

Project MLAT

Dr. Martin Loeser

martin@martinloeser.eu

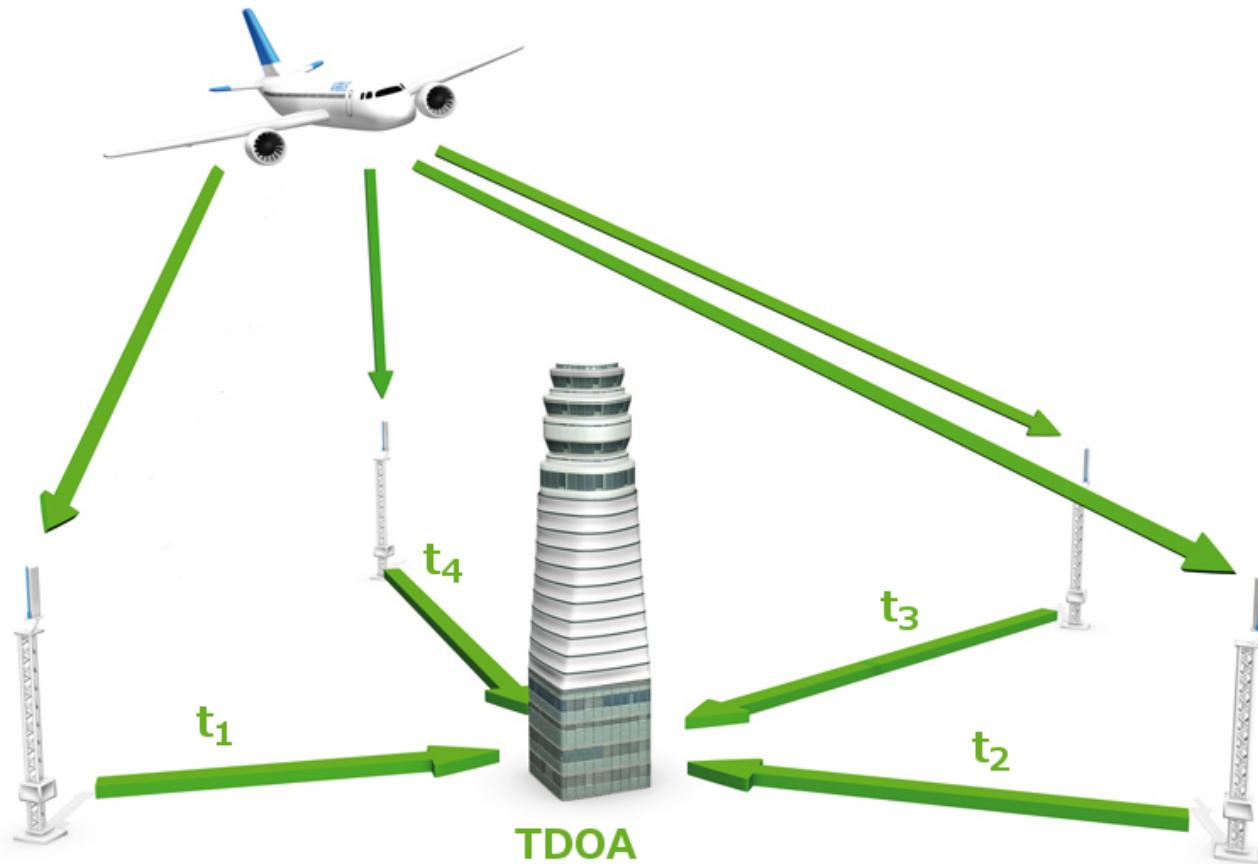
Overview

- Introduction & Project Summary
- Hardware
- Software
- Results and Challenges
- Outlook

Project Summary & Goals

- Project Summary
 - Direct mandate from **skyguide**
- Project Goals
 - Mobile system for high-accuracy aircraft tracking
 - Key features:
 - Tracking accuracy: horizontal deviation about **6m**
 - Tracking method: **multi-lateration (time difference of arrival)**
 - Supplement for GPS and radar-based approaches

The Principle of Multilateration

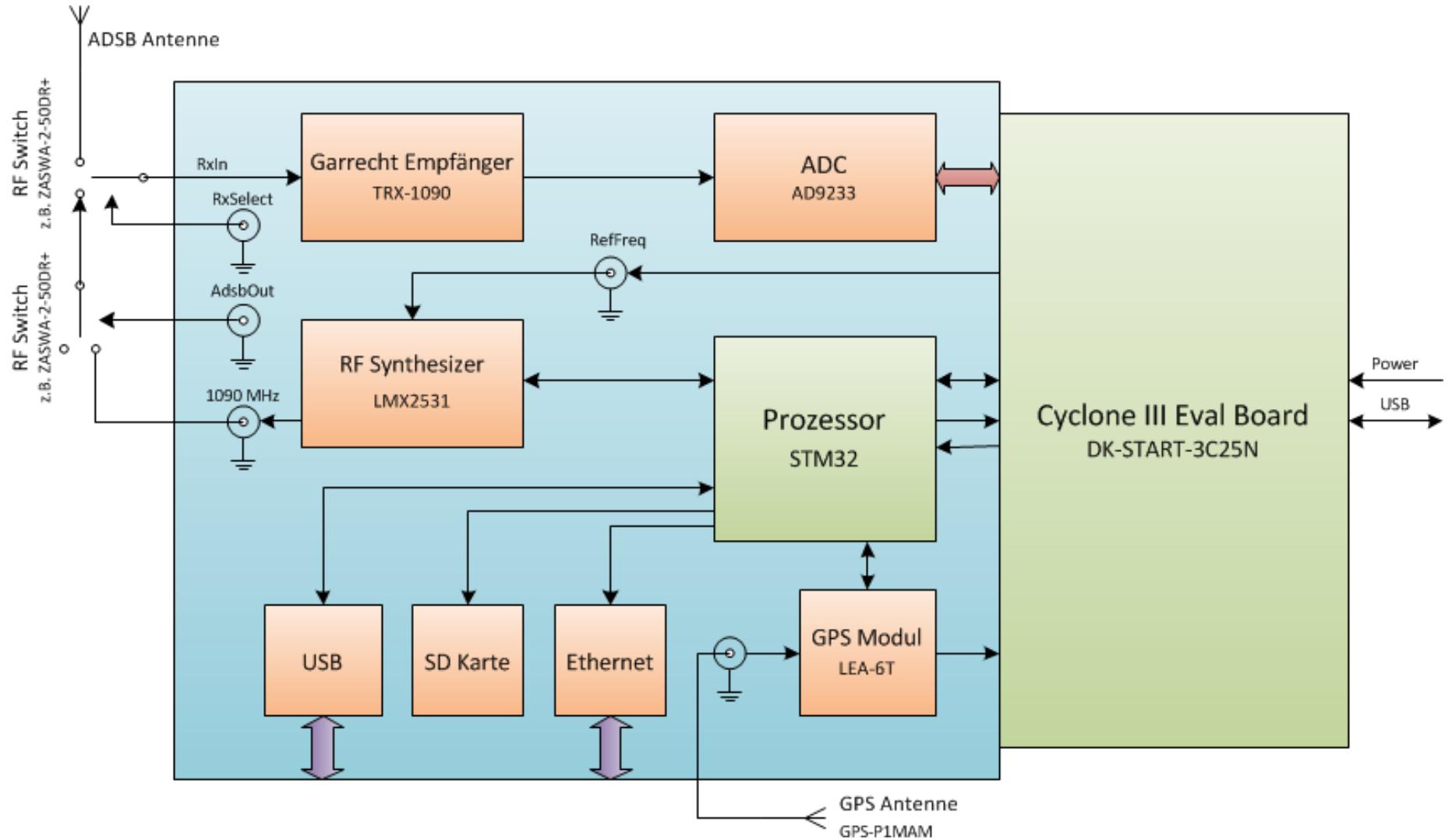


- Compute distance based on **time difference of arrival (TDOA)**
- Critical issue: receiver time stamps

Summary MLAT System

- **Hardware**
 - System comprises **5** battery-powered mobile receivers
 - Autonomous run-time **>48h**
 - Time-stamp accuracy (1σ): **$\pm 21\text{ns}$**
- **Software**
 - ADSB decoder implemented in **Python** (5 million messages per min)
 - **Multilateration** with **Matlab** (parallel code)
 - **Visualization** with Java

MLAT Receiver Unit



MLAT Receiver Unit Output Example

Header
(ID, GPS
coordinates, ...)

```
#ADS-B Data
#Autor: Recv101
#Datum: 14.04.2014
#Zeit: 14:33:24
#ECEF X: 427639304
#ECEF Y: 65169961
#ECEF Z: 467201698
```

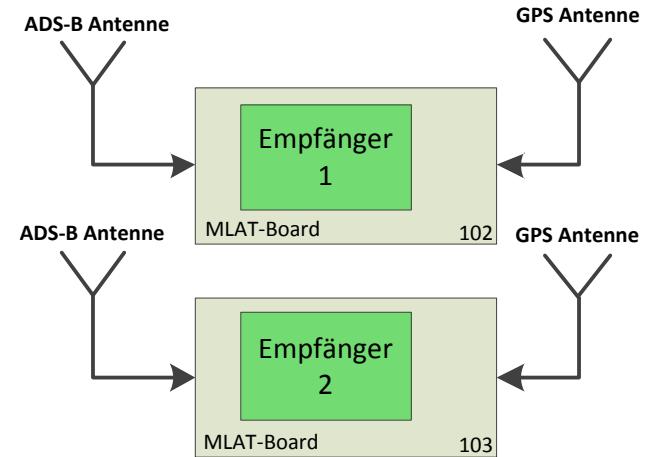
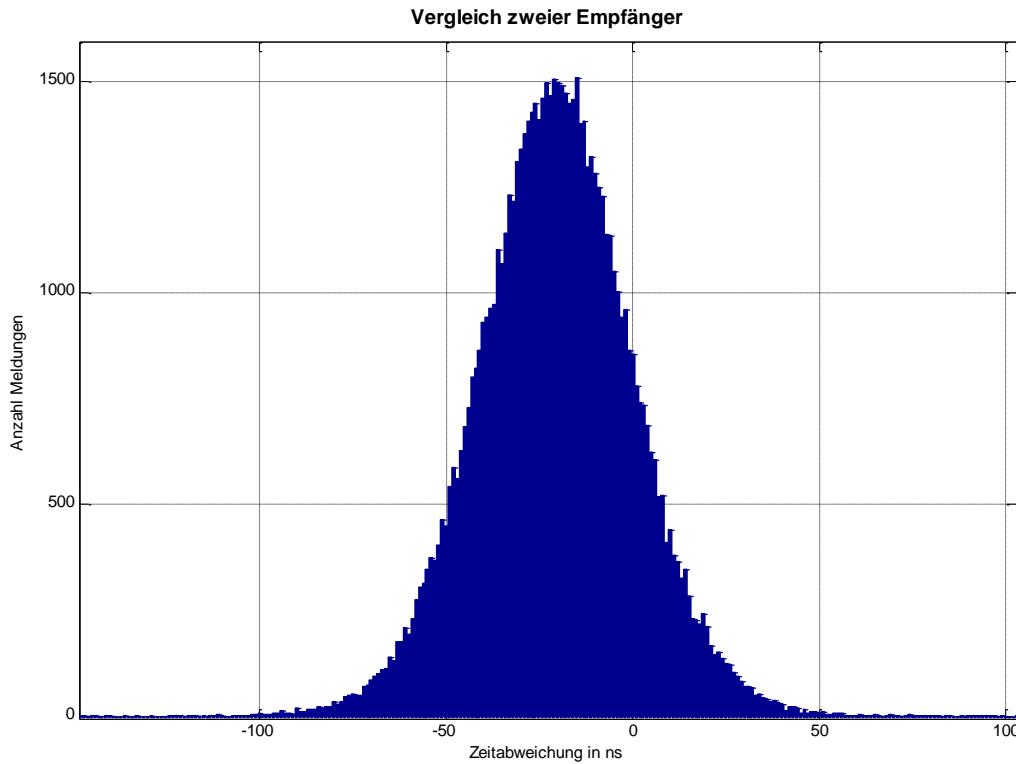
Message Time
Stamp

```
534BEF4C364444FAB20200059218AB1611
534BEF4C36470EDAC00002A1861E4B17A3
534BEF4C364A716DB7008D4B178C9900DD08A00A05000000
534BEF4C364D04F3B800A00008B0000000000000000400E5C
534BEF4C36605E01B801A00008B02015A675CC12E0400E5C
534BEF4C3664E0ACB40202E197173C662B
534BEF4C366AF55AB20100001218AB1611
534BEF4C3676B85EB70002E194973C64C6
534BEF4C3684C997BA005D440C7B000016
534BEF4C36D2CCFB1005D040030000025
534BEF4C36E08C4EBA008D405F0C994063BF080403000000
534BEF4C3720AC02B10E5D406250002159
```

Messages

Receiver Time Stamp Accuracy

- Real aircraft messages
- Time stamp from GPS module



- **1 σ accuracy: +/- 21 ns**
- **2 σ accuracy: +/- 46 ns**

Yet Another MLAT Field Test

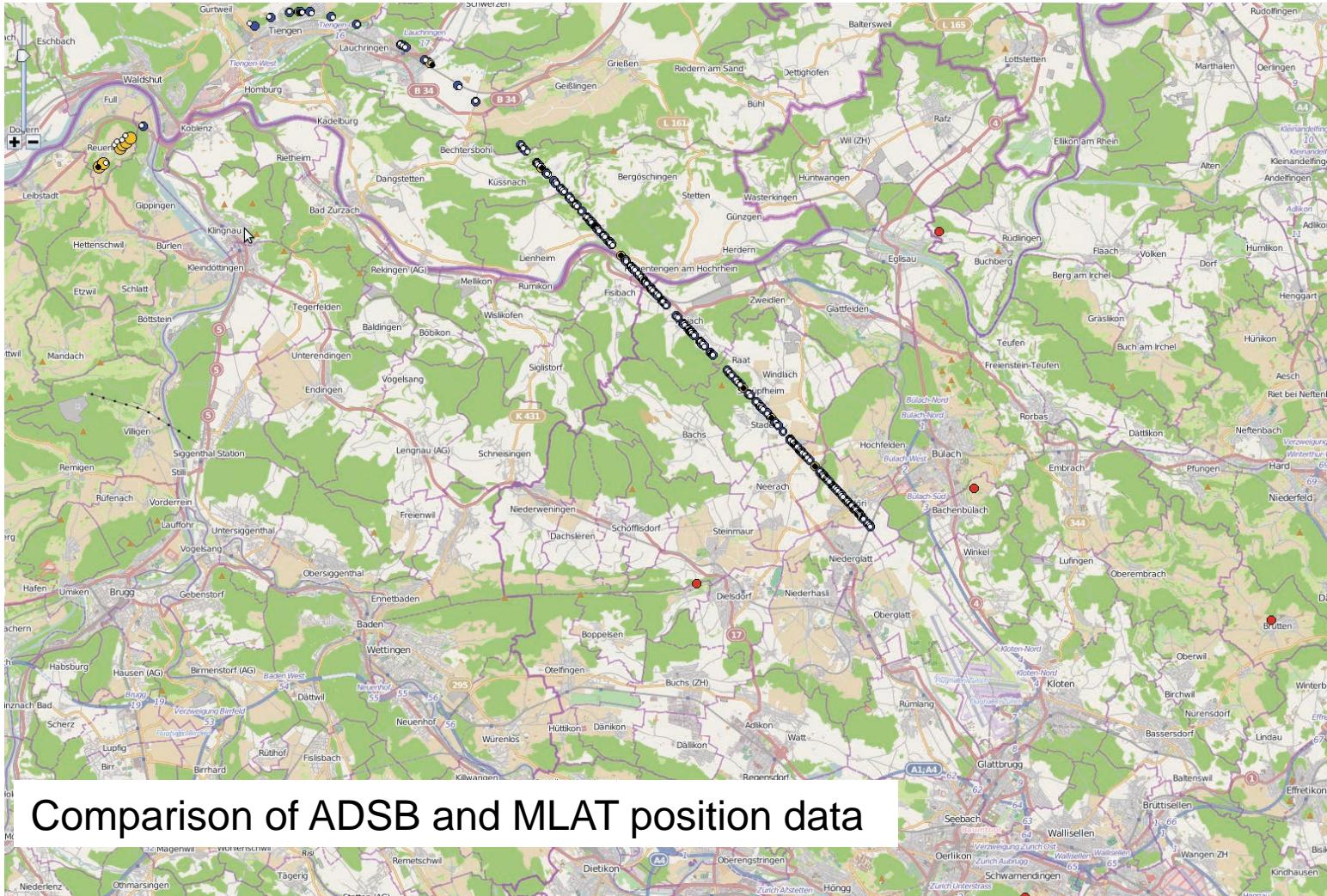
- Multiple field tests in February 2014
- Target area: Zurich airport
- Duration: 12 hours
- Each receiver records about 20 million messages



Field Test Configuration

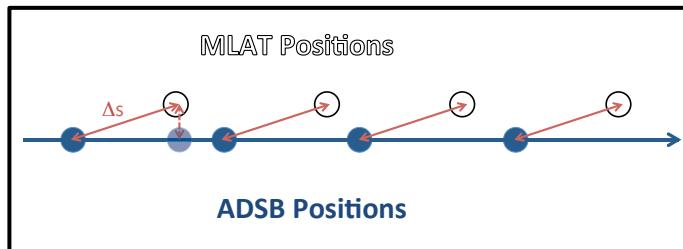


Multilateration Example – Landing Airbus A321

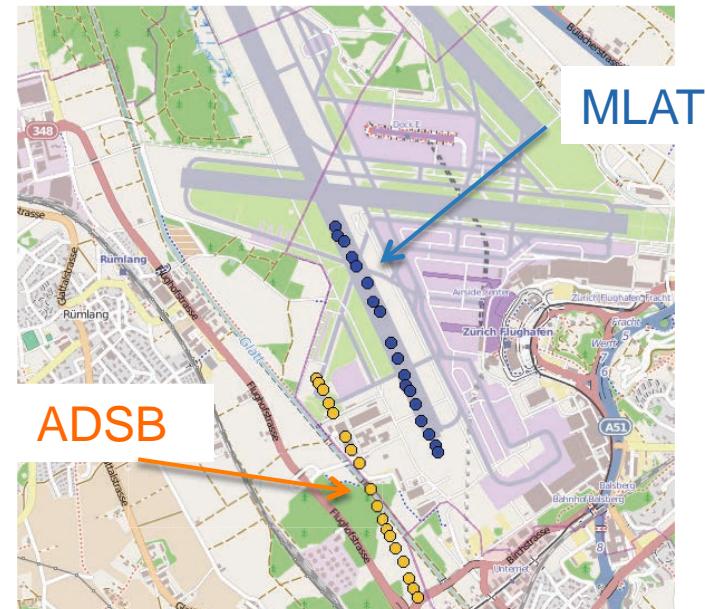


Challenge: Determining the System's Accuracy

- Idea: compare ADSB position data from aircraft with MLAT position data
- Critical issues
 - Aircraft feature a **random time delay up to 1 second** between determination and transmission of position
 - ADSB **aircraft position** can be **very inaccurate**



Impact of time delay



Inaccurate ADSB positions – B767 (1990)
Horizontal deviation > 300m

Calibration Flights with King Air A350

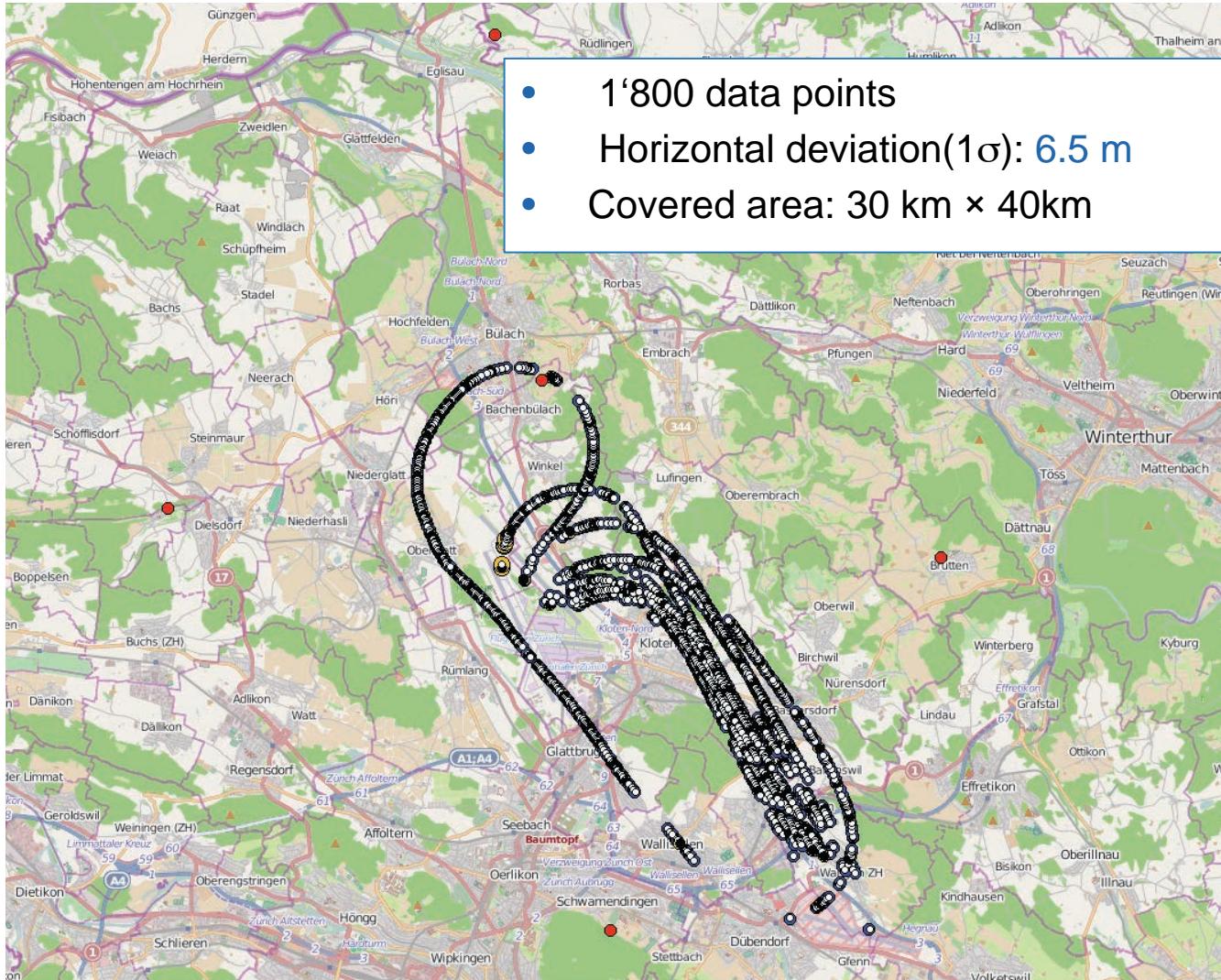
- FCS calibration flights
- Dates: February 25th and 27th
- Duration: 3 hours, 23:00 – 2:00
- Aircraft: B300 King Air A350
- Navigation Equipment
 - GPS with phase solution
 - Laser tracker
- Position accuracy: 2m
- GPS time



First Calibration Flight – Zurich Airport

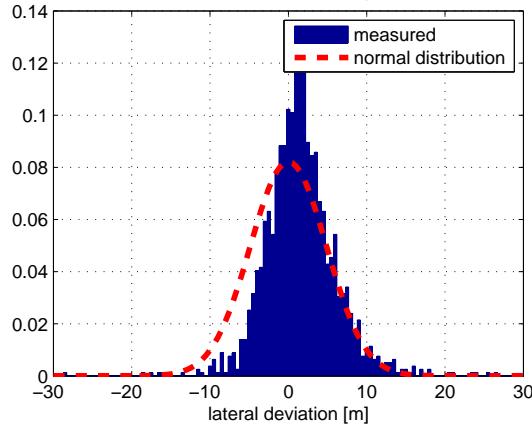


Multilateration Results

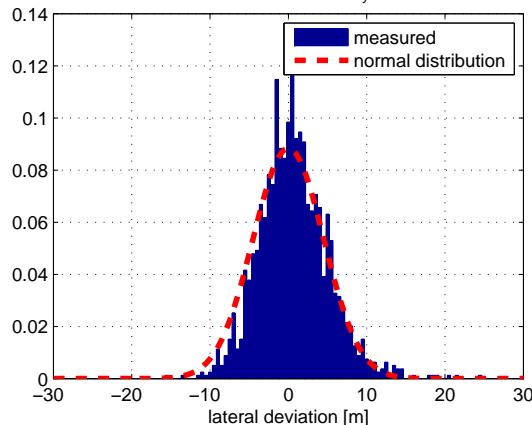


Multilateration Error Analysis

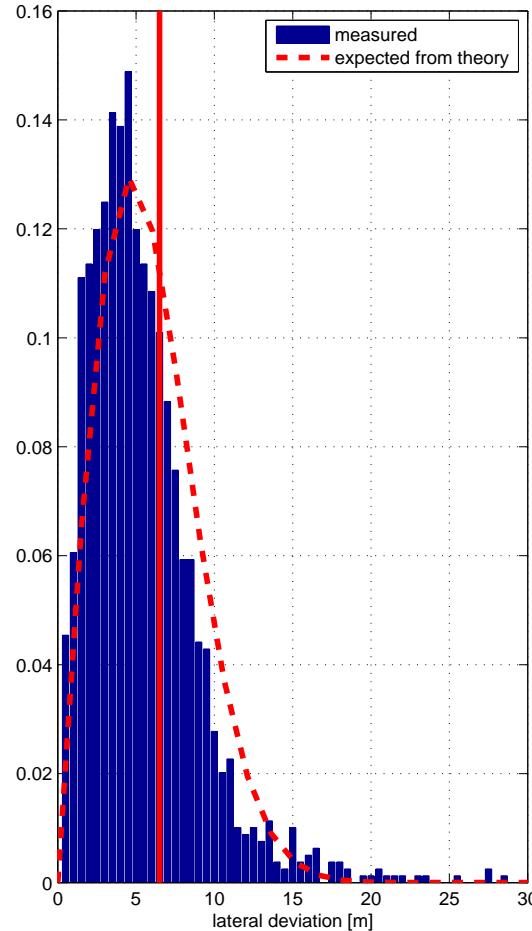
$\Delta X: \mu = 1.6m, \sigma = 4.9m, \rho_{xy} = 0.04$



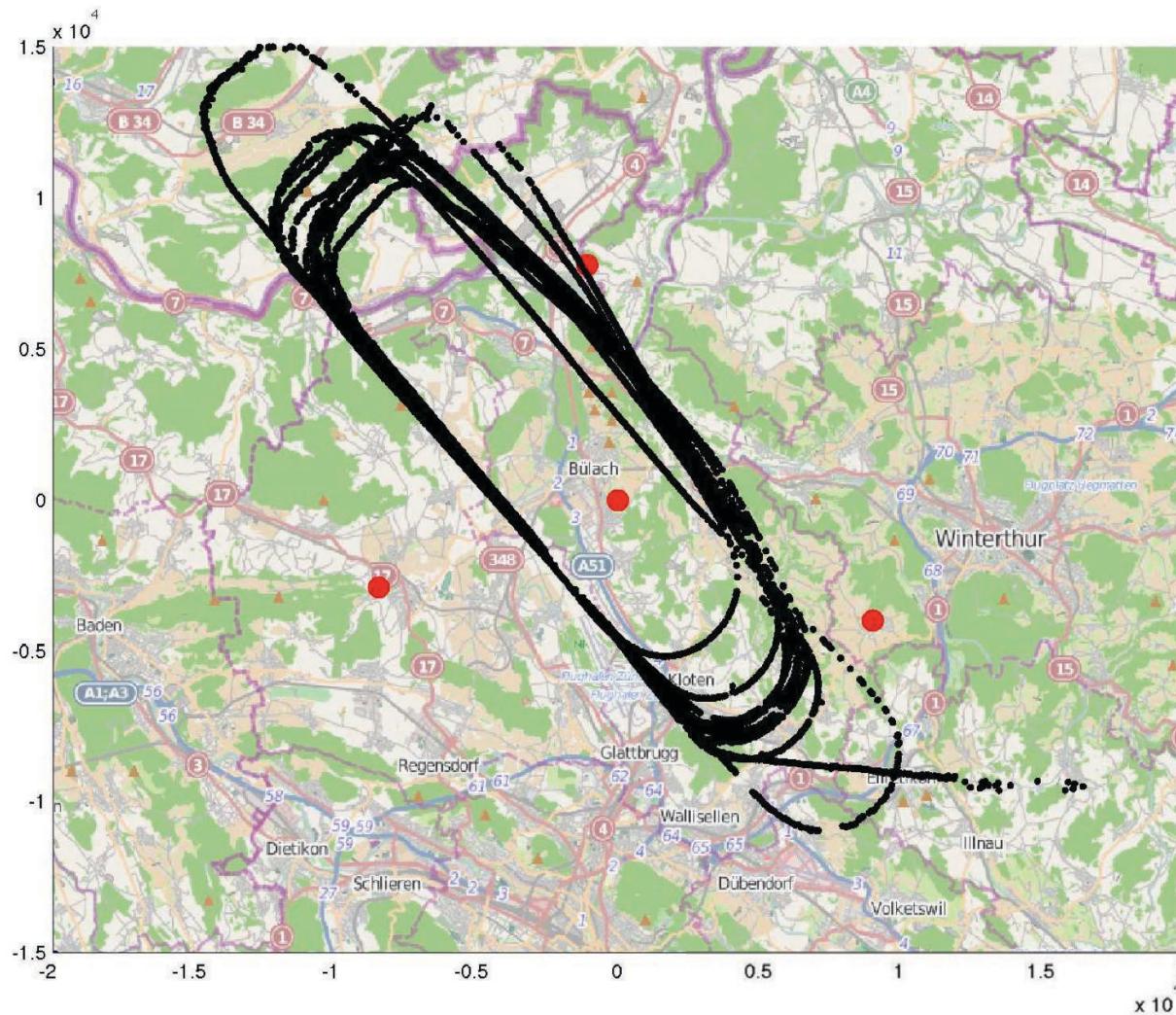
$\Delta Y: \mu = 0.7m, \sigma = 4.5m, \rho_{xy} = 0.04$



$\Delta s: \sigma = 6.5m$

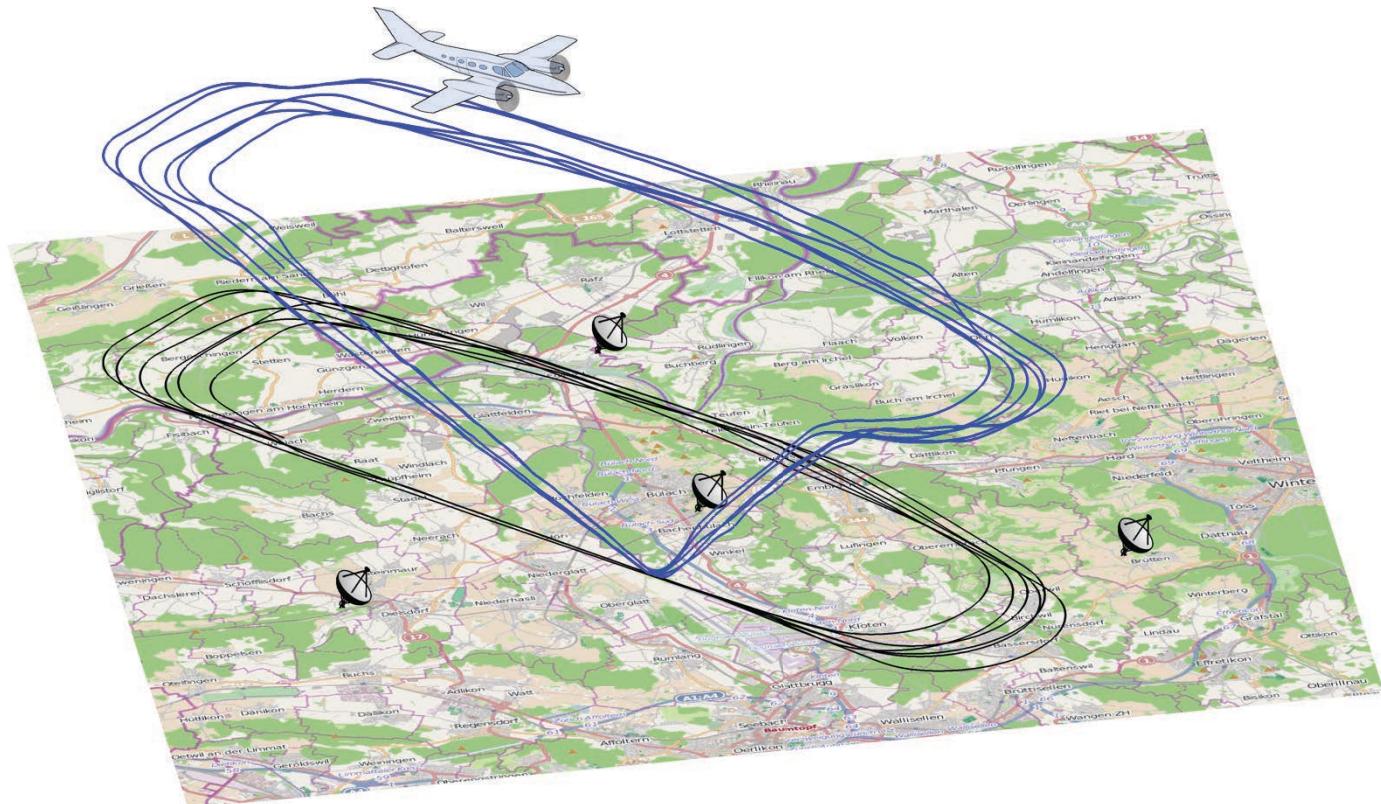


Second Calibration Flight – Zurich Airport

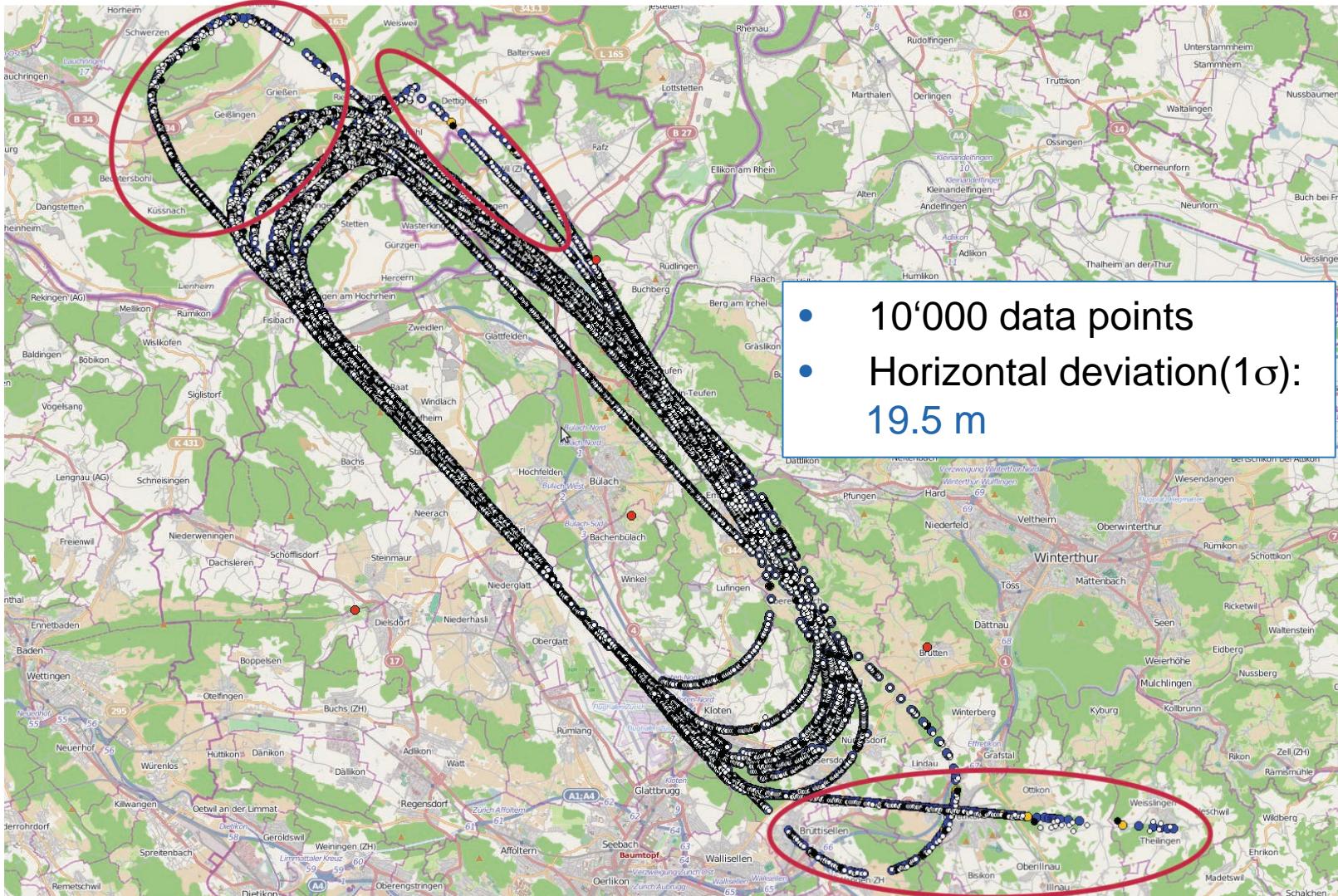


Covered area:
30 km × 40km

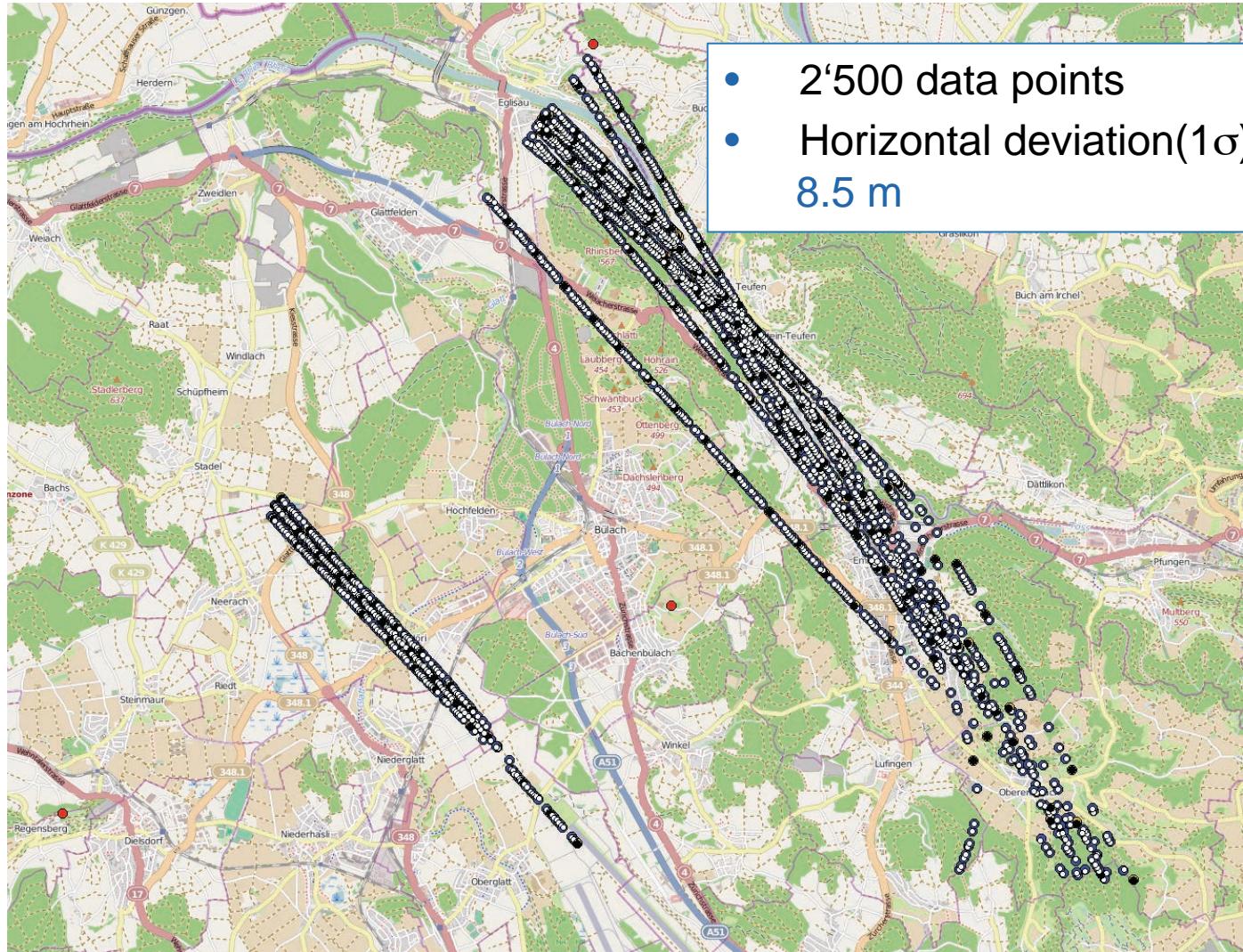
Second Calibration Flight (II)



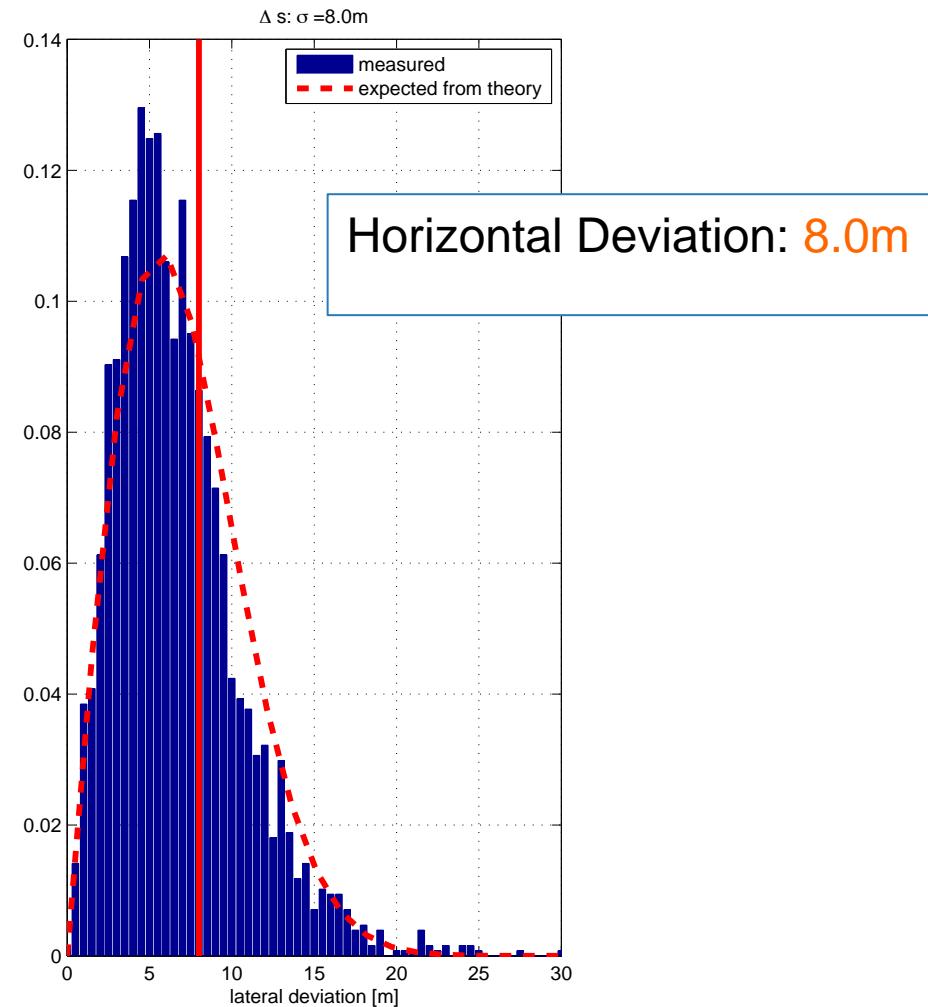
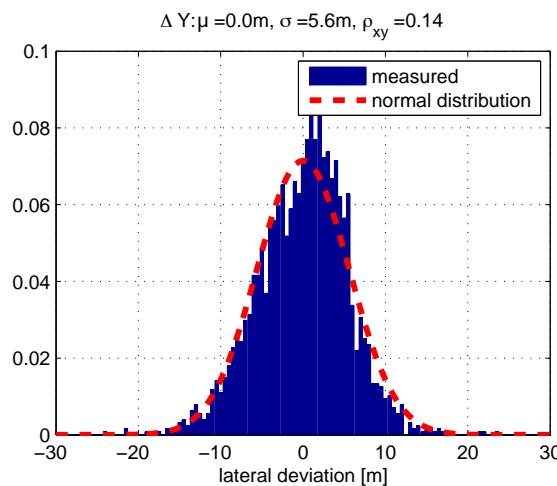
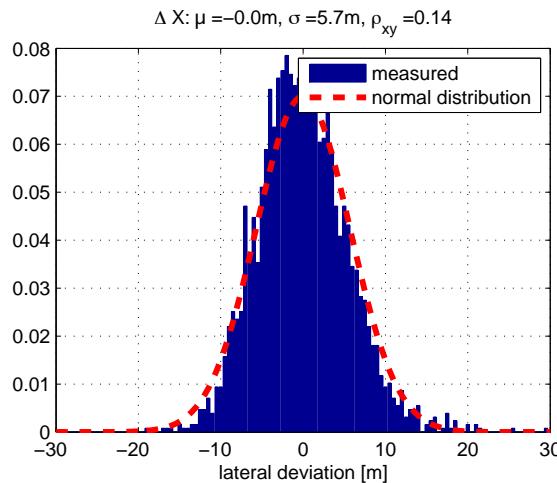
Multilateration Results (I)



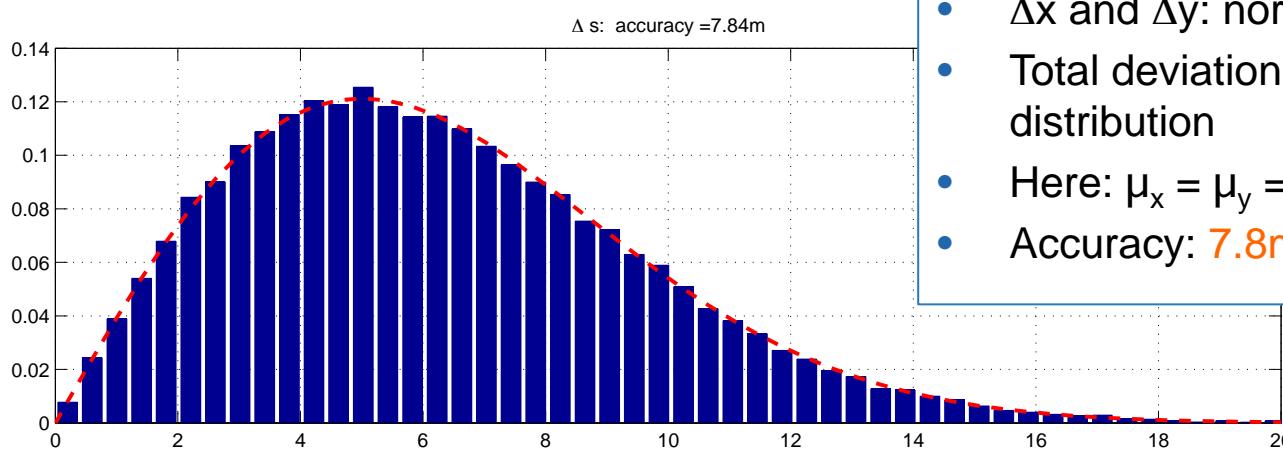
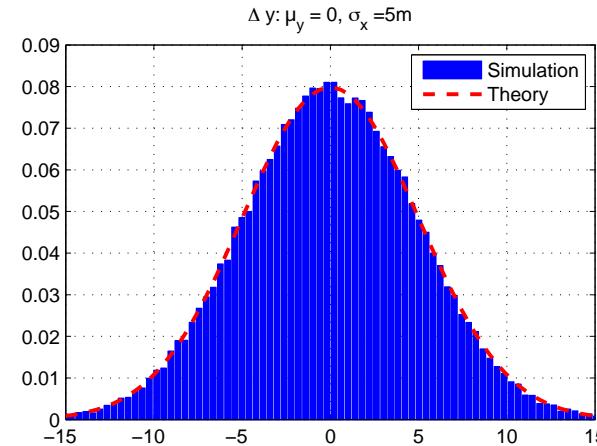
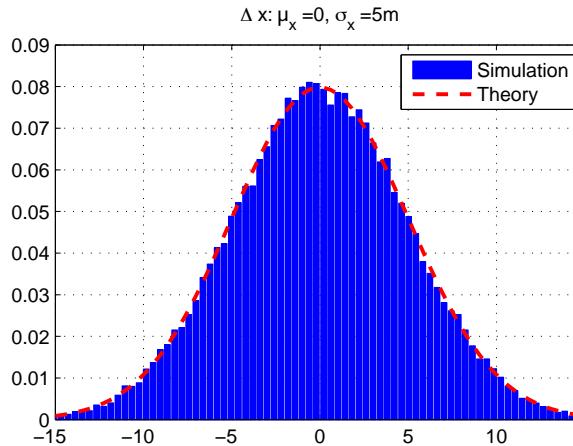
Multilateration Results (II)



Multilateration Error Analysis

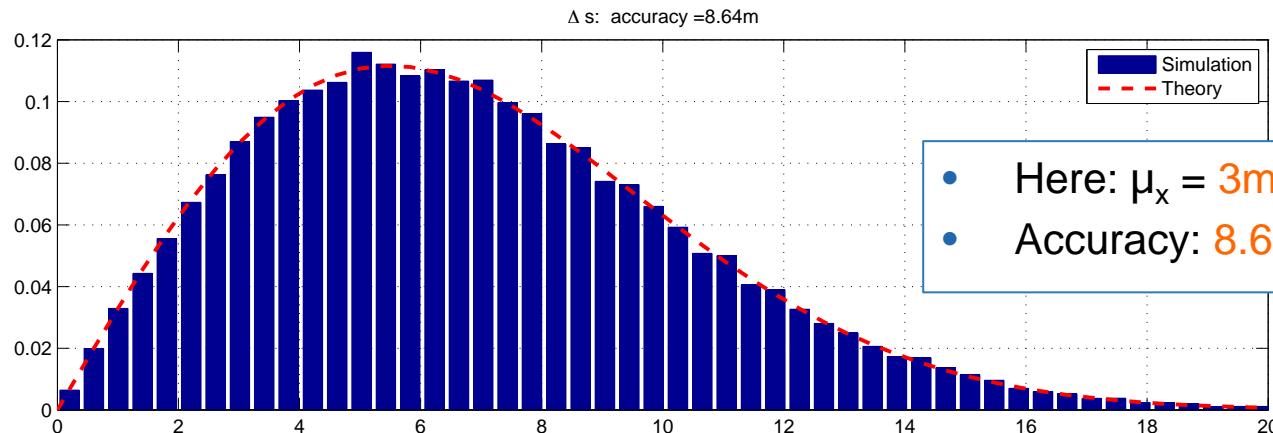
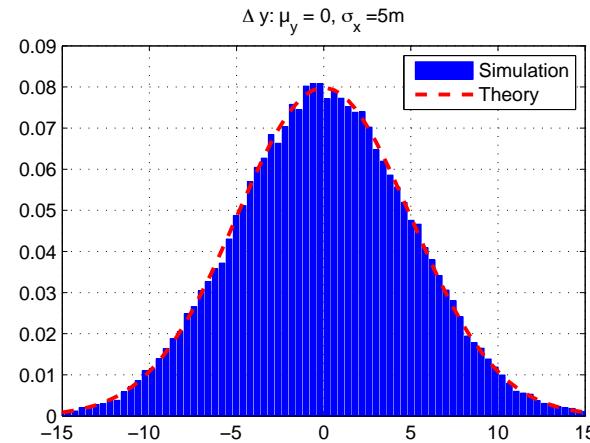
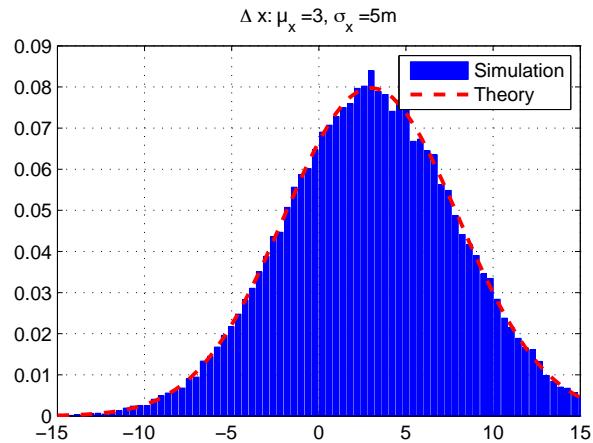


In-Depth Analysis of Lateral Deviation (I)

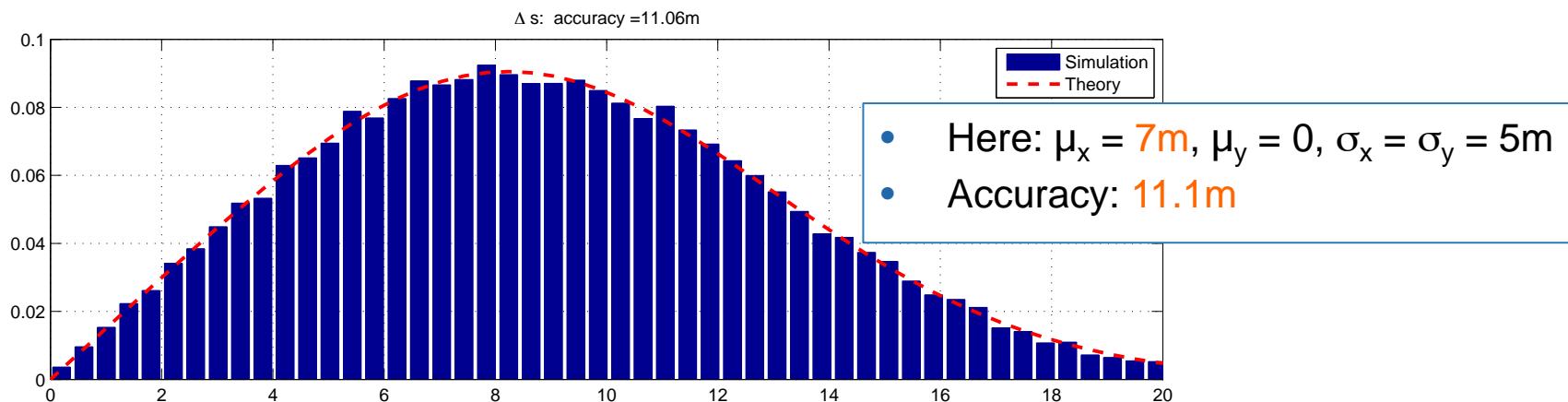
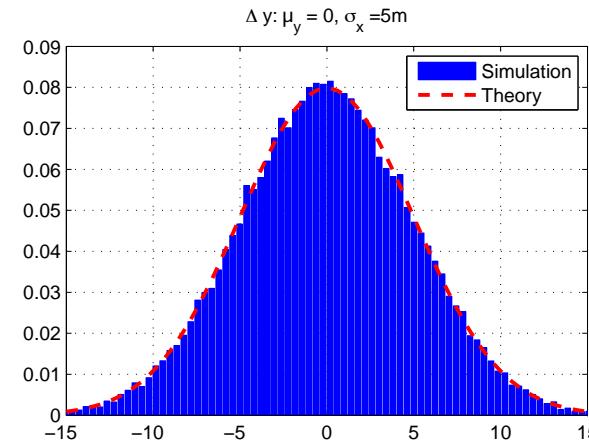
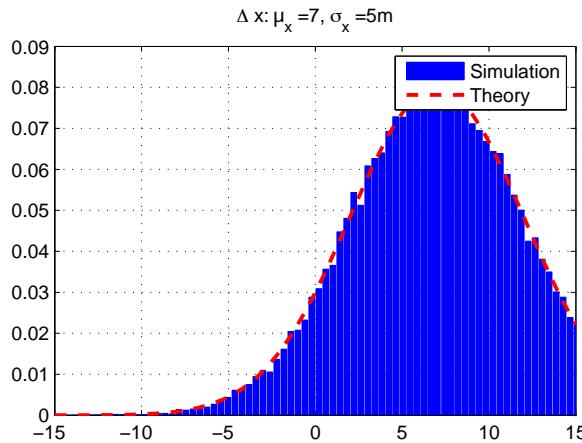


- Δx and Δy : normal distribution
- Total deviation Δs : no normal distribution
- Here: $\mu_x = \mu_y = 0, \sigma_x = \sigma_y = 5m$
- Accuracy: **7.8m**

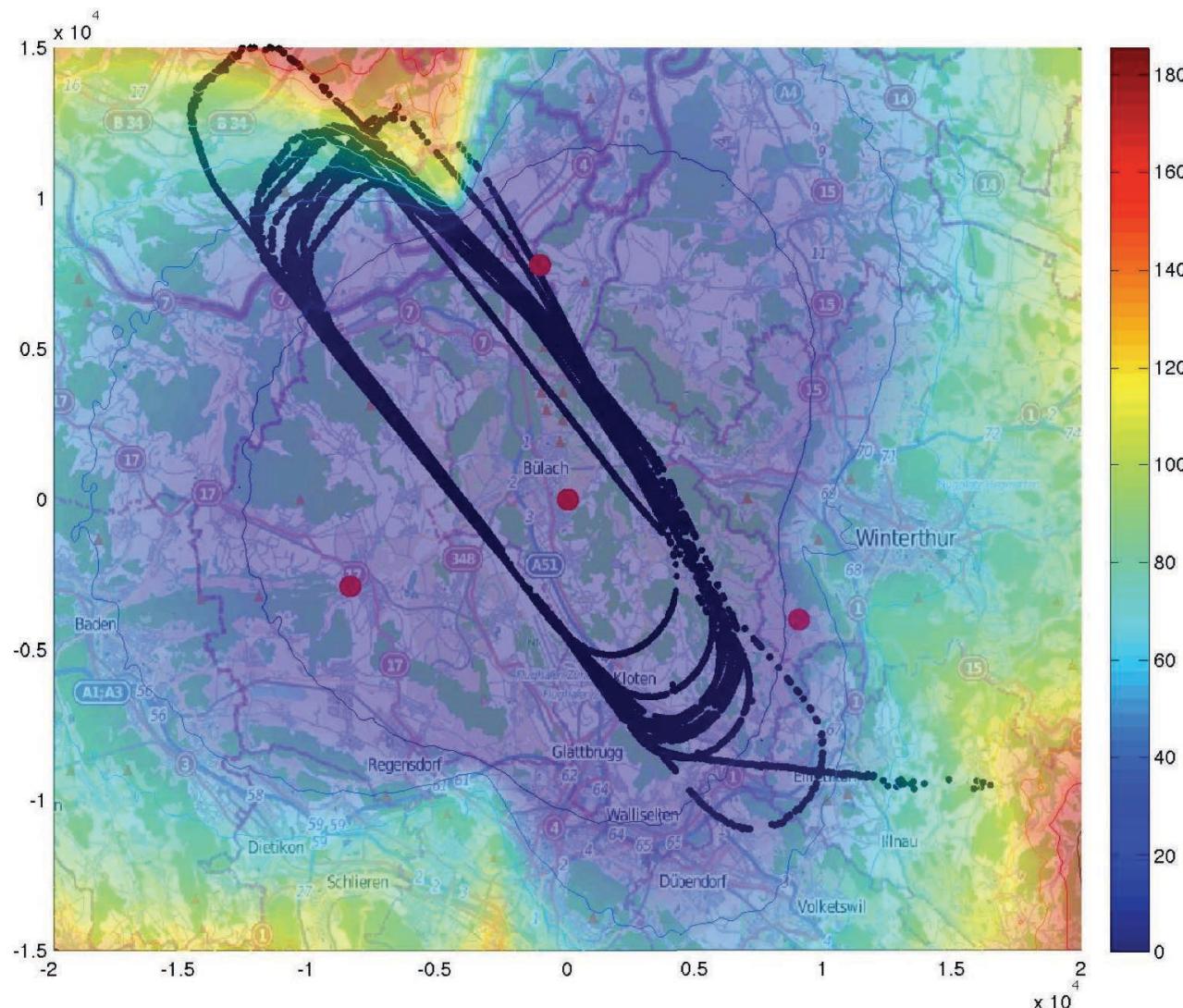
In-Depth Analysis of Lateral Deviation (II)



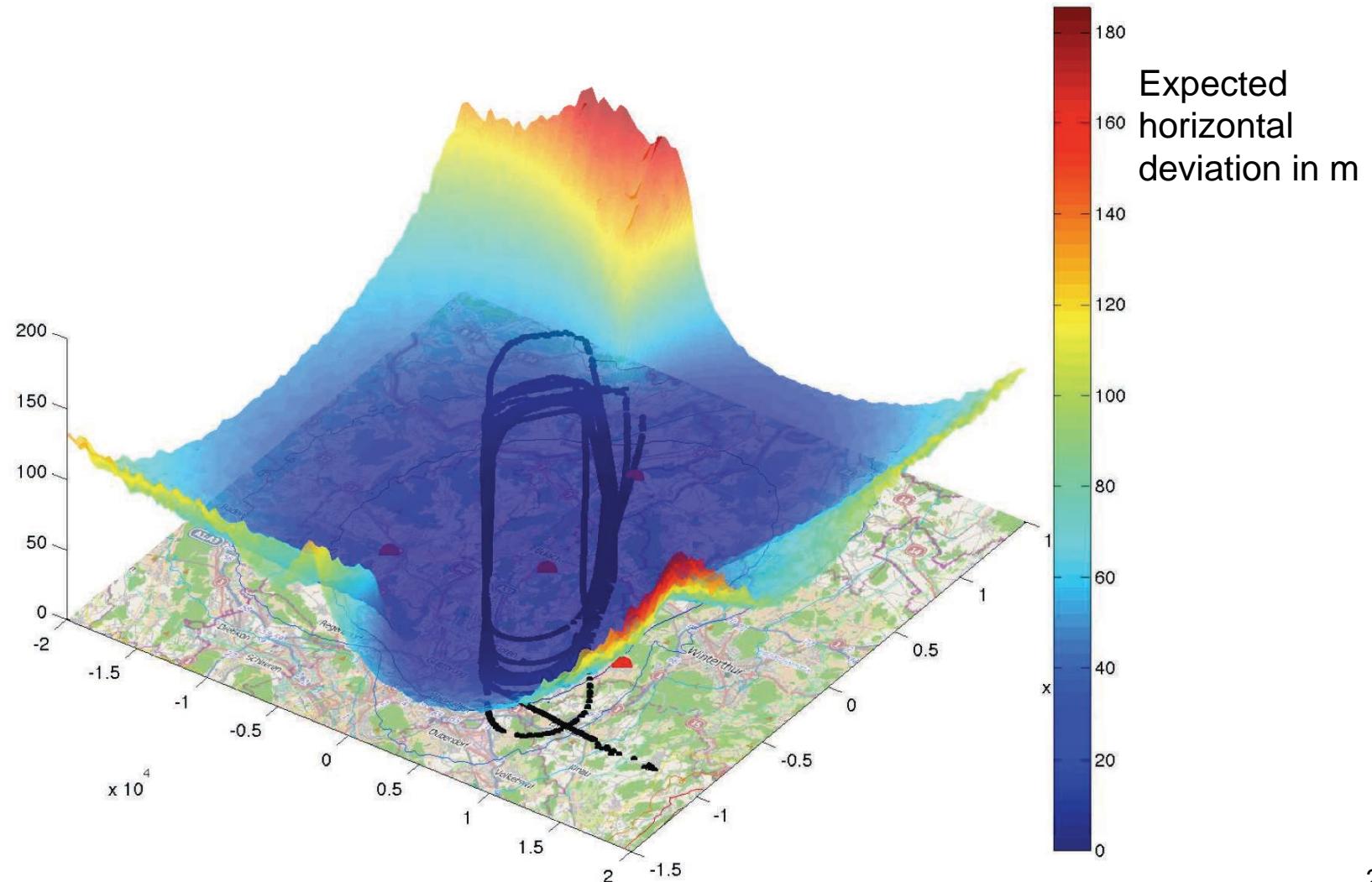
In-Depth Analysis of Lateral Deviation (III)



Expected System Performance (I)



Expected System Performance (II)



Outlook and Next Steps

- Next steps
 - Formal hand-over summer 2014
 - [Follow-up projects](#)
- Outlook
 - Critical system parameters
 - Receiver unit time stamps
 - Receiver locations
 - Aircraft location
 - Options to further boost the system performance
 - More accurate GPS time stamps
 - Increased number of receiver units

Contact

Project Leader: Dr. Martin Loeser

www.martinloeser.eu

martin@martinloeser.eu