A professional equipment

Still easy to use
Why a high-end receiver?
Accuracy matters

Septentrio’s Robust DGPS/SBAS/Standalone

Mobile devices (phones/tablets)

Septentrio’s RTK accuracy

Accuracy: 1cm, 0.5m, 6m
The difference

- **Smartphone / Tablet**
  - GPS (Glonass) L1

- **Septentrio**
  - GPS L1, L2, L5
  - Glonass L1, L2, L5
  - Galileo E1, E5a, E5b, AltBoc, E6
  - Beidou B1, B2, B3
  - IRNSS L5
  - QZSS L1, L2, L5
Tracks all visible signals (GPS, GLONASS, GALILEO, BEIDOU, IRNSS, QZSS, SBAS)

Carrier-to-Noise

System: GPS

Tracking L1CA, P1(Y), P2(Y), L2C, L5, L1C
[unhealthy signal(s): L1CA, P1(Y), P2(Y), L2C, L1C]
Tracks all visible signals (GPS, GLONASS, GALILEO, BEIDOU, IRNSS, QZSS, SBAS)
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Tracks all visible signals (GPS, GLONASS, GALILEO, BEIDOU, IRNSS, QZSS, SBAS)
Differential GPS or RTK

Known X, Y, Z

Differential Corrections

0.8-1.5 m

0.01 m
## GNSS Augmentation Techniques

<table>
<thead>
<tr>
<th>Technique</th>
<th>Horizontal</th>
<th>Vertical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stand Alone, Multi Constellation, Multi Frequency</td>
<td>1.20 m</td>
<td>1.90 m</td>
</tr>
<tr>
<td>SBAS (EGNOS, WAAS, GAGAN, MSAS, ...)</td>
<td>0.60 m</td>
<td>0.80 m</td>
</tr>
<tr>
<td>DGNSS</td>
<td>0.40 m</td>
<td>0.70 m</td>
</tr>
<tr>
<td>PPP (Precise Point Positioning)</td>
<td>0.04 m</td>
<td>0.06 m</td>
</tr>
<tr>
<td>RTK (or PPK)</td>
<td>0.006 m + 0.5 ppm</td>
<td>0.01 m + 1 ppm</td>
</tr>
</tbody>
</table>
### GNSS Augmentation Techniques

- **Stand Alone**, Multi Constellation
  - No ground infrastructure

- **SBAS** (EGNOS, WAAS, GAGAN, MSAS, ...)
  - No ground infrastructure, limited area

- **DGNSS**
  - Base stations (or CORS network) required
  - Based on code information only

- **PPP** (Precise Point Positioning)
  - World wide network of reference stations, low density
  - Code and phase information required
  - Corrections usually provided by satellite
  - Long convergence time (10 to 20 minutes)

- **RTK** (or PPK)
  - Nearby base station or high density CORS network required
  - Code and phase information required
  - Short convergence time
Typical GNSS Vulnerabilities

- Spoofing
  - Covert
  - Deception

- Multipath

- Interference
  - Intentional
  - Unintentional

- Cyber Attacks
  - Non-RF

- GNSS Segment Errors
  - Erroneous upload data
  - SV Faults (E.g., SVN49)

- Atmosphere
  - Scintillation
  - Solar Activity
Heading
GNSS/INS?
GPS as an essential element of sensor fusion
ABSOLUTE POSITIONING
Our markets

Machine Automation
- Marine
- Construction
- Mining
- Logistics
- Agriculture
- Autonomous driving

Survey and Mapping
- Survey
- GIS
- Mobile Mapping
- Unmanned Systems

Scientific/Reference
- Reference Receivers
- Timing Receivers
- Space Weather

Aerospace/Defense
- Aerospace
- Defense
Core Market Segments / Key Customers

**Machine Automation**
- FIGRD
- BNSF Railway
- RAVEN Industries
- DEME
- JAN DE NIJ
- GE
- PSA
- Honeywell
- Vale

**Survey & Mapping**
- senseFly
- FLYING CAM
- DELAIR
- Google
- Kespry
- IXBLUE

**Scientific/Reference**
- USNO
- MIT Haystack Observatory
- Berkeley University of California

**Aerospace / Defense**
- Airbus
- ESA
- General Dynamics
- Bluefin Robotics
- QinetiQ
Our Products

mosaic
Compact receiver module

AsteRx
Rover Receivers and OEM boards for automation and machine control

Altus
Smart antennas for GIS and survey

PolaRx
Reference receivers for science and networks
Robust high precision GNSS receivers in many forms
Our approach

Application Understanding

Application Engineering Assistance

Easy-to-integrate

Reliability

Availability

Accuracy

Security

Technology
Septentrio’s differentiation

Accuracy + Reliability + Availability + Security
It’s not just about accuracy!

- Can the position be trusted?
Septentrio GNSS Products
Flexible choice for your integration

Integrated GNSS Receivers

OEM Receiver Boards

OEM Receiver modules

Platform S (chipsets)
Products
Complete housed receivers and smart antennas for machine control and robotics

AsteRx-SB
- Compact and versatile package
- COM, Ethernet, USB
- Wifi, Bluetooth
- Low power (1.5W)
- IP68

AsteRx-U
- Rugged receiver
- Integrated cellular modem
- optional UHF
- 2-antenna input for heading
- Ethernet, USB and Serial

APS-NR3
- Integrated antenna and receiver
- Internal webserver
- Internal data logging
- Works all day with internal batteries
- Integrated communications (WiFi, Bluetooth, cellular modem)
AsteRx
OEM boards for integration

- Dual antenna multi-frequency GNSS receiver
- All signals and constellations
  - GPS/GLO/GAL/BDS/QZSS
  - L1, L2, L5/E5, L6/E6
- Stand-alone, DGNSS, PPP, RTK, heading
- Scalable power consumption
  - 1-3W depending on configuration
- On-board webserver and multiple interfaces

- Low power compact single-antenna multi-frequency GNSS receiver
- GPS/GLO/GAL/BDS
- Stand-alone, DGNSS, PPP, RTK
- Compact & low power
  - 300mW in single frequency
  - 600 mW 20 Hz GPS/GLO RTK
- Single/Dual antenna
- UAS carrier board
**mosaic™ Compact GNSS receiver module**

GNSS receiver module

**Integrated GNSS receiver**

- Same capabilities as AsteRx-m2:
  - Cm accurate position (RTK/SSR)
  - High update rates
  - Advanced interference mitigation
- Tools included (Rx Tools ...)

**Compact form factor**

- 31x31X4mm
- 9g
- 600mW

**Interfaces**

- Wide array of interfaces, UART, USB, Ethernet

SMT (surface mount) solderable
LGA (Land Grid Array)
Simple integration (no ext. Components needed)
PolaRx5
Multi-frequency GNSS Scientific/CORS Receiver

- Tracks all visible signals (GPS, GLONASS, GALILEO, BEIDOU, IRNSS, QZSS, SBAS)
- High-precision, low-noise measurements
- Best in class interference monitoring and mitigation
- Low and scalable power consumption
- Powerful web interface and logging tools
- Logging up to 24 parallel data records both internally and to an external device
Applications
Autonomous is not a revolution!

- **PRECISION AGRICULTURE**, 2002
- **MACHINE CONTROL**, 2008
- **DRONES**, 2015
- **AUTOMATED X**
Shift from **Pilot** to **User** focus

- From technological innovation to pragmatic business
- Social challenges: legislation and skepticism

Commercial use of drones is now a reality

- Focus on data and services
- Professional products need reliable positioning
  - For Safety
  - For multiple Applications
## Fixed-wing or Rotary?

<table>
<thead>
<tr>
<th></th>
<th>Fixed-wing</th>
<th>Rotary / Multi-rotor</th>
<th>VTOL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Projects</strong></td>
<td>Mapping</td>
<td>Small area mapping &amp; inspection</td>
<td>Mapping (large area Inspection)</td>
</tr>
<tr>
<td><strong>Applications</strong></td>
<td>Land surveying, AG, GIS, Mining, environmental, construction, humanitarian</td>
<td>Inspection, real estate, surveying (urban), construction, emergency response, law enforcement</td>
<td>Land surveying, AG, GIS, Mining, environmental, construction, humanitarian</td>
</tr>
<tr>
<td><strong>Cruising speed</strong></td>
<td>High</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td><strong>Coverage</strong></td>
<td>Large</td>
<td>Small</td>
<td>Large</td>
</tr>
<tr>
<td><strong>Ground resolution</strong></td>
<td>cm per pixel</td>
<td>Mm per pixel</td>
<td>cm per pixel</td>
</tr>
<tr>
<td><strong>Take-off/landing area</strong></td>
<td>Large</td>
<td>Very small</td>
<td>Very small</td>
</tr>
<tr>
<td><strong>Flight times &amp; wind resistance</strong></td>
<td>High</td>
<td>Low</td>
<td><strong>Low</strong></td>
</tr>
</tbody>
</table>
GEO-REFERENCING

- Offline cm geotagging of images or sensordata
- Accurate synchronization with camera
- Integration in image processing chain

NAVIGATION

- Hover for stable camera pointing
- Take off & landing (cm-level)
- Reliable position !!!
  - Anti-jam
  - Anti-spoof
  - Multi-constellation
  - Error reporting
Purposes and use cases of high-end GNSS

Using a high end GNSS for:
- Navigation
- Geo-referencing (survey mapping)
- Stable Hovering
- Take off and landing
- Reliability (legislation)
- Cinema

Using a high end GNSS for Navigation:
- Geo-referencing (survey mapping)
- Stable Hovering
- Take off and landing
- Reliability (legislation)
- Cinema

Using a high end GNSS for Geo-referencing (survey mapping):
- Service drones flying next to high power lines (possible interference)
- Dronebox Take off and landing accuracy (remote drones)
- Kespry stockpile volumetrics

Using a high end GNSS for Stable Hovering:
- Flying cam
  Movie making of James Bond (accuracy and heading)

Using a high end GNSS for Take off and landing:
- Aerialtronics and TMobile inspections of communication towers
- SenseFLY and Turkish 140kms corridor (mountains, roads, urban) Project proved better than traditional methods

Using a high end GNSS for Reliability (legislation):
- Service drones flying next to high power lines (possible interference)
- Dronebox Take off and landing accuracy (remote drones)

Using a high end GNSS for Cinema:
- Flying cam
  Movie making of James Bond (accuracy and heading)
Wingtra

VTOL = vertical take-off and landing
VTOL? For mapping

Requirement for PPK
**Industrial applications - Rail**

Triggered by 2008 Safety act (US mandate)

- Full efficiency
- Reliability (multiple sensors) “fail safe”
- PCT not new!

Working on PTL with GE and BNSF

10k receivers in
How PTC works?

**HOW PTC WORKS**

**BRAKING IN PROGRESS**

- Using GPS, PTC evaluates train’s distance from end of authority limits
- Warning given if engineer doesn’t slow train
- PTC triggers brakes if engineer doesn’t brake to stop short of limits
Industrial applications – Harbour and Marine

GNSS receivers for world leading dredging companies (Jan de Nul, DEME) and offshore energy construction: Oil and Gas, Wind, ...

Equipping fleet of >300 straddle carriers in Antwerp Container Port for improved safety and efficiency
Industrial applications – Agriculture

Tractor auto-steer and specialized control applications with unique dual –antenna set-up

Autonomous agriculture robots
Industrial applications – Machine automation

Positioning for machine control on excavators and dozers operating in challenging environments

GNSS positioning for VALE S11D automated mine project in Carajas - Brazil
Vibrotrucks

With improved reliability and accurate position, Vibrotrucks can detect failures in the ground.

In this case, vibrotrucks drive in Munich, Germany and detect accurately the places where underground thermal waters can be found as an ecological way for providing heating to the city.

Vertical drain installation

With improved position accuracy, vertical drillers can make efficient jobs in even the more difficult environments.

The practical installation of AsteRx SB is ideal for applications requiring flexibility.
Sewer cleaning trucks

With improved reliability and accurate position sewer cleaning trucks can map exactly the areas of maintenance. Septentrio helps in bringing technology which is reliable and easy to install in vehicles.

Airport vehicle tracking

With improved position accuracy and reliability in the most difficult dynamic and difficult environments, airports can manage their vehicle infrastructure keeping safety as a main objective.
Agriculture Robots

With improved reliability and accurate position agriculture and other robots can autonomously work in even the more difficult situations.

The flexibility of the small box and its robustness makes it an ideal product for these applications.

Base station or Static monitoring

With basic features for base station, the AsteRx SB can be deployed as a simple base station product in flexible installations requiring basic corrections.

The AsteRx SB can also be used by integrators of structural monitoring solutions.
UAS base station

With wireless communication and open interfacing UAS integrators can use the NR2 as reliable base station.

Agriculture Robots

With improved reliability, embedded web interface and open interface Agriculture robots can use an smart antenna for the more demanding jobs.
Marine survey & Barimetry

With improved performance and open interference mitigation marine survey integrations can easily and accurately be done.

Machine control

With improved reliability, accuracy, external connectivity and open interface – machine control applications can benefit of Septentrio’s technology for best performance in demanding industrial applications.
GNSS for autonomous

High availability measurement engine

High integrity cm-accurate positioning engine

Open architecture for multiple correction systems (RTK, PPP, SSR)

GNSS/INS integration
UNAVCO typical installations

PolaRx5
Tectonic plates motion...continental drift, earthquakes, volcano activity,
Reference networks

Monitoring
UNAVCO PBO deployment

146 PolaRx5
Mainly in USA west coast
Also in Costa Rica, Greenland, Bangladesh
Geoscience Australia, Iceland, NRCAN, CHAIN, …

RTK and PPP networks

Veripos WW PPP network
RTK networks:
Germany (BW, SAPOS),
UK (OS),
…
What about PolaRx5TR?

GNSS for time transfer

UTC Universal Time
Coordinated determination

Precise (ns) synchronization of equipment
Tracking Electrons from Solar Storms

Map from NASA; Report Cover from NOAA
EMEA (HQ)
Greenhill Campus
Interleuvenlaan 15i,
3001 Leuven, Belgium

Americas
Los Angeles, USA

Asia-Pacific
Melbourne, Australia
Shanghai, China
Yokohama, Japan

septentrio.com
sales@septentrio.com

@septentrio
PolaRx5 product line intro
• GPS / GNSS recap
• What is a reference station
  • Geodetic application
  • RTK networks
• PolaRx5 unique selling points
• PolaRx5S and PolaRx5TR specificities

Disclaimer: the content is simplified with approximations to make it digestible by the most
What is GNSS?

GPS= Stands for "Global Positioning System." GPS is a USA satellite navigation system used to determine the ground position of an object.

There are more satellites systems (usually named constellations) similar to the American GPS: Europe has Galileo, Russia has Glonass, China has Beidou, etc.

When we talk about positioning based on multiple constellations acronym GNSS (Global Navigation Satellite System).

GNSS delivers a position (a velocity and the time) of an object.

You need a receiver and an antenna.

These can be separated or integrated in a single box.
# Smartphone vs high-end GNSS

<table>
<thead>
<tr>
<th></th>
<th>Smartphone/SatNav</th>
<th>Septentrio</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>How many constellations?</td>
<td>Typically 1 (GPS) but in recent devices more than one is becoming available</td>
<td>Several</td>
<td>More constellations=more satellites=more availability</td>
</tr>
<tr>
<td>How many frequencies</td>
<td>typically 1</td>
<td>3 or more</td>
<td>A frequency is way to define “color” of an em wave.</td>
</tr>
<tr>
<td>Accuracy</td>
<td>Meter level</td>
<td>Down to cm</td>
<td>More accurate with corrections</td>
</tr>
</tbody>
</table>
Main errors in GNSS positioning
Main errors in GNSS positioning

More frequency = more accurate
remove the errors due to travelling in the atmosphere
Lost in Brussels?

Why the SATNAV does not work well in Brussels, New York, Hong Kong…?

You see less sky.
(having more than GPS helps because you see more satellites)

You get distorted signals bounced by buildings, called multipath.
(high end receivers have the intelligence to mitigate and reject the reflected signals)
Standalone vs augmented

Stand ...alone! just you your receiver (and antenna) looking at what GNSS sends to you. You know where you are at meter level.

You have your receiver, you still look at what GNSS send you but you get additional information from a one (or network of) reference stations. The correction come to you via a radio, a modem, a satellite, “any” communication link. You know where you are.
What can you do with GNSS?

Let's look at our website

Land survey, aerial mapping, marine and dredging, machine control, agriculture

or…be reference station.
The dynamic earth...DRIFT!

“time lapse” of the measured position by GNSS

Data courtesy of NASA
Volcano, earthquakes, continental drift…

Science needs DATA, as many as possible, as continuously as possible, as precise and complete as possible.

Amazing places on the planet…Iceland, Antarctica, Alaska, Himalaya, South America…deserts, top of mountains, volcanos, slides…

No 220V sockets for power supply
Not easily accessible
Unavco typical installations
USA PACIFIC PLATE BOUNDARY OBSERVATORY
What is an ideal receiver for these applications?

Low (and scalable) power consumption

Robust and reliable measurements

Immune (as much as it is possible) to interference

Complete data and easy data transfer/management

In case of problems, competent and fast support

= POLARX5! Best in class 😊
What GPS can tell us about the Earth

High-precision GPS* stations measure natural phenomena and hazards.

**GPS**

- **Snow Depth**: GPS positions can monitor snow depth measurements in hard-to-reach areas.
- **Ice Height**: Measuring ice thickness. Ice is home to many freshwater reservoirs.
- **Sea Level**: A rising sea level is a regional, and global change in sea level.
- **Vegetation**: GPS can measure the rate of plant growth, plant vigor, and moisture vegetation growth, not just length of the growing season.
- **Soil Moisture**: Sensors measure moisture in broad areas, based on reflected microwaves from the Earth’s surface.

**GPS Signals**

- **Direct GPS Signals**: GPS satellites send signals directly to Earth’s surface.
- **Reflected GPS Signals**: Signals bounce off objects and return to Earth, giving additional information.

**GPS positions give us information about the Earth’s many systems.**

- **Tectonics**: GPS measures Earth's movements in slow as millimeters per year. It's sensitive enough to record tiny motions of plates and tectonic plates.
- **Water Resources**: The gravity moves up and down slightly in response to changes in snow, ice, and groundwater levels, useful in monitoring droughts.
- **Glaciers**: GPS measures the rise and fall of glaciers, which reflects the amount of ice on Earth's surface, useful in understanding climate change.
- **Earthquakes**: GPS measures how Earth's tectonic plates move, useful in understanding seismic activity.
- **Volcanoes**: GPS measures changes in volcanic activity, useful in predicting eruptions.

*GPS is the US global navigation satellite system (GNSS). The technology here can be extended to all GNSS systems.
Ongoing drought-induced uplift in the western United States, A. A. Borsa, D. C. Agnew, D.R. Cayan, Science, 2014
Volcanic Ash Plumes

Wildfires

Awesome graphic from UNAVCO and random fire photo
Snow Depth: Avalanche or Flood

I fell into a burnin' ring of fire
I went down, down, down
As the flames went higher,
And it burns, burns, burns,
The ring of fire, the ring of fire.
PPP for seismic monitoring

Earthquake Early Warning Basics

1. In an earthquake, a rupturing fault sends out different types of waves. The fast-moving P-wave is first to arrive, but damage is caused by the slower S-waves and later-arriving surface waves.

2. Sensors detect the P-wave and immediately transmit data to an earthquake alert center where the location and size of the quake are determined and updated as more data become available.

3. A message from the alert center is immediately transmitted to your computer or mobile phone, which calculates the expected intensity and arrival time of shaking at your location.
Seismic hazard map
Early warning

Up to 1 minute warning

Since seismic waves travel slower than internet and phone communication it is possible to quickly detect the start of the earthquake and send warning out to locations farther away.

Shut down gas lines, electricity etc
Early warning

http://www.shakealert.org

earthquake early warning (EEW) system called ShakeAlert for the west coast of the United States
Some examples

How does land jump with an earthquake? Evidence from GPS stations above subduction zone

In a subduction zone the oceanic plate dives beneath the continental plate.

(Simplified to show processes. Not to scale.)
What about PolaRx5S?

GNSS as sensor to study the ionosphere
What about PolaRx5TR?

GNSS for time transfer

UTC Universal Time
Coordinated determination

Precise (ns) synchronization of equipment
Not only science…RTK networks
RTK & PPP Networks
SAPOS: 100 PolaRx for SAPOS

SAPOS deployments in:

MecklenBurg
Köln
LGL

About 40 PolaRx4 and about 60 PolaRx5 deployed
Ordnance Survey UK: 60 PolaRx5

Part of network update

Interference detection and mitigation as requirement

Thorough evaluation of the receiver performances
TAPAS – Denmark

11 PolaRx5/PolaRx5S for test bed applications

TAPAS is a science and research project aimed to verify to which extend an improved infrastructure can contribute to exploit the full advantage of the technical achievements of the new Global Navigation Satellite Systems (GNSS)
80 reference stations Veripos/Terrastar network
50 PolaRx units in the network. Old PolaRx2/3 still active, demonstrating quality and durability of Septentrio receivers.