TRL6 demonstration of the SFR mission Mobility concept on a LEON4 processor

ASTRA 2023 Oral Presentation

DEFENCE AND SPACE

Anthonius Daoud-Moraru, Duncan Hamill, Ben Brayzier, Chris Barclay, Warren Hamilton, Róbert Marc, **Piotr Weclewski***, Michael Dinsdale, Max Braun, J. Ricardo Sánchez Ibáñez

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Background & history

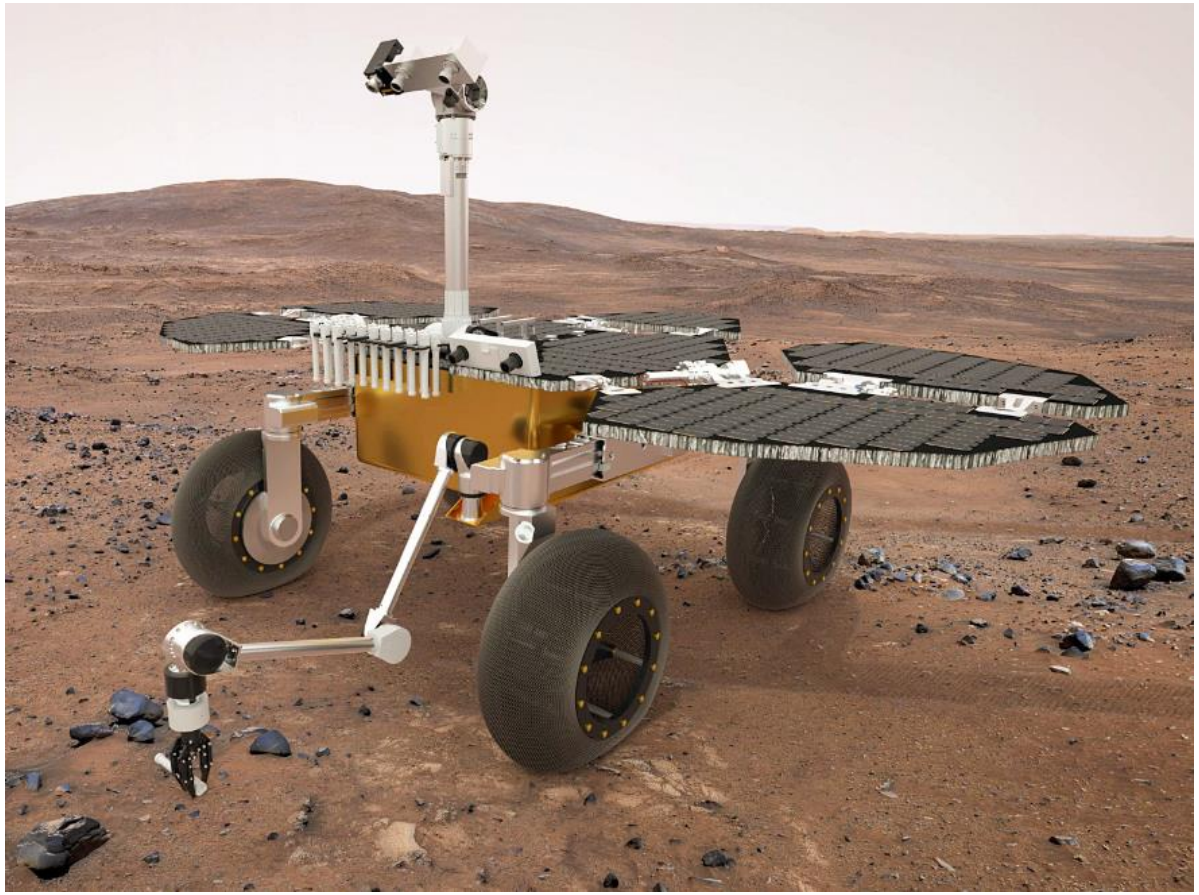
Sample Fetch Rover (SFR)

- Supposed to be collecting Mars sample capsules that was part of the Mars Sample Return series of missions (SFR was cancelled)

- In parallel, A/B1 Breadboards
  - Localisation (two different localisation solutions)
  - Autonomy (Airbus / CNES)

- And.. IBB1
  - Testbed for GNC developments
  - MarsYard and outdoors (locally)

- PIL (UBB)
  - LEON4 multicore breadboard - multiple functionalities tested
  - parallelism across cores - management logic as well as algorithm processing



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Integrated Breadboard 2 (IBB2)

GNC SW based on:

- ExoMars GNC SW (TRL8)
- MDM (ExoMars breadboard)
- IBB1 + A/B1 algorithm breadboard developments
  - Absolute Global Localisation
  - New modes concept
- CNES perception integration

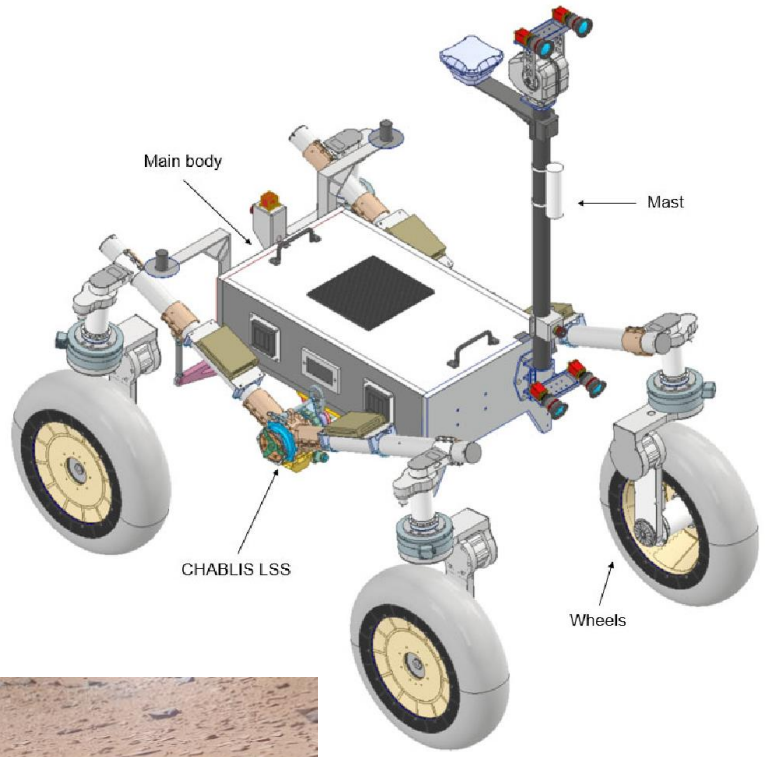
GR740:

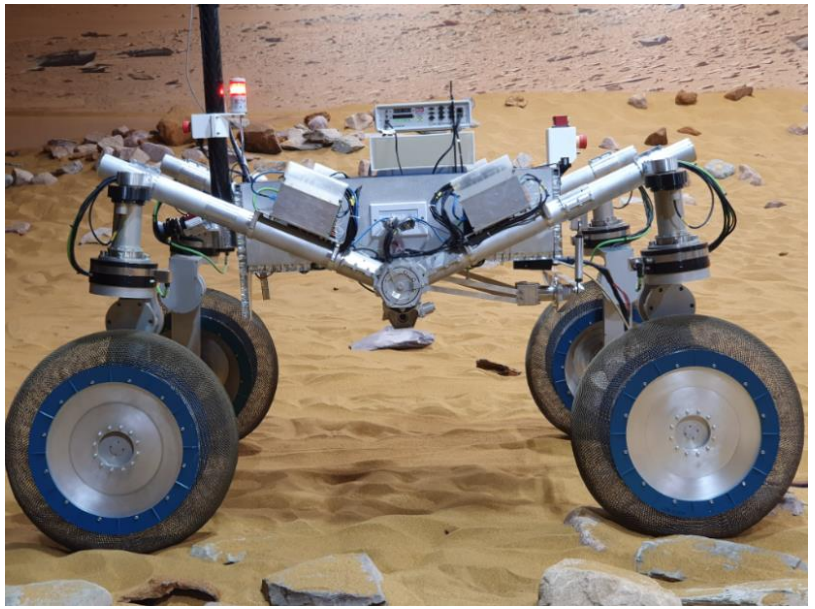
- CoProcessor (all nav calculations)
- LEON4
- 512MB RAM available for the user
- Memory bus clock reduced to 66MHz
- RTEMS 5 - single and multicore harnesses

IBB2:

- integration phase (Mars Yard + shakedown outdoors
- Field trial in a sand quarry
- IBB2 demonstrated GNC for long traverses in a representative environment

FTRS platform





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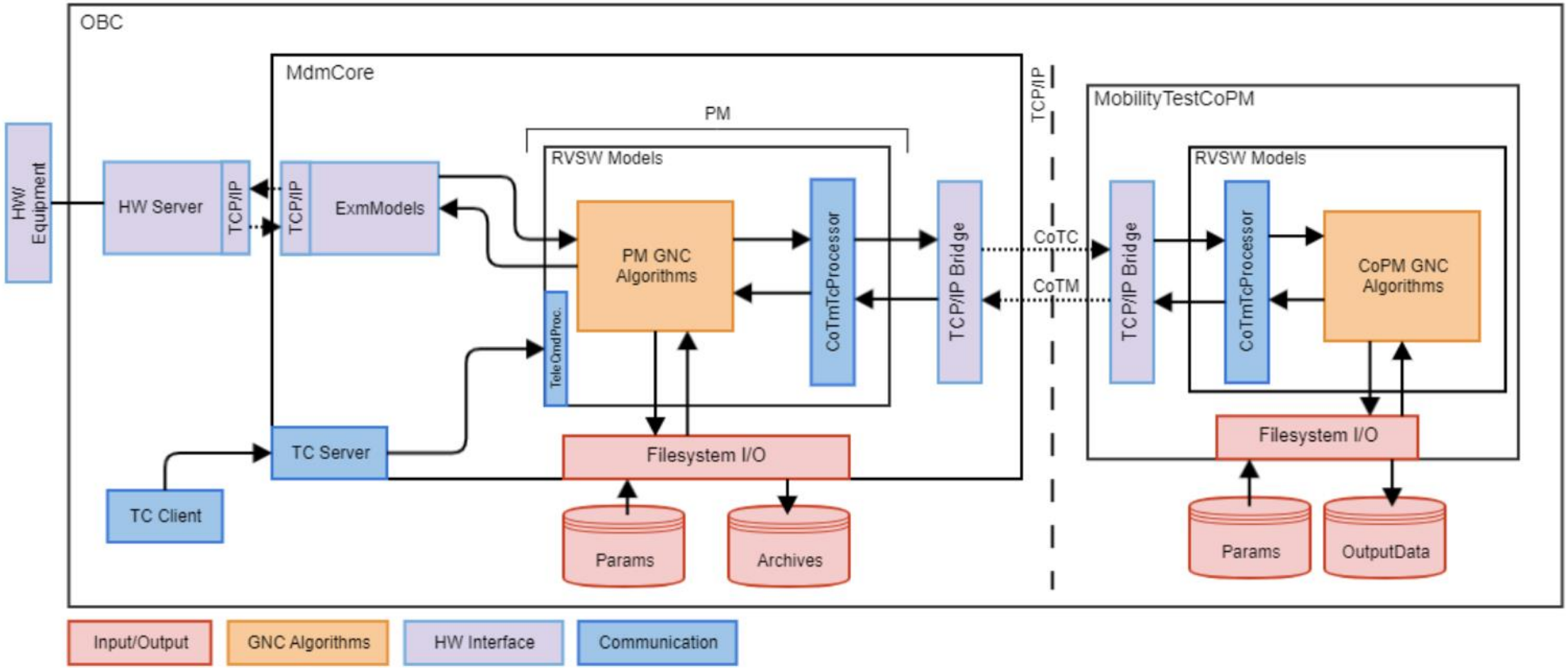
Architecture of PIL Test Harness

- Execution target independent
- Generic coTc/coTm interface



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Use Cases & Stretch Goals

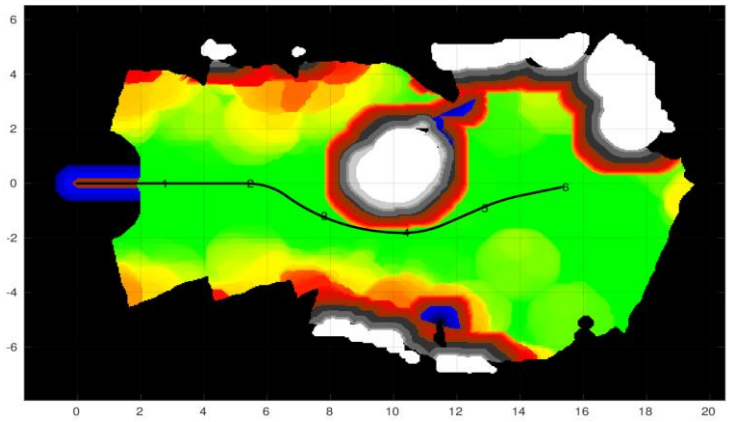
ID	Use Case	Primary Objectives
UC-1	FollowPath	Demonstrate FPath functionality
UC-2	Human Directed Drive	Exercising CheckPath (difficult traverse and nominal in depot driving operations)
UC-3	FOPSA	Demo FOPSA functionality
UC-4	AutoNav	Demo AutoNav functionality
UC-5	Waypoint Navigation	Following defined waypoints
UC-6	Traverse Driving	Demo AGL-T functionality
UC-7	Mock SRL Approach	Demo GNC (incl. Perception + VisLoc) in the presence of a mock-up SRL structure (at close distance)
UC-8	In Depot Driving	Demo AGL-D functionality

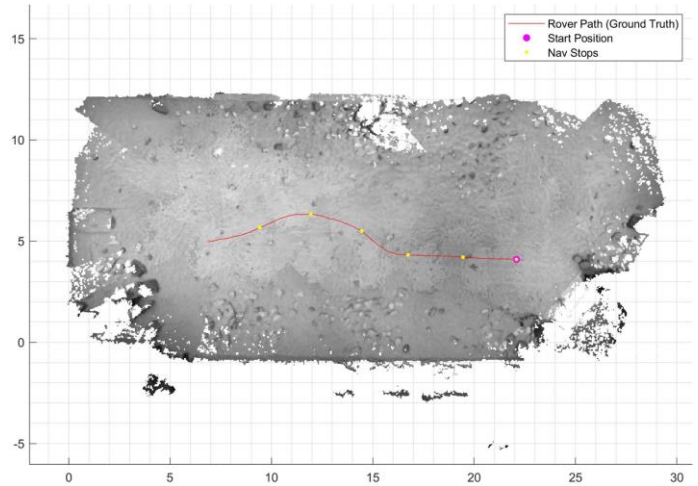
ID	Stretch Goal	Objectives/Comments
SC-1	Sun images	Data collection
SC-2	Rock garden	For assessment of perception performance and/or input to HDD planning
SC-3	Blocked AutoNav (Circle)	Target enclosed in a ring of obstacles blocking AutoNav from achieving the objective
SC-4	Trench Case	Short traverse over a V-shaped trench
SC-5	Rock garden (Airbus Perception)	Repeat SC-2 with alternative perception
SC-6	Inclined drive	Drive up one of the "ramps" available at the quarry site, challenging terrain.
SC-7	300 m AGL-T	300m drive, similar to UC-5/6 but much longer, representing one sol traverse
SC-8	Negative terrain	Complex AutoNav case, involving negative obstacles (i.e. trenches, craters) to the UC-4 setup
SC-9	Negative terrain (Airbus Perception)	Repeat of SC-8 with alternative perception

UC-4 AutoNav PIL

- **Autonomous navigation between initial position and 20m straight ahead**
- Test sequence:
  - Kickstart 2x 2.7m
  - Slopes and cost estimation
  - Single obstacle avoidance
  - Continuation and stop within target tolerance radius (5m)
- Actual test time: 1.5h (including data archiving and systems overheads) (~3x regular test time)
- Path length driven: 16.6m
- Navigation stops: 8
- No replanning events were recorded

- All nominal





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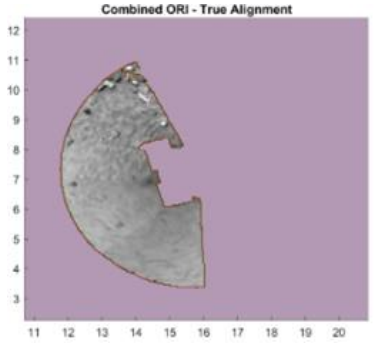
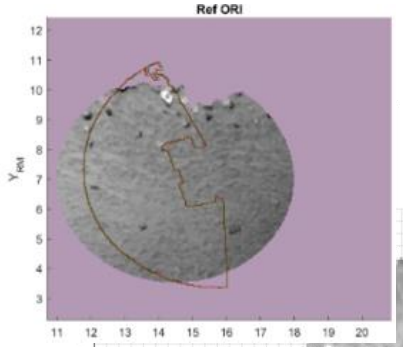
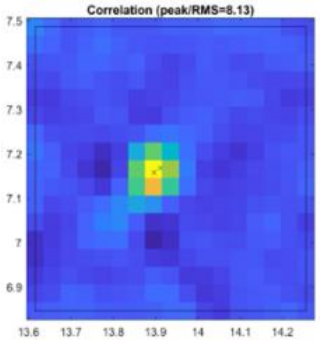
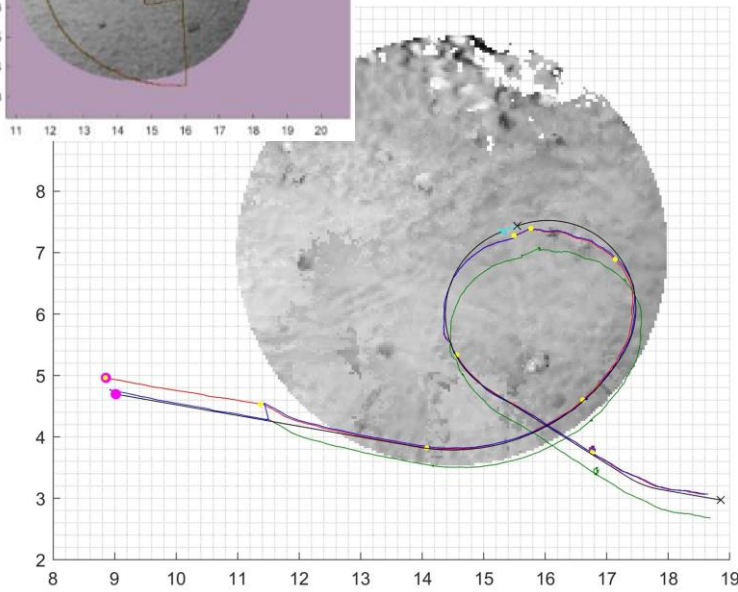
UC-8 AGL-D PIL

- **Predefined path using CheckPath mode with AGL-D enabled**
- Use of depot operation planning tool
  - maximise accuracy of depot operations = safety of the sample
- Initial rover position error = ~20cm
- Statistically representative relative localisation estimation errors added
- Test sequence:
  - approach towards island
  - tube location approach
  - final slow approach (0.5m)
  - hypothetical successful tube acquisition
  - drive out of Island
- Actual test time: 2h (including data archiving and systems overheads) (~3x regular test time)
- Path length driven: 21.07m
- Navigation stops: 9
- No replanning events were recorded
- AGL-D successfully fixed the initial rover position error and continued correcting relative localisation errors
- All nominal









Conclusions, Lessons Learnt

- ADS GNC demonstrated TRL 6 on selected use cases
  - Full GNC algorithm stack execution
  - realistic exploration mission scenarios
  - Flight representative conditions for the algorithms - LEON4 single core execution onto the IBB2 platform at the ADS Mars Yard
- Performance of the presented system has been satisfactory to continue the developments of the overall mission
- Successful execution on a flight like processor with different perception solutions - robustness and flexibility

- Performance of testing and complexity of debugging using target processor board is particularly challenging
- Setup of CI tests on GR740 was interesting solution to catch issues as early as possible and increase confidence

Further Material & Acknowledgement

Field trials: https://www.esa.int/ESA_Multimedia/Images/2023/09/Ready_for_collection_lightsabres_for_Mars
(Credit: ESA/Airbus)

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Questions

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