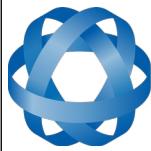


**ADVANCED  
NAVIGATION**

# **Spatial Reference Manual**



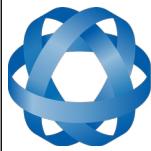


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## 1 Revision History

| Version | Date       | Changes   |
|---------|------------|---|
| 4.4     | 04/06/2019 | <p>Updated firmware changelog, section 2</p> <p>Updated hardware changelog, section 3</p> <p>Updated dynamic pin functions table, section 12.4</p> <p>Updated GPIO configuration packet, section 13.10.8</p> <p>Added pressure depth transducer deprecated input function 12.4.18</p> <p>Added Nortek DVL input function 12.4.27</p> <p>Added Teledyne DVL input function 12.4.23</p> <p>Added Tritech USBL input function 12.4.24</p> <p>Added Linkquest DVL input function 12.4.25</p> <p>Added Linkquest USBL input functionality 12.4.26</p> <p>Added reverse alignment input functions 12.4.45</p> <p>Added zero angular velocity input function 12.4.47</p> <p>Clarified port baud rates in sections 8.5, 12.1, 12.3 and 13.10.3</p> <p>Updated read status for external air data packet, section 13.7</p> <p>Updated read status for external odometer packet, section 13.7</p> <p>Modified quaternion element labels, sections 13.9.8 and 13.9.21</p> <p>Clarified geoid height packet description, section 13.9.35</p> <p>Removed external pitot pressure packet, section 13.9.37</p> <p>Updated external body velocity packet size and definition 13.9.28</p> <p>Updated specifications, section 8</p> <p>Added RTK information, sections 10.12, 12.4.19</p> <p>Added wheel speed sensor specifications, section 12.4.31</p> <p>Corrected Raw GNSS packet velocity units, section 13.9.10</p> <p>Updated GPIO output configuration packet, section 13.10.15</p> <p>Clarified negative acknowledgement packets, section 13.8.1</p> <p>Clarified 1PPS output voltages, section 12.4.1</p> |
| 4.3     | 30/01/2017 | <p>Updated firmware changelog, section 2</p> <p>Updated hardware changelog, section 3</p> <p>Added raw satellite data operation, section 10.13</p> <p>Added post processing operation, section 10.14</p> <p>Added raw satellite data packet, section 13.9.41</p>  |
| 4.2     | 12/04/2016 | <p>Updated firmware changelog, section 2</p> <p>Updated hardware changelog, section 3</p> <p>Updated images in foundation knowledge, section 5</p> <p>Added antenna offset diagrams, section 9.5</p> <p>Updated Spatial Manager changelog, section 11.1</p>   |



| Version | Date       | Changes   |
|---------|------------|---|
|         |            | Updated sensor specifications with more detail, section 8.3   |
| 4.1     | 24/05/2015 | <p>Updated firmware changelog, section 2</p> <p>Updated hardware changelog, section 3</p> <p>Updated axes image, section 5.5</p> <p>Added part numbers and ordering information, section 7</p> <p>Updated optional breakout cable, section 8.11</p> <p>Updated power consumption graph, section 8.8</p> <p>Updated 2D magnetic calibration procedure, section 10.5.1</p> <p>Updated automatic magnetic calibration, section 10.5.3</p> <p>Added differential GNSS, section 10.12</p> <p>Updated Spatial Manager changelog, section 11.1</p> <p>Added gimbal encoder phase a function, section 12.4.41</p> <p>Added gimbal encoder phase b function, section 12.4.42</p> <p>Added odometer direction, forward low, section 12.4.43</p> <p>Added odometer direction, forward high, section 12.4.44</p> <p>Updated reset packet, section 13.8.6</p> <p>Updated UTM position packet, section 13.9.15</p> <p>Added gimbal state packet, section 13.9.44</p> <p>Added automotive packet, section 13.9.45</p> <p>Heave offsets packet changed name to reference point offsets packet, format remains the same, section 13.10.14</p> <p>Added user data packet, section 13.10.16</p> <p>Added GPIO input configuration packet, section 13.10.17</p> <p>Fixed a document heading spacing issue</p> |
| 4.0     | 18/09/2014 | <p>Added firmware changelog, section 2</p> <p>Added hardware changelog, section 3</p> <p>Updated GNSS specifications for version 3.0 hardware, section 8.4</p> <p>Updated connector pin-out to include pink wire, section 8.9</p> <p>Added evaluation kit USB cable, section 8.10</p> <p>Added optional breakout cable, section 8.11</p> <p>Added serial number information, section 8.13</p> <p>Updated GNSS antenna, section 9.5</p> <p>Updated OBDII Odometer, section 9.6.2</p> <p>Updated initialisation with more information, section 10.1</p> <p>Updated hot start for clarity, section 10.2</p> <p>Updated 2D magnetic calibration procedure for clarity, section 10.5.2.1</p> <p>Updated 3D magnetic calibration procedure for clarity, section 10.5.2.1</p> <p>Updated all screenshots in Spatial Manager, section 11</p> <p>Updated Spatial Manager changelog, section 11.1</p> <p>Updated Spatial Manager Linux troubleshooting, section 11.4.3</p> <p>Added Spatial Manager 3D model, section 11.7.8</p> <p>Added Spatial Manager communications statistics, section 11.7.9</p>   |



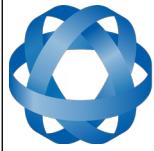
| Version | Date       | Changes   |
|---------|------------|---|
|         |            | <p>Added Spatial Manager GPIO output configuration, section 11.8.11</p> <p>Added Spatial Manager position configuration, section 11.8.12</p> <p>Added serial port pass-through GPIO function, section 12.4.39</p> <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 13.9.42</p> <p>Added external air data packet, section 13.9.43</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 10.10</p> <p>Added motion analysis, section 10.11</p> <p>Updated 3D magnetic calibration procedure, section 10.5.2</p> <p>Added automatic magnetic calibration, section 10.5.3</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 12.4.31</p> <p>Added wheel encoder phase A function, section 12.4.32</p> <p>Added wheel encoder phase B function, section 12.4.33</p> <p>Added event 1 input, section 12.4.34</p> <p>Added event 2 input, section 12.4.35</p> <p>Added TSS1 output, section 12.4.36</p> <p>Added Simrad 1000 output, section 12.4.37</p> <p>Added Simrad 3000 output, section 12.4.38</p> <p>Updated filter status, section 13.9.1.2</p> |



| Version | Date       | Changes  |
|---------|------------|--|
|         |            | <p>Added GNSS fix status, section 13.9.1.3</p> <p>Updated baud rates packet, section 13.10.3</p> <p>Updated filter options packet, section 13.10.6</p> <p>Updated GPIO configuration packet, section 13.10.8</p> <p>Added NMEA output configuration packet, section 13.10.15</p>   |
| 2.7     | 27/03/2013 | <p>Added additional magnetic information, section 10.5</p> <p>Added 1PPS input, section 12.4.30</p> <p>Updated detailed satellites packet, section 13.9.12</p> <p>Corrected geoid height packet, section 13.9.35</p>   |
| 2.6     | 29/01/2013 | <p>Added heave information, section 10.17</p> <p>Added RTCM corrections packet, section 13.9.36</p> <p>Added external pitot pressure packet, section 13.9.37</p> <p>Added wind estimation packet, section 13.9.38</p> <p>Added heave packet, section 13.9.39</p> <p>Added heave configuration packet, section 13.10.14</p>   |
| 2.5     | 07/12/2012 | <p>Added input voltage range to electrical specifications, section 8.7</p> <p>Added left wheel speed sensor input, section 12.4.28</p> <p>Added right wheel speed sensor input, section 12.4.29</p> <p>Added external time packet, section 13.9.33</p> <p>Added external depth packet, section 13.9.34</p> <p>Added geoid height packet, section 13.9.35</p> <p>Updated GPIO functions tables, section 13.10.8</p>   |
| 2.3     | 06/12/2012 | <p>Yaw terminology changed to heading for increased clarity</p> <p>Reworded installation magnetics for increased clarity, section 9.7</p> <p>Reworded initialisation for increased clarity, section 10.1</p> <p>Reworded operation magnetics for increased clarity, section 10.5</p> <p>Added vehicle profiles information, section 10.8</p> <p>Updated NMEA output, section 12.4.7</p>  |
| 2.2     | 19/11/2012 | <p>Installation magnetics changed, section 9.7</p> <p>Heading source added, section 10.4</p> <p>Disabling magnetometers changed, section 10.5.4</p> <p>GPIO information updated, section 12.3</p> <p>Added NMEA input GPGLL support, section 12.4.6</p> <p>Added NMEA input GPHDT support, section 12.4.6</p> <p>Added NMEA input HEHDT support, section 12.4.6</p> <p>Updated NMEA output, section 12.4.7</p> <p>Added RTCM corrections input, section 12.4.19</p> <p>Added Trimble GNSS input, section 12.4.20</p> <p>Added u-blox GNSS input, section 12.4.21</p> <p>Added Hemisphere GNSS input, section 12.4.22</p> <p>Updated GPIO functions tables, section 13.10.8</p> |
| 2.1     | 30/10/2012 | Sensor specifications updated, section 8.3   |



| Version | Date       | Changes   |
|---------|------------|---|
|         |            | Fixed error in odometer state packet, section 13.9.32   |
| 2.0     | 18/10/2012 | <p>Added information on sensor calibration, section 8.12</p> <p>Added odometer installation information, section 9.6</p> <p>Added hot start information, section 10.2</p> <p>Added time information, section 10.3</p> <p>Added odometer pulse length information, section 10.9</p> <p>Added RAIM information, section 10.16</p> <p>Updated Odometer input, section 12.4.3</p> <p>Updated NMEA output, section 12.4.7</p> <p>Added disable magnetometers GPIO function, section 12.4.12</p> <p>Added disable GNSS GPIO function, section 12.4.13</p> <p>Added disable pressure GPIO function, section 12.4.14</p> <p>Added set zero alignment GPIO function, section 12.4.15</p> <p>Added system state packet trigger GPIO function, section 12.4.16</p> <p>Added raw sensors packet trigger GPIO function, section 12.4.17</p> <p>Updated acknowledge packet, section 13.8.1</p> <p>Added running time packet, section 13.9.30</p> <p>Added local magnetic field packet, section 13.9.31</p> <p>Added odometer state packet, section 13.9.32</p> <p>Updated installation alignment packet, section 13.10.5</p> <p>Fixed error in filter options packet, section 13.10.6</p> <p>Updated GPIO configuration packet, section 13.10.8</p> <p>Added odometer configuration packet, section 13.10.12</p> <p>Added set zero orientation alignment packet, section 13.10.13</p> |
| 1.0     | 16/09/2012 | <p>1PPS description updated, section 12.4.1</p> <p>Corrected reset packet, section 13.8.6</p> <p>Corrected external body velocity packet, section 13.9.28</p> <p>Revised alignment packet, section 13.10.5</p> <p>Grammar and spelling corrections</p>  |
| 0.6     | 31/08/2012 | <p>Grammar corrections throughout</p> <p>Spelling corrections throughout</p> <p>Updated 3D magnetic calibration, section 10.5.2</p>   |
| 0.5     | 28/08/2012 | <p>Corrected satellite indexes, section 13.9.12.1</p> <p>Added navigation specifications, section 8.2</p> <p>Added sensor specifications, section 8.3</p> <p>Added GNSS specifications, section 8.4</p> <p>Added communication specifications, section 8.5</p> <p>Added hardware specifications, section 8.6</p>  |
| 0.4     | 23/08/2012 | <p>Clarified anti aliasing, section 10.7</p> <p>Added external data, section 12.2</p> <p>Added GPIO information, section 12.3</p> <p>Added GPIO configuration packet, section 13.10.8</p>   |



| Version | Date       | Changes  |
|---------|------------|--|
| 0.3     | 11/08/2012 | Magnetic calibration values packet corrected<br>Incorrect length fixed on several packets<br>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

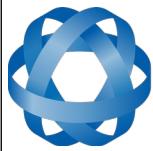
| Version | Date       | Changes   |
|---------|------------|---|
| 5.4     | 31/05/2019 | Fixed regression with integrity monitoring introduced in version 5.3  |
| 5.3     | 07/05/2019 | Improvements to INS performance in urban canyons<br>Improvements to odometer aided navigation<br>Significant improvements to step detection and stride estimation in the Human vehicle profile<br>Added support for u-blox Z9P protocol changes<br>World magnetic model updated to WMM2015v2<br>Added zero angular velocity GPIO input<br>Improvements to water height estimation algorithm<br>Online odometer scaling now adjusts for up to 5% scaling error |
| 5.2     | 14/12/2018 | Support for hardware version 7.0  |
| 5.1     | 30/01/2017 | Improvements to raw satellite data output<br>Improvements to GNSS hot start time<br>Bug fix where “GNSS Failure” could occur for 1 second under specific satellite conditions   |
| 5.0     | 20/12/2016 | Support added for raw satellite data output<br>Bug fix where hardware v2.0 could experience accelerometer and gyroscope failure   |
| 4.5     | 17/10/2016 | Support for hardware version 6.1 added  |
| 4.3     | 21/06/2016 | Maximum baud rate increased to 2,000,000<br>1PPS output and input timing improvements<br>Packet timing jitter improvements<br>New multipath mitigation algorithm provides significant performance improvements in poor signal areas<br>Bug fix for magnetometer and pressure sensor false failure indications after saving configuration  |
| 4.2     | 12/04/2016 | Performance improvements<br>Added support for GPROT and GPHEV<br>Added support for raw GNSS packet input<br>Bug fix for NMEA mode character indicating incorrectly<br>Bug fix for incorrectly indicated over temperature<br>Bug fix for RS232 electronic slew control<br>SBAS is now enabled by default   |
| 4.15    | 22/06/2015 | Support for hardware version 5.1 added  |
| 4.1     | 22/04/2015 | Support for hardware version 5.0 added<br>Enhanced odometer hot start dead reckoning performance<br>Overhauled 2D magnetic calibration algorithm offers improved 2D magnetic calibration<br>Overhauled automatic magnetic calibration algorithm now   |



| Version | Date       | Changes  |
|---------|------------|--|
|         |            | <p>much more robust and enabled by default</p> <p>Bug fix with serial port passthrough incorrect port ID</p> <p>New tightly coupled heave filter operating at 1000Hz</p> <p>Improved hot start performance and functionality</p> <p>New algorithm for use inside gimbals (requires encoder)</p> <p>More robust time acceptance from external sources</p> <p>NMEA time is now perfectly aligned to the millisecond</p> <p>Support for offsetting reference position of output data</p> <p>Improved handling of leap second change during operation</p> <p>Virtual odometer distance filter added</p> <p>Slip filter added</p> <p>Bug fix for differential corrections being sent to GNSS receiver before initialised causing issues</p> <p>Updated world magnetic model to 2015 version</p> <p>Improved reversing detection filter</p> <p>Added gimbal state and configuration packets</p> <p>Added automotive packet</p> <p>Added race car vehicle profile</p> |
| 4.0     | 18/09/2014 | <p>Added support for new hardware version 4.0</p> <p>Significant filter performance improvements under high dynamics</p> <p>Improved filter performance under dead reckoning</p> <p>Improved performance in urban canyon conditions where a GNSS fix is rarely available</p> <p>Improvements to car and fixed wing plane vehicle profiles</p> <p>Improvements to delay compensation filter</p> <p>Raw GNSS packet updated to new format</p> <p>GPIO output configuration packet updated</p> <p>Support for external odometer added</p> <p>Support for external air data added</p> <p>Wind estimation filter improvements</p> <p>Wind packet input support</p> <p>Added stunt plane vehicle profile</p> <p>Added support for serial port passthrough</p> <p>GPIO data output now up to 50Hz</p>   |
| 3.1     | 10/04/2014 | <p>Updated internal AN RTOS to v4.0</p> <p>Added TSS1 output support</p> <p>Added Simrad 1000 output support</p> <p>Added Simrad 3000 output support</p> <p>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)</p>   |
| 3.0     | 17/09/2013 | <p>Added support for new hardware version 3.0</p> <p>Enhanced odometer algorithms</p> <p>Automatic magnetic calibration algorithm added</p>  |



| Version | Date       | Changes   |
|---------|------------|---|
| 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<br>Added experimental post-processing support<br>Issue with RTCM GPIO corrections resolved<br>Detailed satellites packet modified<br>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<br>Added heave filter<br>Added EGM96 geoid model<br>Added dual odometer input support<br>Added Linkquest DVL input support<br>Added pressure depth transducer input support<br>Added external time packet<br>Added external depth packet<br>Added geoid height packet<br>Added RTCM corrections packet<br>Added external pitot pressure packet<br>Added wind estimation packet<br>Added heave packet<br>Added heave offset packet  |
| 2.1     | 11/12/2012 | Better reversing detection for velocity heading when magnetometers are disabled<br>Car vehicle profile enhancements<br>3D underwater vehicle profile enhancements<br>NMEA output GPRMC updated to be v2.3 compliant<br>NMEA output GPHDT added<br>NMEA output changed to 10Hz<br>NMEA input added GPGLL support<br>NMEA input added GPHDT support<br>NMEA input added HEHDT support<br>Added RTCM corrections input support<br>Added Trimble GNSS input support<br>Added u-blox GNSS input support<br>Added Hemisphere GNSS input support<br>Added Teledyne DVL input support<br>Added Tritech USBL input support |
| 2.0     | 23/10/2012 | Enhanced odometer reversing detection<br>Odometer automatic calibration now has stricter conditions and will restart the calibration to prevent erroneous   |



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

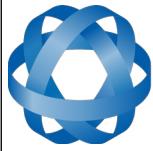
Table 2: Firmware changelog



### 3 Hardware Changelog

| Version | Date       | Changes  |
|---------|------------|--|
| 7.0     | 25/05/2017 | GNSS receiver changed to u-blox M8P which supports RTK   |
| 6.1     | 05/10/2016 | GNSS receiver changed to u-blox M8T which supports raw satellite data output for use with post-processing software. Antenna disconnected detection changed to antenna short circuit detection. |
| 5.1     | 20/10/2015 | Minor internal improvements<br>No noticeable changes for customers   |
| 5.0     | 01/02/2015 | GPIO pins now automatically switch from TTL levels to RS232 levels when operating as data functions<br>Slew rate control on RS232 automatically changes based upon baud rate setting           |
| 4.0     | 10/08/2014 | Internal GNSS receiver changed to the new u-blox M8 which provides increased multipath performance   |
| 3.0     | 17/09/2013 | New gyroscopes<br>New accelerometers<br>Connector changed to ODU<br>GPIO 3 and GPIO 4 became Auxiliary RS232 Tx and Rx<br>Dimensions increased   |
| 2.0     | 10/01/2013 | Minor internal improvements<br>No noticeable changes for customers   |
| 1.0     | 08/05/2013 | Initial release  |

Table 3: Hardware changelog



## 4 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 its 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](mailto:support@advancednavigation.com.au).



## 5 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.

### 5.1 GNSS

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

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

### 5.2 INS

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

### 5.3 GNSS/INS

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

### 5.4 AHRS

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



## 5.5 The Sensor Co-ordinate Frame

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

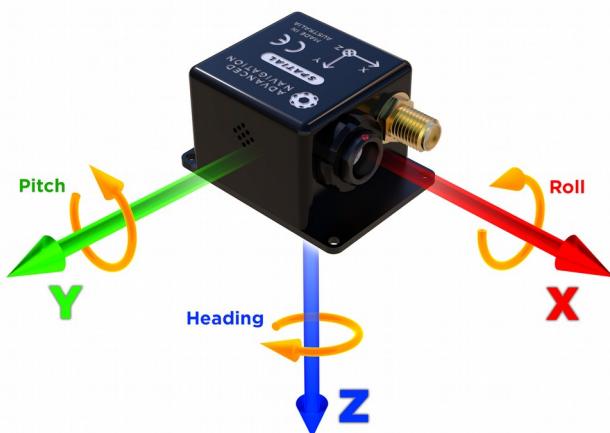


Illustration 1: Spatial axes

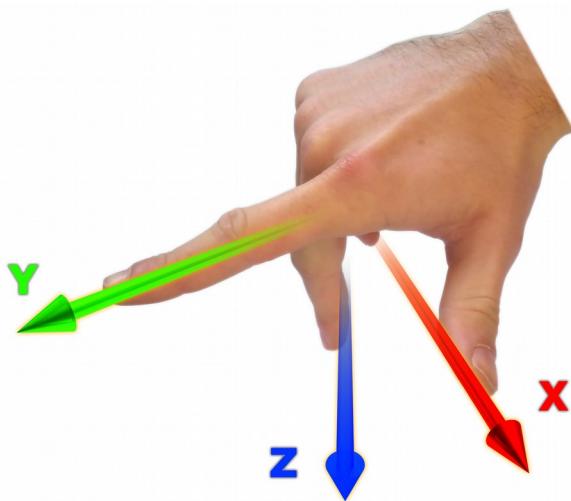


Illustration 2: First right hand rule

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

## 5.6 Roll, Pitch and Heading

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

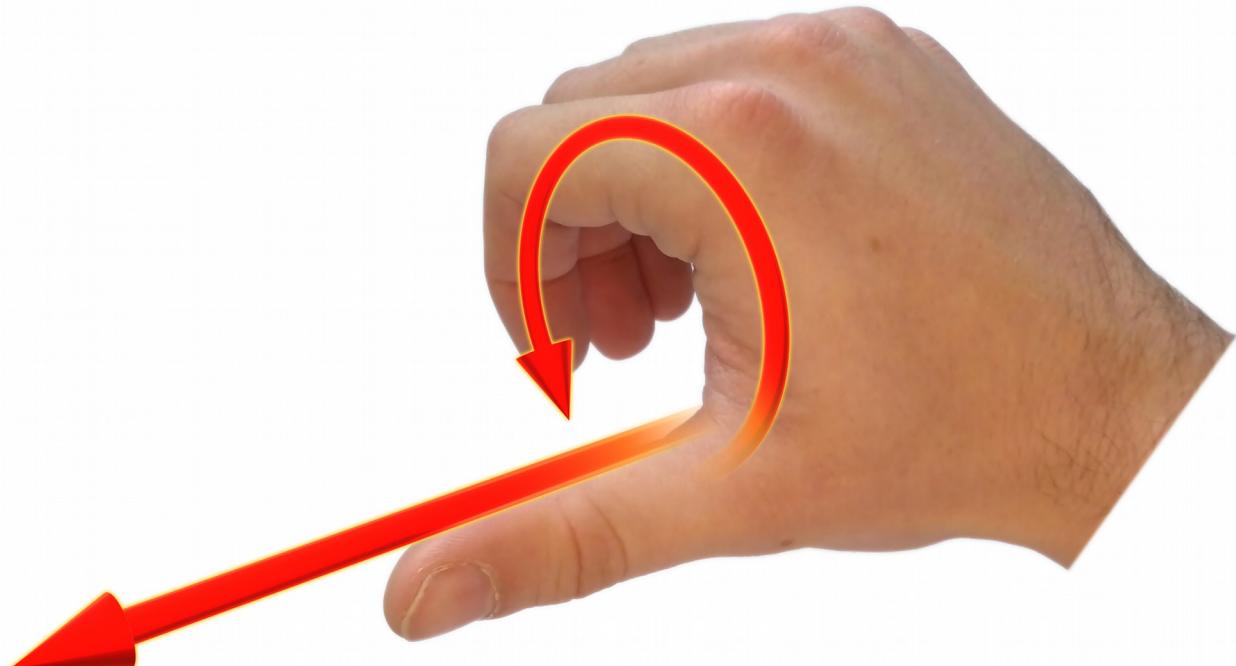
Roll is the angle around the X axis and is zero when the unit is level. Pitch is the angle around the Y axis and is zero when the unit is level. Heading is the angle around the Z axis and is zero when the positive X axis is pointing to true north.

### 5.6.1 Second Right Hand Rule

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



positive rotation on that axis.



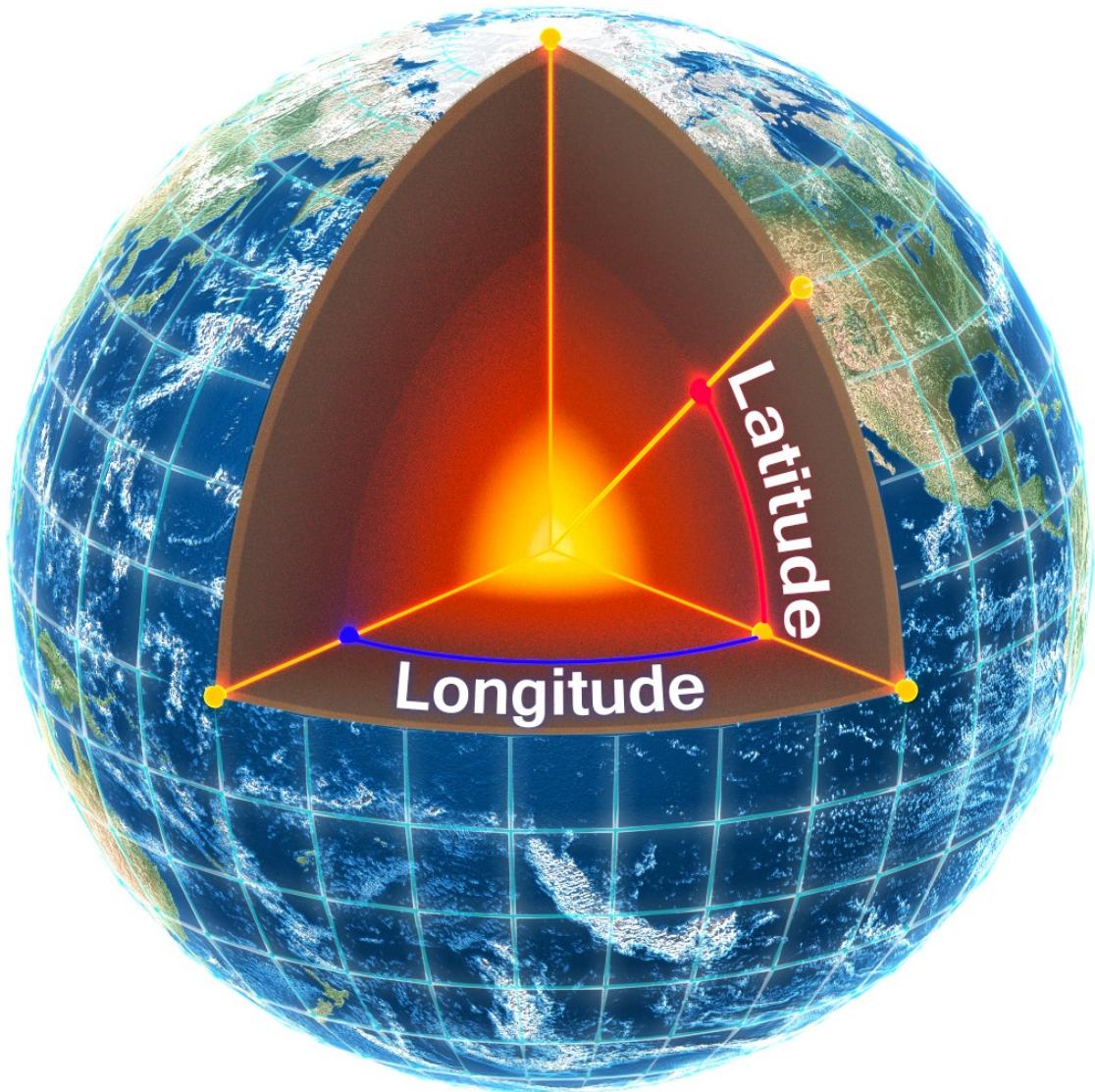
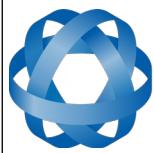
*Illustration 3: Second right hand rule*

### 5.6.2      **Rotation Order**

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

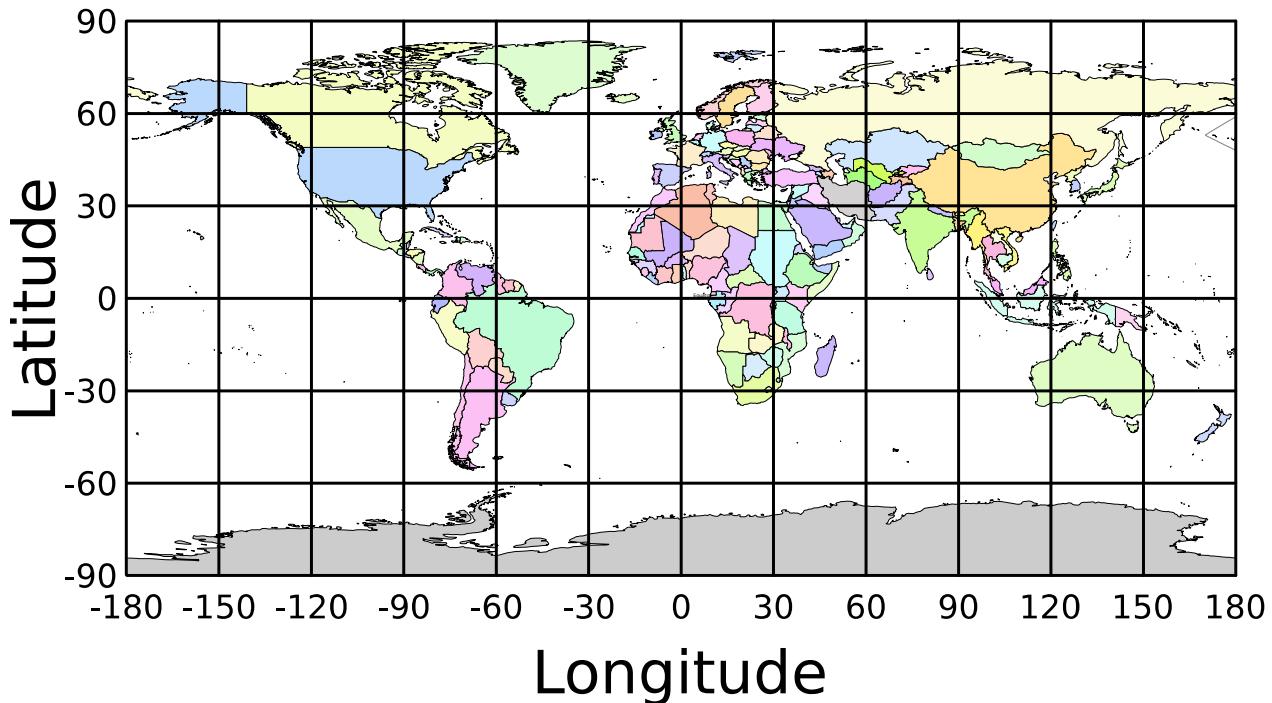
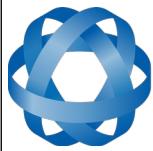
## 5.7      **Geodetic Co-ordinate System**

The geodetic co-ordinate system is the most popular way of describing an absolute position on the Earth. It is made up of the angles latitude and longitude combined with a height relative to the ellipsoid. 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 4 shows how latitude and longitude angles are used to describe a position on the surface of the Earth.



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

Illustration 5 below shows latitude and longitude on a map of the world.



*Illustration 5: World map showing latitudes and longitudes*

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

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.

## 5.8 NED Co-ordinate Frame

The NED (North East Down) co-ordinate frame is used to express velocities and relative positions. The origin of the co-ordinate frame can be considered the current position. From that origin, the north axis points true north and parallel to the line of latitude at that point. The east axis points perpendicular to the north axis and parallel to the line of longitude at that point. The down axis points directly down towards the centre of the Earth. See Illustration 6 for a graphical representation of the NED co-ordinate frame at a position on the Earth.

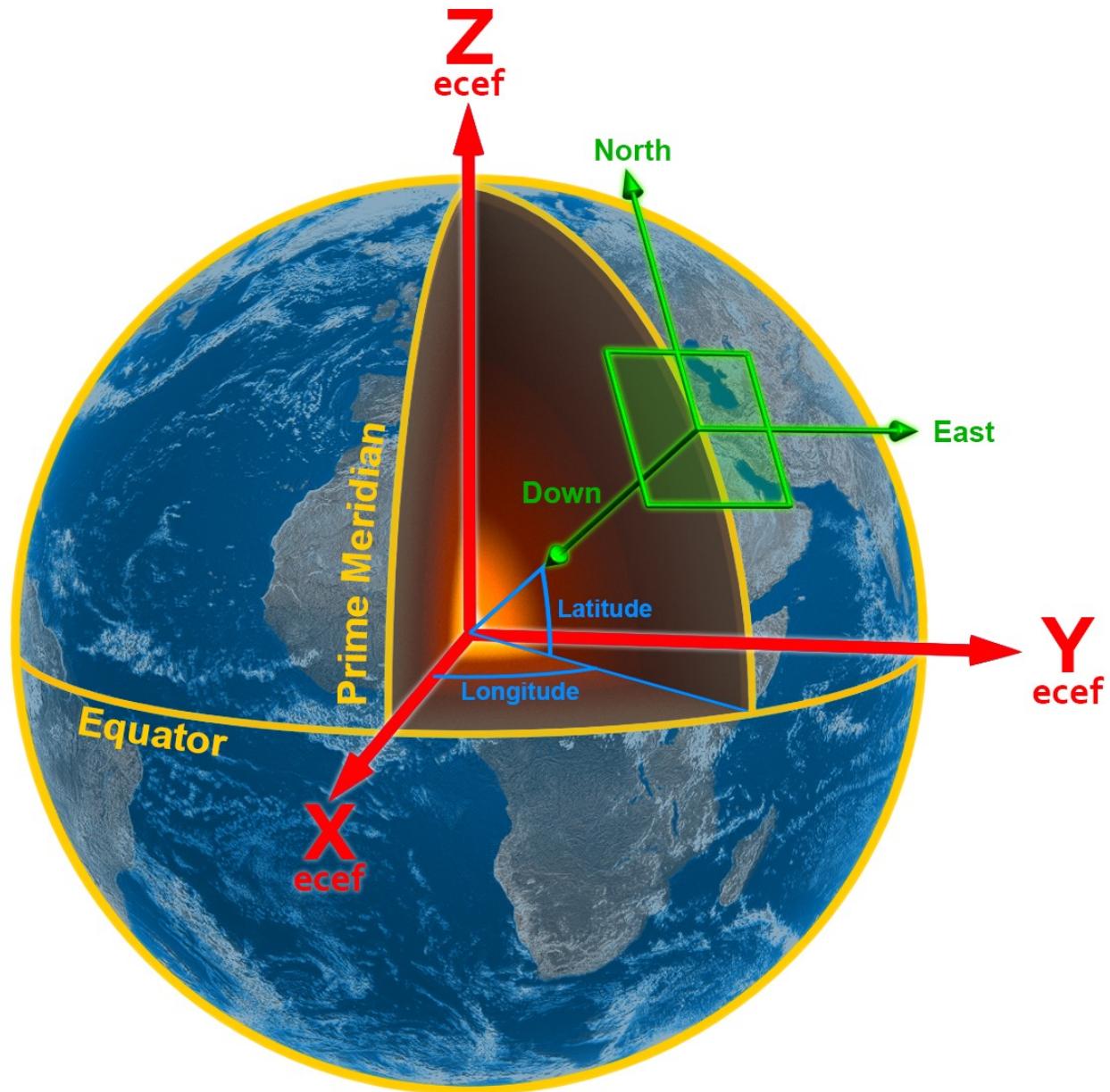
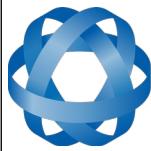


Illustration 6: Graphic showing geodetic, NED and ECEF co-ordinates

## 5.9 ECEF Co-ordinate Frame

The ECEF (Earth-centred earth-fixed) co-ordinate frame is a Cartesian co-ordinate frame used to represent absolute positions on the Earth. Its 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 6. ECEF positions can be retrieved from Advanced Navigation products however the geodetic system is used as the default.



## 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 7: Spatial Evaluation Kit*

### 6.1 Evaluation Kit Contents

1. Spatial GNSS/INS
2. Rugged IP67 GPS/GLONASS/GALILEO/BeiDou GNSS antenna, part number TW4721
3. Spatial connector to USB interface cable, part number A503-SDC20796, 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 page of 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 10.5.
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 coordinate 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. Please see section 11.4.2 for more detail.



## 7 Part Numbers and Ordering Options

### 7.1 Evaluation Kit

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

Table 4: Evaluation kit part numbers

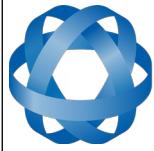
### 7.2 Standalone Unit

| Part Number | Description          | Notes   |
|-------------|----------------------|---|
| SPATIAL     | Spatial Unit         | Spatial Unit<br>L1 RTK supported<br>No cables or antennas included  |
| SPATIAL-422 | Spatial Unit (RS422) | Spatial Unit<br>L1 RTK supported<br>With optional RS422 interface instead of standard RS232 interface<br>No cables or antennas included |

Table 5: Standalone unit part numbers

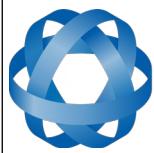
### 7.3 Accessories

| 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 Adaptor             | 1 metre FTDI USB to RS232 Adaptor  |
| 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  |



| Part Number    | Description                | Notes  |
|----------------|----------------------------|--|
| OBDII-ODOMETER | OBDII Odometer             | OBDII Odometer Interface<br>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                             |
| ILU            | Interface and Logging Unit | Interface and logging unit provides an Ethernet interface to Spatial with built in logging, time server and more ports |

Table 6: Accessories part numbers



## 8 Specifications

### 8.1 Mechanical Drawings

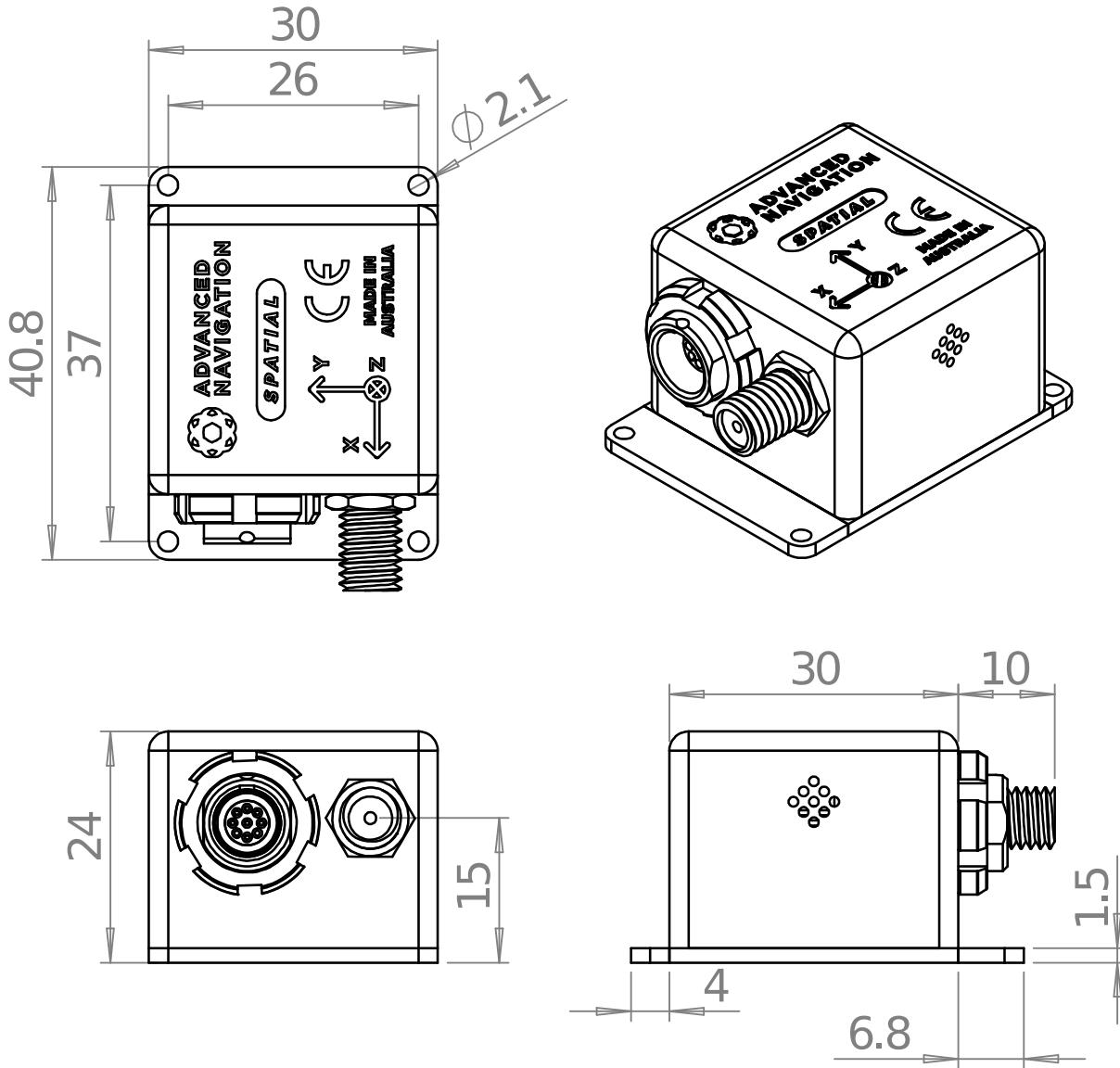
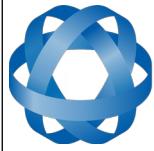


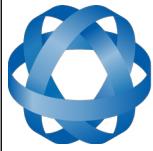
Illustration 8: Mechanical drawings of Spatial



## 8.2 Navigation Specifications

| Parameter                                  | Value                               |
|--|-------------------------------------|
| Horizontal Position Accuracy               | 2.0 m                               |
| Vertical Position Accuracy                 | 3.0 m                               |
| Horizontal Position Accuracy (with L1 RTK) | 0.02 m                              |
| Vertical Position Accuracy (with L1 RTK)   | 0.03 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, whichever is greater |
| Orientation Range                          | Unlimited                           |
| Hot Start Time                             | 500 ms                              |
| Internal Filter Rate                       | 1000 Hz                             |
| Output Data Rate                           | Up to 1000 Hz                       |

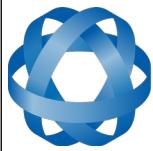
Table 7: Navigation specifications



## 8.3 Sensor Specifications

| Parameter                  | Accelerometers                       | Gyroscopes                                       | Magnetometers                       | Pressure      |
|----------------------------|--------------------------------------|--|-------------------------------------|---------------|
| Range (dynamic)            | $\pm 2$ g<br>$\pm 4$ g<br>$\pm 16$ g | $\pm 250$ °/s<br>$\pm 500$ °/s<br>$\pm 2000$ °/s | $\pm 2$ G<br>$\pm 4$ G<br>$\pm 8$ G | 10 to 120 KPa |
| Bias Instability           | 20 ug                                | 3 °/hr   | -                                   | 10 Pa         |
| Initial Bias               | < 5 mg                               | < 0.2 °/s  | -                                   | < 100 Pa      |
| Initial Scaling Error      | < 0.06 %                             | < 0.04 %   | < 0.07 %                            | -             |
| Scale Factor Stability     | < 0.06 %                             | < 0.05 %   | < 0.09 %                            | -             |
| Non-linearity              | < 0.05 %                             | < 0.05 %   | < 0.08 %                            | -             |
| Cross-axis Alignment Error | < 0.05 °                             | < 0.05 °   | 0.05 °                              | -             |
| Noise Density              | 100 ug/√Hz                           | 0.004 °/s/√Hz                                    | 210 uG/√Hz                          | 0.56 Pa/√Hz   |
| Bandwidth                  | 400 Hz                               | 400 Hz   | 110 Hz                              | 50 Hz         |

Table 8: Sensor specifications



## 8.4 GNSS Specifications

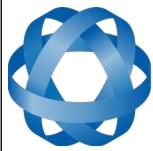
| Parameter                                  | Value   |
|--|---|
| Supported Navigation Systems               | GPS L1<br>GLONASS L1<br>GALILEO E1<br>BeiDou B1 |
| Supported SBAS Systems                     | WAAS<br>EGNOS<br>MSAS<br>GAGAN<br>QZSS          |
| Update Rate                                | 10 Hz   |
| Cold Start Sensitivity                     | -148 dBm  |
| Tracking Sensitivity                       | -160 dBm  |
| Hot Start First Fix                        | 1 s   |
| Cold Start First Fix                       | 26 s  |
| Horizontal Position Accuracy               | 2.5 m   |
| Horizontal Position Accuracy (with L1 RTK) | 0.02 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 (RS422 optional)                       |
| Primary and Auxiliary Port Speed | 2400 to 2 M baud                             |
| GPIO Port Speed                  | 2400 to 250 K baud                           |
| Protocol                         | AN Packet Protocol<br>NMEA<br>TSS1<br>Simrad |
| Peripheral Interface             | 2 x GPIO and Auxiliary RS232                 |
| GPIO Level                       | 5 V or RS232                                 |

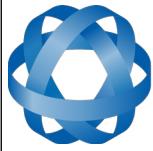
Table 10: Communication specifications



## 8.6 Hardware Specifications

| Parameter                     | Value                |
|-------------------------------|----------------------|
| Operating Voltage             | 5 to 36 V            |
| Input Protection              | $\pm$ 60 V           |
| Power Consumption             | 0.5 W (typical)      |
| Hot Start Battery Capacity    | > 48 hrs             |
| Hot Start Battery Charge Time | 30 mins              |
| Hot Start Battery Endurance   | > 10 years           |
| Operating Temperature         | -40 °C to 85 °C      |
| Environmental Protection      | IP67<br>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             |

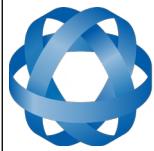
*Table 11: Hardware specifications*



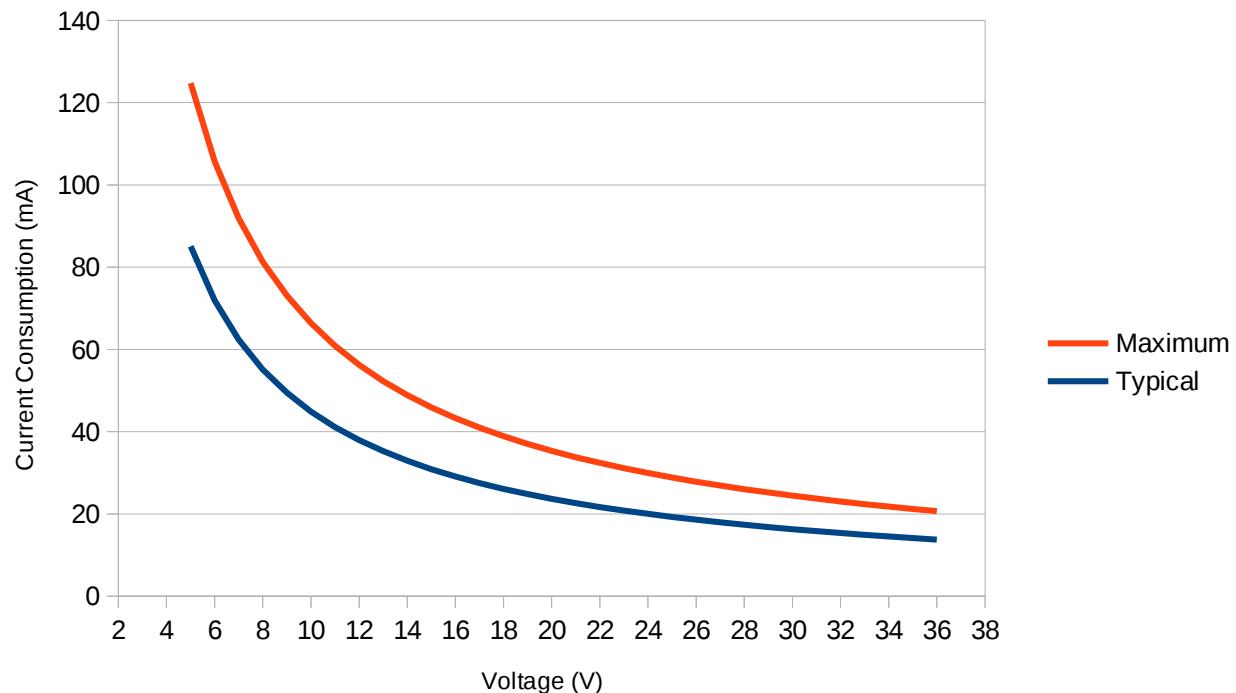
## 8.7 Electrical Specifications

| Parameter                     | Minimum | Typical | Maximum |
|-------------------------------|---------|---------|---------|
| <b>Power Supply</b>           |         |         |         |
| Input Supply Voltage          | 5 V     |         | 36 V    |
| Input Protection Range        | -60 V   |         | 60 V    |
| <b>RS232</b>                  |         |         |         |
| 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   |
| <b>GPIO</b>                   |         |         |         |
| 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    |
| <b>GNSS Antenna</b>           |         |         |         |
| Active Antenna Supply Voltage | 2.9 V   | 3 V     | 3.1 V   |
| Antenna Supply Current        |         |         | 75 mA   |

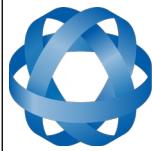
Table 12: Electrical specifications



## 8.8 Power Consumption



*Illustration 9: Maximum and typical current consumption across operating voltage*



## 8.9 Connector Pin-out

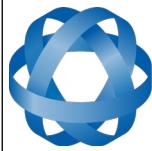
Power supply and signal connections are made through a ODU Mini-Snap Series B 9 pin connector. The ODU part number is S30B0SP09MCC00-5000. The connector provides a reliable and rugged connection to Spatial under demanding conditions and is rated to IP68 in the mated condition. Plugs are supplied with 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 10: ODU B series mating plug for Spatial*

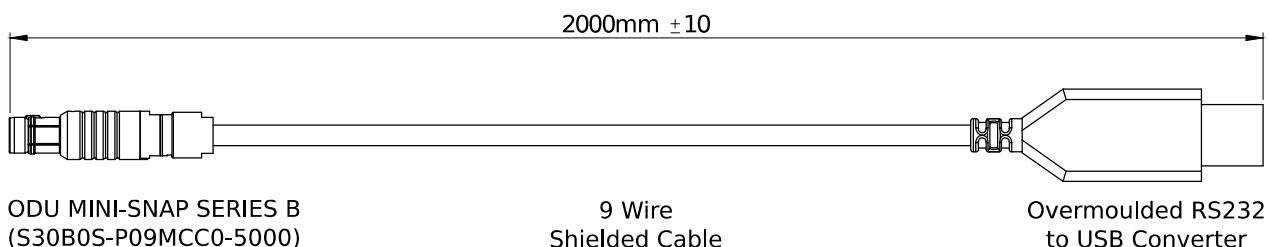
| Pin | Colour | Function                 |
|-----|--------|--------------------------|
| 1   | Black  | Ground                   |
| 2   | Brown  | Power Supply             |
| 3   | White  | GPIO 1                   |
| 4   | Green  | GPIO 2                   |
| 5   | Red    | Primary RS232 Transmit   |
| 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 11. 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 2,000,000 baud.



*Illustration 11: Evaluation kit USB cable*

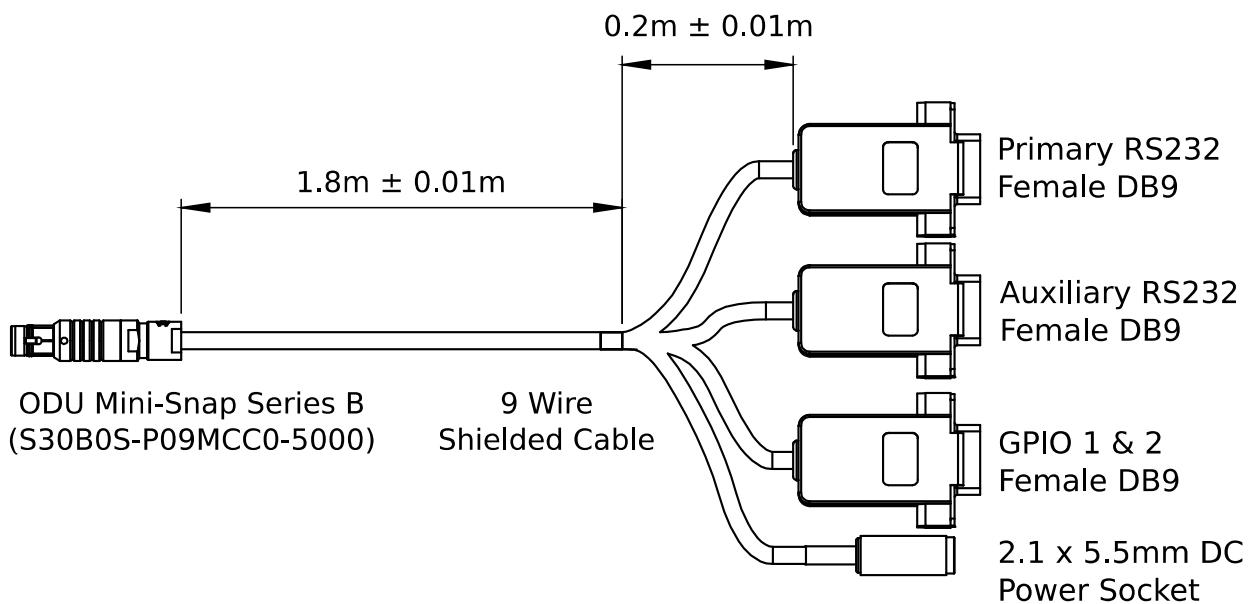
| Pin | Colour | Function           | RS232 Converter Connection |
|-----|--------|--------------------|----------------------------|
| 1   | Black  | Ground             | USB Ground                 |
| 2   | Brown  | Power              | USB 5 volt supply          |
| 3   | White  | GPIO 1             |                            |
| 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.



*Illustration 12: 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 13: 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 10.5. 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 its temperature range and mounted in a manner that will properly dissipate heat; please contact [support@advancednavigation.com](mailto:support@advancednavigation.com) for advice specific to your application.
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.

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.

### 9.3 Mounting Plate

Spatial's mounting plate and hole guide is shown below in Illustration 14. The holes are designed for M2 cap screws.

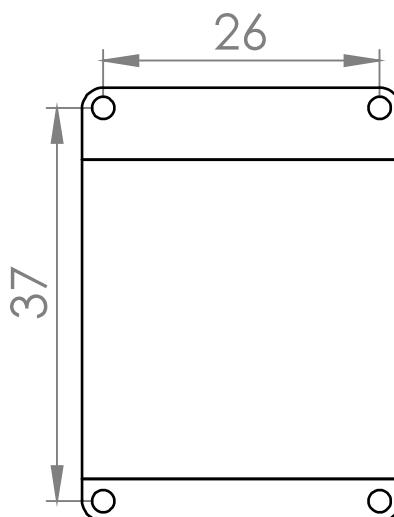
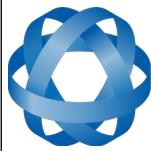


Illustration 14: Spatial mounting plate

### 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 9.

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.

An example installation with axes marked is shown below in Illustration 15 and Illustration 16. In this installation there would be a positive X antenna offset value, a positive Y antenna offset value and a negative Z offset value.

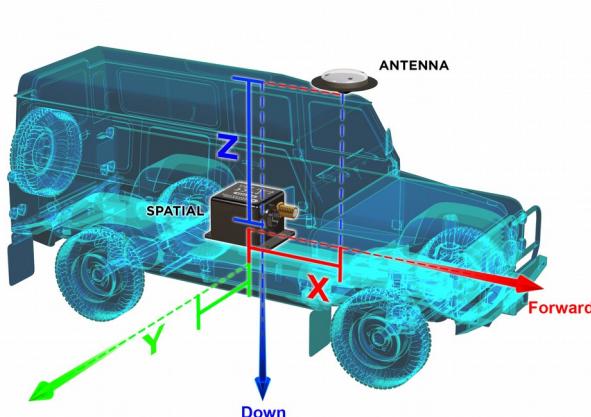
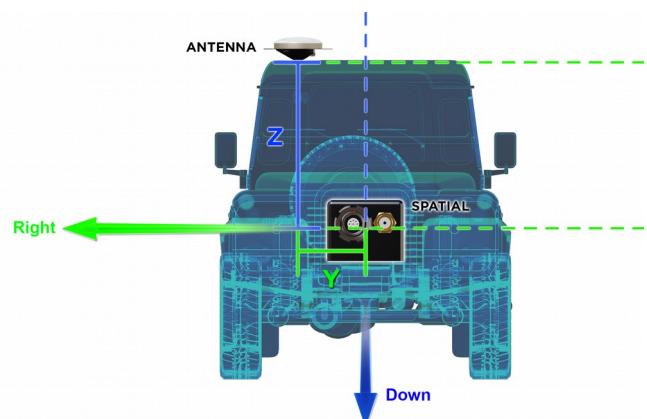
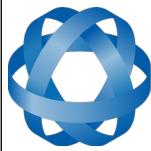


Illustration 15: Spatial antenna offset isometric view



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 @  $\pm 70$  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

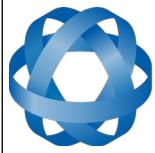
Most road cars since 1980 contain a VSS (vehicle speed sensor) signal that can be wired directly into one of Spatial's GPIO pins. The vehicle should be taken to an automotive electrician to perform the work.

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 10.9 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 17. These units are priced at approximately AUD 500. Please contact Advanced Navigation sales for more information.



**ADVANCED  
NAVIGATION**

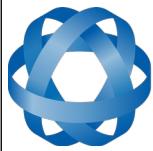
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*Illustration 17: Advanced Navigation OBDII Odometer*



### 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 18:  
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 19: 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 10.5. 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 10.5.4.

## 9.8      **Vibration**

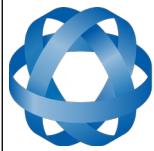
Spatial is able to tolerate a high level of vibration compared to other inertial systems. This is due to a unique gyroscope design and a special filtering algorithm. There is however a limit to the amount of vibration that Spatial can tolerate and large levels of vibration will cause Spatial's accuracy 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 10.6.

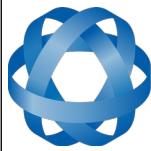
If you are unsure about your vibration level, we recommend emailing a Spatial log file of the vibration to [support@advancednavigation.com.au](mailto:support@advancednavigation.com.au) for feedback.

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.



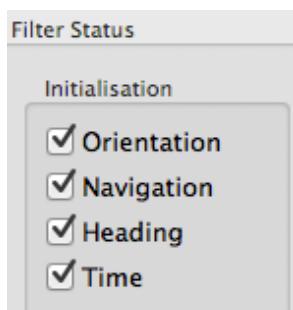
3. Spatial can be mounted to a plate which is then mounted to the platform through vibration isolation mounts.



## 10 Operation

### 10.1 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 20: The four initialisation levels*

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

#### 10.1.1 Orientation Initialisation

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

When Spatial 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.

#### 10.1.2 Navigation Initialisation

Navigation initialisation completes once the system has determined a starting position. The most common method of navigation initialisation is for the system to get a 3D GNSS fix. If the system is hot starting it will remember 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.

### **10.1.3 Heading Initialisation**

Heading initialisation completes once the system has determined a heading. The conditions required to determine a heading depend upon the heading source being used, see section 10.4. 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.

### **10.1.4 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.

## **10.2 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 its 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.



## 10.3 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.

## 10.4 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.

### 10.4.1 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.

### 10.4.2 Velocity Heading

Velocity heading works by deriving heading from the direction of velocity and acceleration. Velocity heading works well with cars, boats, fixed wing aircraft and other vehicles that don't move sideways. Velocity heading does not work with helicopters and other 3D vehicles. 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.

### 10.4.3 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.

## 10.5 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 its 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.

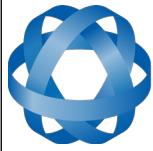
Please note that if Spatial is going to be used in a vehicle, the calibration should be performed while Spatial is mounted in and fixed to that vehicle. This means that the whole vehicle must be moved to perform the calibration. The calibration needs to be performed in an area away from sources of magnetic 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.

### **10.5.1 2D Magnetic Calibration**

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

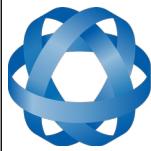
#### **10.5.1.1 Using the Spatial Manager Software**

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.



### 10.5.1.2 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.



## 10.5.2 3D Magnetic Calibration

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

### 10.5.2.1 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.

### 10.5.2.2 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.

## 10.5.3 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.

#### **10.5.4 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 10.4 for information on heading sources. The magnetometers can be disabled using the filter options dialogue in Spatial Manager, see section 11.8.3.

### **10.6 Sensors Range**

Spatial supports dynamic ranging on its sensors. Each of the three sensors have 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.

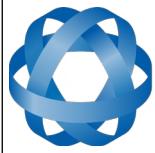
The sensor ranges can be set through the sensor ranges dialogue in the configuration menu in Spatial Manager, see section 11.8.2.

### **10.7 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.

### **10.8 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.



## 10.9 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 10.9.1. By default the odometer will automatically calibrate itself.

### 10.9.1 Odometer Automatic Pulse Length Calibration Procedure

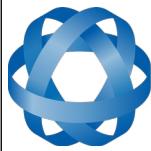
1. Ensure that the signal is connected correctly and that the GPIO pin is configured as an odometer input using the GPIO configuration dialogue in Spatial Manager, see section 11.8.7.
2. Open Spatial Manager, connect to Spatial and open the odometer configuration dialogue, see section 11.8.8. In the 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.

## 10.10 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.

## 10.11 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 its 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.

## 10.12 Differential and RTK GNSS

Spatial supports receiving differential corrections to enhance position accuracy. Spatial hardware version 7.0 and above also supports RTK corrections. The corrections must come from a base station located within a 25 km radius of where the Spatial unit is operating. There are many companies worldwide that provide nationwide network corrections services from a local base station that 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 corrections and feed them into the Spatial unit. Please see section 11.9.5.

The corrections format supported is RTCM v3.

## 10.13 Raw Satellite Data

Spatial hardware version 6.1 and above features a new GNSS receiver that is capable of outputting raw satellite data. This raw satellite data can be used by post-processing programs to achieve high accuracy kinematic positioning.

The maximum output rate for raw satellite data is 10Hz and it can be enabled by turning on the Raw Satellite Data Packet (ID 60) in the packet rates dialogue in Spatial Manager, see Illustration 21. This packet will be automatically converted to RINEX v3.02 by Spatial Managers log converter utility.

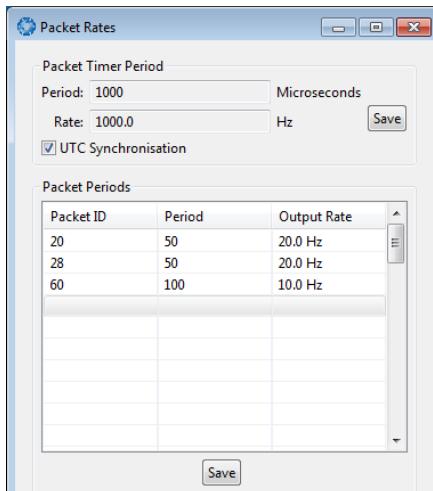
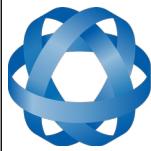


Illustration 21: Enabling packet 60

## 10.14 Post Processing

Spatial hardware version 6.1 and above can be used with Advanced Navigation's post processing platform Kinematica to achieve high accuracy kinematic positioning of



8mm and significantly improved dead reckoning performance.

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

1. Connect to your device using Spatial Manager.
2. Ensure your GNSS offset and any alignment offset has been entered as per the installation checklist in section 9.1.
3. Open the Baud Rates dialogue under the Configuration menu and set the primary port baud rate to 1,000,000. See Illustration 22. If you are using Windows ensure you have adjusted the latency settings for the serial port as detailed in section 11.4.2.
4. Open the Packet Rates dialogue under the Configuration menu and set up the packets as shown in Illustration 22.

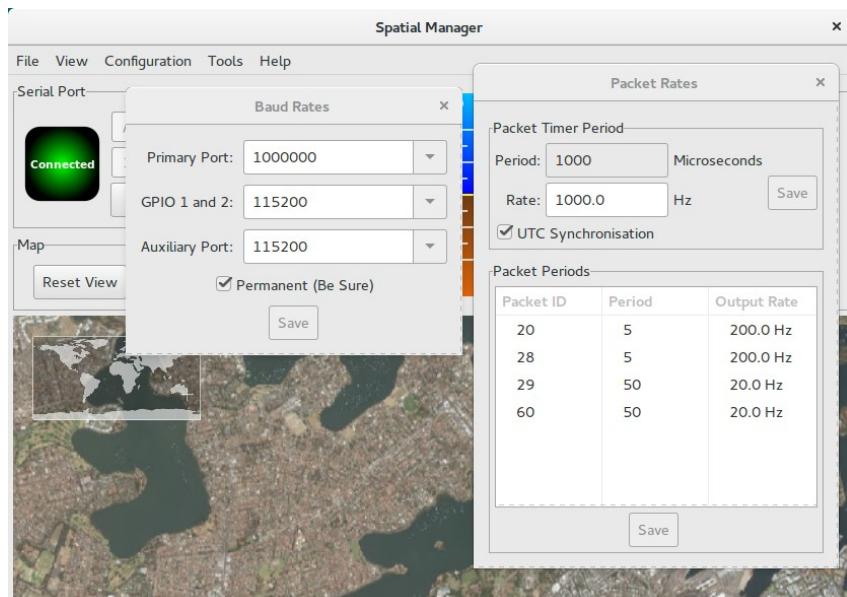


Illustration 22: Spatial post processing configuration

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

## 10.15 Vents

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

## 10.16 RAIM

RAIM stands for receiver autonomous integrity monitoring. It allows a GNSS receiver to



detect and exclude both faulty and fraudulent satellite signals. Spatial's internal GNSS is equipped with RAIM and it is enabled by default.

## 10.17 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 its 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.

## 10.18 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 its 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.

### 10.18.1 Temperature

Spatial should not be subjected to temperatures outside of its operating range. If the temperature rises above 90 degrees Celsius, Spatial will automatically shut off power to its 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.

### 10.18.2 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.

### 10.18.3 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.

### 10.18.4 Dirt and Dust

Spatial is completely sealed against dirt and dust entry. It is important to note that this



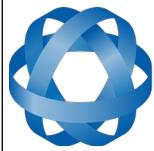
is only the case when the connectors are mated. When un-mating the connectors if the Spatial unit is dirty or dusty, the dirt should be rinsed off with fresh water first and then dried off. This is to prevent dirt or dust entering the connectors which can cause them to fail.

### **10.18.5 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.

### **10.18.6 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.

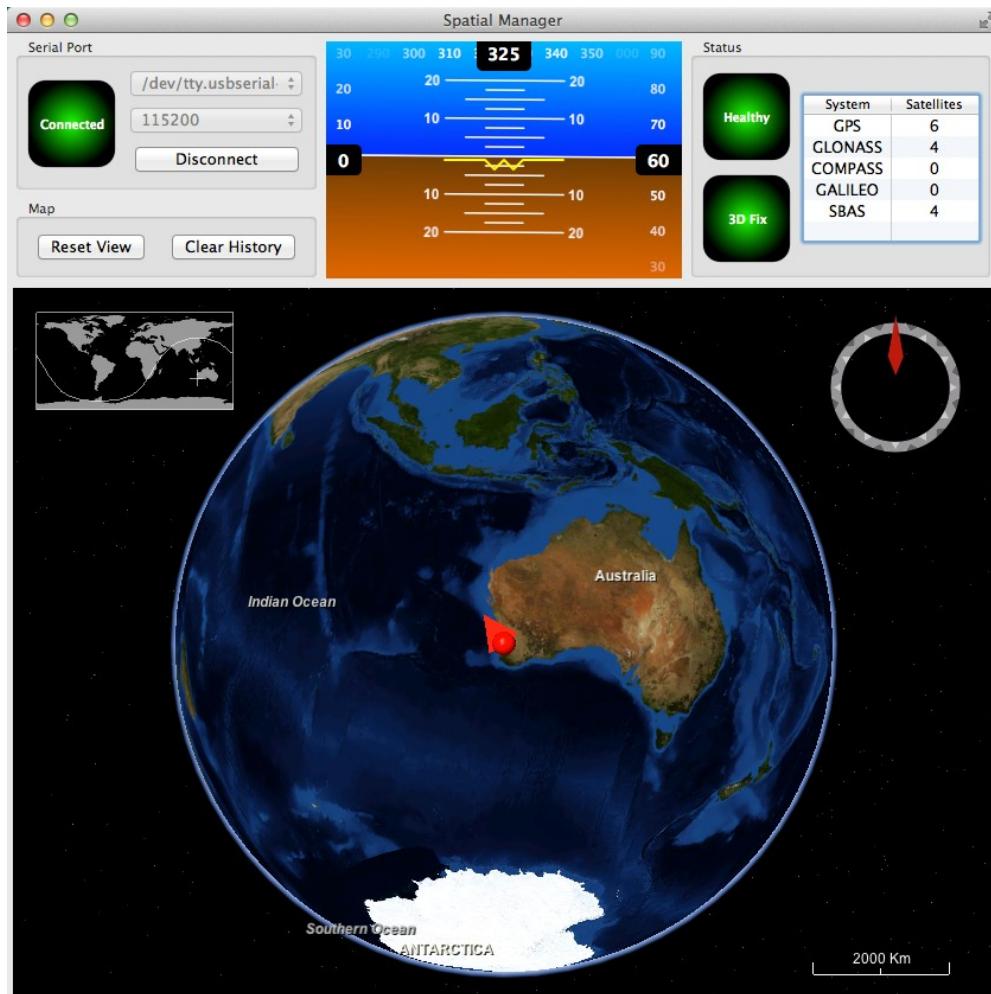
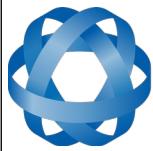


Illustration 23: Screenshot of Spatial Manager



## 11.1 Software Changelog

| <b>Version</b> | <b>Date</b> | <b>Changes</b>   |
|----------------|-------------|--|
| 4.5            | 30/01/2017  | Internet based hot start functionality added<br>Configuration export now contains device information   |
| 4.4            | 12/04/2016  | Extended NTRIP support for older versions<br>Log converter now outputs a KML file for Google Earth with detailed information as well as the GPX file<br>Added serial port passthrough tool   |
| 4.3            | 17/08/2015  | Spatial Manager now requests all configuration upon connection<br>Spatial Manager converts any configuration packets found in ANPP log files into text<br>Bug fix for NTRIP invalid connection   |
| 4.2            | 15/04/2015  | Added network connection capability, section 11.9.6<br>Added NTRIP client, section 11.9.5<br>Two new satellite views in satellites dialogue, section 11.7.3<br>Added gimbal configuration dialogue, section 11.7.10<br>Heave offsets changed to reference point offsets, section 11.8.10<br>Fixed issue with locales that use commas instead of decimal points in floating point numbers<br>GPX export now vectorises paths to minimise points for better performance in Google Earth. |
| 4.0            | 18/09/2014  | Improvements to the 3D map<br>Support for more graphics cards<br>Status display now shows when heading not initialised<br>Orientation standard deviation graph added<br>Latitude and longitude now show in position dialogue<br>3D model dialogue added, section 11.7.8<br>Communications dialogue added, section 11.7.9<br>Added GPIO output configuration dialogue, section 11.8.11<br>Added position configuration dialogue, section 11.8.12  |
| 3.0            | 13/09/2013  | Significantly reduced CPU usage<br>Minor interface enhancements<br>New options added to filter options dialogue<br>Added NMEA output configuration dialogue<br>Added position configuration dialogue, section  |
| 2.4            | 27/03/2013  | Minor interface enhancements<br>Updated GPIO functions<br>Detailed satellites dialogue updated to show frequencies<br>Experimental post-processing log export function added   |
| 2.3            | 14/02/2013  | Added Chinese language translation<br>Changed logging system to binary format  |



|     |            |   |
|-----|------------|---|
|     |            | Added heave offset dialogue<br>Firmware date added to firmware update dialogue<br>Minor changes   |
| 2.0 | 22/10/2012 | Added odometer configuration dialogue<br>Added log converter tool<br>Spatial Manager will now disconnect automatically if USB serial port is removed<br>Firmware update will now change the baud rate automatically when entering bootloader mode<br>Alignment configuration dialogue updated |
| 1.0 | 16/09/2012 | Mac disconnect issue resolved   |
| 0.5 | 23/08/2012 | Initial Release   |

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

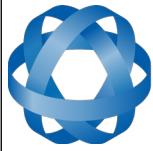
Please contact [support@advancednavigation.com.au](mailto:support@advancednavigation.com.au) if you are having issues.

### 11.4.1 All Platforms

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

### 11.4.2 Windows

There is a well known problem with USB serial devices under Windows known as “crazy mouse”. The problem occurs when the system mistakenly installs the USB serial device as a mouse. Unfortunately Microsoft has not fixed this problem in over 15 years, so it probably won't be fixed. If you experience this problem, often a restart will



resolve it. Otherwise there is a tool available at <http://www.stentec.com/anonftp/pub/wingps/pnpblockersetup.exe> that can fix the issue.

If the serial port does not show up when you plug in your Spatial 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 24.

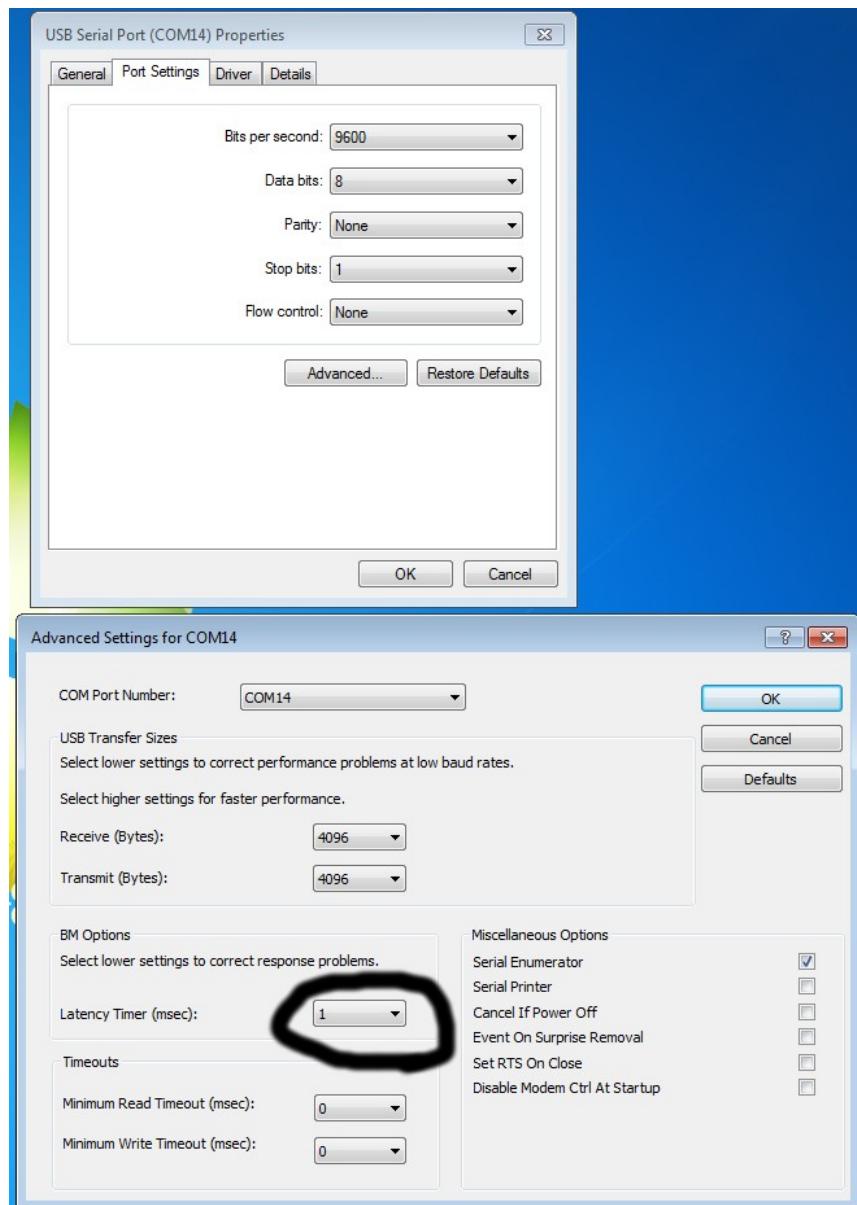
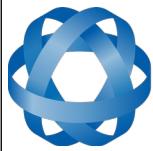


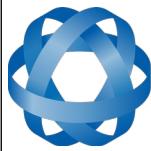
Illustration 24: Screenshot of latency timer setting

### 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

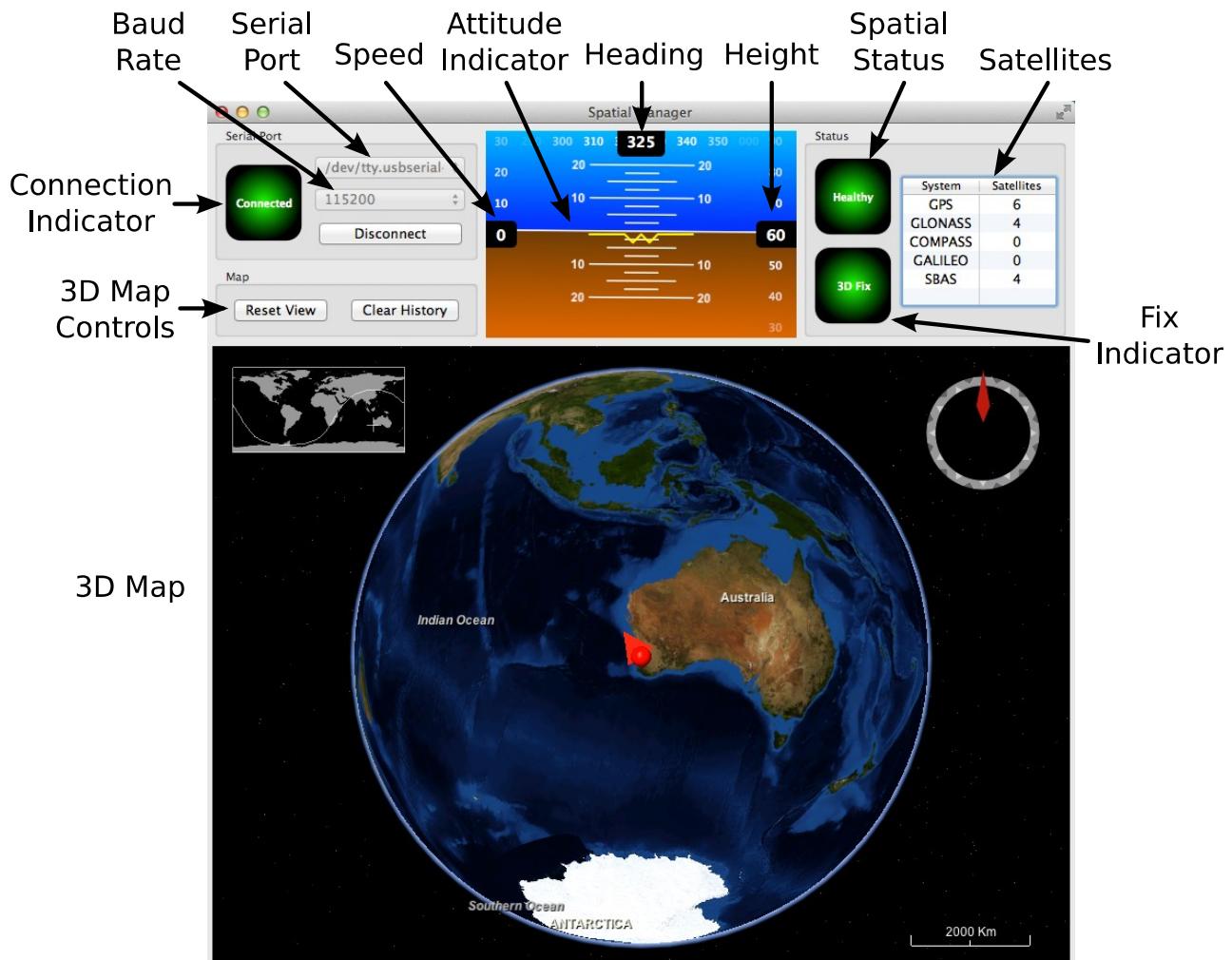


Illustration 25: Screenshot of Spatial Manager main view

### 11.5.1 Serial Port

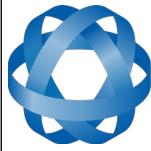
The serial port dialogue is used to connect to Spatial. You should select a serial port and baud rate and click connect. The default baud rate of Spatial is 115200. The connection indicator displays whether there is communication with a Spatial unit.

### 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.

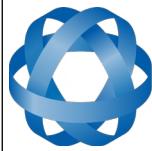
## 11.5.5 3D Map Controls

### 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 and a KML 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      |

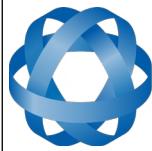
Illustration 26: Screenshot showing log file and log conversion folder

## 11.7 View Menu

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



Illustration 27: Screenshot of Spatial Manager view menu



### 11.7.1 Device Information

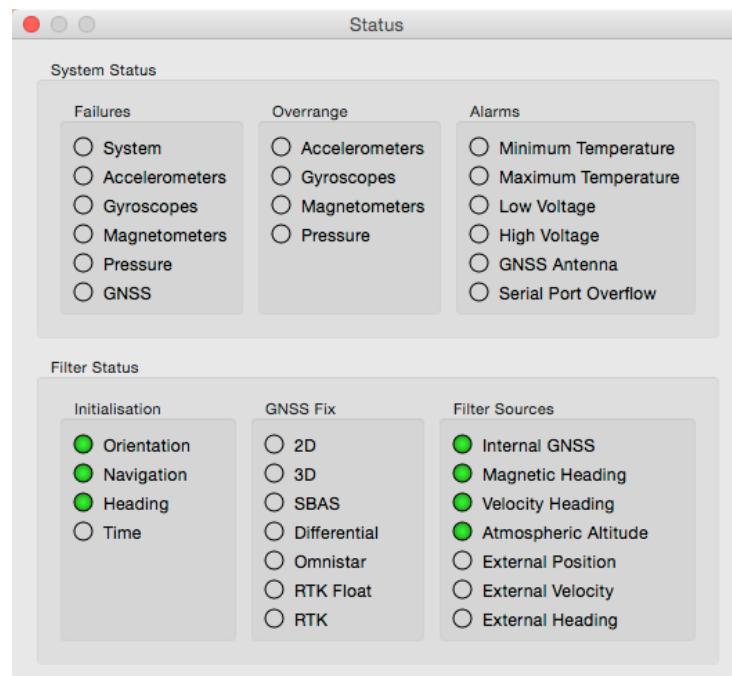
Device information is useful during technical support and for tracking your serial number, firmware and hardware version.



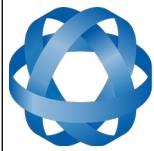
*Illustration 28: Screenshot of Spatial Manager device information dialogue*

### 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 29: Screenshot of Spatial Manager status dialogue*

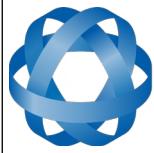


### 11.7.3 Satellites

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

| Satellites |     |           |           |         |     |
|------------|-----|-----------|-----------|---------|-----|
| 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 30: Screenshot of Spatial Manager satellites dialogue*



### 11.7.4 Raw Sensors

Raw sensors shows the temperature calibrated raw sensor values.

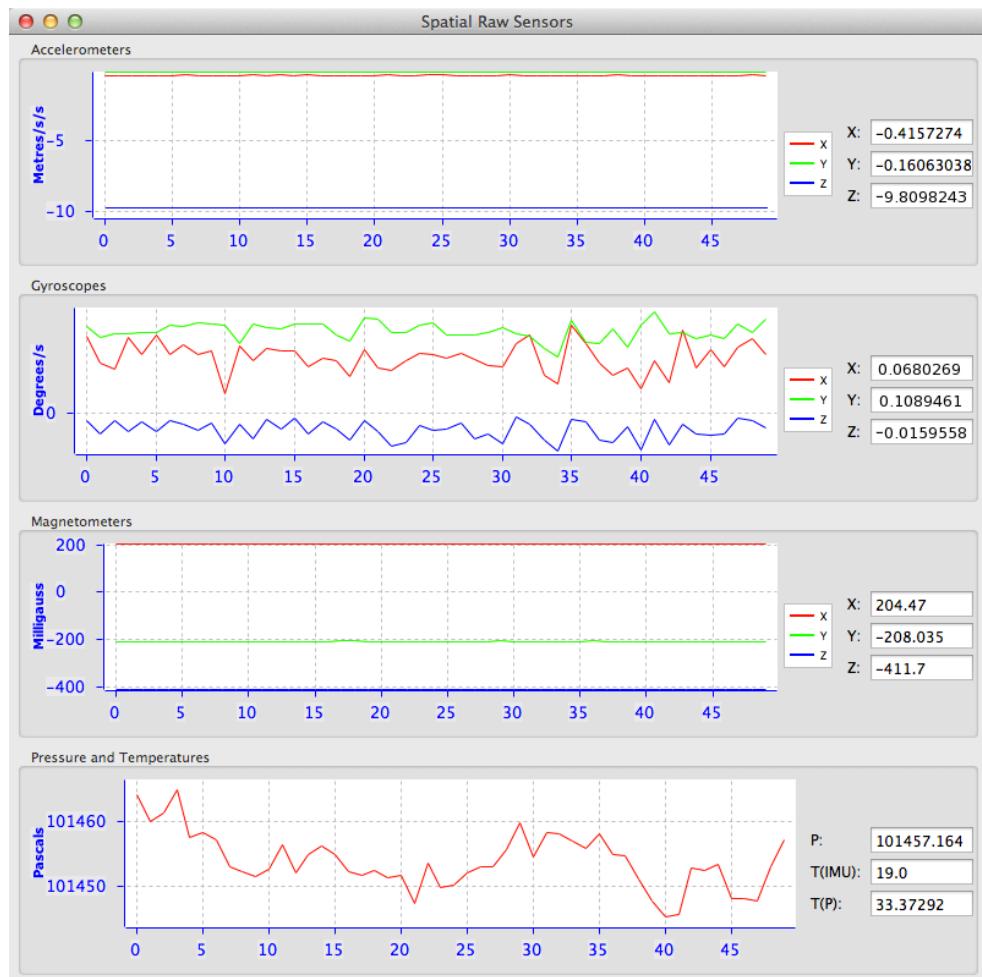
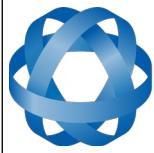


Illustration 31: Screenshot of Spatial Manager raw sensors dialogue



### 11.7.5 Orientation

Orientation shows Spatial's orientation and angular velocity.

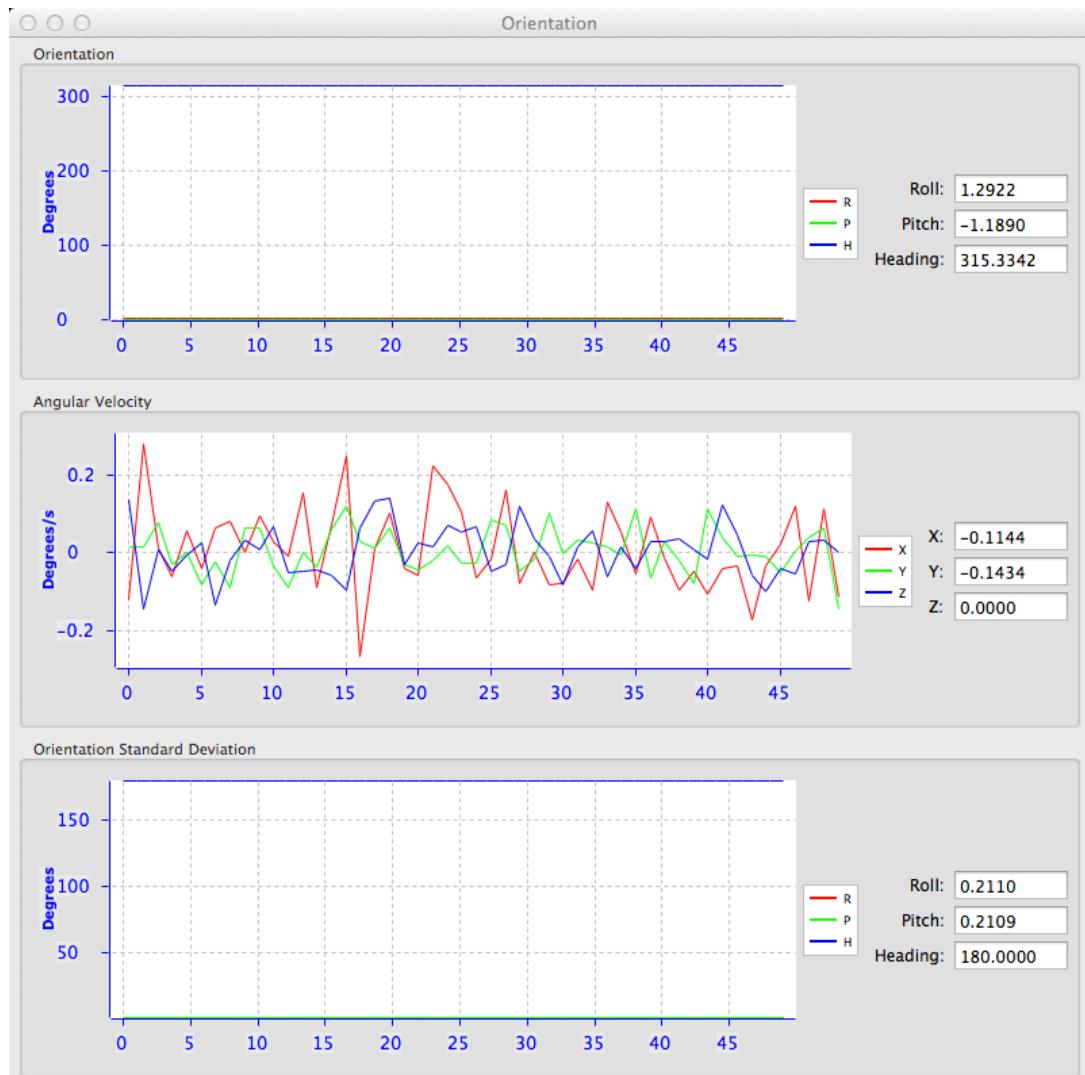
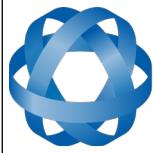


Illustration 32: Screenshot of Spatial Manager orientation dialogue



### 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.

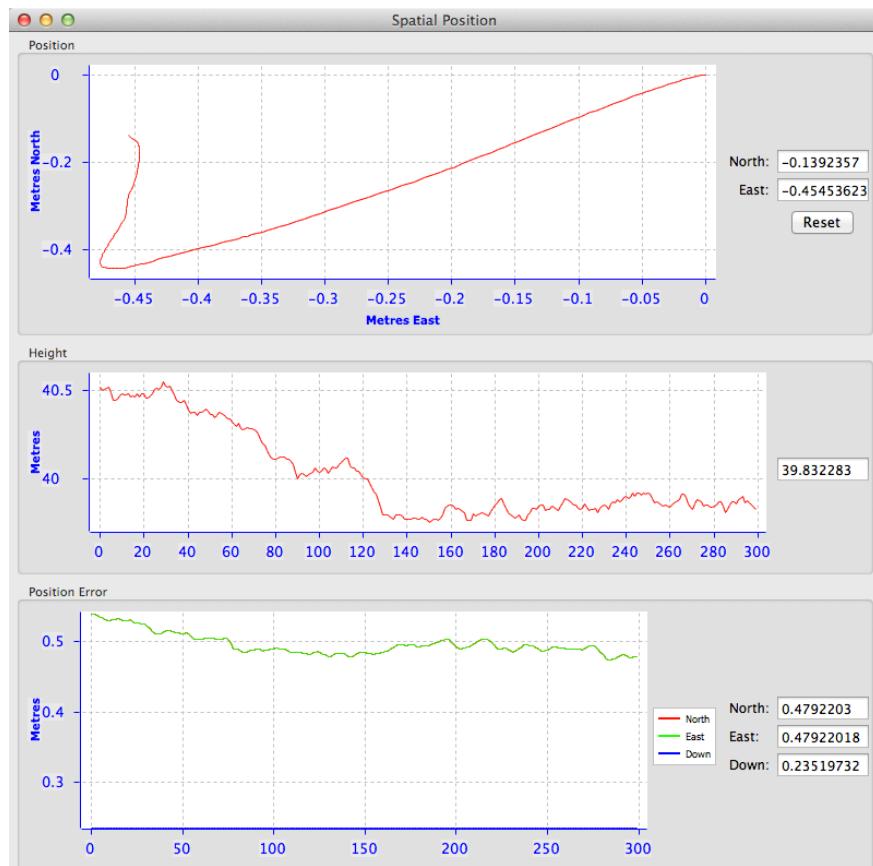
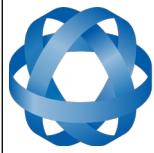


Illustration 33: Screenshot of Spatial Manager position dialogue

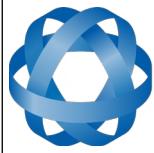


### 11.7.7 Velocity and Acceleration

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



Illustration 34: Screenshot of Spatial Manager velocity and acceleration dialogue



### 11.7.8 3D Model

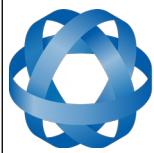


*Illustration 35: Screenshot of Spatial Manager 3D model dialogue*

### 11.7.9 Communications Statistics

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

*Illustration 36: Screenshot of Spatial Manager communications statistics dialogue*



### 11.7.10 Heave

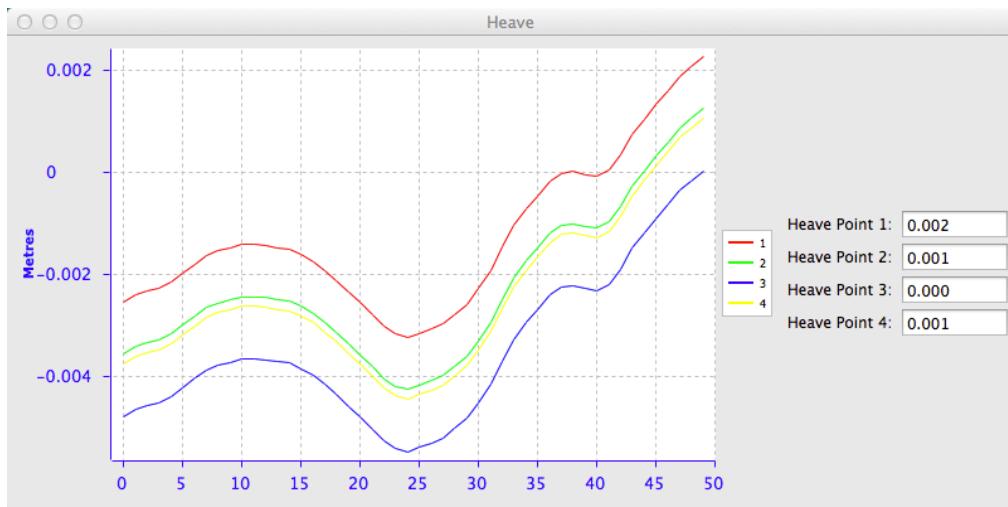
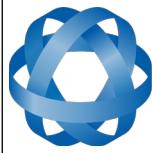


Illustration 37: Screenshot of Spatial Manager heave dialogue



## 11.8 Configuration

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



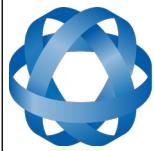
*Illustration 38: Screenshot of Spatial Manager configuration menu*

### 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.

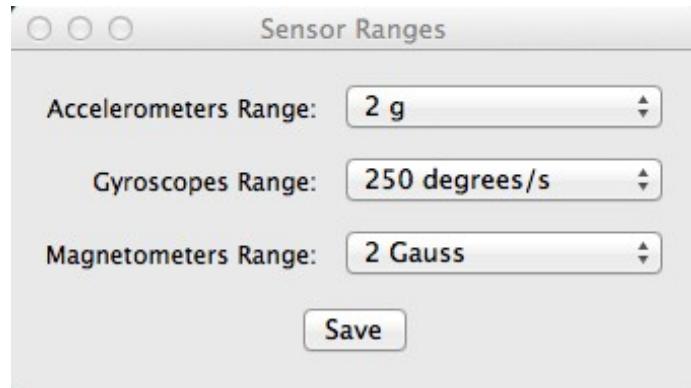


*Illustration 39: Screenshot of Spatial Manager configuration export dialogue*



### 11.8.2 Sensor Ranges

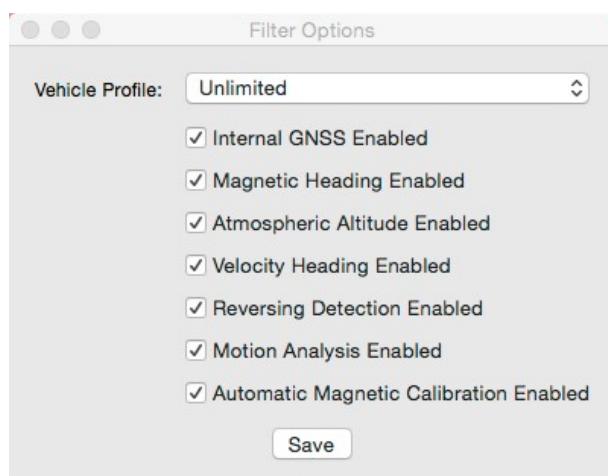
The sensor ranges dialogue is used to set the dynamic range of the sensors. If you are experiencing over-range events during operation this dialogue should be used to increase the range of the offending sensor. The lowest ranges give the best performance so it is preferable not to use the highest range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



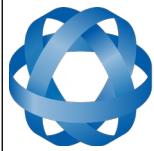
*Illustration 40: Screenshot of Spatial Manager sensor ranges dialogue*

### 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](mailto:support@advancednavigation.com.au).

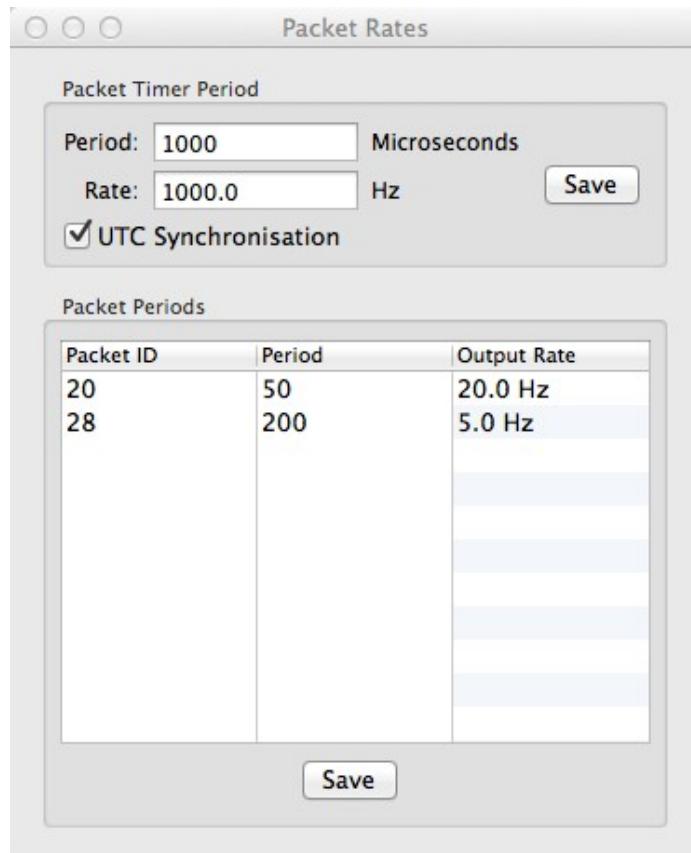


*Illustration 41: Screenshot of Spatial Manager filter options dialogue*

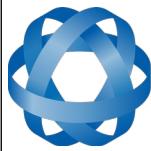


## 11.8.4 Packet Rates

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.

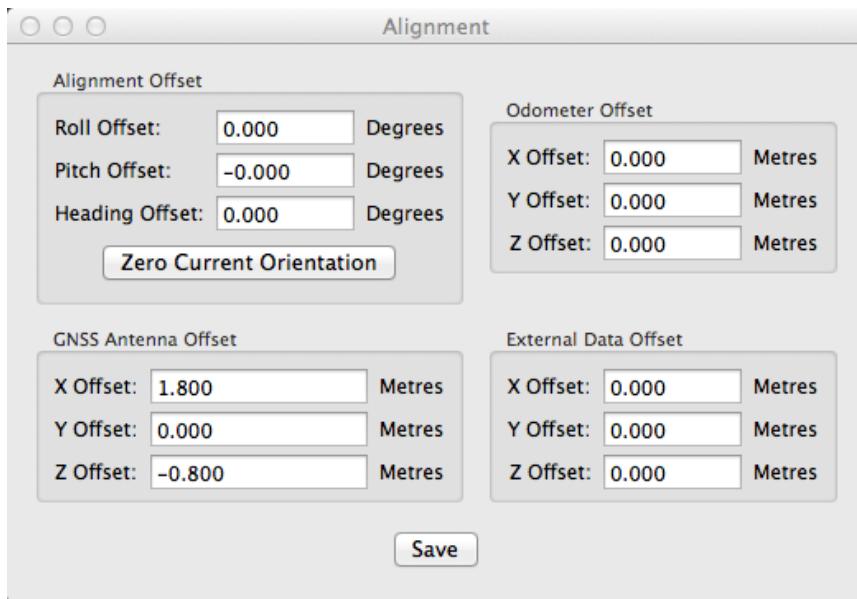


*Illustration 42: Screenshot of Spatial Manager packet rates dialogue*



### 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.



*Illustration 43: 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.

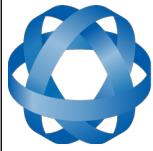
If the unit is installed in a different orientation then the roll, pitch and heading offset must be entered. For example if the unit is installed on its side with the X axis pointing up and the Z axis pointing forwards and no change to the Y axis, then this would result in a pitch offset of +90 degrees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

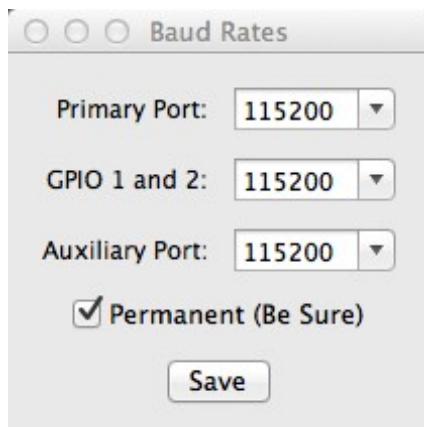
The odometer offset is measured from the centre of the Spatial unit to the point at which the vehicle's tyre makes contact with the road in the body co-ordinate frame (X positive forward, Z positive down).

#### 11.8.5.4 External Data Offset

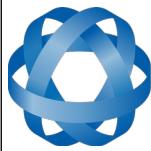
These values are only required for speciality applications operating with external sources of data. Please contact [support@advancednavigation.com.au](mailto:support@advancednavigation.com.au) for assistance with these values.

### 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.

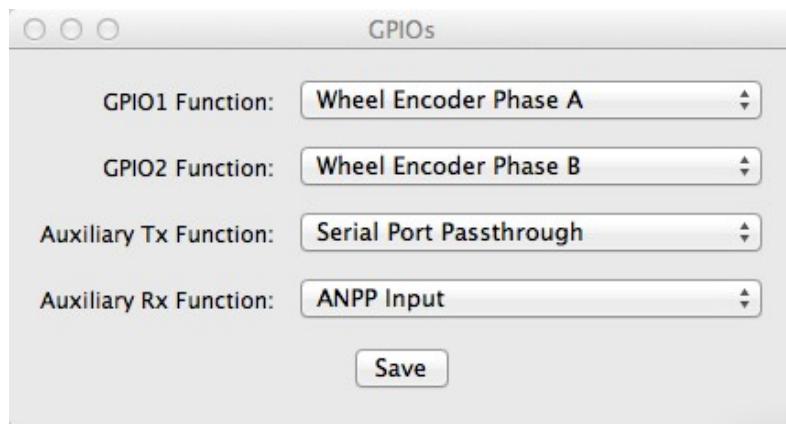


*Illustration 44: Screenshot of Spatial Manager baud rates dialogue*



### 11.8.7 GPIO Configuration

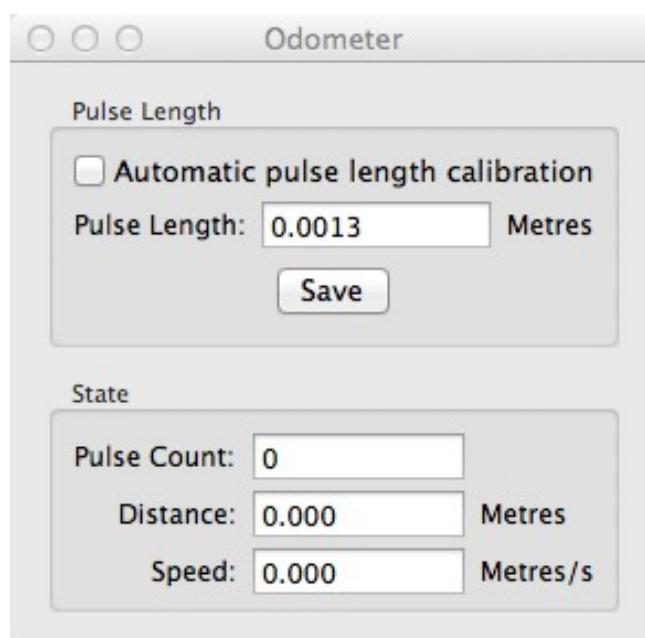
This dialogue allows the user to select the function of the GPIO pins and Auxiliary RS232. These functions change dynamically and are effective immediately upon pressing save. Please note that GPIO pins function at RS232 levels for data functions and 0 to 5 volt levels for all other functions. The internal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



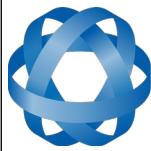
*Illustration 45: Spatial Manager GPIO configuration dialogue*

### 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.

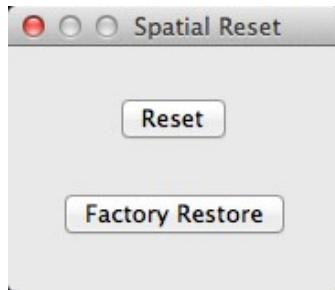


*Illustration 46: Screenshot of Spatial Manager odometer configuration dialogue*



### 11.8.9 Reset

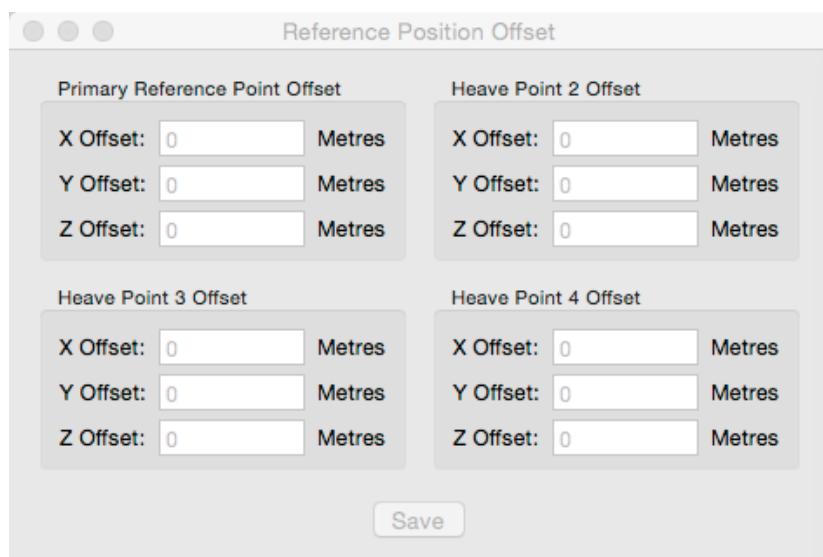
The reset button causes the system to perform a power cycle as if the unit had the power removed and reapplied. The factory restore button causes the system to erase all settings and restore factory defaults. It also erases the hot start data so that the system is forced to perform a cold start.



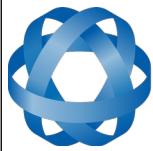
*Illustration 47:  
Screenshot of Spatial  
Manager reset dialogue*

### 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.

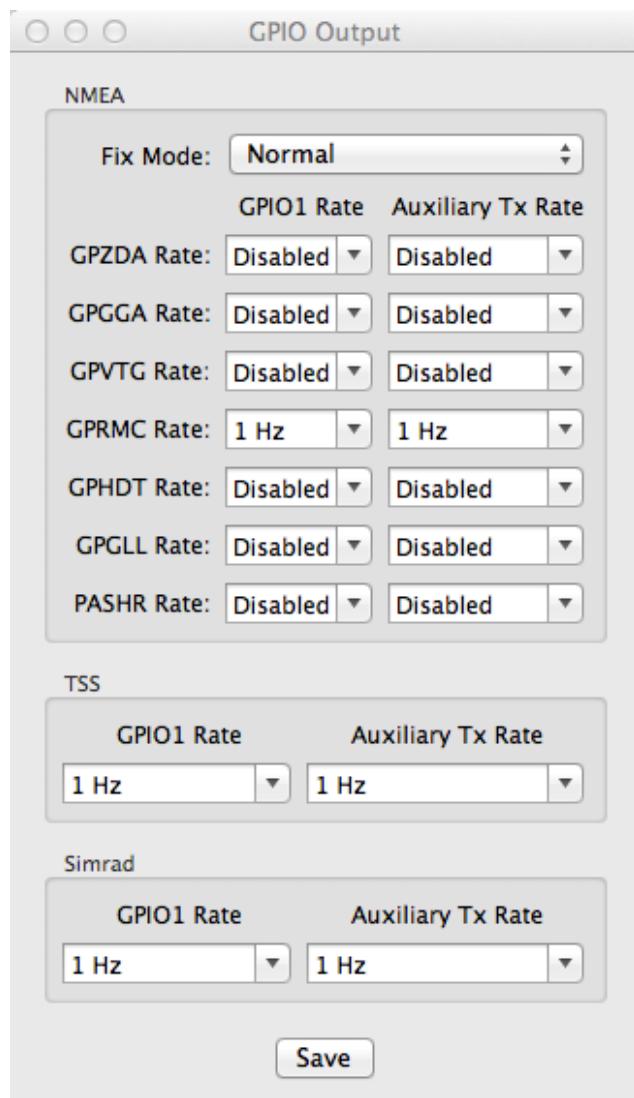


*Illustration 48: Screenshot of Spatial Manager reference position offsets dialogue*

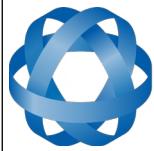


### 11.8.11 GPIO Output Configuration

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.

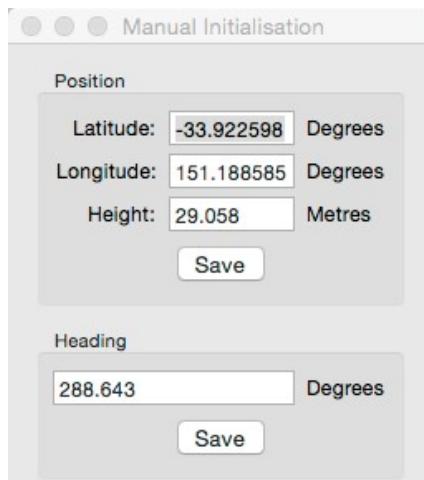


**Illustration 49: Screenshot of Spatial Manager GPIO output configuration dialogue**



### 11.8.12 Manual Initialisation

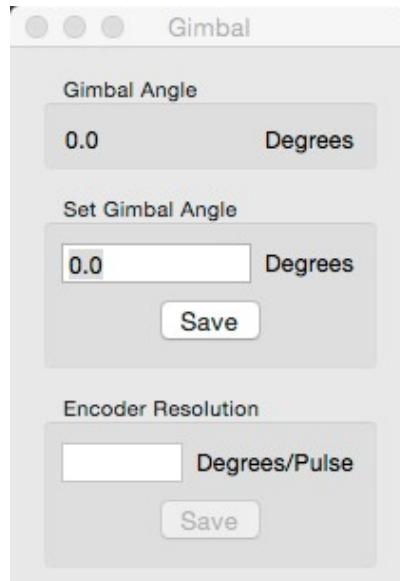
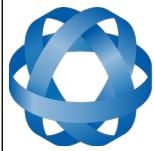
This dialogue can be used to manually initialise Spatial when a GNSS fix is not available. Setting the position will initialise the navigation filter. Setting the heading will initialise the heading.



*Illustration 50: Screenshot of  
Spatial Manager manual  
initialisation dialogue*

### 11.8.13 Gimbal

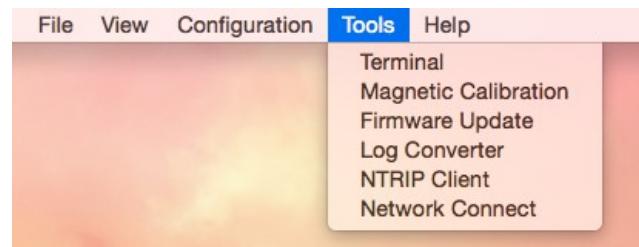
The gimbal configuration dialogue is only used in speciality gimbal applications. Please contact [support@advancednavigation.com.au](mailto:support@advancednavigation.com.au) for more information on using Spatial inside a gimbal.



*Illustration 51: Screenshot of Spatial Manager gimbal dialogue*

## 11.9 Tools

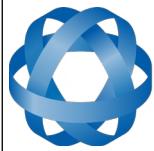
The tools menu contains tools for performing procedures with Spatial.



*Illustration 52: Screenshot of Spatial Manager tools menu*

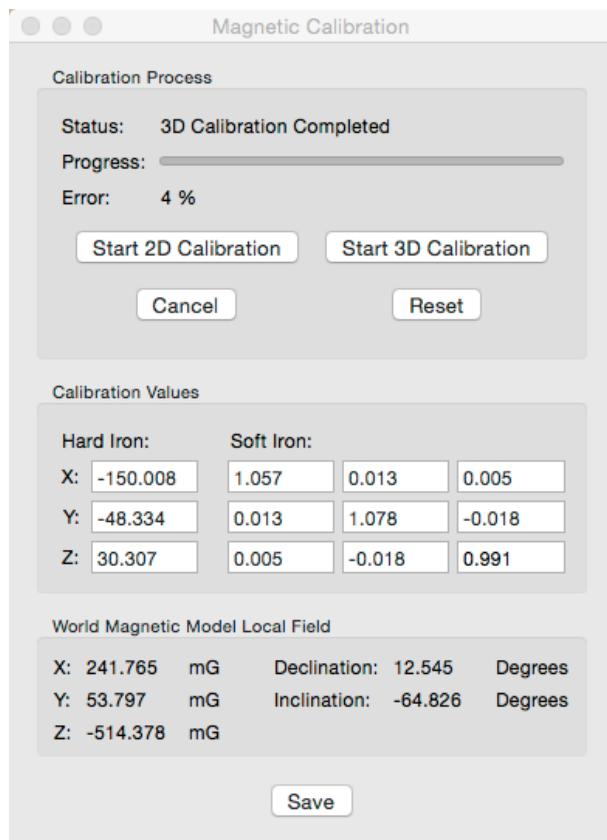
### 11.9.1 Terminal

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

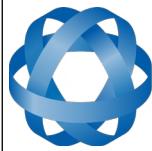


### 11.9.2 Magnetic Calibration

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.

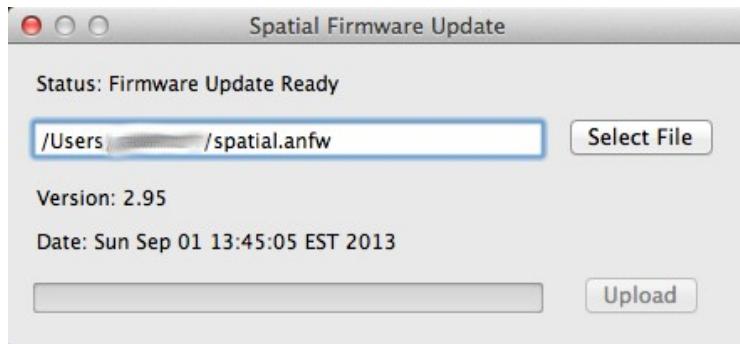


*Illustration 53: Screenshot of Spatial Manager magnetic calibration dialogue*



### 11.9.3 Firmware Update

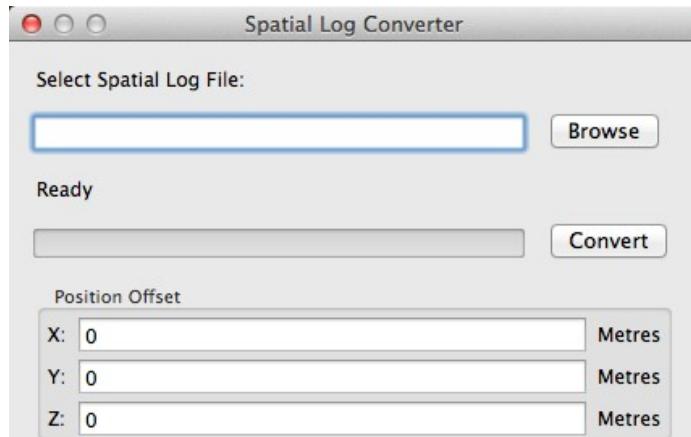
The firmware update dialogue is used to update Spatial's firmware. Advanced Navigation firmware files have the extension .anfw. The dialogue shows the version number of the firmware file along with the date and time it was generated by engineering.



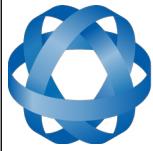
*Illustration 54: Screenshot of Spatial Manager firmware update dialogue*

### 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.

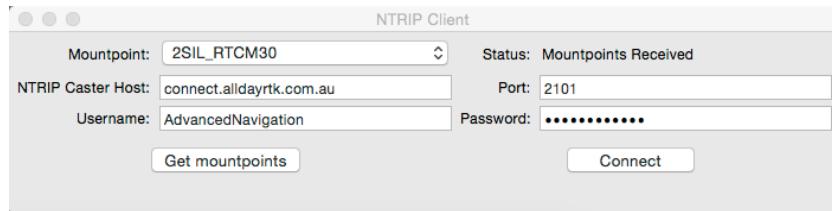


*Illustration 55: Screenshot of Spatial Manager log converter dialogue*



### 11.9.5 NTRIP Client

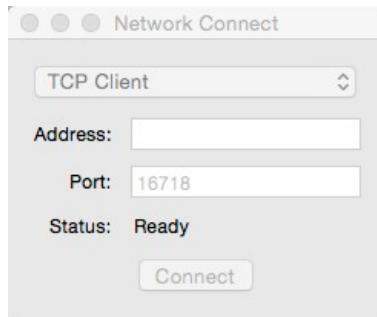
The NTRIP client can be used to connect to a network DGPS or RTK service to stream correction data to Spatial for DGPS or RTK. The NTRIP client requires an internet connection to function. Please contact [support@advancednavigation.com.au](mailto:support@advancednavigation.com.au) for guidance on getting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



*Illustration 56: 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 57: Screenshot of Spatial Manager network connect dialogue*



## 12 Interfacing

### 12.1 Communication

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

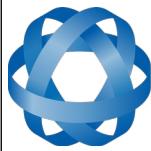
| Model         | Primary Port | Auxiliary Port | GPIO Port |
|---------------|--------------|----------------|-----------|
| Spatial RS232 | Yes          | Yes            | Yes       |
| Spatial RS422 | Yes          | No             | Yes       |

*Table 17: I/O ports available*

The primary port is used to communicate with Spatial using the ANPP format. Any required data in ANPP packet format can be configured to output on request or at predetermined rates.

#### 12.1.1 Baud Rate

The default baud rate for all the ports of Spatial is 115200 bps. The primary port baud rate can be set anywhere from 2400 to 2000000 baud and can be modified using the Spatial Manager software (see section 11.8.6) or the Baud Rates packet, see section 13.10.3. It is important to select a baud rate that is capable of carrying the amount of data that Spatial is configured to output. See Packet Rates in section 13.5 for more details on the data output calculation. The data rate in bytes per second can be calculated by dividing the baud rate by 10. For example, if the baud rate is 115200, then the data rate is 11520 bytes per second.



## 12.2 External Data

External sources of position, velocity, 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 18 below to find the relevant section. If using the GPIO's, 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 Odometer              | 13.9.42 |
| External Air Data              | 13.9.43 |

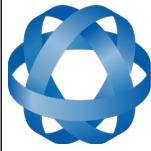
Table 18: ANPP external data reference

## 12.3 GPIO Pins and Auxiliary RS232

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

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

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



## 12.4 Dynamic Pin Functions

| Function                                 | Type            | GPIOs | Auxiliary RS232 |
|--|-----------------|-------|-----------------|
| Inactive                                 | Tristate        | All   | All             |
| 1PPS Output                              | Digital Output  | All   | Transmit        |
| GNSS Fix Output                          | Digital Output  | All   | Transmit        |
| Odometer Input                           | Frequency Input | All   | Receive         |
| Zero Velocity Input                      | Digital Input   | All   | Receive         |
| Pitot Tube Input                         | Frequency Input | All   | Receive         |
| NMEA Input                               | Serial Receive  | 2     | Receive         |
| NMEA Output                              | Serial Transmit | 1     | Transmit        |
| Novatel GNSS Input                       | Serial Receive  | 2     | Receive         |
| Topcon GNSS Input                        | Serial Receive  | 2     | Receive         |
| ANPP Input                               | Serial Receive  | 2     | Receive         |
| ANPP Output                              | Serial Transmit | 1     | Transmit        |
| Disable Magnetometers                    | Digital Input   | All   | Receive         |
| Disable GNSS                             | Digital Input   | All   | Receive         |
| Disable Pressure                         | Digital Input   | All   | Receive         |
| Set Zero Orientation Alignment           | Digital Input   | All   | Receive         |
| System State Packet Trigger              | Digital Input   | All   | Receive         |
| Raw Sensors Packet Trigger               | Digital Input   | All   | Receive         |
| Pressure Depth Transducer                | Frequency Input | All   | Receive         |
| RTCM Differential GNSS Corrections Input | Serial Receive  | 2     | Receive         |
| Trimble GNSS Input                       | Serial Receive  | 2     | Receive         |
| u-blox GNSS Input                        | Serial Receive  | 2     | Receive         |
| Hemisphere GNSS Input                    | Serial Receive  | 2     | Receive         |
| Teledyne DVL Input                       | Serial Receive  | 2     | Receive         |
| Tritech USBL Input                       | Serial Receive  | 2     | Receive         |
| Linkquest DVL Input                      | Serial Receive  | 2     | Receive         |
| Linkquest USBL Input                     | Serial Receive  | 2     | Receive         |
| Nortek DVL Input                         | Serial Receive  | 2     | Receive         |
| Left Wheel Speed Sensor                  | Frequency Input | All   | Receive         |
| Right Wheel Speed Sensor                 | Frequency Input | All   | Receive         |
| 1PPS Input                               | Digital Input   | All   | Receive         |



| Function                         | Type            | GPIOs | Auxiliary RS232 |
|----------------------------------|-----------------|-------|-----------------|
| Wheel Speed Sensor               | Frequency Input | All   | Receive         |
| Wheel Encoder Phase A            | Frequency Input | All   |                 |
| Wheel Encoder Phase B            | Frequency Input | All   |                 |
| Event 1 Input                    | Digital Input   | All   | Receive         |
| Event 2 Input                    | Digital Input   | All   | Receive         |
| TSS1 Output                      | Serial Transmit | 1     | Transmit        |
| Simrad 1000 Output               | Serial Transmit | 1     | Transmit        |
| Simrad 3000 Output               | Serial Transmit | 1     | Transmit        |
| Serial Port Passthrough          | Serial          | All   | All             |
| GNSS Receiver Passthrough        | Serial          | All   | All             |
| Gimbal Encoder Phase A           | Frequency Input | All   |                 |
| Gimbal Encoder Phase B           | Frequency Input | All   |                 |
| Odometer Direction, Forward Low  | Digital Input   | All   | Receive         |
| Odometer Direction, Forward High | Digital Input   | All   | Receive         |
| Reverse Alignment, Forward Low   | Digital Input   | All   | Receive         |
| Reverse Alignment, Forward High  | Digital Input   | All   | Receive         |
| Zero Angular Velocity Input      | Digital Input   | All   | Receive         |

Table 19: GPIO pin and auxiliary RS232 functions

#### 12.4.1 1PPS Output

In this function, the pin pulses for 50 milliseconds to signal the precise second. The 1PPS line starts pulsing approximately 100 milliseconds after power up and always fires irrespective of whether Spatial 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.

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

Table 20: 1PPS Specifications

#### 12.4.2 GNSS Fix Output

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



## 12.4.3 Odometer Input

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

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

Table 21: Odometer input specifications

## 12.4.4 Zero Velocity 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<br>GNGGA          | 3D position                              |
| GPGLL<br>GNGLL          | 2D position                              |
| GPRMC<br>GNRMC          | 2D position, 2D velocity and coarse time |
| GPVTG<br>GNVTG          | 2D velocity                              |
| GPHDT<br>GNHDT<br>HEHDT | Heading                                  |
| GPGSV<br>GNGSV          | Satellites                               |
| GPGSA<br>GNGSA          | Dilution of Position                     |
| GPZDA<br>GNZDA          | Time                                     |

Table 22: Supported NMEA input messages

### 12.4.7 NMEA Output

This function outputs a configurable combination of NMEA messages at up to 50 Hz. The messages output and the output rate can be configured using the NMEA output configuration dialogue in Spatial Manager. A complete list of available messages can be found in section 13.10.15.

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 BESTPOSB and BESTVELB at rates higher than 1 Hz (20Hz recommended). The message BESTSATSB 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

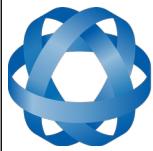
This function accepts a digital input. The input is normally low and a transition from low to high causes Spatial to set its alignment so that the current orientation is zero. Due to the risk of exhausting the flash cycles, the change is not permanent and will disappear on reset. To make it permanent 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 Pressure Depth Transducer**

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

## **12.4.19 RTCM Differential GNSS Corrections Input**

This function accepts RTCM v3 differential and RTK GNSS corrections. This allows for Differential and RTK GNSS with Spatial's internal GNSS receiver.

## **12.4.20 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.

## **12.4.21 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.

## **12.4.22 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.

## **12.4.23 Teledyne DVL Input**

This function accepts DVL data from a Teledyne DVL. For assistance with configuration please contact [support@advancednavigation.com.au](mailto:support@advancednavigation.com.au).

## **12.4.24 Tritech USBL Input**

This function accepts USBL data from a Tritech USBL. For assistance with configuration please contact [support@advancednavigation.com.au](mailto:support@advancednavigation.com.au).

## **12.4.25 Linkquest DVL Input**

This function accepts DVL data from a Linkquest DVL. For assistance with configuration please contact [support@advancednavigation.com.au](mailto:support@advancednavigation.com.au).

## **12.4.26 Linkquest USBL Input**

This function accepts USBL data from a Linkquest USBL. For assistance with



configuration please contact [support@advancednavigation.com.au](mailto:support@advancednavigation.com.au).

### **12.4.27 Nortek DVL Input**

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

### **12.4.28 Left Wheel Speed Sensor**

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

### **12.4.29 Right Wheel Speed Sensor**

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

### **12.4.30 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.

### **12.4.31 Wheel Speed Sensor**

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

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

Table 23: Wheel Speed Sensor Specifications

### **12.4.32 Wheel Encoder Phase A**

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

### **12.4.33 Wheel Encoder Phase B**

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

### **12.4.34 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.

#### **12.4.35 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.

#### **12.4.36 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.

#### **12.4.37 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.

#### **12.4.38 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.

#### **12.4.39 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.

#### **12.4.40 GNSS Receiver Passthrough**

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

#### **12.4.41 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.

#### **12.4.42 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.



## **12.4.43    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.

## **12.4.44    Odometer Direction, Forward High**

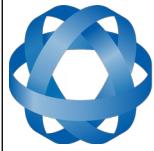
This function is designed to take a reversing indication input for direction with an odometer or wheel encoder. It should be used in combination with Odometer Input or Wheel Speed Sensor.

## **12.4.45    Reverse Alignment, Forward Low**

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

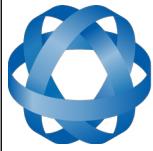
## **12.4.46    Reverse Alignment, Forward High**

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



## 12.4.47    Zero Angular Velocity Input

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



## 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 24: Data type abbreviations used in the ANPP



## 13.2 Packet Structure

The ANPP packet structure is shown in Table 25 and the header format is shown in Table 26. Example code can be downloaded from the software section.

| Header     |           |               |       |             |
|------------|-----------|---------------|-------|-------------|
| Header LRC | Packet ID | Packet Length | CRC16 | Packet Data |

Table 25: 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 26: 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.

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

## 13.5 Packet Rates

The packet rates can be configured either using Spatial 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

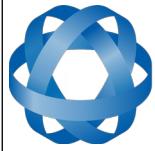
Minimum baud rate = data throughput x 11 = 57750 Baud

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



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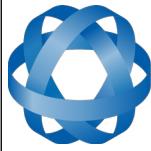
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Version 4.4

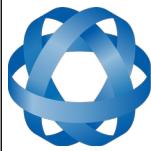
04/06/2019

validity for the other two packets.



## 13.7 Packet Summary

| Packet ID             | Length | R/W | Name   |
|-----------------------|--------|-----|--|
| <b>System Packets</b> |        |     |  |
| 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                  |
| <b>State Packets</b>  |        |     |  |
| 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                          |



| Packet ID             | Length   | R/W | Name                                      |
|-----------------------|----------|-----|---|
| 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 or 24 | R/W | External Body Velocity Packet             |
| 48                    | 8        | R/W | External Heading Packet                   |
| 49                    | 8        | R   | Running Time Packet                       |
| 50                    | 12       | R   | Local Magnetic Field Packet               |
| 51                    | 20       | R   | Odometer State Packet                     |
| 52                    | 8        | R/W | External Time Packet                      |
| 53                    | 8        | R/W | External Depth Packet                     |
| 54                    | 4        | R   | Geoid Height Packet                       |
| 55                    | -        | W   | RTCM Corrections Packet                   |
| 56                    | -        | -   | External Pitot Pressure Packet            |
| 57                    | 12       | R/W | Wind Packet                               |
| 58                    | 16       | R   | Heave Packet                              |
| 59                    | -        | -   | Post Processing Packet                    |
| 60                    | -        | R   | Raw Satellite Data Packet                 |
| 67                    | 13       | R/W | External Odometer Packet                  |
| 68                    | 25       | R/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                   | -        | -   | 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 |



| Packet ID | Length | R/W | Name                                  |
|-----------|--------|-----|---------------------------------------|
| 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 27: Packet summary

## 13.8 System Packets

### 13.8.1 Acknowledge Packet

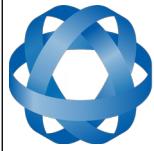
| Acknowledgement Packet |   |     |   |  |
|------------------------|---|-----|---|--|
| Packet ID              |   |     | 0 |  |
| Length                 |   |     | 4 |  |
| Field #                |   |     |   | Description                              |
| 1                      | 0 | u8  | 1 | 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 28: 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 29: 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 30: Request packet

## 13.8.3 Boot Mode Packet

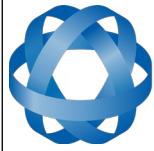
| Boot Mode Packet |              |           |      |                                 |
|------------------|--------------|-----------|------|---------------------------------|
| Packet ID        |              |           |      | 2                               |
| Length           |             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

Table 31: Boot mode packet

### 13.8.3.1 Boot Mode Types

| Value | Description  |
|-------|--------------|
| 0     | Bootloader   |
| 1     | Main Program |

Table 32: 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 33: 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 34: 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 35: Reset packet



### 13.8.6.1 Verification Sequence Values

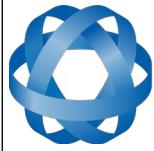
| Value      | Description              |
|------------|--------------------------|
| 0x21057A7E | Standard hot start reset |
| 0x9A5D38B7 | Cold start reset         |

Table 36: 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 #                         |  |  |  | Description                              |
| 1                               |  |  |  | Pass-through route, see section 13.8.7.1 |
| 2                               |  |  |  | Pass-through data                        |

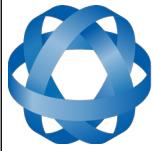
Table 37: Serial port pass-through packet



## 13.8.7.1 Pass-through Routes

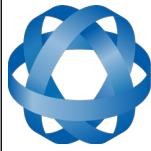
| <b>Value</b> | <b>Description</b> |
|--------------|--------------------|
| 1            | GPIO 1 and 2       |
| 2            | Auxiliary RS232    |

*Table 38: 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.



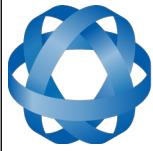
## 13.9.1 System State Packet

| 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 39: System state packet

### 13.9.1.1 System Status

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



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

Table 40: 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 41: Filter status

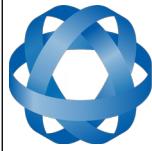
### 13.9.1.3 GNSS Fix Status

| 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 42: 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

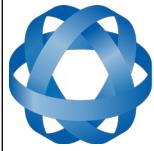
| Unix Time Packet |              |           |      |   |
|------------------|--------------|-----------|------|---|
| Packet ID        |              |           |      | 21  |
| Length           |              |           |      | 8   |
| Field #          | Bytes Offset | Data Type | Size | Description                               |
| 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 43: 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 44: 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 45: Status packet

### 13.9.5 Position Standard Deviation Packet

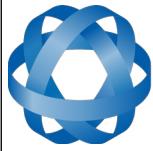
| Position Standard Deviation Packet |              |           |      |                                  |
|------------------------------------|--------------|-----------|------|----------------------------------|
| Packet ID                          |              |           |      | 24                               |
| 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 46: 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 47: Velocity standard deviation packet



### 13.9.7 Euler Orientation Standard Deviation Packet

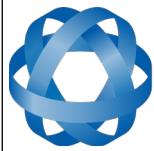
| Euler Orientation Standard Deviation Packet |              |           |      |                                 |
|---|--------------|-----------|------|---------------------------------|
| Packet ID                                   |              |           |      | 26                              |
| 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 48: 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    | Qs standard deviation |
| 2  | 4            | fp32      | 4    | Qx standard deviation |
| 3  | 8            | fp32      | 4    | Qy standard deviation |
| 4  | 12           | fp32      | 4    | Qz standard deviation |

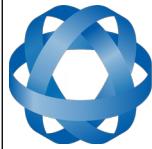
Table 49: Quaternion orientation standard deviation packet



### 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 50: Raw sensors packet

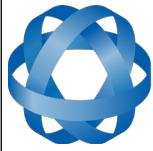


### 13.9.10 Raw GNSS Packet

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

| Raw GNSS Packet |              |           |      |                                  |
|-----------------|--------------|-----------|------|----------------------------------|
| Packet ID       |              |           |      | 29                               |
| Length          |              |           |      | 74                               |
| Field #         | Bytes Offset | Data Type | Size | Description                      |
| 1               | 0            | u32       | 4    | Unix time stamp (seconds)        |
| 2               | 4            | u32       | 4    | Microseconds                     |
| 3               | 8            | fp64      | 8    | Latitude (rad)                   |
| 4               | 16           | fp64      | 8    | Longitude (rad)                  |
| 5               | 24           | fp64      | 8    | Height (m)                       |
| 6               | 32           | fp32      | 4    | Velocity north (m/s)             |
| 7               | 36           | fp32      | 4    | Velocity east (m/s)              |
| 8               | 40           | fp32      | 4    | Velocity down (m/s)              |
| 9               | 44           | fp32      | 4    | Latitude standard deviation (m)  |
| 10              | 48           | fp32      | 4    | Longitude standard deviation (m) |
| 11              | 52           | fp32      | 4    | Height standard deviation (m)    |
| 12              | 56           | fp32      | 4    | 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 51: 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 52: 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 53: 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 54: Detailed satellites packet

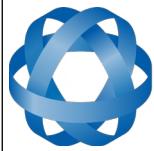
### 13.9.12.1 Satellite Systems

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

Table 55: 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 56: Satellite frequencies

### 13.9.13 Geodetic Position Packet

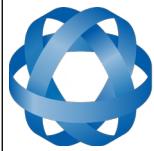
| Geodetic Position Packet |              |           |      |                 |
|--------------------------|--------------|-----------|------|-----------------|
| Packet ID                |              |           |      | 32              |
| Length                   |              |           |      | 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 57: 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 58: 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 59: UTM position packet

### 13.9.16 NED Velocity Packet

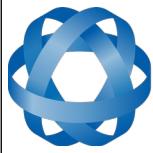
| NED Velocity Packet |              |           |      |                      |
|---------------------|--------------|-----------|------|----------------------|
| Packet ID           |              |           |      | 35                   |
| Length              |              |           |      | 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 60: 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 61: 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 62: Acceleration packet

### 13.9.19 Body Acceleration Packet

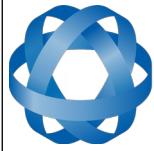
| Body Acceleration Packet |              |           |      |                             |
|--------------------------|--------------|-----------|------|-----------------------------|
| Packet ID                |              |           |      | 38                          |
| Length                   |              |           |      | 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 63: 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 64: Euler orientation packet



### 13.9.21 Quaternion Orientation Packet

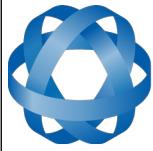
| Quaternion Orientation Packet |              |           |      |             |
|-------------------------------|--------------|-----------|------|-------------|
| Packet ID                     |              |           |      | 40          |
| Length                        |              |           |      | 16          |
| Field #                       | Bytes Offset | Data Type | Size | Description |
| 1                             | 0            | fp32      | 4    | Qs          |
| 2                             | 4            | fp32      | 4    | Qx          |
| 3                             | 8            | fp32      | 4    | Qy          |
| 4                             | 12           | fp32      | 4    | Qz          |

Table 65: 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 66: 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 67: Angular velocity packet

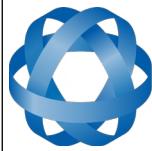
### 13.9.24 Angular Acceleration Packet

| 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 68: 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 69: 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 70: 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 71: External velocity packet



### 13.9.28 External Body Velocity Packet

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

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

Table 72: External body velocity packet

### 13.9.29 External Heading Packet

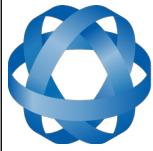
| External Heading Packet |              |           |      |                                  |
|-------------------------|--------------|-----------|------|----------------------------------|
| Packet ID               |              |           |      | 48                               |
| Length 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

Table 73: 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 74: 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 75: Local magnetic field packet

### 13.9.32 Odometer State Packet

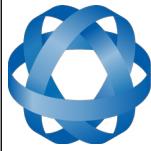
| Odometer State Packet |              |           |      |                       |
|-----------------------|--------------|-----------|------|-----------------------|
| Packet ID             |              |           |      | 51                    |
| Length                |              |           |      | 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 76: 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 77: 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 78: External depth packet

### 13.9.35 Geoid Height Packet

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

Height Above Mean Sea Level = WGS84 Height - Geoid Height

Depth = Geoid Height - WGS84 Height

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

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

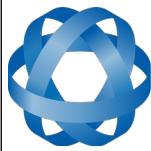
Table 79: Geoid height packet

### 13.9.36 RTCM Corrections Packet

This packet is used to encapsulate RTCM v3 differential and RTK correction data to be sent to Spatial's internal GNSS receiver for differential and RTK GNSS functionality.

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

Table 80: RTCM corrections packet



### 13.9.37 External Pitot Pressure Packet

This packet is no longer supported. The External Air Data packet #68 should be used.

### 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 81: Wind packet

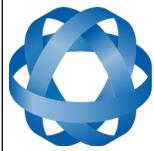
### 13.9.39 Heave Packet

| 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 82: Heave packet

### 13.9.40 Post Processing Packet

This packet is no longer supported. If you need an IMR file please contact Advanced Navigation support for required settings.

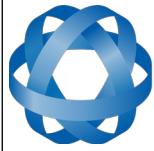


## 13.9.41 Raw Satellite Data Packet

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

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

Table 83: Raw satellite data packet



## 13.9.41.1 Satellite Frequencies

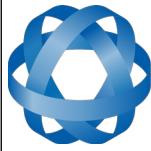
| <b>Value</b> | <b>GPS</b> | <b>GLONASS</b> | <b>Galileo</b> | <b>BeiDou</b> | <b>SBAS</b> | <b>QZSS</b> |
|--------------|------------|----------------|----------------|---------------|-------------|-------------|
| 0            | Unknown    | Unknown        | Unknown        | Unknown       | Unknown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

Table 84: Satellite frequencies

## 13.9.41.2 Tracking Status

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

Table 85: Tracking status



## 13.9.42 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 13.9.42.1 |

Table 86: External odometer packet

### 13.9.42.1 Odometer flags

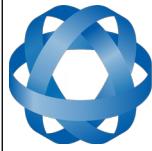
| Bit | Description                   |
|-----|-------------------------------|
| 0   | Reversing detection supported |
| 1-7 | Reserved (set to zero)        |

Table 87: Odometer flags

## 13.9.43 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 13.9.43.1               |

Table 88: External air data packet



### 13.9.43.1 External Air Data Flags

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

Table 89: External air data flags

### 13.9.43.2 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.

## 13.9.44 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 90: Gimbal state packet

## 13.9.45 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 91: 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 92: 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 93: 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

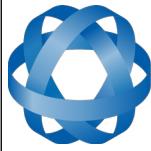
This indicates the period in units of the packet timer period. The packet rate can be calculated as follows.

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

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    | Primary RS232 and RS422 baud rate (2400 to 2000000) |
| 3                 | 5            | u32       | 4    | GPIO 1 & 2 baud rate (2400 to 250000)               |
| 4                 | 9            | u32       | 4    | Auxiliary RS232 Baud Rate (2400 to 2000000)         |
| 5                 | 13           |           | 4    | Reserved (set to zero)                              |

Table 94: Baud rates packet

### 13.10.4 Sensor Ranges Packet

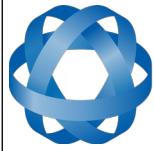
| Sensor Ranges Packet |              |           |      |   |
|----------------------|--------------|-----------|------|---|
| Packet ID            |              |           |      | 184   |
| Length               |              |           |      | 4   |
| Field #              | Bytes Offset | Data 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 95: 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 96: Accelerometers range



## 13.10.4.2 Gyroscopes Range

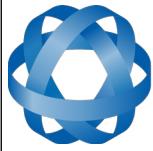
| Value | Description         |
|-------|---------------------|
| 0     | 250 degrees/second  |
| 1     | 500 degrees/second  |
| 2     | 2000 degrees/second |

*Table 97: Gyroscopes range*

## 13.10.4.3 Magnetometers Range

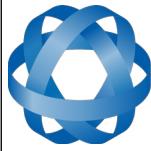
| Value | Description |
|-------|-------------|
| 0     | 2 Gauss     |
| 1     | 4 Gauss     |
| 2     | 8 Gauss     |

*Table 98: Magnetometers range*

**13.10.5 Installation Alignment Packet**

| <b>Installation Alignment Packet</b> |              |           |      |                            |
|--------------------------------------|--------------|-----------|------|----------------------------|
| 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 99: 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 its standard alignment. A DCM is used rather than euler angles for accuracy reasons. To convert euler angles to DCM please use the formula below with angles in radians.

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

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

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

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

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

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

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

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

$$DCM[2][2] = \cos(\text{pitch}) * \cos(\text{roll})$$

### 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 100: Filter options packet



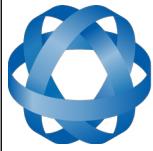
### 13.10.6.1 Vehicle Types

| <b>Value</b> | <b>Description</b>    |
|--------------|-----------------------|
| 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 101: Vehicle types

### 13.10.7 Advanced Filter Parameters Packet

This packet is no longer supported.



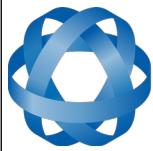
## 13.10.8 GPIO Configuration Packet

| 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 102: GPIO configuration packet

### 13.10.8.1 GPIO1 Functions

| Value | Description                    |
|-------|--------------------------------|
| 0     | Inactive                       |
| 1     | 1PPS Output                    |
| 2     | GNSS Fix Output                |
| 3     | Odometer Input                 |
| 4     | Zero Velocity Input            |
| 5     | Pitot Tube Input               |
| 7     | NMEA Output                    |
| 12    | ANPP Output                    |
| 13    | Disable Magnetometers          |
| 14    | Disable GNSS                   |
| 15    | Disable Pressure               |
| 16    | Set Zero Orientation Alignment |
| 17    | System State Packet Trigger    |
| 18    | Raw Sensors Packet Trigger     |
| 26    | Pressure Depth Transducer      |
| 27    | Left Wheel Speed Sensor        |
| 28    | Right Wheel Speed Sensor       |

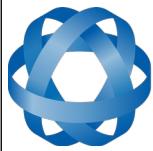


|    |                                  |
|----|----------------------------------|
| 29 | 1PPS Input                       |
| 30 | Wheel Speed Sensor               |
| 31 | Wheel Encoder Phase A            |
| 32 | Wheel Encoder Phase B            |
| 33 | Event 1 Input                    |
| 34 | Event 2 Input                    |
| 38 | GNSS Receiver Passthrough        |
| 39 | TSS1 Output                      |
| 40 | Simrad 1000 Output               |
| 41 | Simrad 3000 Output               |
| 42 | Serial Port Passthrough          |
| 43 | Gimbal Encoder Phase A           |
| 44 | Gimbal Encoder Phase B           |
| 45 | Odometer Direction, Forward Low  |
| 46 | Odometer Direction, Forward High |
| 53 | Reverse Alignment, Forward Low   |
| 54 | Reverse Alignment, Forward High  |
| 55 | Zero Angular Velocity Input      |

Table 103: GPIO1 functions

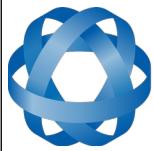
#### 13.10.8.2 GPIO2 Functions

| <b>Value</b> | <b>Description</b>    |
|--------------|-----------------------|
| 0            | Inactive              |
| 1            | 1PPS Output           |
| 2            | GNSS Fix Output       |
| 3            | Odometer Input        |
| 4            | Zero Velocity Input   |
| 5            | Pitot Tube Input      |
| 6            | NMEA Input            |
| 8            | Novatel GNSS Input    |
| 9            | Topcon GNSS Input     |
| 11           | 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                    |
| 23 | Teledyne DVL Input                       |
| 24 | Tritech USBL Input                       |
| 25 | Linkquest DVL Input                      |
| 26 | Pressure Depth Transducer                |
| 27 | Left Wheel Speed Sensor                  |
| 28 | Right Wheel Speed Sensor                 |
| 29 | 1PPS Input                               |
| 30 | Wheel Speed Sensor                       |
| 31 | Wheel Encoder Phase A                    |
| 32 | Wheel Encoder Phase B                    |
| 33 | Event 1 Input                            |
| 34 | Event 2 Input                            |
| 35 | Linkquest USBL Input                     |
| 38 | GNSS Receiver Passthrough                |
| 42 | Serial Port Passthrough                  |
| 43 | Gimbal Encoder Phase A                   |
| 44 | Gimbal Encoder Phase B                   |
| 45 | Odometer Direction, Forward Low          |
| 46 | Odometer Direction, Forward High         |
| 51 | Nortek DVL Input                         |
| 53 | Reverse Alignment, Forward Low           |
| 54 | Reverse Alignment, Forward High          |
| 55 | Zero Angular Velocity Input              |

Table 104: GPIO2 functions



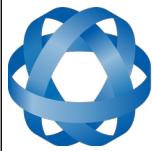
### 13.10.8.3 Auxiliary RS232 Transmit Functions

| <b>Value</b> | <b>Description</b>        |
|--------------|---------------------------|
| 0            | Inactive                  |
| 1            | 1PPS Output               |
| 2            | GNSS Fix Output           |
| 7            | NMEA Output               |
| 12           | ANPP Output               |
| 38           | GNSS Receiver Passthrough |
| 39           | TSS1 Output               |
| 40           | Simrad 1000 Output        |
| 41           | Simrad 3000 Output        |
| 42           | Serial Port Passthrough   |

Table 105: Auxiliary RS232 transmit functions

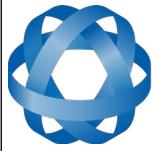
### 13.10.8.4 Auxiliary RS232 Receive Functions

| <b>Value</b> | <b>Description</b>                       |
|--------------|--|
| 0            | Inactive                                 |
| 3            | Odometer Input                           |
| 4            | Zero Velocity Input                      |
| 5            | Pitot Tube Input                         |
| 6            | NMEA Input                               |
| 8            | Novatel GNSS Input                       |
| 9            | Topcon GNSS Input                        |
| 11           | 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                    |



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

Table 106: Auxiliary RS232 receive functions

**13.10.9 Magnetic Calibration Values Packet**

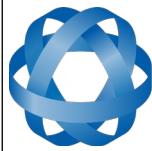
| <b>Magnetic Calibration Values Packet</b> |              |           |      |                             |
|---|--------------|-----------|------|-----------------------------|
| Packet ID                                 |              |           |      | 189                         |
| Length                                    |              |           |      | 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 107: Magnetic calibration values packet

**13.10.10 Magnetic Calibration Configuration Packet**

| <b>Magnetic Calibration Configuration Packet</b> |              |           |      |   |
|--|--------------|-----------|------|---|
| 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 108: 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 109: Magnetic calibration actions

### 13.10.11 Magnetic Calibration Status Packet

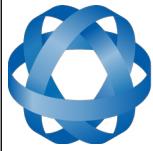
| Magnetic Calibration Status Packet |   |    |     |   |
|------------------------------------|---|----|-----|---|
| Packet ID                          |   |    | 191 |   |
| Length                             |   |    | 3   |   |
| Field #                            |   |    |     | Description   |
| 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 110: 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 111: 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 112: 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 113: 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.

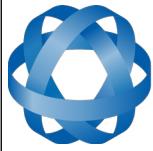
| Reference Point Offsets Packet |              |           |      |                                      |
|--------------------------------|--------------|-----------|------|--------------------------------------|
| Packet ID                      |              |           | 194  |                                      |
| 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 114: Reference point offsets packet

**13.10.15 GPIO Output Configuration Packet**

| <b>GPIO Output Configuration Packet</b> |              |           |      |  |
|---|--------------|-----------|------|--|
| 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    | GPHDT 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           | u16       | 2    | GPROT Rates, see section 13.10.15.2        |
| 13                                      | 22           | u16       | 2    | GPHEV Rates, see section 13.10.15.2        |
| 14                                      | 24           | u16       | 2    | GPGSV Rates, see section 13.10.15.2        |
| 15                                      | 26           | u16       | 2    | PFECAAtt Rates, see section 13.10.15.2     |
| 16                                      | 28           | u16       | 2    | PFECHve Rates, see section 13.10.15.2      |
| 17                                      | 30           |           | 3    | Reserved (set to zero)                     |

Table 115: 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 116: NMEA fix behaviour

### 13.10.15.2 GPIO Output Rates

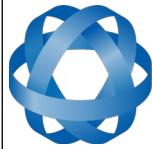
| Bit  | Description                                     |
|------|---|
| 0-3  | GPIO 1 rate, see section 13.10.15.3             |
| 4-7  | Auxiliary RS232 Tx rate, see section 13.10.15.3 |
| 8-15 | Reserved (set to zero)                          |

Table 117: 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 118: 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 119: 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 120: GPIO input configuration packet



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