

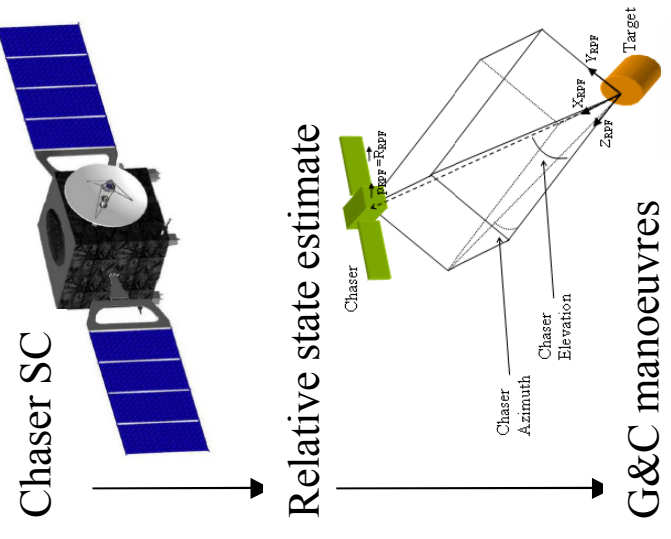
VALIDATION FACILITIES FOR AEROCAPTURE & RV GNC

*ESA Workshop on Avionics Data, Control and
Software Systems (ADCSS 2010)*

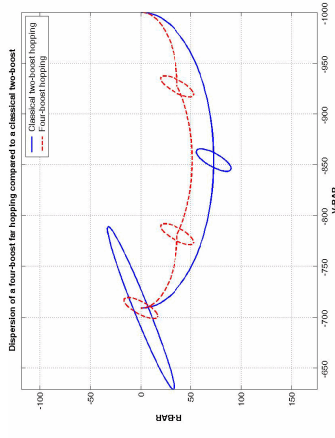
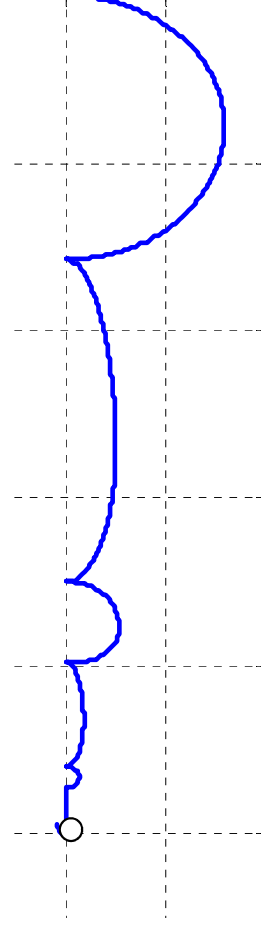
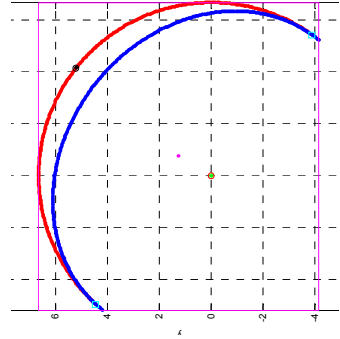
ESA/ESTEC, The Netherlands, Nov 3rd 2010

- **Upgrade of TRL** for technologies enabling next exploration missions calls for the development of **new simulators and validation facilities**
- In this context, new scenarios are being pushed forward as potential improvers of the missions return: among them, **automated RV** (maybe in elliptical orbits), and **aerocapture**.
- In these two cases, **optical measurements** (alone or combined with other sources of info) are among the most common options for feeding the Navigation filter.
- **DEIMOS** has developed a **validation framework** for camera aided GNC, usable for both RV and aerocapture scenarios.

- Validation approach presented based on the **sequential** development of a family of **inter-related simulators**:
 - **Functional Engineering Simulator (FES)**:
 - Functional performances of the designed GNC algorithms, with complete & accurate models of the DKE and realistic simulation of avionics (through performance models where needed, f.i. IP)
 - **Image Processing Laboratory (IP_LAB)**:
 - Generate real world images (non-synthetic) to test and assist IP dev
 - **RTTB with Processor in the Loop (RTTB-PIL)**:
 - Evaluation of GNC performances in real time environment (LEON3/RTEMS). IP simulated still as a performance model
 - **RTTB with Hardware in the Loop (RTTB-HIL)**:
 - Evaluation of GNC+IP performances and their interaction, in real time, with a representative (COTS) camera taking real images of a real target (either canister, either Mars)

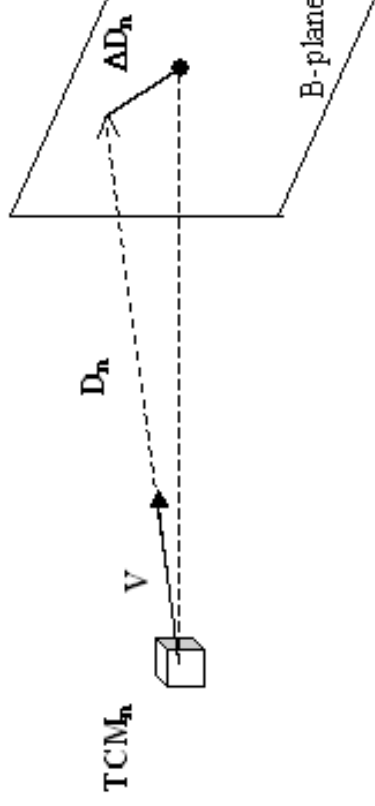


Rendezvous profile: 5 km to docking



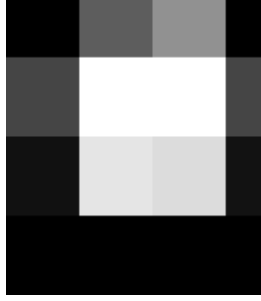
- Main features of DEIMOS RV GNC:
 - **Fully autonomous** (i.e. no need of ground intervention, once a given knowledge of absolute orbit is provided to RV GNC);
 - **Vision-based**: camera is the only sensor for relative motion → range measurements available only for the last ~40metres
 - **Generalised for elliptical orbits**: new algorithms developed specifically to cope with any eccentricity of the reference orbit
- DEIMOS heritage to establish new GNC methods:
 - **TRL 2: GNCO** (“Development of GNC algorithms for Rendezvous and Formation Flying in Non-Circular Orbits”)
- On-going activities to further consolidate technology:
 - **TRL 4: GNCOMAT** (“GNC Maturation and Validation for Rendezvous in Elliptical Orbits”)
 - **TRL 8: PROBA-3** Rendezvous Experiment

- DEIMOS responsible for the development of a pre-aerocapture validation facility in the frame of the AEROFAST consortium (7FP):
 - **Ground intervention** during pre-aerocapture (few days before EIP) is needed and taken into account in the designed GNC;
 - **Multi-sensors:** range, Doppler, DDOR and camera measurements
 - **Optical measurements:** to Mars and Mars Moons
- Final objective: **acquire target state at EIP** with an **accuracy of 3km 3σ** → coupling of attitude & orbit control during manoeuvres execution to be addressed in detail



- IP provides info about the relative position between SC and canister (for RV) or Mars (for aerocapture)

$\phi=40^\circ$



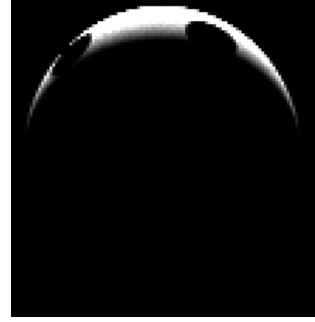
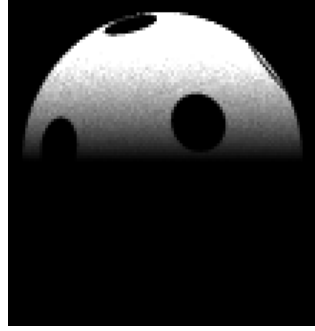
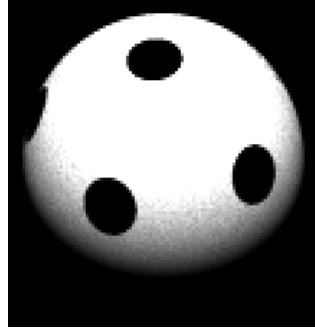
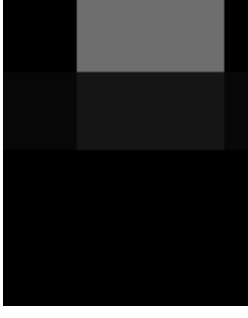
$d=180m$

$\phi=90^\circ$



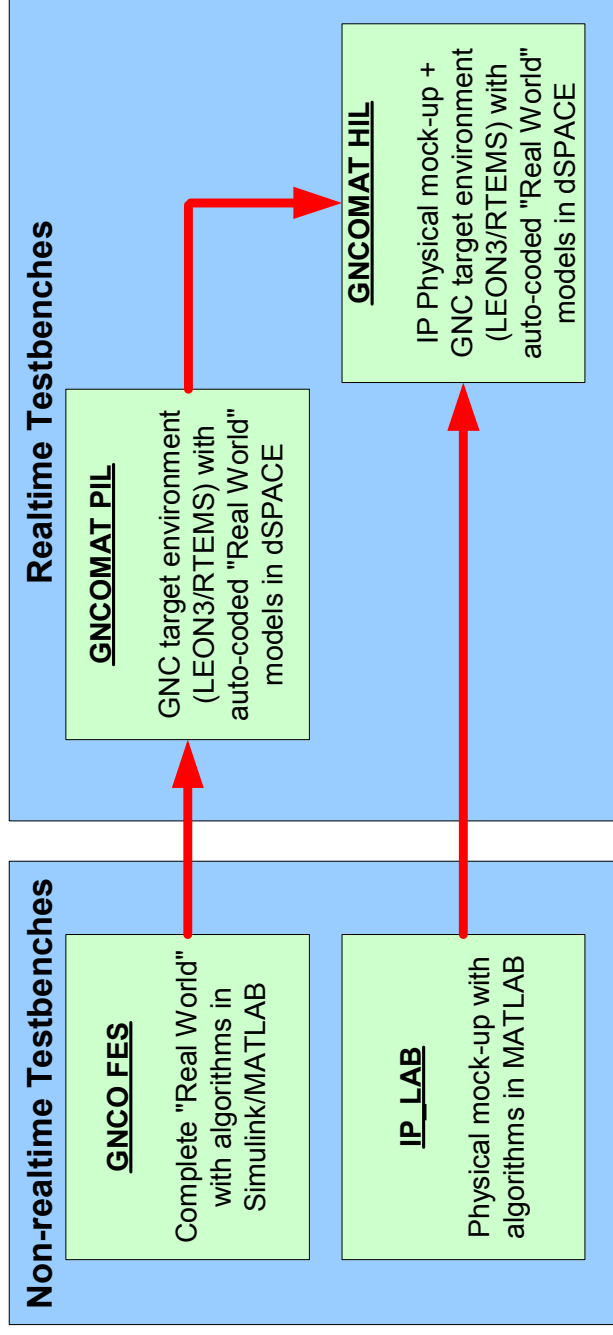
$d=35m$

$\phi=150^\circ$

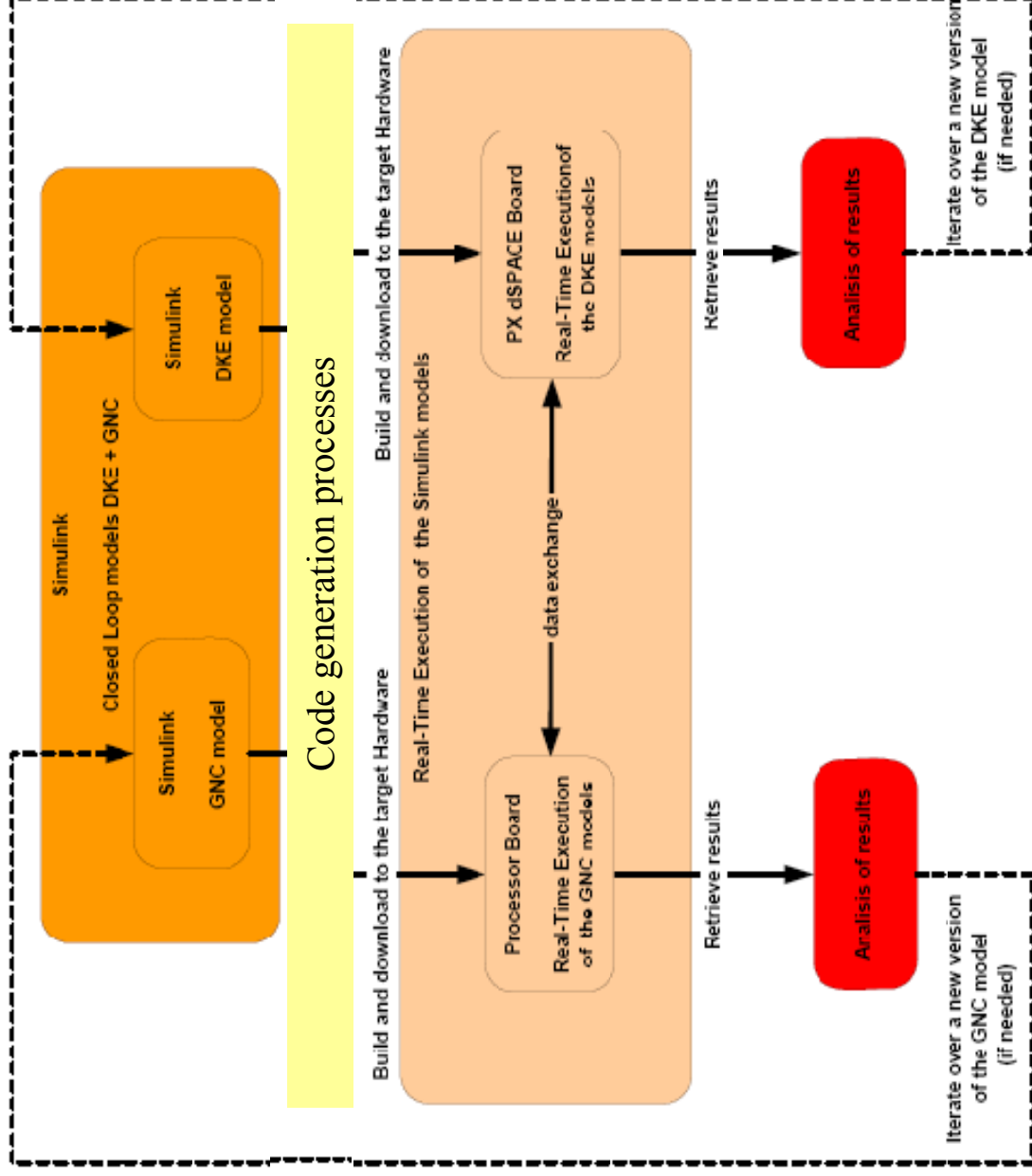


$d=5m$

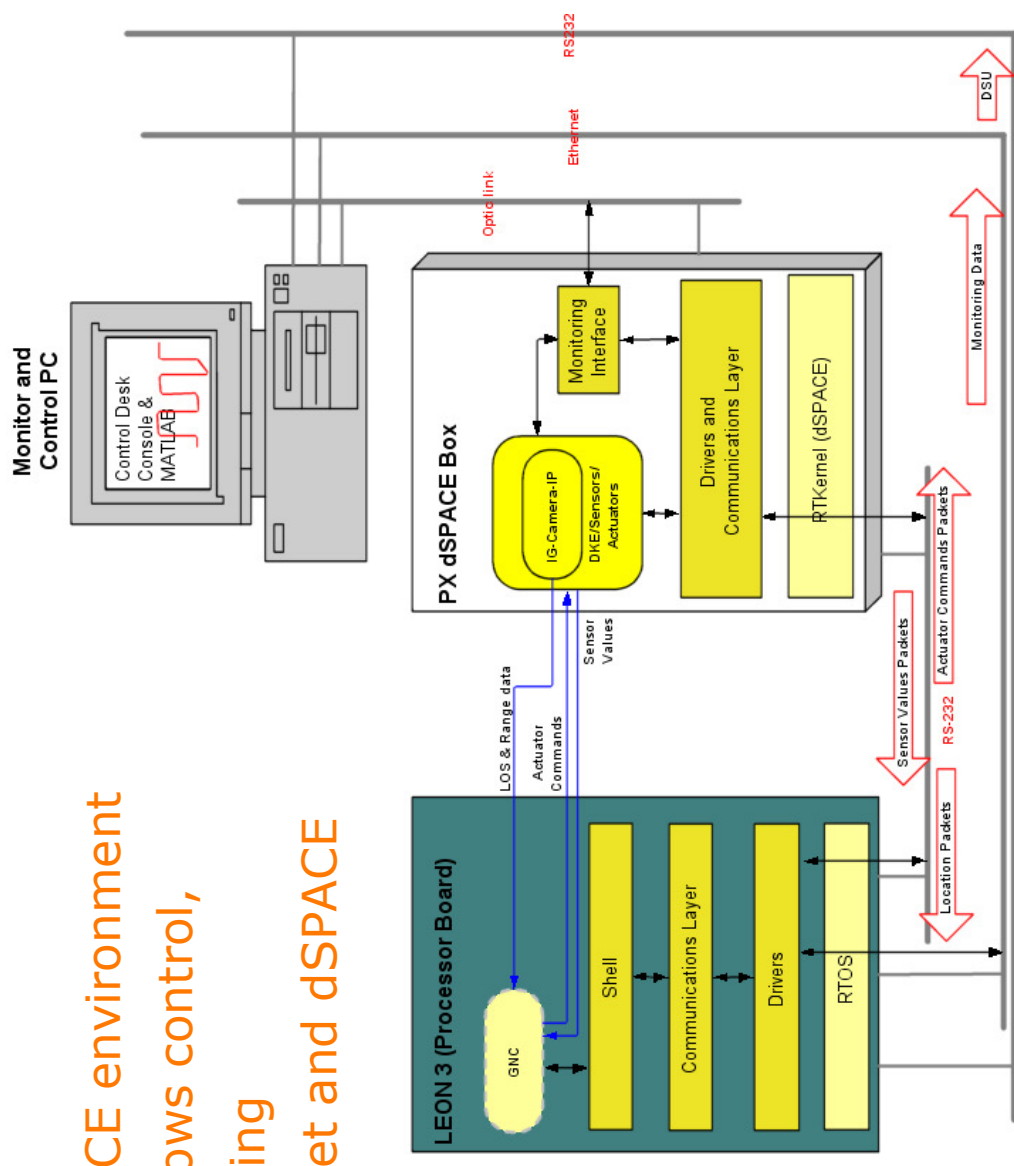
- Development Cycle
 - Iterative process: validated configurations are enhanced → FES is used to validate PIL, which is used to validate HIL
 - Unified approach: building blocks belong to unified architecture



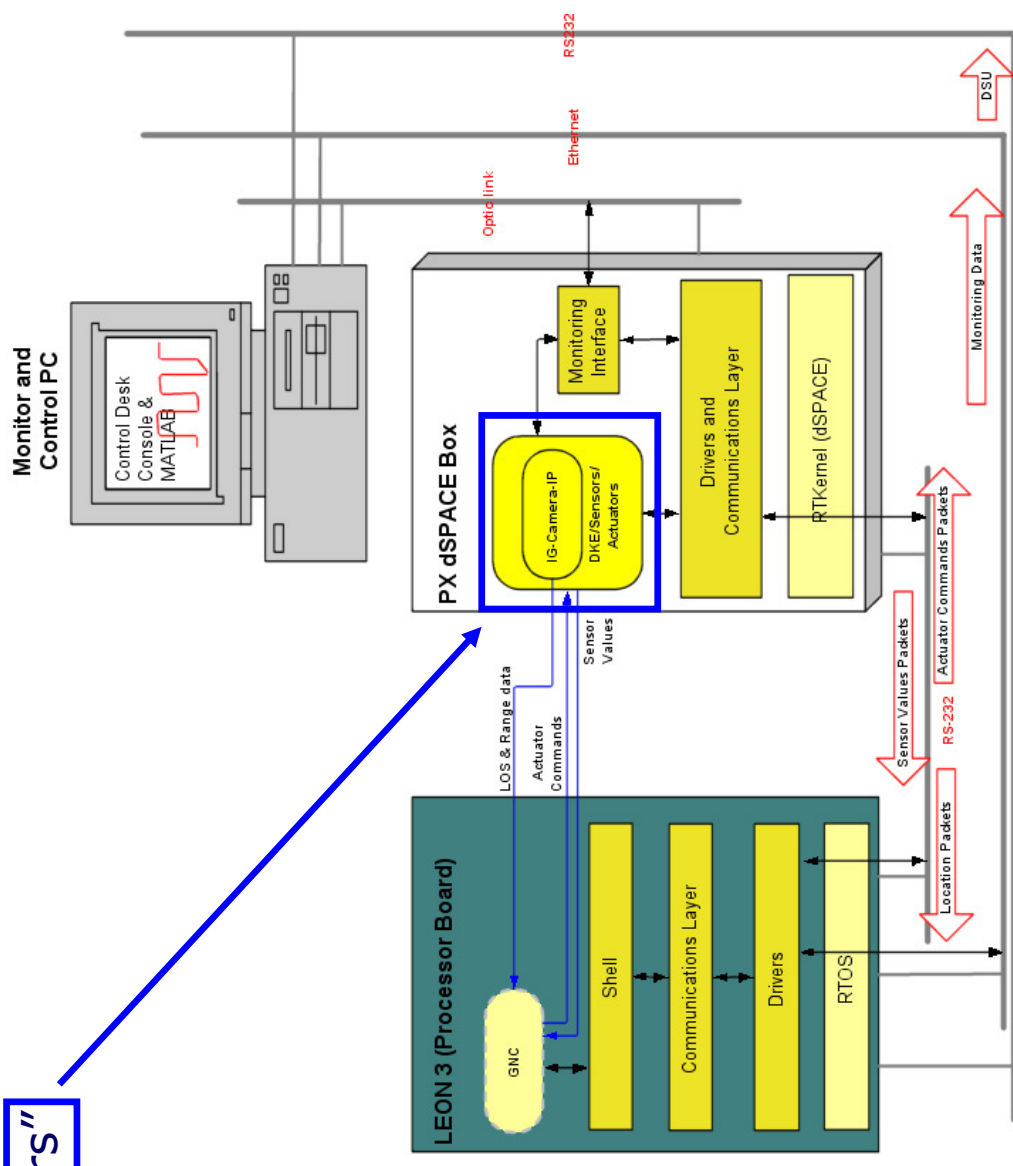
- V&V process



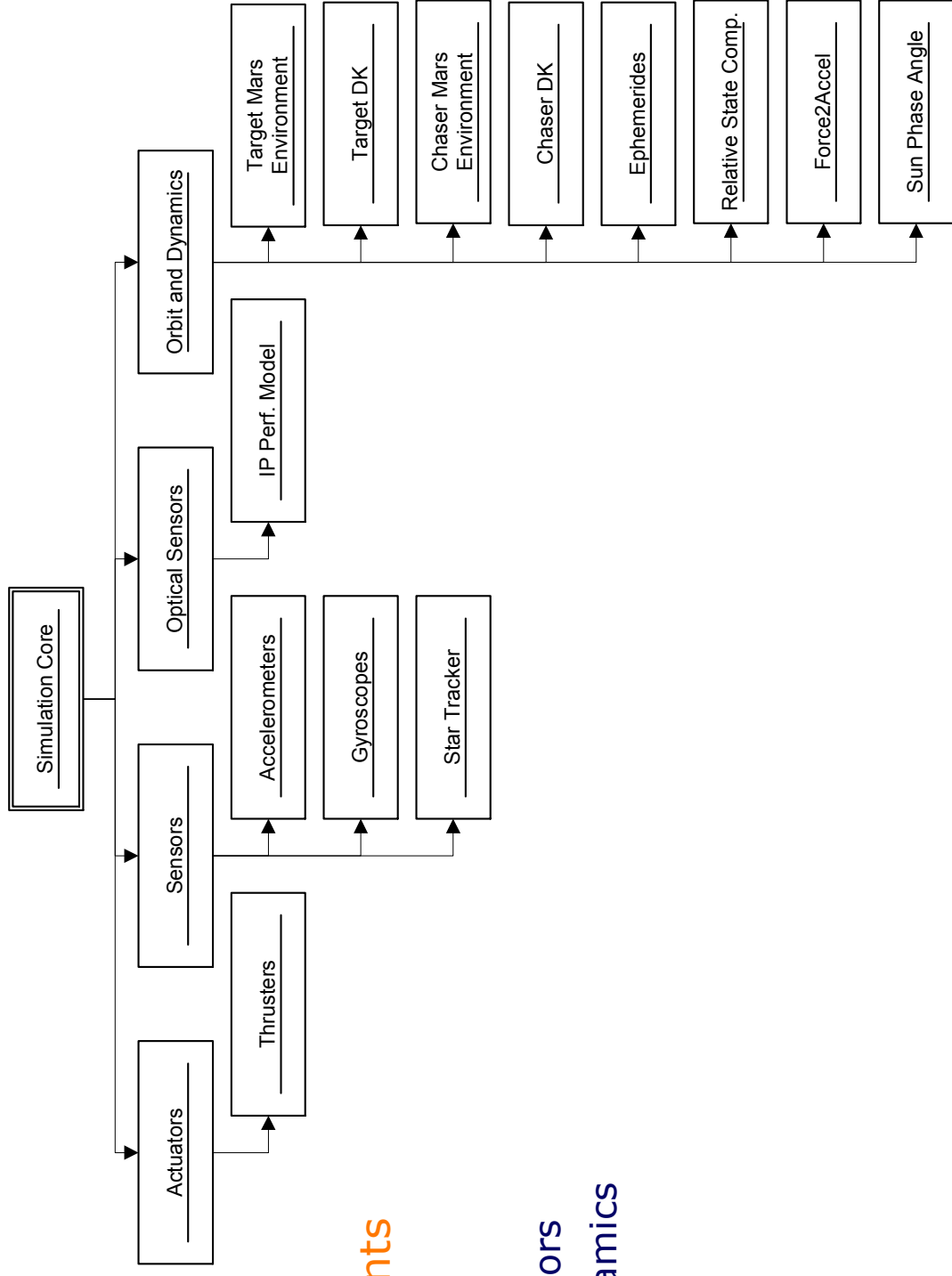
- Functional Architecture Overview:
 - GNC algorithms run on target processor (LEON3/RTEMS)
 - FES compiled/run on dSPACE environment
 - «Monitor & Control PC» allows control, visualization and data logging
 - PIL Buses: RS-232, Ethernet and dSPACE optical link



- Main Elements:
 - PX dSPACE Box
 - "Sensors-DKE-Actuators"
 - dSPACE Environment
- Monitor and Control PC
- LEON3 Processor Board
- RTTB PIL Buses

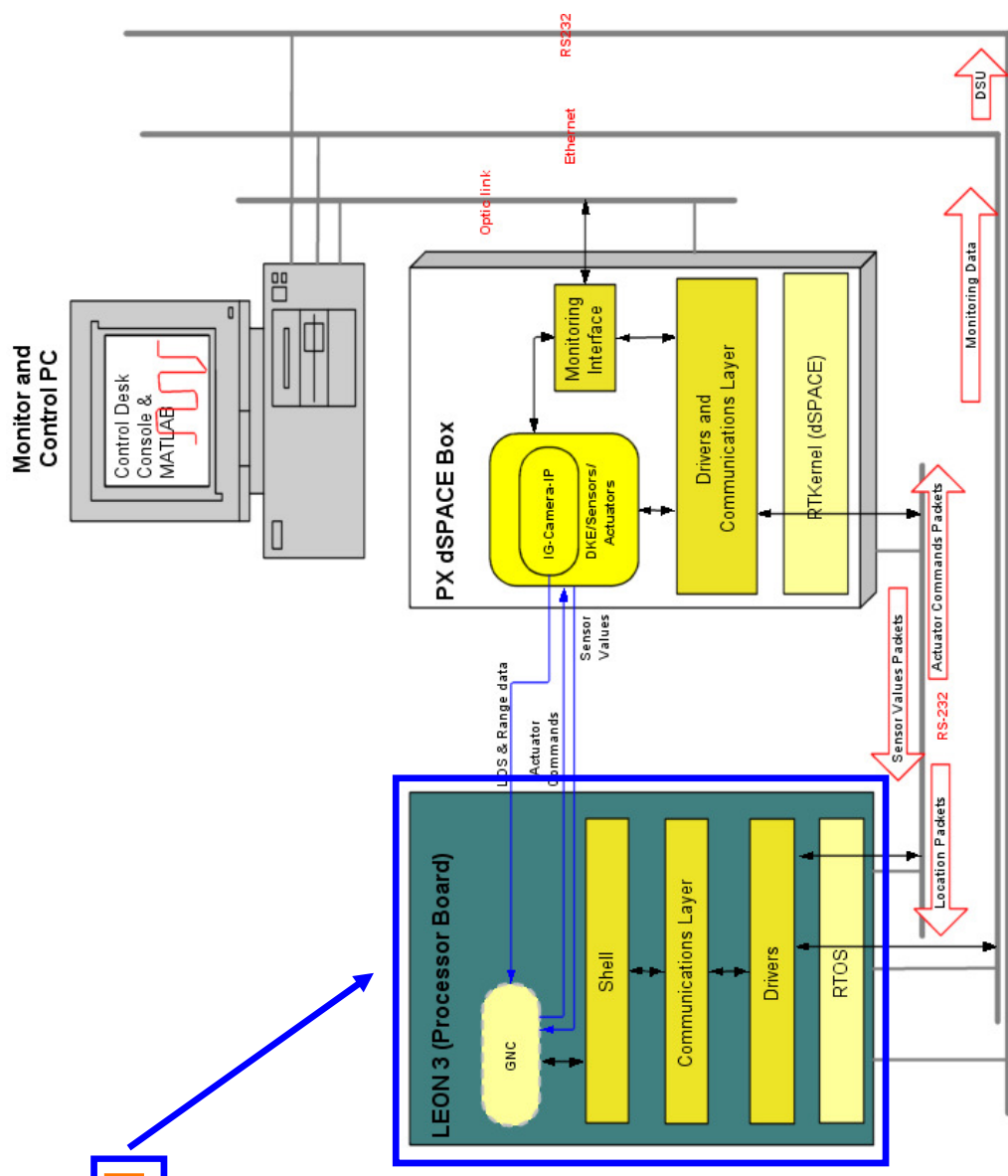


- PX dSPACE Box: Sensors-DKE-Actuators module

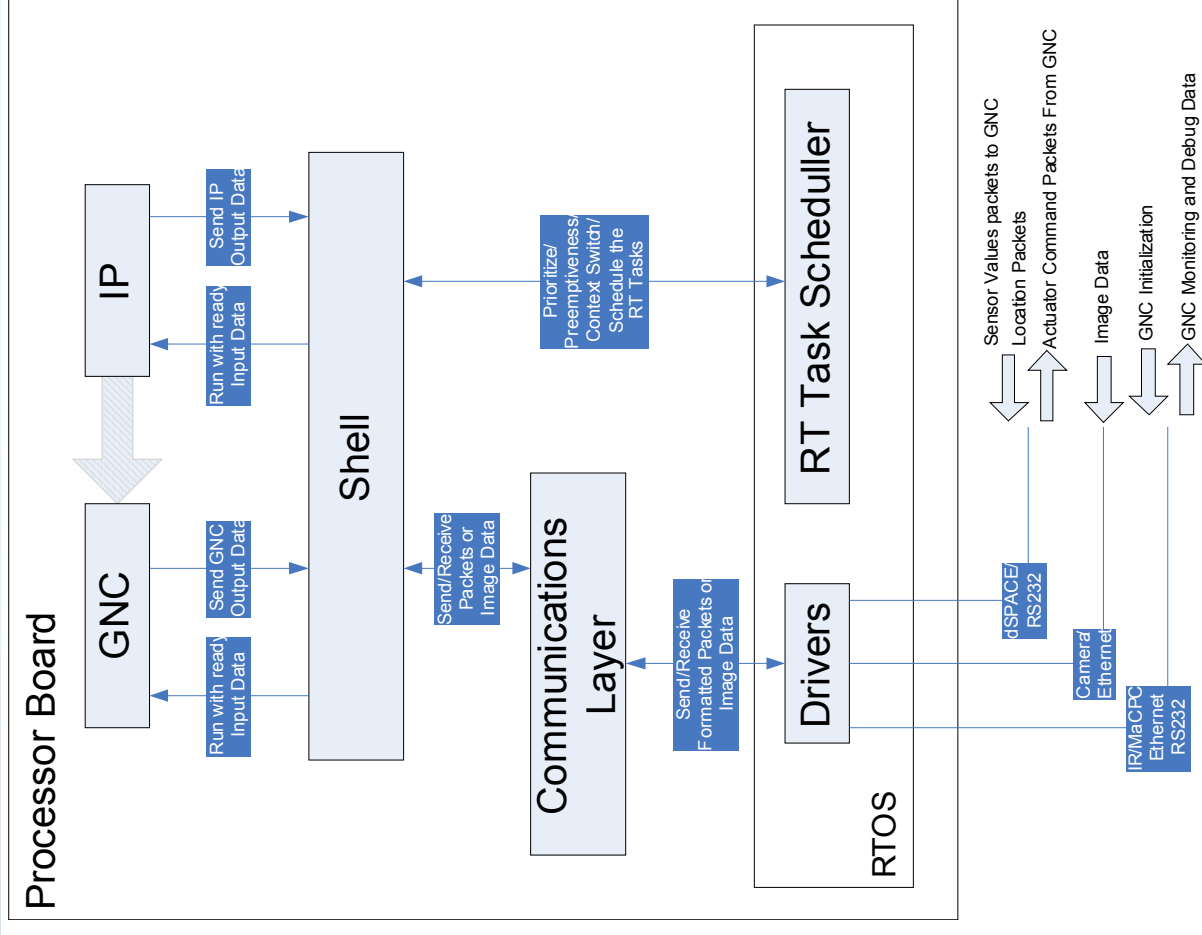


- Main components
 - Actuators
 - Sensors
 - Optical Sensors
 - Orbit & Dynamics

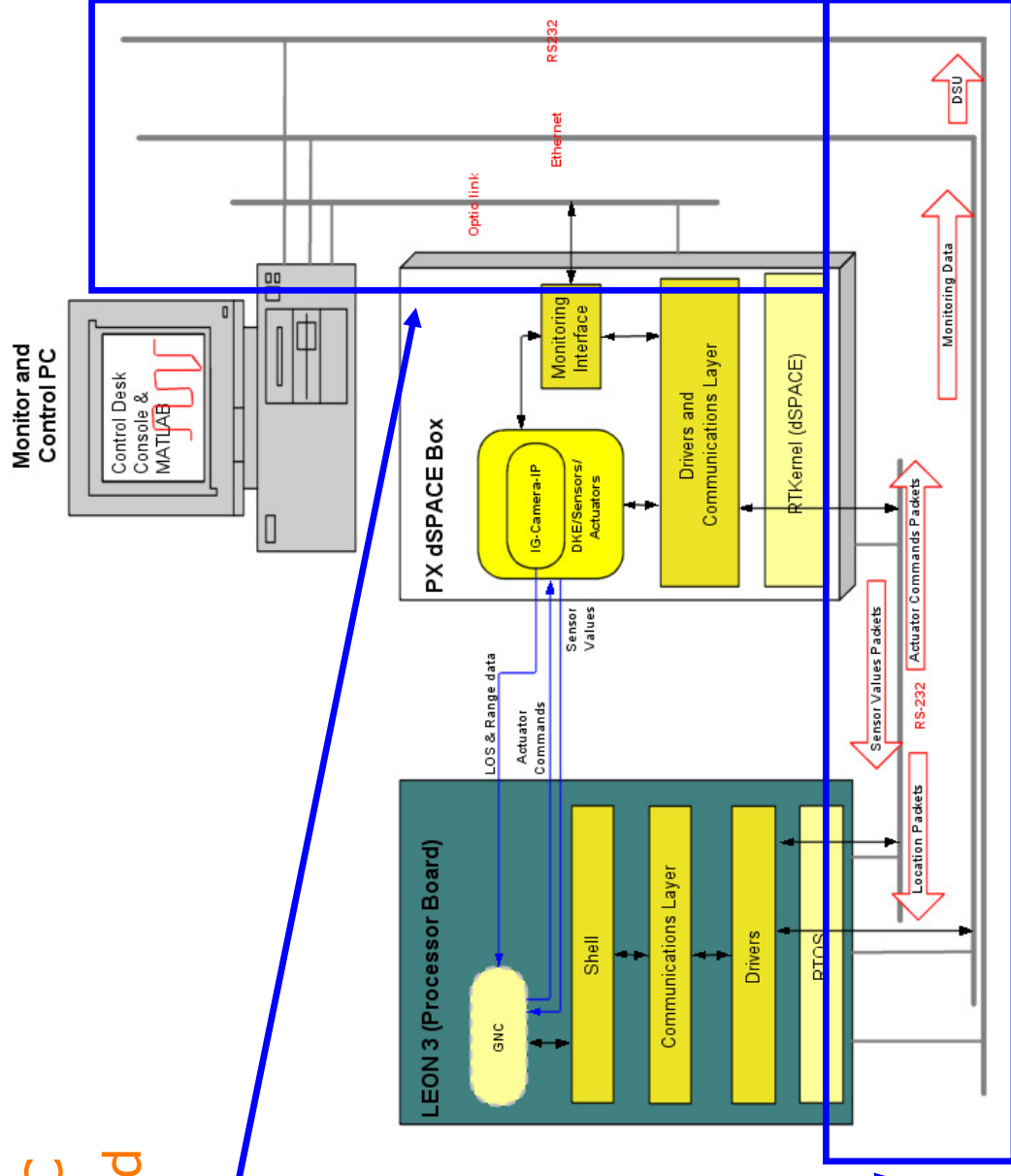
- Main Elements:
 - PX dSPACE Box
 - Monitor and Control PC
 - **LEON3 Processor Board**
 - RTTB PIL Buses



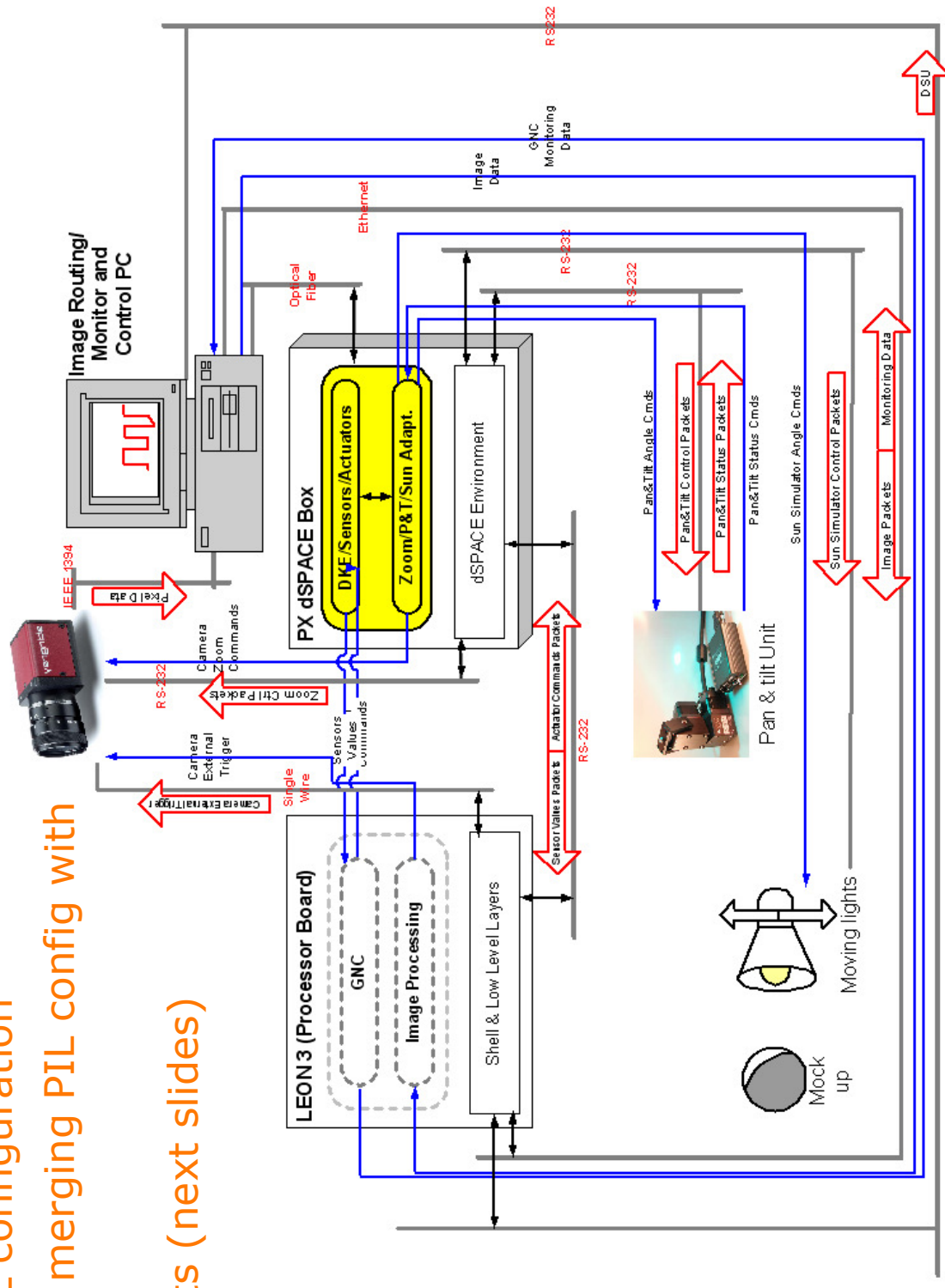
- "GNC Execution Platform" components:
 - Shell
 - Communications Layer
 - Drivers
 - RTOS (RTEMS)



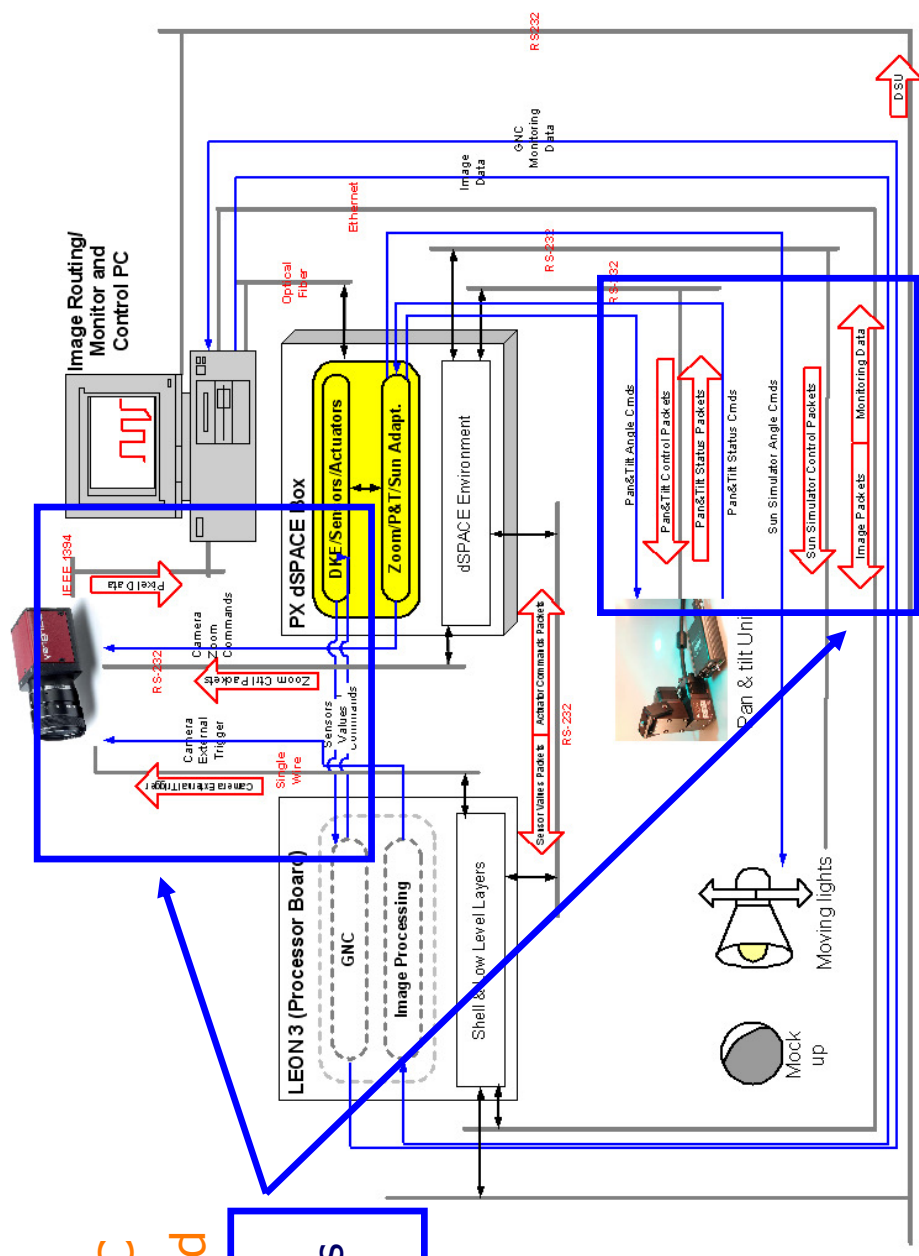
- Main Elements:
 - PX dSPACE Box
 - Monitor and Control PC
 - LEON3 Processor Board
 - RTTB PIL Buses



- General architecture
- Similar to PIL configuration
- Results from merging PIL config with IP laboratory
- New Elements (next slides)

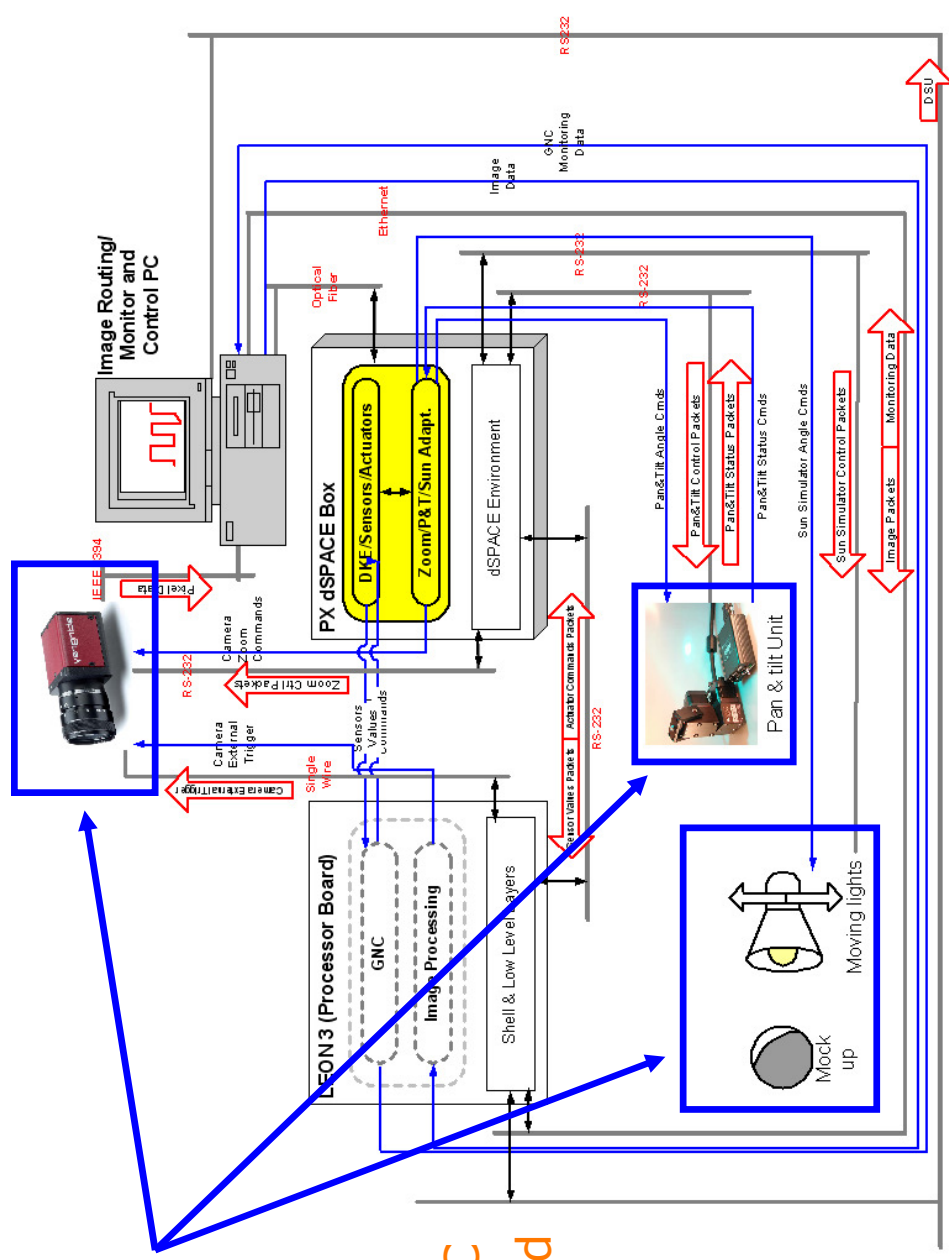


- Main Elements:
 - IP Laboratory
 - PX dSPACE Box
 - Monitor and Control PC
 - LEON3 Processor Board
 - **RTTB HIL Buses**
 - Buses for IP Lab units control



- Main Elements:

- **IP Laboratory**
 - Mock-up
 - Camera Unit
 - Pan/Tilt Unit
 - Zoom Unit
 - Sun Simulator Unit
- **PX dSPACE Box**
- **Monitor and Control PC**
- **LEON3 Processor Board**
- **RTTB HIL Buses**



- IP Laboratory: Mock-up Overview (1)

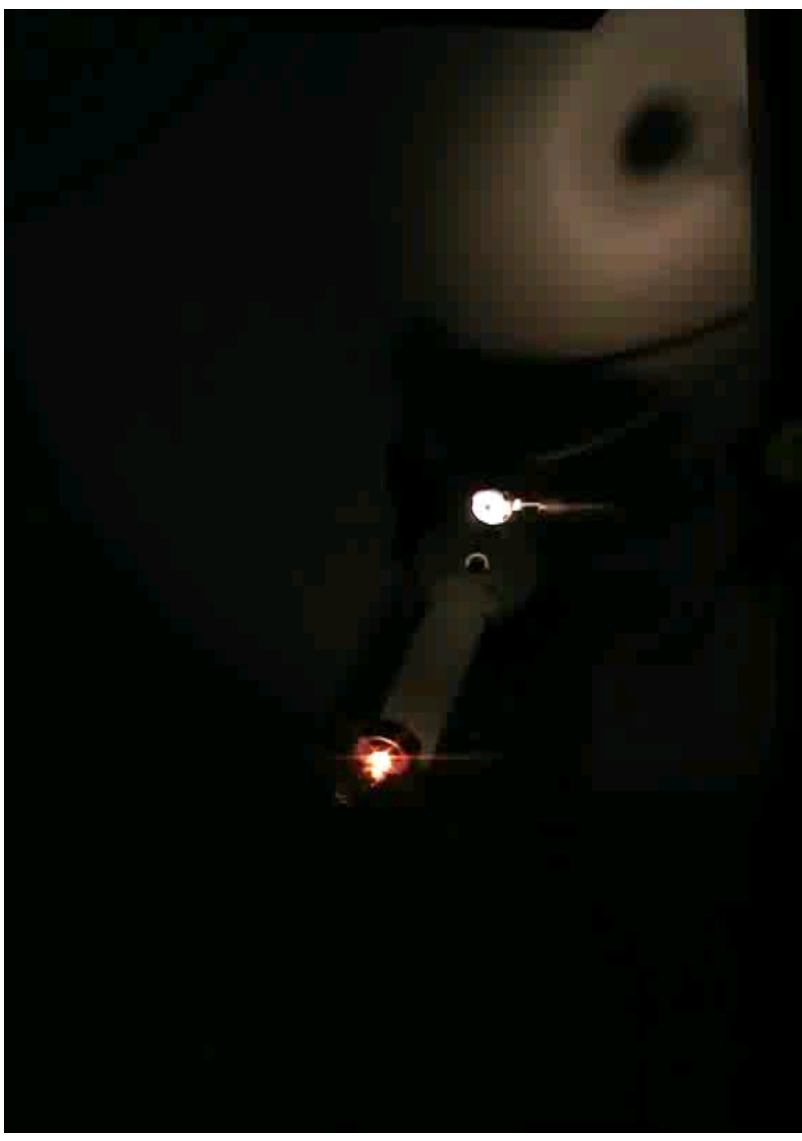
- **Function**

- Generate real-world images (non-synthetic) to:
 - Test and assist IP development
 - Allow closed-loop implementation for realistic evolution of canister imaging conditions

- **Principle of Operation**

- Target/Canister image is based on:
 - Small textured sphere, illuminated by a source to mimic Sun illumination
 - Effect of distance and LOS between Chaser (camera) and Target/Canister
- Camera and lens
 - Generation of (flight) representative images of the canister
 - Image acquisition at fixed distance (2.5m) of simulated sphere (Ø40mm)
- Zoom and Pan/Tilt units
 - Zoom emulates Chaser-Target distance, with additional aid via binning
 - Pan/Tilt emulates the Camera attitude wrt to centre of the canister
- Sun Simulator Unit
 - Light source rotation mimics the sun illumination geometry
 - Ball rotation mimics canister rotation

- IP Laboratory: Mock-up Overview (2)





VALIDATION FACILITIES FOR RV AND AEROCAPTURE GNC

Thank you