Session C5: Land-Based Applications

A novel high-performance attitude determination system based on MEMS IMU and a single high-precision GNSS antenna

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- when it has to be right

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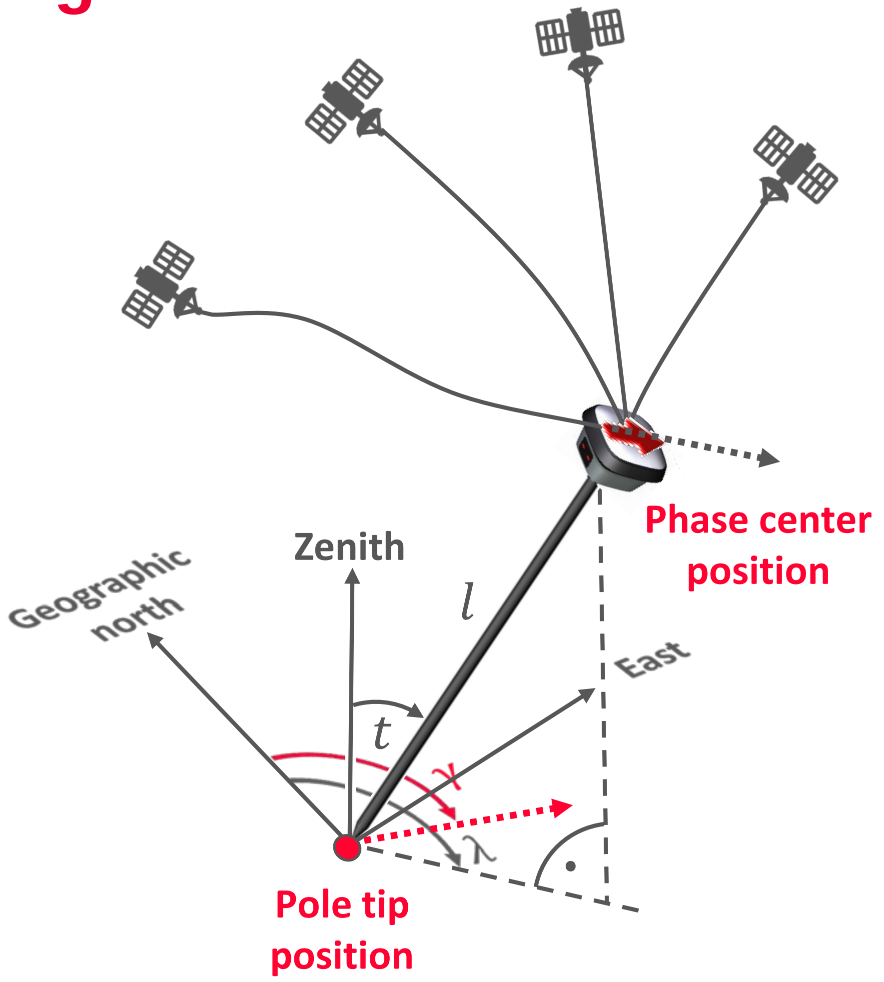
Tilt compensated GNSS RTK surveying

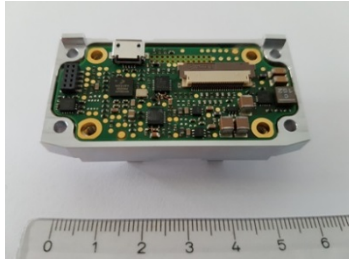
Tilt compensated GNSS RTK surveying

- **Pole tip position derived using**
  - GNSS phase center position
  - Length of the pole *(l)*
  - Attitude of the pole
- **Intepretation of pole attitude**
  - Tilt (t) and direction of tilt (γ)
  - GS heading (λ)



Introduction
Leica GS18 T

GS18 T



MEMS IMU

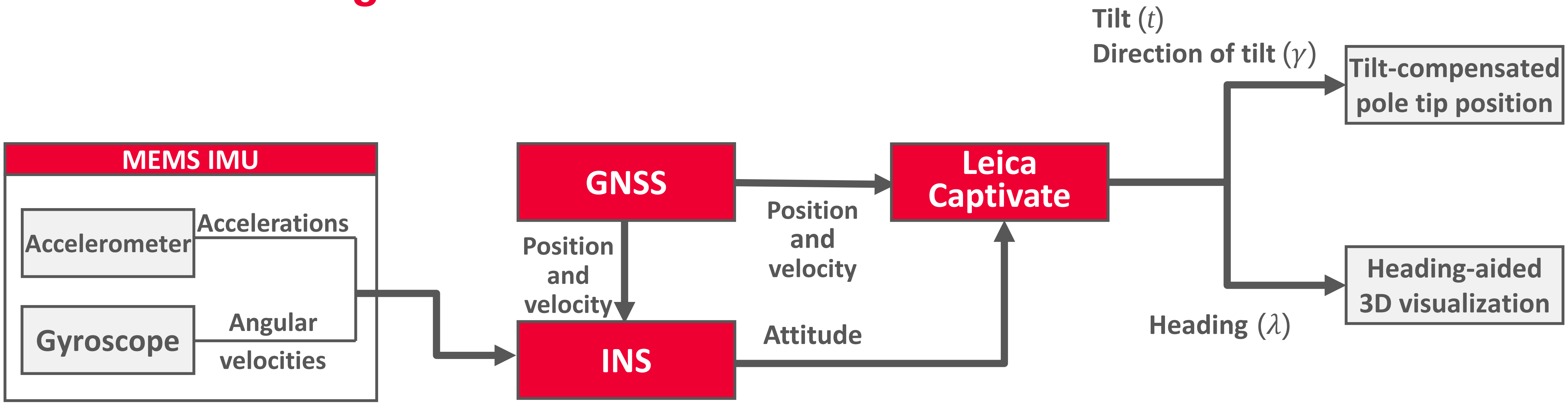
Multi-GNSS Smart Antenna

- **GNSS RTK rover with attitude determination technology**
  - Based on MEMS IMU and GNSS measurements
  - GNSS/INS integration with automatic quality control mechanism
  - Patent calibration process
  - Completely free from on-site calibration

→ Next generation of GNSS RTK surveying

MEMS: micro-electro-mechanical system
IMU: inertial measurement unit
INS: inertial navigation system

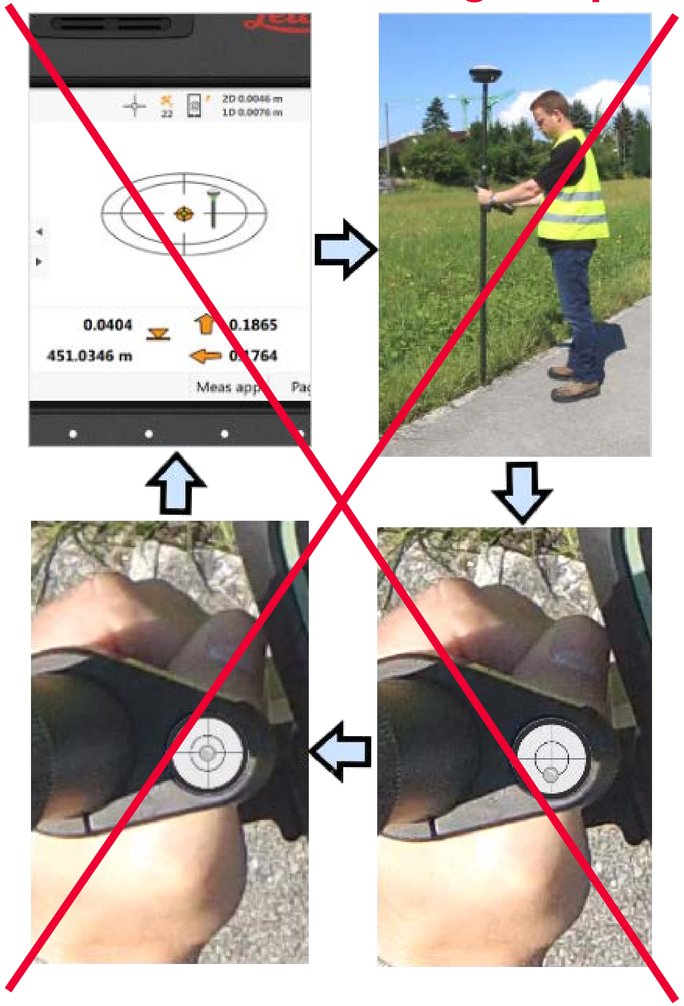
GNSS/INS integration



- **GNSS aided INS**
  - High-precision position and velocity estimates from GNSS
  - IMU is factory calibrated over whole operating temperature range
  - Automatic initialization through meter-level movements
  - Consistency checks between GNSS and INS for high system robustness
  - Reliable quality indicator for the 6DoF estimates

GS18 T is developed to increase productivity in GNSS RTK surveying

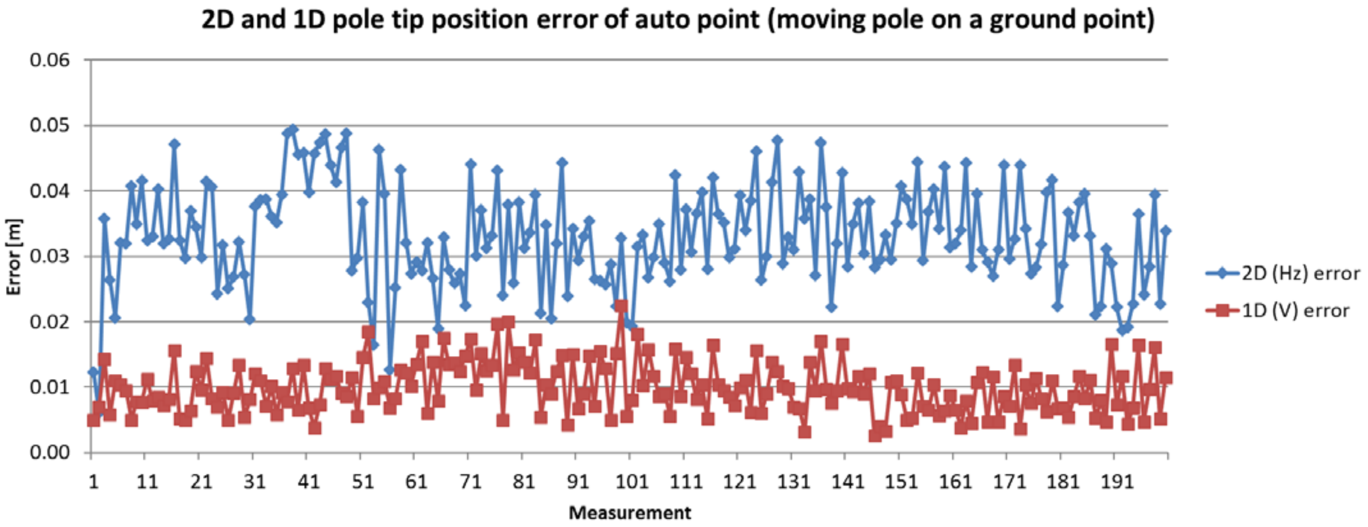
1. No need of levelling the pole



2. Measuring obstructed points

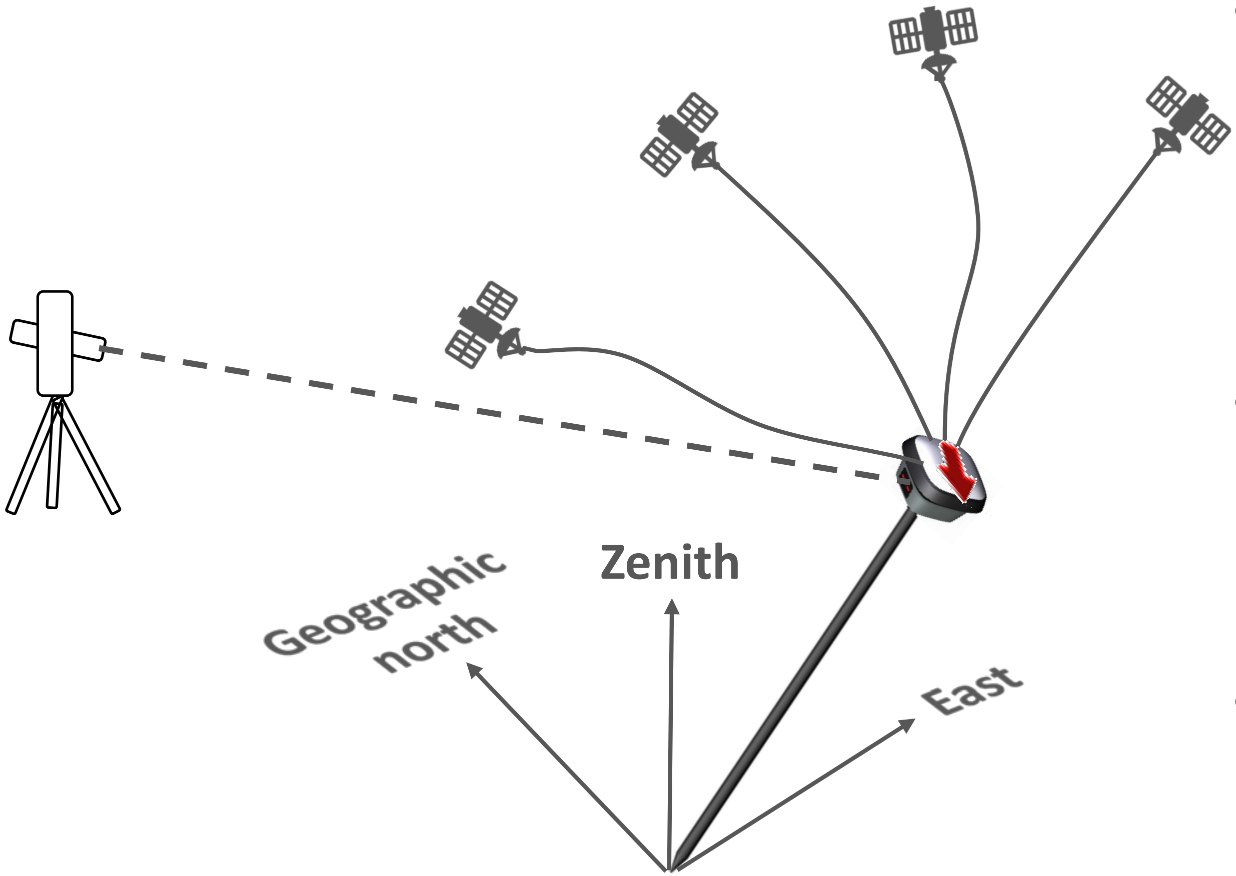
3. No on-site calibrations

Tilt-compensated pole tip position
Accuracy testing



No drift in position result of continuously moving sensor

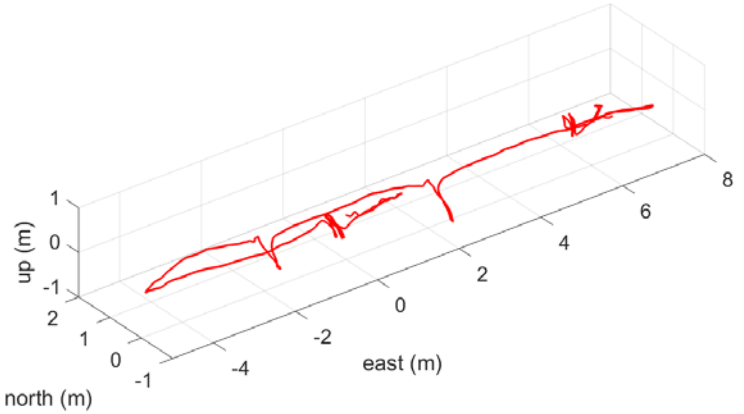
Test setup

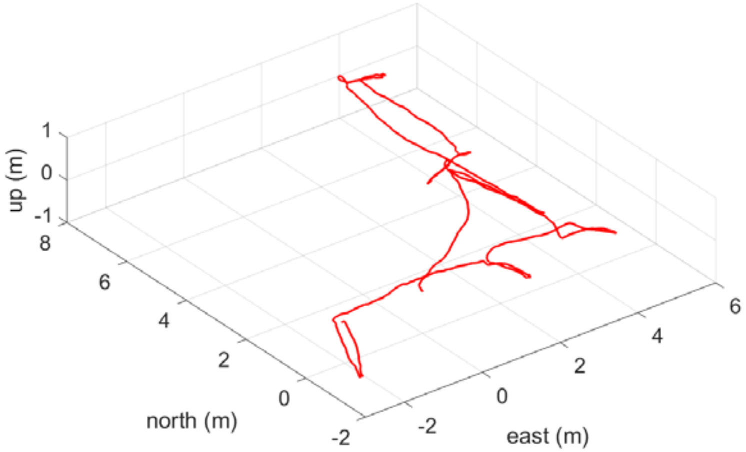


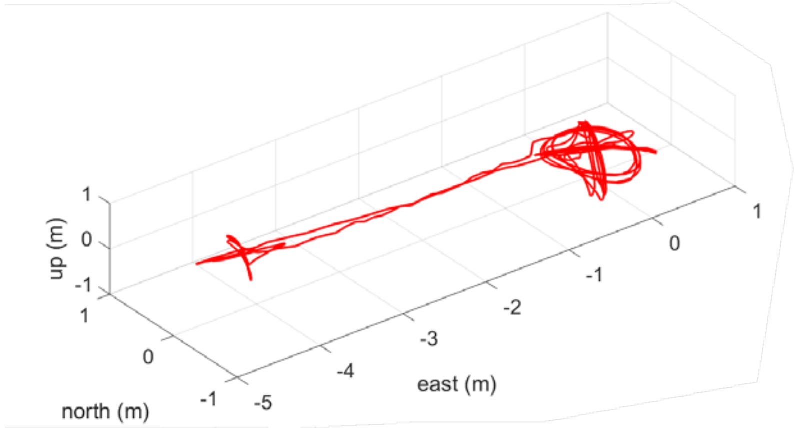
- **Leica GS18 T**
  - Position and attitude estimates
  - 6DoF – X, Y, Z, roll, pitch, heading
  - Quality estimates
- **Reference system**
  - Tracks the movement of the GS18 T
  - Direct 6DoF – serving as reference
- **Testing**
  - Accuracy, reliability, initialization speed, stability
  - Static and kinematic

Test cases
Datasets

- **35 Datasets**
  - Realistic use-case environment
    - Near buildings
    - Challenging GNSS conditions
  - Different trajectories and moving behaviour







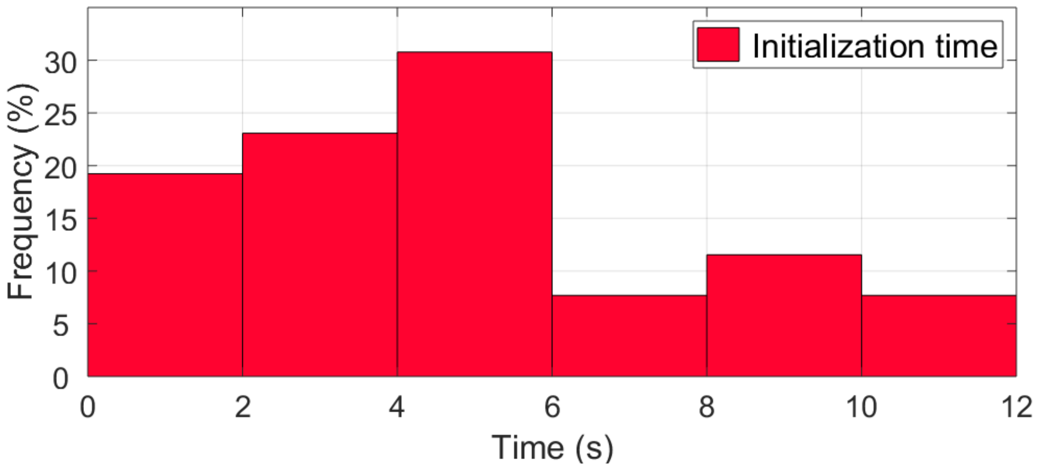
Sensor position

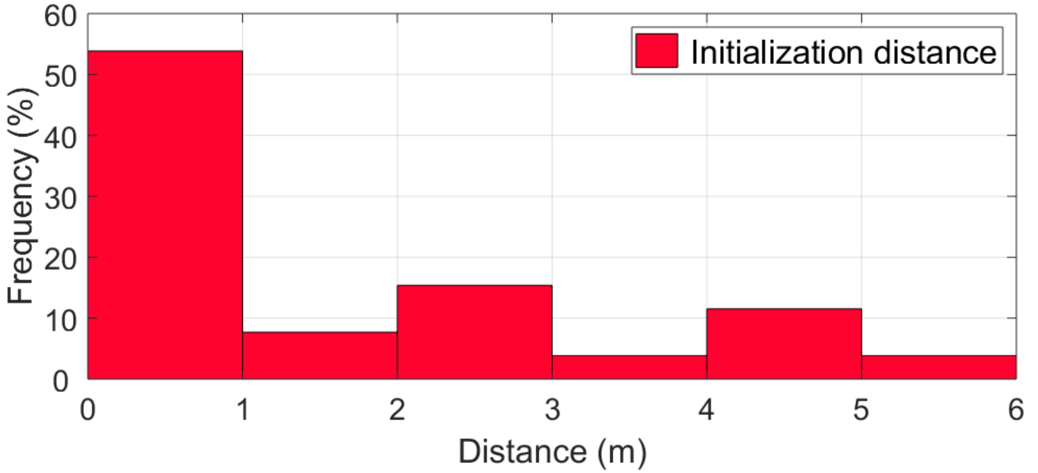
- when it has to be **right**

Test cases
Focusing on

- **(1) Initialization phase**
  - Time until required accuracy is reached?
- **(2) Sensor accuracy during movement**
  - What is the expected accuracy of the 6DoF?
- **(3) Sensor in static state**
  - Stability – How long can the system deliver required accuracy?

Test cases
(1) Initialization phase





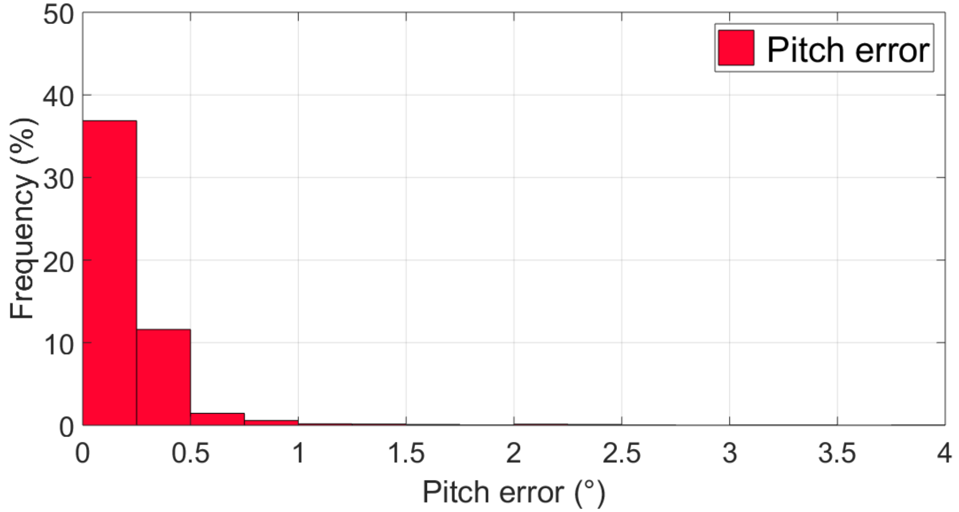
- **System is self-initializing after meter-level movements**
  - Completely free from on-site calibrations
  - Initial position } GNSS Smart Antenna
  - Initial velocity } GNSS Smart Antenna
  - Initial orientation → Kinematic alignment

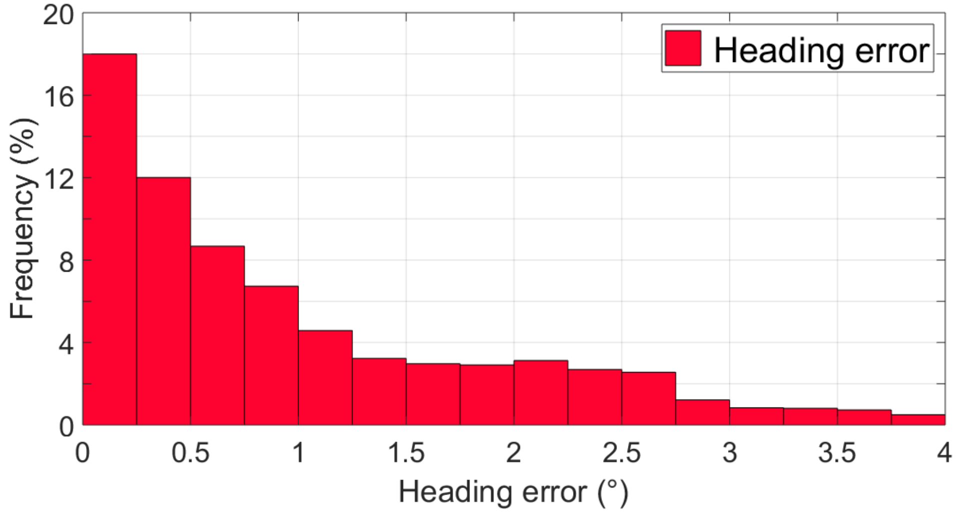
- **Test: Heading angle error < 1°**

Number of datasets	Average time	Average distance
35	4.67 sec	1.79 m ≙ 5.87 ft

Test cases

(2) Kinematic phase

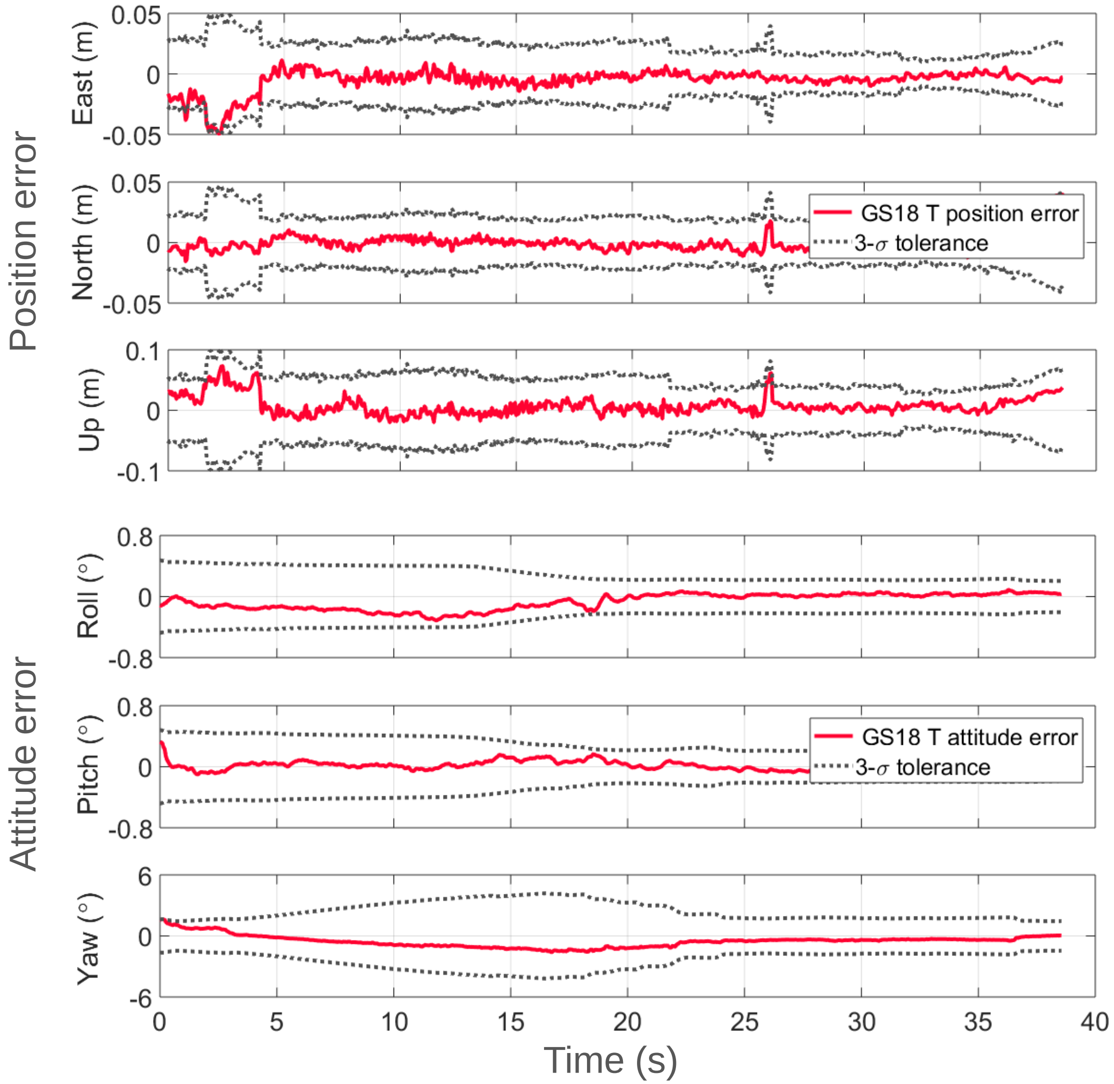




- **Analyse over all datasets**
  - RMS error of position
  - RMS error of orientation

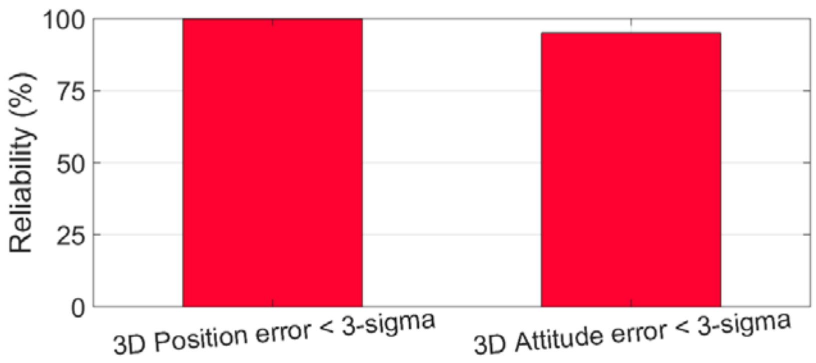
Number of epochs	Position error 3D	Roll error	Pitch error	Heading error
26249	0.025 m	0.194 deg	0.211 deg	1.382 deg

Test cases
(2) Kinematic phase



- **Quality indicator for 6DoF**
  - How reliable is the quality indicator?

Number of epochs	3D position Error < 3-sigma	3D attitude Error < 3-sigma
26249	99.8 %	94.0 %



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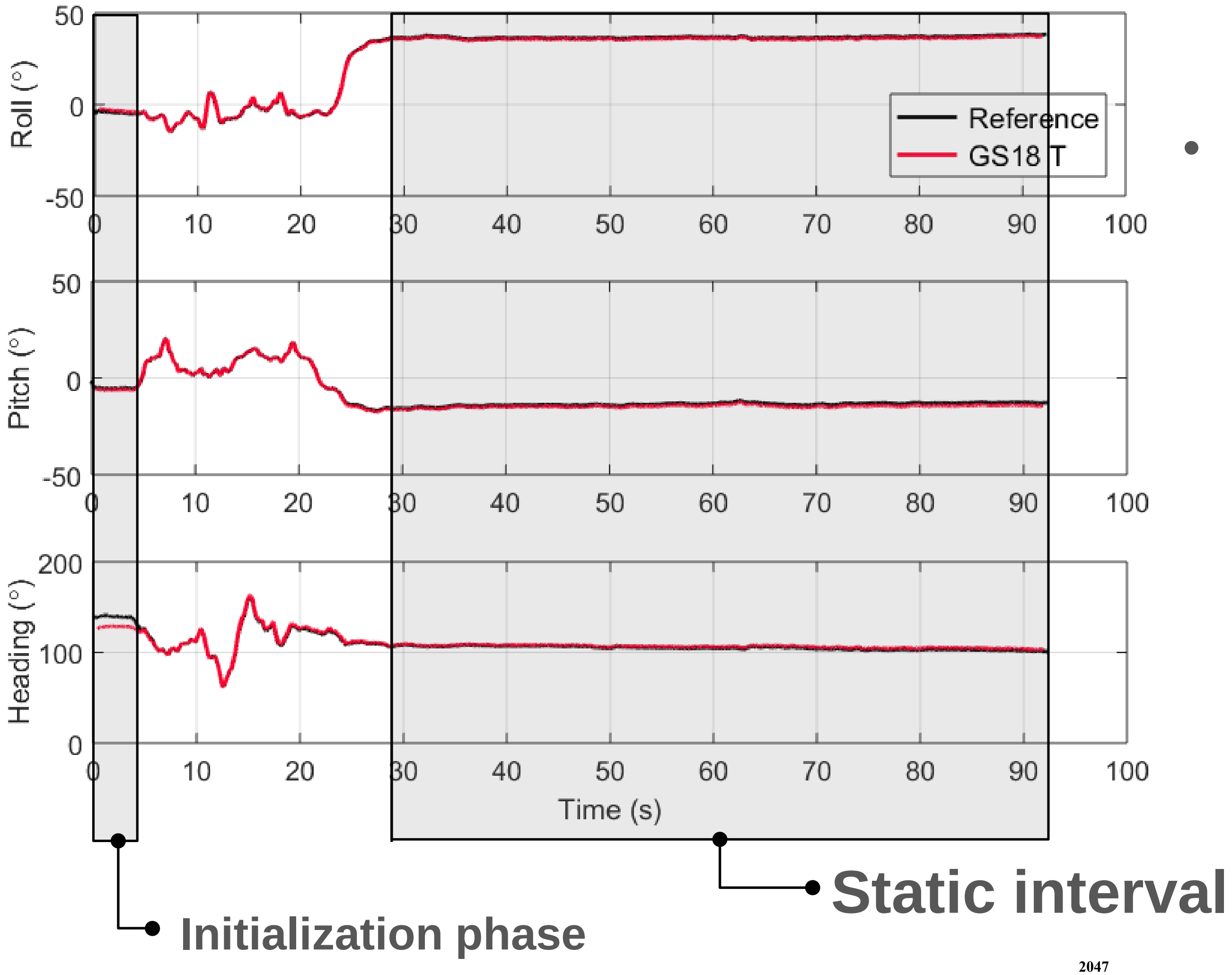
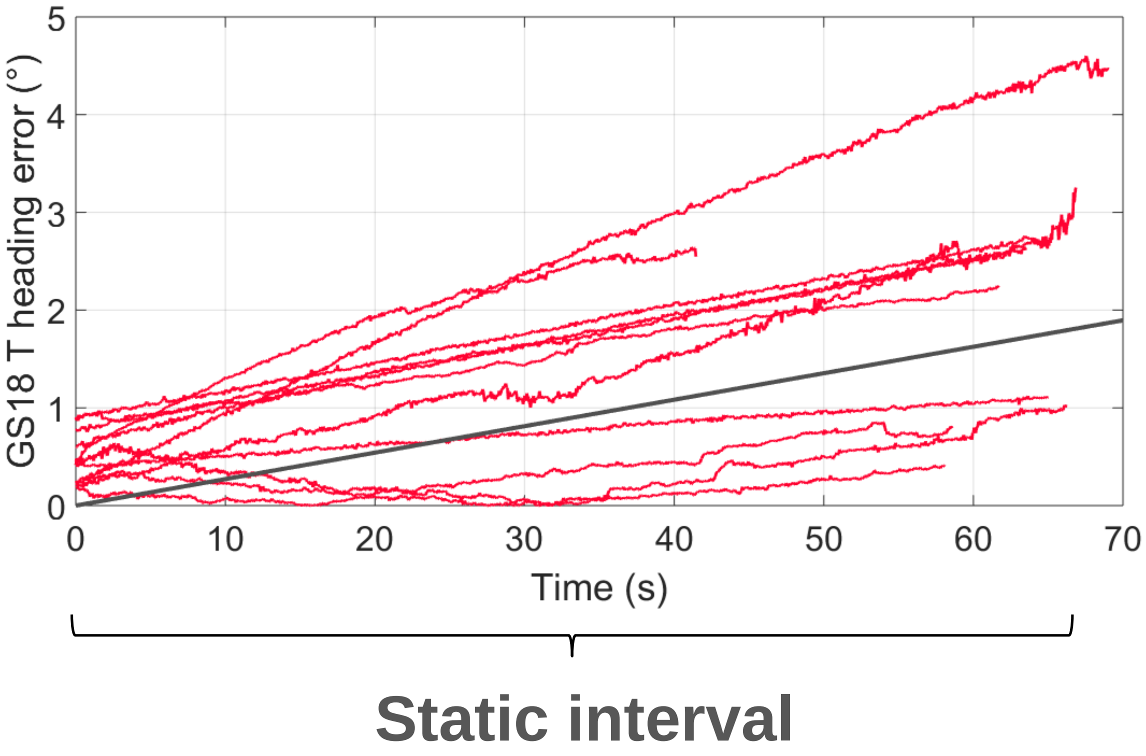
Test cases

(3) Static phase - Stability



- **How does the system behave in static situations?**
  - Using datasets with ~1min static intervalls
  - What is the amount of the attitude drift?

Test cases
(3) Static phase - Stability



- **What is the expected stability?**

Heading drift
Average drift = 1.6 °/min

- **Reliable quality indicator**
  - Informs the user if attitude error > 2°

Conclusions

- **GS18 T developed for tilt compensated GNSS RTK**
  - Based on MEMS IMU measurements and high-end GNSS smart antenna
  - Patent IMU calibration process
  - GNSS/IMU integration with automatic quality control mechanisms

- **User benefits for navigation applications**
  - High-end GNSS RTK rover with real-time attitude information
  - Precise and reliable navigation information
  - Enhancing productivity and user experience in the field
  - Easy-to-use and easily portable device

Thank you very much for your attention

Leica Geosystems AG, Switzerland

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