ASTRA 2023 - EMRS

EUROPEAN MOON ROVER SYSTEM

Date: 18/10/2023
Ref: 0005-0008238691
Template: 83230347-DOC-TAS-EN-009

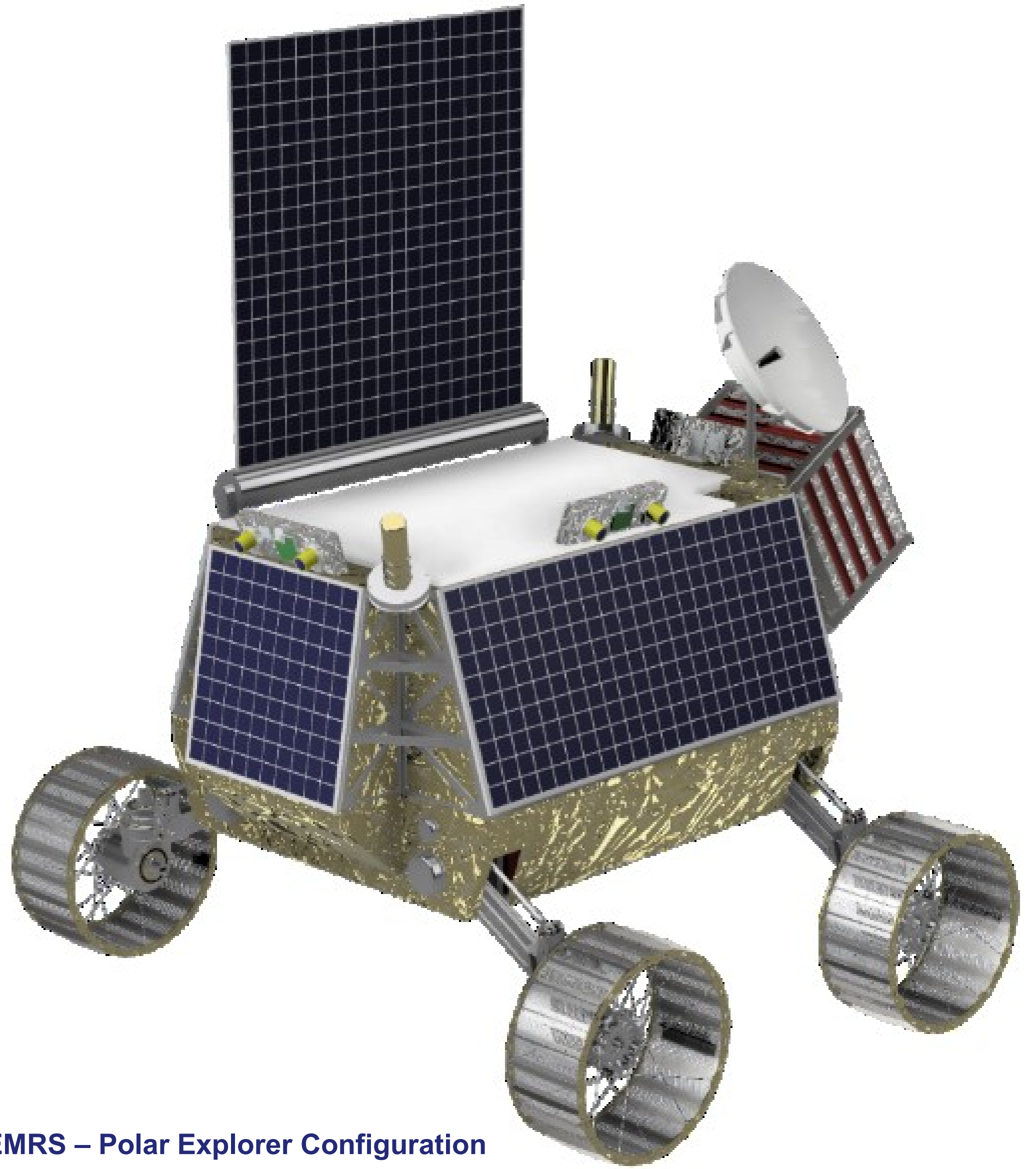
EUROPEAN MOON ROVER SYSTEM - EMRS

TAS-I has completed a preliminary study on an innovative **Lunar Exploration Rover** for the **European Space Agency**

- EMRS is set to launch in **2030** towards the **Lunar South Pole**, carried **ESA Argonaut (EL3) Lander**
- First locomotion breadboard completed and tested

System Requirements:

- **MODULARITY** – reusable elements across different mission scenario
- **FLEXIBILITY** – standardization of I/Fs to P/Ls
- **AUTONOMOUS** – and Tele-operated Navigation
- **SURVIVAL** – Lunar Night / PSRs Operability
- **MANIPULATION** – Lunar surface and assets



TAS-I EMRS – Polar Explorer Configuration

Date: 18/10/2023
Ref: 0005-0008238691
Template: 83230347-DOC-TAS-EN-009

MISSION SCENARIOS - INITIAL EXAMPLES

Re-purposing of the mobility platform is a new paradigm for space exploration, it enables incremental innovation and reduction of costs and time-to-fly.

Polar Explorer

- Scientific Prospecting Mission of the Lunar South Pole

ALO

- Installation of an Astrophysics Observatory on the far side of the Moon

ISRU

- Collect and Process in-loco resources

Location	Rover Mission Requirements
• Shackleton Crater: 89.9° S 0.0° E • Shomaker Crater: 88.1° S 44.9° E	• Navigate in and out of PSRs • Perform scientific experiments • Determine Ice distribution, distribution of rock types etc.
• Tsiolkovsky Crater: 20.4° S 129.1° E • Von Karman Crater: 44.8° S 175.9° E	• Carry (load/unload) a hub containing several antennas • Manipulate the antennas to position them on the surface (precision 0,5 m, 1°)
• Schrödinger Basin: 75.30° S 141.89° E	• Collect and sieve regolith • Deposit the sieved regolith in the ISRU pilot plant

Date: 18/10/2023
Ref: 0005-0008238691
Template: 83230347-DOC-TAS-EN-009

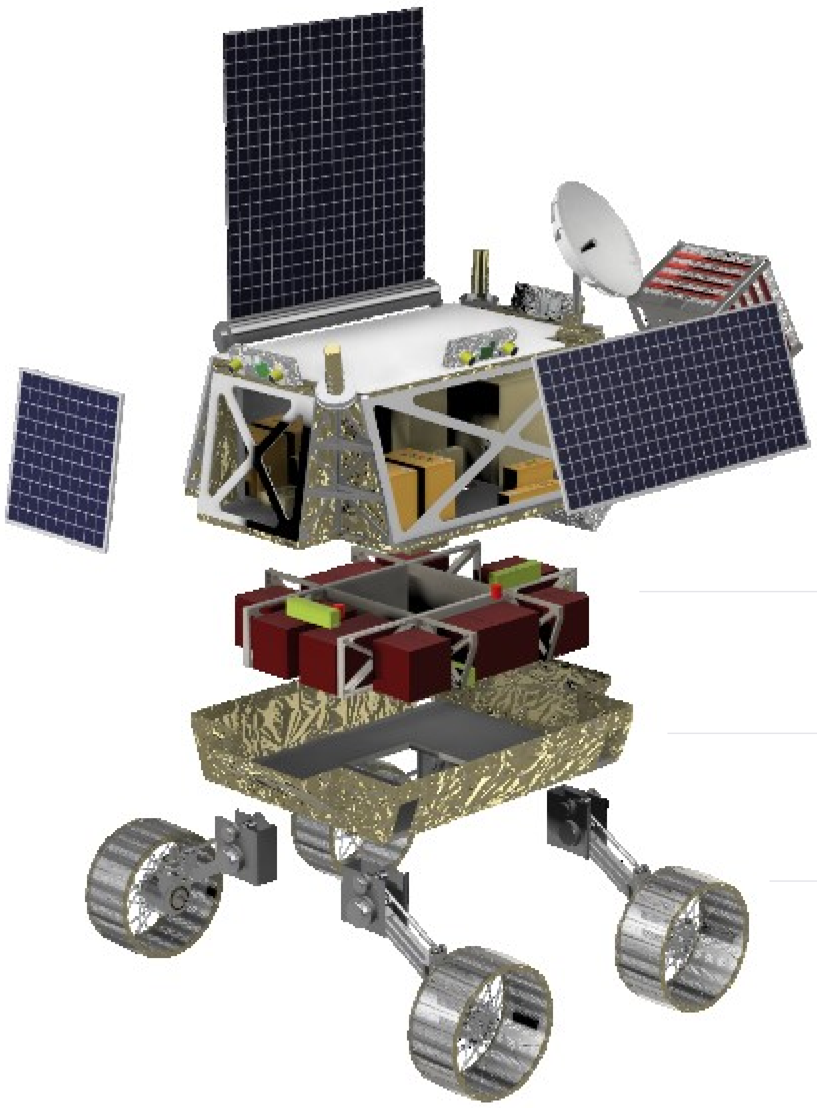
VEHICLE

VEHICLE

- **500 kg** integrated vehicle (locomotion unit + payloads)
  - Payload capacity > 150 kg
- **1500 x 1600 x 1300 mm** (variable envelope based on config.)
- **500 W** average power consumptions
- **5 – 20 cm/s** continuous autonomous navigation
- **20°** slope traverse
- **Lunar Night survival** (RHU) and **PSR** operations (> 10 hrs)
- **Aluminum/Titanium** structures
- **Foldable Solar Panel** for extended recharge

LOCOMOTION

- **Hybrid Active-Passive Suspension System**
  - **Controllable** height, roll, pitch of rover's body
- Each wheel is independently **drivable/steerable** (explicit steering)
- Closed-loop vehicle **attitude control** during navigation
- Active Suspensions enable: e.g. **crater exploration - P/L pointing**



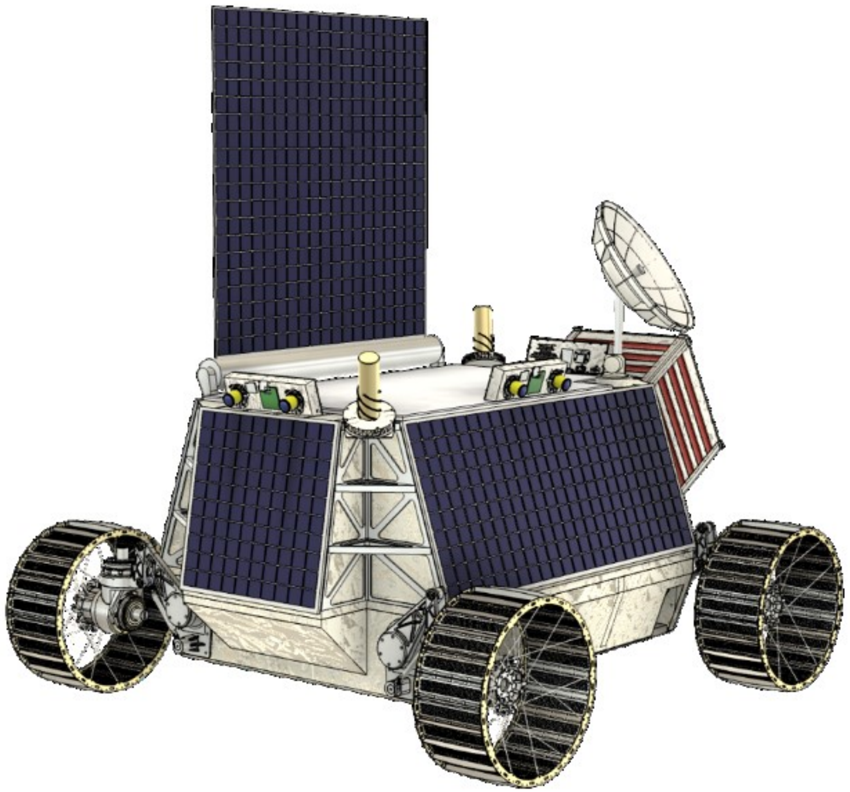
TAS-I EMRS – Polar Explorer Configuration

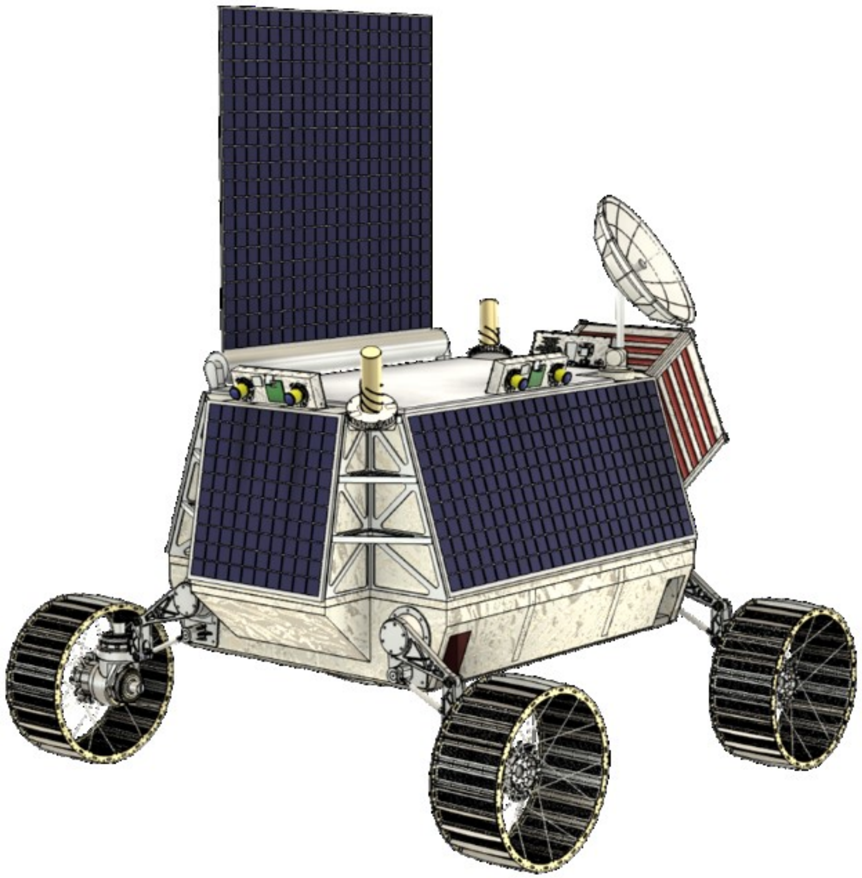
Date: 18/10/2023
Ref: 0005-0008238691
Template: 83230347-DOC-TAS-EN-009

LOCOMOTION

Vertical excursion

- **400 mm** active excursion
- **+/-50 mm** passive compliance (tunable)
- **Lowest** configuration enables surface contact:
  - Excavators
  - Collectors
  - Manipulators
  - Surface-interacting payloads
  - Scientific observations
  - More stability
- **Highest** configuration from surface:
  - Advanced obstacle avoidance
    - Obstacle overcoming
  - Variable camera viewpoint



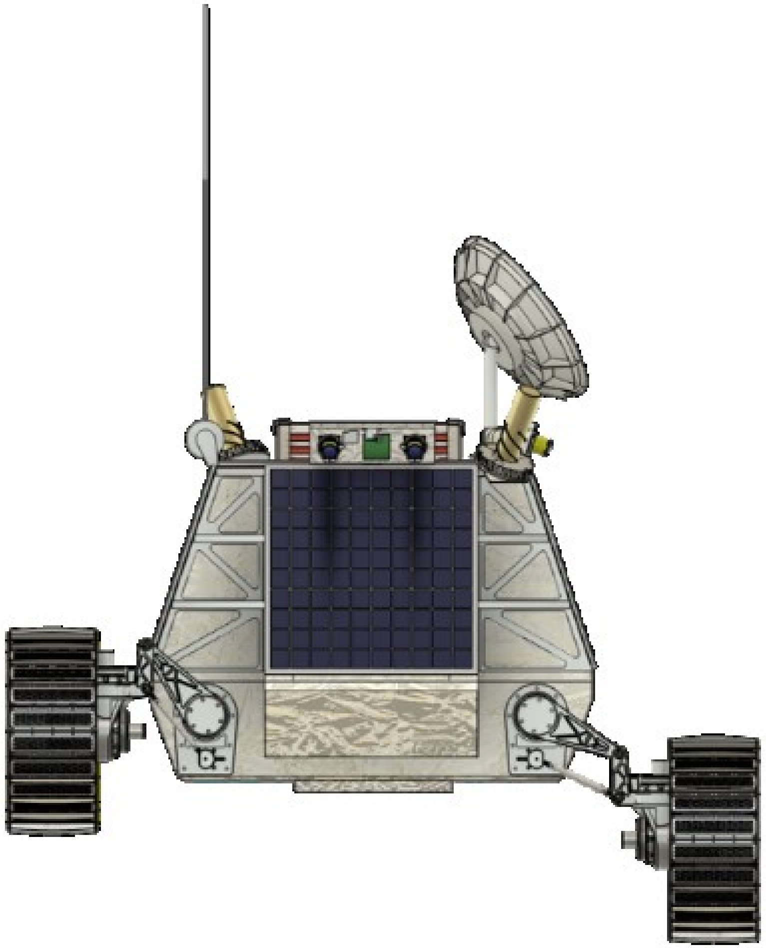


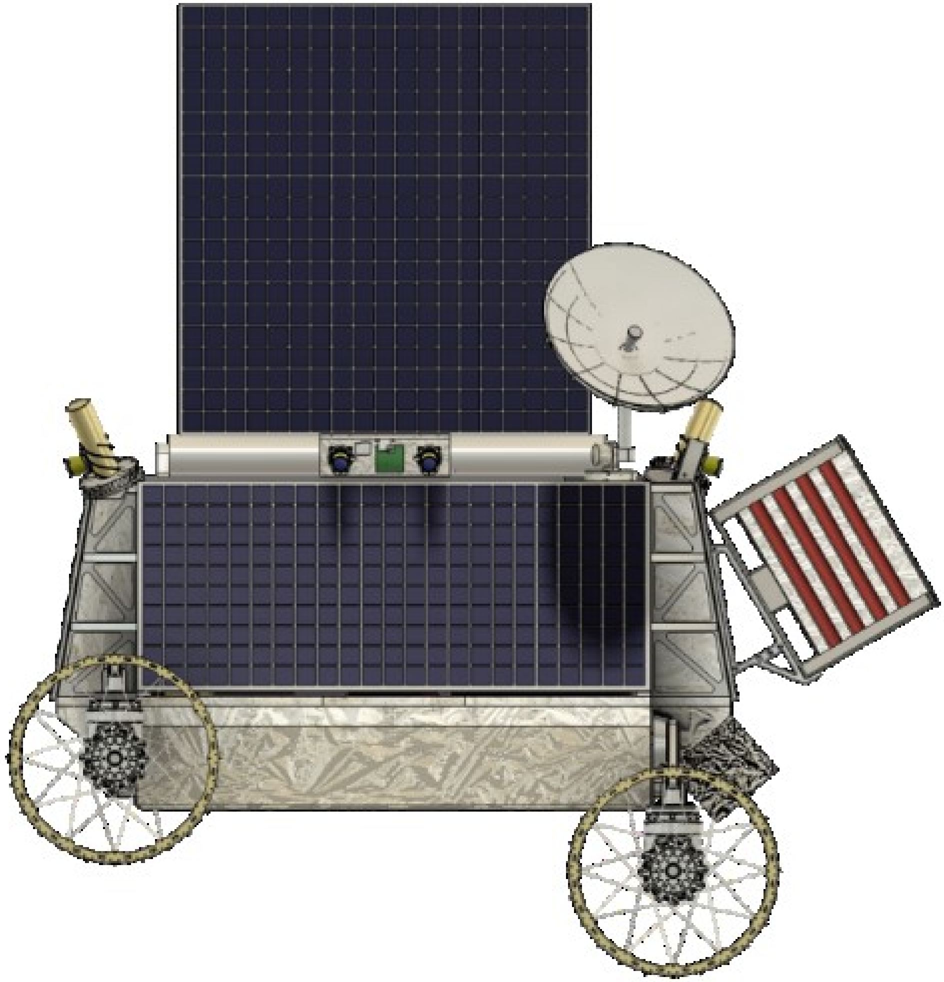
Date: 18/10/2023
Ref: 0005-0008238691
Template: 83230347-DOC-TAS-EN-009

LOCOMOTION

Lateral / Longitudinal compensation

- EMRS Rover can remain **perpendicular** w.r.t. gravity vector up to **15°** longitudinal/lateral slope
- Reconfigurable rover attitude can enable **variable payload pointing** while also navigating

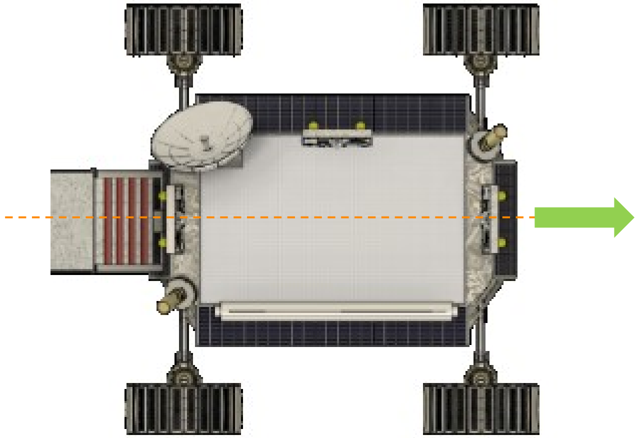




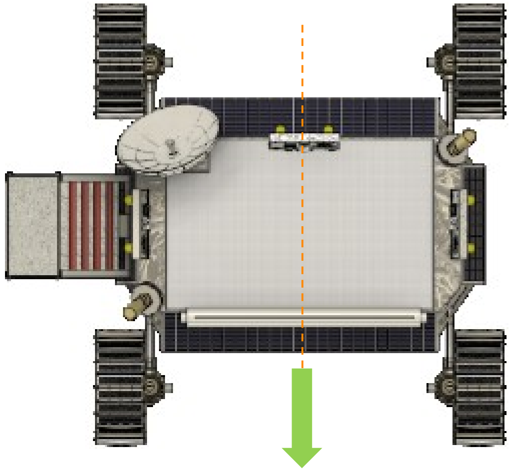
Date: 18/10/2023
Ref: 0005-0008238691
Template: 83230347-DOC-TAS-EN-009

LOCOMOTION MODES

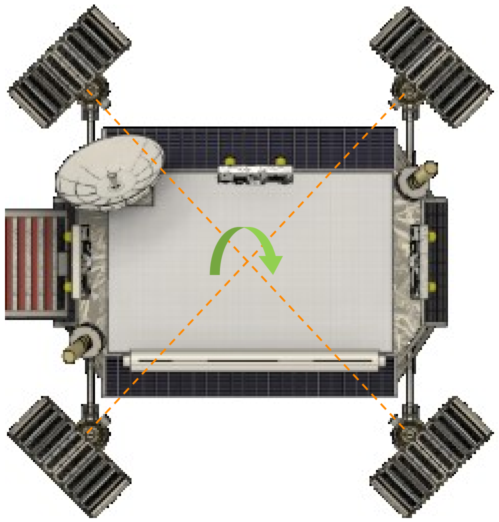
- TAS-I EMRS makes use of the minimum number of degrees of freedom to perform all possible locomotion modes
  - Ackermann
  - Crabbing
  - Point Turn (tunable)
- Payload advantages
  - EMRS can expose all its four sides to forward movement → it is possible to attach payloads and instrumentations on all four sides
  - Point Turn enable 360° observation of a single element of interest (e.g. rock sample, payload inspection)



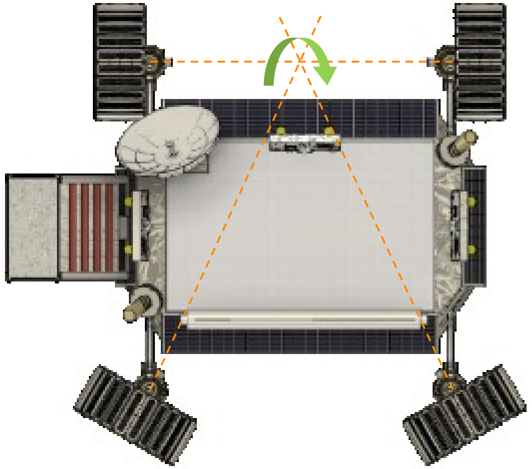
- Nominal Drive
  - Ackermann steering



- Side Drive
  - Limited Ackermann steering



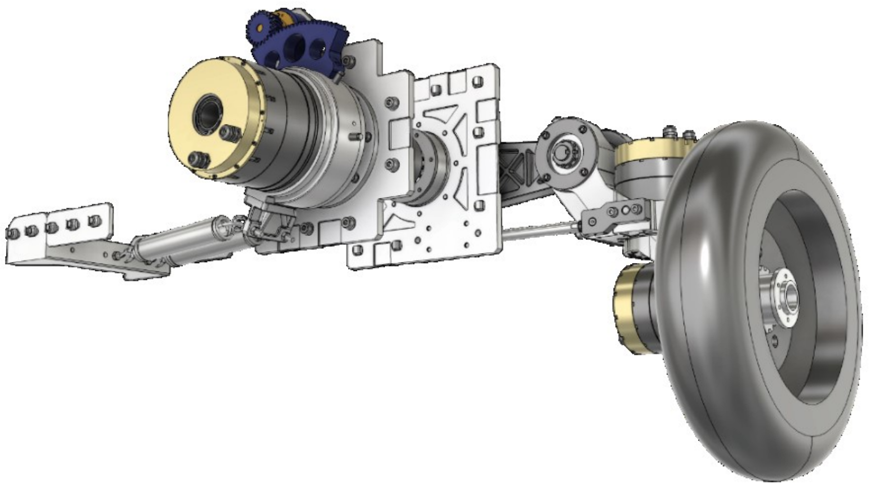
- Centric Point Turn
  - Turning point within chassis



- Eccentric Point Turn
  - Turning point outside chassis

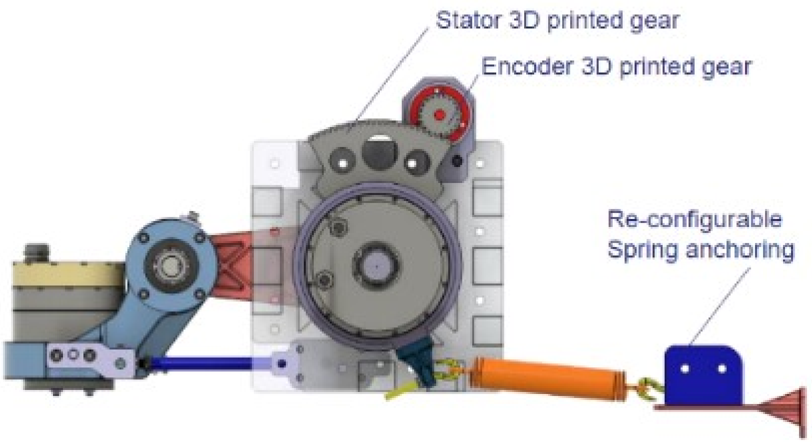
Date: 18/10/2023
Ref: 0005-0008238691
Template: 83230347-DOC-TAS-EN-009

SERIES ELASTIC ACTUATOR - IMPLEME

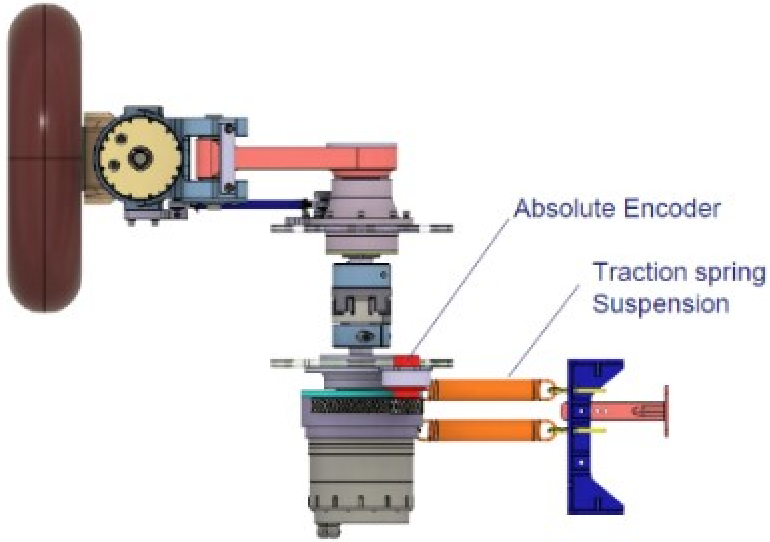


SEA advantages:

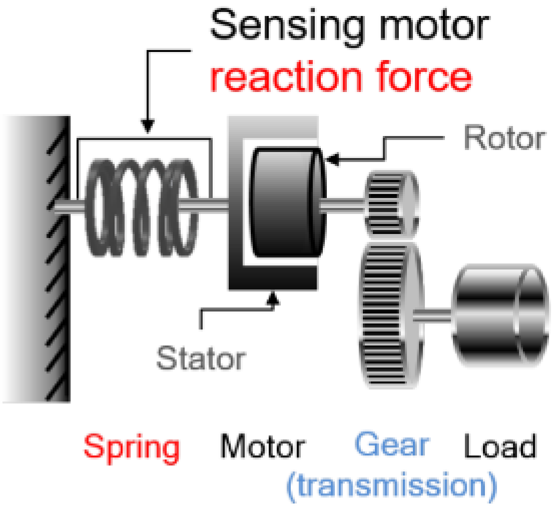
- Passive compliance with terrain
- No need for dedicated FT sensor within kinematic chain
- Possibility to implement impedance control to achieve desired roll/tilt/h pointing/surface interaction needs
- Implementation of SEA at rotor protects gearbox from solicitations (future design change)



EMRS BB Shoulder - Back View



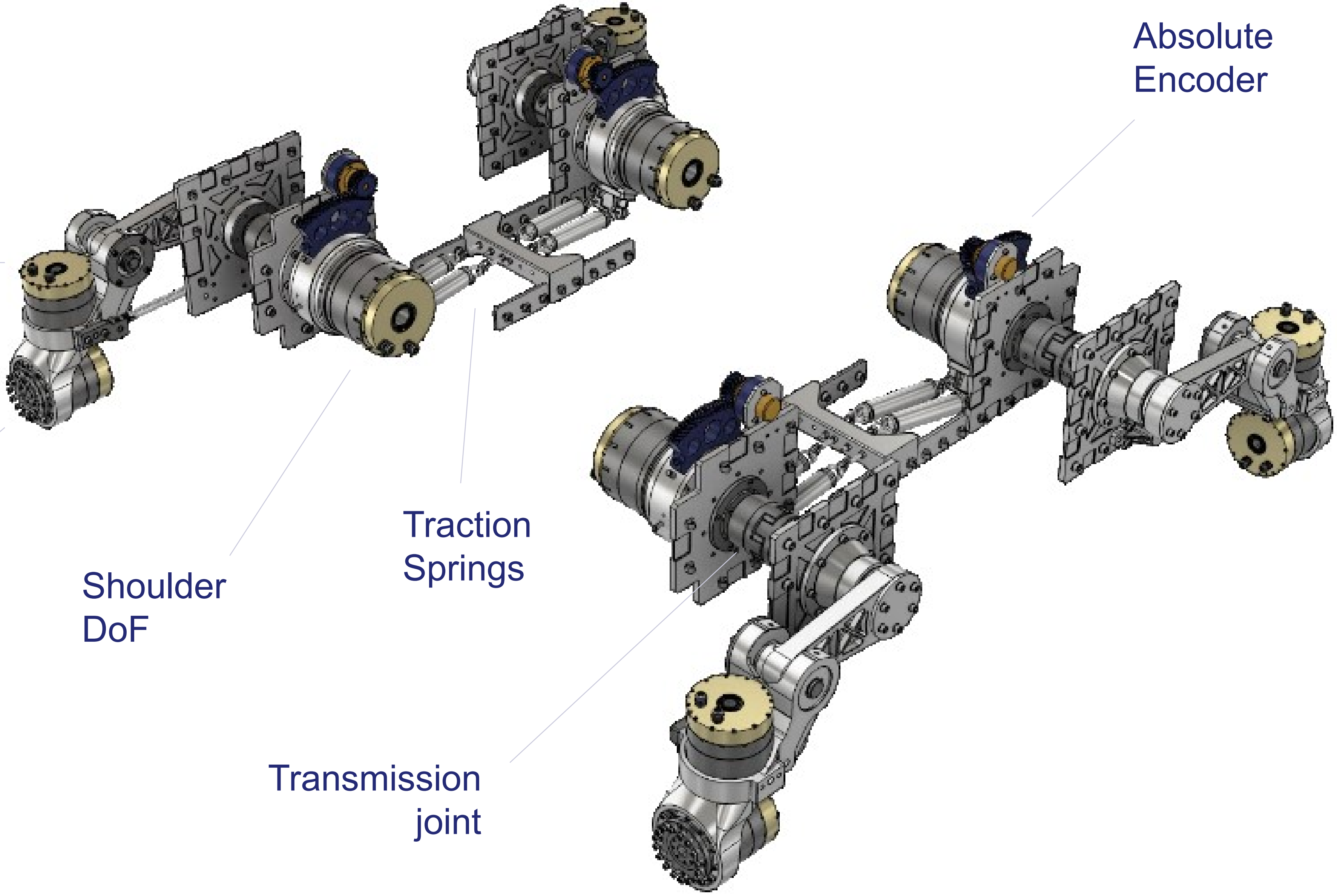
EMRS BB Shoulder - Top View



"Motor Reaction Force" SEA Configuration – Lee et al. 2017

Date: 18/10/2023
Ref: 0005-0008238691
Template: 83230347-DOC-TAS-EN-009

EMRS BB LOCOM



Date: 25/10/2023
Ref: Not referenced
Template: 83230347-DOC-TAS-EN-009

BREADBOARD

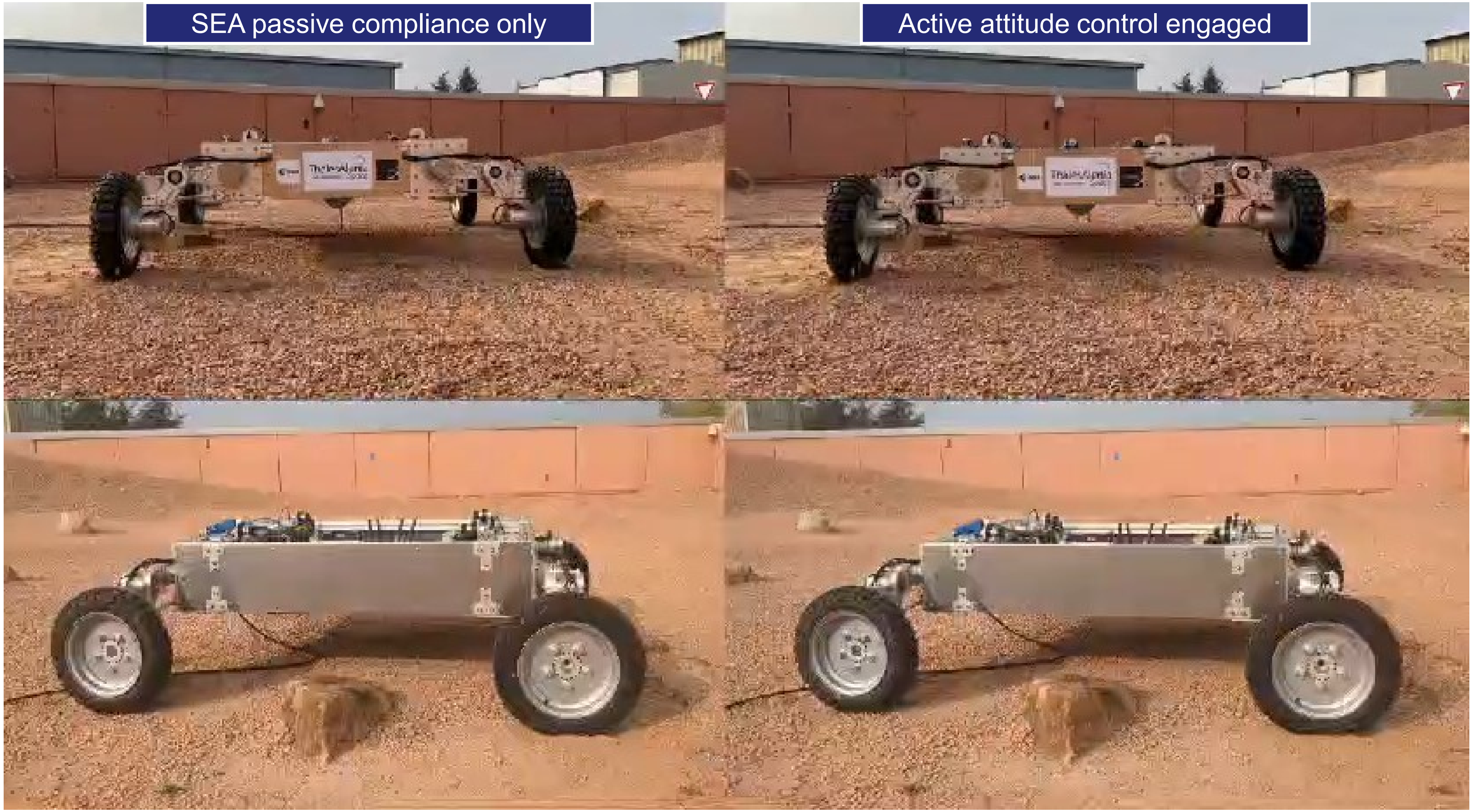
- Result achieved in <12 months of design and manufacturing activity
- Testing underway (NTE 10/23)

Thales Alenia Space Italia – Turin
Rover Exploration Facility – ROXY

Date: 18/10/2023
Ref: 0005-0008238691
Template: 83230347-DOC-TAS-EN-009

BREADBOARD TESTING

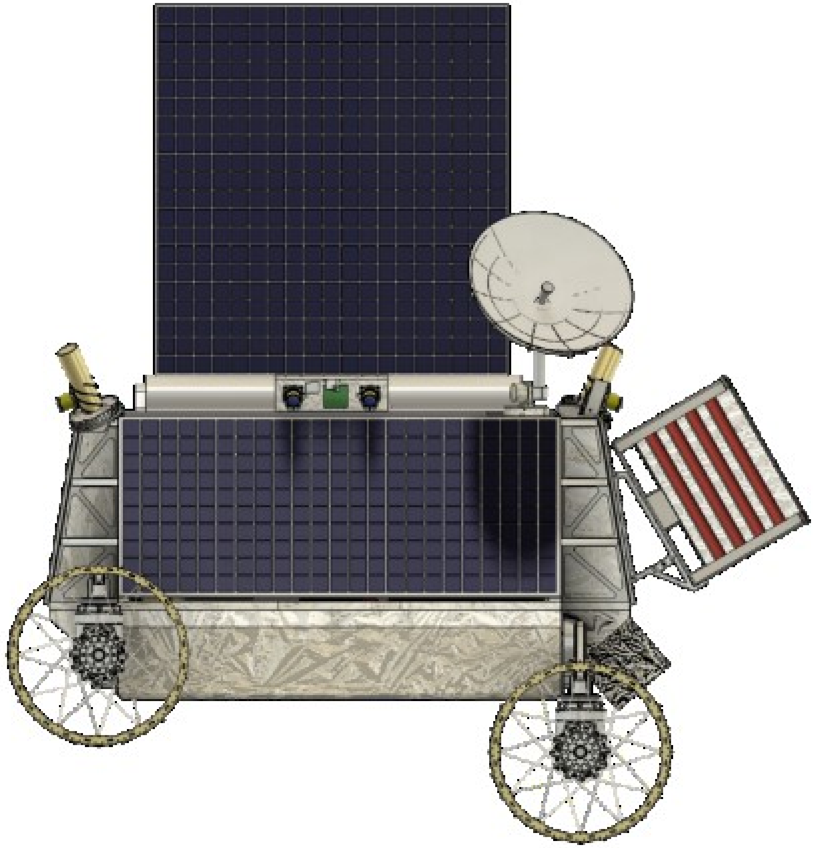
- 15 cm rock
- First iteration of attitude control SW



Date: 18/10/2023
Ref: 0005-0008238691
Template: 83230347-DOC-TAS-EN-009

BREADBOARD

- EMRS BB is capable of accommodating payloads and reproducing locomotion conditions while providing power and data



Date: 18/10/2023
Ref: 0005-0008238691
Template: 83230347-DOC-TAS-EN-009

OTHER DEVELOPMENTS

Further developments and prototyping of rover-size and heavy duties locomotion platforms – **Starts Q1 2024**

Terramechanics studies and wheel prototypes characterization – **Ongoing**

Advanced fully Autonomous Navigation (localization, mapping, planning), autonomous docking of surface elements through vision systems – **Completed, to be deployed on more advanced systems**

Date: 18/10/2023
Ref: 0005-0008238691
Template: 83230347-DOC-TAS-EN-009

THANK YOU!

Alessandro Ruggiero C.
TAS-I Robotics group
alessandro.ruggiero@thalesaleniaspace.com

ROVER EXPLORATION FACILITY
TAS-I ROBOTICS GROUP

Contributors:

Thales Alenia Space:
Antonella Ferri
Andrea Merlo
Patrick Roncagliolo
Stefano Bologna
Alberto Cernusco
European Space Agency:
Jennifer Reynolds
Markus Landgraf
Space Application Services:
Mathieu Deremetz
Maxence Debroise
Raphaël Boitte

Date: 18/10/2023
Ref: 0005-0008238691
Template: 83230347-DOC-TAS-EN-009