CSD 2024 – RAPACE FLIGHT DEMO
AOCS WITH (UN)FOLDABLE MEMBRANE IN VLEO

09/10/2024

Pierre Dandré, Thales Alenia Space

co-auteur Bertrand Raffier, CNES

Date: 09/10/2024
Ref: Not referenced
Template: 83230347-DOC-TAS-EN-009

AGENDA

- Overview
- Presentation of the 3 preliminary studies
- RAPACE objectives

Date: 09/10/2024
Ref: Not referenced
Template: 83230347-DOC-TAS-EN-009

RAPACE - OVERVIEW

/// **Sustainable space = a core vision for Thales Alenia Space**

/// **Leaving space debris is not an option**

/// **Series of 3 studies (R&T & T4SC CNES) to mature the use case, the concept and preliminary design of the HW and SW.**

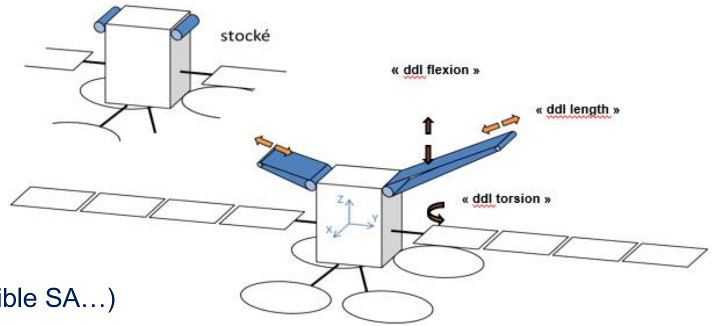
- 2019 - MASSA
- 2020 - MASSA+
- 2022 - MASSA2022

/// **RAPACE (Rentrée Assistée Précise avec AOCS Contrôlé par Enrouleur) flight demo on nanosat**

- 2024-2026 : RAPACE

Angular momentum management via aerodynamics stability

/// Angular momentum management / Wheels unloading while maintaining pointing performances



/// 4 steps

- **Step 1 :** Use cases identification
  - EOR with low perigee crossing: GEO Telecom NEOSAT product line
  - LEO De-orbitation: 1 standard observation satellite and 1 nanosat
- **Step 2** : Mechanical solutions benchmark
  - Use of solar array appendages (solar array drive mechanism, foldable/unfoldable flexible SA…)
  - Use of payload appendages (antenna)
  - Use of dedicated appendages (deployable boom, robotic arm, aerobrakes, foldable/unfoldable appendages…)
- **Step 3** : Mission analysis and AOCS strategy definition
- **Step 4 :** Simulation plan & robustness simulation campaign

Date: 09/10/2024
Ref: Not referenced
Template: 83230347-DOC-TAS-EN-009

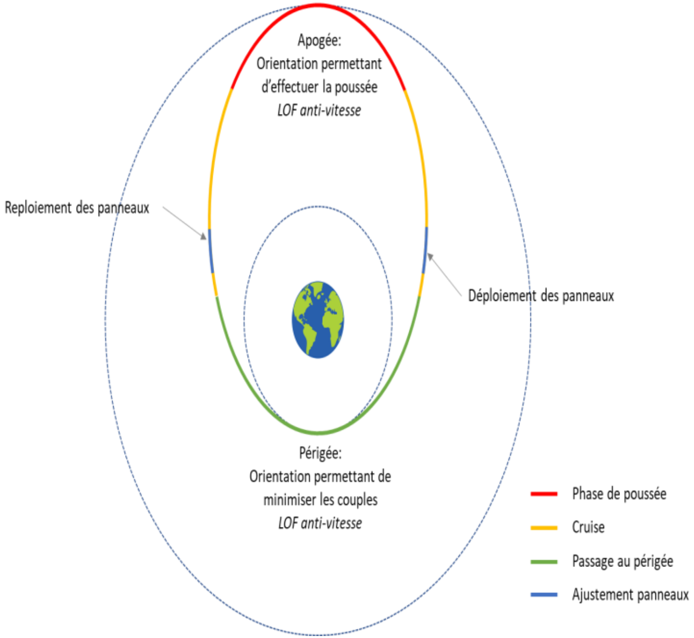
RAPACE – MASSA (2019)

MASSA – step3 : Mission analysis and AOCS strategy definition

Use case ElitBus (LEO constellation)

- Uncontrolled reentry strategy with low AOCS control torque authority < ~300km with need of medium agility to minimize drag at perigee
- Use of (un)foldable membrane to:
  - Increase the dV demand at apogee
  - Increase AOCS control torque authority at perigee (centre of pressure and angular momentum management)

➢ **Objective to reduce the casualty risk on ground during reentry**

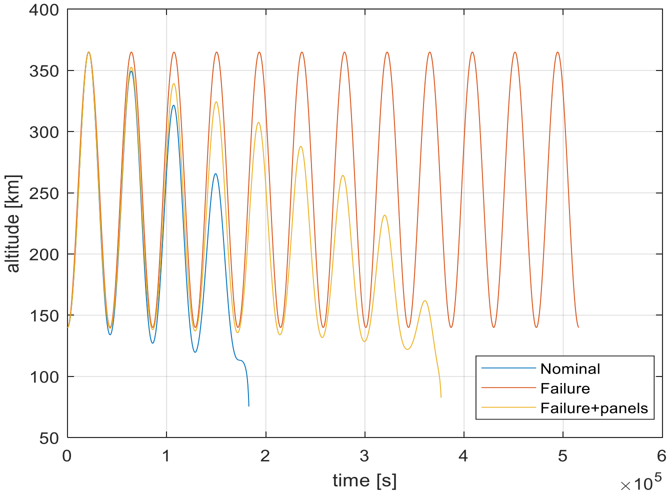


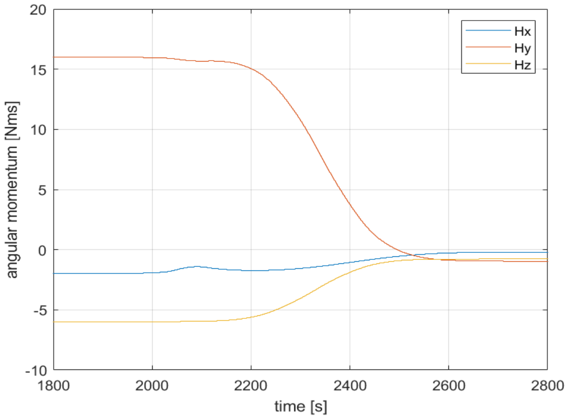
Date: 09/10/2024
Ref: Not referenced
Template: 83230347-DOC-TAS-EN-009

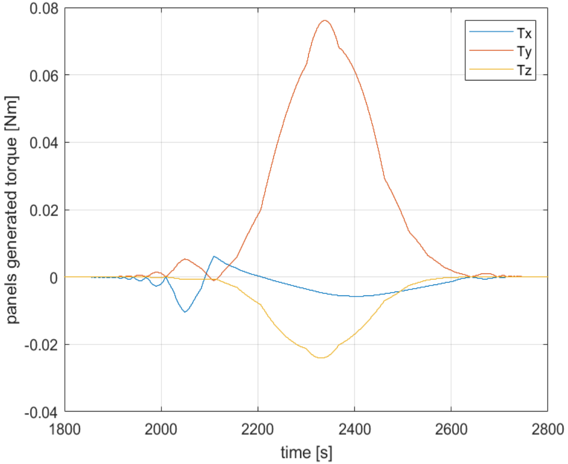
RAPACE – MASSA (2019)

MASSA – step 4 : Simulation plan & robustness simulation campaign

- Good angular momentum control for both use cases
- Deorbit ensured even in case of 2 failures of wheels
- Patent filing done (Thales Alenia Space & CNES)



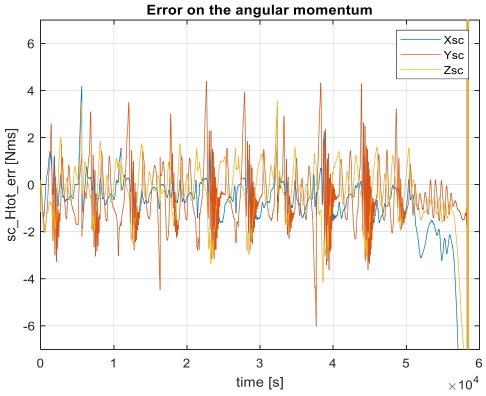


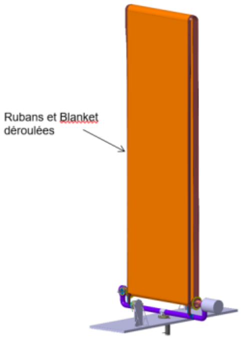


RAPACE – MASSA+ (2020)

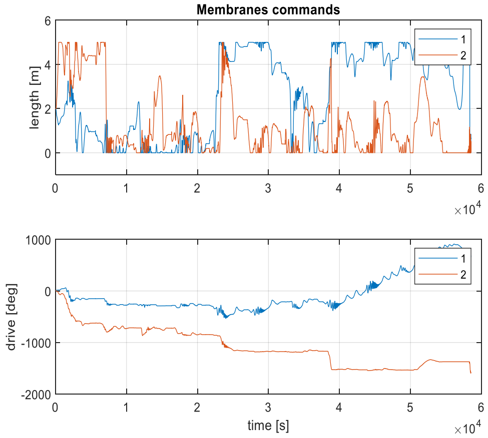
MASSA+ - Preliminary concept and design

- **Step 1 :** Preliminary architecture & sizing of an unfoldable structure mock-up
  - Large heritage from SADM motorization, deployable solar array
- **Step 2** : AOCS algorithms implementation
  - Plant synthesis identification trade-off: Feedback linearization, LTI gain, LPV
  - Control algorithms trade-off: PID, robust, adaptative, predictive.
  - Selection Identification (Q-LPV) / Attitude control (PID) / Angular momentum control (optimal LQR)
- **Step 3** : System analysis: impact of implementation of the system
  - Accommodation constraints, mass impact
- **Step 4 :** Synthesis and recommendations for further development





Concept SCAO déployé, position nominale

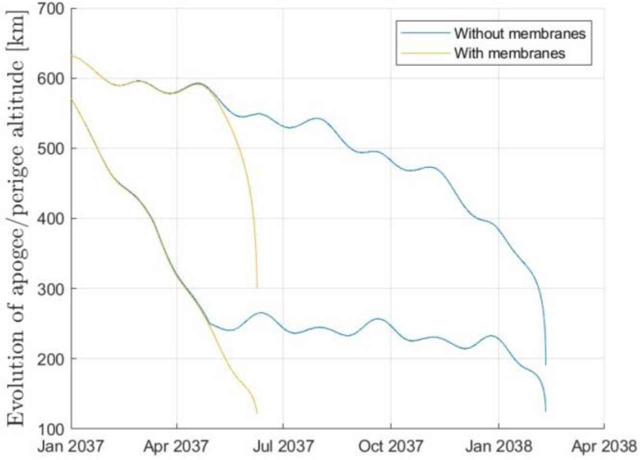


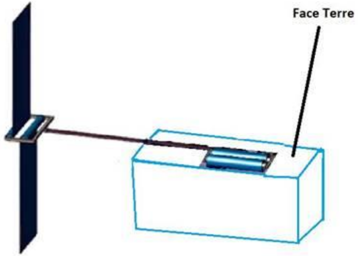
Date: 09/10/2024
Ref: Not referenced
Template: 83230347-DOC-TAS-EN-009

RAPACE – MASSA2022

MASSA2022

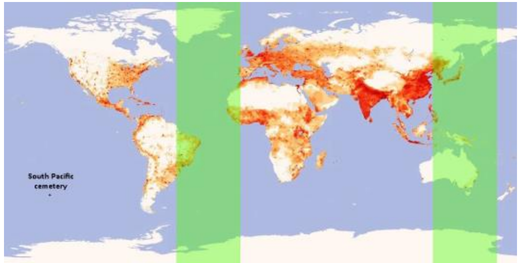
- **Step 1 : LEO PF with electrical propulsion**
  - Preliminary sizing of the membrane length (control torque authority)
  - Power budget impact
  - Mechanical loads
  - Accommodation
  - Mission analysis : impact of the membranes on a full-electric RNA scenario
    - On mission timeline: **decrease up to 8 months** (mainly thanks to control torque authority)
    - On casualty risk: sensitivity analysis on thrust level / air density / solar activity
  - Preliminary sizing of the tape spring (thermal and mechanical analyses)

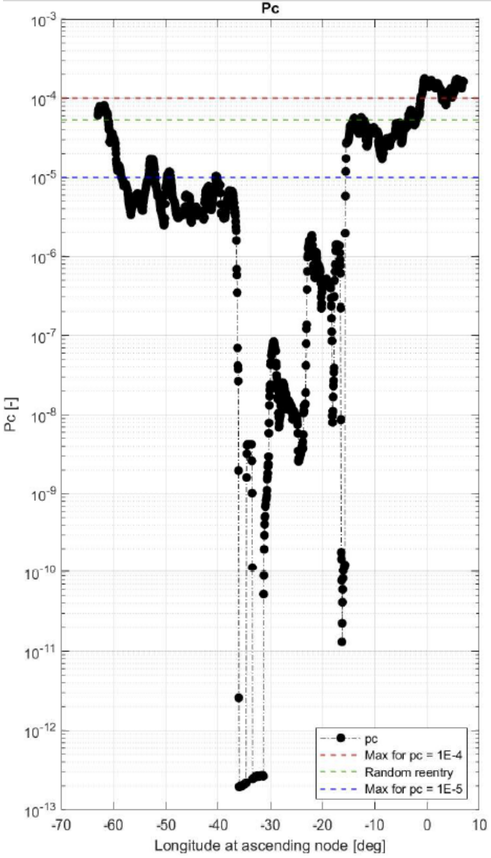


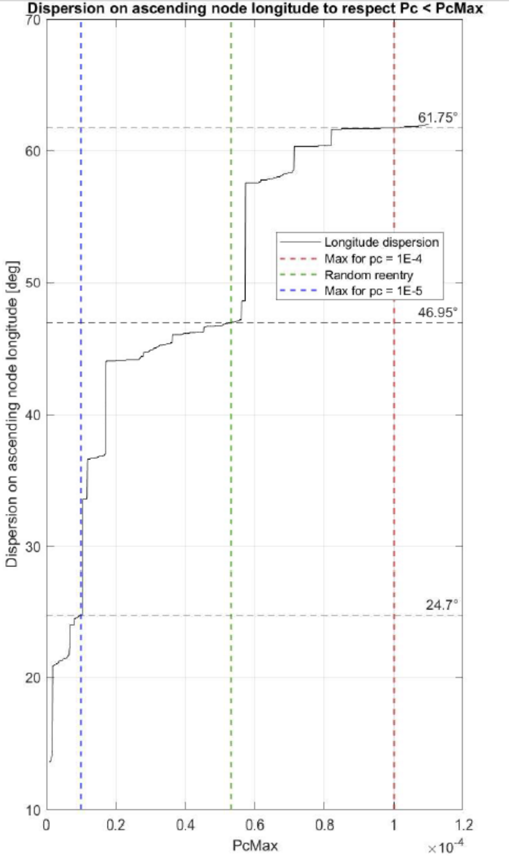


MASSA2022

- Possibility to reduce the casualty risk by a **factor > 5** wrt to uncontrolled reentry (DEBRISK) thanks to :
  - Attitude control up to an altitude of ~130km reducing to about 0.4 revolution the debris Earth track (ELECTRA analysis)
  - Argument of perigee management
- Management of final longitude at ascending node identified as also possible





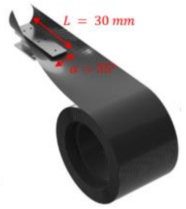


RAPACE – MASSA2022

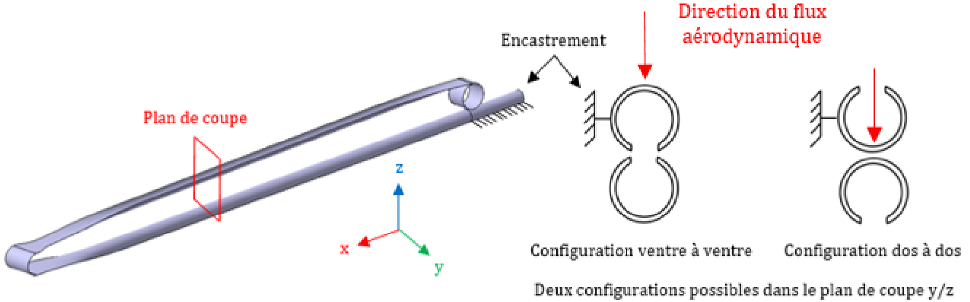
MASSA2022

- **Step 2** : Accommodation on nanosat platform & preliminary sizing (deflection, first bending mode, tsai-hill failure criterion)

10cm wide, length 1 to 2 m, 5kg, 11000 cycles



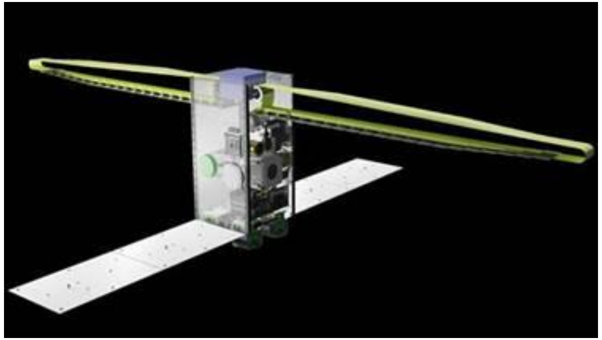
- **Step 3** : Architecture and detailed analysis of membrane actuator

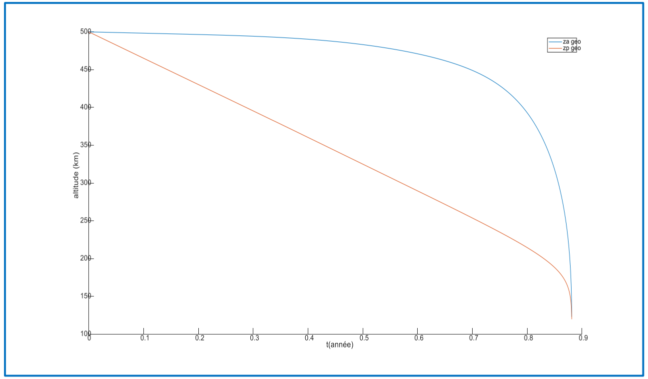


RAPACE OBJECTIVES

RAPACE

- **R&T + T4SC CNES funding and Thales Alenia Space cofunding**
- **Start of activity Q4 2023 (HW) & Q2 2024 (SW)**
- **Flight demo on a nanosat**
  - Main objectives: demonstrate capability of spacecraft to:
    - Ensure a **sustainable** design
    - Perform a **safe reentry (Natural assisted reentry) with electric propulsion compatible with the regulatory rules** (including mega constellation stringent requirement of the LOS) with a substantial improvement vs uncontrolled reentry
    - Avoid the use of controlled reentry reducing **strongly the impact on the systems sizing (mass, volume, cost).**
  - Conclusive Phase 0 (systems level) done by CNES of a Natural assisted reentry solution.
  - HW: Membrane/actuator development
  - SW: AOCS mode development with (un)foldable membranes including qualification embedded in the nanosat avionics/OBSW.
  - Spacecraft operations





Date: 09/10/2024
Ref: Not referenced
Template: 83230347-DOC-TAS-EN-009

THANK YOU FOR YOUR ATTENTION !

Date: 09/10/2024
Ref: 0003-0002987015
Template: 83230347-DOC-TAS-EN-009