INSPECTION TRAJECTORIES AND GNC DESIGN

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GUIDANCE, NAVIGATION AND CONTROL (TEC-SAG)

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GNC Main Objectives & Constraints

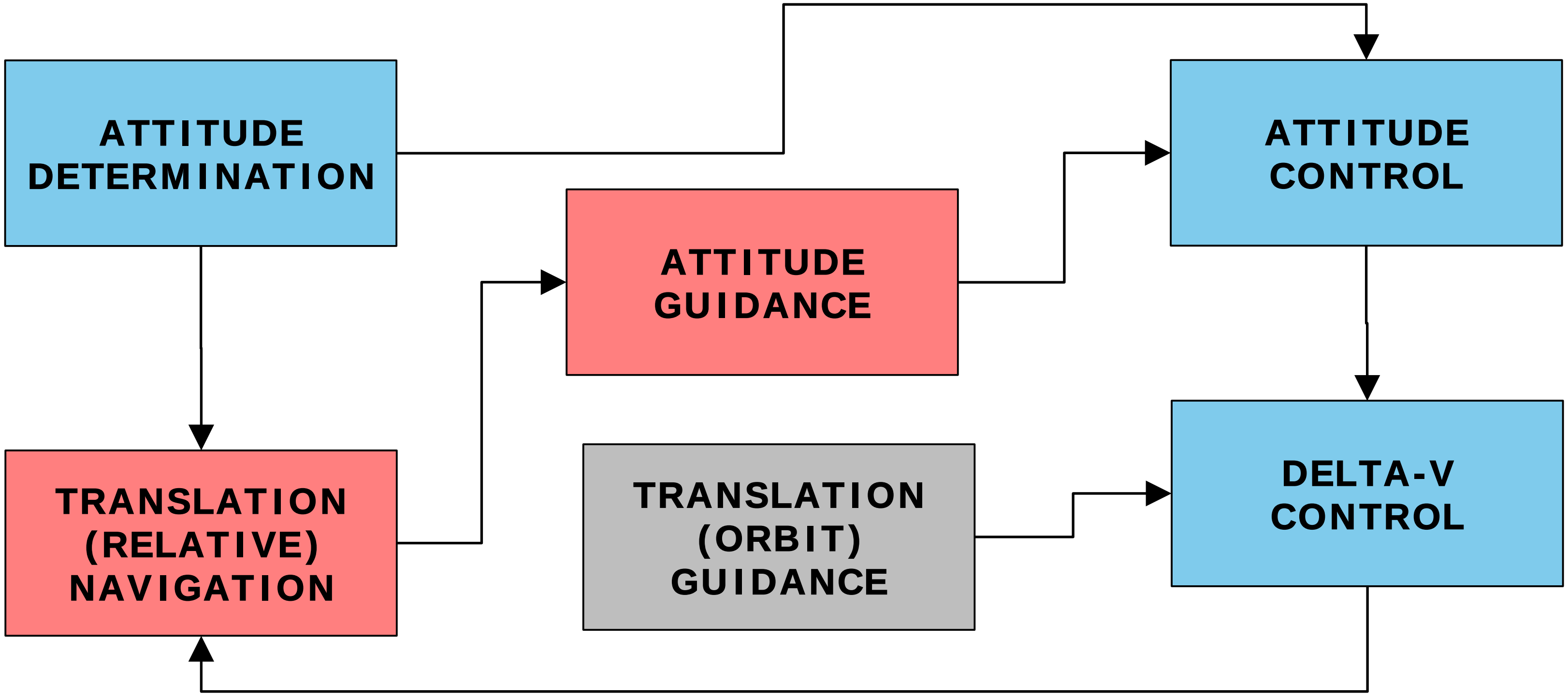
- **KEEP COST LOW**
- Take pictures of Envisat with TBC cm/pixel resolution
- **KEEP COST LOW !**
- Keep SC always in passively safe trajectories
- **KEEP COST LOW !!!**

GNC Requirements and design drivers

- Estimate the relative position of chaser wrt target with sufficient accuracy to take pictures of Envisat during the inspection orbit
- Ensure passively safe trajectories that permit imaging Envisat with sufficient accuracy
  - No ground interaction during inspection phases
  - No translation manoeuvres after injection in inspection orbit
- Use of EP for the injection in inspection trajectories
  - In-plane drift vs. out-of-plane separation
  - RCS vs. propellantless angular momentum management
- Initial knowledge of the target absolute orbit
  - Based on target TLE (not very old)

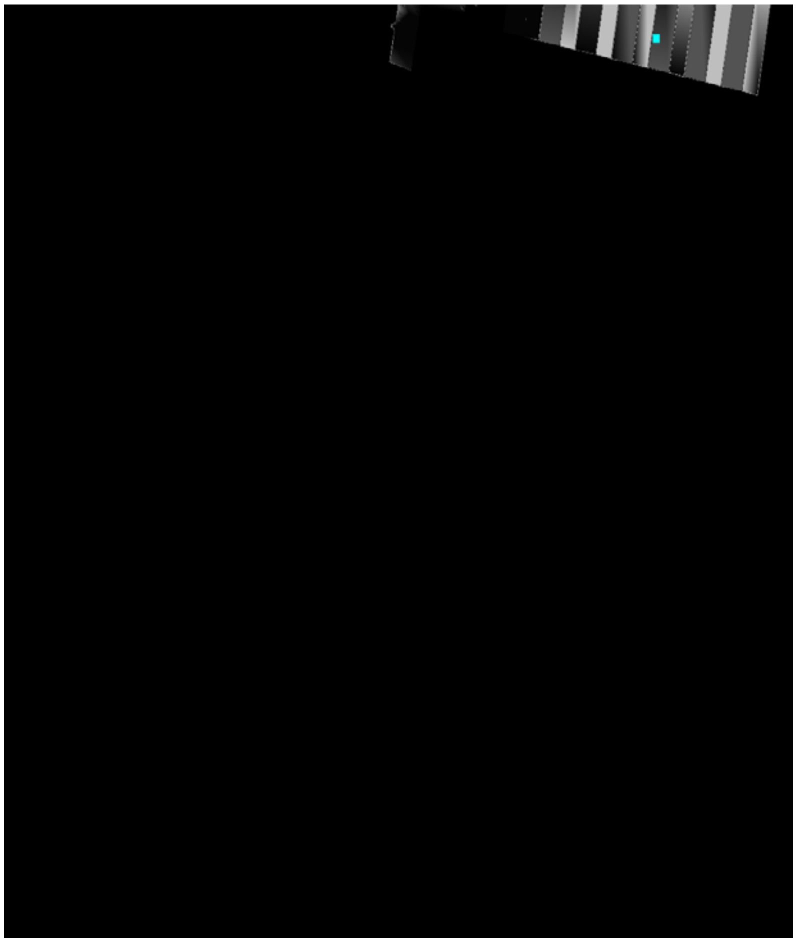
e.inspector FDS-GNC task sharing

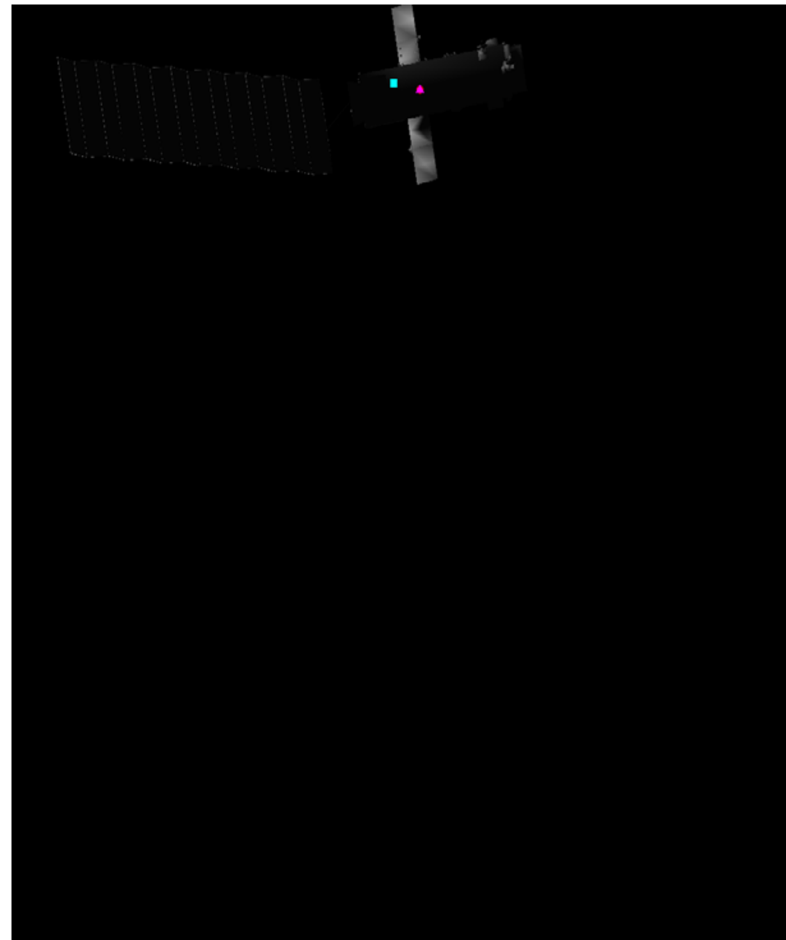
- Ground-based manoeuvre plan (translational guidance)
  - Injection in inspection trajectory
  - Inspection phase is ballistic flight (no thruster activation)
- On-board relative navigation for attitude pointing during inspection phase



No relative navigation

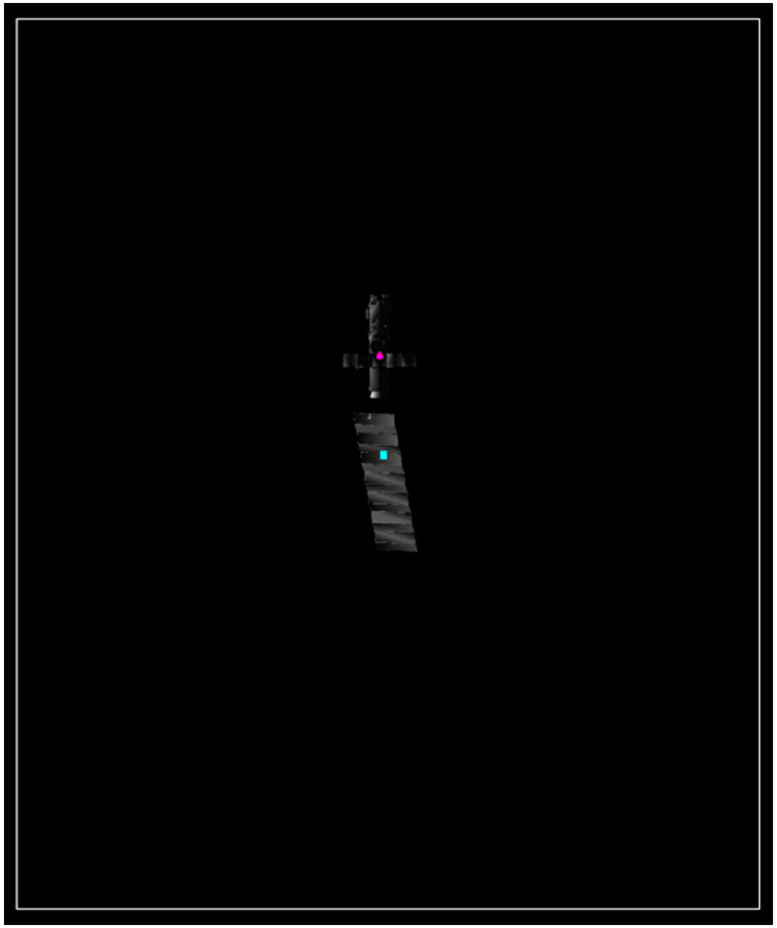
- **<u>Ground-based</u>** attitude pointing in a passive safe inspection trajectory
- Drift below (nominal chaser sma 100 m below Envisat)
- Relative initial error (1σ): 50 m (V-bar) ; 1 m (H-bar) ; 5 m (R-bar)

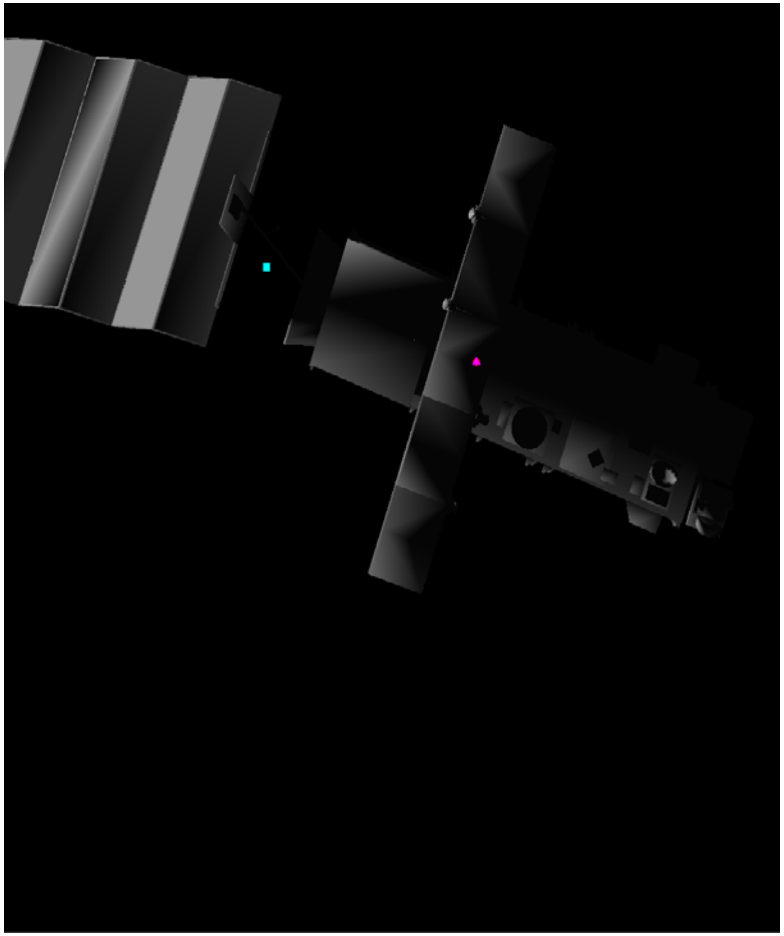




Relative navigation

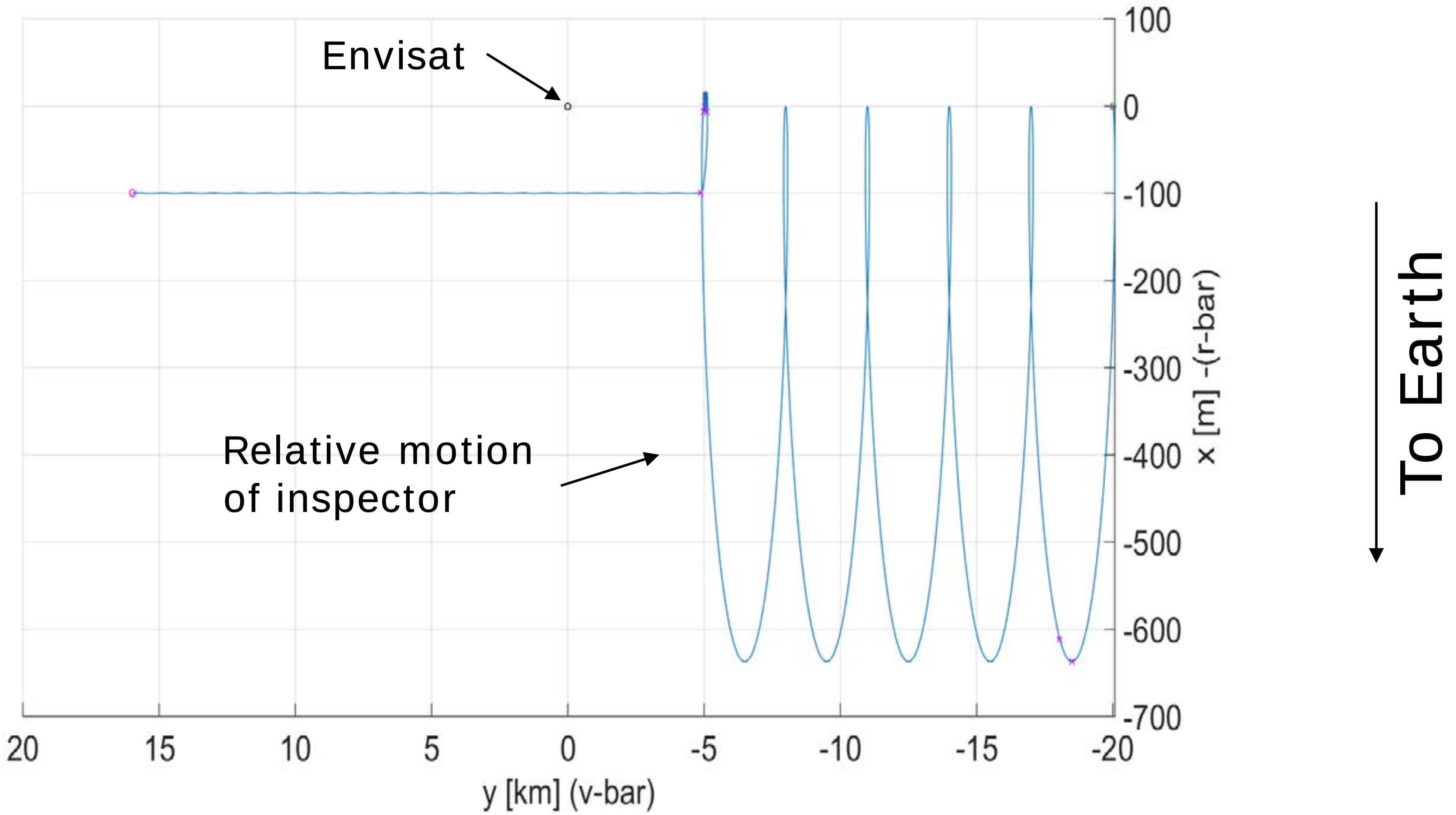
- **<u>On-board</u>** attitude pointing in a passive safe inspection trajectory
- Centroiding image processing
- Line-of-Sight only navigation (fusing also GPS and gyro-stellar attitude)





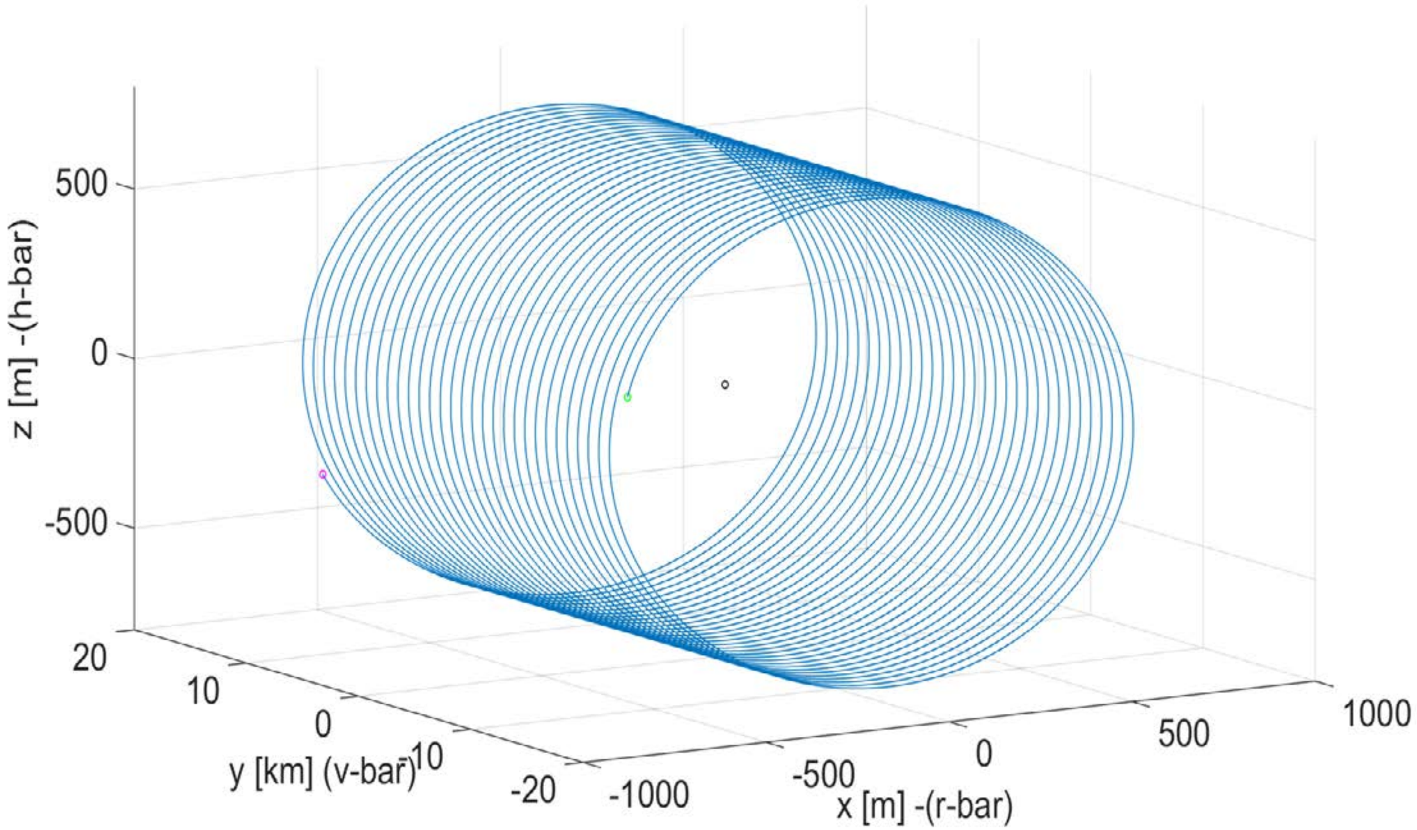
Inspection trajectories #1: in-plane

- V-bar hopping, followed by v-bar drift



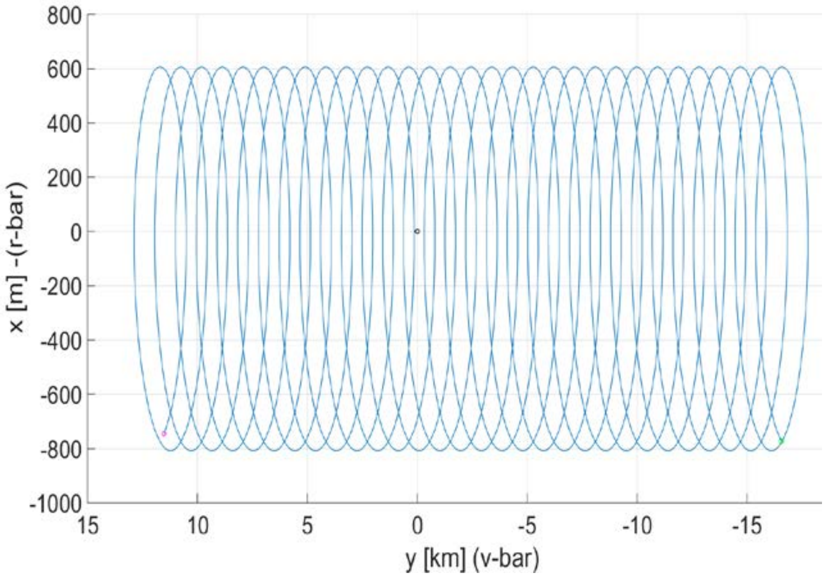
Inspection trajectories #2: helicoid (1/2)

- Safe v-bar drift in combination with relative eccentricity/inclination-vector separation

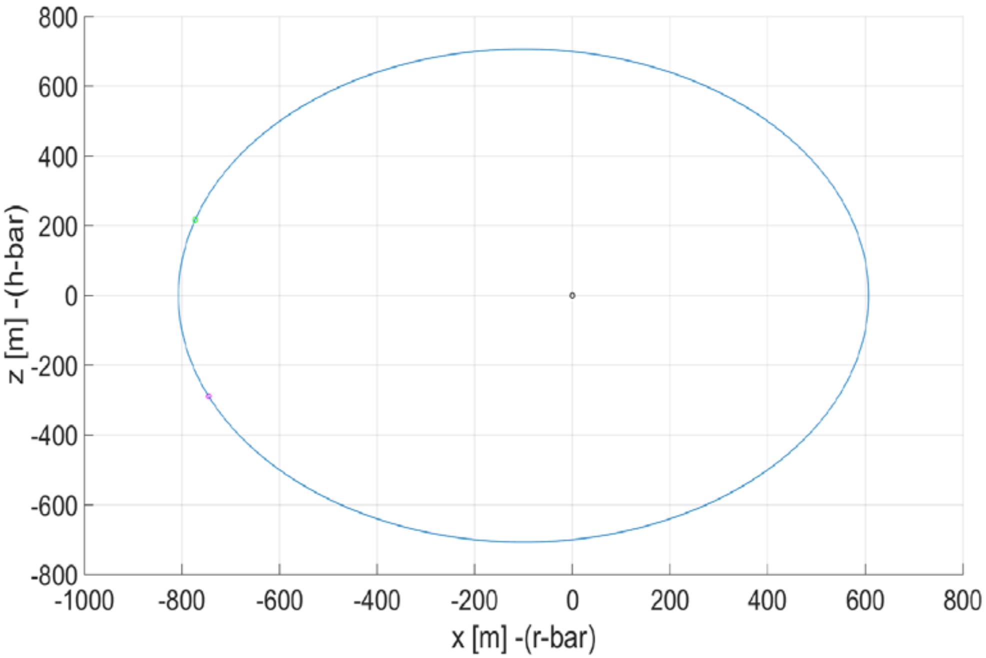


Inspection trajectories #2: helicoid (2/2)

- Projection in different planes



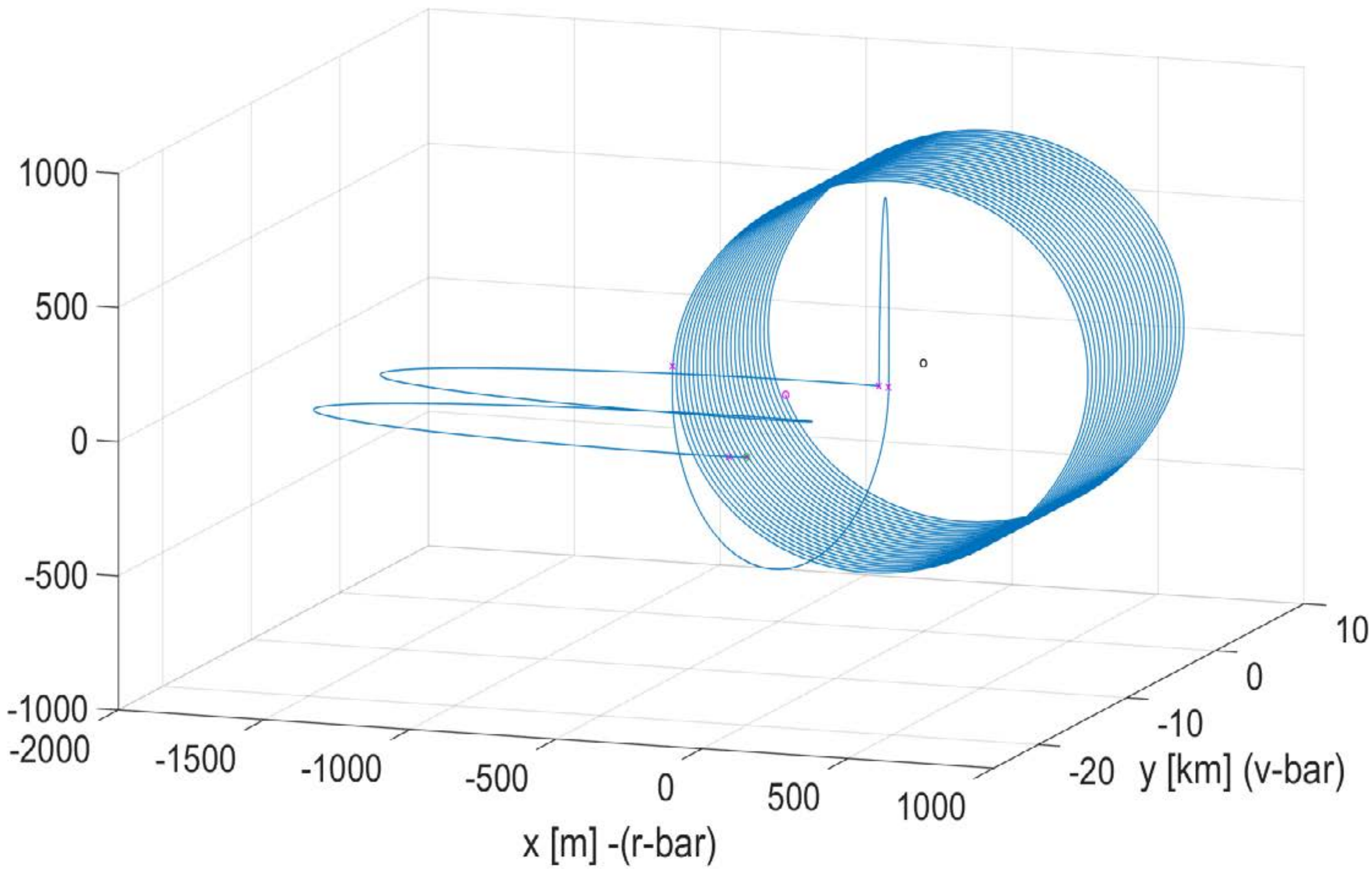
In-plane motion



Out-of-Plane motion

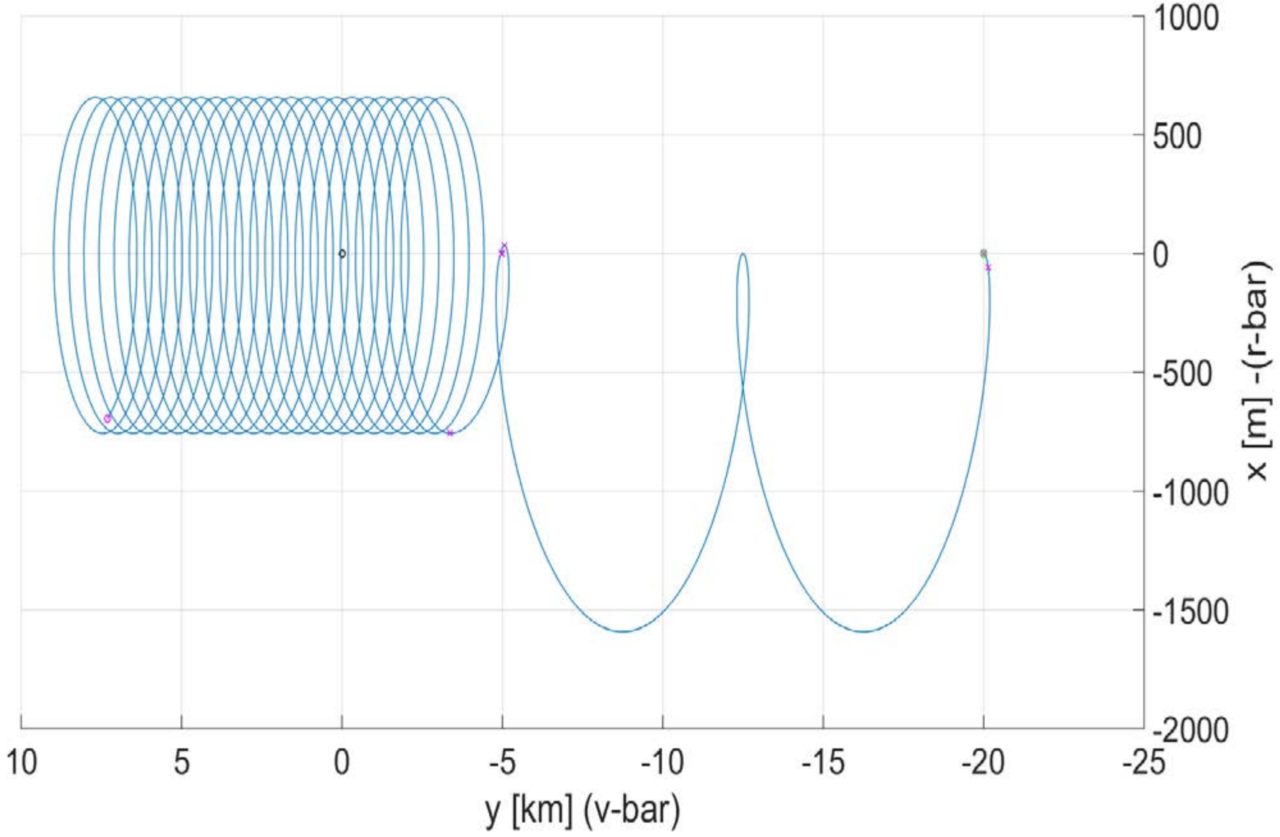
Inspection trajectories #3: hybrid (1/2)

- V-bar hopping, followed by eccentricity/inclination-vector separation (combination of Options 1 & 2)



Inspection trajectories #3: hybrid (2/2)

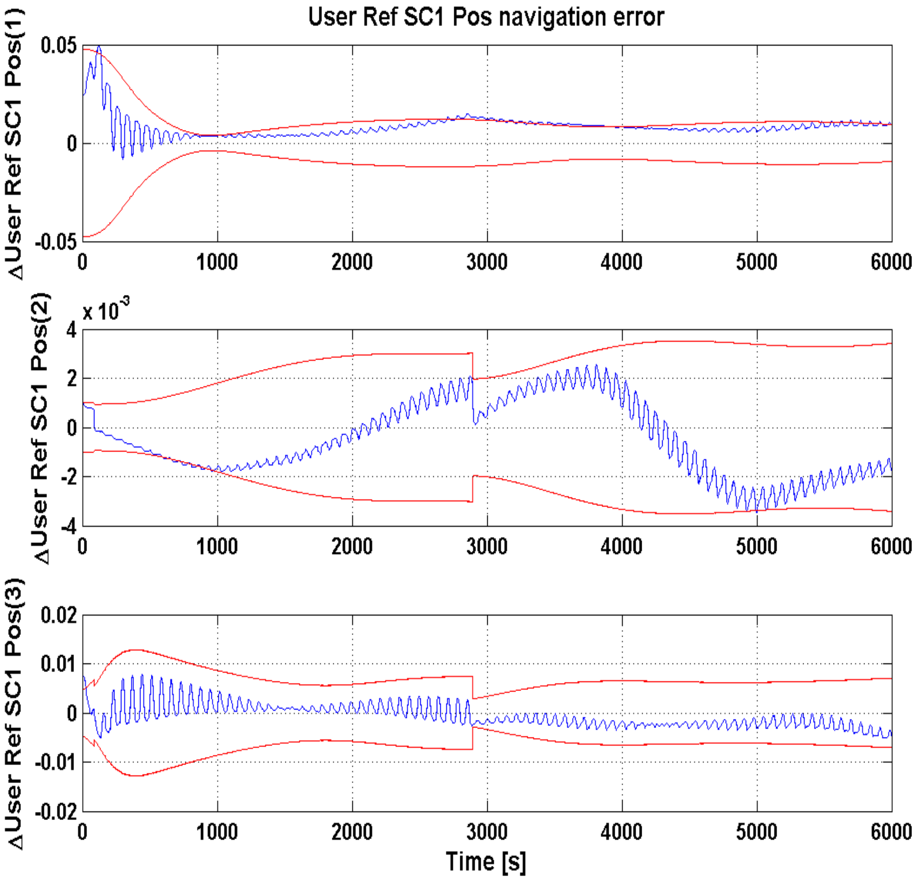
- In-plane projection



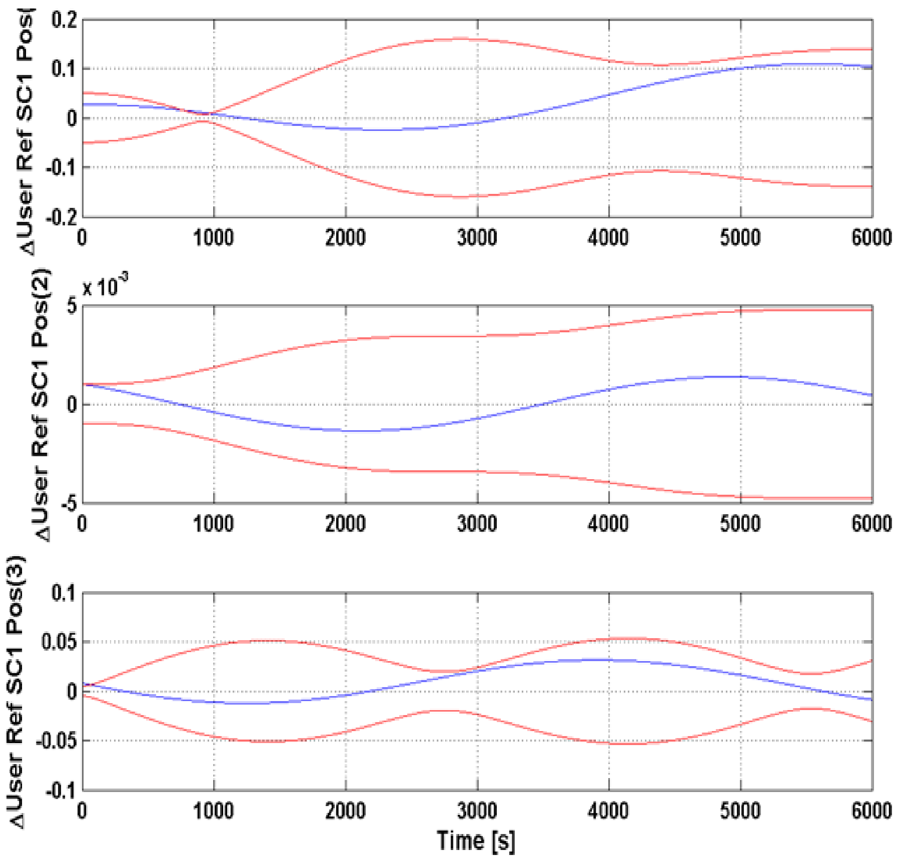
In-plane inspection navigation analysis

- Accurate knowledge to ensure proper pointing provided that the initial knowledge errors are met

LOS-only navigation

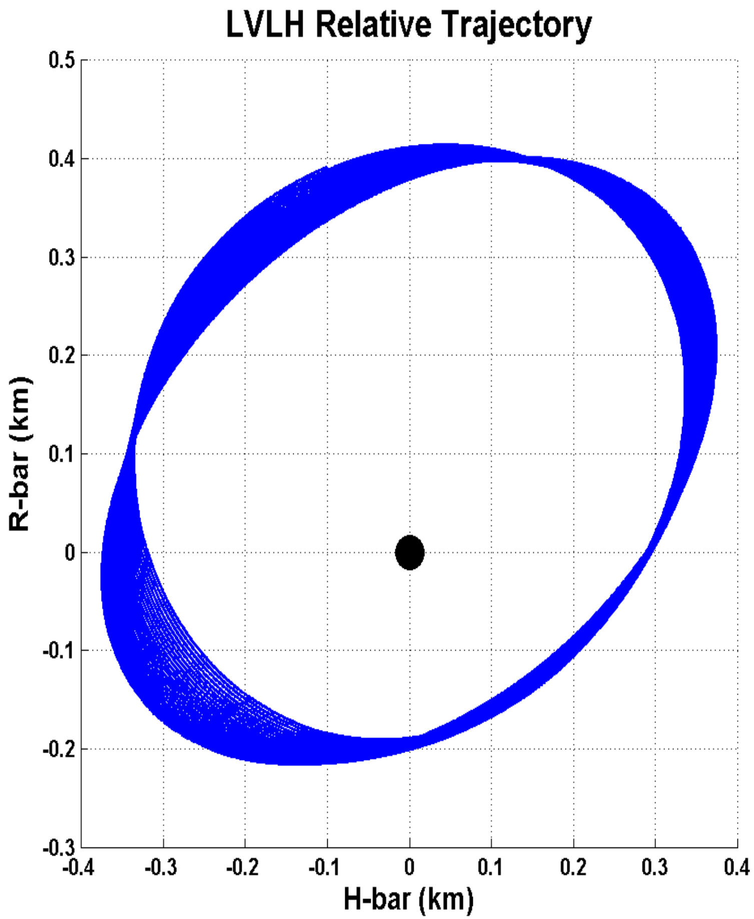


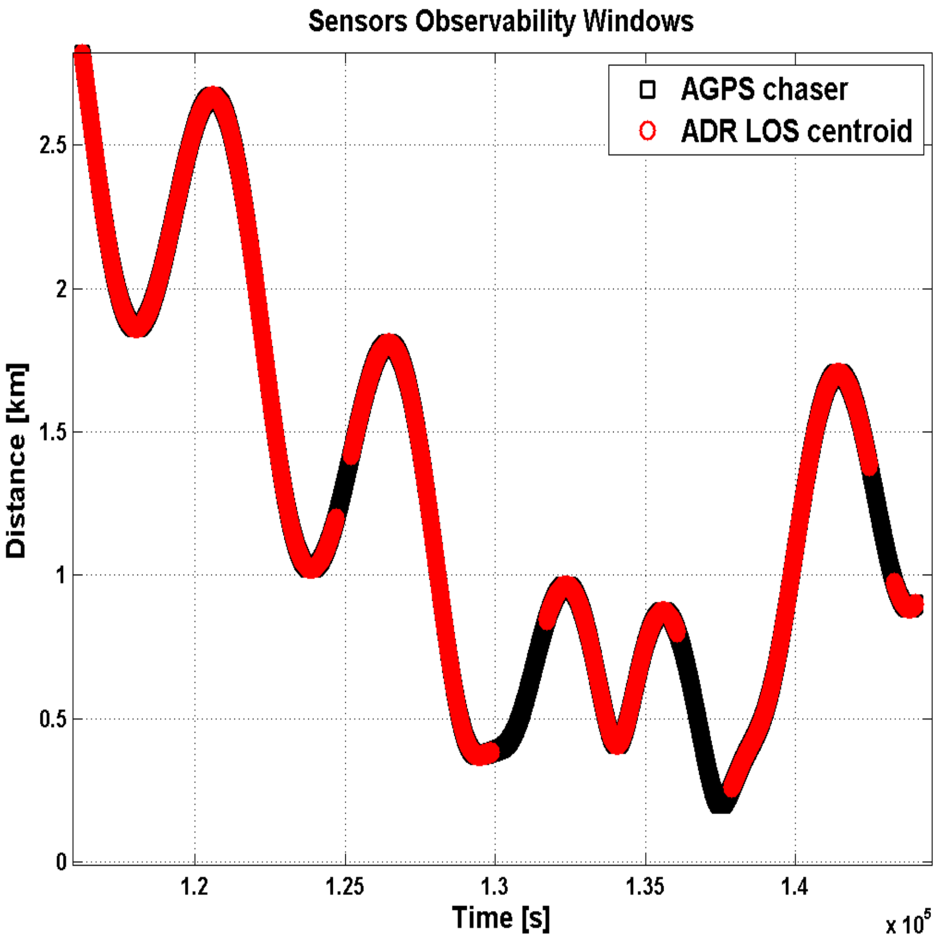
No nav (only propagation)



Out-of-plane inspection navigation analysis (1/3)

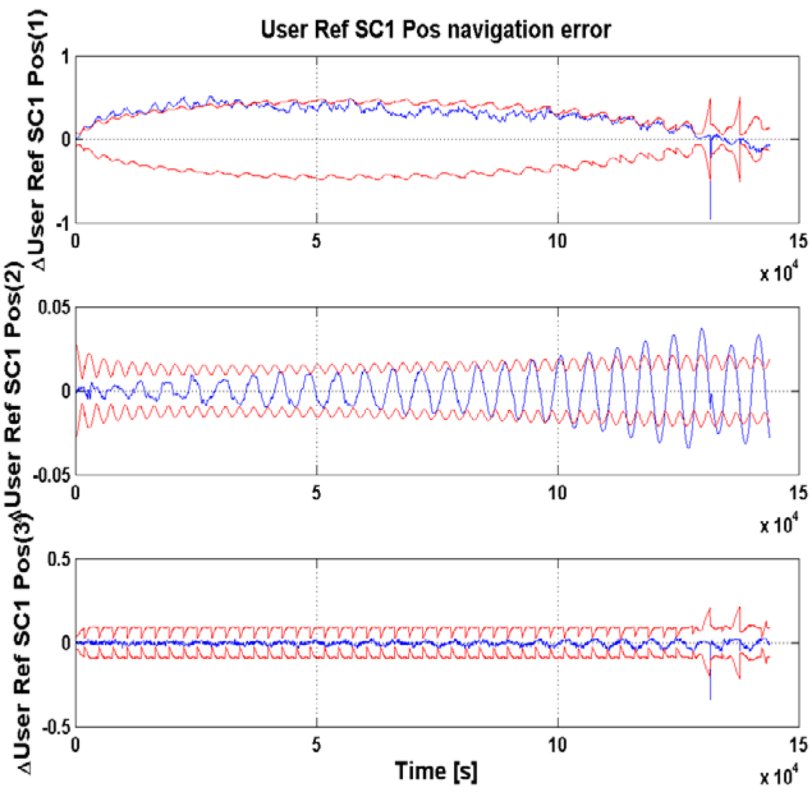
- Very sensitive to initial conditions
- Black-out periods during closest fly-around

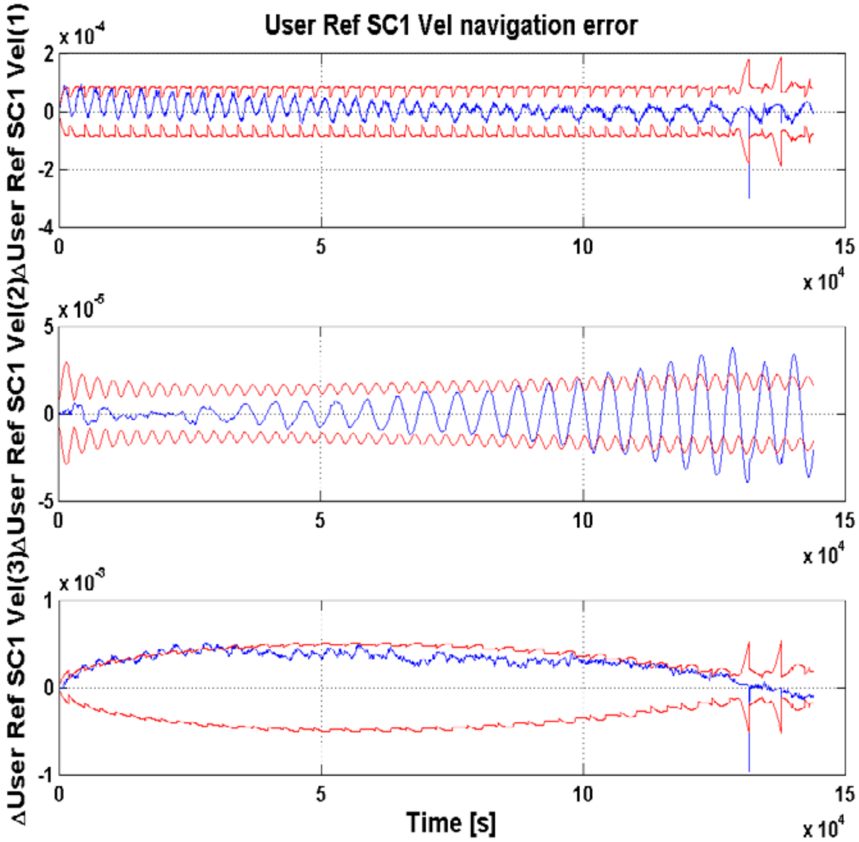




Out-of-plane inspection navigation analysis (2/3)

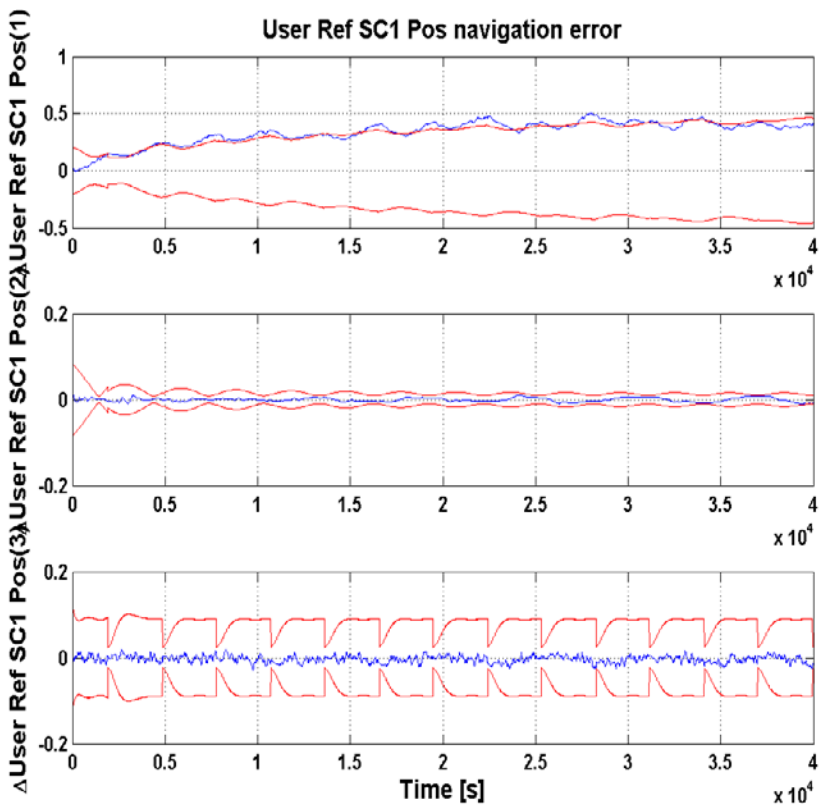
- Single filter tuning for very different phases
- Strong impact of black-outs in the navigation during closest approach

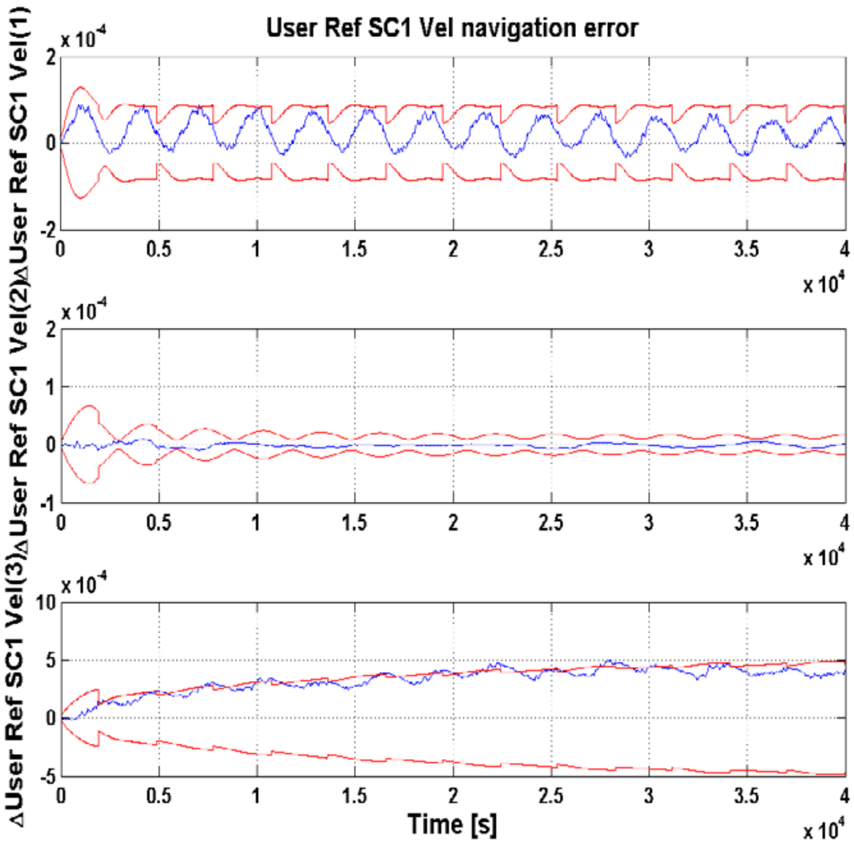




Out-of-plane inspection navigation analysis (3/3)

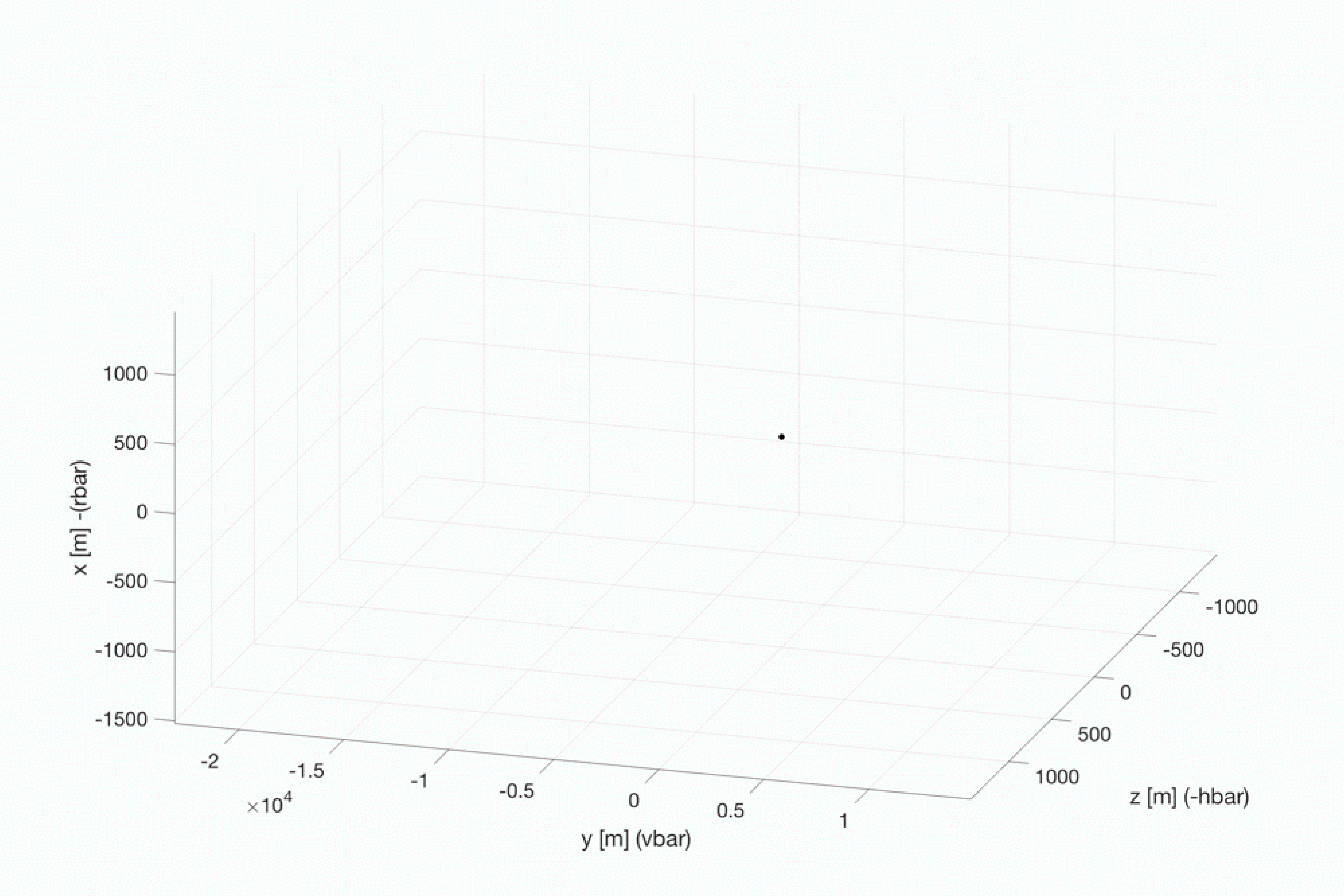
- Increase of initial knowledge error does not impact the performances





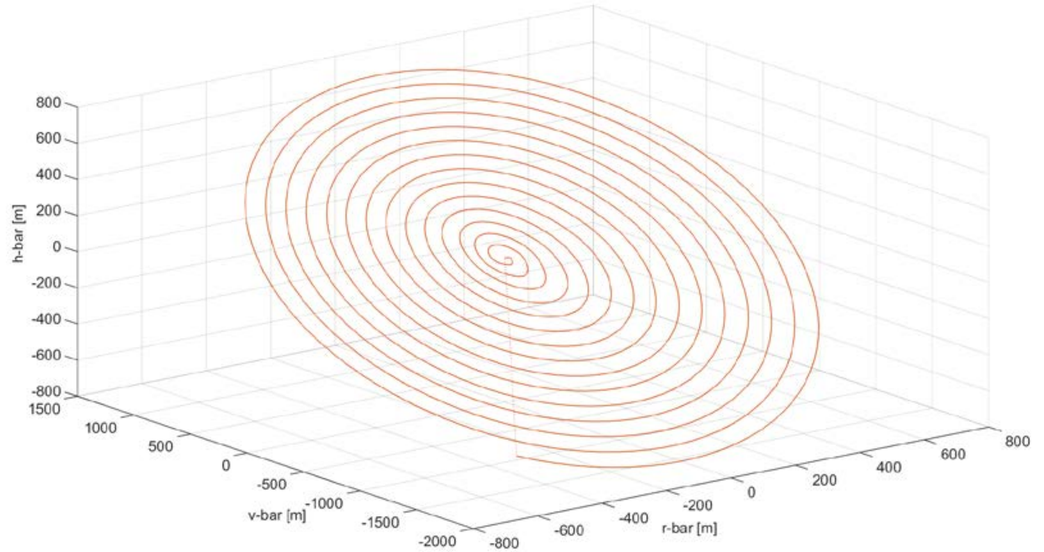
Baseline Inspection Trajectories

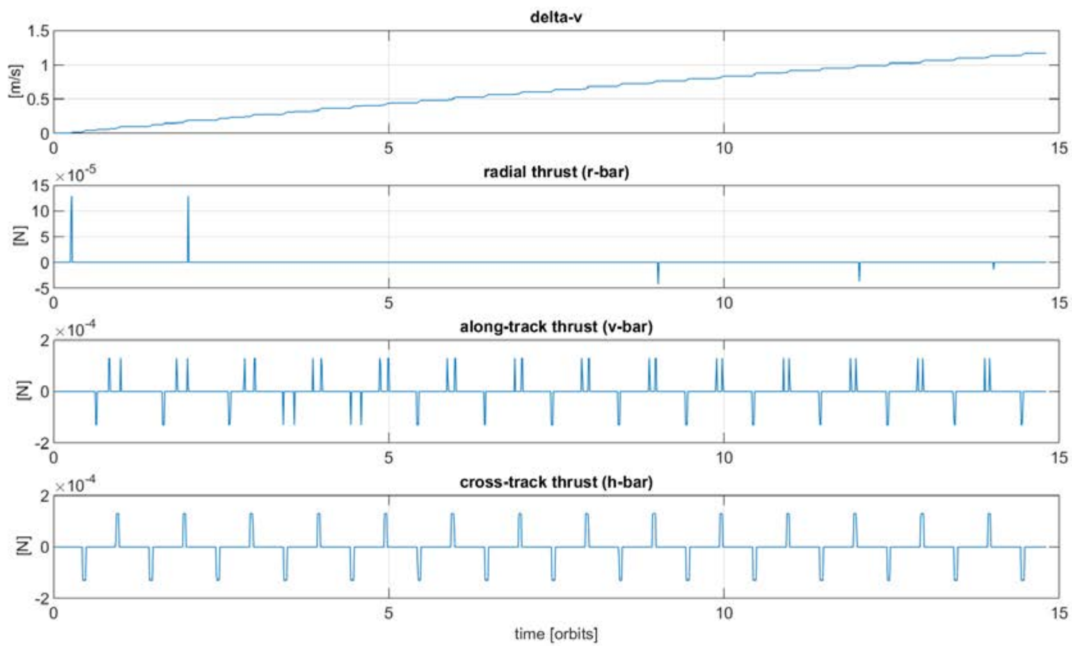
- Reducing minimum distance to target step-wise



Inspection Trajectories

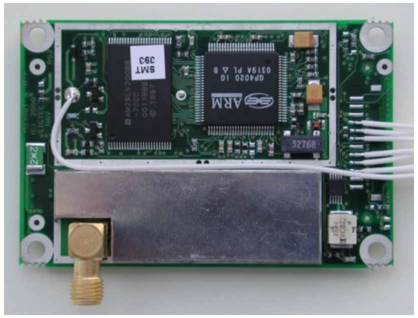
- EP introduces complexity in the design of the injection manoeuvers
- 1st e-i separation
    - Ensure drift away
- 2nd sma separation
- Long injection because e-i can only be applied twice per orbit

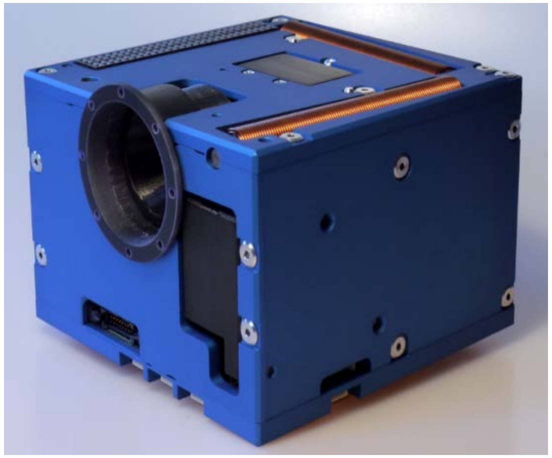




Equipment

- iADCS400 (Hyperion Technologies)
    - 3x reaction wheels
    - 3x magnetorquers
    - 1x star tracker
- GPS Receiver + antenna (DLR)
- IMU (Memsense)
- IM200 Imager (Hyperion Technologies)
- 6x SS200 Sun Sensors (Hyperion Technologies)





Conclusions

- On-board vision-based navigation and attitude guidance required for proper imaging of target
- Further analysis of LOS-only navigation to confirm performances
- EP maneuvers during inspection phase imposes novel methods to perform inspection (rendezvous)
  - Complex injection: *e*-*i* separation and then *a*
  - Combination of in-plane and out-of-plane trajectories might be the best solution to simplify inspection
- Further analysis of sensitivity of out-of-plane trajectories to injection errors and perturbations