POLITECNICO MILANO 1863

2023 Clean Space Industry Days, 16-19 October, ESA-ESTEC

e.Inspector phase B

12U CubeSat for debris target multispectral close inspection

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e.Inspector – *in Orbit Servicing*

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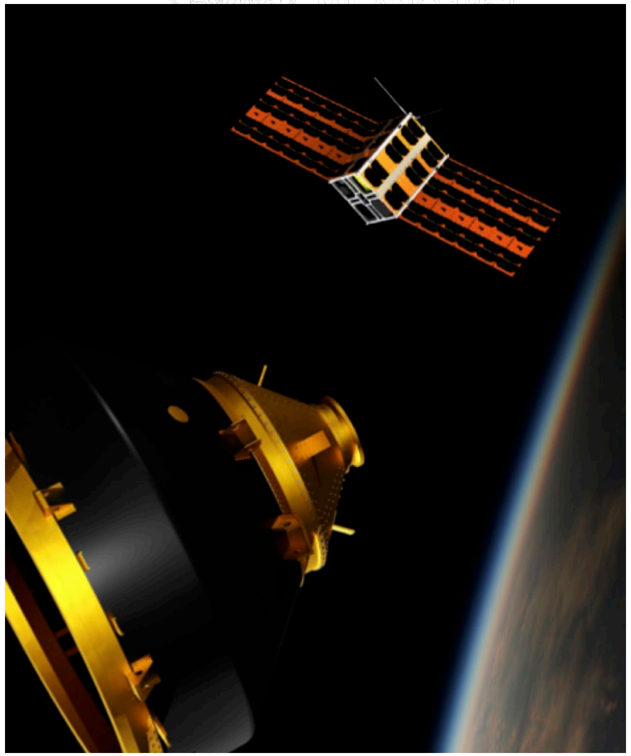
LEAF SPACE

GOAL

- Fly around a Space Debris – VESPA adapter
- Shape and dynamics reconstruction to support Active Debris removal activities



- ***Safety proximity maneuvering around a non cooperative\not a priori known object***

Technology development opportunity

- **Complement** the VIS sensors with **IR imaging** to perform **enhanced relative navigation *on board* in closed loop with control**
- **Exploit the low thrust capabilities** – electric propulsion

Project Engineering

- ***Model based System Engineering***

Advanced GNC

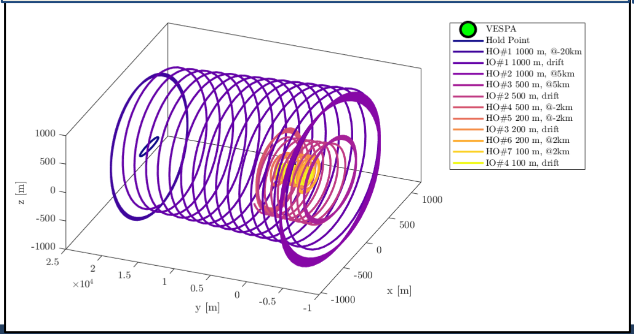
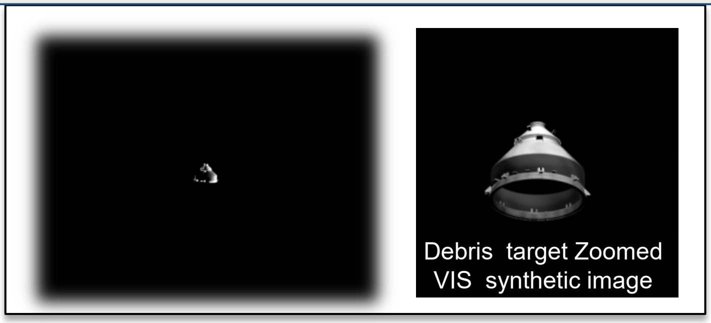
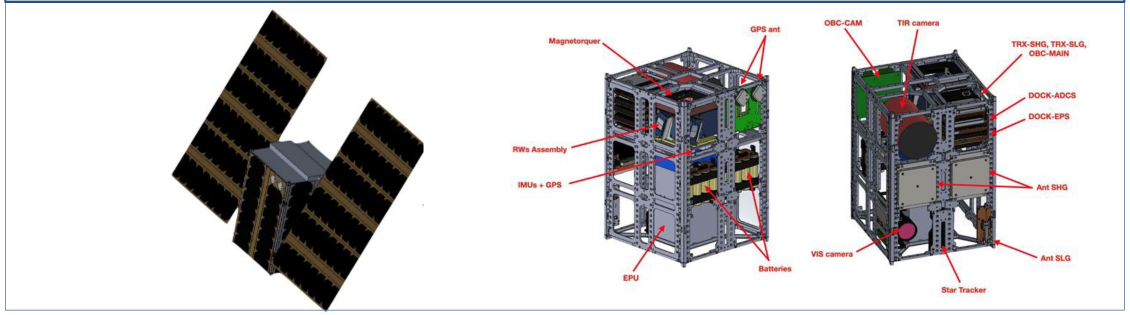


Image processing –on board sw



System Engineering



e.Inspector – *the TEAM & ROLES*

e.Inspector is financed by **ASI** and developed with **ESA** under GSTP

POLIMI-DAER\ASTRA

- **PRIME** System\mission engineering, ***multispectral IP-based proximity GNC*** and related HW\SW breadboarding on **PIL and HIL**

LEONARDO Company

- VIS\IR payload requirements, selection and characterisation\testing

LEAF SPACE

- Ground segment requirements consolidation, baseline settling

Techonology 4 Innovation – T4i

- Low thrust propulsion customization and qualification for endurances TRL increase

PHASE B – 11 months

Dec 2022, KO — Sept 2023, SRR — Nov 2023, PDR

e.Inspector – *phase B*

Phase A identified the hot spots of the mission to be

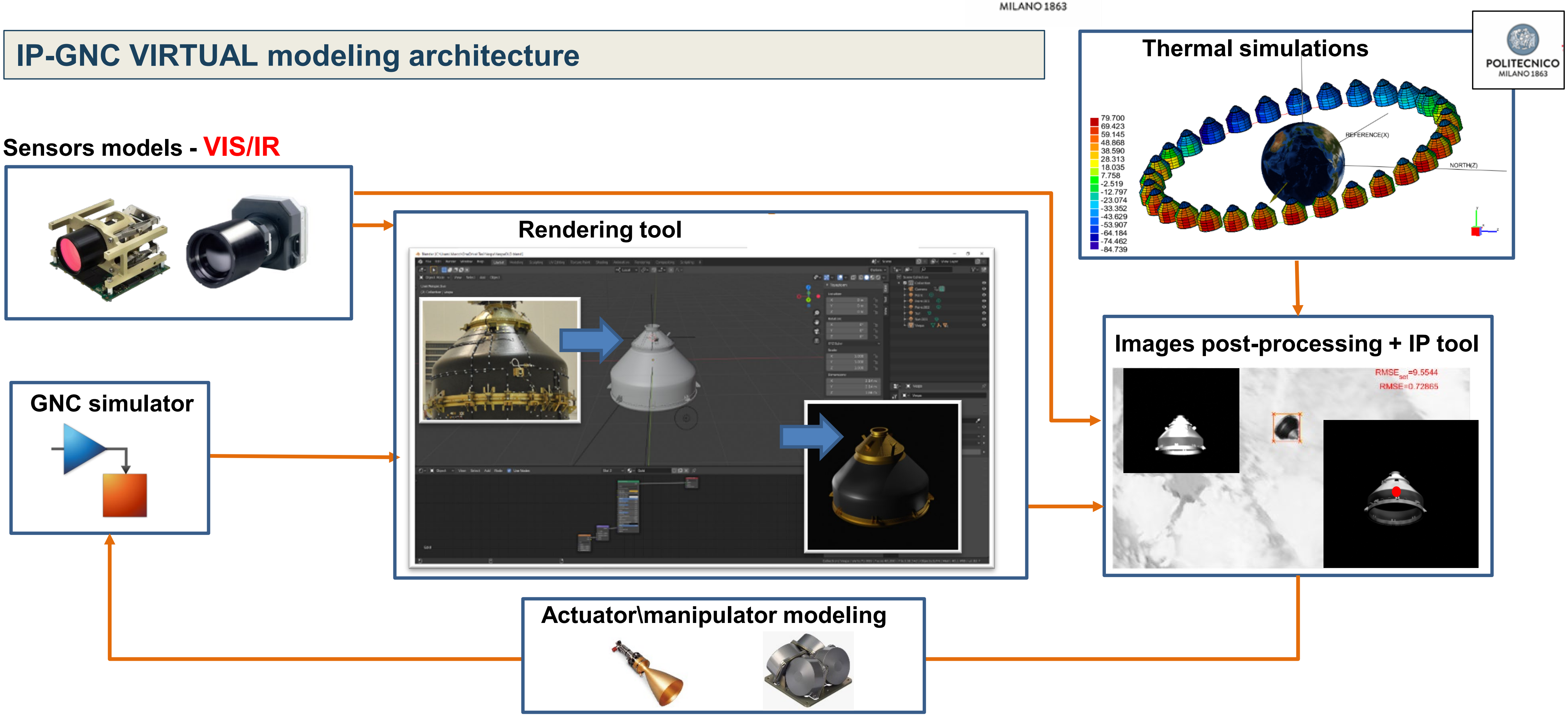
- On board **multispectral image processing** → software\hardware
- **Low thrust** trajectory control **readiness level and reliability**→electric propulsion endurance and cycling
- Prove robustness against debris generation regulations and disposal

Which translate for phase B into

- Design, develop and test multispectral **IP based** relative navigation **software**
- Design and develop the Guidance and Control for all mission phases
- Define, procure and test the **breadboard for the IP-GNC boards**
- Consolidate the **low thrust** based **mission analysis and launch strategy**
- **Assess the validity** of the proposed **image payload** and perform functional tests
- Define and **run endurance tests** on the thruster baseline
- Perform preliminary **RAMS analysis and deorbiting plan** compliance verification

e.Inspector – *Image processing*

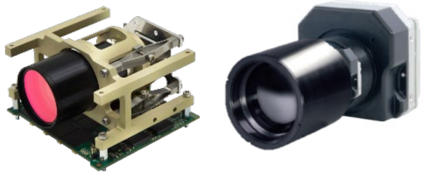
IP-GNC VIRTUAL modeling architecture

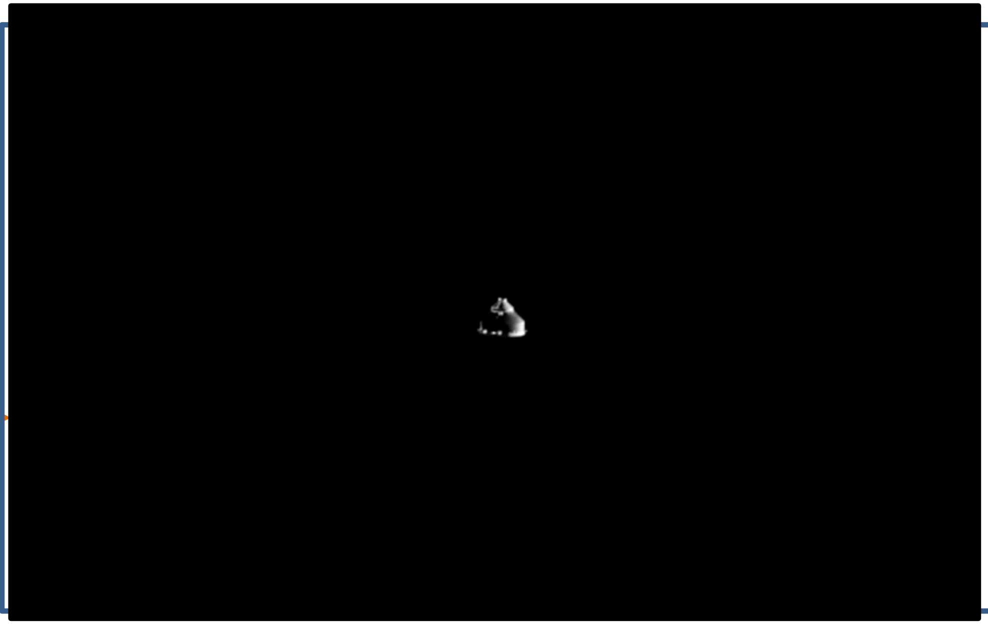


e.Inspector – *Image processing*

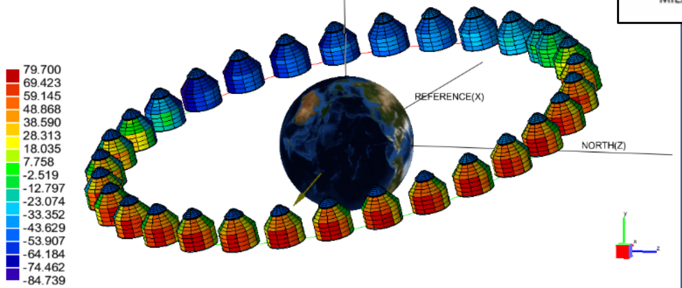
IP-GNC VIRTUAL modeling architecture

Sensors models - VIS/IR

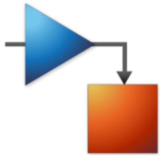




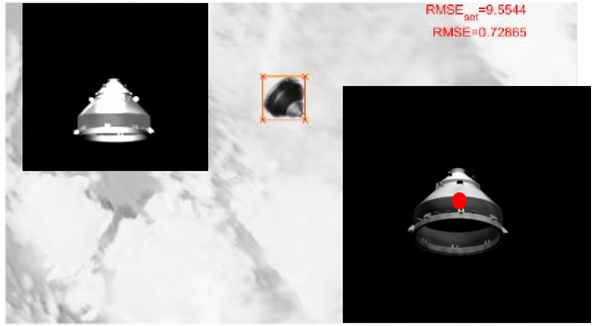
Thermal simulations



GNC simulator



Images post-processing + IP tool

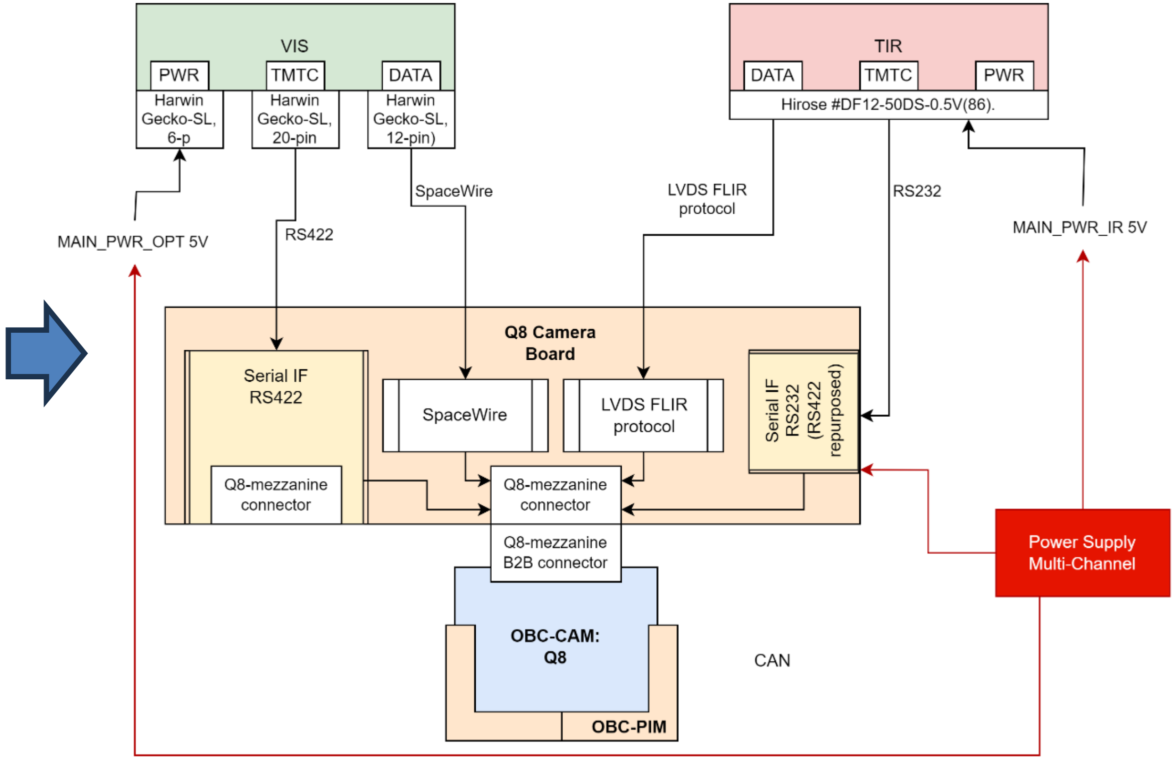


Actuator\manipulator modeling

e.Inspector- *OBC motherboard and breadboarding*

The breadboard is conceived concurrently with the virtual HIL models to be then substituted with EM PL for E2E tests

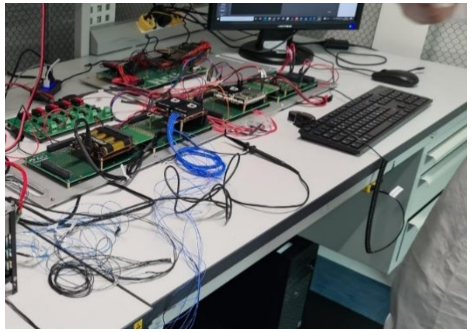
Component	Functionalities
TIR	Emulator or functional model of TIR camera
VIS	Emulator or functional model of VIS camera.
OBC-GNC	OBC in charge for acquisition of sensor readings, control actuation, part of GNC algorithms (TBC).
DOCK-GNC	Routing for OBC-GNC to sensors and actuators.
OBC-CAM	OBC in charge of execution of image processing + GNC modules strongly linked to the IP output.
CAM-BOARD	Interface daughterboard to exploit full compatibility between cameras output (DATA and TMTC) and Q8 inputs.
OBC-PIM	Inteface exposing Ultrascale+ CAN bus from the Q8 board.
PIL-TESTBENCH	
Isolators	Custom and validated isolators board design to interface PC with computers.
Sensors/Actuators	A set of microcontrollers programmed to emulate sensors readings in terms of electrical interface and data protocol.
ASTRA-FES	6-DOF simulator for environment and dynamics.



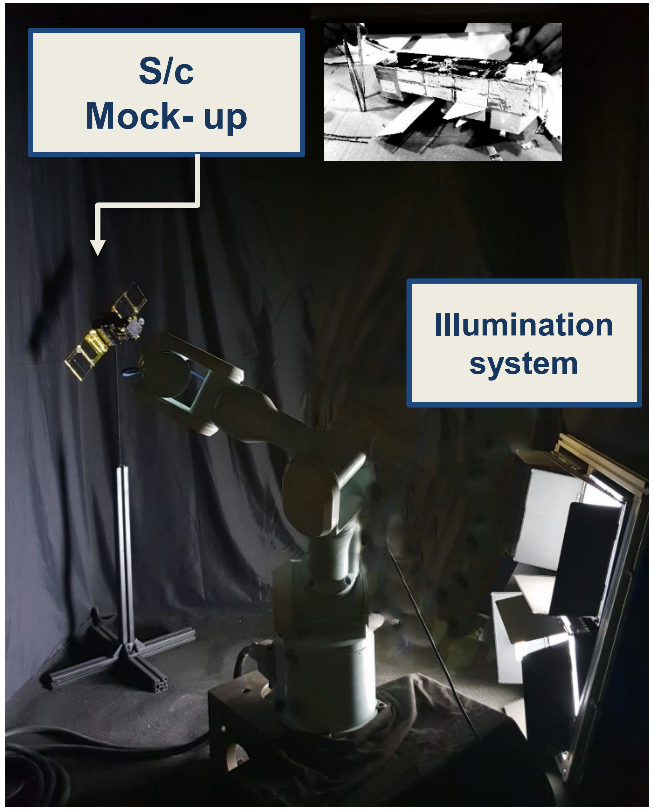
e.Inspector – *IP-GNC HIL testing*

IP-GNC ARGOS ASTRA-PoliMi facility+ HW\SW GSE – calibrated, with heritage on other ESA IP\RVD studies

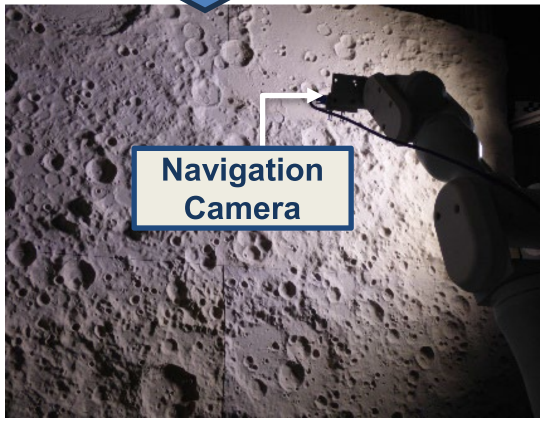
AVIONIC testbench

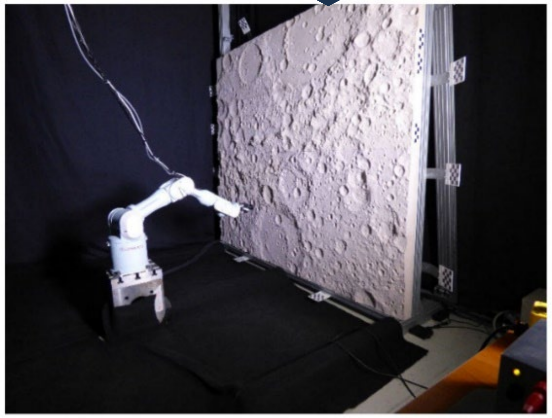


- *1:50 satellite mockup*
- *5700 K tuneable illumination*
- *VIS camera – IR camera upcoming*
- *6 dof Robotic arm*
- *3x2,4m calibrated Moon diorama*

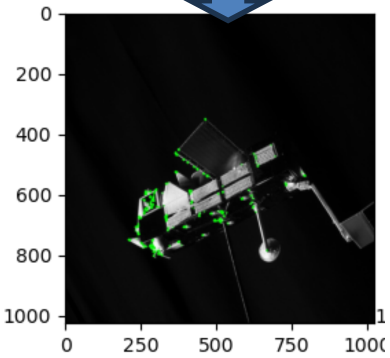


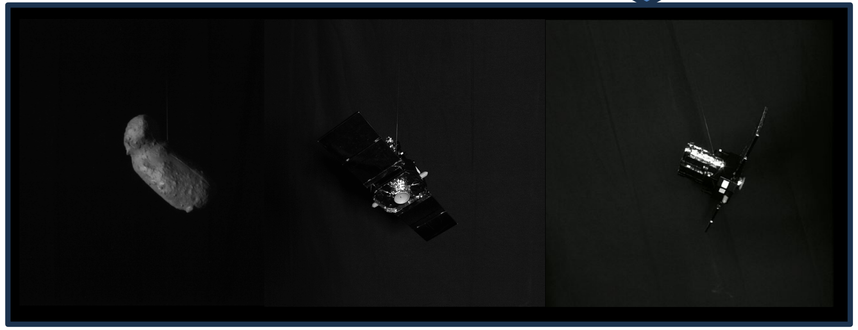
Dark room calibrated facility (8mx5m)





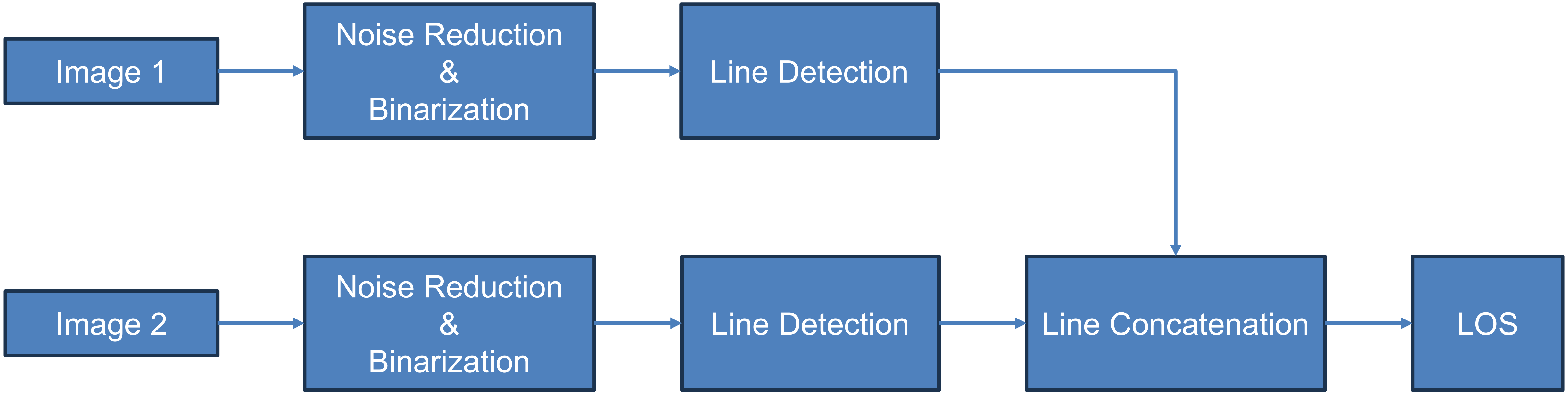
Real in lab images





IP Testing – Far Range

Common IP for both VIS and TIR images in Long Exposure - Inertial Pointing mode

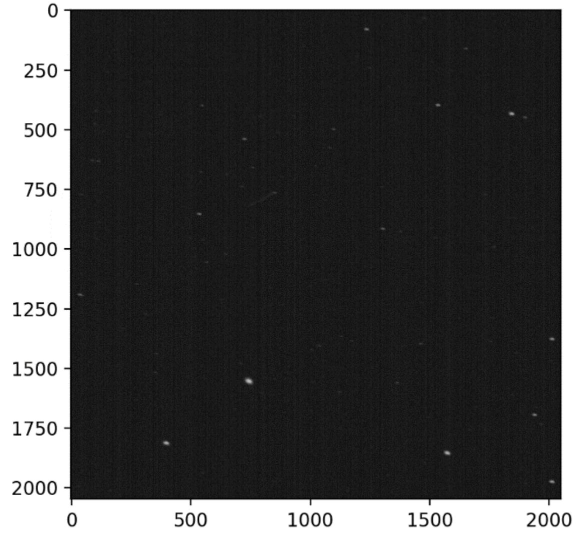


- If the line detection fails to recover a line corresponding to the target wake (or if it is not present), the algorithm restart searching for a “1st Line” in the subsequent images
- If the lines to be concatenated are “far”, the algorithm discard the LOS and restart searching for a “1st Line”
- If the LOS is on the image borders, the LOS is discarded since not necessarily correct

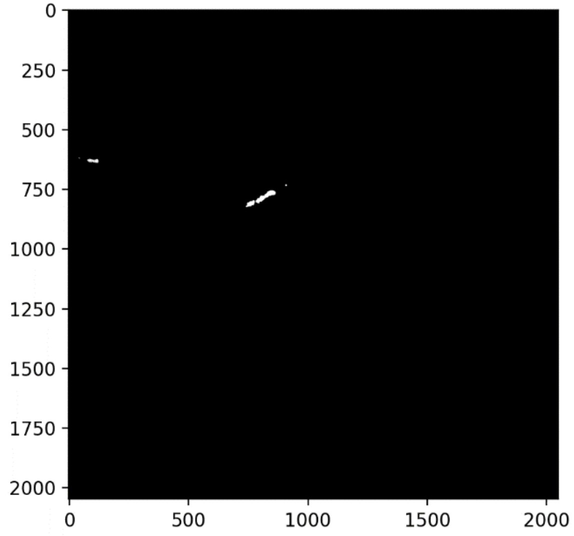
IP Testing – Far Range

Synthetic image

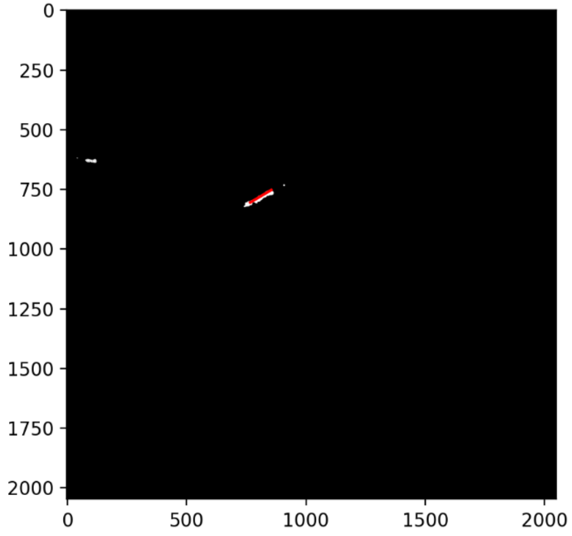
Noisy Image



Binary Image



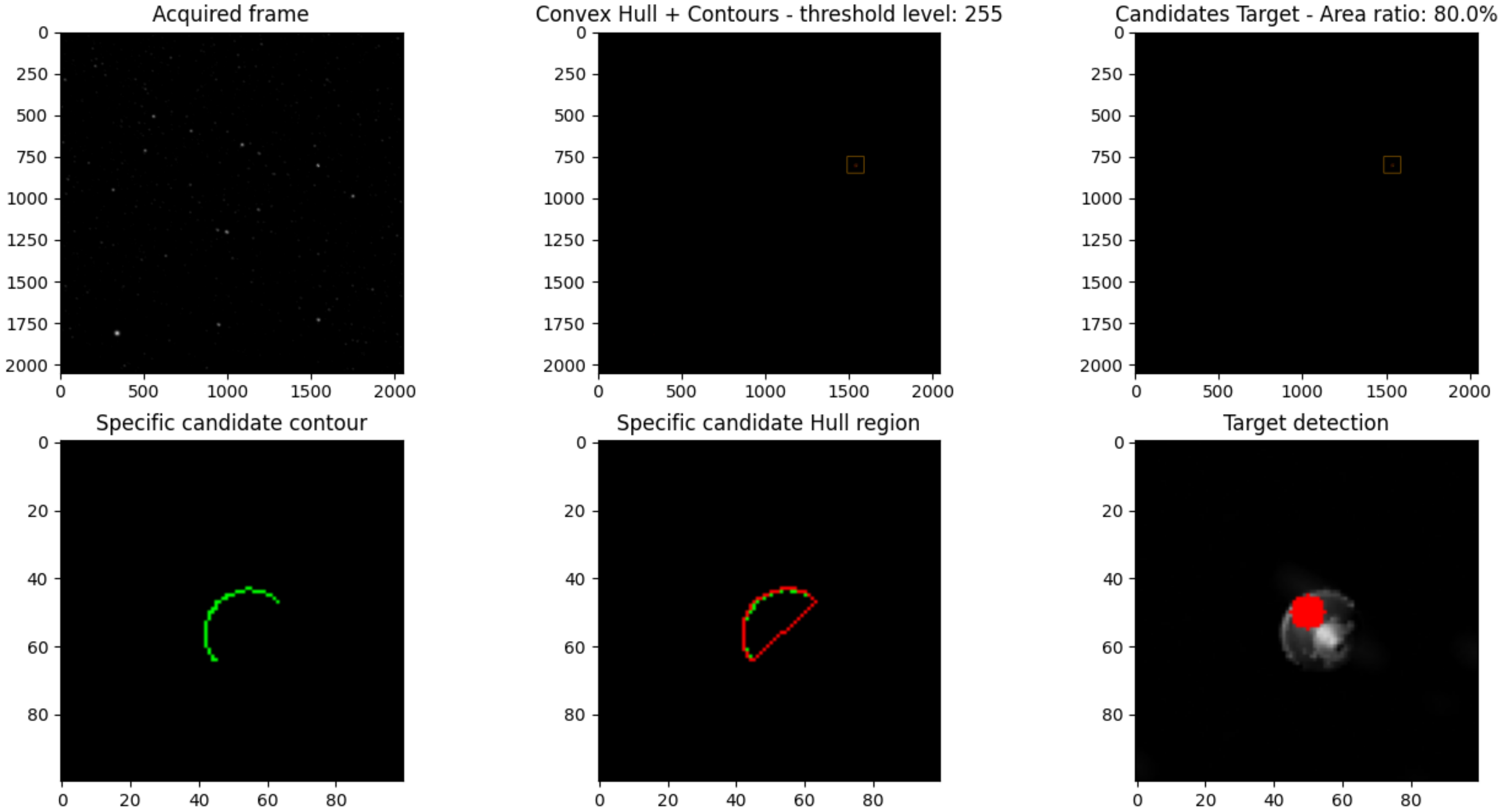
Detected Line



The binary image is obtained after a custom process of noise reduction and contrast enhancement, binarization, bright star removal, and spurious noise removal

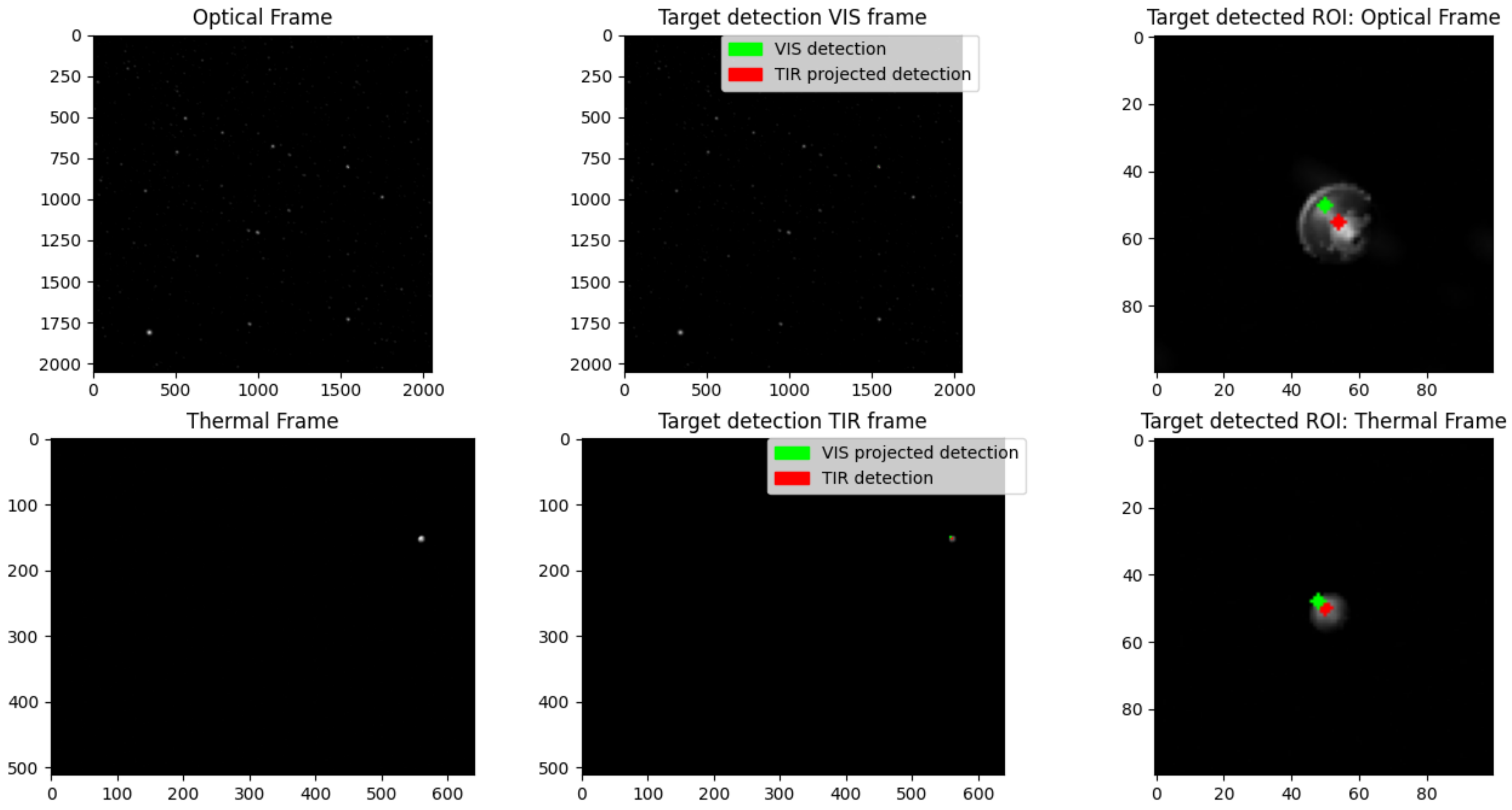
IP Testing – Close Range – VIS detector

Hard to directly process blobs: **custom detector**



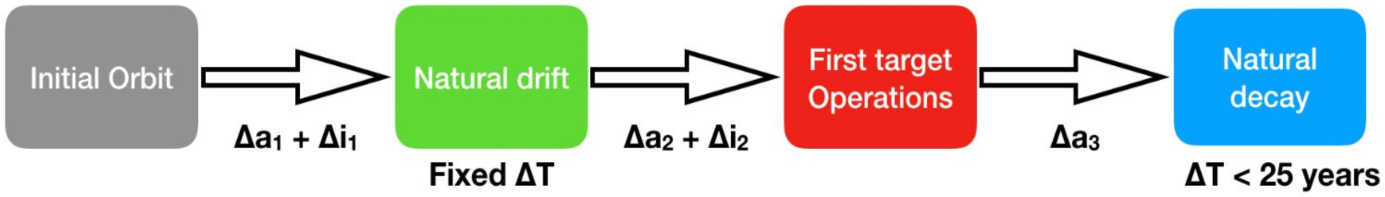
IP Testing – Close Range – TIR detector and reprojection fusion

- TIR frame has less features: **easier to detect target blob**
- VIS is **feature rich due to higher resolution**: it can be exploited for coarse distance estimation (TBC)
- VIS is **larger in FOV**



e.Inspector – *the mission*

Transfer strategy and launcher selection



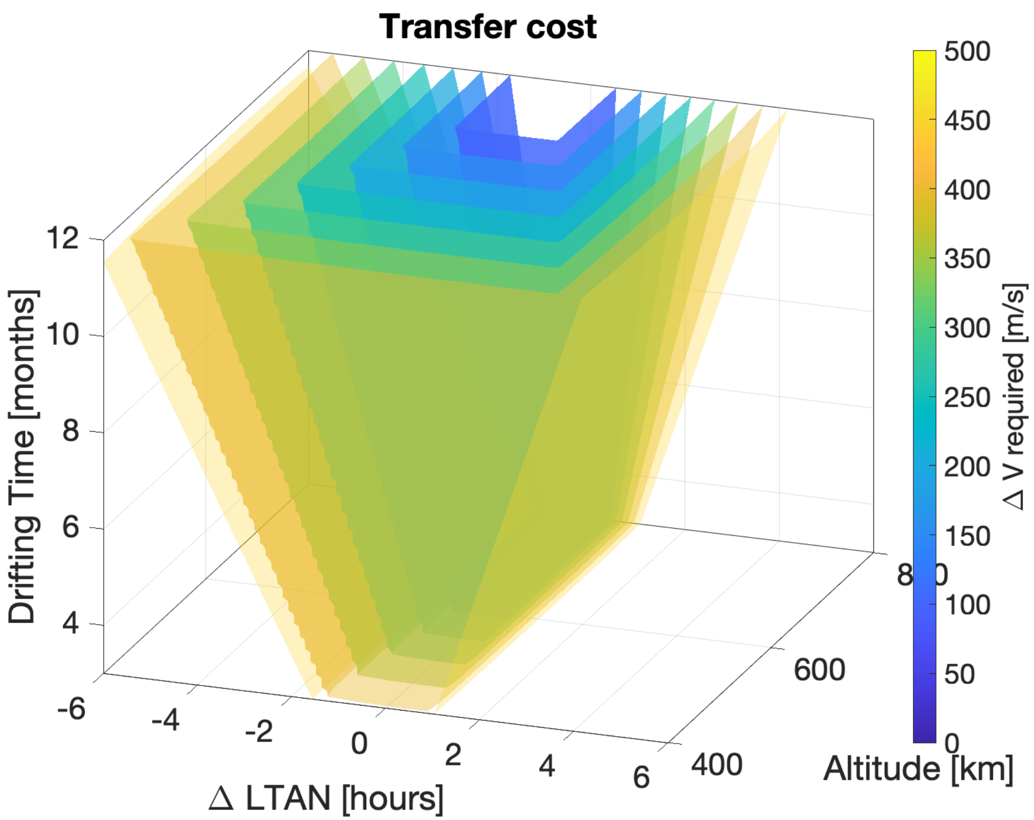
ΔV high sensitivity to:
→launch epoch
→target orbit

⇒ ***parametric analysis performed***

Baseline scenario

- **Primary Target:** VESPA (TLEs propagated with high fidelity simulator)
- **Backup Target:** 23608
- **Launch epoch:** [Q1 2025 – Q4 2025]
- **Launcher LTAN:** TBD. Target depending
- **Launcher altitude:** TBD. Target depending
- **Drifting time:** [3 -12 months]
- **Disposal orbit altitude:** 550 km – new regulations analysis performed

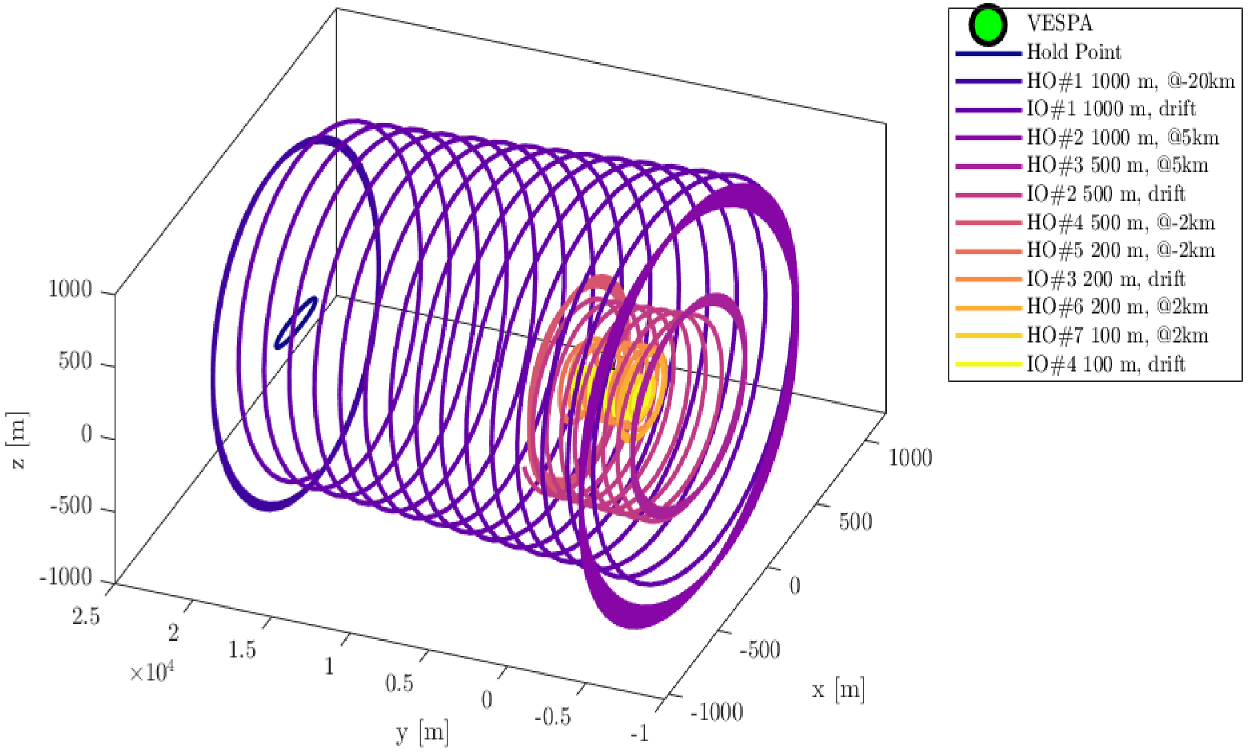
ΔV Maps as function of the Orbit Altitude and LTAN for differen drifting time – VESPA target



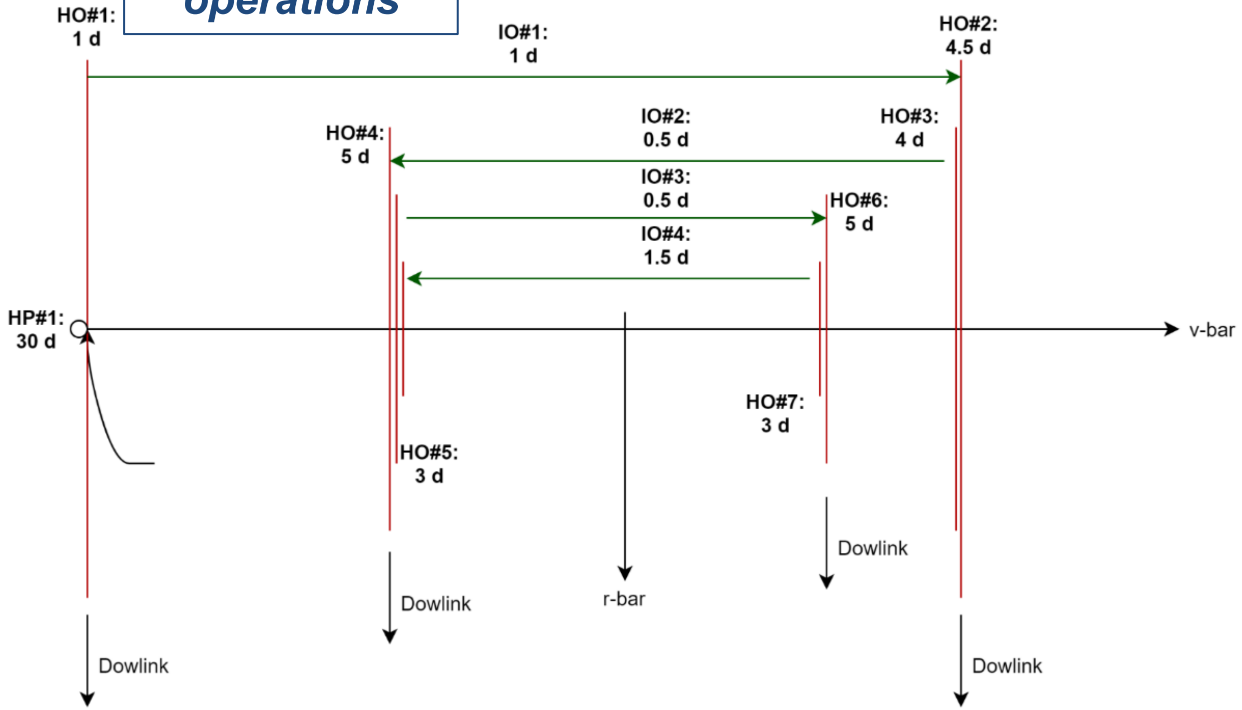
T = 0,6 mN; Usage fraction 0.8

e.Inspector – *flyaround strategy*

Inspection phase from~20 km to 100 m → max resolution requested 1 cm



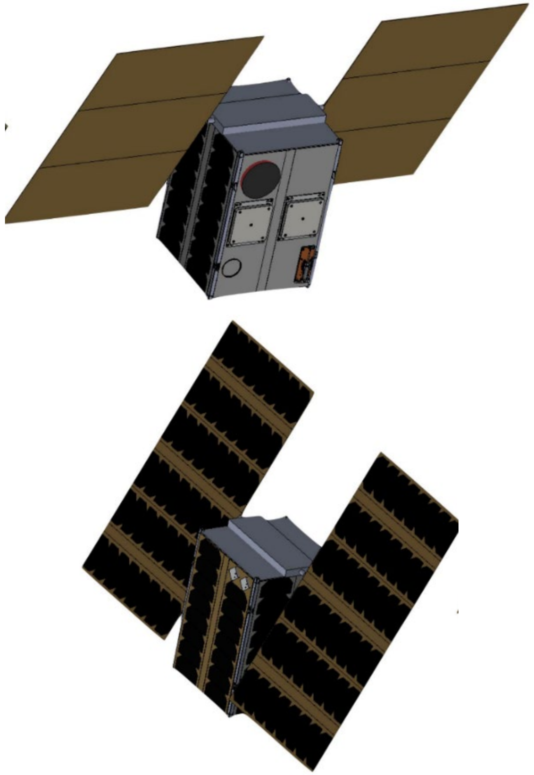
2 months operations

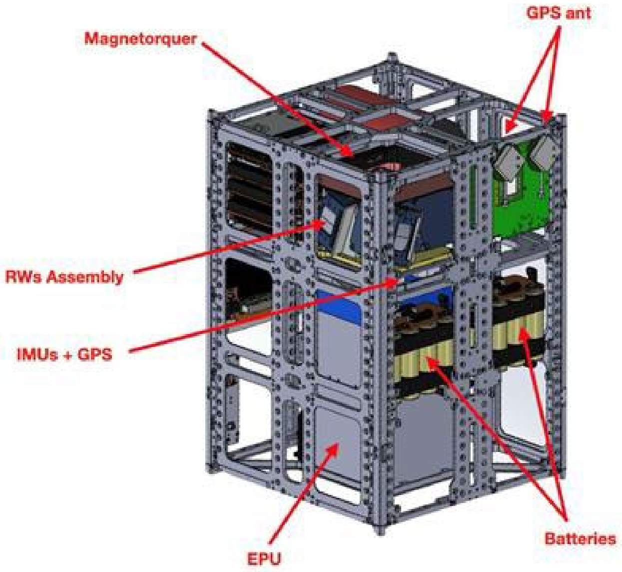


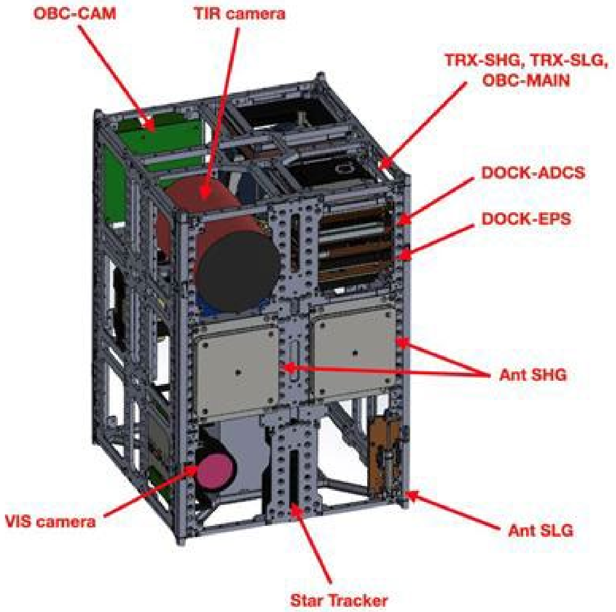
e.Inspector - *Structure & Configuration*

12U form factor

- Payloads and electronics (Gecko+FLIR TAU2) → 1U + 1U
- Electric propulsion unit (EPU) → 2U
- Navigation instruments → 1U
- ADCS stack & RWs → 1U + 1U
- Solar wings+ SADA







Components\ s-s

- EPS boards+ batteries
- GNC (FSS\GNSS\mtorq)
- Main OBC
- TTMTC boards\antennas
- EPS solar panels+cells
- OBC-IP_CAM
- Nav sensors (IMU)
- Nav sensors (startrackers)
- Attitude actuators (RW)
- Electric prop
- Chem propulsion
- Structure

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