Precise Point Positioning to support an automatic entering of a waterway lock

Ralf Ziebold, Xiangdong An, Christoph Lass
German Aerospace Centre
Institute of Communications and Navigation

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aufgrund eines Beschlusses des Deutschen Bundestages

R&D Project SciPPPer

SciPPPer (Lock maneuvering assistance system based on PPP and VDES for inland vessels)

Partners

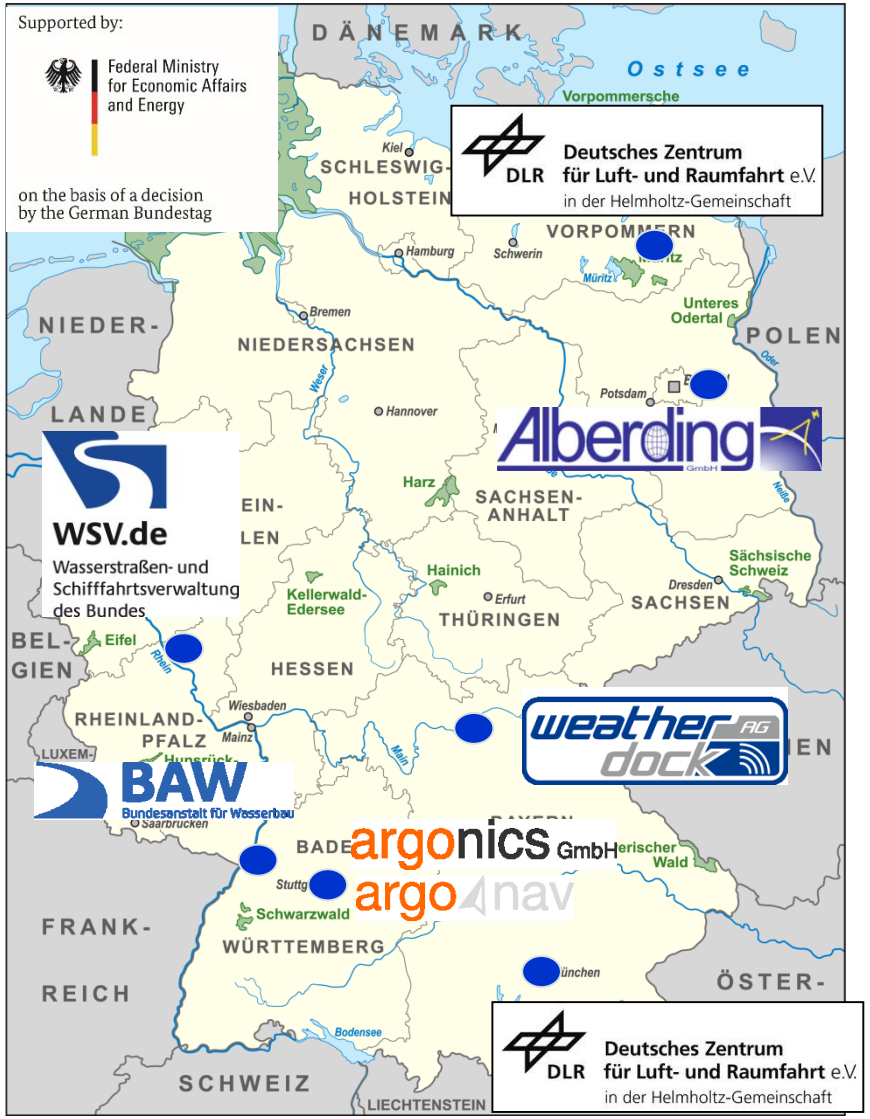
-Argonics GmbH
-Argonav GmbH
-Alberding GmbH
-Weatherdock AG
-German Aerospace Center (DLR)
-WSV (Traffic Technologies Center)
-BAW (Federal Waterways Engineering and Research Institute)

Funding

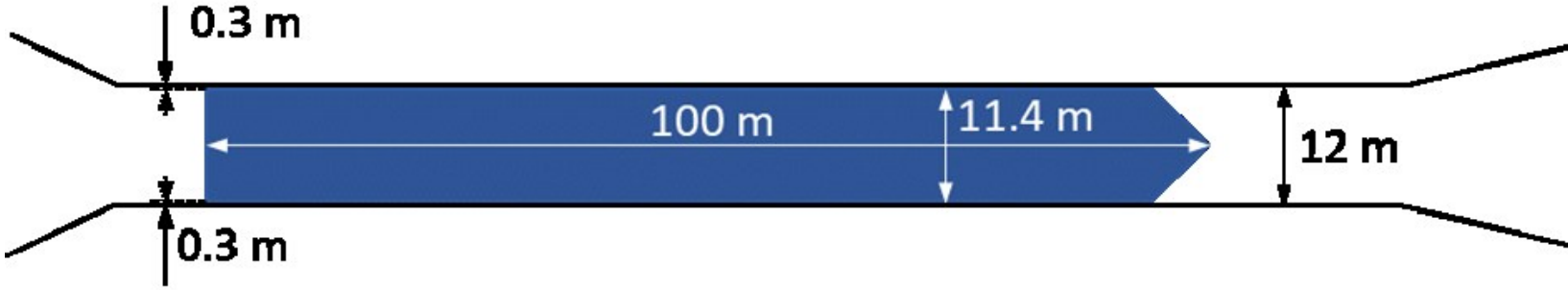
German federal ministry for economic affairs and energy

Duration

11/2018 – 02/2022

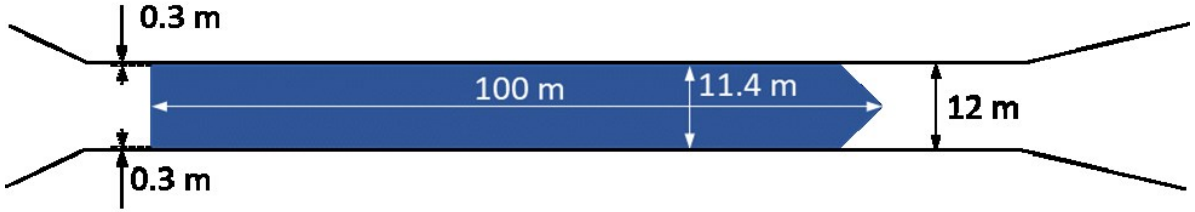


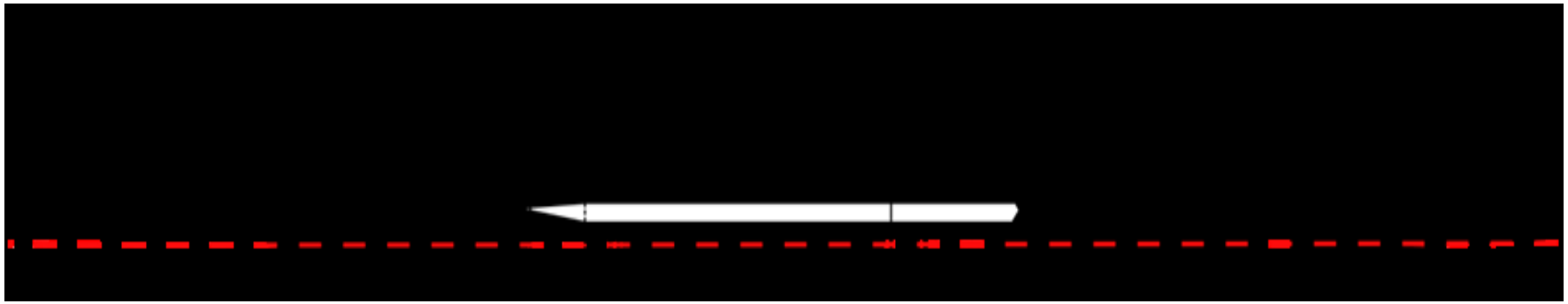
Project topics Overview



- Precise + reliable control of rudder + engine + thrusters
- Highly accurate + reliable determination of ships PNT data:
  - Position
  - Heading
  - Velocity
- Reliable communication channel with sufficient bandwidth shore – ship
- Simulation based testing
- HMI

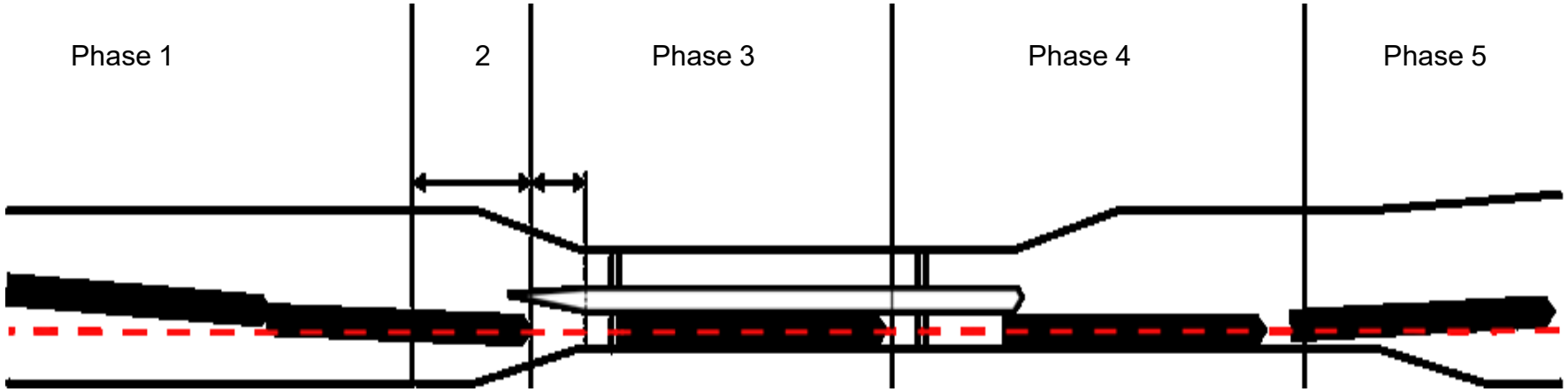
PNT Requirements





	Phase 1,5	Phase 2	Phase 3, 4
Positioning accuracy [cm]	10	1 (Bow), 10 (Stern)	1
Heading accuracy [°] L=100m	11°/L 0.1°	11°/L 0.1°	0.5°/L 0.005°
Velocity [cm/s]	1	1	1

Combination of global and local postioning for automated entering of waterway locks

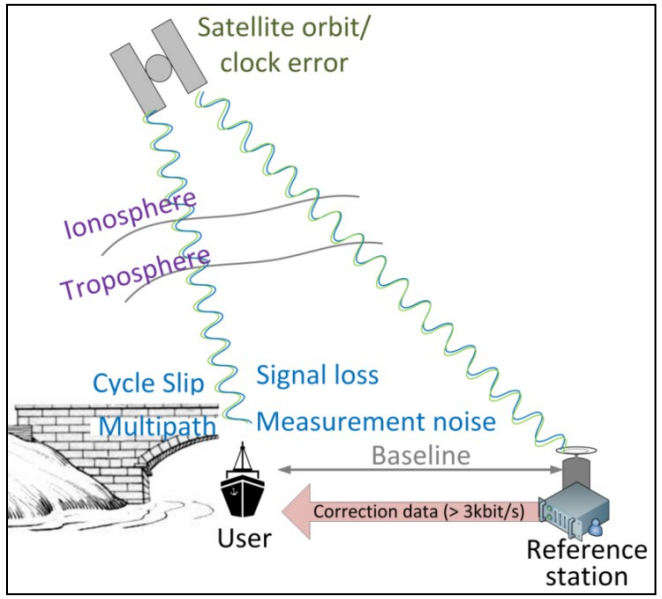


GNSS	**GNSS** + Near field sensors	**Near field sensors** + GNSS	Near field sensors + GNSS	**GNSS**

GNSS phase based positioning

Relative Positioning

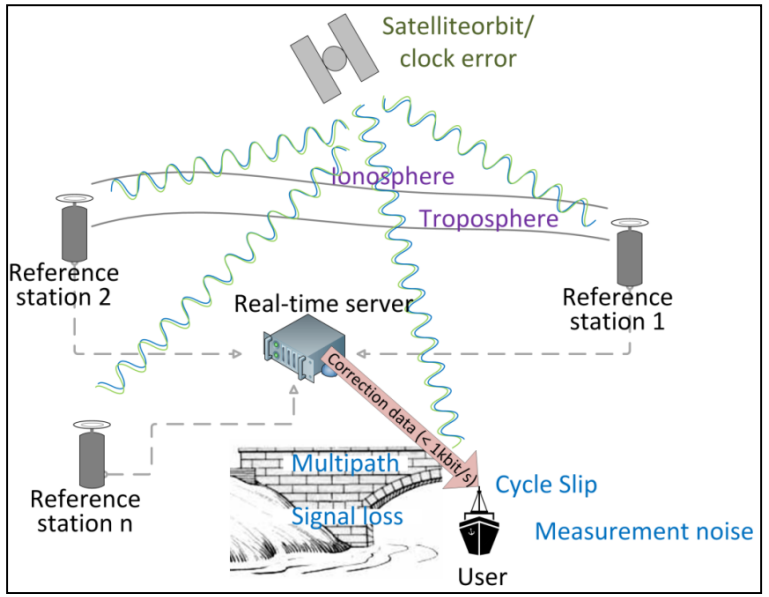
RTK



- Local **OSR** correction
- Double Diffences eliminate most of the errors
- cm-accuracy after several seconds

Absolute Positioning

PPP

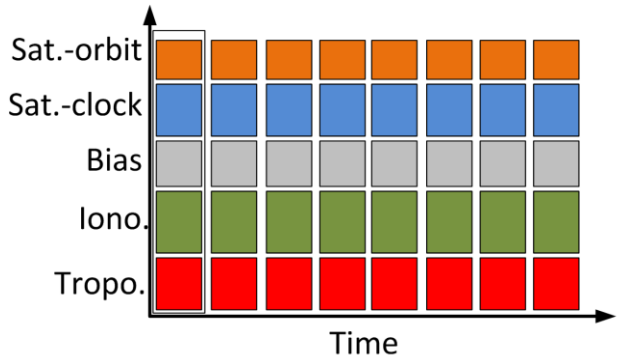


- Regional /global **SSR** correction
- Accurate modelling of single errors sources
- dm-cm accuracy after several minutes

Kind of Correction data

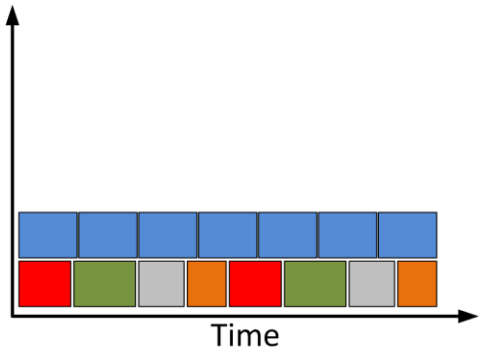
Real Time Kinematic (RTK)

- OSR (Observation state representation)
- For every observation one correction (every frequency, every satellite)
- Big amount of data (> 3 kbits/s)
  linear increasing with increasing number of satellites (GPS, GLONASS, Galileo, Beidou)
- Service area < 10 km
- Two way communication channel required
- Standardized (RTCM 3.1x)

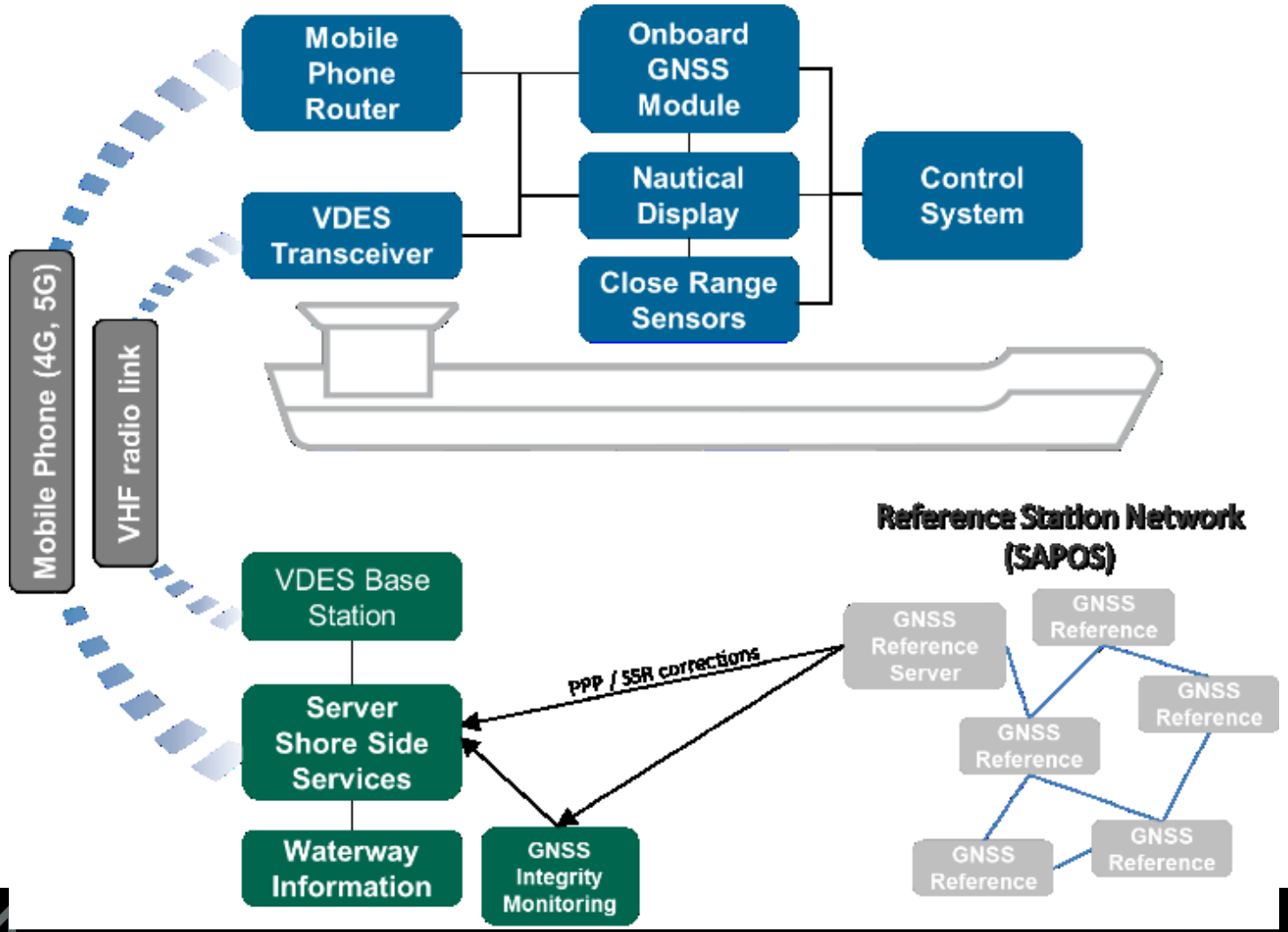


Precise Point Positioning (PPP)

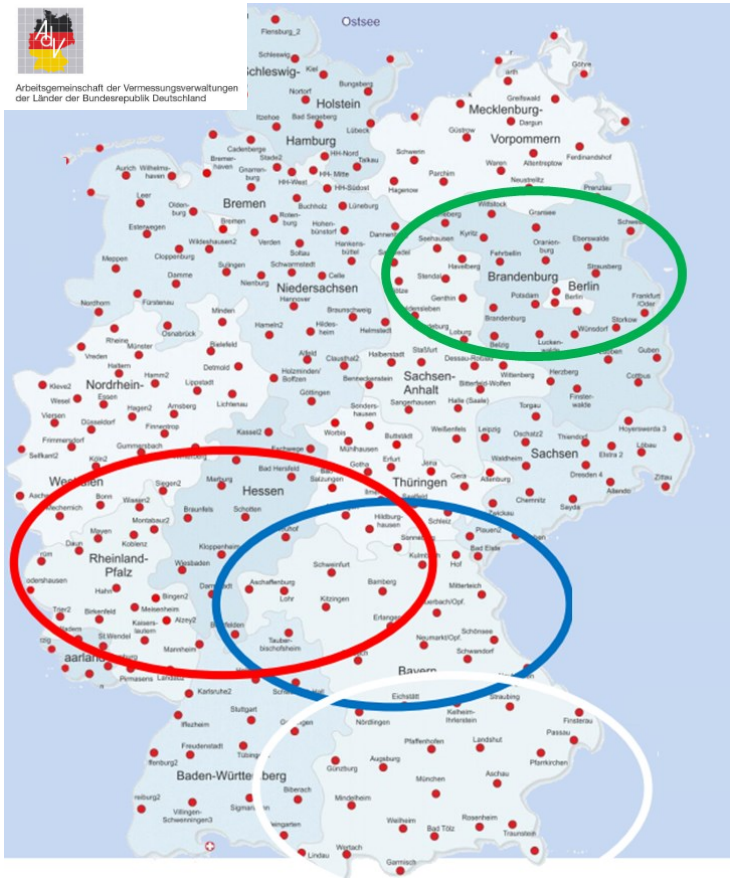
- SSR (Space state representation)
- Split in different error components (clock, orbit, troposphere, ionosphere..)
- Less amount of data (~ 1 Kbits/s)
  => VDES broadcast capable
- Service area >100 km range
- Not (fully) standardized



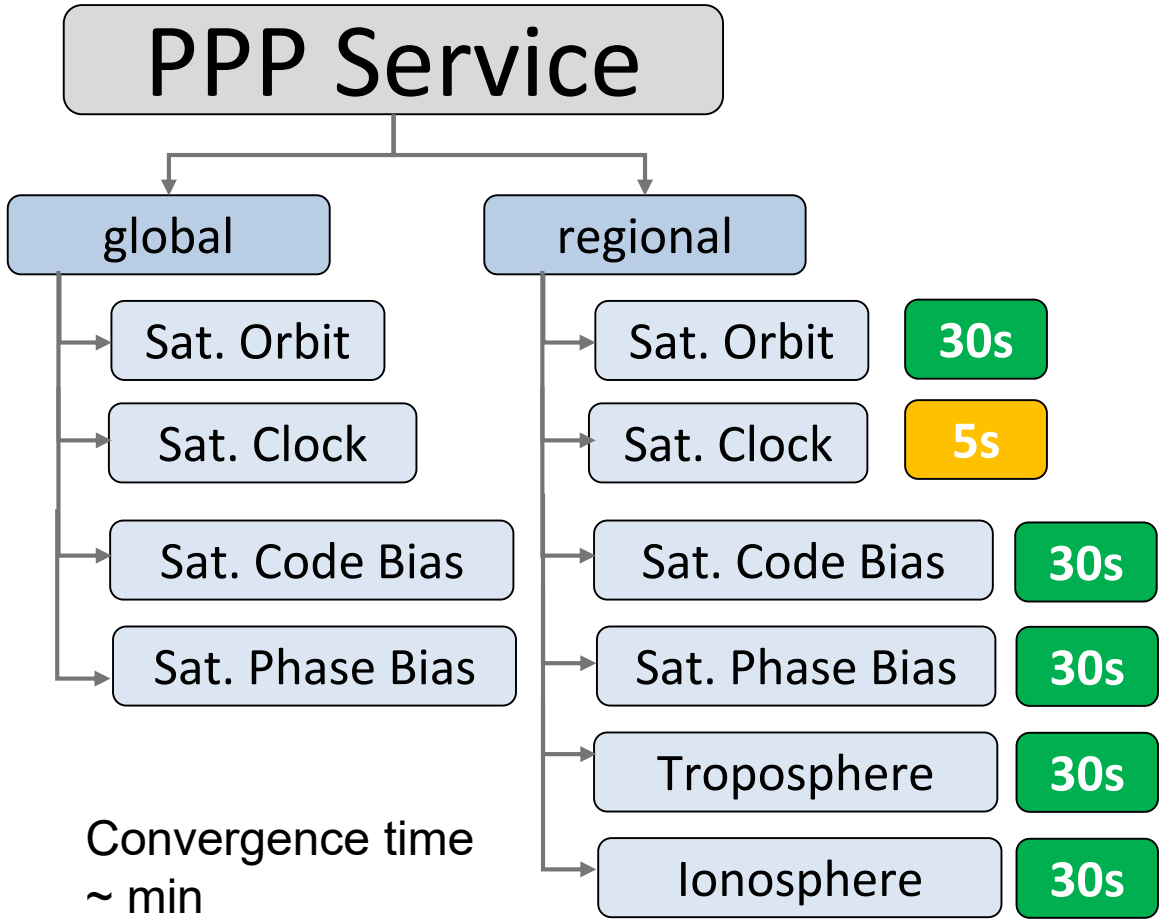
SCIPPPER System concept



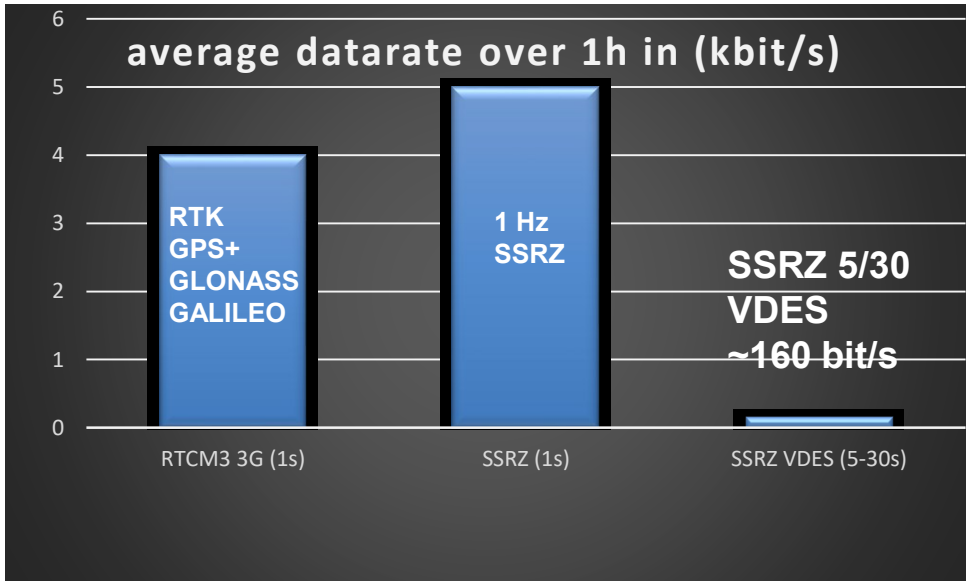
SAPOS reference station network with SSR service areas



Overview PPP Services



Optimization of data rate for inland vessel applications



PPP Mathematical Model

Recover the integer feature of the estimated float ambiguity by a single-difference algorithm between two satellites. (Remove the effects of reciver phase bias)

Estimated float ambiguities

$\widetilde{N}_w^i\ \widetilde{N}_w^j\ \widetilde{N}_w^k\ \widetilde{N}_w^l\ \ldots$ → SD

$\widetilde{N}_1^i\ \widetilde{N}_1^j\ \widetilde{N}_1^k\ \widetilde{N}_1^l\ \ldots$ → SD

Derived amb with a integer feature

$\widetilde{N}_w^{ij} = N_w^{ij}$

$\widetilde{N}_w^{ik} = N_w^{ik}$

$\widetilde{N}_w^{il} = N_w^{il}$

$\vdots$

$\widetilde{N}_1^{ij} = N_1^{ij}$

$\widetilde{N}_1^{ik} = N_1^{ik}$

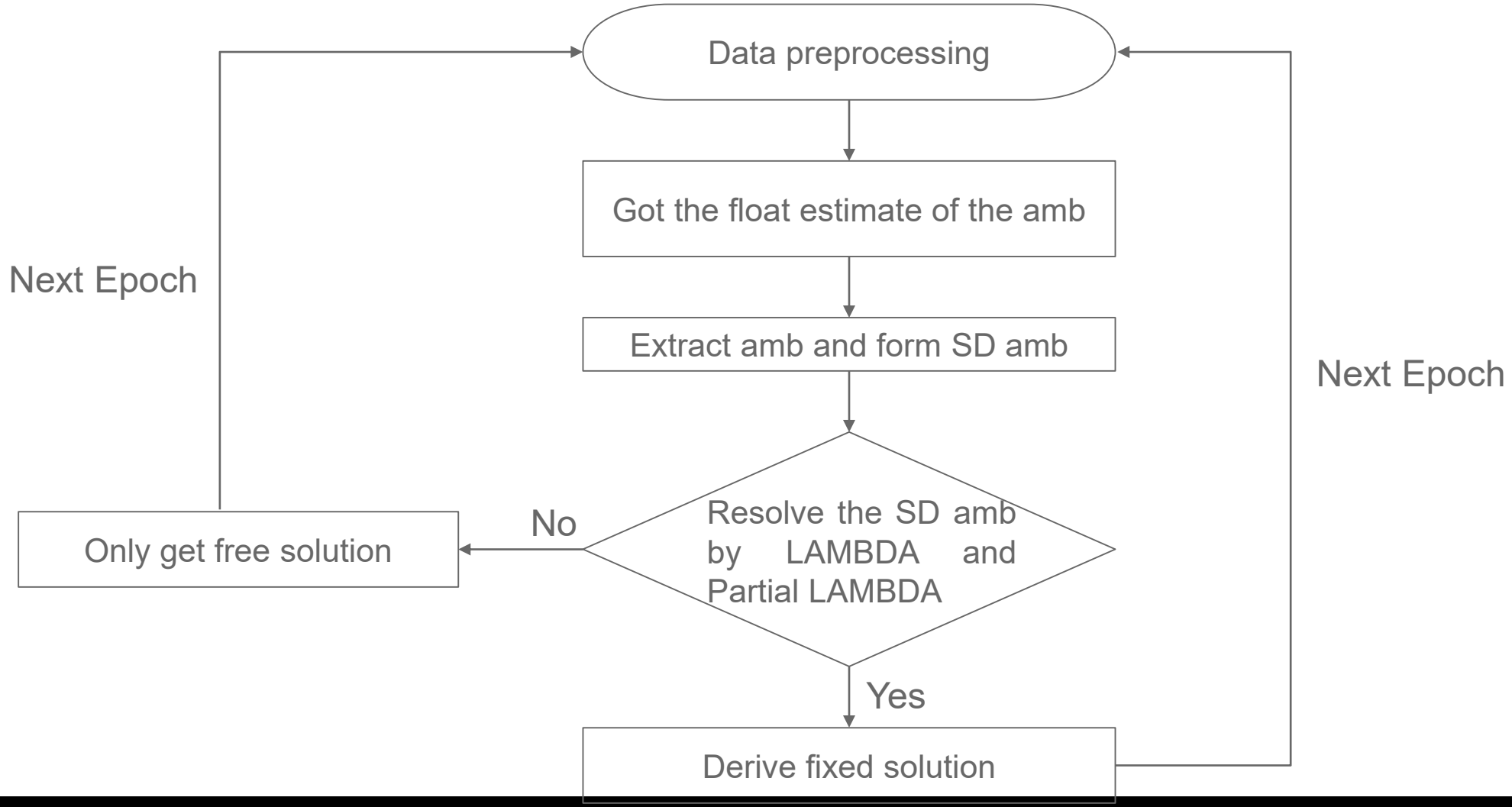
$\widetilde{N}_1^{il} = N_1^{il}$

$\vdots$

→ Resolved by LAMBDA[1] and Partial LAMBDA

[1]. Teunissen, P. (2006). The LAMBDA method for the GNSS compass. Artificial Satellites, 41(3), 89-103.

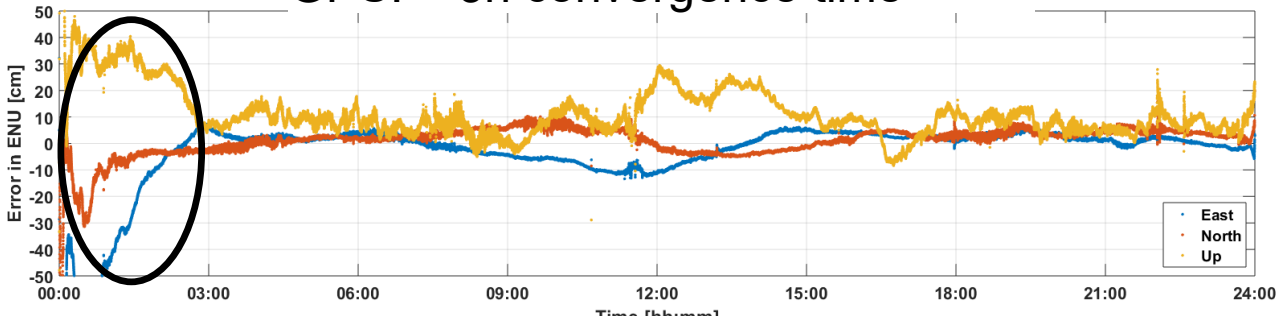
Scheme of PPP Data Processing



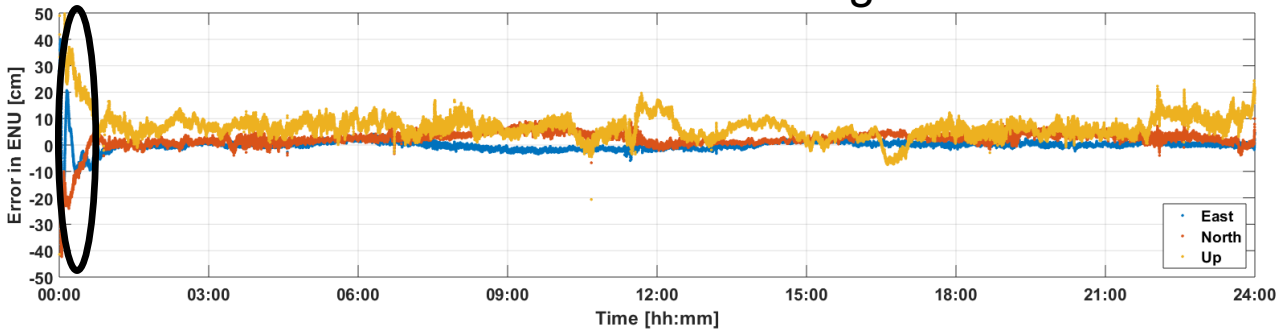
PPP Results: Reduction of convergence time

Classical PPP – only global corrections (float)

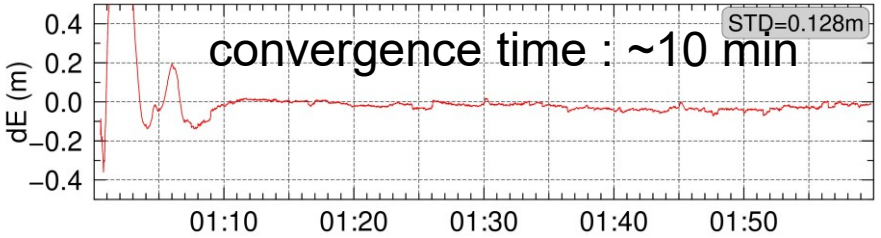
GPS: ~ 3h convergence time



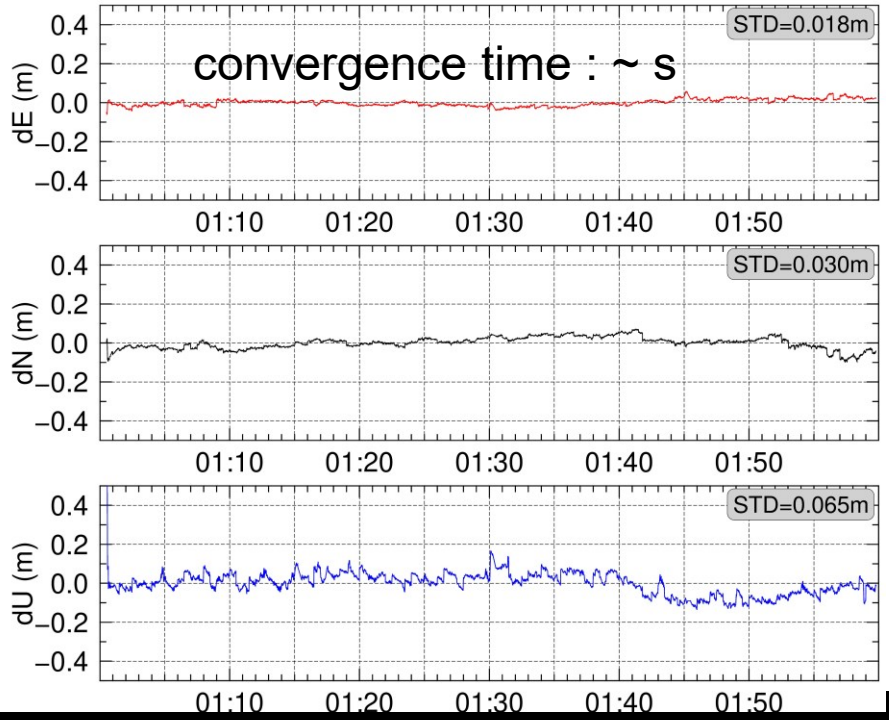
GPS + GALILEO: ~ 30min convergence time



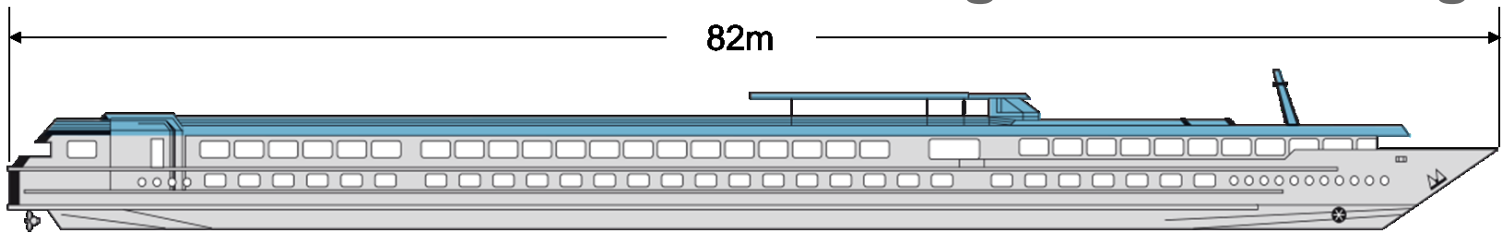
PPP-RTK float SAPOS SSR corrections

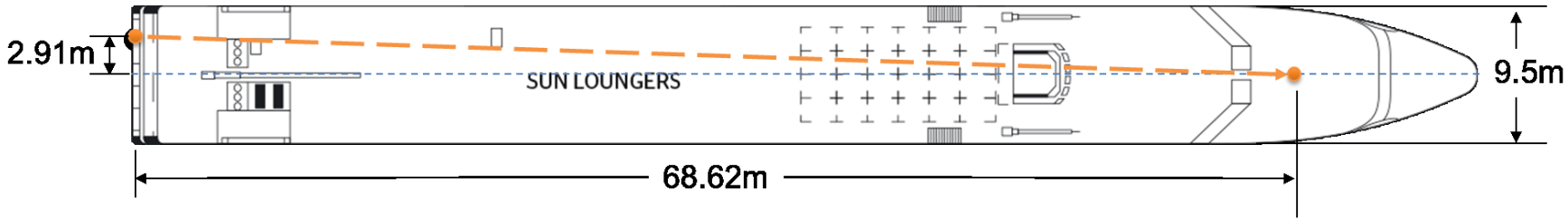


PPP-RTK fix SAPOS SSR corrections

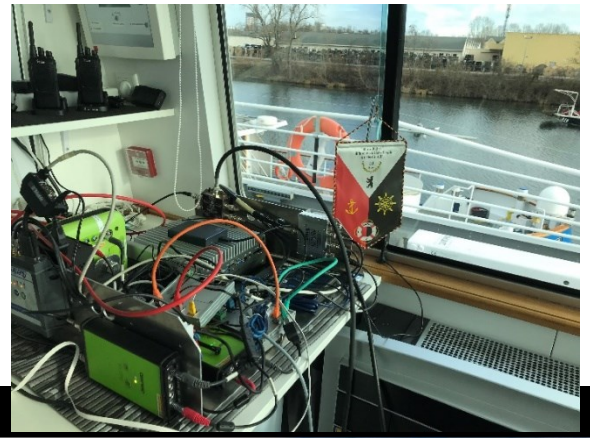


Real Demonstration with Vicor Hugo in Strasbourg : Setup

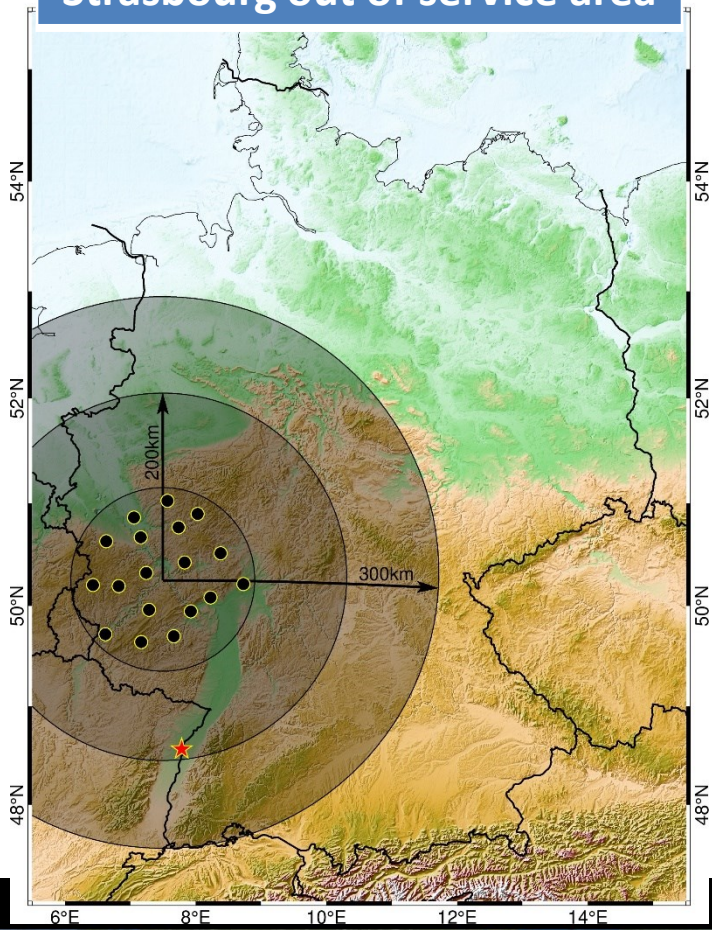




Stern Antenna Receiver + PNT Unit Bow Antenna

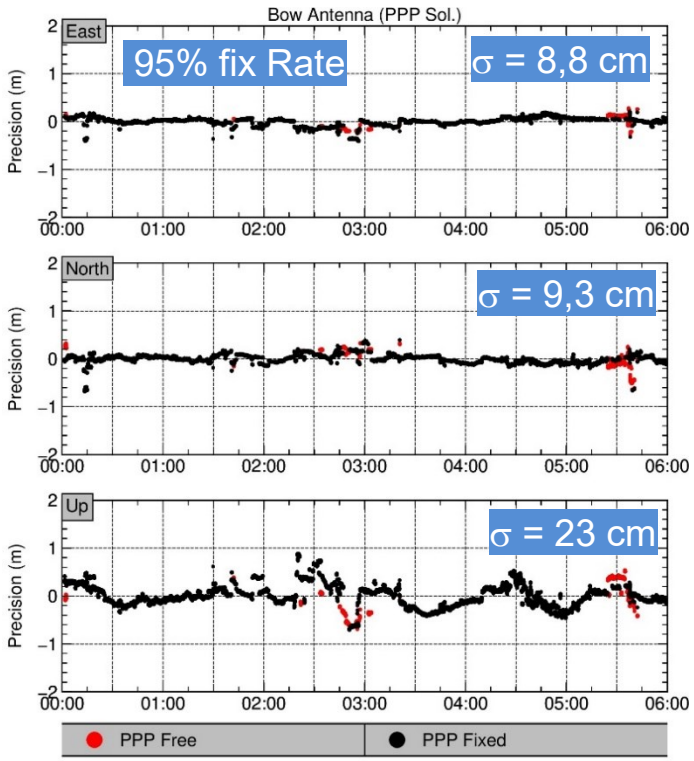


Strasbourg out of service area



Real demonstration with ‚Victor Hugo‘: static results

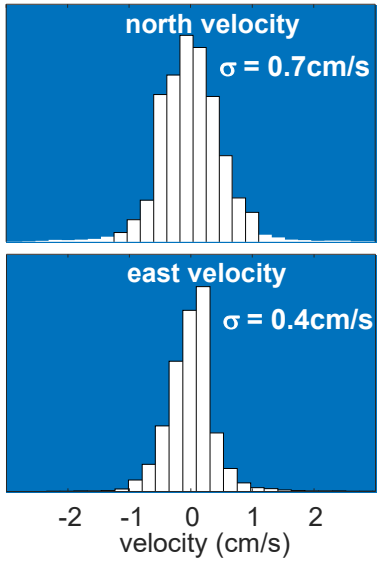
PPP Positioning



Significant worse than in service area

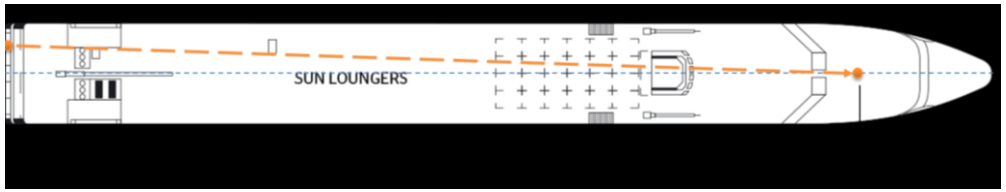
Velocity

Measurement by GNSS phase changes in PPP- KF

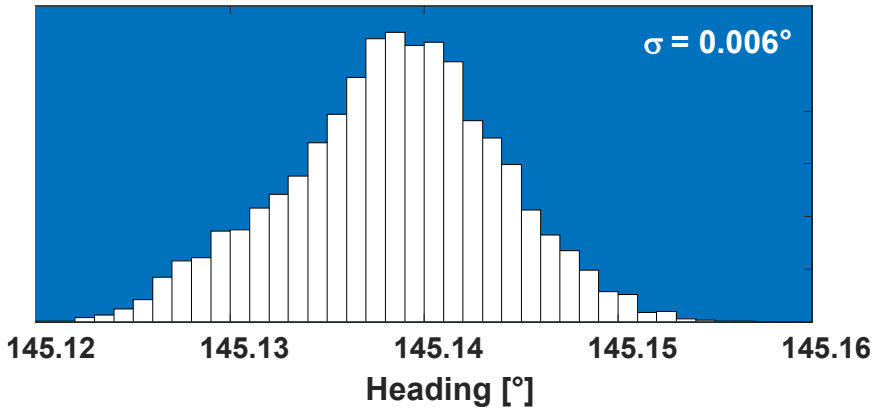


Meets requiremets of 1cm/s

Orientation (heading)



Loosely coupled Kalman Filter
RTK between Antennas
+ z - turnrate MEMS IMU

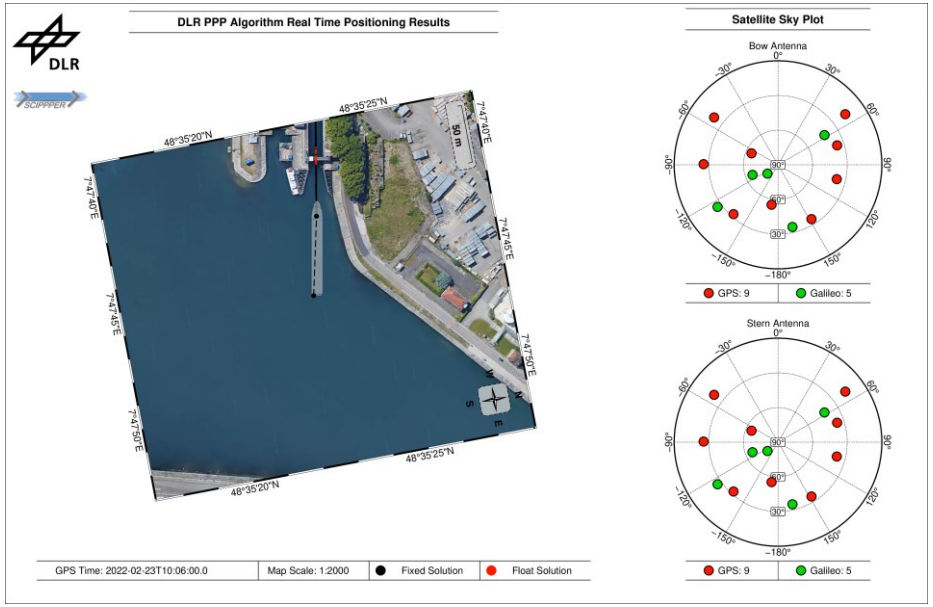


Meets requirements of 0.5° / L for L=85m

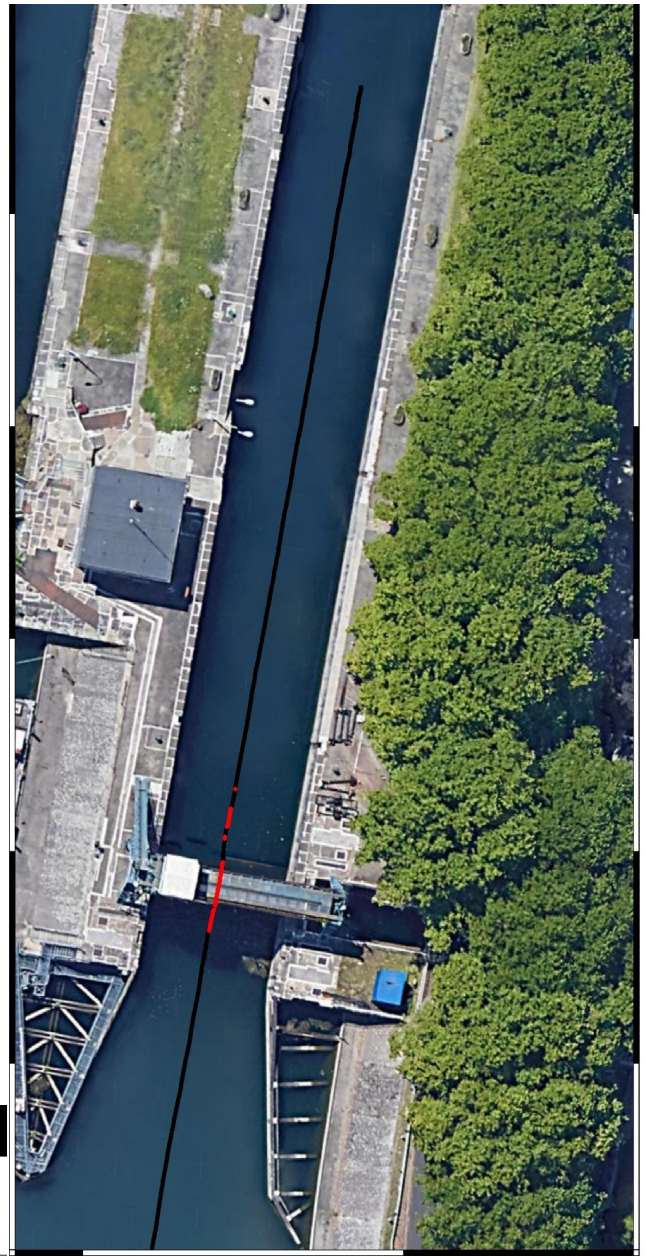
Real Demonstration with MS Victor Hugo

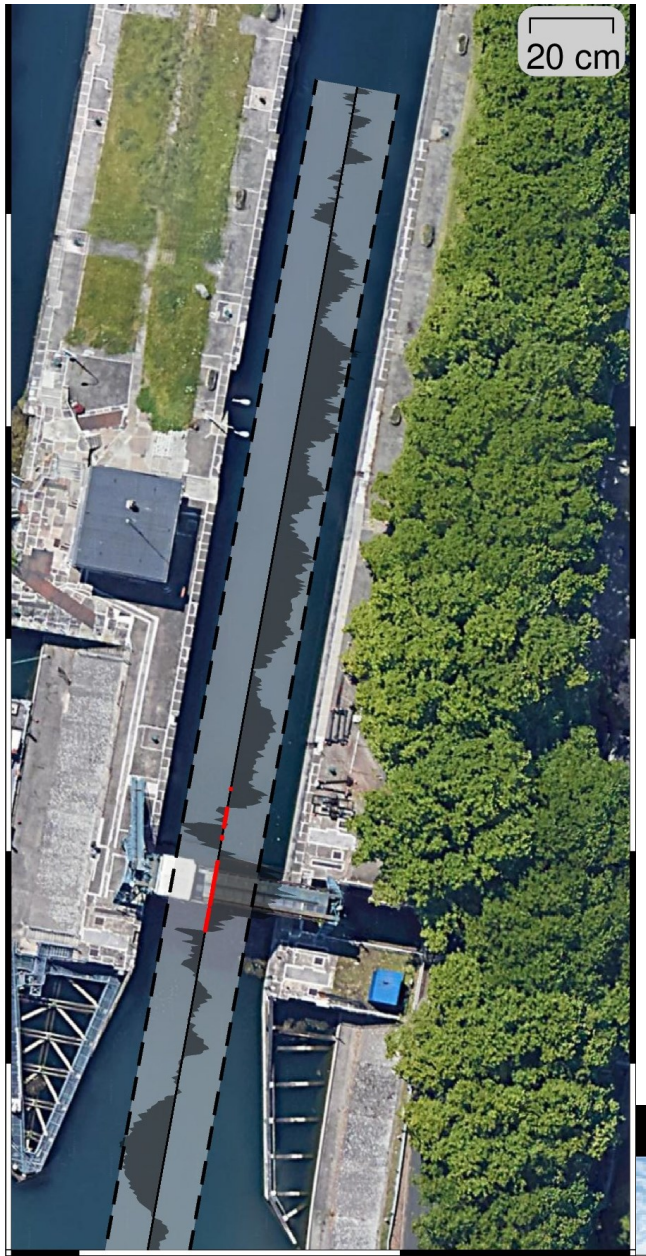
Real Demonstration with ‚Victor Hugo‘

Overview test area and ship route



Real Demonstration with ‚Victor Hugo‘: dynamic results





First automatic entering of the lock

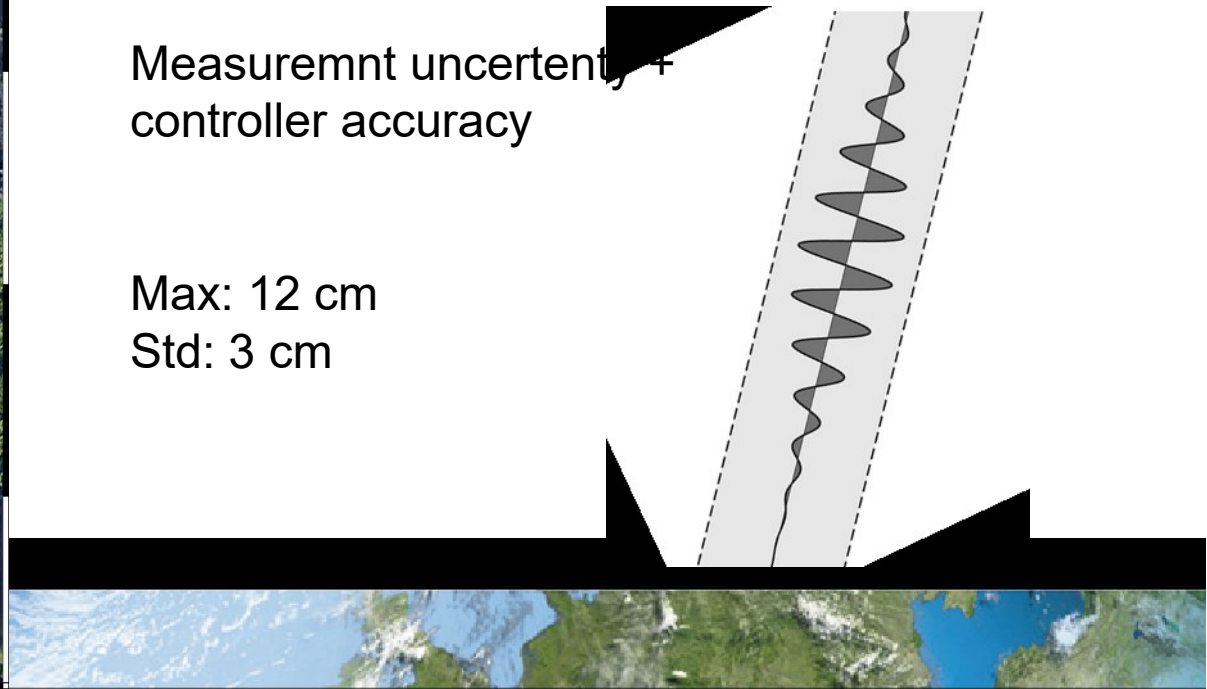
PPP results bow antenna

94% PPP fix , 6 % PPP float

Deviation from ideal trajectory (straight line)

Measuremnt uncertenty +
controller accuracy

Max: 12 cm
Std: 3 cm



Summary and Outlook

PPP–RTK shows great potential for automation of inland vessel automation as demonstrated in real demonstration

+ low data rate
+ broadcast capable
+ sufficient accuracy ~dm
+ short convergence time ~ s

- Not yet standardized SSR data format (RTCM)
- Just first tests with broadcast over VDES

Outlook:

- SSR RTCM standardization process
- Upcomming availability of GALILEO HAS Service and SAPOS German wide SSR service
- Further developments towards autonomous vessels on Digital Testbed on Spree-Oder-Waterway (SOW)

DigitalSOW
www.digitalsow.de

Thank you for your attention !!!

Ralf.Ziebold@DLR.de

Full Movie: https://www.youtube.com/watch?v=o_CUcgbqECQ