6th INTERNATIONAL CONFERENCE ON ASTRODYNAMICS TOOLS AND TECHNIQUES (ICATT)

DYNAMIC TEST FACILITIES AS ULTIMATE GROUND VALIDATION STEP FOR SPACE ROBOTICS AND GNC SYSTEMS

Pablo Colmenarejo, Emanuele di Sotto, Juan Antonio Béjar

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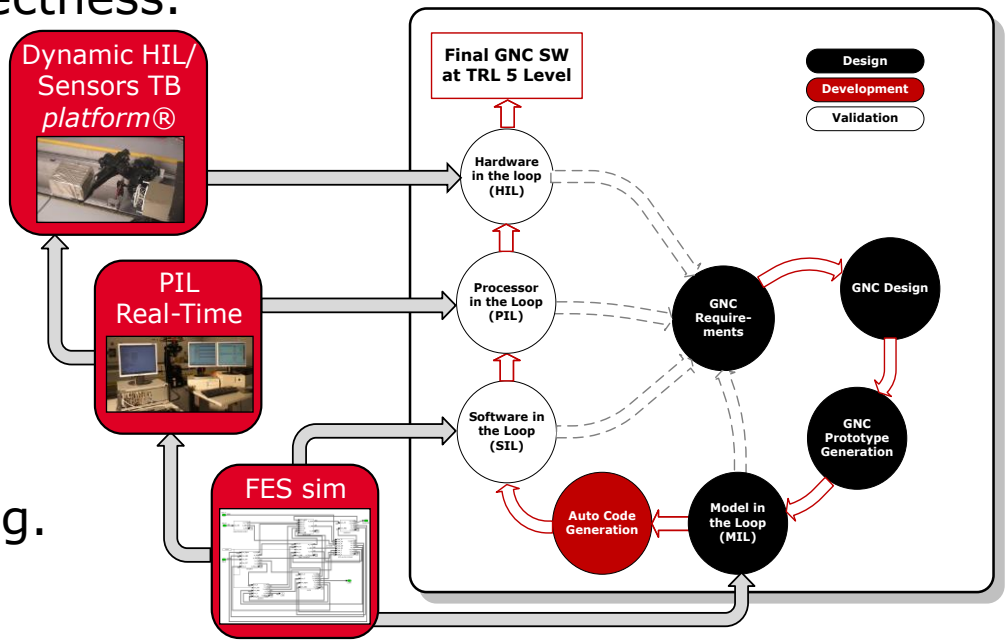
INNOVATING SOLUTIONS

OUTLINE

- Dynamic test facilities role within DDVV cycle
- GMV's ***platform-art©*** description
- Supported scenarios
- Some examples of ***platform-art©*** validation use cases

DYNAMIC TEST FACILITY ROLE WITHIN DDVV

- An already proven efficient approach for the Design, Development, Verification and Validation (DDVV) approach for GNC related technologies is based on an incremental testing fidelity paradigm MIL➔SIL ➔ PIL ➔ HIL:
  - MIL: based on the use of a Functional Engineering Simulator (FES), including environment SW models and reference models of the selected on-board algorithms (GNC, AMM, FDIR). Verifies algos correctness.
  - SIL: autocoded/hand made on-board GNC SW integrated in the MIL. Verifies algos SW coding correctness.
  - PIL: on-board GNC SW integrated in space-representative avionics. Verifies SW correctness vs. real-time OS and platform.
  - Dynamic HIL: includes real sensors with air-to-air stimulation. Verifies system **correctness vs. real HW** (e.g. sensors, point-to-point IFs).



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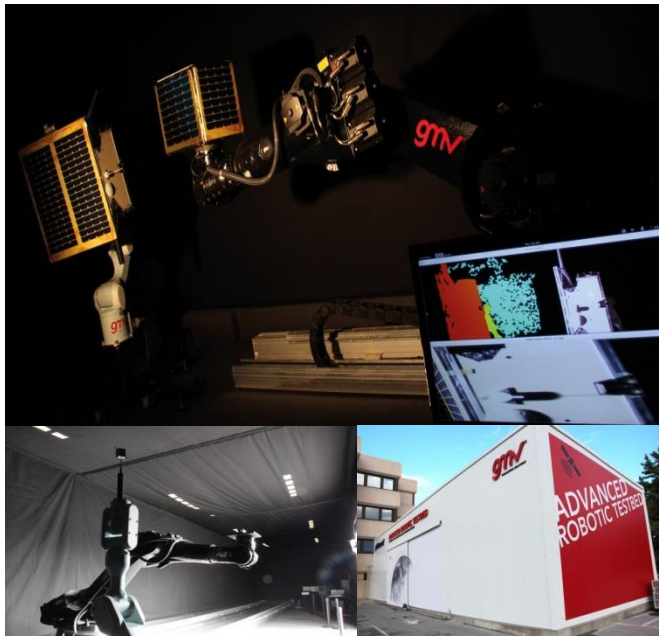
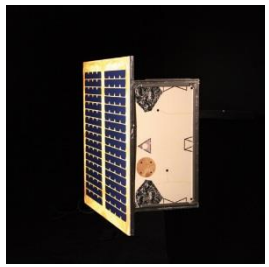
GROUND VALIDATION ON DYNAMIC TEST BEDS

- ***platform-art©*** is the GMV's Dynamic Test Bench with real air-to-air metrology stimulation
- Allows use of sensors measurements in the loop through the recreation of relative trajectory and attitude profile by using robotic arms
- Sensors installed on-board the mock-ups experiment the same relative kinematics and produce the same measurements as in space environment

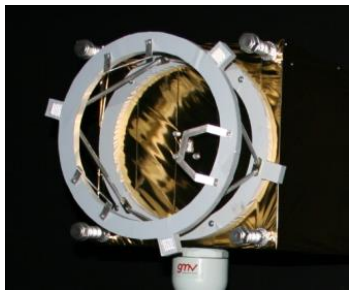


Chaser metrology
Left:Lidar,
Right: visual camera

PRISMA TANGO mock-up



Earth Servicing (docking) scenario target mock-up



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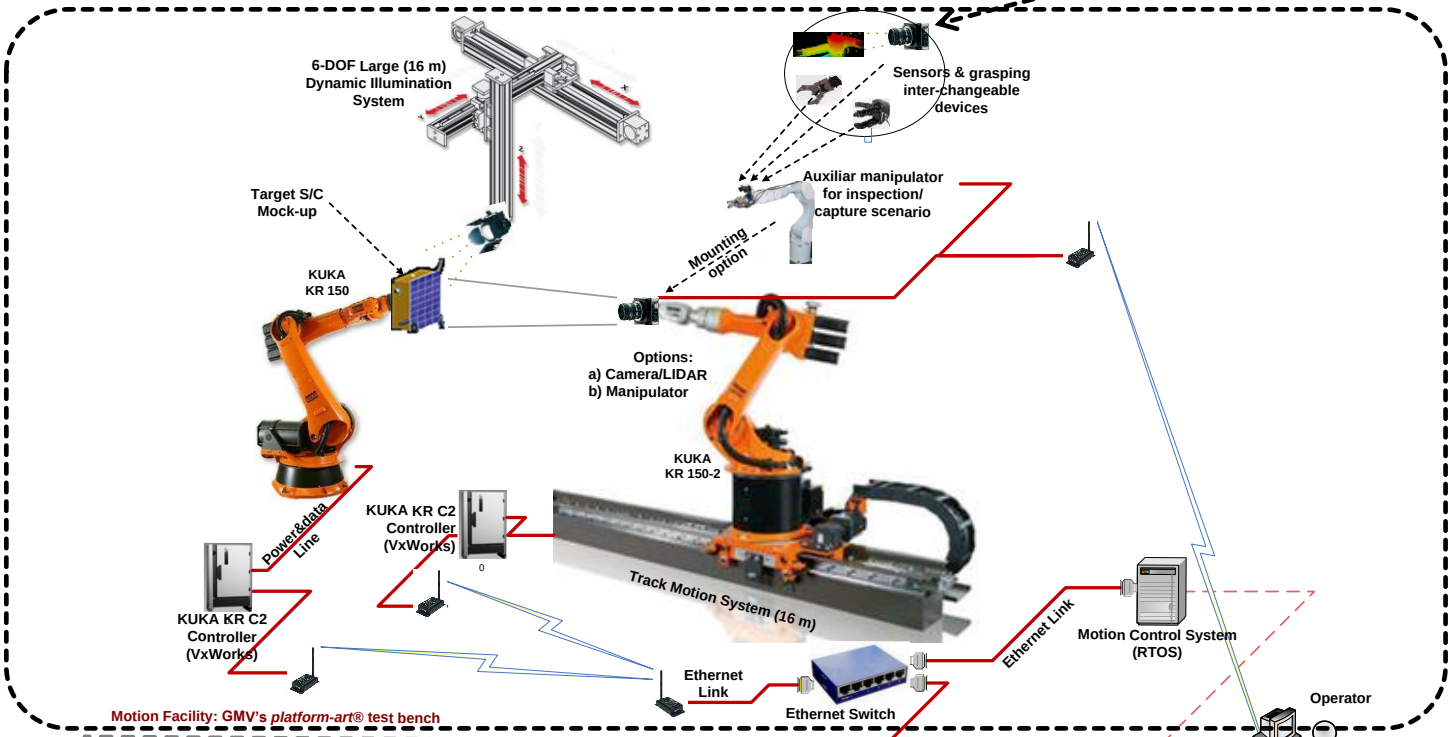
platform-art® FEATURES SHORT DESCRIPTION

- Functional features:
  - Dynamic test bench with real air-to-air metrology stimulation
  - Raises the GNC S/S (SW+sensors) validation till level 5/6 (ESA scale)
  - Two numerically controlled robotic arms + 16 m length rail, allowing:
    - Short-range RdV and FF scenarios (up to 525 meters using scalability factor 1:35, reasonable for 1 m S/C size level; can be higher for bigger S/C), including GNC mode transition, scenario stop/resume, change of sensors, …
    - Robotics/rovers scenarios by ***platform-art©*** configuration update
- Performance features:
  - Dynamic range: 18 m
  - Accuracy: O(0.1 mm) (FARO laser tracker calibration)
  - Resolution: < 0.01 mm
  - Repeatability: < 0.1 mm
  - Mock-ups (Inc. metrology): up to 1 m size, 150 kg
  - Darkness: full darkness room (optical spectrum)
  - Illumination: space representative at optical spectrum
  - Location/Access: GMV head-quarters (Tres Cantos, Madrid)

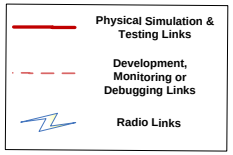
platform-art© ARCHITECTURE

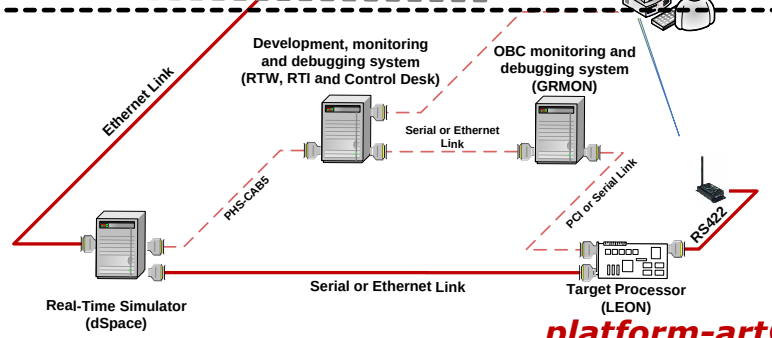
3 platform-art®_SENSORS
(default SENSORS by GMV)
(specific SENSORS by CUSTOMER)



2 platform-art® _MECHATRONICS
(FIXED CORE)

Real-time PIL test bench components





1 platform-art®_AVIONICS
(EXCHANGEABLE/TAILORABLE)

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platform-art© ELEMENTS AND FEATURES

- ***platform-art***© system elements:

AVIONICS

1

- Real time simulator (dSPACE board): I/F with motion control system, Real World and relative kinematics computation
- Target processor (LEON): GNC on-board SW execution
- Development, monitoring & debugging systems

MECHATRONICS

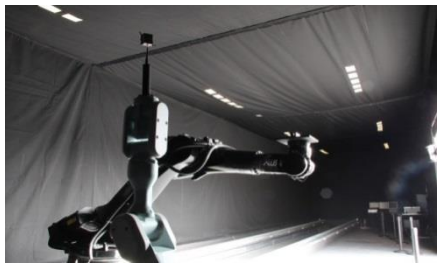
2

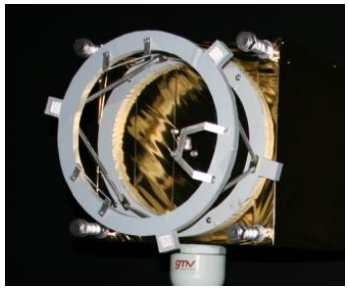
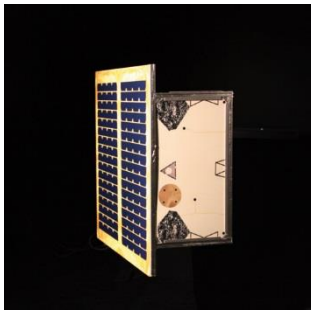
- KUKA KR150-2: 6 DOF robotic arm
  - Target satellite trajectory reproduction
  - Communication delay < 12ms
- Mitsubishi PA10: 6 DOF for manipulation purposes
  - Communication delay < 1ms
- Motion control system:
  - sends control commands to the robotic arms
  - security checks on arms kinematics
- KUKA KR150/Rail: 7DOF system
  - 6 DOF robotic arm
  - 7th DOF provided by a 16m rail track
  - Chaser satellite trajectory reproduction
- Illumination : 6-DOF 16 m length cartesian system
- S/C mock-ups
  - Representative in shape and materials of the target spacecraft

SENSORS

3

- Sensors I/F:
  - Ethernet UDP/IP
  - Serial port (RS-232, RS-422)
  - CAN
- Default sensor:
  - Optical navigation camera by GMV
- Customer sensors (examples of use):
  - ILT LIDAR by Jena Optronik
  - VBS by DTU

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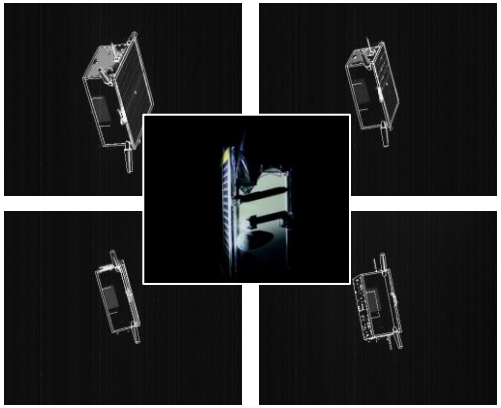
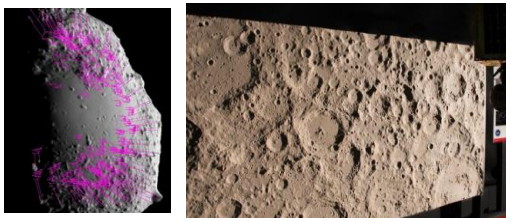
SUPPORTED SCENARIOS

platform-art© can be used for the following scenarios:

- Rendezvous
- Formation Flying
- In-Orbit Servicing
- In-Orbit capture (e.g. MSR)
- Active Debris Removal
- Relative navigation for planetary/asteroid landing





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VALIDATION USE CASES WITH *platform-art©*

iGNC: Approach/capture of Sample Container in Mars (MSR mission)

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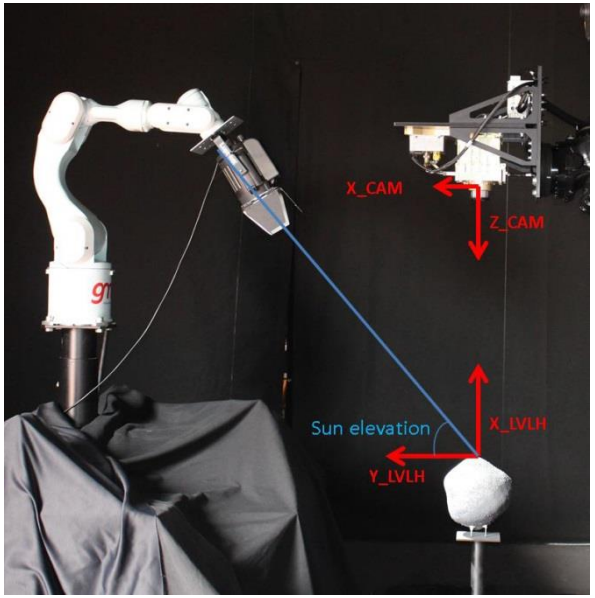
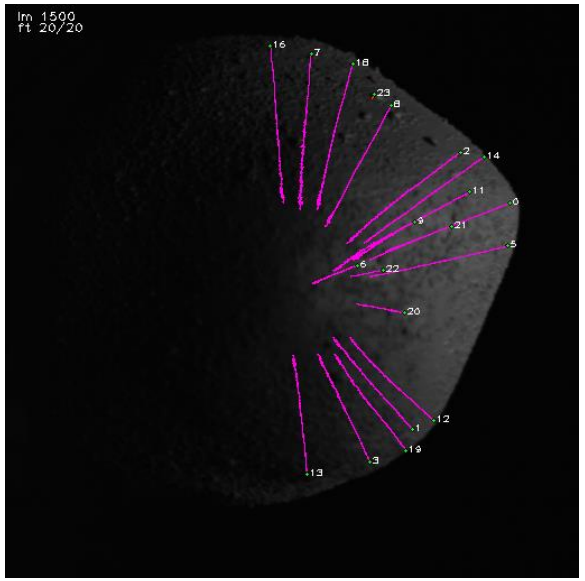
VALIDATION USE CASES WITH *platform-art©*

NEO-GNC-2

- Vision-based GNC system for Descent and Landing on NEO Asteroids
- GNC+IP implemented on space representative avionics
- End-to-end validation with breadboard of space qualified Navigation Camera in GMV's ***platform-art*** dynamic TF.





Nav Camera images with tracked features

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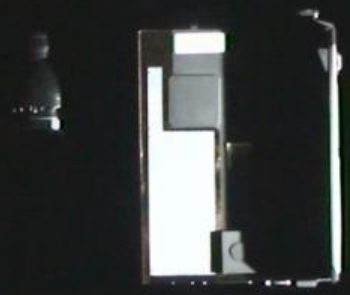
VALIDATION USE CASES WITH *platform-art©*

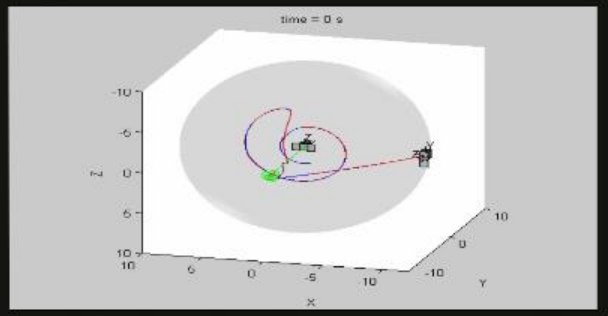
VALIDATION USE CASES WITH *platform-art©*

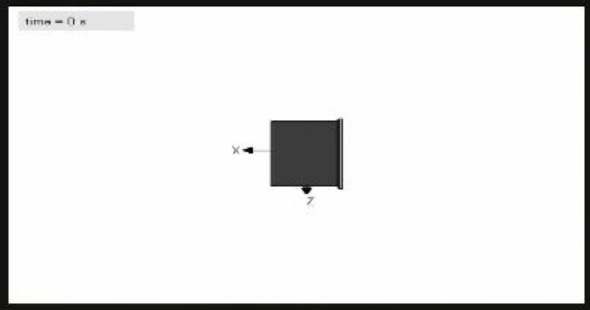
ANDROID
ACTIVE DEBRIS REMOVAL DEMO MISSION

GNC SPIN SYNCHRONISATION TEST



PROBA-2 mockup, courtesy of Qinetic





Executed on GMVs platform-art© test facility

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CONCLUSIONS

- Dynamic test facilities can be very valuable and cost-effective resources for maturing and raising the GNC related (and others) technologies/systems/sensors TRL level
- GMV's ***platform-art©*** has been used in the last 10 years in about 20 (internal and ESA/national agencies) activities with success and providing valuable validation support.
- Wide spectrum of applications have been already demonstrated: planetary/asteroid descent and landing, on-orbit servicing, active debris removal, Rendez-Vous and capture in Mars.
- Key issues are:
  - Appropriate knowledge of the scenarios/technologies to be tested and appropriate matching with the laboratory tuning/set-up capabilities.
  - Not all the laboratory characteristics are equally relevant for all types of scenarios (e.g. scale factor/calibration, illumination, real-time, communication delays, distributed processing, …).
  - Laboratory modularity and configuration flexibility: typical ***platform-art©*** required preparation/set-up for new scenario is 2-4 weeks.


Thank you!
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