System and Operational Coordination

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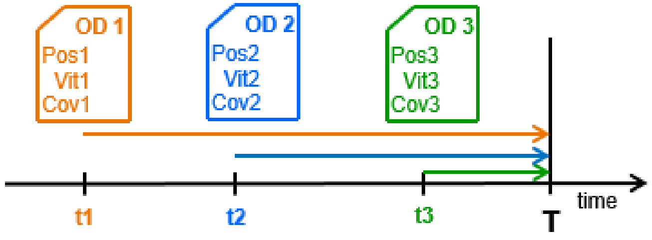
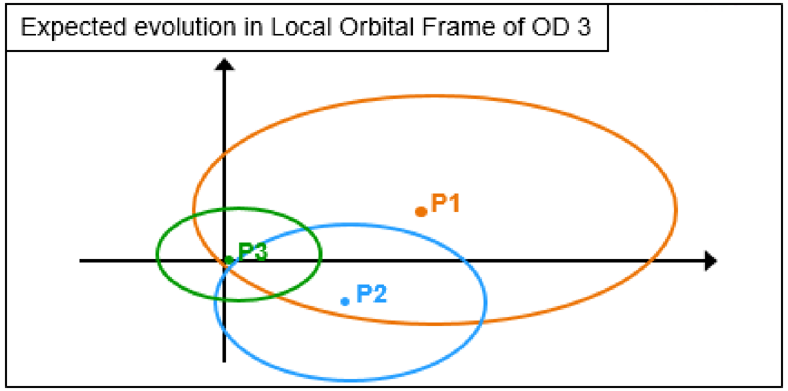
Classical method and Scaled PoC

❖ STM distribution ➔ computation of a Scaled Probability Of Collision (COPoC)

3 Orbit Determination Updates (with Cov. Matrix), of the position at T





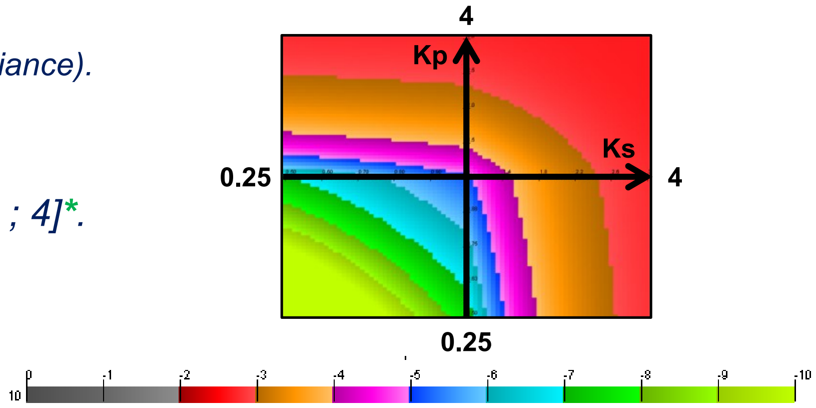
- PoC(Kp, Ks) gives the PoC as a function of scale coefficients:

  with C = Kp Cp + Ks Cs (Kp, Ks independent scale factors applied to Primary's and Secondary's covariance).

- **PoC* is the Maximum value** of PoC(Kp, Ks) with Kp and Ks in an interval:

  at CNES, the automatic monitoring computes PoC with Kp in [0.25 ; 4]* and Ks in [0.25 ; 4]*.*

- **Scaled PoC is the PoC* for Kp and Ks in shrunken-by-the-analyst**** intervals.

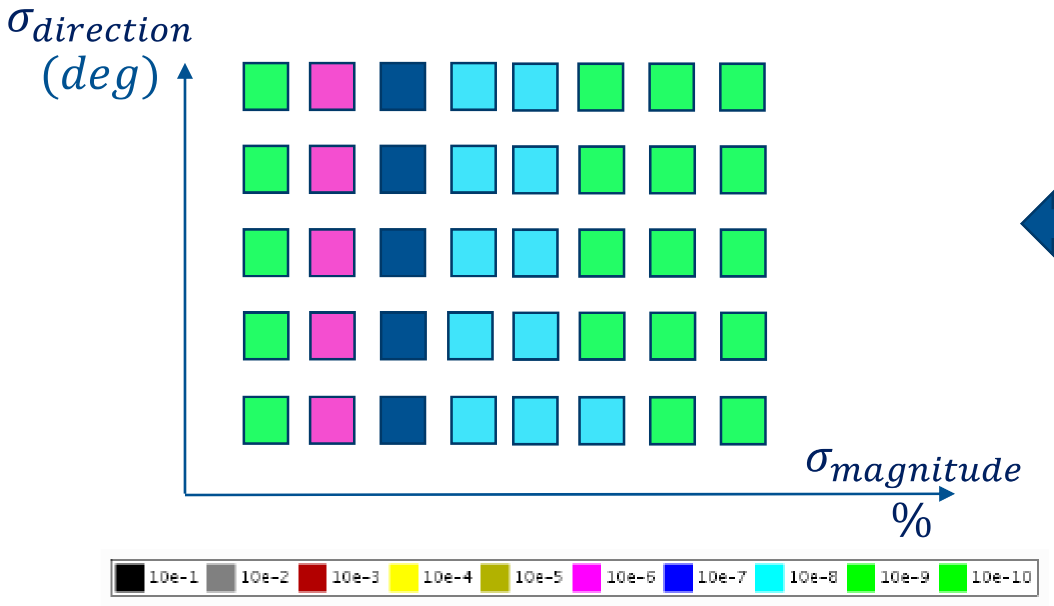


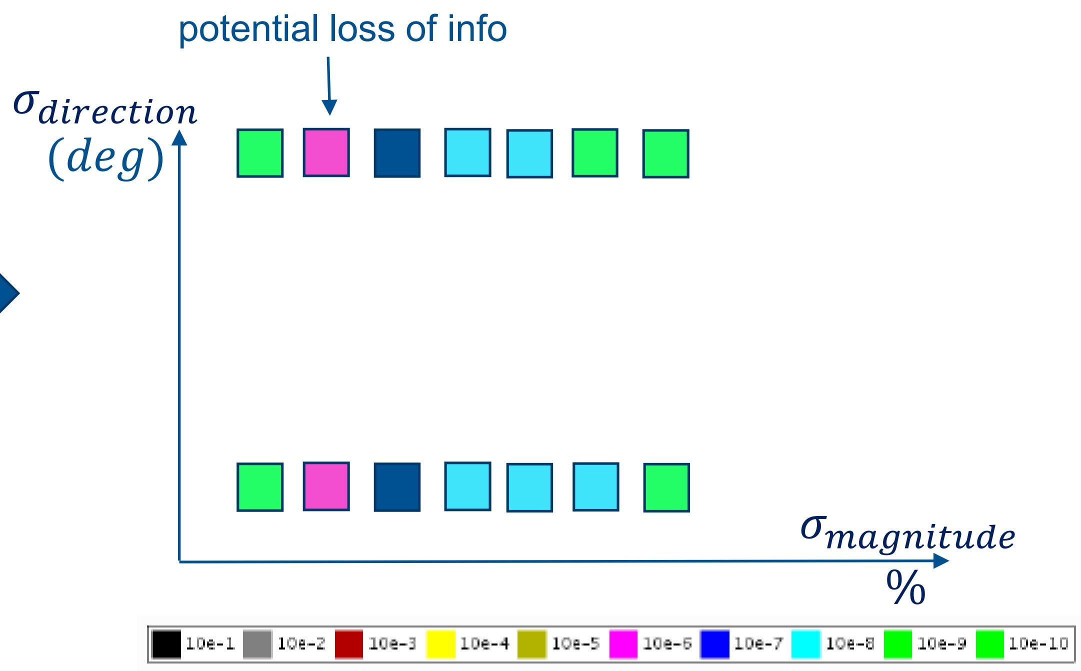
* these intervals have been determined from an historical analysis of operational data.

** the analyst takes into account OD parameters and the evolution of updates with respect to previous covariance to determine sub-intervals to consider.

QtW method and Scaled PoC

- **Computation time greater than standard approach (STM)**
  - Definition of a "covariance grid" with a finite number of $\{\sigma_{direction}; \sigma_{magnitude}\}$
  - Computation duration highly dependent on the grid size
  - Trade-off between performance and precision



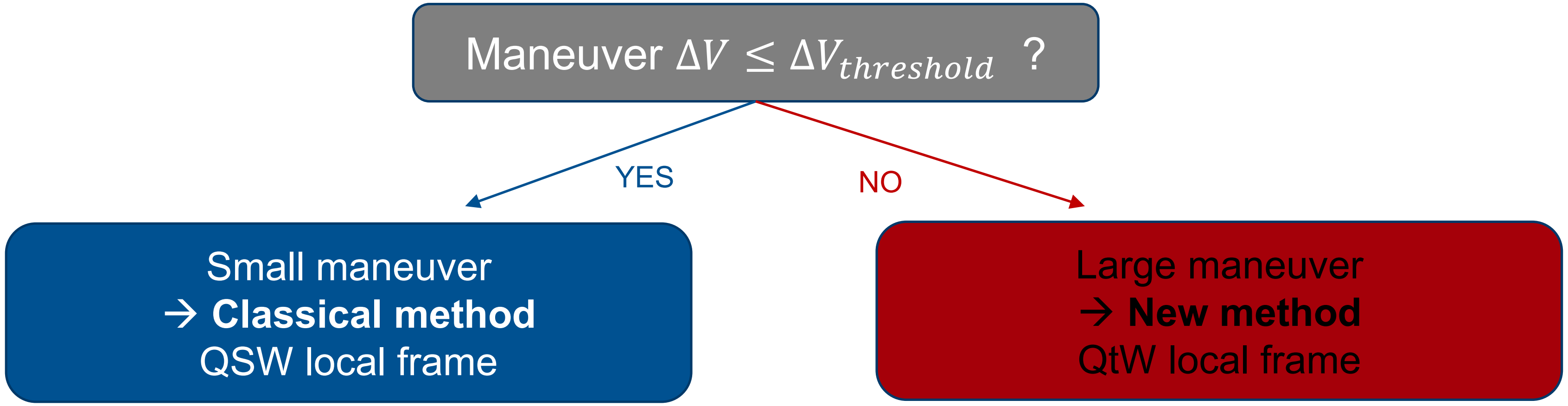


Operational context

- **Need for a better estimation of uncertainties**
- **Limitations due to QtW coordinates use**
  - No covariance consideration for secondary object
  - Computation duration can be significant

which method is best suited ?

- **DV threshold will determine if QtW is suited instead of classical STM (Jacobian) method**

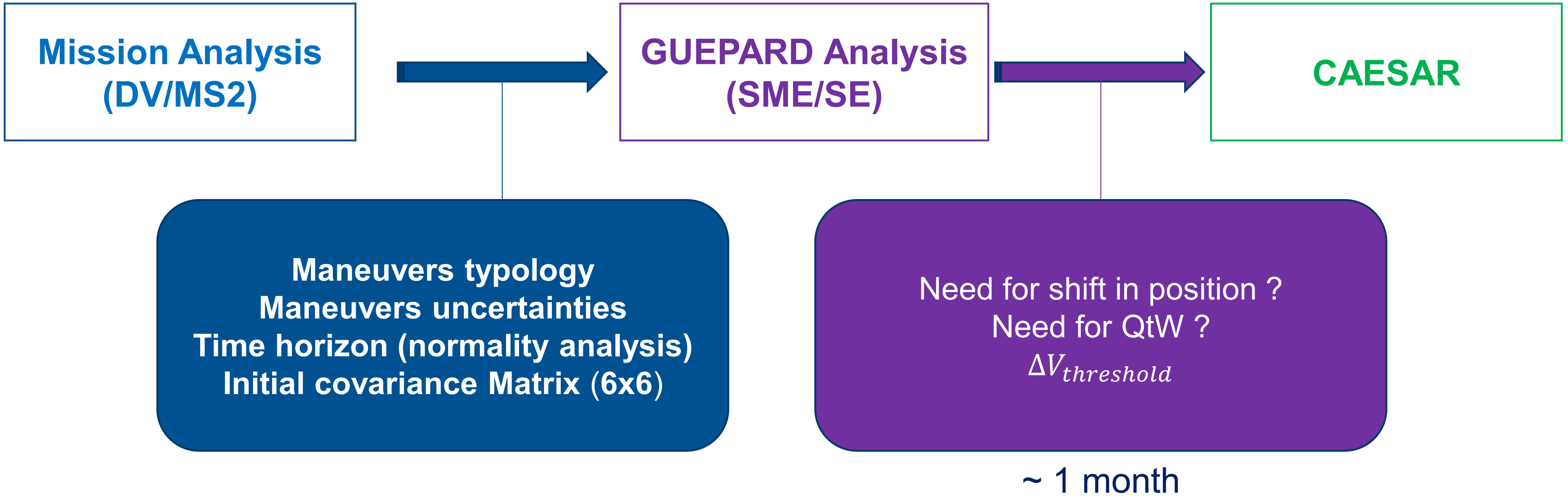


- **Best estimate: if gaussianity is lost with QtW we don't have a better solution:**

Nominal trajectory shift

- **Shift performed by computing the average dispersed trajectory (see previous presentation)**
  - By the future Flight Dynamics System (available on SIRIUS FDS)
  - By CAESAR Team via GUEPARD software for existing missions
- **For future mission, the operational coordination should be simplified since the FDS will handle the shift**
- **For present mission with older FDS, GUEPARD is able to implement :**
  - Post-maneuver collision risk calculation in QtW
  - Nominal trajectory shift
  - Post-maneuver collision risk calculation in QSW, with consideration of
    - maneuver uncertainties
    - primary covariances
    - secondary covariances

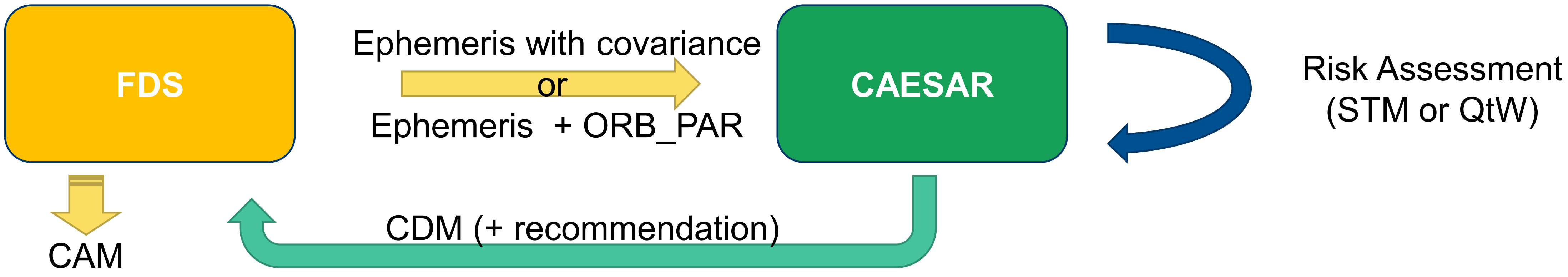
Coordination at system level



Coordination at operational level

- **CAESAR team and OPS team preparation**
  - **Interface check** with FDS team
  - **Process update** to apply the DV threshold (STM or QtW?)
  - **Covariance grid size:** trade-off with system team on the
  - **Operational validation** of GUEPARD before launch or decommissioning

- **During operations**



Conclusion

- **New analysis at system level**
  - To assess the need for QtW method
  - To define $\Delta V_{threshold}$
- **Updates on interfaces and sequence of operations**
- **Results hard to predict ➔ importance of these studies**

THANK YOU FOR YOUR ATTENTION

Questions ?

ANNEX

The importance of a 6x6 matrix

- **Usual Covariance matrix:** $\begin{bmatrix} \mathbf{Position} & & \\ (3x3) & \mathbf{Velocity} & \\ & (3x3) & \end{bmatrix}$

- **Need for the non diagonal terms**
  - Example: at a given time the same uncertainties on position can be due to error on
    - Sma → secular effect on position
    - Eccentricity → periodic effect on position

  - Knowing the relation between the **error in radial position** and the **error in tangential velocity** can discriminate the two cases

Coordination at system level

- **Mission Analysis team: New inputs for these studies**
  - **Maneuvers typology** → example of maneuvers used for LEOP, SK and decommissioning
  - **Maneuvers uncertainties in module and direction** → operational feedback or mission analysis
  - **Time horizon for normality analysis** → reaction delay needed to detect a collision risk and execute a CAM
  - **Initial covariance matrix** (6x6) estimation → best effort (can be tricky)

- **SME/SE (former DV/ISL): Studies output**
  - **Need for nominal trajectory shift** (computation duration saved if not necessary)
  - **Need for QtW method**, depending on the maneuvers typology and uncertainties
    - $\Delta V_{threshold}$ that separate classical method and QtW

} ~ 1 month

