0.2 °
Heading Accuracy (Dynamic with GNSS)	0.2 °
Heading Accuracy (Dynamic, magnetic only)	0.8 °
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

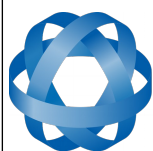
Table 7: Navigation specifications

8.3 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
Noise Density	150 ug/√Hz	0.008 °/s/√Hz	210 uG/√Hz	0.56 Pa/√Hz
Non-linearity	< 0.05 %	< 0.05 %	< 0.05 %	-
Bias Stability	60 ug	3 °/hr	-	100 Pa/yr
Scale Factor Stability	< 0.05 %	< 0.05 %	< 0.05 %	-
Cross-axis Alignment Error	< 0.05 °	< 0.05 °	0.05 °	-
Bandwidth	400 Hz	400 Hz	110 Hz	50 Hz

Table 8: Sensor specifications

8.4 GNSS Specifications



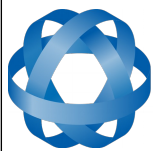
Parameter	Value
Supported Navigation Systems	GPS L1 GLONASS L1 GALILEO E1 BeiDou B1
Supported SBAS Systems	WAAS EGNOS MSAS GAGAN QZSS
Update Rate	10 Hz
Cold Start Sensitivity	-148 dBm
Tracking Sensitivity	-167 dBm
Hot Start First Fix	1 s
Cold Start First Fix	26 s
Horizontal Position Accuracy	2.5 m
Horizontal Position Accuracy (with SBAS)	2 m
Velocity Accuracy	0.05 m/s
Timing Accuracy	30 ns
Acceleration Limit	4 g

Table 9: GNSS specifications

8.5 Communication Specifications

Parameter	Value
Interface	RS232
Speed	4800 to 1M baud
Protocol	AN Packet Protocol NMEA TSS1 Simrad
Peripheral Interface	2x GPIO and Auxiliary RS232
GPIO Level	5 – 20 V

Table 10: Communication specifications



8.6 Hardware Specifications

Parameter	Value
Operating Voltage	5 to 36 V
Input Protection	± 40 V
Power Consumption	100 mA @ 5 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	2000 g
Dimensions (excluding tabs)	30 x 30 x 24 mm
Dimensions (including tabs)	30 x 40.6 x 24 mm
Weight	37 grams

Table 11: Hardware specifications

8.7 Electrical Specifications

Parameter	Minimum	Typical	Maximum
Power Supply			
Input Supply Voltage	5 V		36 V
Input Protection Range	-40 V		40 V
RS232			
Tx Voltage Low		-5.7 V	-5 V
Tx Voltage High	5 V	6.2 V	
Tx Short Circuit Current		±35 mA	±70 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	2.9 V	3 V	3.1 V
Antenna Supply Current			75 mA

Table 12: Electrical specifications



8.8 Power Consumption

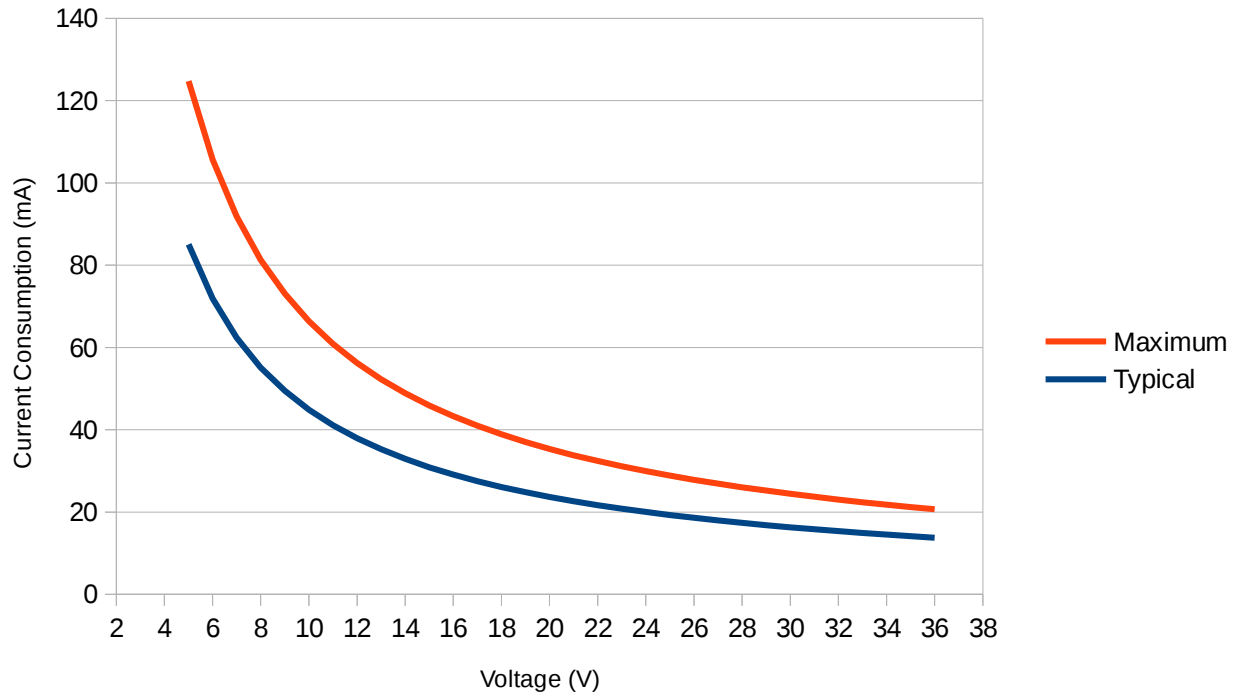


Illustration 15: Maximum and typical current consumption across operating voltage

8.9 Connector Pin-out

Power supply and signal connections are made through a ODU Mini-Snap Series B 9 pin connector. The ODU part number is S30B0SP09MCC00-5000. The connector provides a reliable and rugged connection to Spatial under demanding conditions and is rated to IP68 in the mated condition. Plugs are supplied with 2 metres of unterminated shielded cable with an outer protective jacket. Each individual wire is colour coded PFA coated 28AWG wire with an external shield and insulation. Custom cable lengths can be ordered by request.

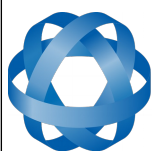


Illustration 16: ODU B series mating plug for Spatial

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

Table 13: Pin allocation table

8.10 Evaluation Kit USB Cable

The evaluation kit is supplied with a 2 metre cable with a Spatial ODU plug on one end and an overmoulded RS232 to USB converter on the other end, please see Illustration 17. The cable is the same 9 wire cable supplied with unterminated ODU cables and all 9 wires are connected on the ODU end. If required, it is possible to cut off the overmoulded RS232 converter to get access to all the individual wires. The chip used in the overmoulded RS232 converter is an FTDI FT232R and supports baud rates of up to 1,000,000 baud.

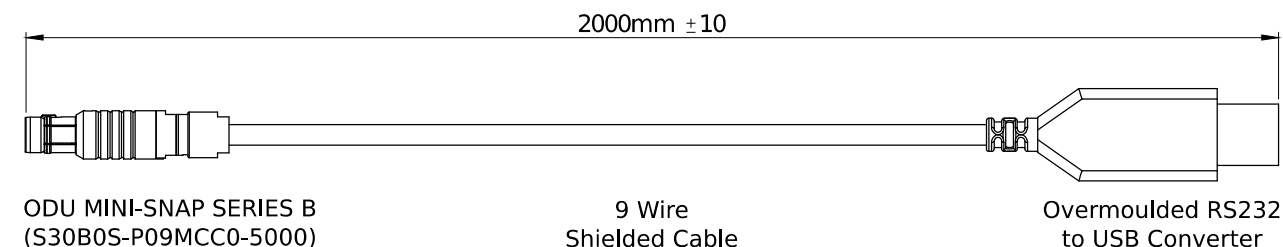
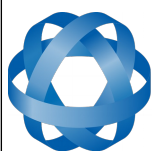


Illustration 17: Evaluation kit USB cable

Pin	Colour	Function	RS232 Converter Connection
1	Black	Ground	USB Ground
2	Brown	Power	USB 5 volt supply
3	White	GPIO 1	
4	Green	GPIO 2	
5	Red	Primary RS232 Tx	FTDI RS232 Rx
6	Orange	Primary RS232 Rx	FTDI RS232 Tx
7	Yellow	Auxiliary RS232 Tx	
8	Blue	Auxiliary RS232 Rx	
9	Pink	Ground	

Table 14: Evaluation kit USB cable pin-out

8.11 Optional Breakout Cable

Advanced Navigation offers a pre-terminated breakout cable for access to all of Spatial's pins. All external signal and power connections are provided with 2m of cable. The interface cable is provided with industry standard 9 pin DSUB connectors for each of the two RS232 communication channels and GPIO pins. The breakout cable is an optional extra and is not supplied as standard with the evaluation kit.

Due to several failures of these cables that were operating in rough conditions, all cables supplied after April 2015 are of a new design with an over moulded splice point, over moulded DB9 connectors and an over moulded power socket to make them much more durable for use in tough conditions.

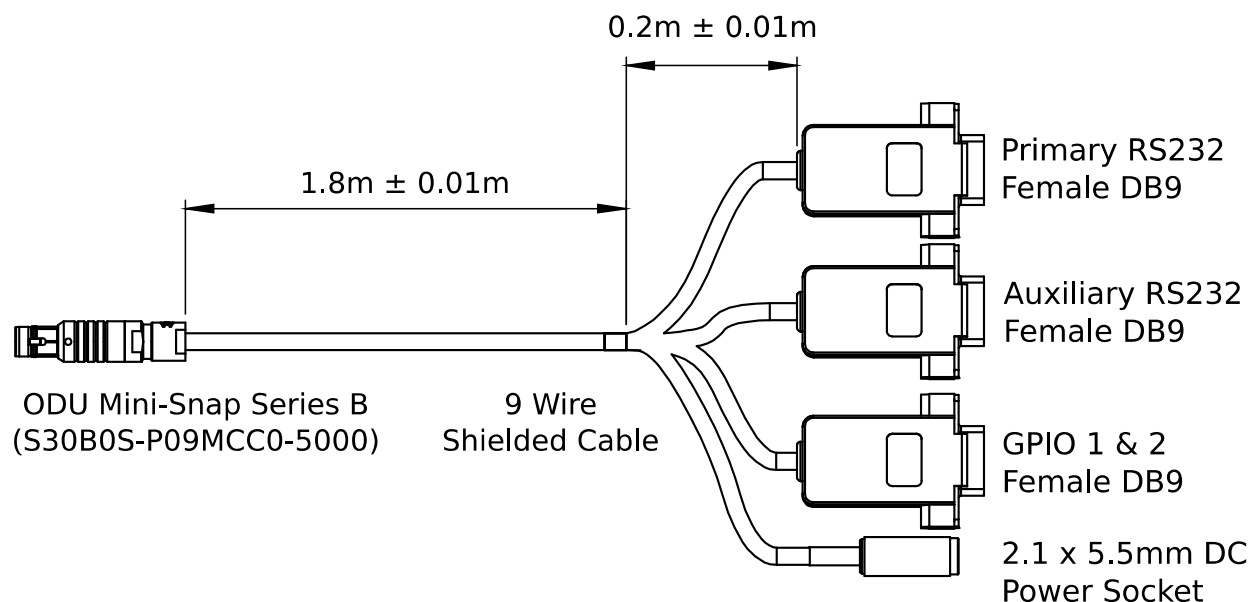
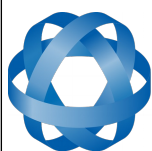


Illustration 18: Optional breakout cable diagram

Pin	Colour	Function	Primary	Auxiliary	GPIO	Power
1	Black	Ground	5	5	5	
2	Brown	Power				Tip
3	White	GPIO 1			2	
4	Green	GPIO 2			3	
5	Red	Primary RS232 Tx	2			
6	Orange	Primary RS232 Rx	3			
7	Yellow	Auxiliary RS232 Tx		2		
8	Blue	Auxiliary RS232 Rx		3		
9	Pink	Ground				Ring

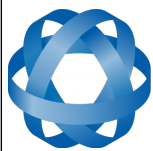
Table 15: Optional breakout cable connector pin-out

8.12 Sensor Calibration

Spatial'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 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 19: Spatial 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 GNSS antenna to the vehicle following the guidelines in section 9.5 and then connect the antenna to Spatial unit.
3. Connect the connector cable to Spatial and then connect the USB end to a computer.
4. Open the Spatial Manager software on the computer and click connect.
5. If the unit is mounted in an alignment other than 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 Manager. Please see section 9.2.1 for more details.
6. Accurately measure the primary GNSS antenna offset from the centre of the Spatial unit to the centre 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 Manager. 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 Manager.
8. Perform a magnetic calibration on the unit as described in section 10.6. If magnetic calibration is going to be too difficult to perform on the vehicle or the operating environment has high levels of magnetic interference then it is recommended to disable magnetic heading in Filter Options and use only GNSS velocity heading. If magnetic heading is disabled a magnetic calibration does not need to be performed.
9. The system is now ready for use.

9.2 Position and Alignment

When installing Spatial 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 should be mounted away from high levels of vibration where possible.
2. Spatial should be mounted in an area that is not going to exceed it's temperature range.
3. The two vents on the sides of Spatial should not be obstructed.
4. If magnetic heading is going to be used, Spatial should be mounted at least 0.5 metres away from sources of dynamic magnetic interference i.e. high current wiring, large motors, moving steel masses and rotating or reciprocating machinery.



5. Spatial should be mounted close to the centre of gravity of the vehicle where possible.
6. Spatial should be mounted within several metres of the GNSS antenna where possible.

9.2.1 Alignment

The easiest way to align Spatial 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. Examples of this are shown below in Illustration 20, Illustration 21 and Illustration 22.

If aligning Spatial 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 the Spatial Manager software, see section 11.8.5. For easy alignment, the set zero orientation button in the Spatial 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.



Illustration 20: Spatial axes aligned with car axes



Illustration 21: Spatial axes aligned with boat axes

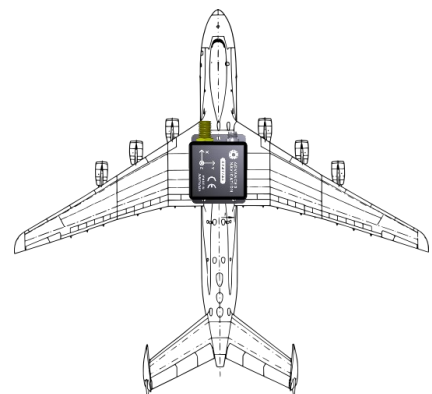
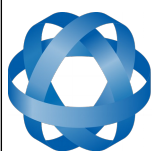


Illustration 22: Spatial axes aligned with plane axes



9.3 Mounting Plate

Spatial's mounting plate and hole guide is shown below in Illustration 23. The holes are designed for M2 cap screws.

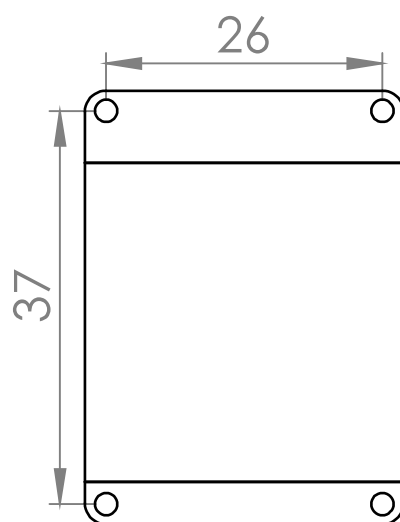


Illustration 23: Spatial mounting plate

9.4 Power Supply

A high level of power supply filtering has been built into Spatial, however it is still recommended that the power supply be free of significant noise. As the communications ground is shared with the supply ground, it is important to ensure that ground wiring is routed to avoid power supply noise from other systems corrupting data communications.

A power supply should be selected that can provide at least the maximum current calculated from the graph in Illustration 15.

Spatial 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 4.2 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 4.7 V or more to avoid issues associated with this.

9.5 GNSS Antenna

The GNSS antenna should be installed level with a clear unobstructed view of the sky and close to the Spatial unit where possible. The antennas should be mounted away from any RF emitters. The antenna cable should be routed away from powerful RF emitters, high current wiring, high temperatures and any rotating or reciprocating machinery. The optimum mounting configuration is above the Spatial unit.



The antenna offset should be configured in the Spatial unit by using the alignment dialogue in the Spatial Manager software, see section 11.8.5. It is very important to set the antenna offset accurately as Spatial 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.

It is important to note that most GNSS antennas contain magnets for mounting. If you are using an antenna with magnets you will need to either keep it a minimum 0.5 metres distance away from Spatial or remove the magnets to ensure that it doesn't interfere with Spatial's magnetometers.

If you are supplying your own antenna it is important to ensure that the antenna is able to receive all constellations and not just GPS, otherwise you will not achieve full performance. It is also important to select an IP67 antenna with an IP67 SMA connector, otherwise the system will not be environmentally sealed.

It is recommended to use an antenna with the following characteristics:

- For GPS/GLONASS, a frequency range of 1575 Mhz to 1606 Mhz
- For GPS/BeiDou, a frequency range of 1559 Mhz to 1593 Mhz
- For all constellations, a frequency range of 1559 Mhz to 1606 Mhz
- Minimum gain of 15 dB and maximum gain of 50 dB
- Antenna LNA noise of < 2 dB
- Out of band rejection of 35 dB @ ± 70 MHz

9.6 Odometer

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

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

9.6.1 Factory VSS Signal

Most road cars since 1980 contain a VSS (vehicle speed sensor) signal that can be wired directly into one of Spatial'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 Manager, see section 11.8.7. The odometer pulse length must then be set either manually or automatically, please see section 10.10 for more information.

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

9.6.2 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 with odometer data over the Auxiliary RS232 port, please see Illustration 24. These units are priced at approximately AUD 500. Please contact Advanced Navigation sales for more information.



Illustration 24: Advanced Navigation OBDII Odometer

9.6.3 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 Pegasem or GMH Engineering.



*Illustration 25:
Aftermarket wheel
speed sensor*

9.6.4 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 26: Radar
speed sensor*

9.7 Magnetics

Spatial contains magnetometers which it uses to measure the Earth's magnetic field in order to determine its heading. The principle is the same as that of a compass. When operating Spatial with magnetic heading enabled, sources of magnetic interference can degrade Spatial's solution if not compensated for. There are two types of magnetic interference, these are static and dynamic.

Static magnetic interference is caused by steel and other magnetic materials mounted in the vehicle. Static disturbances are easily compensated for by running a magnetic calibration, see section 10.6. A magnetic calibration should always be run after installation into a vehicle.

Dynamic magnetic interference is generally a much bigger issue. Sources of dynamic magnetic interference include high current wiring, electric motors, servos, solenoids and large masses of steel that don't move with Spatial. Spatial should be mounted as far as possible from these interference sources.

Spatial contains a special algorithm to remove the effects of dynamic magnetic interference. This is able to compensate for most typical interference sources encountered, however certain types of prolonged dynamic interference cannot be compensated for. The best way to check for dynamic magnetic interference is to use the raw sensors view in Spatial Manager and watch the magnetometer outputs whilst the vehicle is operating but stationary, see section 11.7.4. The values should be constant, if the values are fluctuating there is dynamic magnetic interference present.

If dynamic magnetic interference is causing performance problems and there is no way to mount Spatial away from the interference source, the magnetometers should be disabled, see section 10.6.4.

9.8 Vibration

Spatial 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 can tolerate and large levels of vibration will cause Spatial's accuracy to degrade.

When mounting Spatial to a platform with vibration there are several options. It is

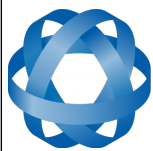


recommended to first try mounting Spatial and see whether it can tolerate the vibrations. The raw sensor view in the Spatial Manager software can give you a good idea of how bad the vibrations are, see section 11.7.4. If the vibrations are causing the sensors to go over range you will need to increase the sensors range, see section 10.7.

If you are unsure about your vibration level, we recommend emailing a Spatial log file of the vibration to support@advancednavigation.com.au for feedback.

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

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



10 Operation

10.1 Filter

Spatial contains a sophisticated filter which it uses to fuse all its sensors into a state estimation. The filter is a set of custom algorithms that have similar principles to a kalman filter, but operate differently. Spatial's custom filter makes decisions based upon context and history which greatly improves performance and makes it more resilient to error sources than a typical kalman filter.

Under rare conditions, when there are large errors present that Spatial's filter cannot compensate for, it can become unstable. If Spatial's filter does become unstable a monitoring process will immediately reset the filter to the last known good state. The filter initialised flag will remain reset until the filter stabilises again. In real time control applications it is very important to monitor Spatial's filter status, so that data can be ignored if a situation occurs causing the filter to reset.

10.2 Initialisation

There are four different levels of initialisation on Spatial. These are orientation, navigation, heading and time. Upon a cold start (more than 48 hours without power) all four levels will typically initialise within 30 seconds and for a hot start (less than 48 hours without power) all four levels will typically initialise within 2 seconds. The initialisation can be monitored by inspecting the status view in Spatial Manager, see section 11.7.2.

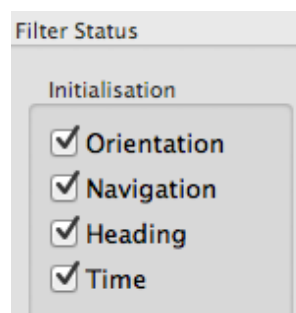
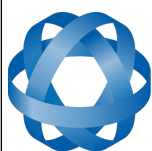


Illustration 27: The four initialisation levels

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

10.2.1 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 starts up, it assumes that it can be in any orientation. To determine its 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 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 will progressively correct the orientation error over a period of several seconds.

10.2.2 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 its 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 position dialogue in Spatial Manager, see section 11.8.12.

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

10.2.3 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 10.5. If magnetic heading is enabled as a heading source the heading initialisation should complete within 2 seconds after power on. If magnetic heading is disabled and velocity heading is used as the only heading source, the heading will initialise once the system travels at a speed of over 1.15 metres/second for over 5 seconds with a 3D GNSS fix. If the system is hot starting it will remember its 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.

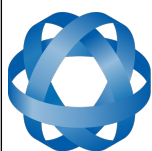
10.2.4 Time Initialisation

Time initialisation completes once the system has determined time to an accuracy of less than 1 microsecond. This normally occurs as soon as the GNSS receiver obtains its 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 outputs will not be valid and may change.

10.3 Hot Start

Spatial is the first GNSS/INS on the market with hot start functionality. This allows Spatial to start inertial navigation within 500 milliseconds and obtain a GNSS fix in as



little as 3 seconds. Spatial's hot start is always on and fully automatic.

A next generation backup battery system within Spatial provides the hot start ability for more than 48 hours without power. When Spatial 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 will jump to the new position without causing any side effects to the filter.

Whilst Spatial 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'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.

10.4 Time

Spatial was designed to provide a highly accurate time reference. When a GNSS fix is available Spatial's time is accurate to within 50 nanoseconds. When a GNSS fix is lost, Spatial's time accuracy typically remains within 10 microseconds over extended time periods. When Spatial 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's high accuracy time, both the packet protocol and a 1PPS line must be used.

10.5 Heading Source

There are three different heading sources available for Spatial. The heading source can be selected using the filter options dialogue in Spatial Manager, see section 11.8.3. It is possible to use multiple heading sources and this can often provide performance benefits.

10.5.1 Magnetic Heading

This is the default heading source and works well in the majority of cases. When using magnetic heading, calibration is required every time Spatial's installation changes. The downside of magnetic heading is that prolonged dynamic magnetic interference sources can cause heading errors.

10.5.2 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. The downside of velocity heading is that heading can not be measured until the vehicle moves at a horizontal speed of over 1.15 metres/second with a GNSS fix. The benefits of velocity heading are that it is immune to magnetic interference and no calibration is required when Spatial's installation changes.



10.5.3 External Heading

This can be used if there is some other way to derive heading that is external to Spatial. Examples include dual antenna GNSS systems, north seeking gyroscopes, reference markers and SLAM systems. The heading must be fed into Spatial using the External Heading Packet or through the auxiliary RS232.

10.6 Magnetics

Static magnetic interference is resolved through magnetic calibration and dynamic magnetic interference is compensated by a filter algorithm but should be minimised where possible through installation location. Please see section 9.7 for more information on magnetic interference. To compensate for static magnetic interference, magnetic calibration should be performed any time Spatial's installation changes.

Spatial contains a dynamic magnetic compensation filter that is able to mitigate the effects of short term magnetic interference sources while in operation. For example if Spatial is installed in a car and the car drives over a large piece of magnetised steel, this will be compensated for. Another example is driving through a tunnel which is built from heavily reinforced concrete. It is important to note that for Spatial's dynamic magnetic compensation filter to operate correctly, Spatial needs to get a GNSS fix at least once every time it is moved more than 50km. Each time Spatial moves more than 50km the new position is stored permanently and allows Spatial to update it's world magnetic model values.

There are three types of magnetic calibration available, these are 2D calibration, 3D calibration and automatic calibration. 2D calibration involves one level rotation about the Z axis and is designed for vehicles that cannot easily or safely be turned upside down, such as full size cars, planes and boats. 3D calibration involves rotating through all orientations and is designed for vehicles that can easily and safely be rotated upside down, such as model size vehicles. 3D calibration offers slightly better performance and is recommended where possible. Automatic magnetic calibration continuously and automatically calibrates for static magnetic interference while the unit is in operation. It is not as accurate as the 2D or 3D calibration, however it is very convenient for applications where Spatial needs to just work without user intervention.

Please note that if Spatial is going to be used in a vehicle, the calibration should be performed while Spatial is mounted in and fixed to that vehicle. This means that the whole vehicle must be moved to perform the calibration. The calibration needs to be performed in an area away from sources of magnetic interference. For example if Spatial is installed in a car, the calibration should not involve driving over steel drains or reinforced concrete etc. If Spatial is being calibrated to operate standalone, the calibration should not be done on a desk with a steel frame.

10.6.1 2D Magnetic Calibration

The following procedure should be used to perform a 2D magnetic calibration.

10.6.1.1 Using the Spatial Manager Software

1. The unit should be powered on while the vehicle is in a level orientation and kept stationary.



2. After power on wait 5 minutes for the temperature and filter to stabilise.
3. Open Spatial Manager and connect to the device. Ensure that the device has a GNSS fix before proceeding.
4. In the Tools menu, open Magnetic Calibration. Click the 2D Calibration button. See section 11.9.2.
5. Whilst keeping as level as possible, rotate the vehicle in either direction through one and a quarter full rotations. In a car this can be achieved by driving in one and a quarter circles.
6. Check the status in the Magnetic Calibration window to ensure that the calibration completed successfully. If not successful click Cancel, wait 2 minutes and repeat from step 4. Do not press the save button in the lower half of the dialogue, this will over write the new calibration values. The calibration values are automatically saved internally.

10.6.1.2 Using the Packet Protocol

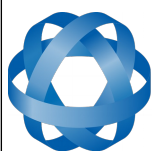
1. The unit should be powered on while the vehicle is in a level orientation and kept stationary.
2. After power on wait 5 minutes for the temperature and filter to stabilise.
3. Ensure that the device has a GNSS fix before proceeding
4. Send the Magnetic Calibration Configuration Packet with the action Start 2D Magnetic Calibration.
5. Whilst keeping as level as possible, rotate the vehicle in either direction through one and a quarter full rotations. In a car this can be achieved by driving in one and a quarter circles.
6. Read the Magnetic Calibration Status Packet to ensure that the calibration completed successfully. If not successful, send the Magnetic Calibration Configuration Packet with the action Cancel, wait 2 minutes and repeat from step 4.

10.6.2 3D Magnetic Calibration

The following procedure should be used to perform a 3D magnetic calibration.

10.6.2.1 Using the Spatial Manager Software

1. The unit should be powered on and the vehicle kept stationary.
2. After power on wait 5 minutes for the temperature and filter to stabilise.
3. Open Spatial Manager and connect to the device. Ensure that the device has a GNSS fix before proceeding.
4. In the Tools menu, open Magnetic Calibration. Click the 3D Calibration button. See section 11.9.2. The following steps 5, 6 and 7 can be performed in any order.
5. Slowly rotate the vehicle twice around the X axis (roll).



6. Slowly rotate the vehicle twice around the Y axis (pitch).
7. Slowly rotate the vehicle twice around the Z axis (heading).
8. Check the status in the Magnetic Calibration window to ensure that the calibration completed successfully. If not successful click Cancel, wait 2 minutes and repeat from step 4. Do not press the save button in the lower half of the dialogue, this will over write the new calibration values. The calibration values are automatically saved internally.

10.6.2.2 Using the Packet Protocol

1. The unit should be powered on and the vehicle kept stationary.
2. After power on wait 5 minutes for the temperature and filter to stabilise.
3. Ensure that the device has a GNSS fix before proceeding
4. Send the Magnetic Calibration Configuration Packet with the action Start 3D Magnetic Calibration. The following steps 5, 6 and 7 can be performed in any order.
5. Slowly rotate the vehicle twice around the X axis (roll).
6. Slowly rotate the vehicle twice around the Y axis (pitch).
7. Slowly rotate the vehicle twice around the Z axis (heading)
8. Read the Magnetic Calibration Status Packet to ensure that the calibration completed successfully. If not successful, send the Magnetic Calibration Configuration Packet with the action Cancel, wait 2 minutes and repeat from step 4.

10.6.3 Automatic Magnetic Calibration

Automatic magnetic calibration is an algorithm that continuously and automatically calibrates for static magnetic interference. Automatic magnetic calibration is enabled by default and it is recommended to keep it enabled for all vehicle types. When used on top of a 2D or 3D calibration it can give the best results from magnetic heading. Every time Spatial is powered on in a cold start (48 hours without power) the automatic calibration is reset. The automatic magnetic calibration starts operating when Spatial is travelling at a speed over 5 m/s with a GNSS fix and velocity heading turned on. Automatic magnetic calibration is not as accurate as 2D or 3D calibration, however it is sufficient for most vehicles and allows Spatial to be installed into vehicles and operated without user intervention. Automatic magnetic calibration can be turned off using the filter options dialogue in Spatial Manager, see section 11.8.3.

10.6.4 Disabling Magnetometers

In situations where there is very strong dynamic magnetic disturbances present, it is recommended to disable the magnetometers. When the magnetometers are disabled a secondary heading source is required otherwise may become inaccurate. Velocity heading is the recommended source. Please see section 10.5 for information on heading sources. The magnetometers can be disabled using the filter options dialogue in Spatial Manager, see section 11.8.3.



10.7 Sensors Range

Spatial supports dynamic ranging on its sensors. Each of the three sensors has three different range levels. At lower ranges the sensor performance is better, but at higher ranges Spatial can be used in more extreme dynamics. It is important to choose a range that your application won't exceed.

Sensor over range events can be detected through the Filter Status. In Spatial 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 solution to become inaccurate and in some cases it can cause the filter to reset.

By default Spatial 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 Manager when you do this.

The sensor ranges can be set through the sensor ranges dialogue in the configuration menu in Spatial Manager, see section 11.8.2.

10.8 Data Anti Aliasing

Internally Spatial's filters update at 1000 Hz. When Spatial 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 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.

10.9 Vehicle Profiles

Spatial 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 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.

10.10 Odometer Pulse Length

For Spatial 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. To enter the pulse length manually, please use the odometer configuration dialogue in Spatial Manager, see section 11.8.8. To automatically calibrate the odometer pulse length please use the procedure listed below in section 10.10.1. By default the odometer will automatically calibrate itself.

10.10.1 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 Manager, see section 11.8.7.

2. Open Spatial Manager, connect to Spatial and open the odometer configuration dialogue, see section 11.8.8. In the odometer configuration dialogue tick the automatic pulse length calibration check box and press the save button.
3. Wait until Spatial has a continuous GNSS fix and then drive 1000 metres over flat terrain with as little turning as possible.
4. If Spatial loses a GNSS fix for more than several seconds 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 becomes un-ticked and the pulse length value has changed. This indicates a successfully completed calibration.

10.11 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. For all other applications it is best to leave it enabled. Reversing detection is enabled by default and it can be disabled using the filter configuration window in Spatial Manager, see section 11.8.3.

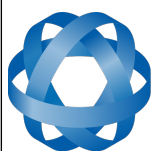
10.12 Motion Analysis

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 moving slowly or 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 window in Spatial Manager, see section 11.8.3.

10.13 Differential GNSS

Spatial supports receiving differential GNSS corrections to enhance position accuracy. Differential corrections must come from a base station located within a 100km radius of where the Spatial unit is operating. There are many companies worldwide that provide nationwide network corrections services where differential corrections from a local station can be received over the internet using a protocol called NTRIP.

Spatial Manager has an NTRIP client built in that can connect to the network corrections service to receive the differential corrections and feed them into the Spatial unit. Please see section 11.9.5.



The differential corrections format supported is RTCM v2.3 SC-104. The supported messages are 1, 2, 3 and 9.

10.14 Vents

Spatial 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.

10.15 RAIM

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

10.16 Heave

Spatial can provide vertical heave position at four different points on a ship. Spatial's heave filter is always on and fully automatic. After power on, Spatial 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 has a GNSS fix.

By default Spatial provides heave from the point at which the Spatial unit is mounted, however it can provide heave at four different offset points on the ship. To set the heave offsets, either use the heave configuration dialogue in Spatial Manager, see section 11.8.10.

10.17 Environmental Exposure

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

Spatial is only protected when it's connector is mated and an IP67 SMA GNSS antenna is attached to it. When either of these two 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.

10.17.1 Temperature

Spatial should not be subjected to temperature's outside of it's operating range. If the temperature rises above 90 degrees Celsius, Spatial 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 to temperature's outside of the storage range can effect the factory sensor calibration which will cause a permanent performance degradation.



10.17.2 Water

Spatial 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.

10.17.3 Salt

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

10.17.4 Dirt and Dust

Spatial 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 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.

10.17.5 PH Level

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

10.17.6 Shocks

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



11 Spatial Manager

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

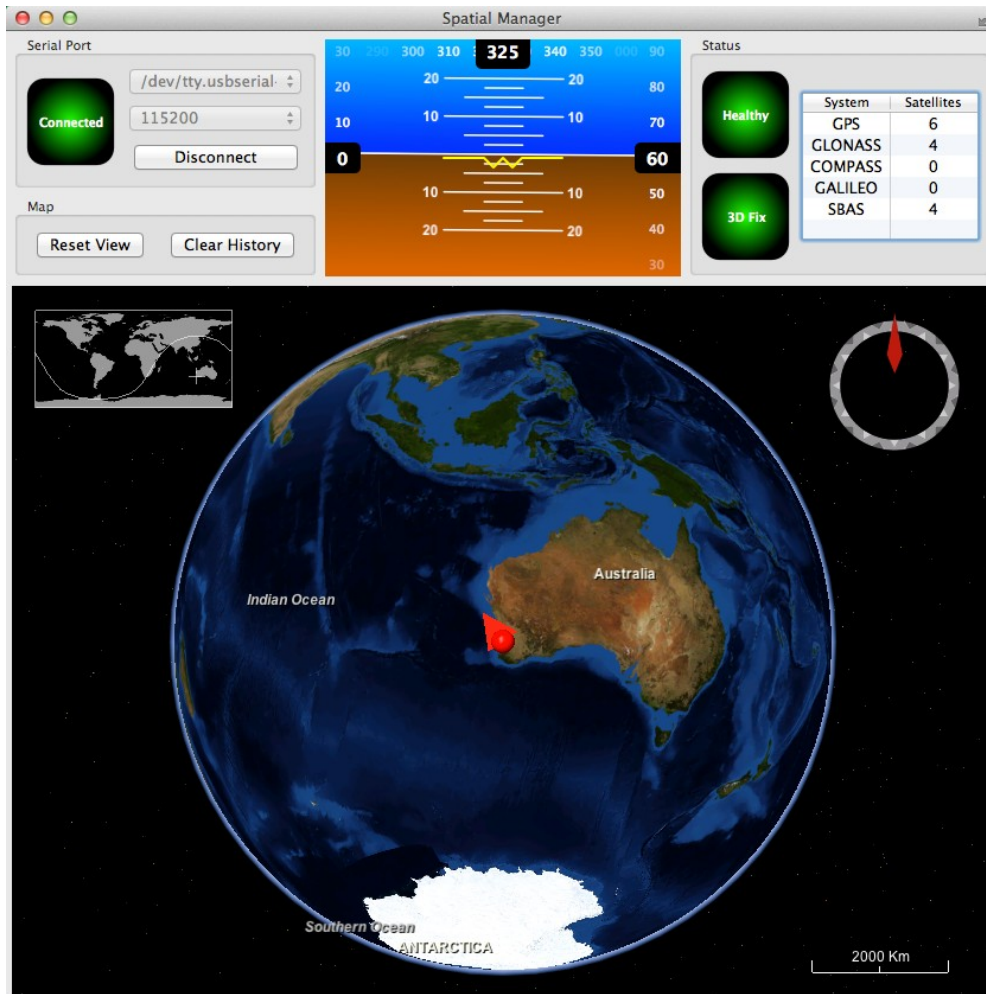
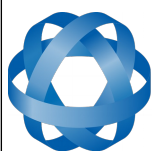


Illustration 28: Screenshot of Spatial Manager



11.1 Software Changelog

Version	Date	Changes
4.2	15/04/2015	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 11.7.10 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 GPX export now vectorises paths to minimise points for better performance in Google Earth.
4.0	18/09/2014	Improvements to the 3D map Support for more graphics cards Status display now shows when heading not initialised Orientation standard deviation graph added Latitude and longitude now show in position dialogue 3D model dialogue added, section 11.7.8 Communications dialogue added, section 11.7.9 Added GPIO output configuration dialogue, section 11.8.11 Added position configuration dialogue, section 11.8.12
3.0	13/09/2013	Significantly reduced CPU usage Minor interface enhancements New options added to filter options dialogue Added NMEA output configuration dialogue Added position configuration dialogue, section
2.4	27/03/2013	Minor interface enhancements Updated GPIO functions Detailed satellites dialogue updated to show frequencies Experimental post-processing log export function added
2.3	14/02/2013	Added Chinese language translation Changed logging system to binary format Added heave offset dialogue Firmware date added to firmware update dialogue Minor changes
2.0	22/10/2012	Added odometer configuration dialogue Added log converter tool Spatial Manager will now disconnect automatically if USB serial port is removed Firmware update will now change the baud rate automatically when entering bootloader mode Alignment configuration dialogue updated
1.0	16/09/2012	Mac disconnect issue resolved

0.5	23/08/2012	Initial Release
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Table 16: Spatial Manager software changelog

11.2 System Requirements

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

11.3 Installation

Spatial Manager does not need to be installed and can be run from any directory by double clicking on it. Spatial Manager requires a recent version of Java, available at <http://www.java.com>. On some systems to open the program it may be necessary to right click and select open with → Java Runtime Environment.

Both the Spatial evaluation kit and the Spatial OEM development kit make use of an FTDI USB 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/pnpblockerssetup.exe> that can fix the issue.

If the serial port does not show up when you plug in your Spatial 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 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 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 29.

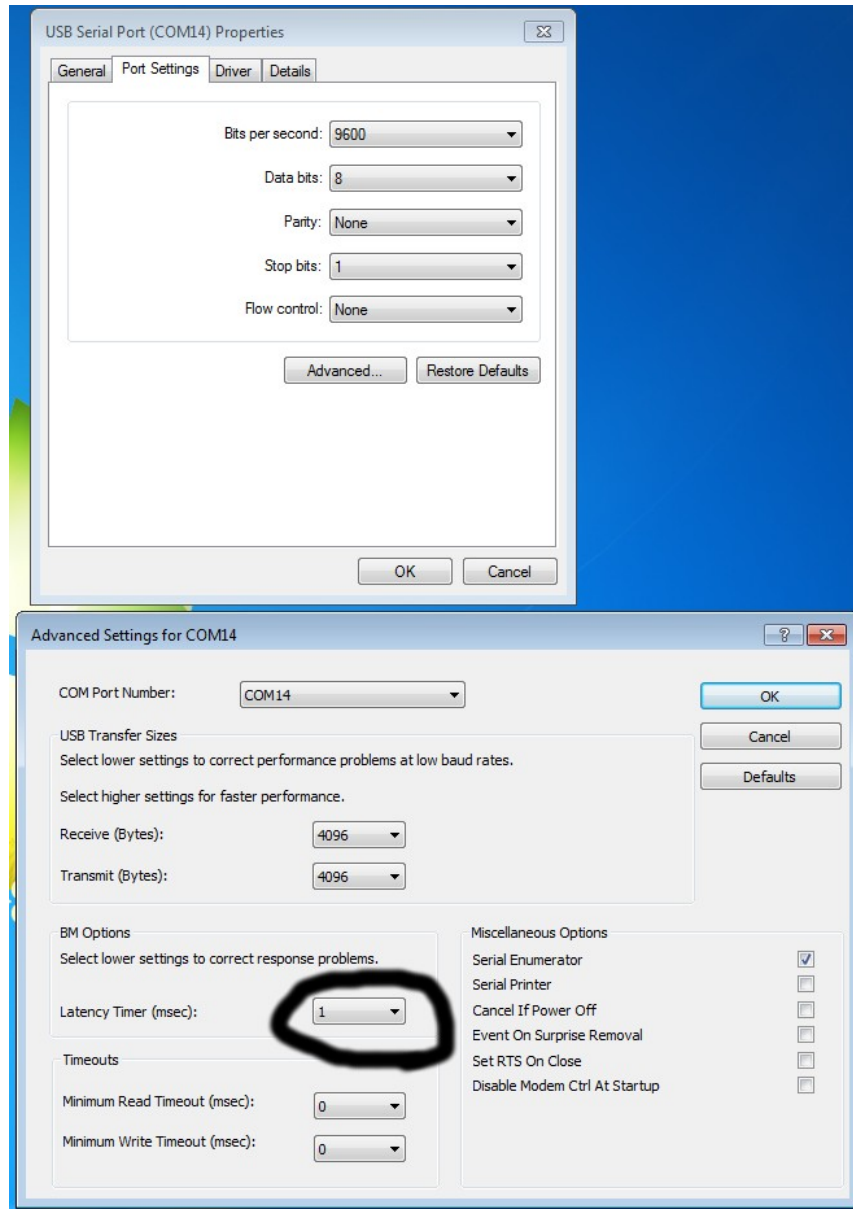
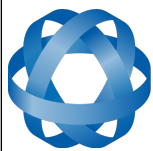


Illustration 29: Screenshot of latency timer setting

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`.

Spatial Manager is able to run on the OpenJDK JRE but it uses significantly more system resources than when it is running on the Oracle JRE.



11.5 Main View

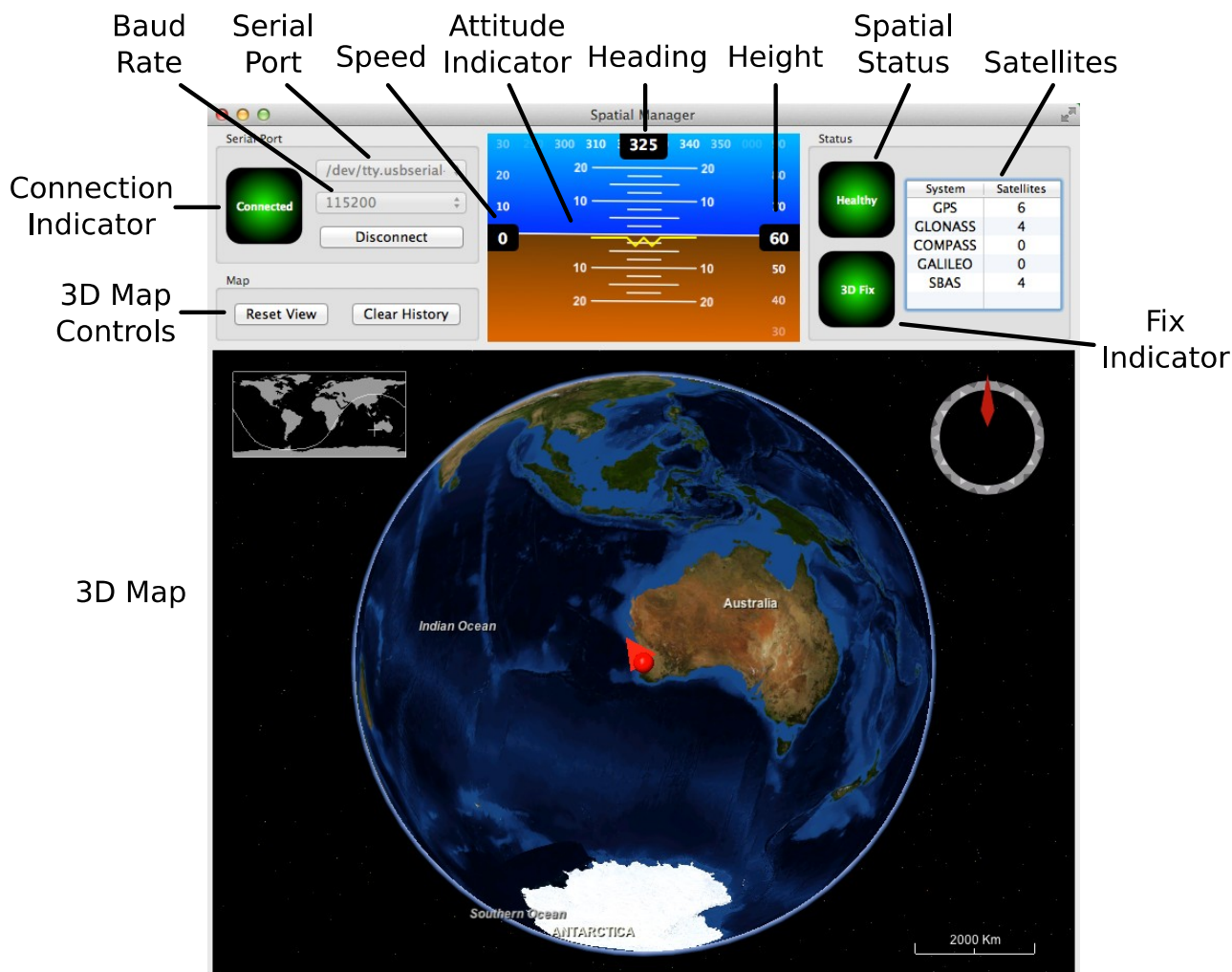


Illustration 30: Screenshot of Spatial Manager main view

11.5.1 Serial Port

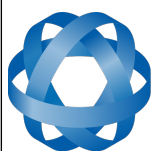
The serial port dialogue is used to connect to Spatial. You should select a serial port and baud rate and click connect. The default baud rate of Spatial is 115200. The connection indicator displays whether there is communication with a Spatial unit.

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 status indicator, a fix indicator and a



satellites table.

11.5.3.1 Spatial Status Indicator

This indicator shows any problems with Spatial. 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, see section 11.7.3.

11.5.4 3D Map

The 3D map shows Spatial'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'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 angle 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'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 Manager features a fully automatic logging system. Every time the serial port connect button is clicked Spatial 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 in the AN packet protocol. The log files are closed when the serial port is disconnected. 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 31: Screenshot showing log file and log conversion folder

11.7 View Menu

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

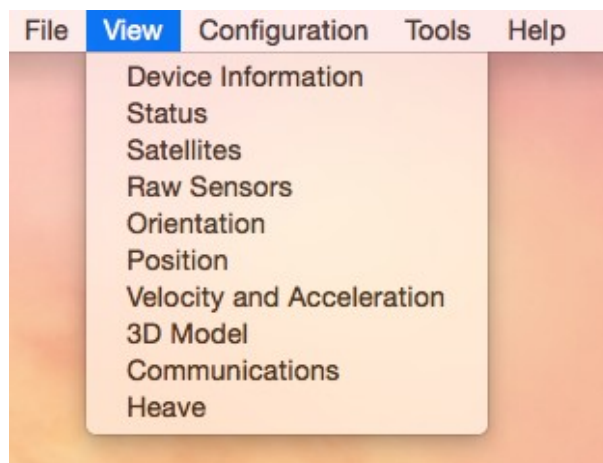


Illustration 32: Screenshot of Spatial Manager view menu



11.7.1 Device Information

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



Illustration 33: Screenshot of Spatial Manager device information dialogue

11.7.2 Status

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

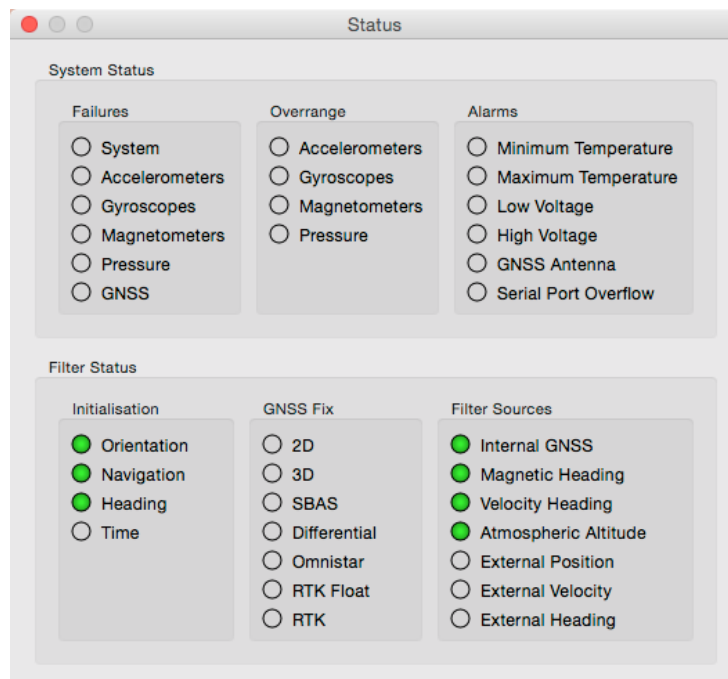
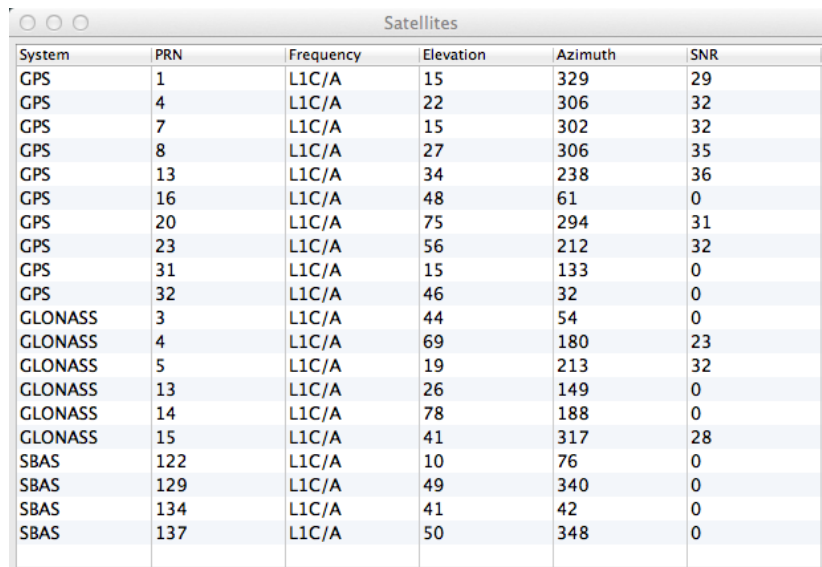


Illustration 34: Screenshot of Spatial Manager status dialogue



11.7.3 Satellites

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



System	PRN	Frequency	Elevation	Azimuth	SNR
GPS	1	L1C/A	15	329	29
GPS	4	L1C/A	22	306	32
GPS	7	L1C/A	15	302	32
GPS	8	L1C/A	27	306	35
GPS	13	L1C/A	34	238	36
GPS	16	L1C/A	48	61	0
GPS	20	L1C/A	75	294	31
GPS	23	L1C/A	56	212	32
GPS	31	L1C/A	15	133	0
GPS	32	L1C/A	46	32	0
GLONASS	3	L1C/A	44	54	0
GLONASS	4	L1C/A	69	180	23
GLONASS	5	L1C/A	19	213	32
GLONASS	13	L1C/A	26	149	0
GLONASS	14	L1C/A	78	188	0
GLONASS	15	L1C/A	41	317	28
SBAS	122	L1C/A	10	76	0
SBAS	129	L1C/A	49	340	0
SBAS	134	L1C/A	41	42	0
SBAS	137	L1C/A	50	348	0

Illustration 35: Screenshot of Spatial Manager satellites dialogue



11.7.4 Raw Sensors

Raw sensors shows the temperature calibrated raw sensor values.

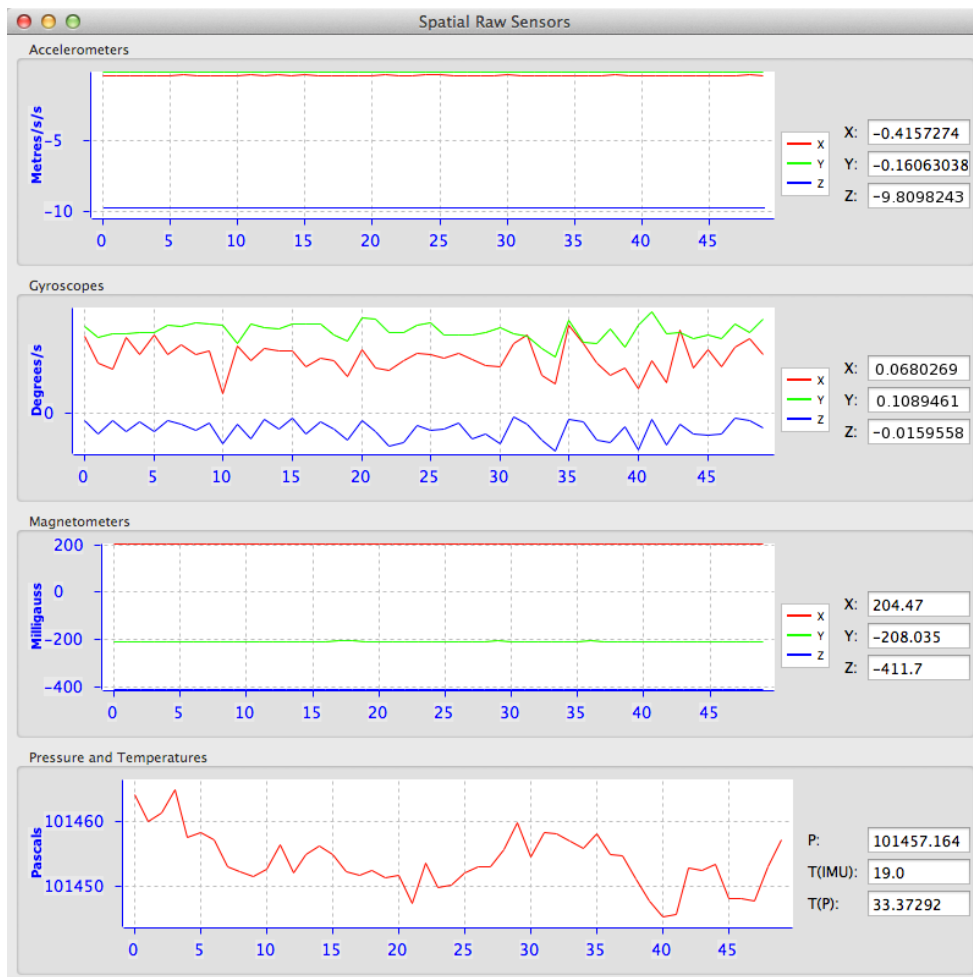


Illustration 36: Screenshot of Spatial Manager raw sensors dialogue



11.7.5 Orientation

Orientation shows Spatial's orientation and angular velocity.

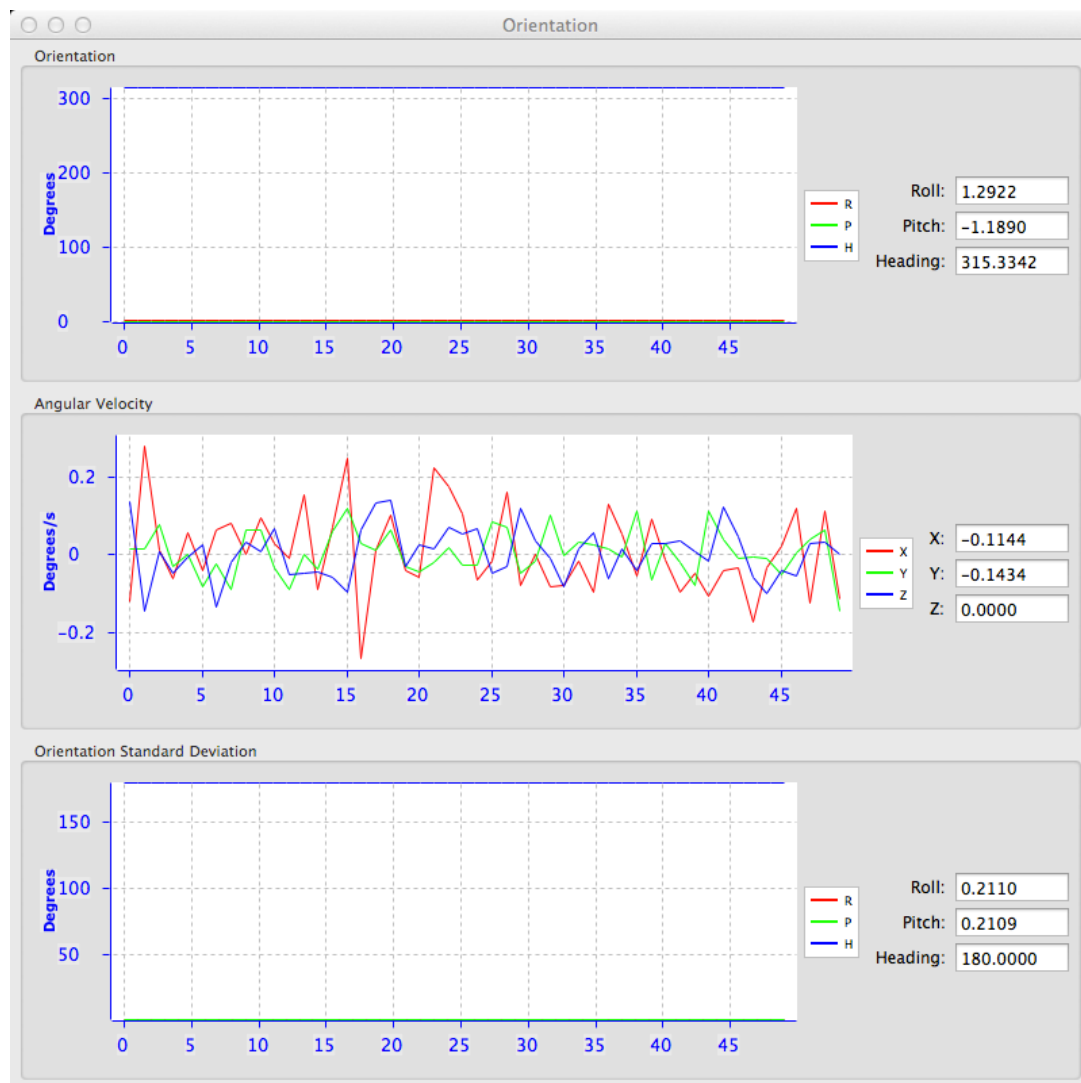


Illustration 37: Screenshot of Spatial Manager orientation dialogue



11.7.6 Position

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

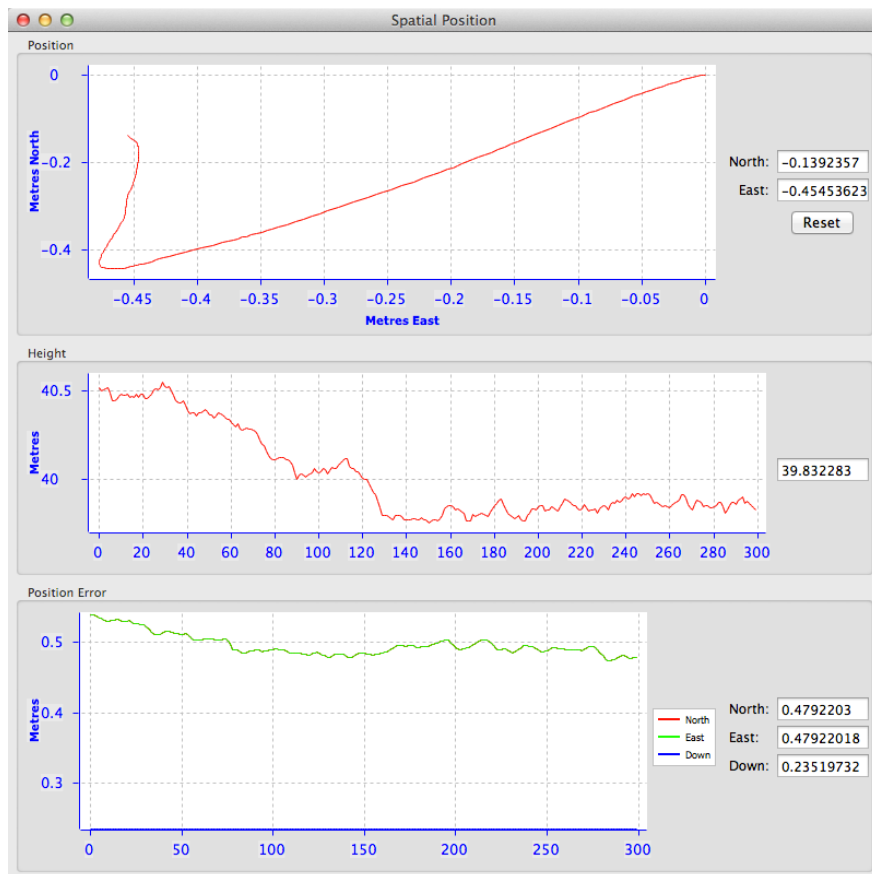


Illustration 38: Screenshot of Spatial Manager position dialogue

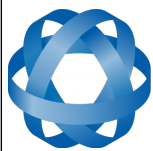


11.7.7 Velocity and Acceleration

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



Illustration 39: Screenshot of Spatial Manager velocity and acceleration dialogue



11.7.8 3D Model



Illustration 40: Screenshot of Spatial Manager 3D model dialogue

11.7.9 Communications Statistics

Communications Statistics	
Packets Decoded:	7796
Bytes Decoded:	649627
Bytes Discarded:	0
LRC Errors:	0
CRC Errors:	0

Illustration 41: Screenshot of Spatial Manager communications statistics dialogue



11.7.10 Heave

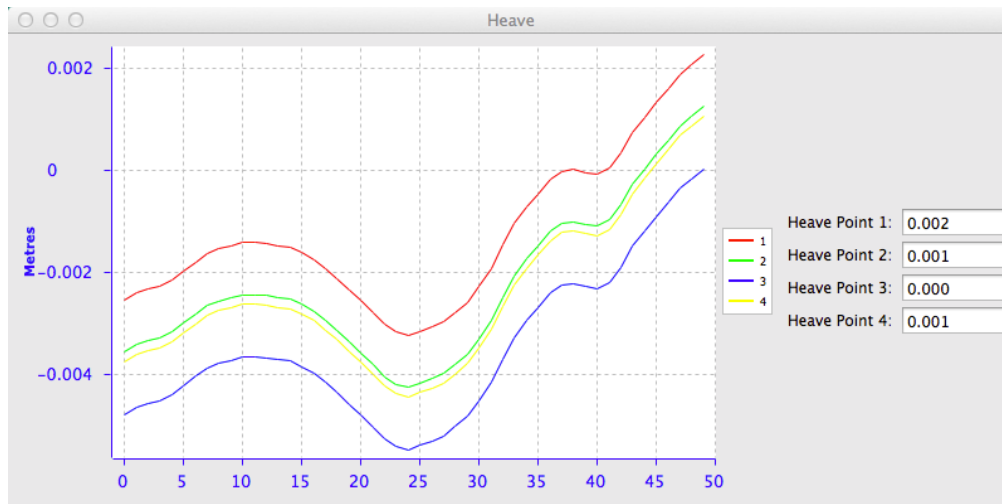


Illustration 42: Screenshot of Spatial Manager heave dialogue

11.8 Configuration

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



Illustration 43: Screenshot of Spatial Manager configuration menu

11.8.1 Configuration Export

The configuration export dialogue can be used to export all Spatial 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.

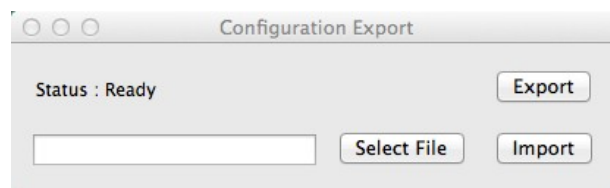


Illustration 44: Screenshot of Spatial Manager configuration export dialogue



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.

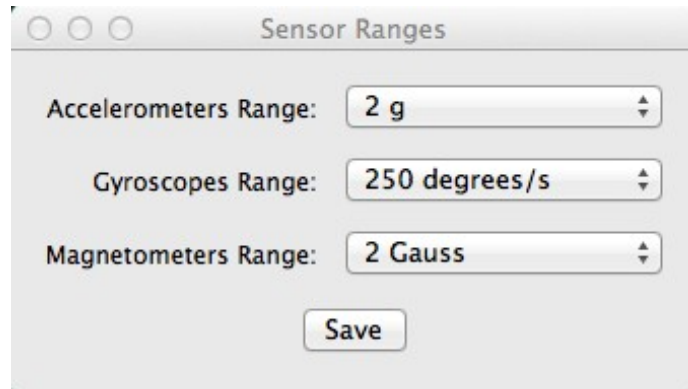


Illustration 45: Screenshot of Spatial Manager sensor ranges dialogue

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.

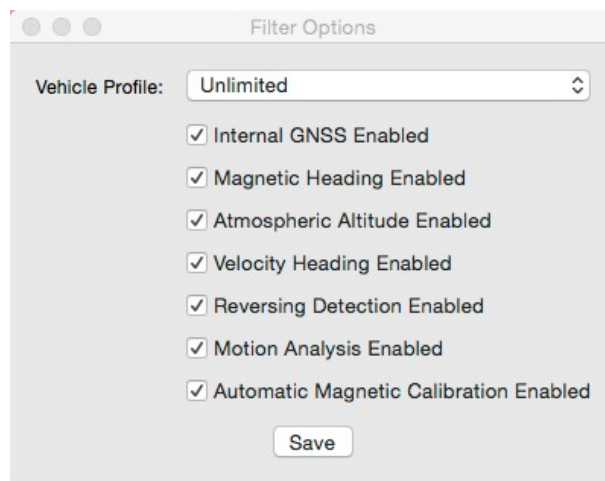
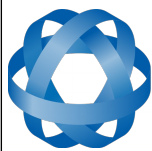


Illustration 46: Screenshot of Spatial Manager filter options dialogue



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 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.

Packet Rates

Packet Timer Period

Period: 1000 Microseconds

Rate: 1000.0 Hz

☒ UTC Synchronisation

Save

Packet Periods

Packet ID	Period	Output Rate
20	50	20.0 Hz
28	200	5.0 Hz

Save

Illustration 47: Screenshot of Spatial 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.

Section	Parameter	Value	Unit
Alignment Offset	Roll Offset	0.000	Degrees
	Pitch Offset	-0.000	Degrees
	Heading Offset	0.000	Degrees
	Zero Current Orientation (button)		
Odometer Offset	X Offset	0.000	Metres
	Y Offset	0.000	Metres
	Z Offset	0.000	Metres
GNSS Antenna Offset	X Offset	1.800	Metres
	Y Offset	0.000	Metres
	Z Offset	-0.800	Metres
External Data Offset	X Offset	0.000	Metres
	Y Offset	0.000	Metres
	Z Offset	0.000	Metres
Save (button)			

Illustration 48: Screenshot of Spatial Manager alignment configuration dialogue

11.8.5.1 Alignment Offset

If Spatial 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.

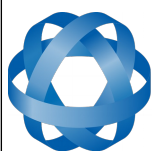
If the unit is installed in a different orientation then the roll, pitch and heading offset must be entered. For example if the unit is installed on its side with the X axis pointing up and the Z axis pointing forwards and no change to the Y axis, then this would result in a pitch offset of +90 degrees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

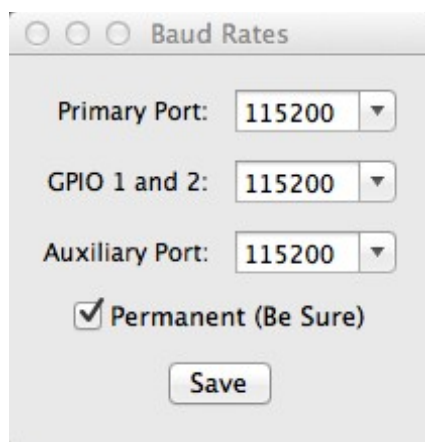
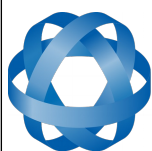


Illustration 49: Screenshot of Spatial Manager baud rates dialogue



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.

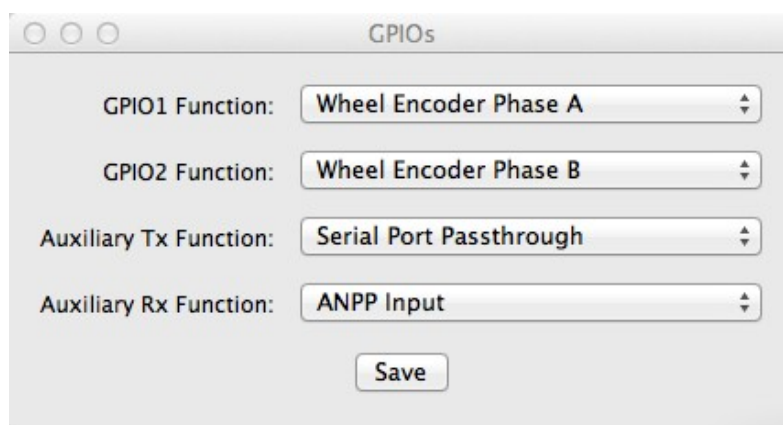


Illustration 50: Spatial Manager GPIO configuration dialogue

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.

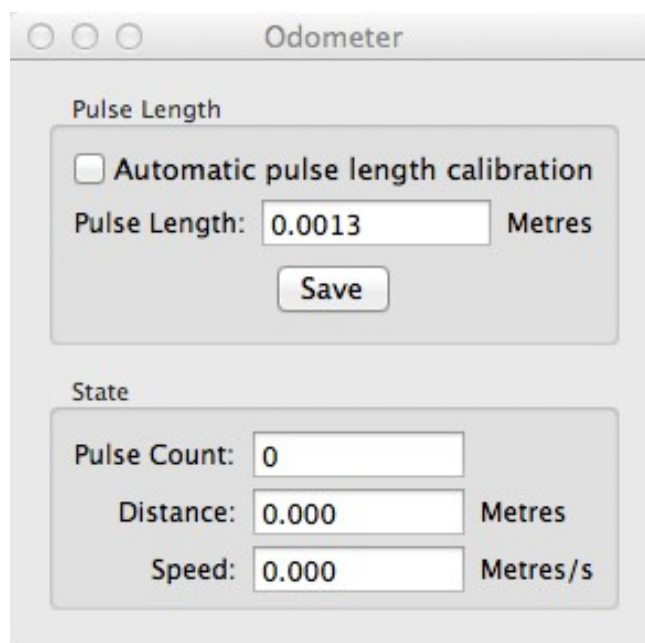
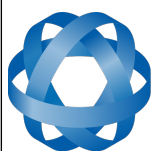
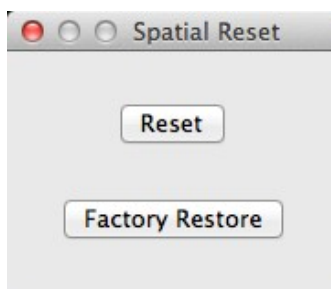


Illustration 51: Screenshot of Spatial Manager odometer configuration dialogue



11.8.9 Reset

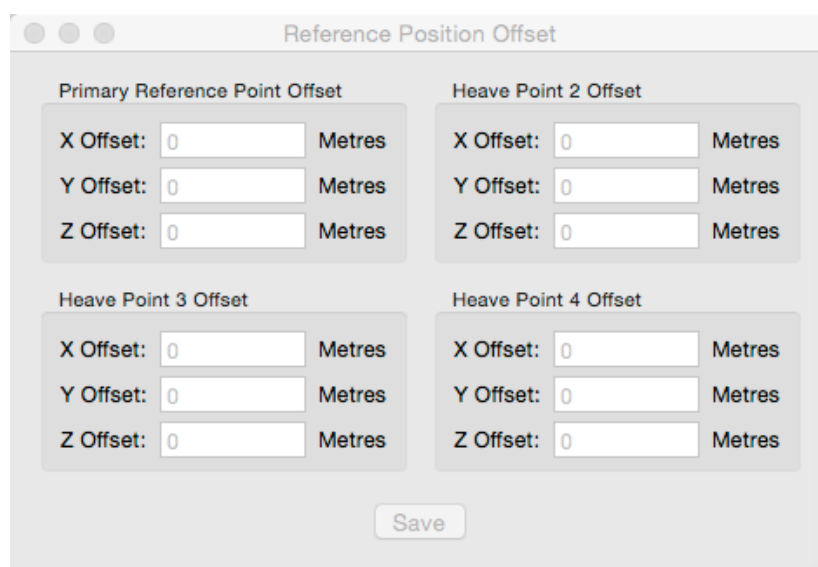
The reset button causes the system to perform a power cycle as if the unit had the power removed and reapplied. The factory restore button causes the system to erase all settings and restore factory defaults. It also erases the hot start data so that the system is forced to perform a cold start.



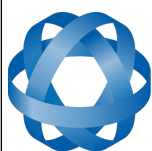
*Illustration 52:
Screenshot of Spatial
Manager reset dialogue*

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 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 53: Screenshot of Spatial Manager reference
position offsets dialogue*



11.8.11 GPIO Output Configuration

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.

GPIO Output

NMEA

Fix Mode: Normal

	GPIO1 Rate	Auxiliary Tx Rate
GPZDA Rate:	Disabled	Disabled
GPVGA Rate:	Disabled	Disabled
GPVTG Rate:	Disabled	Disabled
GPRMC Rate:	1 Hz	1 Hz
GPHDT Rate:	Disabled	Disabled
GPGLL Rate:	Disabled	Disabled
PASHR Rate:	Disabled	Disabled

TSS

GPIO1 Rate	Auxiliary Tx Rate
1 Hz	1 Hz

Simrad

GPIO1 Rate	Auxiliary Tx Rate
1 Hz	1 Hz

Save

Illustration 54: Screenshot of Spatial Manager GPIO output configuration dialogue



11.8.12 Manual Initialisation

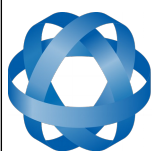
This dialogue can be used to manually initialise Spatial when a GNSS fix is not available. Setting the position will initialise the navigation filter. Setting the heading will initialise the heading.

A screenshot of a software dialog box titled "Manual Initialisation". The dialog has a light gray background and a title bar with standard window controls. It is divided into two main sections: "Position" and "Heading". The "Position" section contains three input fields: "Latitude" with the value "-33.922598", "Longitude" with the value "151.188585", and "Height" with the value "29.058". Each input field is followed by its unit: "Degrees" for Latitude and Longitude, and "Metres" for Height. Below these fields is a "Save" button. The "Heading" section contains one input field with the value "288.643", followed by the unit "Degrees", and a "Save" button below it.

Position	
Latitude:	-33.922598 Degrees
Longitude:	151.188585 Degrees
Height:	29.058 Metres

Heading	
	288.643 Degrees

Illustration 55: Screenshot of Spatial Manager manual initialisation dialogue



11.8.13 Gimbal

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

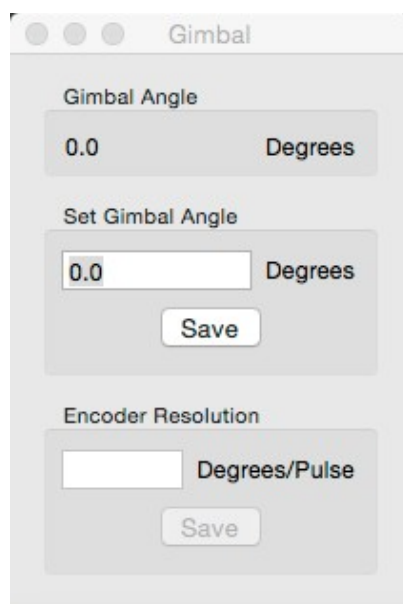


Illustration 56: Screenshot of Spatial Manager gimbal dialogue

11.9 Tools

The tools menu contains tools for performing procedures with Spatial.

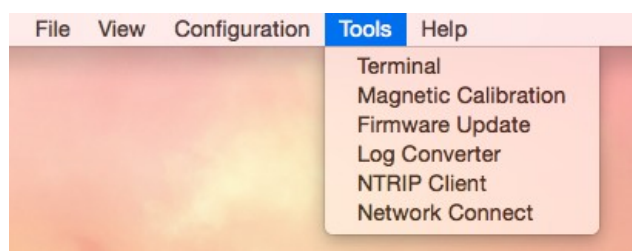
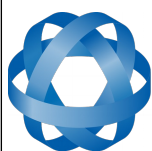


Illustration 57: Screenshot of Spatial Manager tools menu

11.9.1 Terminal

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



11.9.2 Magnetic Calibration

The magnetic calibration dialogue allows the user to perform magnetic calibration as well as view and modify the magnetic calibration values. The actual magnetic calibration is performed inside the Spatial unit. This dialogue does not have any smarts, it is just a control and display interface.

Magnetic Calibration

Calibration Process

Status: 3D Calibration Completed

Progress:

Error: 4 %

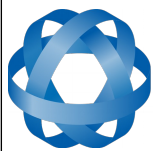
Calibration Values

Hard Iron:		Soft Iron:		
X:	<input type="text" value="-150.008"/>	<input type="text" value="1.057"/>	<input type="text" value="0.013"/>	<input type="text" value="0.005"/>
Y:	<input type="text" value="-48.334"/>	<input type="text" value="0.013"/>	<input type="text" value="1.078"/>	<input type="text" value="-0.018"/>
Z:	<input type="text" value="30.307"/>	<input type="text" value="0.005"/>	<input type="text" value="-0.018"/>	<input type="text" value="0.991"/>

World Magnetic Model Local Field

X: 241.765	mG	Declination: 12.545	Degrees
Y: 53.797	mG	Inclination: -64.826	Degrees
Z: -514.378	mG		

Illustration 58: Screenshot of Spatial Manager magnetic calibration dialogue



11.9.3 Firmware Update

The firmware update dialogue is used to update Spatial'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.

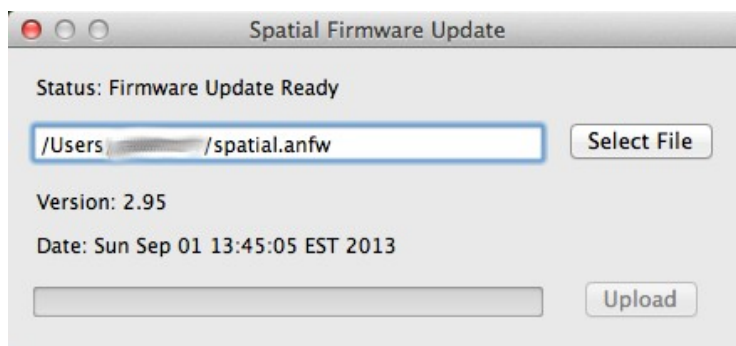


Illustration 59: Screenshot of Spatial Manager firmware update dialogue

11.9.4 Log Converter

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

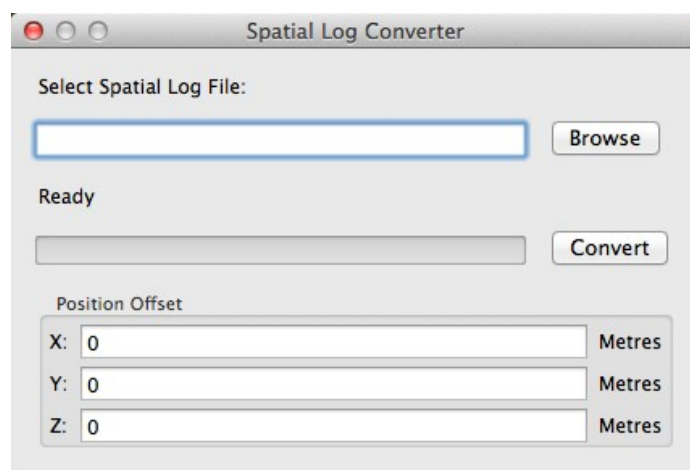
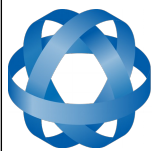


Illustration 60: Screenshot of Spatial Manager log converter dialogue



11.9.5 NTRIP Client

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

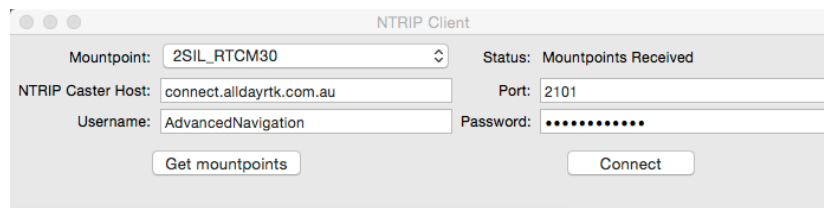


Illustration 61: Screenshot of Spatial Manager NTRIP client dialogue

11.9.6 Network Connect

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

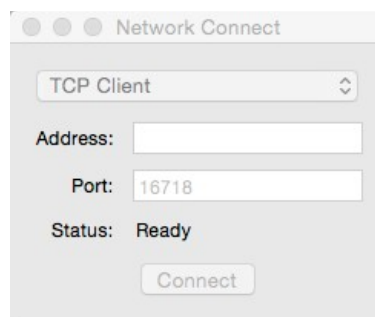


Illustration 62: Screenshot of Spatial Manager network connect dialogue

12 Interfacing

12.1 Communication

All communication to the Spatial module is over the RS232 interface in the Advanced Navigation Packet Protocol (ANPP). The RS232 format is fixed at 1 start bit, 8 data bits, 1 stop bit and no parity. See section 13 for details on the protocol.

12.1.1 Baud Rate

The default baud rate of Spatial is 115200. The baud rate can be set anywhere from 100 to 1000000 baud and can be modified using the Spatial Manager software or the baud rate 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 is set to send. See packet rates in section 13.5 for more details on 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, heading, time, depth and pitot pressure can be integrated into Spatial's filter solution. The data can be sent to Spatial in the ANPP format over the main RS232 port or through one of the GPIO pins in a number of different formats. If using the ANPP, please use Table 17 below to find the relevant section. If using the GPIOs, 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	13.9.40
External Air Data	13.9.41

Table 17: ANPP External Data Reference

12.3 GPIO Pins and Auxiliary RS232

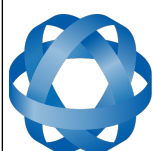
Spatial contains two general purpose input output pins and an auxiliary RS232 port on the main connector. These pins are multi function and can be used to extend Spatial with additional peripherals, sensors and data formats. Both GPIO pins have digital

input, digital output, frequency input and frequency output functionality. Additionally GPIO1 can function as an RS232 serial transmit line and GPIO2 can act as an RS232 serial receive line. The GPIO serial and auxiliary RS232 baud rate can be configured anywhere from 1200 to 1000000 baud by using the baud rate configuration dialogue in Spatial Manager.

The GPIO pins and auxiliary RS232 functions available are listed below in section 12.4. The function of a GPIO pin can be changed at any time using the GPIO configuration dialogue in Spatial Manager. GPIO 1 and GPIO 2 function at 0 - 5 volt levels for digital input, digital output, frequency input and frequency output. 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	
GNSS Fix Output	Digital Output	All	
Odometer Input	Frequency Input	All	
Stationary Input	Digital Input	All	
Pitot Tube Input	Frequency Input	All	
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 Magnetometers	Digital Input	All	
Disable GNSS	Digital Input	All	
Disable Pressure	Digital Input	All	
Set Zero Orientation Alignment	Digital Input	All	
System State Packet Trigger	Digital Input	All	
Raw Sensors Packet Trigger	Digital Input	All	
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
Left Wheel Speed Sensor	Frequency Input	All	



Function	Type	GPIOs	Auxiliary RS232
Right Wheel Speed Sensor	Frequency Input	All	
1PPS Input	Digital Input	All	
Wheel Speed Sensor	Frequency Input	All	
Wheel Encoder Phase A	Frequency Input	All	
Wheel Encoder Phase B	Frequency Input	All	
Event 1 Input	Digital Input	All	
Event 2 Input	Digital Input	All	
TSS1 Output	Serial Transmit	1	Transmit
Simrad 1000 Output	Serial Transmit	1	Transmit
Simrad 3000 Output	Serial Transmit	1	Transmit
Serial Port Passthrough	Serial	All	All

Table 18: GPIO pin and auxiliary RS232 functions

12.4.1 1PPS Output

In this function, the pin is normally low and pulses high 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 has accurate time or not. It is important to note that when Spatial acquires time corrections from its 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.

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 19: Odometer input specifications

12.4.4 Stationary Input

In this function, a high state indicates to Spatial that the vehicle is stationary. The low state indicates that the vehicle could be moving. 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 GNNGGA	3D position
GPGLL GNGLL	2D position
GPRMC GNRMC	2D position, 2D velocity and coarse time
GPVTG GNVTG	2D velocity
GPHDT GNHDT HEHDT	Heading
GPGSV NGSV	Satellites
GPGSA NGSA	Dilution of Position
GPZDA GNZDA	Time

Table 20: Supported NMEA input messages

12.4.7 NMEA Output

This function outputs a configurable combination of the NMEA messages GPZDA, GPGGA, GPVTG, GPRMC, GPHDT and PASHR at up to 20 Hz. The messages output and the output rate can be configured using the NMEA output configuration dialogue in Spatial Manager. Advanced Navigation recommends against using NMEA where possible due to the inefficiency, inaccuracy and poor error checking of the format. 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 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 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.

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 also used when connecting two Spatial units together, for example when using a USBL.

12.4.12 Disable Magnetometers

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

12.4.13 Disable GNSS

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

12.4.14 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.

12.4.15 Set Zero Orientation Alignment

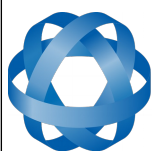
This function accepts a digital input. The input is normally low and a transition from low to high causes Spatial to set its alignment so that the current orientation is zero. Due to the risk of exhausting the flash cycles, the change is not permanent and will disappear on reset. To make it permanent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

12.4.16 System State Packet Trigger

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

12.4.17 Raw Sensors Packet Trigger

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



bouncing if attached to a switch.

12.4.18 RTCM Differential GNSS Corrections Input

This function accepts RTCM SC-104 differential GNSS corrections. This allows for Differential GNSS with Spatial's internal GNSS receiver.

12.4.19 Trimble GNSS Input

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

12.4.21 Hemisphere GNSS Input

This function is designed for interfacing Spatial 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 Left Wheel Speed Sensor

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

12.4.23 Right Wheel Speed Sensor

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

12.4.24 1PPS Input

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

12.4.25 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.



12.4.26 Wheel Encoder Phase A

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

12.4.27 Wheel Encoder Phase B

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

12.4.28 Event 1 Input

This function is designed to allow external events to be recorded inside Spatial'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.

12.4.29 Event 2 Input

This function is designed to allow external events to be recorded inside Spatial'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.

12.4.30 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 Manager, see section 11.8.11.

12.4.31 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 Manager, see section 11.8.11.

12.4.32 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 Manager, see section 11.8.11.

12.4.33 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.

12.4.34 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 is installed in. It should be used in combination with Gimbal Encoder Phase B.



12.4.35 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 is installed in. It should be used in combination with Gimbal Encoder Phase A.

12.4.36 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.

12.4.37 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.

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

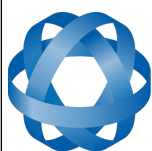
Table 21: Data type abbreviations used in the ANPP

13.2 Packet Structure

The ANPP packet structure is shown in Table 22 and the header format is shown in Table 23. Example code can be downloaded from the software section.

Header				Packet Data
Header LRC	Packet ID	Packet Length	CRC16	

Table 22: 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 23: 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:

$$\text{LRC} = ((\text{packet_id} + \text{packet_length} + \text{crc}[0] + \text{crc}[1]) \wedge 0xFF) + 1$$

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

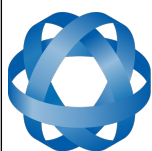
The packet length denotes the length of the packet data, i.e. from byte index 5 onwards inclusive. Packet length has a range of 0 – 255.

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 packet 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, 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.

13.5 Packet Rates

The packet rates can be configured either using Spatial Manager or through the Packets Period Packet. By default Spatial 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

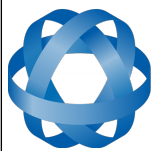
When multiple packets are set to output at the same rate, the order the packets output is from lowest ID to highest ID.

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	-	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	-	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	Raw GNSS Packet
30	13	R	Satellites Packet
31	-	R	Detailed Satellites Packet
32	24	R	Geodetic Position Packet
33	24	R	ECEF Position Packet
34	26	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	16	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/W	External Time Packet



Packet ID	Length	R/W	Name
53	8	R/W	External Depth Packet
54	4	R	Geoid Height Packet
55	-	W	RTCM Corrections Packet
56	8	W	External Pitot Pressure Packet
57	12	R/W	Wind Packet
58	16	R	Heave Packet
67	13	W	External Odometer Packet
68	25	W	External Air Data Packet
72	8	R/W	Gimbal State Packet
73	24	R	Automotive Packet
Configuration Packets			
180	4	R/W	Packet Timer Period Packet
181	-	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
189	49	R/W	Magnetic Calibration Values Packet
190	1	W	Magnetic Calibration Configuration Packet
191	3	R	Magnetic Calibration Status 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
198	64	R/W	User Data Packet
199	65	R/W	GPIO Input Configuration Packet

Table 24: 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 25: Acknowledge packet

13.8.1.1 Acknowledge Result

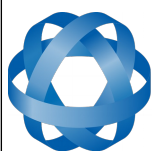
Value	Description
0	Acknowledge success
1	Acknowledge failure, CRC error
2	Acknowledge failure, packet size incorrect
3	Acknowledge failure, values outside of valid ranges
4	Acknowledge failure, system flash memory failure
5	Acknowledge failure, system not ready
6	Acknowledge failure, unknown packet

Table 26: 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 27: 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 28: Boot mode packet

13.8.3.1 Boot Mode Types

Value	Description
0	Bootloader
1	Main Program

Table 29: 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
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 30: Device information packet

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 31: 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 32: Reset packet

13.8.6.1 Verification Sequence Values

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

Table 33: Verification sequence values

13.8.7 Serial Port Pass-through Packet

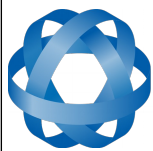
Serial Port Pass-through Packet				
Packet ID		10		
Length		Variable, up to 255 bytes		
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Pass-through route, see section 13.8.7.1
2	1			Pass-through data

Table 34: Serial port pass-through packet

13.8.7.1 Pass-through Routes

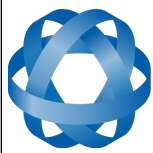
Value	Description
1	GPIO 1 and 2
2	Auxiliary RS232

Table 35: Pass-through routes



13.9 State Packets

Spatial supports a large number of packets providing extensive functionality. However for the majority of users the easiest approach is to configure Spatial using the Spatial 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 (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 36: 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.

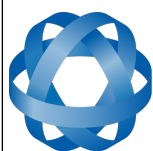


Bit	Description
0	System Failure
1	Accelerometer Sensor Failure
2	Gyroscope Sensor Failure
3	Magnetometer Sensor Failure
4	Pressure Sensor Failure
5	GNSS Failure
6	Accelerometer Over Range
7	Gyroscope Over Range
8	Magnetometer Over Range
9	Pressure Over Range
10	Minimum Temperature Alarm
11	Maximum Temperature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

Table 37: 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	Magnetic Heading Active
11	Velocity Heading Enabled
12	Atmospheric Altitude Enabled
13	External Position Active
14	External Velocity Active
15	External Heading Active

Table 38: 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

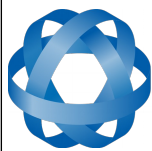
Table 39: GNSS fix status

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 (seconds), see section 13.9.1.4
2	4	u32	4	Microseconds, see section 13.9.1.5

Table 40: 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
7	11	u8	1	Hour, 0 - 23
8	12	u8	1	Minute, 0 - 59
9	13	u8	1	Second, 0 - 59

Table 41: 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 42: Status packet

13.9.5 Position Standard Deviation Packet

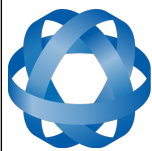
Position Standard Deviation Packet				
Packet ID			24	
Length			12	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Latitude standard deviation (m)
2	4	fp32	4	Longitude standard deviation (m)
3	8	fp32	4	Height standard deviation (m)

Table 43: 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 44: 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 45: 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 46: Quaternion orientation standard deviation packet

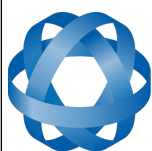
13.9.9 Raw Sensors Packet

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 47: 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)
7	36	fp32	4	Velocity east (m)
8	40	fp32	4	Velocity down (m)
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	Reserved (set to zero)
13	60	fp32	4	Reserved (set to zero)
14	64	fp32	4	Reserved (set to zero)
15	68	fp32	4	Reserved (set to zero)
16	72	u16	2	Status, see section 13.9.10.1

Table 48: 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
6-15	Reserved (set to zero)

Table 49: 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 50: 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 51: 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

Table 52: 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 53: 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 54: 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 55: 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 56: 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 57: 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 58: Body velocity packet

13.9.18 Acceleration Packet

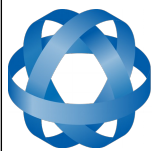
Acceleration Packet				
Packet ID			37	
Length			12	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Acceleration X (m/s/s)
2	4	fp32	4	Acceleration Y (m/s/s)
3	8	fp32	4	Acceleration Z (m/s/s)

Table 59: Acceleration packet

13.9.19 Body Acceleration Packet

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 60: Body acceleration packet



13.9.20 Euler Orientation Packet

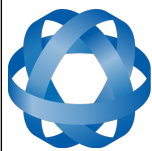
Euler Orientation Packet				
Packet ID			39	
Length			12	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Roll (rad)
2	4	fp32	4	Pitch (rad)
3	8	fp32	4	Heading (rad)

Table 61: 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	Q0
2	4	fp32	4	Q1
3	8	fp32	4	Q2
4	12	fp32	4	Q3

Table 62: Quaternion orientation packet



13.9.22 DCM Orientation Packet

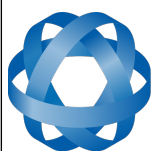
DCM Orientation Packet				
Packet ID				41
Length				36
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	DCM[0][0]
2	4	fp32	4	DCM[0][1]
3	8	fp32	4	DCM[0][2]
4	12	fp32	4	DCM[1][0]
5	16	fp32	4	DCM[1][1]
6	20	fp32	4	DCM[1][2]
7	24	fp32	4	DCM[2][0]
8	28	fp32	4	DCM[2][1]
9	32	fp32	4	DCM[2][2]

Table 63: 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 64: Angular velocity packet



13.9.24 Angular Acceleration Packet

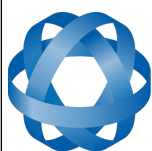
Angular Acceleration Packet				
Packet ID		43		
Length		12		
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Angular acceleration X (rad/s/s)
2	4	fp32	4	Angular acceleration Y (rad/s/s)
3	8	fp32	4	Angular acceleration Z (rad/s/s)

Table 65: 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 66: External position & velocity packet



13.9.26 External Position Packet

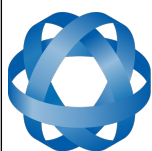
External Position Packet				
Packet ID			45	
Length			36	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp64	8	Latitude (rad)
2	8	fp64	8	Longitude (rad)
3	16	fp64	8	Height (m)
4	24	fp32	4	Latitude standard deviation (m)
5	28	fp32	4	Longitude standard deviation (m)
6	32	fp32	4	Height standard deviation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

Table 67: 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 68: External velocity packet



13.9.28 External Body Velocity Packet

External Body Velocity Packet				
Packet ID		47		
Length		16		
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 standard deviation (m/s)

Table 69: External body velocity packet

13.9.29 External Heading Packet

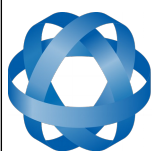
External Heading Packet				
Packet ID		48		
Length		8		
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Heading (rad)
2	4	fp32	4	Heading standard deviation (rad)

Table 70: 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 71: 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 72: Local magnetic field packet

13.9.32 Odometer State Packet

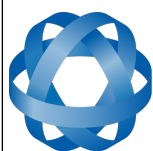
Odometer State Packet				
Packet ID		51		
Length		20		
Field #	Bytes Offset	Data Type	Size	Description
1	0	s32	4	Odometer pulse count
2	4	fp32	4	Odometer distance (m)
3	8	fp32	4	Odometer speed (m/s)
4	12	fp32	4	Odometer slip (m)
5	16	u8	1	Odometer active
6	17		3	Reserved

Table 73: 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 74: 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	fp32	4	Depth (m)
2	4	fp32	4	Depth standard deviation (m)

Table 75: External depth packet

13.9.35 Geoid Height Packet

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

Mean Sea Level Height = Height - Geoid Height

Depth = Geoid Height - Height

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

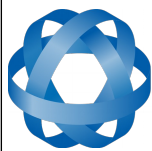
Table 76: Geoid height packet

13.9.36 RTCM Corrections Packet

This packet is used to encapsulate RTCM SC-104 differential correction data to be sent to Spatial's internal GNSS receiver for differential 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 77: RTCM corrections packet



13.9.37 External Pitot Pressure Packet

This packet is used to interface a pitot tube to Spatial for enhanced navigation using aircraft airspeed. The packet should contain differential pressure in pascals. If outside air temperature is available it should be set in the message for increased accuracy, otherwise this field should be set to 15 degrees.

External Pitot Pressure Packet				
Packet ID			56	
Length			8	
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Differential pressure (pascals)
2	4	fp32	4	Outside air temperature (deg C)

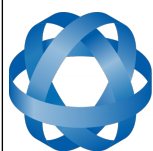
Table 78: External pitot pressure packet

13.9.38 Wind Packet

This packet provides Spatial's current 2D wind velocity. These values are only valid when external air data is provided to Spatial. 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 79: 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 80: Heave packet

13.9.40 External Odometer Packet

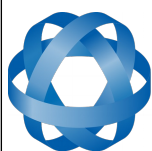
External Odometer Packet				
Packet ID		67		
Length		13		
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Estimated delay (s)
2	4	fp32	4	Speed (m/s)
3	8	fp32	4	Reserved (set to zero)
3	12	u8	1	Odometer flags, see section 13.9.40.1

Table 81: External odometer packet

13.9.40.1 Odometer flags

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

Table 82: Odometer flags

**13.9.41 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 13.9.41.1

*Table 83: External air data packet***13.9.41.1 External Air Data Flags**

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

*Table 84: External air data flags***13.9.41.2 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.

13.9.42 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)

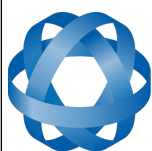
Table 85: Gimbal state packet



13.9.43 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 86: Automotive 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 (stored in RAM), a one indicates that they will be permanent (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 87: Packet timer period packet

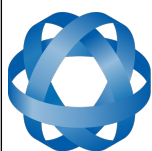
13.10.1.1 UTC Synchronisation

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 = $1000000/(\text{Packet Timer Period})$ 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 88: 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.

$$\text{Packet Rate} = 1000000 / (\text{Packet Period} \times \text{Packet Timer Period}) \text{ Hz}$$

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.

$$\text{Packet 20 Rate} = 1000000 / (50 \times 1000)$$

$$\text{Packet 20 Rate} = 20 \text{ Hz}$$

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	RS232 baud rate (1200 to 1000000)
3	5	u32	4	GPIO 1 & 2 baud rate (1200 to 1000000)
4	9	u32	4	Auxiliary RS232 Baud Rate (1200 to 1000000)
5	13		4	Reserved (set to zero)

Table 89: 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 90: 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 91: Accelerometers range

13.10.4.2 Gyroscopes Range

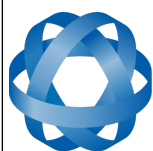
Value	Description
0	250 degrees/second
1	500 degrees/second
2	2000 degrees/second

Table 92: Gyroscopes range

13.10.4.3 Magnetometers Range

Value	Description
0	2 Gauss
1	4 Gauss
2	8 Gauss

Table 93: 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 94: Installation alignment packet

13.10.5.1 Alignment DCM

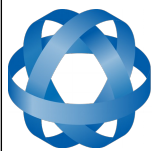
The alignment DCM (direction cosine matrix) is used to represent an alignment offset of Spatial from it's standard alignment. A DCM is used rather than euler angles for accuracy reasons. To convert euler angles to DCM please use the formula below with angles in radians.

$$\text{DCM}[0][0] = \cos(\text{heading}) * \cos(\text{pitch})$$

$$\text{DCM}[0][1] = \sin(\text{heading}) * \cos(\text{pitch})$$

$$\text{DCM}[0][2] = -\sin(\text{pitch})$$

$$\text{DCM}[1][0] = -\sin(\text{heading}) * \cos(\text{roll}) + \cos(\text{heading}) * \sin(\text{pitch}) * \sin(\text{roll})$$


$$\text{DCM}[1][1] = \cos(\text{heading}) * \cos(\text{roll}) + \sin(\text{heading}) * \sin(\text{pitch}) * \sin(\text{roll})$$
$$\text{DCM}[1][2] = \cos(\text{pitch}) * \sin(\text{roll})$$
$$\text{DCM}[2][0] = \sin(\text{heading}) * \sin(\text{roll}) + \cos(\text{heading}) * \sin(\text{pitch}) * \cos(\text{roll})$$
$$\text{DCM}[2][1] = -\cos(\text{heading}) * \sin(\text{roll}) + \sin(\text{heading}) * \sin(\text{pitch}) * \cos(\text{roll})$$
$$\text{DCM}[2][2] = \cos(\text{pitch}) * \cos(\text{roll})$$

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	Magnetometers enabled (boolean)
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	u8	1	Automatic magnetic calibration enabled (boolean)
10	9		8	Reserved (set to zero)

Table 95: 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 96: Vehicle types

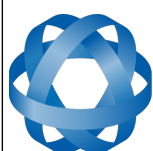
13.10.7 Advanced Filter Parameters Packet

Please contact Advanced Navigation support.

13.10.8 GPIO Configuration Packet

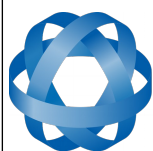
GPIO Configuration Packet				
Packet ID			188	
Length			13	
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u8	1	GPIO1 Function, see section 13.10.8.1
3	2	u8	1	GPIO2 Function, see section 13.10.8.2
4	3	u8	1	Auxiliary RS232 transmit function, see section 13.10.8.3
5	4	u8	1	Auxiliary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

Table 97: GPIO configuration packet

**13.10.8.1 GPIO1 Functions**

Value	Description
0	Inactive
1	1PPS Output
2	GNSS Fix Output
3	Odometer Input
4	Stationary Input
5	Pitot Tube Input
7	NMEA Output
12	ANPP Output
13	Disable Magnetometers
14	Disable GNSS
15	Disable Pressure
16	Set Zero Orientation Alignment
17	System State Packet Trigger
18	Raw Sensors Packet Trigger
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
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

Table 98: GPIO1 functions

**13.10.8.2 GPIO2 Functions**

Value	Description
0	Inactive
1	1PPS Output
2	GNSS Fix Output
3	Odometer Input
4	Stationary Input
5	Pitot Tube Input
6	NMEA Input
8	Novatel GNSS Input
9	Topcon GNSS Input
11	ANPP Input
13	Disable Magnetometers
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
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
42	Serial Port Passthrough
43	Gimbal Encoder Phase A
44	Gimbal Encoder Phase B
45	Odometer Direction, Forward Low
46	Odometer Direction, Forward High

Table 99: GPIO2 functions

13.10.8.3 Auxiliary RS232 Transmit Functions

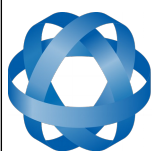
Value	Description
0	Inactive
7	NMEA Output
12	ANPP Output
39	TSS1 Output
40	Simrad 1000 Output
41	Simrad 3000 Output
42	Serial Port Passthrough

Table 100: Auxiliary RS232 transmit functions

13.10.8.4 Auxiliary RS232 Receive Functions

Value	Description
0	Inactive
6	NMEA Input
8	Novatel GNSS Input
9	Topcon GNSS Input
11	ANPP Input
19	RTCM Differential GNSS Corrections Input
20	Trimble GNSS Input
21	u-blox GNSS Input
22	Hemisphere GNSS Input
42	Serial Port Passthrough

Table 101: Auxiliary RS232 receive functions

**13.10.9 Magnetic Calibration Values Packet**

Magnetic Calibration Values Packet				
Packet ID			189	
Length			49	
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	fp32	4	Hard iron bias X
3	5	fp32	4	Hard iron bias Y
4	9	fp32	4	Hard iron bias Z
5	13	fp32	4	Soft iron transformation XX
6	17	fp32	4	Soft iron transformation XY
7	21	fp32	4	Soft iron transformation XZ
8	25	fp32	4	Soft iron transformation YX
9	29	fp32	4	Soft iron transformation YY
10	33	fp32	4	Soft iron transformation YZ
11	37	fp32	4	Soft iron transformation ZX
12	41	fp32	4	Soft iron transformation ZY
13	45	fp32	4	Soft iron transformation ZZ

*Table 102: Magnetic calibration values packet***13.10.10 Magnetic Calibration Configuration Packet**

Magnetic Calibration Configuration Packet				
Packet ID			190	
Length			1	
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Magnetic calibration action, see section 13.10.10.1

Table 103: Magnetic calibration configuration packet

13.10.10.1 Magnetic Calibration Actions

Value	Description
0	Cancel magnetic calibration
2	Start 2D magnetic calibration
3	Start 3D magnetic calibration
4	Reset calibration to defaults

Table 104: Magnetic calibration actions

13.10.11 Magnetic Calibration Status Packet

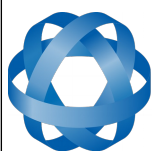
Magnetic Calibration Status Packet				
Packet ID			191	
Length			3	
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Magnetic calibration status, see section 13.10.11.1
2	1	u8	1	Magnetic calibration progress (%)
3	2	u8	1	Local magnetic error (%)

Table 105: Magnetic calibration status packet

13.10.11.1 Magnetic Calibration Status

Value	Description
0	Magnetic calibration not completed
1	2D magnetic calibration completed
2	3D magnetic calibration completed
3	Custom values magnetic calibration completed
5	2D calibration in progress
6	3D calibration in progress
7	2D calibration error: excessive roll
8	2D calibration error: excessive pitch
9	Calibration error: sensor over range event
10	Calibration error: time-out
11	Calibration error: system error
12	Calibration error: interference error

Table 106: Magnetic calibration status



13.10.12 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)
5	4	fp32	4	Pulse length (m)

Table 107: Odometer configuration packet

13.10.13 Set Zero Orientation Alignment Packet

This packet was modified as of firmware version 4.0 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 108: Set zero orientation alignment packet

13.10.14 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 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 109: Reference point offsets packet

13.10.15 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 13.10.15.1
3	2	u16	2	GPZDA Rates, see section 13.10.15.2
4	4	u16	2	GPGGA Rates, see section 13.10.15.2
5	6	u16	2	GPVTG Rates, see section 13.10.15.2
6	8	u16	2	GPRMC Rates, see section 13.10.15.2
7	10	u16	2	GPHTD Rates, see section 13.10.15.2
8	12	u16	2	GPGLL Rates, see section 13.10.15.2
9	14	u16	2	PASHR Rates, see section 13.10.15.2
10	16	u16	2	TSS1 Rates, see section 13.10.15.2
11	18	u16	2	Simrad Rates, see section 13.10.15.2
12	20		12	Reserved (set to zero)

Table 110: GPIO output configuration packet

13.10.15.1 NMEA Fix Behaviour

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

Table 111: NMEA fix behaviour

13.10.15.2 GPIO Output Rates

Bit	Description
0-3	GPIO 1 rate, see 13.10.15.3
4-7	Auxiliary RS232 Tx rate, see 13.10.15.3
8-15	Reserved (set to zero)

Table 112: GPIO output rates

13.10.15.3 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 113: GPIO output rates index

13.10.16 User Data Packet

This packet allows the user to store their own data in Spatial's non-volatile FLASH. This data is not used by Spatial. The data will be reset to all zeros when restoring to factory defaults.

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

Table 114: User data packet

13.10.17 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 115: GPIO input configuration packet



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