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# Xsens GNSS/INS: Supercharge Your GNSS Receiver



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## 1 Introduction

Xsens has a long history in developing industrial grade motion tracking modules. Already in 2007, Xsens released the MTi-G, the first fully integrated but compact GPS/INS device, combining high-quality MEMS-based inertial sensors with satellite positioning for a full plug-and-play navigation solution. Now, several generations and many years of experience in sensor fusion development later, Xsens offers a wide variety of GNSS/INS products in terms of form factor, accuracy and pricing. Like the MTi-G, some of these are plug-and-play solutions with an internal GNSS receiver. Others are “receiver-agnostic” and are able to receive and process satellite information from an external GNSS receiver. This approach offers system integrators full flexibility in selecting the GNSS receiver that fits their system best.

In this application note, we will focus on the second type: The **external-GNSS/INS**. In chapter 2, we will briefly discuss what a GNSS/INS is, and the range of GNSS/INS products offered by Xsens. We will also discuss the key benefits of the external-GNSS/INS: Why is this device able to “supercharge your GNSS receiver” and how does it achieve this?

We will continue in chapter 3 with an introduction to the Xsens GNSS/INS Development Kit – explaining the basics of the included hardware and software. We will demonstrate how easy it is to get started.

In chapters 4 to 7, we will explain how to connect your desired GNSS receiver to an Xsens GNSS/INS device, both in terms of hardware and software. Chapter 8 covers additional best practices that apply to any GNSS/INS setup.

Finally, all documentation and ways to access Xsens’ free-of-charge, global technical support will be discussed in chapter 9.



Figure 1: The Xsens MTi series line-up, showing (from left to right) the MTi 1-series, MTi 600-series and MTi 100-series.

## 2 MTi series and GNSS/INS products

### 2.1 Why combine your GNSS receiver with an Xsens GNSS/INS?

Compared to a standalone GNSS receiver, a combined GNSS/INS offers various benefits for any type of use case. We will shortly cover the four most important advantages below. Actual sample data that demonstrates these advantages will be presented in Appendix A: Sample data.

#### 2.1.1 Update rate

Most GNSS receivers provide their data at rates of 4Hz-10Hz. This is because of the GNSS satellites' update rates and hardware limitations. In today's world, with vehicles becoming faster and more 'intelligent' with additional sensors like cameras, LIDARs, radars etc., a higher position update rate can be very beneficial. The GNSS/INS will interpolate the GNSS updates, using its inertial sensors, and output the position- and velocity data continuously at rates up to 400Hz.

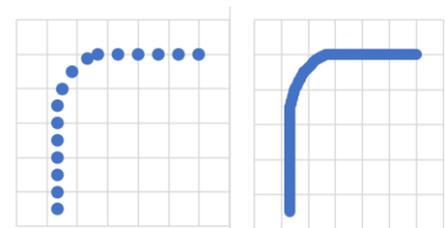


Figure 2: One second of position data, 4 Hz (left) versus 400 Hz (right).

#### 2.1.2 Dead-reckoning

GNSS receivers provide accurate position data of vehicles in most outdoor environments. However, an overpass, tunnel or foliage can severely interfere with the GNSS reception, up to such levels that position output is stopped. In these situations, the GNSS/INS will take over and dead-reckon the vehicle's position based on the internal inertial sensors. This will ensure continuous position- and velocity output, even when the GNSS receiver is struggling.

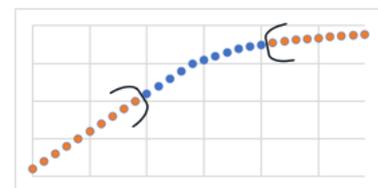


Figure 3: Filling in outages of GNSS data.

#### 2.1.3 Position smoothing

GNSS receivers may struggle with urban canyons or other obstructions which may lead to outliers in the position output, e.g. caused by multipath effects of the GNSS signals from satellites. These outliers can cause severe heading errors or unwanted movements. As the GNSS/INS can determine that outlier jumps in position are not possible by analysing the inertial data, it will smooth out the position such that the data aligns better with the actual path.

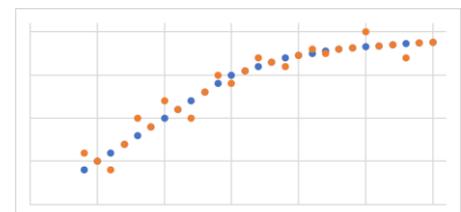


Figure 4: Smoothing out GNSS updates.

#### 2.1.4 Orientation and IMU data

Besides all above 'supercharging', the GNSS/INS is by nature also an IMU and orientation sensor. This means that it will provide the application with 3D acceleration, rate of turn and magnetic field data. Using all the information from the inertial sensors as well as the GNSS receiver, it will calculate orientation (roll/pitch/yaw) at rates up to 400Hz. This supports the navigation of the vehicle, as well as enables many more smart functionalities: tilt or tamper detection, stabilization, driving surface characterization etc.

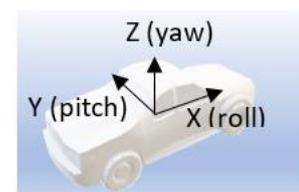


Figure 5: Orientation data: roll, pitch and yaw.

## 2.2 Xsens GNSS/INS products

Xsens' industrial-grade motion tracker (MTi) portfolio consists of various functionalities; all based on an Inertial Measurement Unit (IMU) but with varying degrees of on-board sensor fusion algorithms. In this application note we will focus only the most advanced functionality – the Global Navigation Satellite System / Inertial Navigation System or GNSS/INS. If you would like to learn more about the other functionalities, we recommend reading [From IMU to GNSS/INS](#).

All of Xsens' GNSS/INS products include a fully calibrated IMU that consists of a three-axis accelerometer, a three-axis gyroscope and a three-axis magnetometer. Table 1 shows a compact overview of all GNSS/INS models offered by Xsens at this moment. Note that GNSS/INS products with an internal GNSS receiver have a "G" in their product code.

Table 1: Available Xsens GNSS/INS models

| Product code   | GNSS receiver   | Precision                          | Form factor   |   |
|----------------|-----------------|------------------------------------|---------------|---|
| <b>MTi-7</b>   | <b>External</b> | <b>Standard (meter-level)</b>      | <b>SMD</b>    |    |
| <b>MTi-8</b>   | <b>External</b> | <b>High/RTK (centimeter-level)</b> | <b>SMD</b>    |   |
| <b>MTi-670</b> | <b>External</b> | <b>Standard (meter-level)</b>      | <b>Module</b> |  |
| MTi-670G       | Internal        | Standard (meter-level)             | Robust        |  |
| <b>MTi-680</b> | <b>External</b> | <b>High/RTK (centimeter-level)</b> | <b>Module</b> |  |
| MTi-680G       | Internal        | High/RTK (centimeter-level)        | Robust        |  |
| MTi-G-710      | Internal        | Standard (meter-level)             | Robust        |  |

In the remainder of this document we will focus on the GNSS/INS models that connect with an external GNSS receiver: The MTi-7, MTi-8, MTi-670 and MTi-680.

## 2.3 Supported GNSS receivers and protocols

Figure 6 presents a generic schematic that illustrates how an external GNSS receiver is connected to an MTi. The MCU on the MTi GNSS/INS gathers data from all on-board sensor components as well as from the external GNSS receiver, applies its sensor fusion algorithms, and finally outputs a fully configurable and synchronized output data stream, optionally including also the raw GNSS and sensor measurements.

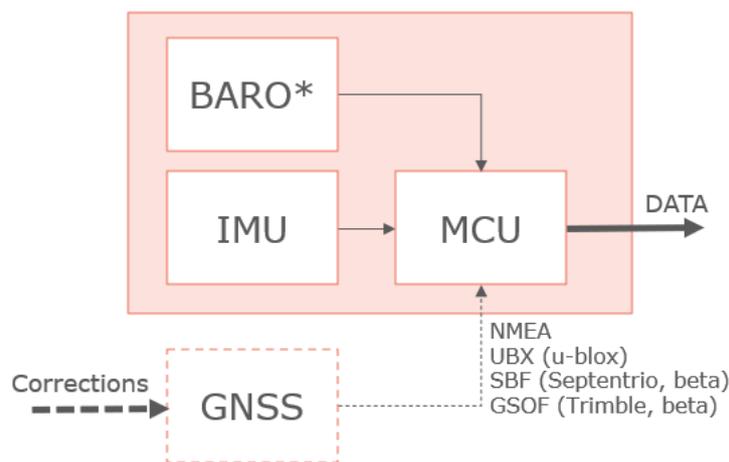


Figure 6: Block diagram of the GNSS/INS and an externally connected GNSS receiver.  
\*Barometer is externally connected for MTi-7 and MTi-8.

The hardware interface for the external GNSS receiver is 3.3V UART for the MTi-7/8, and RS232 for the MTi-670/680. Various native communication protocols are supported, as well as the standard NMEA protocol. For an overview, see Table 2. Other native protocols may be supported in the future or on request.

Table 2: Supported GNSS protocols and their configuration requirements.

| GNSS receiver brand | Protocol  | Receiver configuration                               |
|---------------------|-----------|--|
| -                   | NMEA 0183 | GxGGA, GxRMC, GxGSA, GxGST (minimum), see chapter 0. |
| u-blox              | UBX       | Performed by MTi. See chapter 4.                     |
| Septentrio          | SBF       | See chapter 5.                                       |
| Trimble             | GSOF      | See chapter 6.                                       |

GNSS/INS models that offer support for high precision GNSS receivers (see Table 1) are able to receive and process position information at centimeter-level accuracy, ensuring highly accurate sensor fusion estimates of position, velocity and orientation. In this case, the system integrator is responsible for the reception of correction messages (e.g. RTCM) on the GNSS receiver side. Xsens does however provide a reference design that allows users to easily get started, based on the u-blox ZED-F9 GNSS receiver. The MTi GNSS/INS “Development Kit” is discussed in the next chapter.

### 3 Getting started with the GNSS/INS Development Kit

#### 3.1 Overview of the Development Kit

The MTi development kit is a very easy to use developer’s kit that allows for fast and easy integration of the MTi in any user scenario.

Table 3: Package contents for MTi-7/8 Development Kits

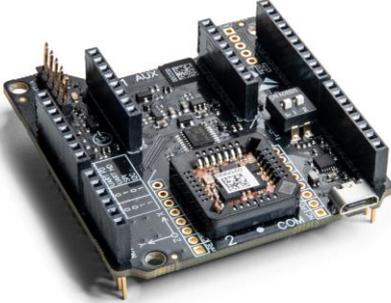
| Component   | Name   |
|---|--|
|    | <p>Shield board</p> <p>Includes MTi-7/8 module mounted in socket</p>   |
|  | <p>GNSS daughter card for MTi-7 (MTI-DK-GNSS)</p> <p>or</p> <p>GNSS RTK daughter card for MTi-8 (MTI-DK-RTK)</p> |
|  | <p>GNSS antenna for MTi-7 (ANT-MULTI)</p> <p>or</p> <p>GNSS antenna for MTi-8 (ANT-GNSS-RTK)</p>                 |
|  | <p>USB cable</p>   |

Table 4: Package contents for MTi-670/680 Development Kits

| Component   | Name   |
|---|--|
|    | <p>MTi 600-series Development Board<br/>(MTi-600-DEV)</p>  |
|    | <p>MTi 600-series module<br/>(MTi-670, MTi-680)</p>  |
|   | <p>3x M2 x 12 mm brass screws<br/>(MTi-600-MP)</p>   |
|  | <p>GNSS daughter card for MTi-670<br/>(MTi-DK-GNSS)</p> <p>GNSS RTK daughter card for MTi-680<br/>(MTi-DK-RTK)</p> |
|  | <p>GNSS antenna for MTi-670<br/>(ANT-MULTI)</p> <p>GNSS antenna for MTi-680<br/>(ANT-GNSS-RTK)</p>                 |
|  | <p>USB cable</p>   |
|  | <p>Ribbon cable<br/>(CA-MTI-FLAT)</p>  |

### Software and documentation

The MTi series Development Kits are supported by the MT Software Suite, which includes the following software components:

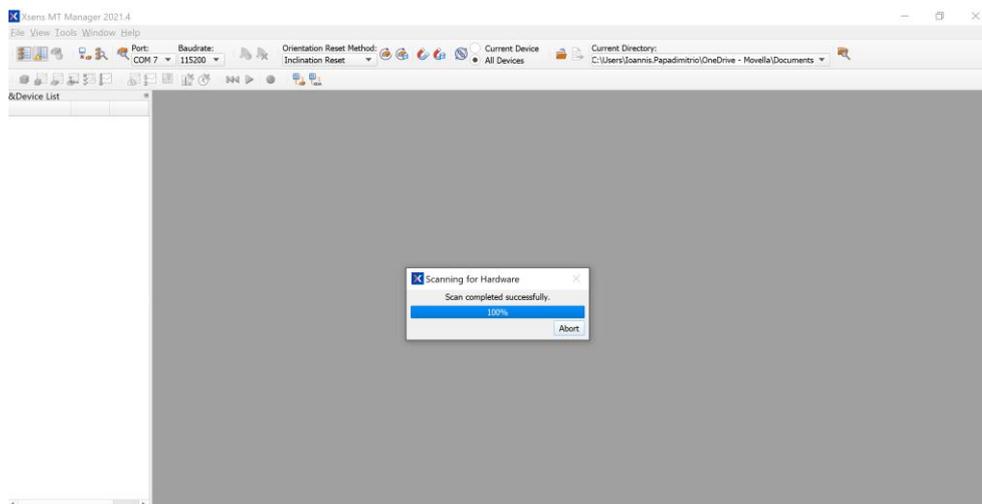
- MT Manager
- Magnetic Field Mapper
- MT SDK including programming examples and documentation

Additionally, the latest firmware for the MTi series can be downloaded and updated using the Firmware Updater which is separately available.

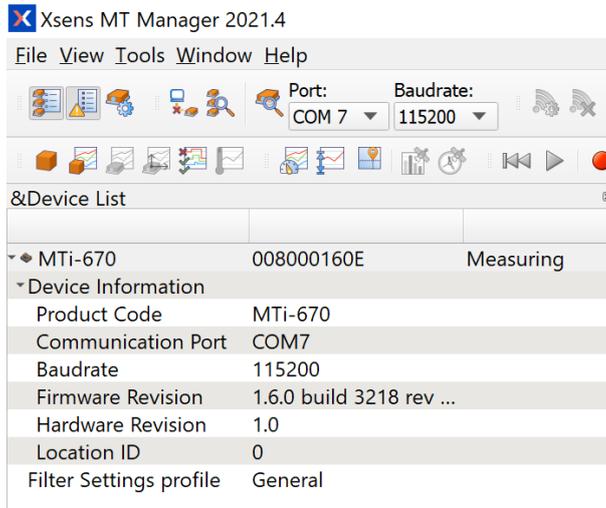
All software components can be downloaded from the Xsens website: <https://www.xsens.com/software-downloads>.

### 3.2 Configuring the MTi

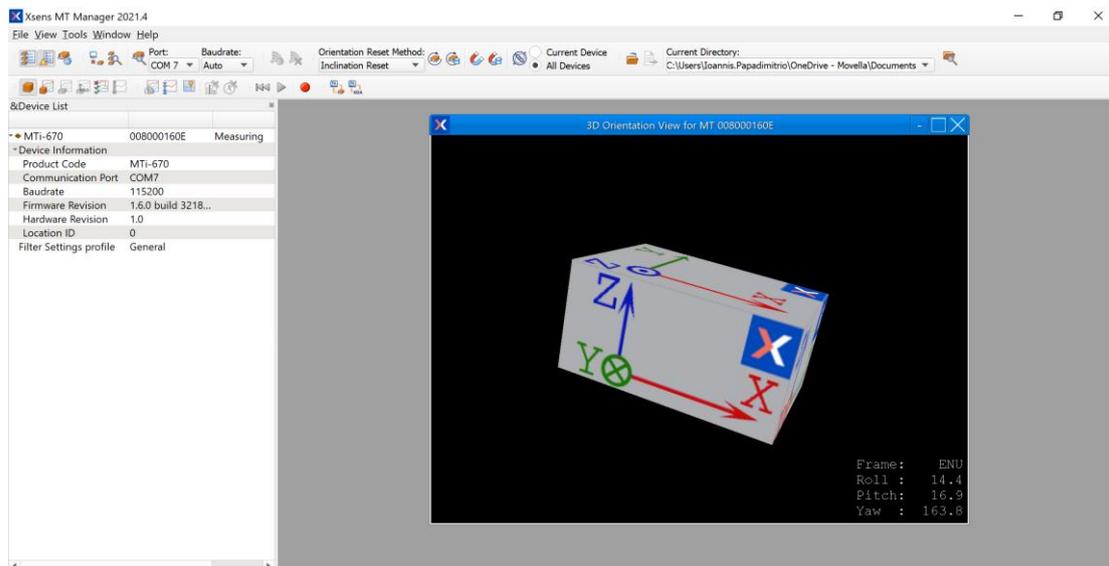
The MTi-series can be directly configured by means of MT Manager. Connect the MTi to your PC using the supplied USB cable. Upon execution of the MT Manager, it automatically scans the available COM-ports and/or MTi USB devices on the PC for connected devices.



The MTi is displayed in the Device List with the respective unique MT device ID number.



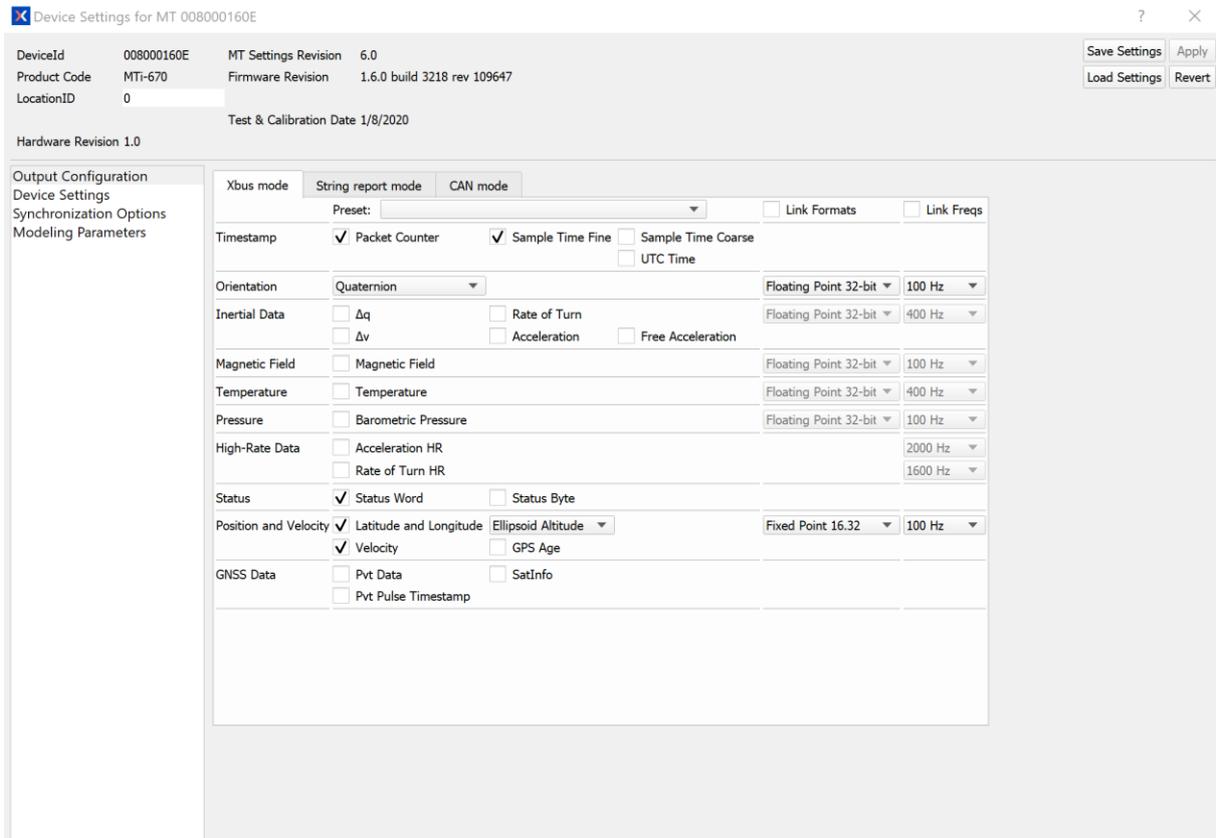
To see a real time 3D visualization of the orientation of the MTi, click the 3D View icon . The inertial data , orientation data in Euler angles , status data , position , altitude  and velocity  can be visualized by clicking their respective icons. In order to open these windows, the corresponding data outputs of the MTi need to be configured. Otherwise, the window icons will be grey.



In MT Manager click the Device Settings button  to open the Output Configuration dialog.

### Output Configuration tab

In the Output Configuration tab you can choose the desired outputs of the MTi:



Once you have selected your desired outputs, click Apply to save the output settings in the MTi's internal memory.

### Device Settings tab

In the Device Settings tab you will find options to set up the MTi's communication interfaces and it is possible to change the behavior of the sensor fusion algorithms of the MTi.

Device Settings for MT 008000160E

DeviceId 008000160E MT Settings Revision 6.0  
 Product Code MTI-670 Firmware Revision 1.6.0 build 3218 rev 109647  
 LocationID 0  
 Hardware Revision 1.0 Test & Calibration Date 1/8/2020

Save Settings Apply  
Load Settings Revert

Output Configuration  
**Device Settings**  
 Synchronization Options  
 Modeling Parameters

COM port name COM7

Port Configuration  
 RS232 Protocol Xbus Baudrate 115200 UART Protocol Xbus Baudrate 115200  
 CAN  Enable 250k Baudrate

Filter Settings  
 XDA: 21.2 General Onboard: 21.2 General Manage

Option Flags  
 In-Run Compass Calibration (ICC) - Beta  
 Orientation Smoother

GNSS Configuration  
 GPS & GLONASS

u-blox GNSS Platform  
 Portable

Receiver Model Baud Rate Input Rate (Hz) Receiver Options  
 u-Blox MAX-M8Q 115200 4 0

GNSS Receiver Type Config.

Position  
 Latitude [deg] Longitude [deg] Altitude [m]  
 52.24049169 6.838216771 0

UTC Time  
 1/1/1970 12:00 AM Get Set current

| RotSensor |   |   | RotLocal |   |   |
|-----------|---|---|----------|---|---|
| 1         | 0 | 0 | 1        | 0 | 0 |
| 0         | 1 | 0 | 0        | 1 | 0 |
| 0         | 0 | 1 | 0        | 0 | 1 |

### Synchronization Option tab

In the Synchronization Option tab you can change and add Synchronization options in your MTi. For detailed explanations of the functions and how to use them, refer to the [Low Level Communication Protocol Documentation](#) and [Synchronization with the MTi](#).

Device Settings for MT 008000160E

DeviceId 008000160E MT Settings Revision 6.0  
 Product Code MTI-670 Firmware Revision 1.6.0 build 3218 rev 109647  
 LocationID 0  
 Hardware Revision 1.0 Test & Calibration Date 1/8/2020

Save Settings Apply  
Load Settings Revert

Output Configuration  
 Device Settings  
**Synchronization Options**  
 Modeling Parameters

Configured Settings  
 In 2: Clock Bias Estimation (In)  
 In 2: 1PPS Time-pulse

Function Trigger Indication (In)  
 Line In 1

Delete Add

### Modeling Parameters tab

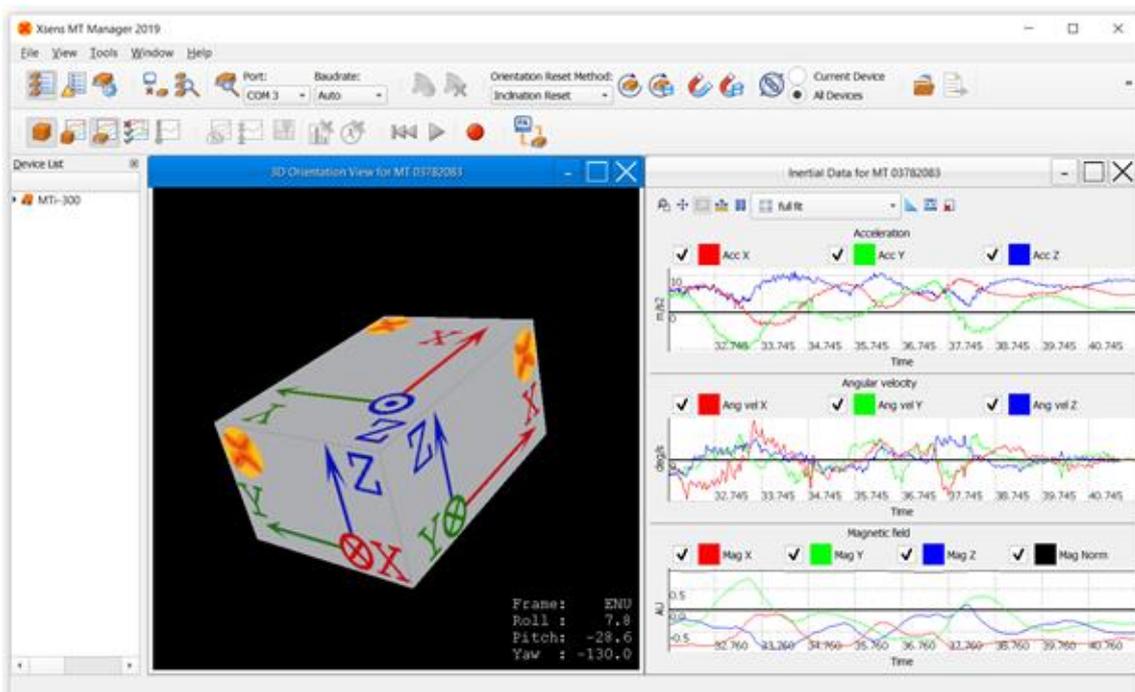
In the Modeling Parameters tab you can find the calibration parameters of the accelerometers, gyroscopes and magnetometers (offset, gain and misalignment; refer to the [MTi Family Reference Manual](#) for details).

| Device Settings for MT 008000160E |              | MT Settings Revision 6.0         |             | Save Settings Apply |                             |               |        |
|-----------------------------------|--------------|----------------------------------|-------------|---------------------|-----------------------------|---------------|--------|
| DeviceId                          | 008000160E   | Product Code                     | MTI-670     | Firmware Revision   | 1.6.0 build 3218 rev 109647 | Load Settings | Revert |
| LocationID                        | 0            | Test & Calibration Date 1/8/2020 |             |                     |                             |               |        |
| Hardware Revision 1.0             |              |                                  |             |                     |                             |               |        |
| Output Configuration              |              |                                  |             |                     |                             |               |        |
| Device Settings                   |              |                                  |             |                     |                             |               |        |
| Synchronization Options           |              |                                  |             |                     |                             |               |        |
| Modeling Parameters               |              |                                  |             |                     |                             |               |        |
| Accelerometers                    |              | Rate Gyros                       |             |                     |                             |               |        |
| Offset                            | 32667.6      | 32666.1                          | 32560.2     | 32775.3             | 32772.2                     | 32761.5       |        |
| Gain                              | 322.615      | 326.932                          | 313.993     | 923.137             | 937.119                     | 939.472       |        |
| Misalignment                      | 0.999992     | -0.000286391                     | -0.00397574 | 0.999955            | -0.00833611                 | -0.0051918    |        |
|                                   | -0.000489338 | 0.999958                         | 0.00915082  | 0.00922184          | 0.999952                    | 0.00422447    |        |
|                                   | 0.00253361   | -0.00921366                      | 0.999955    | 0.0091406           | -0.00307801                 | 0.999956      |        |
| Magnetometers                     |              |                                  |             |                     |                             |               |        |
| Offset                            | 32448.8      | 32746.1                          | 32961       |                     |                             |               |        |
| Gain                              | 2092.69      | 2067.43                          | 2078.62     |                     |                             |               |        |
| Misalignment                      | 0.999716     | 0.0225834                        | -0.00757214 |                     |                             |               |        |
|                                   | -0.016583    | 0.999786                         | 0.0123431   |                     |                             |               |        |
|                                   | -0.000344361 | -0.0307013                       | 0.999529    |                     |                             |               |        |

### 3.3 Recording data

With MT Manager, it is possible to record data and export that data for use in other programs. Once you have configured the MTi to output the desired data, you can use the Record Function of the MT Manager in order to record data and generate log files.

First check if you receive data. Open, for example, the 3D view  and the inertial data graph .



Logging data can be started and stopped by pressing the “Record / Stop Record” button:



The generated log file (.MTB file) will be written to the folder specified in the toolbar at the top of the main window under “Current directory”. By default, this is the root directory of the MT Manager installation (e.g. C:\Program Files\Xsens\MT Software Suite xxxx.x\MT Manager).

These data can be later replayed with MT Manager and exported in different formats (ASCII and KMZ)

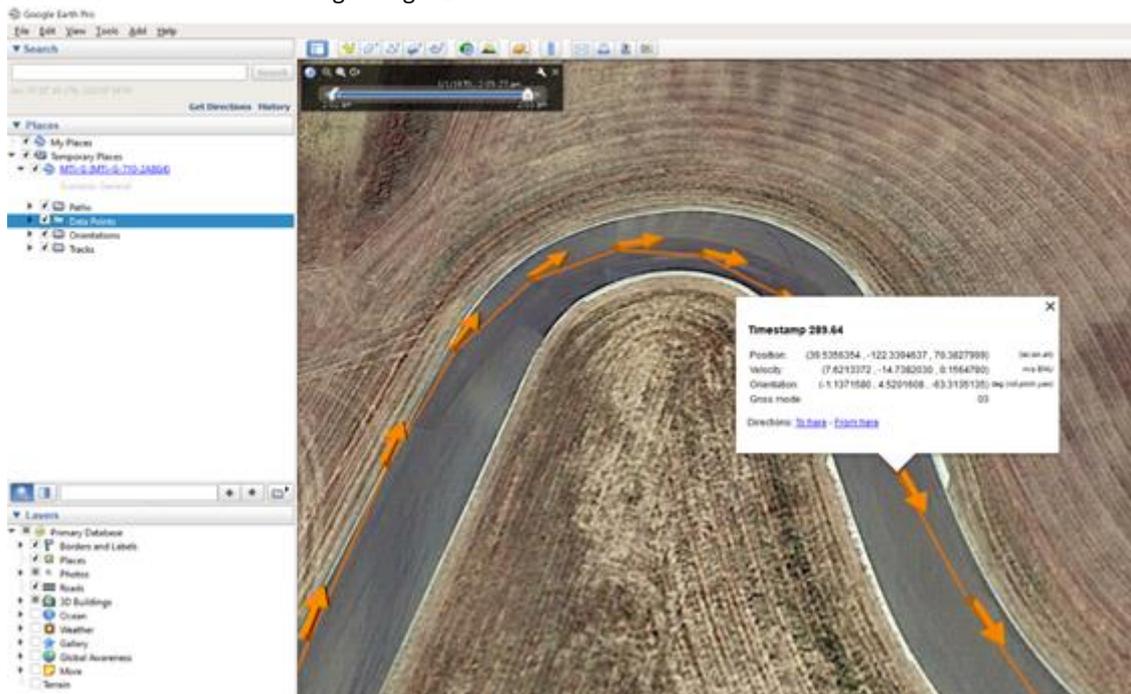
### Export data

Data previously logged into a .MTB file can be exported to the ASCII format and KMZ format. The KMZ file contains geo-referenced data points with corresponding orientation, velocity, GNSS mode and times. The contents of the KMZ file can be customized to match the user’s preferences.

The steps to export a KMZ file are:

1. Load a .mtb file of a GNSS/INS MTi device. This file must contain processed orientation and position, SCR data (including GNSS PVT data) or data that can be processed with XDA.
2. Set the preferences of the KMZ exporter via Tools->Preferences->Exporters.
  - Choose a Filename template.
  - Choose the maximum number of markers per second. The default value is 1; you should adapt this value to your velocity: too many data points per second may cloud the data points in Google Earth.
3. Export the file via File -> Export. You can change the output path and file name here.

The file can now be loaded into e.g. Google Earth:



More information regarding the functions and features of MT Manager can be found in the [MT Manager User Manual](#).

## 4 Connecting with a u-blox GNSS receiver

### 4.1 Configuring the MTi

As mentioned in the previous chapter, all MTi GNSS/INS products are by default configured to be used with u-blox GNSS receivers. When connecting to a u-blox GNSS receiver (e.g. u-blox MAX-M8), the MTi will configure it correctly on start-up. No prior configuration of the u-blox receiver is required. It is, however, recommended to inform the MTi of what type of u-blox receiver is connected. This can be done using the Device Settings window in MT Manager (version 2021.4 and later), or using a binary (Xbus) message called SetGnssReceiverSettings, described in the [MT Low Level Communication Protocol Documentation](#). The user can select one of the officially supported u-blox receiver series: MAX-M8 (default), NEO-M8 or ZED-F9, in addition to the desired input rate in Hz, the desired baud rate in bits/s and the desired GNSS platform (see Choosing a GNSS platform). Due to the different capabilities of each of these series, the commands that are sent out by the MTi at power-up are slightly different as well. Figure 7 shows an example of an MTi-680 that is configured to communicate with a ZED-F9P receiver while using the Automotive GNSS platform.

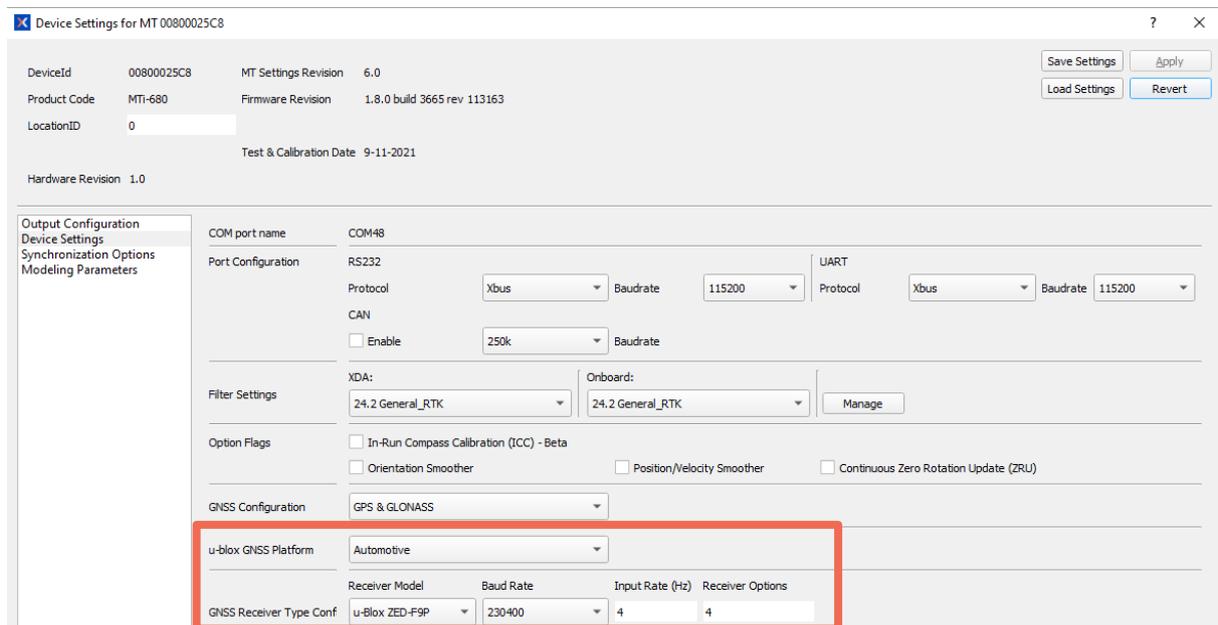


Figure 7: An MTi-680 that is configured to communicate with a u-blox ZED-F9P receiver.

Of course, the MAX-M8, NEO-M8 and ZED-F9 series are only a small subset of all GNSS receiver series offered by u-blox. Fortunately all series use the u-blox protocol (UBX), allowing others to be compatible as well. Other series that have been found compatible with MTi GNSS/INS products are ZOE-M8, SAM-M8 and NEO-M9. For u-blox GNSS receivers that offer standard precision, we recommend using the MAX-M8 receiver model. For u-blox GNSS receivers that offer RTK functionality, we recommend using either the NEO-M8 or the ZED-F9 profile. In case you are experiencing difficulties or if you are looking for advice, please do not hesitate to contact Xsens Technical Support.

### 4.2 Choosing a GNSS platform

u-blox GNSS receivers support different dynamic platform models in order to adjust the navigation engine to the expected application environment. The MTi GNSS/INS products can be configured to communicate a desired platform model upon start-up. This enables the user to adjust the u-blox receiver platform to match

the dynamics of the application. The setting influences the estimates of position and velocity and, therefore, it affects the behavior of the Xsens filter output.

The platform model can be configured using MT Manager or through low-level communication by providing the GNSS Platform ID. For more details on the low-level commands used to set the GNSS Platform (*SetGnssPlatform* for the MTi 1-series and *SetGnssReceiverSettings* for the MTi 600-series), refer to the [MT Low Level Communication Protocol Document](#). For more details on GNSS platform settings themselves, refer to the *u-blox Documentation* that applies to your specific GNSS receiver model. The default platform setting is “Pedestrian”. Especially for high-speed and aerial applications we recommend selecting a more suitable platform setting.

## 5 Connecting with a Septentrio GNSS receiver

### 5.1 Configuring the MTi

As mentioned in the previous chapters, the Xsens MTi-670/680 GNSS/INS devices allow the input of data from an external Septentrio GNSS receiver using the Septentrio ([SBF](#)) protocol. In this application note we are using the Septentrio Mosaic X5 as an example.

All MTi GNSS/INS products are by default configured to be used with u-blox GNSS receivers. For this reason the user should configure the MTi to communicate with the officially supported SBF Septentrio protocol. This can be done using the Device Settings window in MT Manager (version 2021.4 and later), or using a binary (Xbus) message called SetGnssReceiverSettings, described in the [MT Low Level Communication Protocol Documentation](#). The user can select the Septentrio Mosaic X5, in addition to the desired input rate in Hz and the desired baud rate in bits/s. “Receiver Options” field is not used. Figure 8 shows an example of an MTi-680 that is configured to communicate with a Septentrio Mosaic X5 receiver.

The screenshot shows the MT Manager interface for an MTi-680 device. The 'GNSS Receiver Type Config' section is highlighted with a red box. The configuration is as follows:

| Receiver Model       | Baud Rate | Input Rate (Hz) | Receiver Options |
|----------------------|-----------|-----------------|------------------|
| Septentrio Mosaic X5 | 230400    | 5               | 0                |

Other visible settings include: COM port name: COM6; Port Configuration: RS232, Protocol: Xbus, Baudrate: 115200; Filter Settings: XDA: 26.2 GeneralMag\_RTK, Onboard: 26.2 GeneralMag\_RTK; Option Flags: In-Run Compass Calibration (ICC) - Beta, Orientation Smoother, Position/Velocity Smoother, Continuous Zero Rotation Update (ZRU); GNSS Configuration: GPS & GLONASS; u-blox GNSS Platform: Portable; GNSS Lever Arm: -0.205, 0, 0 [m]; Position: Latitude [deg]: 52.2406505, Longitude [deg]: 6.8374517, Altitude [m]: 80.792; UTC Time: 1/1/1970 12:00 AM.

Figure 8: An MTi-680 that is configured to communicate with a Septentrio Mosaic X5 receiver.

### 5.2 Configuring the Septentrio GNSS receiver

A complete interfacing guide with the Septentrio Mosaic X5 receiver which includes hardware connections and detailed Septentrio configuration steps can be found here: [Interfacing a GNSS/INS device with the Septentrio Mosaic-X5 GNSS receiver](#)

Other Septentrio models are expected to be compatible as well, as long as they support the SBF messages in the above article.

## 6 Connecting with a Trimble GNSS receiver

### 6.1 Configuring the MTi

As mentioned in the previous chapters, the Xsens MTi-670/680 GNSS/INS devices allow the input of data from an external Trimble GNSS receiver using the Trimble ([GSOF](#)) protocol. In this application note we are using the Trimble BX992 as an example.

All MTi GNSS/INS products are by default configured to be used with u-blox GNSS receivers. For this reason the user should configure the MTi to communicate with the officially supported GSOF Trimble protocol.

This can be done using the Device Settings window in MT Manager (version 2021.4 and later), or using a binary (Xbus) message called SetGnssReceiverSettings, described in the [MT Low Level Communication Protocol Documentation](#). The user can select the Trimble BX992, in addition to the desired input rate in Hz and the desired baud rate in bits/s. “Receiver Options” field is not used. Figure 9 shows an example of an MTi-680 that is configured to communicate with a Trimble BX992 receiver.

The screenshot shows the 'Device Settings for MT 00800025C8' window. The top section displays device information: DeviceId (00800025C8), MT Settings Revision (6.0), Product Code (MTi-680), Firmware Revision (1.8.0 build 3665 rev 113163), LocationID (0), Hardware Revision (1.0), and Test & Calibration Date (9-11-2021). Buttons for 'Save Settings', 'Apply', 'Load Settings', and 'Revert' are visible.

The 'Output Configuration' section is expanded, showing 'COM port name' as COM48 and 'Port Configuration' as RS232. Under 'Port Configuration', 'Protocol' is set to Xbus, 'Baudrate' is 115200, and 'UART Protocol' is also Xbus with a 'Baudrate' of 115200. The 'CAN' section has 'Enable' unchecked and 'Baudrate' set to 250k.

'Filter Settings' shows 'XDA' and 'Onboard' both set to '24.2 General\_RTK'. 'Option Flags' includes 'In-Run Compass Calibration (ICC) - Beta', 'Orientation Smoother', 'Position/Velocity Smoother', and 'Continuous Zero Rotation Update (ZRU)', all of which are unchecked.

'GNSS Configuration' is set to 'GPS & GLONASS' and 'u-blox GNSS Platform' is 'Portable'.

The 'GNSS Receiver Type Cont' section is highlighted with a red box and contains the following configuration:

| Receiver Model | Baud Rate | Input Rate (Hz) | Receiver Options |
|----------------|-----------|-----------------|------------------|
| Trimble BX992  | 230400    | 5               | 0                |

Below this, 'GNSS Lever Arm' is set to 0, and 'Position' is set to Latitude [deg] 52.2314073, Longitude [deg] 6.8929034, and Altitude [m] 95.667. The 'UTC Time' is set to 1-1-1970 00:00, with 'Get' and 'Set current' buttons.

Figure 9: An MTi-680 that is configured to communicate with a Trimble BX992 receiver.

### 6.2 Configuring the Trimble GNSS receiver

Other Trimble models than the BX992 are expected to be compatible as well, as long as they support the set of GSOF messages that is required by the MTi series. Because the MTi does not configure the Trimble receiver at power-up, the user needs to ensure that the Trimble receiver already outputs the required GSOF messages. The required GSOF messages can be found in the [MTi 600-series Datasheet](#).

## 7 Connecting with a GNSS receiver through the NMEA protocol

The MTi-670/680 and MTi-7/8 can accept GNSS inputs via NMEA protocol. An example of this, using a SinoGNSS receiver, can be found on [BASE](#).

### 7.1 Configuring the MTi

The MTi GNSS/INS products are by default configured to be used with u-blox GNSS receivers. Therefore you will first need to configure the MTi to accept GNSS data using the NMEA input mode. This can be done using the Device Settings window in MT Manager (version 2021.4 and later), or using a binary (Xbus) message called SetGnssReceiverSettings, described in the [MT Low Level Communication Protocol Documentation](#). The user should set the GNSS Receiver Type Configuration to Generic NMEA, in addition to the desired input rate in Hz, the desired baud rate in bits/s and Receiver Options (NMEA Talker ID). If any of these settings does not match with the settings of the GNSS receiver, then the MTi will generate warnings. These will appear at the bottom of the screen in MT Manager in the Message Window.

Figure 10 shows an example of an MTi-670 that is configured to communicate with a GNSS receiver via NMEA input.

The screenshot shows the 'Device Settings for MT 008000160E' window. The 'GNSS Receiver Type Config.' section is highlighted with a red box. The settings are as follows:

| Receiver Model | Baud Rate | Input Rate (Hz) | Receiver Options |
|----------------|-----------|-----------------|------------------|
| Generic NMEA   | 115200    | 4               | 0                |

Other visible settings include: COM port name: COM7; Port Configuration: RS232; Protocol: Xbus; Baudrate: 115200; UART Protocol: Xbus; Baudrate: 115200; Filter Settings: XDA: 21.2 General; Onboard: 21.2 General; Option Flags: In-Run Compass Calibration (ICC) - Beta, Orientation Smoother; GNSS Configuration: GPS & GLONASS; u-blox GNSS Platform: Portable; Position: Latitude [deg] 52.24049169, Longitude [deg] 6.838216771, Altitude [m] 0; UTC Time: 1/1/1970 12:00 AM; RotSensor and RotLocal settings are also visible.

Figure 10: An MTi-670 that is configured to communicate with a GNSS receiver using NMEA Input.

When using the NMEA input mode, the Receiver Options field is used to inform the MTi of what Talker ID (GL, GN or GP) the GNSS receiver uses for its NMEA sentences. NB: Only one Talker ID can be selected! The value for each Talker ID can be found in Table 5.

Table 5: Available GNSS receiver options – Generic NMEA

| NMEA Talker ID | Value |
|----------------|-------|
| GL             | 0     |
| GN (default)   | 1     |
| GP             | 2     |

### 7.2 Configuring the GNSS receiver

The table below summarizes the settings needed to configure the GNSS receiver such that it outputs the correct NMEA sentences. This will enable the MTi to use the GNSS data and provide the user with a full GNSS/INS solution. The MTi will also synchronize its internal clock with the UTC time that is present in the sentences.

Table 6: Settings required to enable the NMEA input mode for the MTi

| Setting                | Description  |
|------------------------|--|
| Baudrate               | Minimum 115200 bps   |
| GNSS Message frequency | 4 Hz recommended/default, 10 Hz maximum  |
| Talker ID              | GN, GP or GL   |
| Required messages      | GGA, GSA, GST and RMC<br>High precision coordinate formats such as GGALONG are also supported. |

## 8 Best practices

### 8.1 Status information

In order to view the (GNSS/RTK) status of the MTi, it is recommended to enable the StatusWord/StatusByte outputs. These outputs provide valuable information regarding the real-time state of your MTi. An overview of the StatusWord contents can be found in the [MT Low Level Communication Protocol Documentation](#).

In this application note, we will explore the GNSS fix, RTK Status, Filter Valid and ClockSync flags.

For example, the MT Manager's Status Data graph (  ), shown in Figure 11, indicates that the connected MTi has a GNSS Fix and an RTK Fix status flag.

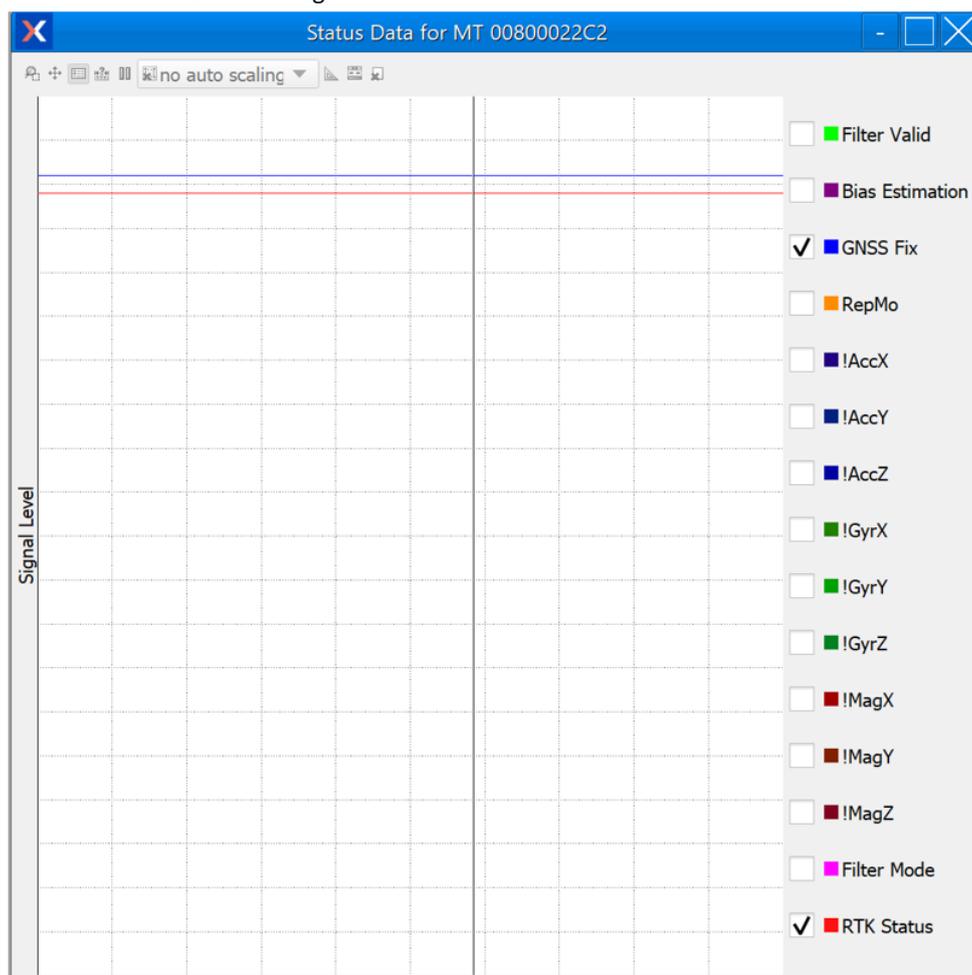


Figure 11: GNSS fix and RTK Status Fix in Status Data graph

- **The GNSS Fix flag** indicates whether the GNSS receiver has a proper fix. This flag has 2 states: High (GNSS fix) and Low (No GNSS fix). An MTi will not output filtered position or velocity data until a GNSS Fix has been achieved. After power-up and under clear sky conditions, this generally takes up to 30 seconds.

- **The RTK Status flag** indicates the availability and status of RTK. This flag has 3 states: High (RTK Fix), Middle (RTK Float) and Low (No RTK). Figure 12 shows the possible states of the RTK Status flag in the Status Data view.

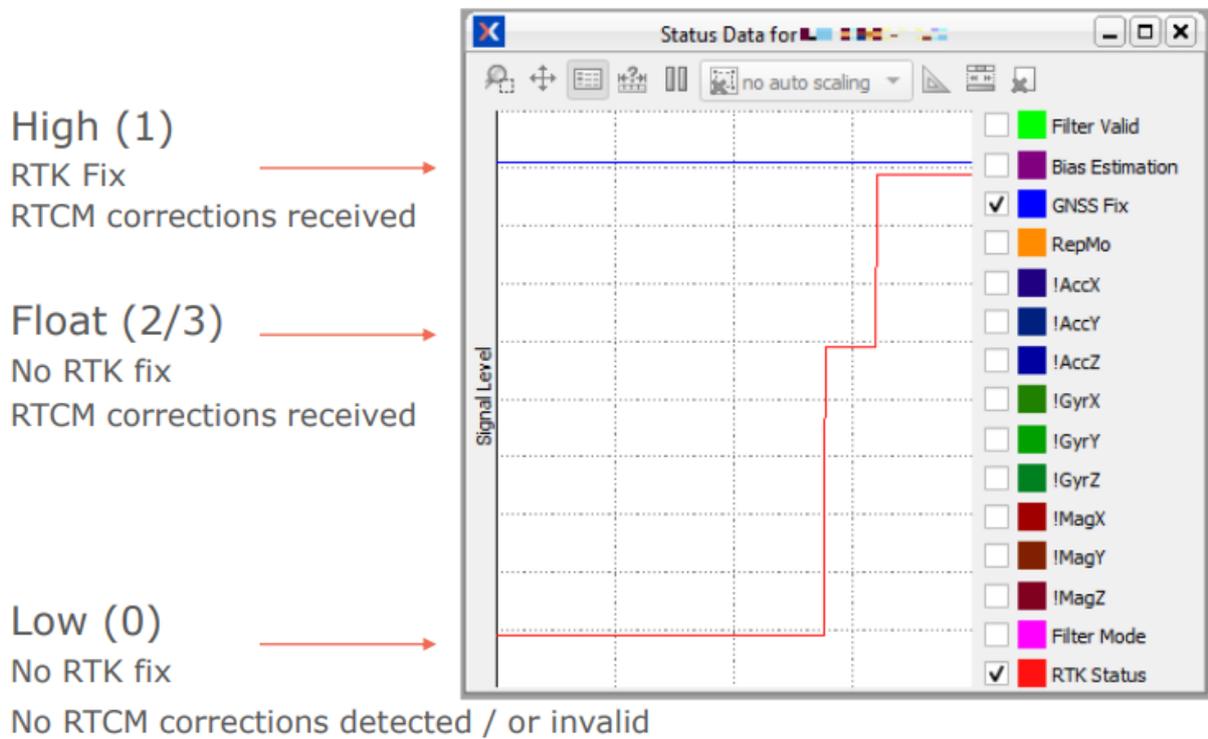


Figure 12: Possible States of the RTK Status Flag

The StatusWord information can be also viewed using the binary (Xbus) message output. In Figure 13 you can see the StatusWord Xbus message in the Device Data View tab (  ) of MT Manager :

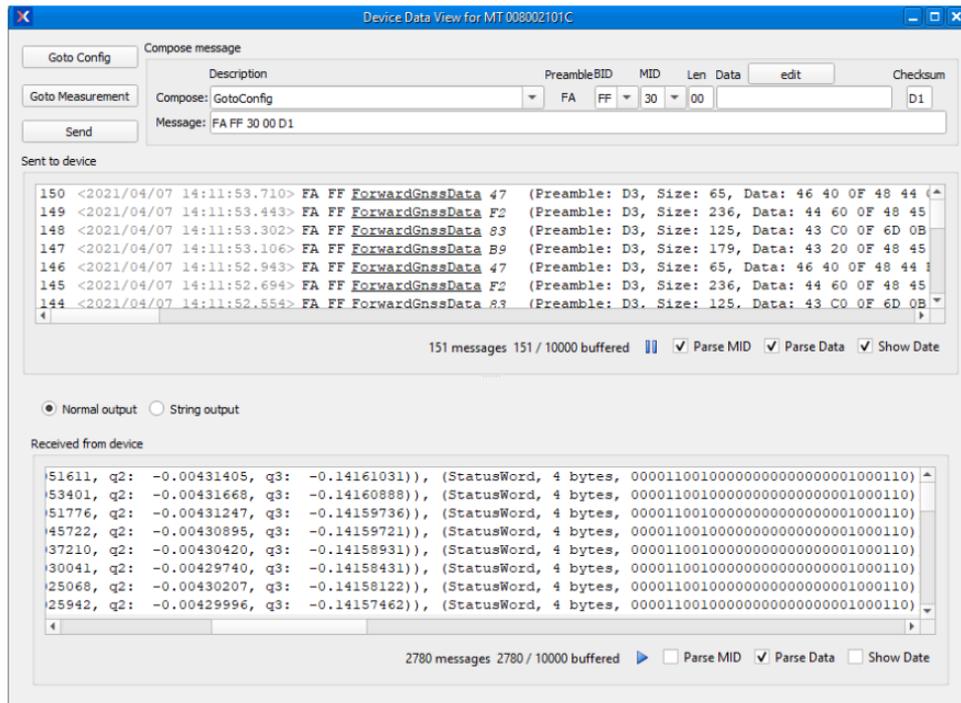


Figure 13: StatusWord message in the Device Data View

The 5th bit from the left indicates an RTK float status, the 4th bit from the left indicates an RTK fix:

```

RTK fix:
000101001000000000000000000000001000110
RTK float:
0000110010000000000000000000000001000110
RTK no fix/float:
0000010110000000000000000000000001000110
  
```

- **The Filter Valid flag** indicates if input into the orientation filter is reliable and / or complete. If, for example, the measurement range of internal sensors is exceeded, the orientation output cannot be reliably estimated and the filter flag will drop to 0. For GNSS/INS devices, the filter flag will also become invalid if the GPS status remains invalid for an extended period.
- **The Clock Bias Estimation flag** indicates that the Clock Bias Estimation synchronization feature is active. For GNSS/INS devices, this means that the MTi is receiving the 1 PPS pulse from the GNSS receiver and that it is synchronizing its outputs with it. More information can be found in the [MTi 600-series datasheet, Synchronization Options](#).

## 8.2 Antenna placement and setting the GNSS lever arm (MTi-8/680 only)

### GNSS Antenna Placement

For GNSS/INS devices with RTK enabled GNSS receivers, the antenna placement becomes more critical and it is even more critical for the GNSS antenna to have a clear view of the sky to receive data from as many satellites as possible. Because RTK enabled GNSS receivers can measure the position down to centimeter level, the used antenna must be properly fixed with respect to the MTi.

The differential measurements in RTK GNSS can compensate for errors due to the satellite clock, the satellite orbit, the ionosphere and troposphere. However, it does not compensate for multipath errors. Therefore, the GNSS antenna used on the MTi should have a good multipath rejection. It is recommended to have a proper ground plane (metal surface) underneath the antenna of at least 150 mm diameter to aid in the multipath rejection.

### GNSS Lever Arm

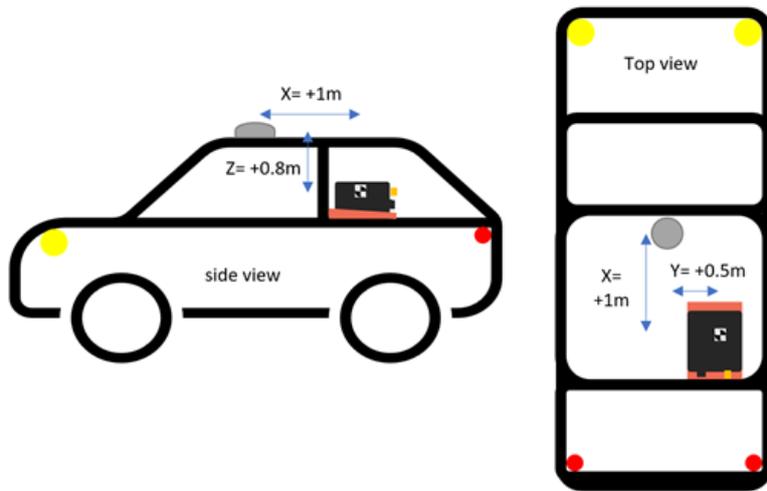
With the release of the MTi-680/8 RTK GNSS/INS, Xsens has also introduced a new configuration parameter called the GNSS lever arm. The GNSS lever arm is an essential parameter in order to achieve reliable cm-level position, velocity and orientation data.

The GNSS lever arm setting accounts for the distance between your MTi (where all inertial data are measured) and the location of the GNSS receiver's antenna. Providing this information to the MTi will allow the sensor fusion core to compensate for the difference in dynamics between these two measurement locations.

The GNSS lever arm is a parameter that needs to be measured and stored by the user after installation of the MTi. It is stored in the MTi's memory as a vector of X-Y-Z coordinates, relative to the origin\* of the sensor frame of the MTi. The unit is meters, but if possible the lever arm should be determined with centimeter-level accuracy.

Below image shows an example of how the GNSS lever arm is measured for an MTi and its GNSS antenna, after they have been integrated into a car. The X-Y-Z coordinates should be measured according to the sensor coordinate frame, which has been printed on the side label of the MTi. Careful attention needs to be paid to the sign of the coordinates: i.e. if the antenna is mounted to the right of the MTi, then the Y coordinate should be a negative value.

The final GNSS lever arm vector for this vehicle is [1.00, 0.50, 0.80] (m).



The GNSS lever arm can be set and stored using the Device Settings window in MT Manager (see Figure 14), or by using the `setGnssLeverArm` low-level communication command; refer to the [MT Low Level Communication Protocol Document](#) for more details.

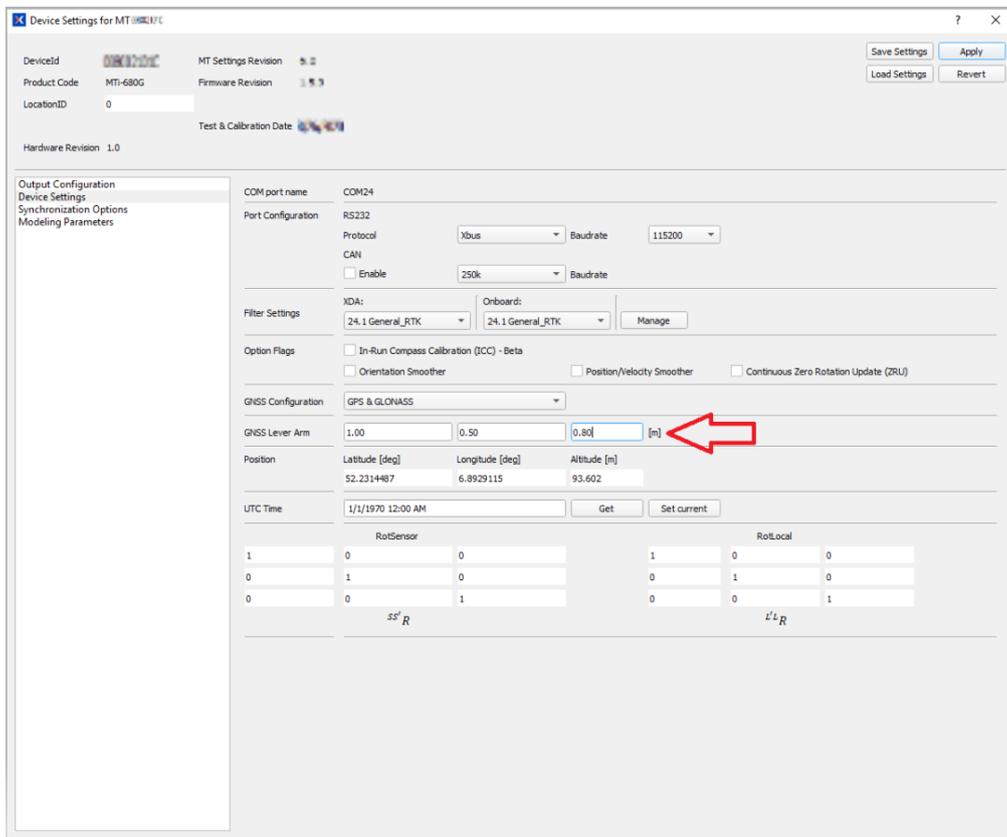


Figure 14: The GNSS lever arm input using the Device Settings window in MT Manager

More information regarding the GNSS Lever Arm and its role in the GNSS/INS sensor fusion algorithm can be found [here](#).

### 8.3 Transparent mode<sup>1</sup> – forwarding messages to the GNSS receiver

In some cases, users of GNSS/INS products may need to send configuration messages or commands to the GNSS receiver after the GNSS/INS combination has been initialized. For this purpose the MTi GNSS/INS products offer a so-called “transparent mode”: Users can send commands or configuration messages to the MTi, which will then be forwarded to the GNSS receiver without modification. The benefit of this transparent mode is that the user no longer needs to maintain two separate communication interfaces – one for the MTi and another for the GNSS receiver.

The transparent mode is based around a low-level Xbus message called “ForwardGnssData”. Upon receipt, the MTi will unpack the ForwardGnssData message and forward its Data field to the connected GNSS receiver. The ForwardGnssData message can be sent while the MTi is in measurement mode. A schematical impression of the transparent mode is shown in Figure 15.

An example case in which the ForwardGnssData message is used, is the NTRIP client in MT Manager. The NTRIP client is used to receive RTK correction messages over the internet. These correction messages are then wrapped as a ForwardGnssData message and sent to the MTi, after which their contents are forwarded to the GNSS receiver. This way, the MTi GNSS/INS can achieve RTK functionality without having to maintain a direct connection with the GNSS receiver.

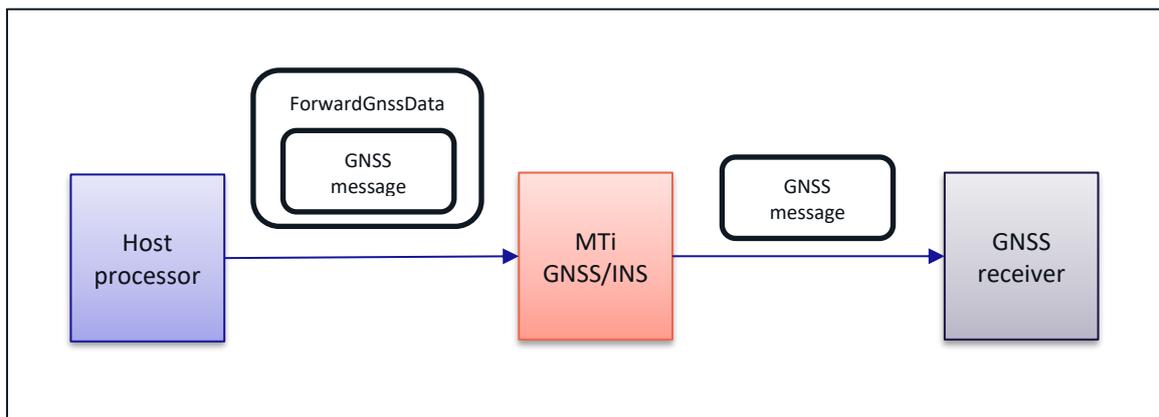


Figure 15: Schematical impression of the transparent mode (ForwardGnssData). A link between the host processor and GNSS receiver is no longer essential.

### 8.4 Providing an initial heading estimate (MTi-600 and 100 series only)

Out of the filter profiles available for the GNSS/INS devices, only the GeneralMag filter profile will provide the user with a North-referenced heading when the MTi is powered up. For all other filter profiles, the Yaw will initialize at 0 degrees. As soon as a GNSS fix is available and the MTi starts moving at a sufficient velocity (min. 7 m/s with standard GNSS, lower with RTK enabled), the Yaw will converge to a North-referenced heading.

<sup>1</sup> The transparent mode is currently not supported by the MTi-7.

If the initial heading of the MTi is approximately known at initialization time, for instance, based on an external sensor or a known starting orientation, then it is highly recommended to manually set the initial heading value. This can be done using the SetInitialHeading low-level communication command. Refer to the [MT Low Level Communication Protocol Documentation](#) for more information.

## 9 Technical Support

### 9.1 Online documentation

All the latest documentation is available at: [www.xsens.com/xsens-mti-documentation](http://www.xsens.com/xsens-mti-documentation)

The table below provides an overview of all documents listed on this page, categorized by MTi product series.

Table 7: Overview of documentation available for the MTi series.

| MTi 1-series                              | MTi 600-series              | MTi 10/100-series |
|---|-----------------------------|-------------------|
| MTi Family Reference Manual               |                             | MTi User Manual   |
| Datasheet                                 | Datasheet                   |                   |
| DK User Manual                            | DK/SK User Manual           |                   |
| Hardware Integration Manual               | Hardware Integration Manual |                   |
| -   | CAN Protocol Documentation  | -                 |
| MT Manager User Manual                    |                             |                   |
| Magnetic Calibration Manual               |                             |                   |
| Low-Level Communication Protocol Document |                             |                   |
| Firmware Updater User Manual              |                             |                   |

### 9.2 BASE by Xsens

BASE by Xsens is the right place to go for additional information, such as best practices, tutorials, troubleshooting and third party integrations. Our documentation often refers to pages on BASE for further reading.



BASE consists of the following three components:

- A public technical support forum, maintained by our Product Specialists
- Articles, guides and FAQs
- Tutorial videos

### 9.3 Private technical support

Finally, please feel free to contact our global team of Product Specialists. We are available every day for technical support, free of charge! To get in contact, please fill in [the web form on BASE](#) or send an e-mail to [support@xsens.com](mailto:support@xsens.com).

## Appendix A: Sample data

The sample data set presented in this appendix can be downloaded by clicking [here](#). The log files can be opened using MT Manager, part of the MT Software Suite. This software package is available free to download from: <https://www.xsens.com/software-downloads>

It contains a (.mtb) log file of the MTi-680 GNSS/INS with RTK support. The 27-minute data set has been recorded during a short drive by car from the city of Enschede to the city of Hengelo, and back again. During the trial a couple GNSS-denied environments were faced.

Also included are:

- a .kmz export file which can be generated by MT Manager and opened in Google Earth;
- a screenshot of Google Earth, showing the full path travelled during the trial.

The GNSS receiver that was connected externally to the MTi-680 was the u-blox ZED-F9P. RTK corrections from a local base station were retrieved through an NTRIP connection.

The images shown below cover small parts of interest. Close-ups of these sections demonstrate the GNSS/INS benefits that were described earlier in chapter 2.1.

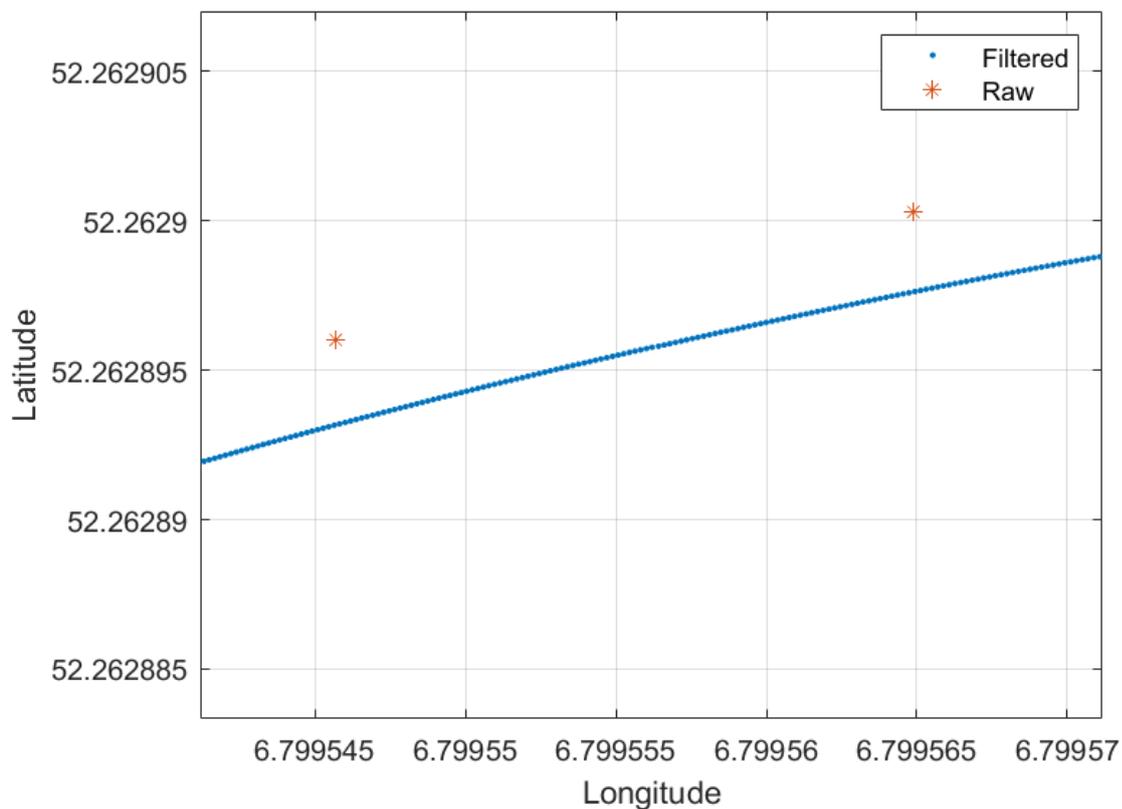


Figure 16: Raw GNSS data (4 Hz, red) versus the filtered position output of the MTi-680 (400 Hz, blue).

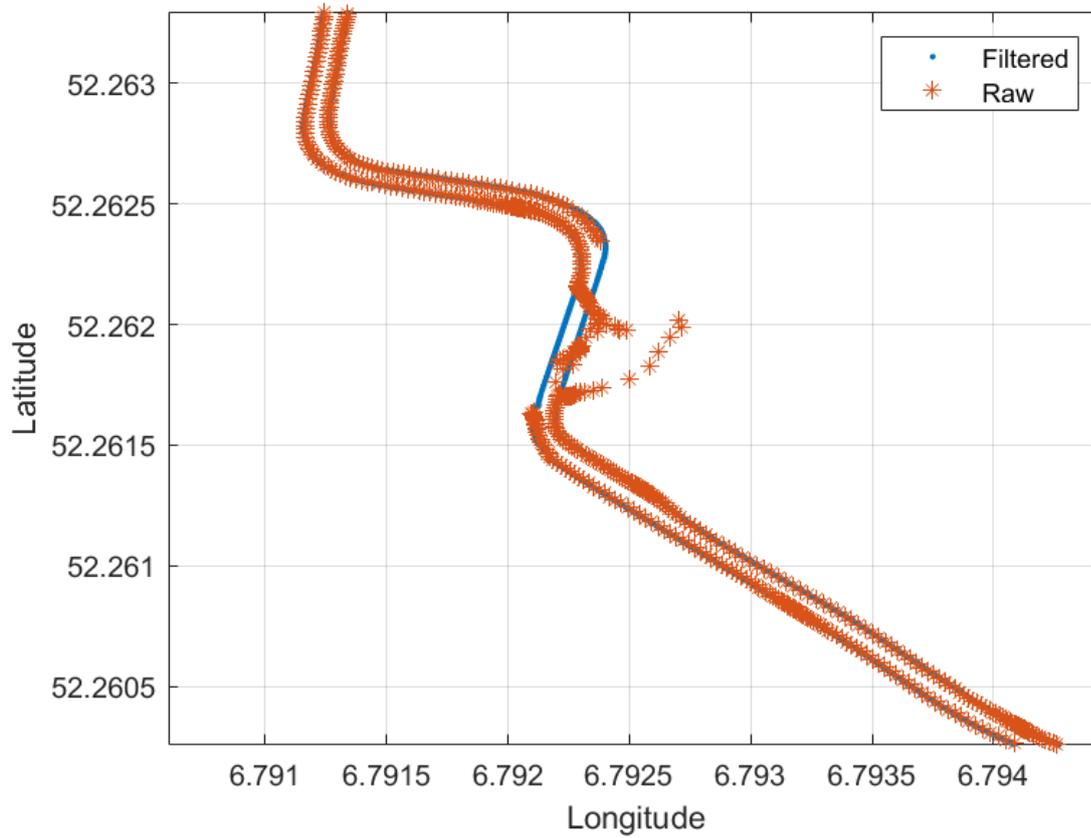


Figure 17: Dead-reckoning and position smoothing while driving through a tunnel (back and forth).

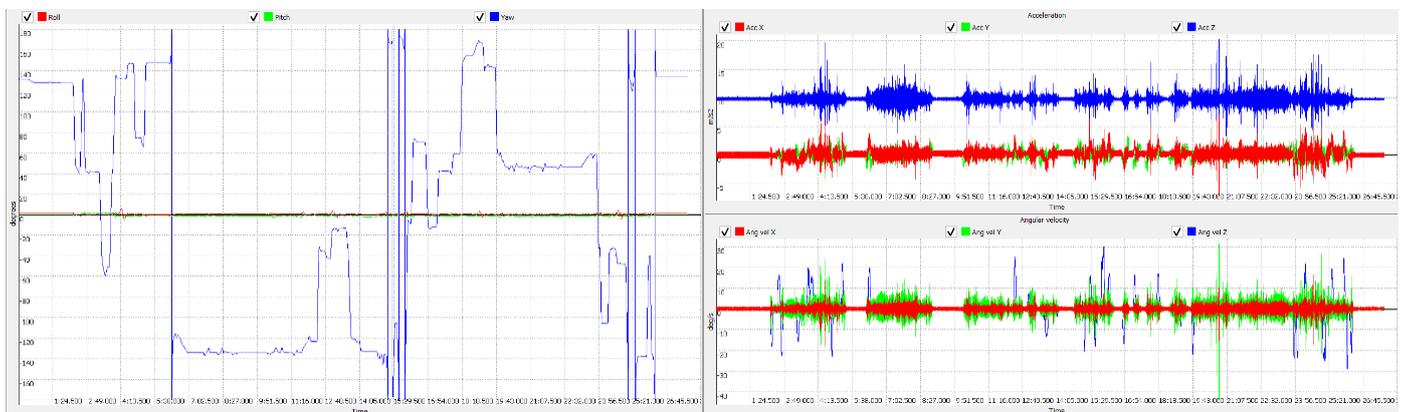


Figure 18: 3D orientation (left), acceleration and angular velocity (right) data recorded during the trial. Other outputs available include 3D velocity, 3D magnetic field, 3D free acceleration, altitude and barometric pressure.