ANavS Positioning and Map-Creation Systems – Reference Guide

Applicable to:

- Multi-Sensor RTK/PPP Module (MS-RTK)
- RTK/RTCM Reference Station
- ISP (Integrated Sensor Platform)

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Abstract

The following guide provides a detailed explanation for the usage of the different ANavS® positioning Systems, the Multi-Sensor RTK/PPP module (MS-RTK), the RTK/RTCM Reference Station and the Integrated-Sensor-Platform (ISP).

The **ANavS® MS-RTK module** (chapter 2) provides a precise position, velocity, and attitude information. It is a turnkey system with a very attractive price/performance ratio and can be easily integrated into users' application. The module includes up to 3 Multi-frequency, Multi-GNSS (GPS, Galileo, Glonass, Beidou) receivers, a MEMS IMU, a barometer, a CAN interface for reception of vehicle data (wheel odometry and steering angle), an LTE module for reception of RTK/ PPP corrections (e.g. from ANavS® RTK reference station), and the powerful ANavS® Sensor Fusion on a single board. The latter one performs a tight coupling of all sensor data with an Extended Kalman Filter (EKF).

The **ANavS® RTK/RTCM Reference Station** (chapter 3) provides correction data in standard RTCM format to guarantee precise positioning in every situation without any integration effort. It only requires a power supply and connected GNSS antenna, thus it is ready to use after a short calibration phase of the fixed position.

The **Integrated Sensor Platform** (chapter 4) is a hardware-platform for easy integration of a large variety of sensors without any effort. It comes with a standard configuration of three GNSS receivers and integrated antennas, a high-grade MEMS IMU, a CAN interface for wheel odometry data and a barometer. On top of the standard sensors a fully integrated computer vision module is equipped, that can be flexibly configured with two cameras and/or a 3D-LiDAR with powerful processor for artificial intelligence (AI) applications.

Helpful tools for system configuration, for solution visualization, for postprocessing and for converters are explained also in this guide.

Typographical Conventions

`abc -param`	Command-line instructions, e.g., in shell
abc -param	MSRTKF command-line instructions

List of Acronyms

AI *Artificial Intelligence*

CAN *Controller Area Network*

GNSS *Global Navigation Satellite System*
GUI *Graphical User Interface*

IMU *Inertial Measurement Unit*
ISP *Integrated Sensor Platform*

LTE *Long Term Evolution*

MEMS *Micro-Electro-Mechanical Systems*

PPP *Precise-Point-Positioning*

ROS *Robot Operating System*
RTCM *Radio Technical Commission for Maritime services*
RTK *Real-Time-Kinematic*

SLAM *Simultaneous Localization and Mapping*
SSH *Secure Shell*

USB-PD *USB-Power Delivery*

VPU *Vision Processing Unit*

Document Change Log

Issue	Revision	Sections Affected	Details of Change
1	0	All	Initial version of document.
1	1	9	Added overview of NTP functionality.
1	2	2.7.8	Added hint for new settings with already running navigation-service.
2	1	13	Added chapter for LTE-VPN configuration.
2	2	6.1.1 9.4	Updated binary protocol with new parameters (inserted in “reserved” fields). Added sub-chapter “Time-Synchronization with MS-RTK clock”.
2	3	Appendix 2/3/4/5 2.2	Added technical drawings for casing types including coordinates of IMU. Changed power-consumption rating for newer hardware versions (=>v9).
2	4	12	Added Java-Version for using Record-Extractor tool
2	5	8	Updated CAN-Interface description
2	6	2.3, 3.2	Recommendation to use triple frequency variant of ANavS positioning modules only with connected GNSS antennas.
2	7	4.2, 4.3, 4.4	Updated chapter “Getting-Started with the Integrated-Sensor-Platform (ISP)”
2	8	8.3.7	Added sub-chapter “Set up CAN hardware filter”
2	9	4.2, 4.4, 10	Updated 4.2 and 4.4 to the current ISP setup with optional two embedded GPU platforms. Added object detection as optional algorithm and corresponding subsection. Updated ROS-Ethernet Adapter description.
2	10	8.2	Updated description with endianness of CAN-Output of ANavS solution
2	11	Appendix 1	Added example DBC file for ANavS solution output
2	12	4.4	Updated section 4.4 with updated VPU setup with optional two embedded GPU platforms.
2	13	Appendix 3	Updated drawing with exact IMU position
2	14	6	Velocity in MSKF filter is given in body frame, not in navigation frame

Inhalt

1. Getting Started with the GUI tools

The suite of GUI tools contains the so called **ANavS® Wizard** for configuring the hardware and the **ANavS®-Visualizer** for showing the real-time sensor fusion solution with all estimated parameters**.** How to use the programs is explained in the chapters for each ANavS Positioning System.

1.1. System Requirements

The following minimum requirements should be fulfilled:

Processor:	Intel®Core™ i5 with 1.60GHz or comparable processors
RAM:	Minimum 4 GB
System type:	Windows 64-Bit architecture or Ubuntu 18.04
Hard-Disk space:	Minimum 500 MB

1.2. Download

Download the latest ANavS® Online Installer for your desired Operating System (Windows 10 or Ubuntu 18.04) from the following link:

https://anavs.com/knowledgebase/anavs-app/

1.3. Windows Installation

- Unzip and double click the installer executable file *ANavS_Wizard_Online_Installer_Win64Bit* and follow the installation-wizard step-by-step.
- Once it is finished, the installer displays an option to run the ANavS® Wizard after completion. If you choose this option, the application should start immediately. Otherwise, you must navigate to your previously defined installation-folder and run the Wizard-executable *ANavS_Wizard.exe*. Besides, it could be important to start the software with admin-rights or to give the software the rights if asked for it.
- The ANavS® Wizard is always proving for new published versions of this tool in the online repository after starting the software.

1.4. Linux Installation

- Unzip the download file
- Launch the executable file *ANavS_Wizard_Online_Installer_Unix64Bit* via command line. If this does not work, please change the file permissions to be an executable file.

- After starting, follow the installation-wizard step-by-step.
- Once it is finished, the installer displays an option to run the ANavS®-Wizard after completion. If you choose this option, the application should start immediately. Otherwise, you must navigate to your installation-destination and run the Wizard-executable *ANavS_Wizard.exe* via command line. Besides, it could be important to start the software with admin-rights or to give the software the rights if asked for it.
- The ANavS® Wizard is always proving for new published versions of this tool after starting the software.

1.5. The ANavS® Wizard Tool

The ANavS® Wizard tool connects to the ANavS® Positioning Systems using a TCP/IP data stream connection. This connection allows the ANavS®-Wizard to operate and control a positioning system remotely via Wi-Fi, Ethernet, or LTE.

Defining a TCP/IP connection is simply done by specifying the IP address of the ANavS Positioning System. This can be done by inserting the IP in the settings dialog (very left bottom button, see Figure 1). On default, the user should be connected via the established Wi-Fi Access-Point of the Positioning System with a SSID named with a substring *"ANAVS"*. The default static IP of the Positioning System is

- 192.168.42.1 or
- 192.168.43.1

The default Ethernet configuration is DHCP. This brings the user the possibility to connect the ANavS Positioning System to a router with a running DHCP-server. Contact your network administrator for more information on how to map or get the IP address to/from a DNS server. A short introduction searching for IP address is also explained in the ANavS knowledge base (https://anavs.com/knowledgebase/using-the-ip-scanning-tool-nmap/)

The status field in the right bottom corner of the ANavS® Wizard shows the status of TCP/IP-connection. The message *"TCP-Conn OK"* says that the ANavS® Wizard can communicate with the MS-RTK module, RTK Reference Station or ISP. The message *"TCP-Conn N/A"* says the ANavS®-Wizard is NOT able to communicate with the ANavS Positioning Syst.

HINT: To get the best possible user-experience with the ANavS® Wizard, please change your global Windows/Linux Display settings of the Symbols to 100%. See Figure 2 for this.

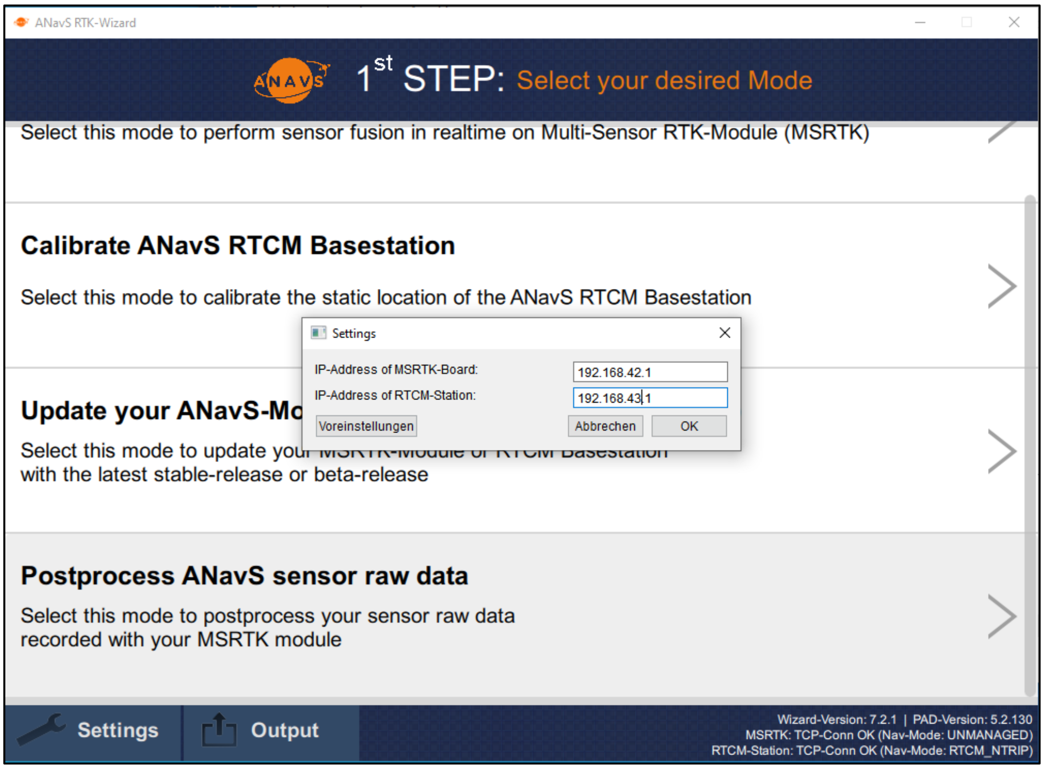


Figure 1: Defining the TCP/IP connection for controlling the positioning systems. The button is found in the left bottom corner. The different Modis of the ANavS® Wizard are explained in chapter 2 with the usage of the different positioning systems.

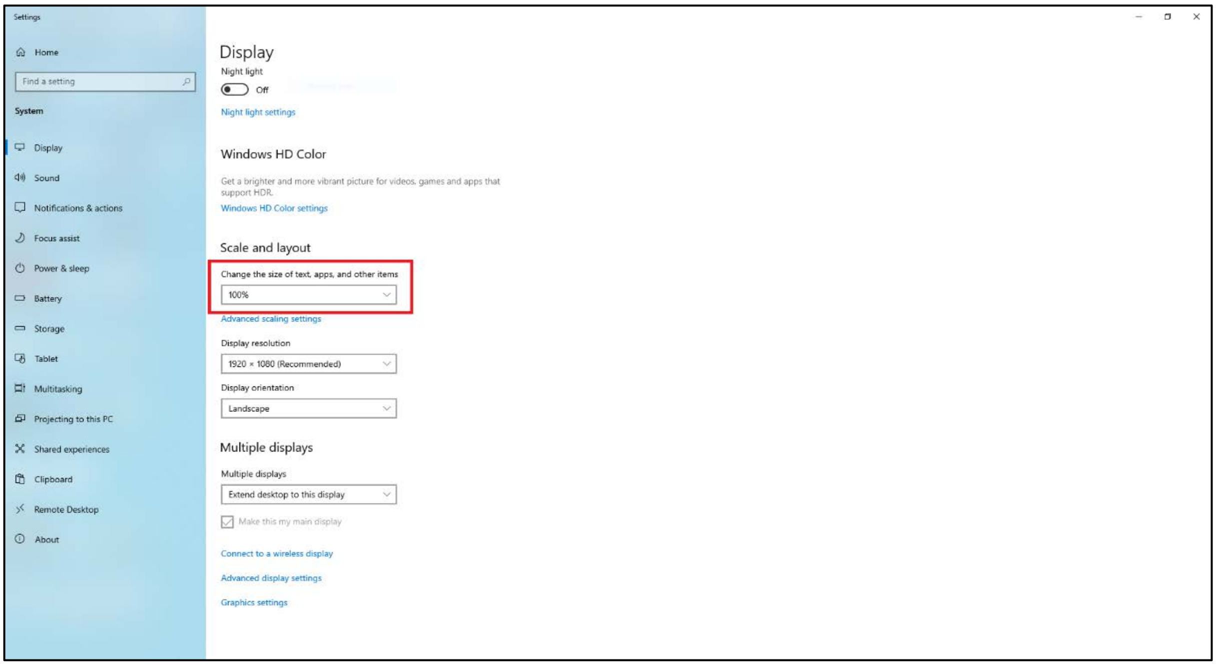


Figure 2: Changing display settings on Windows to 100%

1.6. The ANavS® Visualizer Tool

The ANavS® Visualizer is normally started by the ANavS® Wizard**.** After pushing the green start-button for triggering the ANavS® sensor fusion within the ANavS® Wizard at the end of a stepwise Positioning-System configuration, the ANavS® Visualizer (Figure 3) pops-up and the sensor fusion starts to run. The ANavS® GUI visualizes all sensor fusion estimates via text, graphs and on a map.

HINT: To get the best possible user-experience with the ANavS® Visualizer, please change your global Windows/Linux Display settings of the Symbols to 100%. See Figure 2 for this.

Besides, in case of already running sensor fusion on a positioning system, the user can directly start the ANavS® Visualizer tool. For this, please navigate to the subfolder ***/bin*** in your installation folder and start the visualizer via double click on the *ANavS_GUI.exe*.

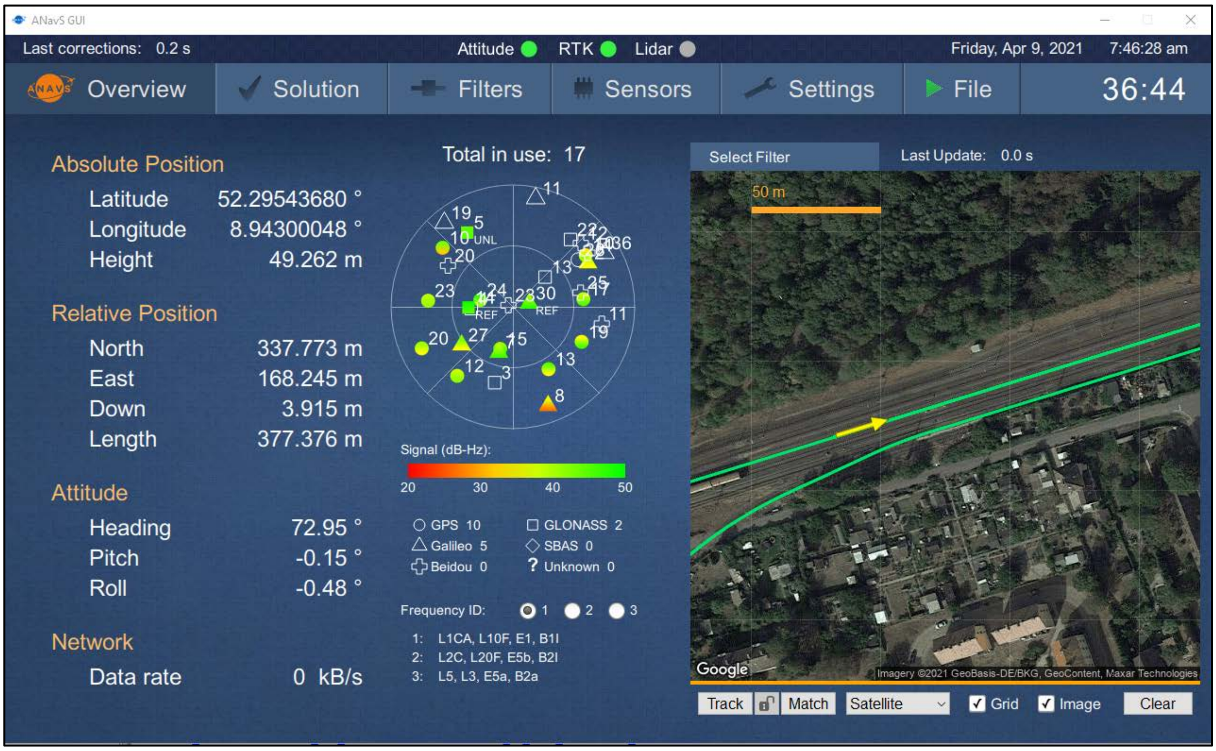


Figure 3: ANavS® Visualizer with graphs, constellation plot and map

At startup time of the application, the visualizer tries to connect via default or user-defined IPs with an ANavS® Positioning System. In addition to this Auto-Connect, the user can also manually insert the IP and Port within the Tab “Settings”, shown in Figure 4. Please note, the Port is in the standard configuration always 6001, which is reserved for the proprietary binary protocol, used by the ANavS® Visualizer decoder to gather all the solution and system information. Changing the port will prevent getting the solution stream into the ANavS® Visualizer in default settings without customer adjustments.

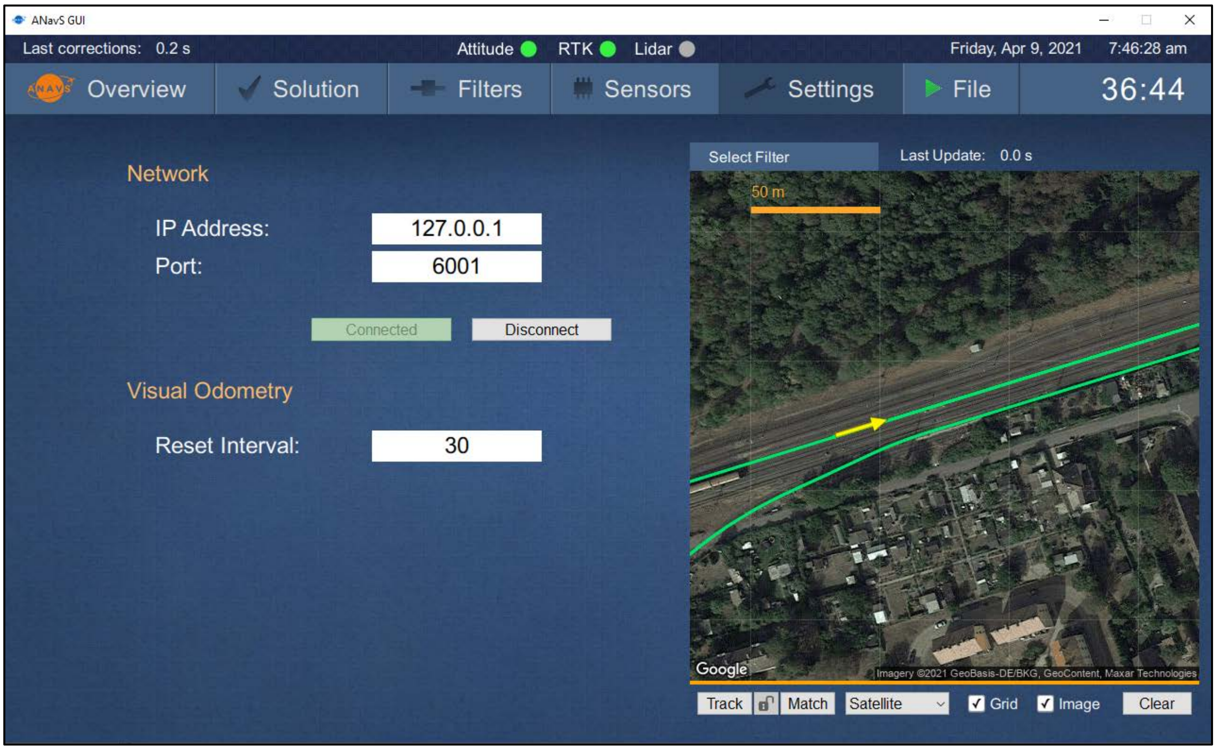


Figure 4: Defining the TCP/IP connection of the Positioning System for data streaming.

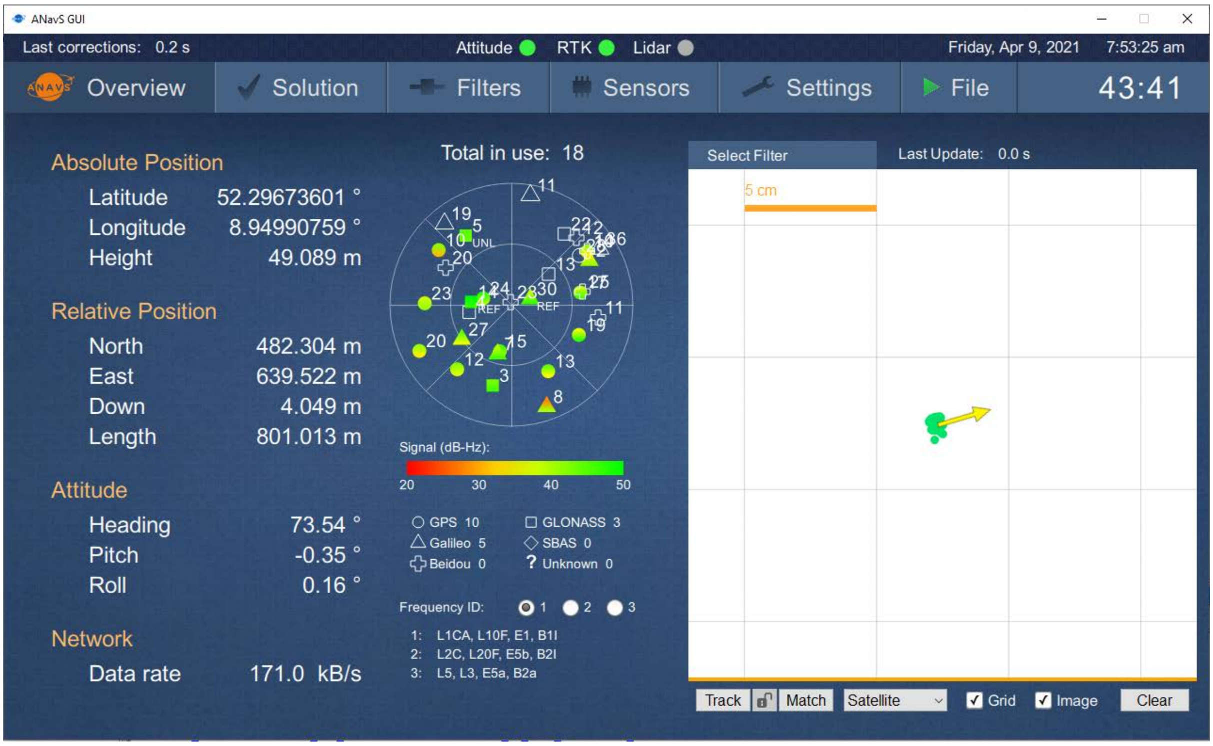


Figure 5: Positioning Accuracy in Centimeter-Level.

Figure 6: Phase-Residuals and many more information about the internal Kalman filter states.

Hints for ANavS® GUI handling:

- A Left-Mouse clicking in the Google-Earth plot zooms-in.
- A Right-Mouse clicking in the Google-Earth plot zooms-out.
- The map through the Google-Earth API is only visible with scale-level 5 meter or higher. Below only a withe map with scaling is visible.
- In the Tab *“**Settings**”*, one can define the IP-address of an ANavS Positioning System to which the GUI should connect.
- The *“**Data rate**”* shows the amount of solution output data streamed to your Laptop/PC. With a successful connection, the data-rate should be always greater than zero.
- The *“**Relative Position**”* shows the baseline-vector from RTCM/RTK Reference Station to your Rover.
- The *“**Last corrections**”* in the left upper corner shows the time since the last RTK correction data was received. The counter should be under 10 seconds to get best RTK performance. If no counter appears but only “N/A”, there is no valid connection between the ANavS Positioning System and the selected RTK correction source. Please prove again your settings in that case.

Important to get best performance:

- The gray or red light for the Attitude-LED signals that the attitude-solution is not fixed with GNSS phase measurements. That means, there is NO highly accurate attitude information available.
- The gray or red light for the RTK-LED signals that the position-solution is not fixed with GNSS phase measurements. That means, there is NO highly accurate position information available.
- The orange light for Attitude/RTK signals that the sensor fusion solution lost the fixed state and the Kalman filters performs in a float mode.
- The green light for Attitude/RTK signal that the position and/or attitude is fixed with GNSS phase measurements, and a highly accurate solution is available.
- To get best experience with the Positioning-Systems, please start movement only with float (orange signal) or fixed (green signal) mode.

2. Getting Started with the MS-RTK module

2.1. General

This guide is intended for first time Multi-Sensor RTK module (MS-RTK) users and provides an overview of how to handle with the required software, connect to and configure the MSRTK module, and acquire position and attitude solutions. By the end of this guide, you will be able to acquire a fixed RTK and Attitude solution using ANavS® MS-RTK modules. The steps in this guide should be performed outdoors.

Figure 7: MS-RTK module in industrial casing with touch panel (left) and 3D-printed casing (right)

2.2. Powering the MS-RTK Module

The MS-RTK module has three different options for power supply which are explained in the following.

Important:
All options should deliver a minimum current supply of **2.1A@5V** (10.5 Watt) until hardware-version **msrtkv8**. From hardware-version **msrtkv9** onwards, all options should deliver minimum current supply of **3.5A@5V** (17.5 Watt).

The first option for power supply is via Powerbank (see **Figure 8**). For this option, please use a Powerbank with USB-C PD (power delivery mode)(Capacity: 10000mAh) and a USB cable with Typ-C connector to connect to the MS-RTK module.

Important: Don’t use the USB-Type-A connector for powering the MS-RTK module.

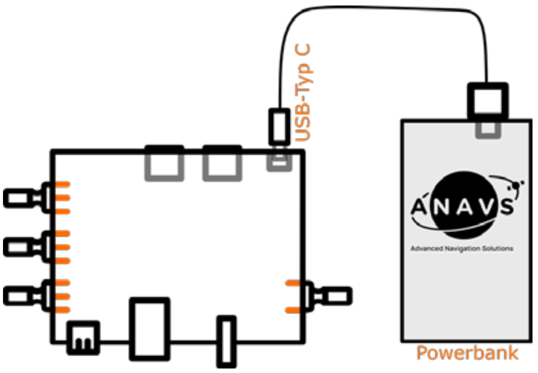


Figure 8: Power supply via Powerbank

The second option for power supply is via standard 230V AC Power plug (see Figure 9). Please use the delivered Power adapter and the USB cable with Typ-C connector at one end.

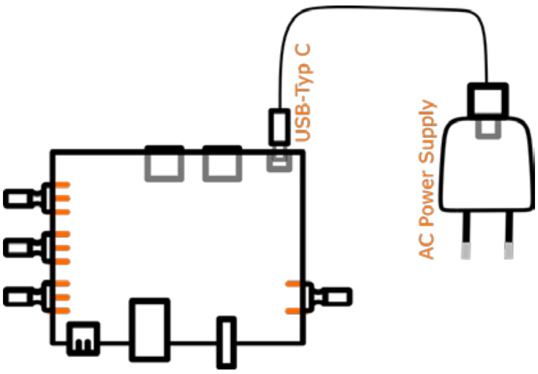


Figure 9: Power-Supply with AC Power Plug

The third option for power supply is via wires (see Figure 10). Please take care of the polarity (+/-) and the allowed voltage-range of 9V – 24V.

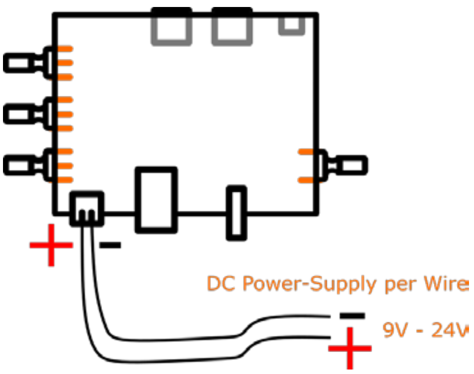


Figure 10: DC Power-Supply per Wires

2.3. Connections of the MS-RTK Module

The following section describes the different standard connectors and interfaces of the MS-RTK module. Figure 11 shows the antenna-connections with up to 3 GNSS antennas/receivers. Please connect for a One-Antenna setup to GNSS 1, for Two-Antenna setup to GNSS 1+2 and for a Three-Antenna setup to GNSS 1+2+3.

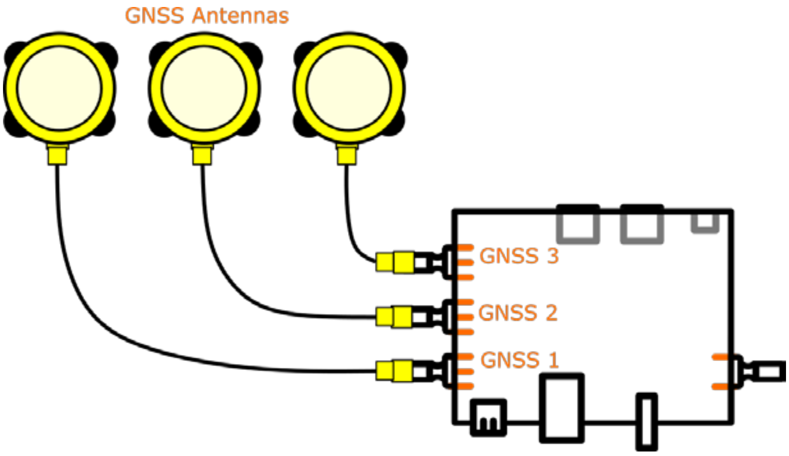


Figure 11: GNSS Antenna connections

Figure 12 shows the standard connectors of the casing:

- **SMA Connectors for GNSS**: As already described in Figure 11, on the left side of the board are the connectors for the GNSS antennas. Please take care to connect in the appropriate order (GNSS 1, GNSS 2, GNSS 3).
- **SMA Connector for LTE/Mobile Network**: Please connect the delivered LTE Antenna in case of using the integrated mobile network chip for internet access (for example to receive correction data from your RTK Reference Station).
- **USB-Typ C for Power-Supply:** As already described, the USB-Typ-C connector is used for the Power-Plug or Powerbank for power supply.
- **Camera Interface 1/2:** The interfaces for ANavS® visual odometry sensor (VIS). Camera 1 can for example be used for the forward movement direction and Camera 2 for backward movement direction.[1]
- **CAN:** The CAN- 2.0A Interface is used for receiving vehicle data for example for wheel-speed information and to output the sensor-fusion solution. More information about adjusting DBC-files can be found in chapter 2.7.2 and chapter 8.

[1] The Camera-Interfaces are only available until hardware version MSRTKv8.

- **USB-Interface:** The standard USB interface can be used for example for data-storage, Wi-Fi-dongle, LTE-dongle, data-transmission, etc.
- **Ethernet:** The ethernet-port can be used for internet/network-connections to stream for example the ANavS sensor fusion solution.
- **Power-Supply per Wires:** As already described in Figure 10, the module can be powered with DC-voltage (9V – 24V) via wires.

Special interfaces and pins like UART, FPGA for incremental-decoder, PPS-Signal and GPIOs are not forwarded to the casing and need special customer adjustments.

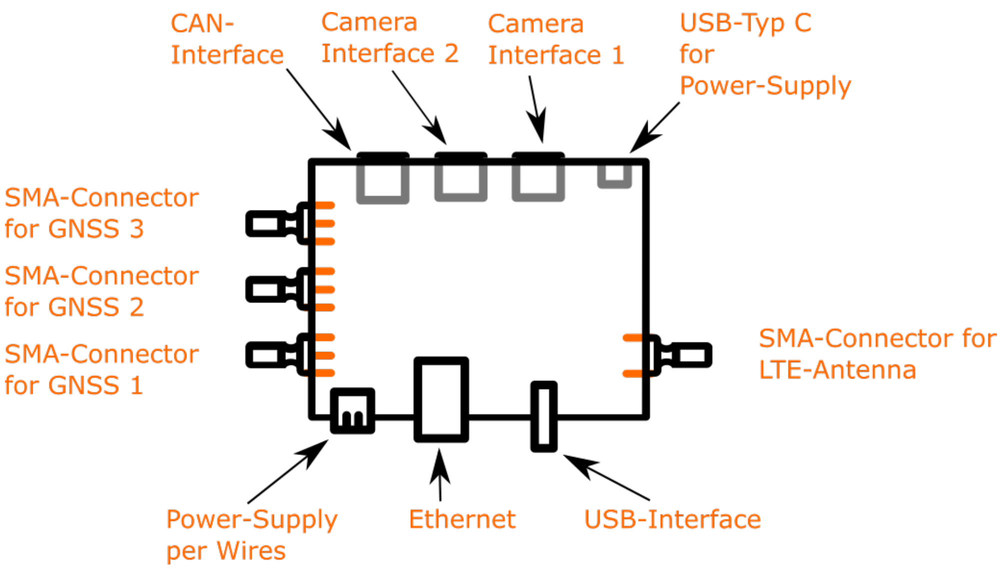


Figure 12: Standard interfaces lead to the casing

2.4. The Setup for RTK- and Attitude-Determination

This chapter describes a typical setup of the MS-RTK module on a rover platform (car, robot, UAV, etc.). The heading and pitch of a vehicle can be derived from the orientation of the baseline between a base and a rover antenna when both antennas are attached to the vehicle. The base GNSS-antenna is connected to the first GNSS-receiver configured as RTK antenna. The second and third GNSS antenna is connected to the second and third receiver configured as Attitude antennas. This is illustrated in Figure 13.

With three GNSS-antennas on top of the car/rover the software can calculate the yaw, pitch, and roll angle of the rover in a very accurate way without the need of movement. The RTK correction data is typically streamed from an ANavS® RTK Reference Station or from an external service-provider via Ethernet, LTE or Wi-Fi connection. The RTK-Baseline defines the centimeter-accurate position of your rover.

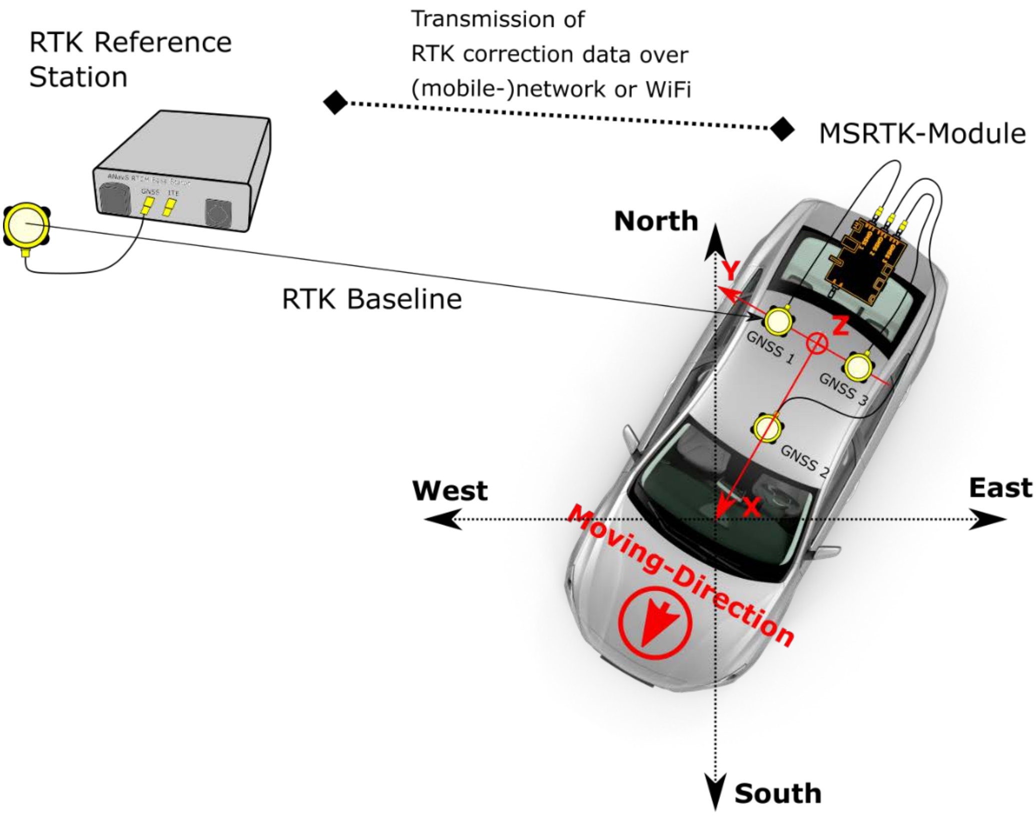


Figure 13: Typical setup on a car. The red coordinate frame indicates the rover's body-frame. The black coordinate-frame indicates the local navigation-frame (ANavS is using the NED-frame).

2.5. GNSS Antenna Placement Guideline

This is a very important step of the setup and has direct impact on the Position- and Attitude performance of the sensor fusion. The placement of the GNSS antennas defines the attitude-baseline, that means the yaw, pitch, and roll angle of your rover. Please mount the antennas in accordance with your use-case and carefully measure the distances between the GNSS antennas (measurement-error <= 1 cm). The configuration of the sensor fusion with these measured distances is done in the ANavS® Wizard and is described in the section 2.7.5.

Please pay attention to the following:

- The minimum distance between two GNSS antennas is 30 cm.

- Please note that the attitude accuracy increases with the distance between the GNSS antennas (sigma=0.25° absolute attitude-accuracy per meter antenna spacing). That means at 2-meter baseline-length a sigma of 0.125° for the heading/pitch/roll.
- Please align your antennas in the same way to minimize the impact of antenna phase center offsets. The high-grade antennas have typically an arrow marked on the bottom or rear side of the antenna. The orientation of the low-cost patch antennas is simply defined by the orientation of the cable-connector.
- Please consider and measure also a height-offset between the mounted GNSS antennas. We recommend a placement at the same height level for the beginning as this prevents any sign errors of the differential height and typically enables the best performance.
- For setups with three GNSS antennas (3D-Setup for yaw, pitch, and roll angle determination), please make sure that distance measurements in perpendicular directions are having a 90° angular spacing as otherwise the distance measurements do not fit to the actual geometry. This would prevent any reliable solution.

2.6. MS-RTK module Placement Guideline

The following Figure 14 shows a placement example of the MS-RTK module and GNSS antennas in the body-frame of your rover (top-view).

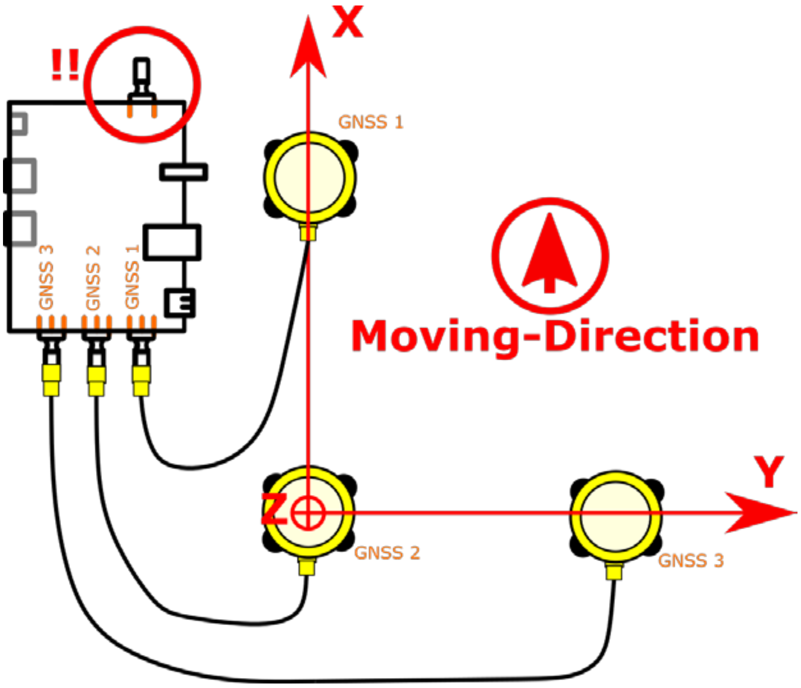


Figure 14: MS-RTK module and GNSS antenna placement in the rover's body-frame

Please pay attention on the following:

- The movement direction of your rover is defining the orientation of the x-axis.
- The MS-RTK module includes an IMU, which needs to be oriented in a certain manner: The MS-RTK module must be oriented such that the SMA-connector of the LTE/mobile-network is pointing towards the movement direction.
- To get the best performance, it is good practice to mount the MS-RTK module in the center of rotation of your rover.

2.7. The ANavS®-Wizard to configure the MSRTK Module

In the previous section, the user became familiar with the hardware and the setup of the MS-RTK module. This section describes the use of the **ANavS® Wizard** software. To be able to configure and receive data of the module, please connect with the Wi-Fi Access-Point "ANAVS_MSRTK_AP" (Password: *anavsrtk*) of your switched-on MS-RTK module. Please note that the boot time of the Linux-OS is approximately 1-2 min. As described in chapter 1.5, the default static IP of the MS-RTK module is:

- 192.168.42.1 or
- 192.168.43.1 (on older hardware)

2.7.1. Wizard Step-1

Figure 15 shows Step-1 of the ANavS® Wizard application. Please select the first option "Starting ANavS Sensor Fusion on MSRTK module".

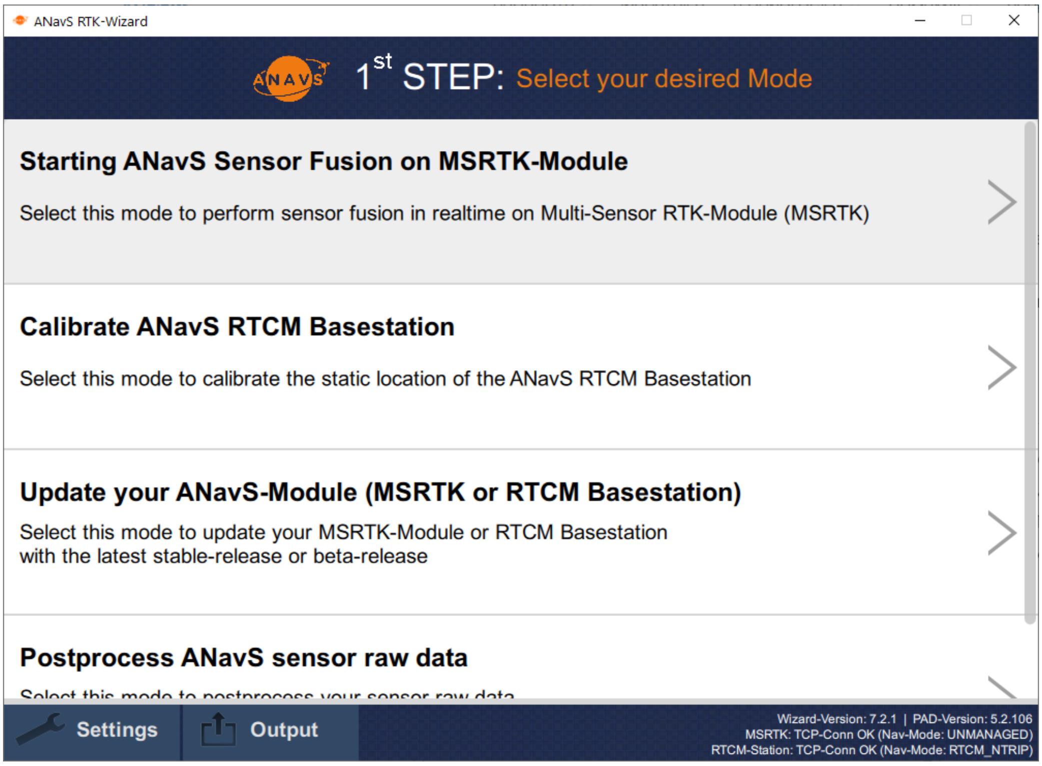


Figure 15: Step-1, Select your desired Modi

Hint: The Modi for Postprocessing ("Postprocess ANavS sensor raw data) is only available as part of a service contract or joint development-agreement.

2.7.2. Wizard Step-2

Figure 16 and Figure 17 shows Step-2 of the ANavS® Wizard application. In this step, the Wizard is proving the communication between the users Laptop/PC and the MS-RTK module. In case the error-dialog as shown in Figure 16 appears, please check again your Wi-Fi/Ethernet connection settings with the button in the bottom left corner ("Settings").

Figure 17 shows the typical window with correct Wi-Fi/Ethernet settings. One can adjust here the settings for the mobile network module, the Wi-Fi module, the Ethernet module and the CAN-transceiver module (described in chapter 8 in more detail).

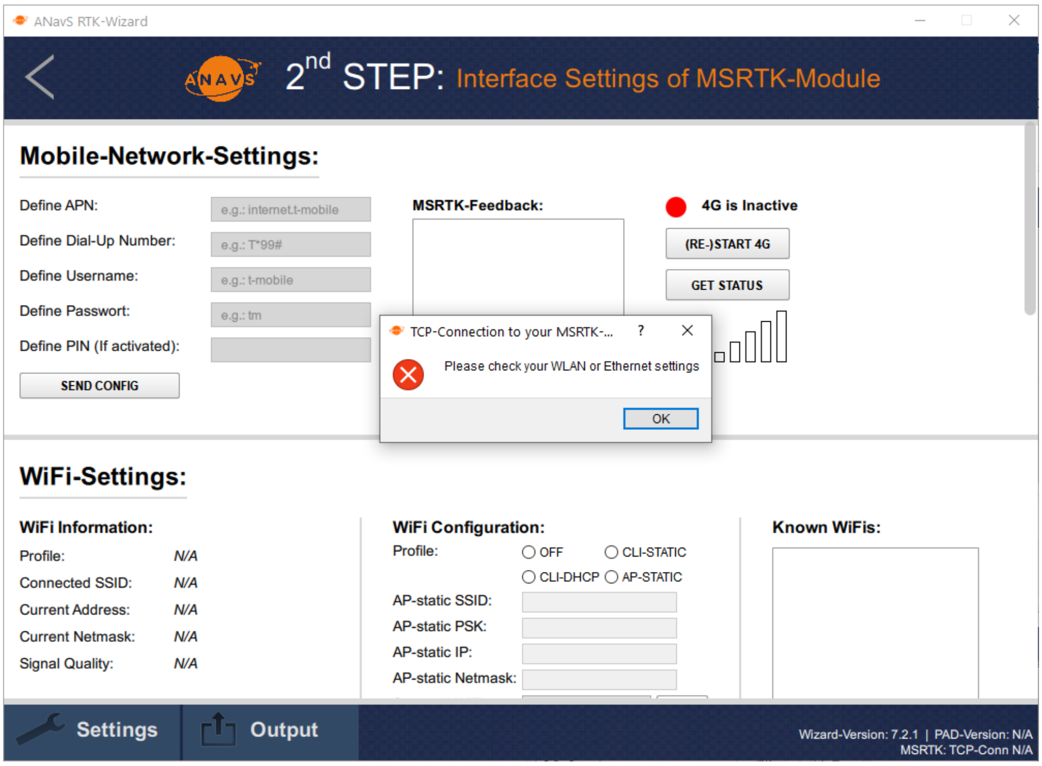


Figure 16: Step-2, Wi-Fi/Ethernet connection error message

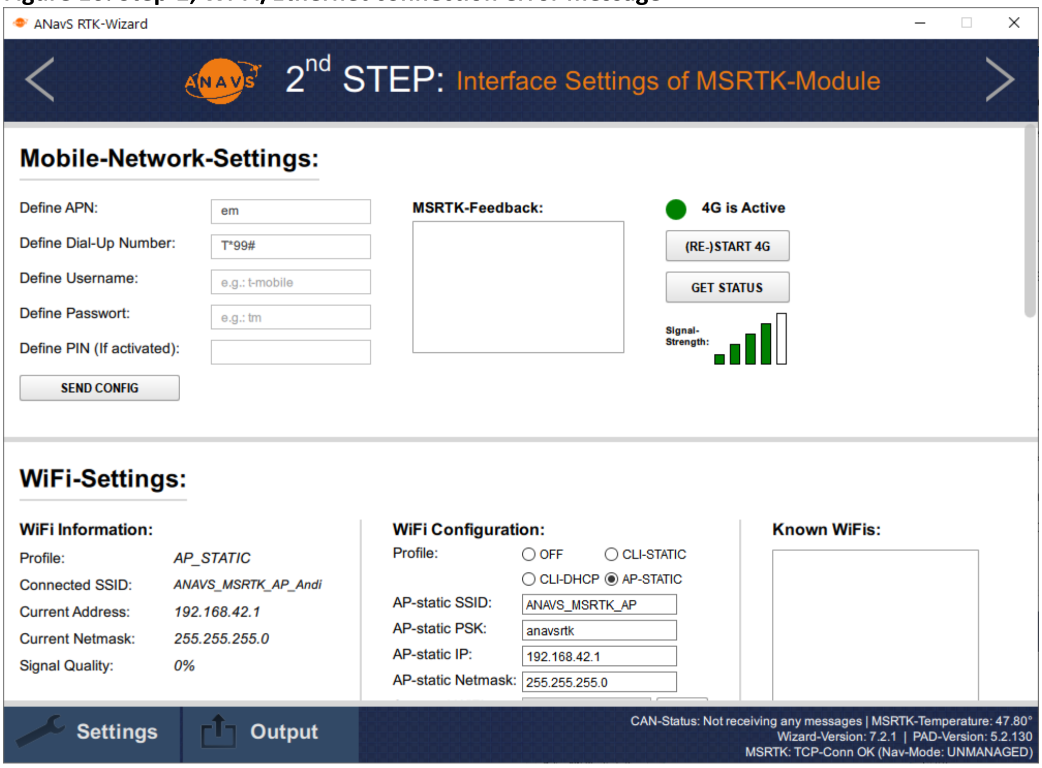


Figure 17: Step-2, Mobile-Network/Wi-Fi/CAN settings of MS-RTK module

Mobile Network Settings:

ANavS delivers all Positioning Systems with already equipped SIM-cards, which are provider-independent and dial-in into the best available mobile network at users' location. The region (Europe, North America, Asia, …) is selectable by the customer in the ordering-process. The fee of the SIM-card is part of a service-contract or directly bookable by ANavS. The following settings are needed for the SIMs:

- **APN:** em
- **Dial-Up Number:** T*99#

Own SIM-cards can also be used. With the 3D printed casing, the user can exchange the SIM-card without any help and extra cost. With the industrial casing, the user must send the SIM to ANavS before delivering the Positioning System. If this change has to be done afterwards, ANavS reserves the right to charge for the replacement.

In case of using an own SIM-card, please change the settings here accordingly and click afterwards to the button "**SEND CONFIG**" to transmit the new settings to the MS-RTK module. In the next step, click **"(RE-)START 4G**" button. If all provided information for the SIM-card are correct and LTE-reception is available at your position, the field "**4G Is Inactive**" becomes "**4G is Active**" and the color turns from red to green.

The configuration is saved to enable an automatic re-connection with the mobile network after each reboot.

Wi-Fi Settings (obsolete):

The left section is showing the current Wi-Fi settings. The right section is for the Wi-Fi configuration. The Wi-Fi-module can be used in four different Modis.

- **Access-Point (AP-STATIC Profile):**
  The standard/default way is the Access-Point (AP) profile. This means that the MS-RTK module is creating its own Wi-Fi-network with the SSID "ANAVS_MSRTK_AP" with password "anavsrtk" and static IP 192.168.42.1. Please use this mode for your first steps to get familiar with the system.
- **Client DHCP-Mode (CLI-DHCP Profile):**
  With this selected profile, the MS-RTK module tries to connect to an existing Wi-Fi network with a running DCHP-server running on it. To give the information to the MSRTK module, please use the "**SCAN"** Button and select the suitable SSID from the dropdown-list. After this, please define the Password in the dialog-window, activate the "**ADD**" radio button and click "**APPLY NEW CONFIGURATION**". It is possible to define a lot of known Wi-Fi-networks. But take care, you must know the assigned IP-

address to your MSRTK module in your network to be able to communicate with the ANavS® Wizard to the MSRTK module. The new IP must be signed in the message box by clicking on the "Settings"-button in the bottom left corner. A detailed description of how to find the IP-address of your MSRTK module is described in the ANavS knowledge base "Using the IP scanning-tool NMAP" [2]. Another knowledge base article is explaining how to broadcast RTK-Data from your ANavS RTK reference station directly via Wi-Fi to your MS-RTK module [3].

- **Client Static-Mode (CLI-STATIC Profile):**
  With this selected profile, the MS-RTK module tries to connect to an existing Wi-Fi network without a running DCHP-server running on it. The procedure for configuration is the same as for the CLI-DHCP profile.
- **Powered-Off Wi-Fi module (OFF Profile):**
  Use this mode to save power consumption or to reduce traffic in the Wi-Fi frequency range. BUT NOT RECOMMENDED.

Ethernet Settings:

The left section is showing the current Ethernet settings. The right section is for the Ethernet configuration. The Ethernet module can be used in three different Modis.

- **DHCP-Mode (DHCP Profile):**
  With this default setting, the Ethernet port is waiting to get an IP address of a DHCP server (e.g., from a router). After connecting the MS-RTK module via Ethernet cable with a router/DHCP-server, you can identify the MSRTK modules IP-address via the Ethernet information section in the Wizard window, the dashboard of your router or scanning the network as explained in the knowledge base article "Using the IP scanning-tool NMAP" [2].
- **Static-Mode (STATIC Profile):**
  Another option is to set a static IP for the MSRTK module and directly connect it with another device or laptop with same static IP range address.
- **Powered-Off Ethernet port (OFF Profile):**
  Use this mode to save power consumption. BUT NOT RECOMMENDED.

CAN Settings:

[2] Using the IP scanning-tool NMAP: https://anavs.com/knowledgebase/using-the-ip-scanning-tool-nmap/

[3] Broadcasting RTCM-Data for MSRTK Modules: https://anavs.com/knowledgebase/publishing-rtcm-data-for-msrtk-modules/

CAN is a robust and widely spread data bus standard which is among other applications also used in almost all modern vehicles for communication between the various controllers in it.

The MS-RTK Module comes with a CAN Interface that allows the user to input wheel odometry values and/or to access the solution data over that interface. The CAN- 2.0A Interface can be fully configured in the ANavS Wizard (Figure 18). The settings are hereby divided in two categories: the bus settings and the solution output (CAN-Output).

CAN Bus Settings:

- **Bus-Speed:** Select the Bit rate of the CAN bus. By default, 500 Kbit/s are selected.
- **Termination enabled:** CAN requires a 120 Ohm hardware termination at the last transceiver. The MS-RTK System has a built in switchable 120 Ohm termination which can be enabled by using this slider.
- **Bus mode:** The normal mode is the default mode in which the CAN Interface is fully operating. In the listen-only mode, the CAN-Controller does not transmit any data and does not acknowledge the received CAN-frames. This mode can be used to monitor the data bus without participate or interfere with the traffic on the bus. In the listen-only mode it is not possible to output solution information.
- **Output enabled:** This function is intended as an extra security layer to avoid unintentional writing on the CAN bus. It must be enabled to use the solution output functionality of the CAN Interface. Otherwise, it is recommended to switch it off.

Solution Output via CAN:

The CAN Interface can be used to receive the output of the position and attitude solution. The CAN Interface sends for each solution variable a unique message containing the value. The CAN address corresponds to the ID of the variable. The variables are bundled in groups which can be activated or deactivated by checking the corresponding boxes. As standard, each packet has a unique ID which is also shown in the table below. To change the IDs of the CAN messages (e.g., to avoid collisions with the information of other devices on the bus), there is the possibility to add an offset to all messages. To use the solution output via CAN, the bus must be configured in the normal mode and the output must be enabled (see also above section “CAN Bus settings”).

ID	Format	Name	Unit	Description
1	uint16	resCode	–	Result code bitfield, which keeps the system status and information.
2	uint16	week	–	Week number of the current epoch.
3	double	tow	s	Time of Week of the current epoch.
4	uint16	weekInit	–	Week number of the epoch when the system was started.

5	double	towInit	s	Time of Week of the epoch when the system was started.
7	double	lat	deg	Latitude.
8	double	lon	deg	Longitude.
9	double	height	m	Height
10	double	ECEF-X	m	X-position in ECEF-coordinate frame
11	double	ECEF-Y	m	Y-position in ECEF-coordinate frame
12	double	ECEF-Z	m	Z-position in ECEF-coordinate frame
13 – 15	3*double	b	m	Baseline in NED frame spanned by the position given by lat, lon and height, and by the position of the reference station.
16 – 18	3*double	bStdDev	m	Standard deviation of the baseline.
19 – 21	3*double	vel	m/s	Velocity in NED frame.
22 – 24	3*double	velStdDev	m/s	Standard deviation of the velocity.
25 – 27	3*double	acc	m/s²	Acceleration in body frame.
28 – 30	3*double	accStdDev	m/s²	Standard deviation of the acceleration.
31 – 33	3*double	att	deg	Attitude/Euler angles (heading, pitch, roll).
34 – 36	3*double	attStdDev	deg	Standard deviation of the attitude.
39 – 43	5*double	timing-Info	s	CPU-Load of used sensors. The sum (green line in the GUI) of elapsed time should not over 1 second (–> to slow processor). First double: Elapsed time GNSS; Second double: Elapsed time IMU; Third double: Elapsed time Baro; Fourth double: Elapsed time Odometry; Fifth double: Reserved
46	double	latency-info	s	Overall end-to-end positioning latency
49	double	gnssReception	–	Scalar, which indicates the GNSS signal reception. The value is between 0 and 20, where 20 is the best, i.e. very good conditions.
50	uint8	numSats	–	Number of satellites.

Table 1: CAN-Bus output messages

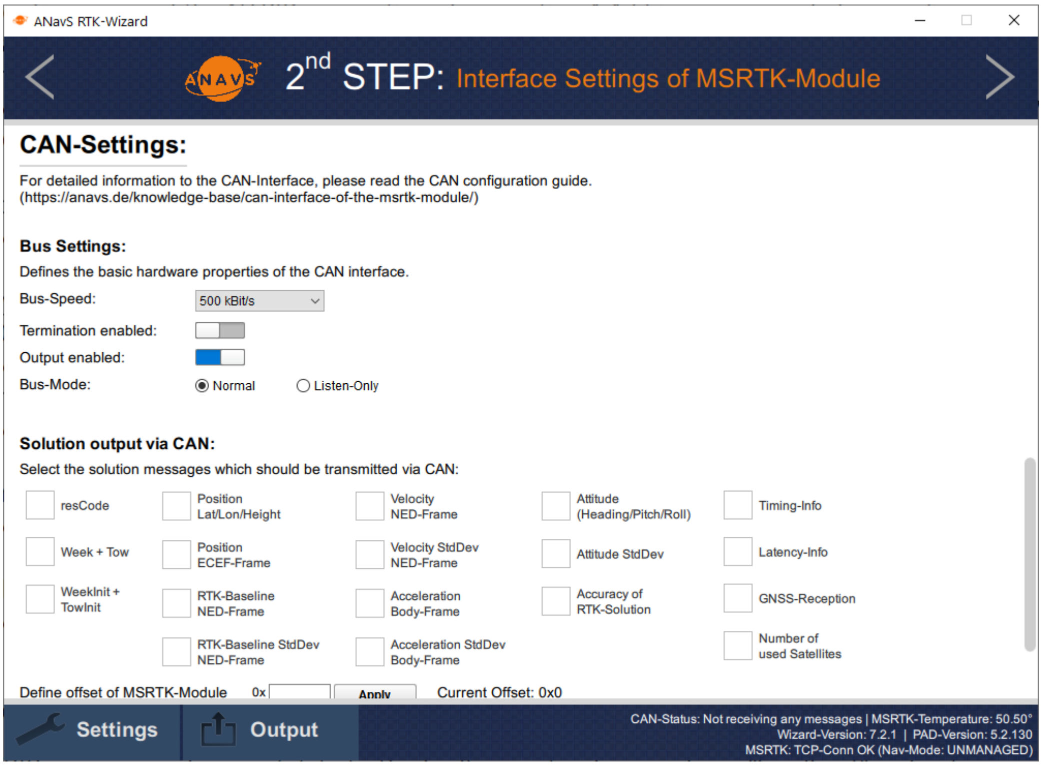


Figure 18: Step-2, CAN settings window of MS-RTK module

<u>Odometry input via CAN:</u>

The ANavS sensor fusion can handle different forms of vehicle odometry. Up to 5 variables can therefore be defined. These are either one, two or four independent wheel speeds, and the steering angle or another heading information of the vehicle in the vehicle frame. The algorithms inside of the sensor fusion software calculate from the different inputs the current velocity and heading information in the body frame of the vehicle for the positioning algorithm.

To adjust the CAN-Interface to user specific CAN messages, a dynamic CAN decoder is part of the MS-RTK module as command-line tool. The Dynamic CAN Decoder allows you to use the MS-RTK system with CAN signals from your .DBC file without sharing the file with third parties or ANavS. The DBC-generation on the MS-RTK module is described in detail in chapter 8.

2.7.3. Wizard Step-3

The Figure 19 shows Step 3 of the ANavS® Wizard application. The user needs to define the number of used GNSS antennas mounted on the rover respectively screwed on the MSRTK module.

The impact of user's selection:

1-Dimensional: The attitude is estimated with movement and coupled with the IMU-gyroscope and accelerometer (one GNSS antenna connected). With this setup, you need some rover dynamic (curves, circles) to get an accurate attitude information of your rover.

2-Dimensional: The attitude (yaw and pitch angle) is already determined without movement using fixed carrier-phase GNSS measurements and coupled with the IMU-gyroscope (two GNSS antennas connected).

3-Dimensional: The attitude (yaw, pitch, and roll angles) is already determined without movement using carrier-phase GNSS measurements and coupled with the IMU-gyroscopes (three GNSS antennas connected).

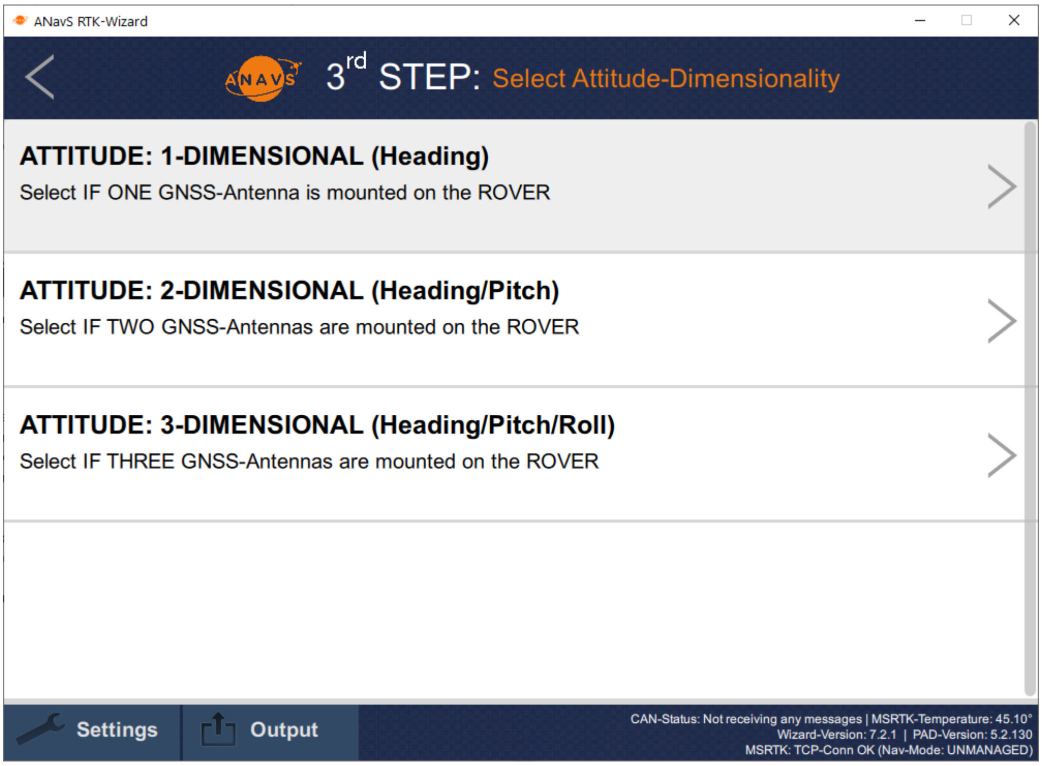


Figure 19: Step-3, Select Attitude-Dimensionality

2.7.4. Wizard Step-4

The next step proves the GNSS antenna connection and if the count of founded GNSS antennas match with the previous selected Attitude dimensionality (Step-3). The user can only go forwards if it matches in a proper way.

The following circumstances would prevent a successful GNSS-antenna connection:

- **Failure in Antenna-Status:** The positioning system need only some more boot-time for the OS and some time for gather satellite information (30 – 90sec).
- **Failure in Antenna-Status:** If the antenna-Status problem stays the same after some retries, to long antenna cables could lead to a missing recognition of the antenna from the GNSS-receiver side. The text field “Antenna-Status” shows **ERROR** or **SHORT** in that case.
- **No Data received/ No Satellites visible:** Please check this step with GNSS antennas outdoor.

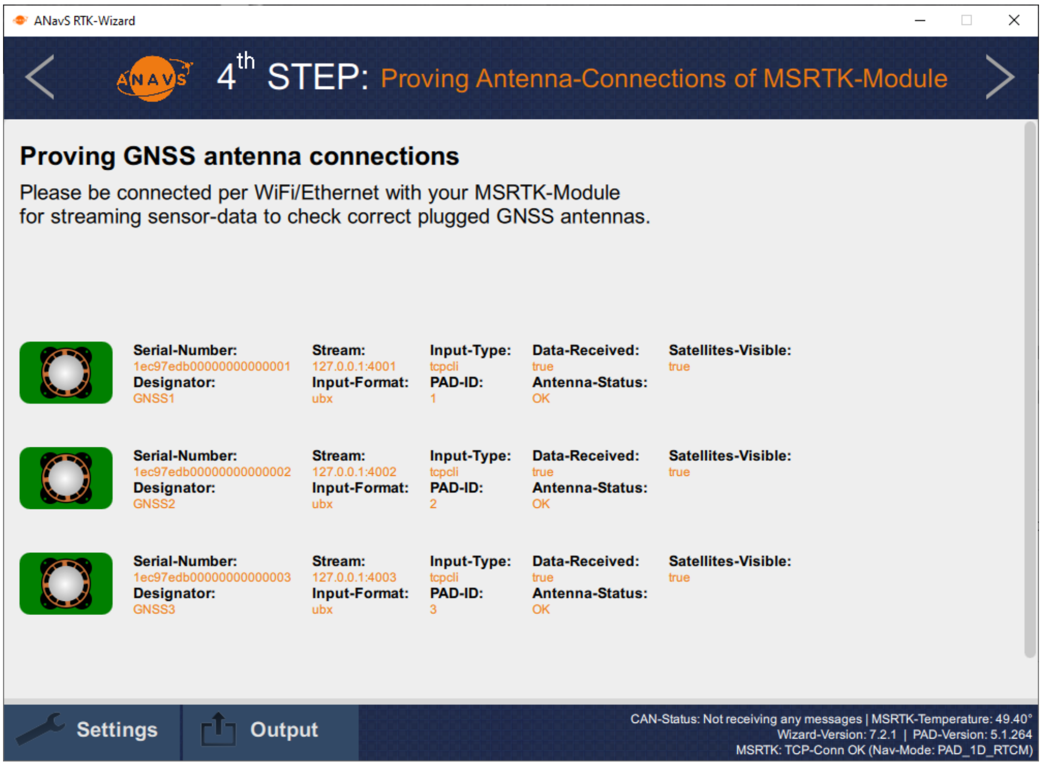


Figure 20: Step-4, Proving Antenna-Connections of MS-RTK module

2.7.5. Wizard Step-5

The following Figure 21 shows the placement input of the users GNSS antennas in the body-frame of your rover (top-view). Each Text field needs input, before proceeding with the next steps.

Please pay attention on the following:

- The x-direction shown in graph/coordinate-frame defines the movement-direction of your rover
- Please measure the distances as accurate as possible. The measurement-error should be below 1 cm
- Defining the z-Axis corresponds to the right-hand-rule. The thumb shows in movement-direction
- For setups with three GNSS Antennas, please use a right-angle measurement-tool

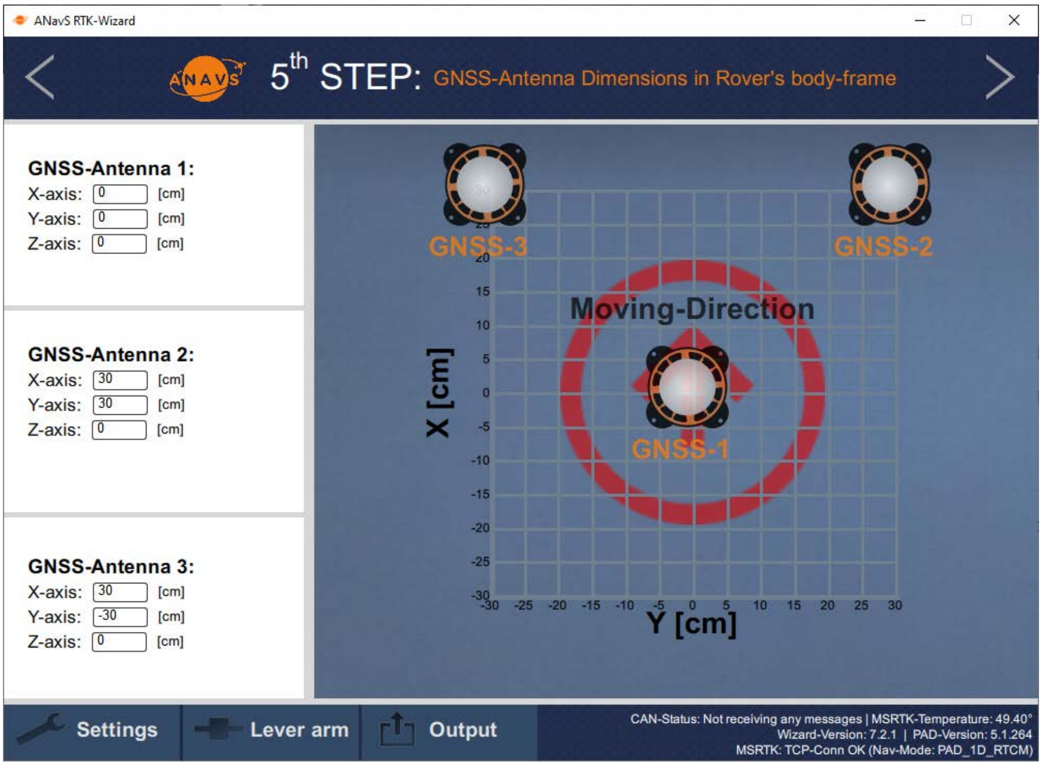


Figure 21: Step-5, GNSS-Antenna Dimension in rover body-frame

In addition, the lever arms of the other sensors can also be configured in this step. Please open the corresponding window "Lever arm" shown in the bottom of this step. Figure 22 shows the input-options.

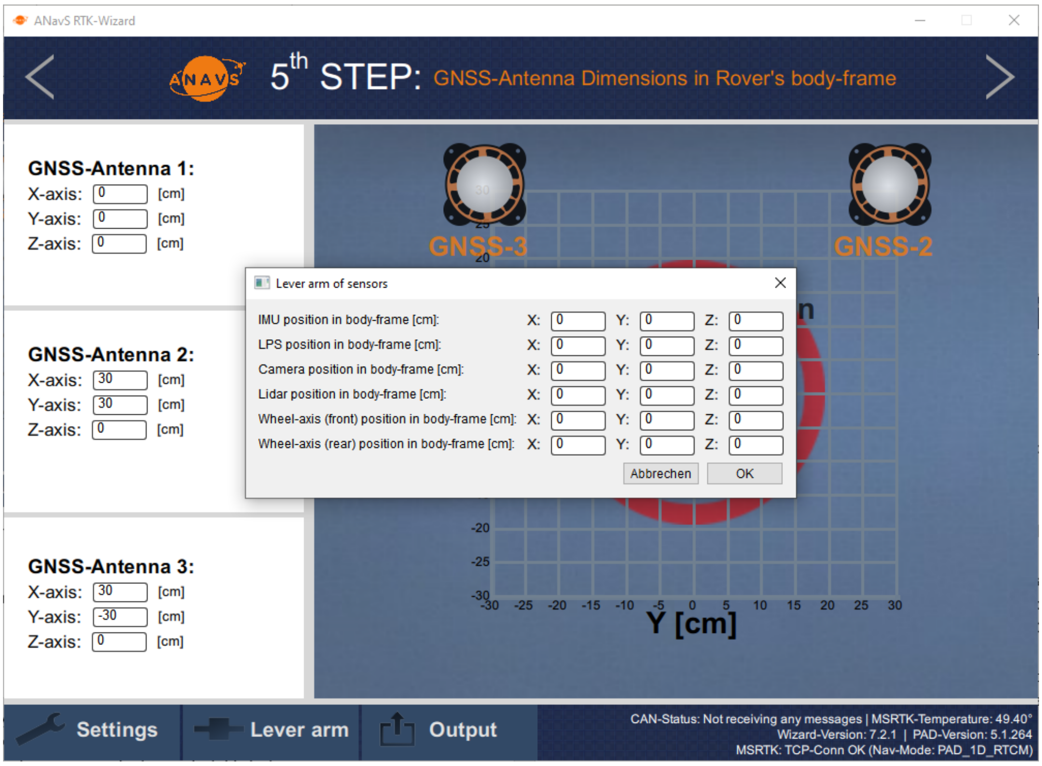


Figure 22: Step-5, configuration of additional sensor lever arm

2.7.6. Wizard Step-6

Step 6 is used for defining the input-stream for RTK correction data. The source could be your own ANavS RTK Reference Station, third-party reference stations or external service provider like SAPOS or Axio-Net. The nomenclature for a suitable RTK input-format notation is given in the Wizard-Window. To facilitate the user input, the last three streams are cached in a selectable history.

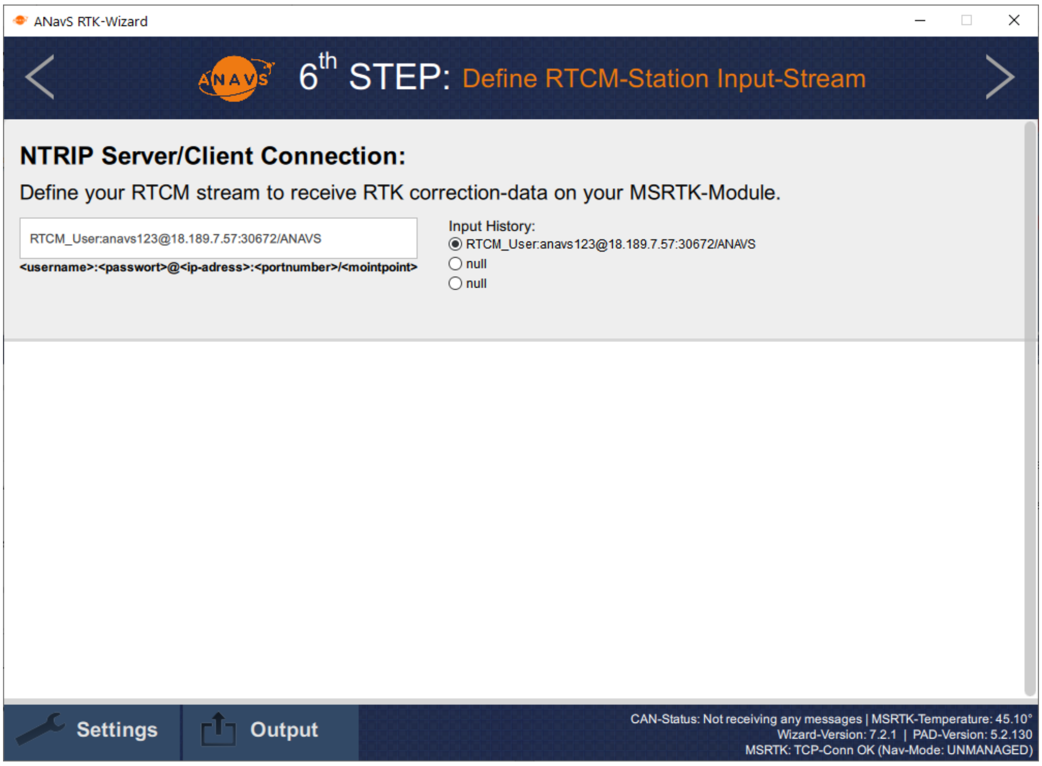


Figure 23: Step-6, Define RTCM/RTK Reference Station Input-Stream

2.7.7. Wizard Step-7

The ANavS® Sensor Fusion Framework is customizable with some specific a priori information.

- For using a priori information about the reference station, an input-option is given in this step. The user can fill the dimension in the NED (North-East-Down)-Frame format for using this mask. Additionally, the accuracy of the measurement can be set and needs to be activated with the appropriate button.
  This input is NOT mandatory: Use this input only if the information is exactly known and the user is introduced in the NED-frame and how one can set this parameter in a correct manner.
- The additional setting “**Up-Velocity**” is for constraining the velocity mainly in the horizontal plane. It’s recommended to activate this option for applications like automotive or robotics. Please deactivate this option for UAV-applications or something similar.
- The additional setting “**Heading<->Velocity**” is for constraining the velocity mainly to the heading direction. It’s recommended to activate this option for applications like

automotive or robotics. Please deactivate this option for UAV-applications or something similar.

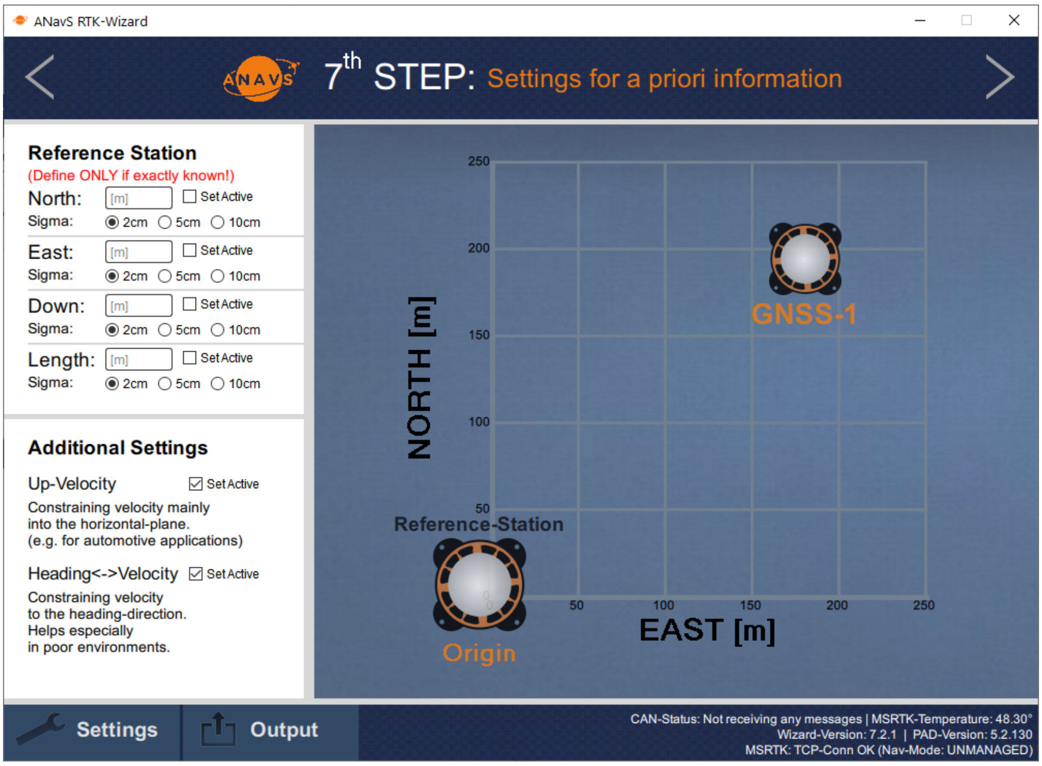


Figure 24: Step-7, Settings for a priori Information

2.7.8. Wizard Step-8

In the last step of the Wizard, the user can start the ANavS® sensor fusion with the green start-button. Before starting, please check further settings:

- The checkbox *"**Enable Save Solution File**"* activates recording the Realtime sensor fusion solution in a file. The format of the file depends on the selected type of solution output. Furthermore, the user gets a converted KML-file, which gives the user the opportunity to see the most interesting information (position, attitude, velocity, and acceleration) in a Google-Earth plot. The files are saved in ***<UserPath>/Documents/AnavsWizardAppData/output_data***. With the button "**Output**" on the bottom of the Wizard, the user can directly step to the generated output-folders. Each recorded dataset is saved in one own folder with the naming "**YYYYMMDD_HHMM_UTC**".
- The checkbox *"**Enable Save Raw Data Files**"* activates recording of all processed sensor data (GNSS, IMU, Barometer, Odometry, Visual-Odometry, …) with highly

accurate timestamps to use the data for postprocessing. The files are saved in ***<UserPath>/Documents/AnavsWizardAppData/output_data***.
With the button "**Output**" on the bottom of the Wizard, the user can directly step to the generated output-folders. Each recorded dataset is saved in one own folder with the naming "**YYYYMMDD_HHMM_UTC**".

- The checkbox *"***Enable Odometry (via USB)***"* is used for enabling the Odometry-Input via USB-Typ-A. Only with activated checkbox, the tightly coupled sensor fusion is using this input sensor data.
- The checkbox *"***Enable Odometry (via CAN)***"* is used for enabling the Odometry-Input via CAN. Only with activated checkbox, the tightly coupled sensor fusion is using this input sensor data.
- The checkbox *"***Enable Autostart of Navigation-Service***"* effects an automated start of the sensor fusion after switching-on the MS-RTK module with the last user-configuration. To see the solution in the ANavS® Visualizer, start the program ***ANavS_GUI.exe*** in the folder **<Installation-Path>*/ANavS_Wizard/bin.***
- The checkbox *"***Enable Low-Latency-Mode***"* can be used for very time-critical applications. The software limits the used GNSS-signals and pushes the solution output in a strict manner.
- The checkbox *"***Enable Dynamic Attitude Fix***"* forces an Attitude-Fix with GNSS phase measurements not only in stand-still mode but also in movement. Applications with less stand-still phases should activate the checkbox.
- The option "**Type of Solution-Output**" is explained in chapters about **ANavS® Binary Solution Output Format** and **NMEA Solution Output Format** in XX and XX.
- The option "**Customer-Code**" is only for experts with appropriate support-level. The default-value is 0.
- The option "**Output-Rate**" is selectable with Low (5Hz), Medium(55-65Hz), and High(105-125Hz). The exact rate depends on the used sensors within the tightly coupled sensor fusion.

After pushing the green start-button for triggering the ANavS® sensor fusion on the MS-RTK module, the settings are stored on the module, the ANavS® Visualizer pops-up and the sensor fusion navigation service starts to run.

HINT: In case of an already running Navigation-Mode, the Wizard and Visualizer is only attaching to this process without restarting the Navigation-Service. Please stop and start again the Navigation-Service to perform with the newest settings.

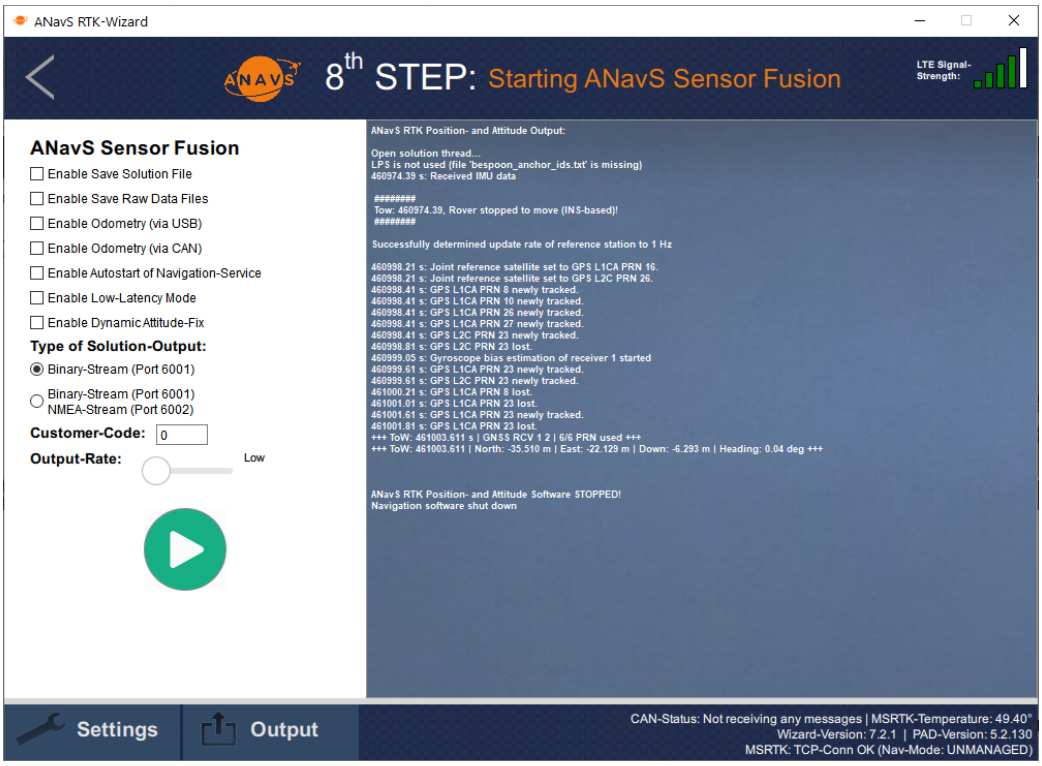


Figure 25: Step-8, Starting ANavS Sensor fusion Navigation Service

2.8. The ANavS®-Wizard to Update the MS-RTK Module

The ANavS® Wizard can also be used for updating the MS-RTK module. Trying this, the user must provide internet access to the MS-RTK module. The default way would be through the mobile network or through Ethernet with a connection to a router. The first step in the Wizard is selecting the option "Update your ANavS-Module (…)" on the starting page.

The next window is showed in Figure 26. The user has two options with the **Online-Updater**. Selecting the button "Stable Update", the user updates the MS-RTK (and also the RTK Reference Station) with the latest stable version on the ANavS repository. It is well tested but is not including all recent minor updates and sensor fusion improvements. Selecting the button "Beta Update", the user updates the MS-RTK (and also the RTK Reference Station) with the latest Beta version on the ANavS repository. It is less tested but is including all recent minor updates and sensor fusion improvements.

In case of problems with getting internet access to the MS-RTK module, ANavS is also providing an **Offline-Updater**. Using this option, please contact the support to get the recent

Update-Zip, load it in the Wizard (do NOT unzip this file) with the SEARCH button and click the update-button.

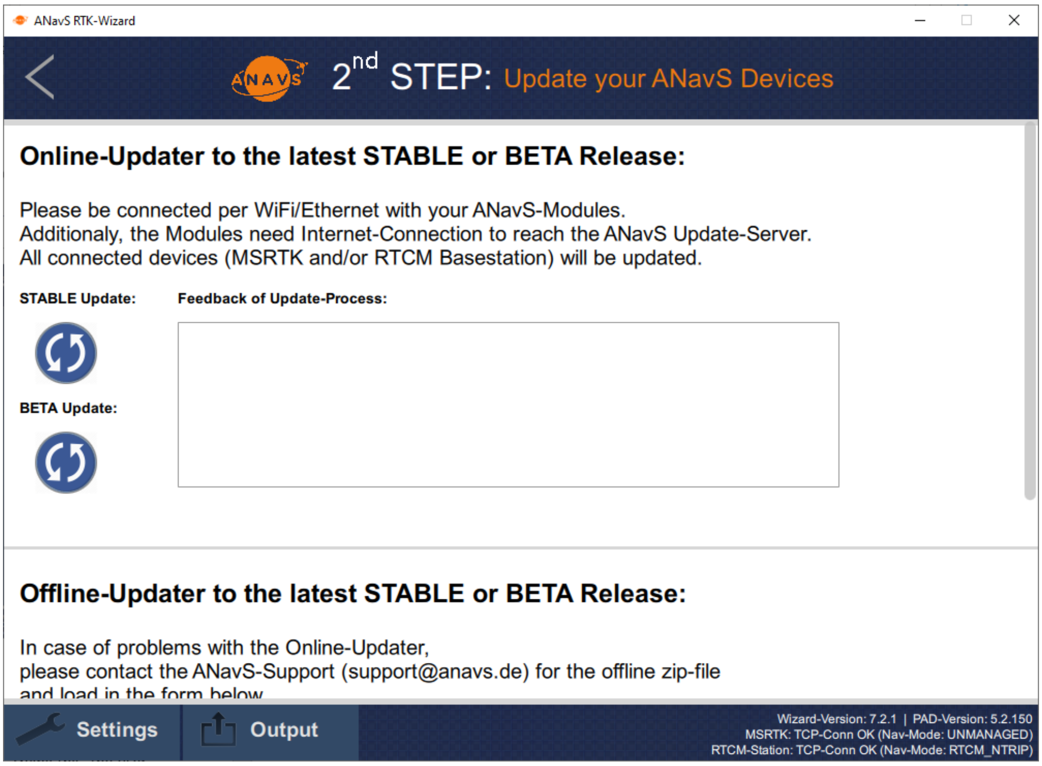


Figure 26: Update of the MS-RTK module with the ANavS Wizard

3. Getting Started with the RTK/RTCM Reference Station

This guide is intended for first time RTK/RTCM Reference Station users and provides an overview of how to handle with the required software, connect to and configure the Reference Station.

Figure 27: RTK/RTCM Reference Station in industrial casing with touch panel

3.1. Powering the RTK/RTCM Reference Station

The RTK/RTCM Reference Station can be powered with standard 230V AC-Voltage plug or with standard USB Type-C (e.g., 5V USB Powerbank with PD (Power-Delivery)).

3.2. The Setup for the RTK/RTCM Reference Station

Figure 28 shows the standard connections for the typical RTK/RTCM Reference Station setup:

- Please connect the GNSS antenna with the marked SMA connector to the Reference Station. The GNSS antenna must stay outside with open-sky environment (see Figure 29).
- Please connect the Wi-Fi antenna with the marked SMA connector to the Reference Station.
- Provide internet-access to the Reference Station for transmitting RTCM 3.2 messages. For this, please connect the station to a router or screw on the mobile network antenna.

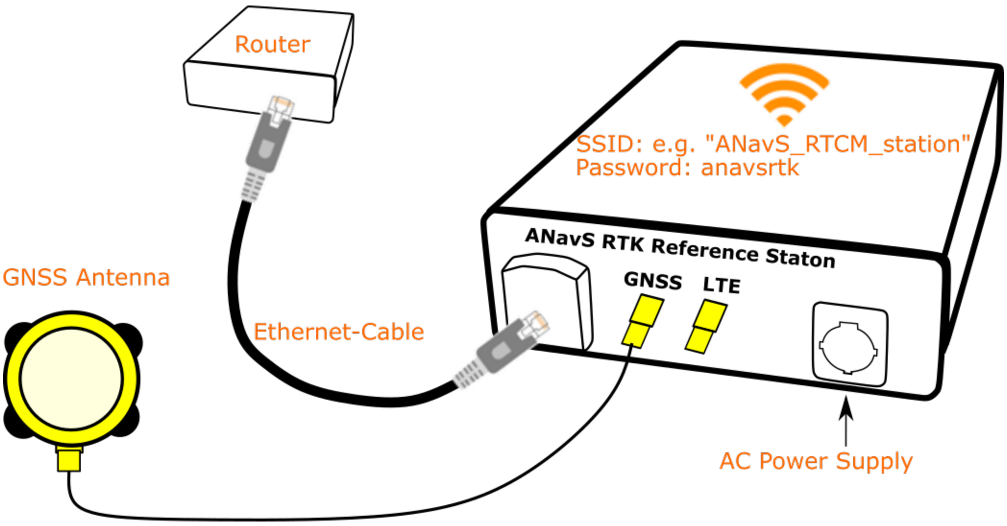


Figure 28: RTK/RTCM Reference Station connections

Recommendation: The GNSS antenna should be fixed mounted on position outside with best possible satellite visibility (see Figure 29). A recommended place would be the roof of a high building or similar places. The RTK correction data of the Reference Station are highly accurate for rovers within 15 km distance from rover (MS-RTK module) to Reference Station. A common way is to fix the Reference Station on a location where the user can calibrate the position once a time and don't change the position again.

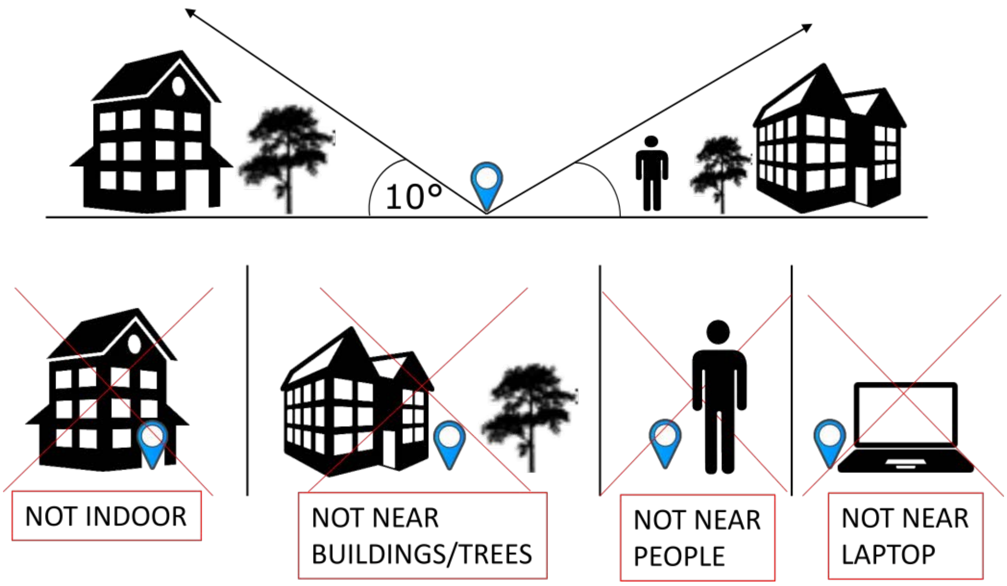


Figure 29: Reference Station placement guideline

3.3. The ANavS®-Wizard to configure the RTK/RTCM Reference Station

In the previous section, you became familiar with the hardware and the setup. This section describes the use of the **ANavS® Wizard** software. To be able to configure and receive data of the module, please connect with the Wi-Fi Access-Point “ANAVS_RTCM_AP” (Password: *anavsrtk*) of your switched-on Reference Station. Please note that the boot time of the Linux-OS is approximately 1-2 min. As described in chapter 1.5, the default static IP of the Reference Station is:

- 192.168.42.1 or
- 192.168.43.1 (on older hardware)

3.3.1. Wizard Step-1

For a precise absolute/relative position solution the Reference Station needs a one-time calibration before using it for the new position. Figure 30 shows Step-1 of the ANavS® Wizard application. Please select the second option “Calibrate ANavS RTCM Basestation”.

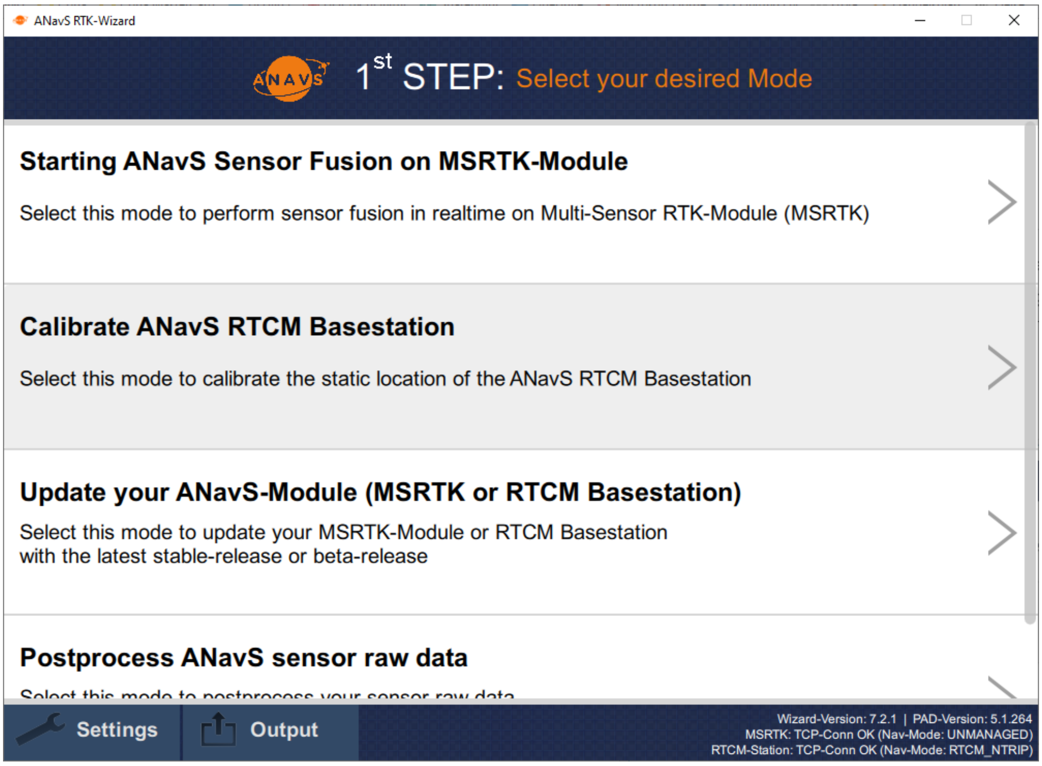


Figure 30: Step-1, Select the desired modus "Calibrate ANavS RTCM Base Station"

3.3.2. Wizard Step-2

Figure 31 shows Step-2 of the ANavS® Wizard application. In this step, the Wizard is proving the communication between the users Laptop/PC and the MS-RTK module. If the error-dialog as shown in Figure 16 appears, please check again your Wi-Fi/Ethernet connection settings with the button in the bottom left corner ("Settings").

On this settings-window one can adjust the settings for the mobile network module, the Wi-Fi module, and the Ethernet module.

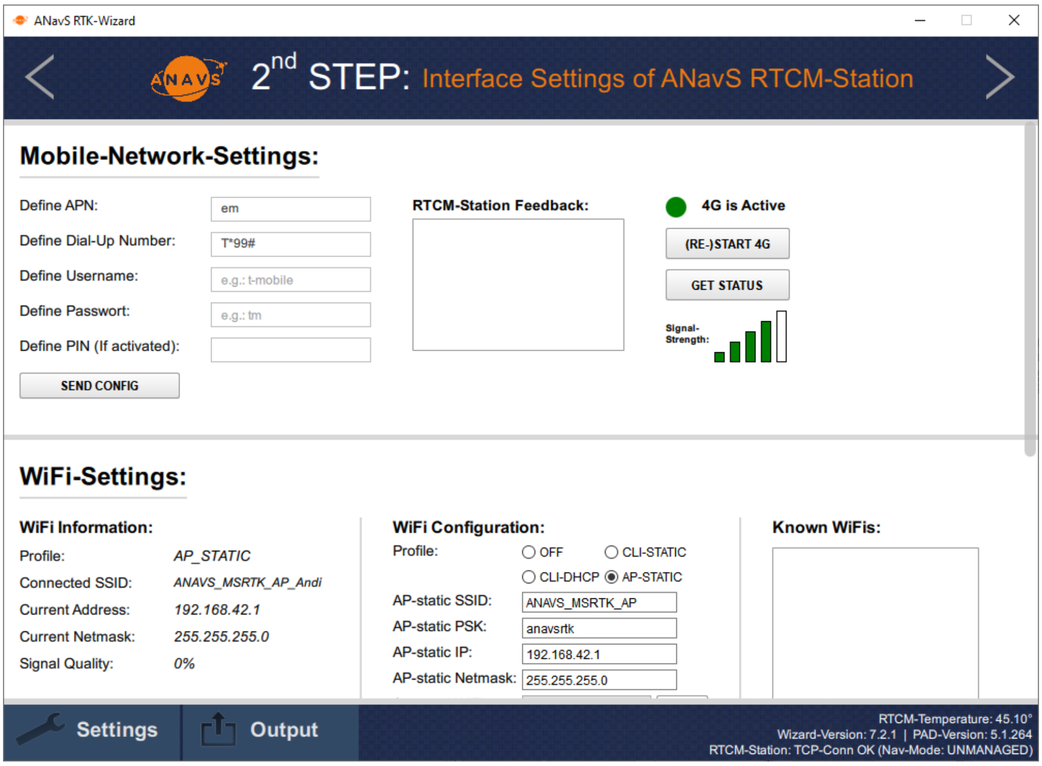


Figure 31: Step-2, Interface settings of ANavS RTCM Base Station

Mobile Network Settings:

ANavS delivers all Positioning Systems with already equipped SIM-cards, which are provider-independent and dial-in into the best available mobile network at users' location. The region (Europe, North America, Asia, …) is selectable by the customer. The fee of the SIM-cards is part of a service-contract or directly bookable with ANavS. The following settings are needed for the SIMs:

- **APN:** em
- **Dial-Up Number:** T*99#

Own SIM-cards can also be used. With the 3D printed casing, the user can exchange the SIM-card without any help and extra cost. With the industrial casing, the user must send the SIM card to ANavS before delivering the Positioning System. If it has to be done afterwards, ANavS reserves the right to charge for the replacement.

In case of using an own SIM-card, please change the settings here accordingly and click afterwards to the button “**SEND CONFIG**” to transmit the new settings to the MS-RTK module. In the next step, click **“(RE-)START 4G**” button. If all provided information for the SIM-card are correct and LTE-reception is available at your position, the field “**4G Is Inactive**” becomes “**4G is Active**” and the color turns from red to green.

The configuration is saved to enable an automatic re-connection with the mobile network after each reboot.

Wi-Fi Settings (obsolete):

The left section is showing the current Wi-Fi settings. The right section is for the Wi-Fi configuration. The Wi-Fi-module can be used in four different Modis.

- **Access-Point (AP-STATIC Profile):**
  The standard/default way is the Access-Point (AP) profile. This means that the MS-RTK module is creating its own Wi-Fi-network with the SSID “ANAVS_MSRTK_AP” with password “anavsrtk” and static IP 192.168.42.1. Please use this mode for your first steps to get familiar with the system.
- **Client DHCP-Mode (CLI-DHCP Profile):**
  With this selected profile, the MS-RTK module tries to connect to an existing Wi-Fi network with a running DCHP-server running on it. To give the information to the MSRTK module, please use the “**SCAN”** Button and select the suitable SSID from the dropdown-list. After this, please define the Password in the dialog-window, activate the “**ADD**” radio button and click “**APPLY NEW CONFIGURATION**”. It is possible to define a lot of known Wi-Fi-networks. But take care, you must know the assigned IP-address to your MSRTK module in your network to be able to communicate with the ANavS® Wizard to the MSRTK module. The new IP must be signed in the message box by clicking on the “Settings”-button in the bottom left corner. A detailed description of how to find the IP-address of your MSRTK module is described in the ANavS knowledge base “Using the IP scanning-tool NMAP” [4]. Another knowledge base

[4] Using the IP scanning-tool NMAP: https://anavs.com/knowledgebase/using-the-ip-scanning-tool-nmap/

article is explaining how to broadcast RTK-Data from your ANavS RTK reference station directly via Wi-Fi to your MS-RTK module [5].

- **Client Static-Mode (CLI-STATIC Profile):**
  With this selected profile, the MS-RTK module tries to connect to an existing Wi-Fi network without a running DCHP-server running on it. The procedure for configuration is the same as for the CLI-DHCP profile.
- **Powered-Off Wi-Fi module (OFF Profile):**
  Use this mode to save power consumption or to reduce traffic in the Wi-Fi frequency range. BUT NOT RECOMMENDED.

Ethernet Settings:

The left section is showing the current Ethernet settings. The right section is for the Ethernet configuration. The Ethernet module can be used in three different Modis.

- **DHCP-Mode (DHCP Profile):**
  With this default setting, the Ethernet port is waiting to get an IP address of a DHCP server (e.g., from a router). After connecting the MS-RTK module via Ethernet cable with a router/DHCP-server, you can identify the MSRTK modules IP-address via the Ethernet information section in the Wizard window, the dashboard of your router or scanning the network as explained in the knowledge base article "Using the IP scanning-tool NMAP".
- **Static-Mode (STATIC Profile):**
  Another option is to set a static IP for the MSRTK module and directly connect it with another device or laptop with same static IP range address.
- **Powered-Off Ethernet port (OFF Profile):**
  Use this mode to save power consumption. BUT NOT RECOMMENDED.

3.3.3. Wizard Step-3

The next step proves the GNSS antenna connection. The user can only go forwards if it matches in a proper way.

The following circumstances would prevent a successful GNSS-antenna connection:

- **Failure in Antenna-Status:** The positioning system need only some more boot-time for the OS and some time for gather satellite information (30 – 90sec).

[5] Broadcasting RTCM-Data for MSRTK Modules: https://anavs.com/knowledgebase/publishing-rtcm-data-for-msrtk-modules/

- **Failure in Antenna-Status:** If the antenna-Status problem stays the same after some retries, to long antenna cables could lead to a missing recognition of the antenna from the GNSS-receiver side. The text field “Antenna-Status” shows **ERROR** or **SHORT** in that case.
- **No Data received/ No Satellites visible:** Please check this step with GNSS antennas outdoor.

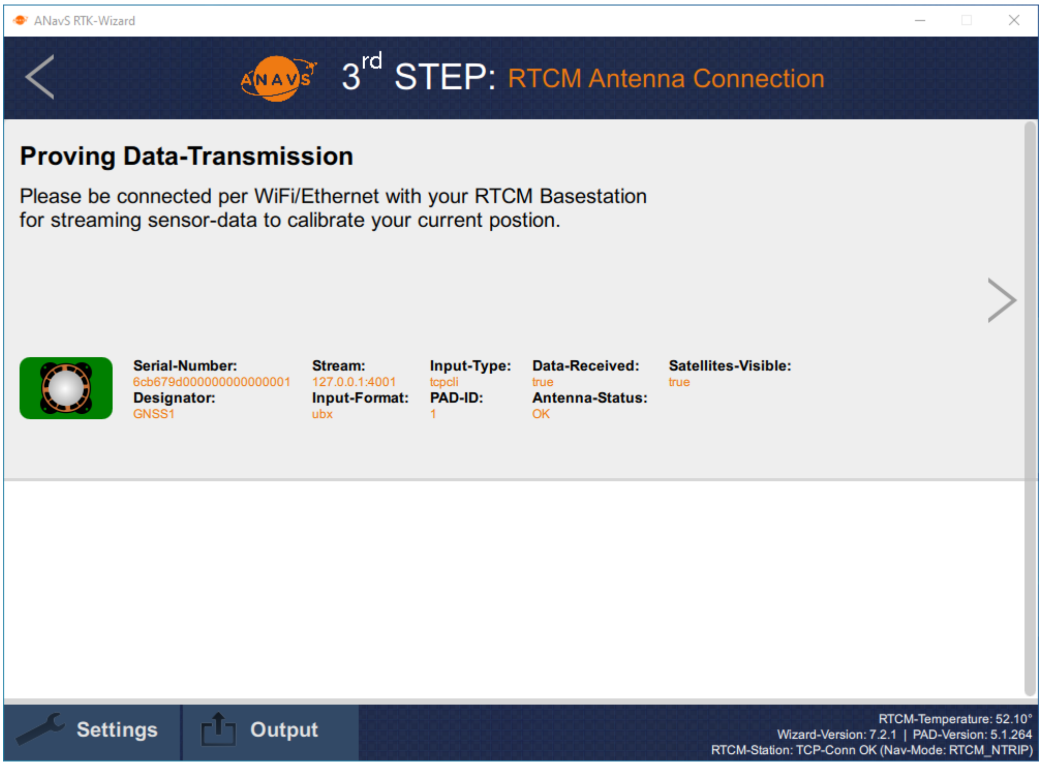


Figure 32: Step-3, Proving GNSS antenna connection

3.3.4. Wizard Step-4

The user has two options for calibrating the stationary position of the RTK/RTCM Reference Station:

- **External RTK correction data:** Use this option to calibrate your Reference Station with centimeter-accurate position. To do this, the user needs an external RTK correction input-stream from an appropriate correction-data service-provider with centimeter accuracy (e.g., SAPOS, Axio-Net). Depending on your service-level, ANavS® can do this also for you. The advantage of this mode is a precise relative and absolute position estimation of your rover equipped with MS-RTK module and its tightly coupled ANavS® sensor fusion framework.

NOTE: To stream the correction data from external service provider, your RTK Reference Station needs internet access (e.g., through the integrated mobile network module or ethernet connection to a router).

- **Filtered Least-Squares Position-Solution:** This is the standard way to calibrate a rough position estimation for the Reference Station. The user can do this without the need of additional services. It has no influence on the accuracy of the relative position-solution between rover (MS-RTK module) and Reference Station, but the absolute position includes a position-offset depending on the accuracy of the position of the RTCM base station.

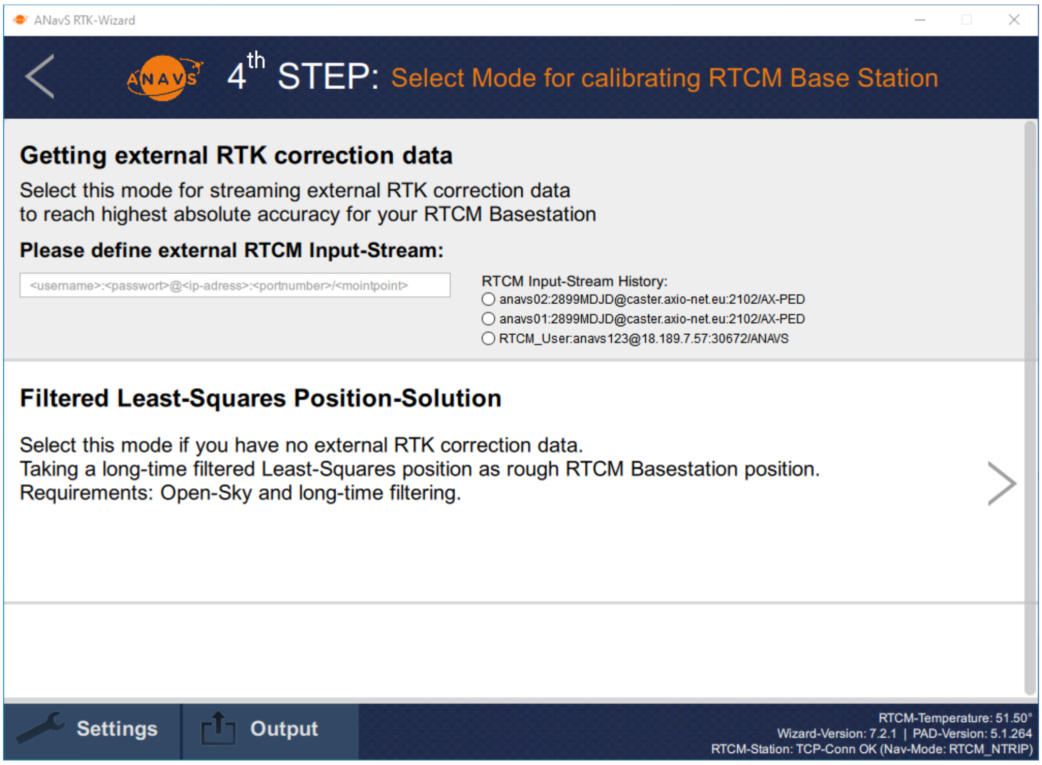


Figure 33: Step-4, select the mode for RTK/RTCM Reference Station position calibration

3.3.5. Wizard Step-5

Figure 34 shows Step-5 of the ANavS® Wizard for Reference Station calibration. Hereby, the user can define the error-bound which must be reached and the time for averaging after being below this defined error-bound. After attaining the limits, the calibration stops, and the position is stored permanently on the Reference Station (also after reboot of the system).

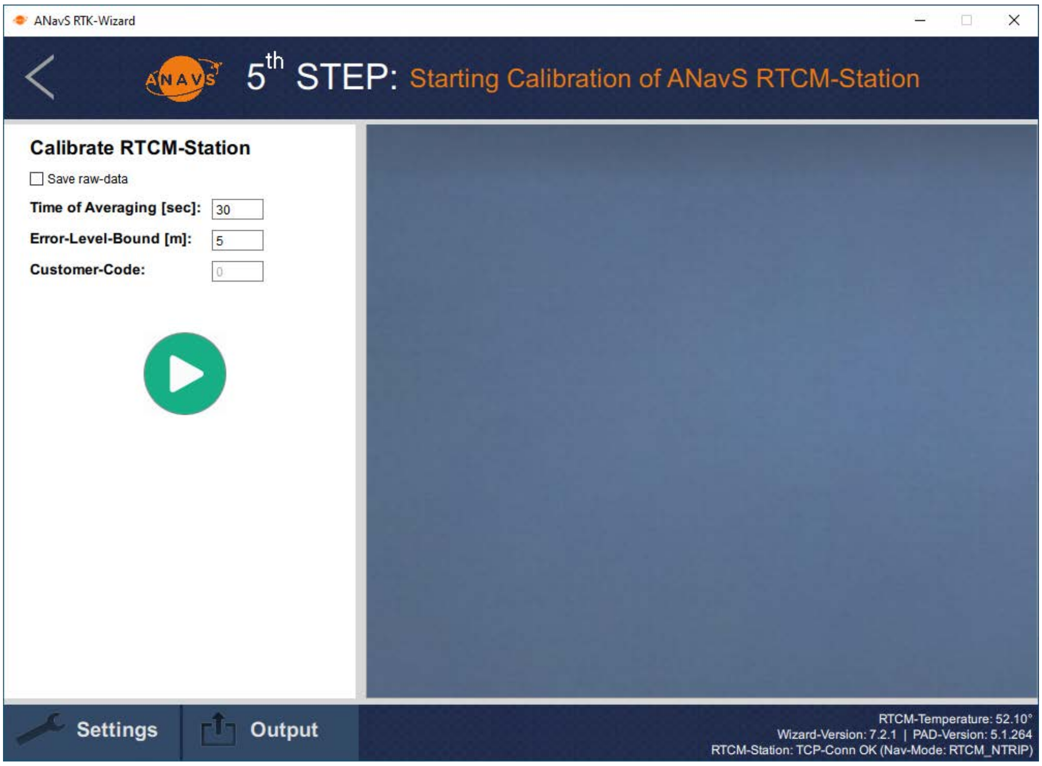


Figure 34: Step-5, Starting calibration process of Reference Station

3.4. Receiving RTCM-Messages from the RTK/RTCM Reference Station

The Reference Station provides an NTRIP-Server which converts the GNSS data into the standardized RTCM 3.2 Format and connects either to a local NTRIP-caster (on the Reference Station itself) or to a cloud-based NTRIP-caster, hosted by ANavS (without fee). To receive this RTK correction data from your Reference Station one could use the own local network or the ANavS cloud-based correction data service via internet-connection.

An example of a defined RTK correction data stream with the ANavS cloud-based correction data service is:

Username:	RTCM_User
Password:	anavs123
IP/URL:	customer-specific; info is included in the system delivery
Port:	customer-specific; info is included in the system delivery
Mountpoint:	ANAVS

This results in the following NTRIP input stream for your MS-RTK module or ISP:
RTCM_User:anavs123@**<customer-specific-IP>**:**<customer-specific-Port>**/ANAVS

The default setting of the Reference Station is using the cloud-based NTRIP-Caster, which ensures the usability independent of any company's network policy (e.g., port-forwarding). The local NTRIP-caster setup is activatable via the global settings file, described in the following subsections.

The used RTCM 3.2[6] messages are the following:

Message-Type	RTCM 3.2	Description
1005	10s	ARP-Station coordinates, ECEF XYZ
1008	10s	Antenna-Type of the RTK Reference Station
1033	10s	Receiver- und Antenna-Type
1077	1s	GPS Observation data (MSM7)
1085	1s	GLONASS Observation data (MSM7)
1095	1s	Galileo Observation data (MSM7)
1125	1s	BeiDou Observation data (MSM7)
1230	10s	GLONASS L1 and L2 Code-Phase Biases

Other RTCM messages or other time-intervals are adjustable via the global configuration file ***<home/user>/device/settings*** on the Reference Station.

The **Range** of the ANavS Reference Stations are only limited by (mobile) network connection and the useful distance of RTK corrections from Reference Station to the rover (MS-RTK module or ISP), which is ~20 km.

3.4.1. Broadcasting RTCM-Data via NTRIP-Caster hosted by ANavS cloud service

It's the most comfortable way to broadcast and reach correction data over the internet (Ethernet, Wi-Fi, or mobile network) and the recommendation to bring the users RTK setup-up working. The RTK correction data is transmitted over internet-access to the ANavS cloud service with a running NTRIP-Caster and broadcasted on a specific IP-address and port-number.

The individual information, IP-address and port-number, is included in the delivered package and defined in the global customer settings file **/home/pi/device/settings** as follows:

[6] The Radio Technical Commission for Maritime Services (RTCM) is a US organization. Among other things, it pursues the goal of realizing internationally standardized data formats for the transmission of corrections for GNSS applications and making correction data available in real time.

```
RTCM.caster.host=<customer-specific-IP-Address>
RTCM.port=<customer-specific-Port>
```

To edit this file, please connect per SSH to the Reference Station. For the SSH-credentials, please ask the support.

3.4.2. Broadcasting RTCM-Data via local NTRIP-Caster

The following description shows broadcasting RTK correction data in a local network or via internet-access via a local NTRIP caster, running on the Reference Station. For receiving the RTK correction data, which are mandatory for RTK-Positioning, the RTCM station must be reachable via TCP/IP for the MS-RTK module or ISP.

Step 1:
Comment out (#) the following line in the global settings file **/home/pi/device/settings**:
#RTCM.caster.host =<customer-specific-IP-Address>
#RTCM.port =<customer-specific-Port>

To edit this file, please connect per SSH to the Reference Station. For the SSH-credentials, please ask the support.

Step 2:
Connect the Reference Station with a router via ethernet cable or Wi-Fi. A DHCP-server running on the router is mandatory. To get correction data outside or inside of this network, the user must follow the next mandatory steps.

Step 3:
First of all, the user needs the IP address of the Reference Station in the local network of the router. The user has the following options: either discover the IP address by connecting to the router (usually by typing http://192.168.1.1 or http://192.168.0.1 in the web browser), then look for a device named "*ANavS XXX*", or you use network discover software like Nmap. More details on this can be found in the article Using the IP scanning-tool NMAP .

Step 4: In case of using the Reference Station from outside of the local network, the IP-address of the router is needed. The easiest way to do this is to call the page https://www.outsideopen.com/ip/ within user's local network. The shown numbers are your public IP address. This public IP address is managed from the users Internet Service Providers. Some providers do not provide with a static IP address, but rather change it usually in a 24h time window. If this is the case, the user will need to set up a Dynamic DNS service that keeps track of the external IP changes. Please refer to your network administrator to know the policy regarding the external IP address.

Step 5: Assuming to have an external IP address set up correctly, the user must configure the router to enable port forwarding. Port forwarding maps requests coming from outside the network at a specific port number to a local IP address from within the local network at a second port number. Therefore, in other words, it redirects the traffic from outside to a specific device inside the local network.

The following example shows the rerouting of correction-data of the Reference Station to an arbitrary Port of the router:

External IP address of the router	external port No.	Local IP address of the Pi	Internal port No.
82.135.2.37	2101	192.168.1.101	2101

In this example, the user configures the port forwarding to reroute the traffic coming from outside (landing so at the external IP of the router, namely 82.135.2.37) at port 2101 to the local IP of the Reference Station (192.168.1.101) at port 2101. Note that choosing external port 2101 is arbitrary (is always best practice not to choose a port that is a well known port). Having the router's port forwarding set up as in the above example, to connect to the Reference Station from outside the local network just configure the RTCM stream on the MS-RTK module or ISP with IP 82.135.2.37 and with port 2101. The traffic will be automatically rerouted to 192.168.1.101 at port 2101 in your local network.

IMPORTANT
The internal port number is not changeable and always **2101**.
In case of a local network without port-forwarding, this results in the following NTRIP input stream for the MS-RTK module or ISP:

RTCM_User: anavs123@**<Local-IP-of-RTCM-station>**:**2101**/ANAVS

In case of port forwarding, the NTRIP input stream for the MS-RTK module or ISP needs the external port number as configured in the router-settings and the external IP-Address of the router. Following an example for this:

RTCM_User: anavs123@**<External-IP-address-of-the-router>**:**<External-Port-No>**/ANAVS

3.5. The ANavS®-Wizard to Update the RTK/RTCM Reference Station

The ANavS® Wizard can also be used for updating the Reference Station. Trying this, the user must provide internet access to the station. The default way would be through the mobile network or through Ethernet with a connection to a router. The first step in the Wizard is selecting the option “Update your ANavS-Module (…)” on the starting page.

The next window is showed in Figure 35. The user has two options with the **Online-Updater**. Selecting the button “Stable Update”, the user updates the Reference Station (and also the MS-RTK module) with the latest stable version on the ANavS repository. It is well tested but is not including all recent minor updates and sensor fusion improvements. Selecting the button “Beta Update”, the user updates the Reference Station (and also the MS-RTK module) with the latest Beta version on the ANavS repository. It is less tested but is including all recent minor updates and sensor fusion improvements.

In case of problems with getting internet access to the Reference Station, ANavS is also providing an **Offline-Updater**. Using this option, please contact the support to get the recent Update-Zip, load it in the Wizard (do NOT unzip this file) with the SEARCH button and click the update-button.

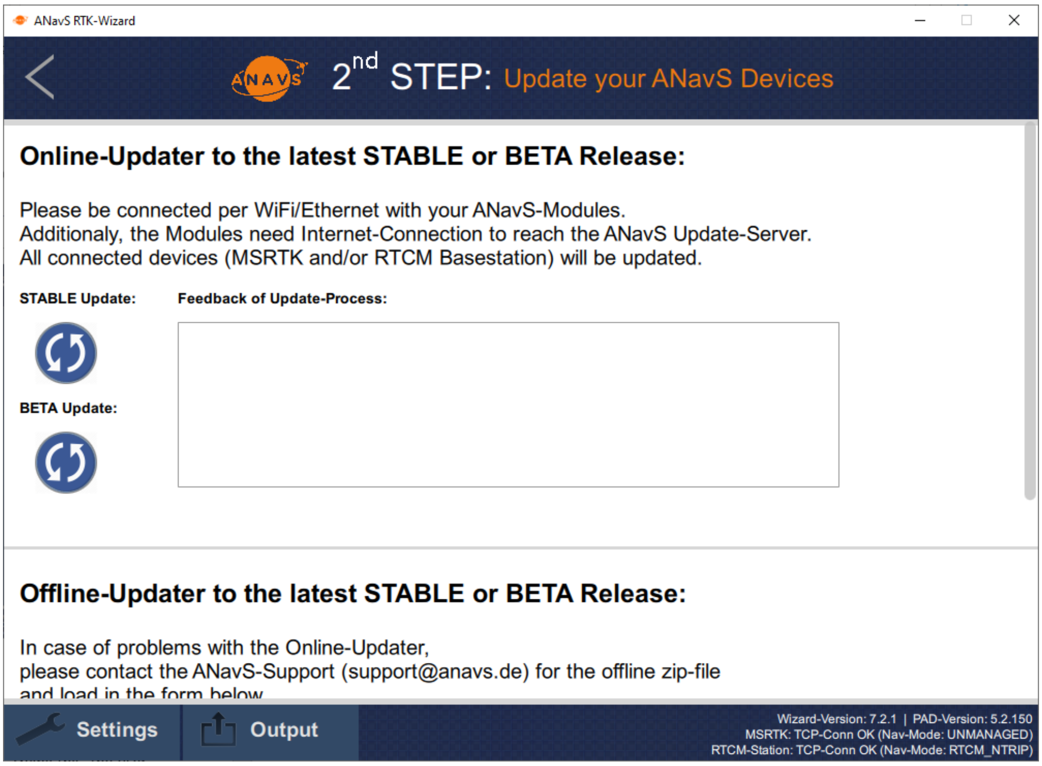


Figure 35: Update of the RTK/RTCM Reference Station with the ANavS Wizard

4. Getting Started with the Integrated-Sensor-Platform (ISP)

This guide is intended for first time ISP users and provides an overview of how to handle with the required software, connect to and configure the ISP.

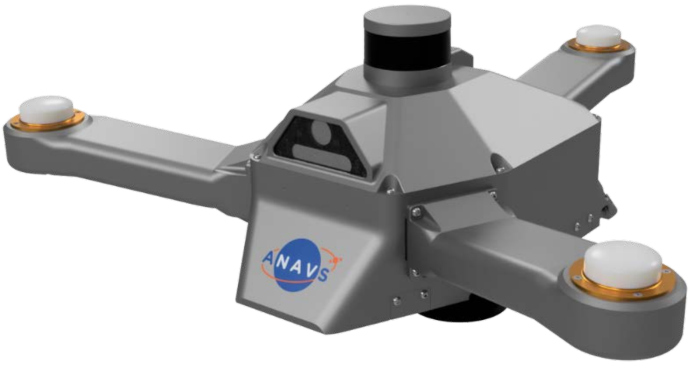


Figure 36: The Integrated-Sensor-Platform (ISP)

4.1. General

The Integrated Sensor Platform (ISP) is a hardware basis for easy integration of a large variety of sensors without any effort. It comes with a standard configuration of three GNSS receivers and integrated antennas, an industrial-grade inertial measurement unit (IMU), a CAN interface for wheel odometry data and a barometer. On top of the standard sensors a fully integrated computer vision module is equipped, that can be flexibly configured with two cameras and/or a 3D-LiDAR.

The camera only configuration includes a high-quality, high frame-rate global shutter monocular HD camera and a global shutter stereo camera with either fisheye objective or depth sensing capabilities.

The LiDAR only configuration includes a high-quality 3D-LiDAR for 360° sensing. On the one hand, both the camera sensors and the LiDAR sensor provide an additional odometry or positioning information through visual-inertial odometry or Simultaneous Localization and Mapping (SLAM). On the other hand, 2D and 3D maps of the environment or road can be generated. Furthermore, semantic segmentation enabled by deep learning algorithms allows to add semantic information to the maps and further enhances the SLAM performance.

The additional positioning information obtained from the computer vision module is coupled with GNSS, IMU and wheel odometry information in the ANavS® Sensor Fusion. This leads to an improved positioning accuracy to overcome also the most challenging environments.

4.2. The ISP Setup

The ISP consists of the following modules and components:

- **Multi-Sensor Fusion System (MS-RTK System Inside):**
    - 3x Multi-GNSS, Multi-Frequency Receivers
    - 3x High-Class, Survey-Grade, Triple-Frequency GNSS Antennas
    - High-grade MEMS IMU
    - Barometer
- **Computer Vision Module**
    - Camera sensors:
        - Industrial high-grade global shutter RGB camera (FLIR Grasshopper3)
        - Stereo camera with integrated IMU (Intel Realsense D435i)
    - Lidar sensor (Velodyne Puck/ VLP16)
    - *Embedded platform for GPU accelerated sensor data processing (NVIDIA Jetson Xavier NX Developer Kit)
      In the following referred to as *Vision Processing Unit (VPU)*
    - *Data storage: Integrated 2TB M.2 NVMe SSD

  *) Optionally two embedded platforms can be integrated (each with integrated data storage).

- **Interfaces**
    - Ethernet, WLAN, CAN, USB, LTE

The ISP is ready to use out-of-the-box. With its vacuum cups (suction cups, Figure 37) it can safely be mounted for any kind of automotive dynamics. Pump the plunger a few times until the suction cup is completely fixed with the surface of mounting. When the red line has faded out, the vacuum is sufficient for lifting. A firm push or pull on the tab on the edge of the cup can loosen the holder. A suction cup protector prevents damage.

Figure 37: The ISP can be mounted with its three suction cups on all smooth, non-porous surfaces

4.3. The Basic-Configuration: GNSS, IMU and Odometry Sensor Fusion

The basic configuration with a tightly coupled sensor fusion of three GNSS receivers, an IMU and Odometry sensor data on the ISP corresponds to the description and handling of the MS-RTK module. Please follow the instructions in chapter 2.

A major advantage of the ISP is the fixed lever arms of the system and of each sensor. Corresponding to this, please use the following dimensions in Step-5 in the ANavS® Wizard Software (see section 2.7.5).

GNSS-Antenna-1 [m]:	X= 0.0	Y= 0.0	Z= 0.0
GNSS-Antenna-2 [m]:	X= 0.708	Y= -0.39	Z= 0.0
GNSS-Antenna-3 [m]:	X= 0.708	Y= 0.39	Z= 0.0
IMU [m]:	X=0.493	Y=0.017	Z= 0.106

All dimensions belong to the body frame. The movement-direction is assigned to the field-of-view of the cameras. The GNSS-Antenna-1 is the rear one, GNSS-Antenna-2 is the right one and GNSS-Antenna-3 the left one.

4.3.1. The ANavS®-Wizard to Update the ISP Basic-Configuration

Please follow the instructions in section 2.8 for updating the ISP regarding the GNSS/IMU/Odometry sensor fusion.

4.4. The Computer-Vision Operation-Modes

The Computer Vision module offers a data acquisition mode and can be extended by customer or application specific algorithms that run on the VPU, such as object detection or SLAM.

4.4.1. Prerequisites

For basic operation any operating system with installed terminal application supporting SSH is suitable.

For live visualization of sensor data on a client an operating system that supports ROS is required, for example a Linux Operating System (tested with Ubuntu 18.04, Ubuntu 20.04) and a ROS environment that supports ROS1 or ROS2 (tested with ROS Melodic, ROS Noetic).

4.4.2. Setup

Connecting to the ISP and login to the VPU:

You can connect via Ethernet, or WLAN. For transferring huge data or visualization of live camera or Lidar data on a client an Ethernet connection is recommended. Ethernet provides a direct Gigabit connection to the VPU. WLAN only provides indirect access to the VPU, but it is sufficient for executing commands.

The VPU may distribute processing onto two embedded GPU platforms/ Jetson Xavier NX devices, termed Master NX (IP address: 192.168.1.101) and Slave NX (IP address: 192.168.1.102). However, to operate the VPU, you only need to connect to the Master NX.

1. Ethernet

   Connect your host to the ISP via Ethernet. You need to set a static IP in the domain 192.168.1.xxx, e.g.: 192.168.1.210. (Do not use these reserved IP addresses: 192.168.1.100, 192.168.1.101, 192.168.1.201, for setup with two embedded GPU platforms: 192.168.1.102)

   Add the following line to /etc/hosts:

   ```
   192.168.1.101          <Master-NX-host-name>
   ```

   The Master NX host name is usually set to: `ubuntu`

   Directly login to the VPU using SSH (Password: *anavsisp*):

   ```
   ssh anavs@192.168.1.101
   ```

2. WLAN

   Connect to the ISP WiFi Access Point *ANAVS_ISP_XXX* (Password: *anavsrtk*).
   Indirectly login to the VPU using SSH:

```
1. ssh pi@192.168.42.1        # login to the Multi-Sensor Fusion System

2. ssh anavs@192.168.1.101    # login to the VPU
```

Before proceeding with the following operation modes make sure the ISP has good satellite view, LTE reception is available and the system is powered on already for some minutes, to ensure completion of MS-RTK system startup including services and internal time-synchronization. Furthermore, configure and start the sensor fusion (described in section 4.3). Starting the sensor fusion is optional if only camera and Lidar sensor data shall be acquired.

4.4.3. Data Acquisition Mode

The Data Acquisition Mode is the basic operation mode that runs the sensor nodes for the cameras and the Lidar sensor and provides sensor data ROS messages. The sensor data consists of RGB imagery, grayscale stereo imagery, Lidar data and IMU data and can be recorded using the rosbag tool. Embedded GPU platform system time is synchronized to the MS-RTK system time. In addition, a ROS wrapper provides the Multi-Sensor Fusion System Solution in ROS. All ROS messages are provided in ROS1 and ROS2, a ROS bridge converts all ROS1 messages to ROS2

1. Login to the VPU using SSH (as described above under *Setup*)
2. Start the VPU components consisting of ROS master, sensor ROS nodes and the ROS recorder:

   ```
   start_vpu
   ```

   To get an overview over optional command line arguments:

   ```
   start_vpu --help
   ```

   Optionally disable verification of NTP time-synchronization
   (to the Multi-Sensor Fusion System):

   ```
   start_vpu --no_ntp_sync
   ```

   Enable recording of ROS topics to bag files:

   ```
   start_vpu --record
   ```

To enable bridge communication between ROS1 and ROS2:

```
start_vpu --enable_ros_bridge
```

To enable object detection container:

```
start_vpu --object_detection
```

To run only specific VPU sensor containers:

e.g.:

```
start_vpu --sensors “d435i gh3”
```

Available VPU components are listed below:

ROS Node	Sensors/ Algorithm	Component Name
ROS Master		ros_master
Industrial RGB Camera ROS Wrapper	FLIR Grasshopper3 USB3	gh3
Stereo Camera ROS Wrapper	Intel Realsense D435i	d435i
Lidar Sensor ROS Wrapper	Velodyne Puck/ VLP16	vlp16
Multi-Sensor Fusion System Solution ROS Wrapper[7]	Multi-GNSS, Inertial Sensor based Sensor Fusion	pad2ros
Rosbag Recorder		ros_recorder
Ros Bridge		ros_bridge
Optional Components:		
Object Detection	2D Object Detection	object_detection

By default, all standard components listed in the table above (except ros_recorder) are launched when executing the `start_vpu` script.

Available ROS topics are listed below:

ROS Topic	Description	ROS Message Type
/camera/image_raw	Raw camera image of the industrial RGB camera.	sensor_msgs/Image
/d435i/infra1/image_rect_raw	Raw camera image 1 of the stereo camera.	sensor_msgs/Image

[7] The VPU provides a ROS Wrapper for the Multi-Sensor Fusion System Solution. Running the component pad2ros will publish an available solution in ROS.

/d435i/infra2/image_rect_raw	Raw camera image 2 of the stereo camera.	sensor_msgs/Image
/d435i/imu	IMU data from stereo camera.	sensor_msgs/Imu
/velodyne_packets	Lidar raw data	velodyne_msgs/VelodyneScan
/anavs/solution/*	ROS messages provided by the ROS wrapper for the Multi-Sensor Fusion System Solution. More details including a list of advertised topics is given in chapter 10, ANavS ROS-Ethernet-Adapter (REA).	
Optional Components:		
Object detection ROS topic specifications see separate section below.		

The topics listed above are recorded by the rosbag recorder by default, if recording is enabled. In addition to these, more topics are available that are advertise by the different nodes. Furthermore, additional components provide specific ROS topics. These are listed in the algorithm specific sections in the following.

3. There are two contexts, i.e., two docker nodes running on different hosts.

   The command `docker context ls` lists all available contexts and marks the current context with an asterisk.

   The context `default` corresponds to the Master NX, the context slave_nx corresponds to the Slave NX.

   To change the context, use the following command:

   ```
   docker use <context_name>
   ```

4. To show log messages coming from all containers running on the Master or Slave NX run

   ```
   vpu_master_logs
   ```

   or

   ```
   vpu_slave_logs
   ```

   respectively.

5. Visualizing sensor data locally on your host

```
export ROS_MASTER_URI=http://192.168.1.101:11311

export ROS_IP=<your-host-IP>

rqt_image_view           # for visualizing camera data

rosrun rviz rviz –f velodyne  # for visualizing lidar
data
```

Note: For accessing ROS messages on your host adjusting */etc/hosts* is required.

6. Data recording in ROS

   Sensor data is recorded in rosbag files that are stored in the folder:

   ~/vpu/data

   The file naming convention is:

   `isp_recording_<year>_<month>_<day>_<h>_<min>_<sec>_<split_index>.bag`

   Rosbag files are automatically split after 30 minutes of recording time to prevent dealing with huge files. Further, LZ4 compression is used, to reduce file sizes.

   Time stamping:

   Recorded ROS messages are timestamped using the VPU system time which is time-synchronized to the Multi-Sensor Fusion System and is based on the UTC time. This requires on the one hand GNSS satellite view, or LTE reception, and on the other hand an adequate NTP-time synchronization offset toward the MS-RTK system. Enable verification of NTP-time synchronization to guarantee a specified time offset when starting data acquisition. Without GNSS satellite view or LTE reception only a local time can be provided.

   ROS message timestamps can be converted from UTC time to GPS time of weeks in post-processing.

   NTP time-synchronization offsets are logged automatically to *data/logs/ntp_log.txt*. In a setup with two embedded GPU platforms the NTP offset of the second device is logged to *data/logs/ntp_log_slave.txt*.

7. Stop the VPU

   stop_vpu

8. Copying recorded data

Recorded data can be copied to your host using an FTP client or using SCP. An Ethernet connection is recommended. Copying via SCP:

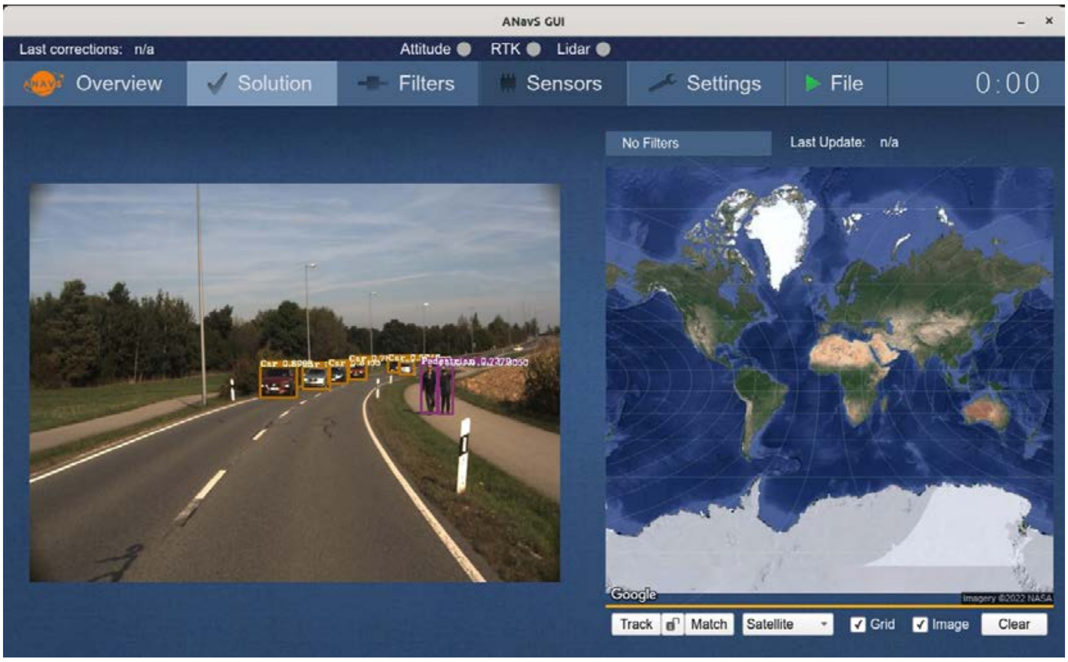
```
scp anavs@192.168.1.101:/home/anavs/vpu/data/ <destination-folder>
```

4.4.4. Object Detection

The object detection component performs real-time 2D object detection using live camera data from the monocular RGB camera. The output is 2D bounding boxes with detection confidences. Object detection output is provided in the ANavS GUI and in ROS.
Note: For visualizing object detections in the ANavS GUI an Ethernet connection to the ISP is required.

ANavS GUI

Object detections are visualized in the Sensors/Camera tab. Bounding boxes and detection confidences are visualized in the live camera image:



ROS

Object detections are provided as an object list using the type derived_object_msgs/ObjectArray. The camera image with visualized bounding boxes is provided as CompressedImage:

ROS Topic	Description	ROS Message Type

/bounding_boxes/array	Object detections list	derived_object_msgs/ObjectArray
/bounding_boxes/compressed	Camera image with object detection bounding boxes	sensor_msgs/CompressedImage

Object Detection Model

An initial pretrained model for the detection of cars, busses, trucks, motorbikes, bicycles, pedestrians, bicyclists and motorcyclists is available. Object detection can be tailored to fit customer specific needs.

4.4.5. Troubleshooting

- No internet connection on the VPU system:
  The VPU system is not connected to the internet by default. If you require an internet connection, you may switch from static to DHCP network setting to obtain connection via an external router. To do so modify the following line in `/etc/network/interfaces`
  - from: `source interfaces.d/eth0_static`
  - to: `source interfaces.d/eth0`

- Issues with Intel Realsense camera device:
  The camera device resource may still be blocked by previous access. Reboot the VPU, or power off and power on the ISP to release the camera device resource.

- NTP offset not available (VPU error: *Command '['./scripts/get_ntp_offset.sh']' returned non-zero exit status 1*)

  The NTP offset may not be retrieved if the NTP daemon on the MS-RTK module is not active, which will result in a failure of the start_vpu script.
  To resolve this issue:

  - make sure satellites are visible or LTE reception is available and wait some minutes after system power on before starting the VPU
  - reboot the Jetson Xavier NX
- NTP offset does not decrease after waiting some time:
  - increase the NTP offset threshold when starting the vpu_start script using the --max_ntp_offset parameter, to allow for a larger offset
  - restart the ntp service: `sudo service ntp restart`

5. The Command Line API Reference Guide

All ANavS Positioning Systems provide an API used by command line. The API is directly used on the modules through the SSH-access or via an external client on your Laptop/PC using a TCP/IP connection. Please ask the support-team for access to this functionality. The following sections describes the most important commands for customers. An autocomplete is available.

A detailed description of each command is also available via command-line:

MSRTKF help -search <command>

5.1. Navigation commands

This section describes the commands regarding the navigation software. With these commands, the user can control the ANavS Systems without using the Wizard Software. Each API command needs the preamble ***MSRTKF*** (Example: ***MSRTKF Navigation.attach***).

Command	Description
Navigation.attach	Prints the sensor fusion software trace into the command line.
Navigation.configNtripPolicy	**Navigation.configNtripPolicy** Get the currently configured policy. **Navigation.configNtripPolicy -set SET** Set the policy. **SET** In **OFF** mode, NTRIP is deactivated. In **AUTO** mode, NTRIP is automatically enabled when the navigation software starts and disabled when it stops. **-set SET** is mandatory. Allowed values for **SET** are **AUTO, OFF**.
Navigation.getLatency	Prints the current solution latency
Navigation.getMode	Prints the current Navigation mode
Navigation.setMode	**Navigation.setMode -mode MODE -temp TEMP** Set navigation mode. **MODE** Navigation mode to set. **-mode MODE** is mandatory. Allowed values for MODE are: **UNMANAGED, PAD_1D_RTCM, PAD_2D_RTCM, PAD_3D_RTCM, RTCM_NTRIP, RTCM_MOSAIC, PPP_RT**. The modes **PAD_1D_RTCM, PAD_2D_RTCM, PAD_3D_RTCM** launches the sensor fusion software with 1-Antenna/2-Antenna/3-Antenna RTCM mode. Automatic start and restart are enabled. The mode **UNMANAGED** deactivates the sensor fusion again. The modes **RTCM_NTRIP, RTCM_MOSAIC** launches the RTCM NTRIP-server/caster software. Automatic start and restart enabled. **TEMP** Set mode only temporary. The change is not saved persistent. -**temp TEMP** is optional. Allowed values for TEMP are: **true, false**.

	Enables/Disables the navigation mode.
Navigation.getState	The navigation software is monitored by the firmware of the positioning systems. The user gets one of these responses: **UNMANAGED:** Binaries are not currently running and are not scheduled to start. **DELAY:** Selected binaries are scheduled to start soon (boot delay). **STARTUP_WAIT:** Selected binaries have been started but have not been verified to be functional (startup period). **RECOVER_WAIT:** The selected binaries are up and have already been verified to be functional, however currently there is a problem. We have started a timer for the problem to disappear before we enforce a module-restart. **NOMINAL:** The selected binaries are up and have been verified to be functional, moreover there is currently no indication of a problem with the navigation binaries. **UNKNOWN:** There is currently no information on the state of the navigation software.
Navigation.restart	Restart the currently active navigation software.
Navigation.PAD.config.generate	Description follows in next version.
Navigation.PAD.config.get	Description follows in next version.
Navigation.PAD.config.reload	Description follows in next version.
Navigation.PAD.config.set	**Navigation.PAD.config.set -rfile RFILE** Upload a PAD configuration resource. **RFILE** Resource that will be used as config file. **-rfile RFILE** is mandatory.
Navigation.PAD.properties	Because of the large amount of text, please have a look for the description of this command via command line: **MSRTKF help -search Navigation.PAD.properties**
Navigation.RTCM.calibrate	Description follows in next version.
Navigation.RTCM.config	**Navigation.RTCM.config -host HOST -port PORT** Set parameters for NTRIP-caster in an RTCM station. **HOST** Host of the NTRIP caster. **-host HOST** is optional. **PORT** Port of the NTRIP caster. **-port PORT** is optional.

5.2. System commands

This section describes the system commands. Each API command needs the preamble ***MSRTKF*** (Example: ***MSRTKF SYS.ping***).

Command	Description
SYS.acmInfo	**SYS.acmInfo -mode MODE** Print information of connected usb ACM devices. **MODE** Select a mode to list data. **-mode MODE** is optional. Allowed values for **MODE** are: **acm**, **devices**.
SYS.assertDevice	**SYS.assertDevice -name NAME -t T** Wait for a given time until the specified device becomes available. **NAME Name** of the device. **-name NAME** is mandatory.

	T is the maximum number of milliseconds to wait before aborting. Defaults to 1000. **-t T** is optional.
SYS.assertInterface	**SYS.assertInterface -name NAME -t T -syslog SYSLOG** Wait for an interface to become ready. **NAME Name** of the interface. **-name NAME** is mandatory. **T** is the maximum number of milliseconds to wait. **-t T** is mandatory. **SYSLOG** is to optionally search the syslog for a message that the chatscript has failed. **-syslog SYSLOG** is optional. Allowed values for **SYSLOG** are: **true**, **false**.
SYS.assertIP	Description follows in next version.
SYS.assertUsbDevice	**SYS.assertUsbDevice -vendor VENDOR -prodid PRODID -t T** Wait for a given time until the specified device becomes available. **VENDOR** Hex encoded vendorId of the device. **-vendor VENDOR** is mandatory. **PRODID** Hex encoded productId of the device. **-prodid PRODID** is mandatory. **T** is the maximum number of milliseconds to wait before aborting. **-t T** is mandatory.
SYS.checklist	**SYS.checklist -index INDEX -verbose VERBOSE** Retrieve the text form of the checklist. **INDEX Index** of the checklist item to be displayed. **-index INDEX** is optional. **VERBOSE** Set true to print the result. **-verbose VERBOSE** is optional. Allowed values for **VERBOSE** are: **true**, **false**.
SYS.initNtp	Description follows in next version.
SYS.Memory.block	Description follows in next version.
SYS.Memory.info	Description follows in next version.
SYS.ping	Proving the current connection state
SYS.productName	**SYS.productName -verbose VERBOSE** Get the product name of the system. **VERBOSE** Print product name. **-verbose VERBOSE** is optional. Allowed values for **VERBOSE** are: **true**, **false**.
SYS.restart	**SYS.restart -mode MODE** Restart a component of the system. **MODE** Name of the restart-mode. **-mode MODE** is mandatory. Allowed values for **MODE** are: **COMMAND_SERVER**, **DRIVER**, **POSITIONING_APPLICATION**, **MCU_REBOOT**, **MCU_RESET**, **SYSTEM_REBOOT**. **SYS.restart -mode MODE** Restart a component of the system. **MODE** Number of the restart-mode. **-mode MODE** is mandatory. Allowed values for **MODE** are: **0, 1, 2, 3, 4, 5**.
SYS.serial	**SYS.serial** Read the system serial number. **SYS.serial -stream STREAM** Read the serial number of a stream.

	STREAM Index of the stream. **-stream STREAM** is mandatory. Allowed values for **STREAM** are: **1, 2, 3**.
SYS.setting	Description follows in next version.
SYS.showInterfaces	Description follows in next version.
SYS.subscribe	**SYS.subscribe -branch BRANCH** Subscribe to an update channel. **BRANCH** Name of the update branch. **-branch BRANCH** is mandatory. Allowed values for **BRANCH** are: **mf-automotive-unstable**, **mf-automotive-stable**. **SYS.subscribe -branch BRANCH -unsafe UNSAFE** Subscribe to an update channel. **BRANCH** Name of the update branch. **-branch BRANCH** is mandatory. Allowed values for **BRANCH** are: **mf-automotive-unstable, mf-automotive-stable, ms-ppp-debug, master, debug**. **UNSAFE** Allow system to subscribe to unsafe update channels. Unsafe channels contain the latest code that currently undergoes internal testing. These channels make no guarantee to be functional. **-unsafe UNSAFE** is mandatory. Allowed values for **UNSAFE** are: **true**.
SYS.temperature	To prove the current temperature of the MSRTK module
SYS.Thread.error	Description follows in next version.
SYS.throttled	To prove if the system is throttled due to under-voltage or over-temperature
SYS.update	**SYS.update** Install the latest update available through the currently selected branch (defined in the file /home/pi/device/settings)
SYS.updateDNS	Description follows in next version.

5.3. Role commands

This section describes the role commands. A role defines a specific customer or internal setup of the MS-RTK-System on a system level. Each API command needs the preamble ***MSRTKF*** (Example: ***MSRTKF Role.get***).

Command	Description
Role.get	**Role.get -silent SILENT** Gets the currently fulfilled role of the system. **SILENT** Suppress readable output. **-silent SILENT** is optional. Allowed values for **SILENT** are: **true**, **false**. To get the current role of your MS-RTK module. The default role is *MSRTK_WIZARD*
Role.install	**Role.install -name NAME** Sets the currently fulfilled role of the system and stores role-specific information to /home/pi/device/settings.

	NAME Name of the new role. **-name NAME** is mandatory. Allowed values for **NAME** are: **MSRTK_WIZARD, PAD_1D, PAD_2D, PAD_3D, RTCM, RTCM_MOSAIC, M_STAR, M_POINT, M_REFERENCE, LEGACY_REFERENCE, STIHL_IMOW, PPP_RT, PREAPARE_SHIPS**. To install a customer specific role, which was assigned to the user by the support. Don't use this command without any support!

5.4. CAN commands

This section describes the commands regarding the CAN-interface. The commands are described in more detail in chapter 8. Each API command needs the preamble ***MSRTKF*** (Example: ***MSRTKF CAN.dbcc***).

Command	Description
CAN.config.reset	Description follows in next version.
CAN.config.solution	Because of the large amount of text, please have a look for the description of this command via command line: **MSRTKF help -search CAN.config.solution**
CAN.config.solution.list	**CAN.config.solution.list -format FORMAT -onlyenabled ONLYENABLED -file FILE** Display list of currently enabled and disabled CAN output signals with their current CAN-Ids. **FORMAT** Allows to select a plain list or dbc. **-format FORMAT** is mandatory. Allowed values for **FORMAT** are: **LIST**, **DBC**. **ONLYENABLED** If set to true, only enabled messages are shown. **-onlyenabled ONLYENABLED** is optional. Allowed values for **ONLYENABLED** are: **true**, **false**. **FILE** Allows to select a plain list or dbc. **-file FILE** is mandatory.
CAN.dbcc	**CAN.dbcc -source SOURCE** Analyze the loaded .dbc file with dbcc **SOURCE** Path of the .dbc file. Defaults to the currently loaded file. **-source SOURCE** is optional.
CAN.generateDecoder	**CAN.generateDecoder** Generate a dynamic decoder binary
CAN.getStatus	**CAN.getStatus** Get a description of the CAN status **CAN.getStatus -item ITEM** Show CAN odometry rates. **ITEM** Item to be displayed. **-item ITEM** is mandatory. Allowed values for **ITEM** are: **CAN_MESSAGE_RATE, DRIVER_SIGNAL_RATE, DRIVER_MEASUREMENT_RATE, PAD_PROCESSING_RATE, ALL**.
CAN.hardwareFilter.config	**CAN.hardwareFilter.config** Automatically generate optimal CAN reception hardware filter settings. **CAN.hardwareFilter.config -clear CLEAR**

	Disable CAN reception hardware filter. **CLEAR** Instructs the command to disable the filter. **-clear CLEAR** is mandatory. Allowed values for **CLEAR** are: **true**.
CAN.loadDbc	**CAN.loadDbc -rsource RSOURCE -encoding ENCODING** Loads a .dbc file and tries to detect in a best-effort way if it really is a .dbc file. **RSOURCE** SOURCE is a resource name used to provide the file. **-rsource RSOURCE** is mandatory. **ENCODING** Name of the encoding. If the encoding is UTF-8 or ISO-8859-1 this can be omitted. **-encoding ENCODING** is optional. **CAN.loadDbc -source SOURCE -encoding ENCODING** Loads a .dbc file and tries to detect in a best-effort way if it really is a .dbc file. **SOURCE** SOURCE absolute path of the source file. **-source SOURCE** is mandatory. **ENCODING** Name of the encoding. If the encoding is UTF-8 or ISO-8859-1 this can be omitted. **-encoding ENCODING** is optional.
CAN.signal	**CAN.signal** lists all available CAN signals. **CAN.signal -find FIND** Lists all available CAN signals that match the search pattern. **FIND** Search pattern. Accepts hex values for CAN-id. **-find FIND** is mandatory. **CAN.signal -map MAP -magn MAGN -sign SIGN** Maps a CAN signal to the magnitude and signum channel of a sensor. **MAP** Sensor to be mapped. **-map MAP** is mandatory. Allowed values for **MAP** are: **FL, FR, RL, RR, STEER**. **MAGN** Magnitude of the sensor value. Can be any character sequence that is part of the signal description. If your signal name is exactly contained in another signal name, use the fully qualified name as displayed by CAN.signal. **-magn MAGN** is mandatory. Allowed values for **MAGN** are: . **SIGN** Signum of the sensor value. Can be any character sequence that is part of the signal description. Has to contain specifiers for enum values of positive and negative. Example: wheeldirFL,+=1,-=2 where wheeldirFL is the CAN signal search term. **-sign SIGN** is optional. **CAN.signal -get GET -sup SUP** Returns the mapping for given sensor. **GET** Sensor to be retrieved. **-get GET** is mandatory. Allowed values for **GET** are: **FL, FR, RL, RR, STEER, ALL**. **SUP** Suppress warning that signal cache will be rebuilt. **-sup SUP** is mandatory. Allowed values for **SUP** are: **true**, **false**. **CAN.signal -clear CLEAR**

	Clears the mapping for given sensor. **CLEAR** Sensor to be cleared. **-clear CLEAR** is mandatory. Allowed values for **CLEAR** are: **FL, FR, RL, RR, STEER, ALL**.

5.5. Driver commands

This section describes the driver commands. Each API command needs the preamble ***MSRTKF*** (Example: ***MSRTKF Driver.config***).

Command	Description
Driver.checkInstallation	**Driver.checkInstallation -source SOURCE** Compare driver installation to an archive file. **SOURCE** Path of the installation archive. **-source SOURCE** is optional.
Driver.config	Description follows in next version.
Driver.createArchive	Description follows in next version.
Driver.deployArchive	**Driver.deployArchive -source SOURCE** Deploy driver files from archive **SOURCE** Path to a local update archive. **-source SOURCE** is optional.
Driver.installUpdate	**Driver.installUpdate** Install the last downloaded update archive. Most users will prefer **SYS.update** instead.
Driver.listInterfaces	Description follows in next version.
Driver.listMappings	Description follows in next version.
Driver.listPlugins	Description follows in next version.
Driver.reinit	**Driver.reinit -reason REASON -dump DUMP** Request to send a SIGINT to the driver **REASON** Log message. **-reason REASON** is optional. **DUMP** Request to dump a stack trace. In some situations, a stack trace will be generated anyway. **-dump DUMP** is optional. Allowed values for **DUMP** are: **true**, **false**.
Driver.setNtripEnabled	**Driver.setNtripEnabled -enabled ENABLED -pushconfig PUSHCONFIG** Connect to driver to set state of NTIP plugin. **ENABLED** True to enable NTRIP. **-enabled ENABLED** is mandatory. Allowed values for **ENABLED** are: **true**, **false**. **PUSHCONFIG** True to also push NTRIP configuration. **-pushconfig PUSHCONFIG** is mandatory. Allowed values for **PUSHCONFIG** are: **true**, **false**.
Driver.start	**Driver.start** Start driver.
Driver.stop	**Driver.stop** Stop driver and guard.
Driver.version	**Driver.version -silent SILENT -cached CACHED** Show version of driver. **SILENT** Don't print the result. **-silent SILENT** is optional. Allowed values for **SILENT** are: **true**, **false**. **CACHED** Don't query the driver, use last response. **-cached CACHED** is optional. Allowed values for **CACHED** are: **true**, **false**.

5.6. GNSS commands

This section describes the commands related to the GNSS receivers. Each API command needs the preamble ***MSRTKF*** (Example: ***MSRTKF GNSS.config***).

Command	Description
GNSS.chat	**GNSS.chat -path PATH -message MESSAGE** Exchange data with a serial device. The command expects some answer data and prints it. **PATH** Path of the device. For example /dev/ttyACM0. **-path PATH** is mandatory. Allowed values for **PATH** are: /dev/ttyACM5, /dev/ttyACM4, /dev/ttyACM3, /dev/ttyACM2, /dev/ttyACM1, /dev/ttyACM0, /dev/ttyAMA0, /dev/ttyprintk, /dev/tty63, /dev/tty62, /dev/tty61, /dev/tty60, /dev/tty59, /dev/tty58, /dev/tty57, /dev/tty56, /dev/tty55, /dev/tty54, /dev/tty53, /dev/tty52, /dev/tty51, /dev/tty50, /dev/tty49, /dev/tty48, /dev/tty47, /dev/tty46, /dev/tty45, /dev/tty44, /dev/tty43, /dev/tty42, /dev/tty41, /dev/tty40, /dev/tty39, /dev/tty38, /dev/tty37, /dev/tty36, /dev/tty35, /dev/tty34, /dev/tty33, /dev/tty32, /dev/tty31, /dev/tty30, /dev/tty29, /dev/tty28, /dev/tty27, /dev/tty26, /dev/tty25, /dev/tty24, /dev/tty23, /dev/tty22, /dev/tty21, /dev/tty20, /dev/tty19, /dev/tty18, /dev/tty17, /dev/tty16, /dev/tty15, /dev/tty14, /dev/tty13, /dev/tty12, /dev/tty11, /dev/tty10, /dev/tty9, /dev/tty8, /dev/tty7, /dev/tty6, /dev/tty5, /dev/tty4, /dev/tty3, /dev/tty2, /dev/tty1, /dev/tty0, /dev/tty. **MESSAGE** Message to send. \r and \n will be changed to newline and carriage return. **-message MESSAGE** is mandatory.
GNSS.config	**GNSS.config** Detect GNSS receiver presence and device. Send correct configuration to all detected devices.
GNSS.config.Mosaic	**GNSS.config.Mosaic -highrate HIGHRATE** Detect Mosaic receivers and write the configuration **HIGHRATE** Set all messages to 100Hz if true, 5Hz otherwise. **-highrate HIGHRATE** is optional. Allowed values for **HIGHRATE** are: **true**, **false**.
GNSS.leapSeconds	Description follows in next version.
GNSS.listMessageTypes	Description follows in next version.
GNSS.reset	**GNSS.reset -num NUM -mode MODE** Reset a GNSS module on one of the three RF ports. **NUM** Index of the GNSS slot. **-num NUM** is mandatory. Allowed values for **NUM** are: **1, 2, 3**. **MODE** Chooses what to do with the reset pin. **-mode MODE** is optional. Allowed values for **MODE** are: **CYCLE, LOW, HIGH, RELEASE**.

5.7. LTE commands

This section describes the commands related to the mobile network module and the SIM-card settings. Each API command needs the preamble ***MSRTKF*** (Example: ***MSRTKF LTE.config***).

Command	Description
LTE.block	**LTE.block** Retrieves the current blocking date. **LTE.block -set SET** Set a blocking date (or null to disable blocking) **SET** Time period in the form 10s or 22m or 1h to set the new blocking date. null to clear the blocking date. **-set SET** is mandatory.
LTE.chat	**LTE.chat -message MESSAGE** Send a command to the AT interface of the LTE modem. **MESSAGE** The AT command. **-message MESSAGE** is mandatory.
LTE.config	**LTE.config -apn APN -dial DIAL -user USER -isppw ISPPW -pin PIN** Set the configuration for the LTE modem. **APN** APN that is required to use your SIM card. Contact your internet service provider for that information. **-apn APN** is mandatory. **DIAL** Dial up number that is required to use your SIM card. Contact your internet service provider for that information. **-dial DIAL** is mandatory. **USER** Username that is required to use your SIM card. Contact your internet service provider for that information. **-user USER** is optional. **ISPPW** Password that is required to use your SIM card. Contact your internet service provider for that information. **-isppw ISPPW** is optional. **PIN** Pin that is required to use your SIM card. Contact your internet service provider for that information. **-pin PIN** is optional.
LTE.config.read	**LTE.config.read -get GET** Retrieve a single configuration item of your LTE configuration. **GET** Name of the item to get. **-get GET** is mandatory. Allowed values for **GET** are: **apn, dial, user, isppw, pin**.
LTE.deviceName	Description follows in next version.
LTE.getIccid	Description follows in next version.
LTE.mobileEquipmentStatus	**LTE.mobileEquipmentStatus** Query the modem for the mobile equipment status.
LTE.receivedSignal	**LTE.receivedSignal -dev DEV** Show the received signal quality. **DEV** tty device of the modem control interface. Defaults to the correct value. **-dev DEV** is optional.
LTE.reception	**LTE.reception** Show the received signal quality in unit of 'bars'.
LTE.restart	**LTE.restart** Restart LTE modem.
LTE.service.reception	Description follows in next version.
LTE.service.state	**LTE.service.state -verbose VERBOSE** Return the state of the LTE modem without blocking.

	VERBOSE Print the LTE state. **-verbose VERBOSE** is optional. Allowed values for **VERBOSE** are: **true**, **false**.
LTE.status	**LTE.status** Do an extensive diagnosis of the LTE modem status.

5.8. Network commands

This section describes the commands related to the network settings. Each API command needs the preamble ***MSRTKF*** (Example: ***MSRTKF Network.config***).

Command	Description
Network.config	**Network.config -interface INTERFACE -get GET** Get a config item. **INTERFACE** Name of the interface to configure (= **ETH**). **-interface INTERFACE** is mandatory. Allowed values for **INTERFACE** are: **ETH**. **GET** Name of the item to retrieve. **-get GET** is mandatory. Allowed values for **GET** are: **profile, static.address, static.netmask, linkLocalAddress, current.address, current.netmask, current.profile**. **Network.config -interface INTERFACE -set SET -value VALUE** Set a config item. **INTERFACE** Name of the interface to configure (= **ETH**). **-interface INTERFACE** is mandatory. Allowed values for **INTERFACE** are: **ETH**. **SET** Name of the item to change. **-set SET** is mandatory. Allowed values for **SET** are: **profile, static.address, static.netmask**. **VALUE** New value of the changed item. **-value VALUE** is mandatory. **Network.config -interface INTERFACE -get GET** Get a config item. **INTERFACE** Name of the interface to configure **(= WIFI). -interface INTERFACE** is mandatory. Allowed values for **INTERFACE** are: **WIFI**. **GET** Name of the item to retrieve. **-get GET** is mandatory. Allowed values for **GET** are: **profile, static.address, static.netmask, linkLocalAddress, current.address, current.netmask, current.ssid, current.quality, current.profile, ap.ssid, ap.psk, client.ssid, client.psk**. **Network.config -interface INTERFACE -set SET -value VALUE** Set a config item. **INTERFACE** Name of the interface to configure (= **WIFI**). **-interface INTERFACE** is mandatory. Allowed values for **INTERFACE** are: **WIFI**. **SET** Name of the item to change. **-set SET** is mandatory. Allowed values for **SET** are: **profile, static.address, static.netmask, ap.ssid, ap.psk, client.ssid, client.psk**. **VALUE** New value of the changed item. **-value VALUE** is mandatory.
Network.config.apply	**Network.config.apply** Apply pending network configuration.
Network.config.reset	Description follows in next version.

Network.profile.config	**Network.profile.config -get GET** Retrieve configured network profile of a single interface. **GET** Interface to be queried. **-get GET** is mandatory. Allowed values for **GET** are: **eth0, wlan0**. **Network.profile.config -set SET -p P** Set configured network profile of a single interface. **SET** Interface to be queried. **-set SET** is mandatory. Allowed values for **SET** are: **eth0, wlan0**. **P** Profile to set. DHCP, STATIC apply only to eth0. CLI_ and AP_ modes apply only to wlan0. **-p P is mandatory**. Allowed values for **P** are: **OFF, DHCP, STATIC, CLI_DHCP, CLI_STATIC, AP_STATIC**.
Network.profile.initialize	Description follows in next version.
Network.renew	**Network.renew** Change operating system network settings to match device/settings. **Network.renew -revert REVERT** Change device/settings to match operating system settings. **REVERT** Set to true to revert device/settings to operating system settings**. -revert REVERT** is mandatory. Allowed values for **REVERT** are: **true**.
Network.test	Description follows in next version.
Network.testConnectionNumber	Description follows in next version.
Network.wifi.info	Description follows in next version.
Network.wifi.NAT	**Network.wifi.NAT -mode MODE** Enable NAT for your Wi-Fi access point (allows clients to use your internet connection). **MODE** Operation mode for NAT. **-mode MODE** is mandatory. Allowed values for **MODE** are: **OFF**, **LTE**.
Network.wifi.scan	Description follows in next version.

5.9. Record commands

This section describes the commands related to recording sensor raw data, the sensor fusion solution and the corresponding logs. Each API command needs the preamble ***MSRTKF*** (Example: ***MSRTKF Record.setMode***).

Command	Description
Record.deleteDataset	**Record.deleteDataset -name NAME** Delete a recordered dataset. **NAME** Name of the dataset. **-name NAME** is mandatory. Allowed values for **NAME** are: **20210409_1149_UTC**, **20210803_1222_UTC** (examples)
Record.extractStream	**Record.extractStream -name NAME -stream STREAM** Extract a stream from a dataset. **NAME** Name of the dataset. **-name NAME** is mandatory. Allowed values for **NAME** are: **20210409_1149_UTC, 20210803_1222_UTC** (examples)

	STREAM Stream to extract. **-stream STREAM** is mandatory. Allowed values for **STREAM** are: **recorder.log, LOGvrs.osr, LOGrover0.ubx, driver.log, maintenance.log, ARCHIVE, LOGrover2.ubx, LOGcan.ubx, LOGrover1.ubx, navigation.log, PAD_solution.bin**.
Record.getMode	**Record.getMode** Get currently active recorder mode.
Record.listDatasets	**Record.listDatasets** Print a list of all datasets.
Record.setMode	**Record.setMode -mode MODE** Select operation mode of the recorder. **MODE** Selected mode. **-mode MODE** is mandatory. Allowed values for **MODE** are: **UNKNOWN, OFF, SOLUTION, RAW, ALL**.

5.10. Server commands

This section describes the server commands. Each API command needs the preamble ***MSRTKF*** (Example: ***MSRTKF Server.installUpdate***).

Command	Description
Server.installUpdate	Description follows in next version.
Server.mirrorStream	Description follows in next version.
Server.performanceLog	**Server.performanceLog -sort SORT** Print performance log. **SORT** Sort by. **-sort SORT** is optional. Allowed values for **SORT** are: **SELF_TIME, TOTAL_DURATION, INVOCATIONS, AVG_DURATION**.
Server.printTrace	**Server.printTrace** Prints the complete trace log of this command server.
Server.remotePerformanceLog	**Server.remotePerformanceLog -sort SORT -summed SUMMED** Print performance log. **SORT** Sort by. **-sort SORT** is optional. Allowed values for **SORT** are: **TERMINATION_TIME, ISSUE_TIME, SERVING_LATENCY, EXECUTION_LATENCY, DURATION, WASTED_TIME, WAITED_TIME, BLOCKED_TIME, CPU_TIME**. **SUMMED** Accumulate over all entries of the same operation. **-summed SUMMED** is optional. Allowed values for **SUMMED** are: **true**, **false**.
Server.traceRetention	**Server.traceRetention** Get current trace retention mode. **Server.traceRetention -set SET** Set current trace retention mode. For safety-reasons, this setting can not be made persistent and will go back to SOFT after a restart. **SET** New mode. **-set SET** is mandatory. Allowed values for **SET** are: **SOLID, SOFT, WEAK**.
Server.updateMaintenanceTool	**Server.updateMaintenanceTool -rbin RBIN** Write binary to temporary location and use atomic file system operation to replace the old binary with the new binary.

	RBIN Resource that will provide the new binary. **-rbin RBIN** is mandatory.
Server.version	Description follows in next version.

5.11. Time commands

This section describes the time commands related to NTP. The commands are described in more detail in chapter 9. Each API command needs the preamble ***MSRTKF*** (Example: ***MSRTKF Time.config***).

Command	Description
Time.adjust	Description follows in next version.
Time.config	**Time.config -set SET -value VALUE** Set a time configuration parameter. **SET** Item to be configured. **-set SET** is mandatory. Allowed values for **SET** are: **timePolicy**, **timeServer**. **VALUE** Time sync policy. **-value VALUE** is mandatory. Allowed values for **VALUE** are: **SYNC_OFF, SYNC_GNSS, SYNC_NETWORK, AUTO, time.nist.gov**. **Time.config -get GET** Get a time configuration parameter. GET Item to be retrieved. **-get GET** is mandatory. Allowed values for **GET** are: **timePolicy, timeServer**.
Time.error	Description follows in next version.
Time.NTP.sync	Description follows in next version.
Time.service.status	Description follows in next version.

6. The ANavS Binary Solution Output Format

The ANavS® sensor fusion solution provides two different output-streams for the position, attitude, velocity and many more states of solution and quality of solution, the standardized NMEA-Format and the proprietary binary protocol. In the following, the proprietary ANavS® binary protocol is described.

By default, it is possible to configure the system simultaneously to write the solution into a file and broadcast the solution via TCP/IP on port **6001**. To stream the solution via Wi-Fi, Ethernet or mobile network, the user needs additionally to the defined port-number the IP-address of the module, which is by default ***192.168.42.1*** in case you are connected with Wi-Fi Access-Point ***"ANavS_MSRTK_XXX"***.

6.1. The Standard Binary Solution Message

The Binary Protocol is defined as follows:

Structure:	**Sync Char 1**	**Sync Char 2**	**Class**	**ID**	**Length**	**Payload**	**ChecksumA**	**ChecksumB**
Bytes:	1 Byte	1 Byte	1 Byte	1 Byte	2 Byte	*Length*-Byte	1 Byte	1 Byte

The endianness of ***Length*** and the following ***Payload*** is little endian. The payload is of ***Length***. The checksum is calculated with the 16-Bit Fletcher algorithm over Class, ID, Length and Payload with modulo 256. The ANavS® binary protocol message can be identified by Sync Char 1 = 0xB5 (dec 181), Sync Char 2 = 0x62 (dec 98), Class = 0x02 (dec 2) and Id = 0xE0 (dec 224).

In the following, the type of double has 8 bytes. If a variable in the Payload is given in the NED frame, the variable has three components (hence 3 times the data type, e.g. 3*double), where the components are north, east and down. This also holds for the body frame, which is the fixed frame of the rover, and where the components are given in x, y and z.

6.1.1. The Payload

The Payload is given as:

				Size	**Scaling**	**Name**	**Unit**	**Description**
				uint8	–	id	–	Identifier of the system/the ANavS Position and Attitude Determination (PAD) solution.

				uint16	–	resCode	–	Result code bitfield, which keeps the system status and information.
				uint16	–	week	–	Week number of the current epoch (epoch means Kalman filter state-update with GNSS, IMU or another sensor data).
				double	–	tow	s	Time of Week of the current epoch.
				uint16	–	weekInit	–	Week number of the epoch when the system was started.
				double	–	towInit	s	Time of Week of the epoch when the system was started.
				int16	–	–	–	Reserved
				double	–	lat	deg	Latitude in WGS84.
				double	–	lon	deg	Longitude in WGS84.
				double	–	height	m	Height in WGS84 with geoid EGM96
				double	–	ECEF-X	m	X-position in ECEF-coordinate frame (WGS84).
				double	–	ECEF-Y	m	Y-position in ECEF-coordinate frame (WGS84).
				double		ECEF-Z	m	Z-position in ECEF-coordinate frame (WGS84).
				3*double	–	b	m	Baseline in NED frame spanned by the position given by lat, lon and height, and by the position of the reference station.
				3*double	–	bStdDev	m	Standard deviation of the baseline.
				3*double	–	vel	m/s	Velocity in NED frame.

				3*double	–	velStdDev	m/s	Standard deviation of the velocity.
				3*double	–	acc	m/s²	Acceleration in body frame.
				3*double	–	accStdDev	m/s²	Standard deviation of the acceleration.
				3*double	–	att	deg	Attitude/Euler angles (heading, pitch, roll).
				3*double	–	attStdDev	deg	Standard deviation of the attitude.
				double	–	accuracy	m	Estimated accuracy of the baseline.
				double	–	systemTimeSolOut	s	System time of solution data output packet
				5*double	–	timingInfo	s	CPU-Load of used sensors. The sum (green line in the GUI) of elapsed time should not over 1 second (–> to slow processor). First double: Elapsed time GNSS; Second double: Elapsed time IMU; Third double: Elapsed time Baro; Fourth double: Elapsed time Odometry; Fifth double: Overall elapsed time
				double	–	systemTimePrevPAD	s	System time before executing sensor data
				double	–	systemTimePostPAD	s	System time after executing sensor data
				3*double	–	accNed	m/s²	Acceleration in NED frame.
				1*double	–	–	–	Reserved
				uint8	–	**numSats**	–	Number of satellites.

			Loop	uint8	–	gnssId	–	Identifier of the GNSS (GPS = 1, SBAS = 2, GLONASS = 4, Galileo = 8).
				uint8	–	svId	–	Identifier of the satellite (“PRN”)
				double	–	elev	deg	Elevation angle of the satellite.
				double	–	azim	deg	Azimuth angle of the satellite.
				uint8	–	**numRcv**	–	Number of GNSS receivers.
		Loop		uint8	–	rcvId	–	Identifier of the receiver (unique within this system).
				char[11]	–	serial	–	Serial number of the receiver (unique).
				bool	–	isRefStation	–	Is true if this receiver is a reference station (stationary).
				uint16	–	week	–	Week number of the current epoch for this receiver. If the following tow is NaN, the week number is not valid!
				double	–	tow	s	Time of week of the current epoch for this receiver. Can be NaN, if there are no measurements at this epoch (e.g. commonly for reference station).
				double	–	lat	deg	Latitude of this receiver. Only given if the receiver is a reference station, otherwise it is NaN.
				double	–	lon	deg	Longitude of this receiver. Only given if the receiver is a reference station, otherwise it is NaN.

				double	–	height	m	Height of this receiver. Only given if the receiver is a reference station, otherwise it is NaN.
				3*double	–	bodyPos	m	Receiver position in x, y and z (body frame).
				3*double	–	bodyMisalign	m	Misalignment of the receiver in x, y and z (body frame).
				uint8	–	–	–	Reserved.
				5*double	–	sensorBufFillLvl	%	Sensor buffer filling level: First double: GNSS Second: IMU Third: BARO Fourth: ODO Fifth: Raw
				uint8	–	**numSatsMeas**	–	Number of satellites for which measurements are available for this receiver.
			Loop	uint8	–	gnssId	–	Identifier of the GNSS.
				uint8	–	svId	–	Identifier of the satellite.
				uint8	–	freq	–	Frequency band (currently that is 1 L1)).
				uint16	–	locktime	ms	Carrier phase locktime counter (maximum 64500ms).
				uint8	–	cno	dBHz	Carrier-to-noise density ratio (signal strength) [dB-Hz].
				uint8	0.01*2^n	prStdDev	m	Standard deviation of the pseudorange measurement.
				uint8	0.004	cpStdDev	cycles	Standard deviation of the carrier phase measurement.

				uint8	0.002*2^n	doStdDev	Hz	Standard deviation of the Doppler frequency.
				uint8	–	trkStat	–	Status bitfield of the tracking (see graphic below).
				uint8	–	**numBl**	–	Number of baselines spanned by a receiver pair.
			Loop	uint8	–	rcvId1	–	Identifier of the receiver the baseline is pointing to.
				uint8	–	rcvId2	–	Identifier of the receiver the baseline is pointing from.
				bool	–	isFixed	–	Is true if the ambiguities of the phase measurements are fixed for this baseline.
				uint8	–	gnssIdJointRefSat	–	GNSS identifier of the joint reference satellite for the single and double differenced measurements.
				uint8	–	svIdJointRefSat	–	Identifier of the reference satellite.
				uint8	–	svIdGloRefSat	–	Identifier of the GLONASS reference satellite.
				uint8	–	svIdUnlSat	–	Identifier of the GLONASS ultra-narrow lane satellite.
				3*double	–	aprioriBl	m	A priori baseline.
				3*double	–	stdDevAprioriBl	m	Standard deviation of the a priori baseline.
				double	–	aprioriLen	m	A priori baseline length.
				double	–	stdDevAprioriLen	m	Standard deviation of the a priori baseline length.

				uint8	–	**numFilter**	–	Number of filters.
Loop				uint8	–	nameLen	Bytes	Length of the filter name.
				char[nameLen]	–	name	–	Filter name.
				uint32	–	params	–	Bitfield of parameters (states, residuals), which are transmitted by the filter.
				bool	–	**isActive**	–	Is true if the filter is active.
		Conditioned on Bit 0, i.e. if Bit 0 is not set, this shall not be considered (no pointer increment, just leave out!).		6*double	–	absPos	deg and m	Absolute position in latitude, longitude (both in deg) and height (in m) (first 3 doubles) and its standard deviation (latter 3 doubles).
		Bit 1		2*double	–	clkErr	s	Receiver clock error (first double) and its standard deviation (latter double).
		Bit 2		uint8	–	rcvId1	–	Identifier of the receiver the baseline is pointing to.
				uint8	–	rcvId2	–	Identifier of the receiver the baseline is pointing from.
				6*double	–	baseline	m	Baseline in NED frame (first 3 doubles) and its standard deviation (latter 3 doubles).
		Bit 3		6*double	–	vel	m/s	Velocity in body frame (first 3 doubles) and its standard deviation (latter 3 doubles).

		Bit 4		6*double	–	acc	m/s²	Acceleration in body frame (first 3 doubles) and its standard deviation (latter 3 doubles).
		Bit 5		6*double	–	accBias	m/s²	Accelerometer bias in body frame (first 3 doubles) and its standard deviation (latter 3 doubles).
		Bit 6		6*double	–	eulerAng	deg	Euler angles in heading, pitch and roll (first 3 doubles) and its standard deviation (latter 3 doubles).
		Bit 7		6*double	–	angRate	deg/s	Angular rate in heading, pitch and roll (first 3 doubles) and its standard deviation (latter 3 doubles).
		Bit 8		6*double	–	gyroBias	deg/s	Gyroscope bias (first 3 doubles) and its standard deviation (latter 3 doubles).
		Bit 9		2*double	–	tropoZenDel	m	Tropospheric zenith delay (first double) and its standard deviation (latter double). Currently not in use (Bit 9 is always 0).
		Bit 10		2*double	–	Accuracy	m	Accuracy of the baseline (first double) and its standard deviation (latter double). Currently not in use (Bit 10 is always 0).
		Bit 11-17		7*double	–	Reserved	–	–
				uint8	–	**numPhase**	–	Number of phase measurements.
			Loop	uint8	–	gnssId	–	Identifier of the GNSS.

				uint8	–	svId	–	Identifier of the satellite.
				uint8	–	freq	–	Frequency band (currently that is 1 (L1)).
		Bit 18		2*double	–	ambiguities	cycles	Double difference ambiguities and std. dev.
		Bit 19		2*double	–	phaseMp	m	Phase multipath and std. dev.
		Bit 20		2*double	–	phaseRes	m	Phase residuals and std. dev.
				uint8	–	**numCode**	–	Number of code measurements.
			Loop	uint8	–	gnssId	–	Identifier of the GNSS.
				uint8	–	svId	–	Identifier of the satellite.
				uint8	–	freq	–	Frequency band (currently that is 1 (L1)).
		Bit 21		2*double	–	codeMp	m	First double is code multipath, second its standard deviation.
		Bit 22		2*double	–	codeRes	m	First double is code residual, second its standard deviation.
				uint8	–	**numDoppler**	–	Number of Doppler measurements.
			Loop	uint8	–	gnssId	–	Identifier of the GNSS.
				uint8	–	svId	–	Identifier of the satellite.
				uint8	–	freq	–	Frequency band (currently that is 1 (L1)).
		Bit 23		2*double	–	doRes	Hz	First double is Doppler residual, second is its standard deviation.

The payload contains loops and conditions. The number of loop iterations and the conditions depends on other payload data. For example, the number of satellites determines, how often the following color-coded data is repeated. For *numSats = 2* and *p* being a pointer to *numSats*, the following data is given as:

Address	Type	Name
p+1	uint8	gnssId1
p+2	uint8	svId1
p+3	double	elev1
p+11	double	azim1
p+19	uint8	gnssId2
p+20	uint8	svId2
p+21	double	elev2
p+29	double	azim2
p+37	uint8	numRcv

For *numSats = 0*, no satellite position data is transmitted, and the next variable would be *numRcv*. If a condition is fulfilled, the following color-coded data is transmitted. For example, if *isActive* is true, then at least the variables *numPhase*, *numCode* and *numDoppler* are transmitted. If *isActive* is false, then the end of the binary message is reached. The bitfield *params* is also a condition, whose bits determine, whether the following data is transmitted. **Example:** Let *p* being a pointer to *isActive* with *isActive = true*, Bit 0 of *params* is false and Bit 1 is true. Then, p+1 points to the receiver clock error *clkErr* and not to the absolute position *absPos* since Bit 0 is false.

6.1.2. The Result-Code

The resCode bitfield in the solution message is defined as:

Bit	Definition
0	Is set for **GNSS** update-epochs processed in the PAD-Software
1	Is set for **IMU** update-epochs processed in the PAD-Software
2	Is set for **Barometer** update-epochs processed in the PAD-Software
3	Is set for **Odometry** update-epochs processed in the PAD-Software
4	Is set for **Camera** update-epochs processed in the PAD-Software
5	Is set for **Steering** update-epochs processed in the PAD-Software
6	Is set if the **IMU** is initialized/calibrated
7	Is set if the **Multi-Sensor RTK-Filter is reset** in the current epoch
8	Is set if **RTK correction** were received initially
9 to 10	State-definition for the Attitude Kalman-Filter: 00 -> No solution 01 -> Least-Squares solution 10 -> Float solution 11 -> Fixed solution
11 to 12	State-definition for the RTK-Position Kalman-Filter: 00 -> No solution 01 -> Least-Squares solution 10 -> Float solution 11 -> Fixed solution

13	Is set if the RTK-Position Kalman-Filter has only a float-solution accuracy but enough satellites in view to try a RTK-refix (the vehicle must be stationary for this try!)
14	Is set if state update is only a prediction step (without sensor data) in our sensor fusion filter. In this case, Bit 0-5 is set to zero.
15	Reserved

6.2. The Extended Integrity Information Message

To extend the existing binary solution message format with more integrity information, ANavS provides since version 5.1.72 an additional message with the following header:

Sync Char 1 = 0xB5 (dec 181), Sync Char 2 = 0x62 (dec 98), Class = 0x02 (dec 2) and **Id = 0xE5 (dec 229).**

The Message is activated via **customer-code 10.**

6.2.1. The Payload

The Payload is given as:

Size	Scaling	Name	Unit	Description
uint16	–	week	–	Week number of the current epoch
double	–	tow	s	Time of Week of the current epoch
double	–	cov_b_xx		Covariance matrix of RTK solution (value xx)
double	–	cov_b_xy		Covariance matrix of RTK solution (value xy)
double	–	cov_b_xz		Covariance matrix of RTK solution (value xz)
double	–	cov_b_yx		Covariance matrix of RTK solution (value yx)
double	–	cov_b_yy		Covariance matrix of RTK solution (value yy)
double	–	cov_b_yz		Covariance matrix of RTK solution (value yz)
double	–	cov_b_zx		Covariance matrix of RTK solution (value zx)
double	–	cov_b_zy		Covariance matrix of RTK solution (value zy)
double	–	cov_b_zz		Covariance matrix of RTK solution (value zz)
double	–	GDOP		Dilution of Precision: GDOP
double	–	PDOP		Dilution of Precision: PDOP
double	–	HDOP		Dilution of Precision: HDOP
double	–	VDOP		Dilution of Precision: VDOP
double	–	TDOP		Dilution of Precision: TDOP
bool	–	Flag: No Movement		**True:** Rover stand still, no movement detected with IMU –> RTK- and Attitude Fix is triggered, bias estimation of IMU also. **False:** Rover is moving –> NO RTK- and Attitude Fix is triggered, NO bias estimation of IMU
double	–	RTK-Fix Validation		Difference of successfully fixed RTK-baseline to the next best candidate. Only if **"Flag No Movement"** is true, this value is relevant for integrity information of RTK baseline.
double	–	Correction-Outage		Time since last RTK correction-data arrived.

7. The NMEA Solution Output Format

The ANavS® sensor fusion solution provides two different output-streams for the position, attitude, velocity and many more states of solution and quality of solution, the standardized NMEA-Format and the proprietary binary protocol. In the following, the NMEA-format is described.

By default, it is possible to configure the system simultaneously to write the solution into a file and broadcast the NMEA solution via TCP/IP on port **6002**. To stream the solution via Wi-Fi, Ethernet or mobile network, the user needs additionally to the defined port-number the IP-address of the module, which is by default ***192.168.42.1*** in case you are connected with Wi-Fi Access-Point ***"ANavS_MSRTK_XXX"***.

7.1. The NMEA-Format

This protocol is based on the international standard for maritime navigation and radio communication, equipment and systems and digital interfaces (IEC 61161-1)[8]. This standard adopted the de-facto standards for interfacing marine electronic devices, known as NMEA 0183. The data is transmitted in sentences of variable length with a specified sentence structure.

7.1.1. Sentence Structure

- Address field
- Data fields
- Checksum field
- Terminating field
- All sentences contain only ASCII characters
- The maximum length of a sentence is 82 characters
- All fields are separated by delimiters

7.1.2. Address field

The address field starts with "$" followed by the talker ID and a sentence identifier. The used talker IDs are:

- GP for GPS only solutions
- GL for GLONASS only solutions

[8] IEC 61162-1 ed.2: http://read.pudn.com/downloads151/ebook/657722/IEC%2061162-1%20ed.2%20(2000).pdf

- GA for GALILEO only solutions
- GN for multi GNSS solutions

The used sentence identifiers are:

- GGA – Global Positioning System Fix Data
- VTG – Course over Ground and Ground Speed
- GSA – GNSS DOP and Active Satellites
- GSV – GNSS Satellites in View
- RMC – Recommended Minimum Specific GNSS Data
- ZDA – Time and Date
- PASHR – Attitude Data
- ROT – Rate of Turn Data
- THS – True Heading State Data

7.1.3. Data fields

Data fields must always be separated by ",". They can contain alpha, numeric, and alphanumeric values all coded in ASCII characters. The length of a data field can be constant, variable or can contain a fixed and variable portion. This differs for each sentence.

7.1.4. Checksum field

The Checksum field starts with "*" followed by the checksum of the sentence. The Checksum is generated with a bitwise exclusive OR of all fields including the "," delimiters, between but not including the "$" and the "*" characters. The hexadecimal value of the checksum is then converted to two ASCII characters.

7.1.5. Terminating field

The terminating sequence contains the two ASCII characters <CR> and <LF> without any delimiter.

7.1.6. Satellite Numbering

- GPS: 1-32
- GLONASS: 33-96
- GALILEO: 301-336 [9]

[9] Currently no standard way to number Galileo satellites.

7.2. Sentence specification

7.2.1. GGA – Global positioning system (GPS) fix data

TALKER ID	XX	All talker IDs usable
SENTECE ID	GGA	
UTC of position	hhmmss.ss	Fixed length 2 digits after dot
Latitude	llll.lllllll	Fixed length 4 digits before and 7 after dot
Hemisphere of latitude	N/S	N if value of latitude is positive
Longitude	lllll.lllllll	Fixed length 5 digits before and 7 after dot
Hemisphere of longitude	E/W	E if value of longitude is positive
GPS quality indicator	X	0: GNSS fix not available 1: GNSS fix valid 4: RTK fixed ambiguities 5: RTK float ambiguities
Number of satellites used for positioning	XX	Fixed length 01 for single digits
HDOP	XX.X	Variable/fixed length 1 digit after dot, variable before
Altitude geoid height	(-)X.XX	Variable/fixed length 2 digits after dot, variable before
Unit of altitude	M	
Geoidal separation	(-)X.XX	Variable/fixed length 2 digits after dot, variable before
Unit of geoidal separation	M	
Age of differential data	XX.X	Age of RTK corrections. Empty if RTK corrections never received. Variable/fixed length: 1 digit after dot, variable before
Differential reference station ID		Empty field

Example:
$GNGGA,185833.80,4808.7402397,N,01133.9325039,E,5,15,1.1,470.50,M,45.65,M,,*75

7.2.2. VTG – Course over ground and ground speed

TALKER ID	XX	All talker IDs usable
SENTENCE ID	VTG	
Course over ground	X.XX	Variable/fixed length 2 digits after dot, variable before Values from 0 to 359.99
Degrees	T	True course
Course over ground	X.XX	Variable/fixes length 2 digits after dot, variable before Values from 0 to 359.99
Degrees	M	Magnetic course
Speed over ground	X.XX	Variable/fixed length 2 digits after dot, variable before
Unit	N	knots

Speed over ground	X.XX	Variable/fixed length 2 digits after dot, variable before
Unit	K	Km/h
Mode indicator	X	A: Autonomous mode

The VTG sentence is empty ($GNVTG,,T,,M,,N,,K,A*3D) until attitude baseline is valid. Course over ground equals heading.

Example:
$GNVTG,112.99,T,109.99,M,0.15,N,0.08,K,A*3B

7.2.3. GSA – GNSS DOP and active satellites

TALKER ID	XX	All talker IDs usable*
SENTENCE ID	GSA	
MODE	X	1: GNSS fix not available 3: 3D
MODE	XX	M: forced to operate in 3D
ID number	XX XX XX XX XX XX XX XX XX XX XX XX	Fixed length: 01 for single digit Up to 12 satellites per constellation Empty field if not used for positioning GPS: ID is PRN (1-32) GLONASS: ID is slot number + 64 GALILEO: PRN + 300
PDOP HDOP VDOP	XX.XX	Fixed length 2 digits before and after dot

*if GN is used for Talker ID a separate sentence must to created for each GNSS constellation all starting with the Talker ID for multi GNSS.

Example:
$GNGSA,2,M,06,12,15,17,19,24,25,32,1.34,0.96,0.93*1D
$GNGSA,2,M,70,71,79,80,81,82,88,1.34,0.96,0.93*3A

7.2.4. GSV – GNSS satellites in view

TALKER ID	XX	GN must not be used*
SENTENCE ID	GSV	
Total number of messages	X	1-9
Message number	X	1-9
Total number of satellites in view	XX	Fixed length: 01 for single digit

Satellite ID number	XX	Fixed length: 01 for single digit Empty field if not used for positioning GPS: ID is PRN (1-32) GLONASS: ID is slot number + 64 GALILEO: PRN + 300
Elevation	XX	Fixed length: 00 for 0° elevation Values from 0 to 90 Empty if not used
Azimuth	XXX	Fixed length: 000 for 0° azimuth Values from 000 to 360 Empty if not used
SNR	XX	Fixed length: 05 for 5 db/Hz Values from 0-99 Empty if not used

*if multi GNSS is used a separate GSV sentence must be created for each constellation starting with the constellation specific talker ID.

This block is repeated 4 times per sentence in total. For more than multiples of 4 a new sentence is started each time. Blocks are left empty if the number of satellites in view is lower than a multiple of 4.
Example:
$GPGSV,6,1,10,02,3.6,133.2,26,10,06,11.7,100.7,39,10,10,9.6,281.5,35,10,12,63.1,256.5,46*58
$GPGSV,6,2,10,15,26.5,186.0,43,10,17,30.5,48.7,42,10,19,43.9,65.3,46,10,24,86.5,103.6,46*5E
$GPGSV,6,3,10,25,21.6,250.8,43,10,32,21.7,316.0,41,,,,,,,,,,*5E
$GLGSV,6,4,09,69,7.0,215.9,30,09,70,30.8,267.4,44,09,71,23.0,324.4,46,09,73,13.0,286.8,33*72
$GLGSV,6,5,09,79,47.8,70.6,43,09,80,54.9,314.5,38,09,81,48.6,86.8,43,09,82,28.4,150.8,46*49
$GLGSV,6,6,09,88,21.3,28.0,40,,,,,,,,,,,,,,,*4E

7.2.5. RMC – Recommended minimum specific GNSS data

TALKER ID	XX	All talker IDs usable
SENTENCE ID	RMC	
UTC time	hhmmss.ss	Fixed length
Status	X	A: data valid
Latitude	llll.lllll11	Fixed length 4 digits before and 7 after dot
Hemisphere of latitude	N/S	N if value of latitude is positive

Longitude	lllll.lllllll	Fixed length 5 digits before and 7 after dot
Hemisphere of longitude	E/W	E if value of longitude is positive
Speed over ground	X.XX	Variable/fixed length 2 digits after dot, variable before
Course over ground	X.XX	Variable/fixed length 2 digits after dot, variable before Values from 0 to 359.99
Date	ddmmyy	
Magnetic variation	X.XX	Variable/fixed length: 2 digits after dot, variable before
	E/W	E if variation positive
Mode indicator		A: Autonomous D: Differential

Example:
$GNRMC,185823.40,A,4808.7402374,N,01133.9324760,E,0.00,112.64,130117,3.00,E,A*14

7.2.6. ZDA – Time and date

TALKER ID	XX	All talker Ids usable
SENTECE ID	ZDA	
UTC time	hhmmss.ss	Fixed length
Day	XX	Fixed length 01 to 31
Month	XX	Fixed length 01 to 12
Year	XXXX	
Local zone hours		Empty field
Local zone minutes		Empty field

Example:
$GNZDA,185823.40,13,01,2017,,*7E

7.2.7. PASHR – Attitude Data

TALKER ID		No talker ID
SENTENCE ID	PASHR	
UTC time	hhmmss.ss	Fixed length

Heading*	XXX.XX	Fixed value: 000.00 for 0° 3 digits before dot, 2 after
	T	True heading
Roll angle*	(-)XXX.XX	Fixed value: 000.00 for 0°
Pitch angle*	(-)XXX.XX	3 digits before dot, 2 after
Heave		Empty field
Roll standard deviation*	XX.XXX	Fixed value
Pitch standard deviation*	XX.XXX	2 digits before dot 3 after
Heading standard deviation*	XX.XXX	
Quality flag	X	0: No position 1: RTK float position 2: RTK fixed position

* attitude angles and corresponding deviation values are only filled for defined setup (3D, 2D)

Example:

$PASHR,190558.56,107.09,T,,-0.16,,,0.067,0.056,2*34

7.2.8. ROT – Rate of Turn Data

TALKER ID	XX	
SENTENCE ID	ROT	
Rate of turn	(-)X.X	In degrees. Variable/fixed length: 2 digits after dot, variable before
Valid/Invalid	X	A: Valid data V: Invalid data

Example:

$GNROT,35.6,A*4E

7.2.9. THS – True Heading State Data

TALKER ID	XX	
SENTENCE ID	ROT	
True Heading	XXX.XX	Fixed value: 000.00 for 0° 3 digits before dot, 2 after
Valid/Invalid	X	A: Valid data V: Invalid data

Example:

$GNTHS,35.6,A*4E

8. CAN-Interface

CAN is a robust and widely spread data bus standard which is among other applications also used in almost all modern vehicles for communication between the various controllers in it.

The ANavS Positioning Systems come with a CAN Interface that allows the user to input wheel odometry values and/or to access the solution data over that interface. When equipped, the Interface can be accessed by the DE-9 connector on the module. The pin assignment is in accordance with CiA® 303-1 and given below:

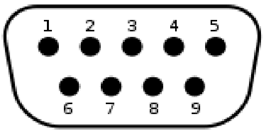


Figure 38: pin assignment is in accordance with CiA® 303-1

Pin	Pin assignment
1	Not connected
2	CAN-L
3	GND
4	Not connected
5	GND
6	Not connected
7	CAN-H
8	Not connected
9	Not connected

The CAN Interface can be fully configured in the ANavS Wizard, where the whole configuration is done in the second step of the initialization process. The CAN-settings are divided in three categories: the **bus settings**, the **solution output (CAN-Output)** and the **odometry input (CAN-Input)**. Every section has three buttons to get, set and restore the configurations of the corresponding section.

8.1. CAN Bus Settings

In this section, all physical settings of the CAN Interface are configured. These are:

- **Bus-Speed:** Select the Bit rate of the CAN bus. By default, 500 kBit/s are selected.
- **Termination:** CAN requires a 120 Ohm hardware termination at the last transceiver. The MSRTK System has a built in switchable 120 Ohm termination which can be enabled by using this slider.

- **Bus-Mode:** The *normal mode* is the default mode in which the CAN Interface is fully operating. In the *listen-only mode*, the CAN-Controller does not transmit any data and does not acknowledge the received CAN-frames. This mode can be used to monitor the data bus without participate or interfere with the traffic on the bus. In the *listen-only mode* it is not possible to output solution information.
- **Output-Enabled:** This function is intended as an extra security layer to avoid unintentional writing on the CAN bus. It has to be enabled in order to use the solution output functionality of the CAN Interface. Otherwise, it is recommended to switch it off.

8.2.CAN-Output: ANavS-Solution

The CAN Interface can be used to output the ANavS solution from the sensor fusion software. The CAN Interface sends for each solution variable a unique message containing the value. The endianness of the values is **big-endian** The CAN address corresponds to the ID of the variable. The variables are bundled in groups which can be activated or deactivated by checking the corresponding boxes in the ANavS Wizard. As standard, each packet has a unique ID which is also shown in the table below. To change the IDs of the CAN messages (e.g. to avoid collisions with the information of other devices on the bus), there is the possibility to add an offset to all messages. To use the solution output via CAN, the bus must be configured in the normal mode and the output must be enabled (see section **CAN Bus Settings** above).

The corresponding DBC file can be found in Appendix 1.

ID	Format	Name	Unit	Description
1	uint16	resCode	–	Result code bitfield, which keeps the system status and information.
2	uint16	week	–	Week number of the current epoch.
3	double	tow	s	Time of Week of the current epoch.
4	uint16	weekInit	–	Week number of the epoch when the system was started.
5	double	towInit	s	Time of Week of the epoch when the system was started.
7	double	lat	deg	Latitude.
8	double	lon	deg	Longitude.

9	double	height	m	Height
10	double	ECEF-X	m	X-position in ECEF-coordinate frame
11	double	ECEF-Y	m	Y-position in ECEF-coordinate frame
12	double	ECEF-Z	m	Z-position in ECEF-coordinate frame
13 – 15	3*double	b	m	Baseline in NED frame spanned by the position given by lat, lon and height, and by the position of the reference station.
16 – 18	3*double	bStdDev	m	Standard deviation of the baseline.
19 – 21	3*double	vel	m/s	Velocity in NED frame.
22 – 24	3*double	velStdDev	m/s	Standard deviation of the velocity.
25 – 27	3*double	acc	m/s²	Acceleration in body frame.
28 – 30	3*double	accStdDev	m/s²	Standard deviation of the acceleration.
31 – 33	3*double	att	deg	Attitude/Euler angles (heading, pitch, roll).
34 – 36	3*double	attStdDev	deg	Standard deviation of the attitude.
39 – 43	5*double	timingInfo	s	CPU-Load of used sensors. The sum (green line in the GUI) of elapsed time should not over 1 second (–> to slow processor). First double: Elapsed time GNSS; Second double: Elapsed time IMU; Third double: Elapsed time Baro; Fourth double: Elapsed time Odometry; Fifth double: Reserved
49	double	gnssReception	–	Scalar, which indicates the GNSS

				signal reception. The value is between 0 and 20, where 20 is the best, i.e. very good conditions.
50	uint8	numSats	–	Number of satellites.

8.3. CAN-Input: Dynamic CAN Decoder with .dbc-file

The ANavS sensor fusion can handle different forms of vehicle odometry. Up to 5 variables can therefore be defined. These are either one, two or four independent wheel speeds, and the steering angle or another heading information of the vehicle in the vehicle frame. The algorithms inside of the sensor fusion software calculate from the different inputs the current velocity information in the body frame of the vehicle for the positioning algorithm.

The wheel speed is processed as a signed value. A negative speed means thereby that the wheel is turning backward. It is possible to define the sign on a different CAN message. This could be used if the turning direction of a wheel is encoded in another message or position than the speed. This can also be done with the steering angle if needed.

The implemented Dynamic CAN Decoder allows you to use the ANavS Positioning Systems with CAN signals from your .DBC file without sharing the file with third parties or ANavS. The .dbc file used in this HOW TO is appended to the appendix.

Minimal required software versions:
MAINTENANCE_TOOL=4.1.3059
DRIVER=4.1.1807
(Both released on 23.01.2020 via beta channel)

8.3.1. Overview

The following Figure 39 shows the overall approach for the preparing of the ANavS Positioning System for the DBC-file, already provided e.g. by the car-manufacturer for an easy decoding of the CAN messages.

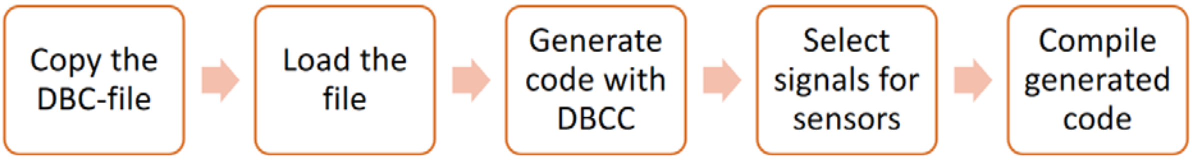


Figure 39: Overview showing the overall approach for preparing the ANavS-System for the DBC-file

8.3.2. Copy the DBC-file

Use an FTP/SCP client of your choice to copy your .DBC file to the ANavS Positioning System. To speed up all steps, the user may want to remove unnecessary signals if the DBC-file is very long. Let's assume the user puts the DBC-file to */home/pi/golf.dbc* The example file used here is included in the appendix.

8.3.3. Load the file

For every remaining step, the user needs to have access to the ANavS Positioning System via SSH. On the MSRTK-System's shell, load the file with:

MSRTKF CAN.loadDbc -source /home/pi/golf.dbc

8.3.4. Generate code with DBCC

Now, the user must run **dbcc** to generate the source code required to understand signals from your DBC-file. Though there is no hard limit on the number of signals in your DBC file, the resulting code may get very inefficient, if the DBC-file consists of millions of signals. A few thousand signals should be fine. On the shell, run **dbcc** with:

MSRTKF CAN.dbcc

8.3.5. Select signals for sensors

Now the user needs to map CAN signals to sensors supported by the ANavS Positioning System. Supported sensors are:

- Wheel odometry
  - Front Left (FL)
  - Front Right (FR)
  - Rear Left (RL)
  - Rear Right (RR)
- Steering angle

As of January 2020, the positioning accuracy only benefits from RL and RR. Some cars use unsigned odometry signals and provide turning direction as a separate signal.

To view the current signal map, run on the MSRTK-System's shell:

MSRTKF CAN.signal -get ALL

To view all imported signals, run on the MSRTK-System's shell:

MSRTKF CAN.signal

In this example, we see these:

>> MSRTKF CAN.signal
can_0x216_WheelDirection.WheelDirRearLeft
can_0x216_WheelDirection.WheelDirRearRight
can_0x217_WheelSpeed.WheelSpeedRearLeft
can_0x217_WheelSpeed.WheelSpeedRearRight

To find out a specific signal, run on the shell:

MSRTKF CAN.signal -find SEARCHTERM

For example:

>> MSRTKF CAN.signal -find rearleft
can_0x216_WheelDirection.WheelDirRearLeft
can_0x217_WheelSpeed.WheelSpeedRearLeft

To map a signal to a sensor, we use the '-map' parameter. It accepts a signal for the magnitude (this may be signed or unsigned) and an optional 'sign' parameter for the turning direction. We run on the shell:

MSRTKF CAN.signal -map RL -magn speedrearleft -sign dirrearleft,+=0,-=1

The '-magn' parameter accepts a search term for the magnitude of the signal. It does not need to be the precise identifier, as long as the search turns up only on result. The (optional) '-sign' parameter requires a search term and the Enum values for forward and backward, separated by comma without space. Here, +=1 means that a signal with value '1' announces positive wheel speed. Likewise, -=2 means that a signal with value '2' announces negative wheel speed.

We do the same thing for the rear right (RR) sensor:

MSRTKF CAN.signal -map RR -magn speedrearright -sign dirrearright,+=0,-=1

If we made a mistake, we could delete a configuration:

MSRTKF CAN.signal -clear FL

Finally, we review our complete setup:

MSRTKF CAN.signal -get ALL

FL magnitude: null
FL signum: null
FR magnitude: null
FR signum: null
RL magnitude:
can_0x217_WheelSpeed.WheelSpeedRearLeft RL signum:
can_0x216_WheelDirection.WheelDirRearLeft,+=0,-=1 RR magnitude:
can_0x217_WheelSpeed.WheelSpeedRearRight RR signum:
can_0x216_WheelDirection.WheelDirRearRight,+=0,-=1
STEER magnitude: null
STEER signum: null
Signals are valid (null counts as disabled)

Note that you should only map signals that are present on your CAN bus, as the system waits for all mapped signals to arrive for a complete measurement.

8.3.6. Compile generated code

In this step, all generated code gets compiled and installed on the system. Once it is installed, it will remain fully configured on the system through reboots and software updates. It will take effect as soon as the process completes.

To have the configuration cross-checked again, build, and install the decoder, run:

MSRTKF CAN.generateDecoder

You may get some warnings depending on your .dbc file and signal map. If everything worked, it would say: “Decoder built [...]” in the end. The driver will restart immediately and load the new decoder.

8.3.7. Setup CAN hardware filter

To reduce the load on the MSRTK System when there is a high CAN load, unrelated messages can be discarded by a hardware filter. The filter is configured with a **mask** and a **tag** value. Each incoming CAN id is only received if this condition holds:

(mask & id) == tag

To generate suitable values for mask and id, run:
MSRTKF CAN.hardwareFilter.config

To obtain **tag**, all used ids (**id0, id1, …, idn**) are combined with the bitwise and operator &:

tag = id0 & id1 & … & idn

This finds all bit positions that have value 1 in every single used id.
To obtain **mask**, all bit positions that are equal for all ids have to be searched:

mask = tag | ~(id0 | id1 |… | idn)

We find all bit positions that have value zero by negating the result of applying the bitwise or opera-tor | on all ids. This combined with the tag, which holds all bit positions which have value 1, is a valid filter-mask.

Note: tag can also be used as **mask**. In this case, all selected ids pass the filter, but it is not as specific as possible. This simplification is used in some earlier software versions.

To disable the filter, use:

MSRTKF CAN.hardwareFilter.config -clear true

8.3.8. Starting Sensor Fusion with ANavS Wizard

The last step is enabling the CAN-Interface and saving raw data for post-processing. Please see the figure below which checkboxes (signed in red) must be activated in the Wizard.

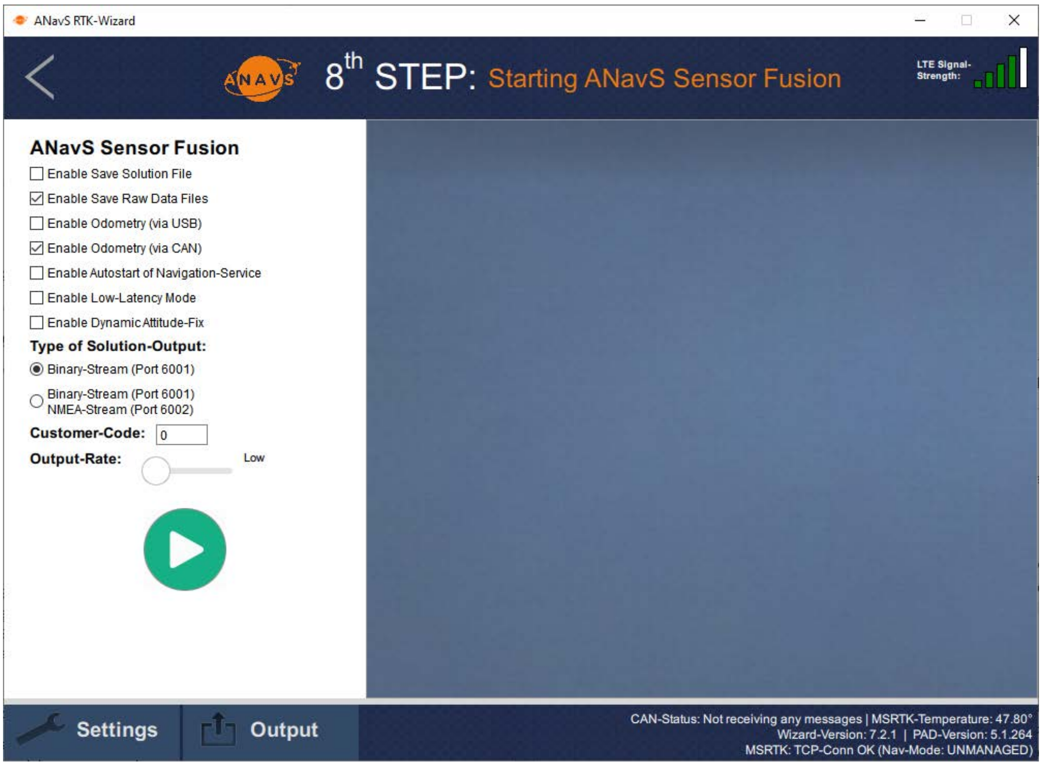


Figure 40: Start ANavS Sensor Fusion with activated CAN-Odometry input

9. The Network-Time-Protocol (NTP)

The ANavS® Positioning Systems are an accurate GNSS and multi sensor positioning system with Ethernet, WIFI, and LTE networking capabilities. These capabilities make it an ideal accurate network time source. This functionality is implemented using the GNU application "ntpd". As of September 2020, the Positioning Systems ships with the NTP functions installed through the Debian package "ntp" in the version "1:4.2.8p10+dfsg-3+deb9u2".

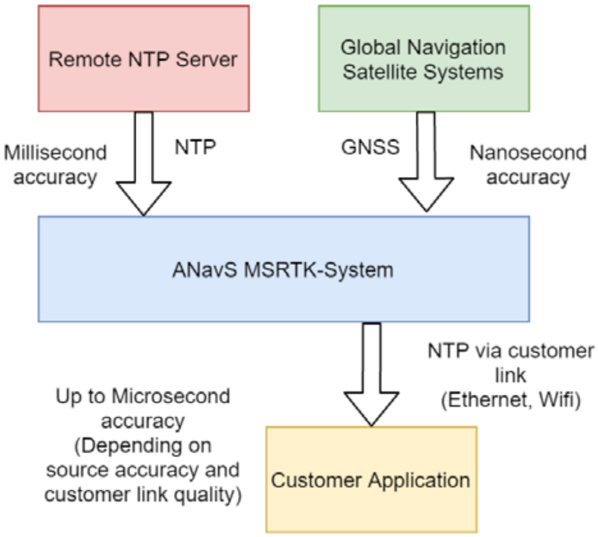


Figure 41: Overview of NTP functionality in the ANavS Positioning Systems

As shown in Figure 40, the Positioning System provides NTP time via ethernet and WIFI, while receiving time data through GNSS and a backup NTP server. The behavior of the NTP system can be configured on the command line of the ANavS Positioning Systems. The configuration is persisted in the file */home/pi/device/settings*. The ntpd-configuration file will be updated accordingly by the system itself.

9.1. Time Policy

Change the time policy on the terminal to select the source of the time provided to the user:

MSRTKF Time.config -set timePolicy -value <PARAMS>

With time policy parameter <**SYNC_GNSS**>, only GNSS is selected as input to ntpd on the ANavS Positioning System. If satellites are visible for the system, the provided time accuracy reaches millisecond accuracy quickly after the satellites become visible. After this initialization phase, a delicate clock calibration process begins and ntpd will achieve accuracy better than 10 microseconds usually in less than 15 minutes.

With time policy <**SYNC_NETWORK**>, only the remote NTP server is selected as input to ntpd on the ANavS Positioning System. If it is reachable, the provided time accuracy reaches millisecond accuracy quickly. Due to noise of time measurements over the network, the clock calibration process is limited to an accuracy of 100 microseconds even in ideal conditions. This synchronization is available through Ethernet, Wi-Fi, and mobile network.

With time policy <**AUTO**>, both NTP and GNSS are selected as input to ntpd on the ANavS Positioning System. Ntpd uses its own algorithm to select which of the two it selects as reference. The selection strategy is not obvious and won't always select GNSS when available. It even may fail to select GNSS, if the remote NTP server is not reachable.

9.2. Time Server

Change the time server that is used as ntpd reference in the Time-Policy <**AUTO**> and <**SYNC_NETWORK**> modes. The value will default to "time.nist.gov" if not configured. This server is also queried during booting the ANavS Positioning System to initialize the local clock before GNSS has acquired any satellites.

MSRTKF Time.config -set timeServer -value time.nist.gov

9.3. Status Information

The following command will print information on the time policy as well as the last successful clock synchronizations to NTP and GNSS. The "last successful …" fields are queried from ntpd only every few seconds, so an update may have happened in this short window and is not reported when calling

MSRTKF Time.service.status

The following command will print information on the time sources used by ntpd. See http://manpages.ub-untu.com/manpages/bionic/man1/ntpq.1.html for details.

ntpq -p

Perform a precision measurement of the local clock error using the best available time source. This may require restarting ntpd and can thus affect clock accuracy:

MSRTKF Time.error

Set local time immediately from best available time source, while bypassing ntpd. This requires restarting ntpd. This method is accurate to 0.5 milliseconds, so it may actually decrease accuracy if ntpd is already optimally calibrated.

MSRTKF Time.adjust

9.4.Time-Synchronization with MS-RTK clock

Prerequisites:

- Network connection to the MS-RTK module. Ethernet connection in a local network with static IPs configured is recommended. A static Ethernet IP for the MS-RKT can be configured via the ANavS Wizard in the Ethernet-Settings section.
- Ubuntu Linux system (tested with Ubuntu 18.04) to apply the steps described below.

Install ***ntp*** from the Ubuntu sources:

>> sudo apt-get install ntp

Adapt the NTP configuration file ***/etc/ntp.conf*** to set the MS-RTK as the only time server. Replace <MSRTK-IP> by the configured MS-RTK IP address:

pool <MSRTK-IP> iburst

 # Provide current local time as a default time source if temporarily internet connectivity is lost.
 # Uncomment lines below, to enable current local time as a time source. Disabled to prevent observed
 # delays when synchronizing time with the MSRTK.
#server 127.127.1.0
#fudge 127.127.1.0 stratum 10

 # Logging
 # Uncomment lines below, to enable logging of ntp statistics.
#statistics loopstats
#statsdir /var/log/ntp
#filegen peerstats file peers type day link enable
#filegen loopstats file loops type day link enable

Restart NTP Service:
>> sudo service ntp restart

Check NTP status to see if service is active and running, and the specified time server is used:
>> service ntp status

Monitor the time-synchronization offset (ms) between the clocks of the local client and the time server.
>> ntpq -p

Wait until the offset falls below the desired accuracy, e.g. 1 ms. If the offset is not decreasing, stopping and starting the ntp service may help:
>> sudo service ntp stop
>> sudo service ntp start

Notes:

- Within a small local area network and Ethernet connection time-synchronization offset < 1 ms is achievable.
- In case there are transitions from non-GNSS to GNSS reception areas the provided time may jump from local time to global GPS-based time of weeks. Furthermore, provided time accuracy depends to the availability and reception quality of GNSS signals.
- Monitoring and continuously logging the ntp offset and statistics is recommended to assess the quality of time-synchronization.
- Please set the poll interval in a range of some seconds (not days or even weeks).

References:
ntpd wiki Ubuntu-Users: https://wiki.ubuntuusers.de/ntpd/
ntpd wiki Windows-Users: https://www.rz.uni-osnabrueck.de/Dienste/NTP/win10.htm

10. ANavS ROS-Ethernet-Adapter (REA)

The ROS-Ethernet Adapter is a command line tool for Linux that provides an adapter between ANavS TCP/IP data streams and ROS. The REA client allows to publish the ANavS sensor fusion solution in ROS (mode 'padsolution2ros').

Please contact the support-team to receive this software package.

10.1. System requirements and dependencies

- OS: Linux/ Ubuntu (tested with Ubuntu 18.04, and Ubuntu 20.04)
- ROS base version installed (tested with ROS Melodic/ Ubuntu 18.04, and ROS Noetic/ Ubuntu 20.04)
  - Follow http://wiki.ros.org/ROS/Installation and install "ROS-Base: (Bare Bones)" version
- Additional Ubuntu packages:
  `ROS_VERSION=melodic`

  sudo apt install ros-${ROS_VERSION}-tf2 ros-${ROS_VERSION}-tf2-ros ros-tf2-msgs libtf2-msgs-devros-${ROS_VERSION}-tf2-geometry-msgs libtf2-dev ros-${ROS_VERSION}-tf libxmlrpcpp-devlibrosconsole-dev libactionlib-dev

10.2. REA Client

10.2.1. Prerequisites

- Linux host with installed REA package.
- ANavS MS-RTK module or Integrated Sensor Platform (ISP)
  - GNSS antennas connected (with sufficient GNSS reception)
  - Device powered on
- Ethernet or WLAN connection between Linux host and ANavS system (Ethernet recommended)
  - Ethernet and WLAN settings can be configured in the ANavS Wizard
- Start ANavS Wizard and configure the ANavS system
- Start sensor fusion
  - A positioning solution should be provided (see 'Solution' tab in the ANavS GUI)

For mode 'padsolution2ros' if a specific customer code is used:
Copy the ANAVS.conf file into the REA subfolder /configs. The file is usually stored on the MS-RTK module at: /share/PAD/configs/ANAVS.conf.

To publish the ANavS sensor data only steps 1-3 are required.

10.2.2. Setup your ROS environment

Use the following commands in the command-line:

```
ROS_VERSION=melodic
source /opt/ros/${ROS_VERISON}/setup.bash
roscore&
```

10.2.3. Sensor fusion solution (mode: padsolution2ros)

Publishes ANavS sensor fusion solution in ROS. Assumes ANavS sensor fusion is running (eg. on either the ANavS MS-RTK or ISP (remote host)) and TCP/IP data streams are available, eg. via Ethernet connection (default settings IP: 127.0.0.1, port: 6001). Specify the remote host's IP for your setup (--ip <host-ip>), and ANavS sensor fusion solution port if deviating from the default (--port <port>).

Usage

```
./client/bin/Release/anavs_ros_ethernet_client padsolution2ros
[--ip <host-ip>] [--port <port>] [options] # specify the MSRTK
host IP
```

Use help to print all options

```
./client/bin/Release/anavs_ros_ethernet_client --help
```

Options

Option	Description
-h --help	Show help.
--ip <host-ip>	IP address of remote host [default: 127.0.0.1].
--port <host-port>	TCP/IP data streams port. ANavS sensor fusion solution [default: 6001], sensor data [default: 4001].
padsolution2ros:	
--topic_prefix <topic-prefix>	Prefix for all ROS topics published [default: /anavs/solution].
--use_original_timestamps	Use original ANavS solution data timestamps (GPS tow) as ROS message timestamp [default: local host ROS time].

--enable_odom	Enables publishing odometry (topic: /odom; type: nav_msgs::Odometry) and angular rate (topic: /ang_rate; type: geometry_msgs/Vector3Stamped).
--enable_pose	Enables publishing pose (topic: /pose_enu; type: geometry_msgs::PoseWithCovarianceStamped).
--odom_only	Publish only the odometry message '/odom'.
--pose_only	Publish only the pose message '/pose_enu'.
--publisher_queue_size <queue-size>	Sets ROS publisher queue sizes for all messages published. [default: 1]
--pose_enu_frame <frame-id>	Specifies frame_id of published pose (topic: /pose_enu)' [default: map].
--remove_pos_offset	Enables removing initial position offset for publishing pose 'pose_enu', and odometry 'odom'.
--publish_to_tf [--published_frame <child-frame-id>]	Enables publishing transformation to ROS tf. Optional: Specify child_frame_id [default: base_link].
--publish_path	Enables publishing path (topic: /path; type: nav_msgs::Path) created from poses (topic: /pose_enu).
--publish_ref_station	Enables publishing of reference station coordinates (topic: /pos_reference_station; type: geometry_msgs/PointStamped).

Remarks

`publisher_queue_size`

- Default: 1. Recommended for real-time settings. Old messages are dropped if they cannot be published fast enough. Prevents messages queueing and delaying the publishing of current messages.
- Increase `publisher_queue_size (> 1)` to avoid message drop. Recommended for post-processing settings, where potential delays are not critical but all messages shall be published by priority.
- For more details refer to Choosing a good queue_size.

Advertised ROS topics

The standard ROS topics provided correspond to the fields of the “Standard Binary Solution Message” documented in Section 6.1. However angular measurements are provided in radians rather than in degrees in the ROS messages.

ROS Topic	Description	ROS Message Type

/anavs/solution/id	ID	std_msgs/Uint8
/anavs/solution/week	Week of current epoch	std_msgs/Uint16
/anavs/solution/tow	Time of Week (sec)	sensor_msgs/TimeReference
/anavs/solution/pos	Position (NED* in meters)	geometry_msgs/PointStamped
/anavs/solution/pos_llh	Position (lat,lon,height in deg,deg,meters)	geometry_msgs/PointStamped
/anavs/solution/pos_xyz	Position (ECEF in meters)	geometry_msgs/PointStamped
/anavs/solution/att_euler	Attitude/ Euler angles (heading, pitch, roll in rad)	geometry_msgs/PointStamped
/anavs/solution/att_state	Attitude filter state	std_msgs/UInt8
/anavs/solution/rtk_state	RTK filter state	std_msgs/UInt8
/anavs/solution/num_sats	Number of satellites	std_msgs/UInt8
/anavs/solution/imu_calibrated	IMU initialized/calibrated	std_msgs/Bool
/anavs/solution/vel	Velocity (NED* in m/s)	geometry_msgs/Vector3Stamped
/anavs/solution/acc	Acceleration (body frame in m/s^2)	geometry_msgs/Vector3Stamped
/anavs/solution/pos_stddev	Std Dev of position (NED* in meters)	geometry_msgs/PointStamped
/anavs/solution/vel_stddev	Std Dev of velocity (NED* in m/s)	geometry_msgs/PointStamped
/anavs/solution/att_euler_stddev	Std Dev of attitude/ Euler angles (in rad)	geometry_msgs/PointStamped

/anavs/solution/accuracy	Estimated accuracy (m) (stored in: point.x)	geometry_msgs/PointStamped
Optional:		
/anavs/solution/pose_enu	Pose (ENU in meters)	geometry_msgs/PoseWithCovarianceStamped
/anavs/solution/odom	Odometry (Pose: ENU in meters/ Twist: body frame, velocity in m/s, angular rate in rad/s)	nav_msgs/Odometry
/anavs/solution/ang_rate	Angular rate (NED* in rad/s)	geometry_msgs/Vector3Stamped
/anavs/solution/pos_reference_station	Position of reference station in geographic coordinates (llh)	geometry_msgs/PointStamped
/path	Path for visualization	nav_msgs/Path

*): The default frame for topics *pos*, *vel* and *ang_rate* is NED, but it may vary if a specific customer code is used (see ANAVS Wizard: Customer-Code, and ANAVS.conf: customer_code). Also the body frame definition may vary if a specific customer code is used.

Topics description

ROS Topic	Description
id	Identifier of the ANavS Position and Attitude Determination (PAD) solution.
week	Week number of the current epoch.
tow	Time reference message containing the ROS time and the GNSS Time of Week (TOW) in seconds.
pos	The position in local coordinate frame (NED*) in meters. Baseline in local coordinate frame spanned by the position given by pos_llh in lat, lon and height, and by the position of the reference station.
pos_llh	The position in geographic coordinates (lat, lon, height) in degree, degree, meters.
pos_xyz	The position in ECEF coordinates (X, Y, Z) in meters.

`att_euler`	The attitude in Euler angles (heading, pitch, roll) in rad.
`att_state`	The State-definition for the Attitude Kalman-filter: {0,1,2,3} - 0: No solution, 1: Least-Squares solution, 2: Float solution (orange light in ANavS GUI), 3: Fixed solution (green light in ANavS GUI)
`rtk_state`	The State-definition for the RTK-Position Kalman-filter {0,1,2,3} - 0: No solution, 1: Least-Squares solution, 2: Float solution (orange light in ANavS GUI), 3: Fixed solution (green light in ANavS GUI)
`num_sats`	Number of satellites (May be larger than the number of USED satellites, indicated in the ANavS GUI).
`imu_calibrated`	Is set if the IMU is initialized/ calibrated.
`vel`	The velocity in local coordinate frame (NED*) in m/s.
`acc`	The acceleration in body frame in m/s^2.
`pos_stddev`	The standard deviation of the position (NED*) in meters.
`vel_stddev`	The standard deviation of the velocity (NED*) in m/s.
`att_euler_stddev`	The standard deviation of the attitude in Euler angles in rad.
`accuracy`	Estimated accuracy of the position in local coordinate frame in meters. The scalar accuracy value is stored in the component point.x. Components point.y and point.z are set to NaN.)
Optional:	
`pose_enu`	The pose in ENU frame in meters. The geographic north direction is aligned with ROS frame y-axis. Heading anlge 0° corresponds to north direction and results in ROS in an orientation where body-frame x-axis (red-axis in rviz) points into ROS frame y-direction. The 6x6 covariance matrix contains the variances of position X, Y, Z and rotation around X, Y, and Z on the diagonal. The covariances are set to zero currently. In case position variances contain NaN/Inf values, the covariance matrix left-upper 3x3 part is set to zeros. In case rotation variances contain NaN/Inf values, the covariance matrix right-lower 3x3 part is set zeros.
`odom`	Pose (ENU) in meters, and twist (body frame), velocity in m/s and angular rate in rad/s. Pose covariance matrix, as described for pose_enu. Twist covariance matrix is set zero (not available).
`ang_rate`	Angular rate (NED*) in rad/s.
`pos_reference_station`	Position of the reference station in geographic coordinates (llh). Applicable for RTK positioning, not available for PPP positioning.
`path`	Path for visualization in RViz.

*): Note, see table above.

Remarks

Please note that the positioning estimates (position, attitude, velocity and acceleration) potentially may jump, ie. they are not guaranteed to be continuous all the time. The nav_msgs/Odometry pose frame is thus set to "map" rather than "odom", to express that measurements are not guaranteed to be continuous.

Visualization in RViz

Run the REA client with enabled options to publish pose and odom topics to publish to tf and to publish a path of the position trajectory. To start at zero position, use the flag --remove_pos_offset to remove the initial position offset from the published positions in pose_enu:

```
./client/bin/Release/anavs_ros_ethernet_client padsolution2ros [--ip <host-ip>] [--port <port>] --enable_pose --enable_odom --remove_pos_offset --publish_to_tf --publish_path [options]
```

Run RViz using the provided config file:

```
rviz -d configs/anavs.rviz
```

Following items are displayed:

- Pose with covariance: /anavs/solution/pose_enu
- Odometry: /anavs/solution/odom
- Path: /path

11. ANavS® Solution Decoder Tool

The ANavS® Solution-Decoder Tool brings the binary solution output file into manageable file formats. The purpose of this tool is mainly for postprocessing. It can transform the .bin/.txt-file into .csv-format (Comma-Separated Values) for quick value visualization and .kml-format for coordinate visualization in Google-Earth.

11.1. Download

Download the latest ANavS® Solution Decoder Tool for your desired Operating System (Windows 10 or Ubuntu 18.04) from the ANavS Knowledgebase with the following link:

https://anavs.com/knowledgebase/anavs-solution-decoder-tool/

11.2. Some Hints

- The Source code has been compiled for Windows systems (MinGW-Windows) and Linux systems (GNU-Linux).
- The path to the datasets shall not contain any space characters or blank spaces.
- If the path is detected to be incorrect, it is safer to close the console and restart because problems tend to arise when trying to correct the path.
- The column header contains the same names as the first 49 variables of the proprietary binary protocol. The protocol is described in chapter 6.
- The decoder tool decodes the ANavS-Solution file commonly known as "PAD_solution.bin" or "PAD_solution.txt". However, the solution file can have another name, as long as it does not contain any blank spaces.
- The delimiter of the .csv files is a semicolon ";"
    - The decoder file can be put in the same folder as the file which is desired to be decoded. If that is done, the path to the file can be the file name itself. However, it is always safer to use a complete path than a relative path, e.g., "C:\Users\ANavS\Documents\Test\PAD_solution.bin" instead of "PAD_solution.bin"

11.3. Hints especially for Linux users

- To use the decoder, please open the bash and change your directory to the path where you saved the decoder file.
- Then enter: "./ubxproject"
    - If the program says that you don't have any access permissions, it probably means that you must change the permission flags/bits of the decoder file
        - Simply enter in the bash: "chmod +x ubxproject"
        - This will give your user the right to access the file which can be seen by the changed flags from "-rw-rw-r–" to à "-rwxrwxr-x"
        - Try it again.

11.4. Decode to .csv-format

The .csv-format is a way to visualize the ANavS solution in an editor or any spreadsheet-program such as Excel and LibreOffice.

1. Please open the "ubxprojext.exe" executable.
2. A console window will open, which asks for the path to the desired document. Please introduce the correct path to the ANavS solution-file.

3. If a correct path was introduced, the console will ask which format you wish to receive. You shall enter 0 for a .csv-format.
4. The console will ask a second time for a format. However, this time it is referring to the format of the .csv-file. There are two formats to choose from basic and complete.
    1. The basic format decodes all the important measurements such as time, position, velocity, and acceleration, in a very compact form.
    2. The complete format includes a few more values than the basic one. However, these extra values are mostly valuable for development purposes and do not represent any added value for the customer. In addition, it requires more space. Until now the complete format includes the satellite information of each satellite recorded. Therefore, the console will first ask you which satellite systems you want to consider in the decoding process.
5. For practicality it is advised to use the basic format. Therefore enter 0.
6. If all values were entered correctly, the tool should begin the decoding process immediately. Thereupon the console visualizes the progress of the decoding process.
7. The resulting .csv-file “PADSolution.csv” will appear in the same folder as the “ubxprojext.exe”.
8. After the decoding process you can open the .csv-file in any spreadsheet-program to see the ANavS® Solution-output.

11.5. Decode to .kml-format

The .kml-format helps to visualize the recorded trajectory with services such as Google Earth or Google Maps. Since the regular data output-rate is quite high, it would make the .kml-file too memory-intensive. As a result, .kml-file only includes the most significant portion of the original data points, that means only GNSS-epochs are visualized.

1. Please open the “ubxprojext.exe” executable.
2. A console window will open, which asks for the path to the desired document. Please introduce the correct path to the ANavS solution file.
3. If a correct path was introduced, the console will ask which format you wish to receive. You shall enter 1 for a .kml-format.
4. If all values were entered correctly, the tool should begin the decoding process immediately. Thereupon the console visualizes the progress of the decoding process.
5. The resulting .kml-file “PADSolution.kml” will appear in the same folder as the “ubxprojext.exe”.
6. After decoding you can use that kml-file to visualize your recorded trajectory, e.g., by incorporating it to Google Earth.

Figure 42: Example kml-file where each purple dot is showing the most interesting states like position, velocity, acceleration, and attitude.

12. ANavS® Record Extractor Tool

When using the ANavS Positioning Systems, it records a variety of data from different sources/sensors and stores it all in a single file within a zip-archive. The Record-Extractor command line tool can be used to extract this data into several files, one for each channel of data recorded. This tool is especially needed for using recorded data is further analysis in post-processing.

NOTE: The target-platform using the Record Extractor Tool is Java 8.

12.1. Download

Download the latest ANavS® Record Extractor Tool from the ANavS Knowledgebase with the following link:

https://anavs.com/knowledgebase/anavs-record-extractor-tool/

12.2. Usage

From command line:

```
java -jar RecordExtractor.jar -i <inputfilepath< [-o
<outputfilepath>]
```

in the directory of the RecordExtractor.jar file

12.2.1. Arguments

`inputfilepath`: Required. The path of the zip archive containing the data to extract.

`outputfilepath`: Optional. The path of the directory where the extracted data should be stored. If the directory doesn't exist, it will be created. If this argument is omitted, the tool will store the extracted data in the same directory as the source zip-file.

12.2.2. Output

Currently the tool will be able to name the output files correctly if the port number of the fragment in the input file is one of the following:

Port number	Corresponding filename
4007	"LOGcan.ubx"
4001	"LOGrover0.ubx"
4002	"LOGrover1.ubx"
4003	"LOGrover2.ubx"
2102	"LOGvrs.osr"
6001	"PAD_solution.bin"

5003	“maintenance.log”
5004	“navigation.log”
5005	“recorder.log”
4000	“driver.log”

If the tool comes across any other port number during extraction it will name the file according to the port number and store the contents as a .bin file.

13. LTE-VPN connection to the ANavS Positioning Systems

All ANavS Positioning Systems are delivered with already equipped SIM cards. The SIMs aren't coupled to a fixed service provider but using the best available service provider in its area, a so-called All-Net SIM card. In addition to providing internet access to your module and in case of Wi-Fi connection (through bridging) also to your PC/Laptop, the SIM card provides VPN connection to get SSH remote access and for data streaming through mobile network.

HINT: Please contact the support team to get your customer-specific config-file and Token for the settings described below.

13.1. Setting up OpenVPN for Linux

- Install OpenVPN software (e.g. "apt-get install openvpn")
- Download **client.conf** (emnify-eu-west-1 .conf) and store it on your server in /etc/openvpn
- Create a file **credentials.txt** in /etc/openvpn with following content to authenticate with your user credentials:

  7133
  YourApplicationToken

  The corresponding Application-Token is given in the txt-file **Application_Token_XXX.txt**
- Start openvpn service (e.g. "service openvpn start") and monitor connection in /var/log/syslog

13.2. Setting up the OpenVPN for Windows

- Install OpenVPN software from https://openvpn.net/index.php/open-source/downloads.html
- Download **client.opvn** (emnify-eu-west-1.ovpn) and store it on your server in C:\Program Files\OpenVPN\config
- Create a file **credentials.txt** in C:\Program Files\OpenVPN\config with following content to authenticate with your user credentials:

7133
YourApplicationToken

The corresponding Application-Token is given in the txt-file
Application_Token_XXX.txt

- Start OpenVPN GUI application and monitor the connection in C:\Program Files\OpenVPN\log\client.txt

Alternatively, you can download OpenVPN clients for Windows, OSX, Android and iOS from https://openvpn.net

Appendix-1: Example CAN DBC-File for the sensor data Input

If you are concerned about undisclosed information in your DBC-file, you can remove most traces of it from the MSRTK-System without impeding operation of the CAN functionality. Files that contain information on your CAN signals after the setup process:

Path	Description	CAN-related content	Clean up notes
/home/pi/device/can_profile.dbc	Copy of your .dbc file	Your DBC	File may be deleted, not required for operation
/home/pi/device/settings	Database for MSRTK-device specific settings	Your signal map	Remove CAN related lines manually, not required for operation
/home/pi/.generator/	Working directory of build process	Generated source code of decoder, binaries	Directory may be deleted, not required for operation
/share/driver/dbcc/can_profile.dbc	Copy of your .dbc file	Your DBC	File may be deleted, not required for operation
/share/driver/dbcc/can_profile.c	Source code of generated decoder	Extensive information on your signals	File may be deleted, not required for operation
/share/driver/dbcc/can_profile.h	Header of generated decoder	Some Information on your signals	File may be deleted, not required for operation
/home/pi/device/libdynamic-decoder.so	Installed decoder binaries	Executable decoder + names of signals	Required for operation

Example golf.dbc file:

```
VERSION ""

NS_ :

	NS_DESC_
	CM_
	BA_DEF_
	BA_
	VAL_
	CAT_DEF_
```

```
    CAT_
    FILTER
    BA_DEF_DEF_
    EV_DATA_
    ENVVAR_DATA_
    SGTYPE_
    SGTYPE_VAL_
    BA_DEF_SGTYPE_
    BA_SGTYPE_
    SIG_TYPE_REF_
    VAL_TABLE_
    SIG_GROUP_
    SIG_VALTYPE_
    SIGTYPE_VALTYPE_

BS_:

BU_:

BO_ 535 WheelSpeed: 8 Car
SG_ WheelSpeedRearLeft : 33|15@1+ (0.0033,0) [0|0] "" Car
SG_ WheelSpeedRearRight : 49|15@1+ (0.0033,0) [0|0] "" Car

BO_ 534 WheelDirection: 8 Car
SG_ WheelDirRearLeft : 33|1@1+ (1,0) [0|0] "" Car
SG_ WheelDirRearRight : 39|1@1+ (1,0) [0|0] "" Car
```

Appendix-2: Example CAN DBC-File for the ANavS solution Output

Example dbc file for all given output parameters according to the Table 1:

```
VERSION ""

NS_ :
	NS_DESC_
	CM_
	BA_DEF_
	BA_
	VAL_
	CAT_DEF_
	CAT_
	FILTER
	BA_DEF_DEF_
	EV_DATA_
	ENVVAR_DATA_
	SGTYPE_
	SGTYPE_VAL_
	BA_DEF_SGTYPE_
	BA_SGTYPE_
	SIG_TYPE_REF_
	VAL_TABLE_
	SIG_GROUP_
	SIG_VALTYPE_
	SIGTYPE_VALTYPE_
	BO_TX_BU_
	BA_DEF_REL_
	BA_REL_
	BA_DEF_DEF_REL_
	BU_SG_REL_
	BU_EV_REL_
	BU_BO_REL_
	SG_MUL_VAL_

BS_:

BU_:


BO_ 50 numSats: 8 Vector__XXX
 SG_ numSats : 0|8@1+ (1,0) [0|255] "" Vector__XXX
```

BO_ 49 gnssReception: 8 Vector__XXX
SG_ gnssReception : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "" Vector__XXX

BO_ 42 timingInfo_Odometry: 8 Vector__XXX
SG_ timingInfo_Odometry : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "s" Vector__XXX

BO_ 41 timingInfo_Baro: 8 Vector__XXX
SG_ timingInfo_Baro : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "s" Vector__XXX

BO_ 40 timingInfo_IMU: 8 Vector__XXX
SG_ timingInfo_IMU : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "s" Vector__XXX

BO_ 39 timingInfo_GNSS: 8 Vector__XXX
SG_ timingInfo_GNSS : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "s" Vector__XXX

BO_ 36 attStdDev_roll: 8 Vector__XXX
SG_ attStdDev_roll : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "deg" Vector__XXX

BO_ 35 attStdDev_pitch: 8 Vector__XXX
SG_ attStdDev_pitch : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "deg" Vector__XXX

BO_ 34 attStdDev_heading: 8 Vector__XXX
SG_ attStdDev_heading : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "deg" Vector__XXX

BO_ 33 att_roll: 8 Vector__XXX
SG_ att_roll : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "deg" Vector__XXX

BO_ 32 att_pitch: 8 Vector__XXX
SG_ att_pitch : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "deg" Vector__XXX

BO_ 31 att_heading: 8 Vector__XXX
SG_ att_heading : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "deg" Vector__XXX

BO_ 30 accStdDev_z: 8 Vector__XXX
SG_ accStdDev_z : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "m/s^2" Vector__XXX

BO_ 29 accStdDev_y: 8 Vector__XXX
SG_ accStdDev_y : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "m/s^2" Vector__XXX

BO_ 28 accStdDev_x: 8 Vector__XXX
SG_ accStdDev_x : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "m/s^2" Vector__XXX

BO_ 27 acc_z: 8 Vector__XXX
SG_ acc_z : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "m/s^2" Vector__XXX

BO_ 26 acc_y: 8 Vector__XXX
SG_ acc_y : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "m/s^2" Vector__XXX

BO_ 25 acc_x: 8 Vector__XXX
SG_ acc_x : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "m/s^2" Vector__XXX

BO_ 24 velStdDev_D: 8 Vector__XXX
SG_ velStdDev_D : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "m/s" Vector__XXX

BO_ 23 velStdDev_E: 8 Vector__XXX
SG_ velStdDev_E : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "m/s" Vector__XXX

BO_ 22 velStdDev_N: 8 Vector__XXX
SG_ velStdDev_N : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "m/s" Vector__XXX

BO_ 21 vel_D: 8 Vector__XXX
SG_ vel_D : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "m/s" Vector__XXX

BO_ 20 vel_E: 8 Vector__XXX
SG_ vel_E : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "m/s" Vector__XXX

BO_ 19 vel_N: 8 Vector__XXX
SG_ vel_N : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "m/s" Vector__XXX

BO_ 18 bStdDev_D: 8 Vector__XXX
SG_ bStdDev_D : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "m" Vector__XXX

BO_ 17 bStdDev_E: 8 Vector__XXX
SG_ bStdDev_E : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "m" Vector__XXX

BO_ 16 bStdDev_N: 8 Vector__XXX
SG_ bStdDev_N : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "m" Vector__XXX

BO_ 15 b_D: 8 Vector__XXX
SG_ b_D : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "m" Vector__XXX

BO_ 14 b_E: 8 Vector__XXX
SG_ b_E : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "m" Vector__XXX

BO_ 13 b_N: 8 Vector__XXX
SG_ b_N : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "m" Vector__XXX

BO_ 12 ECEF_Z: 8 Vector__XXX
SG_ ECEF_Z : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "m" Vector__XXX

BO_ 11 ECEF_Y: 8 Vector__XXX
SG_ ECEF_Y : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "m" Vector__XXX

BO_ 10 ECEF_X: 8 Vector__XXX
SG_ ECEF_X : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "m" Vector__XXX

BO_ 9 height: 8 Vector__XXX
SG_ height : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "m" Vector__XXX

BO_ 8 lon: 8 Vector__XXX
SG_ lon : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "deg" Vector__XXX

BO_ 7 lat: 8 Vector__XXX
SG_ lat : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "deg" Vector__XXX

BO_ 5 towInit: 8 Vector__XXX
SG_ towInit : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "s" Vector__XXX

BO_ 4 weekInit: 8 Vector__XXX
SG_ weekInit : 0|16@1+ (1,0) [0|65535] "" Vector__XXX

BO_ 3 tow: 8 Vector__XXX
SG_ tow : 0|64@1- (1,0) [-1.7E+308|1.7E+308] "s" Vector__XXX

BO_ 2 week: 8 Vector__XXX
SG_ week : 0|16@1+ (1,0) [0|65535] "" Vector__XXX

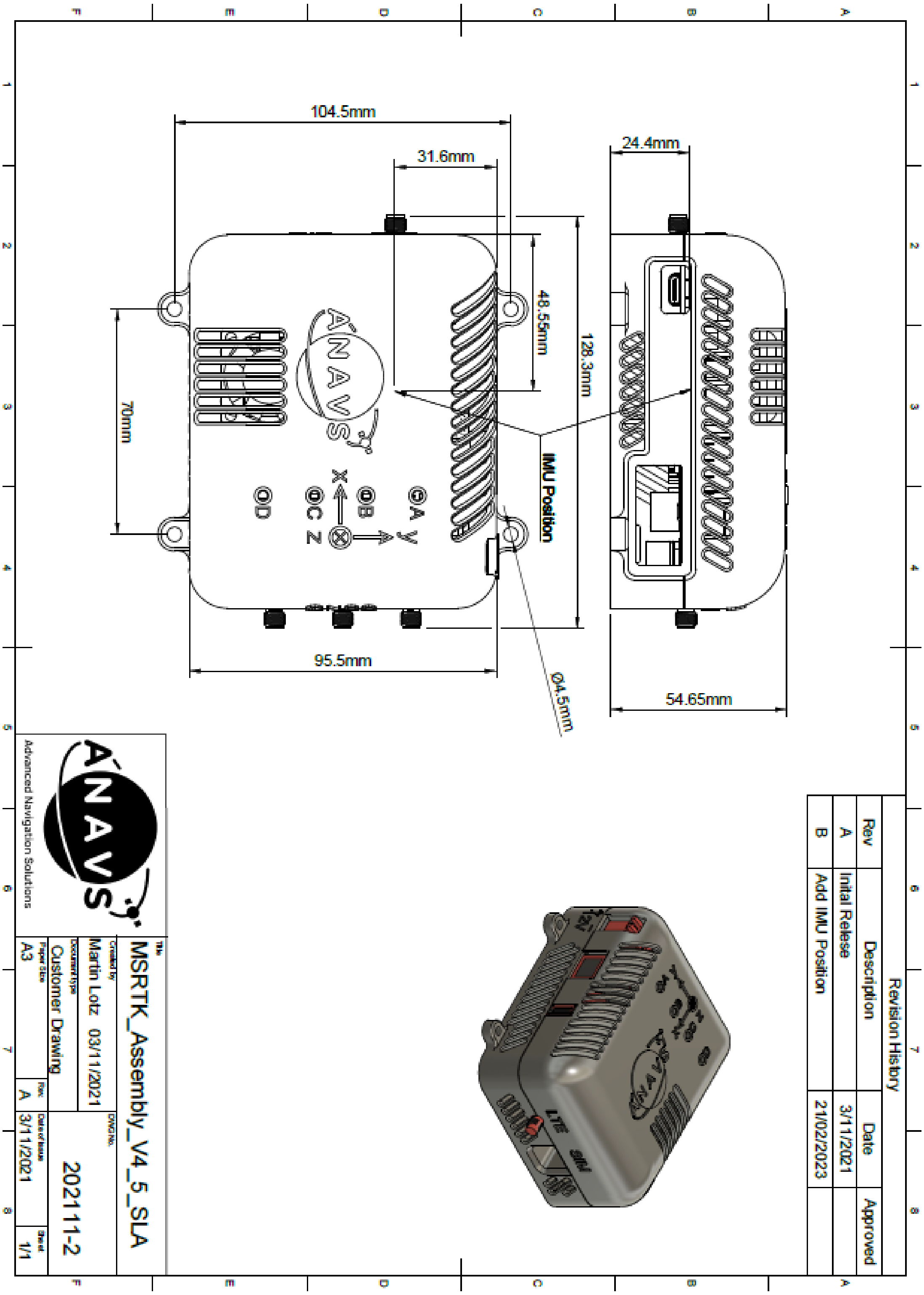
BO_ 1 resCode: 8 Vector__XXX
SG_ resCode : 0|16@1+ (1,0) [0|65535] "" Vector__XXX

CM_ SG_ 50 numSats "Number of satellites";
CM_ SG_ 49 gnssReception "Scalar, which indicates the GNSS signal reception";
CM_ SG_ 42 timingInfo_Odometry "CPU-Load of used sensor. The sum (green line in the GUI) of elapsed time should not over 1 second (–> to slow processor)";
CM_ SG_ 41 timingInfo_Baro "CPU-Load of used sensor. The sum (green line in the GUI) of elapsed time should not over 1 second (–> to slow processor)";
CM_ SG_ 40 timingInfo_IMU "CPU-Load of used sensor. The sum (green line in the GUI) of elapsed time should not over 1 second (–> to slow processor)";
CM_ SG_ 39 timingInfo_GNSS "CPU-Load of used sensor. The sum (green line in the GUI) of elapsed time should not over 1 second (–> to slow processor)";
CM_ SG_ 36 attStdDev_roll "Standard deviation of the attitude";
CM_ SG_ 35 attStdDev_pitch "Standard deviation of the attitude";

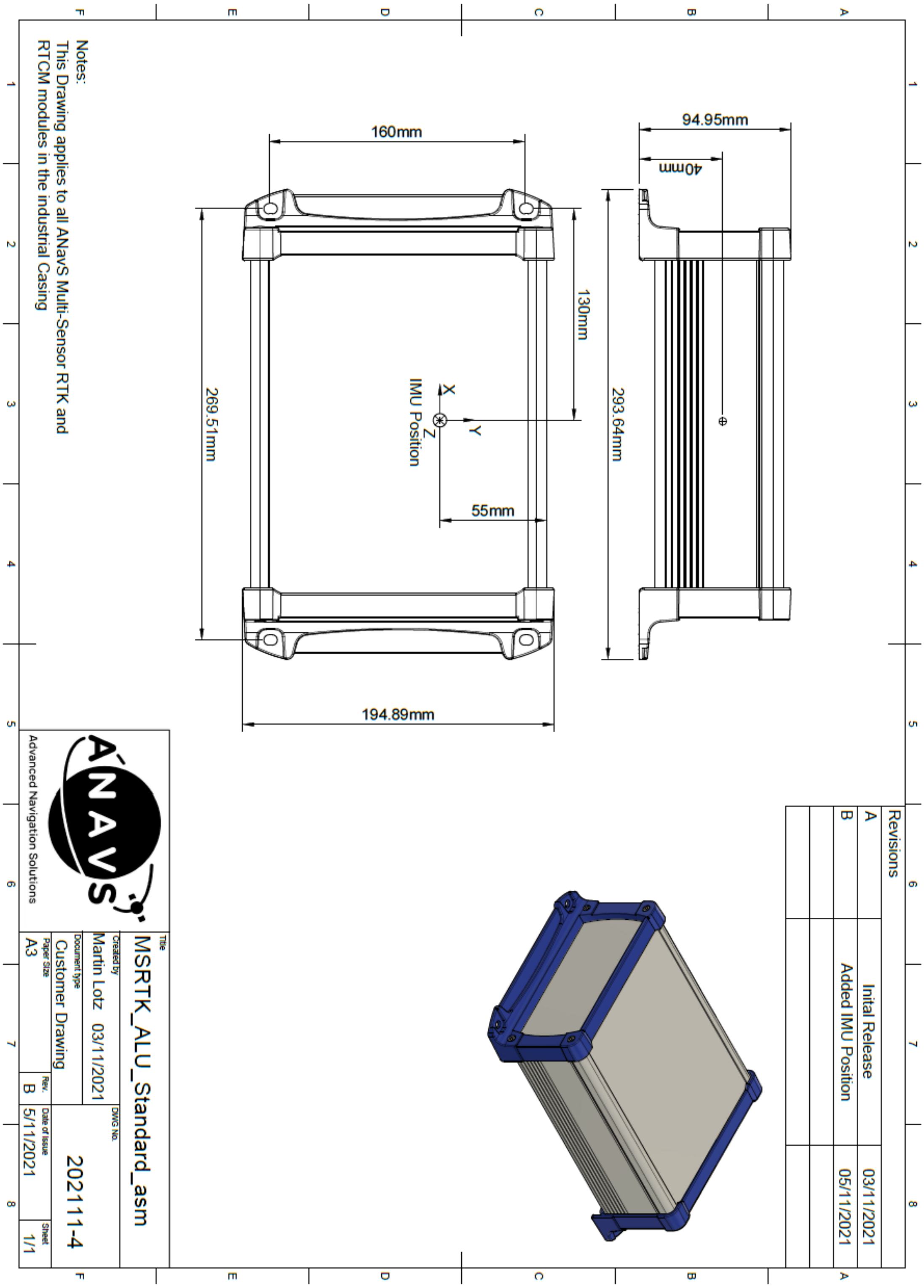
CM_ SG_ 34 attStdDev_heading "Standard deviation of the attitude";
CM_ SG_ 33 att_roll "Attitude/Euler angles (heading, pitch, roll)";
CM_ SG_ 32 att_pitch "Attitude/Euler angles (heading, pitch, roll)";
CM_ SG_ 31 att_heading "Attitude/Euler angles (heading, pitch, roll)";
CM_ SG_ 30 accStdDev_z "Standard deviation of the acceleration";
CM_ SG_ 29 accStdDev_y "Standard deviation of the acceleration";
CM_ SG_ 28 accStdDev_x "Standard deviation of the acceleration";
CM_ SG_ 27 acc_z "Acceleration in body frame";
CM_ SG_ 26 acc_y "Acceleration in body frame";
CM_ SG_ 25 acc_x "Acceleration in body frame";
CM_ SG_ 24 velStdDev_D "Standard deviation of the velocity";
CM_ SG_ 23 velStdDev_E "Standard deviation of the velocity";
CM_ SG_ 22 velStdDev_N "Standard deviation of the velocity";
CM_ SG_ 21 vel_D "Velocity in NED frame";
CM_ SG_ 20 vel_E "Velocity in NED frame";
CM_ SG_ 19 vel_N "Velocity in NED frame";
CM_ SG_ 18 bStdDev_D "Standard deviation of the baseline";
CM_ SG_ 17 bStdDev_E "Standard deviation of the baseline";
CM_ SG_ 16 bStdDev_N "Standard deviation of the baseline";
CM_ SG_ 15 b_D "Baseline in NED frame spanned by the position given by lat, lon and height, and by the position of the reference station";
CM_ SG_ 14 b_E "Baseline in NED frame spanned by the position given by lat, lon and height, and by the position of the reference station";
CM_ SG_ 13 b_N "Baseline in NED frame spanned by the position given by lat, lon and height, and by the position of the reference station";
CM_ SG_ 12 ECEF_Z "Z-position in ECEF-coordinate frame";
CM_ SG_ 11 ECEF_Y "Y-position in ECEF-coordinate frame";
CM_ SG_ 10 ECEF_X "X-position in ECEF-coordinate frame";
CM_ SG_ 9 height "Height";
CM_ SG_ 8 lon "Longitude";
CM_ SG_ 7 lat "Latitude";
CM_ SG_ 5 towInit "Time of Week of the epoch when the system was started";
CM_ SG_ 4 weekInit "Week number of the epoch when the system was started";
CM_ SG_ 3 tow "Time of Week of the current epoch";
CM_ SG_ 2 week "Week number of the current epoch";
CM_ SG_ 1 resCode "Result code bitfield, which keeps the system status and information";
BA_DEF_ "BusType" STRING ;
BA_DEF_DEF_ "BusType" "CAN";
SIG_VALTYPE_ 49 gnssReception : 2;
SIG_VALTYPE_ 42 timingInfo_Odometry : 2;
SIG_VALTYPE_ 41 timingInfo_Baro : 2;
SIG_VALTYPE_ 40 timingInfo_IMU : 2;
SIG_VALTYPE_ 39 timingInfo_GNSS : 2;
SIG_VALTYPE_ 36 attStdDev_roll : 2;
SIG_VALTYPE_ 35 attStdDev_pitch : 2;

SIG_VALTYPE_ 34 attStdDev_heading : 2;
SIG_VALTYPE_ 33 att_roll : 2;
SIG_VALTYPE_ 32 att_pitch : 2;
SIG_VALTYPE_ 31 att_heading : 2;
SIG_VALTYPE_ 30 accStdDev_z : 2;
SIG_VALTYPE_ 29 accStdDev_y : 2;
SIG_VALTYPE_ 28 accStdDev_x : 2;
SIG_VALTYPE_ 27 acc_z : 2;
SIG_VALTYPE_ 26 acc_y : 2;
SIG_VALTYPE_ 25 acc_x : 2;
SIG_VALTYPE_ 24 velStdDev_D : 2;
SIG_VALTYPE_ 23 velStdDev_E : 2;
SIG_VALTYPE_ 22 velStdDev_N : 2;
SIG_VALTYPE_ 21 vel_D : 2;
SIG_VALTYPE_ 20 vel_E : 2;
SIG_VALTYPE_ 19 vel_N : 2;
SIG_VALTYPE_ 18 bStdDev_D : 2;
SIG_VALTYPE_ 17 bStdDev_E : 2;
SIG_VALTYPE_ 16 bStdDev_N : 2;
SIG_VALTYPE_ 15 b_D : 2;
SIG_VALTYPE_ 14 b_E : 2;
SIG_VALTYPE_ 13 b_N : 2;
SIG_VALTYPE_ 12 ECEF_Z : 2;
SIG_VALTYPE_ 11 ECEF_Y : 2;
SIG_VALTYPE_ 10 ECEF_X : 2;
SIG_VALTYPE_ 9 height : 2;
SIG_VALTYPE_ 8 lon : 2;
SIG_VALTYPE_ 7 lat : 2;
SIG_VALTYPE_ 5 towInit : 2;
SIG_VALTYPE_ 3 tow : 2;

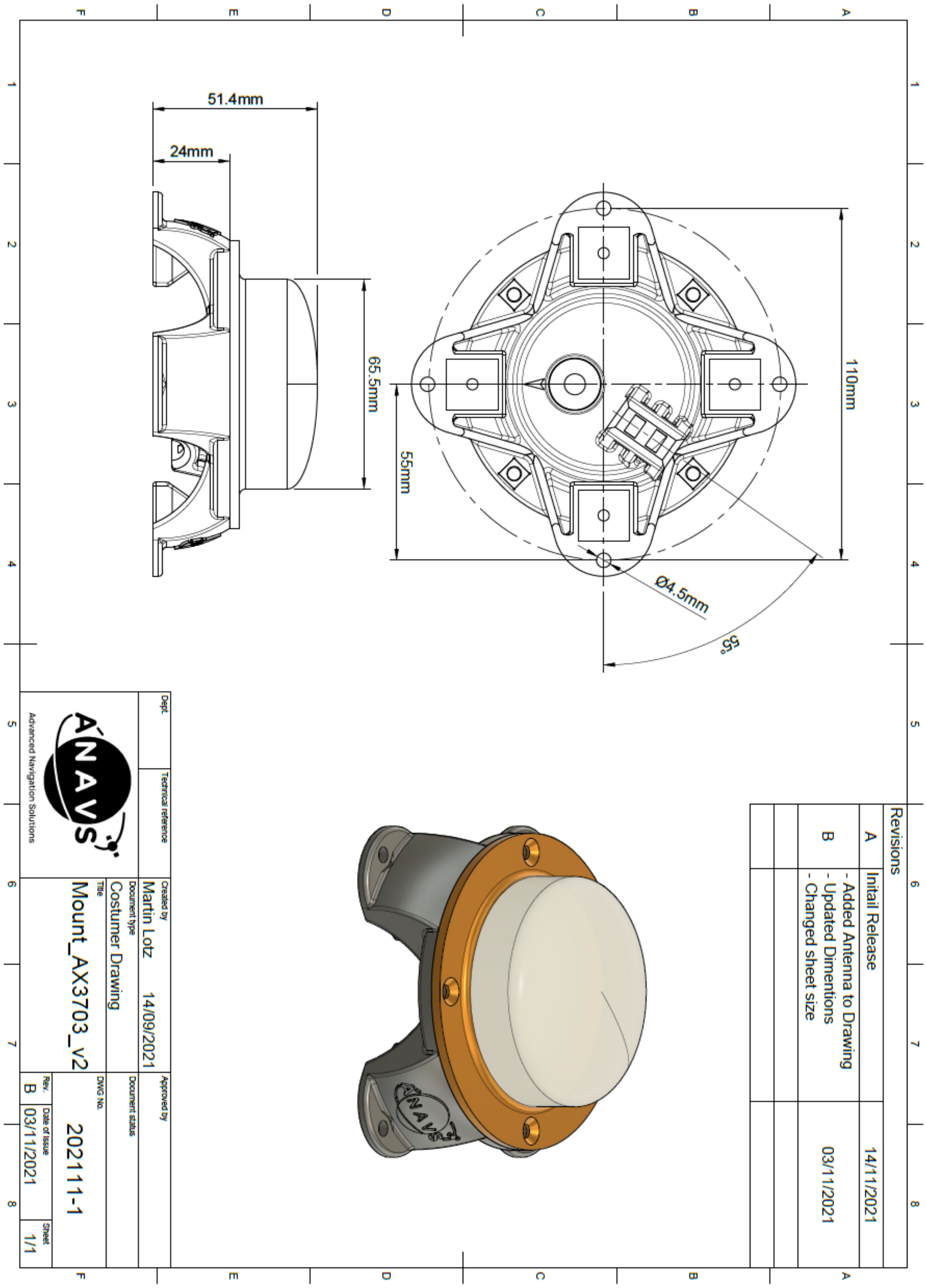
Appendix-3: Drawing 3D-printed Casing Type



APPENDIX-4: DRAWING INDUSTRIAL CASING TYPE



Appendix-5: Drawing High-Class GNSS-Antenna



Appendix-6: Drawing Survey-Grade GNSS-Antenna