TECH NOTE :: QuantumX Data Recorder and GPS / IMU

Mobile data acquisition including position and map based analysis

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Abstract

This Tech Note describes the satellite based position measurement technologies in general and its value in mobile data acquisition jobs. It describes the different types of satellite based systems like GPS, data acquisition with the new QuantumX Data Recorder CX22B-W and position based analysis in catmanAP or GlyphWorks from HBM. Also the use of so called Inertial Measurement Units (IMU) shall be discussed.

Intro

For a deep dive analysis of an overall moving vehicle and its performance, behaviour during manoeuvre, braking or influences of bad roads to chassis and components the trend in state-of-the art data recording is towards sensor and data fusion using as many as necessary locally integrated sensors and status information via vehicle busses, apply additional sensors to parts under investigation, plus video cameras and radio transmitted information of satellite based GPS/GNS data.

The acquired data in return is used to verify the design of the overall vehicle, to improve simulation models with focus on dynamics (multi body), for functional control development and testing but also or life-time calculation (fatigue). In addition to that the data is extracted for lab based testing of parts or full-scale vehicles supporting durability engineering.

QuantumX Data Recorder is the perfect tool for mobile data acquisition collecting all type of inputs. The ability of reading in position by use of GPS/GNS sensors or IMU's alongside with DAQ modules acquiring local sensor information like strain, pressure, acceleration, torque, force, temperature, displacement, voltage, current and many more in addition to bus signals for example from CAN bus is a perfect overall fit. This enables engineers to easily correlate all measured data to vehicle position and behaviour in the time or frequency domains. It also makes it simple to extract data and geographically map it to a certain position of the test track or course.

What is GPS/GNS?

GPS/GNS stands for **G**lobal **P**ositioning **S**ystem and is originally based on the US satellite system ***NAVSTAR***. There is also a system from Russia called ***GLONASS*** which stands for **GLO**balnaja **N**awigazionnaja **S**putnikowaja **S**istema. The system from the European Union is called ***GALILEO*** (which is planned to be fully in operation in 2019). China is also working on a satellite based geographical localization system called ***COMPASS*** (BeiDu-2 navigation system, which shall be in operation around 2020). So there will be plenty of choices with a good chance of getting higher accuracy in position and other information in using the infrastructure of several systems in parallel.

A GPS/GNS sensor receives the following information from satellites circling around the orbit:

- position in x, y and z axis (longitude, latitude and altitude)

- time (also as coded direct PPS signal)
- number of visible satellites

GPS/GNS is used to precisely calculate latitude and longitude of a specific position. The GPS/GNS system is based on a network of many satellites that orbit the earth twice every 24 hours. The precise orbit of the satellites and their use of very accurate clocks allow precise triangulation of a vehicles or users position. Each satellite transmits its exact position and a very accurate time. The accurate time required for GPS/GNS is provided by atomic clocks at the U.S. Naval Observatory to the satellite system, so that the complete system works fully synchronised.

At the moment GPS/GNS sensors need a clear view to the sky, for example mounted on the roof top of a vehicle with a 360° view to the sky to get the maximum number of satellites. This also needs to be checked before testing.

The logger software can then calculate distance travelled, direction, acceleration and so on based on position data.

Some GPS/GNS receivers offer additional calculated information like *speed* or *acceleration.* One major trend in the market driven by many applications is integrating additional sensors into the unit. The sensor or device is then named Inertial Measurement Units (IMU). This type of unit “fine tune” GPS/GNS data based on additional integrated sensors like acceleration and gyro delivering higher precision of position, acceleration and speed, but also angle (pitch, slip, yaw) with an overall higher data rate.

Who uses GPS/GNS?

GPS/GNS is used in many forms - for direct navigation and engineering of vehicles but also for recreational activities like hiking, mountain biking or geo cashing and even in monitoring applications. Smart phones and digital cameras are more and more equipped with a GPS/GNS receiver focussing geographical navigation but also commercial aspects like finding the nearest hotel, restaurant or park. Meteorologists use it for weather forecasting. Geologists use it to survey or measure tectonic motions for earthquake studies. IMU’s are also used in a wide range of different applications. In military and aerospace it is used as main source for guided vehicle navigation. In automotive industry we find kinematic or motion analysis or also validation of vehicles according to standards like ISO4138, ISO7401, ISO7975 or ISO3888-2 - also known as “elk test”, just to name a few. One of the hot topics at the moment is autonomous and automated driving or driver assistance systems (ADAS) of cars or trucks.

QuantumX Data Recorder focusses in motion analysis and load data acquisition of vehicles like cars, trucks, busses, motorcycles, ships, trains and machines for material handling, agriculture and construction.

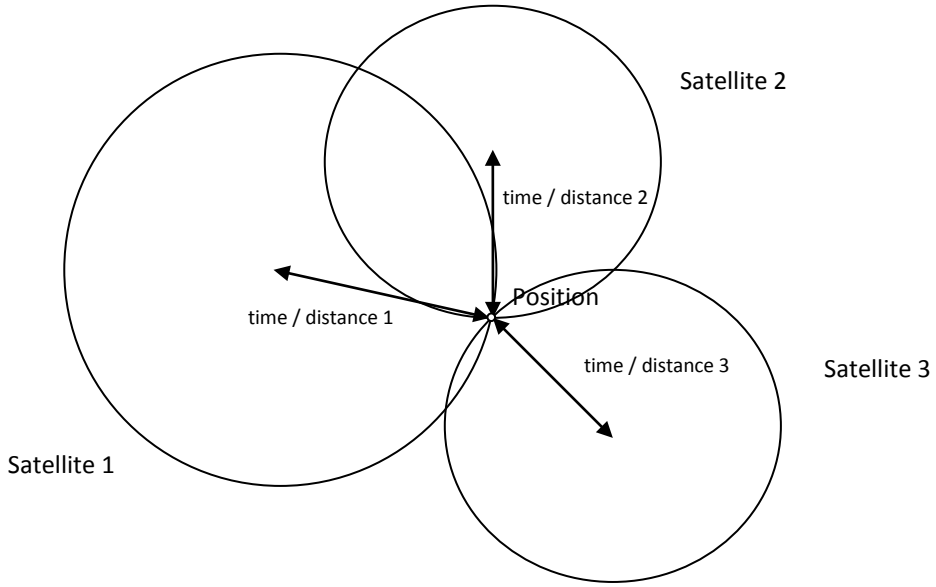
QuantumX is a flexible tool for all kind of measurement, testing and monitoring purposes acquiring analog and digital data in addition to bus signals from CAN, CCP or XCP in parallel to motion picture (video) and GPS/GNS or IMU data.

How does GPS/GNS work?

GPS/GNS is a satellite based navigation system based on 29 satellites (minimum of 24 active satellites). The full name of the system is “Navigational Satellite Timing and Ranging – Global Positioning System – NAVSTAR-GPS/GNS. In the origin this system has been developed by the US Department of Defence. The system has been launched 1995 officially. All satellites circle on an exact orbit so to receive signals from 6-10 satellites from every position in the world and a minimum of 4 at the same time. Every GPS/GNS satellite sends C/A coded data in L1 frequency band with 1575.42 MHz for civil purposes. Beside position and time also a special satellite code is sent to clearly differentiate from other satellites. The GPS/GNS receiver decodes these signals (CDMA). The highly precise military P/Y code is not public

If the GPS/GNS sensor receives signals from minimum 3 satellites the position can be precisely analysed from the sensor: latitude and longitude. 4 satellites allows calculation of altitude in addition (= height above mean sea level). In aviation “height” is generally used to measure distance between the sensor and the ground. The more satellites, the higher is the accuracy. Once you power up the QuantumX system and the GPS/GNS sensor first time, it will begin

searching for satellites. This process can last up to 5 minutes. After the GPS/GNS has been initialized it usually lasts less than a minute to get all the signals. The software checks this.



How accurate is GPS/GNS?

Position accuracy depends on many factors. The more satellite signals the GPS/GNS receiver acquires the better is the signal normally. The position of the satellites and thus the energy level of the signal received is also a driving factor in terms of accuracy Object that is located between the satellite and the sensor, such as a tall building can cause inaccuracy because of non-receivable or reflective signals. The quality of a standard GPS/GNS sensor in general can achieve accuracies of less than 10 m / yard.

Connecting a GPS/GNS sensor to QuantumX

Typical data rates of GPS/GNS receivers are between 1…20 Hz. And as a rule of thumb we can say the higher the performance the more interfaces are available and of course price varies in the same way. Data is normally transmitted according to the international standard NMEA 0183.

QuantumX Data Recorder CX22B supports the following three types of digital interfaces:

- **USB 2.0 or 3.0**
- **RS232 / DSub-9**
- **CAN bus**: via MX840B or MX471B

RS232 based GPS/GNS Sensors

The following GPS/GNS-Sensors have been tested together with QuantumX:

- GARMIN GPS18-5 Hz
- GARMIN GPS 19x HVS
- GARMIN GPS 35 tracpak
- Racelogic VBSS 5/10/20/100 Hz

This type of GPS/GNS sensors come with an embedded antenna and delivers an update rate of 1 - 5 Hz and low power consumption. QuantumX Data Recorder CX22B-W offers a RS232, DSub 9 pin based port for serial communication. Most receivers can track up to 12 satellites. This type of sensor is mostly used in for “just” position tracking of less agile vehicles. An extra power cable needs to be soldered as the RS232 port does not supply any power.

HINT: HBM offers such a sensor in the SOMAT product range which comes along with a M8 male connector. Material number: 1-EGPS/GNS-5HZ-2.

RS232 wiring (DSub-9)

DSub-9

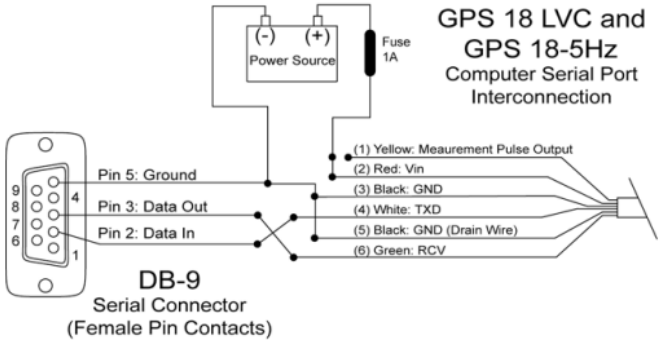
Pin Assignment
-
2 = R_X data in
3 = T_X data out
-
5 = ground

GPS 18 LVC & GPS 18-5Hz PINOUT

GPS 18 Pin #	Color	Signal Name	Wire Gauge
1	Yellow	Measurement Pulse Output	28
2	Red	Vin	26
3	Black	Ground	28
4	White	Transmit Data	28
5	Black	Ground	26
6	Green	Receive Data	28

Table 1: GPS 18 LVC & GPS 18-5Hz Wire Pinout

GPS 18 LVC & GPS 18-5Hz WIRING DIAGRAMS

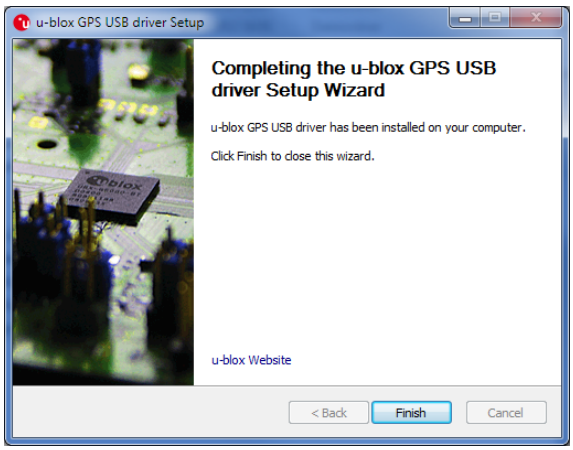


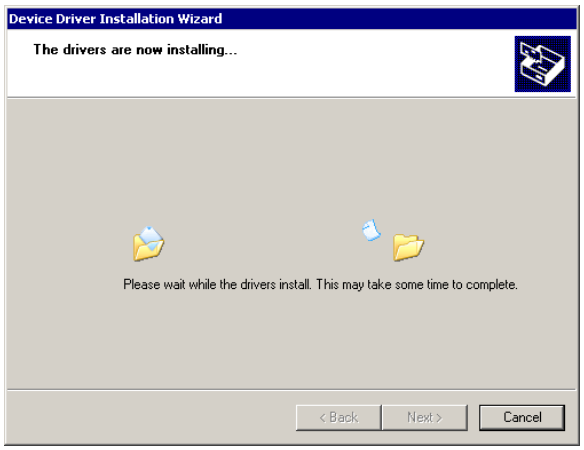
USB based GPS/GNS sensor

The following USB based GPS/GNS sensor can be recommended to work with the QuantumX Data Recorder. This type of sensor is easy to connect – configuration, data and power comes with one single connector.

- NAVILOCK NL-602U GPS, USB based

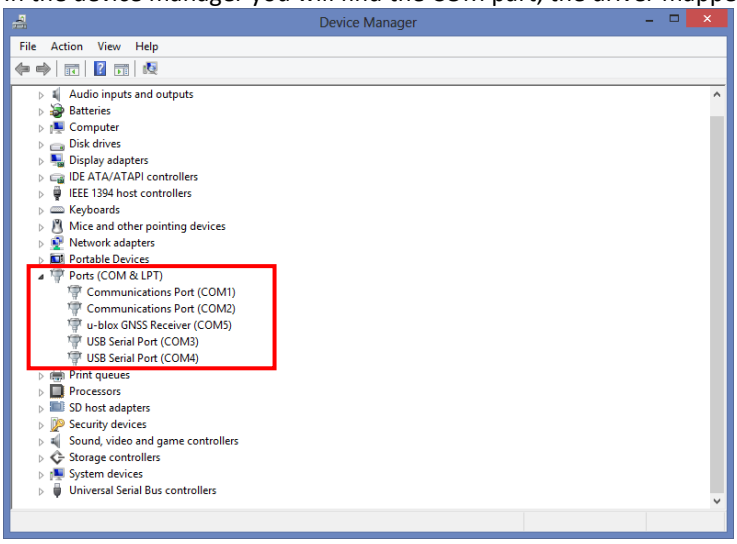
- Install the software and device driver on the Data Recorder CX22B-W.



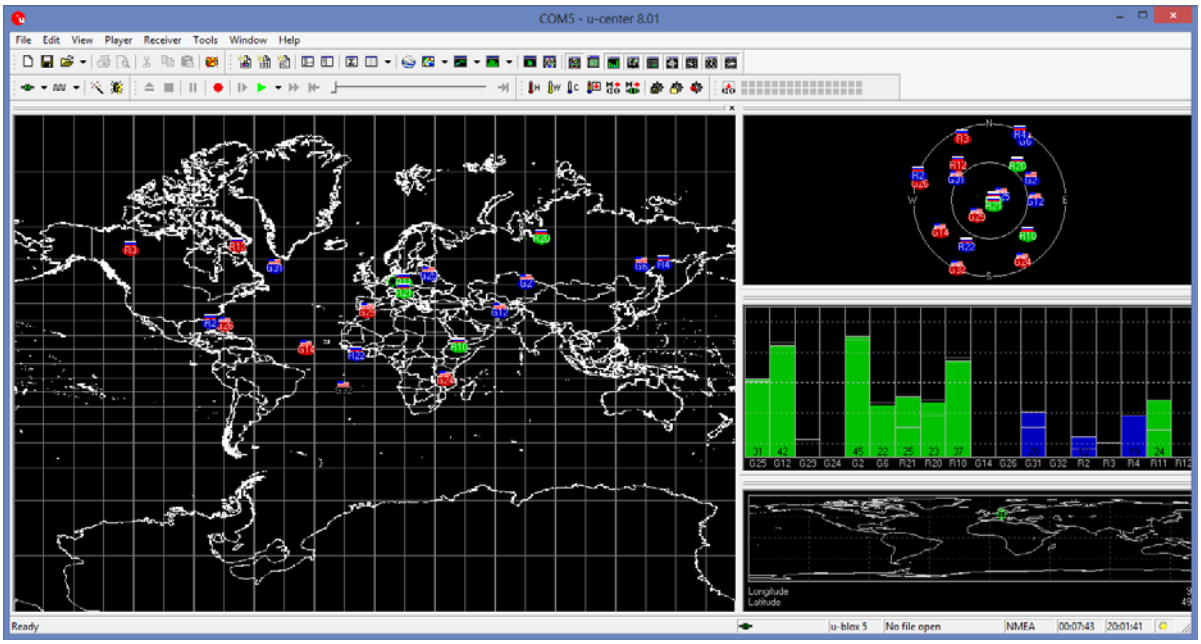


Now go to the device manager via:

START -> Settings -> Control Panel -> System -> Device Manager
In the device manager you will find the COM part, the driver mapped the GPS/GNS sensor to.

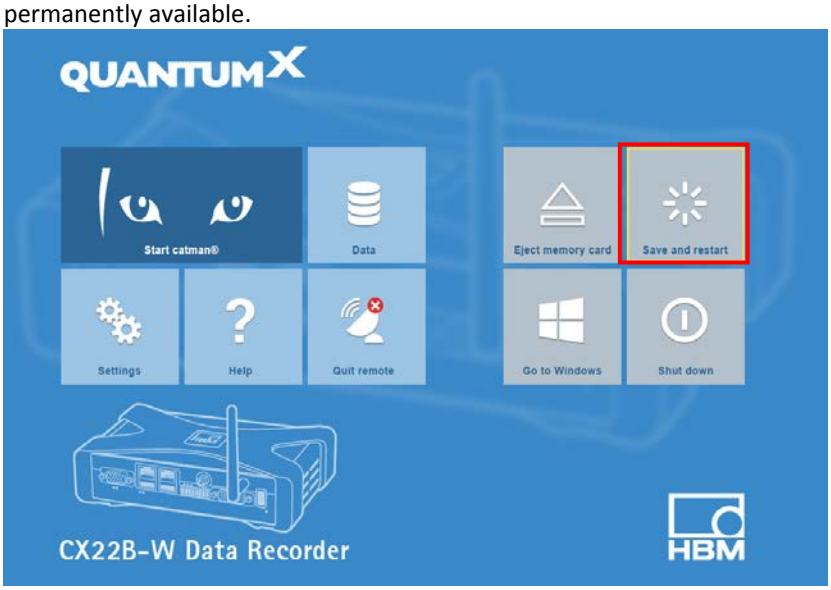


With the delivered GPS software you can hook up to the GPS/GNS sensor via for example COM port 5 and analyse your current position, amount of sattelites and so forth.



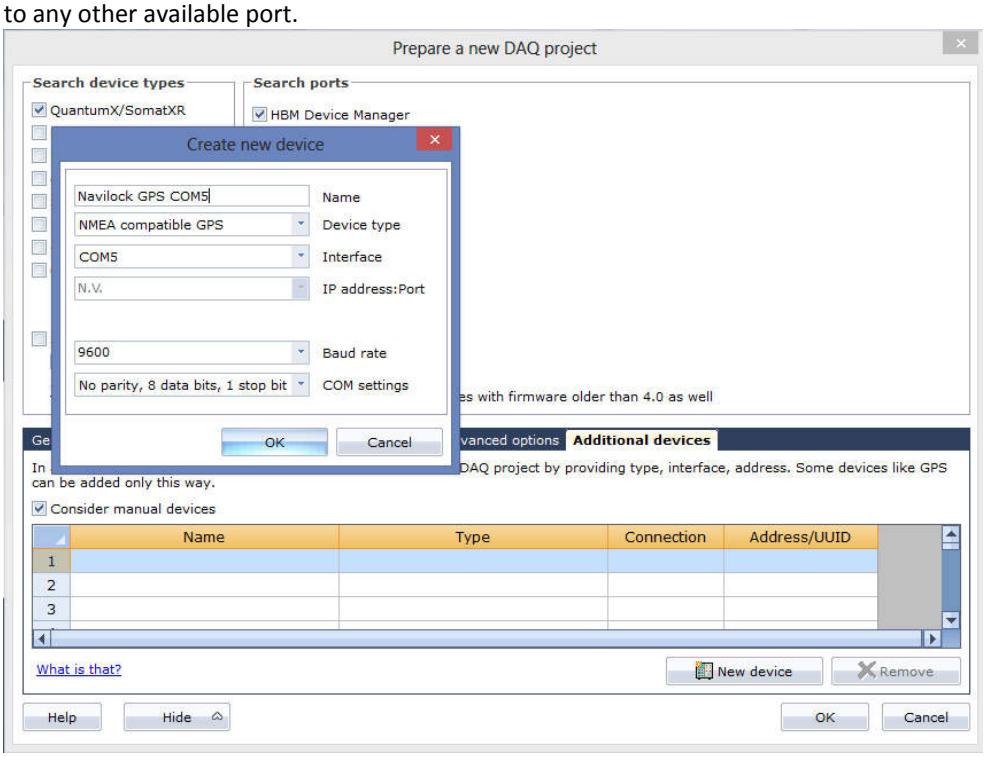
Step by Step parameterization of RS232 or USB based GPS/GNS sensor

1. IMPORTANT: In case you installed a driver or software to the Data Recorder “save and restart” making it permanently available.

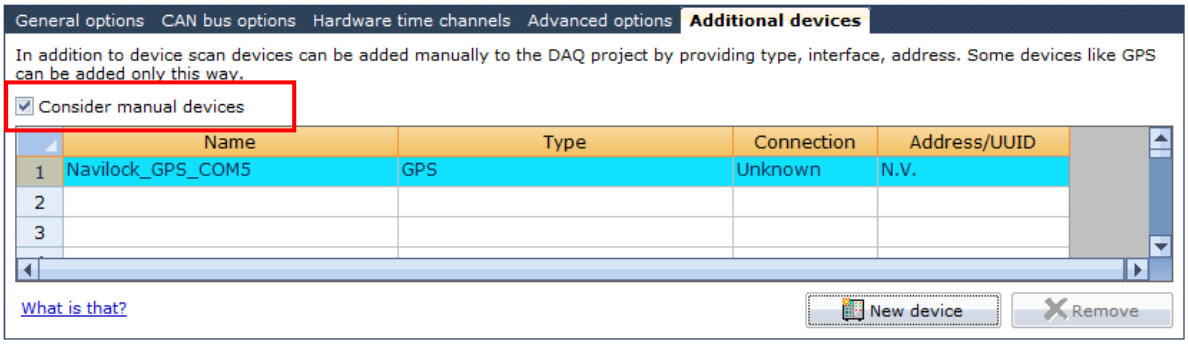


2. Start catman software on the Data Recorder and open “Select device type” Dialogue

3. Open “Options”, go to tab "Additional devices” and add “New device”
4. Configure the port in the following way. COM1-5 is possible. It is always possible to map your GPS/GNS sensor to any other available port.



5. Highlight “Consider manual devices" and finish configuration with OK



From now on your GPS/GNS sensor is connected automatically to future projects.

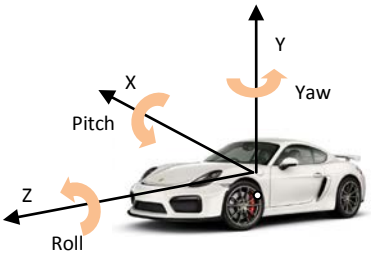
6. The following screenshot shows the channel list with one QuantumX module and the GPS/GNS signals latitude, longitude, altitude, speed and time coming from RS232 based GPS/GNS sensor

Channel name	Reading	Sample rate/Filter	Sensor/Function	Zero value
MX840A Universal				
load cell	**-0.00342 kN**	1200 Hz / BE 100 Hz (Auto)	C18 100kN	-8.117 kN
microphone	**-0.00040 V**	1200 Hz / BE 100 Hz (Auto)	DC Voltage	0.00000 V
voltage input	**-0.00090 V**	1200 Hz / BE 100 Hz (Auto)	DC Voltage	0.00000 V
MX840A Universal_CH 4	**526.1 V**	1200 Hz / BE 100 Hz (Auto)	DC Voltage	0.00000 V
speed sensor	**0.00000 U/min**	1200 Hz / BE 100 Hz (Auto)	Pulse count: 2-phase, 4-fo	0.00000 U/min
MX840A Universal_CH 6	**No signal**	1200 Hz / BE 100 Hz (Auto)	Thermocouple Type T	0.00000 °C
MX840A Universal_CH 7	**No signal**	1200 Hz / BE 100 Hz (Auto)	DC Voltage	0.00000 V
MX840A Universal_CH 8	**No signal**	1200 Hz / BE 100 Hz (Auto)	DC Voltage	0.00000 V
Navilock_GPS_COM5				
Navilock_GPS_COM5_Latitude	**49.89 () °**	10 Hz / NA	LATITUDE	0.00000 °
Navilock_GPS_COM5_Longitude	**8.643 () °**	10 Hz / NA	LONGITUDE	0.00000 °
Navilock_GPS_COM5_Altitude	**121.0 () m**	10 Hz / NA	ALTITUDE_M	0.00000 m
Navilock_GPS_COM5_Speed	**0.9760 () km/h**	10 Hz / NA	SPEED_OVER_GROUND_	0.00000 km/h
Navilock_GPS_COM5_Time	**55525 (1/1/1970 3:2**	10 Hz / NA	TIME	0.00000 s
Navilock_GPS_COM5_Date	**42427 (2/26/2016) --**	10 Hz / NA	DATE	0.00000 ----
Navilock_GPS_COM5_SatStatus	**0.00000 () ----**	10 Hz / NA	SATELLITE_STATUS	0.00000 ----
Navilock_GPS_COM5_Gyro_Pitch	**No signal**	10 Hz / NA	GYRO_PITCH	0.00000 °
Navilock_GPS_COM5_Gyro_Roll	**No signal**	10 Hz / NA	GYRO_ROLL	0.00000 °
Navilock_GPS_COM5_Gyro_Yaw	**No signal**	10 Hz / NA	GYRO_YAW	0.00000 °
Navilock_GPS_COM5_MagHeading	**0.00000 () °**	10 Hz / NA	MAGNETIC_HEADING	0.00000 °
Navilock_GPS_COM5_TrueHeading	**0.00000 () °**	10 Hz / NA	TRUE_HEADING	0.00000 °
Navilock_GPS_COM5_TurnRate	**No signal**	10 Hz / NA	TURN_RATE	0.00000 °/s
Navilock_GPS_COM5_WindDirectio	**No signal**	10 Hz / NA	WIND_DIRECTION	0.00000 °
Navilock_GPS_COM5_WindSpeed	**No signal**	10 Hz / NA	WIND_SPEED	0.00000 m/s

HINT: At least one QuantumX module is necessary relating the GPS/GNS signals to time.

Inertial Measurement Units (IMU)

An Inertial Measurement Units (IMU) is a device attached to a vehicle, ship or aircraft which can measure the overall body position and movement in direction, speed and angular rates, using a combination of satellite based sensors like GPS, accelerometers and gyroscopes (gyro). IMUs are typically used to maneuver aircrafts but also in vehicle testing for non-contact speed measurement for performance and brake testing or as important sensor information in autonomous driving. An IMU can also interpolate absolute position with a higher datarate, even when GPS signals are not available, such in tunnels or inside buildings



Many of these IMU's come along with a digital **CAN bus** interface which can be integrated in QuantumX in an easy way. We recommend using a private bus between IMU and QuantumX. Bus termination might be necessary on both sides. MX471B offers an internal 120 Ohm resistor which can be activated via software terminating the bus. When using a short cable between sensor and QuantumX this single terminator might be OK. For MX840B the termination resistor needs to be soldered into the SubHD plug.

Potential suppliers:

- iMAR, offers IMU – inertial measurement units
  - Output: CAN with maximum 100 Hz
  - http://www.imar-navigation.de
- NovAtel, offers FlexPak
  - CAN with maximum 100 Hz
  - http://www.novatel.com/products/gnss-receivers/enclosures/flexpak6/
- Racelogic, offers VBOX Speed Sensor
  - Output: CAN
  - http://www.racelogic.co.uk/
- Race Technology, offers SPEEDBOX
  - Output: CAN
  - http://www.race-technology.com/speedbox_3_713.html

Step by Step configuration of CAN based IMUs

1. Connect the IMU to a private CAN bus node on MX471B: port 1, 2, 3 or 4 or on port 1 of MX840B
   Hint: take in mind that you might have to terminate the CAN bus on the QuantumX side (MX840B in the plug, MX471B via software command)

2. Go to sensor database: import the CAN configuration file (dbc) from the vendor to the sensor database

3. Go to channel overview: drag and drop the relevant signals to the CAN port and configure the CAN node.
   Example: 500 kBit, termination ON with MX471B

4. Visualize the signals with numerical indicators

HINT: At least one QuantumX module is necessary in combination with GPS/GNS signals.

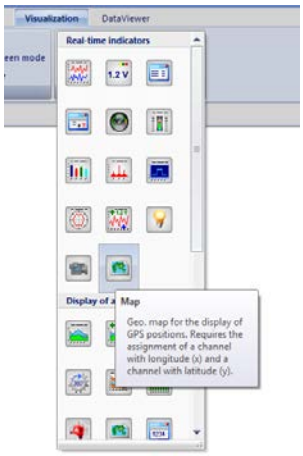
Map based Position Visualization and Analysis

The Data Recorder software catmanEasy can be extended by extra functionality like

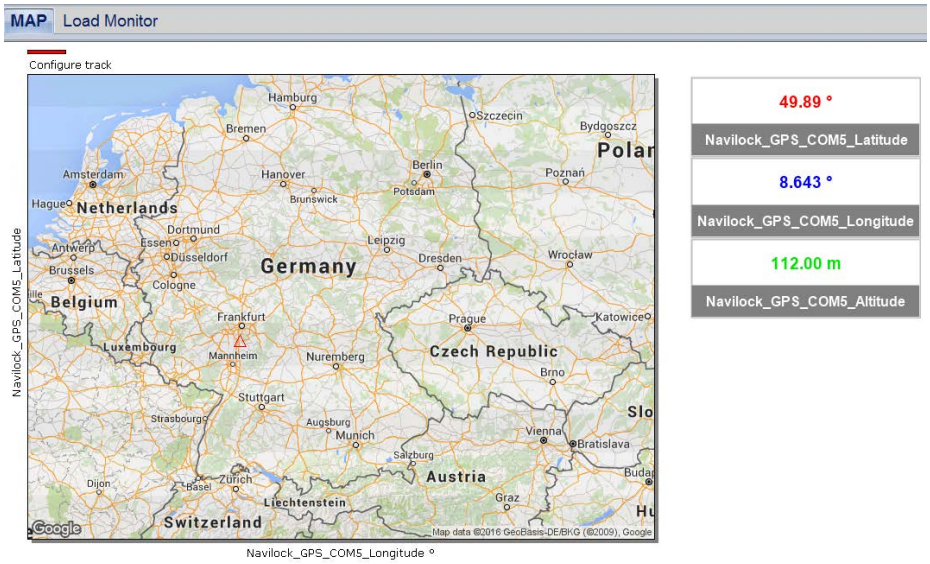
- Visualization of the geographical data in *google maps* (needs internet access)
- Video camera integration
- Integration of wheel force transducers via Ethernet

Activating this functionality a valid license key is necessary. Let's take the EasyRoadLoad package.

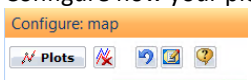
Then go to Visualization map and take the map visualization object.

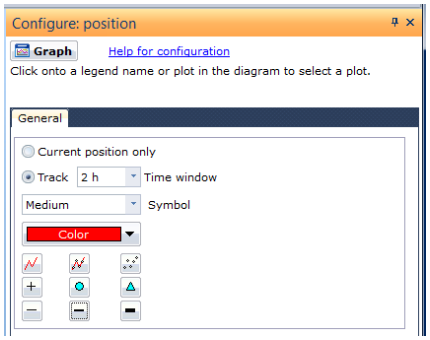


Assign longitude and latitude to the map and visualize also alitude as digital indicator:

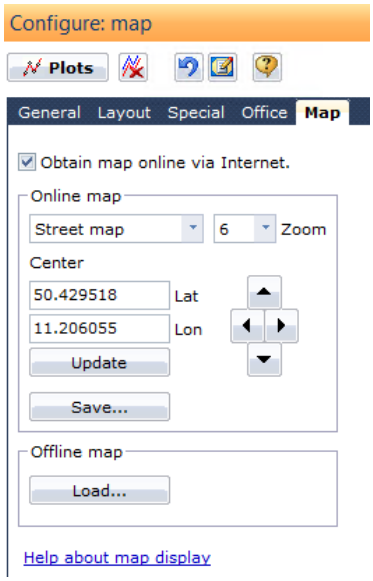


Configure how your plot shall look like in the map: **current position** or **track:**





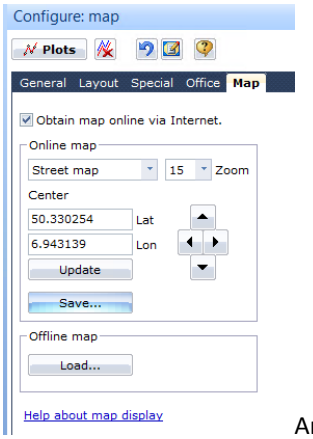
Configure the map type (street map, satellite, terrain or hybrid)



In most of the cases you won't have internet access. In this case enter the rough coordinates of your test track and zoom into the map for positioning.

Example: Racetrack Nuerburgring in Germany with

Save the map



And load it into the recorder software in the field.

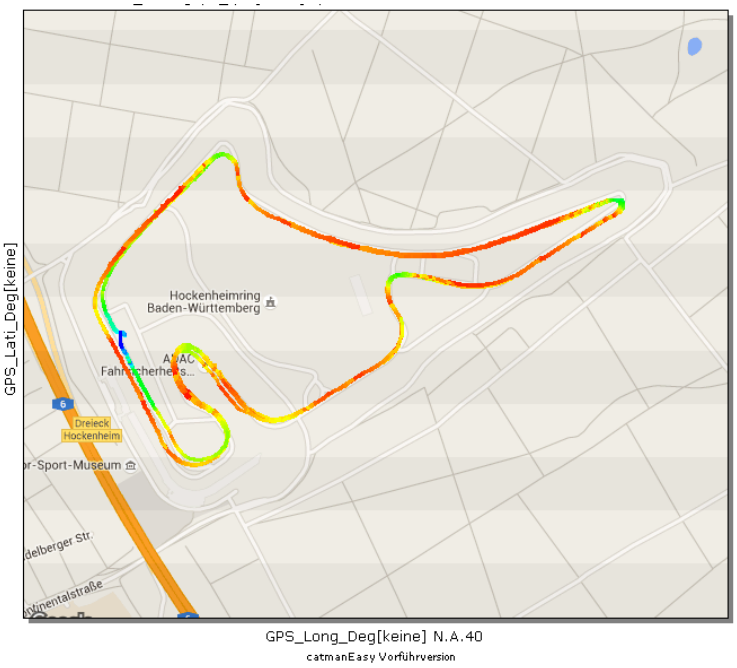
Map based post process analysis in GlyphWorks

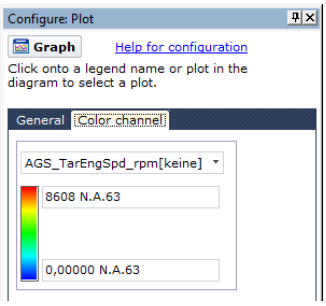
Back in office download all data from the Data Recorder and analyse it in catmanAP.

In this mode you can visualize certain signal inputs in the map in a coloured style according to its value.
Examples shown: Engine speed from 0 (blue)…. 8600 rpm (red)

Others are vehicle speed, gear, brakes or analog inputs like strain, acceleration, temperature, direct torque, pressure, battery voltage, etc.

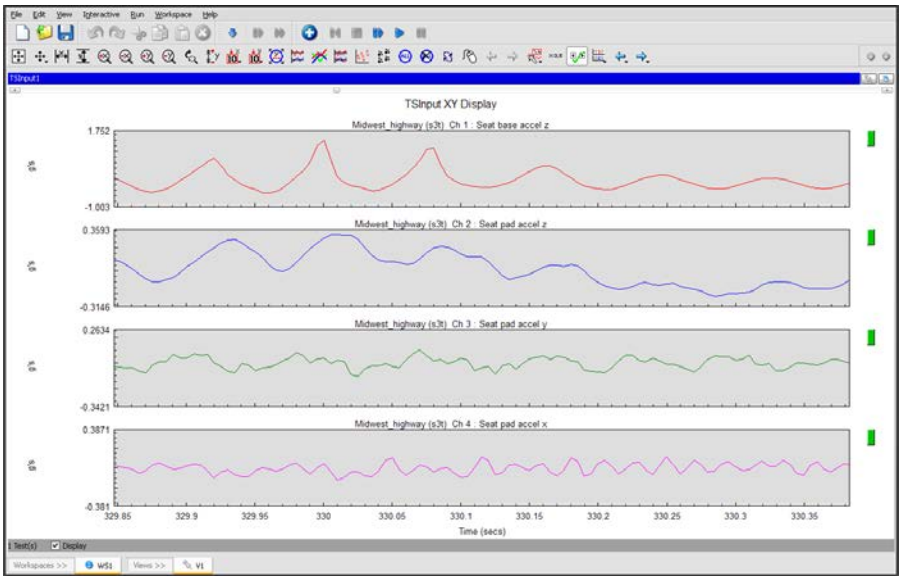
Example shows the Hockenheim Ring in Germany:



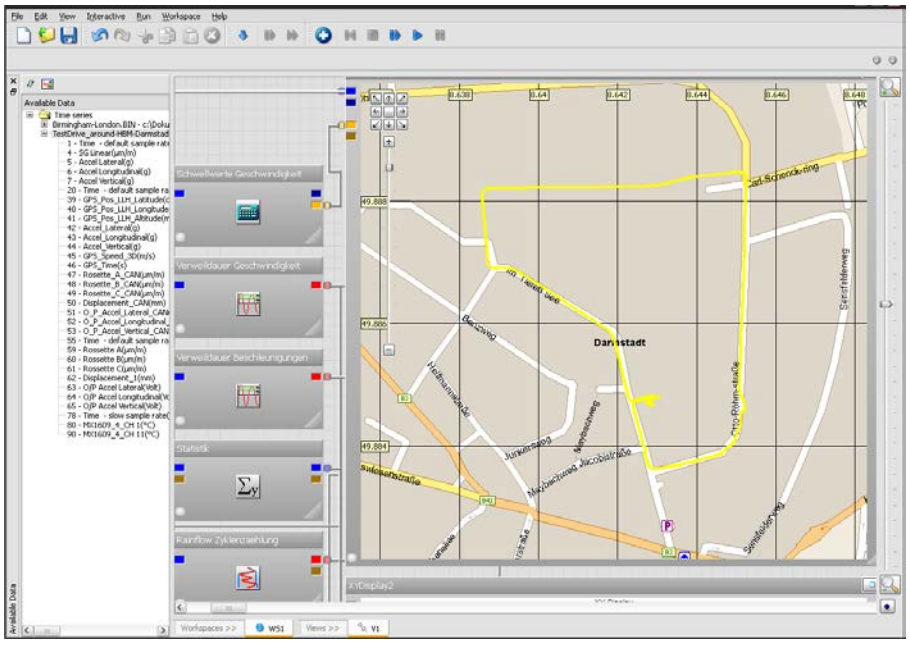


Map based post process analysis in GlyphWorks

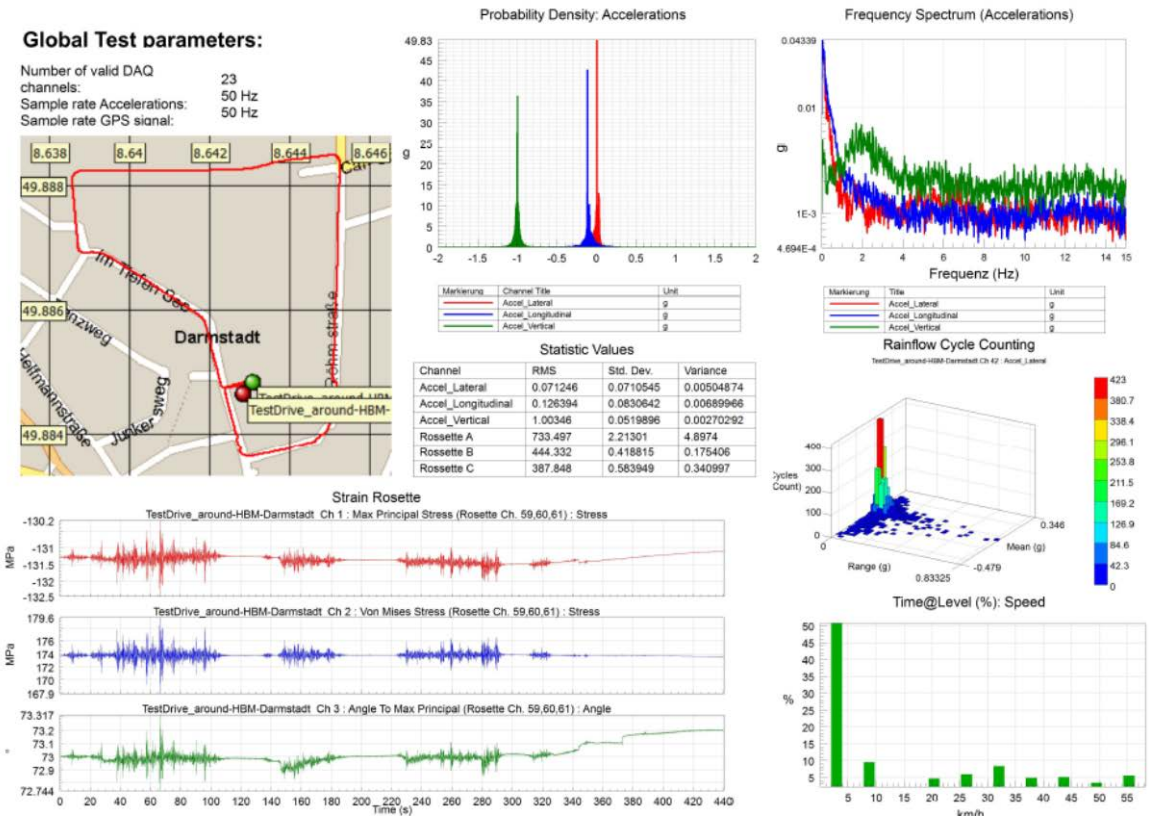
You can also visualise and automatically analyse your data in a block based mathematical way using the powerful graphical and post processing tool **GlpyhWorks** from HBM nCode. The package ***Synchronized Displays*** provides you a toolset displaying GPS/GNS data globally mapped to **Microsoft MapPoint** or export functionality to **Google Earth**. Multiple gage types can display **any input** from sensors or bus data, the exact **position** and even **video** in a synchronized way. One-click single pager **Analysis Reports** from hundreds of field tests in PDF format makes it a perfect tool supporting engineering.



Picture: GlyphWorks - visualize and analyse measurement data
zoom into your set of data and analyse it in time or frequency domain



Picture: GlyphWorks – data analysis in a graphical flow with mathematical tasks
From left to right: data pool, calculation of speed, time at level of acceleration and speed, FFT calculation, map



Picture: GlyphWorks – automatically generated vehicle test report
visualize all aspects of your test drive: meta data, signal data, position, etc.

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