Mobility on the Surface of Phobos for the MMX Rover

Fabian Buse, Julien Baroukh, Stefan Barthelmes, Jean Bertrand, Tim Bodenmüller, Maxime Chalon, Sandra Lagabarre, Naomi Murdoch, Juliane Skibbe, Michal Smisek, Simon Tardivel, Mallikarjuna Vayugundla, Pierre Vernazza

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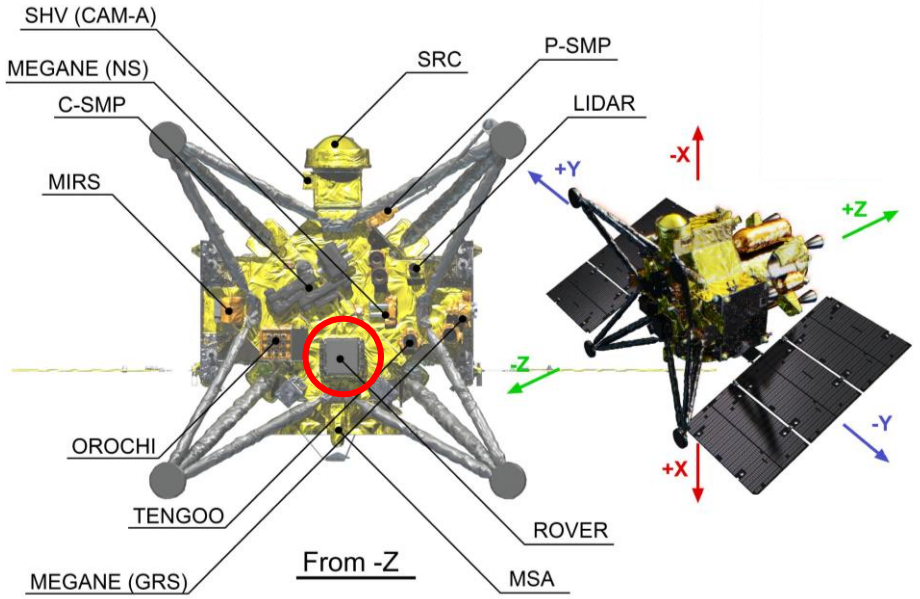
MMX & MMX Rover IDEFIX
Martian Moons eXploration

- JAXA Mission to the Martian Moons
  - Launch 2024
  - Arrival at Mars 2025
  - Arrival at Phobos 2026
  - Rover landing 2027
- Science
  - Clarification of the origin of the Martian moons and the process of planet formation in the Solar System.
  - Clarification of the evolution process of the Martian-sphere (Mars, Phobos, Deimos).
- Rover contribution by CNES and DLR
  - De-risking of the spacecraft landing
  - Providing surface context
  - Technology demonstration of wheel locomotion in milli-g

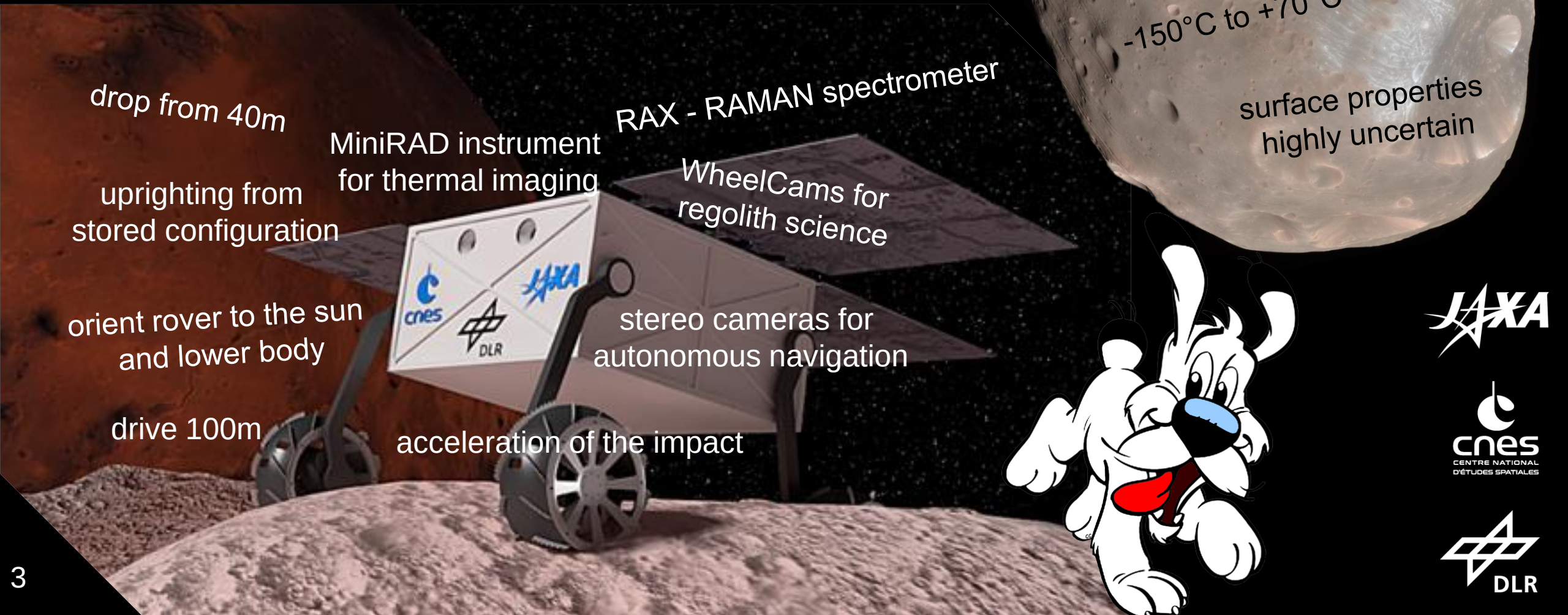
[MRO (NASA/JPL-Caltech/Arizona U.)]

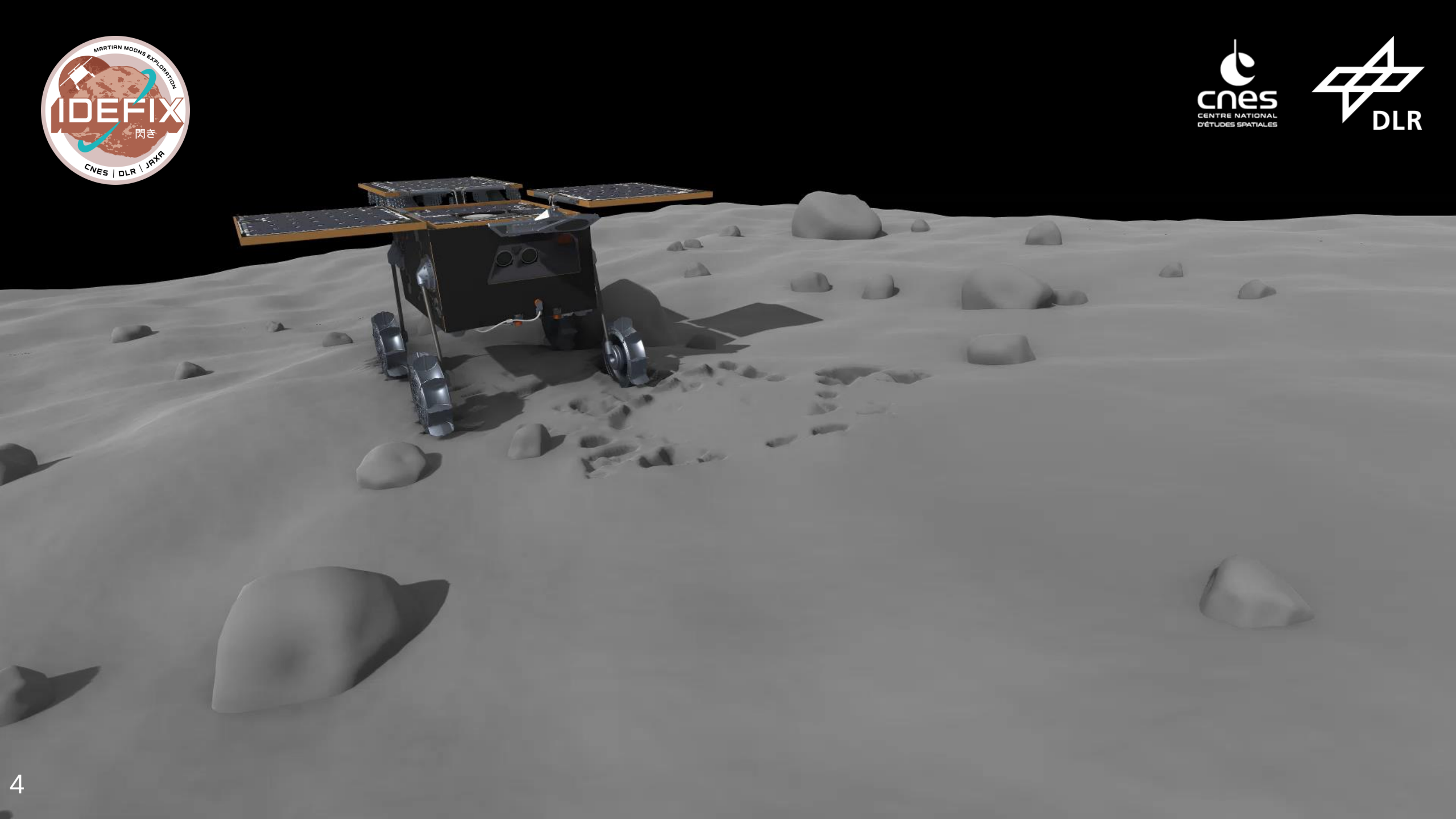
- *potato shape (27 x 22 x 18 km)*
- *very dark (darker than the Moon)*
- *"bi-color" (a "red" unit and a "blue" unit)*
- *low gravity (0.003 – 0.007 ms^{-2})*
- *~7h rotation period*
- *wide surface temperature range*
  - *(70 K to 350 K over the year)*
  - *(100 K variation within a day)*
- *looks quite smooth from orbit (at the m scale, comparable to the Moon)*



MMX Rover IDEFIX
First Rover in milli-g

[MRO (NASA/JPL-Caltech/Arizona U.)]

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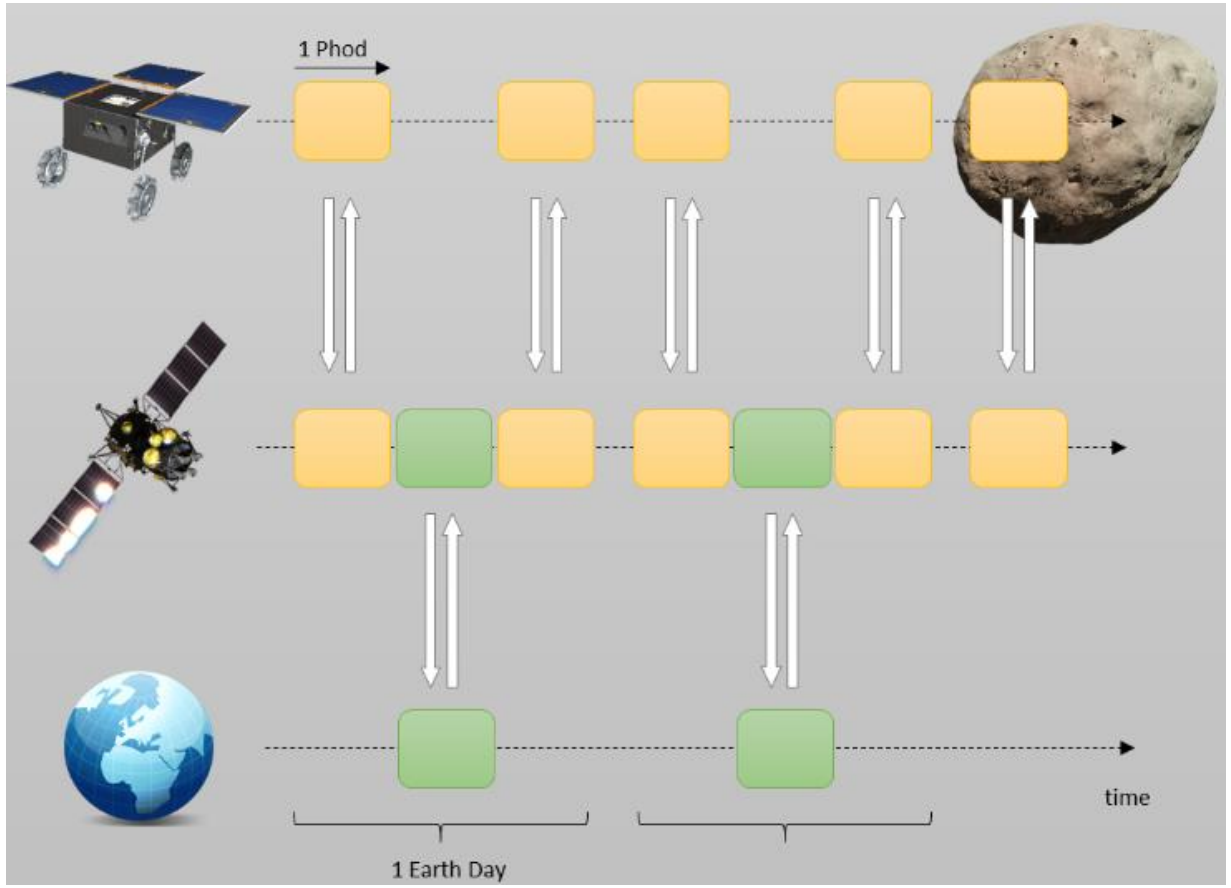
IDEFIX
Operations and Goals

- ~100 Earth day Exploration Phase
- 100m driving
- 1 Phod (Phobos Day) 7h 39m
- No direct Rover ↔ Earth communication
- Rover ↔ Spacecraft communication 2 of 3 Phod's
- Spacecraft ↔ Earth communication 1 of 3 Phod's
- 1 "Drive Slot" each Phod



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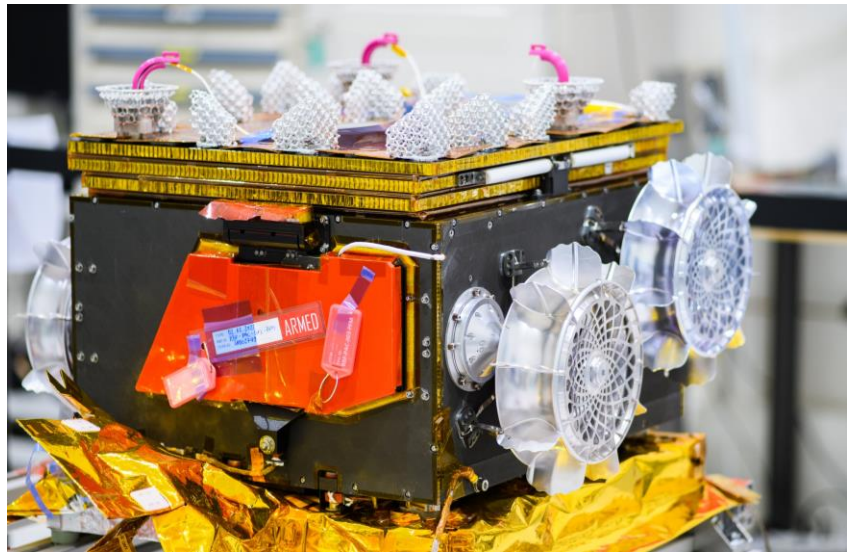
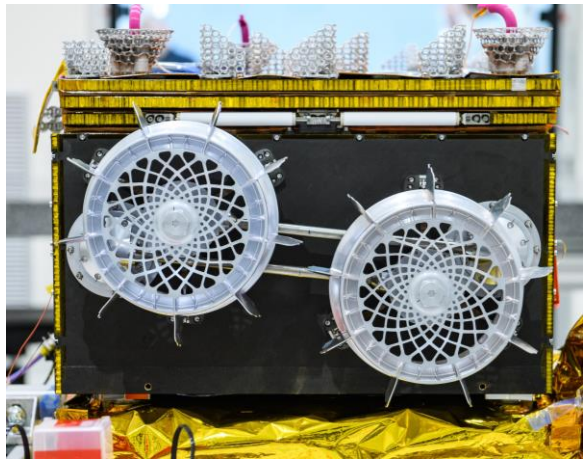
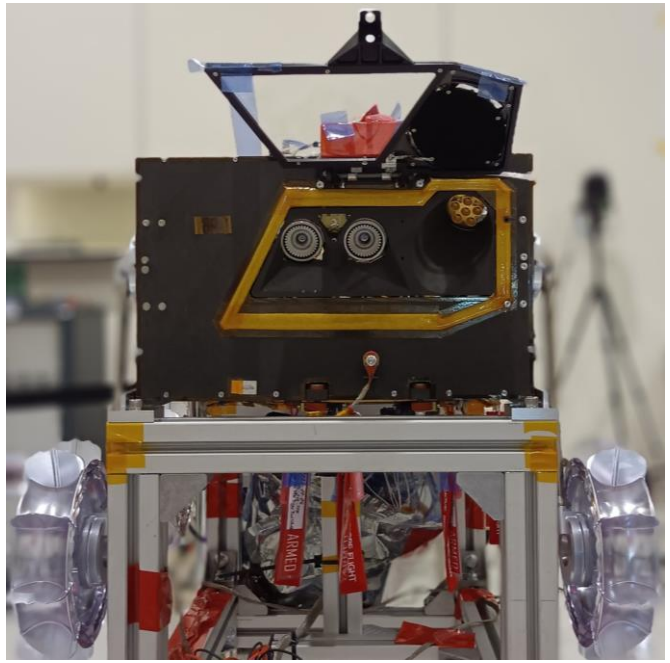
Mobility Tools





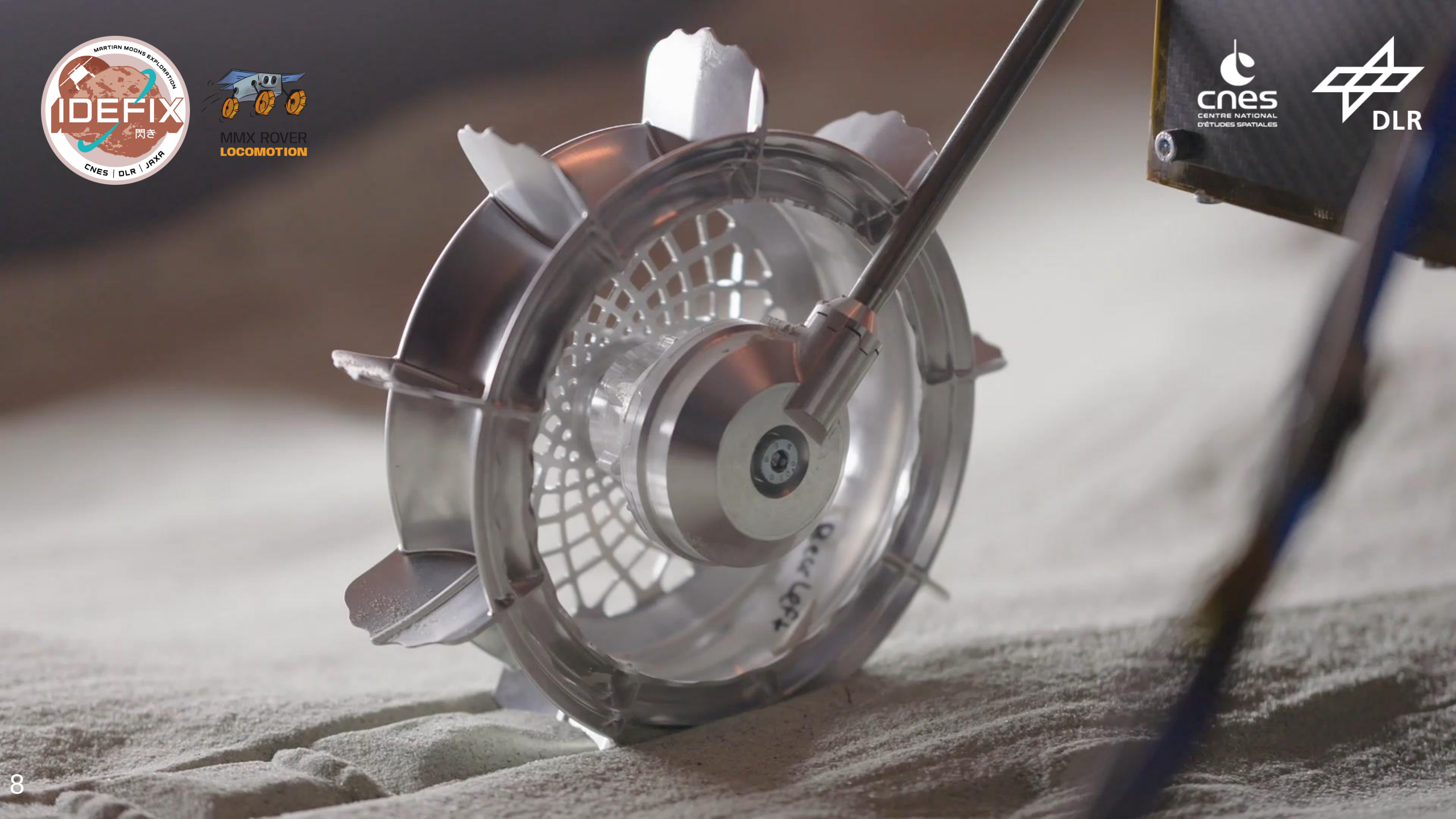


- LOCO
  - Four actuated legs
  - Four actuated wheels
  - Two gyros (roll and pitch)
  - More details tomorrow
- NavCam
  - Stereo Cameras
- WheelCam
  - Pointing at the Wheels
- SKA
  - Attitude control system
- Two Autonomous navigation systems
  - DLR Autonomous Navigation Experiment (DLR NAV)
    - Guarded manual commands
    - Closed loop autonomous navigation
  - ANAKIN (Autonomous Navigation Acquiring Knowledge from Image Nuances) provided by CNES
    - Derived from CNES ExoMars Nav
    - Closed loop autonomous navigation

Locomotion Functions

- Drive
  - Only wheel actuation → skid steering & point turns

MMX ROVER
LOCOMOTION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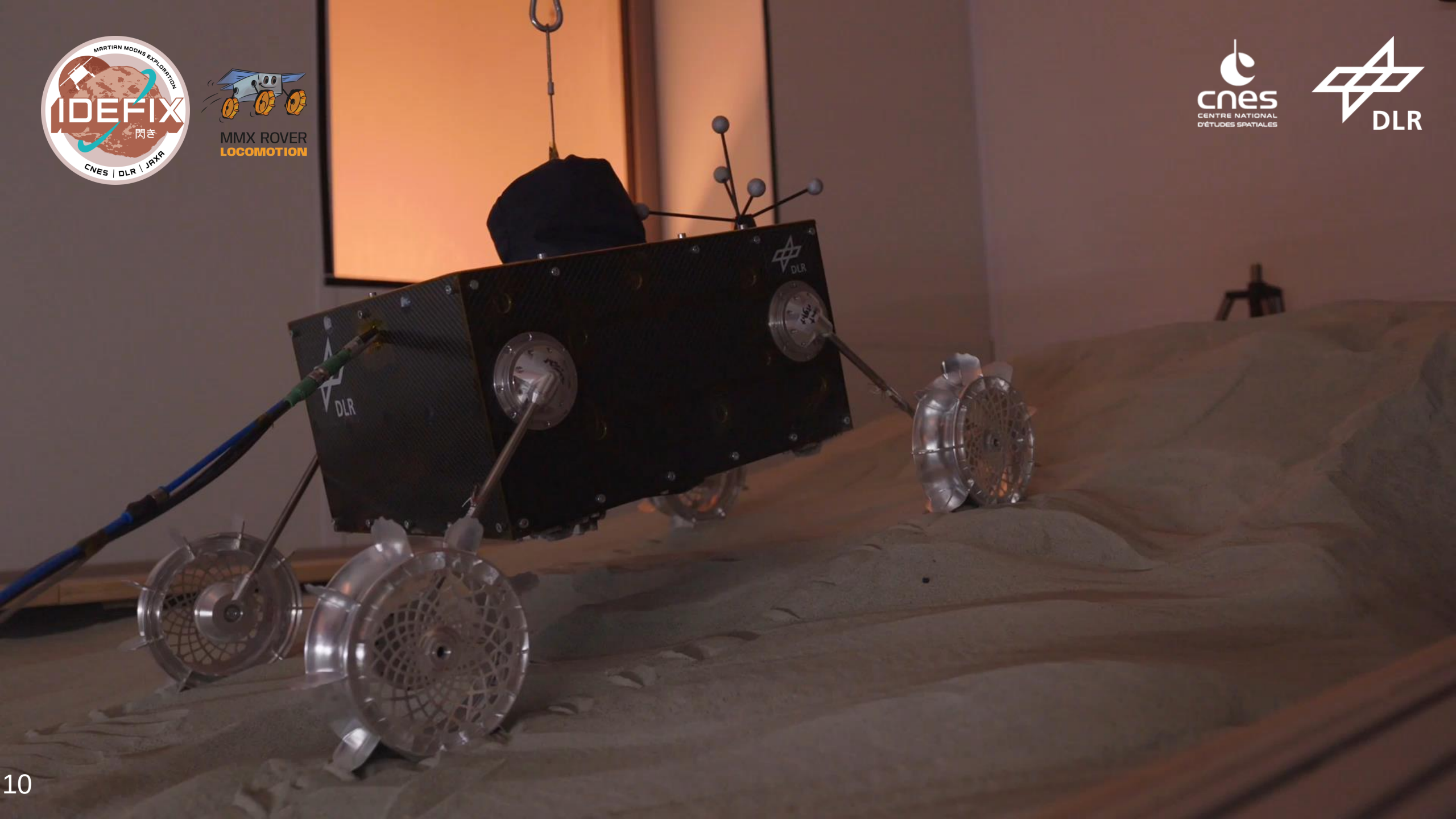
Locomotion Functions

- Drive
  - Only wheel actuation → skid steering & point turns
- Inching
  - Coordinated wheel & leg actuation, increased traverseability on rough terrain

MMX ROVER
LOCOMOTION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Locomotion Functions

- Drive
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  - Coordinated wheel & leg actuation, increased traverseability on rough terrain
- Align
  - Coordinated wheel & leg actuation, orientation and height control of the chassis

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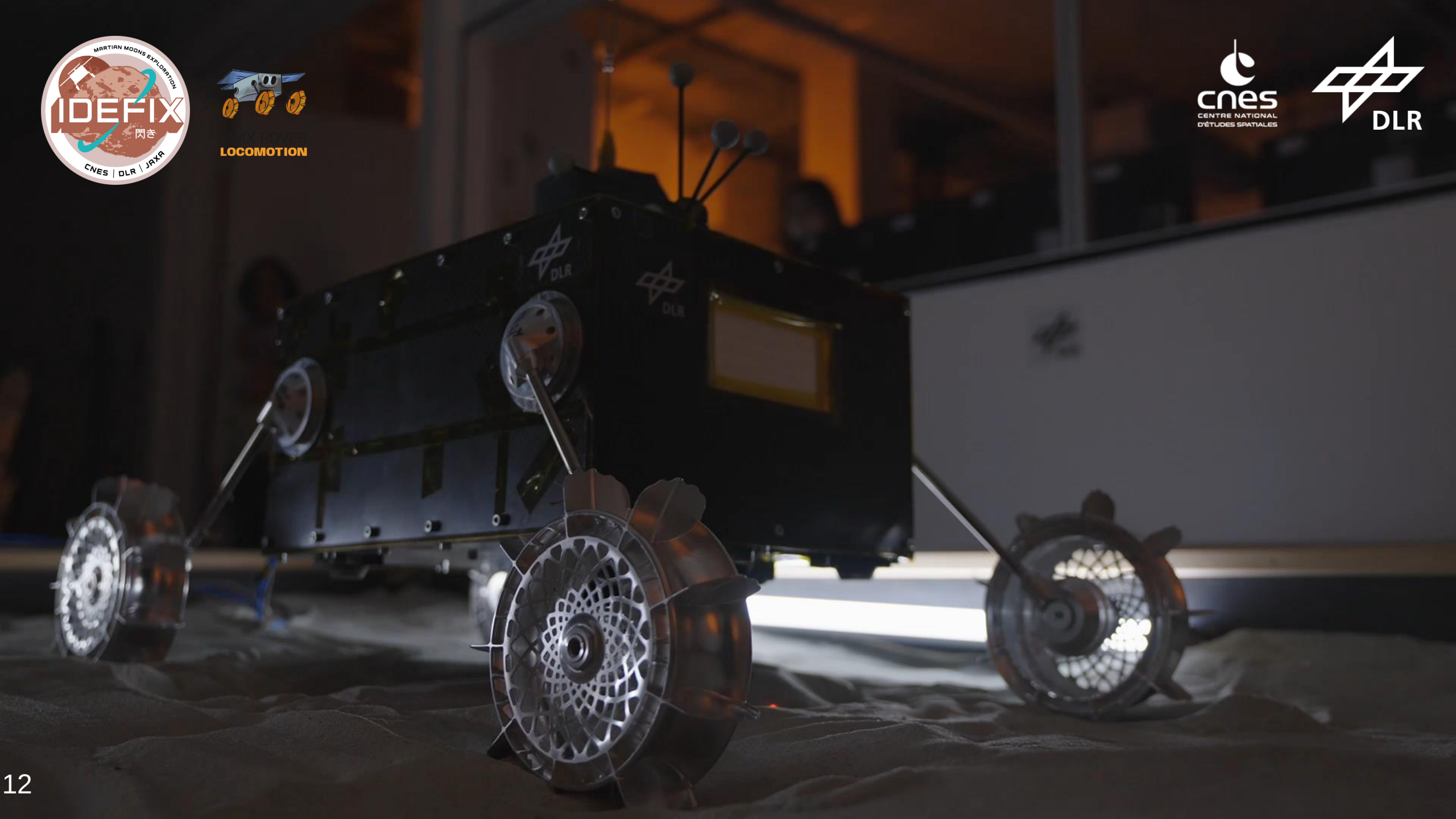
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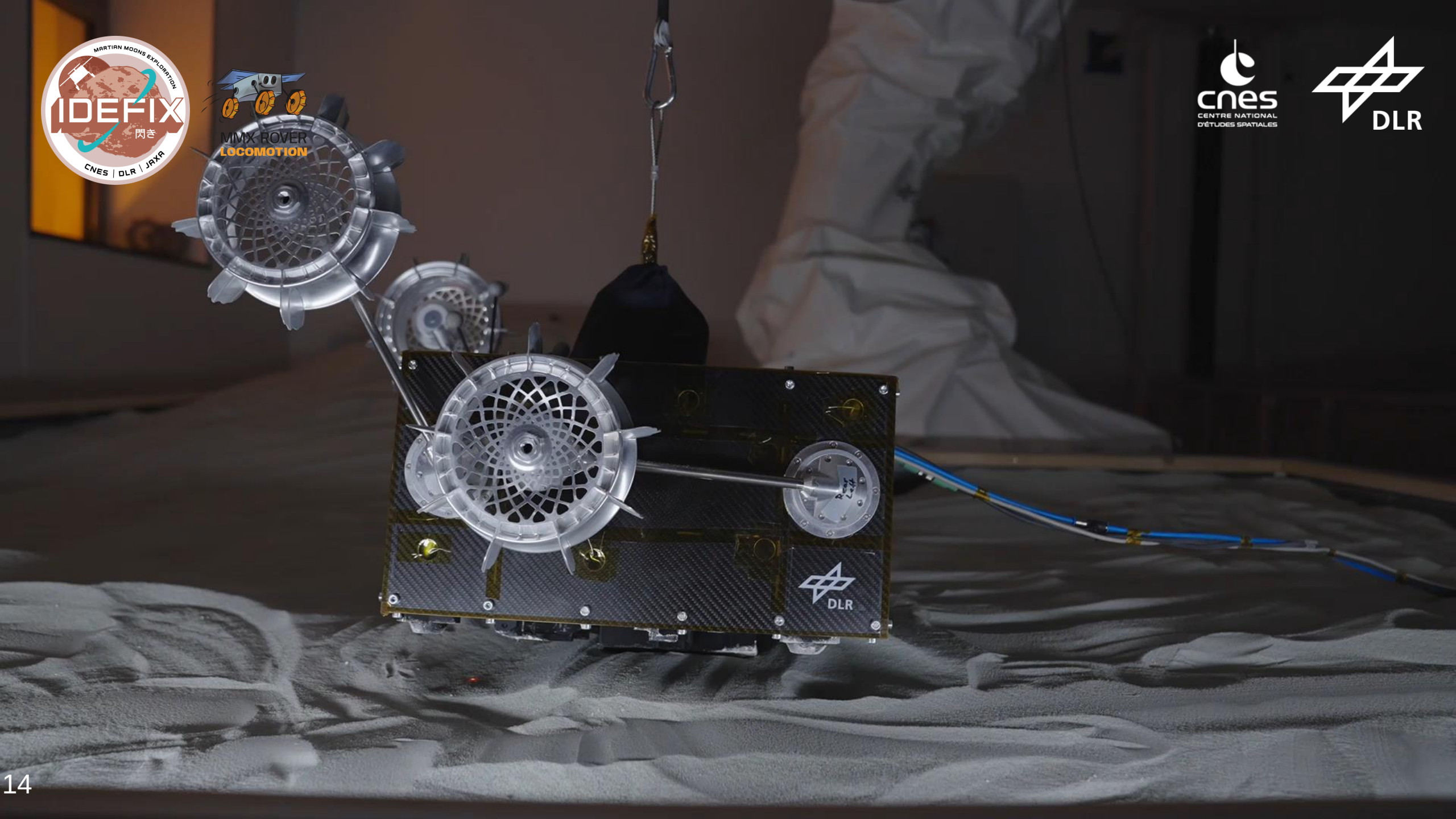
- Passthrough / Uprighting
  - Uncoordinated wheel & leg actuation, used during uprighting phase and to generate custom commands

MMX ROVER
LOCOMOTION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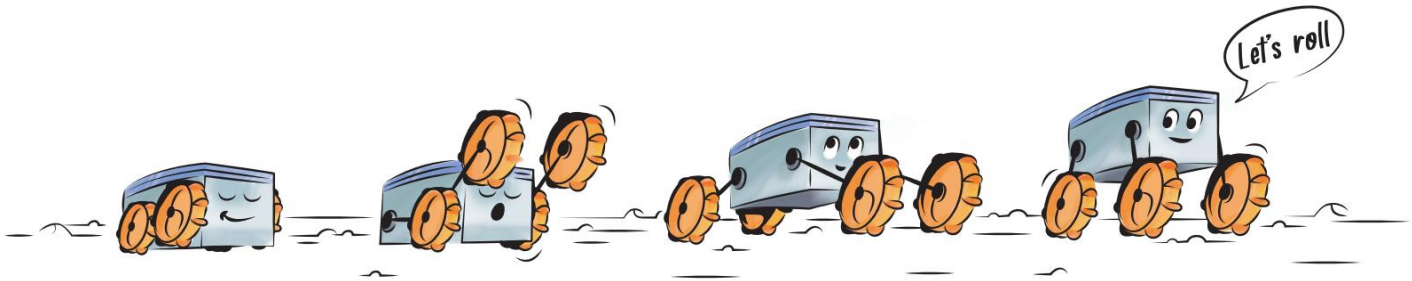
MMX ROVER
LOCOMOTION

IDEFIX Mission on Phobos

- Hitchhike
- Separation, Landing, Uprigting and Deployment (SLUD)
  - Uprighting → Fully autonomous sequence
    orienting the rover to its belly from any orientation

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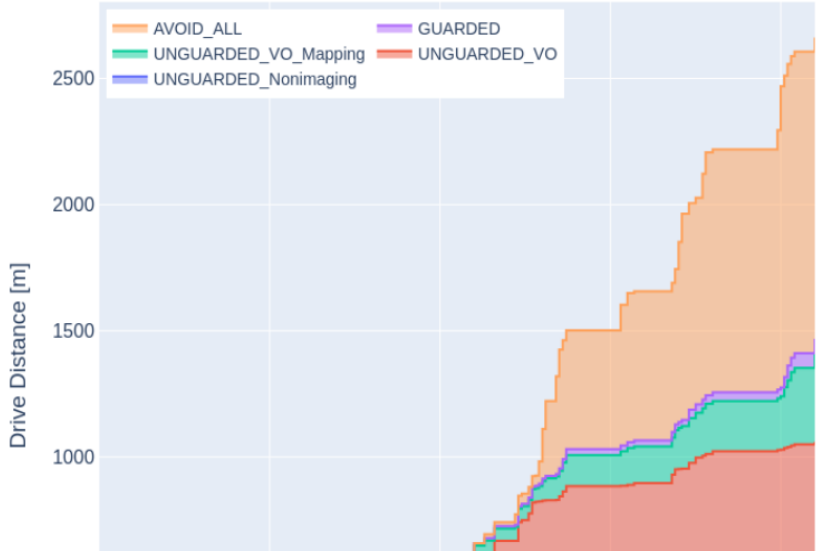
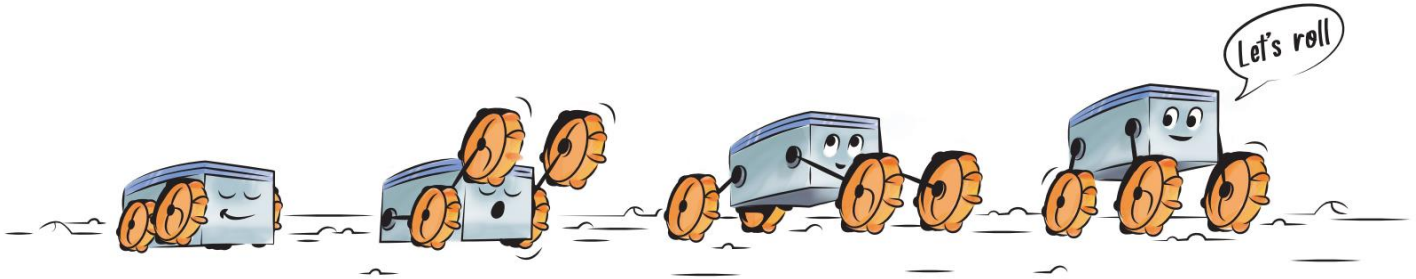
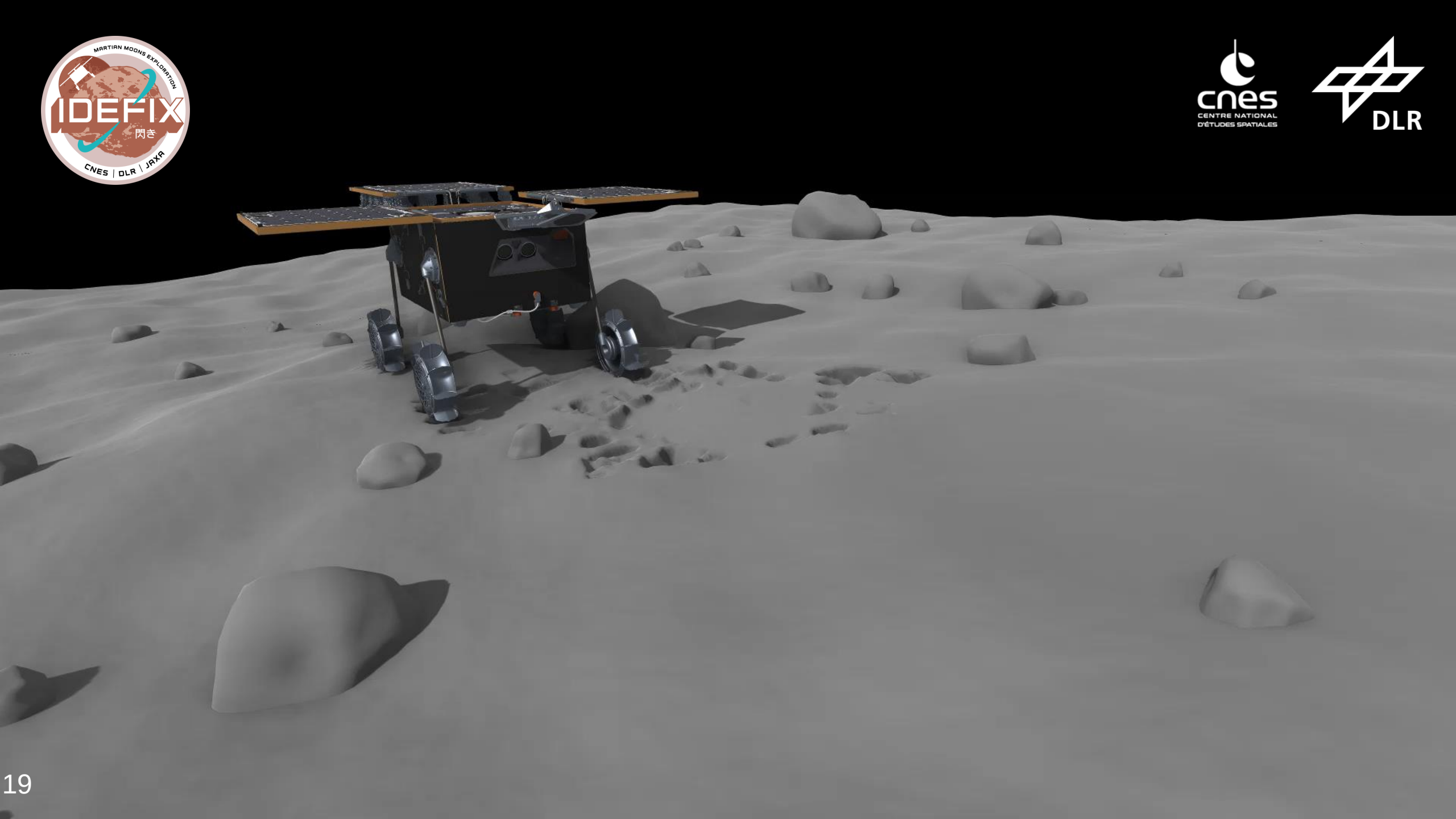
- Locomotion & Mobility Checkout
  - Learning how to drive in milli-g
  - Unknown regolith conditions
- Manual Exploration Phase
  - Path planning on Earth



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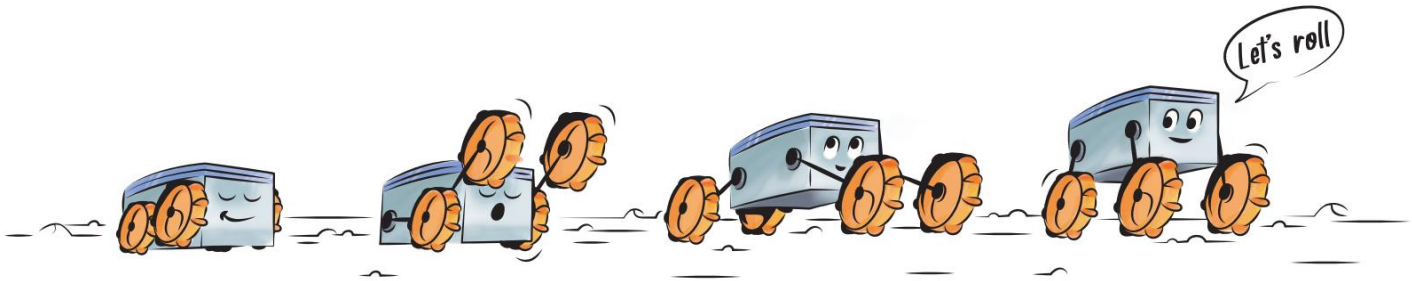
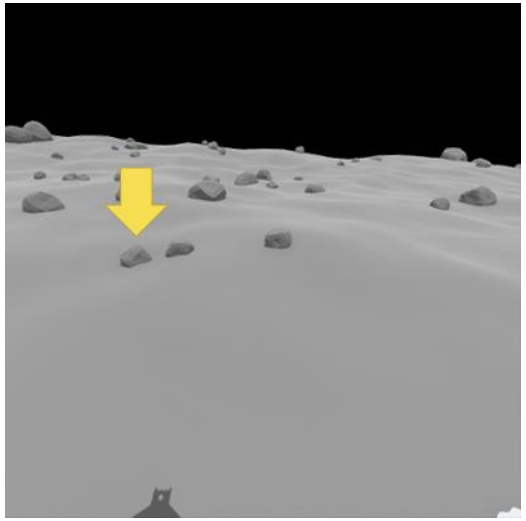
- Manual Exploration Phase
  - Path planning on Earth
- Autonomous Exploration Phase
  - Target selection on Earth

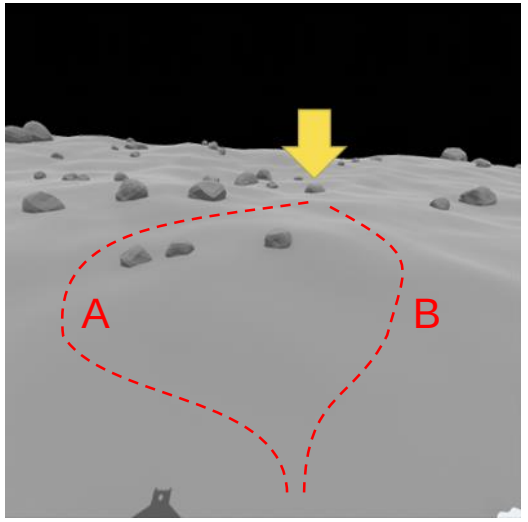


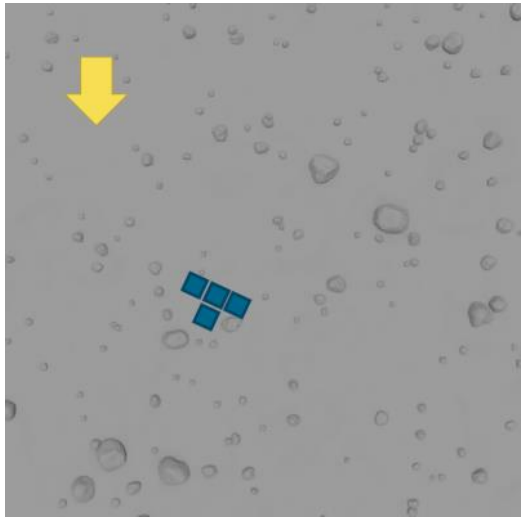
Mobility Planning Tasks



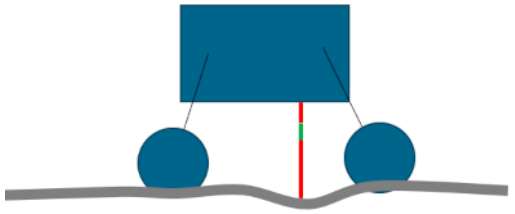
Close Target
In range of a single drive session
No obstacles

Near Target
In view of the NavCams
Multiple drive sessions with ground loop

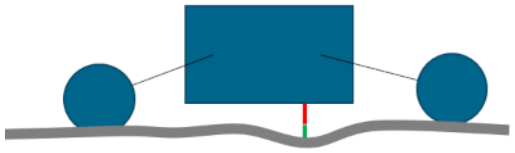


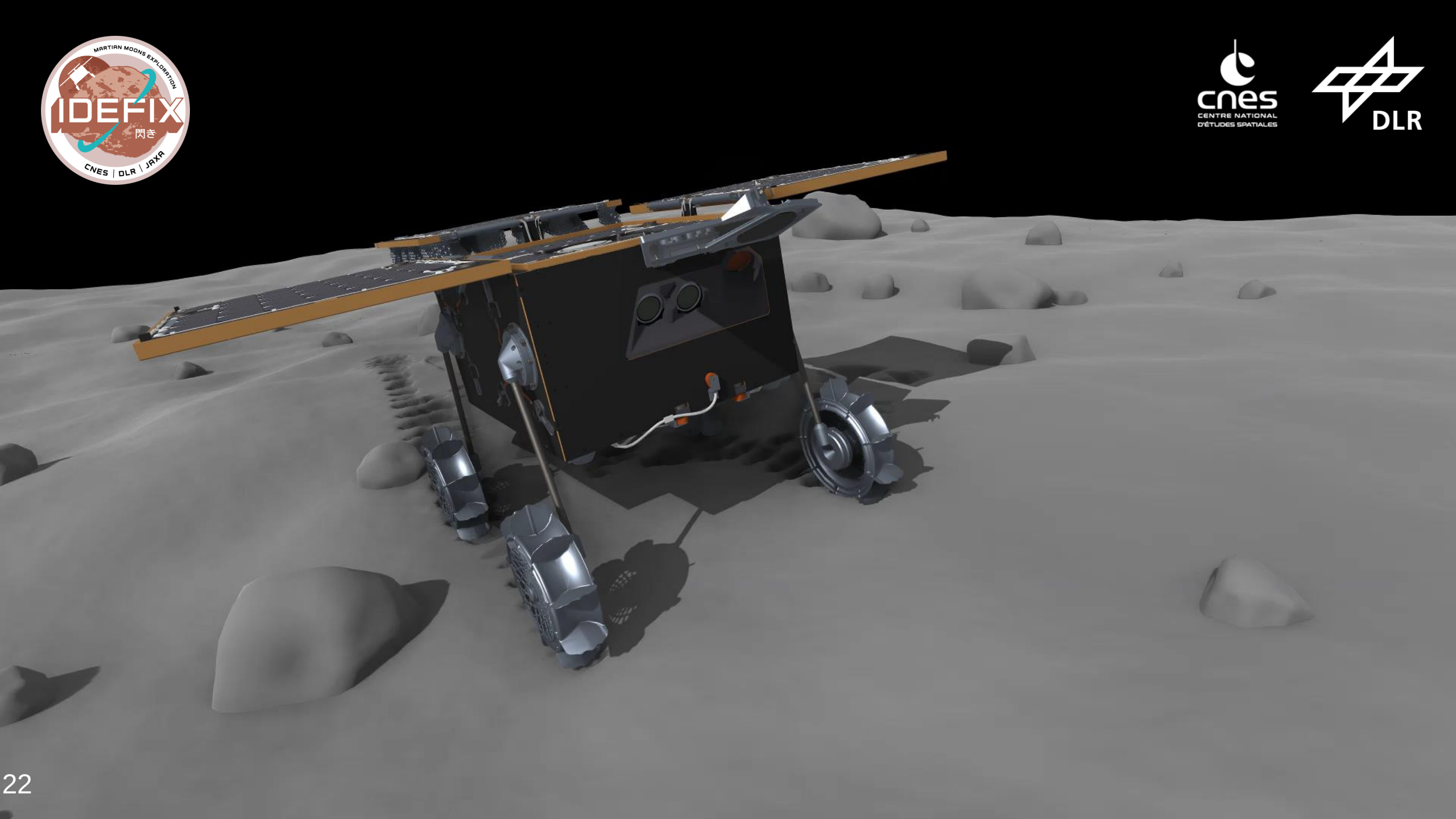


Far Target
Out of view of the NavCams
Visible in orbiter images
Multiple drive sessions with ground loop



RAX Measurement
Requires exact position of the chassis above the surface

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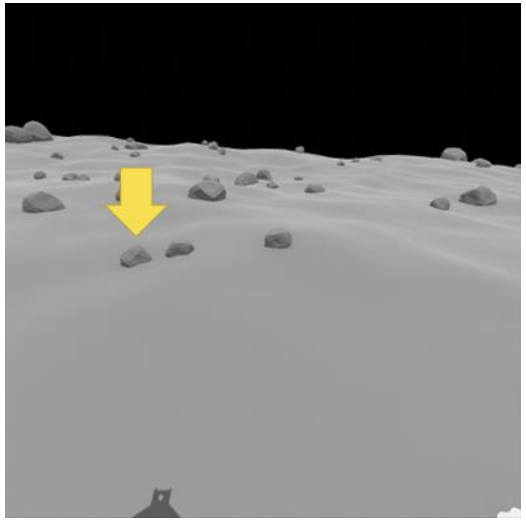

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No obstacles

Near Target
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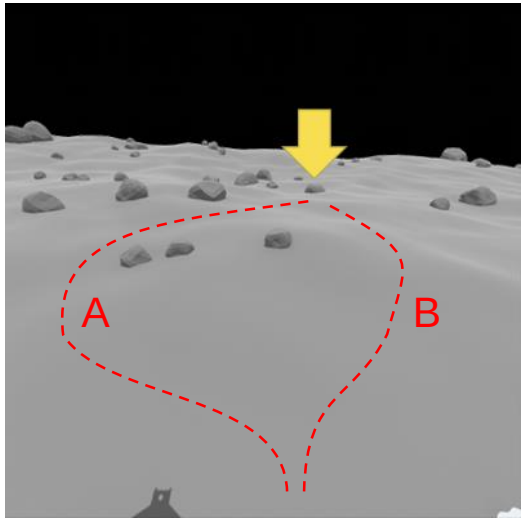
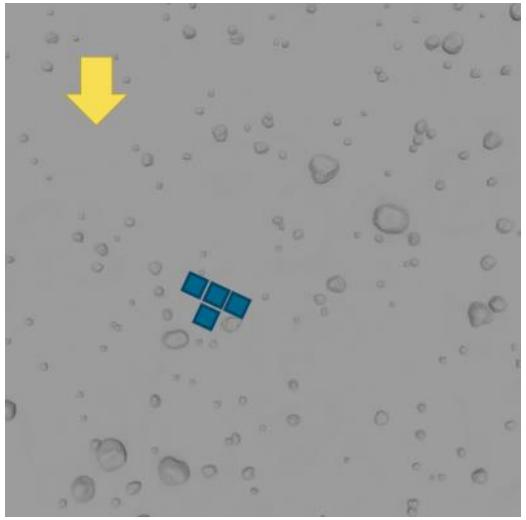
Multiple drive sessions with ground loop





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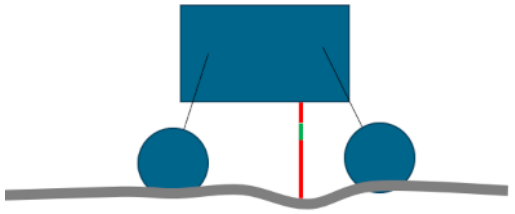

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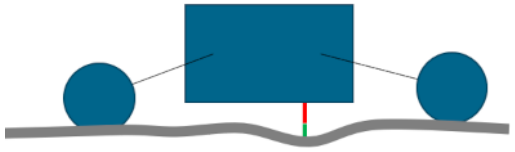
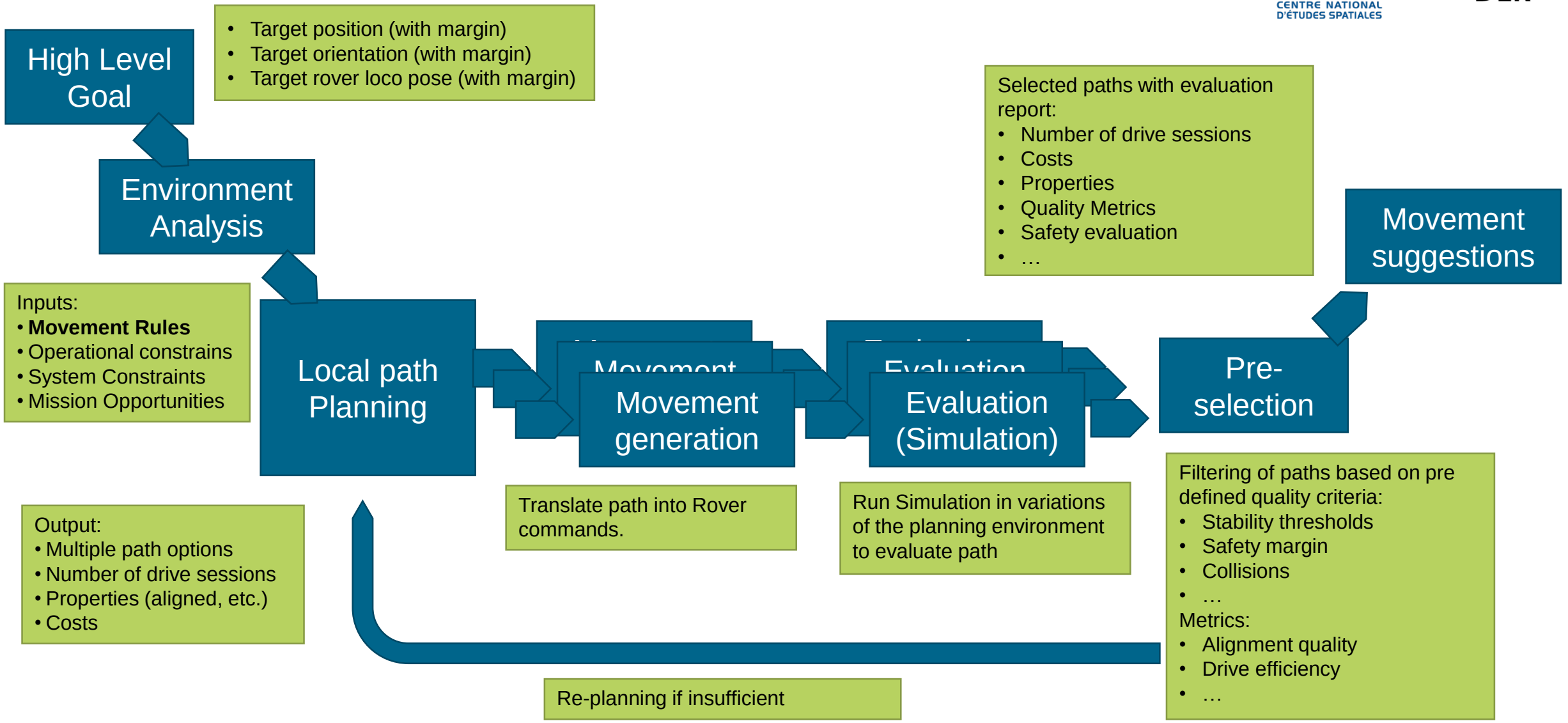


Planning Flow for Close Targets



Thank you, questions?

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