# Long-Term Analysis of Sentinel-6A Orbit Determination: Insights from Three Years of Flight Data

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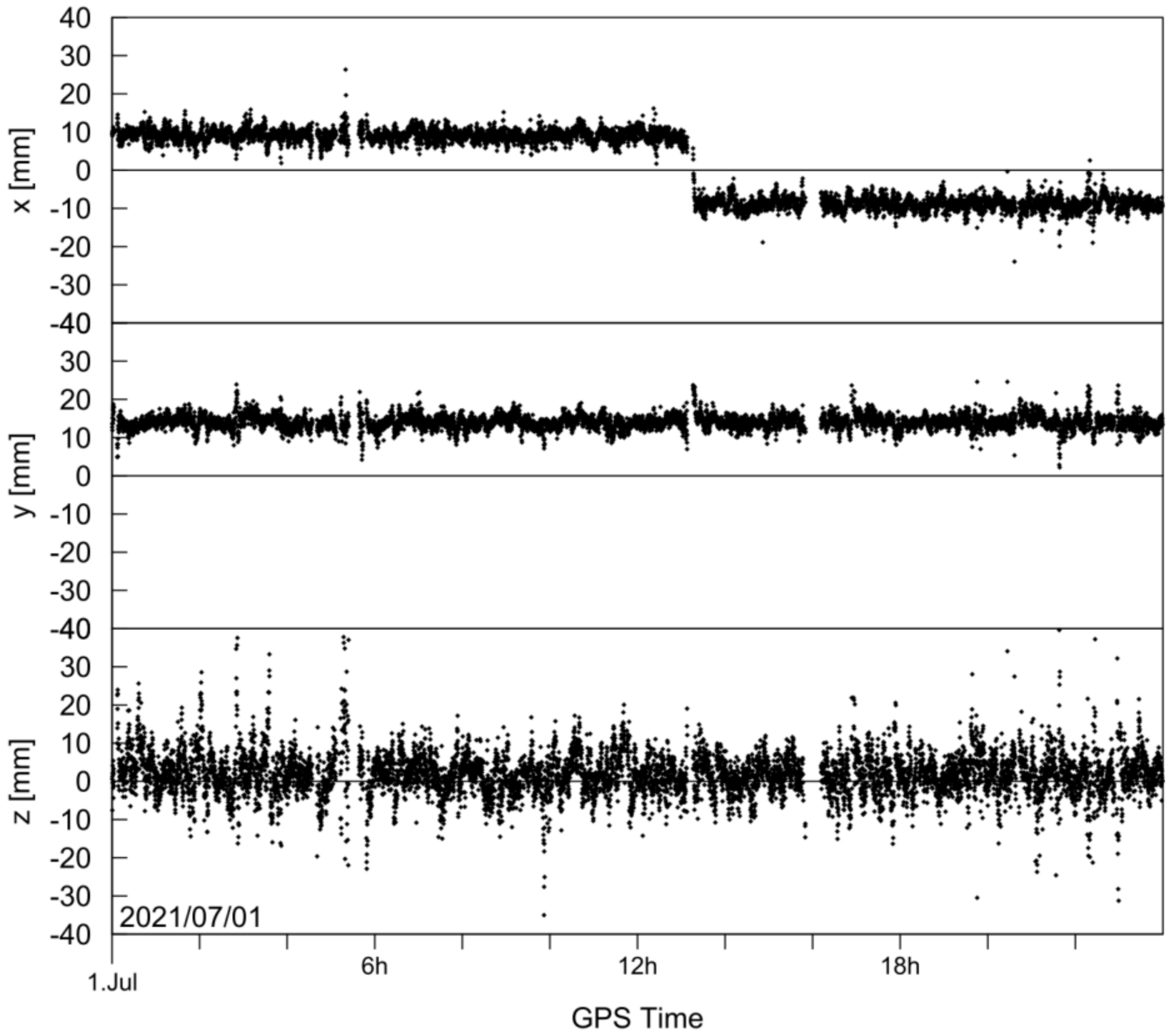
# Motivation

- Sentinel-6A requires high-accuracy orbits for ocean altimetry (goal: 1.0 cm radial)
- 2 GNSS receivers available for precise orbit determination
- High performance of PODRIX-derived POD shown in previous research
- Baseline estimation between PODRIX & TriG reveals obvious inconsistencies
- This Study: comprehensive reprocessing of 3 years of GNSS observations from PODRIX and TriG receivers

# Antenna Baseline Estimation

- Baseline corrections in body-frame from differential GPS carrier phase observations
- TriG observations clock-corrected, aligned to integer seconds
- Y-offset of 14 mm corresponds to yaw bias of -0.43° at 1.8 m antenna separation
- X-offset changes sign in reverse flight orientation
  - 9 mm along-track error
  - 1.3 μs relative timing offset between TriG and PODRIX receiver



# Reprocessing Methodology

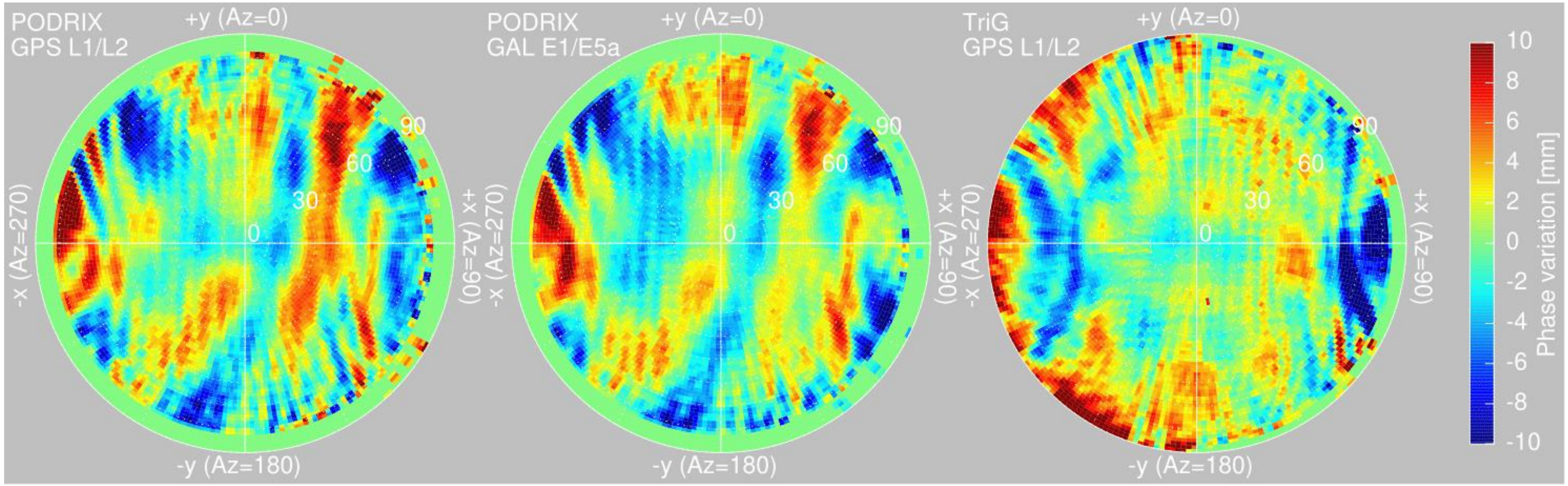
- Reduced-dynamic orbits generated covering January 2021 to December 2023.
- IGb14/IGS20 transition (Nov 27, 2022) requires separate receiver antenna calibrations
- Single receiver ambiguity fixing applied for utmost accuracy
- Yaw angle correction of -0.43° applied to measured attitude quaternions
- IGS antenna models linearly extrapolated beyond off-boresight angles of 14°
  Conrad et al. (2023)

Conrad, A., Desai, S., Haines, B. et al. (2023). Extending the GPS IIIA antenna calibration for precise orbit determination of low Earth orbit satellites. Journal of Geodesy, 97(4), 35. DOI 10.1007/s00190-023-01718-0.

# Antenna Characterisation

- Discrepancy between manufacturer and in-flight PCO calibrations of up to 20 mm
- IGS20 frame yields a clearly improved consistency of the observed phase centers
- Obvious fringes in antenna phase patterns (cross-talk in receivers?)

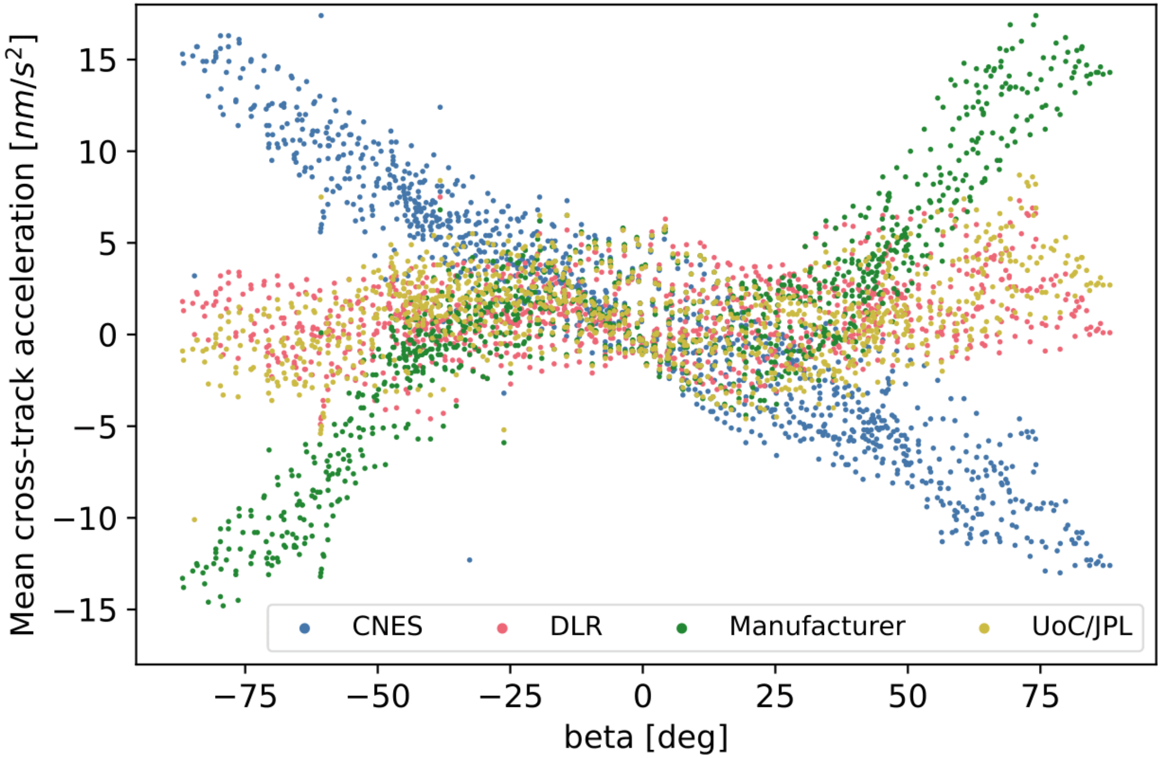
| $z_{PCO}$ (mm) | GPS L1/L2 | GAL E1/E5 |
|---|---|---|
| Manufacturer | 88 | 75 |
| Estimated (igs14) | 69 | 90 |
| Estimated (igs20) | 72 | 85 |



# Nongravitational Force Modeling

- Comparison of four macro-models for drag and radiation pressure
- Self-shadowing neglected
- Two models show strong correlation of cross-track accelerations with β angle
- Improved performance at expense of:
  - unrealistic spacecraft geometry (UoC/JPL)
  - increased re-emission contributions (DLR)

Image Source: NASA



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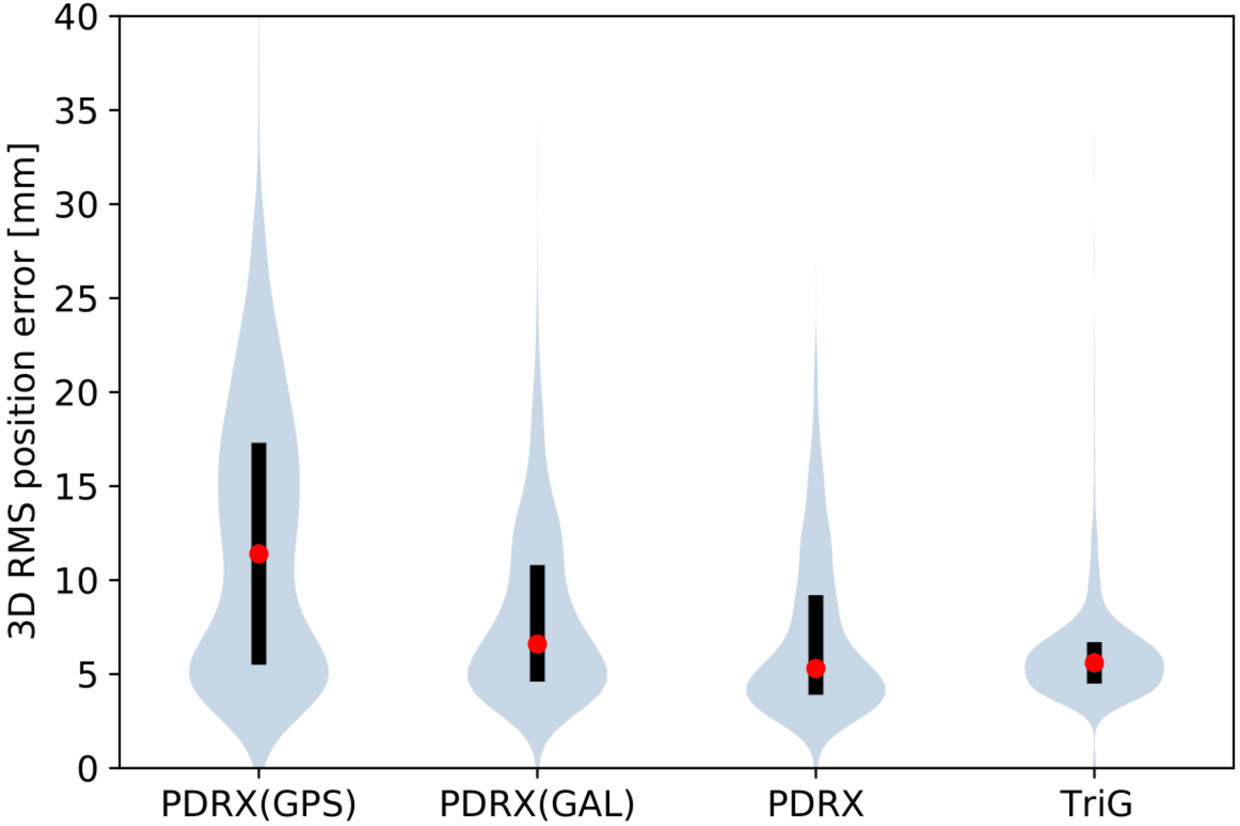
# Orbit Comparison

- Reference: combined orbit solution of CPOD service
- Sub-centimeter consistency of all solutions
- 9 mm along track difference between TriG and PODRIX attributed to 1.3 µs timing error
- High peak errors (3 cm) in PODRIX solutions due to occasional false ambiguity fixing
- TriG results benefit from an increased number of tracked satellites



# SLR Analysis

- Validation of GNSS-based POD using SLR
- Residuals ~6 mm (1 cm 3D RMS accuracy)
- PODRIX and TriG orbits show small (+/- 5 mm) offset wrt. SLR

| Solution | LRA X-offset (mm) |
|---|---|
| PODRIX | +5.1 |
| TriG | -3.9 |

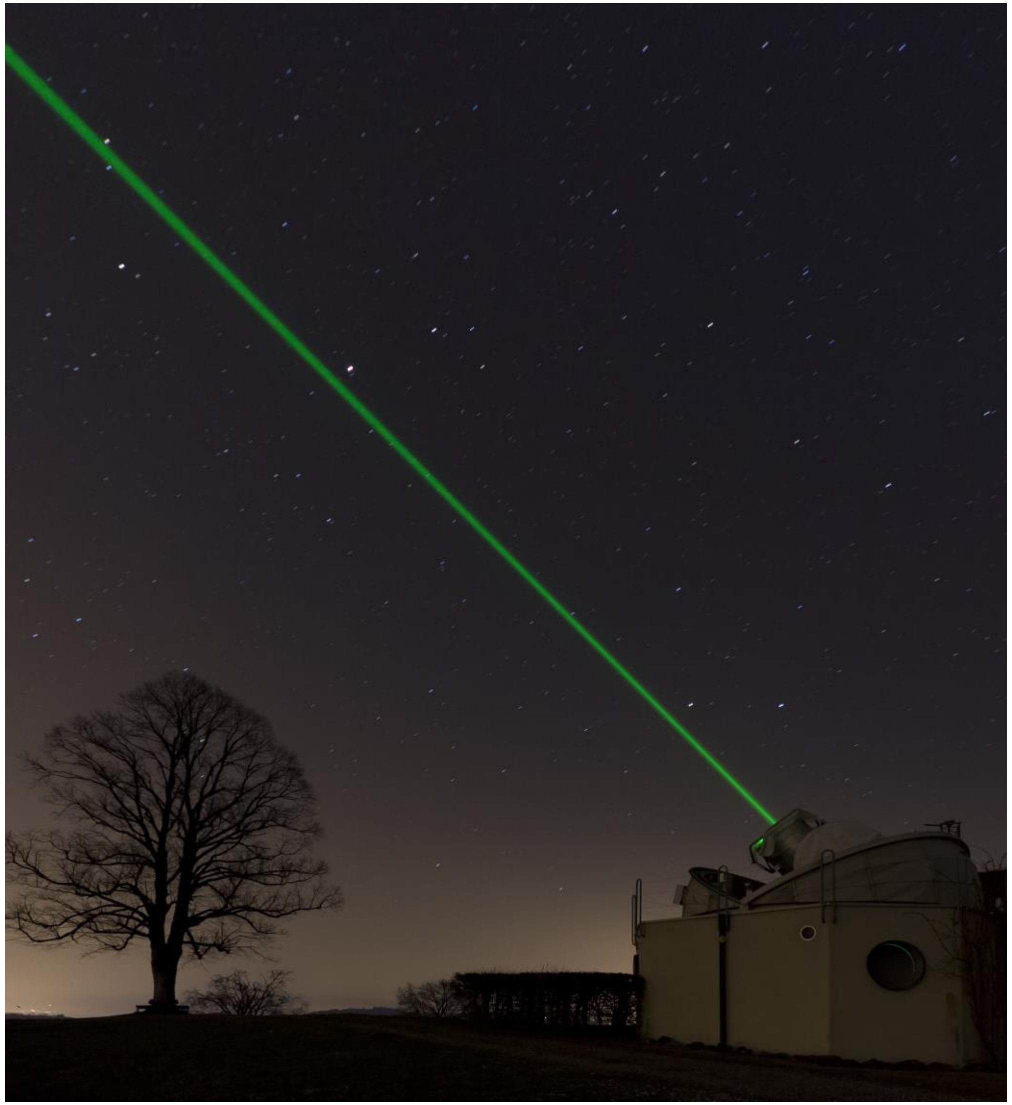


Image Source: Astronomical Institute University Bern

# Conclusion

- Yaw bias of -0.43° inferred from baseline estimation
- Differences between manufacturer and inflight antenna characterisations
- Adjusted macro-models improve performance wrt factory model
- Reprocessed orbits remove inconsistencies between PODRIX & TriG
- Sub-μs timing error in both PODRIX and TriG receiver
- SLR demonstrates 1 cm 3D RMS accuracy
- Sentinel-6A offers GNSS/SLR/DORIS space-tie: important test-bed for Genesis mission