



**ADVANCED
NAVIGATION**



Motus Reference Manual

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1 Revision History

Version	Date	Changes
2.8	25 March 2024	Updated firmware changelog, see 2.1 Firmware Changelog
2.7	20 Feb 2024	Updated firmware changelog, see 2.1 Firmware Changelog Updated automatic magnetometer calibration explanation to reflect Firmware changes, see 8.5 Magnetic Calibration ANPP packets 70 (Raw DVL Data Packet) and 185 (Installation Alignment Packet) updated Content migrated to new documentation platform Minor editorial changes
2.6	14 Nov 2023	Updated software changelog, see 9.1.1 Motus Manager Software Changelog Updated automatic magnetometer calibration explanation to reflect Firmware changes, see 8.5 Magnetic Calibration Updated Disclaimer
2.5	20 Feb 2023	Updated software changelog, see 9.1.1 Motus Manager Software Changelog Updated software installation information to include Java 11 requirement, see 9.1.3 Installation and Starting and 4 Getting Started Added instructions to run Manager on MacOS, see 9.1.3 Installation and Starting
2.4	12 Oct 2022	Added Device ID table, see 11.3.4 Device Information Packet Updated software changelog, see 9.1 Using Motus Manager Updated firmware changelog, see 2.1 Firmware Changelog Updated product part numbers, see 5 Part Numbers and Ordering Options Updated Log Converter Tool image and description, section 12.9.3 Added breakout cables to list of accessories, see 5 Part Numbers and Ordering Options Updated connector pinout to include RS422, section 9.10 Added RS422 breakout cable information, section 9.12.2 Added ODU connector pin location diagram, section 9.10 Clarified geoid, ellipsoid and orthometric heights, section 5.7 Updated automatic magnetometer calibration explanation to reflect Firmware changes, section 11.5.3 Updated External Time Packet to show it is Read only, see 11.4.33 External Time Packet Added note that Motus Manager only works on systems with x64 architecture, sections 7.2 and 10.1
2.3	25 Oct 2021	Updated firmware changelog, see 2.1 Firmware Changelog Updated hardware changelog, see 2.2 Hardware Changelog
2.2	12 Jul 2021	Updated firmware changelog, see 2.1 Firmware Changelog Improved power supply specifics section 13.4 & 14.5
2.1	22 Jan 2021	Updated firmware changelog, see 2.1 Firmware Changelog Updated hardware changelog, see 2.2 Hardware Changelog Updated OEM images section 13, 14 & 14.4
2.0	28 Oct	Update for v2 Hardware, sections 9, v1 hardware now obsolete

Version	Date	Changes
	2020	Update Manager section 12 Updated OEM drawings and detail, sections 13 and 14
1.1	29 Nov 2019	<p>Updated firmware changelog, see 2.1 Firmware Changelog</p> <p>Updated hardware changelog, see 2.2 Hardware Changelog</p> <p>Updated dynamic pin functions table, 10.3.1 Dynamic Pin Functions</p> <p>Updated GPIO configuration packet, see 11.5.6 GPIO Configuration Packet</p> <p>Added pressure depth transducer deprecated input function, see 10.3.1.21 Pressure Depth Transducer (deprecated)</p> <p>Added Nortek DVL input function, see 10.3.1.41 Nortek DVL Input</p> <p>Added Teledyne DVL input function, see 10.3.1.40 Linkquest USBL Input</p> <p>Added Tritech USBL input function, see 10.3.1.40 Linkquest USBL Input</p> <p>Added Linkquest DVL input function, see 10.3.1.39 Linkquest DVL Input</p> <p>Added Linkquest USBL input functionality, see 10.3.1.40 Linkquest USBL Input</p> <p>Added reverse alignment input functions, see 10.3.1.16 Reverse Alignment, Forward Low</p> <p>Added zero angular velocity input function, see 10.3.1.39 Linkquest DVL Input</p> <p>Clarified port baud rates in sections</p> <p>Updated read status for external air data packet, see 11.4.39 External Air Data Packet</p> <p>Updated read status for external odometer packet, see 11.4.38 External Odometer Packet</p> <p>Modified quaternion element labels</p> <p>Clarified geoid height packet description</p> <p>Removed external pitot pressure packet</p> <p>Updated external body velocity packet size and definition, see 11.4.28 External Body Velocity Packet</p> <p>Added wheel speed sensor specifications</p> <p>Corrected Raw GNSS packet velocity units</p> <p>Updated GPIO output configuration packet</p> <p>Clarified negative acknowledgement packets</p> <p>Clarified 1PPS output voltages</p> <p>Updated specifications</p> <p>Clarified navigation specifications</p> <p>Corrected power supply drop out voltage</p> <p>Added odometer information to Installation chapter</p> <p>Added magnetics information to Installation chapter</p> <p>Updated operating temperature information</p> <p>Corrected IP rating of rugged enclosure</p> <p>Clarified raw GNSS data output packets</p> <p>Corrected system status and filter status flags</p> <p>Corrected raw sensors packet fields</p>
1.0	17 Mar 2016	Initial Release

Table 1: Revision History

2 Introduction

Motus is a miniature ultra high accuracy MEMS IMU/AHRS. It features some of the highest accuracy MEMS accelerometers and gyroscopes currently available, combined with magnetometers. Motus is extensively calibrated for all sensor errors over a wide temperature range.

It can be software upgraded to offer GNSS/INS functionality, through the use of an external GNSS receiver.



Figure 1: Motus

Motus will provide outstanding results when mounted, configured and operated correctly. Read through this manual carefully to ensure a successful outcome for your application.

Note: Motus is available in both OEM and enclosed (rugged) packages. All references herein refer to the enclosed (rugged) form factor. See the OEM documentation on the Advanced Navigation [product documentation page](#) for customer integrated units.

A Motus Evaluation Kit, which includes all the cables you will need, is available to get you started quickly. See [3 Evaluation Kit](#). If you have any technical questions, contact support@advancednavigation.com.

More Information...

Use the links below for detailed information about Motus.

- [5 Part Numbers and Ordering Options](#)
- [6 Specifications](#)
- [7 Installing Motus](#)
- [8 Using Motus](#)
- [9 Configuring and Monitoring Motus](#)
- [10 Interfacing](#)
- [11 Advanced Navigation Packet Protocol](#)
- [12 Reference Information](#)

2.1 Firmware Changelog

Motus uses the same firmware as Motus Rugged.

Version	Date	Changes
2.41	18 March 2024	Fixed Pressure Sensor reporting NaN values on v2.3 HW
2.4	2 February 2024	Enabled the pressure sensor for Motus hardware v2.3 and newer Improved stability and performance of automatic magnetometer calibration algorithm for some vehicle profiles, see 8.5 Magnetic Calibration Updated DVL input to use Odometer Offset Fix magnetometer sensor recovery and failure flag triggering when filter options packet is received Increased magnetometer sample rate to 100 Hz on newer hardware version devices Fix intermittent fault on start-up Extended external GNSS lever arm offset range to 50 m horizontal and 100 m vertical Fix Time Filter initialised when receiving 1PPS and Raw GNSS packet in the GPIO or Aux port Fix timestamp occasionally jumping backwards in NMEA0183 packets Fix transient Magnetometer Overage flag on cold boot Fix intermittent filter resets Added check to prevent zero scaling in all magnetometer calibration algorithms Improved reliability of time calculations Fix External GNSS data processing based on Internal GNSS Enabled filter option
2.3	6 September 2021	Update to support hardware v2.3 Fix Magnetometer Axis Swap for hardware v2.0
2.2	29 June 2021	Fix Magnetometer axis swap for hardware v2.1 and v2.2
2.1	14 December 2021	Bug fix for calibration issue (magnetometer scaling) Minor fixes to magnetic initialisation
1.8	2 March 2020	Support for v2 hardware
1.6	28 November	Improvements to raw sensor calibration algorithm

Version	Date	Changes
	2019	Prevents fast temperature variations from introducing digital noise into accelerometer values which was regression from firmware version 1.4
1.5	03 October 2019	Improvements to raw sensor calibration algorithm More accurate temperature compensation of sensors leads to overall performance improvement Improvements to heading integrity monitoring algorithm to better reject erroneous measurements
1.4	05 September 2019	Improvements to raw sensor calibration algorithm Better sensor performance through rapid temperature changes leads to performance improvement in cases of fast temperature ramps
1.3	31 May 2019	Improvements to integrity monitoring allows better rejection of erroneous position and velocity data
1.1	17 July 2018	New zero angular velocity functionality Better hot start performance
1.0	01 March 2016	Initial release

Table 2: Firmware Changelog

2.2 Hardware Changelog

Version	Date	Changes
2.3	6 September 2021	Pressure sensor update
2.2	29 September 2020	Internal manufacturing improvements
2.0	04 September 2020	Minor changes to the baseplate thickness. No increase to overall height, length or width Added alignment markings to baseplate Improved sensor performance Removal of 0.2 mm material from from the inner area of the base of the housing to make mounting onto uneven surfaces easier
1.4	16 July 2018	Internal manufacturing improvements No noticeable changes for customers
1.3	07 September 2017	Improvements to ADC synchronisation results in slightly improved performance under high dynamics
1.2	05 October 2016	Internal manufacturing improvements
1.0	14 September 2015	Initial release

Table 3: Hardware Changelog

3 Evaluation Kit

The Motus Rugged variant is supplied in an Evaluation Kit that contains everything required to get started operating the system right away. The Evaluation Kit is supplied in a rugged transport case to protect the equipment during transit.



Figure 2: Motus Rugged Evaluation Kit transport case

3.1 Rugged Evaluation Kit Contents



Figure 3: Motus Rugged Evaluation Kit Contents

Part Number	Quantity	Description	Notes
MOTUS2-RUG	1	Motus Rugged Unit (RS232)	Motus unit in rugged enclosure
A503-SDC20796	1	ODU plug to FTDI USB cable	Motus rugged ODU plug with 2 metres of cable to FTDI USB plug

Table 4: Rugged Evaluation Kit Contents

4 Getting Started

1. Plug the interface cable into Motus.
2. Plug the USB end of the interface cable into your computer.
3. Download the Motus Manager software from the Motus page of the [Advanced Navigation website](#).
Java 11 is required to run Motus Manager. Adoptium JRE 11 is the recommended Java installer to be used on all platforms. Install the latest version of Java 11 from [Adoptium](#), selecting the correct operating system and architecture for your computer.
4. Click the connect button in Motus Manager.
5. The various windows in Motus Manager can be used to view the real time data.
6. To view the data logs, click disconnect in Motus 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 Motus Manager software.

There are additional factors that you must review before you proceed with the installation. For more information, see [7 Installing Motus](#)

5 Part Numbers and Ordering Options

This section covers information about:

- [5.1 Evaluation Kits](#)
- [5.2 Standalone Units](#)
- [5.3 Software License Upgrades](#)
- [5.4 Accessories](#)

5.1 Evaluation Kits

Part Number	Description	Notes
MOTUS-RUG-EK	MotusRugged Evaluation Kit (RS232)	Motus Rugged Evaluation Kit Includes the items listed in 3.1 Rugged Evaluation Kit Contents . INS upgrade license can be purchased separately, see 5.3 Software License Upgrades

Table 5: Evaluation Kit Part Numbers

5.2 Standalone Units

Part Number	Description	Notes
MOTUS2-RUG	Motus Rugged Unit (RS232)	Motus Rugged unit No cables included IMU/AHRS functionality only INS upgrade license can be purchased separately, see section 5.3 Software License Upgrades
MOTUS2-RUG-422	Motus Rugged Unit (RS422)	As above with optional RS422 interface instead of standard RS232 interface

Table 6: Standalone Unit Part Numbers

5.3 Software License Upgrades

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

Part Number	Description	Notes
MOTUS2-LIC-INS	INS license upgrade for Motus	Software license upgrade that activates INS functionality of Motus unit.

Table 7: Ordering Part Numbers for Software License Upgrades

5.4 Accessories

Part Number	Description	Notes
A503-SDC20796	ODU plug to FTDI USB cable	Motus rugged ODU plug with 2 metres of cable to FTDI USB plug, see 6.7.1 Rugged Evaluation Kit USB Cable
A503-SDC20740-2M	ODU plug with 2m cable (unterminated)	Motus rugged ODU plug with 2 metres of unterminated cable, see 6.6 Connector Pin-out
A503-SDC20740-5M	ODU plug with 5m cable (unterminated)	Motus rugged ODU plug with 5 metres of unterminated cable, see 6.6 Connector Pin-out
A503-SDC20740-10M	ODU plug with 10m cable (unterminated)	Motus rugged ODU plug with 10 metres of unterminated cable, see 6.6 Connector Pin-out
A503-SDC20740-20M	ODU plug with 20m cable (unterminated)	Motus rugged ODU plug with 20 metres of unterminated cable, see 6.6 Connector Pin-out
A503-SDC20753	ODU to D9 connectors and DC socket (RS232)	Motus rugged ODU plug with 2m of cable to industry standard D9 connectors and DC socket, see 6.7.2.1 RS232 Breakout Cable (A503-SDC20753)
A503-SDC20755	ODU to D9 connectors and DC socket (RS422)	Motus rugged ODU plug with 2m of cable to industry standard D9 connectors and DC socket, see 6.7.2.2 RS422 Breakout Cable (A503-SDC20755)

Table 8: Accessories Part Numbers

6 Specifications

For details, review the following specifications for Motus:

- [6.1 Navigation Specifications](#)
- [6.2 Sensor Specifications](#)
- [6.3 Hardware Specifications](#)
- [6.4 Communication Specifications](#)
- [6.5 Electrical Specifications](#)
- [6.6 Connector Pin-out](#)
- [6.7 IO Connection](#)

6.1 Navigation Specifications

Motus as a standalone IMU/AHRS can achieve the following performance:

Parameters	Specification
Roll & Pitch Accuracy	0.05 °
Heading Accuracy (magnetic)	0.8 °
Orientation Range	Unlimited
Hot Start Time	500 ms
Internal Filter Rate	1000 Hz
Output Data Rate	Up to 1000 Hz

Table 9: Motus Orientation Specifications

Motus can be upgraded to full INS capability through a software license upgrade. As an INS it can be interfaced to any of the leading brands of GNSS receivers to create an OEM GNSS/INS solution. When using a Trimble BD992 receiver, for example, the following specifications are achievable:

Parameters	Specification
Horizontal Position Accuracy	0.8 m
Vertical Position Accuracy	1.5 m
Horizontal Position Accuracy (RTK)	0.008 m
Vertical Position Accuracy (RTK)	0.015 m
Velocity Accuracy	0.007 m/s
Roll & Pitch Accuracy (GNSS aided)	0.03 °
Heading Accuracy (GNSS aided)	0.1 °
Heading Accuracy (dual antenna GNSS)	0.05 °

Table 10: Motus Navigation Specifications (with external GNSS)

6.2 Sensor Specifications

Parameter	Accelerometers	Gyroscopes	Magnetometers	Pressure
Range (dynamic)	±10 g	±475 °/s	±8 G	10-120 kPa
Bias Instability	8 ug	0.2 °/hr	-	10 Pa
Initial Bias	< 0.45 mg	< 3 °/hr	-	-
Initial Scaling Error	< 0.03 %	< 0.02 %	< 0.07 %	-
Scale Factor Stability	< 0.04 %	< 0.03 %	< 0.09 %	-
Non-linearity	< 0.05 %	< 0.03 %	< 0.08 %	-
Cross-axis Alignment Error	< 0.05 °	< 0.05 °	< 0.05 °	-
Noise Density	2 ug/√Hz	6 °/hr/√Hz	210 uG/√Hz	0.56 Pa/√Hz
Bandwidth	250 Hz	200 Hz	110 Hz	50 Hz

Table 11: Motus Sensor Specifications

6.2.1 Sensor Calibration

Motus’s sensors are calibrated for bias, sensitivity, misalignment, cross-axis sensitivity, non-linearity and gyroscope linear acceleration sensitivity across the full operating temperature range.

6.3 Hardware Specifications

Parameter	Specification
Operating Voltage	5 to 36 V
Input Protection	±60 V
Power Consumption (typical)	1.4 W
Power Consumption (maximum)	1.8 W
Inrush Current	0.5 A
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 Sealing	IP67 MIL-STD-810G

Parameter	Specification
Shock Limit	150 g, 6 ms, half sine
Vibration Limit	8 g RMS
Dimensions	42 x 67 x 30 mm
Weight	98 grams

Table 12: Hardware Specifications

6.3.1 Rugged Mechanical Drawings

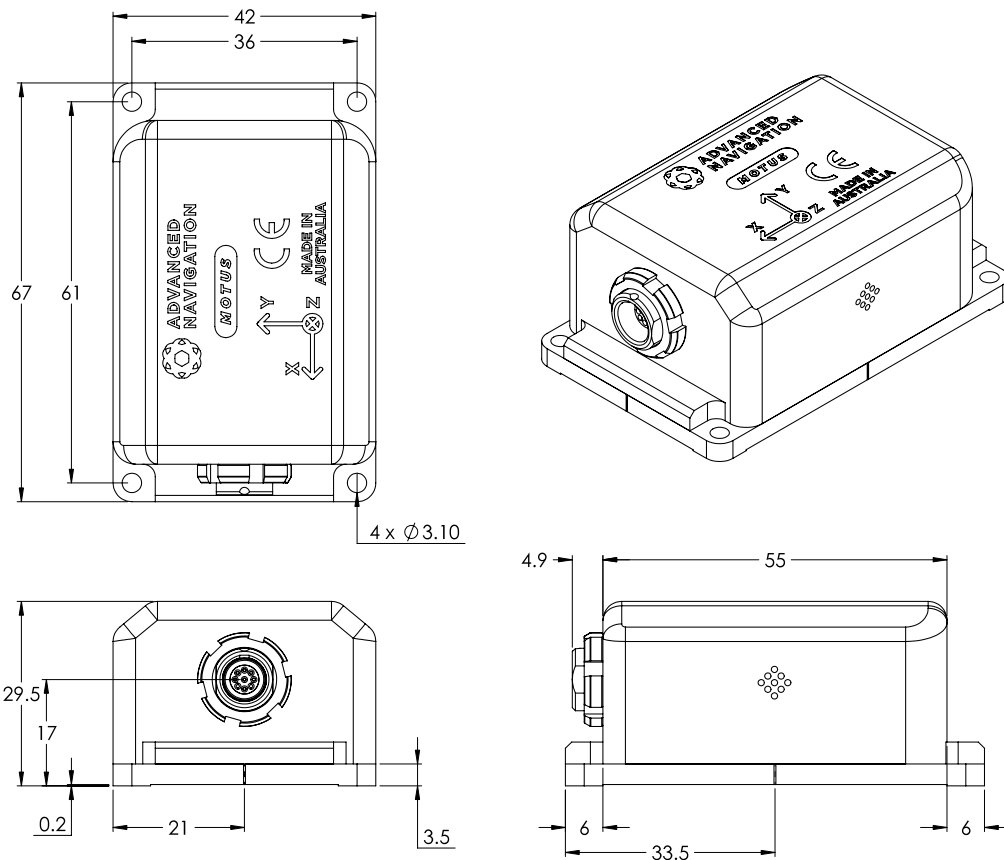


Figure 4: Mechanical drawings of Motus

6.3.2 Serial Number

Units can be identified and tracked using the device serial number. This can be observed in a numbers of ways:

- Through the Device Information page in the [9.1.6.2 Device Information](#) page in the Manager application.

- Via the 2D data matrix bar code on the outside rear of the enclosure. Applications are available for most smart-phones that can scan the 2D data matrix barcode to display the serial number. The label also contains the hardware version and build date.



Figure 5: Motus External Serial Number

6.4 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 NMEA TSS1 Simrad
Peripheral Interface	2 x GPIO and 1 x Auxiliary RS232
GPIO Level	5 V or RS232

Table 13: Communication Specifications

6.5 Electrical Specifications

Parameter	Minimum	Typical	Maximum
Power Supply			
Input Supply Voltage	5 V		36 V
Input Protection Range	-60 V		60 V
RS232			
Tx Voltage Low		-5.7 V	-5 V
Tx Voltage High	5 V	6.2 V	

Parameter	Minimum	Typical	Maximum
Tx Short Circuit Current			±70 mA
Rx Threshold Low	0.8 V	1.3 V	
Rx Threshold High		1.7 V	2.5 V
GPIO			
Output Voltage Low	0 V		0.3 V
Output Voltage High	4.8 V		5 V
Output Current			5 mA
Input Voltage	-20 V		20 V
Input Threshold Low			1.5 V
Input Threshold High	3.5 V		

Table 14: Electrical Specifications

6.6 Connector Pin-out

Power supply and signal connections are made through a ODU Mini-Snap Series B 9 pin connector (part number S30B0S-P09MCC0-5000). The connector provides a reliable and rugged connection to the Motus under demanding conditions and is rated to IP68 in the mated condition. Advanced Navigation stocks 2 metre unterminated ODU cables that are shielded and have external TPE insulation, see [5 Part Numbers and Ordering Options](#) for ordering. Each individual wire is colour coded, FEP coated 28AWG wire, labelled with the ODU pin number on the unterminated end. Custom cable lengths can be ordered by request.



Figure 6: ODU B series mating plug for Motus

See [Figure 7: ODU B series pin locations](#) for ODU connector pin locations and [Table 15: Motus Pin allocation table](#) for each pin function. [Figure 8: Pin-out view perspective](#) shows the perspective used for the pin location diagram.

PIN SIDE VIEW

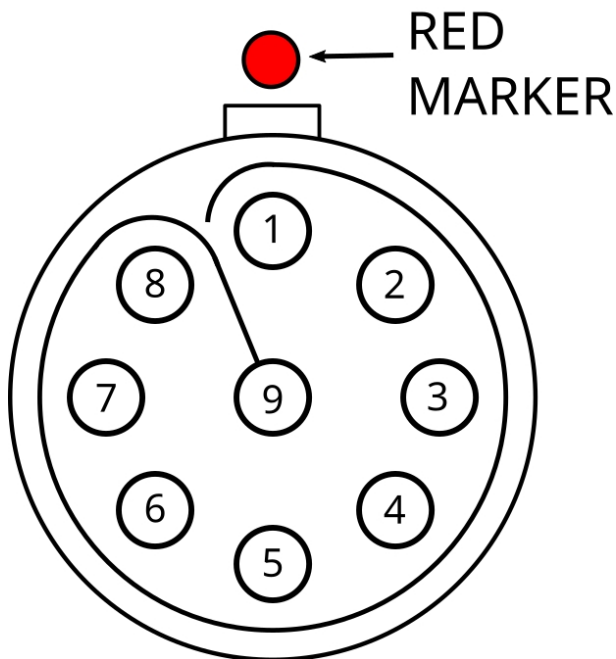


Figure 7: ODU B series pin locations



Figure 8: Pin-out view perspective

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

Table 15: Motus Pin allocation table

6.7 IO Connection

Advanced Navigation offers two pre-terminated IO breakout cables (one for the RS232 version and one for the RS422 version) for quick connection to Motus. The evaluation kit USB Cable is supplied as a part of the Motus Evaluation Kit. See [3 Evaluation Kit](#).

6.7.1 Rugged Evaluation Kit USB Cable

The evaluation kit is supplied with a 2 metre cable with a Motus ODU plug on one end and an overmoulded RS232 to USB converter on the other end, please see [Figure 9: Evaluation kit USB cable](#). 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.

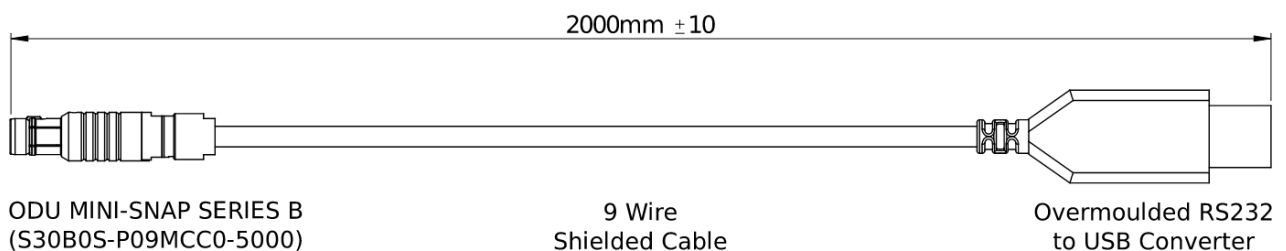


Figure 9: Evaluation kit USB cable

Pin	Function	RS232 Converter Connection
1	Ground	USB Ground
2	Power	USB 5 volt supply
3	GPIO 1	-
4	GPIO 2	-
5	Primary RS232 Tx	FTDI RS232 Rx

Pin	Function	RS232 Converter Connection
6	Primary RS232 Rx	FTDI RS232 Tx
7	Auxiliary RS232 Tx	-
8	Auxiliary RS232 Rx	-
9	Ground	-

Table 16: Evaluation kit USB cable pin-out

6.7.2 Optional Breakout Cables

Advanced Navigation offers pre-terminated breakout cables for access to all of Motus' pins. There are two breakout cables — one for RS232 communication and another for RS422 communication. All external signal and power connections are supported with 2 m of cable. The breakout cables are an optional extra and are not supplied as standard with the evaluation kit.

6.7.2.1 RS232 Breakout Cable (A503-SDC20753)

The RS232 interface cable is provided with industry standard 9 pin DSUB connectors for each of the two RS232 communication channels and GPIO pins.

Please note that this cable is only applicable to the RS232 version of Motus (part number MOTUS2-RUG)

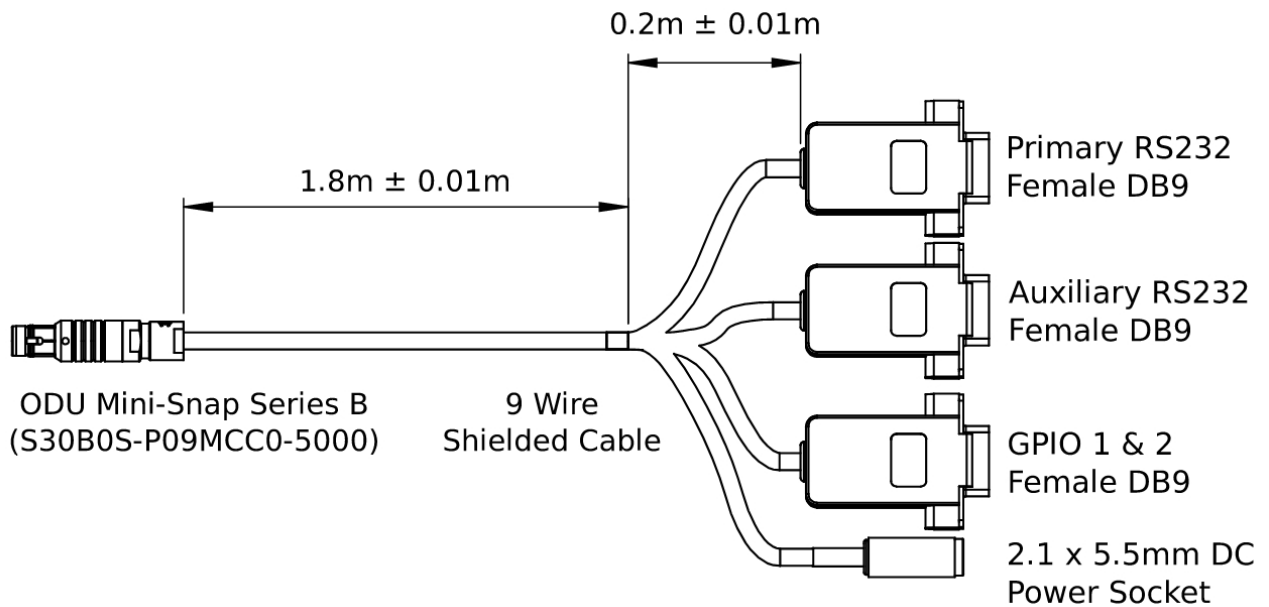


Figure 10: Motus Optional RS232 breakout cable

Pin	Function	Primary	Auxiliary	GPIO	Power
1	Ground	5	5	5	-
2	Power	-	-	-	Tip
3	GPIO 1	-	-	2	-
4	GPIO 2	-	-	3	-

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

Table 17: Motus optional RS232 breakout cable connector pin-out

6.7.2.2 RS422 Breakout Cable (A503-SDC20755)

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

Please note that this cable is only applicable to the RS422 version of Motus (part number MOTUS2-RUG-422)

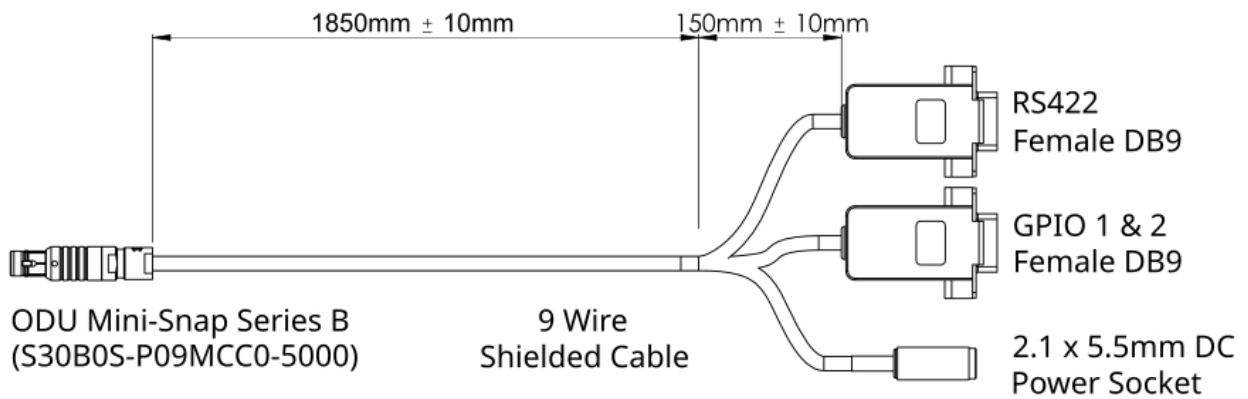


Figure 11: Motus Optional RS422 breakout cable

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

Table 18: Motus optional RS422 breakout cable connector pin-out

7 Installing Motus

To install and quickly get started with Motus, follow the instructions provided in [7.1 Installation Checklist](#).

More Information...

See	For
7.2 Mounting Motus	Guidelines for selecting the mounting location for the unit and setting the alignment with respect to the vehicle.
7.3 Power Supply	Recommendations for setting up power supply.
7.4 Odometer	Different options using an odometer to improve the navigation and orientation.
7.5 Magnetics	Information on the effects of magnetic interference.
7.6 Vibration	Steps to mitigate the adverse effects of vibration on the performance.

Table 19: Additional Information

Note: For ordering an evaluation kit, a standalone kit or accessories for Motus, see [5 Part Numbers and Ordering Options](#).

7.1 Installation Checklist

The following checklist provides the basic steps for connecting, mounting and configuring a Motus unit.

1. Securely mount the unit to the vehicle following the [7.2 Mounting Motus](#)
2. Plug the IO cable into the IO connector on the Motus unit.
3. Connect the Motus to a device by the following:
 - a. Connect the USB to RS232 / RS422 adaptor cable to the Primary port and your computer. The factory default setting is RS232. Check that the mode switch is at the correct setting.
 - b. **Java 11 is required** to run Motus Manager. Adoptium JRE 11 is the recommended Java installer to be used on all platforms. Install the latest version of Java 11 from [Adoptium](#), selecting the correct operating system and architecture for your computer.
 - c. Download Motus Manager from the [Motus](#) product page of the Advanced Navigation website.

Note: Motus Manager is only available for systems with x64 architecture and ARM architecture.

- d. Double click Motus Manager to start the application. See [9.1 Using Motus Manager](#) for specific notes for different platforms
- e. Select the correct COM port.
- f. Select the Baud Rate. The default baud rate is 115200 bps.
- g. Click **Connect**. If you are unable to connect, see [9.1.4 Troubleshooting](#).
4. Mount the unit in the standard alignment of X+ pointing forward and Z+ pointing down. For more information, see [Mounting Alignment](#).

5. Choose a Vehicle Profile in the [9.1.7.2 Filter Options](#) dialogue under the **Configuration** menu. This should be the closest available match to your vehicle type. If you need more information or assistance, contact technical support via email at support@advancednavigation.com.
6. Check that all filters are initialised. See [8.1 Filter Initialisation](#).
The system is now ready for use.

7.2 Mounting Motus

When installing Motus into a vehicle, the mounting position and alignment of the unit are essential for achieving optimal performance. Position refers to the physical location within the vehicle where the unit is installed while alignment refers to the orientation of the unit with respect to the orientation of the vehicle.

7.2.1 Mounting Considerations

Before you install Motus, review the mounting location considerations as follows:

- Mount the unit in an area that will not exceed the rated temperature range, and with minimal fluctuations in temperature.
- Mount the unit away from high levels of vibration where possible.
- Mount the unit within several metres of the GNSS antennas where possible.
- Mount close to the centre of gravity of the vehicle where possible.
- Mount the unit at least 10 cm away (and preferably as far as possible) from sources of dynamic magnetic interference such as high current wiring or large motors for best performance.
- Do not obstruct the two vents on either the side of the enclosure unless [8.8 Atmospheric Altitude](#) is a feature that is not desired and is to be disabled.

7.2.2 Mounting Plate Layout

The Motus mounting plate and hole guide are shown in the following diagram. The holes are designed for M3 screws.

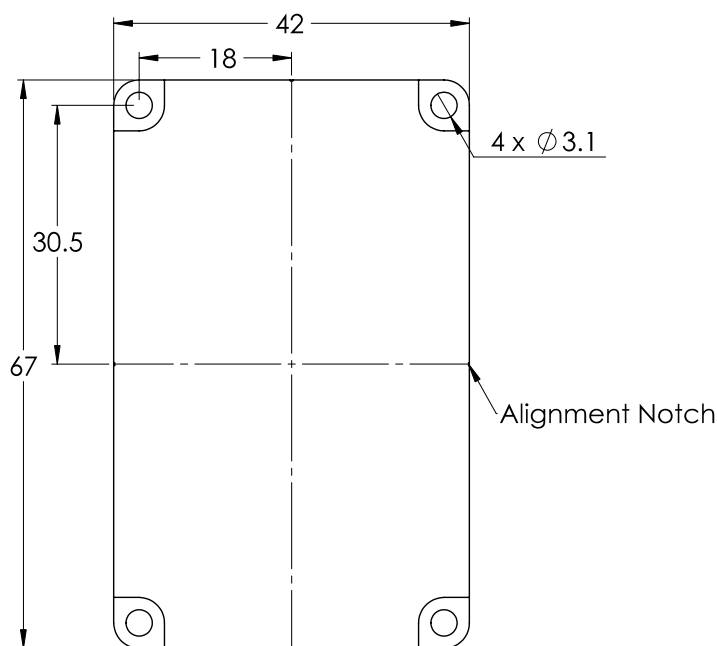


Figure 12: Mechanical drawings of Motus mounting

7.2.3 Mounting Alignment

The following information outlines instructions on alignment of the unit within a vehicle.

The easiest way to align Motus is by installing the unit with its sensor axes aligned with the vehicle axes. There are notches marked on the X and Y axis to assist with alignment. Install the unit such that the X+ axis points forward towards the front of the vehicle and the Z+ axis points straight down towards the ground as shown below.

If aligning Motus with the vehicle axes is not possible within vehicle size or shape constraints, it may be mounted in a different alignment and the alignment offset can be configured in the [9.1.7.4 Alignment](#) dialogue in the Motus Manager.. For easy roll and pitch alignment, use the **Set Zero Orientation** button in the **Alignment** page to set the current orientation as the level alignment.

Note: This will only correct for roll and pitch offsets. Any heading offset will need to be entered manually and saved after using this function.

7.3 Power Supply

A high level of power supply filtering has been built into Motus to allow for reliable operation in demanding environments. However, a power supply with low noise and ripple levels, and adequate transient response is still recommended.

The power supply must be able to reliably provide the maximum current at the chosen voltage, especially in systems with substantial load variations. Make sure that all system components are rated (including safety factors) for the anticipated environmental operating conditions and stressors of the system. Refer to section [6.3 Hardware Specifications](#) for further information.

Motus contains an active protection circuit on the power supply input that protects the unit from under-voltage, over-voltage and reverse polarity events. It is recommended to always operate the unit at a voltage higher than

the minimum mentioned in the Motus [6.5 Electrical Specifications](#). Take caution when using a supply voltage close to the minimum voltage as minor voltage fluctuations could trigger under-voltage protection, leading to unexpected oscillations between the on and off states.

7.4 Odometer

Note: Motus AHRS variants can be upgraded to full INS capability through a software license upgrade. Position and navigation functionality is only to be used when licensed as an INS. As an INS it can be interfaced to any leading brand of GNSS receivers to create an OEM GNSS/INS solution.

On ground vehicles, the use of an odometer input will greatly improve the Motus navigation and orientation solution.

There are several different options for odometer that are explained as follows.

7.4.1 Factory VSS Signal

Most mass-market vehicles since 1980 contain a VSS (vehicle speed sensor) signal that can be wired directly into one of the Motus GPIO pins. Any voltage limits on this pin that must be taken into consideration.

To set up the odometer, the appropriate GPIO pin should be set to Odometer Input using Motus Manager. The odometer pulse length must then be set either manually or automatically, see [8.9 Odometer Pulse Length](#) for more information.

For more information on the GPIO signals and their requirements see [10.3 GPIO Pins and the Auxiliary Port](#).

7.4.2 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 inexpensive OBDII Odometer Interface that plugs into this OBDII port and feeds Motus with odometer data over the Auxiliary RS232 port. See the figure below. Contact the Advanced Navigation sales team at sales@advancednavigation.com for more information.



Figure 13: Advanced Navigation OBDII Odometer

7.4.3 Aftermarket Wheel Speed Sensor

Applications requiring very high performance without GNSS for any length of time are recommended to use a high precision aftermarket wheel speed sensor. Advanced Navigation recommends aftermarket wheel speed sensors from Kistler, Pegasem or GMH Engineering.



Figure 14: Aftermarket Wheel Speed Sensor

7.4.4 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.



Figure 15: Radar Speed Sensor

7.5 Magnetism

Motus contains magnetometers which it can use 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 Motus with magnetic heading enabled, sources of magnetic interference can degrade the Motus solution if not compensated for.

Note: Magnetic interference affects the performance of gyroscopes by causing rotation errors; it is recommended that you mount Motus away from magnetic interference.

There are two types of magnetic interference: **Static** and **Dynamic**.

Sources of static magnetic interference are predominantly ferrous materials (e.g. steel, iron, nickel, cobalt), high-current cables and permanent magnets located near the Motus. Static disturbances are easily compensated for by running a magnetic calibration. A magnetic calibration should always be performed after installation into a vehicle if accurate magnetometer heading is required. See [8.5 Magnetic Calibration](#) for instructions on how to calibrate your device.

Dynamic magnetic interference is a much more complex and problematic issue due to its many variable factors and unpredictability. Sources of dynamic magnetic interference include high current wiring, electric motors, servos, solenoids and nearby large masses of metal that don't move with Motus. Motus should be mounted as far as possible from these interference sources.

Motus contains a special algorithm to reduce 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 Motus Manager and watch the magnetometer outputs whilst the vehicle is operating but stationary. See [9.1 Using Motus Manager](#). 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 Motus away or, where practical, magnetically shield it from these interference sources, the magnetometers should be disabled and an alternative heading source should be used, see [8.5.4 Disabling Magnetometers](#).

7.6 Vibration

Motus 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 among other things. There is, however, a limit to the amount of vibration that a unit can tolerate — temporary degradation in accuracy may occur while operating under high vibration.

When mounting Motus to a platform with vibration present, there are several options to mitigate the negative performance effects. It is recommended to conduct a brief operating check to confirm performance is within specification before conducting longer runs. The Raw Sensor view in the web UI or Motus Manager can give you a good idea of how bad the vibrations are.

If there are persistent issues:

- Try to find a mounting point with less vibration.
- Motus can be mounted with a small flat piece of rubber to provide some isolation. This must not be very soft foam which may result in an incorrect level over time.
- Mount Motus to a plate which is then mounted to the platform through vibration isolation mounts. Be mindful that a plate with very soft mounts may also cause problems with shifts in orientation over time.

8 Using Motus

This section covers the following topics:

- [8.1 Filter Initialisation](#)
- [8.2 Hot Start](#)
- [8.3 Time](#)
- [8.4 Heading Sources](#)
- [8.5 Magnetic Calibration](#)
- [8.6 Data Anti-aliasing](#)
- [8.7 Vehicle Profiles](#)
- [8.8 Atmospheric Altitude](#)
- [8.9 Odometer Pulse Length](#)
- [8.10 Reversing Detection](#)
- [8.11 Motion Analysis](#)
- [8.12 Vents](#)
- [8.13 Heave](#)
- [8.14 Environmental Exposure](#)
- [8.15 Upgrading the Motus Firmware](#)

8.1 Filter Initialisation

There are four different levels of filter initialisation on Motus. These are orientation, navigation, heading and time. The initialisation of each can be monitored by inspecting the [9.1.6 View Menu](#) in the Motus Manager.

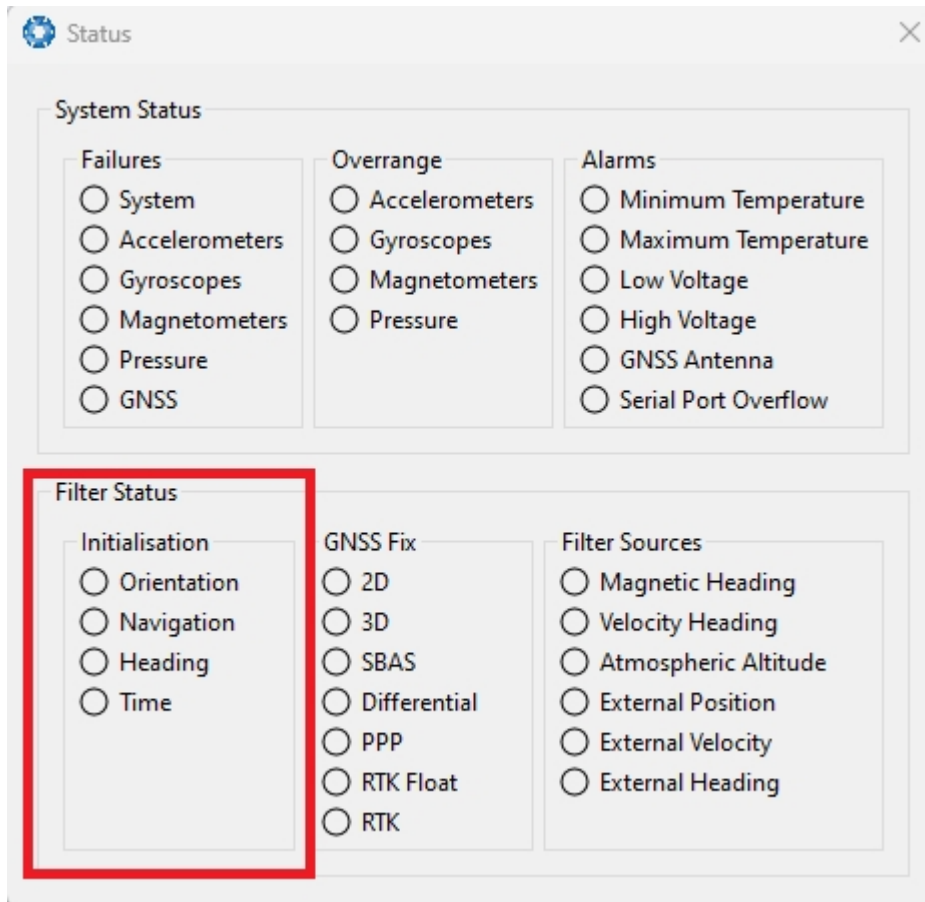


Figure 16: Initialisation Levels

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

8.1.1 Orientation Initialisation

Orientation initialisation occurs automatically upon power on and typically completes within seconds. To determine its orientation it uses the accelerometers to measure the gravity vector. Random accelerations from environmental sources can disturb this process, which can introduce minor orientation errors that will be corrected within several seconds. To prevent this, Motus 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. Motus will progressively correct the orientation error over a period of several seconds.

Once orientation initialisation is complete, the roll, pitch and angular velocity values will be valid.

8.1.2 Navigation Initialisation

Note: Motus AHRS variants can be upgraded to full INS capability through a software license upgrade. Position and navigation functionality is only to be used when licensed as an INS. As an INS it can be interfaced to any leading brand of GNSS receivers to create an OEM GNSS/INS solution.

Navigation initialisation completes once the system has determined a starting absolute position. If the system is hot-starting it will remember its position at the time it was switched off and use this as the starting position. The other possibility for navigation initialisation is an external position source to be used, see [11.4.26 External Position Packet](#) for more information. In a situation where an external position input is not available, it can be initialised manually by entering a position into the [9.1.7.11 Manual Initialisation](#) dialogue in the Motus Manager.

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

8.1.3 Heading Initialisation

Heading initialisation completes once the system has determined a heading using one of its several methods. The conditions required to determine a heading depend upon the heading source being used, see [8.4 Heading Sources](#). If velocity heading is enabled and the vehicle is moving, this will be very fast. If the system hot-starts, the last known heading value will be used. However, in order for the Heading Filter to initialise, the system must have a valid heading source.

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 reach full accuracy.

8.1.4 Time Initialisation

Time initialisation completes once the system has determined time accurately. For this to occur the system must receive rough time as well as a 1PPS signal on one of the GPIO pins. It is also possible to acquire time from an external source, see [11.4.33 External Time Packet](#) for more information.

Until the time has initialised, the Unix or formatted time that Motus outputs will be flagged as invalid.

8.2 Hot Start

Advanced Navigation devices were the first on the market with hot-start functionality. This hot-start functionality allows Motus to start inertial navigation within 500 ms to 2s. The hot-start functionality is always on and fully automatic. See [6.1 Navigation Specifications](#) for details.

A next generation backup battery system within Motus provides the hot-start ability for more than 48 hours without power. When Motus hot-starts, it assumes that it is in the same state it was when it lost power and begins navigating from that position.

Whenever Motus is without power it continues to accurately keep time so that it is immediately valid for a hot-start.

The hot-start functionality 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 start up time.

8.3 Time

Motus was designed to provide a highly accurate time reference. When a GNSS fix is available Motus's time is accurate to within 50 nanoseconds. When a GNSS fix is lost, Motus's time accuracy typically remains within 10 microseconds over extended time periods. When Motus hot starts the time accuracy is typically within 1-2 seconds immediately on startup and corrected to within 50 nanoseconds as soon as a GNSS fix is achieved and 1PPS received. To synchronise with Motus's high accuracy time, both the packet protocol and a 1PPS line must be used.

The time can be accessed via the following means:

- A 1PPS output over GPIO or the Auxiliary port, see [10.3.1.2 1PPS Output](#) of the Dynamic Pin Functions.

8.4 Heading Sources

There are several different heading sources available for Motus. The heading sources can be configured using the **Filter Options** page in the Manager application (see [9.1 Using Motus Manager](#)). It is possible to use multiple heading sources and this can provide performance benefits.

8.4.1 Velocity Heading

Velocity heading works by deriving heading from the direction of velocity and acceleration. Velocity heading works well with cars, fixed wing aircraft and other vehicles that don't move sideways. Velocity heading cannot work for helicopters and other vehicles where the vehicle is pointed somewhere other than the direction of travel. Velocity heading requires a horizontal speed of over 1.15 m/s with a GNSS fix. Velocity heading is disabled by default.

8.4.2 Magnetic Heading

This is the default heading source and works well in the majority of cases. When using magnetic heading, magnetic calibration is required every time the static magnetic field around the Motus changes. This can occur, for example, when moving the mounting location of the unit, or making significant structural changes to the vehicle that alter the distribution of ferrous materials. The downside of magnetic heading is that prolonged exposure to dynamic magnetic interference can cause significant heading errors. See [7.5 Magnetics](#) and [8.5 Magnetic Calibration](#) for further information.

8.4.3 External Heading

This can be used if there is some other way to derive heading that is external to Motus. The heading must be supplied to Motus using the [11.4.29 External Heading Packet](#) or an NMEA message, see [10.3.1.29 NMEA Input](#).

8.4.4 External Magnetometers Packet

Heading can be derived using the magnetometers of an additional external Advanced Navigation product to input external magnetometer values. See [11.4.43 External Magnetometers Packet](#) for details.

8.5 Magnetic Calibration

Static magnetic interference is resolved through magnetic calibration. Dynamic magnetic interference is compensated by a filter algorithm, but should be minimised where possible by selecting the best possible mounting location or implementing magnetic shielding — see [7.5 Magnetics](#) for more information. To compensate for static magnetic interference, magnetic calibration should be performed whenever the Motus mounting location or operation environment changes.

Motus 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 Motus 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 reinforced concrete, which can distort the local magnetic field substantially. It is important to note that for the Motus dynamic magnetic compensation filter to operate correctly, Motus needs to get a GNSS fix at least once every time it is moved more than 50 km. Each time Motus moves more than 50 km the new position is stored permanently and allows Motus to update its world magnetic model values.

There are three types of magnetic calibration available: 2D calibration, 3D calibration and automatic calibration. The three magnetic calibration types and their respective typical applications are described as follows.

- 2D calibration involves at least one full rotation of the vehicle about the Z-axis and is designed for vehicles that are not intended to travel whilst turned upside down, such as full-sized cars, passenger planes and boats.
- 3D calibration involves at least two full rotations of each axis (X, Y and Z) and is designed for vehicles that are intended to be manoeuvred and travel upside down, such as underwater vehicles. 3D calibration offers slightly better performance, and is recommended where possible. Be mindful that the support mechanism used to support the vehicle during calibration can influence the results.
- Automatic magnetic calibration continuously and automatically calibrates for static magnetic interference while the unit is in operation. While it is not as accurate as 2D or 3D calibration, and can take significantly longer to calibrate, automatic magnetic calibration is very convenient for applications where it is impractical to employ those methods.

Note: If Motus is going to be used in a vehicle, the calibration should be performed while Motus 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 other sources of magnetic interference. For example if Motus is installed in a car, the calibration should not involve driving over steel drains or reinforced concrete etc. If Motus is being calibrated to operate standalone, the calibration should not be done on a desk with a steel frame.

8.5.1 2D Magnetic Calibration

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

8.5.1.1 2D Magnetic Calibration Using Motus Manager Software

1. The unit should be powered on while the vehicle is in a level orientation and kept stationary. It is recommended this be done in an outdoor area away from metal or obstructions.
2. After power on wait 5 minutes for the temperature and filter to stabilise.
3. Open Motus Manager and connect to the device.
4. In the **Tools** menu, open **Magnetic Calibration**. Click the **2D Calibration** button.

5. Whilst keeping as level as possible, rotate the vehicle in either direction through one and a quarter full rotations. In a car or boat 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.

Note: Do **not** press the Save button in the lower half of the page, this will overwrite the new calibration values. The auto-generated calibration values are automatically saved internally by Motus.

8.5.1.2 2D Magnetic Calibration 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 position fix, either from an external GNSS receiver, or using the External Position and Velocity packet #44 or the External Position packet #45, before proceeding.
4. Send the [11.5.8 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 [11.5.9 Magnetic Calibration Status Packet](#) to ensure that the calibration completed successfully. If not successful, send the [11.5.8 Magnetic Calibration Configuration Packet](#) with the action **Cancel**, wait 2 minutes and repeat from step 4.

8.5.2 3D Magnetic Calibration

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

8.5.2.1 3D Magnetic Calibration Using the Motus Manager Software

1. The unit should be powered on and the vehicle kept stationary. It is recommended this be done in an outdoor area away from metal or obstructions.
2. After power on wait 5 minutes for the temperature and filter to stabilise.
3. Open Motus 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. 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 page, this will over write the new calibration values. The auto-generated calibration values are automatically saved internally by Motus.

8.5.2.2 3D Magnetic Calibration 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 position fix, either from an external GNSS receiver, or using the External Position and Velocity packet #44 or the External Position packet #45, before proceeding.
4. Send the [11.5.8 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 [11.5.9 Magnetic Calibration Status Packet](#) to ensure that the calibration completed successfully. If not successful, send the [11.5.8 Magnetic Calibration Configuration Packet](#) with the action **Cancel**, wait 2 minutes and repeat from step 4.

8.5.3 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.

The automatic calibration for 2D vehicles differs from that for 3D vehicles. To ensure the correct calibration is being applied, ensure the correct vehicle profile is selected for your application in the [9.1.7.2 Filter Options](#) dialogue in the Motus Manager.

8.5.3.1 2D Vehicle Profiles

2D vehicles are those which cannot easily or safely be turned upside down, and typically include vehicles such as cars and bicycles.

Each time Motus is powered on in a cold start (48 hours without power) the automatic calibration is reset. The automatic magnetic calibration starts operating when Motus is travelling at a speed over 5 m/s with a GNSS fix and either dual antenna is the heading source or velocity heading is turned on.

Automatic magnetic calibration is not as accurate as 2D or 3D calibration, however, it is sufficient for most vehicles and allows Motus to be installed into vehicles and operated without user intervention.

Automatic magnetic calibration can be turned off using the [9.1.7.2 Filter Options](#) dialogue in the Motus Manager.

8.5.3.2 3D Vehicle Profiles

3D vehicles are those which can easily or safely be turned upside down, and typically include vehicles such as humans, underwater vehicles and fixed wing planes.

Each time Motus is powered on in a cold start (48 hours without power) the automatic calibration is reset, and a new calibration will begin if a significant change in calibration values is detected. The automatic calibration for 3D vehicle profiles requires no prior calibration or minimum velocity to begin.

The calibration time is dependent upon the rotation about each axis; approximately, 1 degree of uniform motion in each axis will take up to an hour to converge, motion as low as 0.2-0.5 degrees will take upwards of 12 hours to converge, and 10 degrees of motion will take around 40 seconds to converge. These time estimates are dependent on the environment and nature of the motion.

Automatic magnetic calibration can be turned off using the [9.1.7.2 Filter Options](#) dialogue in the Motus Manager.

8.5.4 Disabling Magnetometers

In situations where there are very strong dynamic magnetic disturbances present, it is recommended to disable the magnetometers. When the magnetometers are disabled, an alternative heading source is required or else Motus may become inaccurate. Dual antenna heading is the recommended source. See [8.4 Heading Sources](#) for information. The magnetometers can be disabled using the Magnetic Heading setting on Filter Options page in the Motus Manager. See [9.1 Using Motus Manager](#).

8.6 Data Anti-aliasing

Internally the Motus filters update at 1,000 Hz. When Motus outputs data, most applications require the data at a much lower rate (typically less than 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, Motus 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.

8.7 Vehicle Profiles

Motus supports a number of different pre-configured vehicle profiles. These vehicle profiles impose constraints upon the filter to increase performance. If your application matches one of the available vehicle profiles, it is required that you select it for use in the [Filter Options](#) page in the Motus Manager. For a list of the different vehicle profiles, see [11.5.5.1 Vehicle Types](#). If the wrong vehicle profile is selected, it can cause a significant decrease in performance.

8.8 Atmospheric Altitude

Motus contains an internal atmospheric pressure sensor. This is used as an altitude aid in the filter. If Motus is mounted in an area subject to unusual pressure waves, for example helicopters, or is mounted inside an enclosure that is not exposed to atmospheric pressure, the pressure sensor input should be disabled. This can be done by disabling Atmospheric Altitude in the [9.1.7.2 Filter Options](#) dialogue in the Motus Manager.

8.9 Odometer Pulse Length

For Motus 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. By default, the odometer will automatically calibrate itself. To automatically calibrate the odometer pulse length, see [8.9.1 Calibrating Odometer Automatic Pulse Length](#).

8.9.1 Calibrating Odometer Automatic Pulse Length

1. Ensure that the signal is connected correctly and that the GPIO pin is configured as an odometer input using the [9.1.7.6 GPIO](#) dialogue in the Motus Manager.

2. Open Motus Manager, connect to Motus and open the Odometer Configuration dialogue. In the **Odometer Configuration** dialogue select the **Automatic pulse length calibration** check box and click **Save**.
3. Wait until Motus has a continuous GNSS fix from an external GNSS receiver and then conduct the test in an area with no obstructions over the test circuit.
4. If Motus loses a GNSS fix for any extended period of time during the calibration, the distance travelled will be reset. The distance travelled can be checked in the Odometer Configuration dialogue to ensure that it has passed 1,000 metres.
5. Once 1000 metres has been driven, check that the automatic pulse length check box has become unticked and the Pulse Length value has changed. This indicates a successfully completed calibration.

Note: To enter the pulse length manually, use the [Odometer](#) page in the Configuration menu in the [Motus Manager](#).

8.10 Reversing Detection

Reversing detection is an algorithm that can detect when the vehicle is travelling backwards. Knowledge of reverse motion is important when using velocity heading or odometer input to provide correct results. If Motus is fitted to a vehicle that does not reverse or doesn't use velocity heading or an odometer, this function should be disabled. Reversing detection is enabled by default and it can be disabled using the Filter Options page in the web UI or Motus Manager. See or [9.1 Using Motus Manager](#).

8.11 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 near stationary. Motion analysis does not work in all situations and its primary benefit is for ground vehicles. It should be enabled in any car application. Motion analysis is enabled by default and can be disabled using the [9.1.7.2 Filter Options](#) dialogue in the Motus Manager.

8.12 Vents

Motus contains a sophisticated venting system that allows it to measure air pressure whilst preventing water ingress. There are two sets of vent holes on either side of the enclosure. It is very important that these remain clear of debris and blockages. Should debris get into the vents they should be gently rinsed with fresh water. Foreign bodies should never be poked into the vent holes, as this will break the environmental seal and void the warranty on the unit. The vents are not resistance to high-pressure jet washing or to waves. Do not direct streams of water directly at the unit.

8.13 Heave

Motus can provide vertical heave position at four different points on a ship. The Motus heave filter is always on and fully automatic. After power on, Motus 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 Motus has a GNSS fix from an external GNSS receiver.

By default Motus provides heave from the point at which the Motus unit is mounted, however it can provide heave at four different offset points on the ship. To configure Heave, see the [9.1.7.9 Reference Position Offsets](#) dialogue in the Motus Manager.

8.14 Environmental Exposure

Whilst Motus is environmentally protected, there are limits to this protection that must be observed to avoid damaging the device.

Motus is only IP67-protected when its connectors are mated (or sealed with the blanking caps). If any of these connections are not tightened to the recommended torque, the unit will not achieve its rated protection.

Spanners or tools should never be used to tighten the connectors. Use your fingers to firmly tighten the connectors. The Motus seals the top of the enclosure to the base using screws and an o-ring. This o-ring is not field serviceable, and attempting to open the housing will invalidate the calibration.

8.14.1 Temperature

Motus should not be subjected to temperatures outside of its operating range. Subjecting Motus to temperatures outside of the operating range can affect the factory sensor calibration, potentially causing a permanent reduction in performance or premature failure. For information about the operating temperature range, see [6.3 Hardware Specifications](#).

8.14.2 Water

Motus complies with IP67 standard, which means that it can be submersed in water to a depth of up to 1 m deep for a maximum of 30 minutes. Submersion to depths beyond 1 metre can cause water entry and destruction of the internal electronics, and the sealing is not designed for prolonged or repetitive immersion. Do not direct streams of water directly at the unit even at low pressure. For cleaning the unit, ensure that no pressure is used.

Note: Connectors must be installed or blanking caps must be used if the unit is likely to be exposed to water.

8.14.3 Salt

The Motus housing is made from hard-anodized marine-grade aluminium and stainless fittings to provide good corrosion resistance, however cannot tolerate extended periods of time in salt water environments. After any contact with salt water or salt spray, Motus should be rinsed with distilled or RO water.

8.14.4 Dirt and Dust

Motus is completely sealed against dirt and dust entry whenever all connectors are mated. When disconnecting the connectors, any dirt or dust should be rinsed or wiped off with fresh water and then dried to minimise the chance of contaminants entering the connectors or plugs.

8.14.5 pH Level

Environments with acidic or alkaline water or atmospheres can cause the Motus enclosure to corrode or discolor. If Motus comes into contact with these environments it should be rinsed in fresh water as soon as possible. It is not recommended to operate Motus in non-neutral pH environments.

8.14.6 Shocks

Motus is a rugged piece of equipment that can withstand reasonable amounts of shock. However, continuous shocks may cause premature failure as a result of materials fatigue, and may also affect the sensor calibration resulting in degraded performance.

Shocks applied directly to the Motus enclosure can affect the unit. Therefore, care should be taken when handling the unit prior to mounting. When mounted in a vehicle, the effect of most operating shocks is negligible.

8.14.7 Atmospheres

Hydrogen-rich atmospheres may damage the MEMS. Motus is not rated for use where explosive gases or dust may be present.

8.15 Upgrading the Motus Firmware

Motus contains firmware which is regularly updated to improve performance and add features. Advanced Navigation recommends that you upgrade to the latest version whenever available. The firmware update function is robust, such that power loss, file corruption or other issues cannot cause problems with units. Check the [Motus](#) product page of the Advanced Navigation website periodically for updates.

Note: Advanced Navigation device firmware files have the extension .anfw.

See [9.1.8.2 Firmware Update](#) for instructions on how to upgrade the firmware using the Motus Manager.

9 Configuring and Monitoring Motus

Motus can be configured and monitored through:

- Motus [Manager](#), accessed on a computer via a serial adaptor
- the Advanced Navigation Packet Protocol ([9.3 Using ANPP](#))

9.1 Using Motus Manager

Motus Manager is a software tool provided by Advanced Navigation for logging, testing, display and configuration of Motus. It is designed to be simple and easy to use. It should run on most Windows, MacOS and Linux computers.

Note: Java 11 is required to run Motus Manager. Adoptium JRE 11 is the recommended Java installer to be used on all platforms. Install the latest version of Java 11 from [Adoptium](#), selecting the correct operating system and architecture for your computer.

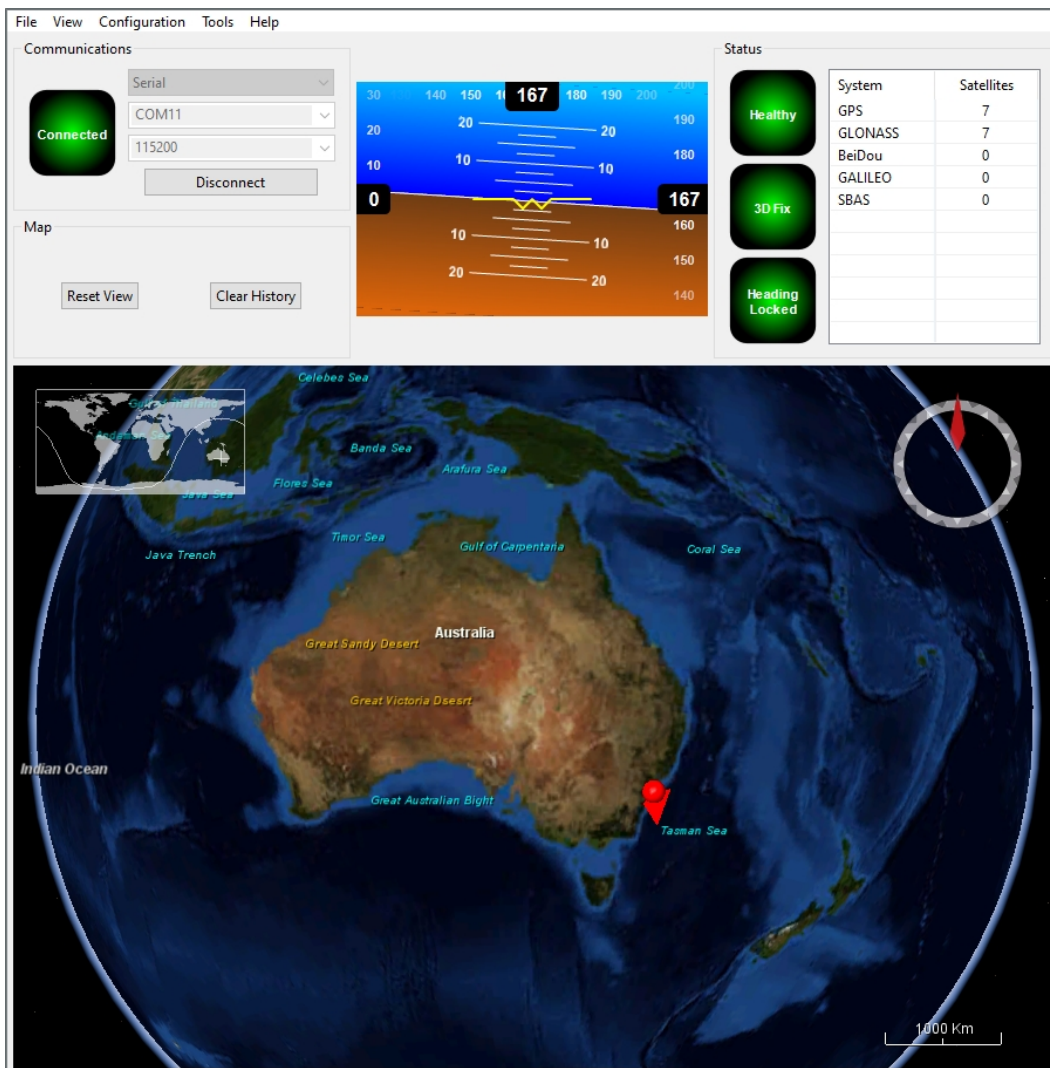


Figure 17: Screenshot of Motus Manager

9.1.1 Motus Manager Software Changelog

Version	Date	Changes
7.2	10 Nov 2023	<ul style="list-style-type: none"> Clear map history on reconnection Fix incorrect timezone text displayed in terminal.csv Updated leap-seconds list URL Add automatically log configuration at the start of a new log Added support for NavIC satellite system Fixed indicators behaviour on disconnect Updated support for Mac silicon with latest macOS Added support for extra NMEA 0183 messages Removed GNSS status indicator Fixed issue with opening windows containing charts Renamed External GNSS Enabled to Internal GNSS Enabled In satellites window, only populate azimuth and elevation fields in the table view when the values have been determined Added elevation to the gimbal state packet
7.0	13 February 2023	<ul style="list-style-type: none"> Updated from JDK8 to JDK11. JRE11/JDK11 required to run this release Refresh Port Mode information on reconnection Refresh Packet Rates information on reconnection Improved reliability of firmware update When the NTRIP sourcetable says authentication type is any of ", 'B', 'N', then use Basic Authentication. This is to workaround NTRIP servers that incorrectly populate the authentication field Overwrite/clear existing packet rates on import of configuration Added support for ARM (aarch64) processors with 64-bit OS Added support for Apple M1 processors and improved MacOS support Various UI improvements
6.2	10 October 2022	<ul style="list-style-type: none"> Added support for NTRIP Casters that request Username & Password to retrieve source table Added copying version numbers etc from Device Information dialog boxes Renamed Log Conversion menu item Added Settings menu item Renamed position error to position standard deviation in position page of view menu
6.1	18 February 2022	<ul style="list-style-type: none"> Device information updated automatically after a firmware update Fixed configuration export Add ability to control log file location Included software version number in title Improved NTRIP server reconnection Improve export configuration reliability Added external GNSS Filter option Improved Log files saved by default in the directory from where the application is launched Improved NTRIP mountpoint selection. Added handling of nonstandard NTRIP server responses Force the device to exit bootloader mode if a firmware update is not in progress

Table 20: Motus Manager Software Changelog

9.1.2 System Requirements

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

Motus Manager includes a 3D mapping display which requires an internet connection. If your machine does not meet the graphics requirements the mapping view will only show space without a globe.

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

9.1.3 Installation and Starting

The latest version of Motus Manager can be downloaded from the [Motus](#) product page of the Advanced Navigation website. Installation notes are as follows:

- **Java 11 is required** to run Motus Manager.
Adoptium JRE 11 is the recommended Java installer to be used on all platforms. Install the latest version of Java 11 from [Adoptium](#), selecting the correct operating system and architecture for your computer.
- No installation process required for the Motus Manager application on a Windows system — it can be run from any directory by simply double clicking on it. To open the program on some systems it may be necessary to right click and select open with → Java Runtime Environment.
- On MacOS systems it may be necessary to run the application from a terminal window:

```
java -jar -XstartOnFirstThread MotusManager.jar
```
- On Linux systems it may be necessary to run the application from a terminal window:

```
java -jar MotusManager.jar
```

The Motus Evaluation Kit includes an FTDI USB to RS232 / RS422 adaptor cable. The drivers are normally installed automatically, but if not they are available for download from www.ftdichip.com/Drivers/VCP.htm.

9.1.4 Troubleshooting

If the application will not start, the most common reason is that you have 32-bit Java installed on a 64-bit operating system. Uninstall Java and reinstall the 64-bit version.

If the globe does not appear in the 3D map area, this indicates that either your graphics card is not powerful enough, your graphics card driver is out of date, or you have no internet connection.

- Ensure the RS232 / RS422 switch is in the correct mode. The Motus factory default mode is RS232.
- Ensure you select the correct COM port. This can be easily identified by unplugging and re-plugging in the USB connector.
- Ensure you have the correct baud rate selected in Motus Manager. The factory default value for the baud rate is 115200 bps for the Primary, GPIO and Auxiliary ports.

Contact technical support support@advancednavigation.com if you have any questions or require further assistance.

9.1.4.1 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. If you experience this problem, often a restart will resolve it. Otherwise there is a tool that can fix this issue available at <http://www.stentec.com/anonftp/pub/wingps/pnpblockersetup.exe>.

If the serial port does not show up when you plug in the FTDI USB to RS232/RS422 adaptor cable, you may need to install the drivers from www.ftdichip.com/Drivers/VCP.htm.

When operating Motus on Windows at a 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 to 1 ms:

1. Start the Windows Device Manager (1) and find the Ports section (2).
2. Identify the specific COM port being used (3) by dis-connecting and re-connecting the USB to RS232 / RS422 adaptor cable.
3. Right click on the identified COM port and select Properties. Select the Port Settings tab (4) and select Advanced (5).
4. Change the Latency Timer value (6) to 1 msec then press OK (7), and OK again for the previous window.

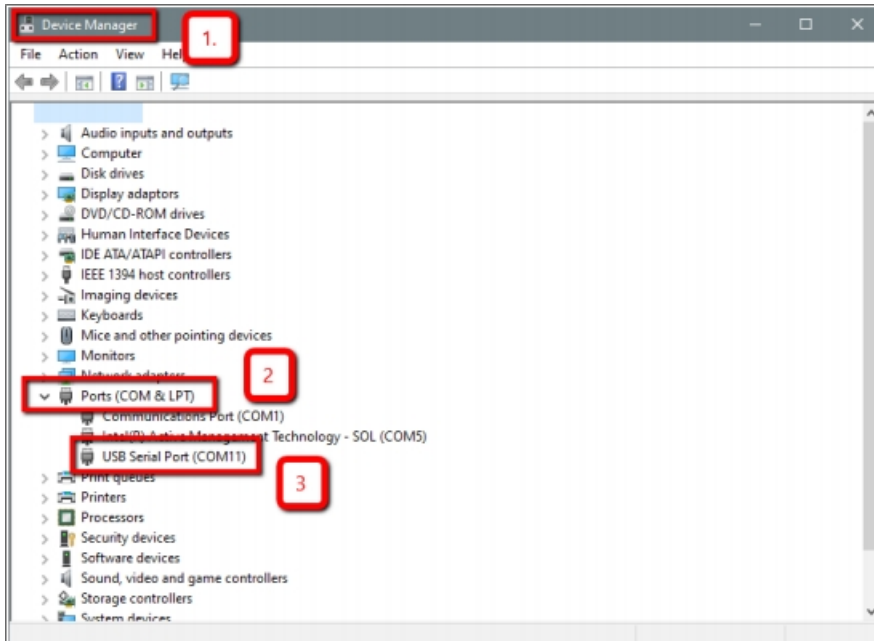


Figure 18: Setting the Windows Port Latency Value - 1

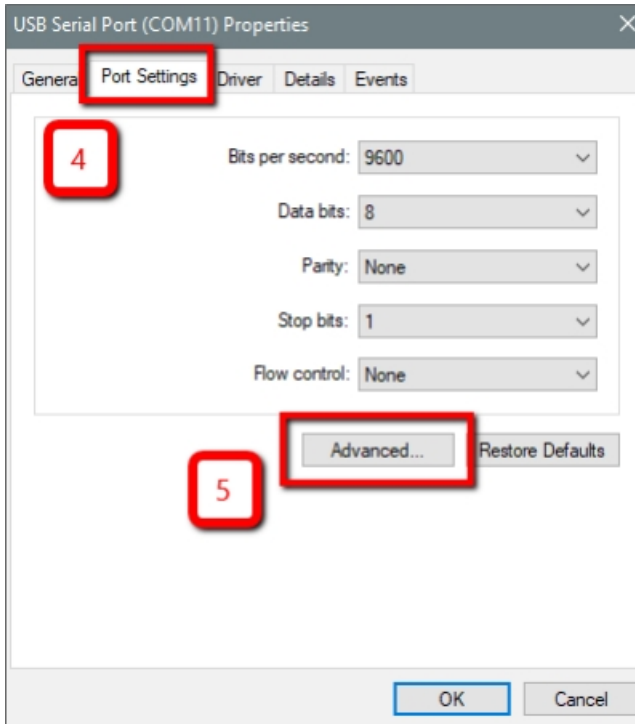


Figure 19: Setting the Windows Port Latency Value - 2

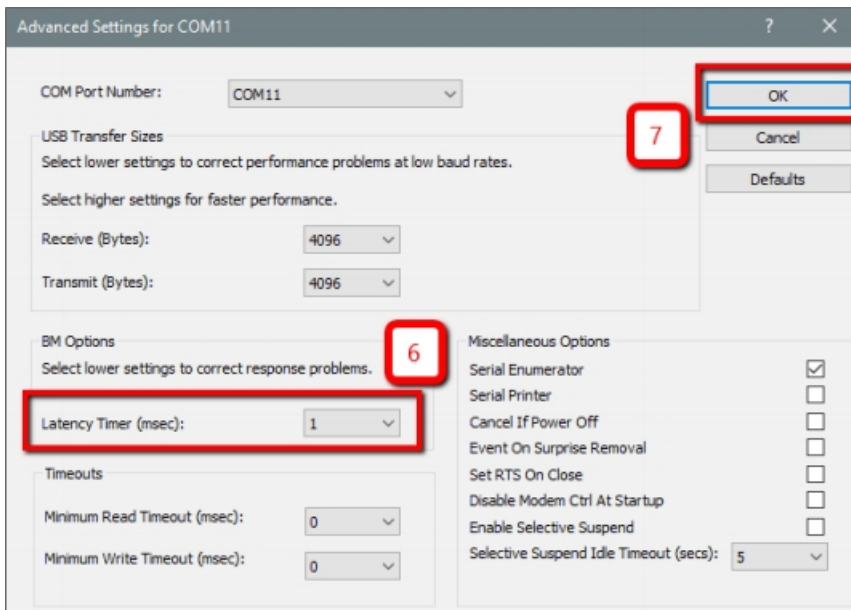


Figure 20: Setting the Windows Port Latency Value - 3

9.1.4.2 Linux

If serial ports do not show up, the typical reason is a lack of 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
```

9.1.5 Main View

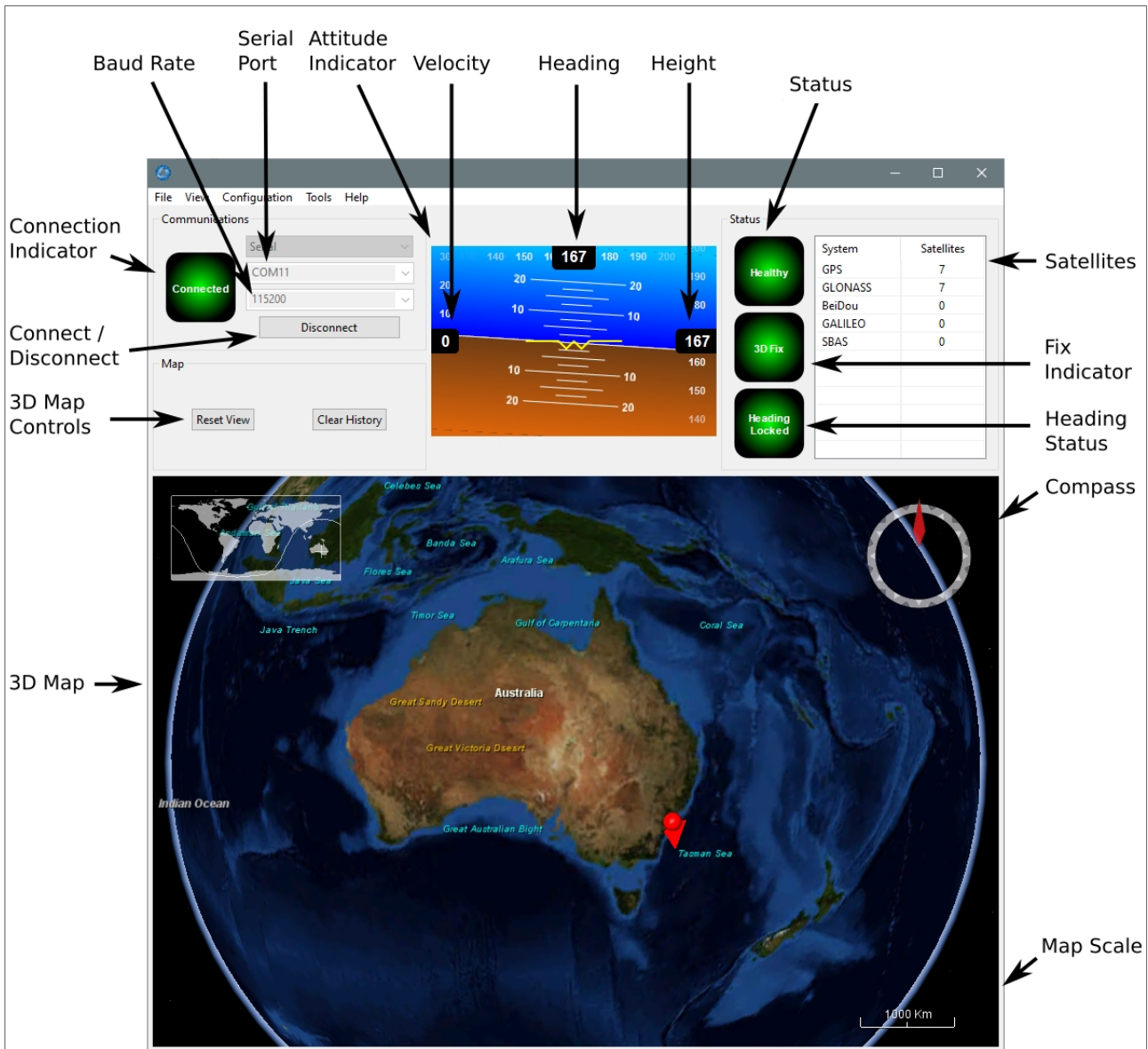


Figure 21: Manager Main View

9.1.5.1 Serial Port

The Serial Port dialogue is used to connect to Motus. Select the serial port and baud rate and click **Connect**. The default baud rate of Motus is 115200. The Connection Indicator displays whether there is communication with a Motus unit.

9.1.5.2 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.

9.1.5.3 Satellites Table

The Satellites table shows the number of satellites visible by the primary antenna. More detailed information can be found in the [9.1.6.4 Satellites](#) sub section under the [9.1.6 View Menu](#).

9.1.5.4 Status Indicator

The Status indicator section contains a Motus status indicator, a fix indicator and a satellites table.

- Motus Status Indicator - This indicator shows any problems with Motus. Before a GNSS position 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.
- Fix Indicator - This shows the status of the GNSS position 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”.
- 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.

9.1.5.5 3D Map

The 3D map shows the Motus 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 the Motus position. To move the camera click and drag on the map. To zoom in and out use the mouse scroll wheel. To change the camera view right click and drag or shift click and drag.

9.1.5.6 3D Map Controls

- Reset View : This resets the map view to current position.
- Clear History: This clears the current position history, this is the red trail shown on the map.

9.1.5.7 Baud Rate

This displays the current and available baud rates options for the serial connection.

9.1.5.8 Connect / Disconnect

This button enables the serial connection to be either connected or disconnected.

9.1.6 View Menu

9.1.6.1 View

The View menu contains a number of different options for viewing data from Motus.

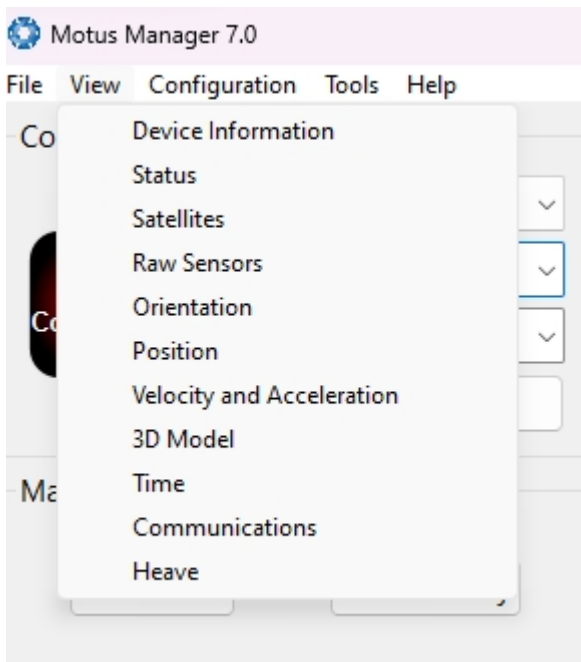


Figure 22: Manager View Menu

9.1.6.2 Device Information

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

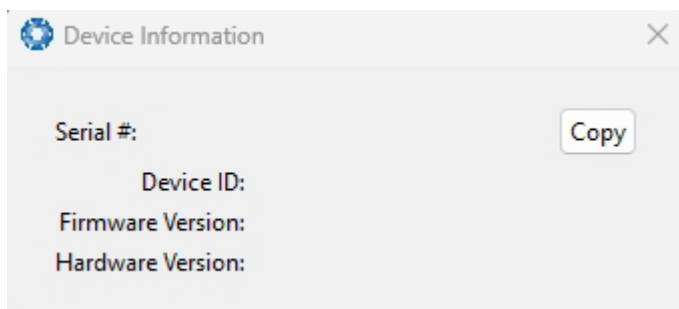


Figure 23: Manager Device Information

9.1.6.3 Status

The Status shows the current status of Motus as reported by sections [11.4.1 System State Packet](#) (ID#20) .

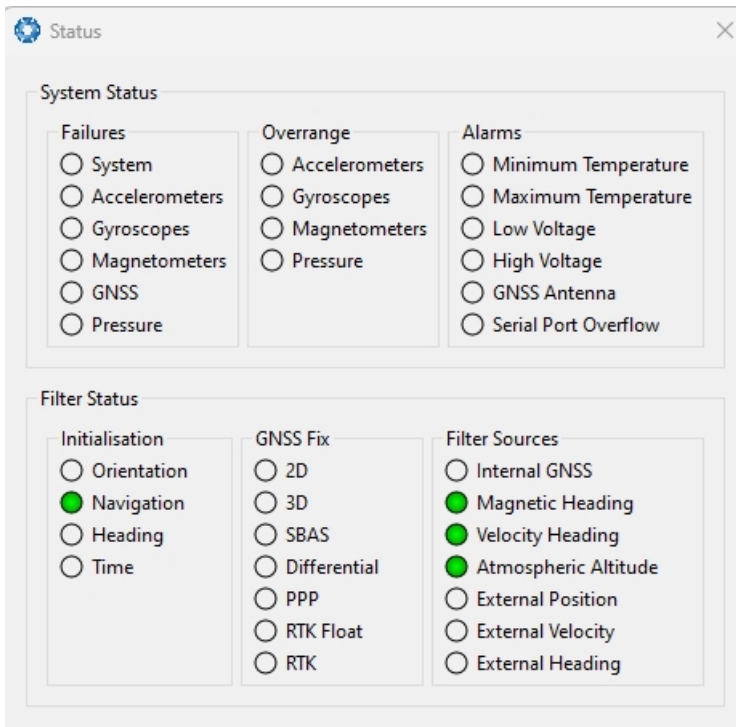


Figure 24: Manager Status Dialogue

9.1.6.4 Satellites

Note: The satellites page will only display satellite data if the Motus has a license upgrade to full INS capability, and is interfaced to an external GNSS receiver.

The information is displayed as a satellite skyplot, a table and an SNR (Signal-to-Noise Ratio) graph. A maximum of 28 satellites will be displayed, even if more are accessible. This plot shows the SNR of each satellite at the primary and secondary antenna. As a guideline, these should be within 5-10 dB of each other in the absence of cable or antenna faults. Elevation and azimuth are in units of degrees.

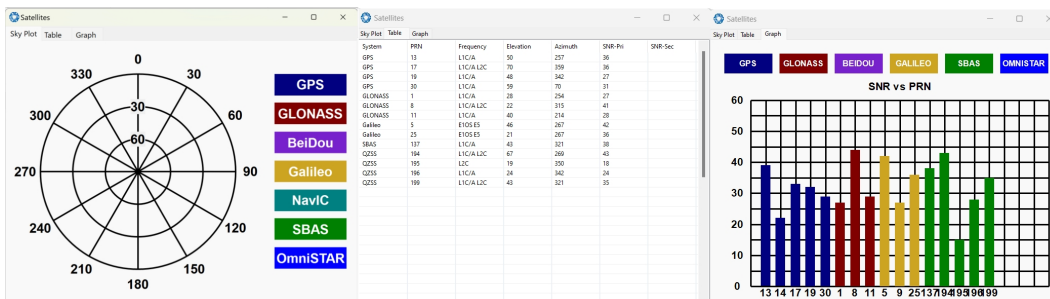


Figure 25: Manager Satellites Table

9.1.6.5 Raw Sensors

Raw sensors shows the temperature calibrated raw sensor values.

Temperature readings are available for a range of sensors: T(Ax), T(Ay), and T(Az) correspond to the accelerometer's x, y, and z axes; T(Gx), T(Gy), and T(Gz) relate to the gyroscope's X, Y, and Z axes; T(M) is for the magnetometer; and T(P) indicates pressure.

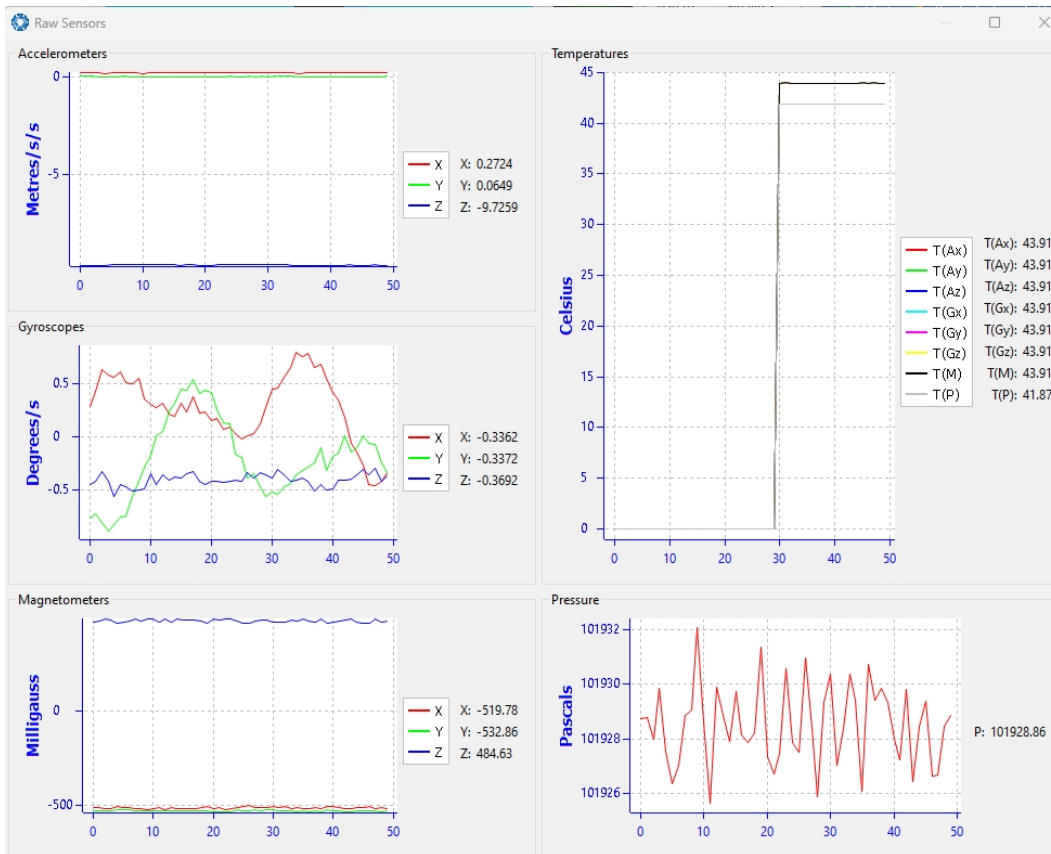


Figure 26: Manager Raw Sensor Outputs

9.1.6.6 Orientation

Orientation shows the Motus orientation, angular velocity and orientation error. To enhance the user's understanding of some of the less intuitive metrics, **Course** is defined as the path determined by measuring sequential positions, and **Slip** is the difference between the heading and the course.

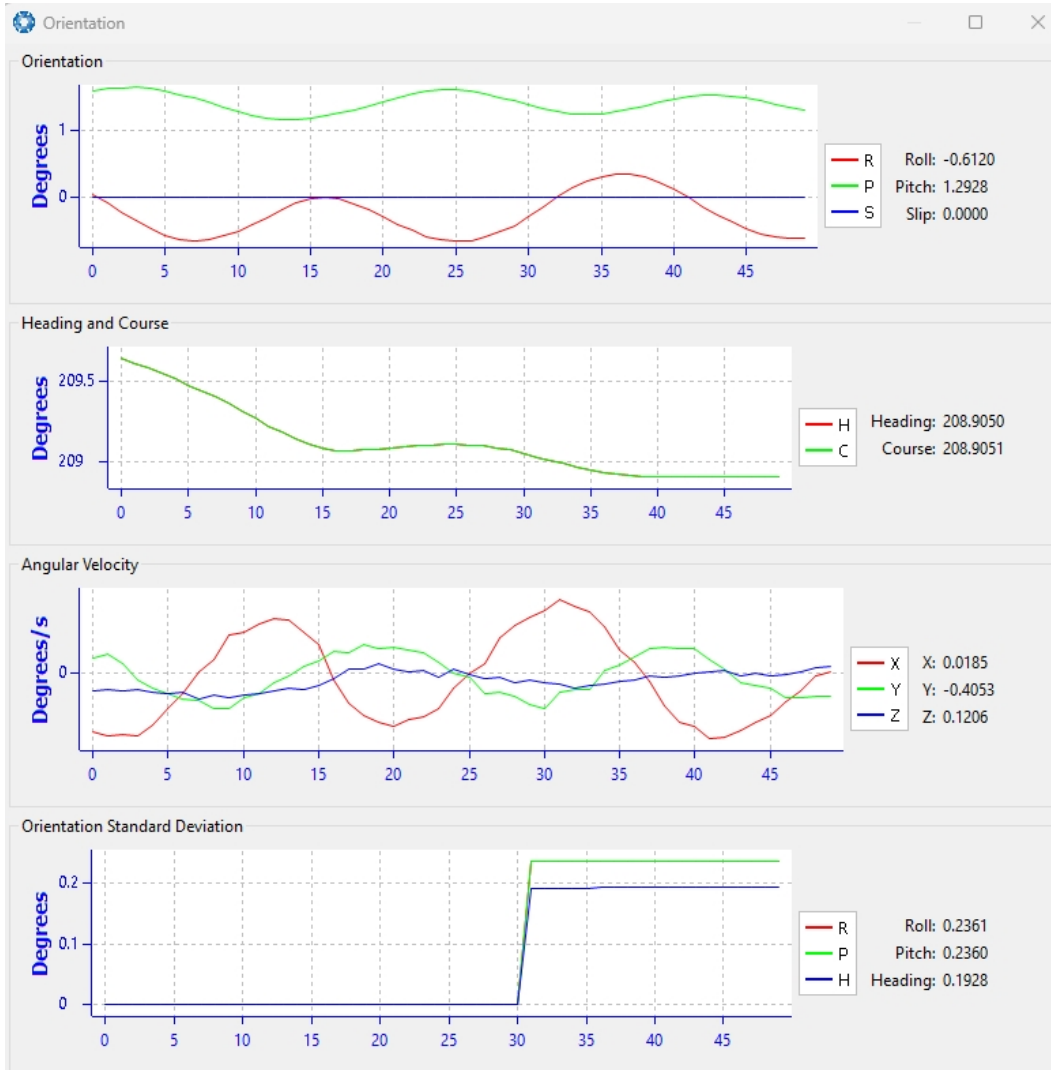


Figure 27: Manager Orientation Outputs

9.1.6.7 Position

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

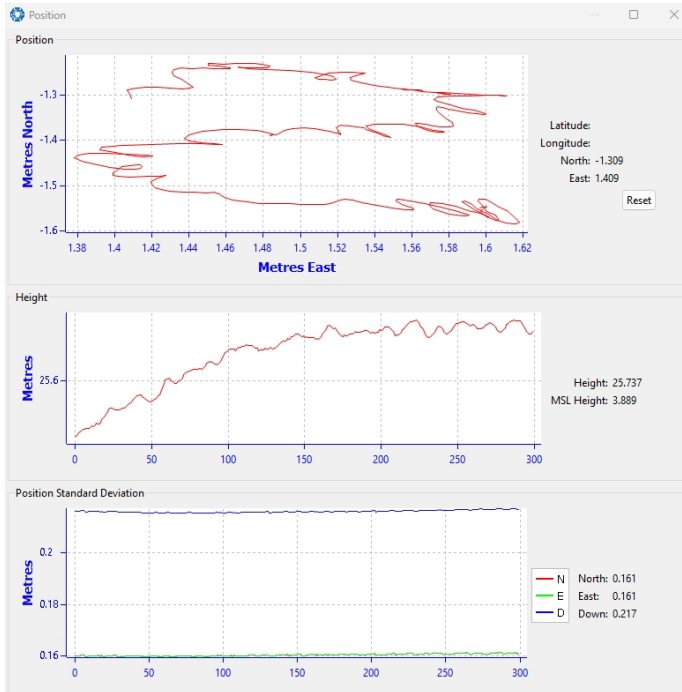


Figure 28: Manager Position Outputs

9.1.6.8 Velocity and Acceleration

Velocity and Acceleration shows the Motus velocity, acceleration and g-force.

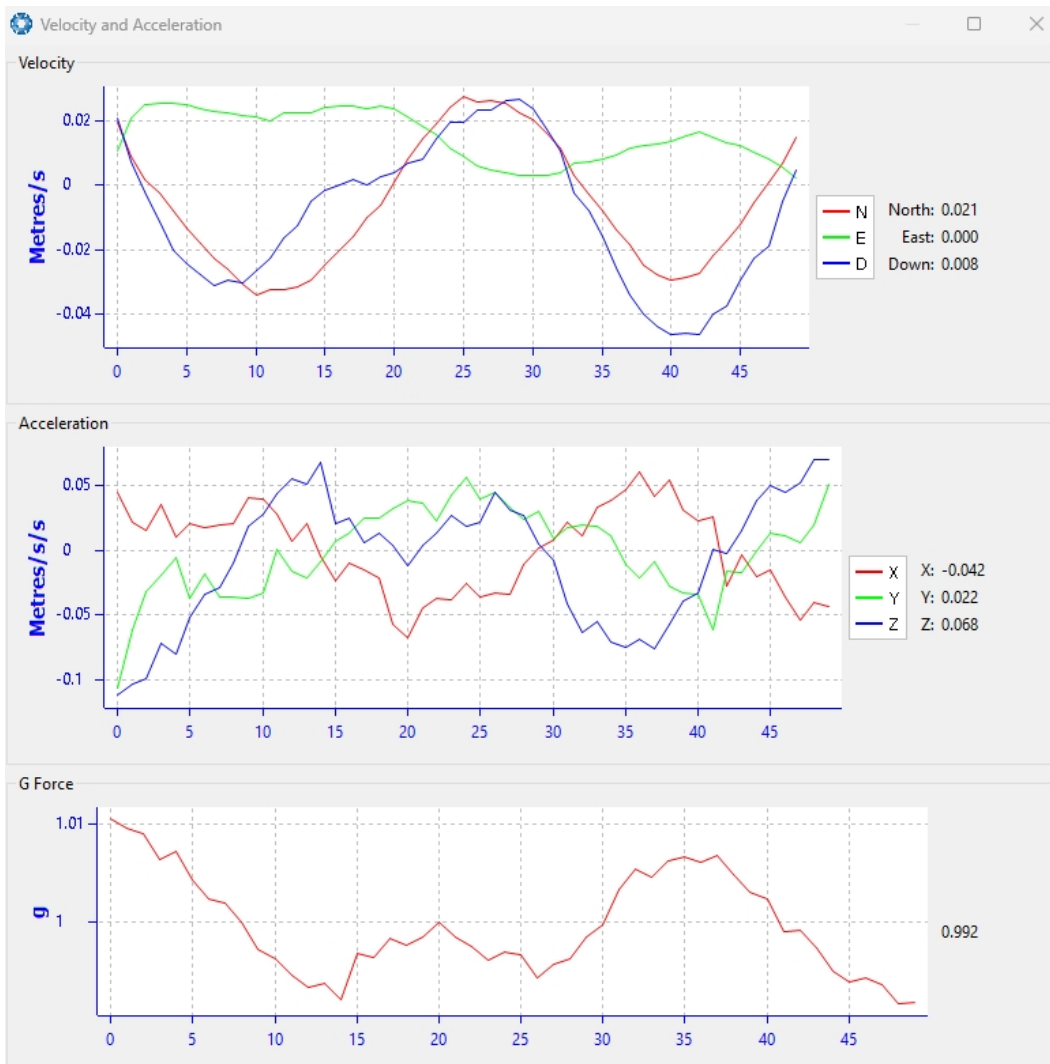


Figure 29: Manager Velocity and Acceleration Outputs

9.1.6.9 Time

This dialogue box allows the to view the time for the connected device. Views are in Unix, UTC, or Local time formats to best suit user requirements to ensure accurate timekeeping and synchronisation across systems.

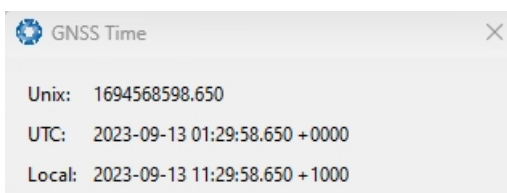


Figure 30: Time Dialogue

9.1.6.10 Communications

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

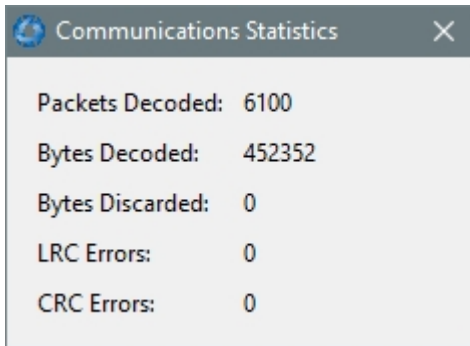


Figure 31: Manager Communications Dialogue

9.1.6.11 Heave

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

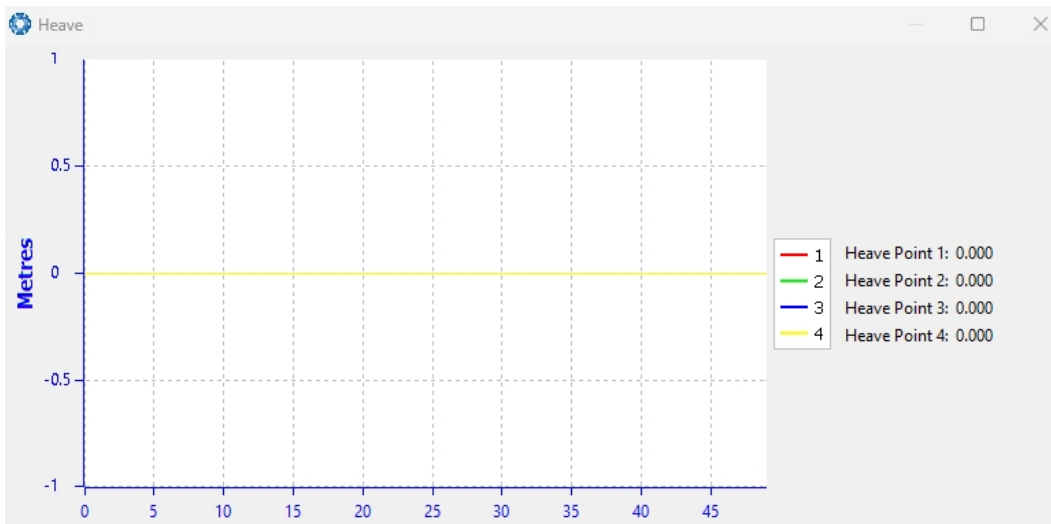


Figure 32: Manager Heave Outputs

9.1.7 Configuration Menu

The Configuration menu contains a number of dialogues for the configuration of Motus.

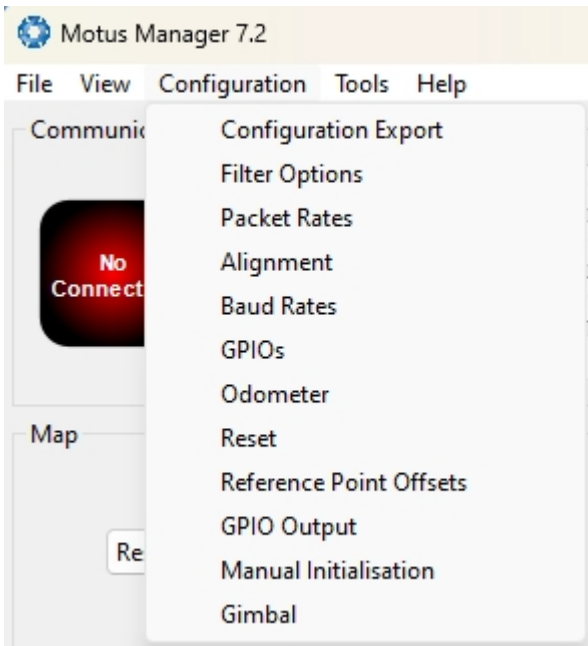


Figure 33: Manager Configuration Menu

9.1.7.1 Configuration Export

The Configuration Export dialogue can be used to export all the Motus 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 a pre set configuration at a later date or for batch configuration of multiple units.



Figure 34: Manager Configuration Export Dialogue

9.1.7.2 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.

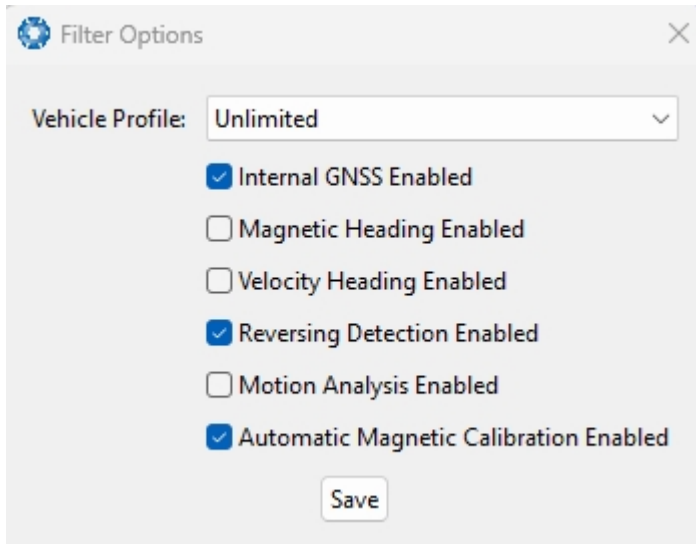


Figure 35: Manager Filter Options

9.1.7.3 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 Motus Manager. Other state packets can be enabled as required.

Note: Packet rate configuration applies only to the data port which the Manager is connected to. To configure other ports, the Manager must be connected to that port.

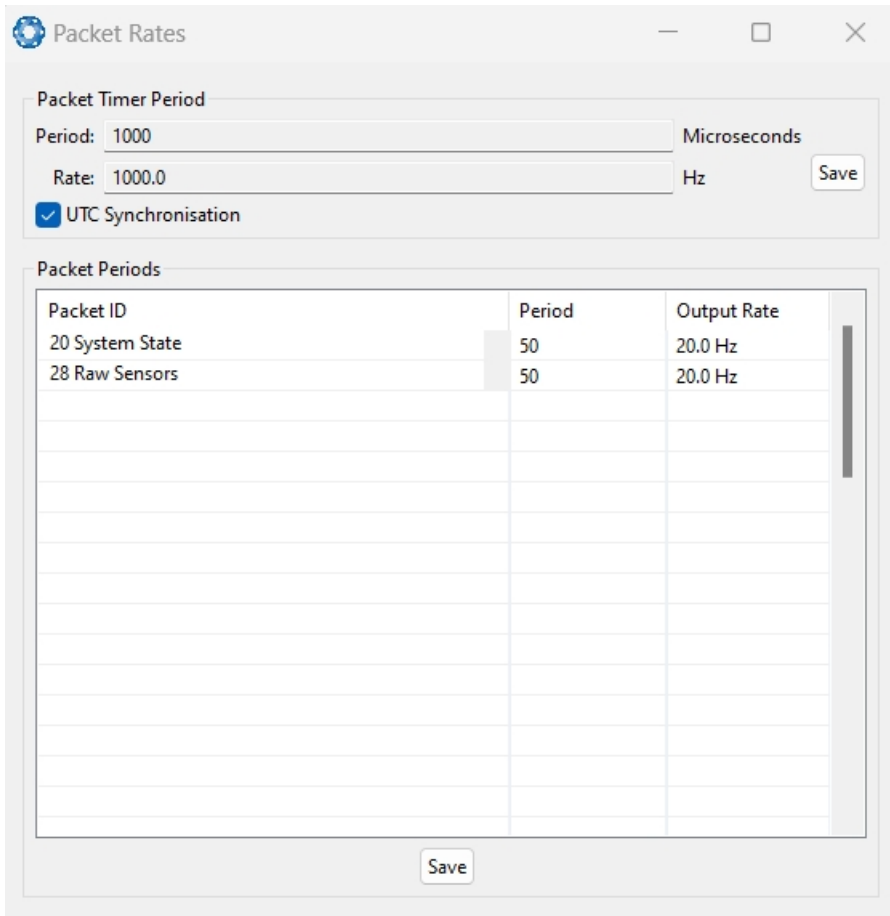


Figure 36: Manager Packet rates

9.1.7.4 Alignment

The Alignment 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.

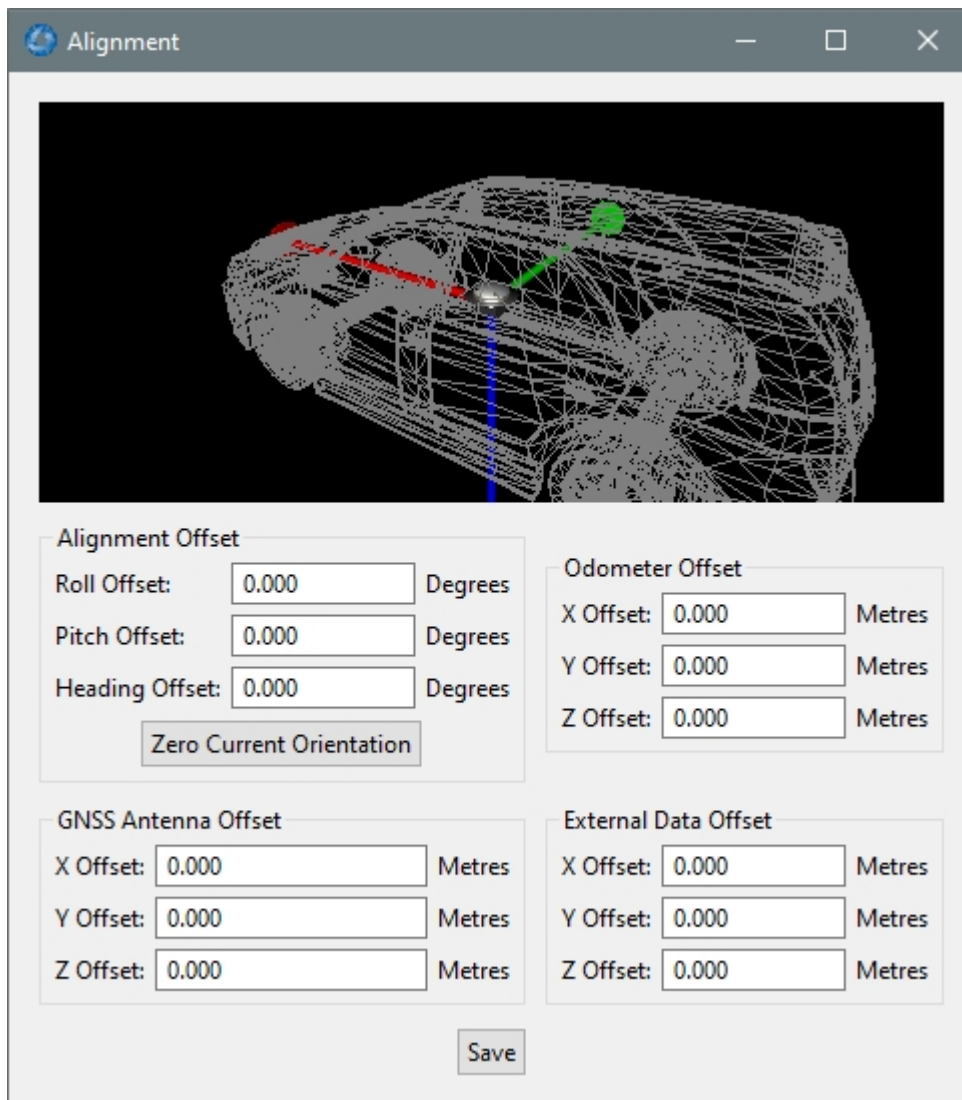


Figure 37: Manager Alignment Dialogue

Alignment Offset

If Motus is installed into the vehicle with the positive X-axis pointing forwards and the positive 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.

Note: Zero Current Orientation will only correct for roll and pitch offsets, the Heading offset must be entered manually and saved before using this function.

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

GNSS Antenna Offset

The GNSS antenna offset is measured from the centre of the Motus unit to the phase centre of the primary antenna in the orientation of the [12.3 The Body Co-ordinate Frame](#) (X positive forward, Z positive down).

Odometer Offset

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

If your odometer is not measuring a specific wheel, the offset should be to the point on the ground beneath the measurement point. If, for example, your car is a front wheel drive and you are using the velocity from the car OBDII port, the measurement point would be midway between the two front wheels.

External Data Offset

These values are only required for speciality applications operating with an external source of velocity data. The offsets are used when providing NMEA Input, External GNSS, or with an Air Data Unit. When using a DVL, use the odometer offset. Contact support@advancednavigation.com for assistance with these values.

9.1.7.5 Baud Rates

Some machines running Microsoft Windows do not support higher baud rates. When changing baud rates, it is recommended to test the baud rate configuration first, without ticking the Permanent box. 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 setting.

The factory default baud rate value for these ports is 115200 bps.

The primary and auxiliary ports can be set to RS232 or RS422. The factory default is RS232 for both ports.

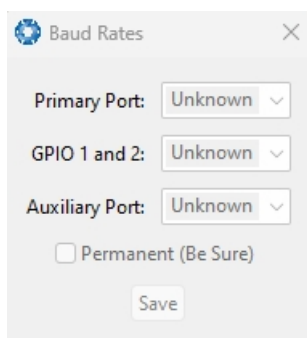


Figure 38: Manager Baud Rates Dialogue

9.1.7.6 GPIO

This page allows the user to configure the input and output functions of the GPIO and Auxiliary ports. These functions are described in detail in [10.3.1 Dynamic Pin Functions](#). These functions change dynamically and are effective immediately upon clicking **Save Changes**.

Note: The GPIO port functions at RS232 levels for data functions and 0 to 5 volt (or 0 to 3.3 V) levels for all other functions. The auxiliary port functions at RS232 or RS422 levels for data functions and 0 to 5 volt (or 0 to 3.3 V) levels for all other functions. The internal hardware automatically reconfigures based upon the selected function.

The default values for these settings are Inactive.

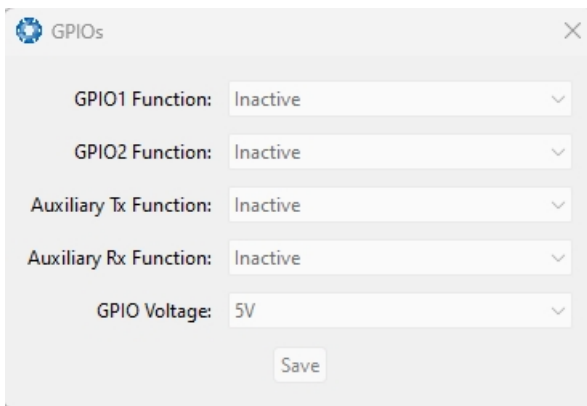


Figure 39: Manager GPIO configuration Dialogue

9.1.7.7 Odometer

The Odometer dialogue allows the user to configure the odometer pulse length and view the real time odometer data to verify correct operation. See [7.4 Odometer](#) and [8.9 Odometer Pulse Length](#) for more information on the use of odometers. The odometer offset is also applied when using a DVL input.

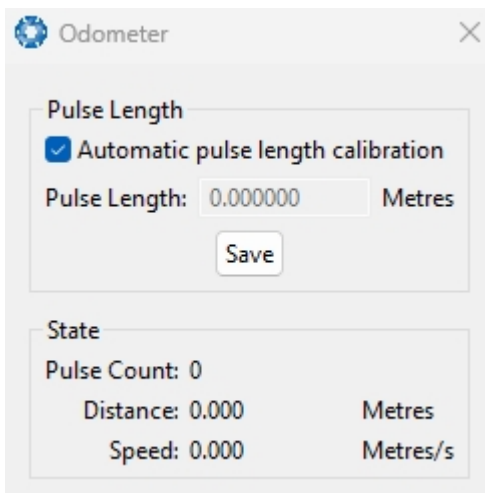


Figure 40: Manager Odometer Dialogue

9.1.7.8 Reset

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

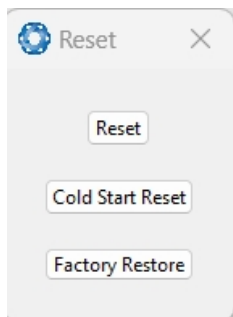


Figure 41: Manager Reset Dialogue

9.1.7.9 Reference Position Offsets

The Reference Point Offsets dialogue allows the user to set measurement points away from its default position at the physical centre of the Motus unit. The primary reference point offset applies to data from all ANPP packets as well as all peripheral output such as NMEA messages and Heave Point 1.

When the values are zero the measurement point is the centre of the Motus unit. This can be offset to a different position on the profile by entering the offset value from the centre of the Motus unit to the desired position in the body co-ordinate frame (X positive forwards, Z positive down).

Note: These values only apply to the Heave Packet. NMEA, TSS and Simrad heave is not affected by the values in this dialogue which are always measured at the centre of the Motus unit.

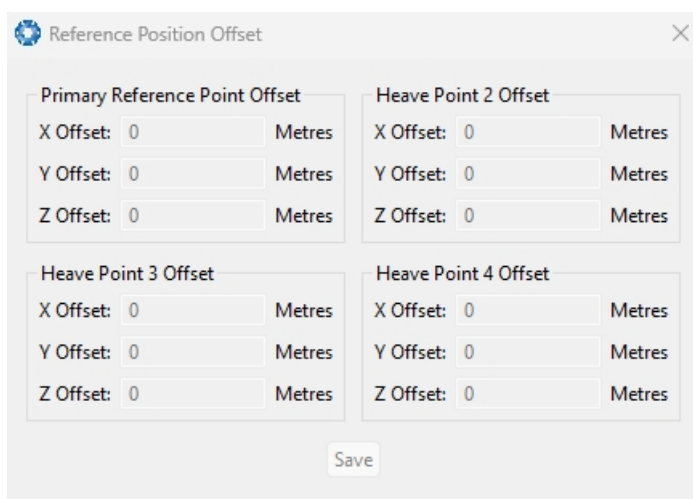


Figure 42: Manager Reference Position Offset

9.1.7.10 GPIO Output

The GPIO output configuration dialogue allows the user to configure the NMEA0183, TSS1 and SIMRAD output rates for the GPIO and Auxiliary port. These output rates will be observed with respect to the actual output selected in the [9.1.7.6 GPIO](#) port configuration.

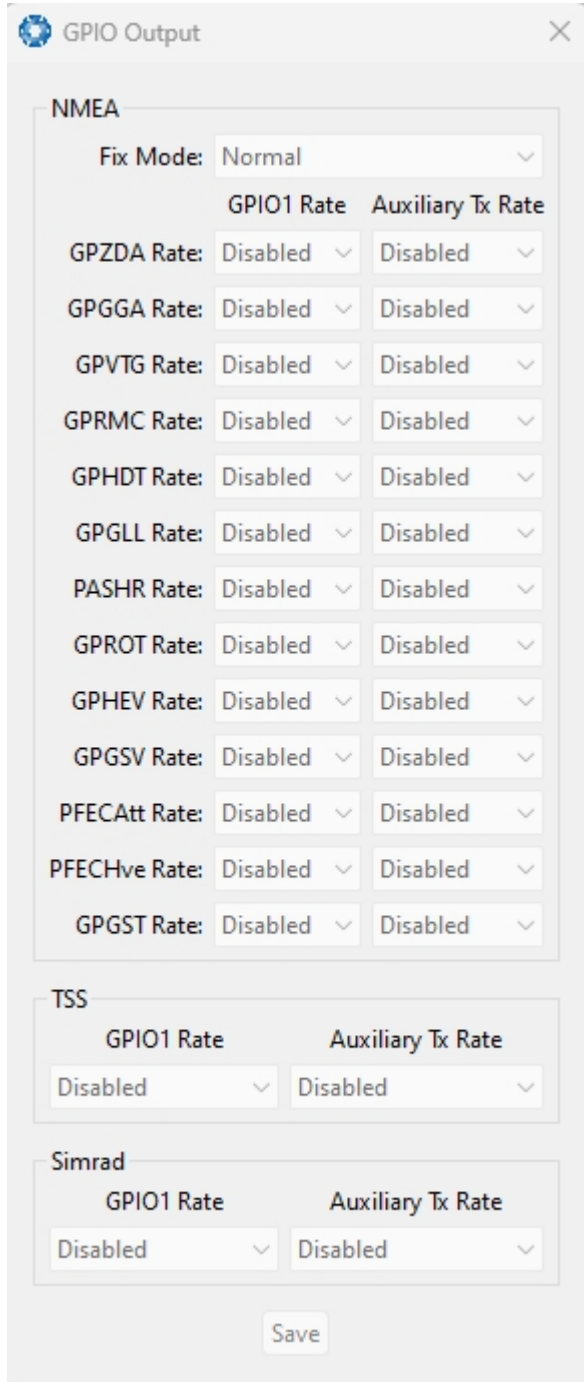


Figure 43: Manager GPIO Output Dialogue

9.1.7.11 Manual Initialisation

The Manual Initialisation dialogue can be used to manually initialise Motus when a GNSS fix is not available. Setting the position will initialise the navigation filter. Setting the heading will also initialise the heading filter.

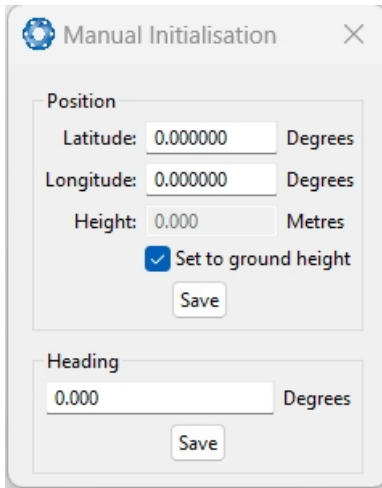


Figure 44: Manual Initialisation Dialogue

9.1.7.12 Gimbal

The Gimbal configuration dialogue is only used in speciality gimbal applications. Contact support@advancednavigation.com for more information on using Motus inside a gimbal.

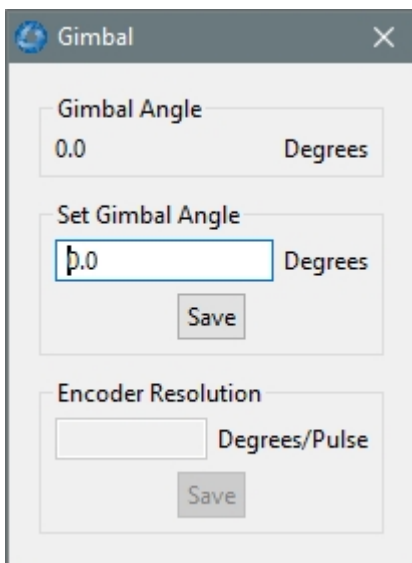


Figure 45: Manager Gimbal Dialogue

9.1.8 Tools Menu

The **Tools** menu contains tools for performing certain procedures with Motus.

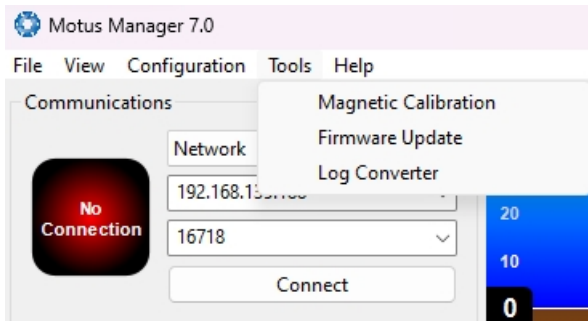


Figure 46: Manager Tools Menu

9.1.8.1 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 Motus unit.

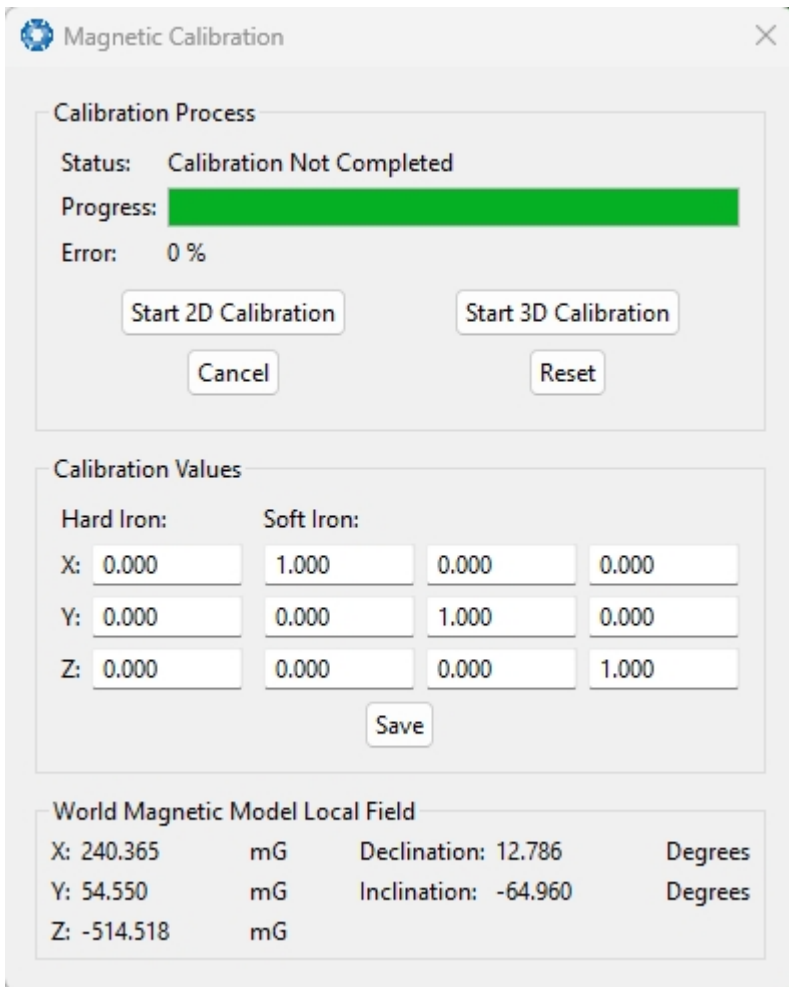


Figure 47: Manager Magnetic Calibration Dialogue

9.1.8.2 Firmware Update

This dialogue is used to update the Motus device firmware.

Motus contains firmware which is regularly updated to improve performance and add features. Advanced Navigation recommends that you upgrade to the latest version whenever available. The firmware update function is robust, such that power loss, file corruption or other issues cannot cause problems with units. Check the [Motus](#) product page of the Advanced Navigation website periodically for updates.

Note: Advanced Navigation device firmware files have the extension .anfw.

After the appropriate file is uploaded, the Firmware Update dialogue will display "**Firmware Update Ready**" in the status line.

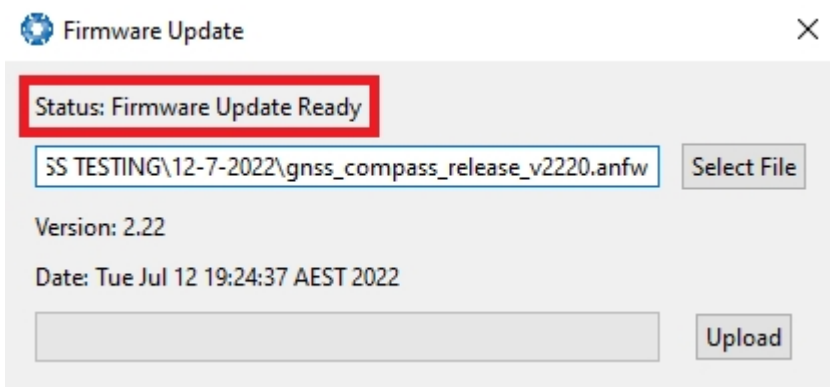


Figure 48: Firmware Update Ready Dialogue

Once the user clicks "upload", the dialogue status line will update to "**In Progress**"

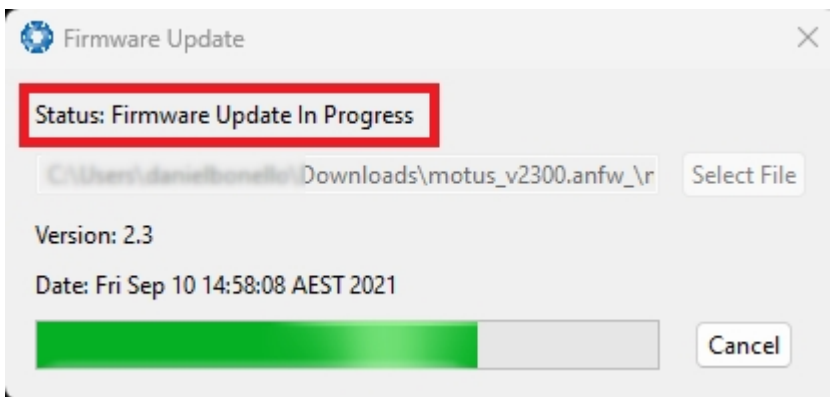


Figure 49: Firmware Update In Progress Dialogue

During this process, the user will notice the connection indicator change from "**Connected**" to "**Bootloader**." This change confirms that the upload is functioning properly.

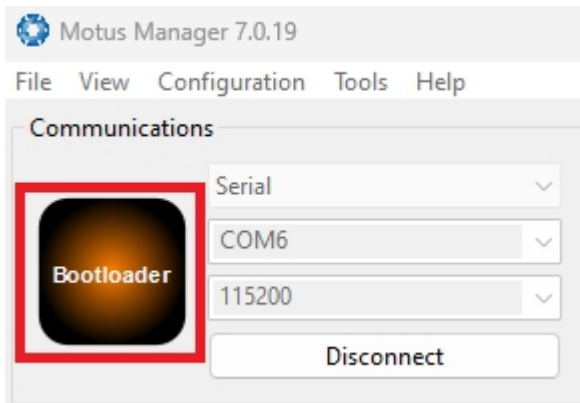


Figure 50: Firmware Update Bootloader Indicator

After the upload finishes, the system will restart. The device indicator will then display "**Connected**," and the firmware update status line will show "**Complete**."

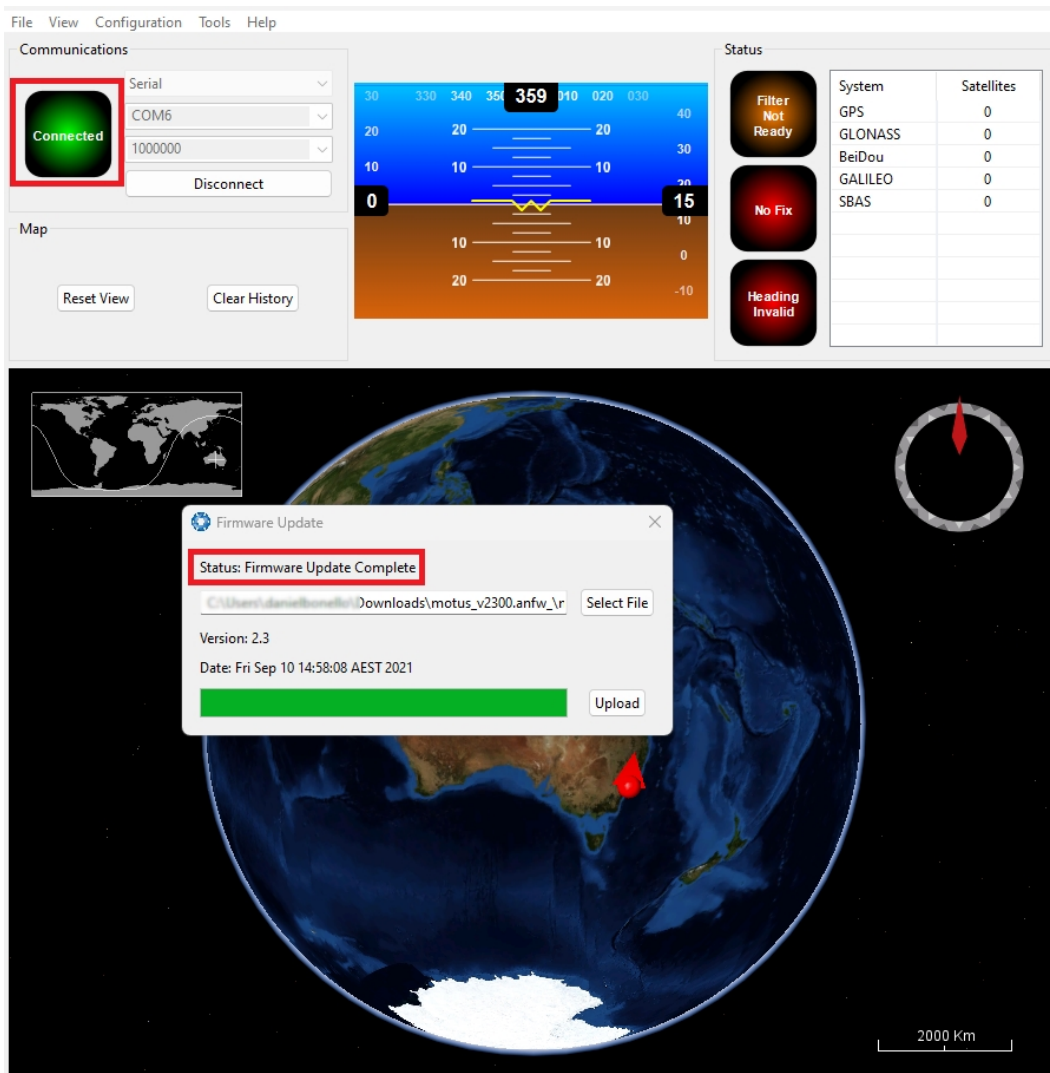


Figure 51: Firmware Update Complete Dialogue

After the update, the user can close the firmware update dialogue and verify the update by looking at the version in the Device Information dialogue, found under the view menu of the manager.

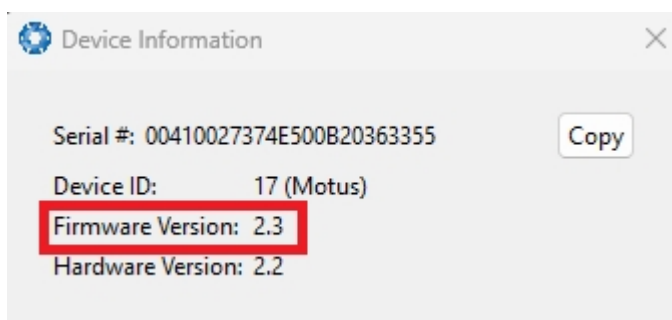


Figure 52: Device Information Dialogue

9.1.8.3 Log Converter

This tool allows the user to convert Motus log files into various standard formats that are interchangeable and readable by many programs. The Position Offset settings are used to project the exported position of origin to a point other than the actual centre of the Motus unit. For most users, these values should be left at zero.

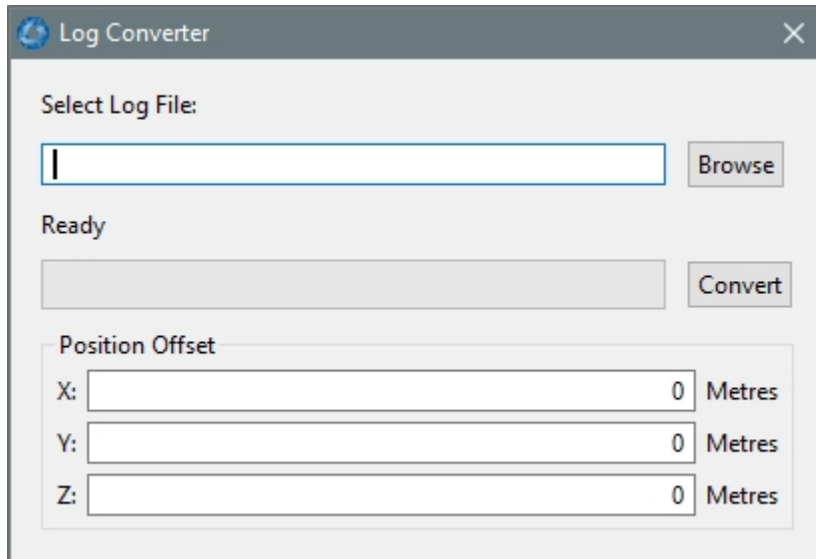


Figure 53: Manager Log Converter Dialogue

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

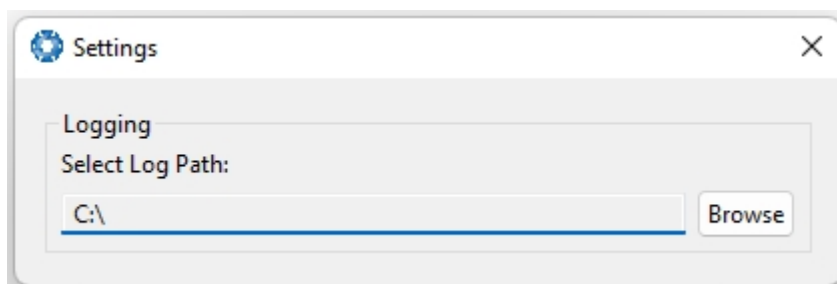
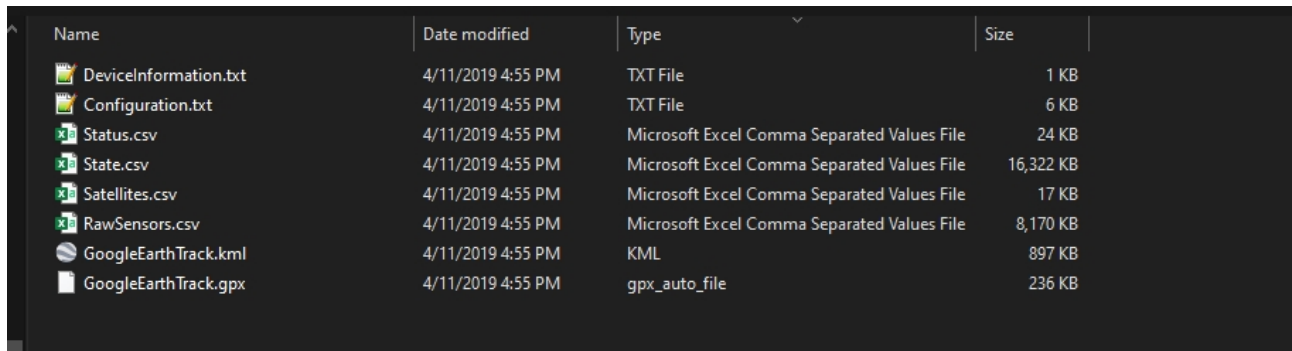


Figure 54: Settings menu for configuring Log Path

9.1.9 Logging

Motus Manager features a fully automatic logging system. Every time the serial port **Connect** button is clicked Motus Manager starts a new log file in the current directory. The log file is given the file name `MotusLog_date_time.anpp` and contains all of the raw data received from Motus 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 [9.1.8.3 Log Converter](#) dialogue in the **Tools** menu can be used. The Log Converter 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 that are designed to be opened with [Google Earth Pro](#).



Name	Date modified	Type	Size
DeviceInformation.txt	4/11/2019 4:55 PM	TXT File	1 KB
Configuration.txt	4/11/2019 4:55 PM	TXT File	6 KB
Status.csv	4/11/2019 4:55 PM	Microsoft Excel Comma Separated Values File	24 KB
State.csv	4/11/2019 4:55 PM	Microsoft Excel Comma Separated Values File	16,322 KB
Satellites.csv	4/11/2019 4:55 PM	Microsoft Excel Comma Separated Values File	17 KB
RawSensors.csv	4/11/2019 4:55 PM	Microsoft Excel Comma Separated Values File	8,170 KB
GoogleEarthTrack.kml	4/11/2019 4:55 PM	KML	897 KB
GoogleEarthTrack.gpx	4/11/2019 4:55 PM	gpx_auto_file	236 KB

Figure 55: Files Generated by the Log Converter

Note: This data logging is performed by the Motus Manager application.

9.2 Using the Android App

The Spatial Manager Android app provides logging and visualisation functions for Android phones and tablets. It is particularly useful for field testing purposes. You can use this app to connect to your Motus via Bluetooth and:

- Monitor position and orientation in real time
- Log real-time data for later analysis and review
- Configure NTRIP stream corrections
- Configure device alignment offsets and manual initialisation

You will require a Serial to Bluetooth adaptor with Bluetooth v2.0 support connected to the primary serial port.

The app can be found by searching the Google Play store for "Advanced Navigation Spatial Manager". Refer to the in-app Quick Start guide for more information. Contact support@advancednavigation.com if you have any questions about the Android app.

9.3 Using ANPP

Motus can be configured and monitored using the Advanced Navigation Packet Protocol (ANPP), which is detailed fully in [11 Advanced Navigation Packet Protocol](#).

A software development kit (SDK) is available at no extra charge to assist you when developing your own applications. It contains example code in a number of programming languages, ready to compile and test. This is available from the Motus [product page](#).

10 Interfacing

Communication with Motus is possible on the following ports:

- [10.1 Serial Interface](#)
- [10.3 GPIO Pins and the Auxiliary Port](#)

Each port has different input and output capabilities.

10.1 Serial Interface

There are two serial ports available for use. The GPIO port can also be used as a serial port, with less functionality.

Model	Primary Port	Auxiliary Port	GPIO Port
Motus	ANPP only over RS232 or RS422. No dynamic pin functions	ANPP over RS232 or RS422, 10.3.1 Dynamic Pin Functions	ANPP over RS232, 10.3.1 Dynamic Pin Functions

Table 21: I/O Ports Available

10.1.1 Baud Rate

The default baud rate of Motus is 115,200. The primary and auxiliary port baud rate can be set anywhere from 4,800 to 4,000,000 baud and can be modified using the Baud Rates page in Motus Manager. The GPIO port baud rate can be set anywhere from 4,800 to 250,000 baud. It is important to select a baud rate that is capable of carrying the amount of data that Motus has been configured to output. See [11.1.4 Packet Rates](#) 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 115,200, the data rate is 11,520 bytes per second. If the selected data rate is insufficient, data may be lost without warning.

The support team can provide a baud rate calculator if it is required. For more information or assistance, contact technical support via email at support@advancednavigation.com.

10.1.2 Format

The format is fixed at 1 start bit, 8 data bits, 1 stop bit and no parity. See [11 Advanced Navigation Packet Protocol](#) for details on the ANPP protocol.

10.2 External Data

External sources of position, velocity and/or heading can be integrated into the Motus filter solution. The data can be sent to Motus in the ANPP format over the primary (RS232 or RS422), auxiliary (RS232 or RS422) or GPIO ports (RS232 only) or in a number of different formats. If using the ANPP format, use the table below to find the relevant section.

Packet
11.4.25 External Position and Velocity Packet
11.4.26 External Position Packet
11.4.27 External Velocity Packet

Packet
11.4.28 External Body Velocity Packet
11.4.29 External Heading Packet
11.4.33 External Time Packet
11.4.34 External Depth Packet
11.4.38 External Odometer Packet
11.4.39 External Air Data Packet
11.4.43 External Magnetometers Packet

Table 22: ANPP External Data Packets

10.3 GPIO Pins and the Auxiliary Port

In addition to the primary port, Motus contains two general purpose input/output (GPIO) pins and an auxiliary port on the IO Breakout Connector. These pins are multi function and can be used to extend Motus with additional peripherals, sensors and data formats. Both GPIO pins have digital input, digital output, frequency input and frequency output functionality.

GPIO1 can also function as an RS232 (only) serial transmit line and GPIO2 can function as an RS232 (only) serial receive line. The GPIO serial baud rate can be configured anywhere from 4800 to 250 K baud. The auxiliary serial baud rate can be configured anywhere from 4800 to 4 M baud. See [11.5.3.1 Supported Baud Rate](#). Changes to these baud rates can be made by using the Baud Rates page in [Motus Manager](#).

The available GPIO and auxiliary functions are listed in the section [10.3.1 Dynamic Pin Functions](#). The function of a GPIO pin or the auxiliary port can be changed at any time using the GPIO Configuration page in [Manager](#). GPIO 1 and GPIO 2 operate at standard voltage levels for digital input, digital output, frequency input and frequency output, but when a serial data function is selected, this GPIO pin automatically switches to RS232 voltage level.

10.3.1 Dynamic Pin Functions

Function Type	Name	
Tristate	10.3.1.1 Inactive	
Digital Output	10.3.1.2 1PPS Output	
	10.3.1.3 GNSS Fix Output	
Digital Input	10.3.1.4 Zero Velocity Input	
	10.3.1.5 Disable Magnetometers	
	10.3.1.6 Disable GNSS	
	10.3.1.7 Disable Pressure	
	10.3.1.8 Set Zero Orientation Alignment	
	10.3.1.9 System State Packet Trigger	
	10.3.1.10 Raw Sensors Packet Trigger	
	10.3.1.11 1PPS Input	
	10.3.1.12 Event 1 Input	
	10.3.1.13 Event 2 Input	
	10.3.1.14 Odometer Direction, Forward Low	
	10.3.1.15 Odometer Direction, Forward High	
	10.3.1.16 Reverse Alignment, Forward Low	
	10.3.1.17 Reverse Alignment, Forward High	
	10.3.1.18 Zero Angular Velocity Input	
	Frequency Input	10.3.1.19 Odometer Input
		10.3.1.20 Pitot Tube Input
		10.3.1.21 Pressure Depth Transducer (deprecated)
10.3.1.22 Left Wheel Speed Sensor		
10.3.1.23 Right Wheel Speed Sensor		
10.3.1.24 Wheel Speed Sensor		
10.3.1.25 Wheel Encoder Phase A		
10.3.1.26 Wheel Encoder Phase B		
10.3.1.27 Gimbal Encoder Phase A		
10.3.1.28 Gimbal Encoder Phase B		

Function Type	Name
Serial Receive	10.3.1.29 NMEA Input
	10.3.1.30 Novatel GNSS Input
	10.3.1.31 Topcon GNSS Input
	10.3.1.32 ANPP Input
	10.3.1.33 RTCM Differential GNSS Corrections Input
	10.3.1.34 Trimble GNSS Input
	10.3.1.35 u-blox GNSS Input
	10.3.1.36 Hemisphere GNSS Input
	10.3.1.37 Teledyne DVL Input
	10.3.1.38 Trittech USBL Input
	10.3.1.39 Linkquest DVL Input
	10.3.1.40 Linkquest USBL Input
10.3.1.41 Nortek DVL Input	
Serial Transmit	10.3.1.42 NMEA Output
	10.3.1.43 ANPP Output
	10.3.1.44 TSS1 Output
	10.3.1.45 Simrad 1000 Output
	10.3.1.46 Simrad 3000 Output
Serial	10.3.1.47 Serial Port Passthrough
	10.3.1.48 GNSS Receiver Passthrough

Table 23: Dynamic Pin Functions

10.3.1.1 Inactive

Type: Tristate
GPIO Port: 1, 2
Auxiliary: All

10.3.1.2 1PPS Output

Type: Digital Output
GPIO Port: 1, 2
Auxiliary: Transmit
Description: There is a difference between the output of the GPIO and auxiliary ports when set to 1PPS output mode.

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

Figure 56: 1PPS Specifications

The pin is normally low and pulses high for 50 milliseconds to signal the precise second. The 1PPS line starts pulsing approximately 100 milliseconds after power up and always fires irrespective of whether Motus has accurate time or not. It is important to note that when Motus 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.

10.3.1.3 GNSS Fix Output

Type:	Digital Output
GPIO Port:	1, 2
Auxiliary:	Transmit
Description:	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.

10.3.1.4 Zero Velocity Input

Type:	Digital Input
GPIO Port:	1, 2
Auxiliary:	Receive
Description:	When using this function, a high state indicates to Motus that it is stationary. The low state indicates that the vehicle is not stationary. Use of this function can prevent drift during periods when a GNSS signal is not available.

10.3.1.5 Disable Magnetometers

Type:	Digital Input
GPIO Port:	All
Auxiliary:	Receive
Description:	This function accepts a digital input with a low state enabling the magnetometers and a high state disabling the magnetometers.

10.3.1.6 Disable GNSS

Type:	Digital Input
GPIO Port:	1, 2
Auxiliary:	Receive
Description:	This function accepts a digital input with a low state enabling the GNSS and a high state disabling the GNSS.

10.3.1.7 Disable Pressure

Type:	Digital Input
GPIO Port:	1, 2
Auxiliary:	Receive
Description:	This function accepts a digital input with a low state enabling the atmospheric pressure sensor and a high state disabling the atmospheric pressure sensor.

10.3.1.8 Set Zero Orientation Alignment

Type:	Digital Input
GPIO Port:	1, 2
Auxiliary:	Receive
Description:	This function accepts a digital input. The input is normally low and a transition from low to high causes Motus 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 11.5.4 Installation Alignment Packet must be read and then sent back to Motus with the permanent flag set. This function requires de-bouncing if attached to a switch.

10.3.1.9 System State Packet Trigger

Type:	Digital Input
GPIO Port:	1, 2
Auxiliary:	Receive
Description:	This function accepts a digital input. The input is normally low and a transition from low to high causes Motus to send the System State Packet. This function requires de-bouncing if attached to a switch.

10.3.1.10 Raw Sensors Packet Trigger

Type:	Digital Input
GPIO Port:	1, 2
Auxiliary:	Receive
Description:	This function accepts a digital input. The input is normally low and a transition from low to high causes Motus to send the 11.4.9 Raw Sensors Packet . This function requires de-bouncing if attached to a switch.

10.3.1.11 1PPS Input

Type:	Digital Input
GPIO Port:	1, 2
Auxiliary:	Receive

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

10.3.1.12 Event 1 Input

Type: Digital Input

GPIO Port: 1, 2

Auxiliary: Receive

Description: This function is designed to allow external events to be recorded by Motus. The event is recorded in the Filter Status (see [11 Advanced Navigation Packet Protocol](#)), and resets after the next packet is output. The event triggers on a transition from low to high.

10.3.1.13 Event 2 Input

Type: Digital Input

GPIO Port: 1, 2

Auxiliary: Receive

Description: This function is designed to allow external events to be recorded by Motus. The event is recorded in the Filter Status (see [11 Advanced Navigation Packet Protocol](#)), and resets after the next packet is output. The event triggers on a transition from low to high.

10.3.1.14 Odometer Direction, Forward Low

Type: Digital Input

GPIO Port: 1, 2

Auxiliary: Receive

Description: 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.

10.3.1.15 Odometer Direction, Forward High

Type: Digital Input

GPIO Port: 1, 2

Auxiliary: Receive

Description: 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.

10.3.1.16 Reverse Alignment, Forward Low

Type: Digital Input

GPIO Port: 1, 2

Auxiliary: Receive

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

10.3.1.17 Reverse Alignment, Forward High

Type: Digital Input

GPIO Port: 1, 2

Auxiliary: Receive

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

10.3.1.18 Zero Angular Velocity Input

Type: Digital Input

GPIO Port: 1, 2

Auxiliary: Receive

Description: In this function, a high state indicates to Motus 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.

10.3.1.19 Odometer Input

Type: Frequency Input

GPIO Port: 1, 2

Auxiliary: Receive

Description: 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 then this odometer input function should be used. If it is less than 0.1 metres, the wheel speed sensor function should be used. Contact technical support at support@advancednavigation.com for help integrating with your speed sensor.

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

Table 24: Odometer Specifications

10.3.1.20 Pitot Tube Input

Type: Frequency Input

GPIO Port: 1, 2

Auxiliary: Receive

Description: This function allows fixed wing aircraft to measure airspeed to improve navigation performance. It requires a differential pressure sensor that has a frequency output such

as the Kavlico P992 (frequency output option) or the Paroscientific series 5300. Contact technical support at support@advancednavigation.com for help integrating with a pitot tube.

10.3.1.21 Pressure Depth Transducer (deprecated)

Type: Frequency Input
GPIO Port: 1, 2
Auxiliary: Receive
Description: This function is designed for interfacing with a legacy pressure depth transducer. These are no longer available and the function is now deprecated.

10.3.1.22 Left Wheel Speed Sensor

Type: Frequency Input
GPIO Port: 1, 2
Auxiliary: Receive
Description: This function is designed for the left wheel of a vehicle with dual wheel speed sensors.

10.3.1.23 Right Wheel Speed Sensor

Type: Frequency Input
GPIO Port: 1, 2
Auxiliary: Receive
Description: This function is designed for the right wheel of a vehicle with dual wheel speed sensors.

10.3.1.24 Wheel Speed Sensor

Type: Frequency Input
GPIO Port: 1, 2
Auxiliary: Receive
Description: 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. Contact technical support via email at support@advancednavigation.com for with 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 25: Wheel Speed Sensor Specifications

10.3.1.25 Wheel Encoder Phase A

Type:	Frequency Input
GPIO Port:	1, 2
Auxiliary:	N/A
Description:	This function is designed for rotary incremental quadrature encoders. It should be used in combination with Wheel Encoder Phase B.

10.3.1.26 Wheel Encoder Phase B

Type:	Frequency Input
GPIO Port:	1, 2
Auxiliary:	N/A
Description:	This function is designed for rotary incremental quadrature encoders. It should be used in combination with Wheel Encoder Phase A.

10.3.1.27 Gimbal Encoder Phase A

Type:	Frequency Input
GPIO Port:	1, 2
Auxiliary:	N/A
Description:	This function is designed for interfacing with a rotary incremental quadrature encoder to measure the azimuth angle of a gimbal in which Motus is installed. It should be used in combination with Gimbal Encoder Phase B.

10.3.1.28 Gimbal Encoder Phase B

Type:	Frequency Input
GPIO Port:	1, 2
Auxiliary:	N/A
Description:	This function is designed for interfacing with a rotary incremental quadrature encoder to measure the azimuth angle of a gimbal in which Motus is installed. It should be used in combination with Gimbal Encoder Phase A .

10.3.1.29 NMEA Input

Type:	Serial Receive
GPIO Port:	2
Auxiliary:	Receive
Description:	This function accepts external data in the NMEA 0183 format. Advanced Navigation recommends against using NMEA 0183 input wherever possible due to the inefficiency, low accuracy and precision and weak 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 and GPVT with optional messages GPGSV and GPGSA.

Message ID	Description
GPGGA GNGGA	3D position
GPGLL GNGLL	2D position
GPRMC GNRMC	2D position, 2D velocity and coarse time
GPVTG GNVTG	2D velocity
GPHDT GNHDT HEHDT	Heading
GPGSV GNGSV	Satellites
GPGSA GNGSA	Dilution of Precision
xxPIPS	Depth below surface
xxVBW	Water speed, ground speed
xxHDM	Magnetic heading
PSIMSSB	SSBL position
xxVHW	Water speed and heading
xxDBS	Depth below surface

Table 26: Supported NMEA messages

10.3.1.30 Novatel GNSS Input

Type: Serial Receive

GPIO Port: 2

Auxiliary: Receive

Description: This function is designed for interfacing Motus 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 (20 Hz recommended). The message BESTSATSB is optional to display detailed satellite information. The message HEADING is also supported for ALIGN capable receivers.

10.3.1.31 Topcon GNSS Input

Type: Serial Receive

GPIO Port: 2

Auxiliary: Receive

Description: This function is designed for interfacing Motus 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.

10.3.1.32 ANPP Input

Type: Serial Receive

GPIO Port:	2
Auxiliary:	Receive
Description:	<p>This function accepts data in the ANPP format as specified in 11 Advanced Navigation Packet Protocol.</p> <p>When this function is enabled, the GPIO and auxiliary ports function the same as the primary port, with two exceptions:</p> <ul style="list-style-type: none"> • The GPIO and auxiliary ports cannot perform a firmware update. • When setting the ANPP packet and message output rates, the changes only apply to the port you are connected to. For example, you cannot change the primary port or GPIO port packet and message rates when connected to the auxiliary port.

10.3.1.33 RTCM Differential GNSS Corrections Input

Type:	Serial Receive
GPIO Port:	2
Auxiliary:	Receive
Description:	This function accepts RTCM v3 GNSS corrections messages. This allows for Differential GNSS or RTK with the Motus internal GNSS receiver.

10.3.1.34 Trimble GNSS Input

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

10.3.1.35 u-blox GNSS Input

Type:	Serial Receive
GPIO Port:	2
Auxiliary:	Receive
Description:	This function is designed for interfacing Motus with an external u-blox GNSS receiver. It accepts data in the u-blox binary format and expects message NAV-PVT at rates higher than 1 Hz.

10.3.1.36 Hemisphere GNSS Input

Type:	Serial Receive
GPIO Port:	2
Auxiliary:	Receive

Description: This function is designed for interfacing Motus with an external Hemisphere GNSS receiver. It accepts data in the Hemisphere binary format and expects message Bin1 at rates higher than 1 Hz. 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.

10.3.1.37 Teledyne DVL Input

Type: Serial Receive
GPIO Port: 2
Auxiliary: Receive
Description: This function accepts DVL data from a Teledyne DVL. For assistance with configuration, contact support@advancednavigation.com.

10.3.1.38 Trittech USBL Input

Type: Serial Receive
GPIO Port: 2
Auxiliary: Receive
Description: This function accepts USBL data from a Trittech USBL. For assistance with configuration, contact support@advancednavigation.com.

10.3.1.39 Linkquest DVL Input

Type: Serial Receive
GPIO Port: 2
Auxiliary: Receive
Description: This function accepts DVL data from a Linkquest DVL. For assistance with configuration, contact support@advancednavigation.com.

10.3.1.40 Linkquest USBL Input

Type: Serial Receive
GPIO Port: 2
Auxiliary: Receive
Description: This function accepts USBL data from a Linkquest USBL. For assistance with configuration, contact support@advancednavigation.com.

10.3.1.41 Nortek DVL Input

Type: Serial Receive
GPIO Port: 2
Auxiliary: Receive
Description: 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 8 Hz.

10.3.1.42 NMEA Output

Type:	Serial Transmit
GPIO Port:	1
Auxiliary:	Transmit
Description:	This function outputs a configurable combination of the NMEA messages GPZDA, GPGGA, GPVTG, GPRMC, GPHDT, PASHR, GPROT, GPHEV, GPGSV, PFECGPAtt, and PFECGPHve at up to 50 Hz. The messages output and the output rate can be configured using the web UI or Motus Manager. 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
```

10.3.1.43 ANPP Output

Type:	Serial Transmit
GPIO Port:	1
Auxiliary:	Transmit
Description:	This function outputs data in the ANPP format as specified in 11 Advanced Navigation Packet Protocol . This function is for ANPP peripheral devices only. When this function is enabled, the GPIO and auxiliary ports function the same as the primary port, with two exceptions: <ul style="list-style-type: none"> • The GPIO and auxiliary ports cannot perform a firmware update. • When setting the ANPP packet and message output rates, the changes only apply to the port you are connected to. For example, you cannot change the primary port or GPIO port packet and message rates when connected to the auxiliary port.

10.3.1.44 TSS1 Output

Type:	Serial Transmit
GPIO Port:	1
Auxiliary:	Transmit
Description:	This function outputs the TSS1 format at a user configurable rate of up to 50 Hz. The

output rate can be configured using the page in the web UI.

10.3.1.45 Simrad 1000 Output

Type:	Serial Transmit
GPIO Port:	1
Auxiliary:	Transmit
Description:	This function outputs the Simrad 1000 format at a user configurable rate of up to 50 Hz. The output rate can be configured using the 9.1.7.10 GPIO Output dialogue in the Motus Manager.

10.3.1.46 Simrad 3000 Output

Type:	Serial Transmit
GPIO Port:	1
Auxiliary:	Transmit
Description:	This function outputs the Simrad 3000 format at a user configurable rate up to 50 Hz. The output rate can be configured using the 9.1.7.10 GPIO Output dialogue in the Motus Manager.

10.3.1.47 Serial Port Passthrough

Type:	Serial
GPIO Port:	1, 2
Auxiliary:	All
Description:	This function allows passthrough communication through either GPIO 1 and 2 or the Auxiliary port. To transmit data use the 11.3.7 Serial Port Passthrough Packet . When data is received it will be sent back using the same 11.3.7 Serial Port Passthrough Packet .

10.3.1.48 GNSS Receiver Passthrough

Type:	Serial
GPIO Port:	1, 2
Auxiliary:	All
Description:	This function allows for pass through connection to the internal GNSS receiver. This is useful for firmware updates of the internal GNSS receiver.

11 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. ANPP is proprietary and is used across all Advanced Navigation products. A packet type can be identified by its unique Packet ID. For more information about packets, see [11.1 About Packets](#).

The following packet types are available:

- [11.3 System Packets](#) - These packets have ID values of less than 20.
- [11.4 State Packets](#) - These packets have ID values between 20 and 179.
- [11.5 Configuration Packets](#) - These packets have IDs greater than 179.

The following table lists Advanced Navigation packets by type.

Packet ID	Name	Length	R/W
System Packets			
0	11.3.1 Acknowledge Packet	4	R
1	11.3.2 Request Packet	Varies	W
2	11.3.3 Boot Mode Packet	1	R/W
3	11.3.4 Device Information Packet	24	R
4	11.3.5 Restore Factory Settings Packet	4	W
5	11.3.6 Reset Packet	4	W
10	11.3.7 Serial Port Passthrough Packet	Varies	R/W
Packet ID	Name	Length	R/W
State Packets			
20	11.4.1 System State Packet	100	R
21	11.4.2 Unix Time Packet	8	R
22	11.4.3 Formatted Time Packet	14	R
23	11.4.4 Status Packet	4	R
24	11.4.5 Position Standard Deviation Packet	12	R
25	11.4.6 Velocity Standard Deviation Packet	12	R
26	11.4.7 Euler Orientation Standard Deviation Packet	12	R
27	11.4.8 Quaternion Orientation Standard Deviation Packet	16	R
28	11.4.9 Raw Sensors Packet	48	R
29	11.4.10 Raw GNSS Packet	74	R/W
30	11.4.11 Satellites Packet	13	R
31	11.4.12 Detailed Satellites Packet	Varies	R
32	11.4.13 Geodetic Position Packet	24	R
33	11.4.14 ECEF Position Packet	24	R

Packet ID	Name	Length	R/W
34	11.4.15 UTM Position Packet	26	R
35	11.4.16 NED Velocity Packet	12	R
36	11.4.17 Body Velocity Packet	12	R
37	11.4.18 Acceleration Packet	12	R
38	11.4.19 Body Acceleration Packet	16	R
39	11.4.20 Euler Orientation Packet	12	R
40	11.4.21 Quaternion Orientation Packet	16	R
41	11.4.22 DCM Orientation Packet	36	R
42	11.4.23 Angular Velocity Packet	12	R
43	11.4.24 Angular Acceleration Packet	12	R
44	11.4.25 External Position and Velocity Packet	60	R/W
45	11.4.26 External Position Packet	36	R/W
46	11.4.27 External Velocity Packet	24	R/W
47	11.4.28 External Body Velocity Packet	16 or 24	R/W
48	11.4.29 External Heading Packet	8	R/W
49	11.4.30 Running Time Packet	8	R
50	11.4.31 Local Magnetic Field Packet	12	R
51	11.4.32 Odometer State Packet	20	R
52	11.4.33 External Time Packet	8	W
53	11.4.34 External Depth Packet	8	R/W
54	11.4.35 Geoid Height Packet	4	R
57	11.4.36 Wind Packet	12	R/W
58	11.4.37 Heave Packet	16	R
67	11.4.38 External Odometer Packet	13	W
68	11.4.39 External Air Data Packet	25	R/W
70	11.4.40 Raw DVL Data Packet	60	R/W
72	11.4.41 Gimbal State Packet	8	R/W
73	11.4.42 Automotive Packet	24	R
75	11.4.43 External Magnetometers Packet	17	R/W
80	11.4.44 Basestation Packet	45	R
83	11.4.45 Zero Angular Velocity Packet	8	W
Packet ID	Name	Length	R/W
Configuration Packets			

Packet ID	Name	Length	R/W
180	11.5.1 Packet Timer Period Packet	4	R/W
181	11.5.2 Packets Period Packet	Varies	R/W
182	11.5.3 Baud Rates Packet	17	R/W
185	11.5.4 Installation Alignment Packet	73	R/W
186	11.5.5 Filter Options Packet	17	R/W
188	11.5.6 GPIO Configuration Packet	13	R/W
189	11.5.7 Magnetic Calibration Values Packet	49	R/W
190	11.5.8 Magnetic Calibration Configuration Packet	1	W
191	11.5.9 Magnetic Calibration Status Packet	3	R
192	11.5.10 Odometer Configuration Packet	8	R/W
193	11.5.11 Set Zero Orientation Alignment Packet	5	W
194	11.5.12 Reference Point Offsets Packet	49	R/W
195	11.5.13 GPIO Output Configuration Packet	183	R/W
198	11.5.14 User Data Packet	64	R/W
199	11.5.15 GPIO Input Configuration Packet	65	R/W

Table 27: Advanced Navigation Packets

11.1 About Packets

11.1.1 Packet Structure

The ANPP packet structure and the header format are shown in the tables below. Example source code is provided in multiple languages via the SDK, available from the [Motus](#) product page of the Advanced Navigation website.

Header				
Header LRC	Packet ID	Packet Length	CRC16	Packet Data

Table 28: ANPP Packet Structure

Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Header LRC
2	1	u8	1	Packet ID
3	2	u8	1	Packet Length
4	3	u16	2	CRC

Table 29: ANPP Header Format

11.1.1.1 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. Only the lower 8 bits of the calculation below are provided in the LRC field of the packet header. The LRC can be found using the following:

$$LRC = (PacketID + PacketLength + crc_0 + crc_1) \oplus 0xFF + 1$$

11.1.1.2 Packet ID

The packet ID is used to distinguish the contents of the packet. Packet IDs range from 0 to 255. See [11 Advanced Navigation Packet Protocol](#).

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.

11.1.1.3 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.

11.1.1.4 CRC

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

11.1.2 Packet Requests

Any of the state and configuration packets can be requested at any time using the [11.3.2 Request Packet](#).

11.1.3 Packet Acknowledgement

When configuration packets are sent to Motus, it will reply with an acknowledgement packet that indicates whether the configuration change was successful or not. See [11.3.1 Acknowledge Packet](#).

External data packets will also generate negative acknowledgement packets if there is a problem with the packet. Positive acknowledgements will not be sent. See [10.2 External Data](#) for a list of External Data Packets.

11.1.4 Packet Rates

The packet rates can be configured either using the web UI, or Motus Manager or through the [11.5.2 Packets Period Packet](#). By default Motus is configured to output the [11.4.1 System State Packet](#) at 20 Hz and the [11.4.9 Raw Sensors Packet](#) at 20 Hz. 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 calculated by adding the packet overhead to the packet length; the packet overhead is a fixed value of 5. For example to output the system state packet at 50Hz the calculation would be:

$$\text{Data throughput} = (100 (\text{packet length}) + 5 (\text{fixed packet overhead})) * 50 (\text{rate})$$

$$\text{Data throughput} = 5250 \text{ bytes per second}$$

$$\text{Minimum baud rate} = \text{data throughput} * 11 = 57750 \text{ Baud}$$

$$\text{Closest standard baud rate} = 115200 \text{ Baud}$$

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

11.1.5 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 [11.4.1 System State Packet](#), the [11.4.2 Unix Time Packet](#) or the [11.4.3 Formatted Time Packet](#). For example if the [11.4.2 Unix Time Packet](#), [11.4.4 Status Packet](#) and [11.4.16 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 [11.4.2 Unix Time Packet](#) providing the time of validity for the other two packets.

11.2 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 30: Data Type Abbreviations used in the ANPP

11.3 System Packets

11.3.1 Acknowledge Packet

Acknowledgement Packet				
Packet ID		0		
Length		4		
Read / Write		Read		
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Packet ID being acknowledged
2	1	u16	2	CRC of packet being acknowledged
3	3	u8	1	11.3.1.1 Acknowledge Result

Table 31: Acknowledge Packet

11.3.1.1 Acknowledge Result

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

Table 32: Acknowledge Result

11.3.2 Request Packet

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

Table 33: Request Packet

11.3.3 Boot Mode Packet

Boot Mode Packet				
Packet ID		2		
Length		1		
Read / Write		Read / Write		
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	11.3.3.1 Boot Mode Types

Table 34: Boot Mode Packet

11.3.3.1 Boot Mode Types

Value	Description
0	Bootloader
1	Main Program

Table 35: Boot Mode Types

11.3.4 Device Information Packet

Device Information Packet				
Packet ID		3		
Length		24		
Read / Write		Read		
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Software version
2	4	u32	4	11.3.4.1 Device ID
3	8	u32	4	Hardware revision
4	12	u32	4	Motus Serial number part 1
5	16	u32	4	Motus Serial number part 2
6	20	u32	4	Motus Serial number part 3

Table 36: Device Information Packet

11.3.4.1 Device ID

Value	Description
1	Spatial
4	Spatial FOG
5	Spatial Dual
11	Orientus (>v3)
13	Air Data Unit
14	Subsonus
16	Spatial FOG Dual
17	Motus
19	GNSS Compass
21	Subsonus Tag
22	Poseidon
26	Certus
27	Aries
28	Boreas D90
41	Boreas D70

Table 37: Device IDs

11.3.5 Restore Factory Settings Packet

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

Table 38: Restore Factory Settings Packet

11.3.6 Reset Packet

Reset Packet				
Packet ID		5		
Length		4		
Read / Write		Write		
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	11.3.6.1 Verification Sequence Values

Table 39: Reset Packet

11.3.6.1 Verification Sequence Values

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

Table 40: Verification Sequence Values

11.3.7 Serial Port Passthrough Packet

Serial Port Passthrough Packet				
Packet ID		10		
Length		Variable, up to 255 bytes		
Read / Write		Read / Write		
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Passthrough Route
2	1			Passthrough Data

Table 41: Serial Port Passthrough Packet

11.3.7.1 Passthrough Route

Value	Description
1	GPIO 1 and 2
2	Auxiliary

Table 42: Passthrough Route

11.3.7.2 Discovery Network Setting Overwrite

Settings 7,8 and 9 are optional over standard network interfaces but required to overwrite settings over multi-cast discovery. To overwrite network settings for a device over multi-cast send this packet to address 239.48.81.7 port 48817, the serial number must be set to the serial number of the device you want to overwrite settings for.

11.4 State Packets

Motus supports a ANPP number of packets providing extensive functionality. However for the majority of users the easiest approach is to configure Motus using the web UI or Motus Manager software and then support only the single system state packet shown in [11.4.1 System State Packet](#). Advanced functionality can be added as required through the other packets.

This section covers the following topics:

Packet ID	Name	Length	R/W
State Packets			
20	11.4.1 System State Packet	100	R
21	11.4.2 Unix Time Packet	8	R
22	11.4.3 Formatted Time Packet	14	R
23	11.4.4 Status Packet	4	R
24	11.4.5 Position Standard Deviation Packet	12	R
25	11.4.6 Velocity Standard Deviation Packet	12	R
26	11.4.7 Euler Orientation Standard Deviation Packet	12	R
27	11.4.8 Quaternion Orientation Standard Deviation Packet	16	R
28	11.4.9 Raw Sensors Packet	48	R
29	11.4.10 Raw GNSS Packet	74	R/W
30	11.4.11 Satellites Packet	13	R
31	11.4.12 Detailed Satellites Packet	Varies	R
32	11.4.13 Geodetic Position Packet	24	R
33	11.4.14 ECEF Position Packet	24	R
34	11.4.15 UTM Position Packet	26	R
35	11.4.16 NED Velocity Packet	12	R
36	11.4.17 Body Velocity Packet	12	R
37	11.4.18 Acceleration Packet	12	R
38	11.4.19 Body Acceleration Packet	16	R
39	11.4.20 Euler Orientation Packet	12	R
40	11.4.21 Quaternion Orientation Packet	16	R
41	11.4.22 DCM Orientation Packet	36	R
42	11.4.23 Angular Velocity Packet	12	R
43	11.4.24 Angular Acceleration Packet	12	R
44	11.4.25 External Position and Velocity Packet	60	R/W

Packet ID	Name	Length	R/W
45	11.4.26 External Position Packet	36	R/W
46	11.4.27 External Velocity Packet	24	R/W
47	11.4.28 External Body Velocity Packet	16 or 24	R/W
48	11.4.29 External Heading Packet	8	R/W
49	11.4.30 Running Time Packet	8	R
50	11.4.31 Local Magnetic Field Packet	12	R
51	11.4.32 Odometer State Packet	20	R
52	11.4.33 External Time Packet	8	W
53	11.4.34 External Depth Packet	8	R/W
54	11.4.35 Geoid Height Packet	4	R
57	11.4.36 Wind Packet	12	R/W
58	11.4.37 Heave Packet	16	R
67	11.4.38 External Odometer Packet	13	W
68	11.4.39 External Air Data Packet	25	R/W
70	11.4.40 Raw DVL Data Packet	60	R/W
72	11.4.41 Gimbal State Packet	8	R/W
73	11.4.42 Automotive Packet	24	R
75	11.4.43 External Magnetometers Packet	17	R/W
80	11.4.44 Basestation Packet	45	R
83	11.4.45 Zero Angular Velocity Packet	8	W

Table 43: State Packets

11.4.1 System State Packet

System State Packet				
Packet ID		20		
Length		100		
Read / Write		Read		
Field #	Bytes Offset	Data Type	Size	Description
1	0	u16	2	11.4.1.1 System Status
2	2	u16	2	11.4.1.2 Filter Status
3	4	u32	4	11.4.1.4 Unix Time Seconds
4	8	u32	4	11.4.1.5 Microseconds
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 44: System State Packet

11.4.1.1 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	ReservedPressure Sensor Failure
5	Reserved (set to zero)
6	Accelerometer Over Range
7	Gyroscope Over Range
8	Magnetometer Over Range
9	ReservedPressure Over Range
10	Minimum Temperature Alarm
11	Maximum Temperature Alarm
12	Low Voltage Alarm
13	High Voltage Alarm
14	Reserved (set to zero)
15	Data Output Overflow Alarm

Table 45: System Status

11.4.1.2 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	11.4.1.3 GNSS Fix Status
5	
6	
7	Event 1 Occurred
8	Event 2 Occurred
9	Internal GNSS Enabled
10	Heading Active
11	Velocity Heading Enabled
12	Atmospheric Altitude Enabled
13	External Position Active
14	External Velocity Active
15	External Heading Active

Table 46: Filter Status

11.4.1.3 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	PPP GNSS fix
6	1	1	0	RTK Float GNSS fix
7	1	1	1	RTK Fixed GNSS fix

Table 47: GNSS Fix Status

11.4.1.4 Unix Time Seconds

This field provides the Unix time in seconds, using the standard epoch of January 1, 1970.

11.4.1.5 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.

11.4.2 Unix Time Packet

Unix Time Packet				
Packet ID		21		
Length		8		
Read / Write		Read		
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Unix time stamp (seconds). See 11.4.1.4 Unix Time Seconds
2	4	u32	4	Microseconds

Table 48: Unix Time Packet

11.4.3 Formatted Time Packet

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

Table 49: Formatted Time Packet

11.4.4 Status Packet

Status Packet				
Packet ID		23		
Length		4		
Read / Write		Read		
Field #	Bytes Offset	Data Type	Size	Description
1	0	u16	2	System Status
2	2	u16	2	Filter Status

Table 50: Status Packet

11.4.5 Position Standard Deviation Packet

Position Standard Deviation Packet				
Packet ID		24		
Length		12		
Read / Write		Read		
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 51: Position Standard Deviation Packet

11.4.6 Velocity Standard Deviation Packet

Velocity Standard Deviation Packet				
Packet ID		25		
Length		12		
Read / Write		Read		
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 52: Velocity Standard Deviation Packet

11.4.7 Euler Orientation Standard Deviation Packet

Euler Orientation Standard Deviation Packet				
Packet ID		26		
Length		12		
Read / Write		Read		
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 53: Euler Orientation Standard Deviation Packet

11.4.8 Quaternion Orientation Standard Deviation Packet

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

Table 54: Quaternion Orientation Standard Deviation Packet

11.4.9 Raw Sensors Packet

Raw Sensors Packet				
Packet ID			28	
Length			48	
Read / Write			Read	
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 55: Raw Sensors Packet

11.4.10 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.

Note: Raw GNSS is only available if the Motus Rugged or has a license upgrade to full INS capability, and is interfaced to an external GNSS receiver.

Raw GNSS Packet				
Packet ID		29		
Length		74		
Read / Write		Read		
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Unix time stamp (seconds)
2	4	u32	4	Microseconds
3	8	fp64	8	Latitude (rad)
4	16	fp64	8	Longitude (rad)
5	24	fp64	8	Height (m)
6	32	fp32	4	Velocity north (m/s)
7	36	fp32	4	Velocity east (m/s)
8	40	fp32	4	Velocity down (m/s)
9	44	fp32	4	Latitude standard deviation (m)
10	48	fp32	4	Longitude standard deviation (m)
11	52	fp32	4	Height standard deviation (m)
12	56	fp32	4	Tilt (rad)
13	60	fp32	4	Heading (rad)
14	64	fp32	4	Tilt standard deviation (rad)
15	68	fp32	4	Heading standard deviation (rad)
16	72	u16	2	Status. See 11.4.10.1 Raw GNSS Status

Table 56: Raw GNSS Packet

11.4.10.1 Raw GNSS Status

Bit	Description
0	GNSS Fix Status
1	
2	
3	Doppler velocity valid

Bit	Description
4	Time valid
5	External GNSS
6	Tilt valid
7	Heading valid
8	Floating ambiguity heading
9-15	Reserved (set to zero)

Table 57: Raw GNSS Status

11.4.11 Satellites Packet

Satellites Packet				
Packet ID		30		
Length		13		
Read / Write		Read		
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 58: Satellites Packet

11.4.12 Detailed Satellites Packet

Detailed Satellites Packet				
Packet ID		31		
Length		7 x number of satellites		
Read / Write		Read		
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Satellite System
2	1	u8	1	Satellite number (PRN)
3	2	u8	1	11.4.12.2 Satellite Frequencies
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 59: Detailed Satellites Packet

Each packet can contain information for up to 36 satellites. If there are more than 36 satellites to report, only one packet will be sent per epoch.

11.4.12.1 Satellite Systems

Value	System
0	Unknown
1	GPS
2	GLONASS
3	BeiDou
4	Galileo
5	SBAS
6	QZSS
7	Reserved
8	Reserved
9	Reserved

Table 60: Satellite Systems

11.4.12.2 Satellite Frequencies

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

Bit	Description
3	L1 M
4	L2 C
5	L2 P
6	L2 M
7	L5

Table 61: Satellite Frequencies

11.4.13 Geodetic Position Packet

Geodetic Position Packet				
Packet ID		32		
Length		24		
Read / Write		Read		
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 62: Geodetic Position Packet

11.4.14 ECEF Position Packet

ECEF Position Packet				
Packet ID		33		
Length		24		
Read / Write		Read		
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 63: ECEF Position Packet

11.4.15 UTM Position Packet

UTM Position Packet	
Packet ID	34
Length	26
Read / Write	Read

UTM Position Packet				
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 64: UTM Position Packet

11.4.16 NED Velocity Packet

NED Velocity Packet				
Packet ID			35	
Length			12	
Read / Write			Read	
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 65: NED Velocity Packet

11.4.17 Body Velocity Packet

Body Velocity Packet				
Packet ID			36	
Length			12	
Read / Write			Read	
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 66: Body Velocity Packet

11.4.18 Acceleration Packet

This packet includes the acceleration due to gravity.

Acceleration Packet	
Packet ID	37
Length	12

Acceleration Packet				
Read / Write				Read
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 67: Acceleration Packet

11.4.19 Body Acceleration Packet

This packet does not include the acceleration due to gravity.

Body Acceleration Packet				
Packet ID		38		
Length		16		
Read / Write		Read		
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 68: Body Acceleration Packet

11.4.20 Euler Orientation Packet

Euler Orientation Packet				
Packet ID		39		
Length		12		
Read / Write		Read		
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 69: Euler Orientation Packet

11.4.21 Quaternion Orientation Packet

Quaternion Orientation Packet				
Packet ID		40		
Length		16		
Read / Write		Read		
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 70: Quaternion Orientation Packet

11.4.22 DCM Orientation Packet

DCM Orientation Packet				
Packet ID				41
Length				36
Read / Write				Read
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 71: DCM Orientation Packet

11.4.23 Angular Velocity Packet

Angular Velocity Packet				
Packet ID				42
Length				12
Read / Write				Read
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 72: Angular Velocity Packet

11.4.24 Angular Acceleration Packet

Angular Acceleration Packet				
Packet ID		43		
Length		12		
Read / Write		Read		
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 73: Angular Acceleration Packet

11.4.25 External Position and Velocity Packet

External Position and Velocity Packet				
Packet ID		44		
Length		60		
Read / Write		Read / Write		
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 74: External Position and Velocity Packet

11.4.26 External Position Packet

External Position Packet				
Packet ID		45		
Length		36		
Read / Write		Read / Write		
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) Must be non-zero positive value
5	28	fp32	4	Longitude standard deviation (m) Must be non-zero positive value
6	32	fp32	4	Height standard deviation (m) Must be non-zero positive value

Table 75: External Position Packet

11.4.27 External Velocity Packet

External Velocity Packet				
Packet ID		46		
Length		24		
Read / Write		Read / Write		
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 76: External Velocity Packet

11.4.28 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. 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		
Read / Write		Read / Write		
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Velocity X (m/s)
2	4	fp32	4	Velocity Y (m/s)
3	8	fp32	4	Velocity Z (m/s)
4	12	fp32	4	Velocity X standard deviation (m/s)
5	16	fp32	4	OPTIONAL: Velocity standard deviation Y (m/s)
6	20	fp32	4	OPTIONAL: Velocity standard deviation Z (m/s)

Table 77: External Body Velocity Packet

11.4.29 External Heading Packet

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

Table 78: External Heading Packet

11.4.30 Running Time Packet

This packet provides the running time in seconds since the most recent power on.

Running Time Packet				
Packet ID		49		
Length		8		
Read / Write		Read		
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Running time (seconds)
2	4	u32	4	11.4.1.5 Microseconds

Table 79: Running Time Packet

11.4.31 Local Magnetic Field Packet

Local Magnetic Field Packet				
Packet ID		50		
Length		12		
Read / Write		Read		
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 80: Local Magnetic Field Packet

11.4.32 Odometer State Packet

Odometer State Packet				
Packet ID		51		
Length		20		
Read / Write		Read		
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 81: Odometer State Packet

11.4.33 External Time Packet

External Time Packet				
Packet ID		52		
Length		8		
Read / Write		Write		
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	11.4.1.4 Unix Time Seconds
2	4	u32	4	11.4.1.5 Microseconds

Table 82: External Time Packet

11.4.34 External Depth Packet

External Depth is the measured distance below Mean Sea Level

External Depth Packet				
Packet ID		53		
Length		8		
Read / Write		Read / Write		
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Depth (m)
2	4	fp32	4	Depth standard deviation (m)

Table 83: External Depth Packet

11.4.35 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:

$$\text{Height Above Mean Sea Level} = \text{WGS84 Height} - \text{Geoid Height}$$

$$\text{Depth} = \text{Geoid Height} - \text{WGS84 Height}$$

WGS84 Height is the height at the current location in the System State packet, see [11.4.1 System State Packet](#)

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

Table 84: Geoid Height Packet

11.4.36 Wind Packet

This packet provides the Motus current 2D wind velocity. These values are only valid when external air data is provided to Motus. This can be either through the [11.4.39 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		
Read / Write		Read / Write		
Field #	Bytes Offset	Data Type	Size	Description

Wind Packet				
1	0	fp32	4	Wind velocity north (m/s)
2	4	fp32	4	Wind velocity east (m/s)
3	8	fp32	4	Wind velocity standard deviation (m/s)

Table 85: Wind Packet

11.4.37 Heave Packet

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

Table 86: Heave Packet

11.4.38 External Odometer Packet

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

Table 87: External Odometer Packet

11.4.38.1 Odometer Flags

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

Table 88: Odometer Flags

11.4.39 External Air Data Packet

External Air Data Packet				
Packet ID		68		
Length		25		
Read / Write		Read / Write		
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

Table 89: External Air Data Packet

11.4.39.1 External Air Data Flags

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

Table 90: External Air Data Flags

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.

11.4.40 Raw DVL Data Packet

Raw DVL Data Packet				
Packet ID				70
Length				60
Read / Write				Read / Write
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	Unix timestamp (seconds)
2	4	u32	4	Microseconds
3	8	u32	4	Flags, see 11.4.40.1 Raw DVL Data Flags
4	12	fp32	4	Bottom velocity X (m/s)
5	16	fp32	4	Bottom velocity Y (m/s)
6	20	fp32	4	Bottom velocity Z (m/s)
7	24	fp32	4	Bottom velocity standard deviation (m/s)
8	28	fp32	4	Water velocity X (m/s)
9	32	fp32	4	Water velocity Y (m/s)
10	36	fp32	4	Water velocity Z (m/s)
11	40	fp32	4	Water velocity standard deviation (m/s)
12	44	fp32	4	Water velocity layer depth (m)
13	48	fp32	4	Depth (m)
14	52	fp32	4	Altitude (m)
15	56	fp32	4	Temperature (deg C)

Table 91: Raw DVL Data Packet

11.4.40.1 Raw DVL Data Flags

Bit	Description
0	Bottom velocity valid
1	Water velocity valid
2	Temperature valid
3	Depth valid
4	Altitude valid

Table 92: Raw DVL Data Flags

11.4.41 Gimbal State Packet

Motus will accept (write) Current angle values between -2π and 2π exclusive.

Motus will output (read) values between $-\pi$ and π for current angle.

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

Table 93: Gimbal State Packet

11.4.42 Automotive Packet

The value of the slip angle will be zero unless velocity is greater than 3.45 m/s and heading is valid.

Automotive Packet				
Packet ID		73		
Length		24		
Read / Write		Read		
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Virtual odometer distance (m)
2	4	fp32	4	Slip Angle (rad) Value reported is zero, unless heading is valid and the velocity is greater than 3.45 m/s
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 94: Automotive Packet

11.4.43 External Magnetometers Packet

Heading can be derived using the magnetometers of an additional external Advanced Navigation product to input external magnetometer values.

The 2D, 3D or automatic magnetic calibration of Motus cannot be used to calibrate the external magnetometer values. External magnetometers need to be calibrated before feeding into Motus.

To use External Magnetic Heading, disable Magnetic Heading Enabled and Automatic Magnetic Calibration Enabled options in the [9.1.7.2 Filter Options](#) of the Configuration Menu.

When sending external magnetometers the external heading flag will become active.

External Magnetometers Packet	
Packet ID	75
Length	17

External Magnetometers Packet				
Read / Write				Read / Write
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Delay (s)
2	4	fp32	4	Magnetometer X (milligauss)
3	8	fp32	4	Magnetometer Y (milligauss)
4	12	fp32	4	Magnetometer Z (milligauss)
6	16	u8	1	External Magnetometer Flags

Table 95: External Magnetometers Packet

11.4.43.1 External Magnetometers Flags

Bit	Description
0	Magnetometers failure
1	Magnetometers over-range

Table 96: External magnetometers Flags

11.4.44 Basestation Packet

Basestation Packet				
Packet ID				80
Length				45
Read / Write				Read
Field #	Bytes Offset	Data Type	Size	Description
1	0	u32	4	11.4.1.4 Unix Time Seconds
2	4	u32	4	11.4.1.5 Microseconds
3	8	fp64	8	Basestation position, latitude (rad)
4	16	fp64	8	Basestation position, longitude (rad)
5	24	fp64	8	Basestation position, altitude (rad)
6	32	fp32	4	Basestation relative position, north (m)
7	36	fp32	4	Basestation relative position, east (m)
8	40	fp32	4	Basestation relative position, down (m)
9	44	u8	1	11.4.44.1 GNSS Fix Status

Table 97: Basestation packet

11.4.44.1 GNSS Fix Status

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

Table 98: GNSS Fix Status

11.4.45 Zero Angular Velocity Packet

Zero Angular Velocity Packet				
Packet ID		83		
Length		8		
Read / Write		Write		
Field #	Bytes Offset	Data Type	Size	Description
1	0	fp32	4	Duration. See 11.4.45.1 Zero Angular Velocity Duration
2	4		4	Reserved (set to zero)

Table 99: Zero Angular Velocity Packet

11.4.45.1 Zero Angular Velocity Duration

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

11.5 Configuration Packets

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

This section covers the following topics:

Packet ID	Name	Length	R/W
Configuration Packets			
180	11.5.1 Packet Timer Period Packet	4	R/W
181	11.5.2 Packets Period Packet	Varies	R/W

Packet ID	Name	Length	R/W
182	11.5.3 Baud Rates Packet	17	R/W
185	11.5.4 Installation Alignment Packet	73	R/W
186	11.5.5 Filter Options Packet	17	R/W
188	11.5.6 GPIO Configuration Packet	13	R/W
189	11.5.7 Magnetic Calibration Values Packet	49	R/W
190	11.5.8 Magnetic Calibration Configuration Packet	1	W
191	11.5.9 Magnetic Calibration Status Packet	3	R
192	11.5.10 Odometer Configuration Packet	8	R/W
193	11.5.11 Set Zero Orientation Alignment Packet	5	W
194	11.5.12 Reference Point Offsets Packet	49	R/W
195	11.5.13 GPIO Output Configuration Packet	183	R/W
198	11.5.14 User Data Packet	64	R/W
199	11.5.15 GPIO Input Configuration Packet	65	R/W

11.5.1 Packet Timer Period Packet

Packet Timer Period Packet				
Packet ID		180		
Length		4		
Read / Write		Read / Write		
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u8	1	11.5.1.1 UTC Synchronisation
3	2	u16	2	11.5.1.2 Packet Timer Period

Table 100: Packet Timer Period Packet

11.5.1.1 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 formula:

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

11.5.1.2 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 65000 (65 ms) or 15.38 Hz. The packet timer period must be in increments of 1000.

11.5.2 Packets Period Packet

This packet allows the user to configure, add, remove, modify and clear state packets (packets 20 through 180).

Note: This packet will only affect the port from which the packet is sent, leaving the other ports unaffected. e.g. If you are connected to the Primary serial port, sending this packet will only change the ANPP output for the Primary serial port.

Packets Period Packet				
Packet ID		181		
Length		2 + (5 x number of packet periods)		
Read / Write		Read / Write		
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u8	1	Clear Existing Packet Periods
3	2	u8	1	Packet ID

Packets Period Packet				
4	3	u32	4	Packet Period
+				Fields 3-4 repeat for additional packet periods

Table 101: Packets Period Packet

11.5.2.1 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.

11.5.2.2 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.

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

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

11.5.3 Baud Rates Packet

Baud Rates Packet				
Packet ID		182		
Length		17		
Read / Write		Read / Write		
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u32	4	Primary RS232 and RS422 see 11.5.3.1 Supported Baud Rate
3	5	u32	4	GPIO 1 & 2 Maximum Baud Rate 250000 see 11.5.3.1 Supported Baud Rate
4	9	u32	4	Auxiliary RS232 see 11.5.3.1 Supported Baud Rate
5	13		4	Reserved (set to zero)

Table 102: Baud Rates Packet

11.5.3.1 Supported Baud Rate

Note: Not all Advanced Navigation products support minimum and maximum baud rates.

Supported Baud Rates - Bits 0-30
2400
4800
9600
19200
38400
57600
115200
230400
250000
460800
500000
800000
921600
1000000
1250000
2000000
4000000

Table 103: Supported Baud Rates

11.5.4 Installation Alignment Packet

Installation Alignment Packet				
Packet ID				185
Length				73
Read / Write				Read / Write
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) ¹
15	53	fp32	4	Odometer offset Y (m) ¹
16	57	fp32	4	Odometer offset Z (m) ¹
17	61	fp32	4	External data offset X (m) ²
18	65	fp32	4	External data offset Y (m) ²
19	69	fp32	4	External data offset Z (m) ²
¹ Odometer offset is used for Odometer and DVL input				
² External data offset is used for NMEA input, External GNSS and Air Data Unit				

Table 104: Installation Alignment Packet

11.5.4.1 Alignment DCM

The alignment DCM (Direction Cosine Matrix) is used to represent an alignment offset of Motus from its standard alignment. A DCM is used rather than Euler angles for accuracy reasons. To convert Euler angles to DCM, use the formula below with angles in radians.

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

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

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

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

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

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

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

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

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

11.5.5 Filter Options Packet

Filter Options Packet				
Packet ID		186		
Length		17		
Read / Write		Read / Write		
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u8	1	11.5.5.1 Vehicle Types
3	2	u8	1	Internal GNSS enabled (boolean)
4	3	u8	1	Magnetic Heading 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 105: Filter Options Packet

11.5.5.1 Vehicle Types

Value	Description
0	Unlimited
1	Bicycle or Motorcycle
2	Car
3	Hovercraft

Value	Description
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 106: Vehicle Types

11.5.6 GPIO Configuration Packet

GPIO Configuration Packet				
Packet ID		188		
Length		13		
Read / Write		Read / Write		
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u8	1	GPIO1 function. See 11.5.6.1 GPIO Functions
3	2	u8	1	GPIO2 function. See 11.5.6.1 GPIO Functions
4	3	u8	1	Auxiliary RS232 transmit function. See 11.5.6.2 Auxiliary Functions
5	4	u8	1	Auxiliary RS232 receive function. See 11.5.6.2 Auxiliary Functions
6	5	u8	1	Reserved (set to zero)

Table 107: GPIO Configuration Packet

11.5.6.1 GPIO Functions

Value	Description	GPIO Function Type
0	Inactive	GPIO1, GPIO2
1	1PPS Output	
2	GNSS Fix Output	
3	Odometer Input	
4	Zero Velocity Input	
5	Pitot Tube Input	
6	NMEA Input	GPIO2
7	NMEA Output	GPIO1
8	Novatel GNSS Input	GPIO2
9	Topcon GNSS Input	
11	ANPP Input	
12	ANPP Output	GPIO1
13	Disable Magnetometers	GPIO1, GPIO2
15	Disable Pressure	GPIO1, GPIO2
16	Set Zero Orientation Alignment	
17	System State Packet Trigger	
18	Raw Sensors Packet Trigger	
19	RTCM Differential GNSS Corrections Input	GPIO2
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	

Value	Description	GPIO Function Type
26	Pressure Depth Transducer	GPIO1, GPIO2
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	GPIO1, GPIO2
39	TSS1 Output	GPIO1
40	Simrad 1000 Output	
41	Simrad 3000 Output	
42	Serial Port Passthrough	GPIO1, GPIO2
43	Gimbal Encoder Phase A	
44	Gimbal Encoder Phase B	
45	Odometer Direction, Forward Low	
46	Odometer Direction, Forward High	
51	Nortek DVL Input	GPIO2
53	Reverse Alignment, Forward Low	GPIO1, GPIO2
54	Reverse Alignment, Forward High	
55	Zero Angular Velocity Input	

Table 108: GPIO functions

11.5.6.2 Auxiliary Functions

Value	Description	Auxiliary Function Type
0	Inactive	Transmit, Receive
1	1PPS Output	Transmit
2	GNSS Fix Output	
3	Odometer Input	Receive
4	Zero Velocity Input	
5	Pitot Tube Input	
6	NMEA Input	
7	NMEA Output	Transmit

Value	Description	Auxiliary Function Type
8	Novatel GNSS Input	Receive
9	Topcon GNSS Input	
11	ANPP Input	
12	ANPP Output	Transmit
13	Disable magnetometers	Receive
14	Disable GNSS	Receive
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	Transmit, Receive
39	TSS1 Output	Transmit
40	Simrad 1000 Output	
41	Simrad 3000 Output	
42	Serial Port Passthrough	Transmit, receive

Value	Description	Auxiliary Function Type
45	Odometer Direction, Forward Low	Receive
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 109: Auxiliary Functions

11.5.7 Magnetic Calibration Values Packet

This packet can be used to inspect the magnetic calibration values or write custom magnetic calibration values to the system. Under normal operation with automatic magnetic calibration the user should not need to use this packet.

Magnetic Calibration Values Packet				
Packet ID		189		
Length		49		
Read / Write		Read / Write		
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 110: Magnetic Calibration Values Packet

11.5.8 Magnetic Calibration Configuration Packet

Magnetic Calibration Configuration Packet	
Packet ID	190

Magnetic Calibration Configuration Packet				
Length		1		
Read / Write		Write		
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	11.5.8.1 Magnetic Calibration Actions

Table 111: Magnetic Calibration Configuration Packet

11.5.8.1 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 112: Magnetic Calibration Actions

11.5.9 Magnetic Calibration Status Packet

Magnetic Calibration Status Packet				
Packet ID		191		
Length		3		
Read / Write		Read		
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	11.5.9.1 Magnetic Calibration Status
2	1	u8	1	Magnetic calibration progress (%)
3	2	u8	1	Local magnetic error (%)

Table 113: Magnetic Calibration Status Packet

11.5.9.1 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

Value	Description
9	Calibration error: sensor over range event
10	Calibration error: time-out
11	Calibration error: system error
12	Calibration error: interference error

Table 114: Magnetic Calibration Status

11.5.10 Odometer Configuration Packet

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

Table 115: Odometer Configuration Packet

11.5.11 Set Zero Orientation Alignment Packet

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

Table 116: Set Zero Orientation Alignment Packet

11.5.12 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 Motus unit. The primary reference point offset can be used to adjust the measurement point to a different location on the vehicle, in the body co-ordinate frame. The primary reference point offset applies to all data output including NMEA etc as well as heave point 1.

The other heave point offsets do not apply to heave point 1 in the [11.4.37 Heave Packet](#).

Reference Point Offsets Packet				
Packet ID		194		
Length		49		
Read / Write		Read / Write		
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	fp32	4	Heave point 1 offset X (m) / Primary reference point offset X (m)
3	5	fp32	4	Heave point 1 offset Y (m) / Primary reference point offset Y (m)
4	9	fp32	4	Heave point 1 offset Z (m) / 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 117: Reference Point Offsets Packet

11.5.13 GPIO Output Configuration Packet

GPIO Output Configuration Packet				
Packet ID		195		
Length		33		
Read / Write		Read / Write		
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	u8	1	NMEA fix behaviour, see 11.5.13.1 NMEA Fix Behaviour
3	2	u16	2	GPZDA Rates, see 11.5.13.2 GPIO Output Rates
4	4	u16	2	GPGGA Rates, see 11.5.13.2 GPIO Output Rates
5	6	u16	2	GPVTG Rates, see 11.5.13.2 GPIO Output Rates
6	8	u16	2	GPRMC Rates, see 11.5.13.2 GPIO Output Rates
7	10	u16	2	GPHDT Rates, see 11.5.13.2 GPIO Output Rates
8	12	u16	2	GPGLL Rates, see 11.5.13.2 GPIO Output Rates
9	14	u16	2	PASHR Rates, see 11.5.13.2 GPIO Output Rates
10	16	u16	2	TSS1 Rates, see 11.5.13.2 GPIO Output Rates
11	18	u16	2	Simrad Rates, see 11.5.13.2 GPIO Output Rates
12	20	u16	2	GPROT Rates, see 11.5.13.2 GPIO Output Rates
13	22	u16	2	GPHEV Rates, see 11.5.13.2 GPIO Output Rates
14	24	u16	2	GPGSV Rates, see 11.5.13.2 GPIO Output Rates
15	26	u16	2	PFECAtt Rates, see 11.5.13.2 GPIO Output Rates
16	28	u16	2	PFECHve Rates, see 11.5.13.2 GPIO Output Rates
17	30	u16	3	Reserved (set to zero)

Table 118: GPIO Output Configuration Packet

11.5.13.1 NMEA Fix Behaviour

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

Table 119: NMEA Fix Behaviour

11.5.13.2 GPIO Output Rates

Value	Description
0-3	GPIO 1 rate, see 11.5.13.3 Port Output Rates

Value	Description
4-7	Auxiliary RS232 Tx rate, see 11.5.13.3 Port Output Rates
8-15	Reserved (set to zero)

Table 120: GPIO output rates

11.5.13.3 Port Output Rates

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
10	1	0	1	0	8 Hz

Table 121: Port Output Rates

11.5.14 User Data Packet

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

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

Table 122: User Data Packet

11.5.15 GPIO Input Configuration Packet

GPIO Input Configuration Packet	
Packet ID	199
Length	65
Read / Write	Read / Write

GPIO Input Configuration Packet				
Field #	Bytes Offset	Data Type	Size	Description
1	0	u8	1	Permanent
2	1	fp32	4	Gimbal radians per encoder tick
3	5		60	Reserved (set to zero)

Table 123: GPIO Input Configuration Packet

12 Reference Information

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

- [12.1 Technology Overview](#), including Global Navigation Satellite System (GNSS), Inertial Navigation System (INS) and Attitude and Heading Reference System (AHRS)
- [12.2 The Sensor Co-ordinate Frame](#)
- [12.3 The Body Co-ordinate Frame](#)
- [12.4 Roll, Pitch and Heading](#)
- [12.5 Geodetic Co-ordinate System](#)
- [12.6 NED Co-ordinate Frame](#)
- [12.7 ECEF Co-ordinate Frame](#)

12.1 Technology Overview

12.1.1 GNSS

GNSS stands for Global Navigation Satellite System. A GNSS consists of a set of satellites in medium Earth orbit that broadcast navigation signals with a common operator. These navigation signals can be picked up by a GNSS receiver on the earth to estimate that receiver's position and velocity. For a long time the only operational GNSS was the United States GPS. However, the Russian GLONASS, the Chinese BeiDou GNSS, and the European Union's Galileo GNSS are fully operational.

GNSS provides a fairly accurate absolute position (down to 1.2 metres without assistance and as low as 8 mm with) and velocity (as low as 0.007 metres/second). The main drawback of GNSS is that the receiver must have a clear signal from at least 4 satellites to function. GNSS signals are very weak and struggle to penetrate through buildings, trees and other objects obstructing an uninterrupted view of the sky. GNSS can also occasionally drop out due to disturbances in the upper atmosphere, or the presence of jammers.

12.1.2 AHRS

AHRS stands for Attitude and Heading Reference System. An AHRS uses accelerometers, magnetometer data and gyroscopes combined in a mathematical algorithm to provide orientation. Orientation consists of the three body angles roll, pitch and heading.

12.1.3 INS

INS stands for Inertial Navigation System. An inertial navigation system can provide position and velocity similar to GNSS but with some major differences. The principle of inertial navigation is the measurement of acceleration, which is then integrated into velocity. The velocity is then further integrated to estimate position. Due to noise in the measurement and the compounding of that noise through the integration steps, 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 enormously.

12.1.4 GNSS/INS

By combining GNSS and INS together in a mathematical algorithm, it is possible to take advantage of the benefits of the long-term precision of GNSS and the short-term accuracy of inertial sensors. This provides an

enhanced position and velocity solution that can withstand GNSS drop outs.

Note: Motus can be upgraded to full INS capability through a software license upgrade. As an INS it can be interfaced to any of the leading brands of GNSS receivers to create an OEM GNSS/INS solution.

12.2 The Sensor Co-ordinate Frame

Inertial sensors have 3 different axes: X, Y and Z and these determine the references around which angles and accelerations are measured. It is very important to align these axes correctly in installation, otherwise the system won't work correctly.

These axes are marked on the top of the device as shown in [Figure 57: Motus Axes](#) 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.

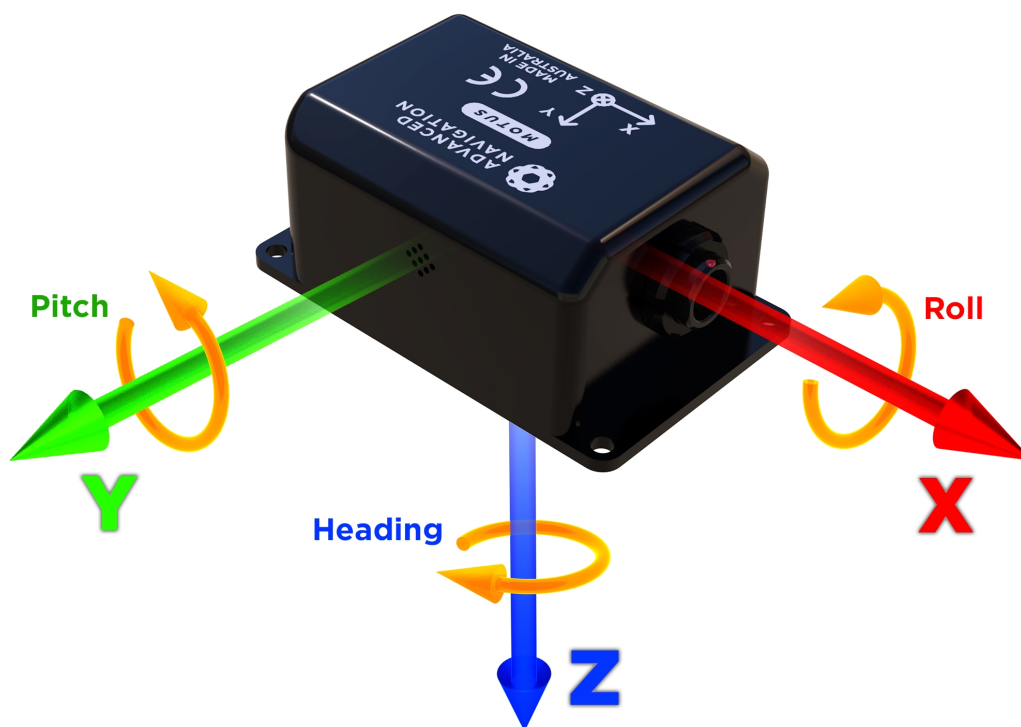


Figure 57: Motus Axes

12.2.1 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 the system is level. A good way to remember the sensor axes is the right hand rule, which is visualised in [Figure 58: First Right-hand Rule](#).

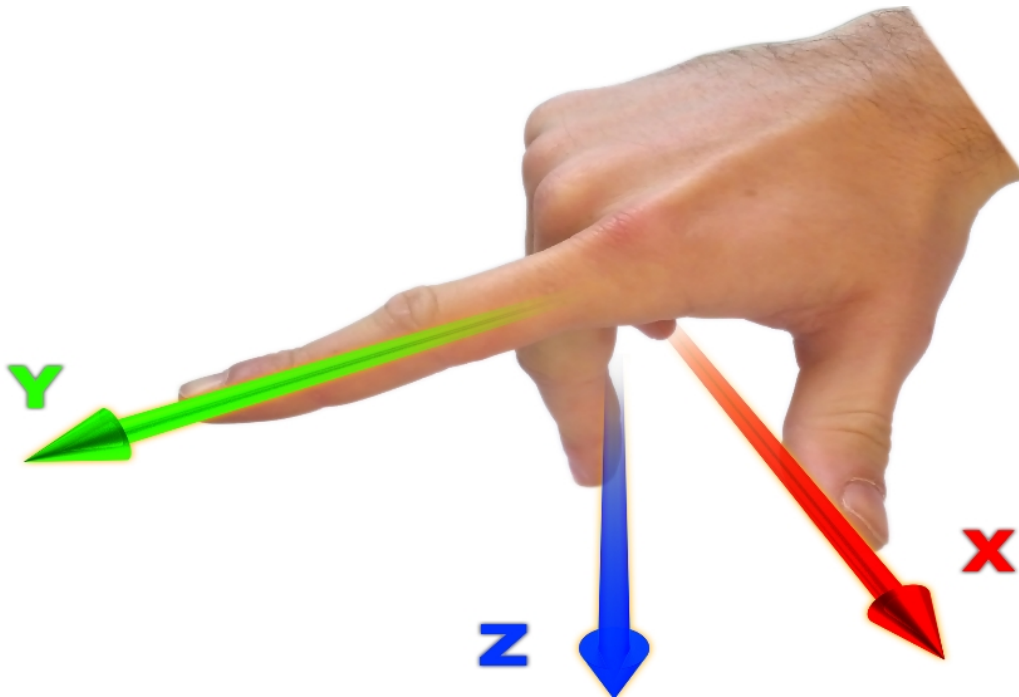


Figure 58: First Right-hand Rule

You take your right hand and extend your thumb, index and middle. Your thumb then denotes the positive X axis, your index denotes the positive Y axis and your middle denotes the positive Z axis.

12.3 The Body Co-ordinate Frame

Also known as the vehicle co-ordinate (reference) frame, this can be described most easily using a car (the body or vehicle) as an example. The forward direction of travel for a car is the positive X axis, out to the right of the car is the positive Y axis, and down is the positive Z axis. The distinction between the sensor co-ordinate frame and the body co-ordinate frame becomes important when the INS device is not mounted with its axes aligned to the vehicle axes, for example when the INS is mounted with a 90 degree heading rotation. Offset measurements, which are described later in this document, will always be in the body co-ordinate frame to remove any INS alignment variations. Generally any data output by the INS using the X, Y and Z axes will be using the body co-ordinate frame.

12.4 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 [Figure 57: Motus Axes](#). 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.

12.4.1 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 [12.2 The Sensor Co-ordinate Frame](#). The second right hand rule shown in the figure below 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 shows the positive rotation on that axis.

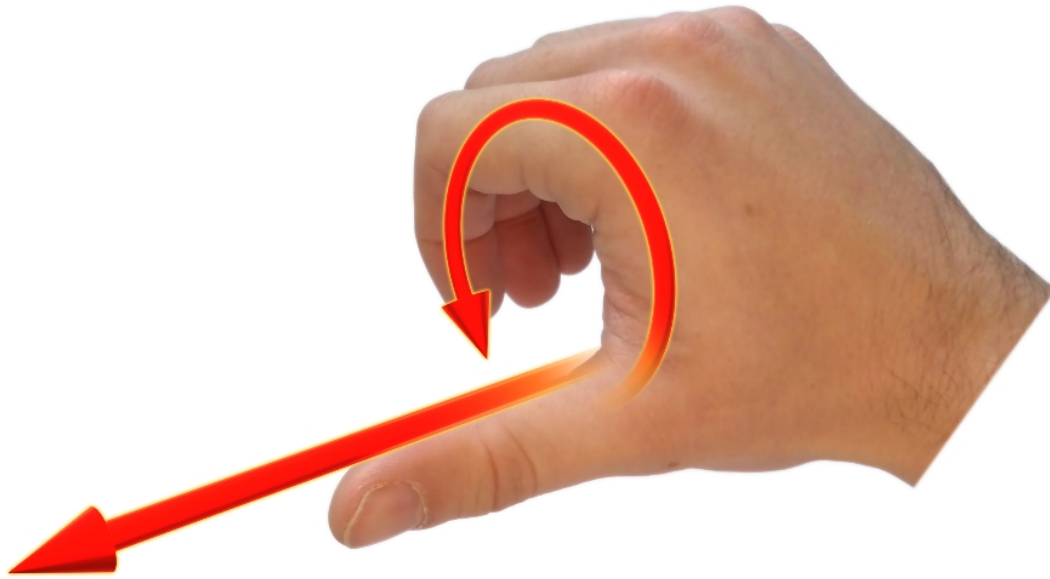


Figure 59: Second right Hand Rule

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

12.5 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 two angles, latitude and longitude, combined with a height relative to an ellipsoid.

12.5.1 Latitude and Longitude

Latitude is the angle that specifies the north to south position of a point on the Earth's surface, reported as $\pm 90^\circ$. Longitude is the angle that specifies the east to west position of a point on the Earth's surface, reported as $\pm 180^\circ$. The line of zero latitude is the equator, and the line of zero longitude is the prime meridian. See [Figure 60: Latitude and longitude represented visually to describe a position on an ellipsoid](#).

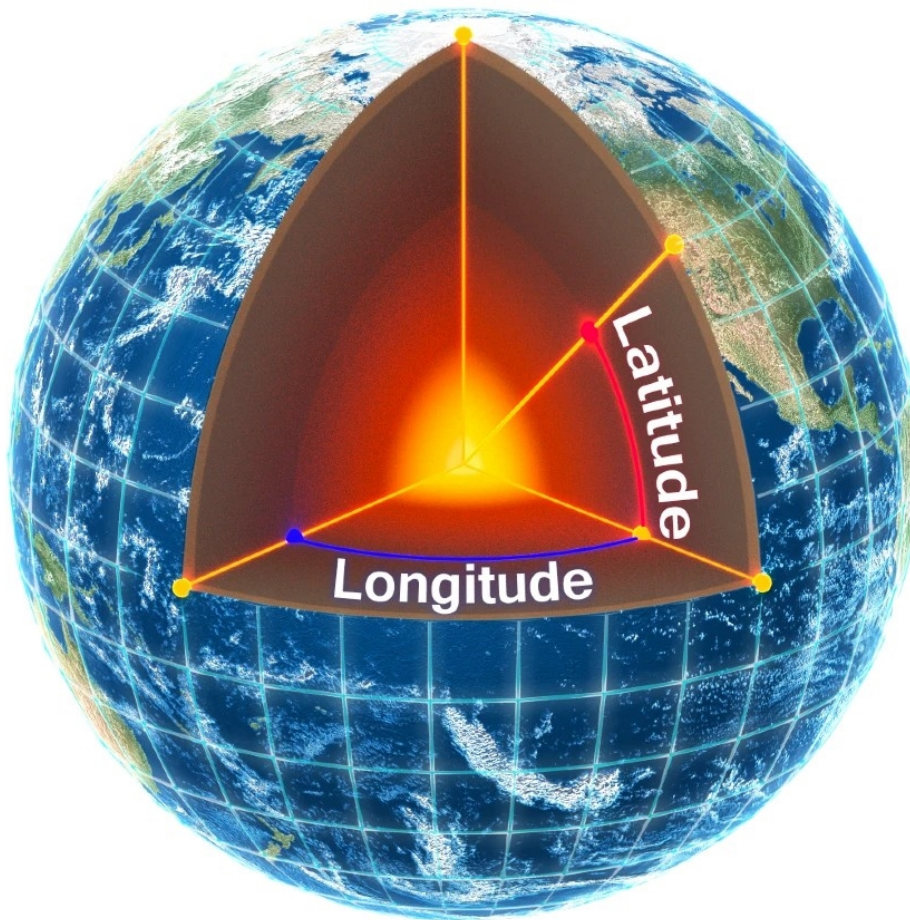


Figure 60: Latitude and longitude represented visually to describe a position on an ellipsoid

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

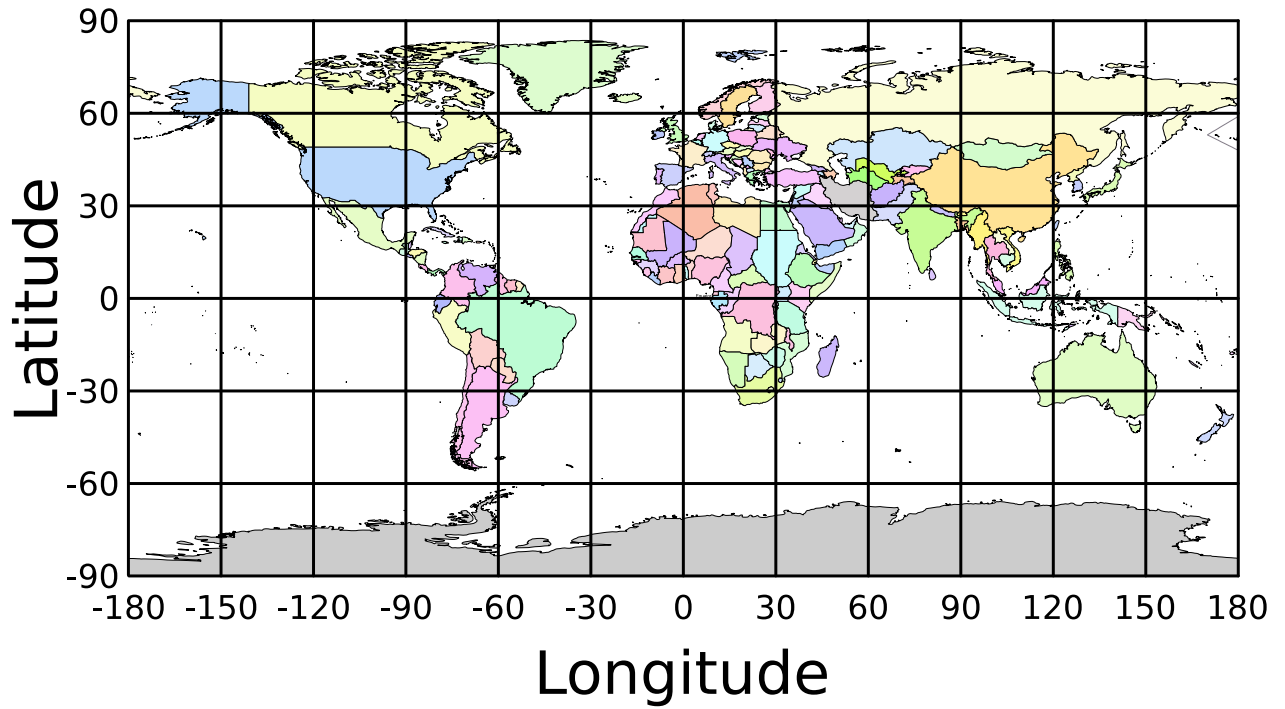


Figure 61: World map showing latitudes and longitudes

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.

12.5.2 Height

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

See [Figure 62: Orthometric, ellipsoid and geoid height diagram](#) below for a visual representation of geoid height, ellipsoid height and orthometric height (height above mean sea level).

Note:

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

Orthometric height is the height at a point of interest referenced to the EGM96 geoid.

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

$$H = h - N$$



Figure 62: Orthometric, ellipsoid and geoid height diagram

The value required to convert the WGS84 ellipsoid height to orthometric height can be found in the geoid height packet, see [11.4.35 Geoid Height Packet](#).

12.6 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 is 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 the figure below for a graphical representation of the NED co-ordinate frame at a position on the Earth.

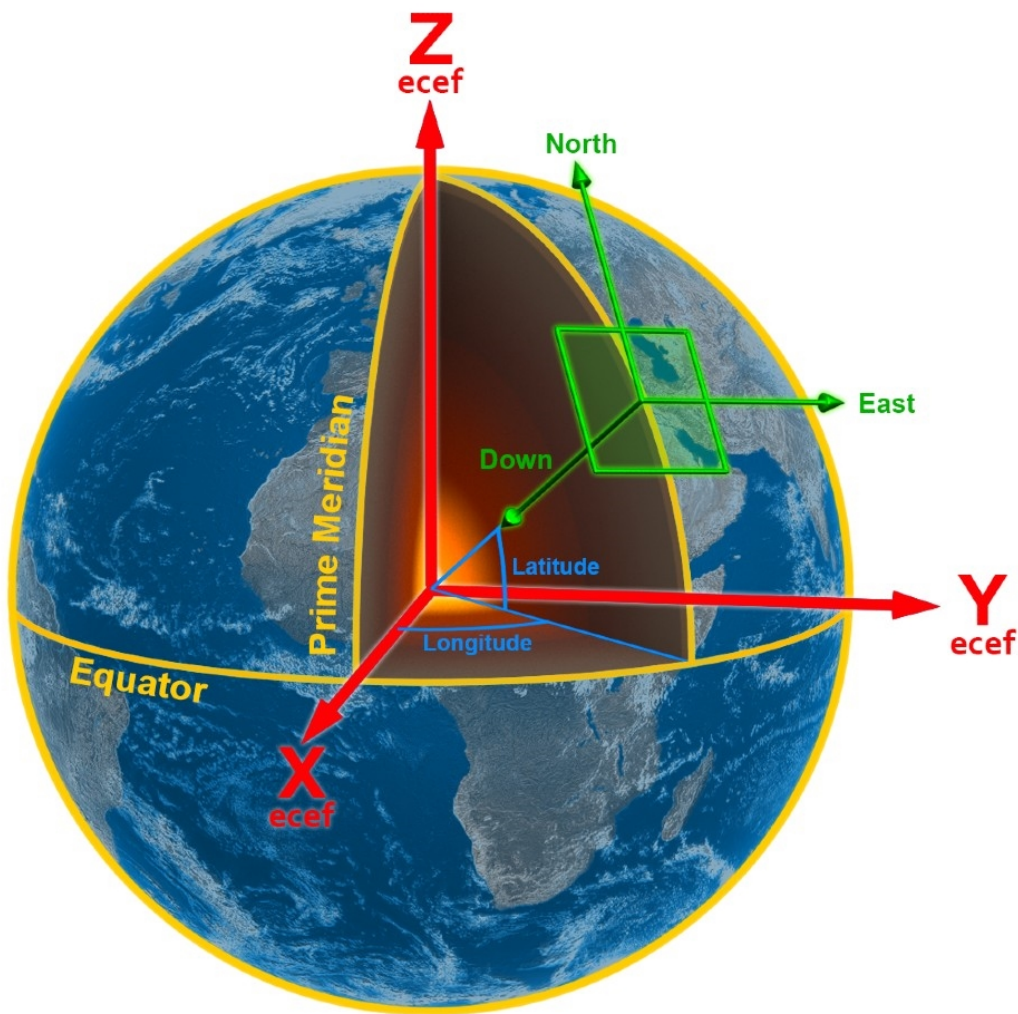


Figure 63: Graphic Showing Geodetic, NED and ECEF Co-ordinates

12.7 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 [Figure 63: Graphic Showing Geodetic, NED and ECEF Co-ordinates](#). ECEF positions can be retrieved from Advanced Navigation products, however the geodetic system is used as the default.