Robust Aerial Navigation and Georeferencing in GNSS-Challenged Environments

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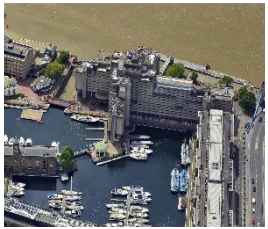
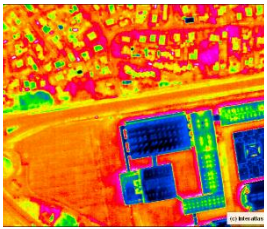
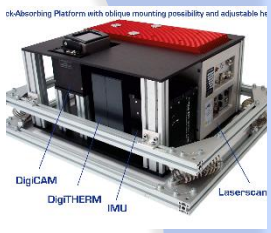









- 47 Years in the Geospatial Market
- Mission Planning & Flight Guidance
- Sensor Management
- GNSS/IMU Navigation

- Airborne Sensor Systems
- Mobile Mapping Solutions
- Turn-key Solutions
- Defense Solutions

IGI

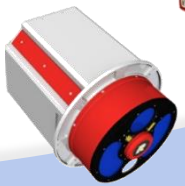
Modular Sensor Systems



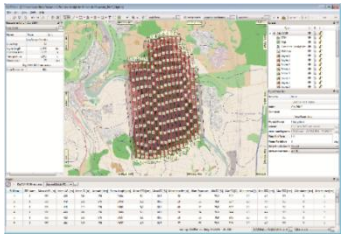


- Mission Planning
- Guidance
- Georeferencing
- Sensor Management
- Quality Control in Real-Time
- Data Storage



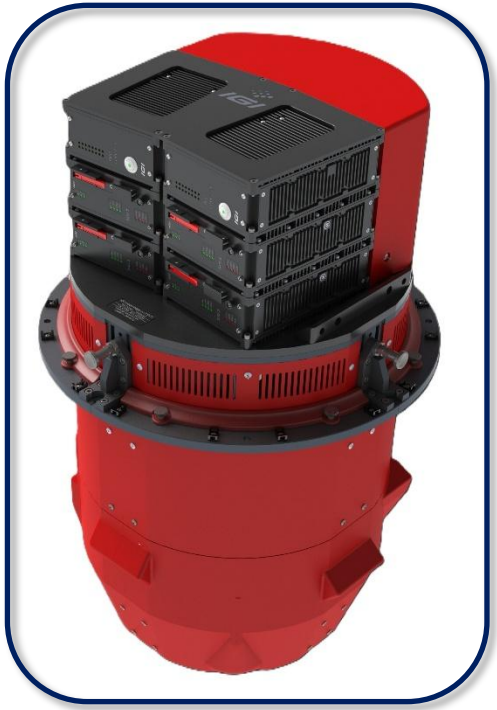




Modular Sensor Systems



IGIplan

AEROoffice, IPS, 3rd party

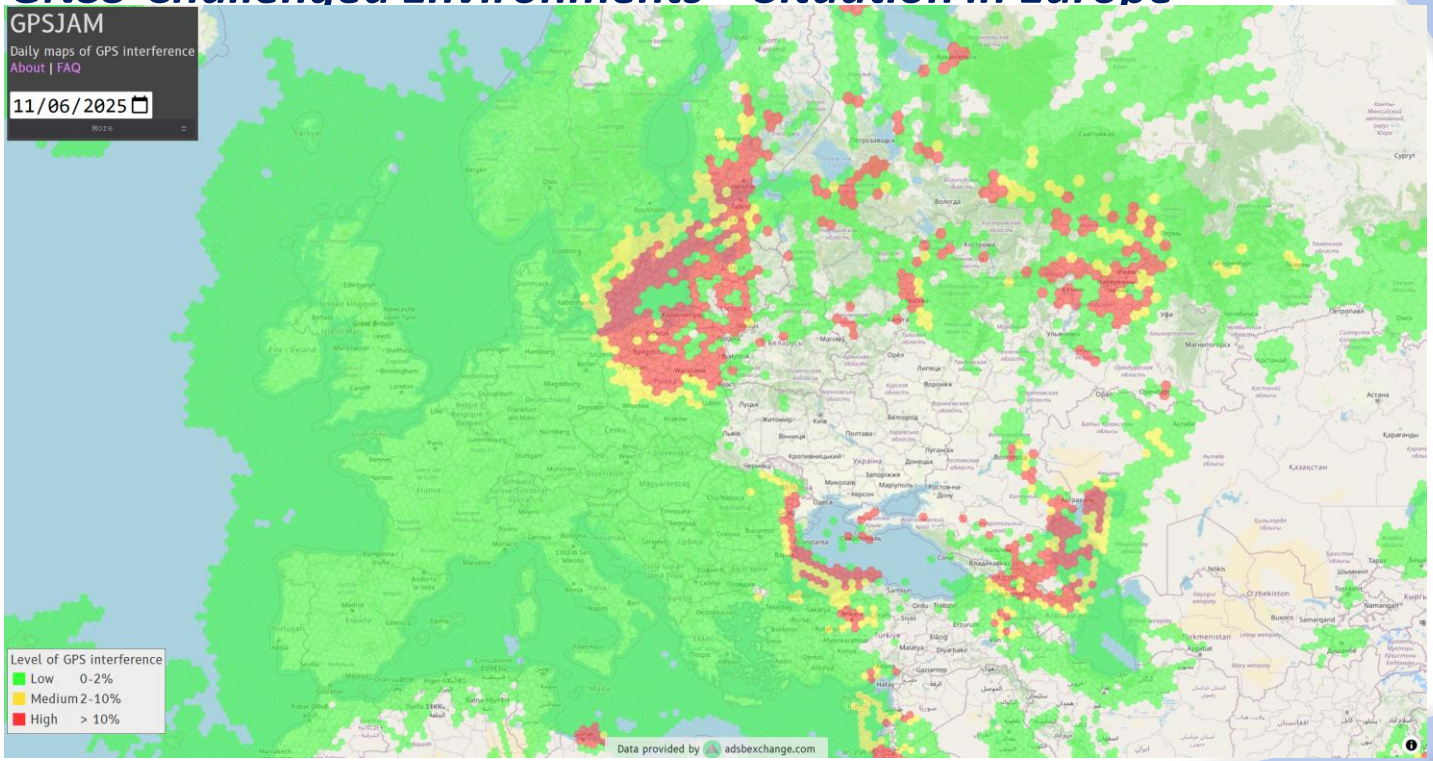


CCNS-5

AEROcontrol

SMU / IGIvisu

GNSS-Challenged Environments – Situation in Europe



Source: jpsjam.org

IGI UrbanMapper-2P Demo in Estonia Sept. 4th-9th 2024

Test carried out with Estonian Land and Spatial Development Board (ELB), National Mapping Agency operating the latest generation of UrbanMapper-2 EVO

Test objectives:

- **Execute a survey in area affected and not affected by GNSS jamming**
- **Deploying two independent systems - with and without anti-jamming capabilities**
- **Attempt processing jammed trajectories**
- **Analyse usability of jammed trajectories for data processing**

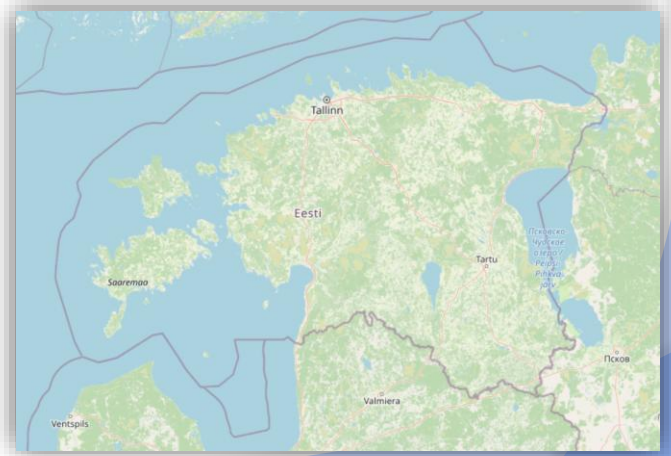
IGI UrbanMapper-2P Demo in Estonia Sept. 4th-9th 2024

REPUBLIC OF ESTONIA
LAND AND SPATIAL
DEVELOPMENT BOARD

Test locations:

- **Various areas across Estonian Territory, where jamming was very likely to be expected (central and eastern Estonia) and the opposite – mainly West of the country (situation Spet. 2024)**

Testing areas designed at different altitudes from 500m AGL to 3 500m AGL



IGI UrbanMapper-2P Demo in Estonia Sept. 4th-9th 2024

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Testing Setup:

- **UrbanMapper-2 Perfomrance + AEROcontrol CF-III with antijamming technology + CCNS-5**
- **ELB own LiDAR system with identified jamming vulnerability (deployment discontinued in 2024)**

IGI UrbanMapper-2P Demo in Estonia Sept. 4th-9th 2024

Cessna 208B Grand Caravan of ELB

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IGI UrbanMapper-2P Demo in Estonia Sept. 4th-9th 2024

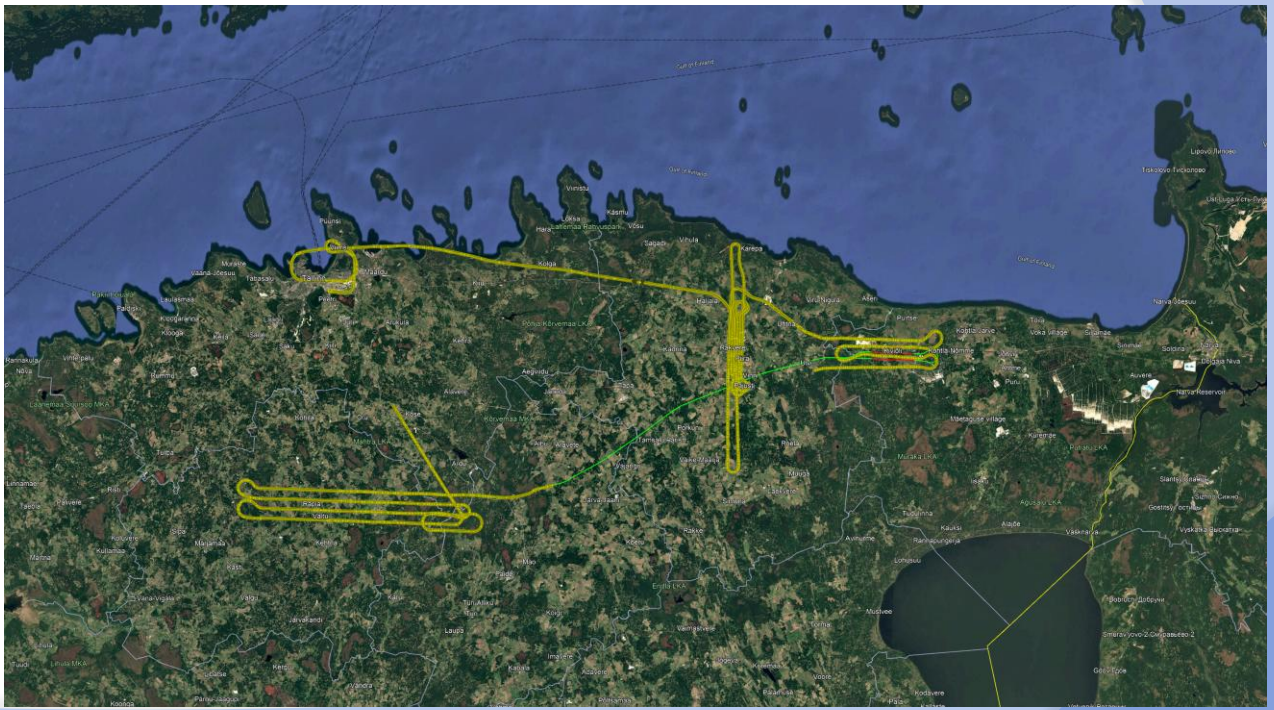
UrbanMapper-2 Perfomrance with AEROcontrol CF-III

IGI UrbanMapper-2P Demo in Estonia Sept. 4th-9th 2024

CCNS-5 in C208

IGI UrbanMapper-2P Demo in Estonia Sept. 4th-9th 2024

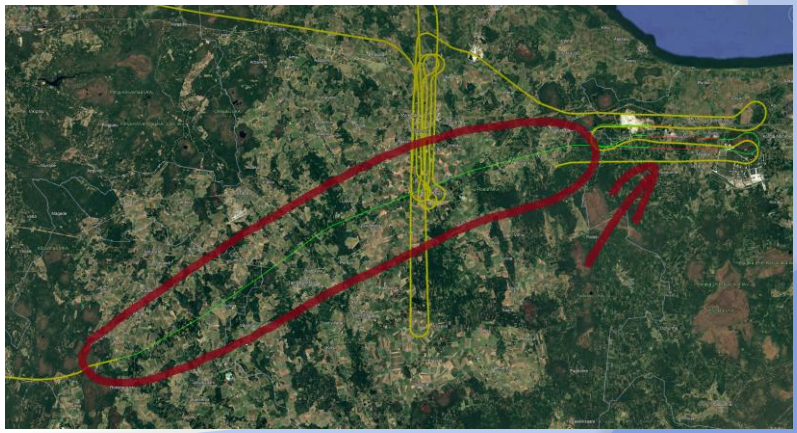
Example of a flight during GNSS jamming event:



IGI UrbanMapper-2P Demo in Estonia Sept. 4th-9th 2024

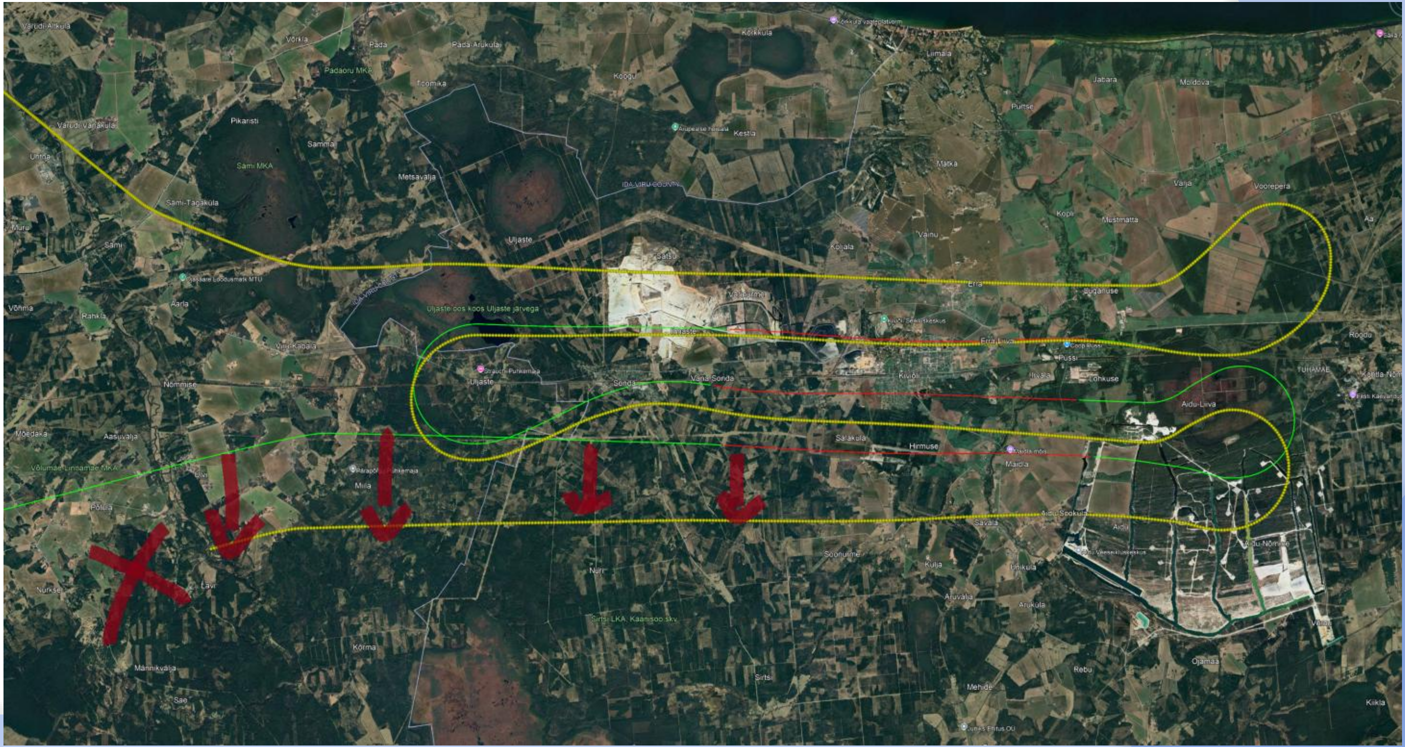
Example of a flight during GNSS jamming event – observations:

- **ELB System Realtime Solution started to deteriorate and finally no position was available in a certain part of the flight until getting out of the area with GPS jamming**
- **IGI system maintained Realtime Solution which allowed the survey and sensor operation**

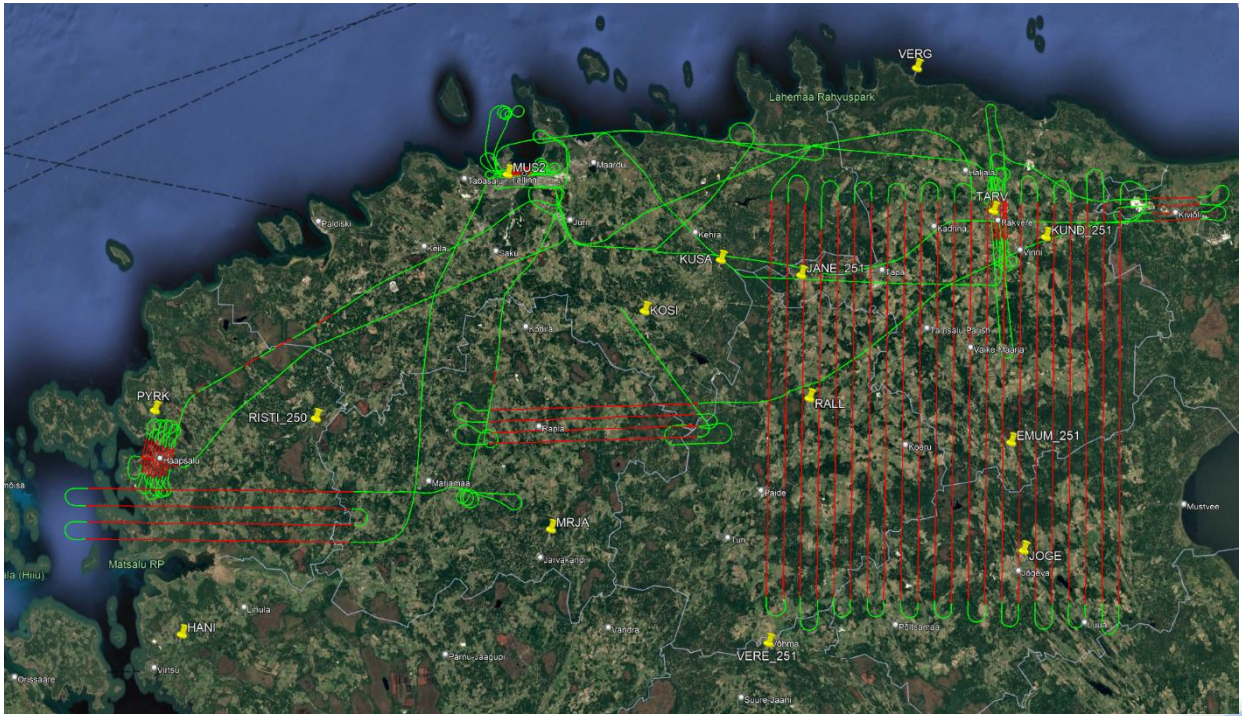


IGI UrbanMapper-2P Demo in Estonia Sept. 4th-9th 2024

Realtime solution comparison of both systems:

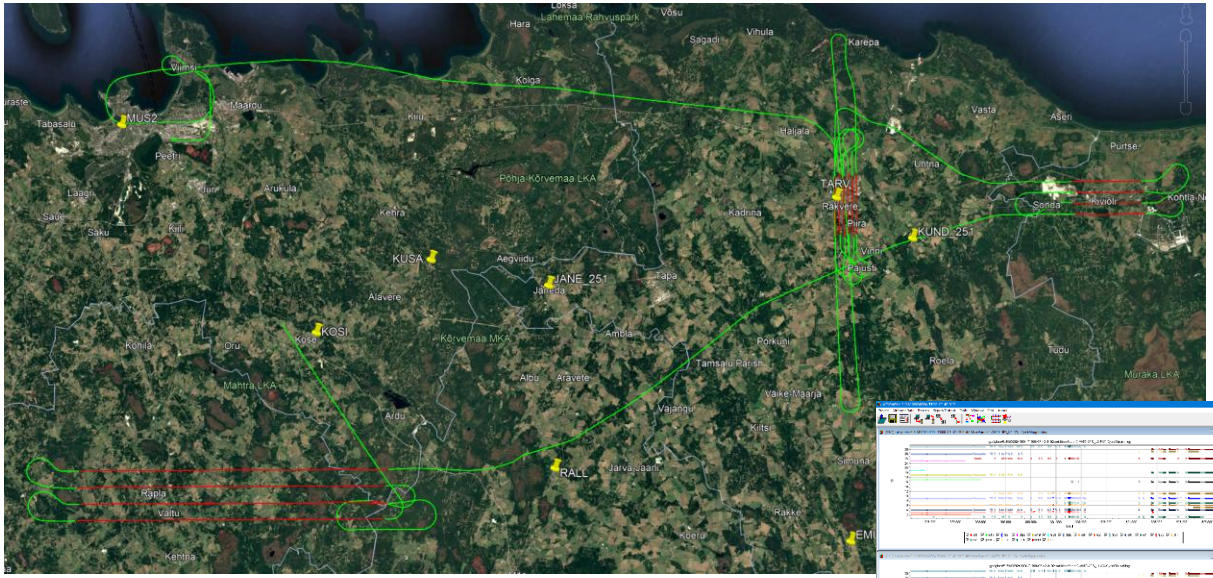


IGI UrbanMapper-2P Demo in Estonia Sept. 4th to 9th 2024



For some areas and flying days, strong jamming was present, especially in the eastern parts of the mission area

Flight 1: 4.9.2024



Strong jamming,
especially in the eastern parts of the flight mission

Flight 2: 5.9.2024

No jamming visible

Flight 1: 4.9.2024

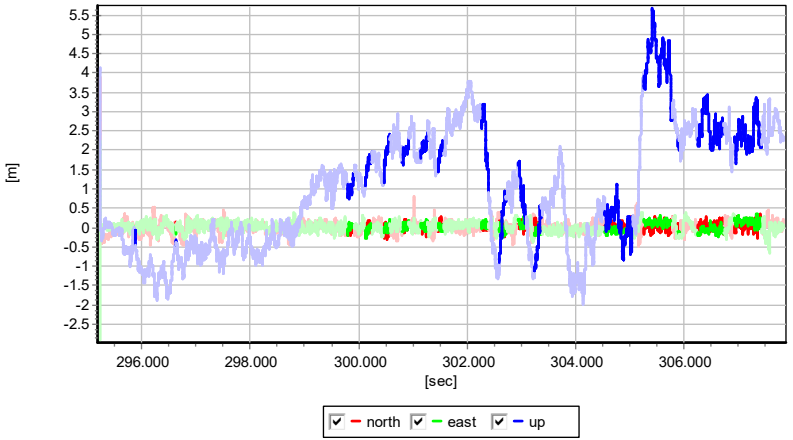
No GNSS post-processing was possible with GrafNav.
PPSDK with standard setting did not produce a useful post-processed solution.

The jammed signals were identified and excluded in PPSDK.
The GNSS solution was introduced into AEROoffice.

An important quality indicator is the difference between the GNSS measurements and the predicted positions from the INS.

These values show larger values
compared to an unjammed flight:
RMS north: 14cm
RMS east: 12cm
RMS up: 183cm

The estimated position accuracy is about 0.5m



Flight 2: 5.9.2024

No jamming was observed.
GNSS post-processing was possible with GrafNav and PPSDK.

This allows to simulate effect of the jamming and compare the results with and without these effects.

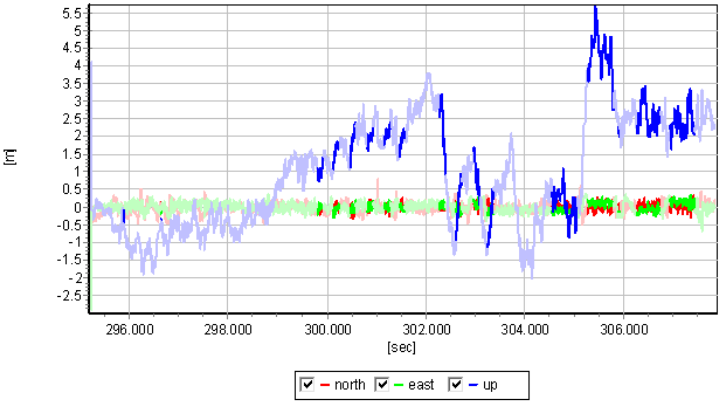
For this comparison, two INS solutions were produced:

1. A reference solution using the standard workflow with GrafNav and AEROoffice.
2. A PPSDK solution choosing the constellation that was usable on the 4.9.2024 (jamming) integrated into AEROoffice.

Flight 1 & 2

Comparison of the quality indicator “GNSS/INS position difference” between the jammed flight on the 4.9.2024 and the solution for the 5.9.2024 with simulated jamming effects.

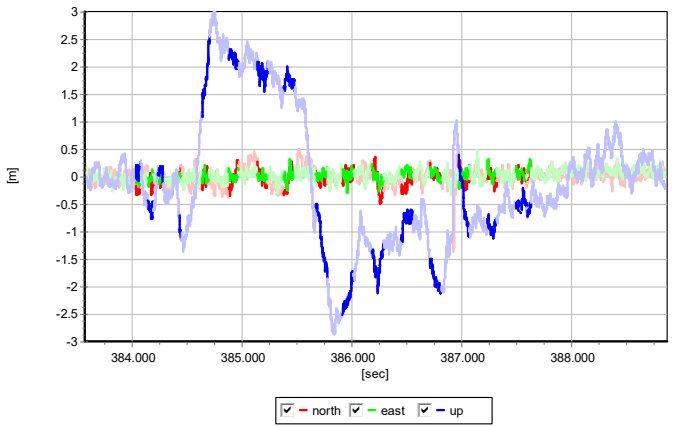
Jammed flight 4.9.:



RMS north: 14 cm
RMS east: 12 cm
RMS up: 183 cm

comparable!

Simulated jamming solution for 5.9.:

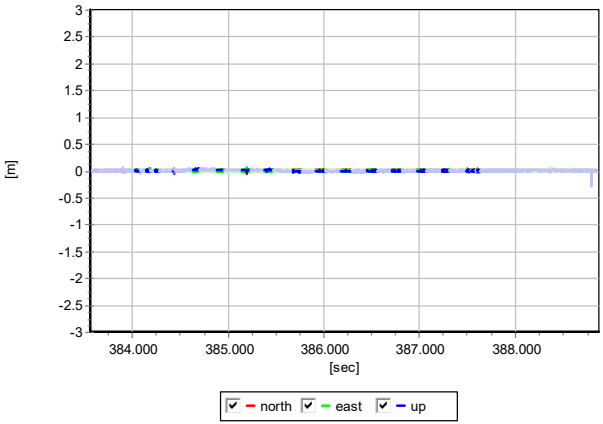


RMS north: 15 cm
RMS east: 10 cm
RMS up: 121 cm

Flight 2: 5.9.2024

Quality indicator: difference between the GNSS measurements and the predicted positions from the INS.

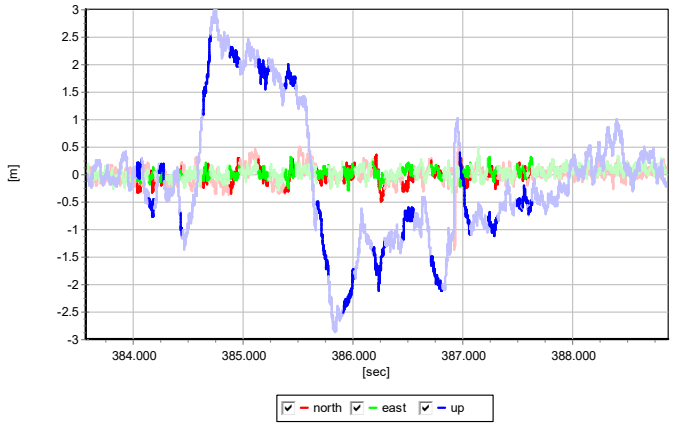
Reference solution:



RMS north: 0.46 cm
RMS east: 0.35 cm
RMS up: 1.13 cm

~ factor 30

Simulated jamming solution:

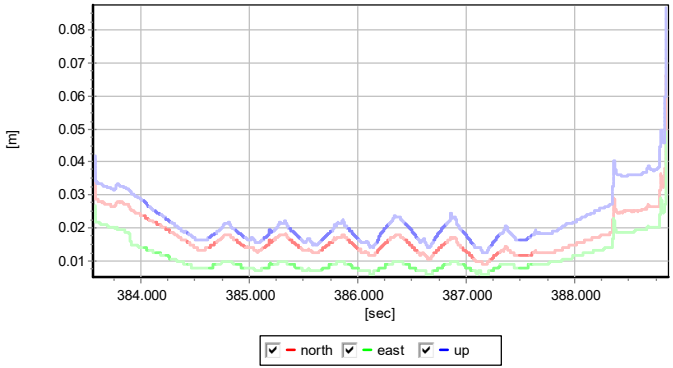


RMS north: 15.5 cm
RMS east: 10.2 cm
RMS up: 121 cm

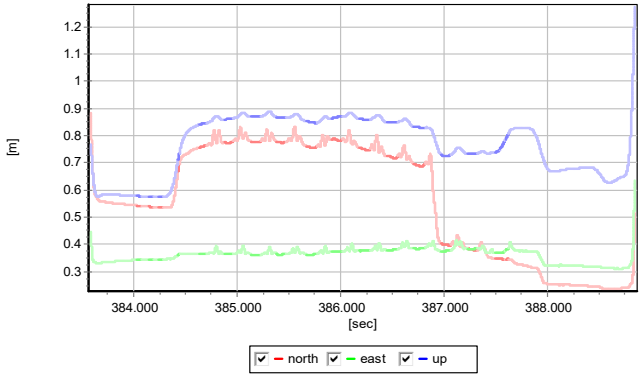
Flight 2: 5.9.2024

Quality indicator: estimated position accuracy.

Reference solution:



Simulated jamming solution:



~ 2cm

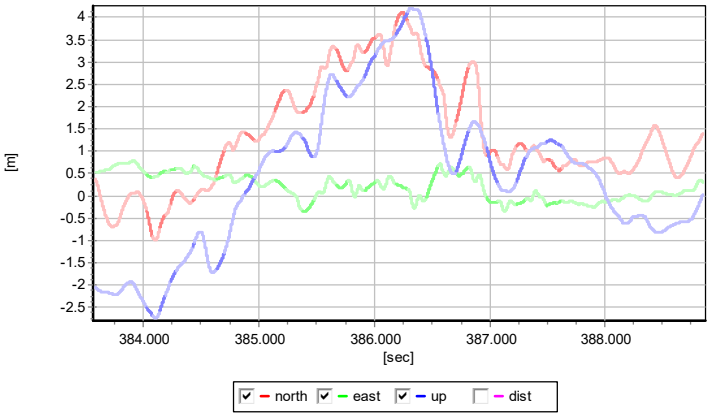
~ factor 40

~ 80cm

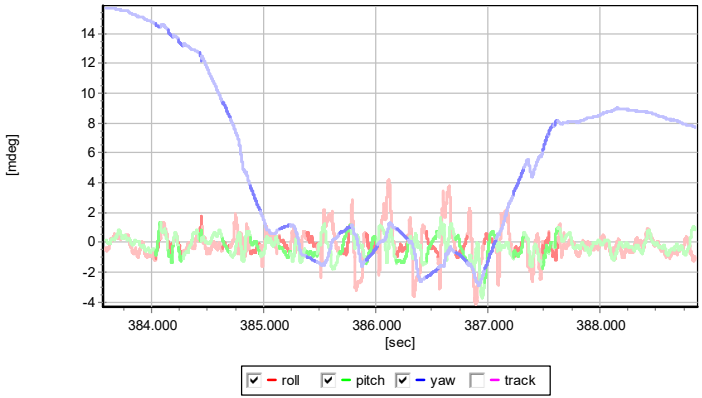
Flight 2: 5.9.2024

Comparison of the final position and attitude.

Position difference:



Attitude difference:



Flight 1 & 2

If the GNSS reception is affected by jamming as seen on the 4.9.2024, the standard processing chain incl. GrafNav can’t produce a usable trajectory.

A modified processing chain using PPSDK allows for the creation of a usable trajectory solution. The comparison above shows a reduction in the estimated position accuracy from the range of below one dm to values in the one-meter range.

In this simulation for the flight from the 5.9.2024, the maximum position difference between the reference trajectory and the trajectory with simulated jamming went up to 4m in the middle of the flight. The roll and pitch angle were affected very little and showed differences of 1/1000deg. The heading angle showed differences in the range of 1/100deg.

Flight 1 & 2: Conclusion

The use of the latest GNSS-receiver technology together with a modified workflow employing PPSDK allowed for the creation of a usable trajectory for all flight.

The comparison between simulated jamming and real jamming, as well as the comparison of standard-processing with simulated-jammed processing gives indications for the reachable accuracies.

The usability for “direct georeferencing” under these conditions is limited to projects with low accuracy requirements.
-> Direct Georeferencing is not suitable under Jamming Conditions

We found, that the trajectory quality under jamming-conditions is good enough for a combined INS/AT georeferencing workflow. The reduced trajectory accuracy should be considered by reducing the related accuracy estimations in the used AT software.
-> Combined INS/AT imagery processing delivers good results under Jamming Conditions

-> For LiDAR georeferencing, adjustment techniques need to be used


Skyline
IGI

Thank you!