# Operational optical data service for Geosynchronous satellites

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Space Flight Dynamics Services, Systems and Operations

*Theme: Service Models*

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# Presentation layout

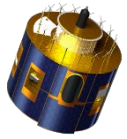
- The EUMETSAT GEO fleet: Meteosat
- Operations differences: MSG vs MTG
- Orbit determination baselines for Meteosat
- The new optical data service procurement:
  - Service components, Operational modes
  - Service requirements
  - Service Level Targets and Credit Scheme

# Meteosat spacecraft: 1st, 2nd and 3rd generation

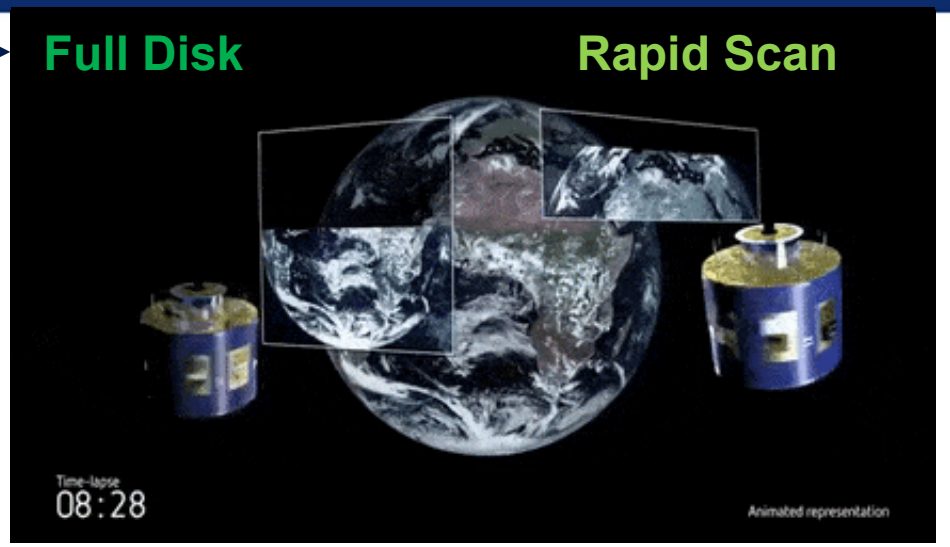
*Meteosat 1st Generation (MFG)*

- *… till 2017*


Meteosat 2nd Generation (MSG), currently flying



- 4 satellites, spin-stabilized (~100 rpm)
- 2 ton class; 2 imaging services

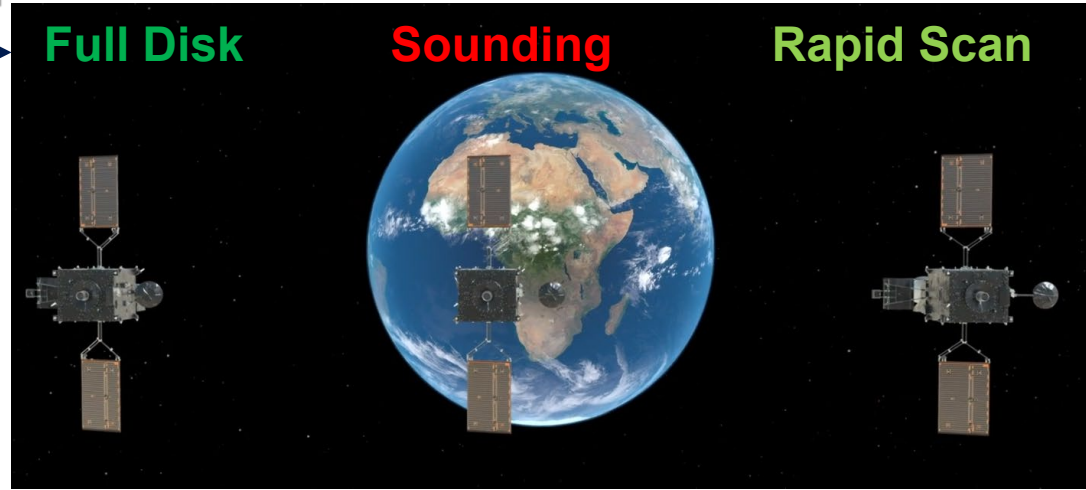




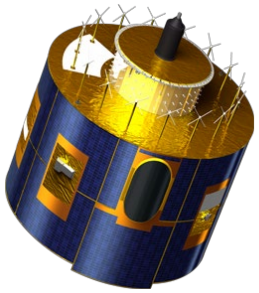
**[ EUM Longitude slots assignment for flying fleet ]**

## Meteosat 3rd Generation (MTG)

- **6 satellites, 3-axis-stabilized**
- **4 ton, 2+1(sounding) services**
- **…from Oct/2022**



# Meteosat operations differences: MSG vs MTG

| | Meteosat Second Generation MSG | Meteosat Third Generation MTG |
|---|---|---|
| |  |  |
| *Orbit Determination requirements* | 3km/3km/0.3km 3σ ACR*<br>* = Along-track/Cross-track/Radial | 1.5km/0.5km/0.3km 3σ ACR*<br>(50m Radial for INR initialisation) |
| *Manoeuvres frequency:*<br>• *North-South Station Keeping*<br>• *East-West Station Keeping*<br>• *Reaction Wheels Off-loading* | <br>1 per year<br>1 per 8 weeks cycle<br>None | <br>2 (sequence) per 8 weeks cycle<br>1 per 4 weeks cycle<br>1 per 4 weeks cycle |
| *Antennas per N satellites* | N+1 | N |
| *Safe Mode, orbit disturbance* | None | A-priori unknown manoeuvre<br>(Longitude drift max 0.2°/day) |
| *Satellite Co-location* | No | Yes (up to 4) |

# Meteosat ranging antennas

- **Operational Orbit Determination (OD) based on S-band ranging, from 2 alternating stations per satellite**
- **Antennas procured per satellites family, but re-used for successive programmes**
- **Physical Relocation in time:**

  **Contractual reasons, cost savings, synergies between SC programmes**

*Past Satellites* *x7 (MFG)*

*x2, Proprietary Antennas (Antenna 1&2)*

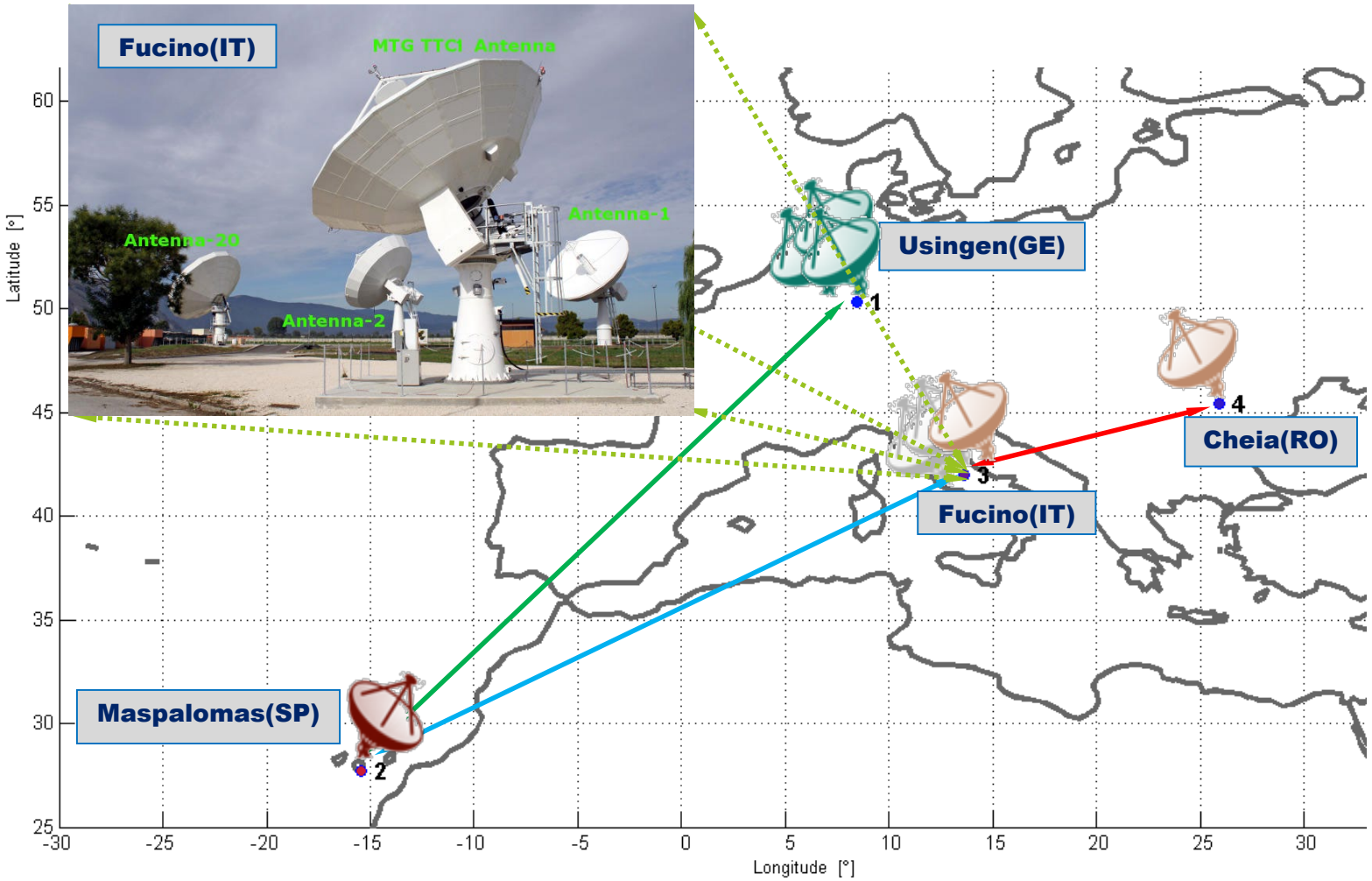
**Current Satellites** **x4 (MSG)**

**x3, Proprietary Antennas** *(Antenna 18,19, 20)*

**x1, External Service**

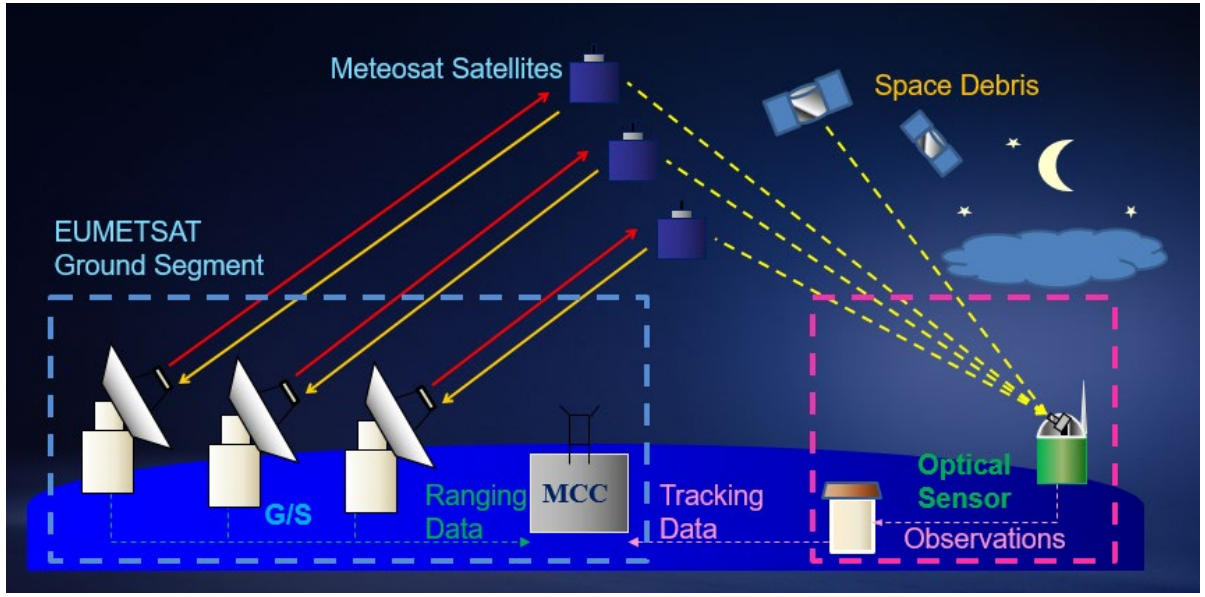
*Future Satellites* *x6 (MTG 4I+2S)*

*x2, Proprietary Antennas (TTC1&2)*



# Optical Tracking Data Service in support to OD

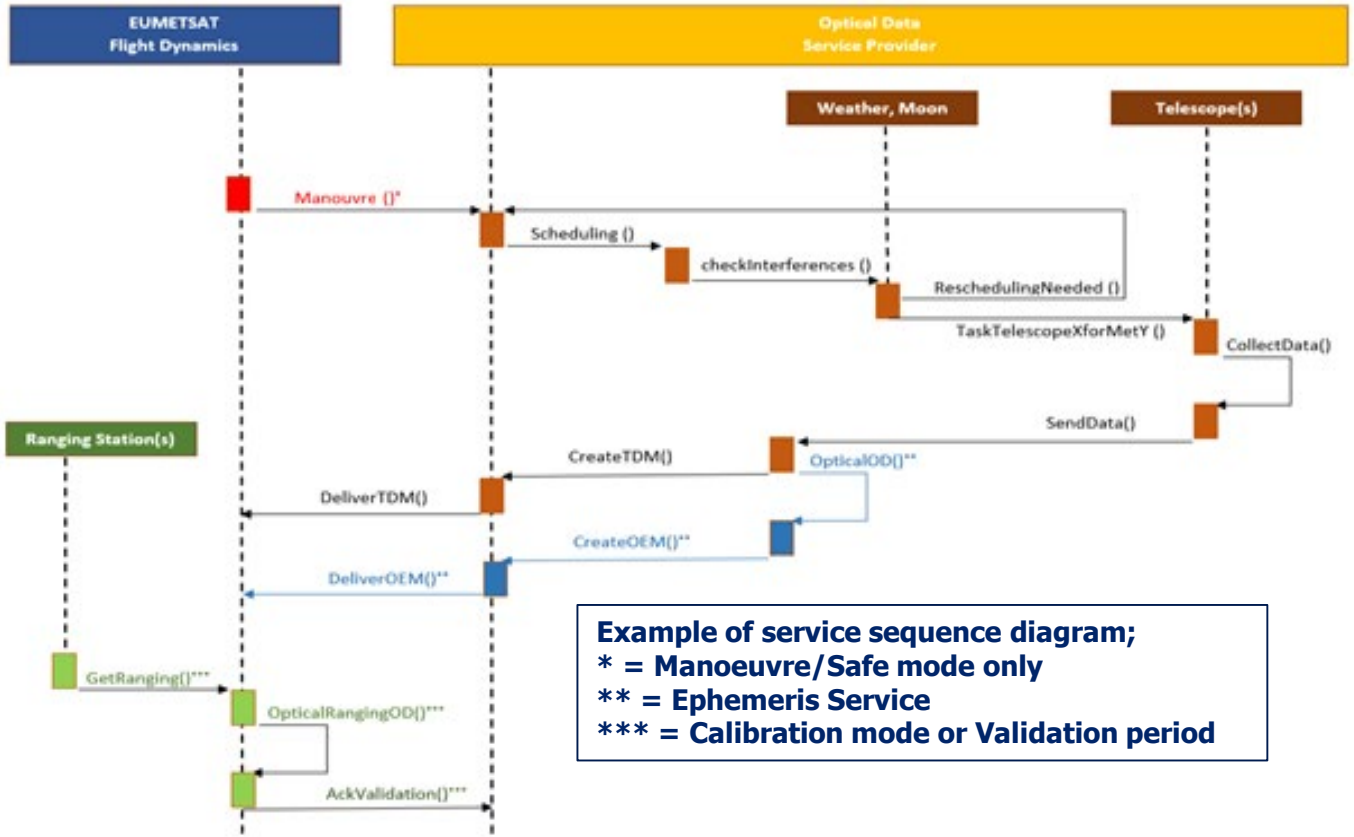
- Ground-based telescope measurements for OD, Pro/Con:
  - ✓ Completely passive solution
  - ✓ Cheaper than ranging, for comparable OD accuracy
  - ✓ High accuracy angular measurement
  - ○ Weather and illumination conditions dependencies
- EUMETSAT previous experience with telescope networks:
  - Met-7 EOL re-orbiting
  - Prototype 1+1+1 years service (running till end 2021)
  - Service ran in parallel to operations for cross checking OD results, also establishing standard interfaces
- New needs:
  - More demanding system requirements
  - More intense operational load
  - Reduced antennas redundancy and ranging baseline
  - More frequent manoeuvres also in case of contingencies (safe mode)




- MTG system enabled by design to ingest and use optical tracking data & derived orbits, fully integrated in the ground segment
- New ITT 21-221726 on EUMITS: 5 years initial contract period, ITT closed on 30/June/2021, Under evaluation at the moment;
- Service model and procurement approach presented in next slides

# Statement Of Work: Service components and modes

The service consists of 2 components:
- Tracking Service : Provision of optical angular tracking data, CCSDS Tracking Data Message (TDM)
- Ephemeris Service : Provision of orbit determination solutions, CCSDS Orbit Ephemeris Message (OEM)



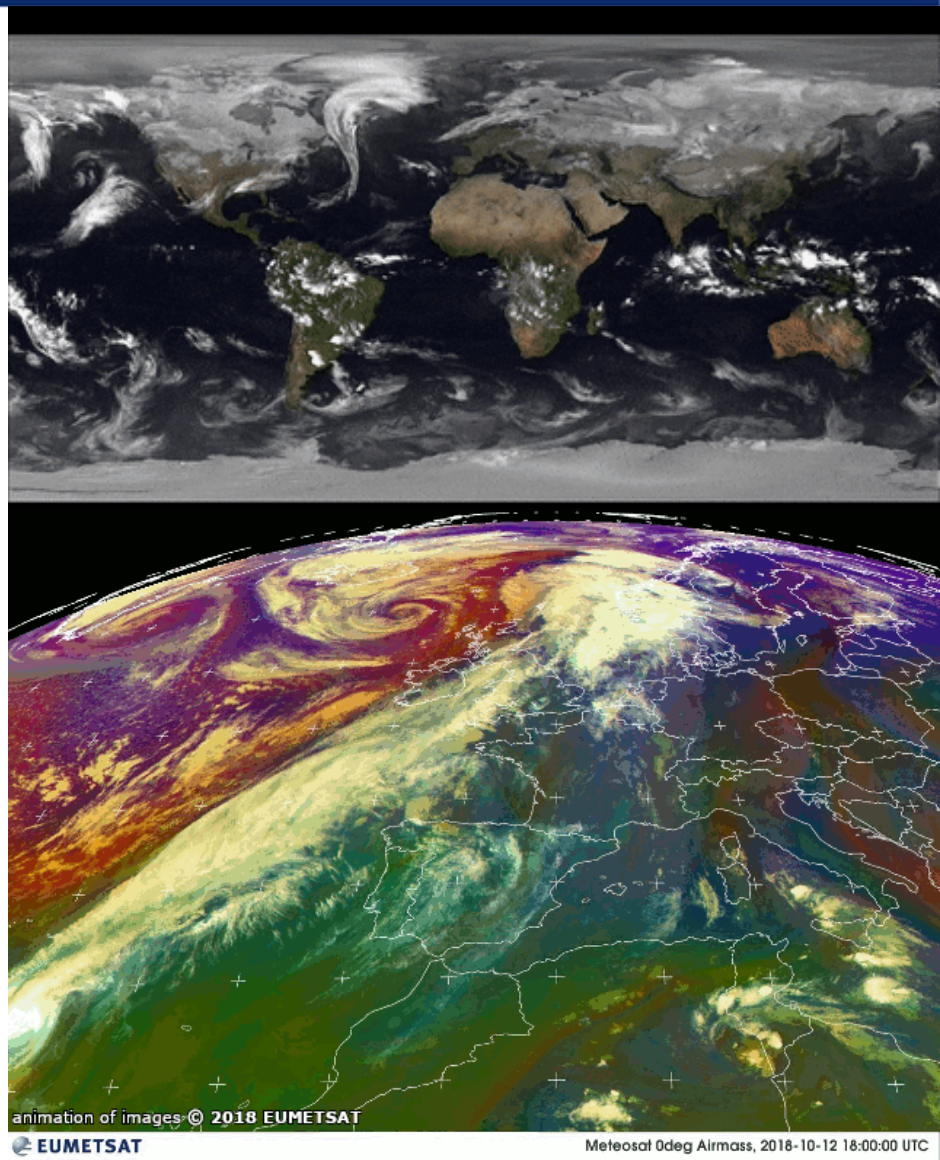

The service is based on 4 modes:

- *Routine Mode:* continuous/regular basis, without explicit activation request by EUMETSAT, with flexibility in scheduling optical measurements acquisition (e.g. 1 or 2 night every week)
- *Manoeuvre Mode:* planned and advanced activation, with the purpose of speeding-up the post-ΔV orbit determination and to cope with ground stations outages.
- **Safe Mode:** supporting contingency spacecraft operations, service activated with short notice just after the spacecraft enters survival mode
- **Calibration Mode:** periodic regular calibration of the tracking system(s), by means of extended observability periods and augmented tracking geometry, generating ephemerides based on data fusion (optical data + EUM ranging).

*Validation phase* for all modes at service start

# Statement Of Work: Service Requirements

- Statement of Work contains ~70 requirements
- Requirements are grouped in Functional, Interface and Effectiveness. Example of tracking Functional scheduling requirements:
  - Tracking period : minimum of 2 slots of measurements, each with duration of 15 min, separated by at least 2 hours, containing at least 60 measurements regularly spaced.
- The service is required to adapt to the variable size of the EUMETSAT GEO fleet with time
- Focus on telescopes redundancy and weather pattern decorrelation for the sensors' sites to cope with MTG availability and timeliness needs.
- Required capability of activating at least 2 sensors located in different sites (separated at least 100km), in the same tracking period.
  - in Calibration Mode this increases the observability
  - in all the other modes this ensures weather diversity, also monitored by service level targets (see next slide)



# Service Level Targets and Credit scheme

Outages due to reduced availability or lack of redundancies and the overall quality of Service are monitored via Service Level Targets (SLTs) and regulated by a Credit scheme.
Firm fixed prices for the deliveries, differentiate for each mode

SLT-01 **Timeliness** of deliveries to EUMETSAT:

- "Routine Mode", 3rd working day after tracking; "Manoeuvre Mode", 24h after manoeuvre. "Safe Mode", 1h after collecting each slot

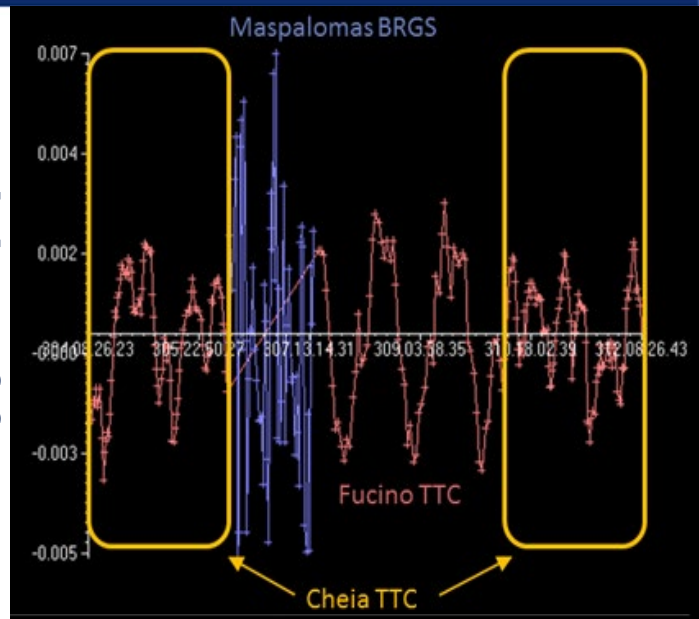
SLT-02 Tracking Service, **Measurements distribution** according to required scheduling

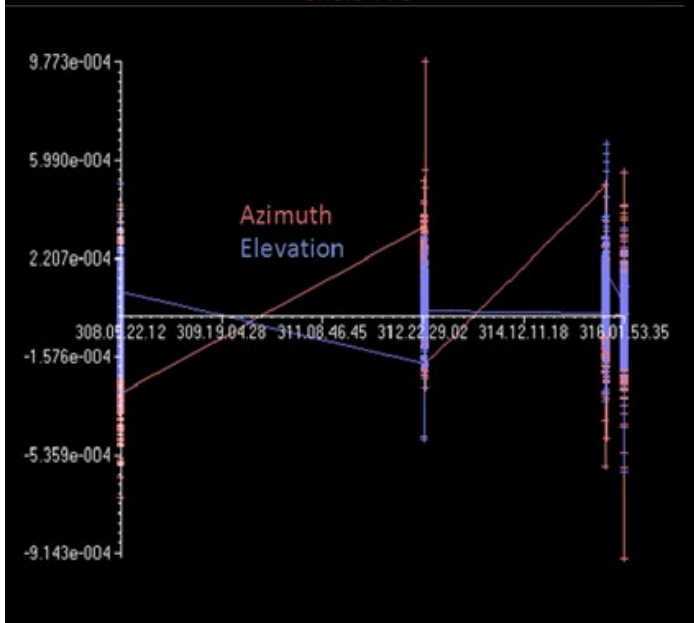
SLT-03 **Tracking Service, quality** indicator: EUMETSAT performs OD based on data fusion (optical data + stations ranging, see plots aside). The service TDM residuals are evaluated as follows:

- Mean and standard-deviation (Azimuth/Elevation) below 0.75 millidegrees (in absolute value) for 97% of measurements.

SLT-04 **Ephemeris Service, quality** indicator: EUMETSAT performs OD based on data fusion. The service OEM position error (ACR) are compared to these thresholds:

- <500m/300m/35m "Routine Mode"; <1200m/350m/350m in "Manoeuvre Mode"; <1200m/350m/350m in "Safe Mode"



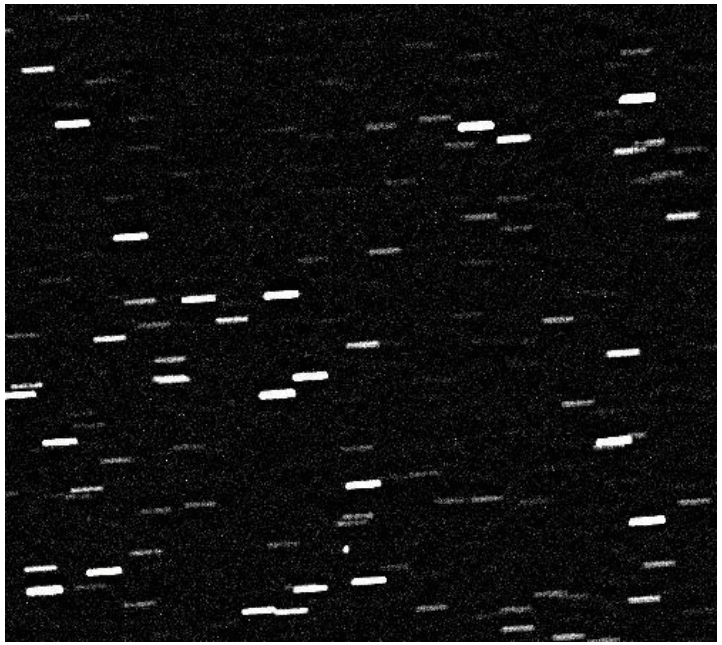

For every delivery, the non-fulfilment of the SLTs is penalised based on the following factor:

$$Px = \left[1 - \frac{(A+\Sigma Wi)}{S}\right] \times 100\%$$

of the relevant Firm Fixed Price per delivery. S is the total number of satellites target for the delivery; A is the number of satellites achieving the SLT; the weight coefficients Wi are defined as follows:

| | Routine | Manouvre | Safe | Calibration |
|---|---|---|---|---|
| **SLT-01 Tracking** | Wi= ⅔, ⅓, 0 for delay up to 2, 4, more days | Wi= ⅔, ⅓, 0 for delay up to 6, 12, more hours | Wi= ⅔, ⅓, 0 for delay up to 6, 12, more hours | N/A |
| **SLT-01 Ephemeris** | Wi= ⅔, ⅓, 0 for delay up to 2, 4, more days | N/A | N/A | N/A |
| **SLT-02 Tracking** | Wi= 0.9 | Wi= 0.9 | Wi= 0.9 | Wi= 0.9 |
| **SLT-03 Tracking** | Wi= 0.5 | Wi= 0.5 | Wi= 0.5 | Wi= 0.1 |
| **SLT-04 Ephemeris** | Wi= 0.5 | Wi= 0.5 | Wi= 0.5 | Wi= 0.1 |

# Conclusions



- Optical Data are effectively improving robustness and accuracy of the Orbit Determination in GEO
- This kind of service was extensively tested by EUMETSAT in the past, with prototypes in parallel to operations
- The MSG antennas relocation and the MTG demanding system requirements (manoeuvres, safe mode, etc..) led to the full integration of optical data service as part of the baseline design

- The procurement approach (EUM ITT 21/221726) and the service model has been presented today
- Service validation and operational phase to start in Q4-2021
- Questions???