Precision Orbit Determination

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Contributors:

Sentinel-6A:
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Jason-3:
CNES. (Cyril Kobel)

Jason-1:
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SLR Analysis:
AIUB. (Daniel Arnold)
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POD Systems on Sentinel-6A

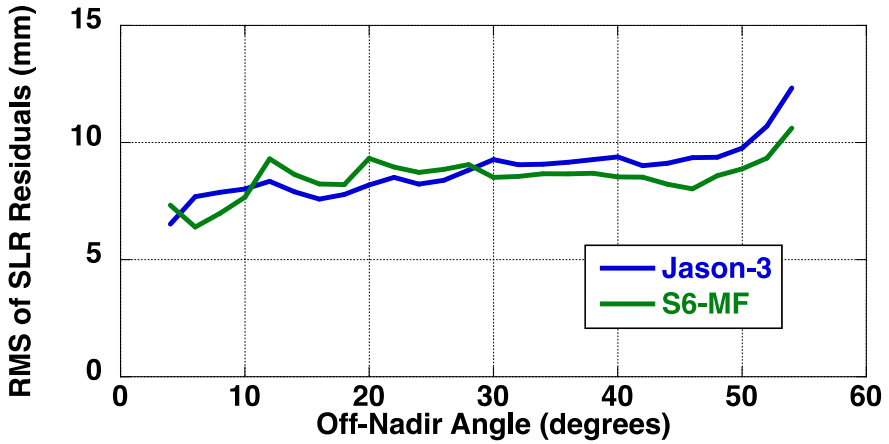
SLR Retroreflector.
DORIS (DGXX).
GNSS
- PODRIX Receiver (GPS + Galileo) -- RUAG
- TRIG RO Receiver (GPS-only, at present) – JPL/NASA

Other Topics:
AIUB. (Adrien Jäggi). - **COST-G Geopotential Service**
Univ Colorado (Alex Conrad). - **GPS Block III Antenna Calibration**
CNES. (Georgia Katsigianni) - **Aspects of GNSS POD.**

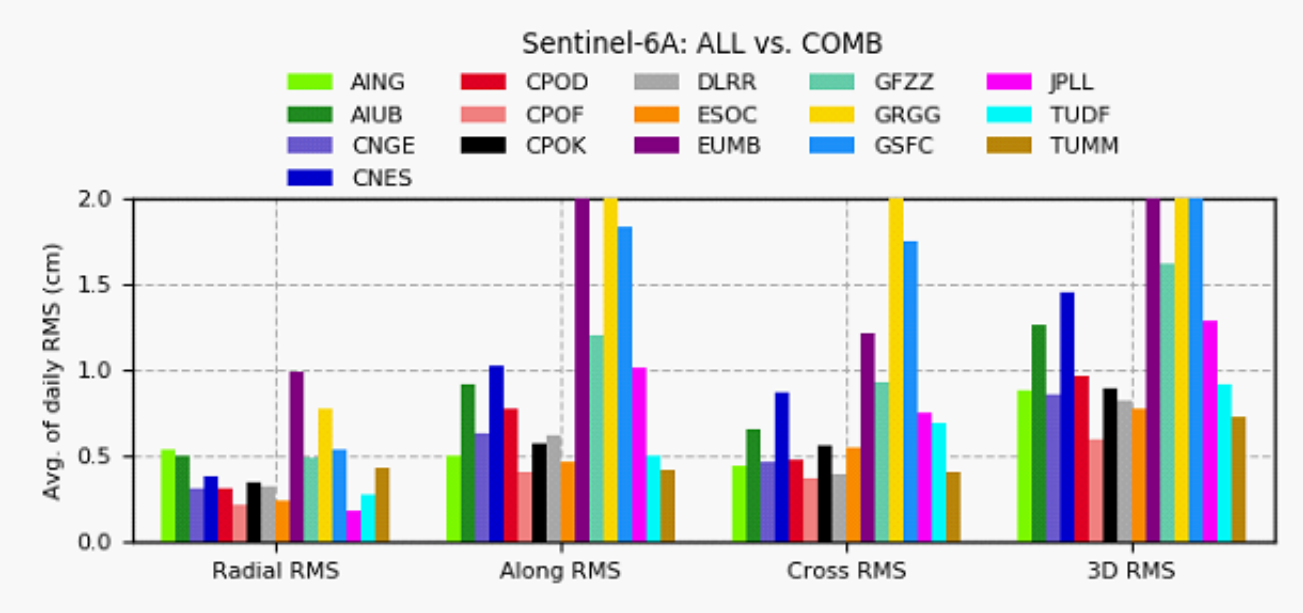
Sentinel-6 MF Orbit Performance Summary

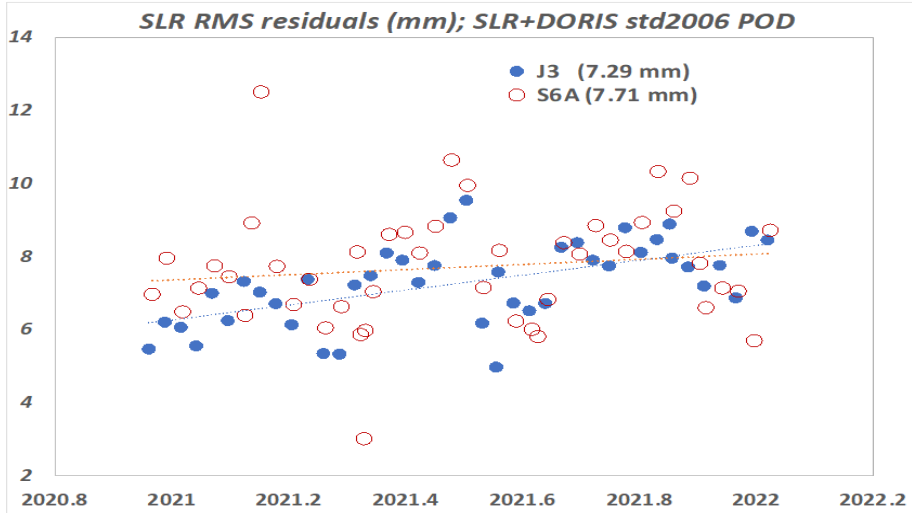
In short: Accuracy requirements are fulfilled on all timelines (NRT, STC, NTC).

- **POD Performance on S6/MF is at the same level as Jason-3 (< 1 cm rad RMS)**
- **SLR residuals to S6A and J3 orbits are at the same level (6-10 mm RMS).**
- **Xover Analysis (***by TU Delft, TUM***):** 5.22 to 5.23 cm RMS for CPOD/CPOF orbits.
- Radial Orbit Consistency of orbits by ACs in POD analysis is usually better than 6 mm RMS (*from Copernicus POD Service*).



SLR Residuals to GNSS (GPS) orbits (JPL)





SLR Residuals to SLR+DORIS orbits (GSFC)

S6A. POD System Performance Summary

• S6A/MF is the first LEO Science mission with a dual-constellation (GPS+Galileo) GNSS Receiver (PODRIX receiver from RUAG)

• Galileo appears to offer reduced measurement error and improved ambiguity fixing compared to GPS, but Galileo still offers lower no. of operational satellites compared to GPS (*Montenbruck et al., JoG, 2021*).

• S6A Trig Receiver (JPL) performs better than on Jason-3, and its data alone support < 1 cm radial orbit accuracy (*Desai et al.*).

• GNSS data of two receivers (PODRIX & TRIG) support baseline determination on S6A s/c. Analysis reveals error in x-y components of baseline; x component error might also be signature of time-tag inconsistency between the two receivers. (*from O. Montenbruck, DLR*).

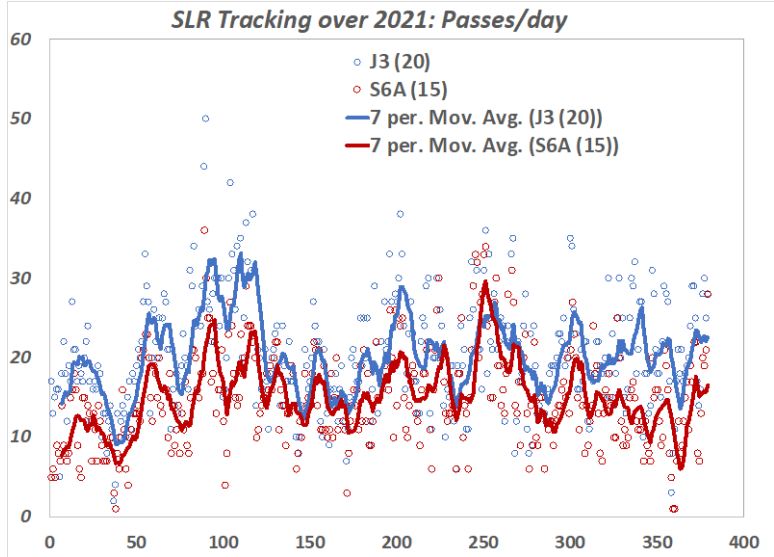
• **SLR**: During tandem phase, on average 15-20 SLR passes/day; Per 10-day cycle SLR tracking provided ~2300 & ~2900 SLR normal points; Top tracking stations are: **Yarragadee (*Australia*), Changchun (*China*); Zimmerwald (*Switz.*), Herstmonceux (*UK*), Greenbelt (*USA*).**

• **DORIS**: Nominal operation so far; One Analysis Center noted increase in S6A RMS of fit in 2021; Should be monitored.

S6A & Jason-3 GNSS Trig. Performance 2020-12-18 to 2022-02-26

	J3	S6
Median Satellites Tracked	9.5	10.3
Median Track Length (min)	38.6	40.8
Median RMS Phase Residual (mm)	4.39	4.35
Median RMS Range Residual (mm)	375	568
Median Radial Orbit Overlap (mm)	0.96	0.89

(Desai et al. 2022)



(Lemoine et al. 2022)

Recommendations Sentinel-6 MF

- **Further assessment and testing of dynamic model improvement (notably Time Variable Gravity and SRP/albedo).**

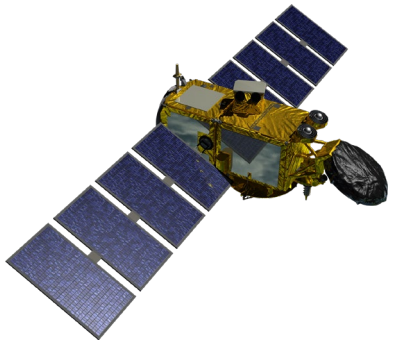
- GNSS receiver antennae should minimize multipath by design to reduce the necessity of calibrating antenna phase maps in flight.
- Calibration phases of the different instruments on board the satellite could be requested to see the impact of turning on/off them on the orbit (in terms of power/thermal emissions and associated accelerations).
- **Attitude flip maneuvers at low beta angles are very useful to disentangle center of phase errors from time-tagging, dynamic modeling errors.**

- Provide RUAG calibration file for TRIG antenna (consistent with PODRIX calibration data base).
- Measure TRIG-PODRIX timing bias with signal simulator (e.g. during s/c tests at IABG).
- Conduct critical review of design data for antenna mounting and reference points of TRIG and PODRIX antenna.

- **Need to investigate sources of geographically correlated orbit error for S6A.**
- **Multi-constellation GNSS receivers should be the baseline for future altimeter missions.**

Recommendations Sentinel-6 MF

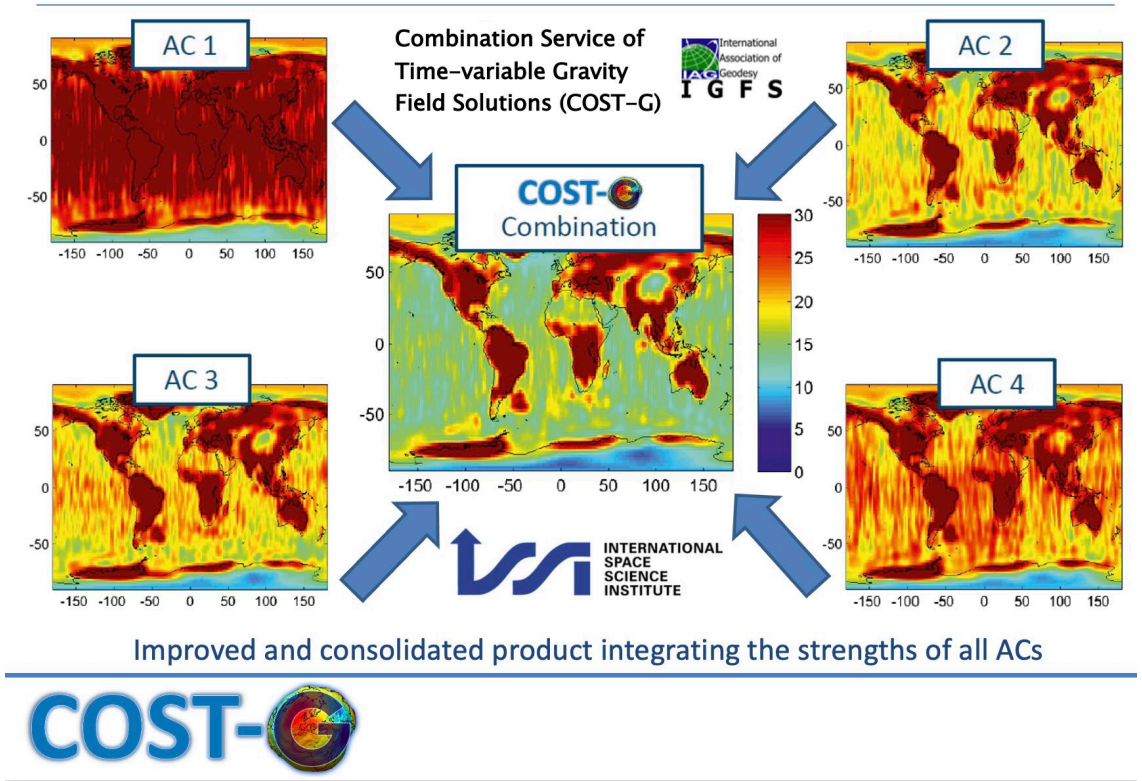
- **Take the satellite shape/design into account in the future – S6-MF has complicated shape.**
- **Consider use of Products from Time-Variable Gravity COST-G Service for POD.**



Lessons learned from the new Sentinel-6 platform:

• Cavities below the solar panels introduce self-shadowing and thermal couplings with the platform, albedo effects, as well as details of drag modelling.

• Nadir surface on S6A is 5X bigger than on Jason-3 (up to 5 times bigger than Jason-3) exposes the orbit to albedo/IR modeling errors, as well as possible unmodeled thermal fluxes from radiators.



Other POD Studies and Results

Jason-3 :

- Kinematic orbit solutions are limited by errors in the determination of Phase Center Offset and Variation.
- Notable Along-track offset in Satellite laser ranging validation of about 12.5mm independent of attitude mode w.r.t. GPS-only orbits.

Jason-1:

- **. 15-20% reduction in SLR RMS with new CNES POE-F vs POE-E.**

SLR:

- Stations of the ILRS show range biases. SLR residuals on active LEO satellites tracked by GNSS are a suitable tool to calibrate these biases and offsets.
- New estimation of GM with SLR (.4419 vs .4415).

TVG:

- **Application of the new COST-G FSM, with good prediction capability for at least 3 months, improved accuracy of all Copernicus Sentinel satellites. The COST-G FSM is updated every month.**

GPS:

- Recommend extrapolating Block III IGS14 calibration to produce consistent results relative to Block II orbits.
- Use of consistent attitude modeling for the GNSS satellites (new ORBEX files) with the IGS clock files selected.