Presented at the FIG Congress 2018, May 6-11, 2018 in Istanbul, Turkey

TS04E: GNSS, PPP and Networks

FIG 2018 İSTANBUL
6-11 May 2018
İSTANBUL, TURKEY

High-Precision RTK Positioning with Calibration-Free Tilt Compensation

X. Luo, S. Schaufler, M. Carrera, I. Celebi
Leica Geosystems AG, Switzerland

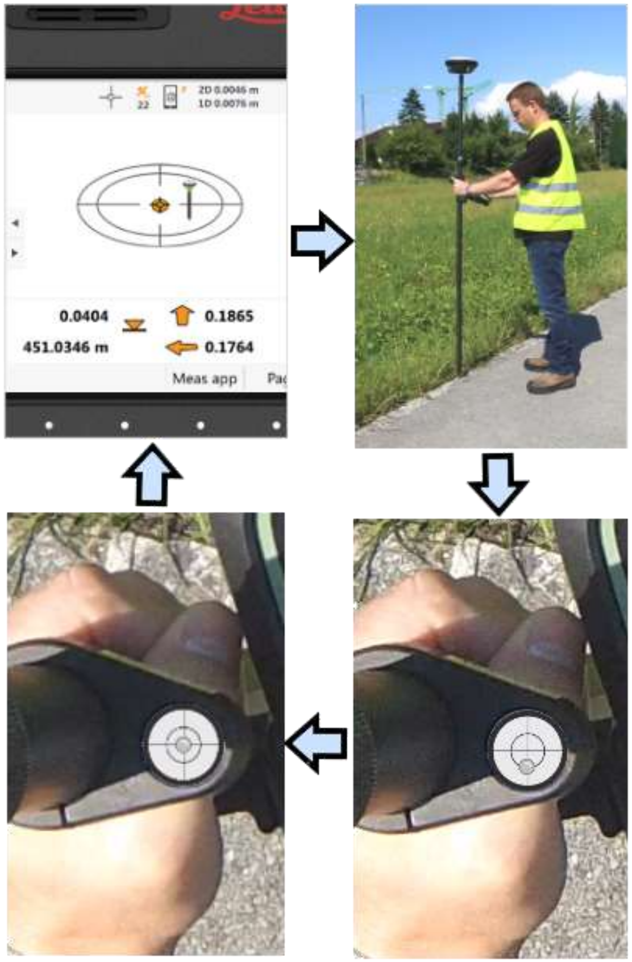
May 8, 2018

- when it has to be right

Leica Geosystems

Three things I don't like in GNSS RTK surveying…

1. Levelling the pole



2. Measuring obstructed points

3. Any kind of on-site calibrations

- when it has to be **right**

Leica Geosystems

Tilt compensation RTK of the Leica GS18 T

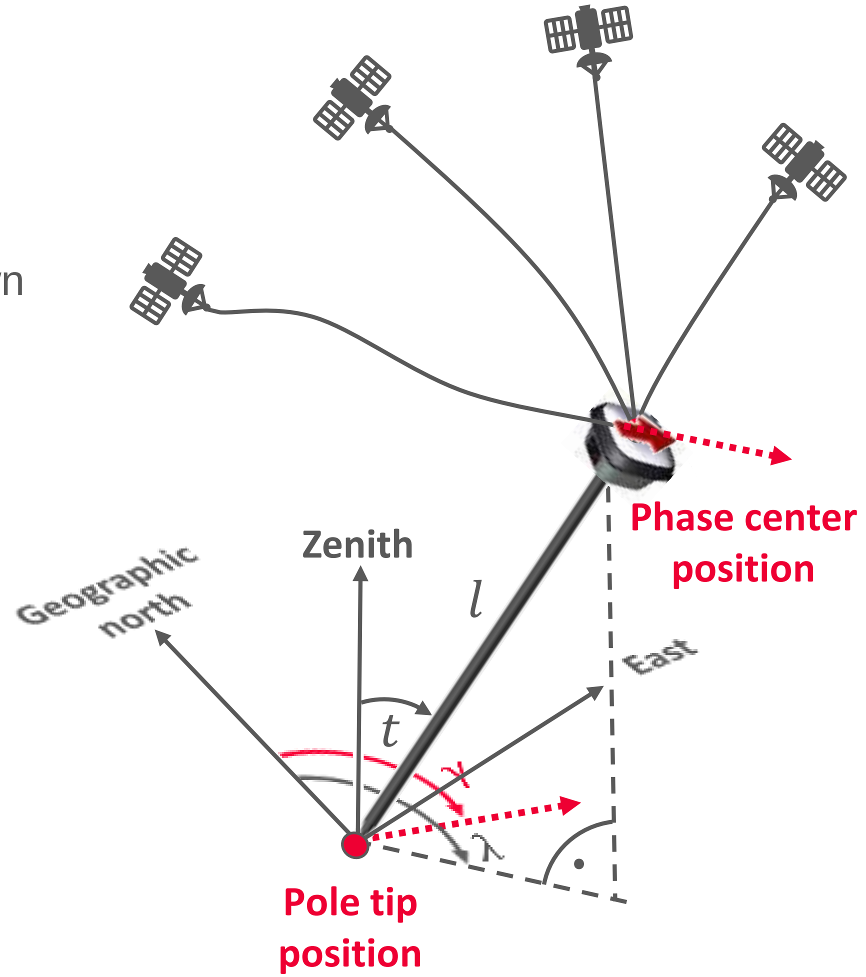
- **Main advantages over magnetometer-based approaches**
  - Completely free from on-site calibrations
  - Immune to magnetic disturbances
  - Applicable at large tilt angles (≥ 30 degrees)
- **Innovative tilt compensation technologies**
  - Based on precise IMU measurements (instead of magnetometer)
  - Sophisticated GNSS/INS integration with quality control mechanisms

IMU: inertial measurement unit
INS: inertial navigation system

- when it has to be right
Leica
Geosystems

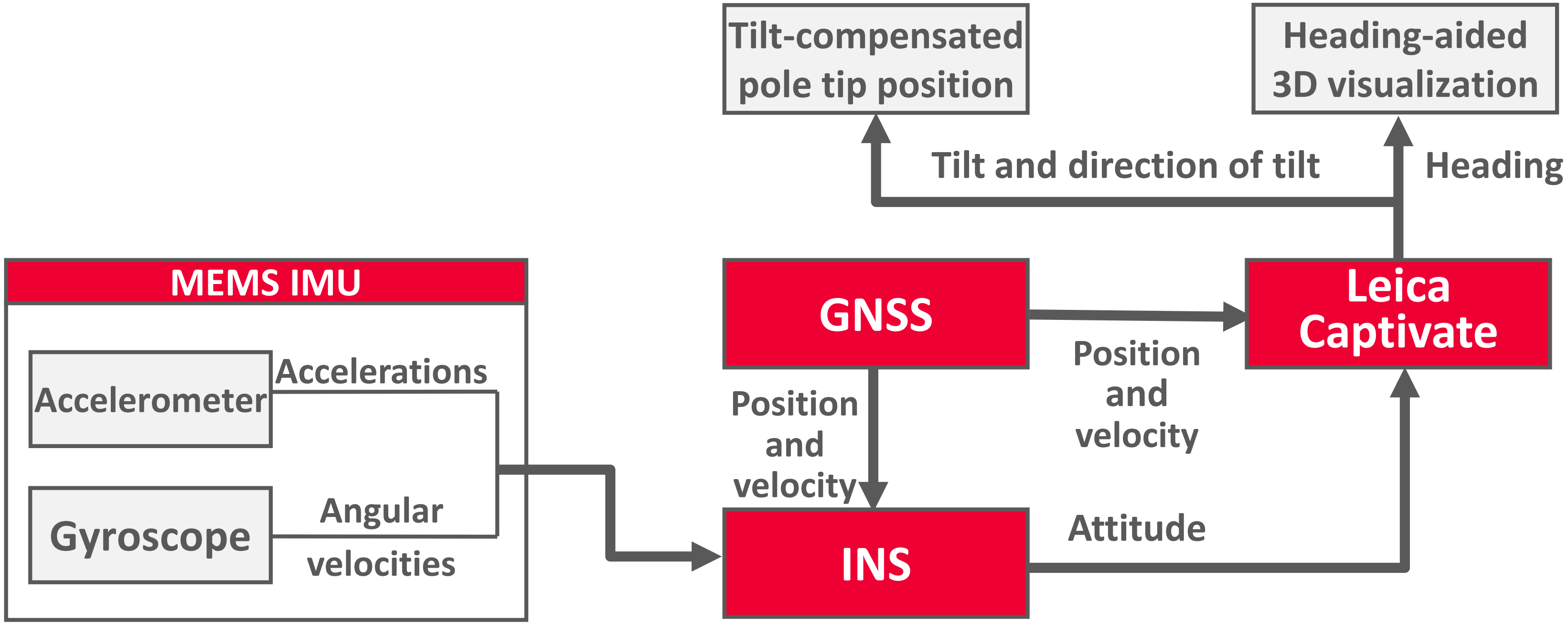
Compensation of pole tilt

- Assumptions
  - Surveying pole is a rigid body
  - Length of the pole is precisely known
- Pole tip position derived using
  - GNSS phase center position
  - Length of the pole (l)
  - Attitude of the pole
- Interpretation of pole attitude
  - Tilt (t) and direction of tilt (lambda)
  - Sensor heading (gamma)



- when it has to be right
Leica
Geosystems

GNSS/INS integration



- Each IMU is factory calibrated over the whole operating temperature range
- Consistency checks between GNSS and INS for high system robustness
- Automatic start of tilt compensation through meter-level movements

MEMS: micro-electro-mechanical sensors

Accuracy aspects

- Accuracy evaluation using a laser tracker system as reference
- Considering different pole dynamics: static, kinematic, stop-and-go, etc.

Attitude and position RMS errors of the Leica GS18 T (pole length: 1.800 m)

Number of positions	Tilt error	3D attitude error	GNSS 3D error (PC)	INS 3D error (PT)	Total 3D error (PT)
18986	0.150 deg	1.014 deg	0.018 m	0.011 m	0.022 m

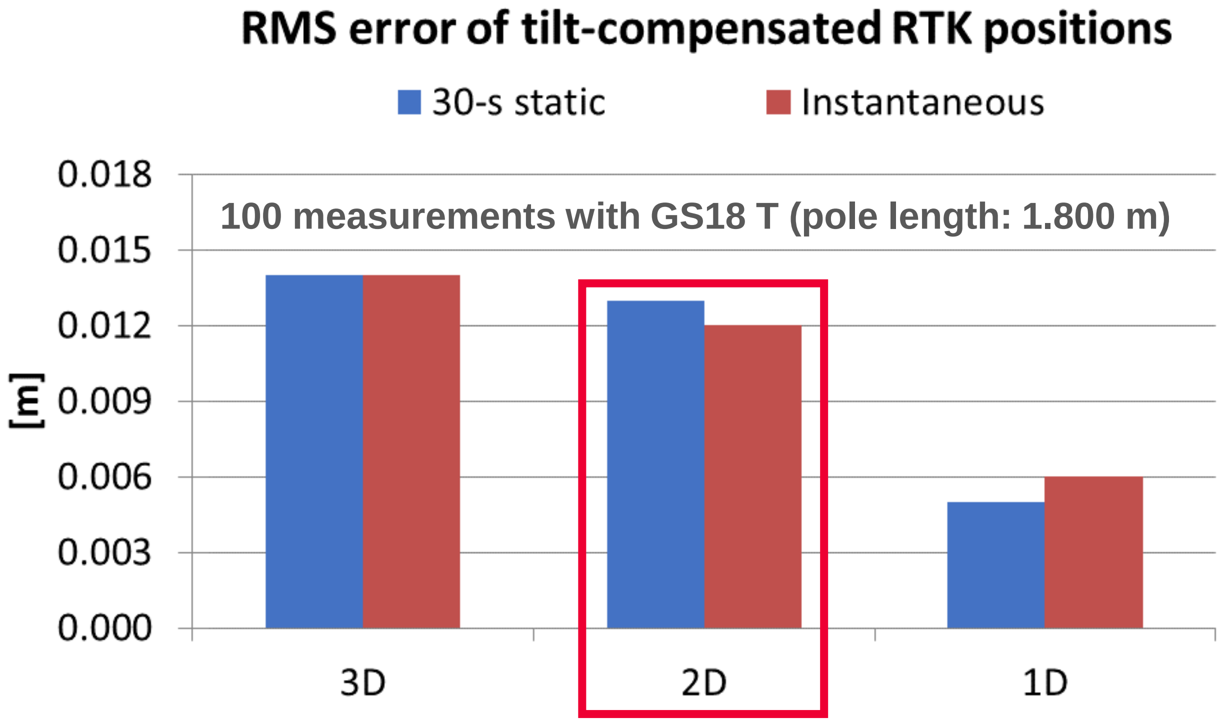
- Total error budget behaves according to the error propagation law

$$\sigma_{Total} = \sqrt{\sigma_{GNSS}^2 + \sigma_{INS}^2}$$

PC: phase center
PT: pole tip

- when it has to be right
Leica Geosystems

Performance analysis
Static vs. Instantaneous

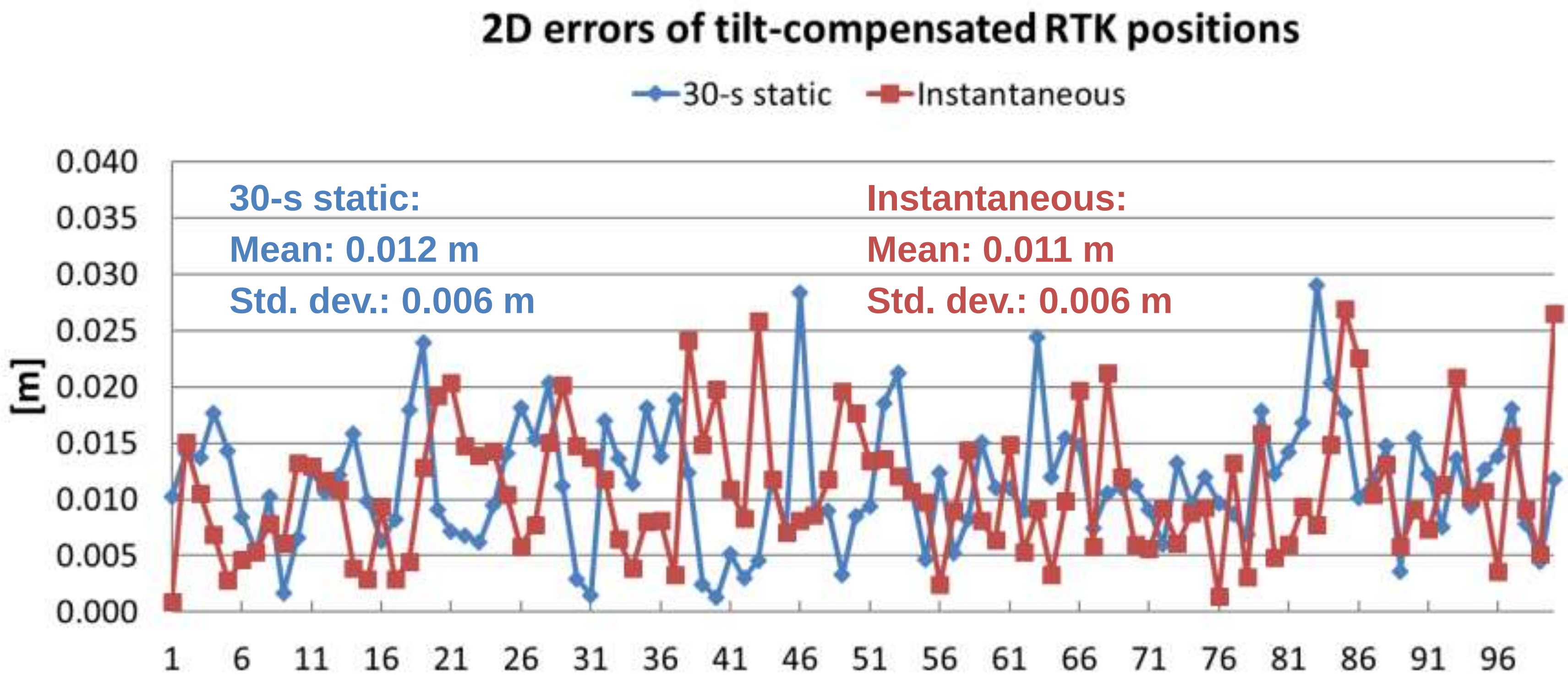


- Increasing productivity by measuring points instantaneously
- Similar accuracy between 30-static and instantaneous measurements

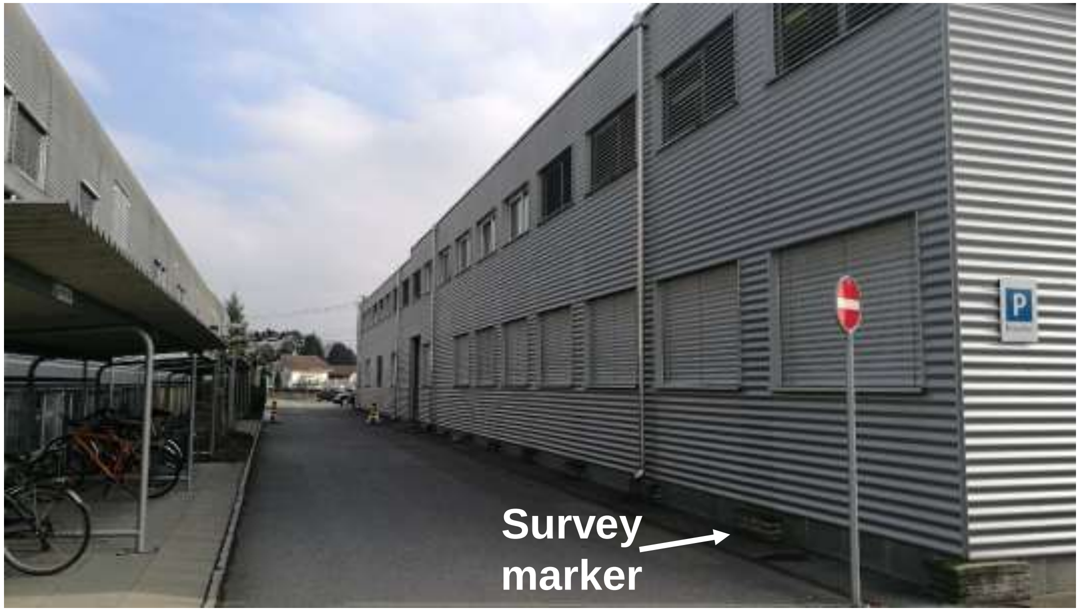
- when it has to be **right**

Leica Geosystems

Performance analysis
Static vs. Instantaneous



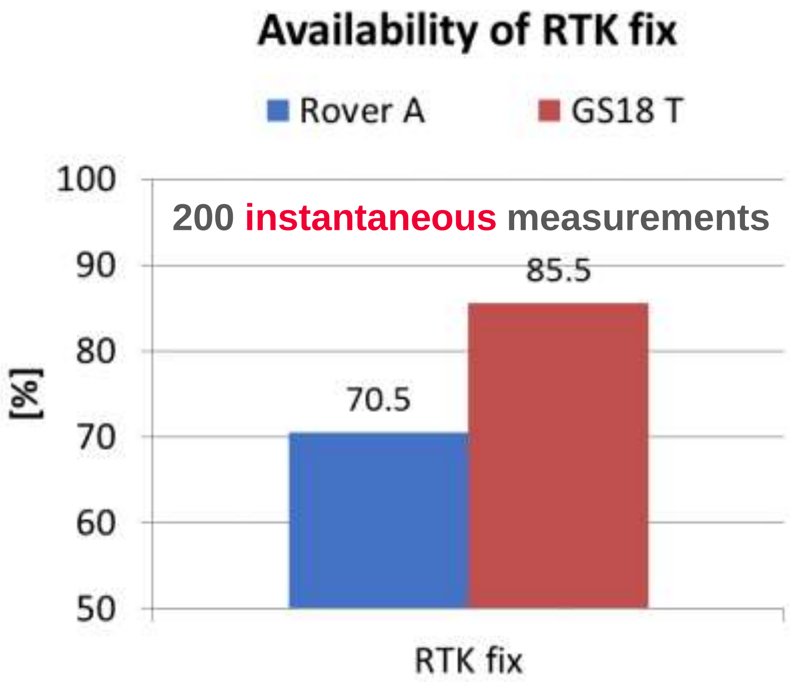
Performance analysis
Conventional RTK vs. Tilt compensation RTK

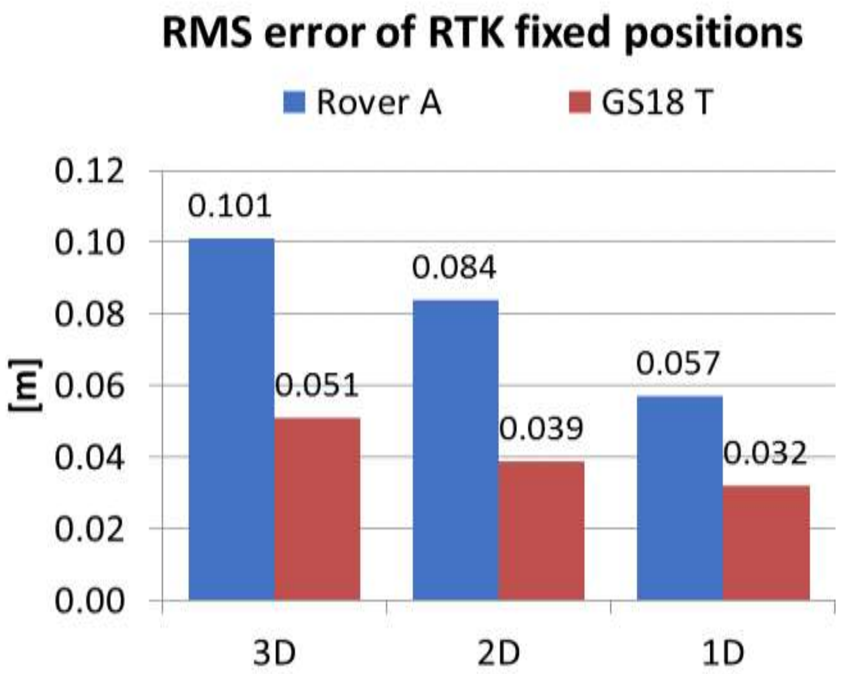


- Survey marker located close to a building (conventional RTK still possible)
- Metal facades causing strong magnetic disturbances and multipath effects

- when it has to be right
Leica Geosystems

Performance analysis
Conventional RTK vs. Tilt compensation RTK

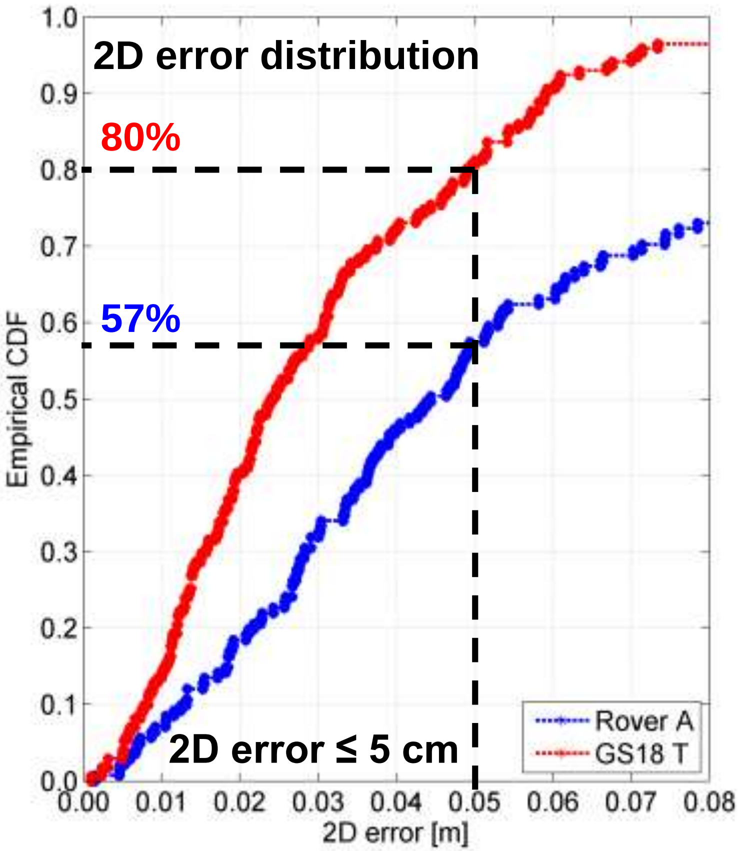


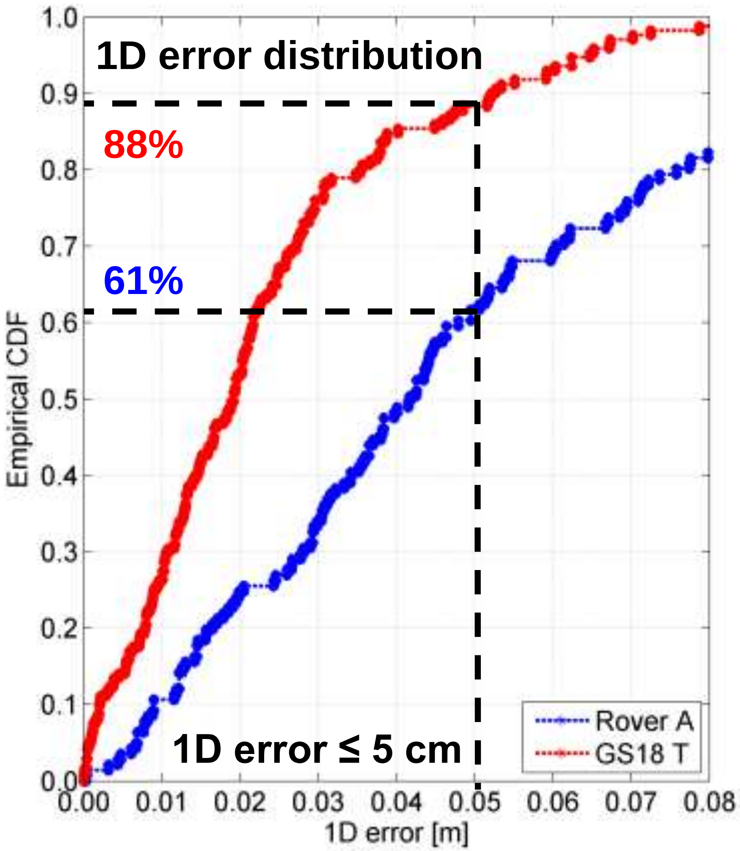


- Rover A: Conventional survey-grade GNSS smart antenna
- Increasing availability of RTK fixed positions by 15% with the GS18 T
- Significant improvements in positioning accuracy (by 50% for 3D)

- when it has to be right
Leica Geosystems

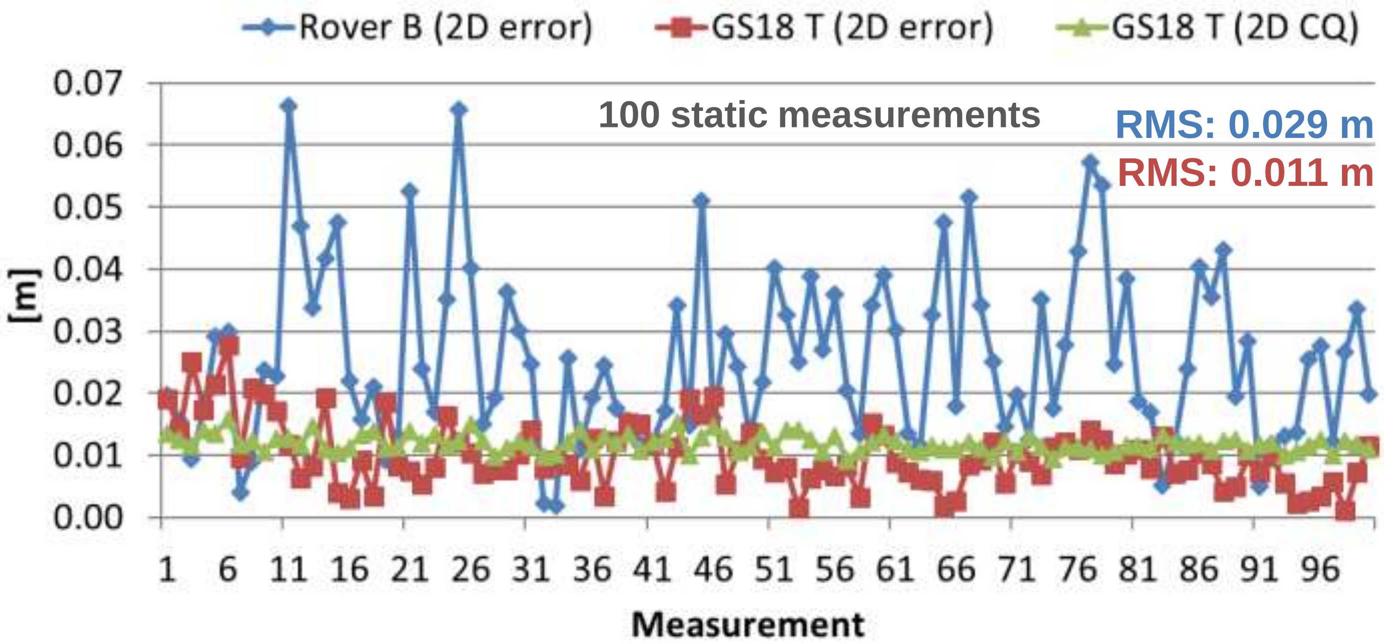
Performance analysis
Conventional RTK vs. Tilt compensation RTK





- when it has to be right
Leica Geosystems

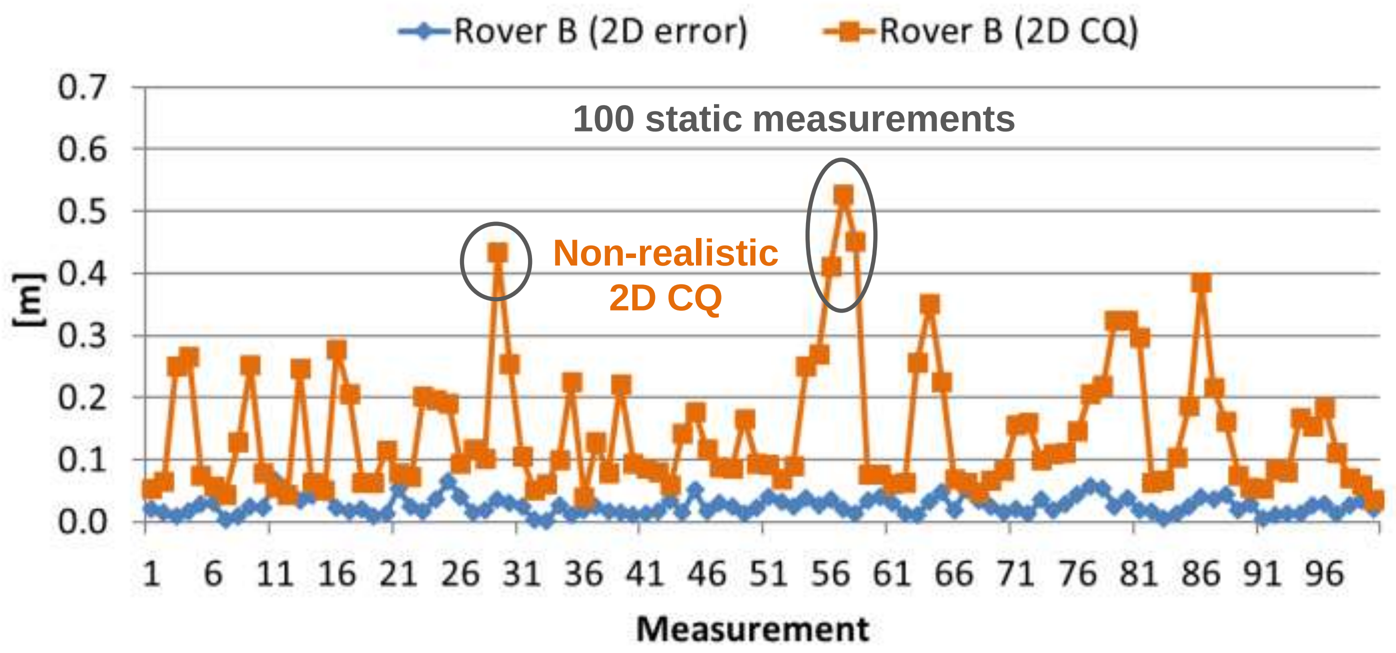
Performance analysis
Magnetometer-based vs. IMU-based



- Rover B: RTK rover with magnetometer-based tilt compensation
- GS18 T: Higher 2D accuracy with realistic coordinate quality (CQ) indicator

- when it has to be right
Leica Geosystems

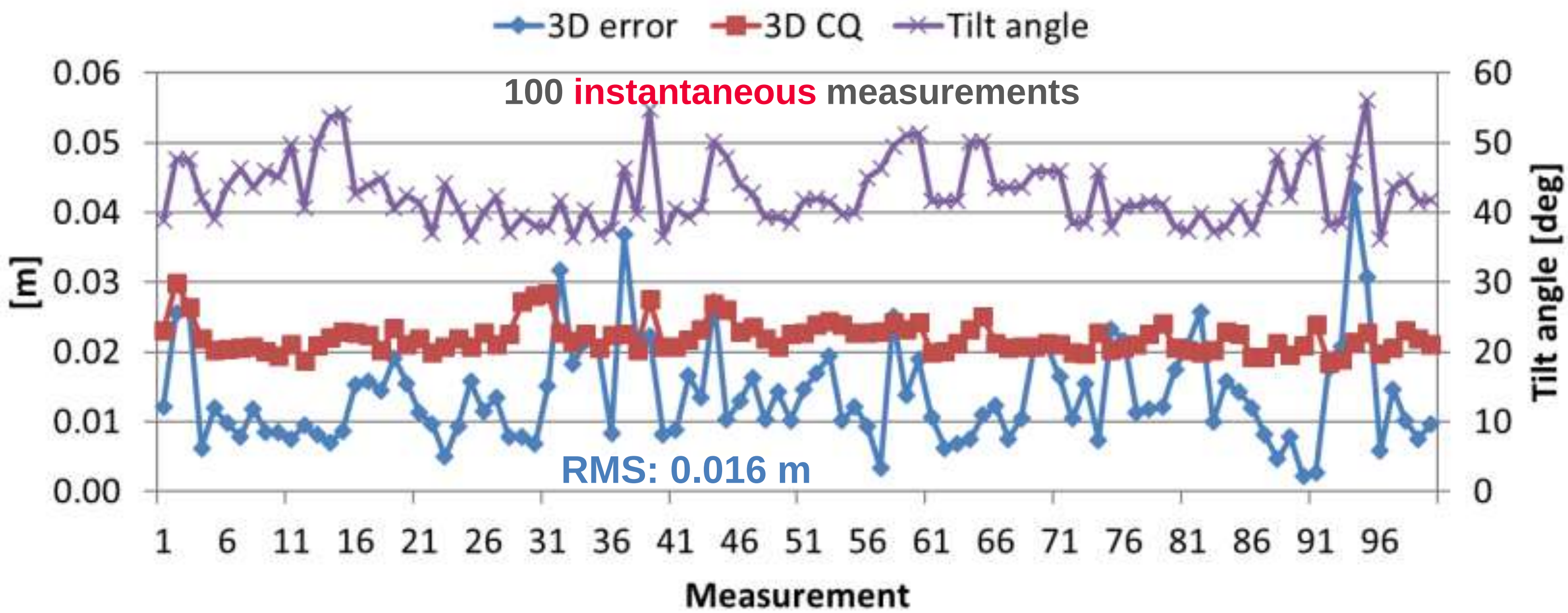
Performance analysis
Magnetometer-based vs. IMU-based



- Rover B: RTK rover with magnetometer-based tilt compensation
- Significantly large 2D CQ when magnetic disturbances are detected

- when it has to be right
Leica Geosystems

Performance analysis
Large tilt angles



- Measuring an obstructed point with large tilt angles between 36° and 56°
- 3D accuracy below 2 cm with a realistic uncertainty level

- when it has to be right

Leica Geosystems

Heading-aided 3D visualization

Augmented stake-out

- Automatic updates of the 3D viewer depending on the sensor heading
- Easy orientation for enhanced productivity and user experience

- when it has to be right

Leica Geosystems

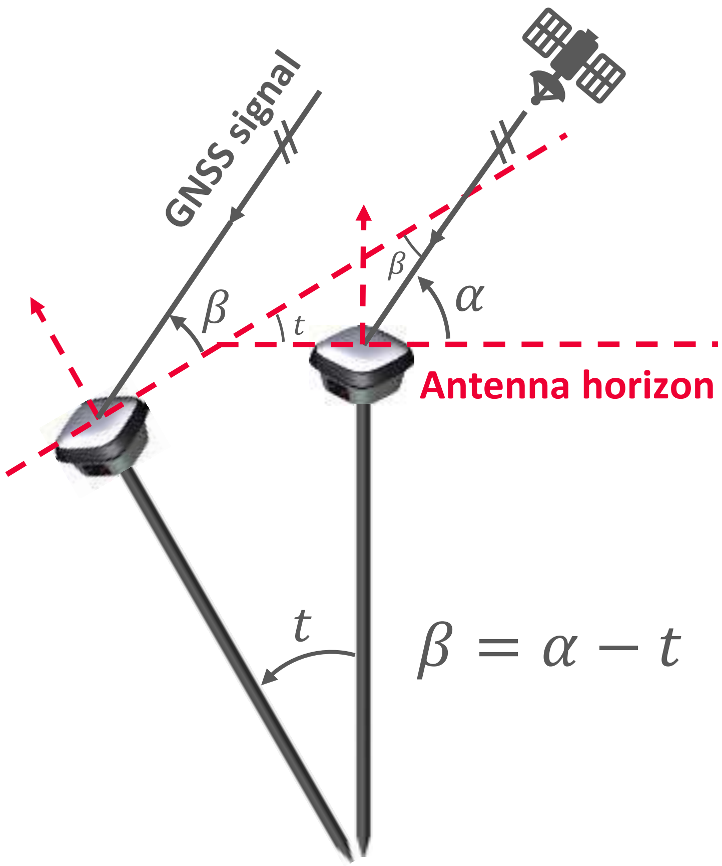
Conclusions

- Tilt compensation RTK of the Leica GS18 T
  - Based on precise IMU measurements (instead of magnetometer)
  - Sophisticated GNSS/INS integration with quality control mechanisms
- Main technological advantages
  - Completely free from on-site calibrations
  - Immune to magnetic disturbances
  - Applicable at large tilt angles
  - Heading-aided 3D visualization
- User benefits
  - Improving RTK applicability and positioning performance
  - Enhancing productivity and user experience in the field

Thank you very much for your attention!

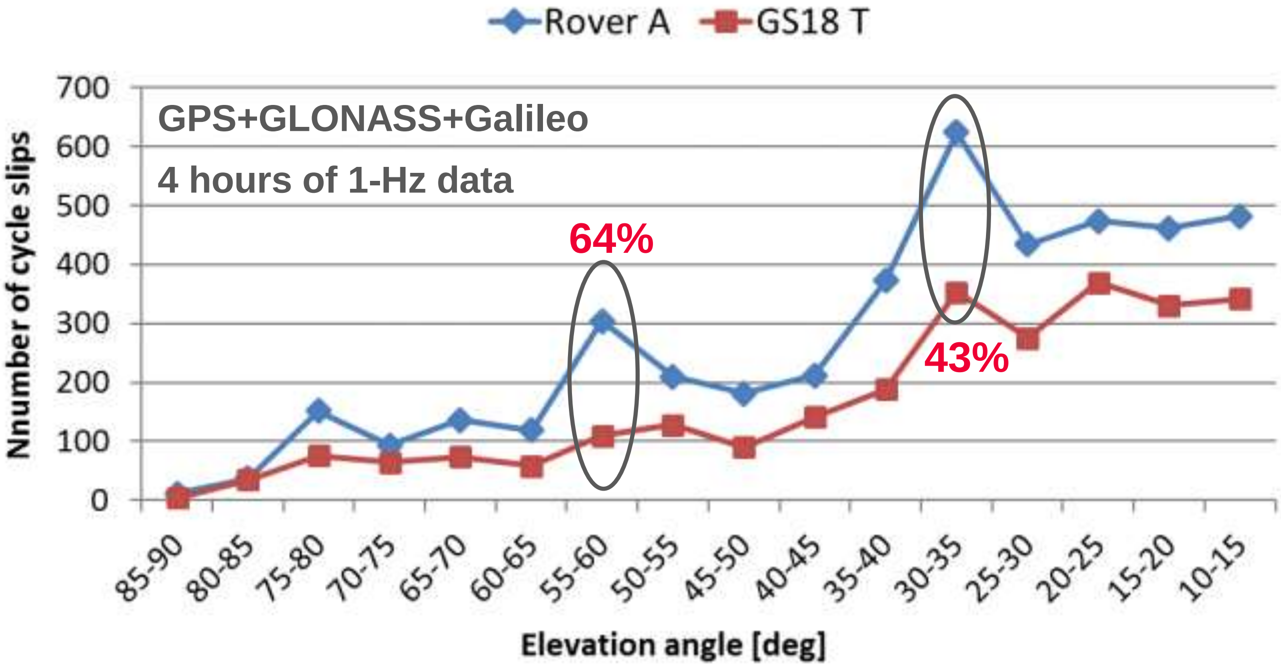
Advanced signal tracking technologies

- Importance of low-elevation signal tracking in the tilt compensation use case
- Advanced GNSS antenna technologies
  - Parasitic circular array loading technology
  - Ultra-wideband antenna feeding technology
- High-performance measurement engine
  - Multi-constellation and multi-frequency GNSS
  - High sensitivity also at low elevation angles



- when it has to be right
Leica Geosystems

Benefits of advanced signal tracking
Number of cycle slips

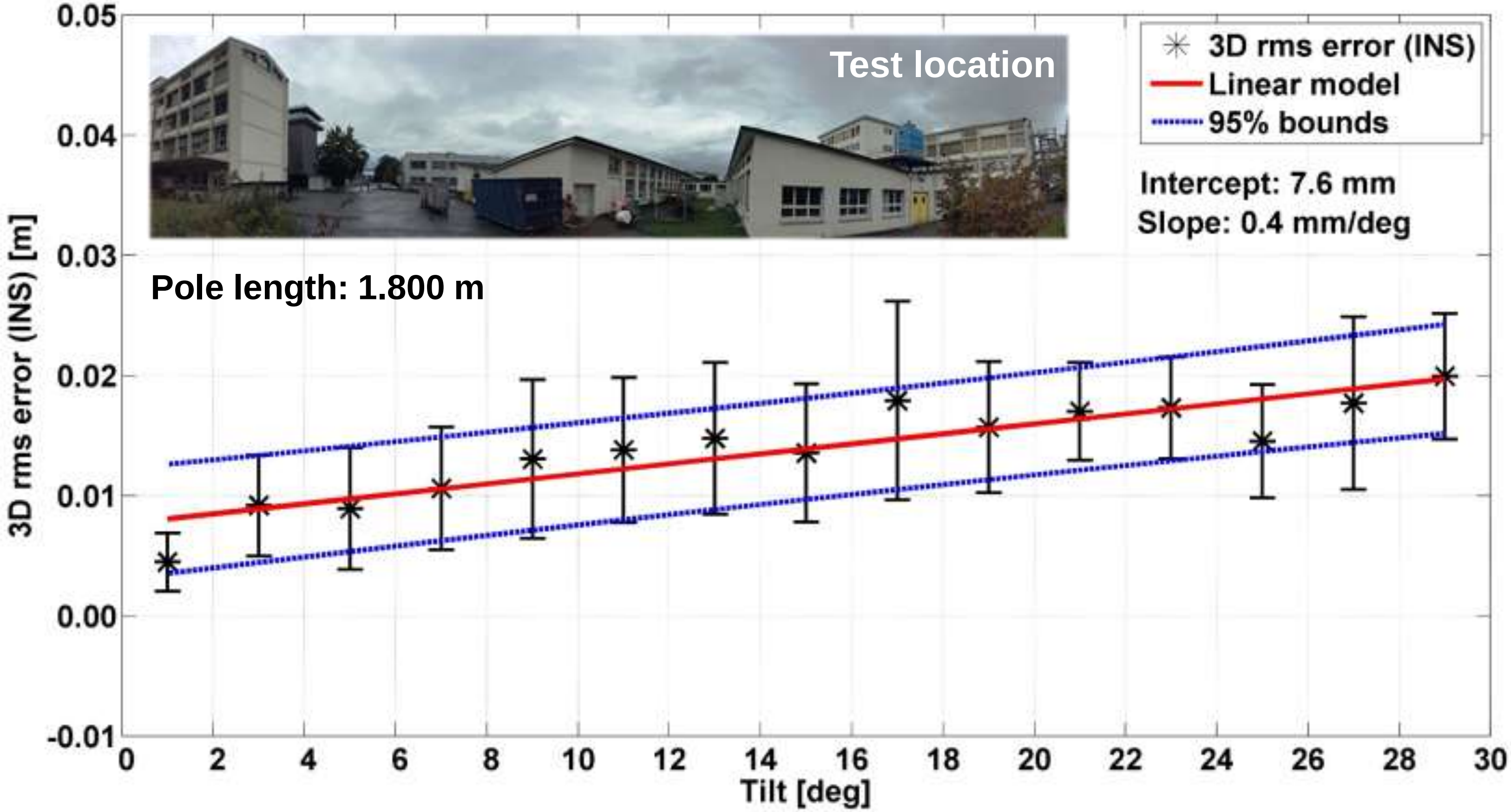


- Rover A: Survey-grade GNSS smart antenna
- GS18 T: Reduction of total cycle slips by 40%

- when it has to be **right**

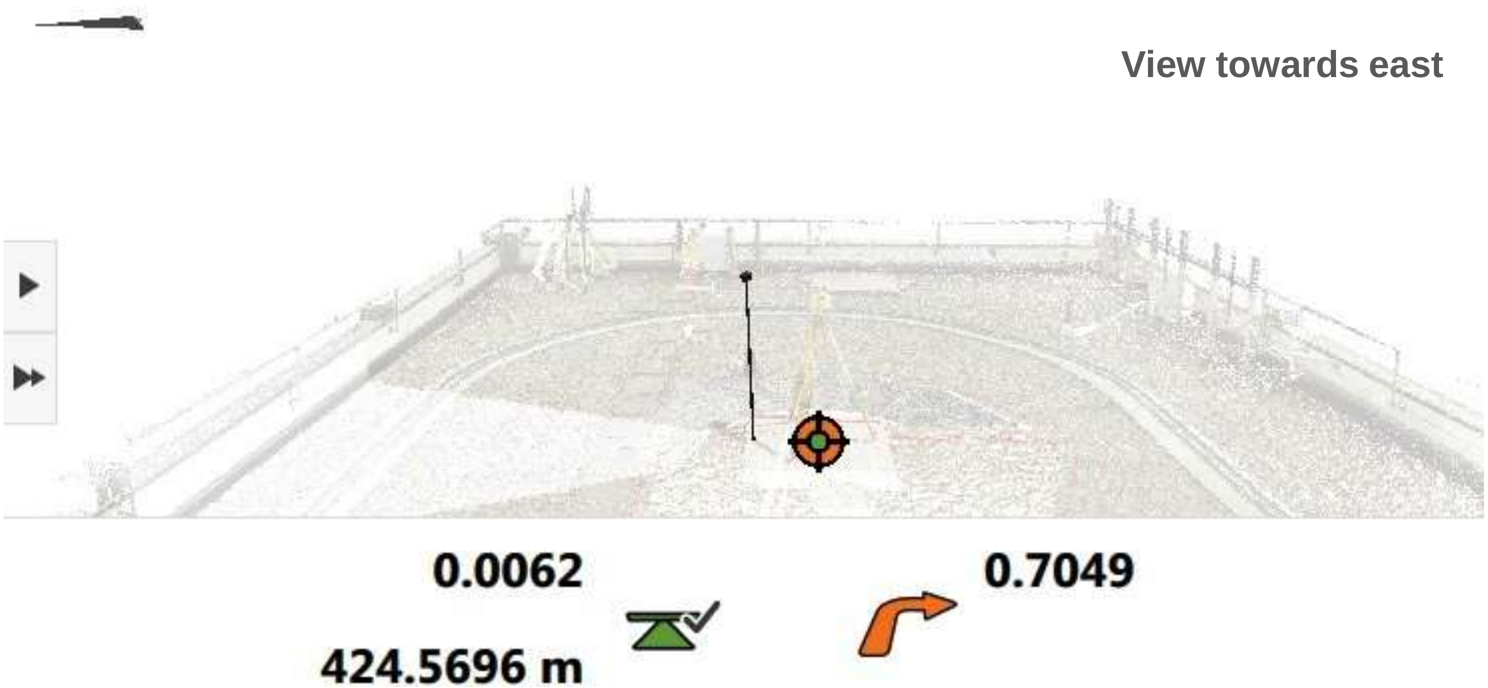
Leica Geosystems

Accuracy aspects



- when it has to be right
Leica
Geosystems

Heading-aided 3D visualization



- Automatic updates of the 3D viewer depending on the sensor heading
- Easy orientation for enhanced productivity and user experience