Autonomous Agriculture
The Need for GNSS Safety Critical Systems

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NovAtel® Inc.

Hexagon AB

Global Positioning Solutions and Services

Land **Air** **Sea**

High Accuracy and Reliability

- **Head office located in Calgary, Canada**
- **More than 400 employees**
- **Part of the Hexagon Group**
- **25+ Years in GNSS**
- **Market leader in our space with >50% market share.**

Trends in GNSS…..

90s and early 2000s: Accuracy

- Positioning techniques
- DGPS, RTK
- Multipath mitigation

Now: Availability

- Multi-constellation: GPS, GLONASS, Galileo, Beidou
- Sensor Fusion
- Position + orientation

Future: Safety & Reliability

- Safety of Life applications
- Functional Safety and Integrity
- Protection from spoofing/jamming

Increasing Demand for Safety in Guidance

IEC EN 61508

DO-178C

DO-254

DO-178C

DO-254

ISO 25119
ISO/FDIS 18497 (draft)
ISO 10975

ISO 26262

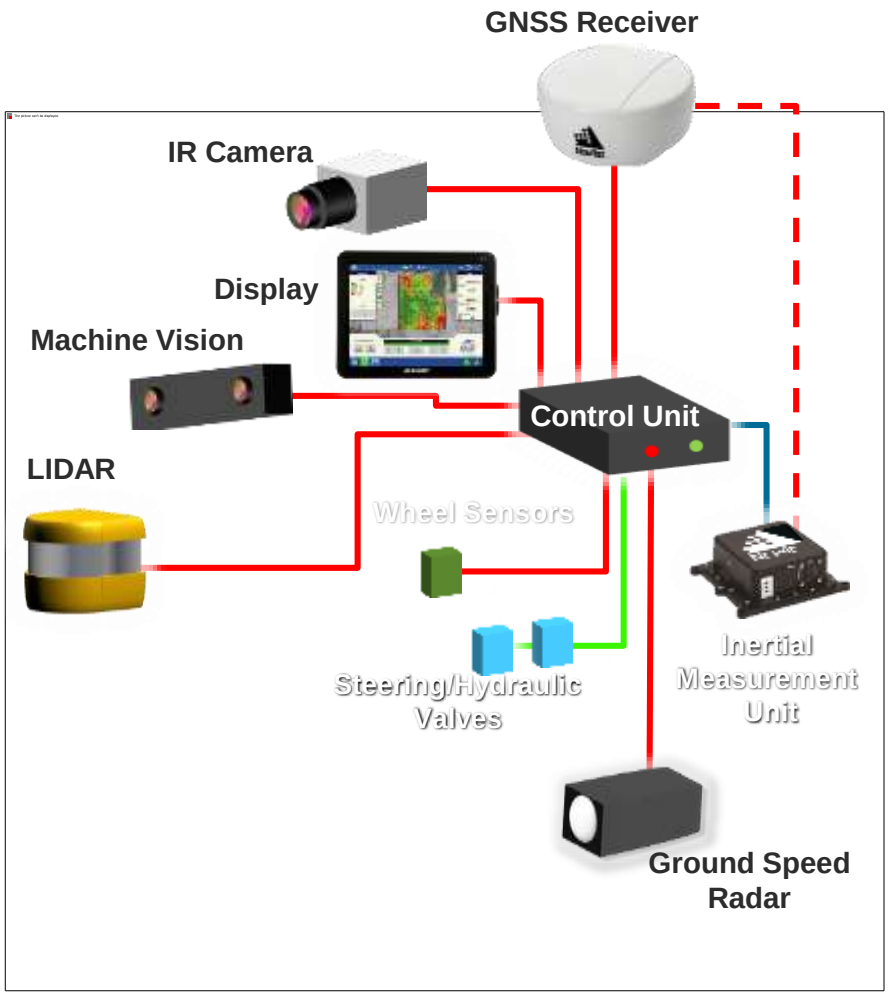
EN 50126
EN 50128
EN 50129

Robotics in Agriculture Tomorrow

- Continue to operate semi-autonomously as we do today plus:
  - Make better use of big data;
  - Operate independent of human input;
  - Operate independent of the time of the day;
- **But not without safety!**

How GNSS fits into Autonomous Agriculture

- GNSS has been in use for well over two decades to guide equipment through fields — along with a host of other ag-related, site-specific applications.
- GNSS dominates as the source of Absolute PVT for the autonomous control of agricultural vehicles
- A fully autonomous tractor will need 100% availability in all conditions and locations
  - All weather, all field conditions, all visibility conditions.
- GNSS plays a critical role but cannot be the sole positioning source.
- A fusion of multiple sensors is required with GNSS playing a key role. Time alignment of sensor data is needed as well as positioning.

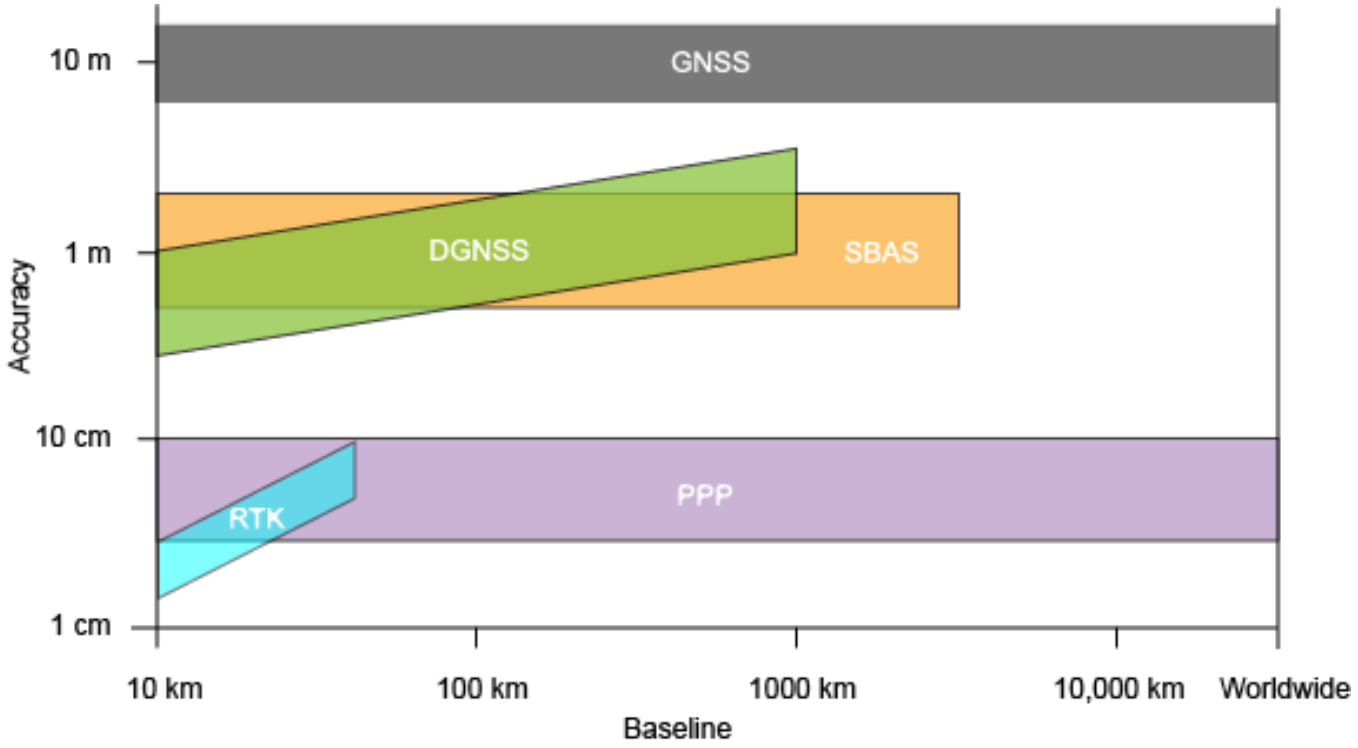


GNSS requirements for autonomous driving

- Position accuracy “Goal” - **< 2” 3-sigma**
  - **needed for vehicle to vehicle applications**
  - **Automotive accuracy goal is 3’ 3-sigma**
  - Data rate outputs > 10 Hz
  - **3D** Position and Velocity outputs
- Multi-frequency, Multi-constellation, Multi-engine receiver **and** antenna
  - Improves overall accuracy
  - Required to assist in solution convergence time
  - Increases position availability - more satellites in view
- Supporting **precise corrections service (PPP)** required over satellite, as well as seamless/error constrained transition between RTK and PPP.
- Functional Safety
  - **ISO25119** Development
  - **Integrity** outputs to support protection levels
  - **Authentication** function

Positioning Technology Options

- To allow for ubiquitous positioning at the decimeter level we believe a Precise Point Positioning (PPP) level of service is required.
- RTK is certainly more accurate (cm level) but infrastructure costs are high, unreliable and unnecessary



Defining Safety for a Navigation System

- **Integrity** = degree to which you can trust the information being provided by a navigation system.
- **Continuity** = ability of any navigation system to execute its function through a specified time period or operation.
- **Accuracy** = degree to which the estimated solution from a navigation system conforms to the true solution.
- **Availability** = percentage of the time that a system can be used for navigation purposes

Path to an GNSS Integrity Solution

- The targeted performance of a position solution from a safety perspective has been described with the following requirements:
  - The GNSS Receiver shall provide a dynamic protection level indicating the maximum undetected Error for Position, Velocity, Heading & Time
  - Maximum undetected Position Error ➔ Safety “Goal” < 2m
  - Maximum undetected Velocity Error ➔ Safety “Goal” < 0.1 m/s
  - Maximum undetected Heading Error ➔ Safety “Goal” < 0.5 °
  - Maximum undetected Time Error ➔ Safety “Goal” < 0.1 ms
  - The GNSS Receiver shall fulfill Protection Limit requirements for times ≥ 70 sec after Start up
  - The GNSS Receiver must detect leaving the Safety Limit < 1 sec, with ASIL B, AgPL C
  - Failure rate shall be under 10^{-7} / hour

How to achieve these levels will require development of capabilities beyond current state of the art.

Questions?

High Precision GNSS System Diagram