SPACECRAFT PASSIVE DETUMBLING WITH MTB AT END OF LIFE

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THALES ALENIA SPACE

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Date: 23/09/2021
Ref: TASF SC PASSIVE DETUMBLING AT EOL
Template: 83230347-DOC-TAS-EN-008

Content

/// Aim

- This presentation shows the results of the technical feasibility assessment run by TAS-F in the subject of passive spacecraft detumbling with MTB short-circuit at the end of life

/// Content

Introduction

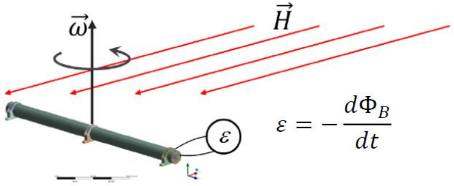
/// Active Debris Removal (ADR)

- Little introduction is required on the need of Active Debris Removal
- Spacecraft can be cooperative of uncooperative from a ADR perspective. The aim is that all new missions are at least prepared for ADR, even if they remain uncooperative.
- Passive spacecraft detumbling using MTBs is one of the possible solutions to facilitate a rendezvous even if control has been lost.

Envisat

/// Passive detumbling using MTB

- Low cost solution as MTB are actuators already on board
- Principle: Faraday and Lentz Law – The electromagnetic force is always opposed to change of flux that induced it.
- If the MTBs are in short-circuit, the variations in the Earth Magnetic Field due to spacecraft rotation will generate an induced current that will cause a torque opposite to the spacecraft rate.



$$\varepsilon = -\frac{d\Phi_B}{dt}$$

MTB

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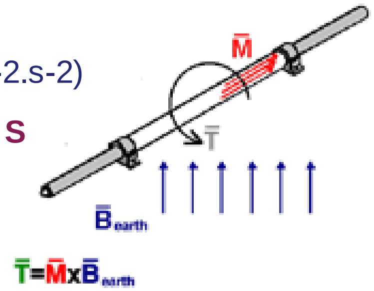
MTB Model

/// MTB Moment

$$M = \mu r * N * S * I \ \ (A.m^2)$$



- With I = Intensity (A) ; N = Number of spins; S = surface (m2); µr = magnetic permeability (kg.m.A-2.s-2)
- We can simplify the expression as ***M = SF * I*** with a constant scale factor defined as SF = **µr * N * S**
- The torque generated by an MTB is then expressed as **T = M x B** = SF x I x B
- So at a larger scale factor, the MTB generates a higher torque for a given intensity

/// Induced torque after short-circuit

- Combining the expressions of electromagnetic force, the MTB represented as a circuit with a resistance (R_{MTB}) and the MTB torque, we find that the detumbling torque can be expressed as:
- Detumbling torque: => $T = \frac{SF^2}{R_{MTB}} \cdot \frac{dB}{dT}$
- So at a larger scale factor, the detumbling torque is higher for a given field variation
- The MTB resistance has an impact on the response time and the electric drivers of the MTB during the SC lifetime

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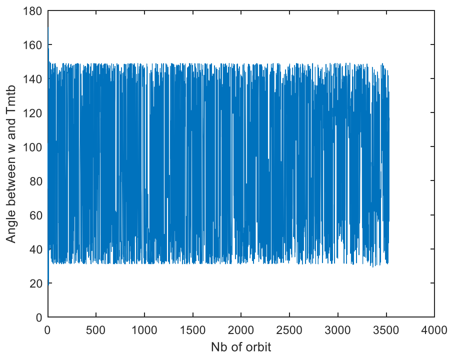
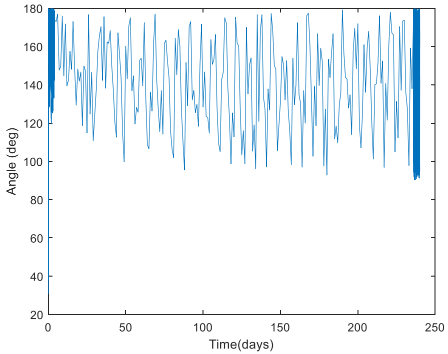
MTB Model

/// Hysteresis

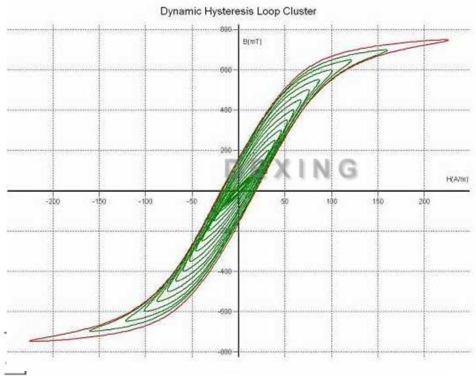
- When modeling the passivized MTB, the question rose on whether hysteresis should be taken into account or not.
- Conclusion:
  - There is a transitory phase at the beginning with stronger hysteresis. But when considering a dynamic hysteresis model, given that there is a very small current, the hysteresis soon becomes negligible.
  - Results also show that if hysteresis is considered static, it becomes the main source of magnetic field, which is constant, and the induced moment opposed to the SC rate becomes negligible.



Angle between SC rate and MTB torque with static hysteresis



Angle between SC rate and MTB torque with dynamics hysteresis

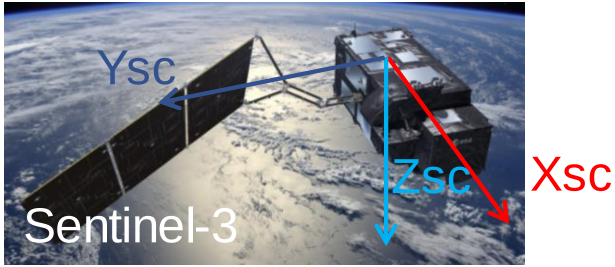


Hysteresis diagram

TAS feasability analysis

/// TAS first assessment on the capacity of MTB Passivation for SC detumbling

- Based on the requirements for new Copernicus missions, TAS performed a study to gain a first sensibility on the capacities for MTB detumbling and the main driver parameters.
- The study assessed the following objectives:
  - Aim to reduce the SC rate from 3 deg/s to 0.5 deg/s in 6 months
  - Aim to use existing MTB, or MTB under development
- It was performed on a simplified simulator to run multiple long duration simulations.



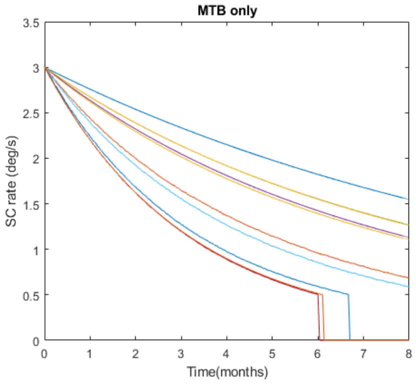
/// Hypothesis

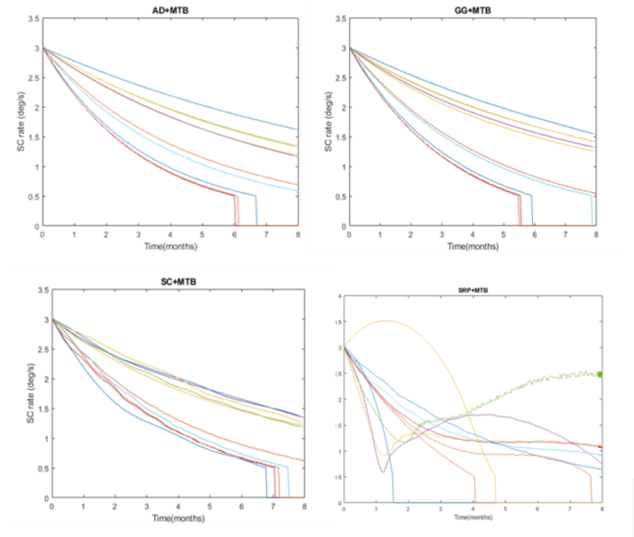
- Sentinel-3 is used as the reference spacecraft
- Initial tumbling rate along one of the main axis of inertia, having proved that after a few hours without control the spacecraft tumbling would stabilize around one axis regardless of the initial conditions.
- External torques considered: Air drag, gravity gradient, residual spacecraft momentum and solar radiation pressure.

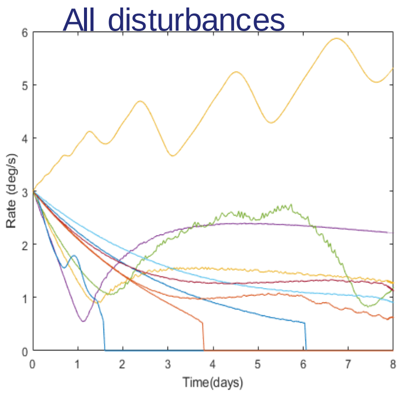
Influence of external torques

/// Scattered scenarios

- Taking a scattered range of initial conditions, the tendency becomes clear: **The MTB alone is capable of SC detumblng**, with the actual detumbling rate depending on the scenario.
- The gravity gradient (GG), air drag (AD) and SC residual momentum (SC) have an impact on the final achieved detumbling but the SC rate is reduced in all cases.
- However, the nature of the Solar Radiation Pressure (SRP) does not show a tendency, causing the SC rate detumbling to be less efficient or diverging. There is a correlation between SRP and SA angle, although more scenarios would be required to confirm it.



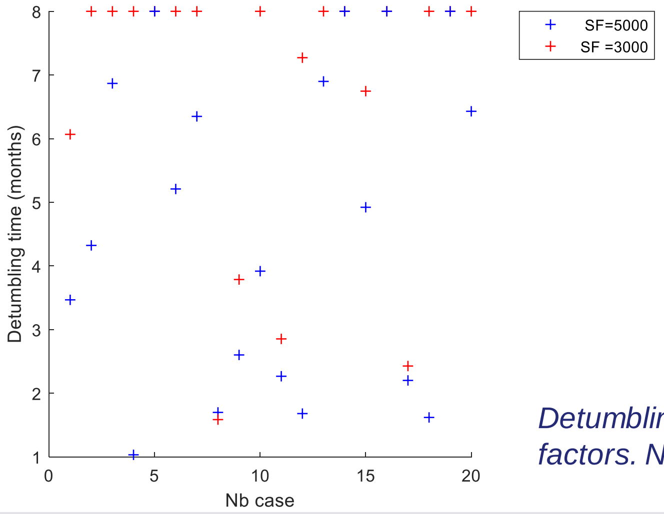




Influence of the MTB design

/// MTB scale factor

- The scale factor has a direct impact on the detumbling factor achieved with MTB passivation.
- With the scale factor from existing COTS MTB (3000) the observed detumbling is not very significant
- Using larger scale factors corresponding to units in development, the time to reach a rate of 0.5 deg/s is reduced.
- The design of the MTB is assessed only in terms of detumbling performance, without considering other impacts such as response time.



Detumbling time from 3deg/s to 0.5 deg/s for different scale factors. NOTE that the simulations end after 8 monts

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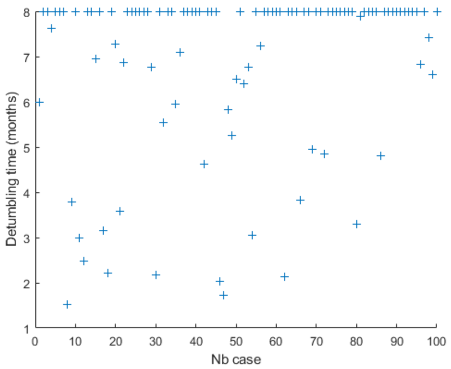
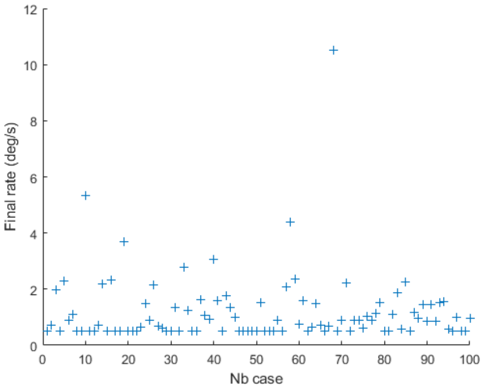
Monte-Carlo campaign

/// S3 campaign with 100 scenarios

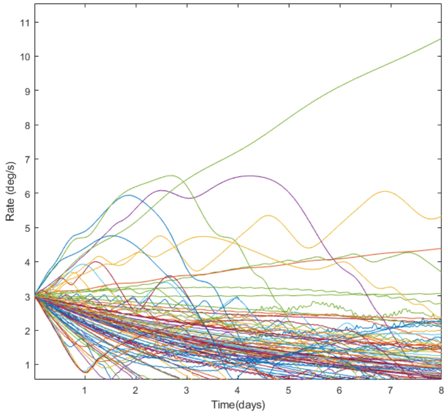
- Scattering: Position on orbit, height (+/- 100 km), Initial dynamic conditions, air density, solar array angle.
- The simulation stops either when it reaches 0.5 deg/s or a duration of 8 months
  - 37% of scenarios need less than 8 months to reach 0.5 deg/s
  - There are 5 critical scenarios where the SC rate diverges.
  - The rest show a decreasing tendency after 8 months, so the detumbling should be completed at a later date.



Time to reach 0.5 deg/s



SC rate after 8 months



Temporal variations of SC rate (norm)

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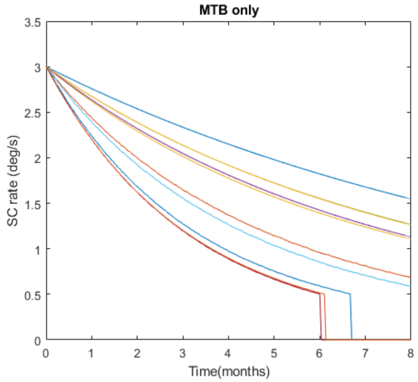
Conclusion and way forward



- Conclusions
- The detumbling effect after passivating the MTB is confirmed.
- A detumbling in 6 months can not be assured for Sentinel-3.
- The Solar Radiation Pressures appears as one of the main contributors to instabilities.

- Way forward for detumbling performance assessment
- Further analysis on SRP effects depending on Solar Array Angle
- Use other satellite geometries to understand the dependency on satellite geometry (focus on new Copernicus missions)
- Run more simulations with longer duration.

- Way forward for future missions implementation
- New Copernicus missions developed by TAS will fly this technology.
- The avionics design includes a mechanism for MTB short-circuit to enable spacecraft detumbling at the end of life.

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THANK YOU VERY MUCH

QUESTIONS ?

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