e.Deorbit Symposium

ELECNOR DEIMOS Participation in e.Deorbit and ADR Activities

Mariano Sánchez Nogales
Head of the Flight Systems Business Unit

Conference Centre Leeuwenhorst, 6 May 2014

Table of Contents

Introduction

Motivation for ADR Activities

- ADR scenario represents a **challenge** to the traditional areas of expertise of DEIMOS
  - Mission Design and Analysis
    - Trajectory definition compatible with ADR constraints
    - Optimisation of manoeuvre sequencing
  - GNC
    - Single and multi-body problems
    - Close-proximity operations
    - Non-cooperative targets
  - Atmospheric re-entry capabilities
    - Break-up Burn-up Analysis
    - Debris footprint computation
    - Prediction of controlled and uncontrolled trajectories

GNC for ADR based on Clamping Mechanisms

CLGADR

Rendezvous, capture, de-tumbling and de-orbiting of an uncooperative target using clamping mechanisms

- **Main objectives:**
  - Design, implement and evaluate an **autonomous GNC** system for an **ADR scenario** using a **clamping mechanism**
  - Derive **requirements for future missions** within the CleanSpace initiative
  - Promote **technology developments** required to develop the concept

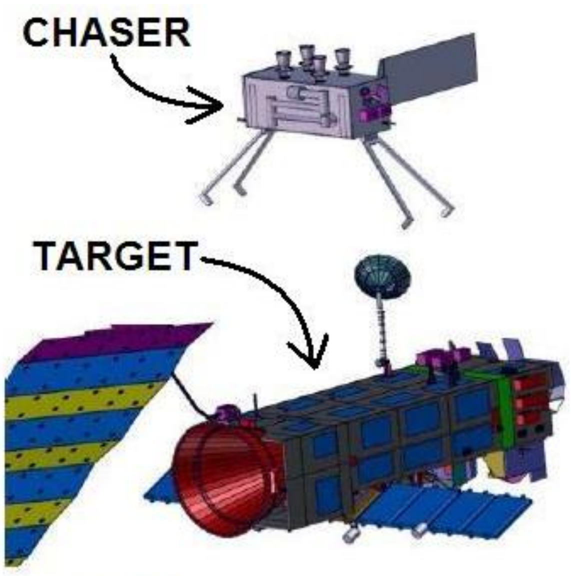


Image source: ESA e.Deorbit CDF Study

- **Overview of Activities:**
  - Review **state of the art** on missions, clamping mechanisms, GNC algorithms, multi-body dynamics, etc.
  - Complete **system modeling** for GNC design and simulation
  - **Multi-body dynamics** models of complete stack:
    - Flexible modes
    - Fuel sloshing
  - **GNC design and solution** will cover the following phases:
    - Rendezvous and capture
    - Target de-tumbling and de-orbiting
  - Develop a **MIL simulation framework** for performance assessment of the GNC concept
  - Provide **lessons learnt** and derive a set of **requirements for future ADR GNC** solutions using clamping mechanisms

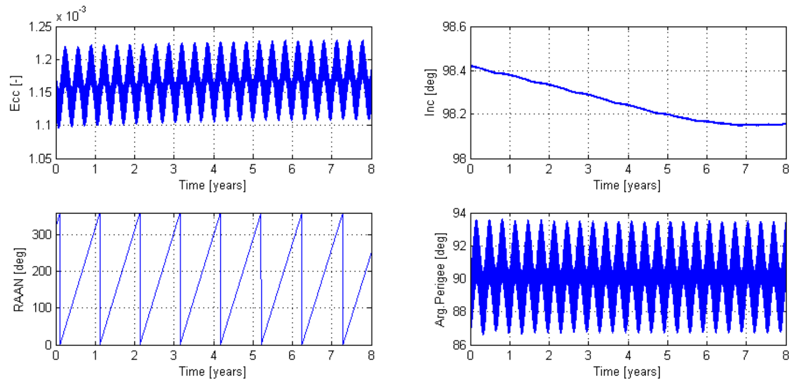
e.Deorbit Phase A

DEIMOS is developing its activities in the consortium led by TAS-F

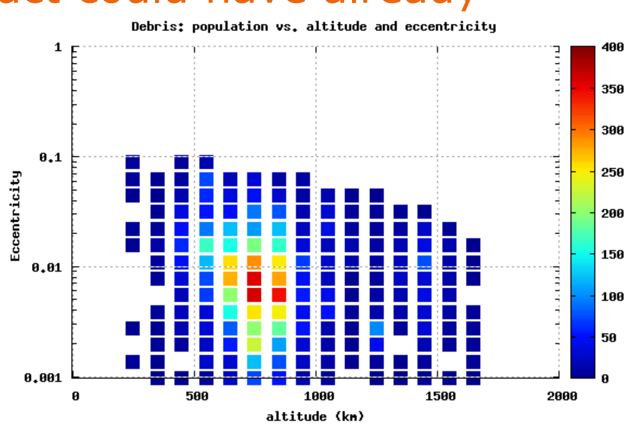
- **Overview of Activities:**
  - Confirmation of **target** selection
  - Analysis of **target orbit** and **attitude dynamics** up to launch
  - Selection of **injection orbit** for nominal and backup launch opportunities together with definition of **phasing strategy**
  - **Manoeuvre optimisation** for de-orbit and re-orbit options:
    - Chemical for de-orbitation
    - Low-thrust for re-orbitation
  - Eclipse and Ground station **visibility analysis**
  - **Radiation** dose analysis
  - **Monte Carlo** analysis of errors during de-orbiting burn:
    - Assessment of impact on re-entry footprint of debris area
    - Definition of the final **perigee altitude**
  - Analysis of **graveyard orbit** outside of **LEO protected region**

Current Results

- **Selected Target: ENVISAT**

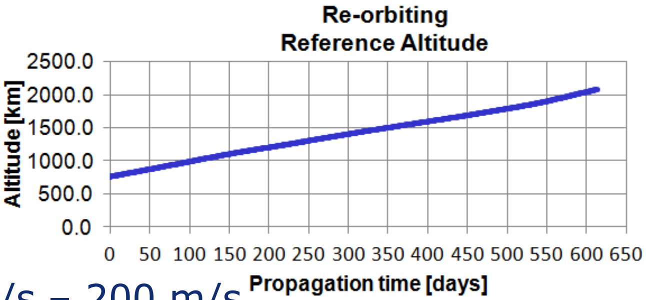


  - ESA-owned, non-operational and non-passivated satellite in LEO with a mass higher than 4000 kg
  - Attitude evolution is not known accurately:
    - Rotation of 3.5 deg/s almost aligned with orbital momentum
    - Gravity torque is not sufficient to slow down rotation
    - Earth's magnetic field could slow rotation but effect is hard to determine
    - Spin up due to debris or micrometeorite impact could have already happened and must be taken into account
  - Orbit acquisition
    - Vega: 1550 kg
      - 300 km injection + transfer to operational orbit
    - Soyuz: 4450 kg
      - Direct injection at operational orbit

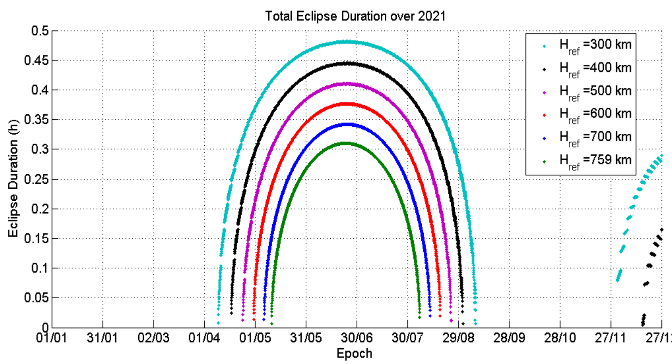


Results on ENVISAT target (cont'd)

- Re-orbiting option
  - Duration depends on thrust capability
    - *1 x Qinetiq T6: 1.7 years* *SELECTED option for a total ΔV of 607 m/s*
    - 1 x Qinetiq T5: 12 years
    - 2 x Qinetiq T5: 6 years



- De-orbiting option
  - With two or more burns almost same ΔV
    - For target perigee altitude 40-90 km → 185 m/s – 200 m/s
  - Pre de-orbiting perigee altitude can be fixed at 200 km
    - Time from de-orbiting to final perigee: 37m – 44m
- Eclipses during operational orbit acquisition
  - Best mission windows from
    - *01/01/2020 to 01/04/2020*
    - *10/09/2020 to 30/11/2020*
  - Max duration 30 min at Envisat's orbit



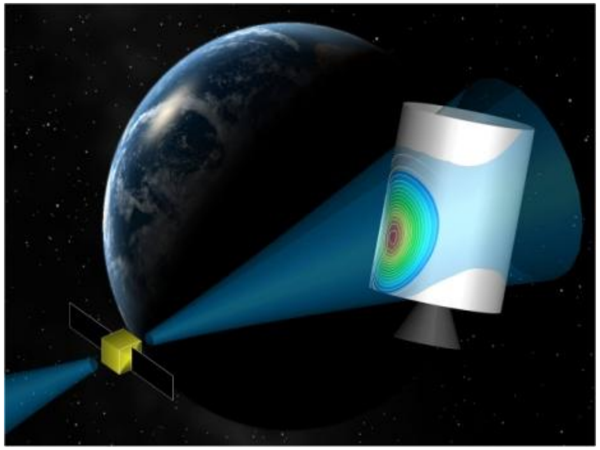
IBS-IOD Study

Consortium and Goals

- DEIMOS currently leads an ESA Phase 0 study for an IOD for demonstration of the IBS concept for de-orbiting. Partners:
  - Universidad Politécnica de Madrid (UPM) as IBS experts
  - Thales Alenia Space (TAS) as platform providers
  - Universidad Carlos III de Madrid (UC3M) as SEP experts

IBS-IOD mission shall demonstrate contactless transmission of linear momentum to a non-cooperative target by means of an ion beam

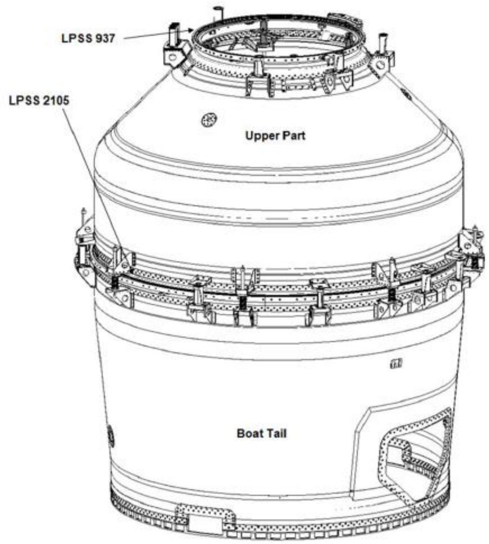
- Other objectives:
  - Design-to-cost approach
  - Demonstrate autonomous GNC capabilities
    - Proximity and IBS operations
  - Demonstrate flexible solar panel technology



elecnor deimos

Mission and Spacecraft Concept

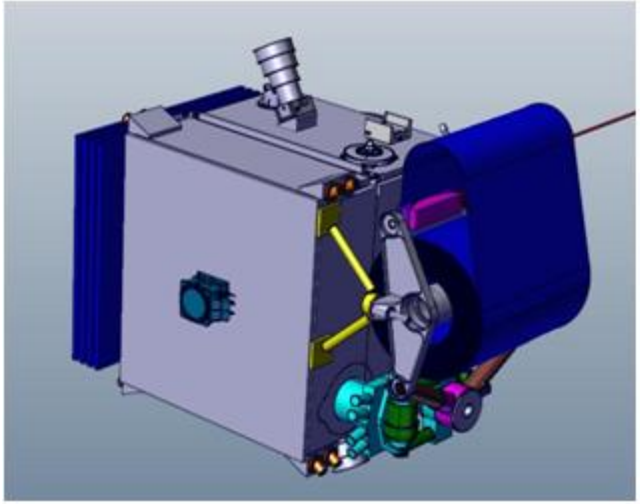
- Mission
  - Launch: VEGA / VESPA in 2020 (within adapter)
  - Orbit: LEO between 500 km and 850 km (SSO baseline)
  - Target: VESPA Upper Stage (100 kg and radius of 1.1 m)
  - Mission duration: 4-5 weeks
- Spacecraft
  - Platform: adapted Myriad Evolution
  - Engines: 2 x Alta MEPS / Xenon / 300 W per MEPS
  - Power: rigid SA wing + flexible SA wing / 1250 W
  - Communications: S-band
- GNC
  - Autonomous proximity operations
  - Sensors: LIDAR + WAC
  - Actuators: MEPS + cold gas RCS attached to Xenon feed

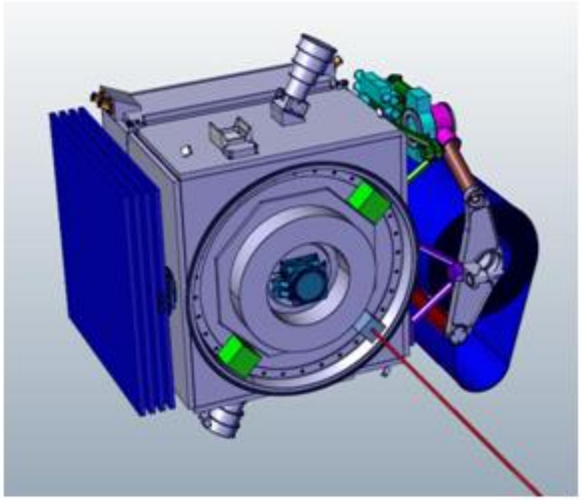


IBS-IOD Study

Current Status and Conclusions

- Study focused on deriving a feasible concept to **de-orbit non-cooperative targets through IBS** with a **design-to-cost approach**
- Currently under finalisation
- Final Presentation scheduled at ESTEC on 27th of May



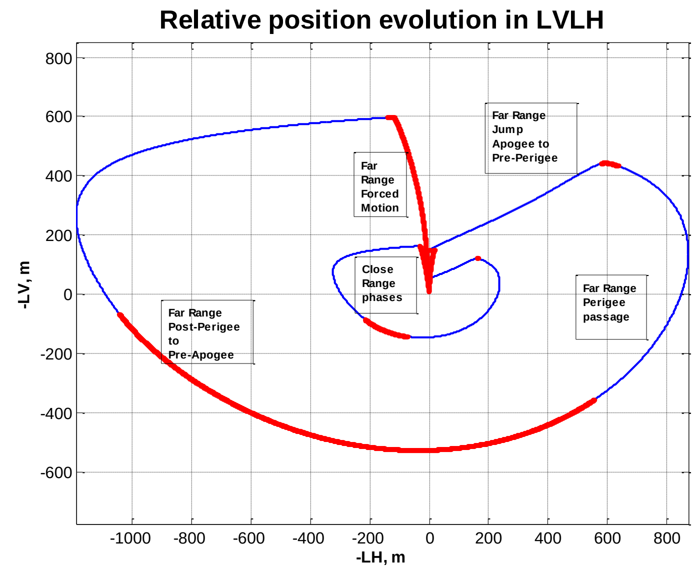


Overview of PROBA-3 Rendezvous Experiment

- PROBA-3 is a mission aiming at the **in-orbit demonstration** of Formation Flying and its associated technologies.
- DEIMOS is responsible for the definition, implementation and exploitation of a **rendezvous experiment** in PROBA-3.
- The RVX aims to:
  - Demonstrate the feasibility of performing representative operations applicable for future missions → **ADR scenarios**
  - In-orbit validation of **guidance and image based navigation** algorithms
  - Consolidation and maturation up to flight level of a **GNC architecture and concept**
- It covers the rendezvous in elliptical orbits for both cooperative and **non-cooperative targets**

Application to ADR scenario

- RV experiment designed with a typical ADR scenario in mind:
  - Non-cooperative target
  - Focus on close proximity operations
  - Inclusion of typical manoeuvres:
    - Station keeping, forced approach, etc.
- In-flight validation of GNC and IP technologies required for this scenario
- Elliptical orbit scenario is relevant for multi-boost de-orbiting strategies



- Sensor interfaces with GNC are compatible with a typical suite of sensors foreseen for ADR missions
  - Camera + LIDAR
  - Camera-based sensor suite

Conclusions

ADR in the core of DEIMOS activities

- DEIMOS is leading several activities directly related to ADR concepts such as:
  - GNC for a mission based on clamping mechanisms
  - Mission concept based on IBS
- DEIMOS is participating actively in one of the e-Deorbit studies
- Traditional areas of expertise at DEIMOS are directly applicable to ADR mission concepts:
  - Mission design
  - Atmospheric flight
  - GNC
- PROBA-3 rendezvous experiment will provide in-flight validation of a GNC concept for close-proximity operations around non-cooperative targets
  - Increase TRL of GNC-related technologies up to 8