

National Aeronautics and
Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California



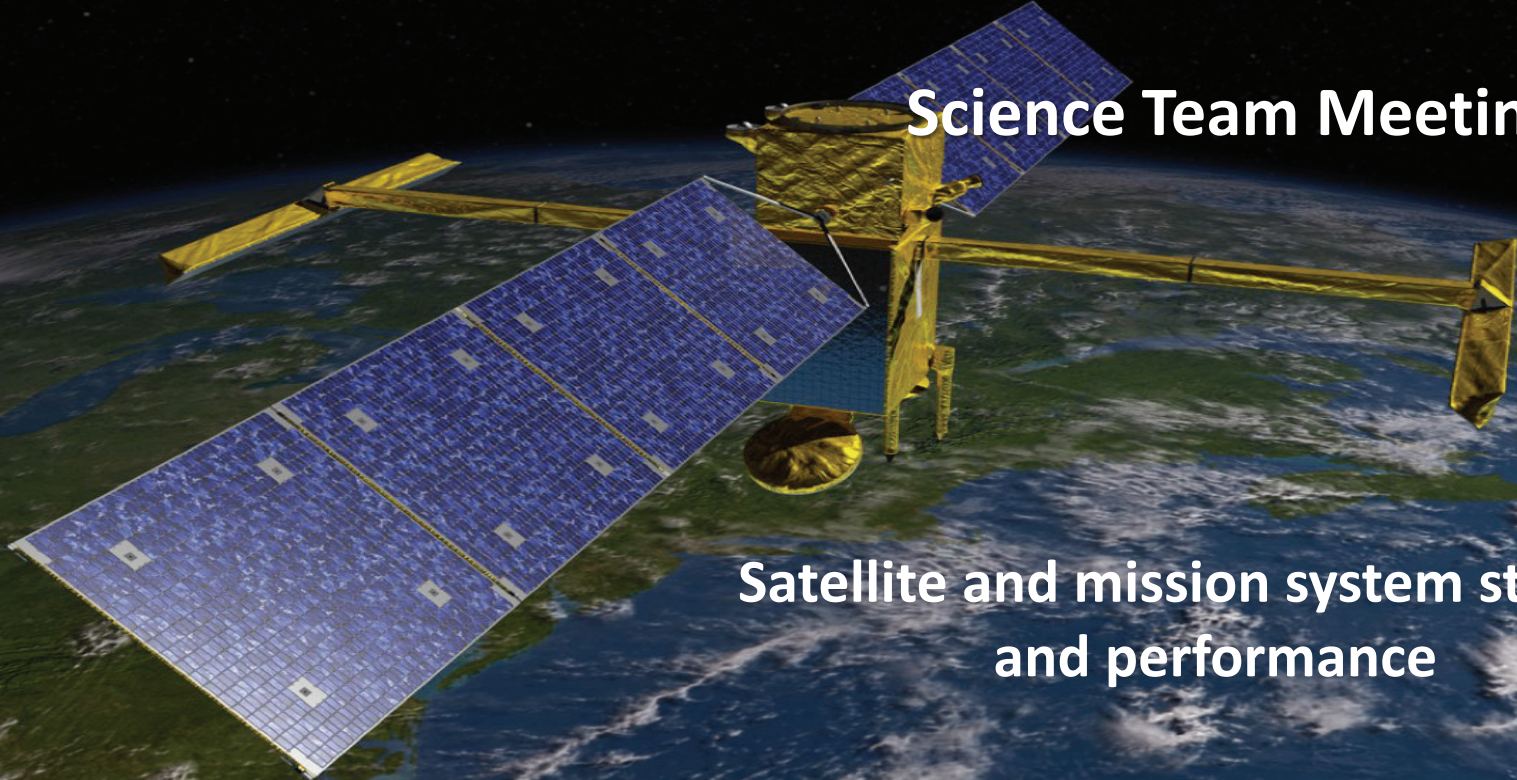
Surface Water and Ocean Topography (SWOT) Mission

Science Team Meeting

Satellite and mission system status
and performance

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19th September, 2023



Global satellite status and performance

Operations performed during LEO and Commissioning phases (Dec.16, 2023 - March 31, 2023) allowed to assess the good health and the performance of the various sub-systems of SWOT spacecraft

- **Power chain behavior is nominal** and margins have been confirmed (ex: relaxed PL constraints during maneuvers)
- **PF units and avionics have a nominal functioning**; redundant units and boards have been used successfully
- **AOCS works nominally**; the modes behavior is nominal and the capacity of the safe/nominal and maneuvers modes has been demonstrated; the performance fulfill the mission needs with margins (pointing, control and knowledge errors)
 - THR over-efficiency has been observed in flight -> TAS and CNES experts have updated the model to provide operational team with the efficiency to be used as a function of requested Delta-V, for maneuver/thrust commanding
 - This model has proven its accuracy for station keeping and orbit change maneuvers
 - Pointing Control errors are compliant with the requirement : Control Error < 0,003° with some peaks < 0,005° at given period (phenomenon observed in simulations which were compliant with the dynamical stability requirement)
 - Star trackers : Good Quality index, noise is twice lower than required, and availability is greater than 99,99%

Global satellite status and performance

- **CC functionalities are as expected**; performances are in line with the needs (ex: TM/TC, S-band mass memory, services to the PL, Software CPU load,...)
- **Thermal control** for PF and PL works perfectly and is well within the allocated power budget
- **TTC RF chain has large margin**, particularly in TC channel; TM masking due to KaRIn masts has very low impact
- **PL Mass memory (SSR)** behavior is as expected
 - Since SSR turn ON, a few occurrences of data gaps were observed and analyzed
 - The memory components of the SSR are sensitive to radiations (SEFI) leading to some unavailability during Check-out and CalVal phases.
 - Due to the impact on the mission, it has been decided to implement automatic recovery procedures on board, in several steps to encompass the complete set of causes identified -> the unavailability when an event occurs is strongly reduced

Operations and Ground System

- **Very good behavior since beginning of LEOP, no blocking anomaly, all the operations have been performed nominally, and the satellite is monitored**
 - CNES operational team at Satellite Control Center are fully in routine since several months
- **FDS (Flight Dynamic System) software and procedures allow to ensure SWOT operations with good reliability:**
 - Orbit determination and Orbit prediction
 - Comparison between FDS restituted orbit from GNSS measurements and POD MOE (based on Doris and GPSP) → **Typical residual signal $\lt; \pm 1 \text{ m}$**, well below the CBE and requirements
 - Orbital maneuvers scheduling : station keeping and collision mitigation
 - Routine programming : SADM rotation, Yaw Flip, POS3C Cross and gyro calibrations
 - Interface consumption and production -> some major interfaces are produced for Mission Center and have been refined after launch
 - Center of mass -> updates were made to account for the latest ground/AIT measurements
 - Maneuvers, eclipses and other events prediction and realization are exchanged

Main orbital events since Launch

LEOP and CHECKOUT

17 maneuvers were realized

- ✓ 6 for the 1 day orbit acquisition
- ✓ 3 calibration maneuvers as part of PF checkout
- ✓ 6 Station Keeping maneuvers
- ✓ 2 collision avoidance
 - One with KaRIn in STBY
 - One with all PL in mission mode

7 solar arrays rotations (5 after PL is ON)

→ 4 times in 78 days period (beta angle @ -25° / -6° / +6° / +25°)

2 Yaw Flips (1 after PL is ON)

→ ≈ every 78 days

1 gyro calibration

→ 1/year

2 POS-3C attitude cross calibration

❖ Only in checkout

CALIBRATION

8 maneuvers were realized

- ✓ 7 Station Keeping maneuvers
- ✓ 1 collision avoidance
 - One with all PL in mission mode

4 solar arrays rotations

→ 4 times in 78 days period (beta angle @ -25° / -6° / +6° / +25°)

1 Yaw Flip

→ ≈ every 78 days

1 gyro calibration

→ 1/year

Orbit change

July 11th to July 21st : 4 maneuvers (2 thrusts)

SCIENCE (till August 31st)

1 maneuver was realized

- ✓ 1 Station Keeping maneuvers

2 solar arrays rotations

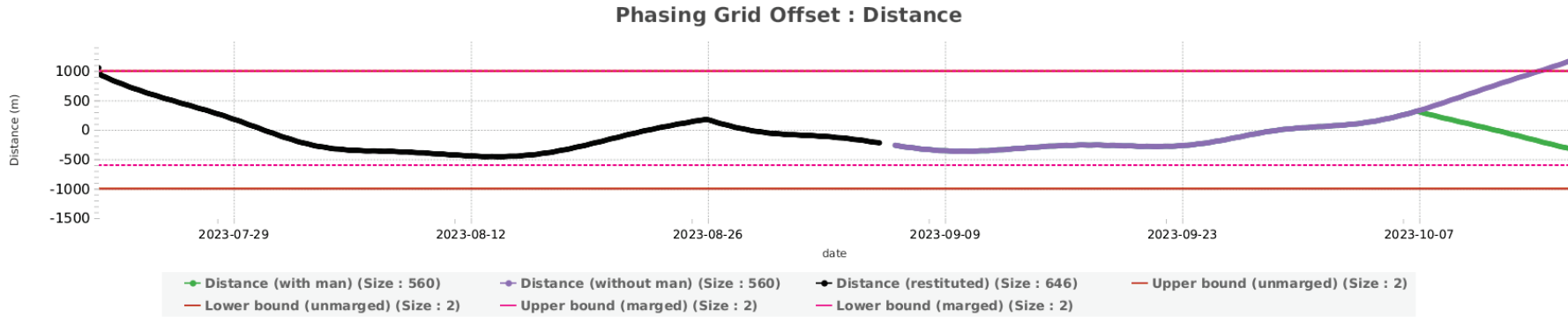
→ 4 times in 78 days period (beta angle @ -25° / -6° / +6° / +25°)

→ **Orbital events are consistent with pre-flight analysis, except for SK frequency on 1 day orbit, but with no major impact**



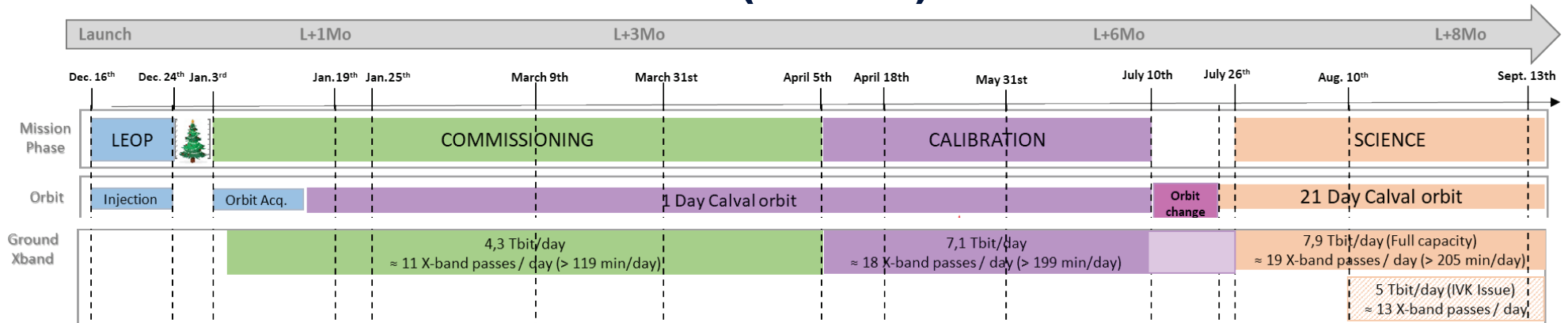
Satellite Control Center

Station Keeping on Science orbit

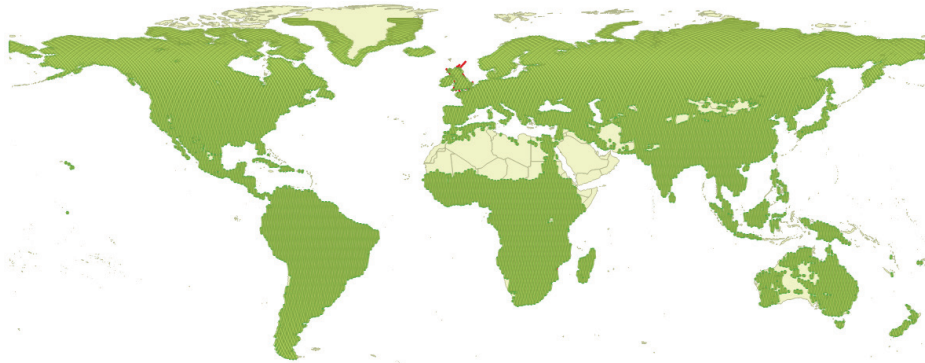


- Station keeping maneuvers ensure that SWOT remains in the +/- 1 km window along the target ground track
- Since SWOT is on Science Orbit, SK maneuvers frequency is lower, and consistent with prelaunch mission analysis
 - > 1 SK man. every 28 days or 42 days foreseen

Ground stations and network (X-band)

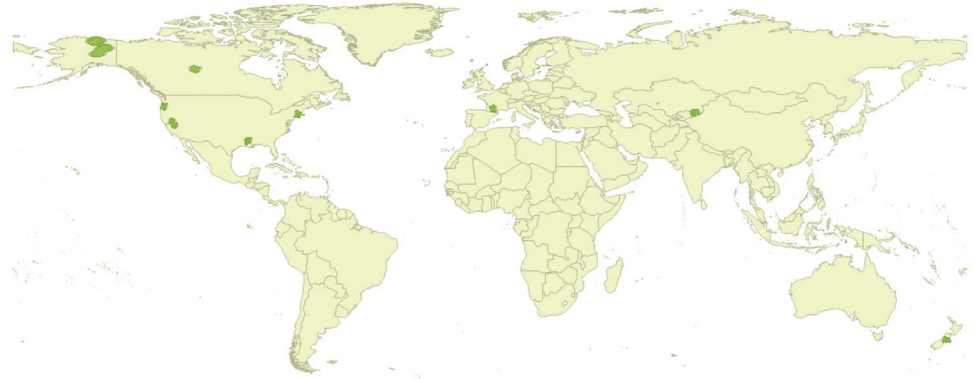


- ❖ During checkout only 2 GS used as planned (Kiruna and CNES Inuvik), checkout stations as planned
- ❖ Since August 7th : unprecedented IVK station issue due to major fires in Canada, leading to complete unavailability in S- and X-band
 - IVK and KRX, polar stations, are the most used for SWOT X-band DL (about 6 passes / day on IVK in routine)
 - The X-band download system design cannot support this IVK unavailability without decreasing on board produced data volume
 - KaRIn HR Downlink mask has been resized to fill with these new constraints (basically 80 minutes decrease on downloading time)
 - Until September 15th : 44% of nominal science HR DL mask are acquired.
 - **Nominal operations has been resumed last Friday !! Just in time for the SWOT ST meeting 😊**



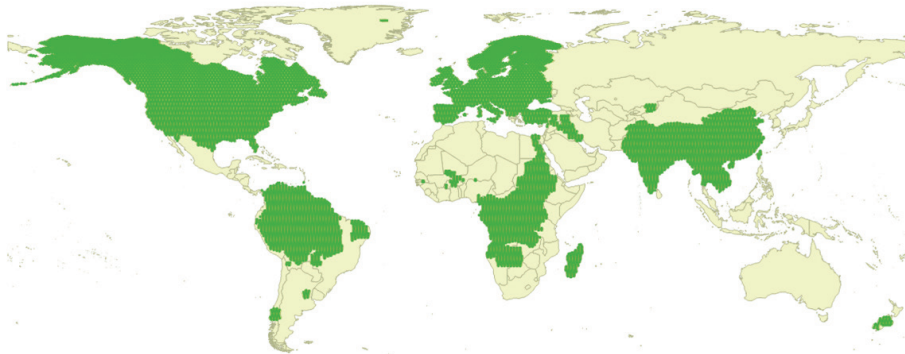
HR Science mask v5 (nominal summer)

→ July 26th to Aug. 11th, and from Sept. 15th



HR Science mask reduced to Calval areas

→ Aug. 11th to Aug. 21st



HR Science mask v6b → Aug. 21st to Sept. 15th

Summary of HR Downlink masks used on science orbit

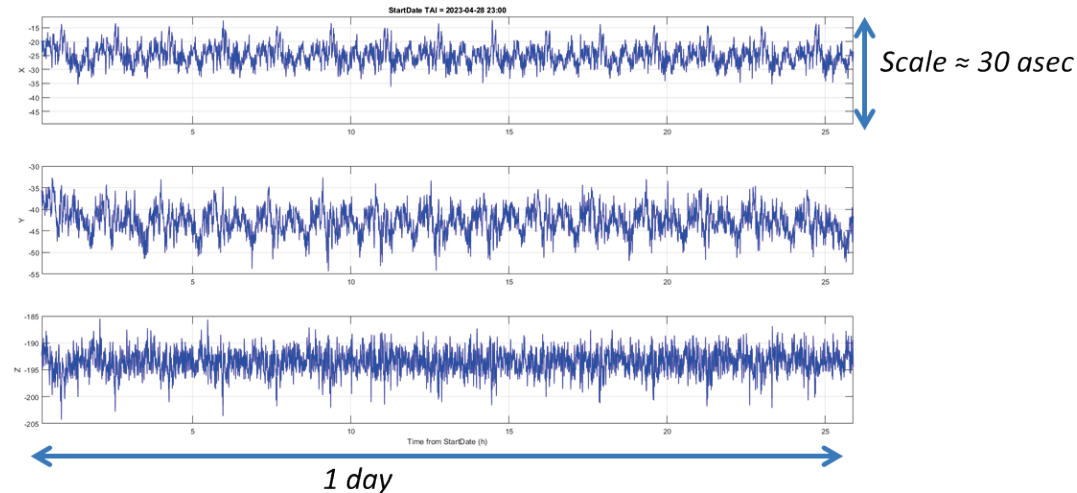
Pointing : Checkout specific pointing activities

- KaRIn antennas initial in flight alignment was acceptable -> only fine alignment was done
- SC repointing for KaRIn pointing improvement (deduced from KaRIn data, and bias added to preflight KMSF bias)
 - Roll : -7,5 mdeg
 - Pitch : -12,46 mdeg
 - Yaw : +53,37 mdeg
- 2 Cross maneuvers for Nadir Altimeter antenna RF axis pointing estimation, repointing for KaRIn had a minor impact on POS-3C pointing

Pointing : Reconstructed attitude

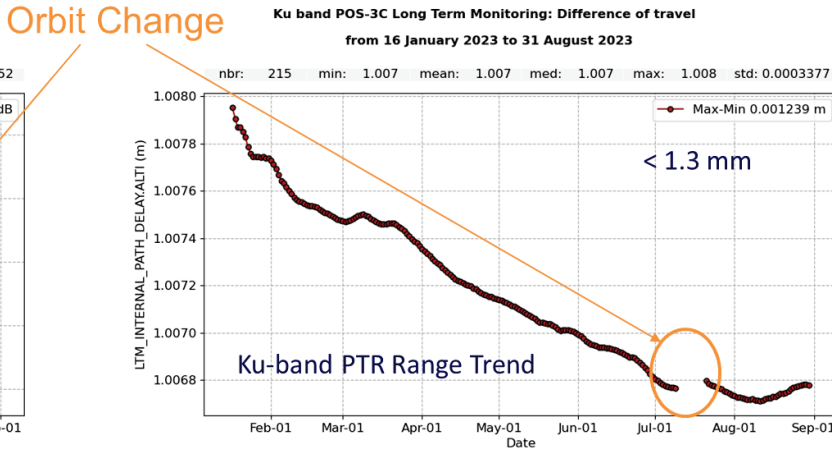
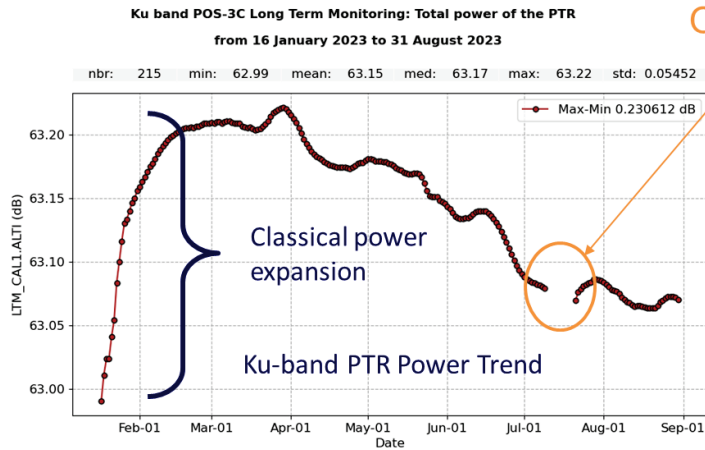
- Reminder : CNES is responsible or ATTD_RECONSTRUCTED production
- It provides the most accurate estimate of KMSF attitude based on Platform Star Trackers and KaRIn Gyro measurements
- Several updates were made, in iterations with JPL team
- The product has been successfully validated, including some observations in KaRIn radar data during some specific AOCS events (Solar array rotations)

*Routine behavior example, time series of the difference between the estimated attitude of KMSF and the reference target attitude, so including control error : **very weak perturbation along the orbit***



Nadir Payload : POS-3C and Doris, a few highlights

- **Nadir altimeter** behaves as expected, measured performance and stability are within **specifications**



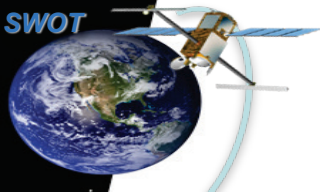
Internal calibrations are daily acquired and monitored, Used for corrections of altimeter data (power and range) and to assess long term performance and stability

- **DORIS** instrument is performing very well, with excellent availability
 - On Board performances meet or exceed the expectations
 - Navigation performances (radial accuracy of ~2 cm RMS compared to MOE) compliant with near-real-time altimetry and OLTC altimeter mode
 - Time restitution accuracy below requirements (<1.5 μsec)
 - KaRIn Bulletin accuracy largely below requirements (<10 cm)

Conclusion

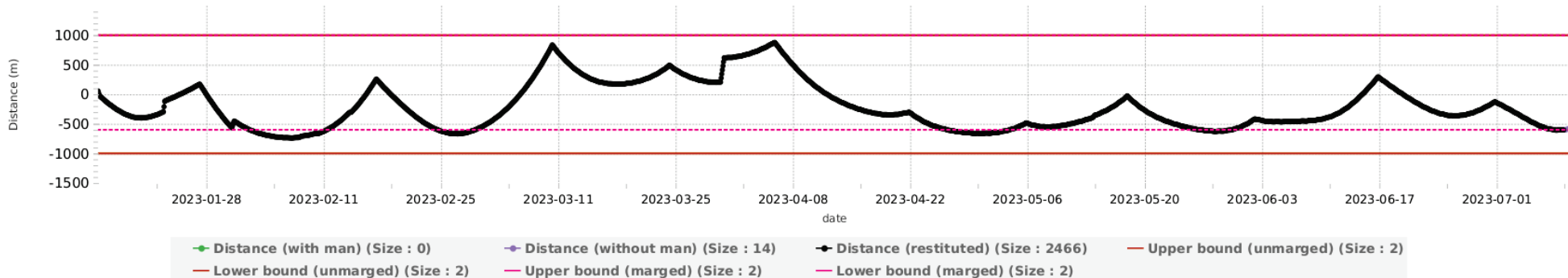
- **SWOT system is fully operational**
- **SWOT platform is performing very well, all measured performances are largely within requirements, and no unexpected behavior is observed**
- **Flight Dynamic System provides all the required inputs to the mission center, and largely meet the level of requirements**
- **Routine orbital events are well planned and communicated, with an induced unavailability meeting the requirements**

Back-up slides

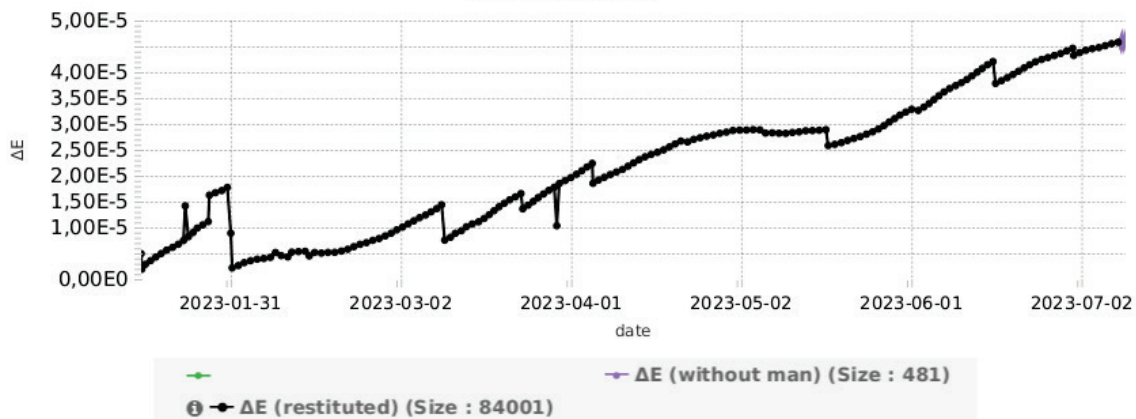


Station Keeping on CalVal orbit

Phasing Grid Offset : Distance



Eccentricity

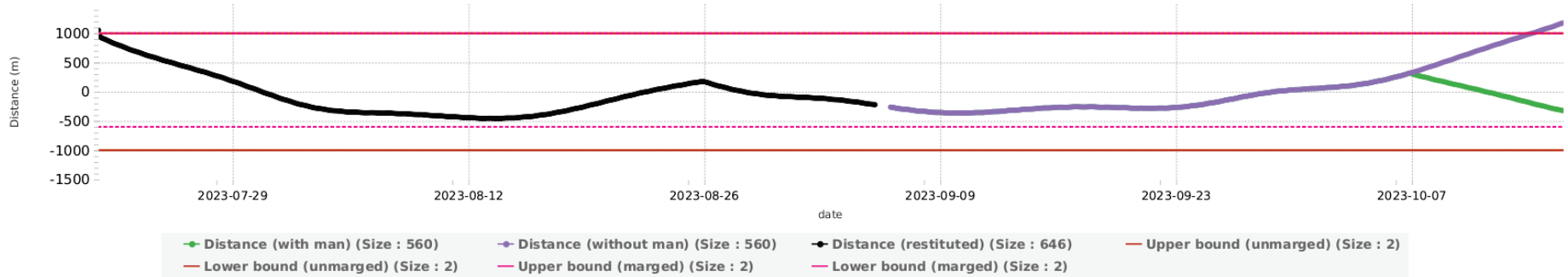


- SWOT remained in the +/- 1 km window along the target ground track
- Δe always stayed way below 10^{-4} from frozen eccentricity
- Maneuvers frequency was higher than expected :
 -> SK maneuvers every 2 weeks during Checkout and CalVal phases (instead of pre-launch estimation of 40 days), because of stronger perturbation forces, and synchronization with PRF tables update cycle

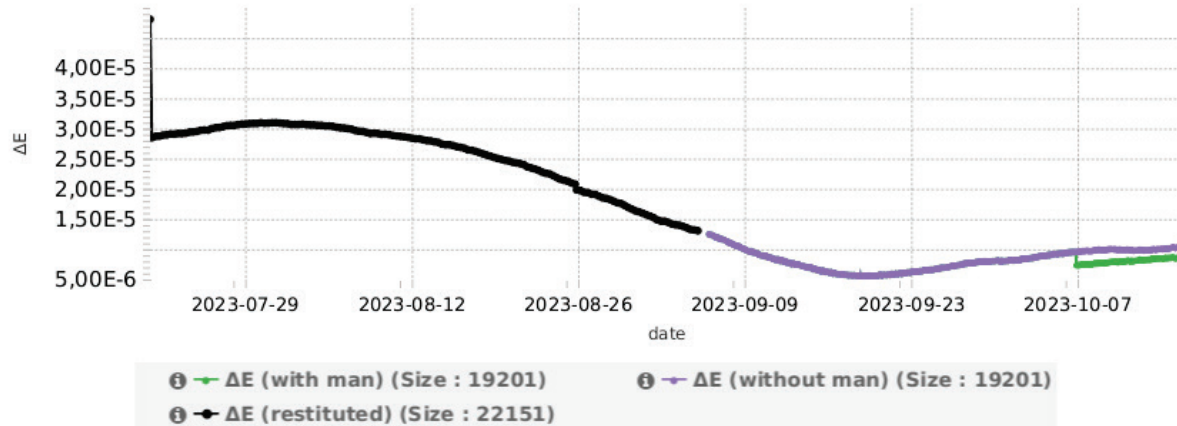


Station Keeping on Science orbit

Phasing Grid Offset : Distance



Eccentricity



- [SK frequency on Science Orbit is lower](#), and consistent with prelaunch mission analysis
-> 1 SK every 28 days or 42 days foreseen
- Eccentricity maneuver frequency should be around 1/year as expected