MICROSCOPE
Mission operational concept

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1) Major points of the operational system

Mission and objectives

- Test of EP with a relative accuracy of 10^{-15}, 100 times better than on Earth
- **Need for long observation durations** (measurement sessions ranging from 1 to 9 days)

Space segment

- CNES MYRIADE spacecraft (Micro-satellite) with major adaptations
- Cold Gaz Propulsion System for drag-free → **limited resources**, typically 1.5 years
- **Strong coupling between AACS and T-SAGE**
  - Coupling at the heart of the operational concept
  - Payload also considered as a sensor (no dedicated payload TeleMetry, only platform TM)
  - MYRIADE modes and onboard handling adapted for MICROSCOPE
- No need for a specific monitoring once the first critical steps are passed
  - Ground segment human activities during **working days and working hours only**

1) Major points of the operational system

Orbit (sun synchronous, 700km, 6h or 18h) and impact on operations

✦**2 major orbital unavailability** preventing from scientific sessions:

» Eclipse season (~3 months) once a year

» Star tracker blinding by the Moon (~2.5 days, 8 times per year)

→ stop drag-free system, idle mode

✦**~8 pass per day** over a CNES ground station

» 8min typical duration, 6hours max inter-visibility

✦**No phasing between mission scenario and 24H days**

» Scientific needs based on 20 orbits segment (1 orb = 1h40min // 1 day = 14,4 orb)

» We stick to the scientific need to minimize the gas consumption

» **Anticipation and automatic process** allow to stay on a working days/hours scheme for the ground operations

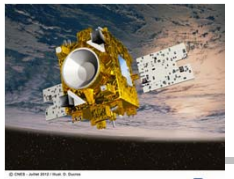
1) Major points of the operational system

Mission scenario

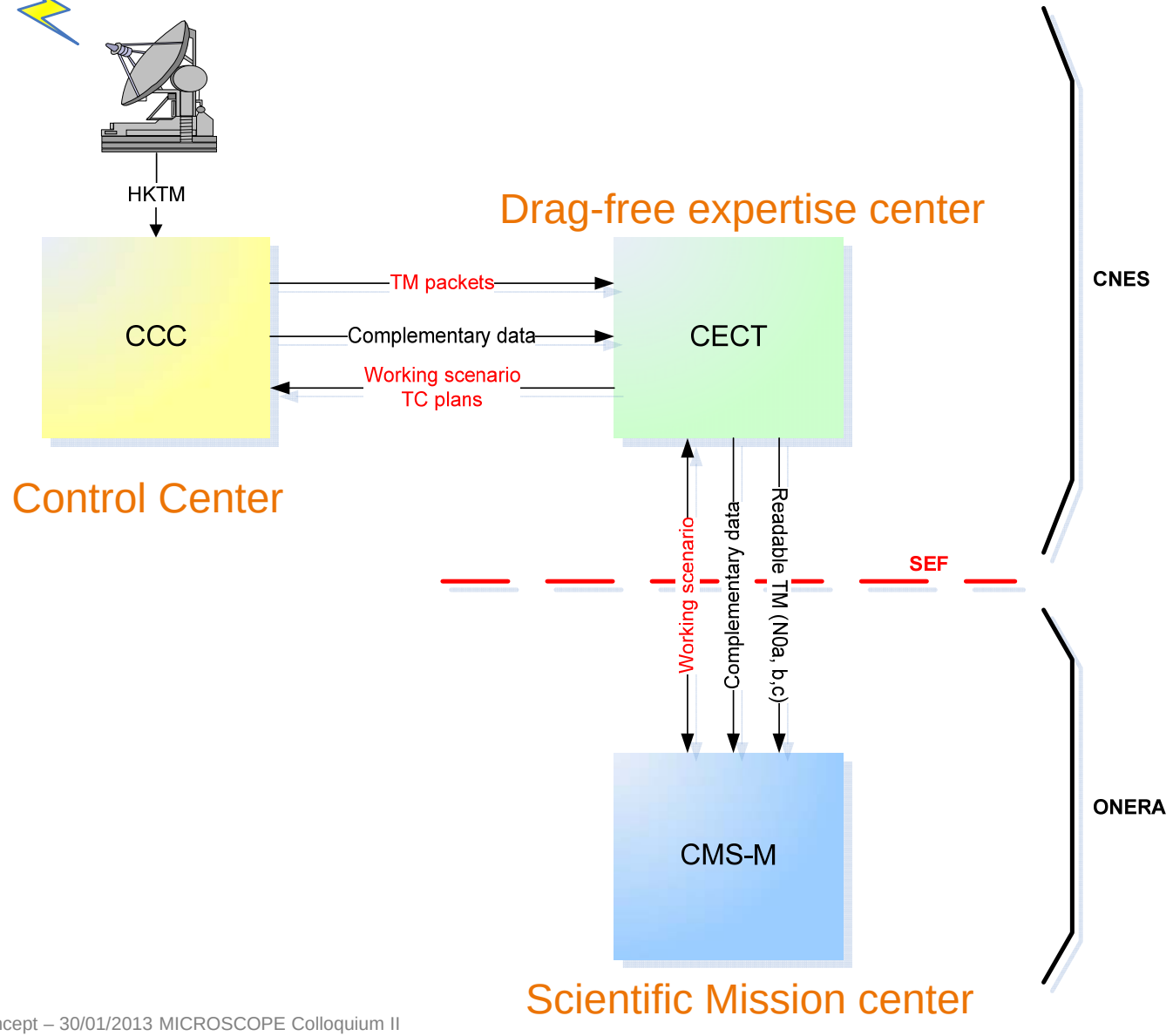
- Made of **scientific sessions (EP measurement sessions, calibration session)**

- **Final in-flight scenario will be close to the actual reference scenario**:
  - Sessions list and T-SAGE parameters already known
  - No link between mission programming and orbital event (except for the predictable Eclipse season and STR blinding periods)
  - Partially “static” aspect of the mission programming

- BUT we’ll **get ready for the unforeseen**:
  - Mission success relies on the confidence within the results → **working scenario** will be weekly adjusted depending on the observation, requesting pre-validated scientific sessions
  - “Technical sessions” may be requested (for preliminary activities and tuning, investigation, SW update…) relying on a more flexible approach



1) Major points of the operational system



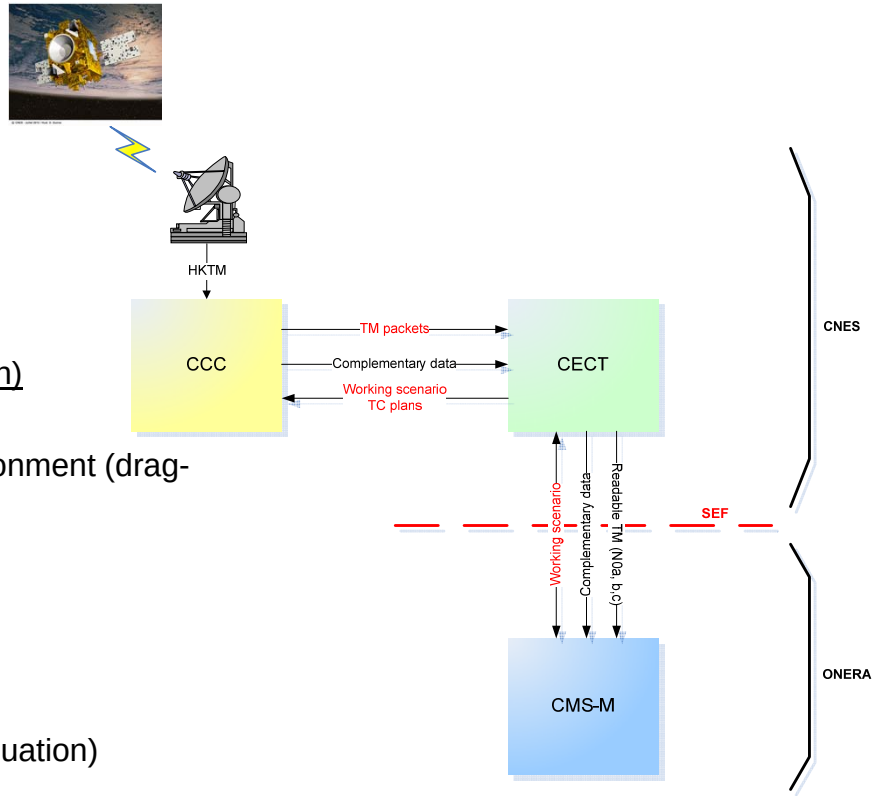
1) Major points of the operational system

3 main entities composing the ground segment

- Command and Control Center **CCC**
  - Almost generic CNES MYRIADE CCC
  - Platform handling (programming and monitoring)
  - AACS handling outside mission modes

- Drag free expertise center **CECT**
  - Specific center for MICROSCOPE
  - Output N0 mission data (TM, orbit and attitude determination)
  - Mission programming implementation (T-SAGE and AACS)
  - Monitoring of the status and performance for T-SAGE environment (drag-free, propulsion, thermal…)

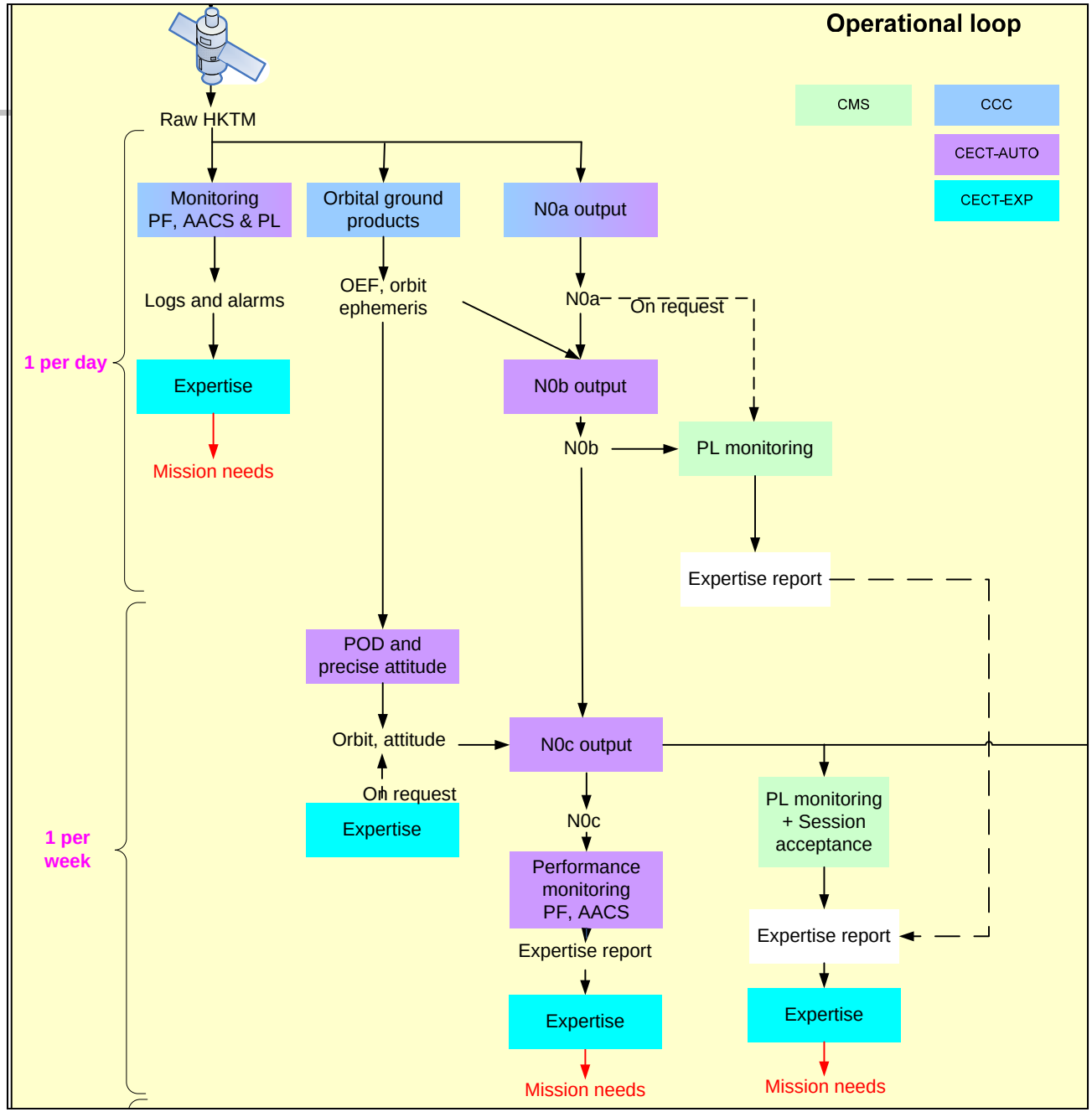
- Scientific mission center **CMS**
  - Payload and mission monitoring
  - Mission programming definition
  - Scientific processing (N1 data for calibration, N2 for EP evaluation)



2) Operational loop

Monitoring and sessions acceptance based on N0 data:

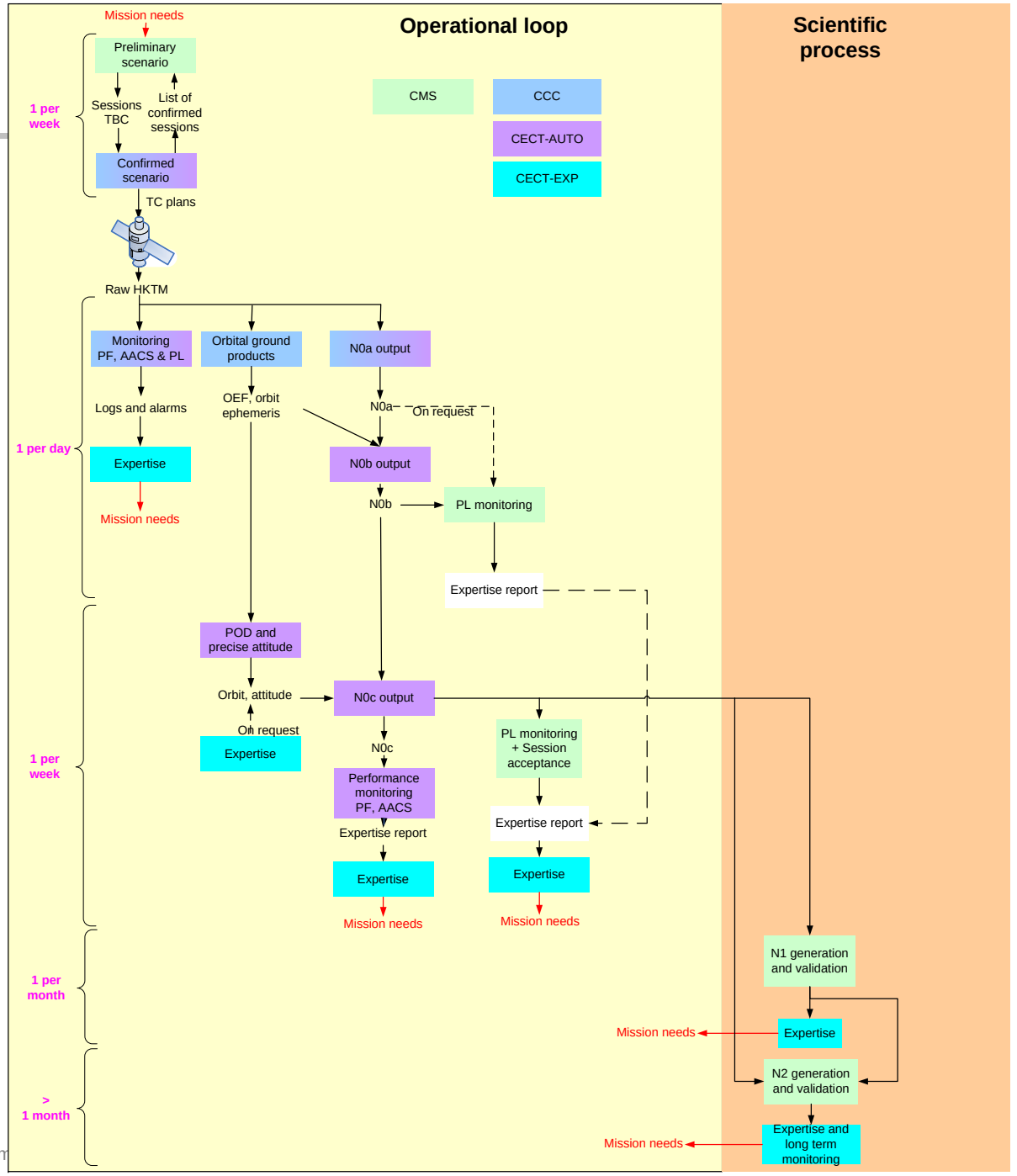
- N0a = every pass
- **N0b = every day**
- **N0c = every week (for each session)**



2) Operational loop

Scenario update every week

N1 and N2 data out of the operational loop, but possible long term impact on the mission scenario for adjustment



3) Orbit determination

Need of orbit determination for gravity gradient knowledge. Most stringent requirement = 7m radial and 14m tangential @Fep

- Use of Doppler measurement from the telemetry signal (S-Band @2.2GHz)
- Marginally consistent with performance requirement:
  - With 9 passes per day over ground stations “well” distributed
  - Assuming a good performance of the Tx oscillator (for signal frequency stability)
- Very difficult to guarantee the performance and to monitor it

GPS receiver introduced as a nominal onboard equipment in 2011:

- Guarantee metric accuracy: using GPS Code measurement fed into a Precise Orbit Determination tool (in addition to the Doppler measurements)
- Allow to evaluate the performance of the Doppler based measurements (and to characterize in orbit the transmitter oscillator for ground compensation of its defaults)

Precise Orbit Determination will allow for T-SAGE linear bias evaluation while in inertial mode: systematically performed, for expertise only

4) Data time stamping

Scientific data time stamping shall be better than 50ms (w.r.t. UTC) :

- **Consistent with Myriade onboard time prediction** (OBT, w.r.t. UTC), periodically updated via the "Top TC":
  1. Ground station time stamping (ground GPS) of a direct TC uploaded to satellite
  2. Onboard time stamping of this direct TC when received
  3. Propagation time computed from the number of TM frames received between events 1 and 2

No onboard time update allowed during a session:

- Up to 9 days between 2 updates of the onboard time prediction
- Consistent with OBT performance: long term stability of the oscillator with compensation of its bias and drift

Time stamping stability @Fep shall be better than 3µs:

- **Consistent with OBT performance**: stability of the oscillator w.r.t. temperature variation

Use of the onboard GPS receiver:

- **Not used for onboard time stamping**: too big modification, and no need of better performance
- Used to continuously perform correlation of the onboard time prediction and the GPS time: ground monitoring of the onboard time stamping accuracy with a 1ms accuracy

5) Telemetry (TM) loss and recovery

TM availability is not 100% on CNES Myriade mission:

- Requirement = 98.5 % for S-Band TM (house-keeping)
- Typical observed availability = 99.3% (PICARD mission data)
  - 1 TM gap (> 1 min) duration every 4 days
  - Cause = transient anomaly during a pass (bad tracking) or full pass loss (wrong conf. or breakdown)

MICROSCOPE uses S-Band TM for both HK and scientific data.

Data gaps shall be minimized to ensure EP signal processing: no gap during session in spin mode (1.5 day), max. 3 gaps during session in inertial mode (9 days).

Better availability is required, and redundancy is introduced in the system:

- Data is available onboard during ~9 hours (capacity of the cyclic memory).
- CCC ensures automatic detection of data loss and when needed generates a command to be uploaded next pass (few hours later) to re-download the missing data.
- Requirement: 90% gaps shall be recovered.

➔ **Availability of 99.93% of the data expected for MICROSCOPE**

➔ **Typically one remaining TM gap (> 1min) every 40 days**

Conclusions

Operational concept in place to face MICROSCOPE challenges:

- Based on CNES MYRIADE standards
- CECT = dedicated center for drag-free expertise and support to the Scientific Mission Center
- Weekly activities for expertise and scenario update + daily monitoring

Improvement with respect to previous CNES MYRIADE system:

- GPS receiver to improve and guarantee the orbit determination (usually only based on Doppler measurement)
- GPS receiver will also guarantee data time stamping (based on the daily Top TC mechanism)
- Automatic process for TM loss detection and re-download to improve even more the data availability