



Driving in Milli-G: The Flight Model of the MMX Rover Locomotion Subsystem and its Integration & Testing in the Rover

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MMX Rover Mission

First Rover in milli-g

Martian Moon Phobos



~20km diameter

1/2000 earth-g

-150°C to +70°C

surface properties highly uncertain

The MMX Rover IDEFIX

drop from 40m

stereo cameras for autonomous navigation

locomotion science

acceleration of the impact

RAMAN spectrometer

uprighting from stored configuration

MiniRAD instrument for thermal imaging

orient rover to the sun and lower body

wheel cameras for regolith science

drive 100m



Challenges

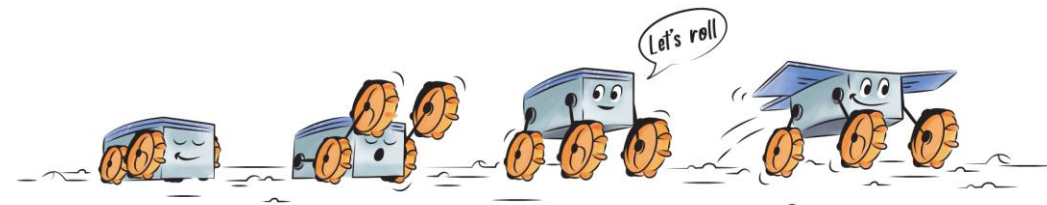
- Dynamics: Gravitational force vs. inertia
- Soil: Inter-particle friction vs. cohesion
- Mechanics: Friction vs. external loads
- Thermal: -150°C to $+70^{\circ}\text{C}$ cycle within 7.6h



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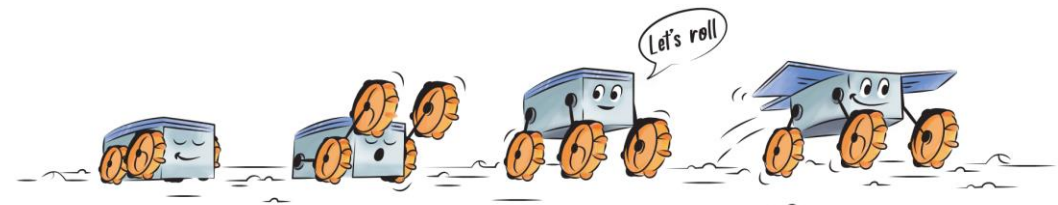
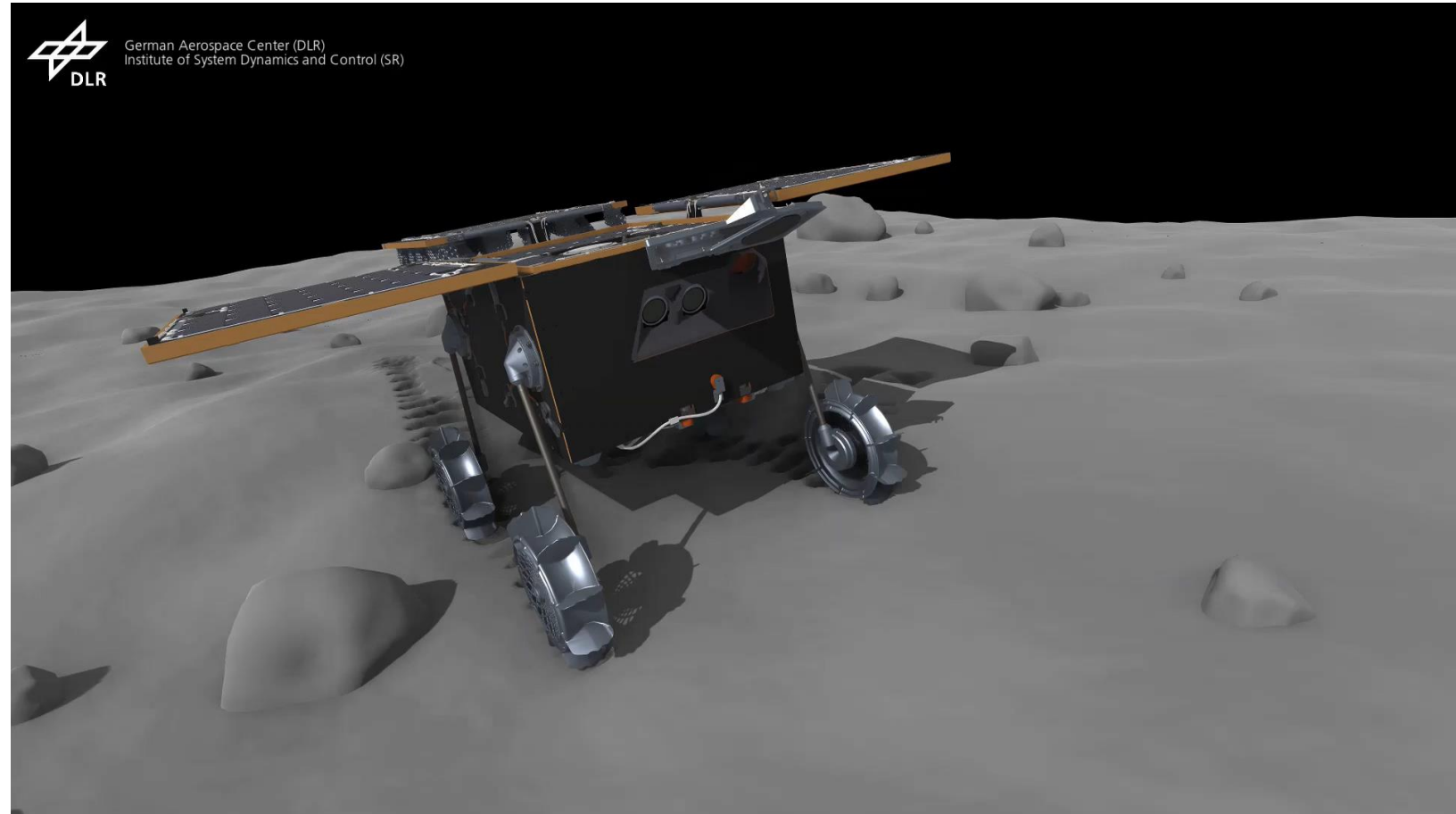


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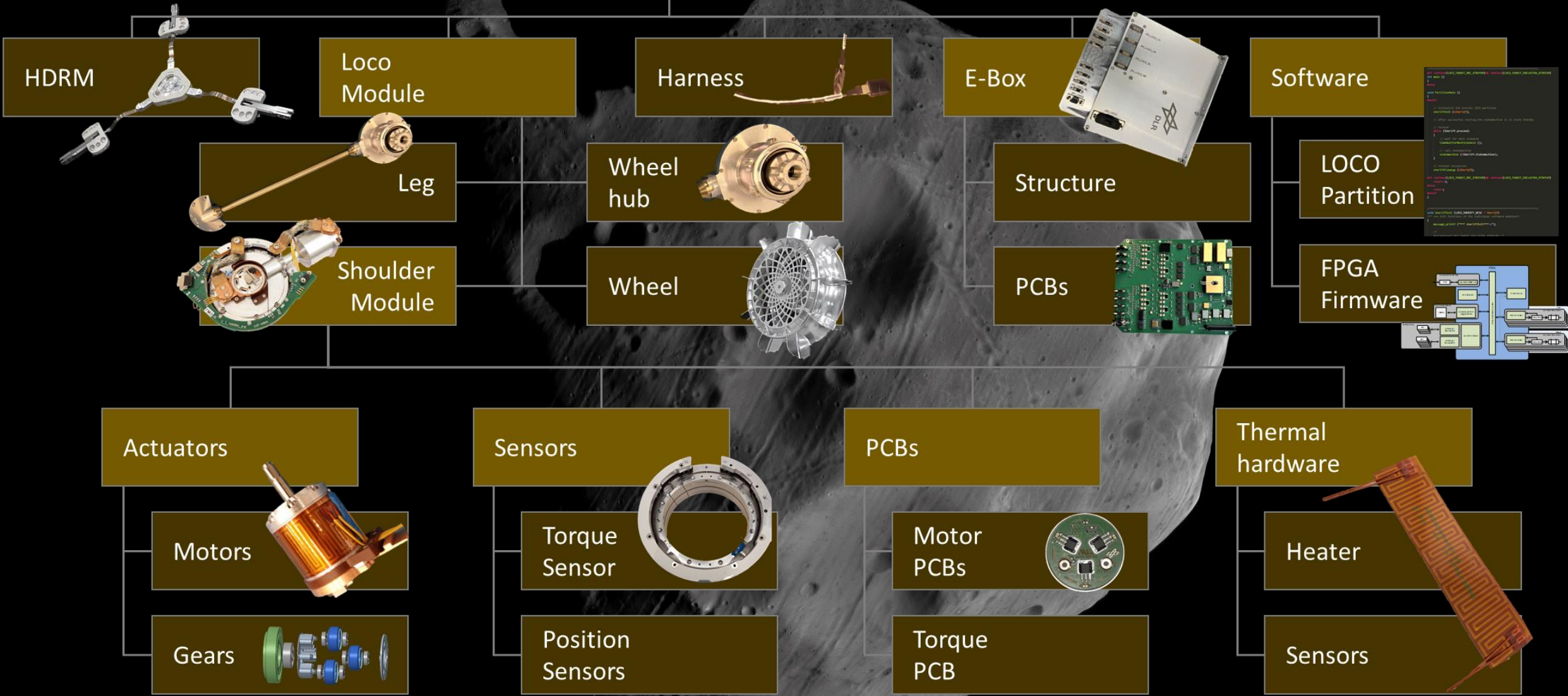


Main functional requirements

- Drive 100m
- Uprighting
- Body alignment
- Body height
- Provide pose

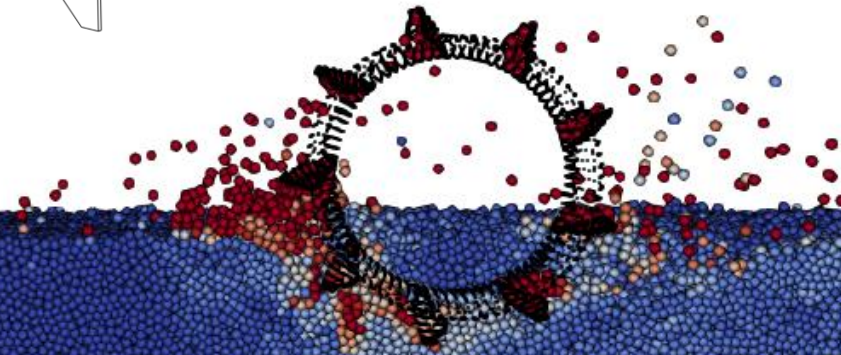
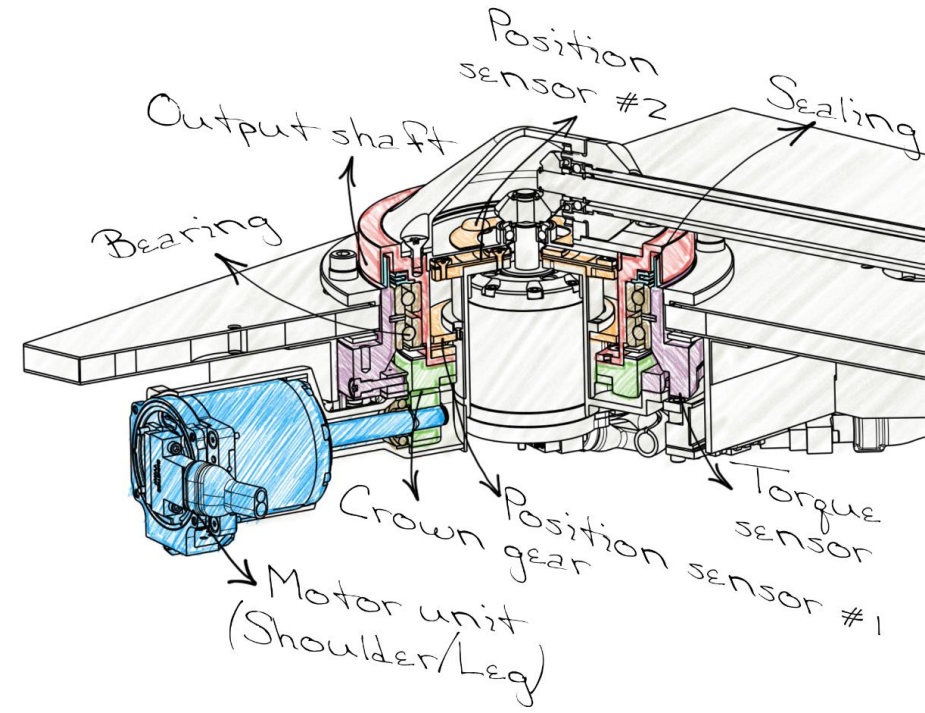
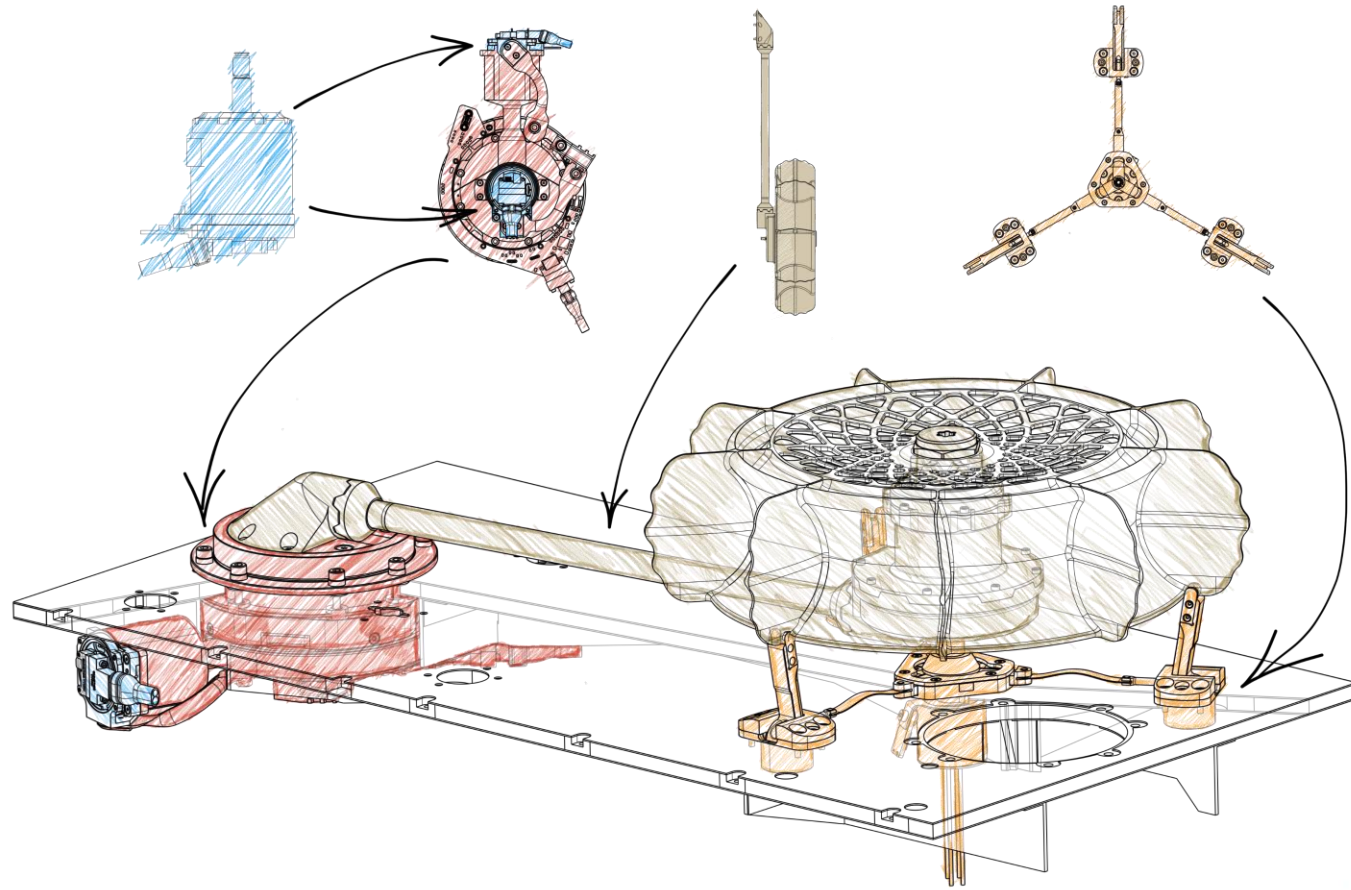


MMX Locomotion Subsystem by DLR-RMC



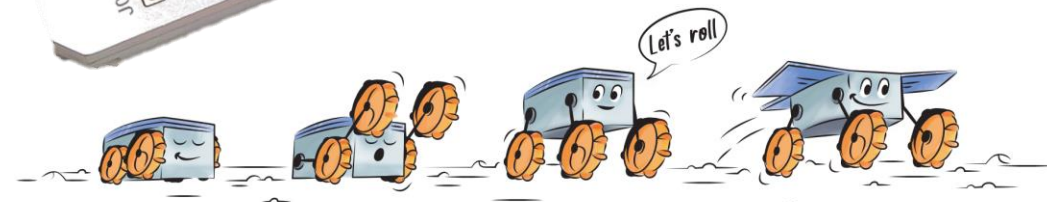
Mechanical design

Sketches from Viktor Langofer, Ralph Bayer, and Alexander Kolb. "MMX Locomotion Subsystem: mechanics for extraterrestrial low gravity drive". In: Proceedings of the IEEE Aerospace Conference, 2023.



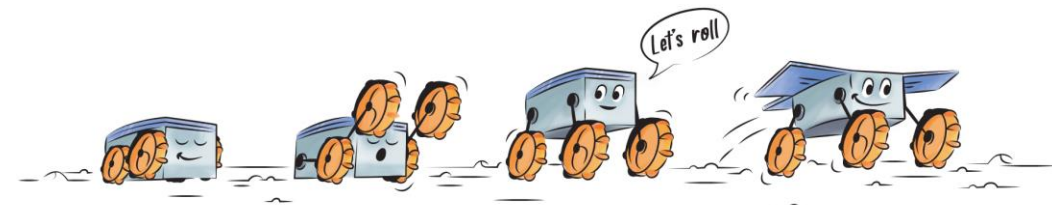
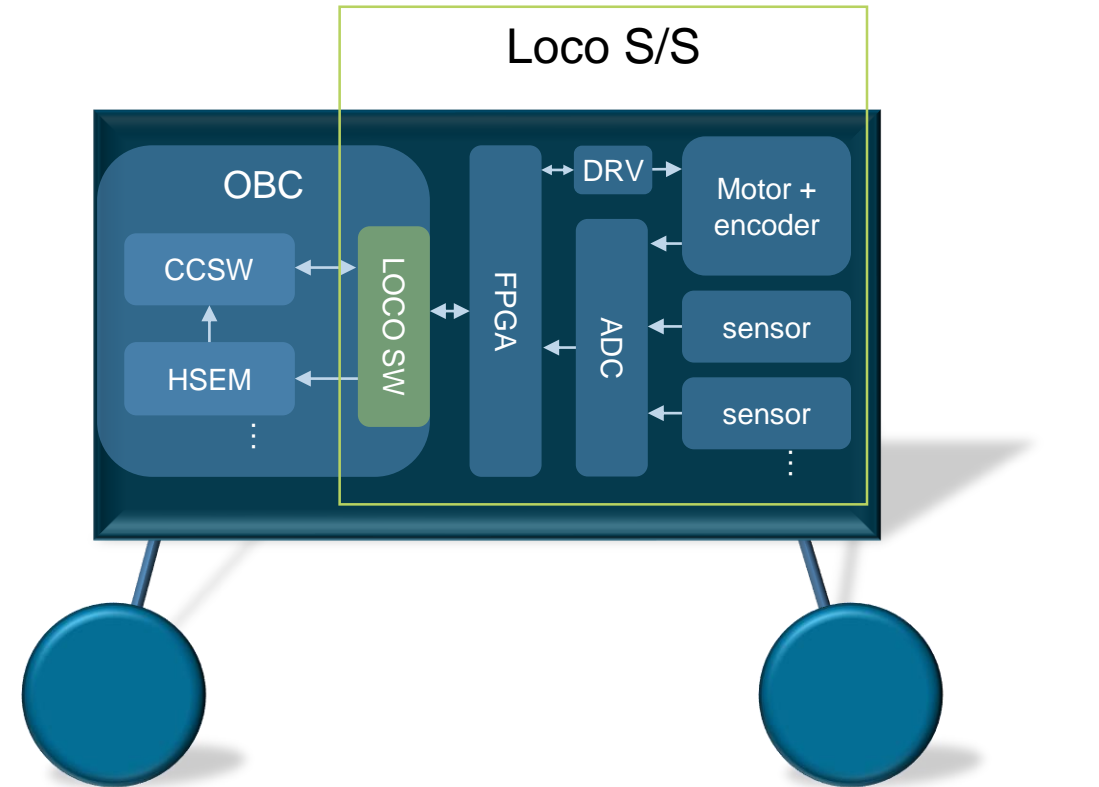
E-Box & Firmware

- FPGA with firmware
 - SpaceWire communication (RMAP)
 - Closed loop motor control
 - ADC reading
 - Safety shutdown
- 80 ADC channels
- Analog filtering
- 8 motor drivers
- Non-volatile memory (MRAM)



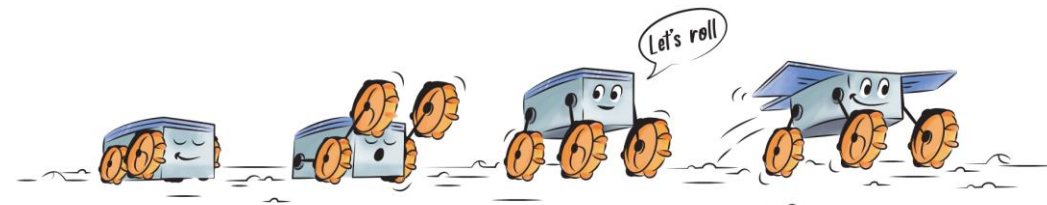
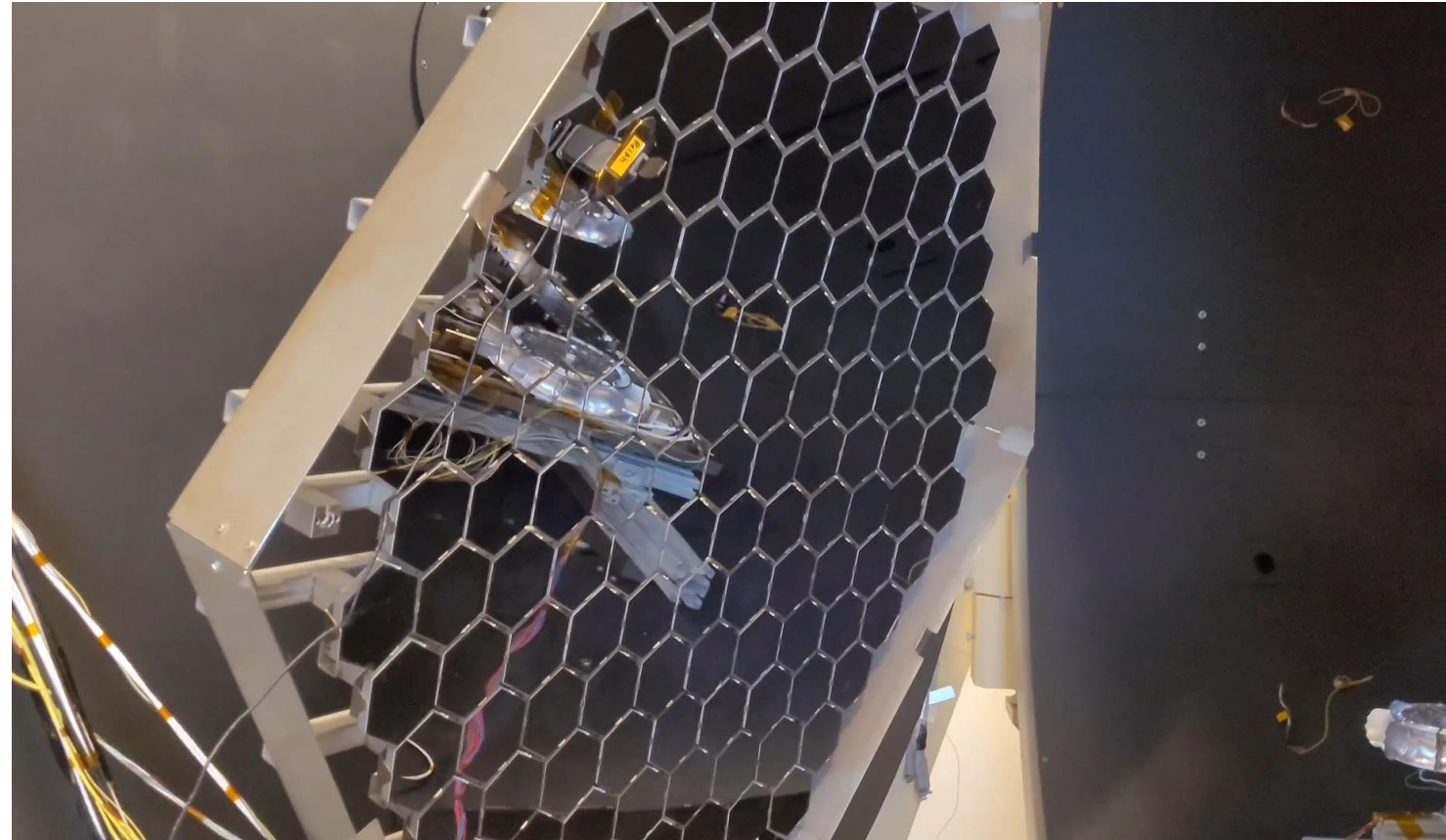
Software

- Runs on the main on-board computer
- 10Hz communication to E-Box
- Kinematic control functions
- Subsystem monitoring and FDIR
- Telecommand and Telemetry handling
- MRAM dump



Subsystem qualification

- QM + FM strategy
- 150 lab days
 - Vibrations, shock, impact, dust
 - Thermal cycling, balance
 - Conductive emissivity + susceptibility
 - Burn-in
 - Functional tests
 - Performance + life test
- QAR passed 06/2022

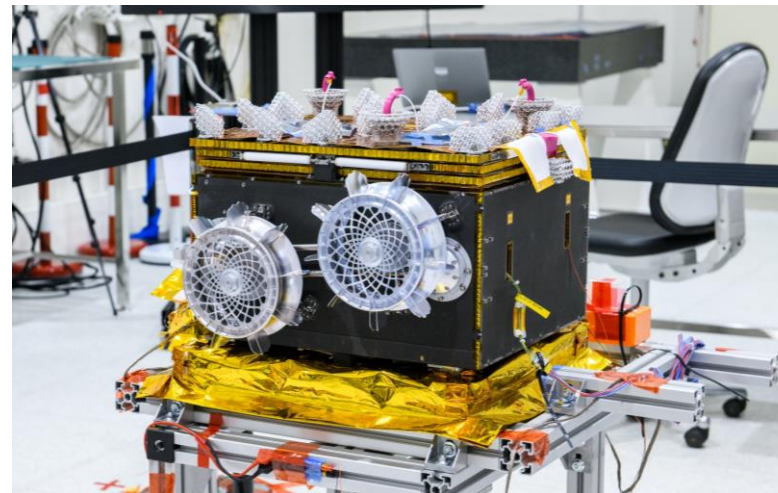


IDEFIX Assembly, Integration & Testing

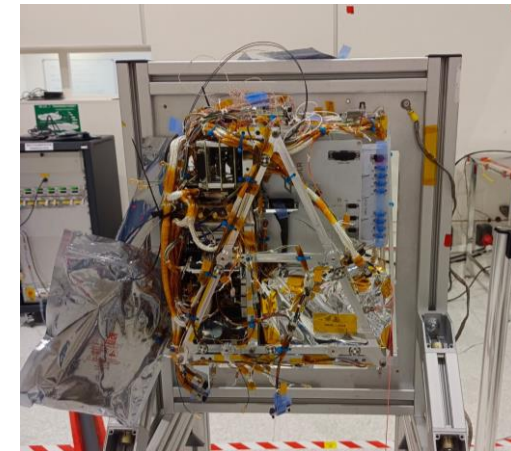
- Bremen, DE: Loco modules into chassis
- Toulouse, FR: Loco E-Box into Service Module
- Toulouse, FR: SEM into pre-integrated chassis
- Toulouse, FR: Rover level PFM tests



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Active Health Check

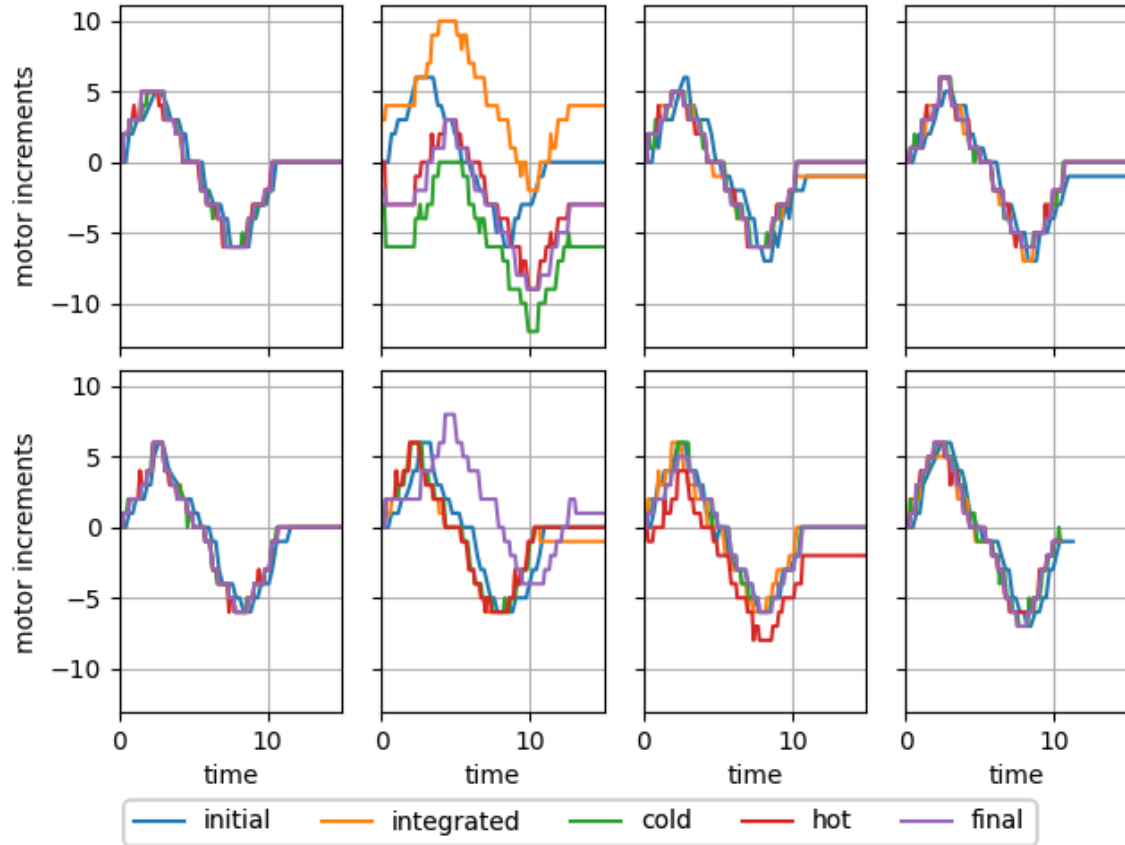


Fig. 1: Motor increments

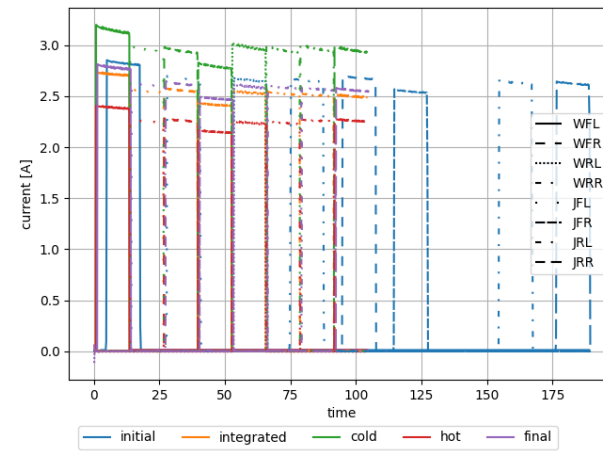


Fig. 2: Motor currents

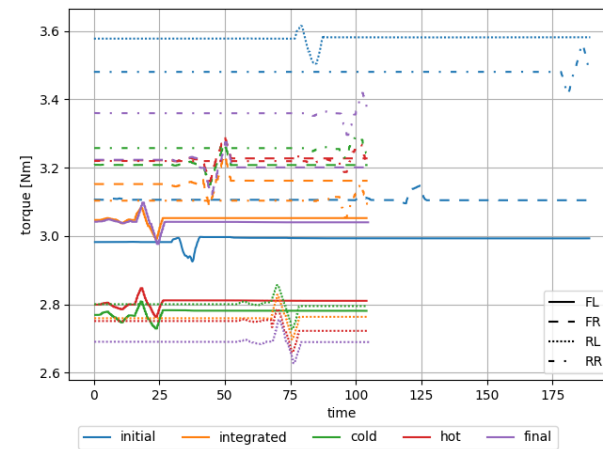


Fig. 4: Shoulder torque sensor

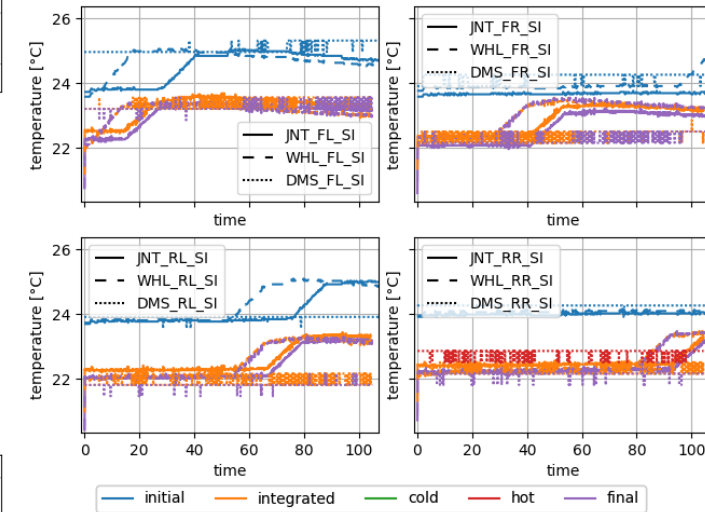


Fig. 3: Shoulder temperatures



