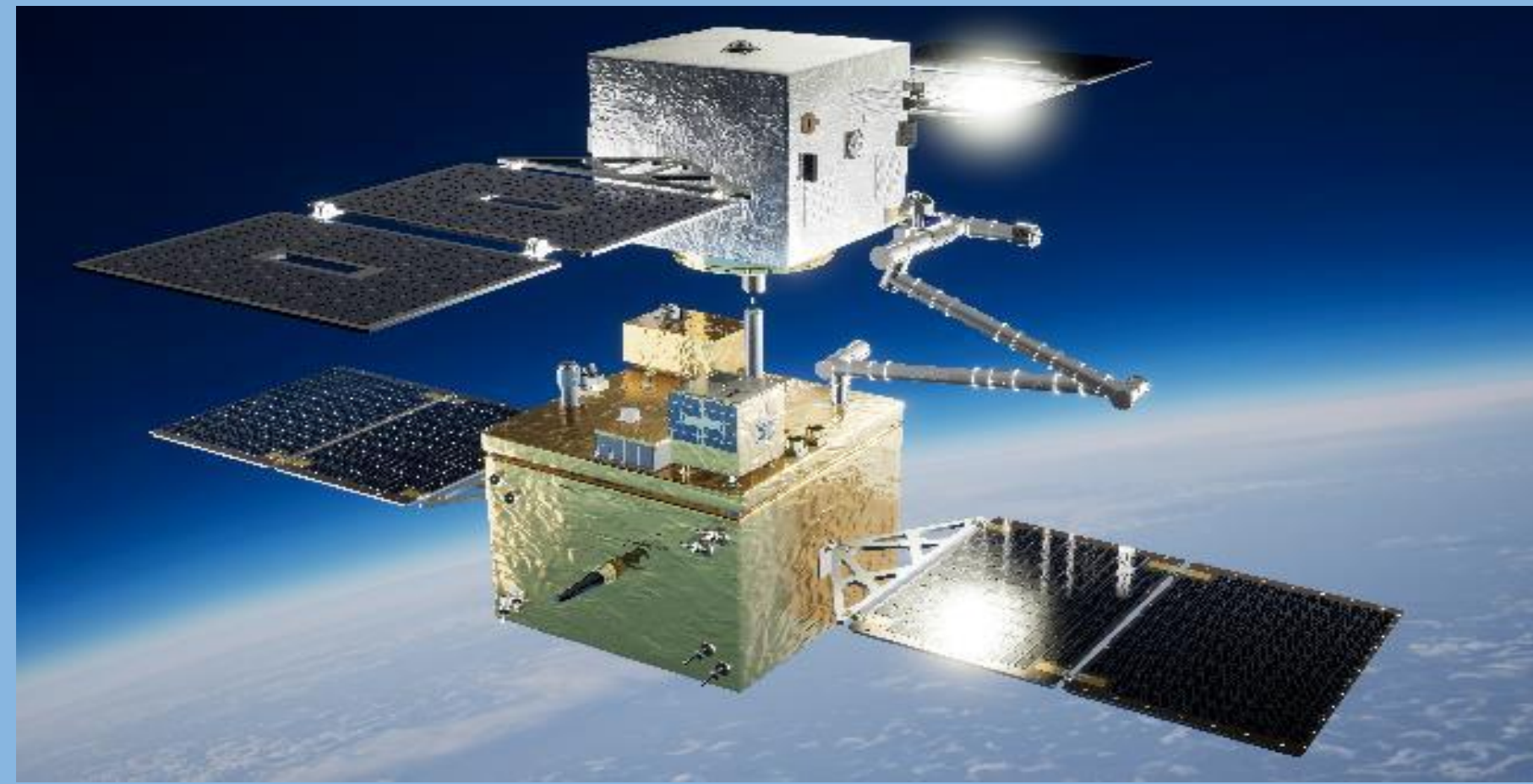
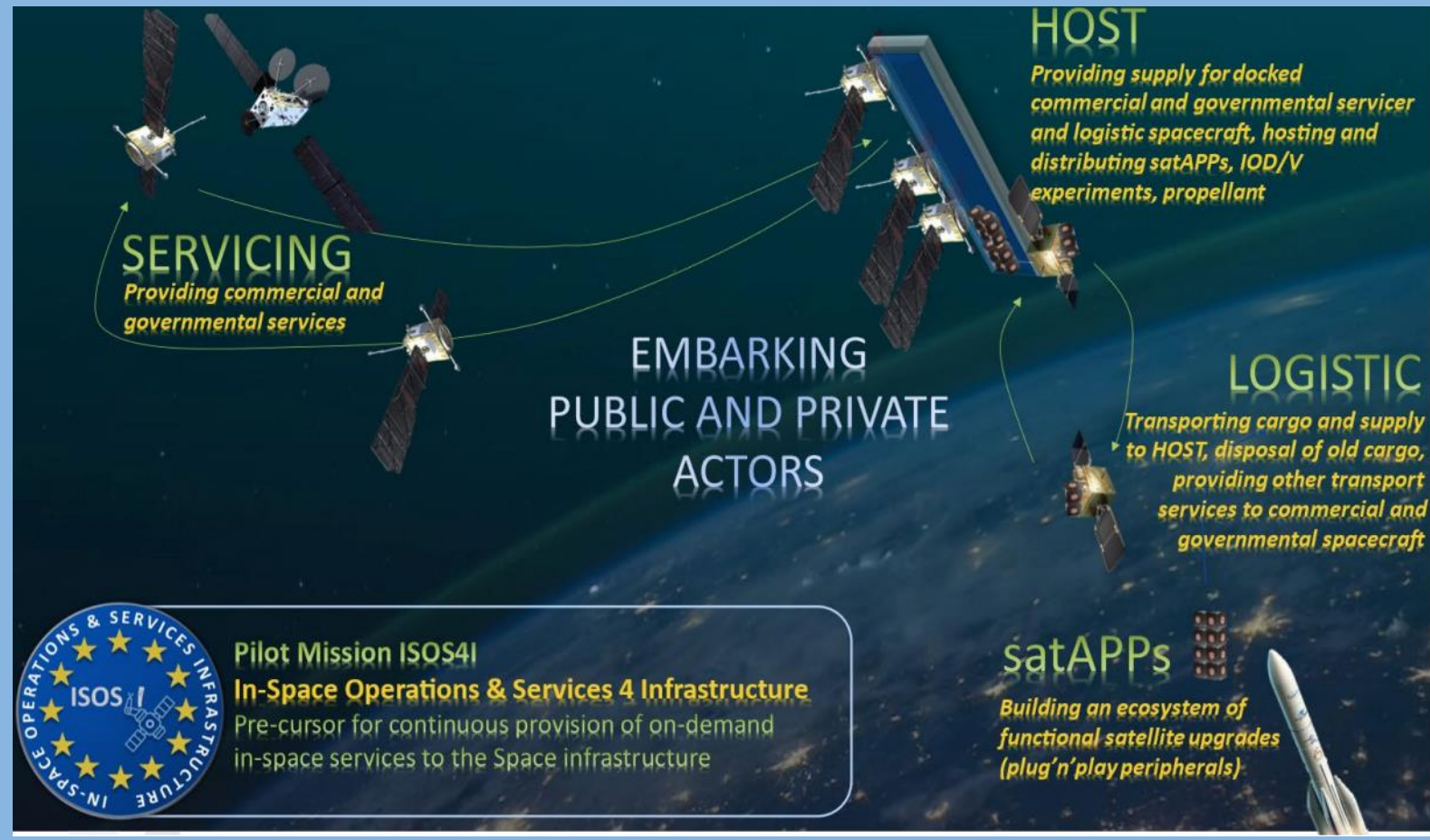


"EROSS SC" Mission Context, Goals, and Current Achievements

1. INTRODUCTION

- Thales Alenia Space in France (TAS-F) is leading the EROSS program since 2023 with a flight demonstration initially foreseen by 2026 shifted to 2028.
- Based on the European Commission Framework, the previous H2020 projects heritage "3DS, EROSS, EROSS+" have covered until the Phase A/B1 with ground demonstrations over 2016 – 2023.
- Now focused on the In-Orbit Demonstration (IOD) and on commercial applications, the European Commission has developed the « In-Space Operations and Services » (ISOS) framework in which EROSS represents the « Servicing Component » (SC)
- EROSS SC program will provide a Servicer robotic vehicle capable of (active) rendezvous, inspection, capture, refuelling and manipulation/upgrade.
- While the other « components » will provide logistics, fuel depot, and unit storage...

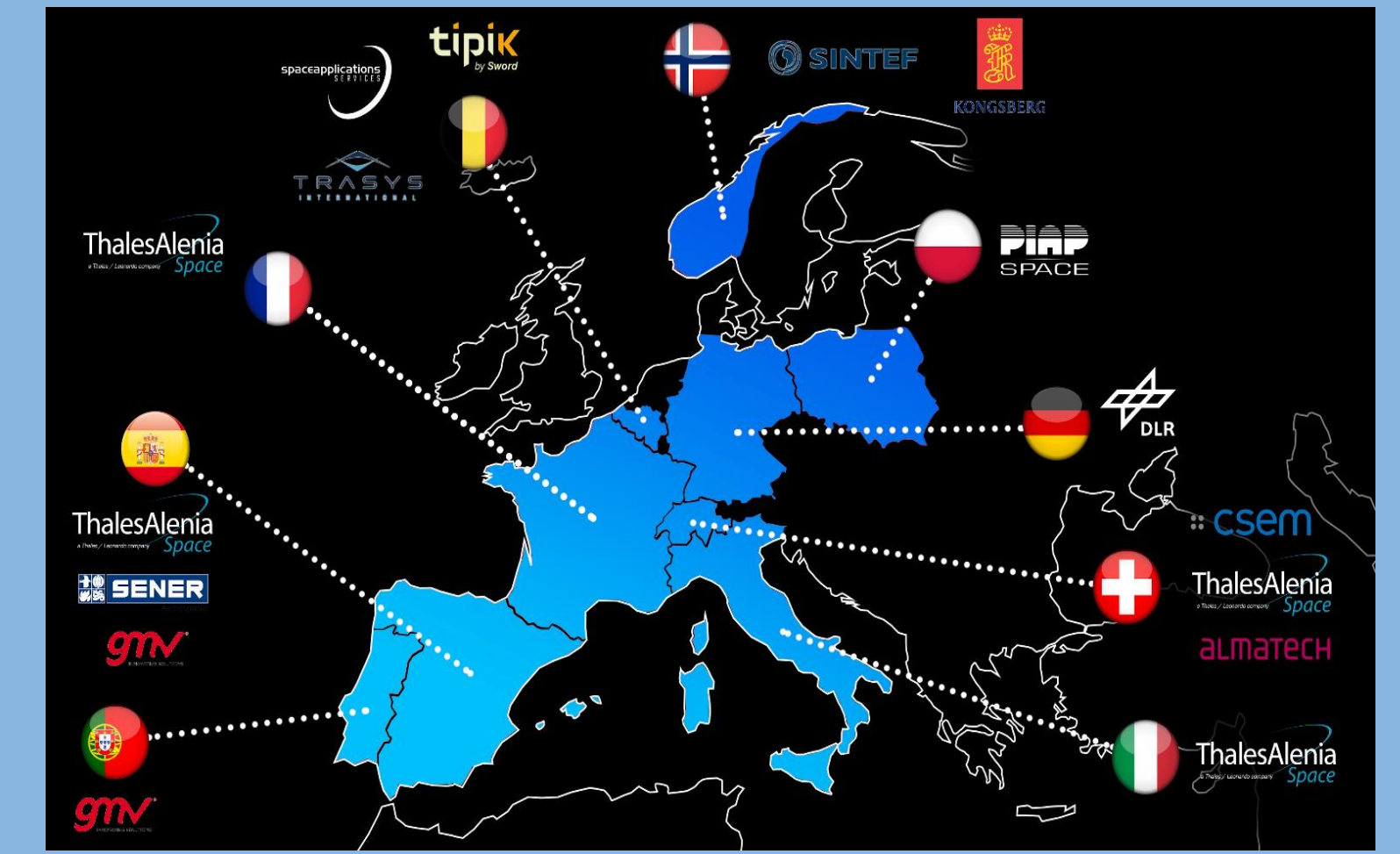


2. MISSION GOALS

- Demonstrate autonomous & safe rendezvous in orbit
- Demonstrate autonomous robotics for capture & servicing in orbit
 - Client capture and berthing with vision-in-the-loop
 - Client refuelling through mating interface
 - Assembly of Orbital Replaceable Units (ORUs)
 - Client repair / upgrade by mounting/dismounting ORU unit
- Demonstrate services for Prepared / Unprepared Client vehicles
- Provide services to operational Clients vehicles
 - Inspection, AOCs takeover, orbit relocation, end-of-life disposal...

3. CURRENT ACHIEVEMENTS

- Design Reviews completed for major subsystems
 - Guidance, Navigation and Control SW (GNC)
 - Servicer Vision System (SVS) for rendezvous sensing
 - Robotic Assembly System (RAS) for robotic operations
- Ground Demonstrations on-going for derisking key technologies
 - GNC SW validation on the Avionics Test Bench (ATB) – done Feb. 2025 FRANCE @TAS-F
 - SVS HW/SW validation on Optical & Robotic Benches – by April 2025 SPAIN @GMV
 - RAS HW/SW validation on CAESAR Robotic Bench – by December 2025 GERMANY @DLR



SAFE CONOPS ANALYSES FOR CLOSE PROXIMITY OPERATIONS : EROSS SC USE-CASE

Vincent DUBANCHET, Romain MORA, Davide CASU, Angelo AUSIELLO
- Thales Alenia Space, 5 allée des Gabians, 06150 Cannes, FRANCE -

- #Servicing
- #Rendezvous
- #LinCov
- #Safety

Track: « Efficient V&V Tools and Methodologies for Systems Using Modern GNC Technologies »

MISSION SAFETY HANDLING

External Inputs

- Law** : French "LOS"
 - "Loi sur les Opérations Spatiales"
 - (In-flight) Collision avoidance check
 - (In-flight) Collision risk assessment
- Standards** : ISO
 - [2022] "ISO 24330: Rendezvous and Proximity Operations (RPO) and On Orbit Servicing (OOS)"
- Guidelines** : ESA
 - [2024] "Guidelines on Safe Close Proximity Operations (CPO)" - Issue 3
- Guidelines** : CONFERS
 - [2022] "Recommended Design and Operational Practices"
 - [2025] "Best Practices, Functional Reqs, and Norms for Prepared Free-Flyer Capture and Release"

Mission Design

- STEP A.1 : Draft CONOPS**
 - Rendezvous & Safety Functional Analysis
 - Key waypoints & transfers definition
 - Preliminary DV & Fuel Budget
- STEP A.2 : GDC-NAV Nominal Design**
 - Guidance for nominal trajectories
 - Navigation filter design wrt measures
 - Control error as hypothesis / input

Design Validation

- STEP B.1: Robustness Check**
 - Linear scattering wrt reference
 - Performances over simplified model
 - Safe behaviour analysis for failures
- STEP B.2: HiFi Verif. & Validation**
 - G-N-C implementation in HiFi simulator
 - Nonlinear scattering wrt reference
 - Safety margins assessment
- STEP B.3: GNC Design Loop**
 - (if required) CONOPS & G-N-C update
 - FDIR mechanisms implementation



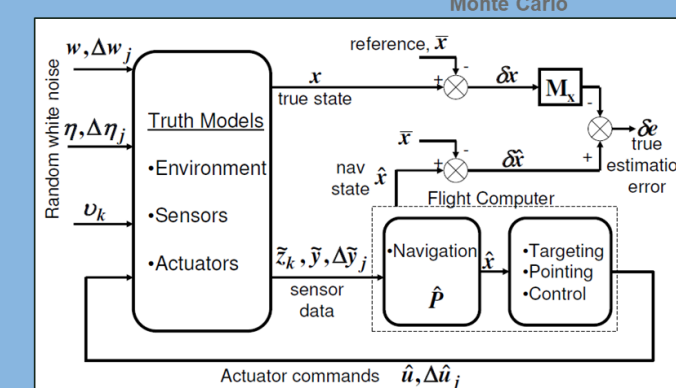
APPROACH

"Rendezvous Trajectory Design & Validation" (RTDV)



TOOL

Principles



$$\dot{\mathbf{C}}_A = \mathcal{F}\mathbf{C}_A + \mathbf{C}_A\mathcal{F}^T + \mathbf{G}\mathbf{S}\mathbf{G}^T + \mathbf{W}\mathbf{S}_w\mathbf{W}^T$$

$$\mathbf{C}_A(t_k^+) = \mathbf{A}_k\mathbf{C}_A(t_k^-)\mathbf{A}_k^T + \mathbf{B}_k\mathbf{R}_k(t_k)\mathbf{B}_k^T$$

$$\mathbf{C}_A(t_k^+) = \mathbf{D}_k\mathbf{C}_A(t_k^-)\mathbf{D}_k^T + \mathbf{M}_k\mathbf{S}_{\Delta y}(t_k)\mathbf{M}_k^T + \mathbf{N}_k\mathbf{S}_{\Delta y}(t_k)\mathbf{N}_k^T$$

$$\mathbf{X} = \begin{pmatrix} \mathbf{x} \\ \mathbf{x} \end{pmatrix} \quad \mathbf{C}_A = \mathbb{E}[\mathbf{X}(t)\mathbf{X}^T(t)]$$

Features

- Orbit propagation with disturbances model (i.e., drag, SRP, Gravity...)
- Simplified GNC with Navigation & Guidance functions

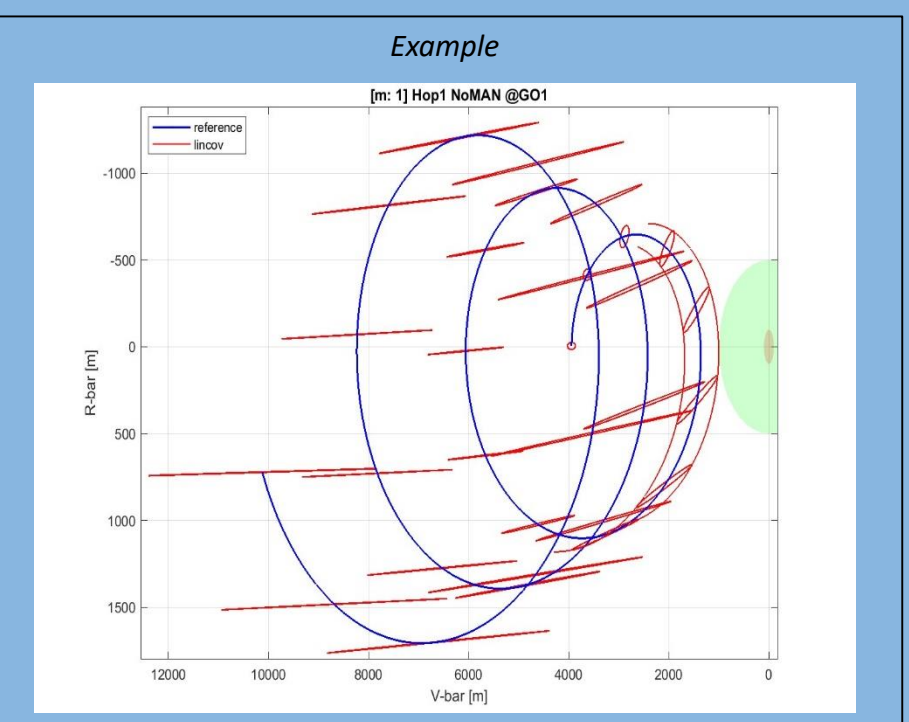
- Guidance, Control & Navigation**
 - Representative algorithms
 - Unitary functions implementation
 - Executed at OBSW frequency
- Sensor & measurements**
 - Performance models
 - A-priori cross-correlated
 - Representative sensor behaviour

- Ability to perform stochastic analysis (e.g., LCA, Monte Carlo analysis)
- Ability to extract key indexes for the full scenario
 - State estimation error covariance
 - Delta-V covariance
 - Probability of collision
 - ...

Complexity

- Early-stages "simplified" simulator to mature Conops & Safety
- Preliminary derisking & performances assessment wrt a High-Fidelity simulator
- Stochastic analysis with increasing complexity

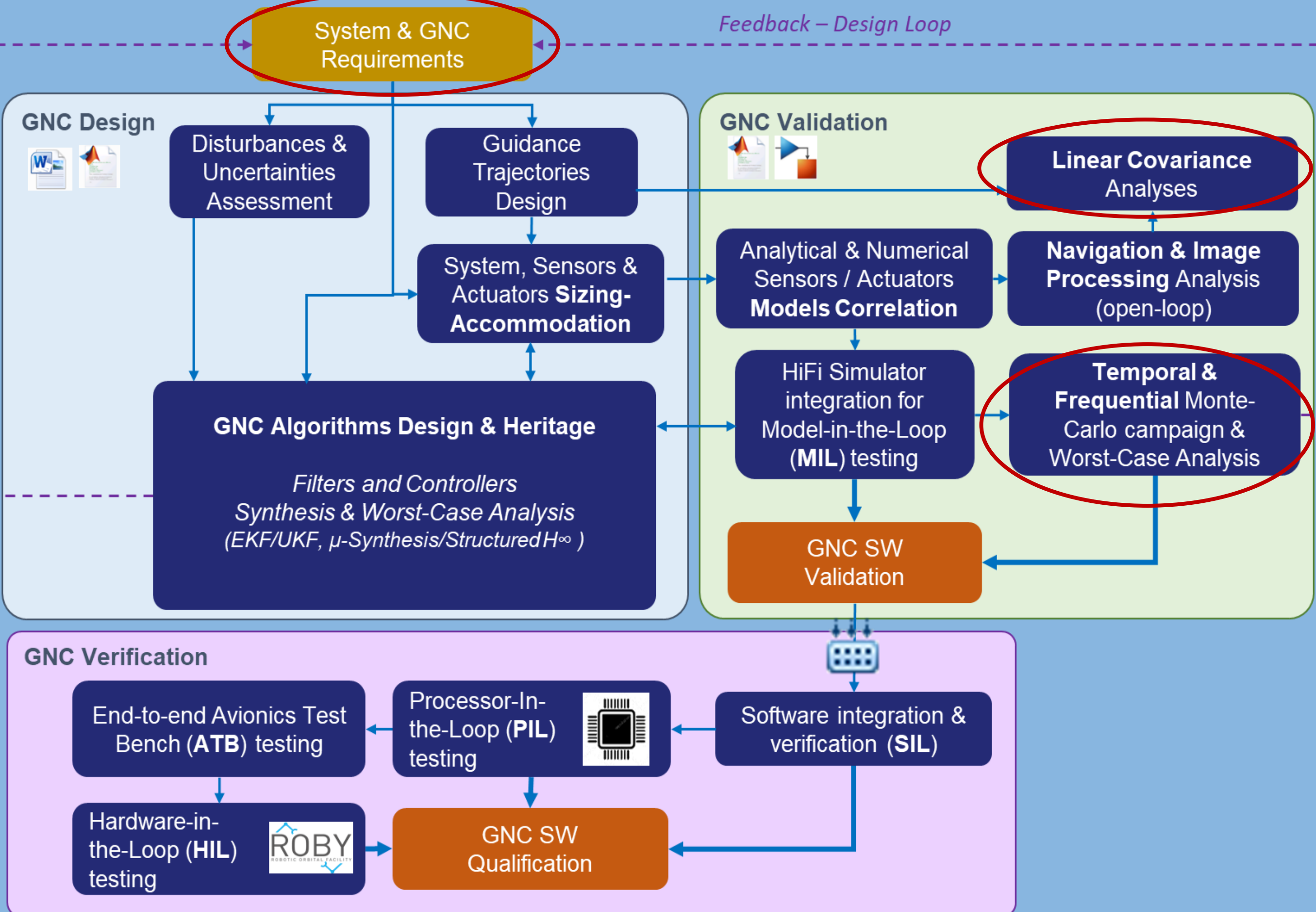
D. Geller, "Linear covariance techniques for orbital rendezvous analysis and autonomous onboard mission planning," Journal of Guidance, Control, and Dynamics, vol. 29, no. 4, pp. 775-782, 2006. doi: 10.2514/1.19447



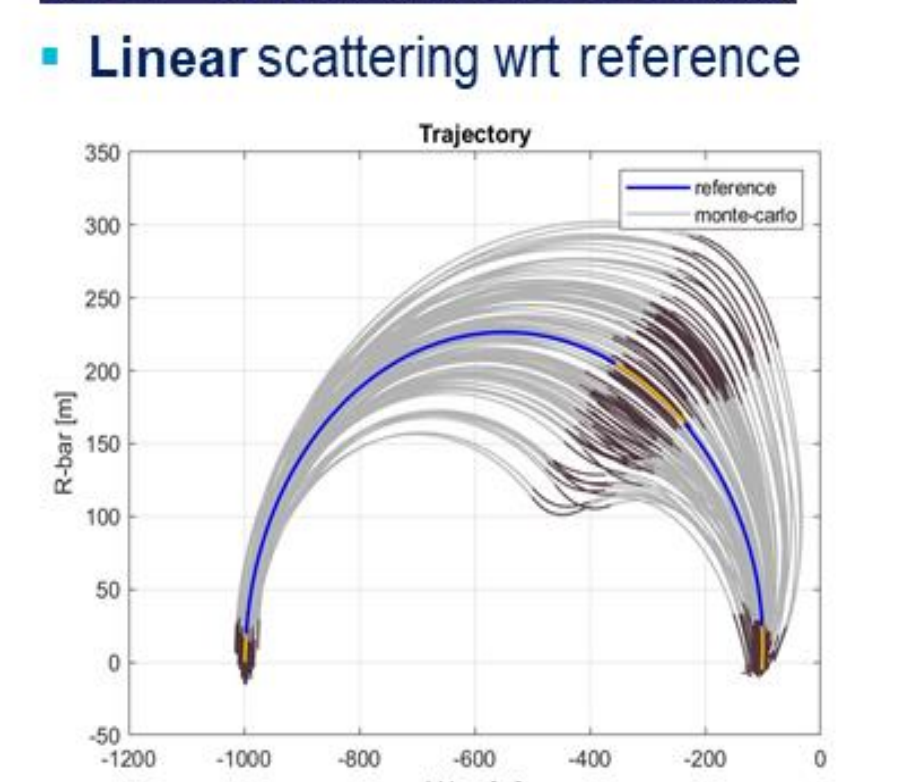
IMPLEMENTATION & RESULTS



RESULTS

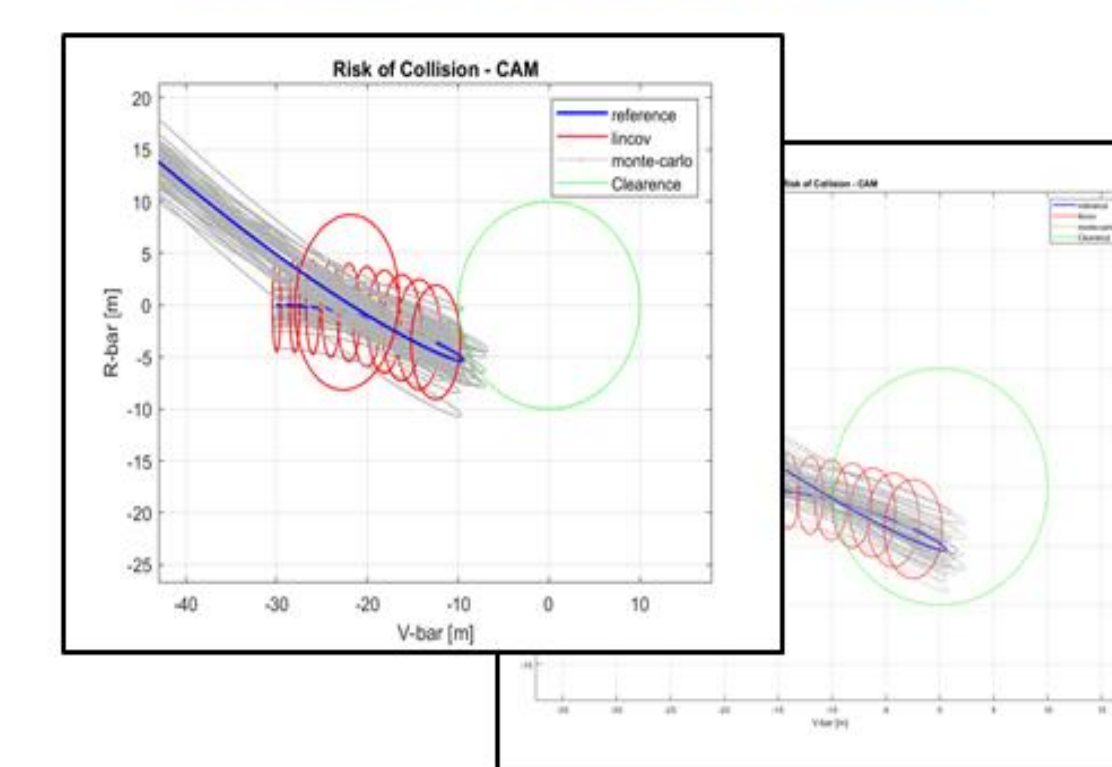


STEP B.1: Robustness Check



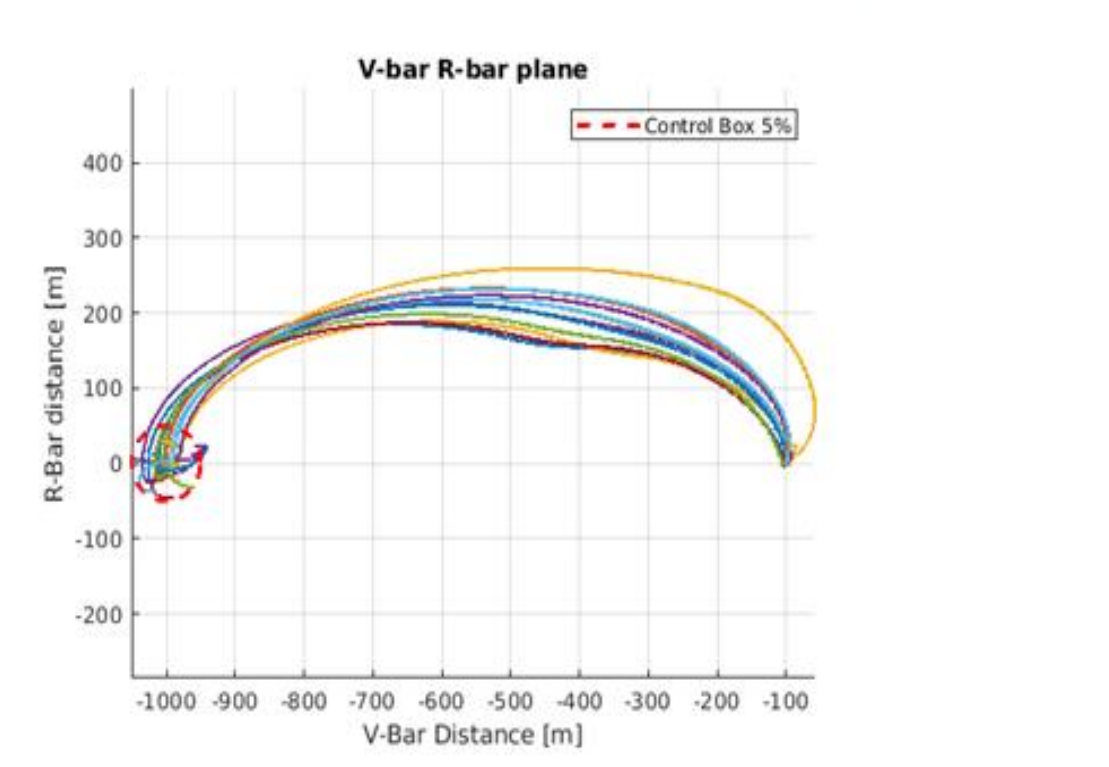
Design Validation

- Safe behaviour analysis for failures

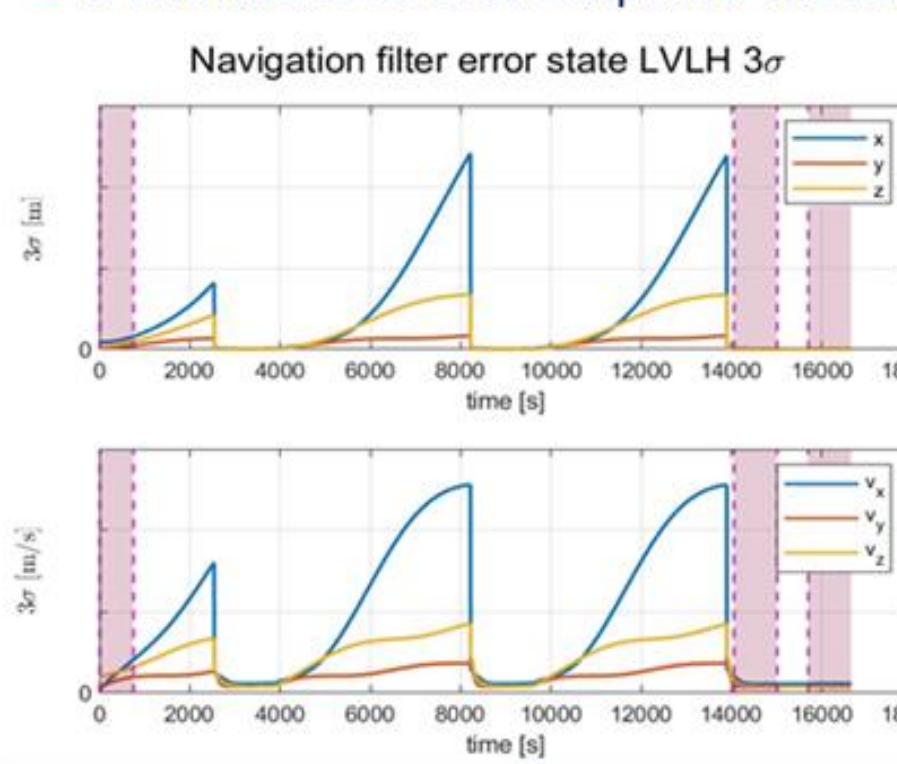


STEP B.2: Verif. & Validation

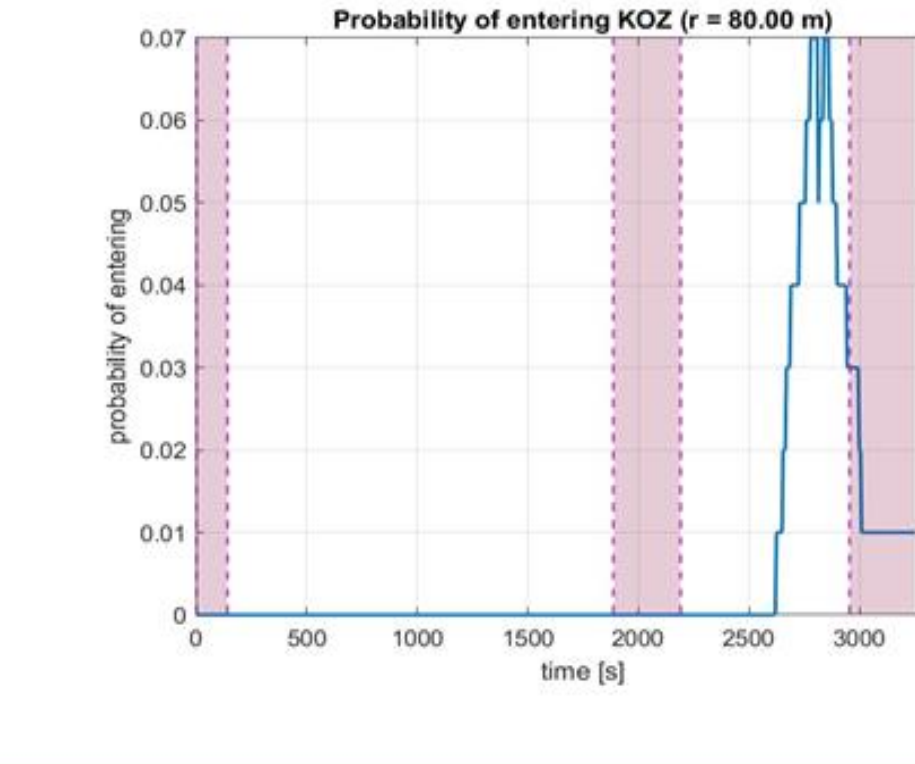
- Nonlinear scattering wrt reference



- Performances over simplified model



- Safety margins assessment



- Percentage of Norm Error on DV Hopping

