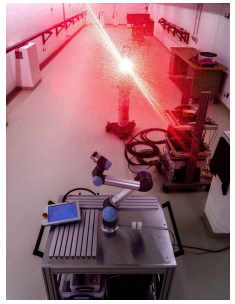
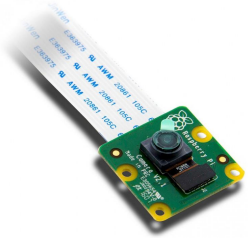




# Konzeptionen innerhalb der Robot Operating System (ROS)-Umgebung im geodätischen Zusammenhang



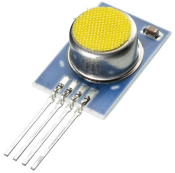


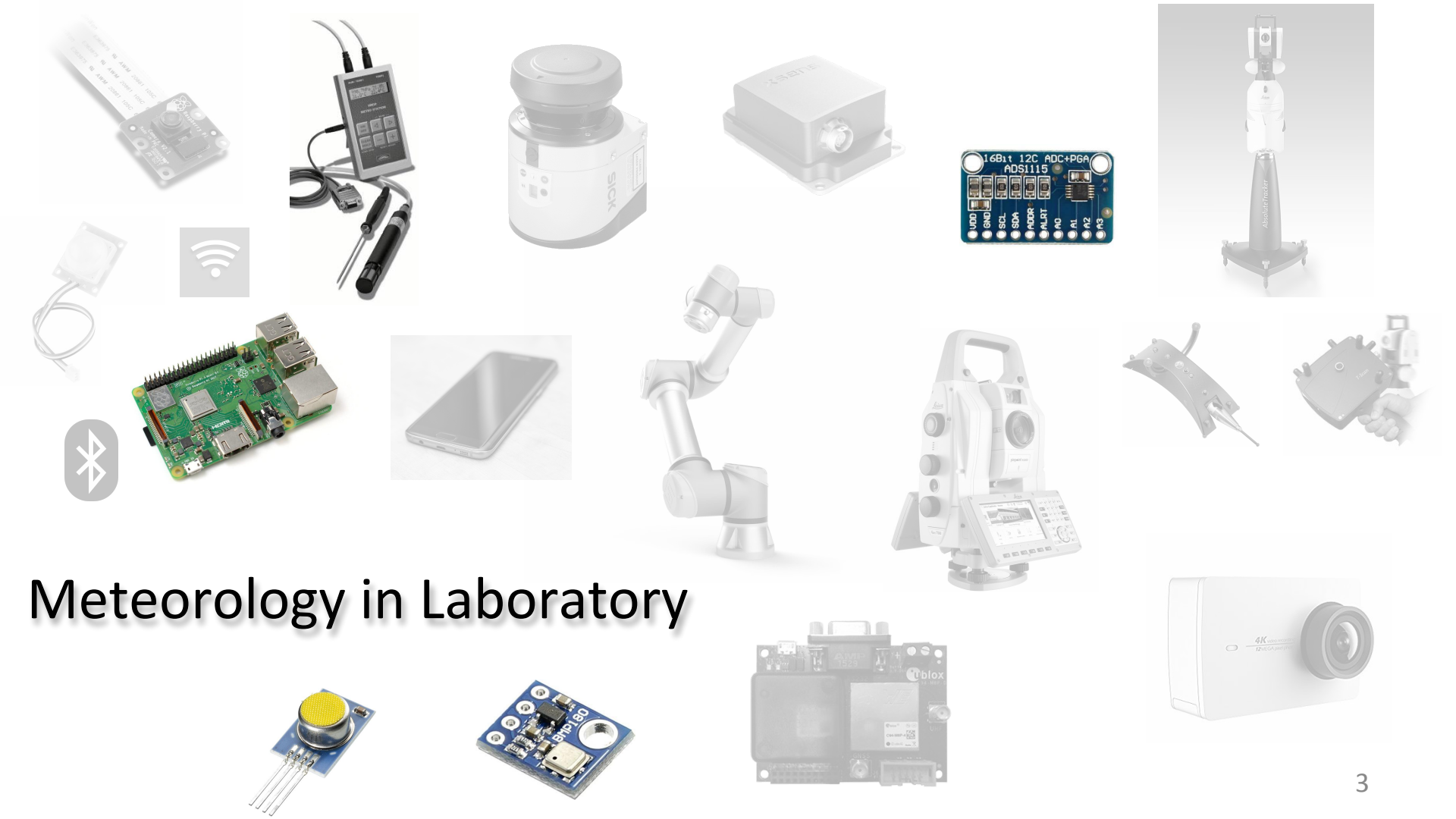






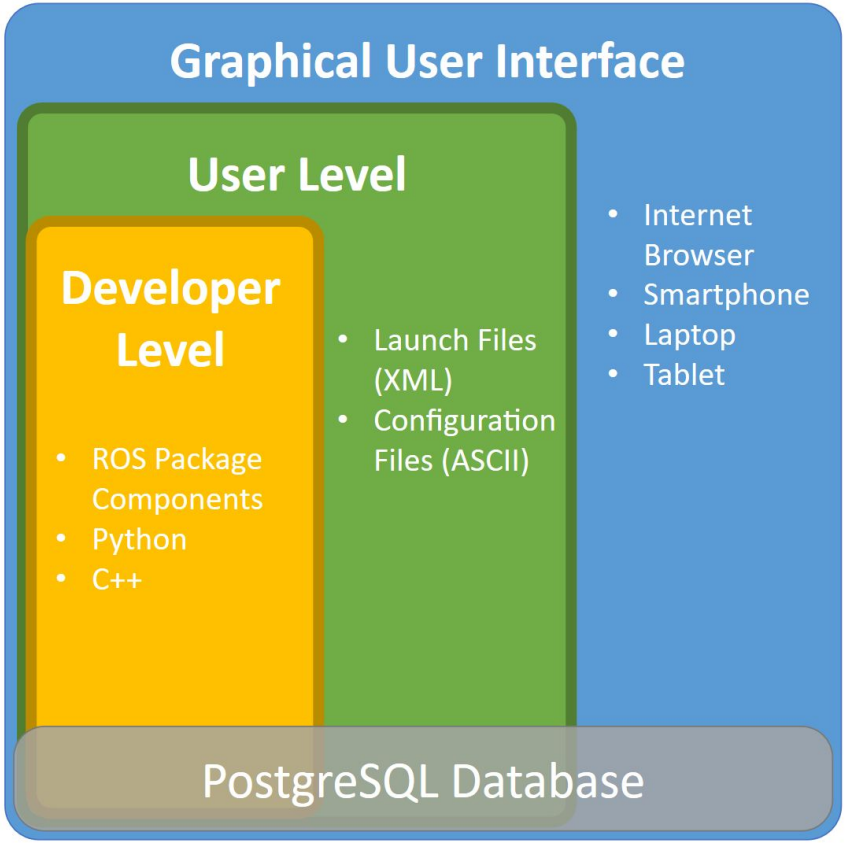

# Sensors integrated in ROS at TU Wien

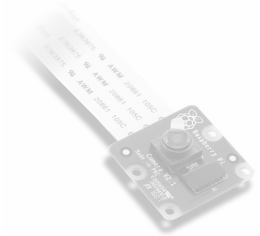


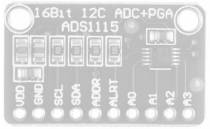




# Meteorology in Laboratory

# Web-Application





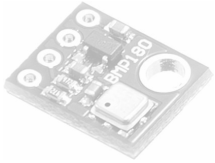





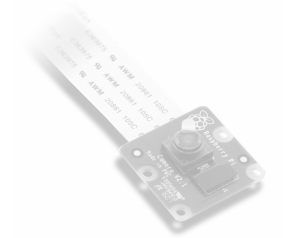


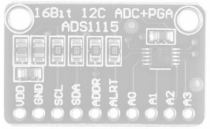







# Temporal Calibration of Robotic Total Station



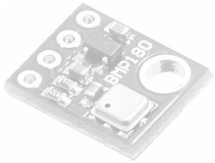



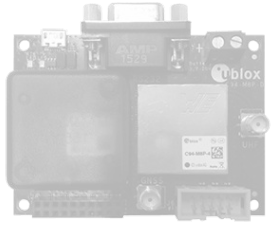




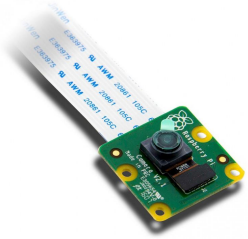


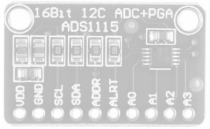






# IMU Calibration



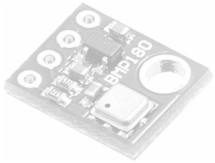









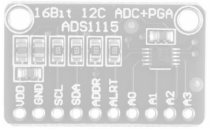




# UAV Tracking

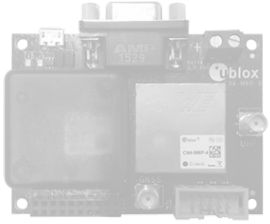


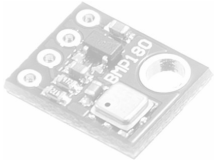


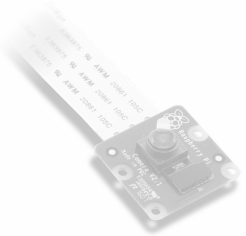


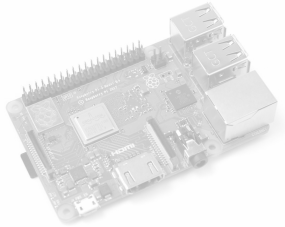






# Indoor Positioning and Navigation

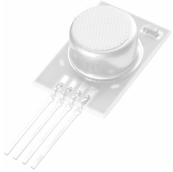
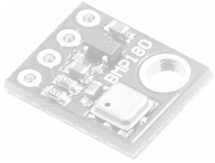


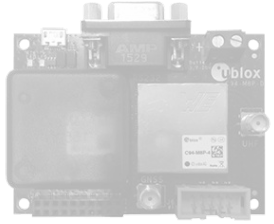



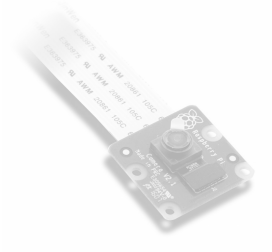


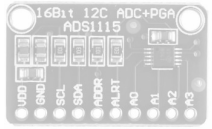


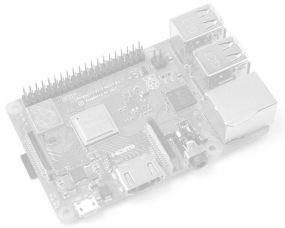
# Lasertracker and Equipment





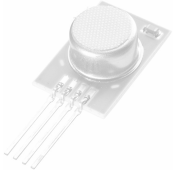
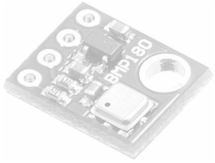



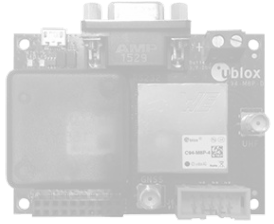


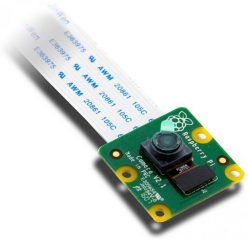




# Industrial Robot Arm Calibration





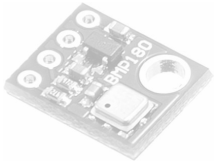


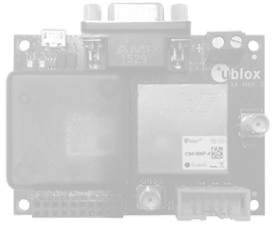






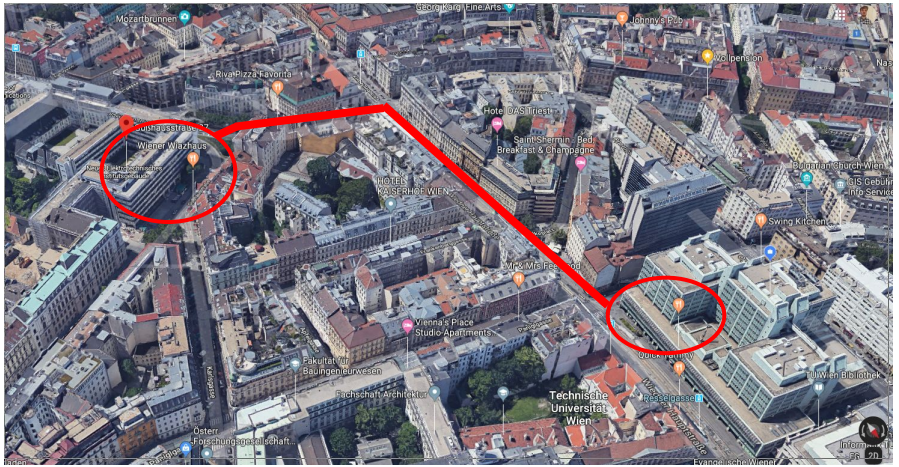

# Surveillance of Measurement Lab

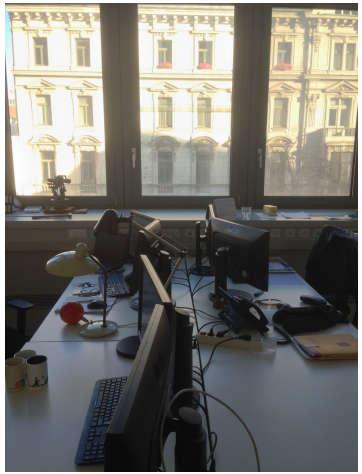





# Geo-Sensornetz

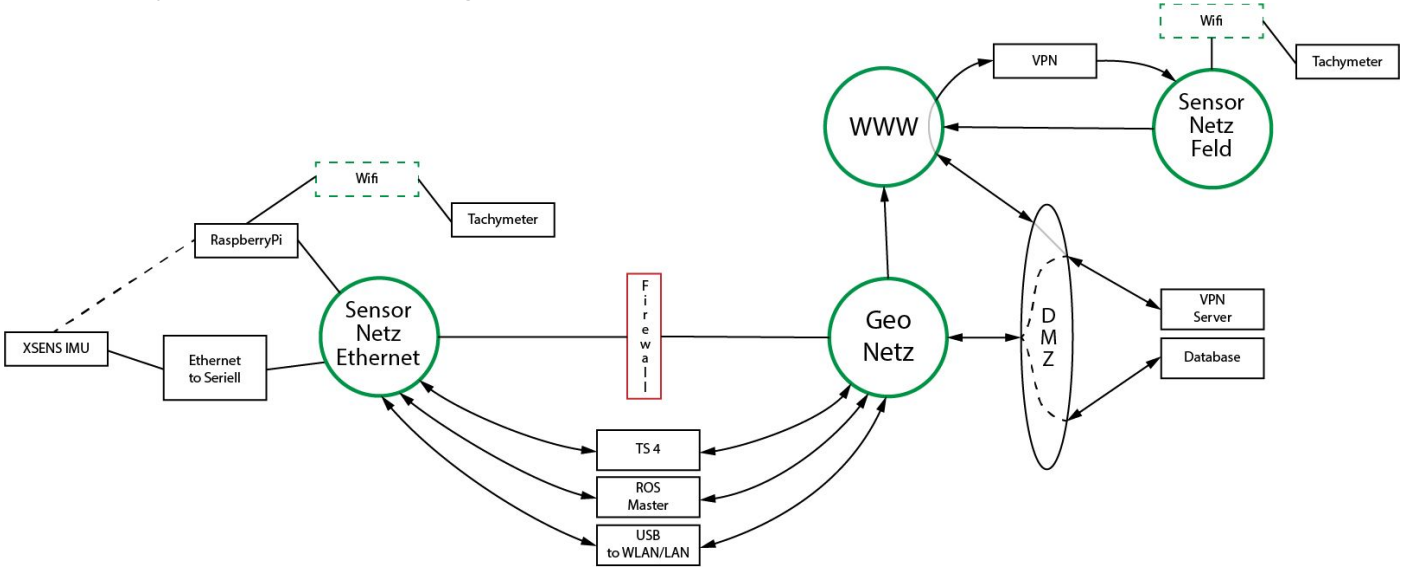
- Decentralized network
- Communication network for multi sensors and multi-sensor systems
- Ethernet, cable based
- WLAN, wireless based
- Location range from office over lab to field work with one configuration

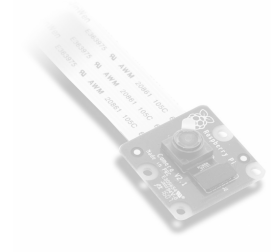


# Why a seperate Network?

- Security on the sensor and client side. Connection often without using a firewall on both sides.
- Direct communication in one IP-address range between both locations, Freihaus and Neues EI. (Not possible in the TUNet)
- Direct communication between the WLAN and the ethernet cabel connected sensores
- No time delays based on routings inside the TUNet Backbone





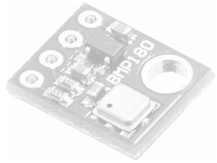
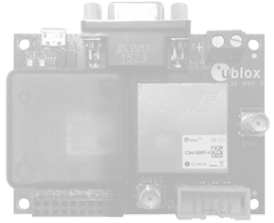






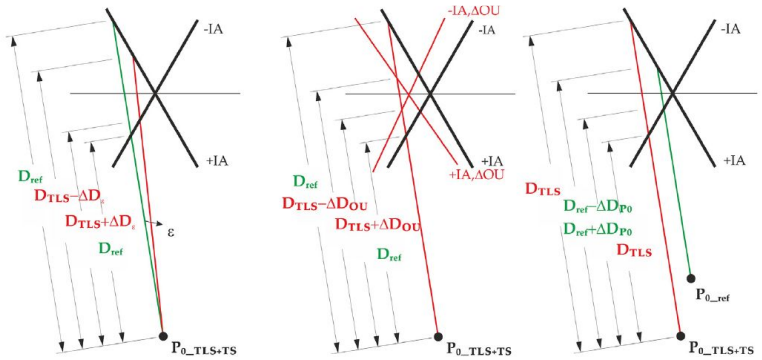



# Quantification of systematic distance deviations

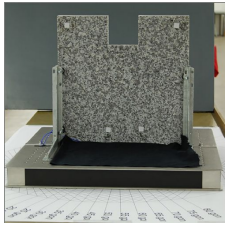




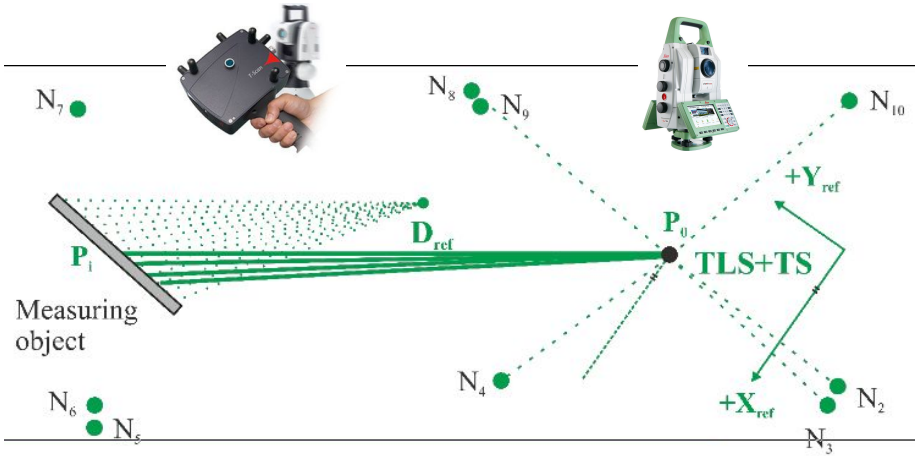
# Quantification of systematic distance deviations

- Combined Influence of Incidence Angle and Roughness on Reflectorless Distance Measurements Scanners



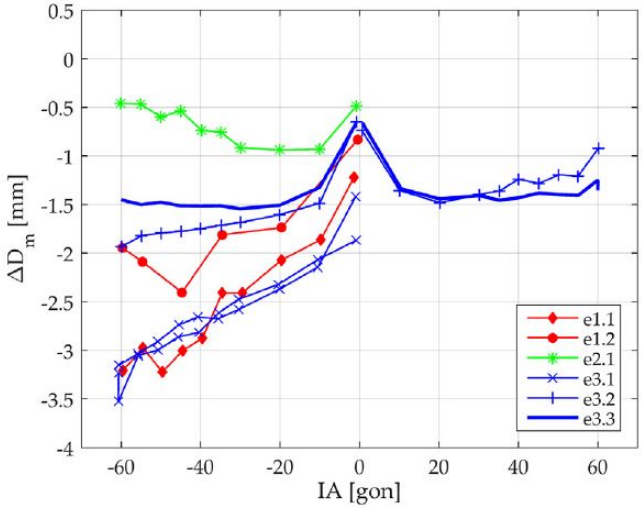

A. Determination of a common reference frame: high-accuracy network
B. Starting point: resection - angular measurements to the network points
C. End points: reference scan of the object with close range scanner

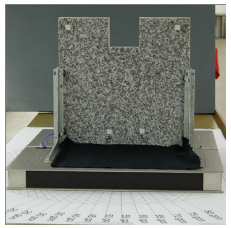


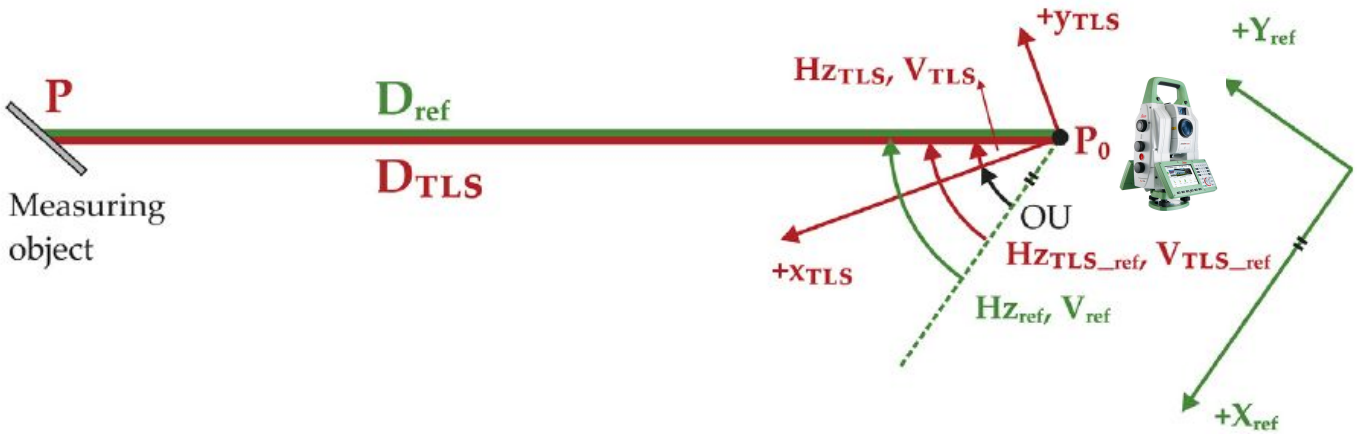


# Quantification of systematic distance deviations

- Key feature of the principle:
  Direct analysis of single measured distances
- ROS helps to generate faster and more reliable measurement results
- The repeatability is ensured by the automation of the measuring process. The human influencing factor is eliminated.



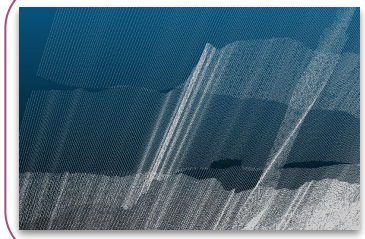



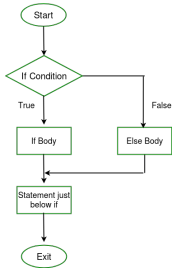


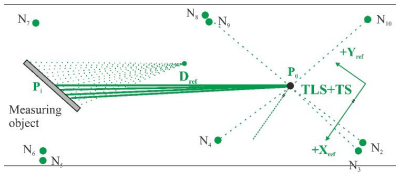
# ROS Services

/sensor_data
*150 Hz*
*Acquire data*

/topic_ms50
/topic_scan
/topic_tracker



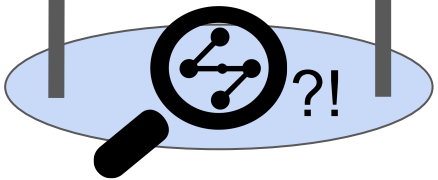



/algorithm
*300 Hz*
*Process Data*

/topic_diff
/topic_filter

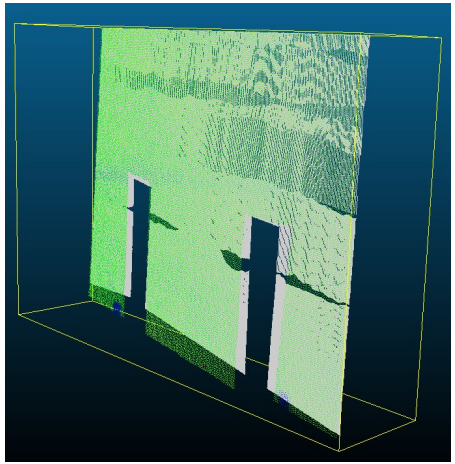
/service
*300 Hz*
*Propose Data*

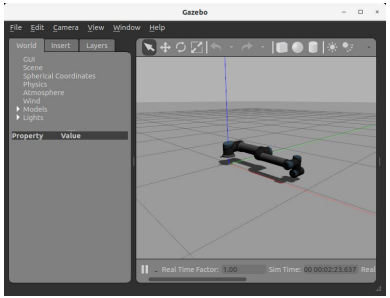



- ROS Services can be used to query individual processes of a process assigned to the measurement setup.
- Dynamic adjustment of the measuring sequence

# Findings along the way

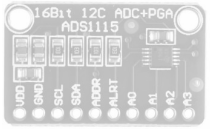
- The integration of the laser tracker is possible via the emScon interface, just in a similar way as the tachymeter is accessible via geocom
- Via ROS Services, processes can be used in a targeted way
- A realization as Cloudcompare Plug-in should be possible
- T-Probe and T-Scan can also be addressed in C++ code
- Saving the point cloud of the MS50 as PointCloud2 poses a hurdle
- With Gazebo as a simulation environment, virtual poses can be approached in order to test the workflow and control the algorithms.





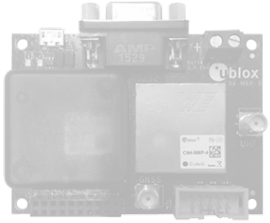


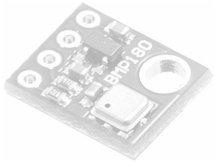






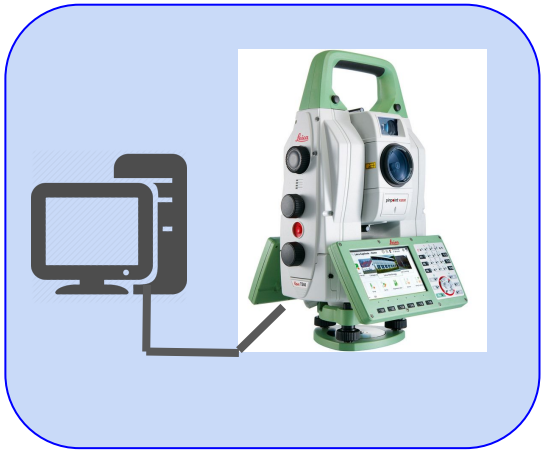





# Indoor Positioning and Navigation

# Indoor Positioning and Navigation

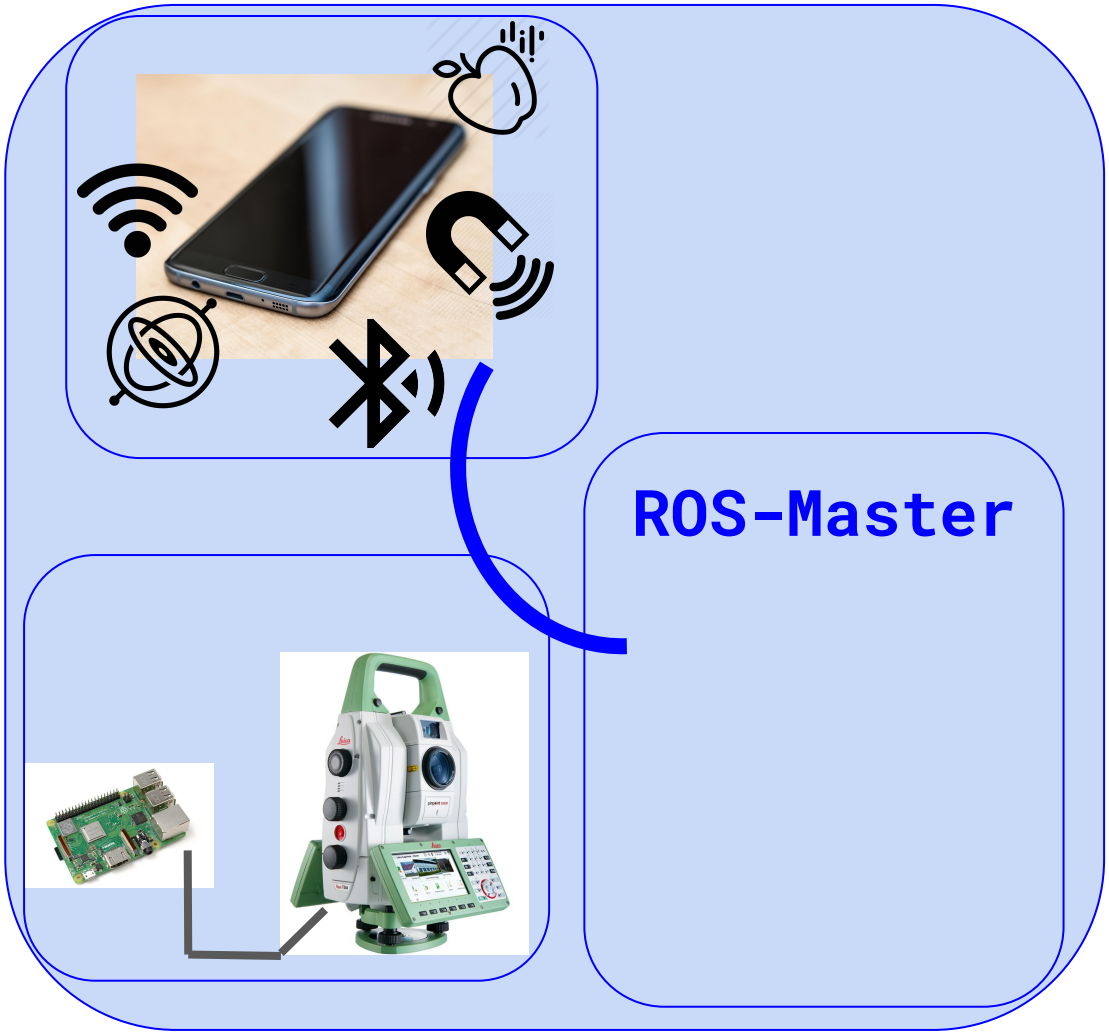
- Positioning based on smartphone-sensors
  - Motion sensors - relative position
  - Radio signals - absolute position
- Reference data from total-station
  - Tracking 360°-prism
- Measurement data
  - Smartphone - existing apps
  - Total-station - Matlab/Geocom
- Evaluation post-processing



Time Synchronization
Central data storage

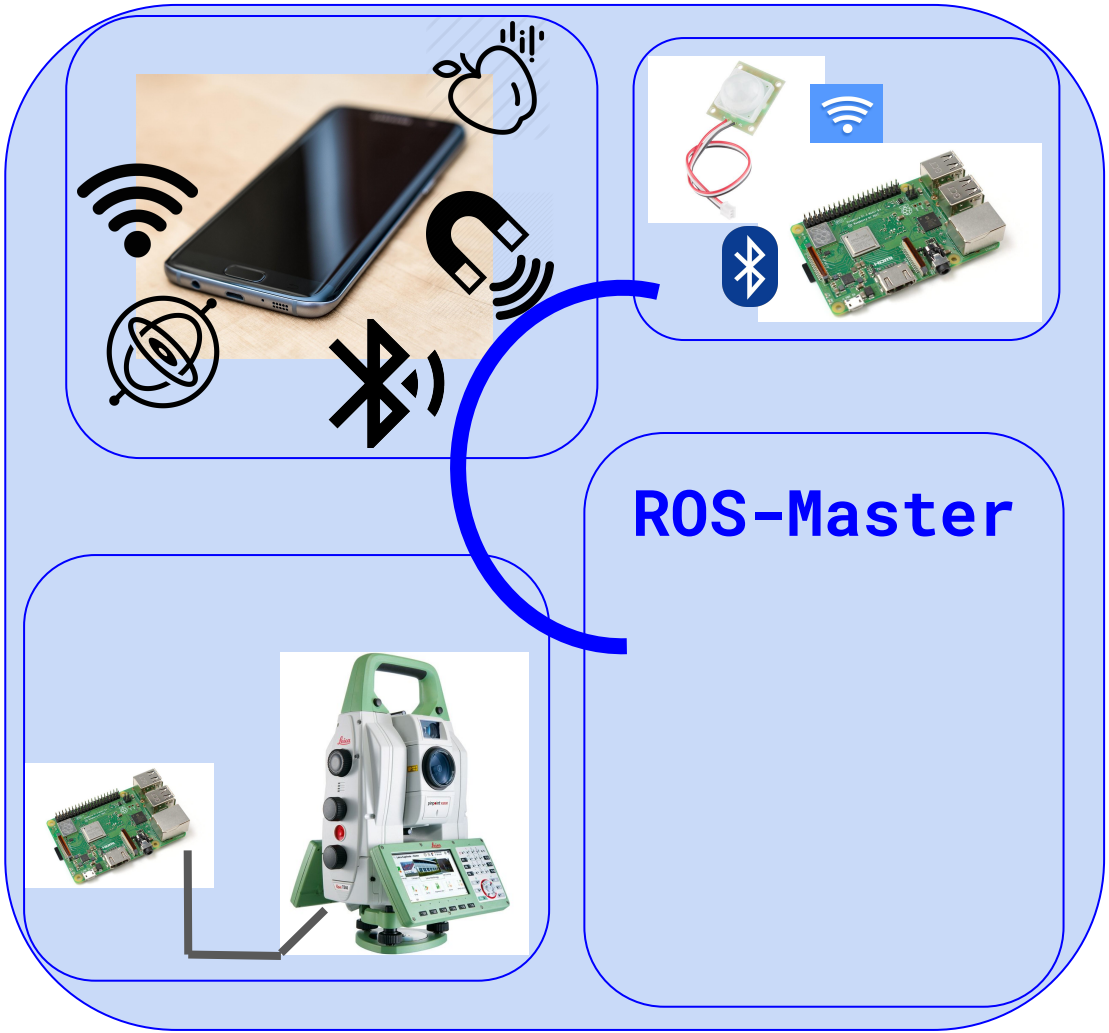
# Indoor Positioning and Navigation

- Positioning based on smartphone-sensors
  - Motion sensors - relative position
  - Radio signals - absolute position
- Reference data from total-station
  - Tracking 360°-prism
- Measurement data - **ROS**
  - Smartphone
  - Total-station
  - Time-synchronization
  - Data storage - Rosbag, JSON, MQTT-Bridge, msg-converter
- Evaluation post-processing



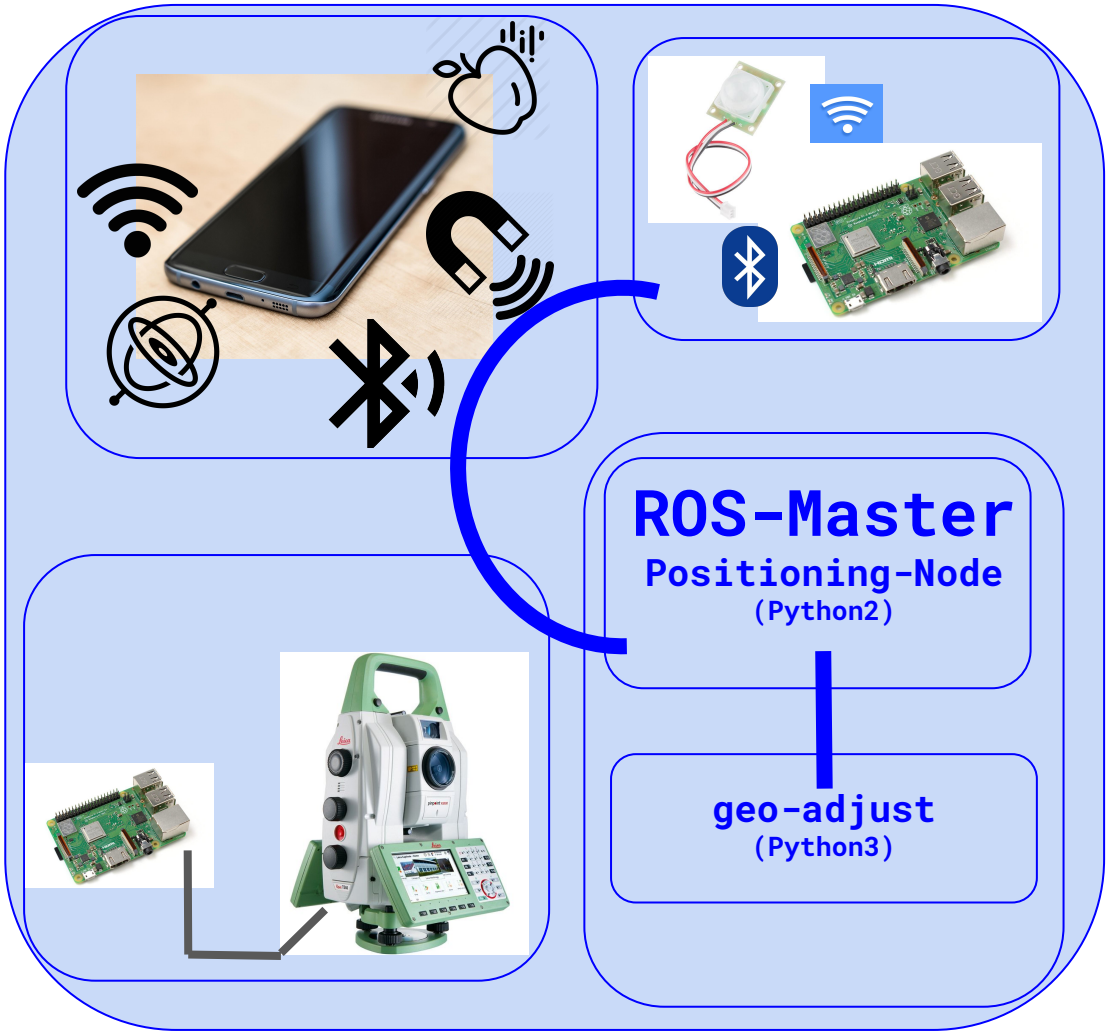
# Indoor Positioning and Navigation

- Positioning based on smartphone-sensors
  - Motion sensors - relative position
  - Radio signals - absolute position
- Reference data from total-station
  - Tracking 360°-prism
- Building sensor infrastructure
  - Wi-Fi, BLE
  - PIR motion detector
- Measurement data - **ROS**
  - Smartphone
  - Total-station
  - Sensor infrastructure
  - Time-synchronization
  - Data storage - Rosbag, JSON, MQTT-Bridge, msg-converter
- Evaluation post-processing



# Indoor Positioning and Navigation

- Positioning based on smartphone-sensors
  - Motion sensors - relative position
  - Radio signals - absolute position
- Reference data from total-station
  - Tracking 360°-prism
- Building sensor infrastructure
  - Wi-Fi, BLE
  - PIR motion detector
- Measurement data - **ROS**
  - Smartphone
  - Total-station
  - Sensor infrastructure
  - Time-synchronization
  - Data storage - Rosbag, JSON, MQTT-Bridge, msg-converter
- Online evaluation
  - Package: geo-adjust
  - Python2-Python3-Bridge

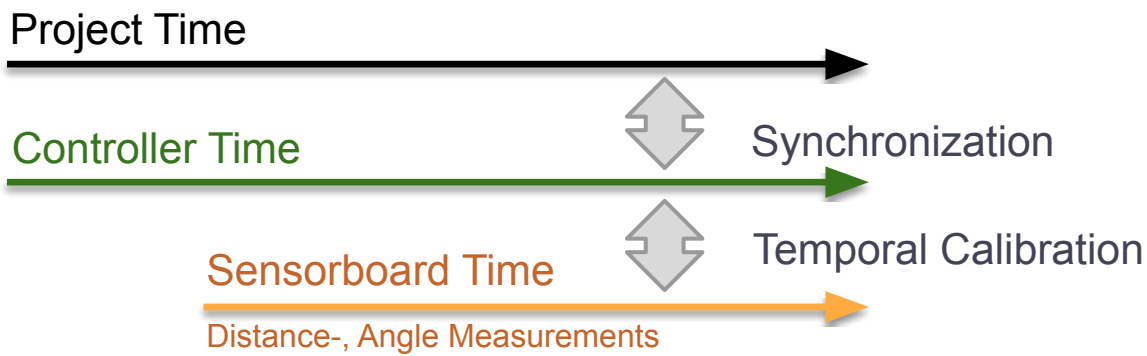



# Temporal Calibration of Robotic Total Station

# Motivation

- Kinematic Operation of RTS
- Precise Synchronization
  - ROS != Synchronization

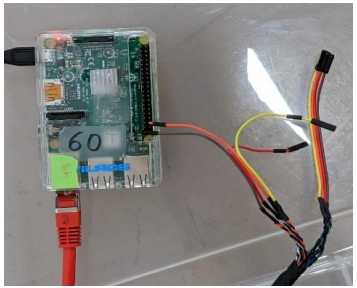
# Synchronization & Temporal Calibration?

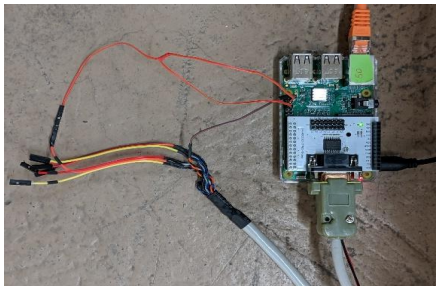


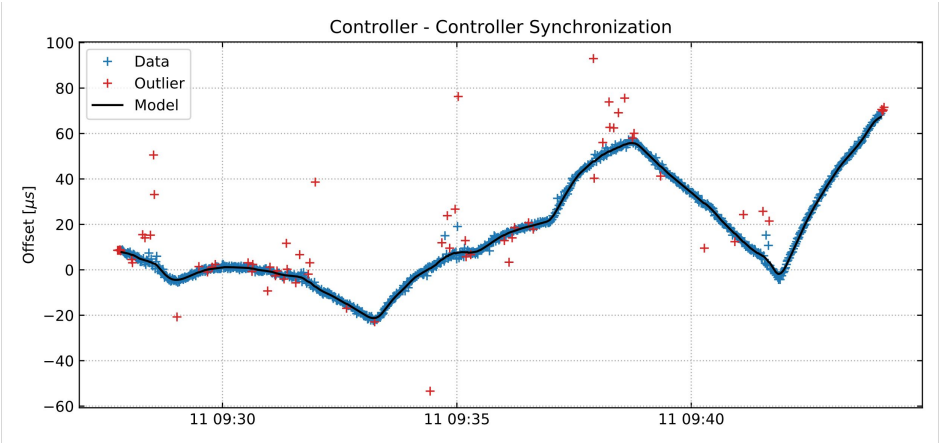

- Time Frame
  - Network Time Protocol
  - Electrical Trigger Signal
- Estimation of Latencies
  - System Latency of Robotic Total Station in Tracking Mode
  - Intrinsic Latency between Angle and Distance
- Prerequisites
  - Common Time Frame of Reference Sensor and Sensor under investigation
  - Common Spatial Frame – „ –

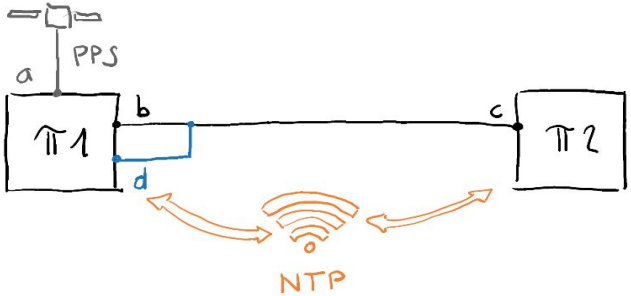
# Synchronization Hardware and Results

- Linux Realtime Kernels
- Additional Tuning








Synchronization Accuracy

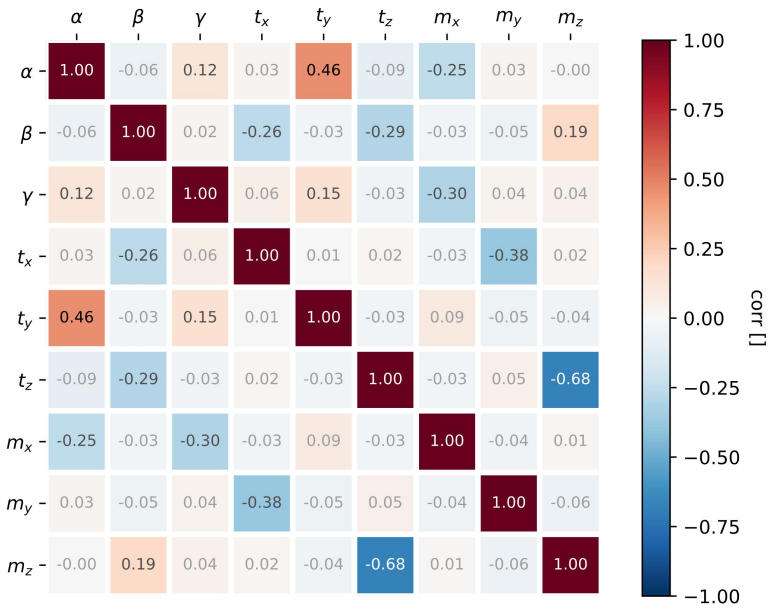
**30 µs**

# Spatial Reference Transformation RTS <> UR5

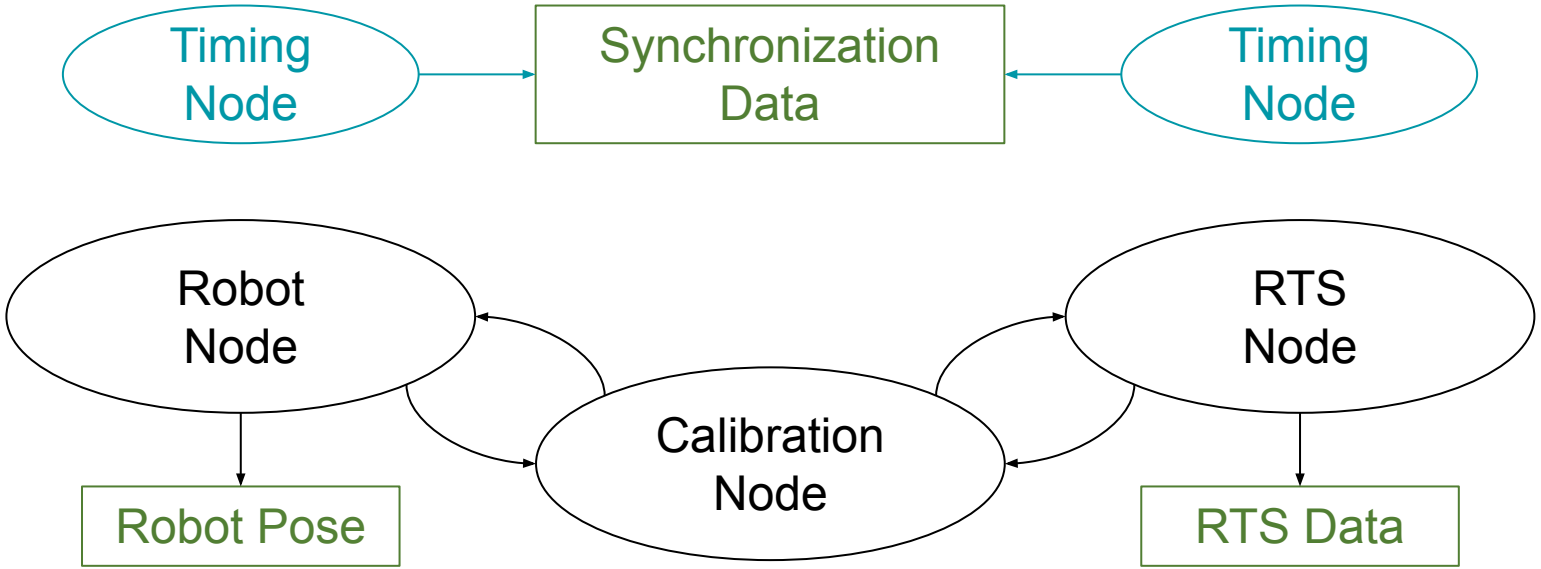
- Transformation Parameters and Prism Mounting Vector

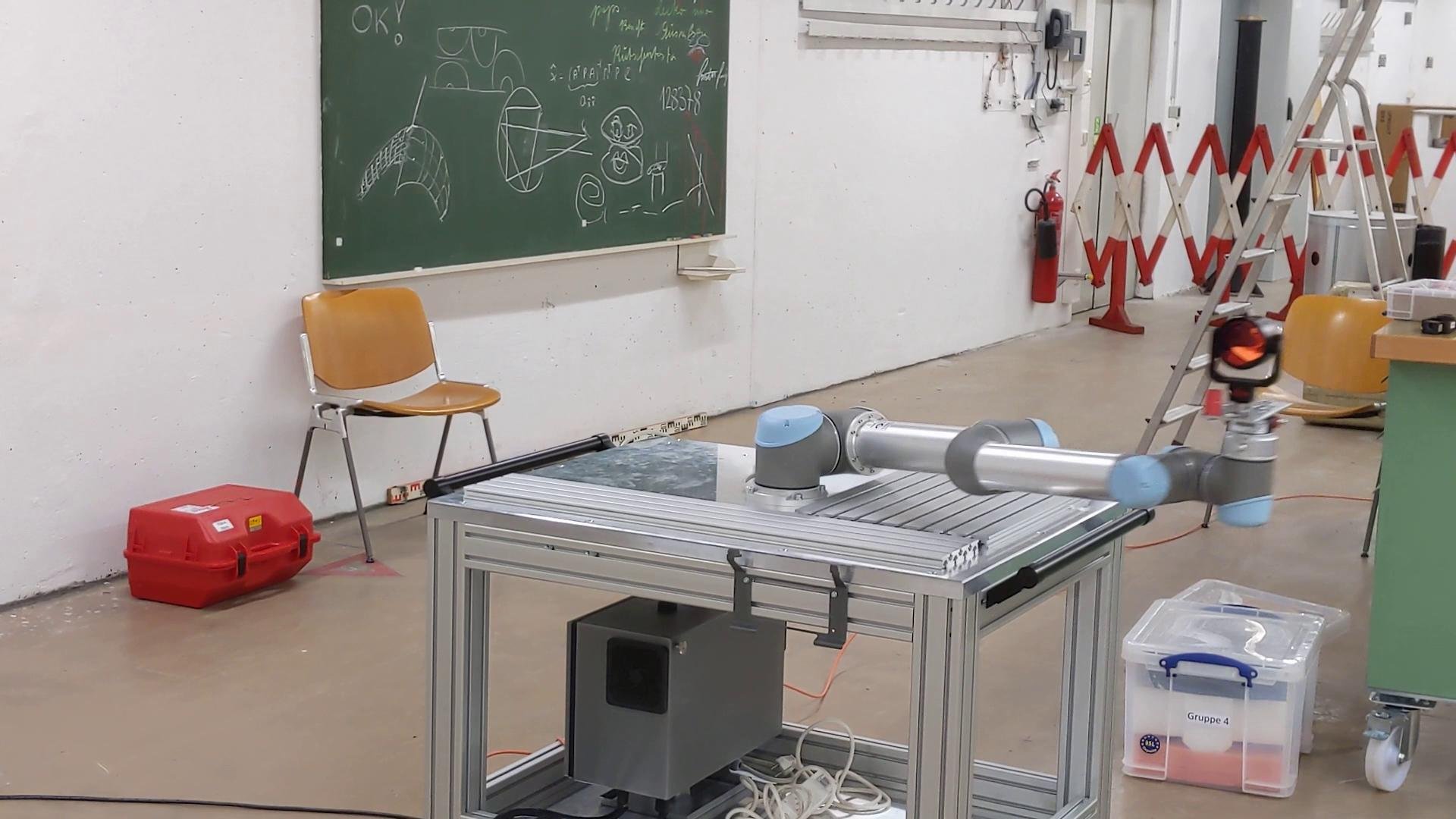
$$\boldsymbol{t}_{pr}^{rt} = \boldsymbol{R}_{ur}^{rt}\left(\boldsymbol{t}_{ee}^{ur} + \boldsymbol{R}_{ee}^{ur}\,\boldsymbol{t}_{pr}^{ee}\right) + \boldsymbol{t}_{ur}^{rt}$$

| | | | | |
|---|---|---|---|---|
| α: | 0.41231 | ± | 0.00484 | [gon] |
| β: | 0.14328 | ± | 0.00507 | [gon] |
| γ: | -1.58505 | ± | 0.00473 | [gon] |
| t□: | 16.15224 | ± | 0.00010 | [m] |
| t_y: | -0.55589 | ± | 0.00006 | [m] |
| t_z: | -0.59646 | ± | 0.00007 | [m] |
| m□: | 0.42 | ± | 0.06 | [mm] |
| m_y: | -65.37 | ± | 0.07 | [mm] |
| m_z: | 137.38 | ± | 0.07 | [mm] |



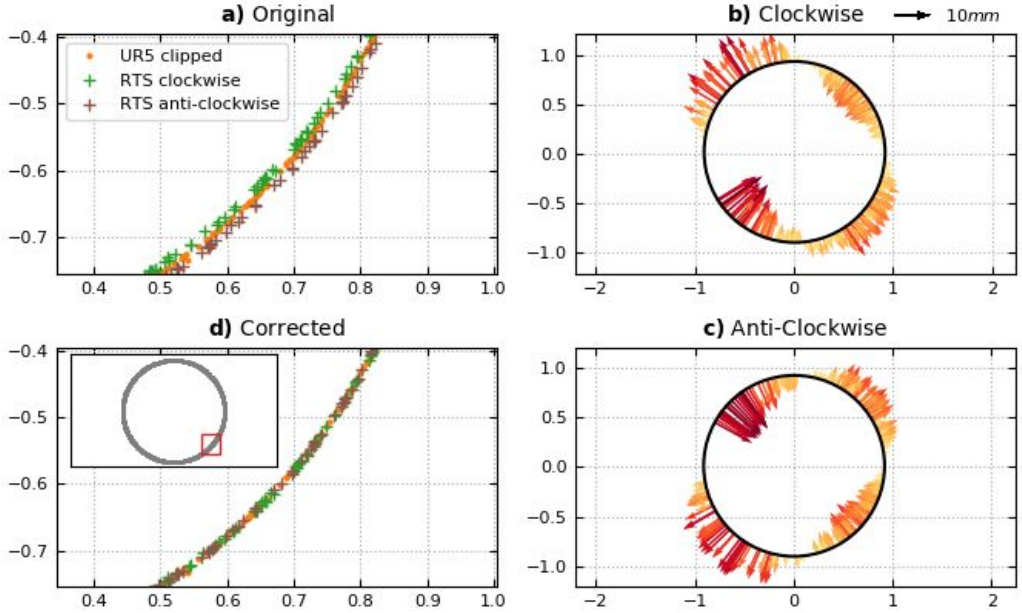
# ROS Framework




OK!
Gruppe 4

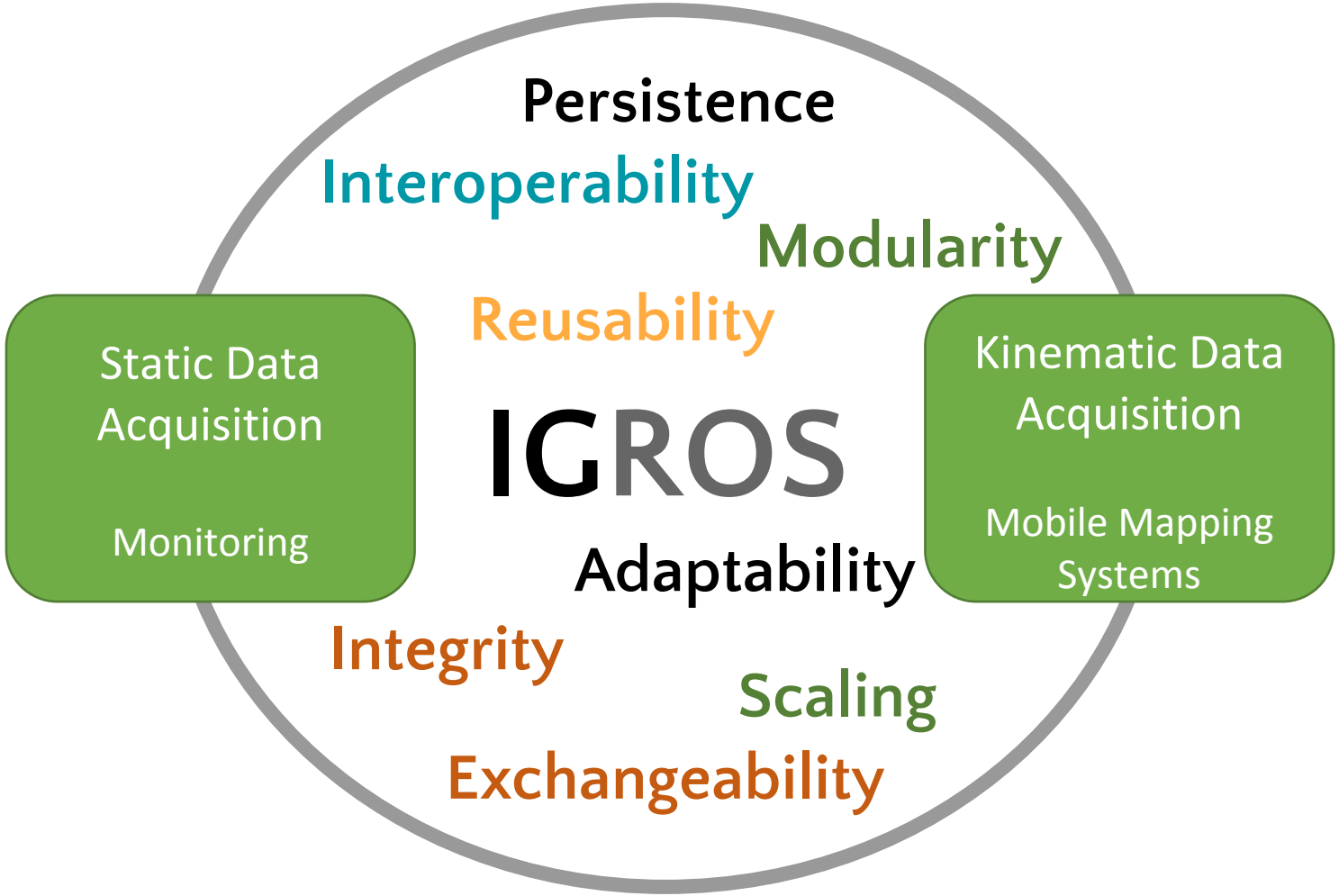
# Summary

- ROS Package for Synchronization
  - Interaction with Kernel Module for Trigger Synchronization
  - Interaction with NTP
- Temporal Calibration of RTS
  - Fully Automated Procedure
  - Estimation of
    Latency Parameters



# ROS @ TU Wien

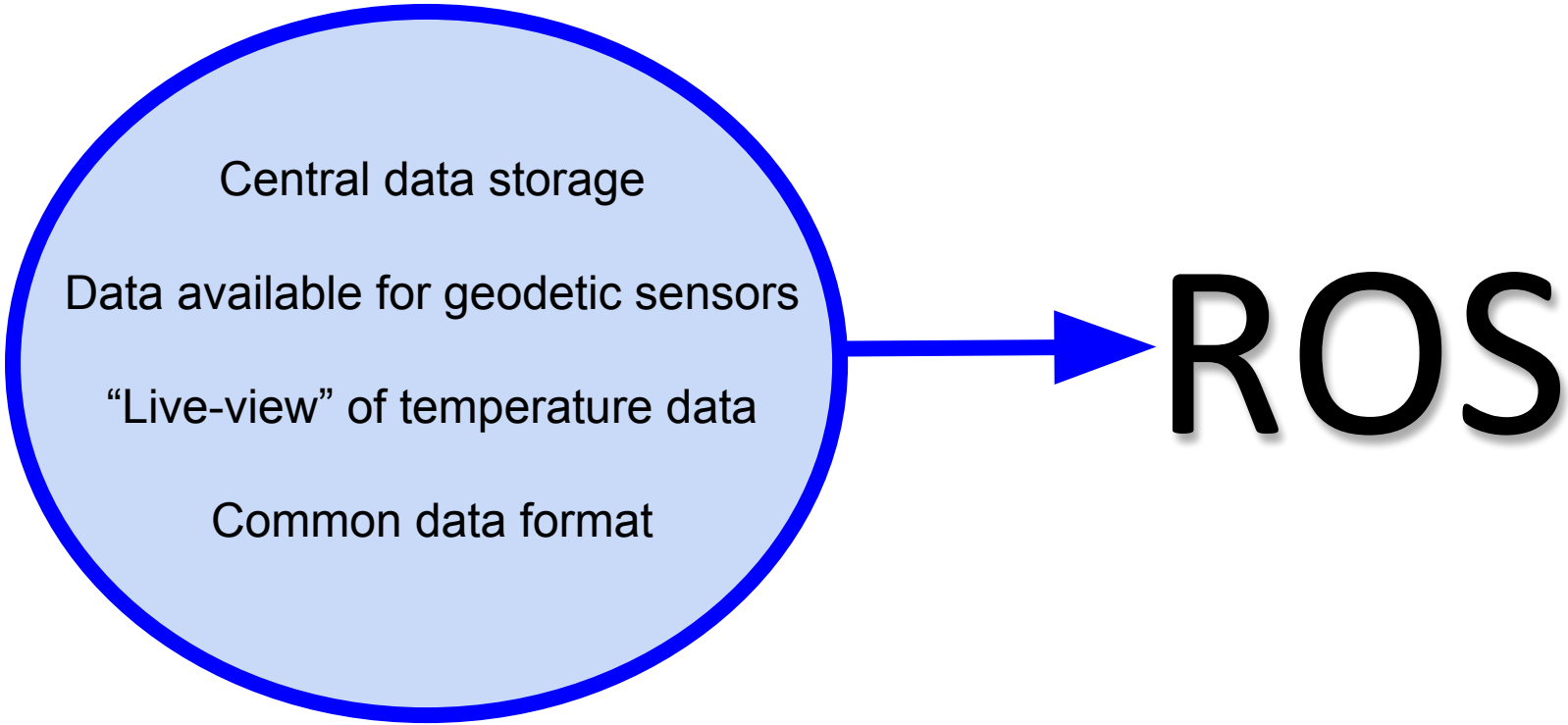
- ROS Bags and Database as Data Storage
- ROS as Framework for distributed Sensors
  - Laboratory Installations with permanent ROS-Server
  - Including Webinterface for Data-Repository
- In Conjunction with
  - Geo-Sensornetz
  - Singleboard Computers
- ***Collaboration*** with Colleagues (Nodes/Packages)
- ROS for Automatization (Launch-Files)
  - Measurement Tasks like Calibration
- Teaching


Persistence
Interoperability
Modularity
Reusability
Static Data Acquisition
Monitoring
IGROS
Kinematic Data Acquisition
Mobile Mapping Systems
Adaptability
Integrity
Scaling
Exchangeability

# Why using ROS?

- Including temperature field in distance measurement analysis
- Distributed temperature sensors

# Why using ROS?



# Web-Application